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Oral session abstract

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A1.01

Conformal window from conformal expansion

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Abstract:

Non-ablelian gauge theories coupled to fermion matter, such as the quantum chromodynamics (QCD), have played a prominent role in particle and nuclear physics for the last several decades. In recent days, our interests in such theories are diversifying since they can serve as ultra-violet complete models for physics beyond the standard model. In this talk, I will discuss the nature of chiral phase transition in asymptotic free gauge theories at zero temperature and chemical potential, quantum phase transition between infra-red conformal and chirally broken phases, which is characterized by a critical condition to the anomalous dimension of a fermion bilinear. We compute the anomalous dimension by exploiting the Banks-Zaks conformal expansion and estimate the critical number of flavors using the finite-order critical condition, where we quantify theory errors by treating the large-order behavior separately, either convergent or divergent asymptotic. In the former case, we take the difference in the Pad₩'e approximants to the two definitions of the critical condition, whereas in the latter case the truncation error associated with the singularity in the Borel plane is taken into account. We critically assess our results by comparing to other analytical methods as well as lattice results available in the literature.

Keywords:

conformal window, Banks-Zaks conformal expansion, quantum phase transition

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A1.02

Thermal transition of QCD with Nf=2+1 flavors of Wilson quark

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Abstract:

Recent results from the study of QCD thermal transition with 2 light (u,d) quark and 1 strange quark is reported. In our study, Wilson's formulation of fermion action is used, in contrast to "staggered fermion action. Various observables such as Polyakov loop and chiral condensate together with their susceptibilities are investigated. Also, the onset of parity doubling in the light and strange baryon channels are studied.

Keywords:

QCD, thermal transition, lattice gauge theory, quark-gluon plasma, light and strange baryons

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A1.03

Reconciling dark cosmology with condensates of gravitational fluctuations

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Abstract:

Primordial gravitational fluctuations may condense to a highly uniform state about the de Sitter temperature of the Universe by entanglement with the Hubble horizon. Mediated by self-gravity, non-relativistic dark matter will emerge from boson pairings seen in atomic condensates. We derive the mass spectrum of dark matter particles thus created, whose mean set by the de Sitter temperature is consistent with an upper bound $8.8\times 10^{-24}\,\mbox{eV}$ inferred from high-resolution SPARC galaxy rotation curves in 6σ departure from ΛCDM across the de Sitter scale of acceleration $a_{dS}=cH$ with velocity of light c and Hubble parameter $H(z)$ = $H_0\sqrt{1+\Omega_{r,0}[(1+z)^6-1]+(6/5)\Omega_{M,0}[(1+z)^5-1]}/(1+z)$ as a function of cosmological redshift z. At negligible radiation density today, $H(z)$ explains with no free parameters the H_0-tension between ΛCDM and the Local Distance Ladder, presently approaching $5\,\sigma$ significance. The expected $q_0=3\Omega_{M,0}-2$ is twice the value in ΛCDM, which may be confirmed by upcoming surveys of the Universe at low and high redshift.

Keywords:

Dark energy, Dark matter, H0-tension

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A1.04

Phenomenological constraints on the family-dependent extra U(1) gauge bosons

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Abstract:

We discuss some phenomenological constraints on the family-dependent extra U(1) gauge bosons.

Keywords:

extra U(1)

A1.05

Unitarity and the dilaton effective theory

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Abstract:

When the Yang-Mills (YM) theory, which is classically scale-invariant, undergoes the confinement phase transition to break the scale symmetry spontaneously, a dilation is created out of vacuum. We analyze the ground-state glueballs as a dilaton. As the energy increases, the dilation effective theory breaks down, violating the unitarity, at a scale given by the dilaton decay constant. To restore the unitarity in the effective theory we consider the states heavier than the dilaton, which is the spin-2 glueball. We calculate the scattering amplitudes of the dilation at the tree level, one loop and the box loop and the spin-2 glueball at the tree level. We then show the unitarity of the scattering amplitude is restored at the mass scale of the spin-2 glueball, that is much higher than the decay constant of dilaton.

Keywords:

Yang-Mills, glueball, dilaton, unitarity

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A1.06

Gravitational probes of flavor models with the continuum Clockwork

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Abstract:

We consider the 5D linear dilaton background as a continuum Clockwork model. We introduce general dilaton couplings for bulk scalars, fermions and gauge bosons in this model. Using the localization of zero modes of bulk fermions, we explain the hierarchy and mixing for fermion masses in the Standard Model and discuss the implications of several flavor models for the decay rates of the Kaluza-Klein gravitons.

Keywords:

Clockwork, flavor model, dilaton, graviton, hierarchy problem

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A1.07

The effective theory of nuclear scattering for a WIMP of arbitrary spin

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Abstract:

Abstract: We introduce a systematic approach to characterize the most general non-relativistic WIMP-nucleus interaction allowed by Galilean invariance for a WIMP of arbitrary spin in the approximation of one-nucleon currents. For a particle with spin j we find a basis of 4+20*j independent operators that exhaust all the possible operators that drive elastic WIMP-nucleus scattering. By comparing our operator basis, which is complete, to the operators already introduced in the literature we show that some of the latter for j =1 were not independent and some were missing. We provide explicit formulas for the squared scattering amplitudes in terms of the nuclear response functions available in the literature for most of the targets used in WIMP direct detection experiments, and show a few phenomenological examples of the corresponding expected signals.

Keywords:

A1.08

Self-interacting dark matter via massive spin-2 mediator

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Abstract:

We consider self-interacting dark matter of arbitrary spin with a massive spin-2 mediator in the effective theory. We derive the effective potential for self-interactions of dark matter in the expansion with momentum transfer and dark matter velocity. We find the self-scattering cross sections in Born and non-perturbative regimes. The results show that it is possible to solve the small scale problems at galaxies as well as satisfy the bounds from galaxy clusters in dark matter models with a massive spin-2 mediator.

Keywords:

self-interacting dark matter, spin-2 mediator, effective theory, non-perturbative effect, small scale problems

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A1.09

Searching for Boosted Dark Matter mediated by a new Gauge Boson

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Abstract:

We study the possibility to directly detect the boosted dark matter generated from the scatterings with high energetic cosmic particles such as protons and electrons. As a concrete example, we consider the sub-GeV dark matter mediated by a $U(1)_D$ gauge boson which has mixing with $U(1)_Y$ gauge boson in the standard model. The enhanced kinetic energy of the light dark matter from the collision with the cosmic rays can recoil the target nucleus and electron in the underground direct detection experiments transferring enough energy to them to be detectable. We show the impact of BDM with existing direct detection experiments as well as collider and beam-dump experiments.

Keywords:

Boosted Dark Matter

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A1.10

Boosted Dark Matter at Dark Matter Direct Detection Experiments

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Abstract:

We explore a class of multi-particle dark sectors, called Boosted Dark Matter. We consider both the cases of elastic and inelastic scattering off electrons. Taking a broad and fairly model-independent approach, we find that MeV-range boosted dark matter can be probed at conventional direct detection experiments via relativistic scattering of electrons inside target material. In particular, we point out that the XENON1T experiment can be sensitive to fast-moving or boosted dark matter scattering off electrons.

Keywords:

Dark Matter, Boosted dark matter, Dark matter direct detection, XENON1T

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A1.11

Implications of the XENON1T Excess on the (energetic) Dark Matter Interpretation

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Abstract:

The dark matter interpretation for a recent observation of excessive electron recoil events at the XENON1T detector seems challenging because its velocity is not large enough to give rise to recoiling electrons of O(keV). Fast-moving or boosted dark matter scenarios are receiving attention as a remedy for this issue, rendering the dark matter interpretation a possibility to explain the anomaly. We investigate various scenarios where such dark matter of spin 0 and 1/2 interacts with electrons via an exchange of vector, pseudo-scalar, or scalar mediators. We find parameter values not only to reproduce the excess but to be consistent with existing bounds. Our study suggests that the scales of mass and coupling parameters preferred by the excess can be mostly affected by the type of mediator, and that significantly boosted dark matter can explain the excess depending on the mediator type and its mass choice. The method proposed in this work is general, and hence readily applicable to the interpretation of observed data in the dark matter direct detection experiment.

Keywords:

Dark Matter, Energetic Dark Matter, Boosted Dark Matter, XENON1T, Dark Matter Direct Detection Experiments

A2.01

Differential cross section measurement of ttbb in lepton+jets channel with the full Run 2 dataset using deep learning

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Abstract:

For the Run 2 period, the Large Hadron Collider (LHC) has accumulated proton-proton collision data corresponding to an integrated luminosity of 137 fb^{-1} at a center-of-mass energy of 13 TeV with the CMS detector. Several million top quark candidates are produced in this data set. This large data set allows us to measure the differential cross-section of two additional b jets in association with the top quark pair production. Deep Neural Network helps us to find two b jets that are not from the top quark using multiple variables from this large data set. We present the differential cross-section result using the events of one lepton, 6 jets, and 4 b jets final state.

Keywords:

CMS, ttbb, differential cross section, DNN

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A2.02

Search for chromoelectric dipole moment of top quark in pp collisions at sqrt(s) = 13 TeV using 2016 data

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Abstract:

We conduct the study of CP violation in ttbar events decaying into the dilepton channel (ee,mumu, and emu), collected by the CMS experiment at a centre-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 35.9 fb^-1. In this search, two physics observables (O1, O3), which are the Levi-Civita tensors of the four vectors of leptons, b quark jets and top quarks, are probed. These observables allow us to test the CP-odd correlation. Asymmetries of a physics observable are measured. The chromoelectric dipole moment (CEDM) of the top quark is extracted from the linear correlation between CEDM and asymmetry. Combination of three channels for the CEDM is also presented.

Keywords:

CMS , LHC, CEDM, top quark, dilepton

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A2.03

Measurement of CP violation by using an angular distribution in single top t-channel @ 13 TeV

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Abstract:

The top quark is one of the elementary particles in the Standard Model (SM) which is the heaviest and decays before hadronization. Nowadays the precision measurements of characteristics of top quark is important in the particle physics since its deviations from the SM predictions can be probes for physics beyond the SM. We are looking for the asymmetry of an angular distribution between byproducts of top quark decay which contributes to CP violation in the SM. We present preliminary studies of measuring the CP violation contribution in the t-channel production of single top quarks.

Keywords:

top quark, LHC, CMS, Standard Model

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A2.04

Study of event Jettiness in the Higgs to 4 lepton decay

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Abstract:

In 2012, a new boson discovery was reported by two experiment CMS, ATLAS at LHC. H→ZZ→4l was paramount in the discovery of the Higgs boson. This channel is so called "golden channel" of Higgs analysis since the clear signal of 4 leptons in final state and high signal to background ratio allows the full reconstruction of the decay kinematics. Nowadays, with the Higgs discovery well established, the focus of Higgs research is shifted on the studies of rare Higgs boson production modes.
The event jettiness (τ_N), is a theoretical value, yields a factorization formula with inclusive jet and beam functions and it allows the summation of logarithms to next -to-next-to leading logarithmic (NNLL) order. Since all final state hadrons information are used for the τ calculation, τ can be used to distinguish different Higgs production topologies. τ algorithm is useful also for theoretical comparisons.
In this study, I will show the results of newly introduced τ algorithm discriminating ability and the possibility of being a new discriminant variable to distinguish the different Higgs production modes in the H→ZZ→4l analysis.

Keywords:

Tau, Jettiness, Higgs, Production modes, Discriminant variable

A2.05

Study for a direct Vts measurement in top pair production at LHC 13 TeV

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Abstract:

Vts is one of the parameters of the standard model that has yet to be directly measured. This parameter is important because the Standard Model assumes unitarity of the CKM matrix, which describes charged weak interaction. The quantity is much smaller than the dominant Vtb (b-quark decay) and is well-known under the assumption of the unitarity of the CKM matrix. However, in BSM scenarios, the unitarity may be broken, and the effective Vts may be far from the assumed value. In this analysis, we plan to directly measure the branching rate of the decay of the top quark into s-quarks, using machine learning to discriminate s-jets from top and background jets. This will then allow us to directly measure Vts.

Keywords:

CKM, top, Vts, LHC

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A2.06

Search for LFV in top quark sector with charm, muon, and tau final states

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Abstract:

Searching for Lepton Flavor Violation (LFV) in the top quark sector will open a new physics with third-generation elementary particles. It is the first analysis to look at the final states with charm quark, muon, and hadronic tau leptons. The proton-proton collision dataset in 2018 is used which has the luminosity of 59.74 fb^{-1}, and, 2016 and 2017 datasets will be added to analyze full Run 2 datasets with the center of mass energy of 13 TeV. To accept more LFV signals without depending on a certain model, the couplings are calculated with the Effective Field Theory (EFT) operators. In this analysis, the generator level study is performed to understand the kinematics of particles from LFV signal. Also, through data and MC sample comparison, the upper limits of each coupling will be calculated.

Keywords:

Lepton Flavor Violation, EFT, Top, BSM

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A2.07

Search for Supersymmetry with Compressed Mass Spectrum in the Vector Boson Fusion Topology with 0-lepton Final State at 13 TeV

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Abstract:

Supersymmetry (SUSY) models with a small, or "compressed", mass
splitting between the SUSY particles (sparticles) is a well-motivated Beyond the Standard Model scenario testable at the LHC. In this study, we consider a highly compressed mass spectrum, where the very small mass splitting between the
sparticles involved in a decay cascade leads to a final state where the leptons are too soft to be reconstructed by the detector. The cascade therefore has a detector signature consisting purely of missing transverse momentum (MET). We
present a search for highly compressed mass spectrum SUSY via electroweak Vector Boson Fusion (VBF), which uses the distinctive dijet topology of VBF to search for the signature in this low pT lepton regime. Our analysis uses proton–proton collision data at a center-of-mass energy of 13 TeV corresponding to an integrated luminosity of 137.1 fb−1 recorded by the CMS detector at the LHC.

Keywords:

CMS, SUSY, LHC

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A2.08

The measurement of forward-backward asymmetry in Drell-Yan with single b-jet events at LHC

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Abstract:

The precise understanding of the electroweak mixing angle is very important in particle physics. The most precise measurements of the mixing angle is conducted by LEP experiment and SLD experiment, and their results still have 3 sigma discrepancy. Especially, the results from LEP used forward-backward asymmetry(AFB) in single Z boson events decaying into the pairs of b quark. This AFB measurement from Zbb vertex also can be measured at Large Hadron Collider(LHC) via Drell-Yan(DY) with single b-jet events. Large background from ttbar events, and DY events with b,bbar or misidentified b-jet can be rejected by the novel method, and also efficient discriminating b and bbar can be achieved in this measurement.

Keywords:

AFB, CMS, Mixing angle, b-jet, Drell-Yan

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A2.09

Hadronic showers in Fast Simulation

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Abstract:

CMS fast simulation(FastSim) is efficient method to generate events while keeping comparable level of accuracy as full simulation(FullSim). Particularly, fast simulation becomes important with the increase of the LHC luminosity.
Simulating both electromagnetic and hadronic showers play an important role in many experimental physics. Those processes are represented via the GFLASH algorithm in the CMS fast simulation which is based on a parametrization approach. Usually hadronic showers are more complicated than electromagnetic showers due to their interaction processes.
In this presentation, the current status of hadronic shower parametrization study for GFLASH interface will be shown.

Keywords:

fast simulation, hadronic shower, calorimetry, CMS

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A3.01

Overview of Nuclear Data Production System at RAON

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Abstract:

Neutron beams have been utilized not only in the basic science, but also in the various industry sectors such as nuclear power, aerospace, defense industry, and semiconductor industry, over the past decades. The needs for the nuclear data extensively have been increased worldwidely, however, it is still insufficient, in particular for the high energy neutron-induced cross sections. Neutron beam facility, so-called as Nuclear Data Production System (NDPS) is being constructed, so as to measure the nuclear data by employing Time-of-Flight (ToF) technique at Rare isotope Accelerator complex for ON-line experiment (RAON) in Korea. NDPS will provide both white and mono-energetic neutrons using 49 MeV/nucleon deuteron and 88 MeV/nucleon proton beams with graphite and lithium targets, respectively. Since the ToF technique is employed in NDPS, pulsed beams at least less than 1 MHz repetitions with 1-2 nsec width of micro bunch are required in order to obtain sufficient accuracy of the nuclear data. The current status of NDPS will be presented along with the brief overview of RAON.

Keywords:

RAON, NDPS, neutron

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A3.02

RAON/NDPS의 세부장치 설계

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Abstract:

기초과학연구원 중이온가속기 활용연구시설인 NDPS (Nuclear Data Production System)은 양성자 및 중양자 빔을 이용하여 수십 MeV 고속 중성자를 생산하고, 고속 중성자 핵데이터 생산 및 중성자 관련 연구를 수행하기 위한 시설이다. NDPS를 구성하는 세부장치로는 98 MeV 중양자 빔을 C 표적에 입사하여 백색 중성자를 생산하고, 83 MeV 양성자 빔을 Li 표적에 조사하여 단색 중성자를 생산하는 표적시스템과 양질의 중성자 빔 획득 및 백그라운드 감소를 위한 중성자 콜리메이터가 있다. 또한, Li 표적을 통과하는 양성자 빔을 정지시키는 양성자 빔 덤프와 고속 중성자를 저감시키기 위한 중성자 빔 덤프가 있으며, 양성자 및 중양자 수송을 위한 빔 라인으로 구성되어 있다. NDPS를 구성하는 각 장치에 대한 구조, 열 및 방사선 해석을 수행하였다.

Keywords:

NDPS

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A3.03

RAON/NDPS 빔광학 설계

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Abstract:

기초과학연구원 중이온가속기 활용연구시설의 하나인 NDPS (Nuclear Data Production System) 표적실 내의 중양자 표적과 양성자 표적에 98 MeV의 중양자 빔과 82 MeV의 양성자 빔을 사용자가 요구하는 크기로 표적에 전송할 수 있도록 4개의 사극 전자석을 사용하는 빔 광학계를 탐색하였다. 또한 양성자 표적을 통과한 양성자빔을 빔진행 방향인 중성자 집속 경로로부터 휘게하는 2극 전자석과, 빔의 미세한 변위를 교정하는 역할을 하는 steering 전자석의 사양도 도출하였다. 빔라인, 중양자 및 양성자 표적 챔버, 빔덤프 등에서 요구되는 진공시스템을 구축하기 위하여 10-2 mbar 까지와 10-7 mbar 이하 까지 구간에 서로 다른 물리해석 모형을 적용하였다.

Keywords:

NDPS, Beam optics, vcuum

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A3.04

고해상도 TOF (Time of Flight) 중성자 실험을 위한 단일 번치 빔 생성 방법 연구

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Abstract:

최근 양성자 및 중양자 가속기는 기초과학 연구 및 응용과학 연구를 위한 중성자원으로 자주 이용되며, 해당 가속기들은 빔을 타겟에 충돌시켜 중성자를 생성하는 방식을 사용한다. 이에 따라 중성자의 반복 시간 (repetition time)은 빔의 반복 시간에 따라 결정되고 보통 수십 나노 초의 반복 시간을 가진다. 하지만 수십 나노 초의 반복 시간을 가질 경우, 빔 번치 사이의 시간 간격이 너무 짧아 고해상도 TOF 중성자 실험에 부적합하다. 이를 해결하기 위해 이 연구에서는 fast chopper와 DGB (Double Gap Buncher)를 이용한 단일 번치 빔 생성 방법을 제안한다. Fast chopper는 수십 나노 초의 rising time을 가지며 LEBT구간에서 CW 빔을 펄스 빔으로 변환하고, DGB는 fast chopper에 의해 생성된 펄스 빔의 번치 길이를 RFQ의 동작 주기보다 짧게 감소시킨다. 이상적인 경우, RFQ 가속 이후 단일 번치 빔을 얻을 수 있게 된다. 이번 발표에서는 단일 번치 빔 생성을 위한 빔 동역학 시뮬레이션 결과와 이를 바탕으로 한 장치 설계에 대해 논의한다.

Keywords:

단일 번치 빔, 중성자원, TOF 실험, Chopper, Double Gap Buncher

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A3.05

The detection system of Nuclear Data Production System

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Abstract:

Nuclear Data Production System(NDPS) is the experimental system for measuring nuclear data by use of neutron Time-of-Flight technique. Deuterons and protons up to 98 MeV and 88 MeV will be accelerated and delivered to neutron production targets such as graphite and lithium targets, respectively. High energy neutrons will be produced from the target and will be delivered to the measurement room. Neutrons from the production target will be monitored in real time by using Time-of-Flight(ToF) technique. MICROMEGAS and PPAC detectors will be installed at the meaurement room for monitoring neutrons. ^{10}B, ^{232}Th, and ^{238}U have been considered as a neutron-to-charged particle converter to cover the wide range of incident neutron energies. Furthermore, Monte-Carlo simulation studies are performed for the design of the neutron detector.

Keywords:

RAON, NDPS, neutron, neutron detector, Monte-Carlo simulation

A3.06

High Statistics Measurements of 12C(K-,p) Reaction at J-PARC

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Abstract:

We present the simulation results on measurement of 12C(K-,p) reaction in J-PARC H-dibaryon search experiment (E42) at J-PARC, based on Geant4 simulation toolkit. We plan a comprehensive measurement of K-p inelastic scattering reactions such as K*(892) meson and Lambda, Sigma hyperons with high statistics during the E42 beam commissioning. We performed a Geant4 simulation study of K-p reaction with a full geometry of the experiment including two magnetic spectrometers, Hyperon Spectrometer and KURAMA Spectrometer. The KURAMA Spectrometer consists of a dipole magnet and several detectors involving Water Cherenkov Detector (WC) at the most downstream. The WC plays a crucial role in the online trigger system by suppressing low-momentum protons and discriminating K+ from proton. In this talk, we will present preliminary Geant4 simulation results of 12C(K-,p) reaction.

Keywords:

A three-dimensional electromagnetic sampling calorimeter for the future KL0 -> pi0 nu nu_bar experiment

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Abstract:

We present designs of the three-dimensional (3D) sampling electromagnetic calorimeter (ECAL) for the KOTO2 experiment. We model 3D ECAL prototypes with alternative stacking of thin Pb sheets and scintillator strips. The KOTO2 experiment aims at observing high-statistics CP-violating KL0->pi0 nu nu_bar decays. The 3D ECAL will substitute for a CsI detector array of the KOTO experiment, which will measure several hundred MeV photons from pi0 decays with good energy resolution and angle information. We will present Geant4 simulation results for the ECAL performance depending on design and gamma reconstruction algorithm. We will also discuss front-end electronics requirements for the 3D ECAL.

Keywords:

A5.01

Electrinc structure studies of $SrRuO_3$ films in the ultrathin limit - spin structures and topological features

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Abstract:

Ultra-thin films may provide a useful platform to realize ideal 2D physics. As such, electronic structure studies should be an important part of ultra-thin films studies. However, electronic structure studies of films have been mostly limited to relatively thick films. In this presentation, I will show our recent in situ electronic stucture studies of $SrRuO_3$ ultra-thin films by using recently constructed in situ ARPES cluster system at SNU.
More sepcifically, I will present two examples of ultra-thin films studies. The first is on the spin structure of $SrRuO_3$ ultra-thin films. In their ferromagnetic states, films show clear band structures in ARPES data. Spin ARPES performed on these films show clear spin polarized bands, revealing spin majority and minority bands. The other example is the topological features that are responsible for the anomalous Hall effects. DFT and TB analyses of the measured magnetic band structure reveal that the sign changing anomalous Hall effect stems from symmetry-protected nodal structures (i.e., nodal lines and quadratic band crossings). This study is the first to directly characterize the topological band structure of 2D spin-polarized bands and the corresponding AHE, which could facillitate new switchable devices based on ferromagnetic ultrathin films.

Keywords:

SrRuO3 films, electronic structures, topological features

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A5.02

Mimicking superconductivity of Sr_2RuO_4 using $SrRuO_3$-$SrTiO_3$ superlattice

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Abstract:

The superconductivity in Sr_2RuO_4 has been one of the most challenging topics. Unlike cuprates whose mechanisms for superconductivity is understood with comparative studies within rich family, Sr_2RuO_4 is a lone superconductor. Using first-principles study, we show that $SrRuO_3$-$SrTiO_3$ (SRO-STO) heterostructure is endowed with all key characteristics of Sr_2RuO_4 such as two-dimensional electronic structures, spin-density-wave type magnetic instability, and strong nesting feature. Stronger and more frustrated magnetic instability in SRO-STO offers a unique opportunity of tunable magnetic and superconducting phases, which can be experimentally accessible for further intensitve studies and open a new platform to investigate the unconventional superconductivity in ruthenates.

Keywords:

ruthenates, heterostructures

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A5.03

Phase Instability amid Dimensional Crossover in Artificial Oxide Crystal

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Abstract:

Artificial crystals synthesized by atomic-scale precision epitaxy is a suitable platform for exploring, controlling, and understanding the quantum mechanical regime of solid state. A judiciously designed dimensional crossover from a 3D to 2D system can be realized using the monolayer control, which is frequently employed in transition metal oxides. Emergent quantum phenomena including magnetoelectric coupling, Mottronics, and topological electronics have been demonstrated for the artificial systems. Among them, atomic thickness dependents metal-insulator transition (MIT) is a one of the key topics for the atomic-scale electronics, which let us assess the low dimensional behavior of a material, which is typically intertwined with spin ordering in transition metal oxides.
In this talk, we demonstrate the dimensional crossover-induced MIT of $SrRuO_3$ (SRO) in atomically designed SRO/$SrTiO_3$ (STO) superlattices (SLs) using Pulsed Laser Epitaxy (PLE). The alignment of O-2p bands across the SRO/STO interface lead to the absence of the electronic reconstruction, which usually prevails in most oxide heterostructures. The absence of the charge transfer across the interface enable us to study an intrinsic dimensional crossover effect of SRO. Indeed, an intrinsic MIT of SRO was clearly revealed with a combined magnetic phase transition, from a ferromagnetic metallic phase to an antiferromagnetic insulating phase. Furthermore, we will discuss a dimensional instability for the 2 u.c. of SRO layers, indicative of a strong coupling between spin and charge ordering.

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Keywords:

Transition metal oxides, SrRuO3, Dimensional Crossover, Atomic-scale precision epitaxy

A5.04

Oxygen-vacancy-endurable conductors with enhanced transparency using correlated $4d^2$ $SrMoO_3$ thin films

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Abstract:

Degenerately doped wide-bandgap semiconductors, such as Sn-doped In_2O_3, are the most conventional transparent conductors (TCs). However, degradation of TC performance caused by a doping bottleneck and instability due to oxygen vacancies have been reported. Recently, non-doped correlated metals have attracted significant attention as a new approach for developing next-generation TCs. To date, most studies on this brand-new type of TC have been biased toward $3d^1$ vanadates.

Here, compared with $3d^1$ $SrVO_3$, we find that $4d^2$ $SrMoO_3$ thin films show promising TC properties, including a higher ultraviolet-visible transmittance of 80% and an extremely low resistivity of 0.0001 ohm cm at room temperature. We ascribe these enhanced characteristics of $SrMoO_3$ to a p-4d transition occurring at higher photon energy and a higher number of electrons in the outermost 4d orbitals. In addition, the TC properties of correlated $SrMoO_3$ are stable against oxygen vacancies. Using spectroscopic ellipsometry, we observe that this robustness is due to a lack of defect states near the Fermi level, different from conventional TCs. Taking these observations together, correlated $4d^2$ $SrMoO_3$ is a promising candidate for a next-generation oxygen-vacancy-robust conductor with enhanced transparency.

Keywords:

SrMoO3, correlated metal, transparent conductor

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A6.01

Topological physics in the 2D kagome network

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Abstract:

The kagome network, very popular in Japanese art, is one of the possible tilings of two-dimensional space, one with the same point symmetries as the hexagonal lattice of graphene. Recent theoretical developments suggest that the combination of unusual magnetism, spin-orbit coupling, and geometric frustration in kagome metals may lead to a wide range of novel topological physics, such as fractional quantum Hall effect and intrinsic anomalous Hall effect. In these phenomena, a major role is played by the topologically nontrivial flat bands and massive Dirac cones, both of which are predicted to exist from the unique geometrical hopping pathways of kagome lattice. Despite these predictions, the experimental band structure of kagome compounds has long remained unreported.
In this talk, I will report on the experimental band structure of various kagome compounds belonging to the family of transition metal stannides, and in particular Fe3Sn2, FeSn, and CoSn. In these systems which intertwine robust magnetism and electronic topology, we observed various manifestations of topological physics. These include the realization of the Kane-Mele model for 2D Dirac fermions with a spin-orbit-induced topological gap, as well as the discovery of the elusive flat bands and its nontrivial topology.
In sum, transition metal-based kagome lattices have emerged a new platform for intriguing phenomena arising from the combination of topology, magnetism, and correlations. I will discuss the prospects and outlook for further exploration of novel topological physics in this materials family.

Keywords:

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A6.02

Generation and control of Berry curvature dipole in 2D honeycomb lattices

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Abstract:

Berry curvature dipole, a physical quantity intrinsic in some periodic crystals, can give rise to many interesting physical phenomena in solid-state materials. Monolayer two-dimensional (2D) honeycomb lattices such as molybdenum disulfide (MoS_2) have non-zero Berry curvature at the edges of the conduction band, which are known as valleys. However, monolayer MoS_2 does not possess a finite Berry curvature dipole due to the 3-fold rotational symmetry of the crystal structure. In this talk, we will show the generation of the Berry curvature dipole in MoS_2 through the application of an external strain which breaks the crystal's 3-fold rotational symmetry. The magnitude and direction of the Berry curvature dipole is continuously and reversibly controlled by the external strain. We show that the Berry curvature dipole in monolayer MoS_2, when subjected to an external electric field, can create valley orbital magnetization in the out-of-plane direction which is relevant to room-temperature 2D magnetoelectric devices.

Keywords:

2D materials, strain, magnetoelectricity

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A6.03

Geometrical photon drag shift current in centrosymmetric crystals

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Abstract:

Symmetry in a crystal, Berry curvature and geometric-phase related phenomena have an intimate relationship. For instance in the presence of time-reversal symmetry, Berry flux across a Fermi surface is zero, and anomalous Hall effects vanish. Similarly, even though geometric phases can be large in centrosymmetric crystals, inversion symmetry leads to a vanishing non-linear shift photocurrent (linear photogalvanic effect). In this talk, I will discuss how such symmetry requirements can be circumvented. First, I will discuss how a nonlinear shift current can be activated in centrosymmetric crystals. In particular, I will discuss how non-vertical transitions (enabled by a photon drag processes) produce finite shift currents even in the presence of crystal inversion symmetry. While arising from a finite momentum transfer, such photon drag shift current is intrinsic and geometric with a magnitude controlled by a “shift-current dipole" that captures the interband geometry of a material. Strikingly, photon-drag shift current can manifest a purely transverse response underscoring its geometric phase origin. If time permits, I will also discuss other ways in which symmetry requirements in a crystal can be circumvented.

Keywords:

A6.04

Anomalous thermal transport in magnetic insulators

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Abstract:

Understanding the origin of the anomalous thermal transport in insulating magnets is one interesting topic in the study of magnets. In this talk, I am going to propose new mechanisms for anomalous thermal transport in magnets. One idea is based on magnon-phonon coupling arising from exchange striction and Dzyaloshinskii-Moriya interaction. Here we show how topological magneto-elastic mode can contribute to topological thermal transport. The second idea is about a new transport phenomenon due to phonon angular momentum. Here we propose the concept of phonon angular momentum Hall effect and discuss related anomalous transport properties.

Keywords:

Thermal transport, Magnon-phonon coupling, Phonon angular momentum

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A6.05

Longitudinal Spin Seebeck effect in Pt/YIG structure with monolayer WSe_2 interlayer

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Abstract:

We demonstrate a novel approach for enhancing the spin current injected into a normal metal, Pt, using interface effects with a ferromagnetic insulator, yttrium iron garnet (YIG). This was accomplished by inserting atomically thin monolayer (ML), tungsten diselenide (WSe_2) between Pt and YIG layers using longitudinal spin Seebeck effect (LSSE) measurements. We found that the insertion of ML WSe_2 between the Pt and YIG layers significantly enhanced the thermopower, V_{LSSE}/DT by a factor of approximately 5.6 compared with that of the Pt/YIG reference sample. This enhancement in the measured LSSE voltages in the Pt/ML WSe_2/YIG trilayer can be explained by the increased spin-to-charge conversion at the interface owing to the large spin-orbit coupling and improved spin mixing conductance with the ML WSe_2 intermediate layer. We also discuss the enhanced spin current in terms of magnetic properties of the chalcogenide materials.

Keywords:

Spin Seebeck effect, Thermally injected spin current, 2D transition metal dichalcogenide

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A7.01

Current Status of European XFEL Facility and Future Perspectives

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Abstract:

Since 2017, a world best performance X-ray Free-Electron Laser (XFEL) facility, named European XFEL (EuXFEL), has been operational with extreme operating conditions, e.g., a high pulse energy (close to 10mJ/pulse: limited by a radiation safety limit) and a high repetition rate (up to 4.5MHz) [1]. Currently, six end-stations, SPB/SFX (Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography), FXE (Femtosecond X-ray Experiments), SCS (Spectroscopy and Coherent Scattering), SQS (Small Quantum Systems), MID (Materials Imaging and Dynamics), and HED (High Energy Density Science), are up and running [2] and three independent experiments at three different end-stations can be performed in parallel, which makes the EuXFEL more efficient. The most important merit of the XFEL experiments will be ultrafast time-resolved experiments since X-ray pulse width can be shorten down to a few femtoseconds. Laser pump/X-ray probe technique is one of standardized techniques, which allows us to investigate atomic and electronic motions in femtosecond and picosecond timescale [3,4]. All six end-stations are equipped with femtosecond pumping laser systems [5] and some of them are also equipped with picosecond and nanosecond laser systems. Also, a hard X-ray split-and-delay line at MID [6] was commissioned recently and will be ready for X-ray pump/X-ray probe experiments in the near future. A unique X-ray pulse structure of the EuXFEL allows us to perform MHz imaging only with X-ray pulses themselves [7].

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Keywords:

A7.02

Pulsed laser-induced dewetting of Co/Sapphire(0001) thin films

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Abstract:

Dewetting of metal thin films has extensively been investigated to elucidate fundamental aspects of atomic-scale surface phenomena under intermolecular interactions. The energy required for dewetting of metal thin films is typically supplied by thermal annealing or pulsed laser irradiation. The pulsed laser-induced dewetting (PLID) is highly attractive, owing to distinct physical phenomena associated with the laser-matter interactions initiated by pulsed laser irradiation. In this study, we investigated PLID of Co thin films in vacuum, air, and water environment as a function of the number of laser pulses. A Nd:YAG laser was used to introduce PLID of the as-deposited Co thin films. The repetition rate was 20 Hz, and pulse duration was 8 ns at 532 nm wavelength. In this talk, we will introduce the recent achievements on PLID of Co/sapphire(0001) thin films. Basically, the morphological transition from thin films to nanoparticles complies with the grooving model involving the formation of holes and Rayleigh instability of rims. We observed the soft wetting behavior of Co NP and sapphire substrate in both vacuum and air atmosphere, while laser-induced hydrothermal process became dominant in a water environment producing CoO nanowalls. Detailed results will be presented.

Keywords:

Pulsed laser-induced dewetting, Co thin films, Grooving model, Soft wetting, Laser-induced hydrothermal process

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A7.03

Graphene in organic-inorganic hybrid PVs: synchrotron x-ray studies

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Abstract:

Graphene has shown outstanding potential in organic electronics as a transparent conductor and functional interface. In addition, it has used as an effective templating layer to induce special molecular stacking in pi-conjugated molecules due to the strong pi-pi face-to-face interactions stemmed from sp2 hybridized carbon by graphene. Recently, we successfully induce the face-to-face stacking of pi-conjugated polymer system using roll-to-roll transferred graphene. We also found that graphene can protect the organic-inorganic hybrid devices from H2O. In this work, we present the molecular templating effect of graphene in pi-conjugated molecular systems and encapsulating effect in metal-halide hybrid PV systems.

Keywords:

synchrotron x-rays, graphene, perovskite PV

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A7.04

Structural phase control and thermochromic modulation of VO_2 thin films by post thermal annealing

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Abstract:

Monoclinic M1 to rutile structural phase transition (SPT) in thermochromic VO_2 is accompanied by the insulator to metal transition and transition from an infrared (IR) transparent to IR opaque phase. Fine control over the phase stabilization and the functional properties without additional doping can offer the ability to tailor VO_2 thin films for their respective applications. In this work, post deposition thermal annealing was used to control the phase stabilization and the modulation in thermochromic performance of polycrystalline VO_2 thin films. Monoclinic M1 to rutile SPT in VO_2 thin films was tracked by in-situ temperature dependent synchrotron X-ray diffraction measurements and an increase in the SPT temperature was observed with increasing annealing temperature. Intermediate monoclinic M2 phase emerges near the SPT temperature at higher annealing temperature. Temperature dependent X-ray absorption spectroscopy (XAS) measurements revealed the higher electron correlation effect among the V $3d_{||}$ states across the phase transition in VO_2 thin film having the intermediate phase. Spectral weight of V $3d_{||}$ states was found to increase with the annealing temperature. Lower annealing temperature drives the IR switching temperature towards room temperature while the higher annealing temperature improves the IR switching performance of VO_2 thin films.

Keywords:

VO2, Thin film, Synchrotron XRD, Thermochromic, Phase transition modulation

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A7.05

Femtosecond Dynamics of Strongly Photoexcited Electrons in Noble Metals

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Abstract:

Upon exposure to intense femtosecond laser irradiation, significant portions of both the s/p and d electrons in the noble metals are excited, and the strongly perturbed system evolves into warm dense matter with temperatures of a few eV. In this contribution, I present the two experiments. The first one is self-reflectivity measurement of femtosecond laser pulse from Au nano layer. The second is the fs-XAS measurement for Cu nano-foil excited by fs-laser pulses. Optical and X-ray data visualize the strong down-shifts and recovery process of highly excited s/p and d band in the noble metal. Comparison of the experiment with the two-temperature-model enabled the initial nonequilibrium durations to be determined at a stage at which the TTM is non-applicable. This investigation allows us to quantify the lifetimes of non-thermal electron and electron thermalization time-scale in noble metal under warm dense conditions. It also raises an issue of the fast thermalization concept and the widely used two-temperature model to describe the nascent stage of intensively photoinduced material responses.

Keywords:

femtosecond laser, free electron laser, warm dense matter

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A8.01

Topological Jeff=2 Cooper Pairs in the Spin-Orbit Mott Insulator $GaTa_4Se_8$

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Abstract:

Among various many-body interactions in solid-state matters, electron-electron Hubbard interaction is the most evidently existing, but simultaneously the most elusive form of interaction for superconductivity. This is because the repulsive nature of electron-electron interaction is inadequate to serve as the source of superconducting pairings. Simply saying, the repulsive interaction does not glue Cooper pairs. In this work, we show that the confluence of the strong spin-orbit coupling completely changes the picture. By exemplifying the spin-orbit-coupled Mott insulator $GaTa_4Se_8$ whose strong spin-orbit coupling drives j=3/2 multiband nature of molecular states. We identify the particular pairing channel even with the repulsive origin. Intriguingly, this particular channel is characterized by 'spin-2 Cooper pair', which would not be possible without the aid of spin-orbit coupling. Furthermore, we show that its Bogoliubov quasiparticles and their surface states exhibit novel topological nature. To verify our theory, we propose unique experimental signatures that can be measured by Josephson junction transport and scanning tunneling microscope.

Keywords:

Topological Superconductivity, Unconventional Superconductivity, Spin-orbit coupled materials

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A8.02

Proposals to detect Bogoliubov Fermi surfaces

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Abstract:

An exotic superconducting state with Fermi surfaces of Bogoliubov quasiparticles, Bogoliubov Fermi-surface (BG-FS), has recently been proposed in a centrosymmetric $j=3/2$ system with a Z$_2$ topological invariant. Several candidate materials of a BG-FS are proposed in Sr2RuO4 and doped FeSe, but its existence has not been confirmed yet. In this work, we provide theoretical proposals to pin down a BG-FS. First, we use the inversion instability of a BG-FS and suggest that second-harmonic-generation (SHG) experiments with a strain gradient to identify enhanced fluctuations of an inversion order parameter. [1] Second, a nontrivial current response of a Bogoliubov Fermi surface superconductivity is used. The importance of dissipation channels from a Fermi surface of Bogoliubov quasi-particles is emphasized. Specifically, we derive the expressions for the optical conductivity and compare them with that of conventional Bardeen-Cooper-Schrieffer superconductivity. Possible applications of our theory to iron-based superconductors and heavy fermion systems including FeSe will also be discussed.

[1] Hanbit Oh and Eun-Gook Moon,Phys. Rev. B **102**, 020501(R)

Keywords:

Bogoliubov Fermi surfaces , superconductivity, inversion symmetry, optical conductivity, supercurrent

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A8.03

Off-diagonal singlet state in the infinite-layer nickelate with Ni^{2+} ion

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Abstract:

Layered nickelates have been highlighted due to the similarities to the layered cuprates that lead to high-Tc superconductors. Recently, a new layered nickelate $Ba_2NiO_2(AgSe)_2$ (BNOAS) with a Ni2+ square lattice was synthesized under high pressure and high temperature technique[1]. This system shows a remarkable magnetic behavior, although systems with Ni^{2+} ions are usually nonmagnetic, when there is no structural distortion. The observed susceptibility data of BNOAS is very unconventional: a sharp peak at Tm=150 K , but nearly T-independent behavior for the other regions. For the field cooling, the susceptibility shows a small upturn at low temperature and an increasing width of the peak.

Our results from correlated band theory indicates that the unusual susceptibility of BNOAS is due to a novel orbital-polarized low spin (S=0) state, named the "off-diagonal singlet (ODS) state", with compensating up $d(x^2-y^2)$ and down $d(z^2)$ spins. So, the ODS state shows complete spin polarization of the $d(x^2-y^2)$ and $d(z^2)$ orbitals, but the total spin moment is zero [2]. This unique state results from significantly stretched Ni-O distances. Our results suggest that the quasi-2D BNOAS is the first realization of the Kondo sieve model (2D Kondo necklace mode) of localized $d(z^2)$ spins coupled with $d(x^2-y^2)$ spins. Furthermore, this system would be a new host for superconductivity, similar to the recently discovered superconducting cuprate $Ba_2CuO_{3+\delta}$.

[Acknowledgements]
This research was collaborated with W. E. Pickett and was supported by NRF-2019R1A2C1009588.

[Reference]
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Keywords:

layered nickelate, first principles, off-diagonal singlet

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A8.04

Distinct nodal and nematic superconducting phases in the 2D Ising superconductor $NbSe_2$

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Abstract:

Superconducting transition metal dichalcogenides like 2H-$NbSe_2$ in their two-dimensional form (2D) exhibit a special form of Ising superconductivity in which the quasiparticle spins are firmly pinned in the direction perpendicular to the basal plane. This enables them to withstand exceptionally high magnetic fields far beyond the Pauli limit for superconductivity. We use field-angle-resolved magnetoresistance experiments for magnetic fields strictly rotated in the basal plane to investigate the dependence of the upper critical field (H_{c2}) on the orientation of the field in the plane. The field dependence of H_{c2} directly reflects the symmetry near $H_{c2}(T)$ to a two-fold nodeless symmetry at lower temperatures. While the first phase agrees with theoretical predictions of a nodal topological superconducting phase, the observation of a second distinct superconducting phase with nodeless two-fold symmetry is unexpected and contradicts the crystalline symmetry. It may therefore be another example of an unconventional nematic superconducting phase besides doped superconducting Bi_2Se_3, and we demonstrate that in $NbSe_2$ such a nematic state can indeed arise from the presence of several competing superconducting channels.

Keywords:

Ising Superconductivity, Field-angle-resolved magnetoresistance, nodal topological supeconductivity, Transition metal dichalcogenides

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A8.05

Coherent photogalvanic effect in fluctuating superconductors

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Abstract:

We develop a theory of the coherent photogalvanic effect (CPGE) in low-dimensional superconductors in the fluctuating regime.
It manifests itself in the appearance of a stationary electric current of Cooper pairs under the action of two coherent electromagnetic fields of light with frequencies lying in the sub-terahertz range. We derive the general formula for the electric current density, study the particular cases of linear and circular polarizations of the external light fields, and show that the current might have a non-monotonous spectrum at certain polarization angles and turns out very sensitive to the proximity of the ambient temperature to the critical temperature of superconducting transition: Approaching the critical temperature, the peak in the spectrum becomes narrower, its frequency experiences a redshift, and the intensity of the peak drastically grows.

Keywords:

Superconductivity

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A8.06

Electron-spin correlation in the electron-doped cuprate high temperature superconductor

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Abstract:

The mechanism of high temperature superconductivity in copper oxide (cuprate) materials is a more than three decades mystery from its discovery in 1986. As its superconducting phase forms a dome in the vicinity of antiferromagnetic (AF) phase, AF spin fluctuation has been considered to be one of the most probable candidates that mediates the superconductivity in cuprates. The first step toward proving the long-standing belief is to show a clear link between spin fluctuation and electron motion, especially across the entire phase diagram. Motivated by Eliashberg theory that bridges the bosonic and fermionic spectra in conventional superconductors, combined studies of inelastic neutron scattering and angle resolved photoelectron spectroscopy (ARPES) on hole-doped cuprates demonstrated a connection between spin excitations and fermionic quasiparticles through a band renormalization feature along zone diagonal dubbed ‘nodal kink’. However, its universality is still unclear.

In this ARPES study on the electron-doped cuprate $Pr_{1-x}LaCe_xCuO_4$, we investigated temperature and doping dependence of the nodal kink in order to understand electron and antiferromagnetic spin correlation across the entire phase diagram. We observed gradual weakening of the kink feature as temperature and doping increase, suggesting that the kink feature is mainly attributed to magnetic correlation. By comparing previous inelastic neutron scattering measurement result, it is manifested that the nodal band and magnon dispersions cross each other around binding energy ~70-80 meV where the nodal kink feature appears. In addition, we found out that too strong kink feature results in the band gap opening and suppresses superconductivity. Our result provides phenomenological reason why the intermediate electron spin fluctuation interaction is favored by superconductivity instead of strong interaction.

Keywords:

cuprate, electron-spin correlation, ARPES

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A8.07

Optical properties of electron doped cuprate $Pr_{0.85}LaCe_{0.15}CuO_{4-\delta}$: unusually low charge carrier density

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Abstract:

An optical spectroscopy study was performed on single crystals of $Pr_{0.85}LaCe_{0.15}CuO_{4-\delta}$ (PLCCO) with four different electron concentrations. The electron concentrations (n) determined by angle-resolved photoemission spectroscopy (ARPES) are unknown, 0.11, 0.14, and 0.17. Our optical results confirmed the electron concentrations determined by ARPES. Interestingly, the low-energy spectral weights in our PLCCO samples are significantly lower than those of other electron-doped cuprates ($Nd_{2-x}Ce_xCuO_{4-\delta}$ and $Pr_{2-x}Ce_xCuO_{4-\delta}$) with similar superconducting transition temperatures. The low-energy spectral weights of PLCCO are close to those of hole-doped $La_{2-x}Sr_xCuO4$ (LSCO). Furthermore, the doping-dependent properties of PLCCO are closer to those of LSCO than to other electron-doped cuprates. These observations might be associated with the previously reported particle–hole symmetric phase diagrams of the 214 family of cuprates based on investigations on the same PLCCO systems.

Keywords:

cuprate, superconductivity, optical conductivity

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A8.08

B_{1g} phonon anomaly in pseudogap phase of $YBa_2Cu_3O_{7-\delta}$ revealed by Raman spectroscopy

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Abstract:

In conventional superconductors, it has been known that the electron-phonon coupling can mediate Cooper pairs. However, the relationship between superconductivity and electron-phonon coupling in copper oxide high-T_c superconductors is still controversial. In addition, the electron-phonon coupling in various exotic phases such as pseudogap is not well understood. Here, we have used Raman spectroscopy with fine temperature step to observe the temperature dependence of oxygen buckling phonon (B_{1g}) in $YBa_2Cu_3O_{7-\delta}$. We found that the anomalous behavior of B_{1g} phonon appears above superconducting transition temperature (T_c). The onset temperature of B_{1g} phonon anomaly is very close to the pseudogap temperature (T*) measured by different experimental technique and the strength of phonon anomaly increases rapidly as the hole doping concentration approaches critical doping p_c. Such findings can not be interpreted as phonon self-energy effect which has been accepted so far to explain the temperature dependence of B_{1g} phonon. These observations suggest that B_{1g} phonon may be closely related to the quantum fluctuation emanating from pseudogap quantum critical point.

Keywords:

Superconductivity, copper oxide high Tc superconductor, cuprates, electron-phonon coupling, quantum critical point, Raman spectroscopy

A9.01

Synthesis of wafer-scale hexagonal boron nitride films via chemical vapor deposition

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Abstract:

Hexagonal boron nitride (hBN) film has been attracted due to multifunction roles for 2D materials such as ideal substrate, capping layer, and growth template. In this presentation, we present the recent progress of hBN film growth via chemical vapor deposition. Various growth mechanisms to achieve wafer-scale monolayer and multilayer hBN film is discussed. Furthermore, the growth of single-crystal hBN film in a wafer-scale is also introduced.

Keywords:

A9.02

Photolithography-like direct pattern growth technique for two-dimensional materials in layered structures – Focus on hexagonal boron nitride

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Abstract:

Hexagonal boron nitride (h-BN) is the only insulator among two-dimensional materials and is a very important material because it allows the intrinsic properties of other two-dimensional materials such as graphene to be expressed.

In particular, h-BN and graphene do not have etching selectivity for each other, and both the transfer process and post-patterning process distort the intrinsic properties of two-dimensional materials such as graphene.
Therefore, it is necessary to grow each two-dimensional material in a pattern form from the beginning, and this talk introduces the direct pattern growth technology for two-dimensional materials in layered structures that we developed.

In this technology, micro-patterned master substrate like a stamp acts as a photomask, and a two-dimensional material grows in a pattern form as a patterned photoresist is formed.
The key to implementing this technology is the delaminatable wafer-bonding technology, and using this technology, it is possible to achieve a 40 nm pattern resolution in the case of h-BN.

Keywords:

Photolithography-like, direct pattern growth, two-dimensional material, hexagonaol boron nitride

A9.03

Amorphous Boron Nitride

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Abstract:

Miniaturisation of electronic devices has resulted in increased interconnect resistance–capacitance delay and high power dissipation. Integration of low-k dielectrics—insulating materials that exhibit weak polarisation under applied electric fields—which also serve as diffusion barriers, facilitates miniaturisation beyond the current state-of-the-art. Recommendations of the International Roadmap for Devices and Systems require low-k materials to possess dielectric (k values ≤ 2 by 2028, be mechanically robust, and serve as diffusion barriers against interconnect-atom (typically Cu) migration into semiconductors. However, typical non-polar low-k materials, such as oxide derivatives (SiCOH), organic compounds, and aerogels, exhibit k values exceeding 2 and poor thermo-mechanical properties. This paper reports realisation of ultra-low k values of 1.78 and 1.16 at 100 kHz and 1 MHz, respectively, in amorphous boron nitride (a-BN) via complementary metal-oxide semiconductor (CMOS)-compatible deposition at 400 °C. The resulting structure is mechanically robust, with excellent diffusion-barrier characteristics. Detailed structural characterisation indicates that a-BN is sp^2-hybridised, with no measurable crystallinity. The breakdown strength of a 3-nm thick a-BN sample was 7.3 MV/cm – high enough for contemporary applications. Cross-sectional transmission electron micrographs revealed no diffusion of metal atoms across a-BN under harsh conditions when compared against TiN barriers considered as reference. Hence, our results suggest that the amorphous counterpart of two-dimensional hexagonal boron nitride possesses ideal characteristics for use in next-generation low-k dielectrics for high-performance electronic applications.

Keywords:

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A10.01

Surface Treatment and Passivation of Resistively Switchable SnO_2 Thin Films under Different Ambient Conditions

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Abstract:

SnO_2 is an n-type metal oxide semiconductor that has wide band gap (3.6 eV). Widely used in fields such as memory technology, thin film transistors, solar cells and lithium ion storages, SnO_2 has become a technologically important material. The intrinsic n-type semiconductor with its own oxygen vacancies makes SnO_2 available for memristive applications. The bipolar resistive switching (RS) characteristics of spin coated SnO_2 thin films on transparent conducting substrates were investigated by conductive atomic force microscopy (C-AFM) at different atmospheric conditions. We showed the mechanisms of SnO_2 oxygen vacancies by controlling with Ultraviolet ozone (UVO) treatment at different oxygen atmospheric conditions (oxygen concentrations under 1.0 ppm and 2.1 x 10^5 ppm). Distribution of switching voltages are decreasing along with increasing UVO treatment time. The ranges of set and reset voltage were observed ±1 V ~ ±3 V. As compared with controlling oxygen atmospheric conditions, NH_4Cl solution was capped on the SnO_2 thin films. Capping with NH_4Cl on SnO_2 thin film have been revealed as blocking oxygen effects in our study.

Keywords:

SnO2 thin film, NH4Cl passivation, Resistive switching

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A10.02

Highly reliable titanium oxide memristor array device for neuromorphic computing system

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Abstract:

Recently, the progress of memristor device that mimic biological synapse in human brain are expected to organize potentially basis component for future neuromorphic computing system to replace the conventional CMOS system due to their unstructured data process-ability and spatial efficiency. The electrical conductance of each memristor cell in array matrix can be strengthened or weakened depending on the quantitative properties of pre-synaptic pulse stimulus, and the memorizing and computing process in neuromorphic system are simultaneously performed in each device in terms of synaptic plasticity. With this property, the matrix element in artificial neural network can be modulated in specified direction, which would be utilized in complex and unstructured task such as learning and inference.[1,2] Here, we achieved the reliable and uniform titanium oxide memristor device with 25 × 25 matrix array structure representing outstanding synaptic plasticity. The memristor device showed superb fabrication yield (100 %) and repetitive stability (3,000 pulse spikes) for analogue resistive switching characteristics and it was utilized to constituent of neuromorphic computing system for image recognition process.

[1] C. Wu, T. W. Kim, H. Y. Choi, D. B. Strukov, and J. J. Yang, Nat. Commun., 8, 752 (2017).
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Keywords:

Neuromorphic system, memristor device, synaptic plasticity

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A10.03

Titanium oxide thin films for heat mirror applications

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Abstract:

We have grown titanium oxide thin films on glass substrates for heat mirror application by direct-current magnetron sputtering methods. We have controlled the population and energy of titanium and titanium oxide plasma species by varying the sputtering plasma power (from 100 to 200 W). The composite titanium oxide of metallic and dielectric phases including Ti_2O_3, TiO_2 and amorphous TiOx were diagnosed from the comparative study of x-ray diffraction and Raman spectroscopy. The most notably, the narrow transmittance bands were observed in the visible region. The best performance of infrared reflectance, up to 60 % at 2300 nm, was found for the films grown at the highest plasma power. The interesting heat mirror properties were successfully analyzed with reference to the surface plasmon resonance phenomenon.

Keywords:

Heat mirror, Titanium oxide

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A10.04

Fabrication of tunnel selectors using selective filament formation for high-density memristors

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Abstract:

Memristor has been highlighted as a future non-volatile memory due to its versatile operation characteristics as well as a high density with 3-dimensional stacking potential. These features generally demand large crossbar array of memristors, in which suffers from sneak path currents from neighboring cells. It disturbs accurate writing and reading process of a target cell. To solve the sneak path current problem variety of selectors were reported in passive crossbar array of memristors, such as metal-insulator transition and tunnel junction. Key point is non-linearity in low resistance states, however, most of the previous results of passive crossbar array were achieved with thermochemical or valence changing system due to challenging realization of non-linearity with filamentary channel of electrochemically active metal, such as Ag and Cu, in oxide and chalcogenide films. We propose halide selectors as a tunneling barrier layer, which has large Gibbs free energy. Silver ion migration procedure under external electric field consists of the three steps: electro dissolution, ion transport and electro deposition. Large Gibbs free energy prevents electro dissolution in halide and thin halide layer remains tunneling barrier in low resistance states. We measured current-voltage (I-V) hysteresis of stacked structure of 1 selector and 1 memristor (1S-1M), which consist of different anion. Higher non-linearity was observed as a function of thickness of tunneling barrier, which would enhance the selectivity of the 1S-1M structure. The non-linearity examined to relate with tunneling phenomena and the concept is expected to solve the sneak path current problem.

Keywords:

memristor, sneak path current, non-volatile memory, tunnel selector

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A10.05

Nanorod-shaped SiO_x Memristor for Stochastic Artificial Neuron and Computing Application

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Abstract:

Memristor, which simply consists of a switching layer inserted between two electrodes, is one of the most strong candidates to become a device-platform for imitating the principal of biological neural network due to its nonlinear and dynamic electrical characteristics depending on the history of applied electrical programming [1]. In this study, we fabricated a nanorod-shaped SiO_x memristor using E-beam evaporator with glancing angle deposition at the wafer-scale and utilized the device as an artificial neuron for probabilistic computing applications. The device can exhibit a low forming voltage (< 2 V), a high ON-OFF ratio (> 10^5), reliable switching performances, and fast switching time (~40 ns), where the switching event is attributed to the transition between two Si phases (amorphous Si and Si nanocrystal). Notably, the nanopores naturally formed by the gap between nanorod-shaped SiO_x can lead to the considerable reduction of forming voltage, when compared with the typical SiO_x memristor (~20 V). Moreover, using voltage pulse trains, the nanorod-shaped SiO memristor has successfully mimicked fundamental neuronal dynamics called integrate-and-fire process. Based on the inherently stochastic switching characteristics of the nanoporous SiO_x memristor, we experimentally demonstrated the stochastic neuronal functionalities for the bayesian network in which each node is probabilistic variables. Then, as a proof of concept, we simulated the probabilistic inference for the correlation between three biological genes. Taken all together, the designed SiO_x memristor neuron could pave the way for stochastic artificial neurons and its based probabilistic computing technology.

References

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Keywords:

Silicon oxide, Nanorod, Memristor, Stochastic artificial neuron, Probabilistic computing

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A10.06

Reduced extrinsic recombination process in anatase and rutile TiO_2 epitaxial thin films for efficient electron transport layers

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Abstract:

The effective electron transport layer (ETL) are essential for high-power conversion efficiency (PCE) of perovskite solar cell (PSC). TiO_2 is the most widely used material for ETL owing to proper band alignment, enough optical transmittance and high electron mobility. There are two representative thermodynamically stable crystal phases of TiO_2: anatase and rutile. However, it is still debate which phase is more effective for the ETL. To solve the concern, single-phase thin film is strongly needed. We demonstrate the different effects of using epitaxial anatase TiO_2 and epitaxial rutile TiO_2 (both grown using pulsed laser deposition) as the ETL material on the electrical and optical properties. Epitaxial Nb-doped TiO_2 layers were used as the electrode material for the epitaxial ETLs for which the crystalline structural analysis revealed high crystalline qualities and good coherency for both phases. By analyzing the recombination kinetics, the anatase phase shows a preferable performance in comparison with the rutile phase, although both epitaxial phases show remarkably reduced extrinsic recombination properties, such as trap-assisted recombination. This study demonstrates not only a better electron transporting performance of anatase phase but also reduced extrinsic recombination through epitaxy growth.

Keywords:

Halide perovskite solar cell, electron transport layer, TiO2, anatase, rutile

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A10.07

Development of unstable front of ionic flow with power-law in crystalline solids

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Abstract:

Visualizing ionic flow in solids is potentially important for energy applications, such as solid electrolytes for batteries and fuel cells. Our model material, a $Bi_{0.7}Ca_{0.3}FeO_{3-\delta}$ thin film, is not only a ionic conductor but an electrochromic material which show different colors according to its oxygen stoichiometry (3-δ).[1] We can induce dynamically changing color distribution of the thin film by applying voltage, thereby observing the effect of the ionic flows in it.[2,3] Here, we focus on the development of unstable boundary between as-grown phase (δ = 0.15) and oxygen-rich (δ = 0) phase. The width of boundaries shows power-law relation with applied voltage and with the position of boundaries. Besides, there exist transitions of power-law exponent of the width-position relation in the middle of the flow processes. In addition, roughness exponents of the boundaries are saturating to ζ = 1. Studies on unstable boundaries are quite active in various systems such as ferroelectric/magnetic domain walls or fluid invasion in porous media.[4,5] However, studies are lacking in the area about the dynamics of charges in spite of its importance in technological applications.
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Keywords:

Ionic conduction, Domain wall propagation, Power-law behaviors, Roughness exponents, Solid electrolytes

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A10.08

Polarization-controlled PVDF-based hybrid nanogenerator for an effective vibrational energy harvesting from human foot

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Abstract:

We reported an electric polarization-controlled PVDF-based hybrid triboelectric-Piezoelectric nanogenerator (TP-NG) as for an energy harvesting of human foot vibration. The hybrid TP-NG simply consists of PVDF, Al, acrylic and the triboelectric NG component is vertically stacked on the Piezoelectric nanogenerator. For the effective conversion of mechanical vibration in a hybrid TP-NG, in-phase power generation from each TENG and PENG is inevitable. In our device structure, the TP-NG showed in-phase power generation from each TENG and PENG. After confirming the in-phase power generation from each TENG and PENG component, we investigate the electric polarization-dependent open-circuit voltage and short-circuit current of hybrid TP-NGs. This TP-NG is efficient for harvesting vertical vibration energy. We installed the PVDF-based hybrid TP-NG in a shoe insole. This device effectively harvests the random and irregular vibrational energy from the human foot. To propose application of our hybrid TP-NG, we lightened LED and charged Li-battery to operate wireless sensor network.

Keywords:

PVDF, Hybrid nanogenerator, Human foot, Shoe insole, Wireless pressure sensor network

A10.09

Interface Band Offset and Band Alignment in Ga-graded $Cu(In,Ga)Se_2$ Thin Film Solar Cells

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Abstract:

$Cu(In,Ga)Se_2$ (CIGS) thin film solar cells have been widely studied, and numbers of research have been done to maximize its performance. To enhance the CIGS solar cell device, appropriate bandgap grading in CIGS absorber and well-aligned absorber/buffer interface is required. In this work, three samples having different Ga-grading in CIGS with CdS buffer layer were prepared and samples were mechanically dimpled to examine its structural properties. Using micro-Raman spectroscopy and secondary ion mass spectrometry (SIMS), the formation of Ga-grading was confirmed. Also, energy-dispersive X-ray spectroscopy (EDS) result showed that greater Ga-grading device have high remaining Ga on CIGS absorber surface. In order to investigate electrical properties at CIGS/CdS interface, Kelvin probe force microscopy (KPFM) was used. Surface potential was obtained through KPFM, and line profile of surface potential was extracted. Higher surface potential value was observed in CdS buffer region, and drastic decrease at CIGS/CdS interface implying that spike-like band offset was formed. In greater Ga-grading device, surface potential difference about 30 mV was observed which is referred as slight spike-like conduction band offset. However, less Ga-grading device showed excessive surface potential difference implying formation of band barrier at interface. Therefore, appropriate Ga-grading in CIGS absorber layer facilitate to form well-aligned band structure at CIGS/CdS interface. In conclusion, we suggest optimized bandgap grading in CIGS absorber layer form additional electric field and beneficial spike like band offset at CIGS/CdS
interface resulting in improving cell performance.

Keywords:

Cu(In,Ga)Se2 (CIGS) thin film solar cells, band gap grading, Kelvin probe force microscopy (KPFM), band offset

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A12.01

COVID-19 Genomic Surveillance

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Abstract:

COVID-19 genomic surveillance designates changes in SARS-CoV-2 proteins that are targeted by vaccines and therapeutic drugs. In addition, genomic surveillance can be used to identify close-contact transmission chains and alert transmission hotspots with safeguards for individual privacy. This talk will discuss about global SARS-CoV-2 evolution patterns and demonstrate how we can trace the spread of infection in real time using viral genomes alongside with contact tracing.

Keywords:

COVID19, Genomic surveillance

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A12.02

COVID-19 related epidemic patterns and scaling behaviors based on minimal model studies

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Abstract:

Throughout the world, the COVID-19 epidemic research is one of the most popular project in a variety of aspects. In particular, it is the most crucial to figure out how to stop the spreading behavior of the COVID-19. In this talk, we briefly overview minimal models for epidemic spreading, phase transition types, and the universality classes. Among them, we propose the most relevant model with additional key ingredients, such as quarantine, incubation, and physical distance. Finally, we discuss how to understand the COVID-19 related epidemic patterns and scaling behaviors, in terms of minimal model studies.

Keywords:

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A12.03

Epidemics spreading with time-varying transmission rates: case of Covid19

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Abstract:

We study the spread of epidemics with time-dependent transmission rates in order to model temporal variation of dynamical parameters. We infer the correlation and causality between the transmission rates and the number of newly confirmed individuals by using the empirical data of Covid19. We study and predict the effect of time-varying transmission rates based on the inferred value. We also attempt to infer the effect of interactions between different countries from the empirical data.

Keywords:

Relationship between transmission of Malaria and Climate change in Africa

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Abstract:

The climate change is associated with infectious diseases. For example, malaria is the greatest public health problem in African continent. The spreading of malaria diseases is related to the climate change. Temperature and rainfall are paramount key factors for climate change and transmission of malaria. The fluctuation of temperature and the amount of rainfall affects the transmission and spreading of malaria by lowering or speeding up the rate of transmission of Malaria. Because of the high percentage of malaria incidences and death rates in African region, in this study, we construct and analyze the multilayer networks to show not only how malaria networks relates with climate networks but also how nodes are correlated. Malaria networks show both positively and negatively linear correlation to temperature networks and rainfall networks.

Keywords:

Climate change, malaria incidences, malaria disease, malaria network, rainfall network, temperature network, and multilayer network

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A15.01

Non-Thermal Molecular Vibrational Excitation Induced by Plasmonic Hot Carriers

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Abstract:

Plasmons of metallic nanoparticles drastically boost the chemical reaction rates and often create unusual reaction products. Whether or not such plasmon catalytic activity mainly comes from non-thermal hot carriers of plasmons is still hotly debated, despite many studies. In this talk, I will show a spectroscopic proof that the plasmons excited by a continuous-wave light with a moderate power create highly non-thermal vibrational states of reactant during a plasmon-catalyzed reaction. The associated vibrational excitation rates are as large as ~10^{10} s^{-1}, which is 6 orders of magnitude larger than what is achievable with pure optical pumping, approaching a few percent of molecular vibrational relaxation rate. The resonant electron-molecule scattering model fully reproduces the observed mode-specificity of the excitation. The result provides a firm physical basis for the hot-carrier mechanism of plasmon-catalysis and also open up a new way of vibrationally controlling surface chemistry on metals.

Keywords:

plasmonics, single-particle spectroscopy

Fluidic metamolecules: from synthetic approach to dynamic self-assembly

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Abstract:

Here, we present the fabrication of fluidic metamolecules exhibiting strong magnetic resonances. Firstly, we have developed a synthetic method to generate raspberry-like assemblies of metal nanoparticles, which is termed raspberry-like metamolecules (RMM). The nanoparticle assemblies show useful optical properties such as strong magnetic resonances and broad surface plasmon resonance spectra due to the densely packed assembly structure. Secondly, we present a similar type of RMMs fabricated with a thermo-responsive hydrogel. In this approach, the assembly structure can be dynamically controlled, which allows for in-depth investigation of structure-dependent optical properties without having to fabricate a series of different assemblies. In the presentation, we will discuss the unique structure-property relationships in the dynamic metamolecules.

Keywords:

Plasmonic, Metal nanoparticle, Magnetic resonance, metamaterial, matemolecule

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A15.03

Plasmonic Nanoparticle Superlattice for Unnaturally High Optical Refraction

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Abstract:

Refractive index (n) is foundational material parameter for transformative optical technologies. In general, semiconductors, such as Si, Ge, and GaAs, offer higher n of ~4.0 than other elements. Beyond this natural upper limit of n, we can strongly push the light–matter interactions to the unnaturally available, extreme regime. This unnaturally high n of materials in turn enriches the accessible optical applications. In this talk, I'll briefly introduce the basic design rule for achieving unnaturally high n particularly at the optical regimes, which would be readily available with the self-assembly of plasmonic nanoparticle (NP) superlattice. Especially, the close-packing of polyhedral gold (Au) NP (i.e., Au nanocubes) into 2D superlattice promise for achieving n of 6.4 at the resonant wavelength and 4.5 in the off-resonant regimes, which couldn't be accessible with naturally occurring materials.

Keywords:

Refractive index, Optical metamaterials, Self-assembly, Plasmonic nanoparticles, Unnaturally high refraction

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A15.04

Peptide Induced Chirality in Single Gold Nanoparticle

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Abstract:

Chiral structure controlled at nanoscale provides a new route to achieve intriguing optical properties such as polarization control and negative refractive index. However, asymmetric structure control with nanometer precision is difficult to accomplish due to limited resolution and complex processes of conventional methods. In this regards, utilizing chirality transfer occurring at organic-inorganic materials offers viable route to overcome these limitations. Previously we developed a unique synthesis strategy that characteristic of molecule is transferred to gold nanoparticle morphology [1,2]. Based on the system, here, we demonstrated novel chiral gold nanostructures exploiting chirality transfer between peptide and high-Miller-index gold surfaces [3]. Enantioselective adsorption of peptides results in unequal development of nanoparticle surface and this asymmetric evolution leads to highly twisted chiral element in single nanoparticle making unprecedented 432 helicoid morphology. The synthesized helicoid nanoparticle showed strong optical activity (dissymmetry factor of 0.2 at 622 nm) which was substantiated by distinct transmittance color change of helicoid solution under polarized light. Modulation of peptide recognition and crystal growth enabled diverse morphological evolution and the structural alterations provided tailored optical response, such as optical activity, handedness, and resonance wavelength. We believe that our peptide directed synthesis strategy offers a truly new paradigm in chiral metamaterial fabrication and will be beneficial in the rational design of chiral nanostructures for use in novel applications.

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Keywords:

chirality, plasmon, gold nanoparticle

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A20.01

그리고 나에게 주어진 길을 걸어가야겠다

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Abstract:

시대에 대해 이야기하고자 한다.
윤동주가 "그리고 나에게 주어진 길을 걸어가야겠다"고 다짐하던 가장 어두운 시절에서 10년 이상이 더 지난 때가 내가 태어나던 시대였다. 그러나 그 이후 30여년이 흘러도 어두움은 늘 우리 곁에 머무르고 있었다. 그 어둠 속에서 우리는 어떻게 과학자의 꿈을 키웠고 어떻게 실천했는지 이야기한다. 지금 21세기 글로벌 시대에 우리나라는 다른 위상을 가지고 있다. 우리의 다음 세대는 과학자로서 나에게 주어진 길을 어떻게 가야 할 지 논의해 본다.

Keywords:

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A20.02

물리가 있는 풍경: 감마선 폭발과 중력파(Gamma ray bursts and gravitational waves)

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Abstract:

감마선 폭발과 중력파의 관측은 우주에는 태양질량과 맞먹는 에너지를 짧은 시간에 방출하는 우주전체의 밝기보다 훨씬 밝은 현상이 존재한다는 것을 알려주었다. 이 현상들의 중심에 블랙홀이나 중성자별등 올찬별(compact star)에 의해 조성된 풍경과 물리적 과정을 살펴본다. 블랙홀계에서의 중력결합에너지의 방출과정, 회전 운동에너지가 짧은 시간에 방출될 수 있는 자기제동 과정과 감마선 폭발의 중심을 살펴 볼 수 있는 중력파의 특징을 논의한다. 감마선 폭발과 중력파는 거시적인 풍경 뿐 만 아니라 중성자 별의 내부와 같은 고밀도 극한 환경의 미시적인 풍경에 대한 이해의 가능성을 열어 주고 있다.

Keywords:

감마선, Gamma ray bursts, gravitational waves

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B2.01

Search for resonant new phenomena in high-mass dilepton final states at √s =13 TeV with CMS

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Abstract:

A search for new high-mass resonances decaying into electron or muon pairs is performed using data collected from 2016 to 2018 by the CMS experiment at 13 TeV and corresponding to a total integrated luminosity of 140 fb^{-1}. No significant deviation is observed from the standard model expectation. Upper limits are set on the ratio of the product of production cross section and branching ratio of a new dilepton resonance to that of the Z boson in a model-independent manner. Lower limits on the masses of various hypothetical spin-1 particles with decaying widths from 0.6 to 10% of the resonance mass are set at 95% confidence level. Lower limits on the mass of spin-2 gravitons in models with large extra dimensions are set for values of the coupling parameter $k/\bar{M}_{Pl}$ between 0.01 and 0.1. Limits are set on the masses of the dark matter (DM) particle and its associated vector or axial vector mediator in the simplified model of DM production. We look for evidence of lepton flavor universality violation using the ratio $R_{\mu\mu/ee}$ of the differential dilepton production cross sections in the dimuon and dielectron channels as a function of dilepton mass.

Keywords:

CMS, LHC, BSM

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B2.02

Search for Z′ bosons decaying into tau pairs in bottom fermion fusion process

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Abstract:

Anomalies in the B-meson decays reported by the b physics experiment could be explained by a heavy neutral gauge boson, Z′, with flavor changing b_s coupling and a nonuniversal coupling to leptons. In this study, we investigate the Z′ decaying to tau tau in association with at least one b-jet.

Keywords:

BSM, Tau, BFF, Z'

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B2.04

Search for Charged Higgs Boson decaying to c bbar in ttbar lepton+jets channel with CMS Run2 Data

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Abstract:

We present the search result of charged Higgs boson in top quark pair events using the CMS Run2 data from pp collisions at 13 TeV. In this search where charged Higgs bosons are lighter than top quark, they can appear in top quark decays as like t->H+b. In particular, the branching ratio of charged Higgs decay into c b-bar can be enhanced in type-Y two Higgs doublet model.
In the lepton+jets channel of the Standard Model top pair events, the final state has one lepton, four jets (two b-jets and two light jets), and missing transverse energy. If the charged Higgs is produced from top decay, three b-jets are expected in the final state. Thus, a search for the light charged Higgs at two & three b-jets channel is performed using 137.2/fb of the data.

Keywords:

Charged Higgs

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B2.06

Search for a heavy neutrino in top quark decays using CMS detector

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Abstract:

We present a search for a heavy neutrino in top quark decays at CMS. Top quarks are produced in pairs from proton-proton collisions at center of mass energy of 13 TeV. Final states with same-sign dilepton, trilepton, and tetralepton are considered. Feasibility of the neutrino mass between 20 and 100 GeV at the CMS Run-2 condition is investigated.

Keywords:

Neutrino, Top, CMS

B2.07

Search for long-lived particles using HCAL timing at CMS

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Abstract:

Long-lived particles are predicted in many BSM models. If they are produced at the LHC, they can travel a considerable distance before decaying into visible particles and leave a signal of displaced non-prompt jets. A signal of this nature can be detected using displaced vertices and/or the timing information. Recently, there was an attempt to detect these decay patterns using the timing capabilities of the CMS electromagnetic calorimeter(ECAL). With the Phase1 upgrade to the hadronic calorimeter(HCAL), we can take advantage of its timing measurements to extend the sensitivity to such particle searches. We report the feasibility of using HCAL timing in the context of searching for an LLP model with large missing energy and delayed jets.

Keywords:

long-lived particles, CMS, HCAL, timing

B2.08

Studies of efficiencies and scale factors in monophoton final state for dark matter search at CMS

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Abstract:

The production of events containing photons with large transverse momentum and having large missing transverse momentum at the CERN LHC is sensitive to physics beyond the standard model (SM). At the LHC, dark matter (DM) particles (χ) can be produced in the process q-qbar→γχχ , where the photon is radiated by one of the incoming quarks. With a photon in the final state, we gain sensitivity to the production of invisible particles. In order to obtain meaningful data from the Monophoton final state, it is important to effectively eliminate background events from various processes. The background estimation mainly relies on the MC simulations, higher corrections and efficiencies. In this talk, the studies of trigger efficiency, object scale factor and higher order corrections for the DM search using monophoton final state will be presented.

Keywords:

Dark matter, Monophoton, LHC, CMS

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B2.09

Search for Long-lived Particle Using Delayed Photons with CMS

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Abstract:

Neutral particles with long lifetimes are predicted in many models of physics beyond the standard model (SM). In the supersymmetric benchmarking scenario using the gauge-mediated SUSY Breaking called the SPS8 benchmark model, pair-generated squarks and gluinos decay and produce stable and weakly interacting lightest SUSY particles, the gravitino. These decay chains are determined by the characteristics of the next-to-lightest SUSY particle (NLSP), and if the NLSP of the SPS8 model has an appropriate decay length, the photons produced will arrive at ECAL with a delay time of nanoseconds and an unusual incident angle. In this talk, the delayed photon search with 77 fb^{-1} of proton-proton collisions recorded by the CMS experiment during 2016 and 2017 will be presented.

Keywords:

LHC, delayed photon

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B3.01

The development of LAMPS starting counter

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Abstract:

Starting counter 란 입자 충돌 실험을 진행 할 때 입사 입자의 기준 시간을 정해주는 검출기이다. 두 입자 간의 충돌 이후 여러 방향으로 산란되는 파편 입자는 시간 투영 챔버(TPC)나 중성자 검출기 같이 다른 검출기들을 통하여 입자를 식별 할 수 있다. 이러한 입자 식별 과정에서 필수적인 정보가 바로 기준 시간이다. 현재 LAMPS 에서는 중이온 입자 빔(Beam)을 통하여 충돌 실험을 진행 할 예정이다. 입자 빔 내의 각각의 개별 입자의 기준 시간을 파악하기 위해서는 좋은 시간 분해능(Timing resolution)을 갖는 Starting counter를 만드는 것이 중요하다.

본 연구에서는 EJ-230 scinillator를 사용하였으며 생성된 광자를 검출하기 위하여 광전자 증배관(Photo-multiplier)과 다중 픽셀 광자 검출기 (Multi-pixel photon counter)를 사용하여 각각의 Starting counter를 제작하였다. 또한 뮤온과 아메리슘 소스를 통하여 신호를 측정하였고 DAQ 과정을 통해 시간 분해능을 비교하였다.

Keywords:

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B3.02

Development of a Barrel ToF Counter for LAMPS at RAON

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Abstract:

We are developing a Barrel ToF (BTOF) counter for LAMPS experiment at RAON. BTOF determines the timing of the outgoing particles from the target, and also defines their timing along with start counter. The BTOF consists of 48 fast timing scintillators (EJ230), with each segment being 1500 mm long, 10 mm thick and 90 mm wide. We have tested three candidates with different cross-sections of the scintillator at both ends. We have also tested various MPPCs for better light collection and timing resolution.
In this talk, we will present prototype test results and simulation results for 12C+p reactions.

Keywords:

MPPC, RAON, LAMPS, Scintillation counter

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B3.03

Development of an active-target TPC demonstrator for the study of 12C(alpha, gamma)16O reaction in stellar nucleosynthesis

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Abstract:

An active-target time projection chamber (aTPC) demonstrator has been newly developed for a precise measurement of the 12C(alpha, gamma)16O reaction relevant for stellar nucleosynthesis. The high-rate 12C beam up to 100 puA at 500 keV/u should be taken into special account in the design of the aTPC. The chamber is filled with 0.5 atm He gas. Considering the particle trajectories under the magnetic field of 2.0 T, a special readout pad configuration was designed. For the amplification of the drift electron signals, the several high-end technologies such as GEM, uPIC, and TH-GEM are being considered. In this talk, we will discuss the expected high-rate performance of the aTPC in the commissioning experiment to be conducted at KOMAC, based on the Geant4 simulation results.

Keywords:

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B3.04

Single-photoelectron response of MCP-PMT and MPPC for the LEPS2 aerogel Cherenkov detector

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Abstract:

We have been developing a large array of 30 aerogel Cherenkov counters (AC1) for K/pi separation in the lab angles between 40 and 50 degrees. The AC1 should be very compact and works properly against a strong magnetic field of 1 T. We will use fine-mesh PMTs for 25 counters, while for the rest we need to use different types of the photosensor because of the limited space. The Multi-Pixel Photon Counter (MPPC) and Multi-Channel Plate (MCP) photomultiplier are considered as good candidates. We present the single-photoelectron response of the MPPC and MCP-PMT with the bench test and Geant4 simulation results.

Keywords:

B3.05

Ξ_c^0 production in p+Pb collisions at √sNN = 5.02 TeV

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Abstract:

Studying charmed-baryon production could play an important role in the investigation of strongly interacting matter at extreme temperatures and densities in heavy ion collisions because heavy quarks pass through the entire evolution of the hot medium. The measurement in proton–nucleus collisions is crucial to disentangle cold nuclear matter effect from the effects related to the formation of the Quark Gluon Plasma. In this study, the Ξ_c^0 is reconstructed via the semileptonic channel $\Xi_c^0 \rightarrow \Xi^-$ e+ ν_e (and charge conjugates) using the ALICE detector. The first measurement ofthe Ξ_c^0 nuclear modification factor R_{pPb} will be presented. Also, this study will provide charmed baryon per meson ratio which is sensitive to the hadronisation mechanism in particular to the production of baryons.

Keywords:

Heavy Ion Collisions, Quark Gluon Plasma, Charmed Baryon, ALICE

Ξc0 and Ξc+ production in pp collisions at 13 TeV

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Abstract:

The high-collision energies available at the LHC allow for an abundant production of heavy quarks (charm and beauty), which are sensitive probes for investigating the properties of the Quark-Gluon Plasma (QGP) formed in relativistic heavy-ion collisions. Due to their large masses, they are produced in initial hard parton scattering processes on a timescale shorter than the QGP formation time and experience the whole system evolution. There have been extensive researches regarding the production of charm mesons in order to investigate the interactions of charm quarks with the QGP constituents and the transport properties of the medium. The measurement of charm-baryon production, and in particular the baryon-to-meson production ratios, provides unique information on hadronisation mechanisms, constraining the role of coalescence and testing the universality of the fragmentation function. Measurements of charm-baryon production in pp collisions are important to set up a benchmark for Pb-Pb collisions and provide essential tests of pQCD calculations and models of charm-hadronisation process.
In this presentation, the pT differential cross section of the Ξ0c baryon measured by the electronic decay channel Ξc0→Ξ−e+ν and by the hadronic decay channel Ξc0→Ξ−π+ and Ξc+ baryon measured by the hadronic decay channel Ξc+→Ξ−π+π+ (and its charge conjugate) in pp collision will be shown. The charmed baryon-to-meson ratio Ξc0,+/D0 and the charmed baryon-to-baryon ratio Ξc0,+/Λc+ will be discussed and compared with model predictions. The decay-branching ratio of Ξc0 between the electronic and hadronic decays will be reported.

Keywords:

heavy-ion collisions, charm-baryon

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B3.07

J/psi near Tc

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Abstract:

We calculate the mass shift and thermal decay width of the J/ψ near the QCD transition temperature Tc by imposing two independent constraints on these variables that can be obtained first by solving the Schrödinger equation and second from the QCD sum rule approach. While the real part of the potential is determined by comparing the QCD sum rule result for charmonium and the D meson to that from the potential model result, the imaginary potential is taken to be proportional to the perturbative form multiplied by a constant factor, which in turn can be determined by applying the two independent constraints. The result shows that the binding energy and the thermal width becomes similar in magnitude at around T=1.09Tc, above which the sum rule analysis also becomes unstable, strongly suggesting that the J/ψ will melt slightly above Tc.

Keywords:

J/psi, critical temperature

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B4.01

KNO Overview

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Abstract:

The Korean Neutrino Observatory (KNO) was proposed as a next generation neutrino detector in Korea. The KNO will be a powerful neutrino telescope to observe neutrinos of astronomical origins such as sun, supernova, galaxies, and many others providing a new window for multi-messenger astronomy. The KNO will also provide the opportunity to fully probe the leptonic CP violation, neutrino mass ordering, and non-standard neutrino interactions utilizing neutrino beam from J-PARC. In this presentation, we report the status of ongoing effort to realize the project and the prospect for KNO.

Keywords:

KNO, supernova, multi-messenger astronomy

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B4.02

Neutrino Observatories around the World

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Abstract:

The dream of observing our Universe through neutrinos is rapidly becoming a reality. Followingthe first glimpse of the prospects of this field through the observation of neutrinos from Supernova SN1987A, the field is now in the midst of a revolution following the discovery of a diffuse high-energy astrophysical neutrino flux and the detection of neutrinos in direction of an extragalacticsource. Latest developments in field of neutrino astronomy will be reviewed and prospects withcurrent and future detectors accessed. This presentation will review Neutrino Observatories around the world. Recent results and priorities for future measurements will be discussed.

Keywords:

KNO, Neutrino Astronomy, IceCube, KM3NeT, Hyper-K

Studies of High-Energy Astrophysical Neutrinos with KN

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Abstract:

Cosmic-ray protons (CRp) are ubiquitous in astrophysical environments. They are known to be accelerated via various processes, involving shock waves, turbulence, magnetic reconnection, and etc. These CRp can produce high-energy neutrinos through inelastic collisions with background protons and photons. In this talk, we present possible astrophysical sources of high-energy neutrinos in the energy range of 1 to 100 GeV, and discuss the possibility of detecting such neutrinos with the KNO (Korean Neutrino Observatory).

Keywords:

high-energy neutrino

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B4.04

Neutrinos from supernovae and compact objects

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Abstract:

The successful detection of neutrinos and gravitational waves from astrophysical sources has shown that the era of multi-messenger astronomy has begun and will be one of the most important topics in astronomy and astrophysics. I will review the astrophysical neutrinos from supernovae and compact objects, and how they can be observed with current or planned neutrino telescopes, such as Korean Neutrino Observatory.

Keywords:

Astrophysical neutrinos, gamma-ray burst, supernova

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B5.01

Correlation between symmetry and phase transition temperature of VO_2

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Abstract:

A vanadium dioxide (VO_2), a prototypical example of strongly correlated oxide, exhibits the insulator-metal transition (IMT). In the structural aspect, this phase transition is associated with a high asymmetric VO_6 octahedron to a high symmetric one during the transition. Therefore, the IMT characteristics of VO_2 can be described in terms of the octahedron symmetry.
In this presentation, we show the correlation between the local structure symmetry and IMT characteristics of VO_2 films grown on Al_2O_3 substrates with various orientations (c-, a- and m-plane). The VO_2 film grown on m-plane (c-plane) Al_2O_3 shows the low (high) asymmetric octahedron at room temperature and the lowest (highest) IMT temperature. Furthermore, temperature-dependent Raman spectra revealed that the low asymmetric octahedron for the VO_2 film grown on m-plane Al_2O_3 quickly turned into symmetry, resulting in the structural phase transition at low temperature. This may because the low symmetry reduced the activation energy for IMT by decreasing thermodynamic energy. These results prove that structural symmetry plays a critical role in tuning the IMT characteristics of VO_2.

This work is supported in part by NRF-Korea (2018R1D1A1B07045663).

Keywords:

metal-insulator phase transition, VO2, VO6 octahedron symmetry

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B5.02

First-principles investigation of strain and oxygen vacancy formation in titanates

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Abstract:

Mechanical strain impacts on defect formation and doping property conjunction with changes of physics and chemistry in host material. The effects of strain can be more pronounced in low dimensional environments where strains accumulate (e.g., heterogeneous interfaces and grain boundaries), because the larger strains, the larger changes in defect formation. In this talk, we present first-principles calculations to address how mechanical strains impact on the oxygen vacancy formation in 2D and 3D titanates. Our results indicates that change in the electronic features (e.g., band gap energy) strongly correlates with the vacancy formation in the oxides.

Keywords:

first-principles calculations, oxygen vacancy, strain

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B5.03

Enhanced Hund's metallicity by van Hove singularity in three-band systems

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Abstract:

Hund's metallicity refers to strong paramagnetic fluctuations and bad metallic behavior. The low-temperature response of the Hund's metal is an intriguing topic, considering its potential relevance to the superconductivity. We perform systematic dynamical mean-field calculations for a three-band model combined with electronic structure accompanying van Hove singularity. Targeting low temperatures, we employ the exact diagonalization as an impurity solver. We find that the van Hove singularity significantly enhances Hund's metallicity at low temperatures. We discuss its origin by comparing the results to the Bethe lattice counterpart.

Keywords:

Hund's metal, Dynamical mean-field theory

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B5.04

Understanding the superconductivity in infinite-layer nickelate: 2B(band) or not 2B(band)?

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Abstract:

A long quest for non-Cu-based but cuprate-like superconductivity has recently ended in a success by synthesizing an infinite-layer thin film $Nd_{1-x}Sr_xNiO_2$ whose Tc~9-15K [1]. In the first part of this talk, I will try to review the electronic structure and magnetic property of this recently-reported material after presenting a brief summary of historical background. Not surprisingly, the similarities with and differences from cuprates has been a focus of discussion in literature. Roughly speaking, the suggested theoretical pictures can be categorized into either one-band or two band model. Given that the two-band theory emphasizes its distincitve feature from cuprate, the key question can also be casted as 'two-band physics or not?' In the second part, I will present our own results. Remarkably, we first found that magnetic interactions in this material become two-dimensional by hole doping [2]. While the undoped $NdNiO_2$ has the sizable out-of-plane interaction contrary to the cuprate case, hole dopings strongly suppress it. This two-dimensionality is maximized at the hole concentration ~ 0.25 [2]. Simultaneously, however, we also found the intriguing multi-band nature in this material [3]. By performing the DMFT (dynamical mean-field theory) calculation of quarter-filled two-orbital Hubbard model, we identify three different correlated metal regimes; one of which stems from the proximity to a Mott insulator and the other two from the effect of Hund's coupling being away from Mottness. This study establishes Hund's metallicity and further a group of metals exhibiting spin-orbital separation in the two-orbital model. Our picture provides a useful insight to the physics of the infinite-layer nickelates [3].

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Keywords:

Nickelate superconductivity, Hund metal

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B6.01

Topological magnons and magnon-polarons in 2D magnets

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Abstract:

Topological magnons have emerged as a new research area in magnetism and spintronics due to their fundamental interest as well as practical utilities such as back-scattering-free spin-transport channels. In particular, recently discovered two-dimensional magnets have been shown to support a variety of new topological phases of magnons and their cousins. In this talk, we will discuss two illuminating examples in this research direction. The first one is a magnonic topological insulator realized in a two-dimensional ferromagnet such as CrI_3, which is shown to give rise to the thermal Hall effect via the finite Berry curvature of magnons [1]. The second one is a topologically non-trivial magnon-phonon hybridized mode called a magnon-polaron, which can be realized in a two-dimensional antiferromagnet such as $MnPS_3$ via generic magnetoelastic coupling [2]. The former and the latter concerns the SU(2) and the SU(3) topology of quasiparticle bands, respectively. The talk will be concluded with a future outlook.

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[2] S. Zhang, G. Go, K.-J. Lee, S. K. Kim, "SU(3) Topology of Magnon-Phonon Hybridization in 2D Antiferromagnets," Phys. Rev. Lett. 124, 147204 (2020)

Keywords:

magnon, phonon, 2D magnet

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B6.02

Majorana-mediated spin transport without spin polarization in quantum spin liquids

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Abstract:

Transport phenomena of spin excitations have attracted considerable attention in condensed matter physics. In insulating magnets, spin excitations are carried by magnons in the presence of a magnetic order. On the other hand, it was suggested that the spin transport can be also governed by spinons, which are elementary excitations fractionalized from spins in one-dimensional Heisenberg systems. The Kitaev quantum spin model is another candidate of the magnetic systems associated with fractional quasiparticles. In this model, the ground state is exactly shown to be a quantum spin liquid and the elementary excitations are described by two kinds of quasiparticles: itinerant and localized Majorana fermions. In the present study, we investigate the spin transport through the Kitaev spin liquid and discuss the role of the Majorana fermions for the spin transport. Here, we examine the real-time dynamics of the local spin moments in the Kitaev model on a honeycomb lattice with open boundary conditions. We apply the magnetic field pulse on the left edge and calculate the time evolution using the time-dependent mean-field theory and exact diagonalization. In the presence of the static magnetic field in the bulk, the magnetic excitation triggered by the pulse propagates to the right side. On the other hand, we find that this propagation occurs even in the absence of the magnetic field in the bulk without spin polarization. We clarified that this is attributed to the itinerant Majorana fermions [1]. We also discuss the effect of the Heisenberg interaction and extension to the S=1 Kitaev model [2] on this phenomenon.

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Keywords:

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B6.03

Majorana bound states vs. spin waves in Kitaev candidate materials

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Abstract:

The Kitaev honeycomb magnet realizes an Abelian spin liquid ground state that can be driven to a non-Abelian spin liquid upon breaking time-reversal symmetry, e.g., by applying a magnetic field [1,2]. Using Raman spectroscopy we show that in the candidate material □-RuCl3 a continuum of fractionalized, deconfined Majorana fermions exists together with conventional spin-wave excitations [3,4,5]. By applying magnetic fields, a new mode emerges from the continuum in the vicinity of quantum criticality, signaling the formation of a new field-induced state. We also comment on the effect of magnetic dilution [6], which systematically suppresses non-Kitaev interactions, and thereby reveals a continuum mainly comprised of fractionalized excitations.
Work supported by the Institute for Basic Science (Grant No. IBS-R009-Y3) and the National Research Foundation (NRF) of Korea (Grant no. 2020R1A2C3012367).

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Keywords:

B6.04

Theory of Two-Dimensional Nonlinear Spectroscopy for the Kitaev Spin Liquid

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Abstract:

Unambiguous identification of fractionalized excitations in quantum spin liquids has been a longstanding issue in correlated topological phases. Conventional spectroscopic probes, such as the dynamical spin structure factor, can only detect fractionalized excitations' composites, equivalent to a superposition of single spin flips, leading to a broad continuum in energy. Lacking a clear signature in conventional probes has been the biggest obstacle in the field. In this work, we theoretically investigate what kinds of distinctive signatures of fractionalized excitations can be probed in two-dimensional nonlinear spectroscopy by considering the exactly solvable Kitaev spin liquids. We demonstrate the existence of some salient features of the Majorana fermions and fluxes in two-dimensional nonlinear spectroscopy, which provide crucial information about such excitations.

Keywords:

quantum spin liquid, nonlinear optical susceptibility, Kitaev model, terahertz spectroscopy

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B7.01

Electron-phonon coupling and its role for superconductivity in twisted graphene layers

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Abstract:

Magic-angle twisted bilayer graphene (MA-TBG) has been drawing a lot of attention for its superconducting and insulating phases derived from flat bands. We studied electronic structures, phonon dispersions, and electron-phonon coupling strength in MA-TBG based on atomistic calculations, showing that the electron-phonon coupling in MA-TBG is strong enough to produce experimentally observed superconductivity [1]. We also studied electronic structures of twisted double bilayer graphene (TDBG), showing that flat bands can be produced in TDBG by applied electric fields [2]. Now, we investigate phonon dispersions and electron-phonon coupling strength in TDBG based on atomistic calculations, and compare electron-phonon coupling in MA-TBG and TDBG from an atomistic point of view. Based on these results, we discuss role of electron-phonon interaction for superconductivity in twisted graphene layers. This work was supported by NRF of Korea (Grant No. 2020R1A2C3013673) and KISTI supercomputing center (Project No. KSC-2019-CRE-0195). Y.W.C. acknowledges support from NRF of Korea (Global Ph.D. Fellowship Program NRF-2017H1A2A1042152).
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Keywords:

electron-phonon interaction, superconductivity, twisted bilayer graphene, twisted double bilayer graphene

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B7.02

Enhanced superconductivity in the vicinity of CDW quantum critical points in chalcogenide superconductors Pd-intercalated $TaSe_2$

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Abstract:

We present doping and pressure induced optimization of superconductivitiy, particularly focusing on tuning of electronic states in Pd-intercalated $TaSe_2$ Pd_xTaSe_2, in which superconducting transition is optimized from 0.14 ($TaSe_2$) to 3.1 K (x=~0.08) with simultaneous suppression of a commensurate charge density wave (CDW) state. We found that the Pd intercalation can involve a Lifshitz transition in the underlying electronic states at normal states without CDW ground states, which seems to be useful for increasing density of states (DOS) and electron-phonon coupling and in turn two band BCS superconductivity at low temperatures, arbeit its relative importance to enhace superconductivity is not clear yet. Furthermore, an increase of DOS in the vicinity of a doping induced collapse of a commensurate CDW state can certainly help increaseing DOS and opmizing superconducting transition. Although it was not clear with intercalation, with tuning of pressure, we found that a second order quantum phase transition of a CDW transtion can occur around 22 GPa and fluctuating CDW ground states can institate to enhance the superconductivity up to 8.3 K. With systematic Raman and transport results we discuss how a CDW quantum crticality and related fluctuation can be involved in boosting up superconductivity with pressure.

Keywords:

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B7.03

On the origin of charge density waves and superconductivity in Pd-intercalated 2H-$TaSe_2$

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Abstract:

Single crystals of the pristine and Pd-intercalated 2H-$TaSe_2$ have been studied by means of ^{77}Se nuclear magnetic resonance (NMR). The doping and temperature dependence of the ^{77}Se spectrum unravels that the local periodic lattice distortions (PLDs) drive the commensurate charge density wave (CDW) transition, thereby evidencing that a strong coupling CDW mechanism is at play in 2H-$TaSe_2$. The low-energy spin excitation spectrum probed by the ^{77}Se spin-lattice relaxation rate $1/T_1$ is governed by a pseudogap behavior, which becomes stronger with Pd-doping along with superconductivity. Our data suggest that the commensurate CDW and superconducting transition temperatures are essentially determined by the competition between the locally correlated PLDs and the pseudogap in the normal state.
We propose that the commensurability of the CDW is the key to understanding the interplay between charge and superconducting degrees of freedom.

Keywords:

Transition metal dichalcogenide, Nuclear Magnetic Resonance

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B7.04

Superconductivity emerging from a stripe charge order in $IrTe_2$ nanoflakes

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Abstract:

Superconductivity in the vicinity of a competing electronic order often manifests itself with a superconducting dome, centred at a presumed quantum critical point in the phase diagram. This common feature, found in many unconventional superconductors has supported a prevalent scenario that fluctuations or partial melting of a parent order are essential for inducing or enhancing superconductivity. Here we present a contrary example, found in $IrTe_2$ nanoflakes of which the superconducting dome is identified well inside the parent stripe charge ordering phase in the thickness-dependent phase diagram. The coexisting stripe charge order in $IrTe_2$ nanoflakes significantly increases the out-of-plane coherence length and the coupling strength of superconductivity, in contrast to the doped bulk $IrTe_2$. These findings clarify that the inherent instabilities of the parent stripe phase to other hierarchical stripe phases are sufficient to induce superconductivity in $IrTe_2$ without its complete or partial melting. Our study highlights the thickness control as an effective means to unveil intrinsic phase diagrams of correlated vdW materials.

Keywords:

Superconductivity, Van der Waals materials, Charge ordering

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B7.05

Yu-Shiba-Rusinov states in the unconventional superconductor $FeTe_{0.55}Se_{0.45}$

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Abstract:

By using scanning tunneling microscopy (STM) we find and characterize dispersive, energy symmetric in-gap states in the iron-based superconductor $FeTe_{0.55}Se_{0.45}$, a material that exhibits signatures of topological superconductivity, and Majorana bound states at vortex cores or at impurity locations. We use a superconducting STM tip for enhanced energy resolution, which enables us to show that impurity states can be tuned through the Fermi level with varying tip-sample distance. We find that the impurity state is of the Yu-Shiba-Rusinov (YSR) type, and argue that the energy shift is caused by the low superfuid density in $FeTe_{0.55}Se_{0.45}$, which allows the electric field of the tip to slightly penetrate the sample. We model the newly introduced tip-gating scenario within the single-impurity Anderson model and find good agreement to the experimental data.

Keywords:

scanning tunneling microscopy, iron-based superconductor FeTe0.55Se0.45, Yu-Shiba-Rusinov states

Berezinskii-Kosterlitz-Thouless transitions in easy-plane spin-triplet superconductor

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Abstract:

As the spin-triplet superconductivity arises from the condensation of spinful Cooper pairs, spin ordering is an essential feature. Hence the possibility arises for the Berezinskii-Kosterlitz-Thouless (BKT) phase transitions in not only the charge sector but also the spin sector in a 2d easy-plane spin-triplet superconductivity. However, it turns out that there are actually three possible BKT transitions, involving the unbinding of, respectively, the conventional vortices, the merons and the half-quantum vortices with vorticity in both the charge and the spin current. We show how all the transitions can be characterized by the relation between the voltage drop and the spin-polarized current bias and each phase by its characteristic Josephson coupling.

Keywords:

spin-triplet superconductivity, Berezinskii-Kosterlitz-Thouless (BKT) phase transition, spin superfluid transport, unconventional Josephson coupling

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B8.02

Exact three-colored quantum scars from geometric frustration

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Abstract:

Nonequilibrium properties of quantum materials present many intriguing properties, among them athermal behavior, which violates the eigenstate thermalization hypothesis. Such behavior has primarily been observed in disordered systems. More recently, experimental and theoretical evidence for athermal eigenstates, known as “quantum scars,” has emerged in nonintegrable disorder-free models in one dimension with constrained dynamics. In this Rapid Communication, we show the existence of quantum scar eigenstates and investigate their dynamical properties in many simple two-body Hamiltonians with “staggered” interactions, involving ferromagnetic and antiferromagnetic motifs, in arbitrary dimensions. These magnetic models include simple modifications of widely studied ones (e.g., the XXZ model) on a variety of frustrated and unfrustrated lattices. We demonstrate our ideas by focusing on the two-dimensional frustrated spin-1/2 kagome antiferromagnet, which was previously shown to harbor a special exactly solvable point with “three-coloring” ground states in its phase diagram. For appropriately chosen initial product states—for example, those which correspond to any state of valid three-colors—we show the presence of robust quantum revivals, which survive the addition of anisotropic terms. We also suggest avenues for future experiments which may see this effect in real materials.

Keywords:

Eigenstate thermalization, Frustrated magnetism, Quantum scars, Spin dynamics, Kagome lattice, Nonequilibrium systems, Strongly correlated systems

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B8.03

Hidden phases born of a quantum spin liquid: Application to pyrochlore spin ice

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Abstract:

Quantum spin liquid (QSL) has been extensively studied as a deconfined phase of matter with its emergent gauge structure. The phase transitions out of QSLs are commonly argued by the violating the gauge invariance, Higgs transitions separating deconfined vs Higgs phases. However, the fate of QSL between them beyond the perturbative limit is a puzzling problem. Here, we develop a new formalism of interacting fractionalized quasiparticles to study the evolution of QSLs. Applying to the pyrochlore ice, it turns out that the intermediate hidden phases exist, which are not smoothly connected to the limits, deconfined vs Higgs phases. We discuss experimental identifications and the relevant numerical reports supporting our analysis.

Keywords:

Quantum spin liquid, Higgs transition

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B8.04

Quantum geometric characterization of anomalous Landau levels of isolated flat bands

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Abstract:

The Onsager's semi-classical quantization rule is a powerful tool for predicting the Landau level structure.
However, its validity is questionable in flat band systems.
In this work, we show that the Landau levels of an isolated and topologically trivial flat band show anomalous behavior with spreading into the gapped region of the original band structure, which is contradictory to the prediction based on the Onsager's rule.
First, we show that the upper and lower bounds of such Landau level spreading (LLS) are determined by a quantum geometric quantity, known as the Wilczek-Zee connection.
Second, we demonstrate the role of symmetry on the Landau level spreading of flat bands.
Our general mechanism for the LLS of flat band reveals the quantum geometric aspects of flat-band systems that go beyond the conventional idea based on the Berry curvature.

Keywords:

Flat band, Landau level, Berry phase, Semi-classical theory

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B8.05

Observation of topological surface states in antiferromagnetic Sm-doped Bi_2Te_3

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Abstract:

One essential point in topological insulators (TIs) is the time-reversal symmetry. The symmetry can be broken by magnetic ordering or magnetic perturbation such as magnetic impurities. Interestingly, the interplay between magnetism and topology can induce exotic quantum phenomena in condensed matter physics, one of which is that the ferromagnetic ordering in TIs shows quantum anomalous Hall effect with losing TI phase due to the broken time-reversal symmetry. Recently, novel antiferromagnetic TI phase has been to be of interest as one of the classes of topological matters because the antiferromagnetic ordering can not disturb the topologically nontrivial states without time-reversal symmetry [1]. Experimentally, our previous works showed that the antiferromagnetic order observed in Ce- and Gd-doped Bi_2Se_3 and Bi_2Te_3 samples are strongly competing with topological surface states [2-4].
However, in this work, we find the signature of the topological surface state in an antiferromagnetic ordered Sm-doped Bi_2Te_3. We fabricate single crystals of $Sm_xBi_{2-x}Te_3$ (x = 0.004, 0.010, 0.025). The magnetic data reveal that the antiferromagnetic phase transition occurs at T_N = 3.3 K for x = 0.025. The transport measurements show the multi-band Hall effect with two conduction channels and anisotropic Shubnikov-de Haas oscillations. We observe the signature of nontrivial topological surface states with surface electron density $n_s = 7.9 \times 10^{11}$ cm^{-2} and its high mobility m_s = 2,200 cm^2/Vs, compared to $n_b = 2.0 \times 10^{19}$ cm^{-2} and m_b = 2.3 cm^2/Vs for bulk electrons. From the analysis of Shubnikov-de Haas oscillations in x = 0.025 with antiferromagnetic order, we obtain p Berry phase, inferring a linear energy dispersion of topological surface states. These experimental results suggest a possible topological phase in a bulk antiferromagnet of $Sm_xBi_{2-x}Te_3$.

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[3] H. S. Lee et al., Appl. Phys. Lett. **107**, 182409 (2015)
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Keywords:

Topological insulator, Topological surface state, Antiferromagnetic topological insulator, Antiferromagnetism

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B8.06

The Orbit topology of Dirac semimetal determined from Magnetic Quantum Oscillation

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Abstract:

Dirac fermions in graphene were revealed by the non-trivial p Berry phase observed in magnetic quantum oscillations (MQOs), [1] which makes the p phase in MQOs a signature of Dirac fermions. Subsequently, researchers have revealed Dirac fermions in topological insulators, [2] which possess Dirac cones in their surface electronic structures. [3] With the emergence of Dirac and Weyl semimetals, which have bulk electronic states that effectively manifest the Dirac and Weyl fermions, [4] the p phase in MQOs have been widely used to detect the topology of orbits. However, many previous researches have relied on the single-orbit Lifshiftz–Kosevich formula, which overlooks the significant effect of degenerate orbits on MQOs based on the specific symmetry of a material. This report demonstrates how spin-degenerate orbits affect the phases in the MQOs of $NbSb_2$, which has time-reversal and spatial-inversion symmetry. By varying the direction of a magnetic field, an abrupt p phase shift was observed in the MQOs due to the angle-dependent interference between the spin-degenerate orbits. The orbit topology was also analysed using the p phase shift, and it was found that the p phase shift occurs when the cyclotron mass is a half-integer multiple of the electron mass. To the best of our knowledge, this is the first time that the orbit topology has been determined for a Dirac semimetal considering degenerate orbits. Not only will our approach be useful to analyse the MQOs of Dirac semimetals, but it will also provide new perspectives for analysing the MQOs of materials with strong spin-orbit coupling and degenerate orbits.

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Keywords:

Magnetic quantum oscillation, Orbit topology, Dirac semimetal, Spin-degenerate orbit

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B8.07

Strong correlation between the electronic and magnetic properties in the Dirac semimetal of $Ti_xZr_{1-x}Te_5$

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Abstract:

$ZrTe_5$ is known as a Dirac semimetal (DSM) predicted to possess a topological phase transition to a weak topological insulator (WTI) or strong topological insulator (STI). Since the bandgap is sensitively affected by the volume expansion ratio, it can be close or open, depending on the crystal volume. In order to control the crystal volume, we chemically dope the isovalent atom of Ti to $ZrTe_5$ with the nominal composition of x=0, 0.1, 0.2 in $Ti_xZr_{1-x}Te_5$. The hallmark of $ZrTe_5$ is that the electrical resistivity shows a maximum at a certain temperature, T_p due to the temperature-dependent band shift. The x=0 single crystal shows T_p ~ 135 K, which is consistent with previous results. As x increases to 0.2, T_p decreases systematically down to 89 K. The Shubnikov-de Haas and de Haas-van Alphen quantum oscillations are clearly observed in all the crystals. From the temperature- and angle-dependent oscillations, we find that the Fermi surface is contracted as x increases. Interestingly, the magnetic susceptibility exhibits a minimum near T_p, which is also dependent on x. From the careful analyses of the electrical and magnetic properties, it seems that the Dirac fermions play an important role in the strongly temperature-dependent susceptibility.

Keywords:

Topological material, Magnetism, Dirac semimetal

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B8.08

Hidden magnetic state of kagome-lattice $Co_3Sn_2(S,Se)_2$ single crystals

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Abstract:

A kagomé 2D lattice, the trihexagonal tiling in geometry, has been predicted retaining remarkable topological quantum properties. In detail, both spin frustration (or fluctuation) and non-coplanar magnetic structure of the kagomé lattice are expected to enrich its physical properties[1]. Particularly, $Co_3Sn_2S_2$ with magnetic kagomé sublattices of Co atoms possesses exotic topological properties such as magnetic Weyl phase and large intrinsic anomalous Hall conductivity[2,3]. The spin frustration and the non-coplanar magnetic structure have been reported in a few neutron studies, and there is one report to propose a hidden magnetic phase, which has not been understood yet[4].

To clarify the hidden magnetic phase in temperature and magnetic field, we have tuned the distance between kagomé layers by substituting Se for S in $Co_3Sn_2S_2$, while retaining its magnetism. We have grown high-quality single crystals of $Co_3Sn_2S_{2-x}Se_x$ (x = 0, 0.26, and 0.86). According to electron probe microanalysis measurement, the S atoms are homogenously replaced by the Se atoms. For the pristine $Co_3Sn_2S_2$ (x = 0), the Curie temperature T_C = 181.6 K is observed with a magnetic moment ~0.33 m_B/Co at 2 K along the c_{hex}-axis, which is the easy magnetization direction, in consistent with previous reports[3]. With increasing x, the lattice parameter increases and the Curie temperature decreases. In the remanent magnetization versus temperature curve, we observe another magnetic transition at T_{com} = 149.5, 134.7, and 90.2 K for x = 0, 0.26, and 0.86, respectively. In this study, we mostly discuss this hidden magnetic state by designing possible spin structures taking its symmetry into account, and further discuss how this hidden magnetic state evolves with increasing x.

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Keywords:

magnetism, Co3Sn2S2, kagome lattice

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B9.01

Theoretical investigation on various color centers in hexagonal boron nitride

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Abstract:

Using the first-principles calculations, we investigate the structural, electronic, and optical properties of hexagonal boron nitride (hBN) with various edge structures and point defects. We find that the armchair edge is the most stable edge structure, while the relatively-less-stable zigzag counterpart may be stabilized by the 5-7 reconstruction. We further explore the dependencies of such edge reconstruction on the external applied electric fields and shear stresses. On the other hand, there are a lot of point defect structures that can be created by various experimental conditions, such as oxygen plasma treatment. We evaluate the formation energies of edges and defects to determine the possibility of their existence while considering their charged states with the pertinent correction for spurious long-range Coulomb interaction due to the periodic image charges. Our electronic structure calculations based on GW approximation and hybrid exchange-correlation functional show that both edge structures and point defects can be utilized as color centers emitting lights with various colors. We find that edge configurations exhibit specific gap states corresponding to luminescence from ultraviolet (UV) to near UV (NUV) regions observed in experiments. Contrarily, it is found that different point defects can generate different gap states corresponding to broad luminescence in the visible region.

Keywords:

hBN, color centers, edge structures, point defects

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B9.02

Investigation of growth and defects of hBN using atomic resolution TEM

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Abstract:

Atomic resolution TEM enables in-depth studies of growth mechanism, defects, and the structure of atomically-thin two dimensional hBN. I will present a growth mechanism study of 2D hBN synthesized using chemical vapor deposition. The formation of intertwined double-spiral few-layer hBN is driven by screw dislocations located at the antiphase boundaries of monolayer domains. We also found that the occurrence of shear strains at the boundaries of merged spiral islands is dependent on the propagation directions of encountering screw dislocations and reported the strained features. This study unveils the double-spiral growth of 2D h-BN multilayers and the creation of a shear strain band at the coalescence boundary of two h-BN spiral clusters. In addition, I will present atomically sharp twin boundaries at AA′/AB stacking boundaries in chemical vapor deposition–synthesized few-layer hBN. We found that the twin boundary is composed of a 6′6′ configuration, showing conducting feature with a zero bandgap. Furthermore, the formation mechanism of the atomically sharp twin boundaries is suggested by an analogy with stacking combinations of AA′/AB based on the observations of extended Klein edges at the layer boundaries of AB-stacked hBN.

Keywords:

growth mechanism, defect, hBN, TEM

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B9.03

Deep ultraviolet light emission from atomically thin hexagonal boron nitride van der Waals heterostructures

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Abstract:

Two-dimensional (2D) van der Waals materials and their heterostructures, such as graphene, and transition metal dichalcogenides (TMDC) emerge as key materials for the next-generation nanoscale optoelectronics for lighting, next-generation display modules, and quantum information processing. To date, however, limited color emission spectrum (< 2 eV) and lack of efficient up-conversion strategy in van der Waals materials are key challenges for developments of practical 2D material-based optoelectronics in the visible range.

Color centers in solids are responsible for the unique optical properties and developments of nanoscale optoelectronic devices in the broadband spectrum. Especially, natural and artificial color centers in wide bandgap semiconductors are considered the key architectures for ultraviolet (UV) nanophotonics, bio-sensing, high precision metrology, and single photon source. Thus, creation and manipulation of color centers in wide bandgap van der Waals materials such as hexagonal boron nitride (hBN) are very important for UV-visible optoelectronics developments. Here, I will present the deep UV (220~390nm) electroluminescence (EL) and broadband photodetection from hBN heterostructures. Broad UV EL in hBN are attributed to the electric field induced artificial color centers, which are vacancy-related defects with an excitonic mode in the intrinsic band gap of hBN (> 6.4 eV). These results demonstrate the promise of hBN-based van der Waals heterostructures for light sources and optoelectronics in the UV to the visible regime.

Keywords:

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B10.01

Annealing effect on the magnetic properties due to the structural change of Mn_3Ga thin films

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Abstract:

Heat treatment is the most common method to change hardness, crystallinity, and phase in metallurgy[1,2]. Among those various effects of heat treatment, we report the annealing effect on the magnetic properties of Mn_3Ga thin films. Mainly, we focus on the structural phase transition in thin films due to the annealing process with relatively low temperatures. Two different phases of Mn_3Ga thin films were grown by RF/DC magnetron sputtering method on MgO (001) substrate. One is the $D0_{22}$ tetragonal ferrimagnetic phase Mn_3Ga, and the other is the disordered-$L1_2$ cubic antiferromagnetic phase Mn_3Ga. After deposition, the thin films were annealed at different temperatures (200, 300, 400, 500, and 600^{o}C) and Ar pressures (10^{-3}, 10^{-1}, and 10^{3} Torr). As a result, the $D0_{22}$ tetragonal ferrimagnetic phase Mn_3Ga is transformed to $L1_0$ cubic ferromagnetic phase MnGa, while retaining perpendicular magnetic anisotropy, whereas the disordered-$L1_2$ cubic antiferromagnetic phase Mn_3Ga is changed to ordered-$L1_2$ cubic ferrimagnetic phase Mn_3Ga with no magnetic anisotropy. We discuss the structural and magnetic properties to unveil the annealing mechanism in the Mn-Ga phase. These results will provide a better understanding of the magnetic phase transition with the structural phase transition in the composition sensitive Heusler thin films.
Keyword: Heusler materials, annealing effect, magnetic thin film, phase transition
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Keywords:

Heusler materials, annealing effect, magnetic thinfilm, phase transition

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B10.02

Scaling of anomalous Hall effect in perpendicular magnetic CoSiB/Pt multilayers

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Abstract:

Anomalous Hall effect (AHE) in a marginally bad metal regime($\sigma_{xx}\sim$10^4 Ω^{-1}cm^{-1}) is investigated in perpendicular magnetic CoSiB/Pt multilayers. Both the conventional power-law scaling, $\rho_{xy}^{AH} \propto \rho_{xx}^{\gamma}$, and the empirical scaling, $\rho_{xy}^{AH} = a'\rho_{xx0} + b\rho_{xx}^2$, appear to be invalid. The AHE resistivity of the multilayers is well fitted with a new scaling,$\rho_{xy}^{AH} = a'\rho_{xxo} + a''\rho_{xxT} + b\rho_{xx}^2$, where the skew scattering contribution is treated as the sum of two independent contributions: temperature independent impurity skew scattering, $a'\rho_{xxo}$, and temperature dependent phonon skew-scattering, a $a''\rho_{xxT}$. The fact that AHE resistivity do not match if we omit $a''\rho_{xxT}$ term and fit the data to the relation $\rho_{xy}^{AH} = a'\rho_{xxo} + b\rho_{xx}^2$, suggests that there is a significant phonon contribution to the skew-scattering in anomalous Hall resistivity in CoSiB/Pt multilayers. This is in direct contradiction to the theoretical study by Crepieux et al. [Phys. Rev. B **64**, 014416 (2001)] which predicts negligibly small phonon contribution to the skew scattering. The observed non-negligible phonon skew-scattering in AHE of CoSiB/Pt multilayers is believed to be related to the unique phonon contributions to the spin Hall angle in Pt layer [Karnad et al., Phys. Rev. B **97**, 100405 (2018)]. We find that the phonon skew-scattering parameter (a'') is positive whereas impurity skew-scattering parameter (a') and side-jump plus intrinsic parameter (b) is negative.

Keywords:

AHE , skew-scattering, side-jump, intrinsic

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B10.03

Resonant coupling between two macro-spins by acoustic phonons

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Abstract:

The coherent transfer of information between different waveform is an important ingredient of information technology as it allows transport of quantum states without loss of frequency or phase. An efficient hybridization, though, requires to reach the strong coupling regime, where the interaction rate between two collective states becomes larger than their relaxation rates. This has revived interest for insulating magnetic garnets with low magnetic and acoustic dampings. It was recently shown that the circularly polarized phonons in dielectric crystals can transfer angular momentum over millimeters due to the strong magnon phonon coupling in a dielectric spin valve system, which is composed of two yittrium iron garnet (YIG) layers on both sides of gadolium gallium garnet substrate [1]. The evidence of this coupling is the emergence of a bright and a dark collective states that can be revealed through an interference pattern in the ferromagnetic resonance signal.
In this work, we will focus on the collective behavior when the splitting between two Kittel modes is within the coupling strength. We tune the splitting either i) by applying a temperature gradient along the stack direction or ii) by varying the polar angle of an external magnetic field. We describe their mutual coupling as provided by a dissipative cavity, which represents the nearly degenerate standing acoustic shear wave mode that resonates across the whole crystal thickness. A remarkable feature in our system is that the acoustic coupling provides both the reactive and dissipative part, whose relative strength can be continuously adjusted by the frequency bias. This allows to achieve either level repulsion or level attraction depending on the parity of the acoustic mode. The long range coherent coupling by phononic angular momentum currents adds new functionalities to insulator spintronic circuits and devices.

[1]] K. An, et al., Physical Review B, 101, 060407 (2020)

Keywords:

Phonon magnon coupling, Spin transport, Circularly polarized phonons, YIG, Dissipative coupling

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B10.04

Role of non-thermal electrons in ultrafast spin dynamics of ferromagnetic multilayer

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Abstract:

Understanding of ultrafast spin dynamics is crucial for future spintronic applications. In particular, a fundamental understanding of a photoinduced demagnetization and remagnetization on a femtosecond time scale, still on much debates, remains a scientific challenge to date. We experimentally demonstrate, for for the first time, that the nonthermal electrons exist in the very early phase of the photoinduced demagnetization process, playing a key role in governing an overall ultrafast spin dynamics behavior, by means of the time-resolved reflectivity and magneto-optical Kerr effect measurement for Co/Pt multilayer film. With systematic variation of pump fluences, it is revealed that energy flow among nonthermal electrons, thermal electrons, spin, and lattice should be taken into account, where the net energy flow in and out of spin sub-system determines the overall spin dynamics behavior. At higher laser fluences, it has been found that nonthermal electrons play a key role, letting the ultrafast spin dynamics behavior be the so called type II with a slow remagnetization dynamics. We propose that the nonthermal electrons, rather neglected so far, could be one of major elements in determining the ultrafast spin dynamics.

Keywords:

Non-thermal electron, Ultrafast spin dynamics

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B10.05

Electrical detection of the inverse Edelstein effect on the surface of SmB_6

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Abstract:

Recently, SmB_6, a Kondo insulator, has been predicted to be a member of a newly classified family of strong topological insulators, topological Kondo insulators (TKIs), where the topologically protected surface states reside in the bulk Kondo band gap at low temperatures and the Fermi level is guaranteed to be inside the bulk gap. A large degree of current-induced spin polarization on the surface of SmB_6 as well as robust surface conduction have been demonstrated in various experiments, implying that SmB_6 is a strong candidate for TKIs free from bulk effect. Particularly, the Edelstein effect is one of the well-known effects involving current-induced spin polarization arising in materials with spin-momentum locking, which was reported through our previous experiment using potentiometric measurement on the surface of SmB_6. In this presentation, I will report the electrical measurement of spin current-induced charge accumulation, the inverse Edelstein effect (IEE), on the surface of single-crystal candidate topological Kondo insulator SmB_6. The dependence of the IEE signal on a bias current, an external magnetic field direction, and temperature are consistent with an anticlockwise spin texture of the SmB_6 surface band in momentum space, which provides an additional demonstration that the surface state of SmB_6 is metallic surface with chiral spin texture.

Keywords:

Topological Kondo insulator, SmB6, spin-momentum locking, inverse Edelstein effect

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B10.06

Probing hydrogen environments in quasicrystals by high-resolution ^{1}H MAS NMR

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Abstract:

Quasicrystals are known to store moderate amounts of hydrogen under ambient conditions. The predominant tetrahedral interstitial sites in TiZrNi quasicrystals are suitable for storing of hydrogen. While detailed atomic environments around hydrogen and the nature of bonding with near metal elements in quasicrystals are crucial for better understanding on quasicrystals for hydrogen-storage applications, direct quantification of hydrogen content in hydrogen-bearing metal compounds including metal hydrides and quasicrystals is challenging. Here, we report the first ^{1}H nuclear magnetic resonance (NMR) spectra for quasicrystals under fast sample spinning, revealing previously unknown details of bonding environments and hydrogen contents. The NMR spectra of $Ti_{53}Zr_{27}Ni_{20}$ quasicrystals with different hydrogen-to-metal (H/M) ratios of 0.5 to 1.8 show multiple sites of hydrogen in $Ti_{53}Zr_{27}Ni_{20}$ quasicrystals. The ^{1}H peak maximum linearly shifts toward lower frequencies in the range of -21 ppm to -26 ppm with the increase in hydrogen content (H/M). The changes in peak position and shape with varying H/M indicate that the metal element around the absorbed hydrogen changes from Zr to Ti to Ni with the increase in hydrogen concentration and the interactions between hydrogen and metal elements may increase with increasing hydrogen content. The line narrowing of the main peak with increasing temperature indicates the motional narrowing due to the enhanced hydrogen mobility at higher temperature conditions. These results open a new window to estimate the hydrogen contents in quasicrystals and other hydrogen-bearing energy materials by using high-resolution ^{1}H MAS NMR.

Keywords:

Ti53Zr27Ni20 quasicrystals, Hydrogen storage, Metal hydrides, High-resolution 1H MAS NMR

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B11.01

Deep learning enhanced individual nuclear spin detection in diamond

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Abstract:

The detection of nuclear spins using individual electron spins has enabled new opportunities in quantum sensing and quantum information processing. Proof-of-principle experiments have demonstrated atomic-scale imaging of nuclear-spin samples and controlled multi-qubit registers. However, to image more complex samples and to realize larger-scale quantum processors, computerized methods that efficiently and automatically characterize spin systems are required. Here, we realize a deep learning model for automatic identification of nuclear spins using the electron spin of single nitrogen-vacancy (NV) centers in diamond as a sensor. Based on neural network algorithms, we develop noise recovery procedures and training sequences for highly non-linear spectra. We apply these methods to experimentally demonstrate fast identification of 31 nuclear spins around a single NV center and accurately determine the hyperfine parameters. Our methods can be extended to larger spin systems and are applicable to a wide range of electron-nuclear interaction strengths. These results enable efficient imaging of complex spin samples and automatic characterization of large spin-qubit registers.

Keywords:

NV center, Nuclear-spin detection, Deep learning, Hyperfine interaction

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B11.02

Adaptive compressive quantum process tomography

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Abstract:

Recent quantum technologies utilize complex multidimensional processes that govern the dynamics of quantum systems. Thus, reliable characterizations of quantum processes are crucial pre-requisites for enhancing the quality of quantum technologies. However, such a characterization is conventionally too resource intensive to perform for large d. If the unknown process has a certain maximum possible rank, the concept of compressed sensing, originally developed for sparse signal and image recovery, has for some time been the status quo for reconstructing the unknown process with a small set of specialized measurements. In practice however, this concept is only as reliable as the accuracy of the rank knowledge, and lacks an independent verification method to check the reconstruction results without fidelity comparison with target processes. Existing remedies for tackling these issues in compressed sensing are generally ad hoc and incomplete. To overcome the limitation, we develop an adaptive element-probing compression technique that feasibly characterizes any unknown quantum processes using much fewer measurements compared to conventional methods. This technique employs only separable measurement resources and is easily generalizable to arbitrary number of subsystems in practice. Both numerical analysis and experimental results with unitary gates demonstrate low measurement costs and robust reliability against statistical noise. Our work potentially paves the way for a reliable and highly compressive characterization of general quantum devices.

Keywords:

Adaptive, Quantum process tomography

B11.03

Three individual control of singlet-triplet qubits in a micromagnet integrated quantum dot array

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Abstract:

We report individual confinement and two-axis qubit operations of two electron spin qubits in GaAs gate-defined sextuple quantum dot array with integrated micro-magnet. As a first step toward multiple qubit operations, we demonstrate coherent manipulations of three singlet-triplet qubits showing underdamped Larmor and Ramsey oscillations in all double dot sites. We provide accurate measure of site dependent field gradients and discuss the adequacy of simple rectangular micromagnet for practical use in multiple quantum dot arrays. We also discuss current limitations and possible strategies for realizing simultaneous multi qubit operations in extended linear arrays.

Keywords:

quantum dot, spin qubit

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B11.04

Arbitrary parameter estimation via generalized weak value measurement

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Abstract:

Standard weak value amplification(SWVA) can amplify tiny changes of the interaction strength in the von Newmann measurement, where the system state and meter state interact, by measuring anomalous weak value(AWV). AWV, which is dependent on the system state, refers to a quantity when the pre-selected system state and the post-selected state becomes nearly orthogonal. There have been many experiments estimating small parameters (i.e. interaction strength) with high sensitivity due to the amplification effect of AWV. SWVA, however, is only applicable when the parameter is an infinitesimal value. Studies that analyzed the signal-to-noise ratio(SNR) with an arbitrary parameter, shows decreased SNR when the parameter becomes larger, resulting in reduced quantum Fisher information(QFI).
In this work, we have demonstrated two main results. First, we have theoretically analyzed QFI for arbitrary parameters and found that it is possible to observe amplification effect in the arbitrary parameter without loss of SNR with generalized weak value measurement. Differently from the SWVA, where the amplification factor is only related to the system state, for the arbitrary parameter, the amplification factor comes from a generalized form of weak value with joint Hilbert space of the system and meter. Our experiment result clearly shows an amplification effect without loss of SNR in the observable's expectation value with an arbitrary parameter.
Second, we have applied our method to a feedback measurement loop, which enables us to estimate an unknown parameter without any prior information. The error of estimation is reduced as the number of loop cycles is increased. As a result, we have estimated an unknown parameter with a 1.7*10^-4 -radian error after 11 cycles of feedback loop.

Keywords:

Weak value amplification

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B11.05

Realtime nanoscale quantum thermometry under arbitrary magnetic field using microwave dressed spin states in diamond

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Abstract:

Versatile nanoscale sensors susceptible to changes in variety of physical quantities often exhibit limited selectivity. We present a new scheme for optically probed nanoscale temperature detection using diamond quantum sensors that is insensitive to changes in the magnetic field. Based on double resonant microwaves, the technique maps change in the zero-field splitting, hence temperature, to the microwave dressed eigenstates with net spin zero enabling selective temperature sensing with tolerance to the effect of uncalibrated arbitrary magnetic field. We exemplify thermal sensitivity of ~ $100mK/\sqrt{Hz}$ for single NV centers in high-purity bulk diamond and demonstrate magnetic field insensitivity using single NV centers in nanodiamonds. By removing the constraints on the external magnetic field environment, the results are favorable for practical application of nanoscale quantum sensing where independent imaging of both magnetic field and temperature is desired.

Keywords:

Temperature sensing, quantum sensing, NV center, dressed state

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B11.06

Time-bin qubit entanglement distribution over a wavelength-multiplexing quantum network

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Abstract:

Long-distance distribution of quantum entanglement is of the essential necessity for quantum communications. Distributed quantum entanglement enables two distant parties to perform communication protocols that are impossible with classical counterparts, such as quantum teleportation and quantum key distributions. Recently, experimental efforts have been made toward the real-world application, but most of the implementations have been restricted only to two communicating users. To this end, the advanced network techniques have been demonstrated adopting widely-used in the classical communications; such as time-division multiplexing (TDM) in which an end-user can request to be connected to any other end-user one at a time domain using active switching skills, and wavelength-division multiplexing (WDM), in which the frequency-correlations were exploited, and the bipartite entanglement is distributed toward end-users in separate channels. These proof-of-principle experiments presented a step achievement that could extend the QKD protocol's benefit to more than two distant users.
In this work, by extension, we demonstrate a fully WDM-based quantum network in which a single entanglement photon source distributes entangled photons pairs to many users while minimizing the resources necessary for each user. We developed a source of frequency-correlated time-bin-entangled photon pairs at telecommunications wavelengths. Three time-bin entangled states are de-multiplexed into six wavelength channels and distributed between three end-users so that, ultimately, each pair of users shares one pair of photons. In the end, each user receives two channels using only one fiber and one analysis module per user. Our network comprises all-passive fiber-based components and presents the most adaptable ways to connect many end-users without active switching. Further, no entanglement source adjustments are required to add users, so the network can easily be scaled to many end-users. The feasibility of the time-bin entanglement is investigated on our fiber-based network. The time-bin entanglement is not susceptible to polarization mode dispersions in optic fiber, which makes it suitable for long-distance fiber transmission. Employing the time-bin degree of freedom, time-bin entangled states are distributed to three communicating users over a long-range distance (up to ~60 km) while preserving a high-grade entanglement needed for each user. Finally, we could obtain 0.965 ± 0.0192 in two-photon visibility. The CHSH inequality measurements gave 2.58 ± 0.0952 in the CHSH S parameter, which shows $S > 2$ and 6σ violation of inequality.

Keywords:

quantum network, time-bin entanglement, Wavelength-multiplex

2020 KPS Fall Meeting
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B11.07

Fast, scalable auto-tuning of the semiconductor quantum dot qubits via deep reinforcement learning

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Abstract:

Semiconductor-based qubit system keeps drawing attention because of its advantages such as long coherence time, scalability via semiconductor fabrication technology, and high degrees of tunable parameters. Unfortunately, its high degrees of freedom make challengeable to scale up towards larger integrated systems because the tuning process has been manually done via measuring the stability diagram of two gates. Many researchers try to adopt machine learning techniques for auto-tuning the quantum dot qubits. However, most of them apply the algorithm in restricted ways, such as only using it for state recognition or step by step tuning with different methods for different types of gates.
In this work, we use deep reinforcement learning to fully automate the tuning of the multiple qubits. We demonstrate the trained agent to find an optimal path in the tuning parameter space in a fast, scalable, and automated way.

Keywords:

semiconductor qubit, qubit auto-tuning, deep learning, reinforcement learning

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B11.08

Trapping a Free-propagating Single-photon into an Atomic Ensemble

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Abstract:

We experimentally demonstrate the trapping of a free-propagating single-photon into an atomic ensemble for a duration of 1 μs while retaining its electromagnetic field via the process of stationary light field (SLP). The heralded single-photon is generated by the double-Λ type spontaneous four-wave mixing (SFWM) process in a ^{87}Rb cold atomic ensemble. Then, the heralded single-photon is sent to the another ^{87}Rb cold atomic ensemble at which the single-photon gets trapped for a duration of 1 ms via the stationary light process in which the group velocity of the photon is zero while retaining its electromagnetic field. Trapping of the single-photon via the stationary light process is verified by comparing it with the single-photon storage via the process of electromagnetically-induced transparency (EIT) which fully maps the photonic state into an atomic state. The cross-correlation between the heralding photons and the heralded single-photons and the conditional self-correlation of the heralded single-photons are conserved in quantum regime even after the trapping duration. Our work paves a way to build the new platform for efficient photon-photon interactions, an exotic photonic state, and many-body simulations in a precisely controllable system.

Keywords:

Stationary Light Pulse

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B11.09

Dispersion cancellation in a quantum interferometer with independent single-photons

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Abstract:

Quantum interference effects are at the heart of various quantum information processing tasks, including quantum communication, quantum teleportation, quantum imaging, quantum metrology, and quantum computing. Therefore, in photonic quantum information, attaining high visibility quantum interference is crucial in demonstrating the desired quantum information tasks. One of the main physical effects that affects quantum interference detrimentally is group velocity dispersion and it occurs whenever a photon interacts with an optical device. Even a small amount of group velocity dispersion is often enough to fully destroy quantum interference.
When photons are entangled in a specific way, such as, frequency-time entangled photon pairs, it has been known that dispersion cancellation on the two-photon interference is possible by taking advantage of frequency anti-correlation feature. However, this dispersion cancellation effect is not scalable to N independent single photons with a large multi-port quantum interferometer which is used for various quantum information tasks.
In this paper, we theoretically and experimentally demonstrate that the effect of group velocity dispersion in a quantum interferometer can be cancelled even with independent single photons at the input. Specifically, we show that Hong-Ou-Mandel type two-photon interference with independent single photons at the input to the beam splitter exhibits cancellation of the group velocity dispersion effect if two independent single photons experience the same amount of pulse broadening before injected into a beam splitter. Each single photon pulse, prepared by heralding a photon of the photon pair born in the process of SPDC pumped by a femtosecond pulsed laser, becomes broadened as a result of propagation through a single-mode optical fiber. However, the two-photon interference does not exhibit any broadening, thereby exhibiting cancellation of group velocity dispersion in a quantum interferometer if the independent single photon pulse experiences the same amount of dispersion before the beam splitter. Moreover, our theoretical analyses show that our results can be generalized to N-photon multi-port quantum circuits and networks.

Keywords:

Dispersion, Quantum interferometer, Single-photons

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B12.01

Numerical simulation approaches for stochastic epidemic model under the self-isolation

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Abstract:

The Korea centers for disease control and prevention (KCDC) implements self-isolation for those who contact patients as a preemptive quarantine measure, because some COVID-19 carriers have weak or no symptom. We propose a stochastic epidemic model on networks considering the asymptomatic carriers and simulate the model under the so-called K-quarantine measure of the KCDC, which locally lock-down around confirmed patients. Here, we introduce two stochastic algorithms for the numerical simulation of the K-quarantine model. One is the discrete-time approach (DA) which is based on unit time and the other is the Gillespie algorithm (GA) which is based on unit event. We have the same results because both methods simulate the epidemic spreading as a Poisson process. Generally, the GA is faster in simulations, but the DA is easier to tune model parameters during the dynamic process. Taking these strong and weak points into account, we employ the GA and the DA to simulate the K-quarantine model under several pandemic scenarios.

Keywords:

COVID19, Stoachastic epidemic model , Numerical algorithm

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B12.02

Covid-19 outbreak under the K-quarantine model: numerical simulations on networks

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Abstract:

Covid-19 pandemic is ongoing worldwide and its damage is unprecedentedly severe. South Korea has adopted a local quarantine strategy rather than a global lockdown. This approach not only minimizes economic damage but also efficiently prevents the spread of the disease. Here, the spread of Covid-19 under local quarantine measures is modeled using the Susceptible-Exposed-Infectious-Recovered (SEIR) model on complex networks. This network approach easily realizes local quarantine by disconnecting the links connected to isolated people and their releases by reinstating the removed links. Numerical simulations are performed on networks with the reaction rates that are estimated from empirical data. The temporal pattern of the number of accumulated confirmed cases is reproduced. It is revealed that a large number of asymptomatic infected patients are detected as they are quarantined together with infected patients. The possible consequences of the local quarantine measures breaking down and of a drastic change of social circumstance are considered.

Keywords:

COVID19, K-quarantine measure, Stochastic epidemic model

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B12.03

코로나19 확산 예측 및 비약물적 방역 정책 분석

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Abstract:

자료동화 기법(data assimilation method)과 microsimulatin model을 이용하여 코로나19 확산을 예측하고 비약물적 방역 정책 효과를 분석하였다. 자료동화 기법은 코로나19 확진 자료 업데이트 주기에 따라, 즉 매일 지역별 구획 모델(compartment model)로부터 계산한 사전(prior) 예측 결과를 확진 자료를 통한 우도(likelihood)와 베이즈 정리(Bayes' theorem)를 이용하여 사후(posterior) 예측 결과를 업데이트하는 과정을 거친다. 이를 통하여 지역별 코로나19 확산을 예측하였다. 지역간 일상적 인구 이동(통근/통학)은 휴대폰 자료로부터 추출한 주/야간 상주 인구 자료를, 그리고 비일상적 인구 이동은 한국교통연구원이 제공하는 대중교통 이용자료(KTX, 고속버스, 국내선 항공 등)을 이용하였다. Microsimulation model은 가구, 지역, 연령, 직장, 학교, 종교 시설 등의 인구사회학적 정보를 포함한 국내 인구와 동일한 크기의 가상 인구 집단을 이용하여 코로나19 확산을 시뮬레이션한다. 이를 통하여 휴교령, 직장 재택 근무, 종교 시설 폐쇄, 지역간 인구 이동 감소 등의 비약물적 방역 정책이 코로나19 확산 방지에 어떤 효과를 지니는지 분석하였다.

Keywords:

COVID-19, data assimilation, microsimulation

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B12.04

Data-driven modeling of COVID-19 pandemic

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Abstract:

The new Coronavirus disease 2019 (COVID-19) has forced an unprecedented response from the authorities, first from the government of China and the World Health Organization, and later from many more countries as the disease spread worldwide. Despite the adoption of drastic measures, the pandemic is still ongoing worldwide, and surges of infections are being observed in more than 188 countries. Due to the lack of new specific pharmaceutical interventions or vaccines, the extent to which the adopted non-pharmaceutical interventions would be effective in the long term remains open. Here we present results from simulations using data-driven models tailored to mobility data from China, Spain, and the U.S. The models are used to estimate the effectiveness of customary public interventions on the spread of COVID-19 in these locations. Our main findings support incentivizing the adoption of actions that reduce the transmissibility of the disease as well as those aimed at improving the efficacy of early detection and isolation of newly symptomatic individuals. This highlights that having a coordinated response system could be key for the containment of the spread of COVID19 and its possible eradication at the lowest possible cost.

Keywords:

COVID19, Data-driven models, Pandemic spreading

B15.01

On-demand Delivery of Colloidal Metal Nanoparticles onto Arbitrary Solid Surfaces for Sensitive Molecular Detections

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Abstract:

Colloidal metal nanoparticles have attracted significant interests as a promising candidate for a multitude of applications including electronics, biomedicine, photonics, catalysis, environmental monitoring and energy harvesting. However, their practical applications still require solving a few critical problems: (1) active and adaptive control of colloidal nanoparticles' motion and orientation, (2) on-demand printing of the colloidal nanoparticles onto solid surfaces irrespective of surface topography and chemistry, and (3) efficient integration into functional optical, electrical, or microfluidic devices. In order to address these issues, our group has been working on the assembly and transfer of colloidal nanoparticles at various interfaces.

In this talk, I will highlight our recent achievements on the formation of novel three-dimensional (3D) plasmonic particles at a water/polymer interface and autonomous vertical orientation of colloidal nanorods at an oil/water interface. Interestingly, both events take place spontaneously at these liquid/liquid interfaces which less attention has been paid than other solid/liquid or solid/gas interfaces. Finally, I will finish my talk with capillarity-mediated inverse transfer that enables on-demand delivery of colloidal nanoparticles to the surface of arbitrary solids by simple glass capillary tubes.

Keywords:

On-demand transfer, colloidal nanoparticles, interfaces, capillarity, inverse transfer, assembly

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B15.02

Microfluidic Platforms for Surface Enhanced Raman Sensing

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Abstract:

The development of a surface-enhanced Raman scattering (SERS)-based microfluidic platform has recently attracted significant attention to wide scientific communities. SERS has a highly sensitive detection capability, and microfluidic platforms provide many advantages such as automatic sampling and reduced sample volume. Therefore, the integration of SERS with microfluidic platforms offers a wide application in chemical or biological analysis. In this work, we developed a fully integrated SERS-based droplet microfluidic platform for automatic immunoassay of several infectious diseases. In this system, an efficient immuno-reaction was achieved through sequential droplet generation, transport and merging processes while a wash-free immuno-detection was realized through the droplet-splitting process. Indeed, a novel multifunctional microfluidic platform, capable of performing a complicated multi-step immunoassay process in nanoliter scale droplets, has been successfully developed in this work. This assay system also has many advantages including small sample consumption (less than 100 μL), fast assay time (less than 5 min) and fully automated fluid controls. We anticipate that this fully integrated SERS-based droplet microfluidic device what overcomes the limitations of conventional methods for high-risk pathogen assay opens new insights in the development of a facile assay platform for various hazardous materials.

Keywords:

surface-enhanced Raman scattering, microfluidics, infectious diseases, miniaturization

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B15.03

Nanoframes: Synthesis and Applications

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Abstract:

Surface plasmonics of nanomaterials has been one of the major research themes in nanoscience. Here we successfully synthesized a new class of nanomaterials, saying, 2-dimensional and/or 3-dimensional nanoframes with high uniformity through wet-chemistry. The synthetic strategy comprised serial reactions involving site-selective growth of Pt on the rim of Au nanoparticles, subsequent etching of Au, followed by regrowth of Au on the Pt rim, if the final structures are Au nanoframes. The resultant product exhibited unique localized surface plasmon resonance (LSPR) bands originating from the Au shell. The inner Pt skeleton turns out to be important to hold structural stability. We will discuss how one can rationally design and synthesize complex nanoframes, and their unique applications in sensors.

Keywords:

plasmonics, surface-enhanced Raman spectroscopy

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B15.04

Lipid Nanotablet for Modular and Scalable DNA Computing

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Abstract:

I will introduce and discuss about a new molecular computing chip, lipid nanotablet (LNT), that is based on a plasmonic nanoprobe-modified lipid bilayer. It will be shown that this LNT platform is versatile and powerful in providing a modular, scalable DNA computing platform for building a nanoparticle-based computing architecture and nanoparticle neural networks that can make autonomous logic decisions.

Keywords:

DNA Computing, Nanoparticle Computing, DNA Circuits, Nanoparticle Neural Networks, Nanoparticle Logic Gates

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B20.01

How can you introduce computational science to your research?

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Abstract:

Since the materials development requires a lot of trial and error, it takes a lot of cost and a long time to develop a material. Accordingly, computational techniques have been introduced in earnest since the 2000s to improve time and cost. In practical, the attempts to solve problems in materials and understand physical phenomena by using computational techniques were endless. Although successful results using computational techniques have been shown, computational techniques have not been widely used until now. This is because there are several barriers to the introduction of computational techniques. To introduce computational techniques, expensive supercomputers are required, and the space is required for them. In addition, software costs are required to use the computational techniques. Moreover, if there is no expert for using computational techniques, the computational techniques can not be used properly. In practical, the education on computational techniques is limited.

As part of the easy introduction of the computational science, our company developed the web-based graphical user interface (GUI) computational science platform, so called “Materials Square”. This platform supports the materials simulation such as the first-principles calculation from structural modeling to calculations and pre-processing in a web environment. Because of web-based GUI platform, this platform is easy to access and is designed for anyone to use. our tutorial discusses how to introduce the computational science to various research with minimal effort using the web-based GUI platform.

Keywords:

computational science, first-principles calculations, DFT, cloud-based simulation

Future Circular e+e- Colliders

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Abstract:

Future circular e+e- colliders offer unique opportunities to answer important questions in particle physics today. These powerful machines have the capacity to provide measurements with unprecedented precision, sensitivity, and energy reach. In this presentation, I give an overview of the physics motivation and discuss the status of future e+e- collider projects

Keywords:

C1.02

Calorimetry in the 21st Century

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Abstract:

In the past 50 years, calorimeters have become the most important detectors for many experiments in particle physics, especially at colliders. Whereas these instruments allow measurements of the properties of high-energy electrons and γs with unprecedented precision, their performance for hadrons and jets leaves much to be desired. Poor energy resolution, signal non-linearities and non-Gaussian response functions limit the quality of the physics information they can provide.
In this talk, I will describe the root causes of these problems, and discuss three solutions that have been proposed to remedy this situation: compensation, dual readout and particle flow analysis. Experimental results obtained with these techniques will be presented and their merits compared.

Keywords:

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C1.03

Dual-Readout Calorimeter R&D in Korea for future e+e- colliders

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Abstract:

The dual-readout method is a state of the art calorimetry technique enables high-quality energy measurement for both electromagnetic and hadronic particles, which has been developed during last two decades. The dual-readout calorimeter detector mainly designed by Korean team has been included in the conceptual design reports of both FCC-ee and CEPC projects published in 2018. As a next step, Korean team has a plan to build a prototype detector and demonstrate all necessary requirements of the detector toward TDRs of the FCC-ee and CEPC projects. Recent progress and plan of the dual-readout calorimeter R&D in Korea will be presented in this talk.

Keywords:

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C1.04

ML application for future e+e- colliders

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Abstract:

Machine learning has exploded in the tech industry and its applications in particle physics are escalating rapidly. It has already assisted in the discovery of the Higgs boson and continues to contribute to maximising the physics potential of modern experiments all around the world. We survey the current applications of machine learning in our field as well as future uses that are being actively explored.

Keywords:

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C3.01

String shoving model in PYTHIA8 for long-range correlation in pp collisions

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Abstract:

The physical source of long-range correlations in pp and p-Pb collisions remains an open ques- tion, implicating collective motion in both small and large systems. Theoretical models, such as Color Glass Condensate, hydrodynamics or interplay of them, dedicated to understanding these observations have been proposed, turning out to be insufficient to understand how quantitatively initial and final state effects interplay. The string shoving model describes long-range correlations in an environment of dense strings in pp collisions. Since this model is implemented in the Pythia8 Monte Carlo event generator, it is allowed to perform a study to compare with various experimental measurements. We will present the study of this model to understand the origin of collectivity in small collision systems.

Keywords:

PYTHIA, Correlations, String Shoving

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C3.02

Development of Monte Carlo simulation for quarkonia production in heavy-ion collisions

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Abstract:

Heavy quarkonia production has been studied extensively in relativistic heavy-ion collision experiments to understand the properties of a hot and dense medium from heavy-ion collisions. Model study to fully understand experimental results show that it is important to consider not only suppression e ects but also e ects to regenerate quarkonia particularly at the LHC energies. A recent theoretical calculation taking into account the gluo-dissociation and inelastic parton scattering, and their inverse reaction reasonably describe the suppression of Y(1S) in Pb+Pb collisions. Based on this theory, a Monte Carlo simulation is under development to incorporate the medium produced heavy-ion collisions more realistically with hydrodynamics simulations. In addition, more di er- ential measurements proposed for future experiments also can be studied with the Monte Carlo simulation. In this talk, we will introduce the Monte Carlo simulation for Y(1S) production and present the current status of development.

Keywords:

Heavy ion collision, Quarkonia, Simulation

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C3.03

Status of the measurement of electrons from beauty-hadron decays in pp collisions at √s = 13 TeV in ALICE

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Abstract:

Heavy quarks (charm and beauty), due to their large masses exceeding the QCD parameter, are produced via hard scattering in early stage of heavy-ion collisions, compared to the formation time of the Quark-Gluon Plasma (QGP). Due to their long lifetime, heavy quarks can experience the full evolution of the system created by such collisions. Therefore, heavy quarks are natural probe of the QGP. By separating beauty quarks from charm quarks, the mass dependence of the parton energy loss in the QGP can be studied. Long lifetime of beauty hadrons leads large impact parameter of decay products. Therefore the electrons from beauty-hadron decays are separated from background electrons based on wider impact parameter distribution than the others. In the ALICE experiment, the excellent vertex and impact parameter resolution are provided by ITS, and electron identification capability is provided by TPC and TOF. Measurements in pp collisions are essential as a reference to quantify medium effects in heavy ion collisions. In addition, it can be tests for perturbative QCD calculations. We present the current status of the measurement of beauty-decay electrons in pp collisions at √s = 13 TeV in ALICE.

Keywords:

ALICE, HF

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C3.04

Measurement of electrons from beauty-hadron decays in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE detector

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Abstract:

The LHC heavy-ion physics program aims at investigating the properties of strongly-interacting matter in extreme conditions of tem- perature and energy density, where the formation of the Quark-Gluon Plasma (QGP) is expected. Heavy quarks (charm and beauty) are regarded as unique probes of the properties of the QGP as they are created on a very short time scale in initial hard scattering processes, therefore, they witness the full evolution of the system. In particular, beauty quarks, being four times heavier than charm quarks, can be used to study the in-medium mass dependent energy loss.
Beauty production can be studied via semi-electronic decays of beauty hadrons. The yield of electrons coming from open beauty- hadron decays is obtained by fitting the impact parameter distribution with templates of different electron sources.
In this contribution, the measurements of electrons from beauty- hadron decays in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with the ALICE detector will be presented.

Keywords:

ALICE, heavy flavor

Recent recents of photo-production of vector meson and jet in CMS heavy ion experiment.

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Abstract:

The recent results of photo-production of vector mesons and jets from the CMS heavy ion experiment are reviewed.
In November 2018, LHC delivered the L=1.8 nb^-1 lead-lead beam at 5.02TeV which allowed the precision measurement of photo-produced vector mesons, jets, and photons. The correlation of di-jet, di-muon acoplanarity, exclusive photo-production of upsilon, and the rapidity gap distribution are discussed. In addition, the performance of zero degree calorimeter (ZDC) for the estimation of impact parameter in UPC event will be shown.

Keywords:

heavy ion, upc, CMS

2020 KPS Fall Meeting
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C3.06

The K_1 meson abundance in relativistic heavy-ion collisions

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Abstract:

We study the reduction of K_1 mesons during the hadronic stages of relativistic heavy-ion collisions.
For that purpose, we first construct an effective model that reproduces well the experimentally measured decay width of these particles.
We then calculate the K_1 meson scattering by light mesons in the hadronic phase.
We assume that the initial number of K* and K1 are equal due to the chiral symmetry restoration at the chiral phase transition point. We then evaluate the final abundance of K1 meson and discuss the difference to the naive yield expected from statistical hadronization model.

Keywords:

K1 meson

C3.07

Bose-Einstein correlation measurements at CMS

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Abstract:

Bose-Einstein correlations (BEC) are useful tools to probe the size and shape of the particle emitting region in high-energy collisions. The BEC correlations are measured in pp, pPb and PbPb collisions at different energies with three different techniques at CMS experiment. The correlation functions are extracted in terms of different components of the relative momentum of the pair, in order to investigate the extension of the emission source in different directions. The results are presented for different intervals of transverse pair momentum, k_T, and charged particle multiplicity of the collision, N_{ch}, as well as for their integrated values for both inclusive charged particles, as well as for identified pions and kaons.

Keywords:

CMS, Bose-Einstein correlations

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C5.01

Observation of exotic many-body exciton in $NiPS_3$

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Abstract:

$NiPS_3$ belongs to a class of antiferromagnetic van der Waals materials, and it is one of the first magnetic van der Waals materials to be exfoliated down to monolayer. When it undergoes an XY-type, or more precisely, an XXZ-type ordering below T_N=155 K, there is a drastic spectra transfer in the optical data over a wide energy range, a hallmark of correlation physics at work. More interestingly, it also displays a clear thickness dependence of the magnetic order, which is suddenly destroyed between bilayer and monolayer $NiPS_3$.
More recently, we have undertaken extensive studies of its optical and electronic studies using PL, optical absorption, and RIXS to find that it hosts highly unusual exciton features around 1.5 eV. By carrying out massive many-body calculations, we could identify it as an exciton due to a transition from a Zhang-Rice Triplet to a Zhang-Rice singlet, i.e., a spin-entangled exciton of many-body origin. In this talk, I will discuss several salient features of this recently discovered exciton with a particular reference to the correlation physics.

Keywords:

van der Waals materials, Correlation, Exciton

C5.02

Observation of excitonic instability in Ta2NiSe5

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Abstract:

Excitonic insulator is an elusive phase of matter predicted many decades ago to occur in a narrow gap semiconductor or a semi-metal. Analogous to Cooper pairs in superconductors, Coulomb attractions bind electrons and holes in pairs to form charge-neutral excitons, which undergo a Bose-Einstein condensation at a sufficiently low temperature. However, unambiguous identification of an excitonic insulator remains challenging because candidate materials invariably display simultaneous structural phase transitions. In this talk, I will discuss the case of Ta2NiSe5, for which a fierce debate continues for more than a decade on the physical origin of its semimetal-to-insulator transition. Using Raman scattering, we have observed an incipient divergence in the uniform static electronic susceptibility. Critical fluctuations of the excitonic order give rise to quasi-elastic scattering of B_{2g} symmetry, whose intensity grows inversely with temperature toward the Weiss temperature of T_W~237 K, which is arrested by a structural phase transition driven by an acoustic phonon of the same symmetry at T_C=325 K. Concurrently, a B_{2g} optical phonon becomes heavily overdamped to the extent that its trace is almost invisible around T_C, which manifests a strong electron-phonon coupling that has obscured the identification of the low-temperature phase as an excitonic insulator for more than a decade. Our result unambiguously reveals the electronic origin of the phase transition.

Keywords:

excitonic insulator, Raman spectroscopy

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C5.03

Identification of the many-body exciton in the van der Waals antiferromagnet NiPS3

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Abstract:

The magnetic van der Waals (vdW) materials have recently drawn much attention as an ideal platform for investigating the two dimensional magnetism and a potential element for device application [1]. $NiPS_3$ is one of vdW systems with the layered honeycomb lattice to show the zigzag antiferromagnetic order with the XY-type magnetism. It has been reported that $NiPS_3$ is the correlated electronic systems with the optical gap of about 1.8 eV and the Neel temperature of 150 K [2]. Moreover, we have recently addressed that the coherent many-body exciton with ultra-narrow line width about 0.4 meV appears around 1.5 eV in $NiPS_3$ [3]. In this talk, we will present the characteristic feature of electronic excitation in $NiPS_3$ measured by the photoluminescence, optical absorption, and resonant inelastic x-ray scattering techniques and identify the origin many-body exciton based on spectroscopic observations and configuration interaction calculations. Further, we will propose putative mechanism of the strong coupling between exciton and magnetic order.

[1] K. S. Burch, D. Mandrus, and J.-G. Park, Nature **563**, 47 (2018)
[2] S. Y. Kim et al., Phys. Rev. Lett. **120**, 136402 (2018)
[3] S. Kang et al., Nature **583**, 785 (2020)

Keywords:

Many-body exciton, NiPS3, Magnetic van der Waals system, Zhang-Rice singlet

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C5.04

Excitons in twisted $MoSe_2/MoSe_2$ bilayers: the effect of broken mirror symmetry

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Abstract:

Van der Waals heterostructures made by stacking dissimilar materials or by introducing a twist angle between layers can exhibit many exotic properties that are not present from their bulk counterparts. Indeed, recent experiments on transition metal dichalcogenide (TMD) bilayers suggest that this structural engineering can lead to periodic confinement of excitons and exciton hybridization. These systems, a solid-state analogue of an optical lattice for ultracold atoms and molecules, are therefore a particularly promising platform for a multitude of applications, such as the creation of quantum dot arrays and the realization of excitonic topological insulators. However, in order to harness their full potential, it is critical to first understand how the local exciton properties are modified by the crystal structure. To date, such studies have remained a significant challenge due to the small size in reconstructed domains in typical heterostructures (on the order of 1-10 nanometers and thus much smaller than the optical diffraction limit).

In the present work, we overcome this limitation and explore the impacts of the local crystal structure on TMD excitons by fabricating near zero twist angle $MoSe_2/MoSe_2$ bilayers. This enables us to create large, twinned rhombohedral AB and BA domains with broken mirror and inversion symmetry. By performing far-field, spatially resolved, spectroscopic measurements of the individual domains, we demonstrate that both momentum-indirect interlayer excitons ($X_{I,1}$) and momentum-direct interlayer excitons ($X_{I,2}$) have domain-specific dipole orientations that are perpendicular to the basal plane. Furthermore, we show that it is possible to electrostatically control both the preferred dipole orientation of $X_{I,1}$ and hybridization between $X_{I,2}$ and the intralayer excitons (X_0). Importantly, we support our experimental observations with first-principle density functional theory calculations, which are in quantitative agreement. Our results shed light on the effect of crystal symmetry on TMD optical properties and form the foundation for engineering exciton properties via domain engineering in van der Waals heterostructures. Therefore, they open up new avenues for designing periodic domain structures to explore quantum emitter arrays, topological exciton insulators and strongly correlated exciton lattices for Hubbard model physics.

Keywords:

Excitons, 2D materials

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C6.01

Opportunities of high-pressure researches as an effective route for tuning electronic states of solids

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Abstract:

High pressure has been an important physical parameter, of which applications to solids can lead to findings of e.g., unexplored exotic phases of various quantum matters or their putative quantum mechanical ground states. With such recent developments of techniques, one can now apply conventionally up to ~200 GPa in diamond anvil cells and high quality hydrostatic pressure up to ~20 GPa at high field and low temperature environment. Herein, reapid developments of high-pressure research tools at CeNSCMR will be summarized with emphasis on recently commercialized DAC cells for magnetization, Raman, transport measurements at KIMTECH, a start-up company created for high pressure tools. For updating exciting science progresses, pressure induced tuning of band topologoloy in $CrSiTe_3$ and optimization of superconductivitiy will be covered, particularly focusing on tuning of electronic states in Fe-based superconductors. The latter will show how pressure leads to unexpected increase of superconducting transition temperatures up to ~ 52 K, in which found are experimental evidences of quantum critical fluctuation that is closely associated with the enhancement of superconducting transition. The former will discuss anomalous Hall effects mainly originating from the nontrivial topology change in the band structure of $CrSiTe_3$ with pressure.

Keywords:

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C6.02

Multi-step pathways of water freezing and ice melting under dynamic compression

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Abstract:

일반적으로 상온의 물은 0.9 GPa 에서 ice VI 상으로 상전이 한다. 만약 물을 균일하고 빠르게 압축하면, 물은 0.9 GPa 이상으로 과압이 되고 ice VI 상의 영역에서 준안정 ice VII 상을 거친 후 안정상인 ice VI 으로 상전이 한다 [1]. 상온에서 물을 매우 빠르게 압축하면, 상온에서 high density amorphous ice 상도 형성될 것이라는 추측도 보고되었다 [2]. 이와 같이 상온에서 준안정 ice 상이 발견될 수 있었던 것은 dynamic diamond anvil cell (dDAC) 이라는 새로운 기술이 개발되어 압축과정에서 발생할 수 있는 기계적 요동을 최소화 시켜, 준안정 상태의 물이 쉽게 결정화 되는 것을 막아 줄 수 있기 때문에 가능하였다.
본 연구에서는 압축된 상온 물이 다섯 가지의 응고와 용융 (freezing and melting) 경로를 가진다는 것을 보고한다. 이는 새로이 개발한 advanced dDAC 을 이용하여 발견한 것으로써, 과압과정에서 압력과 영상, 또는 압력과 원자 및 분자 산란을 동시에 측정함으로써 가능하였다. In-situ micro-Raman 과 싱크로트론 X-선 산란을 통해 상전이 과정에 나타난 안정 및 준안정 물질 상을 확인하였다. 또한 본 연구에서는 이 다섯가지 상전이 경로에 대해 가능한 메커니즘을 상전이 구동력과 계면에너지, 그리고 초과압 물 및 ice 결정구조를 비교함으로써 설명한다.

[1] Geun Woo Lee, William J. Evans, and Choong-Shik Yoo, Phys.Rev. B (2006)
[2] Jing-Yin Chen and Choong-Shik Yoo, PNAS, (2011)

Keywords:

High pressure, Dynamic diamond anvil cell, Ice, Phase transition

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C6.03

Pressure-induced superconductivity in the double helical antiferromagnet CrAs

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Abstract:

Unconventional superconductivity commonly emerges in proximity to a magnetically ordered phase, raising the possibility that critical spin fluctuations may mediate the formation of superconducting Cooper pairs. CrAs is an interesting example in which antiferromagnetic order is tuned to zero temperature at a pressure where a dome of superconductivity reaches a maximum T_c. When doped with 0.7% Al, however, the superconductivity is completely detached from tunable quantum critical point in the 0.7% Al-doped CrAs, suggesting that the Cooper pair formation is not mediated by critical magnetic fluctuations. These discoveries, which are very different from other classes of unconventional superconductors, not only point to new understanding of superconductivity in CrAs but also indicate more broadly the power of using multiple non-thermal tuning parameters simultaneously to reveal the intricate relationship between superconductivity and a hidden quantum critical point.

Keywords:

pressure, superconductivity, quantum criticality

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C6.04

Crystal growth in water and aqueous solutions under dynamic compression condition

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Abstract:

Water is an attractive material because it can dissolve various solutes and also has more than twenty different phases. By changing pressure, water can be changed into few high-pressure phases such as ice VI, VII, X, and XII even at ambient temperature. Thus pressure-induced crystallization of water and water solutions is interesting issue in the fields of biology, environment, food science, chemistry and physics. In order to monitor crystal growth in water or aqueous solutions we use an advanced dynamic-diamond anvil cell (d-DAC) which combines d-DAC with high speed camera and micro Raman spectroscope to measure dynamic response of a sample with sub-ms time resolution. In detail, dynamic pressure is applied to an ice-water coexistence system in order to grow an ice VI seed crystal surrounded by compressed liquid water at its equilibrium melting pressure. Generally, a rounded seed crystal showed faceting process at the early stage of the compressing and formed an octahedral crystal which is the equilibrium crystal morphology of the ice VI phase. The crystal showed a three-dimensional growth without change of the faceted geometry at comparatively low compression rates. However the crystal grew into two-dimensionally quickly above a critical compression rate. Growth speed of the crystal increases by an order of magnitude under fast compression. During the dynamic compression, pressure inside of the d-DAC is also monitored. As expected, tiny overpressure is formed and kept constant during the 3D facet growth. However, a slight overpressure in the range of few tens of megapascals is accumulated with fast compression and partially released due to the anomalous 2D crystal growth. This anomalous growth transition can be explained with interface ordering of a specific crystal plane under large imaginary overpressure. While seed crystal in aqueous solutions containing NaCl, KDP and ADP as solutes grows dendrite shape under dynamic compression. The overpressure related to this dendrite gorwth is also measured. Furthermore various crystal growth morphologies and their transitions were discussed from the viewpoint of driving force of crystal growth.

Keywords:

Advanced, dynamic-diamond anvil cell, water and aqueous solutions, pressure-induced crystal growth, driving force of crystal growth

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C7.01

First-principles study on rotation-driven ferroelectricity in $CaTiO_3$ induced by interfacial coupling

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Abstract:

In many perovskite oxides, the octahedral rotation pattern is one of the important parameters that can be tuned to alter the phase of the matter, such as inducing metal insulator transitions and changes in magnetic structures. In particular ferroelectricity in perovskite oxides is closely related to the octahedral rotation pattern, as a certain rotation pattern can induce polarization in the materials having tri-linear coupling and conversely can suppress polarization in many displacive-type of ferroelectric materials. This leads to questions that which types of the metastable octahedral rotation patterns would be compatible with the stable polarization and if so, how to stabilize the metastable rotation pattern, which can induce switchable polarization. In this talk, we investigate the relation between octahedral rotation patterns and polar instability in $CaTiO_3$ using first-principles density functional theory. The unstable polar modes in all possible locally stable rotation patterns are systematically investigated. We find that low-energy $a^-a^-a^-$ type rotation pattern has polar instability with sizable polarization. Moreover, by atomic-scaling imaging and second harmonic generation measurements, we show that thin-film $CaTiO_3$ film that grown on (111)-$LaAlO_3$ substrate can stabilize the metastable $a^-a^-a^-$ rotation pattern which induces polar distortion at the room temperature. The control of the metastable octahedral rotational pattern and the associated formation of polarization provide a new way to control a phase of matter and to design new functional materials utilizing interfacial coupling.

Keywords:

Ferroelectricity, Dielectric properties, Thin-film oxides, Oxide heterostructures, Density functional theory

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C7.02

Reversible photoluminescence modulation of multifunctional optical materials Eu^{3+} doped Sr_2SnO_4 ceramics based on photochromism

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Abstract:

It is highly significant to develop multifunctional optical materials to meet the huge demand of modern optics. Usually, it is difficult to realize multiple optical properties in one single material. In this work, a series of Eu^{3+}-doped Sr_2SnO_4 ceramics were synthesized by a conventional solid-state reaction method, and their crystal structure, photoluminescence (PL), photochromism (PC) and luminesce modulation properties have been investigated. The PL intensities under the UV excitation increased with the increasing Eu^{3+} content. It is found that excellent photochromism (PC) and luminesce modulation properties were observed. After 280 nm light irradiation, the color of our samples changed from white to gray. At the same time, the PL intensity decreased significantly. The luminescence intensity decrement ratio, ΔI_{dec}, reached a high value of about 80%. More interestingly, the decreased luminescence intensity of Eu^{3+} was completely recovered via 450-nm light irradiation, i.e., reversible photochromism. The mechanisms connected to the luminescence, luminescence manipulation, and PC effect were discussed.

Keywords:

photochromism, photoluminescence, Sr2SnO4

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C7.03

Thickness dependence of electrocatalytic activity in epitaxial $La_{0.7}Sr_{0.3}MnO_3$ thin films

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Abstract:

Transition metal oxide thin films offer an ideal platform for exploring the fundamental mechanisms of electrochemical catalytic reactions, owing to its facile controllability over electronic orbital state, epitaxial strain, film thickness, and capping layer. Among them, the film thickness control offers a direct approach for identifying the electrochemical “active depth” for the electrocatalytic reaction. Increasing film thickness increases active sites for electrocatalytic activity until a saturated thickness, defining the “active depth”. This concept is closely related to understanding what the actual surface is, for electrocatalytic activities.
In this study, we propose a way of understanding the electrocatalytic “active depth” with atomic-scale precision thickness control of epitaxial $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films using pulsed laser epitaxy (PLE). The film thickness was densely and systematically modified from ultrathin limit to ~70 unit cells (u.c.) (~30 nm). The electrocatalytic activities for the oxygen evolution reactions determined by specific current density and Tafel slope increased as the thickness of the LSMO thin films (t) increased up to t = 23 u.c., and then decreased. The non-monotonous t-dependence could be reproduced in the fast-redox reaction experiment. Three t-dependent regions could be identified: (1) resistivity-, (2) active depth-, and (3) surface recombination time-dominant regions. While the (1) resistivity and (3) surface recombination time were previously reported and well-defined, we clearly identified the role of active depth for the first time. By further employing the advantage of atomic-scale heterostructuring and fabricating LSMO t (u.c.) / $SrRuO_3$ // Nb:$SrTiO_3$ heterostructures, we could further scrutinize the active depth and electrocatalytic surface of LSMO layer to be t = 23 u.c. (~ 10 nm). Our study shows that epitaxial transition metal oxide thin films and heterostructures provide a vast advantage in understanding the fundamental mechanism of electrocatalytic activities.

Keywords:

Transition metal oxide, Thin film, Electrocatalyst, Electrocatalytic active depth, Thickness dependence

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C7.04

Emerging Soft Phonon Mode of the Ferroelastic WO_3 Twin Wall Explored by Raman Spectromicroscopy

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Abstract:

Tungsten trioxide (WO_3) as a A-site vacant perovskite shows interesting ferroelastic and mechanoelastic properties [1,2]. The optical phonons of epitaxial WO_3 thin films with the hierarchical ferroelastic twin structures [1] are investigated by polarized Raman spectromicroscopy at room temperature. The A_g normal modes are analyzed based on the group theory and polarization selection rule. We find that the intensified Raman peak appears near 46 cm^{-1} and the peak becomes strong when the light polarization is parallel to [110] direction. Additionally, we compare the surface topographic image with the Raman imaging result, confirming the soft phonon originates from the twin walls.

[1] S. Yun et al., Ferroelastic twin structures in epitaxial WO_3 thin films, Appl. Phys. Lett. 107, 252904 (2015).
[2] S. Yun et al., Flexopiezoelectricity at ferroelastic domain walls in WO_3 films, Nature Communications (in press).

Keywords:

WO3 thin film, Raman scattering, ferroelastic twin wall, soft phonon mode

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C7.05

Decoupling of Metal-to-Insulator Transition and Crystal Field Effects of VO_2

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Abstract:

VO_2 is a highly correlated electron system which has a metal-to-insulator transiton (MIT) with a dramatic change of conductivity accompanied by a first order structural phase transition (SPT) near room temperature. The origin of the MIT is still controversial and there is ongoing debate whether a SPT induces the MIT and the T_c can be engineered using artificial parameters. We examined the electrical and the local structural properties of Cr- and Co-ion implanted VO_2 (Cr-VO_2 and Co-VO_2) films using temperature-dependent resistance and x-ray absorption fine structure (XAFS) measurements at V K edge. The temperature-dependent resistance measurements of both Cr-VO_2 and Co-VO_2 films showed sharp MIT features. The T_cs of both Cr-VO_2 and Co-VO_2 first decreased and then increased as ion flux increased relative to that of a pristine VO_2. The pre-edge peak of V K edge from Cr-VO_2 films with Cr ion flux ≥ 10^{13} ions/cm^2 showed no temperature-dependent behaviors, implying no changes in the local density of states of V 3d t_{2g} and e_g orbitals during MIT. Extended XAFS (EXAFS) revealed that implanted Cr and Co ions and their tracks cause a substantial amount of structural disorder and distortion at both vanadium (V) and oxygen (O) siites. The resistance and XAFS measurements revealed that VO_2 experienced a shart MIT when the distance of V-V pairs showed a SPT without transitons in either the VO_6 octahedrons or the V 3d t_{2g} and e_g states. This indicated that the MIT of VO_2 occurs without a transition of the crystal field.

Keywords:

MIT, VO2, XAFS

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C8.01

Tunable phase transition temperature of FeRh thin film by Co doping

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Abstract:

FeRh, which is an intriguing material revealing the temperature-induced first-order magnetic transition from antiferromagnetic to ferromagnetic phase, has been studied for its applicability to spintronics. However, the magnetic transition temperature of FeRh occurs at T_T ~ 370 K above room temperature [1], so that the tuning of T_T is one of the most important issues. Magnetic doping is one way to effectively tune the transition temperature, and there is a previous report that Co-doped FeRh has a lower transition temperature than the pristine FeRh [2]. In this study, we fabricated pristine FeRh(001) and Co-doped FeRh(001) thin films on MgO(001) substrates by using the magnetron co-sputtering method with FeRh alloy target and Co target. The thin films show clear magnetic transition in both magnetic and electronic properties. The magnetic transition temperature dramatically decreases to a value as low as 100 K by 3% Co doping. The energy dispersive spectroscopy measurements revealed that the Co atom is substituted for the Rh site, which can influence such dramatic change of T_T. Furthermore, Co-doped FeRh films display giant magnetoresistance depending on the temperature. These results offer potential applications in the fields of magnetic random access memory and antiferromagnetic spintronics.

[1] S. Maat, J.-U. Thiele, and Eric E. Fullerton, Phys. Rev. B 72, 214432 (2005)
[2] 0S. Yuasa, Y. Otani, H. Miyajima, and A. Sakuma, IEEE Trans. J. Magn. Jpn. 9, 202 (1994)

Keywords:

FeRh, thin film, magnetic transition, doping

2020 KPS Fall Meeting
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C8.02

Epitaxial growth of FeRh thin films and adjusting transition temperature through proximity effect between Co doped Mn_3Ga

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Abstract:

FeRh, that shows an antiferromagnetic to ferromagnetic phase transition, has gained exotic interests for potential applicable in antiferromagnetic spintronics as well as magnetic media because of its large resistance change of ~30% with temperature and ~50% with magnetic field. The most attractive point of FeRh as a magnetic material is that the transition temperature is just above room temperature, and it can be tuned by various physical methods such as Fe-Rh composition, structural strain, and chemical doping. Many studies have attempted to utilize FeRh to device area such as spin pump. Although the results are adorable, there are limitations to use FeRh with wide phase transition range, resulting in low selectivity and high power consumption. In order to achieve a sharp transition and adjust the transition temperature, we have grown thin films of FeRh by using magnetron sputtering system and found the optimal conditions for the epitaxial growth. In this study, we discuss the physical properties for various deposition conditions.

Next, on top of the epitaxial films of FeRh we have deposited Co-doped Mn_3Ga films, which is a ferrimagnet used for controlling the transition temperature by proximity effect. As a result, we found that the transition temperature of FeRh is adjusted up and down by 40 K through proximity effect of the ferrimagnet of Co- Mn_3Ga. All other physical properties are kept in the FeRh/Co-Mn_3Ga bilayer system, which undergoes the large magnetoresistance and sharp transition. These results give the advance approaching its use in antiferromagnetic spintronics.

Keywords:

Magnetic phase transition, FeRh thin film, antiferromagnetic spintronics, adjust transition temperature

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C8.03

Resonance Raman Scattering Studies of localized spin excitation in hexagonal $LuMnO_3$

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Abstract:

Hexagonal $RMnO_3$ (R = rare earths, Y, and Sc) system has been investigated by diverse measurements to investigate the origin of the multiferroic properties. $LuMnO_3$ particularly is one of the candidates to study the spin excitations attributed to the Mn ions without the stray effects from the Lu-ion. In this study, we have explored the localized spin excitations in the Mn plane by analyzing the resonant Raman signal from the hexagonal $LuMnO_3$ and by designing a model associated with the antiferromagnetic spin rotation of the Mn ions in the symmetry of the triangular lattice.
Temperature dependence of the Raman spectra (15 ~ 120 K) of hexagonal $LuMnO_3$ single crystals are obtained under the cross polarization by 671 nm wavelength excitation. The resonance condition of the spin excitation peaks are analyzed by comparing with previous Raman studies. We propose a Hamiltonian which takes into account the two kinds of spin exchange integrals in the Mn plane. Excitation energy calculations with regard to three-spin rotation are performed. The results well match with our Raman measurements, and they explain the localized spin excitations within the allowance of the triangular symmetry.
Taking all the consideration, we could suggest a possibility of the localized spin excitation by optical resonance with the Mn d-d transition in hexagonal $RMnO_3$. Raman spectroscopy would be a powerful optical tool for locally perturbing the spin excitations associated with the Mn-ions specifically through the resonance condition.

Keywords:

Resonance Raman, LuMnO3, spin excitation

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C8.04

Electronic and Magnetic Properties of GdPtBi

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Abstract:

The anomalous Hall effect is normally observed without applied magnetic fields in magnetic materials. Recently, an intriguing phenomenon called as nonlinear Hall effect has been reported in non-magnetic Weyl semimetals such as WTe_2 [1] with time-reversal symmetry, which requires a broken inversion symmetry. On the other hand, GdPtBi is a magnetic Weyl semimetal with broken time-reversal symmetry and inversion symmetry, and there is a theoretical prediction that the nonlinear Hall effect can be observed in magnetic Weyl semimetals [2]. Thus, we synthesized high-quality single crystals of GdPtBi and measured the magnetic and electronic properties. The magnetic data clearly show the antiferromagnetic transition at T_N =10 K, which is consistent with previous reports [3]. The electrical resistivity increases with increasing temperature, followed by a maximum of around 40 K, and then it decreases. As the magnetic field increases, the peak moves to a higher temperature and reaches ~70 K at 7 T. The overall shape of magnetoresistance exhibits a positive slope except for the field range from 1 to 3 T, where the magnetoresistance has a negative slope. This is characteristic of Weyl behavior. The negative slope is smeared out with increasing temperature and becomes parabolic above 100 K. Furthermore, we estimate the charge carrier density from the Hall measurement, which is about n = $3.58´10^{18}$ cm^{-3} and $4.36´10^{19}$ cm^{-3} at 2 K and 300 K, respectively. The antiferromagnetic spin texture can affect the time-reversal and inversion symmetry, which can tune the Berry curvature of GdPtBi Weyl semimetal. We will discuss the angle-dependent magnetotransport properties based on the Berry phase physics.

Keywords:

GdPtBi , Magnetic Weyl semimetal, Anti-ferromagnetism

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C8.05

Effect of thermal annealing on electronic properties and microstructure of polycrystalline $SrFe_{12}O_{19}$

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Abstract:

Strontium hexaferrite ($SrFe_{12}O_{19}$, SrM) has unique anisotropic crystal structure. Recently, it was claimed that anisotropic thermal transport in this material. In this presentation, we present another type of structure-property relation. We synthesized polycrystalline SrM by the solid state reaction in air. Calcined SrM was sintered for various times: 6, 12, and 24 hours, in air in disk form. We analyzed stoichiometry and magnetic property using electron probe micro analyzer and vibrating sample magnetometer. It turns out that sintering time do not change magnetic properties and sample stoichiometry. However, when the sintering time is increased, the tendency to align the c-axis along disk-surface is observed. In addition , evolutions in electronic structure and transport properties are observed from normal-incident XAS and impedance measurements in capacitor geometry.

Keywords:

M-type ferrite, XAS, Ferromagnet

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C8.06

Observation of unconventional anomalous Hall effect at compensated $Mn_{2.3}Pd_{0.7}Ga$ thin film

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Abstract:

The magnetic properties of tetragonal ferrimagnetic Heusler compound Mn_3Ga, which has two magnetic sublattices of Mn Ⅰ and Mn Ⅱ, can be tuned by substituting a non-magnetic transition metal element such as Pt and Pd for the Mn Ⅱ site. Theoretically, a fully compensated point where the net magnetization becomes zero has been proposed as x = 0.65 in $Mn_{3-x}Pd_xGa$ [1]. In this study, we experimentally demonstrate the compensated point at x_C = 0.7 and report the magnetic and electrical properties focusing on the compensated regime. The $Mn_{3-x}Pd_xGa$ thin films with various Pd contents (x = 0.6, 0.65, 0.7, 0.75 and 0.8) were fabricated on MgO (001) substrates using DC/RF magnetron co-sputtering system. The magnetic data revealed that the magnetic moment is minimized at x_c = 0.7. In addition, unexpected magnetic transitions at T = 305 K and 320 K have been observed in the remanent M-T curve for x_c, which have never reported in previous studies on the similar $Mn_{3-x}Pt_xGa$ system. In order to unveil the origin of several magnetic transitions, we further measured the magnetic field dependence of magnetization, Hall resistivity, and longitudinal resistivity. The Hall data is analyzed with three components of normal Hall effect, anomalous Hall effect, and topological Hall effect. From the systematic analyses, we suggest the most possible magnetic phase diagram with complicated non-collinear spin configuration such as magnetic skyrmion or anti-skyrmion in $Mn_{2.3}Pd_{0.7}Ga$ thin film.

References

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Keywords:

Heusler, skyrmion, thin films, compensated ferrimagnetism

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C8.07

Comparison between Perpendicular and Longitudinal Exchange Bias Effects in (Mn, Co)$_3$Ga/Mn$_3$Ga Bilayers

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Abstract:

Exchange bias (EB) originates from the magnetic interaction at the interface between a ferromagnetism (FM) and an antiferromagnet (AFM), FM/AFM bilayer which is practically used to pin the spin direction of giant magnetoresistance head in hard disk drives. Nevertheless, its mechanism is still unveiled. In the material viewpoint, most studies have been performed in in-plane magnetic anisotropic (IMA) geometry, i.e., FM(IMA)/AFM bilayer, and there are few reports on FM/AFM bilayer with perpendicular magnetic anisotropic (PMA) geometry. In this study, we report the EB characteristics not only for IMA but also for PMA, where the spin structure is controlled by the amount of Co doping in Mn_3Ga. We fabricated the bilayer system composed of two magnetic materials; $Mn_{3-x}Co_xGa$ tetragonal ferrimagnetic layer and Mn_3Ga cubic antiferromagnetic layer. By adjusting the Co composition ratio, we could change the magnetic anisotropy of the ferrimagnetic $Mn_{3-x}Co_xGa$ film from PMA with hard magnetization to IMA with soft magnetization. Since the antiferromagnetic Mn3Ga is cubic, there is no magnetic anisotropy, so that we tune the magnetic anisotropy of Mn3Ga through the field cooling process. In order to explain the complex EB effect, we have modified the spin glass model, and we propose new spin interfacial structures.

Keywords:

Heusler compound, magnetic anisotropy, exchange bias

2020 KPS Fall Meeting
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C8.08

Structural study of nitrogen ion beam implanted $GdFe_{12}$ films

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Abstract:

From previous research, we optimized growth condition of Mo-capped $GdFe_{12}$ films on epitaxial-Mo-buffered c-cut Al_2O_3 substrates. In this presentation, we studied effect of nitrogen ions on Mo-capped $GdFe_{12}$ thin films on epitaxial Mo buffered c-cut Al_2O_3. The conditions of ion beam are 100 keV of ion beam energy, and 1 x 10^{15}, 5 x 10^{15}, and 1 x 10^{16} ions/cm^2 of different ion dose. After the implantation, the structural evolution of $GdFe_{12}$ films were investigated by x-ray diffraction, x-ray reflectivity, and atomic force microscopy. TRIM simulation is performed to see recoiled ion distribution and nitrogen concentration along depth. We obtained significant expansion of lattice constant of buffer Mo films compared to that of $GdFe_{12}$ films after implantation. As a closely related results, the total thickness of nitride thin films are increased. In contrast to such lattice information, the films retained identical surface morphology after ion beam implantation. Lastly, we will share detailed structural information along the depth based on x-ray reflectivity and fitting. Then, we will argue the origin of enlargement of total thickness. This work is supported by the National Research Foundation of Korea (NFR) (NRF-2018M2A2B3A01071859).

Keywords:

ReFe12

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C9.01

Quantum Information Processing using Superconducting Quantum Devices

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Abstract:

Superconducting quantum device is now the leading platform for quantum information processing, especially in the quantum computing. In this talk, I will present the up-to-date status of the superconducting qubits and systems using them. Being an electronics circuit, the superconducting qubit has an excellent tunability and scalability. Last two decade has evidenced how we can avoid decoherence and infidelity by precision quantum engineering of device fabrication and microwave control, and multi-qubit operation strategies. Here I will also introduce our domestic research activity to build a small-scale universal quantum computing system with this technology.

Keywords:

superconducting qubit, quantum computing, quantum information

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C9.02

Quantum simulations with ultracold atoms

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Abstract:

Ultracold atoms in optical lattice provide an outstanding opportunity to solve complex many-body quantum problems, exploring a wide range of physics from condensed matter, statistical physics, and high-energy physics. With the advent of the quantum gas microscope, single-site and single atoms resolved imaging system in optical lattices, microscopic information of many-body states can be measured and arbitrary density or spin patterns can be generated for the study of many-body dynamics. In many cases, experiments are carried out in a regime where classical computers cannot within reach, demonstrating a practical quantum advantage. In this talk, we will present the recent achievements of the site-resolved-imaging system of the ^{7}Li atoms in two-dimensional optical lattices and introduce on-going experiments using Bose-Einstein condensates in quasi-2D optical dipole trap.

Keywords:

Ultracold atoms, Optical lattices, Quantum gas microscope, Quantum simulator

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C9.03

Spin sensing and quantum control of single molecules

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Abstract:

The desire of scaling down information devices to atom-scale has brought the interest of using single spins as basic storage unit. This requires precise control of spin states and deep understanding of spin-spin interactions. Scanning tunneling microscopy (STM) combined with electron spin resonance (ESR) technique has been proved a powerful tool to access and coherently control single spins in atomic scale [1,2]. However, current ESR-STM studies are focusing on metal atom spins. Driving ESR on single molecules has not been reported yet. Here, we realize single molecule ESR by using iron phthalocyanine (FePc) molecules on a bilayer magnesium oxide (MgO) surface supported by Ag(100). We found that FePc on MgO has spin S = 1/2 due to additional electron transferred from the metal substrate. In contrast to a highly localized atom spin, the spin density of FePc molecule extends markedly from the Fe center to outer ligands. This results in anisotropic exchange interaction when a molecule spin is involved. In FePc-FePc dimers, the coupling strength differs significantly depending on the relative ligand orientations. DFT calculations reveal that the subtle difference in ligand-ligand distance accounts for the change in coupling strength. We further verified the important role of delocalized ligand spin in exchange interaction by measuring FePc-Ti pairs. By positioning Ti atoms on different sites with respect to the molecule skeleton, the coupling strength shows strong declining trend as a function of both Ti-Fe and Ti-ligand distance.
Furthermore, we achieved the coherent manipulation of individual FePc spin by driving Rabi oscillations. Exploring the influence of intermolecular interaction on coherence control of molecule spins is our next step. We have demonstrated the feasibility of employing single molecules in atom-scale quantum control studies and shed light on intriguing magnetic interactions between non-localized spins, which is crucial for developing molecule-based spintronic devices.

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Keywords:

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C9.04

Quantum information with trapped ions

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Abstract:

Quantum technology provides the tools for measurements, communications, and computations which are impossible to achieve with any classical devices. Among several competing quantum hardware, trapped ions are the best-controlled system for realizing these quantum advantages. Here, we present recent developments in ion-based quantum technology. For example, we have employed single trapped ions as a quantum sensor to measure the light field of an optical resonator without destroying the photons. We have also generated high-fidelity ion-photon entanglement constituting key resources for quantum networks. These techniques are especially associated with long-distance quantum communication, which requires a quantum repeater protocol for connecting multiple quantum nodes via photonic links. Moreover, quantum networks also provide a framework for distributed quantum computing.
In order to reach quantum supremacy using trapped ions, the hardware needs to be scalable in the number of qubits and quantum operations: It is therefore essential to miniaturize the trapped-ion quantum computer while maintaining the near-perfect control over the qubits. Toward this goal, we envisage interdisciplinary research themes, including not only the quantum physics background but also the insight of the engineering experts in nanofabrication, MEMS technology, RF technology, and even cryogenics. We review the recent experimental progress in the state-of-the-art engineering of ion traps, and outline future research directions.

Keywords:

ion trap, cavity QED

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C10.01

Engineering domain topology and symmetry in the twisted bilayer vdW materials

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Abstract:

Two-dimensional (2-D) van der Waals (vdW) heterostructure exhibits unconventional degree of freedom to engineer the system. First, control of interlayer twist angle enables one to engineer a quasiperiodic moiré superlattice that modifies the electronic properties.
More interestingly, collective atomic scale modulation occurs at the vdW interface, creating the arrays of commensurate domains and domain boundaries, as we have recently shown in the twisted bilayer graphene. We note that such atomic scale reconstruction is expected to occur at various types of vdW homo- and heterointerfaces, but the reconstruction patterns and the resulting domain topology can differ significantly. In this talk, we will discuss the connection between crystal symmetry and tunable domain topology at the reconstructed interfaces in twisted bilayer transition metal dichalcogenides. The interplay between the underlying crystal symmetries of each layer and the boundary conditions of global twist angle determines the topologies of the emergent domain structures and their functionalities. We will also discuss our recent efforts to manipulate the crystal symmetry via electrical means to induce the change in the domain structures in a dynamic manner.

Keywords:

atomic reconstruction, twisted bilayer transition metal dichalcogenides, transmission electron microscopy, domain topology engineering

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C10.02

Cooperative study of TEM and simulation on mediator atom in 2D materials and various van der Waals heterostructures.

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Abstract:

The structural transformations of graphene defects have been extensively researched through aberration corrected transmission electron microscopy (AC-TEM) and theoretical calculations. For a long time a core concept in understanding the structural evolution of graphene defects has been the Stone-Thrower-Wales (STW) type bond rotation. In this study, we show that under-coordinated atoms induce bond formation and breaking, with much lower energy barriers than the STW type bond rotation. We refer to them as “mediator atoms” because of their mediating role in the breaking and forming of bonds. Here we report the direct observation of mediator atoms in graphene defect structures using AC-TEM and annular dark-field scanning TEM (ADF-STEM), and explain their catalytic role by tight binding molecular dynamics (TBMD) simulations and image simulations based on density functional theory (DFT) calculations [1]. I will introduce the recent results on the epitaxial Pt bilayers on graphene [2] and scanning Moiré fringe method in 2D material [3]. Our very recent TEM and simulation cooperative results on Iodine fluoride (IF) double layer on WSe_2 will be also discussed [4].

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[2] A.Robertson*, G-D.Lee*, S.Lee, P.Buntin, M.Drexler, Al.Abdelhafiz, E.Yoon, J.Warner, F.Alamgir, ACS Nano, 13, 12162 (2019)
[3] Y.-C.Lin, H.Ji, L.Chang, Y.Chang, Z.Liu, G.-D.Lee, P.Chiu, H.Ago, K.Suenaga* ACS Nano, 14, 6034 (2020)
[4] Y.-C.Lin*, S.Lee, Y.Chang, P.Chiu, G.-D.Lee*, K.Suenaga*, submitted

Keywords:

TEM, Simulation, 2D materials, mediator atom

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C10.03

Advanced interface analysis of 2D-TMD materials using cross-sectional transmission electron microscopy

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Abstract:

Transmission Electron Microscopy (TEM) has been considered as a useful technique to investigate the structural, chemical, and electronic properties of two-dimensional transition metal dichalcogenides (2D-TMDs). Especially, the advanced scanning TEM (STEM) equipped with a spherical aberration corrector was introduced and actively used for uncovering the atomic-scale structure and chemical composition of 2D materials in a sub-Å level. In the real electronic devices and catalytic systems, revealing the interface structure found at the regions between metal and 2D material or among different 2D materials is so crucial for improving the performance. In this case, the cross-sectional TEM analysis combined well-prepared TEM samples is needed. In this presentation, I will present various cross-sectional STEM works which were performed using a Cs corrected STEM combined with a focused ion beam (FIB) sample preparation technique. Firstly, I will show the unique interface analysis which are important for characterizing the fundamental phenomena found at the interface between metal (In/Au alloy) and 2D monolayer MoS_2 using field-effect transistors. In addition, metallic 2H phase of niobium disulfide ($Nb_{1+X}S_2$) with additional niobium atoms for potential hydrogen revolution reaction (HER) catalysts is clearly visualized via cross-sectional STEM images.

Keywords:

two-dimensional transition metal dichalcogenide, interface analysis, cross-sectional STEM

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C11.01

The Interface Mixing Effect of Solution Processed OLEDs

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Abstract:

It is very difficult to realize highly efficient and stable solution processed organic light emitting diodes (OLEDs) due to an interface mixing behavior during continuous wet processes. To eliminate this problem, we need to form a cross-linkable hole transport layer (x-HTL) before depositing an emitting layer (EML). However, we cannot clearly solve interface mixing problem although we use such x-HTL during process. Especially, we found that the crosslinking of HTL causes serious reduction of hole mobility, which results in shift of exciton formation zone toward HTL / EML interface. Thus, we need to focus on EML composition because the interface mixing could be accelerated if the thermal stability of materials in EML is very poor. In other words, small molecules in EML often diffuse into the preceding HTL although it's crosslinked. Besides, we also found that the thermal stability of host materials in EML is very important for this interface mixing behavior.

Keywords:

Solution processed OLEDs, Continuous Wet Process, Interface Mixing, Stability, Molecular Structure of Host

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C11.02

Metal halide perovskite LEDs prepared by ultrasonic spray coating process

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Abstract:

Metal halide perovskites have attracted great attention as a promising candidate of next-generation light emitter because of their unique properties such as high color purity due to narrow emission spectrum at full visible wavelength region, high photoluminescent quantum yield reaching to a unit, quantum-well like atomic structure, and solution processability. However, the bulk-like metal halide perovskites do not have strong emission due to thermal ionization of the exciton by small exciton binding energy. Therefore, the excitons should be physically confined in small crystallite of perovskite. Here, we fabricated polycrystalline metal halide perovskite film via ultrasonic spray coating process and characterized their performance.

Keywords:

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C11.03

Ultrathin wearable quantum dot light emitting diodes

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Abstract:

Recent advances in soft electronics have attracted great attention due in large to its potential applications in personalized mobile and wearable electronic devices. The mechanical mismatch between conventional electronic/optoelectronic devices and soft human tissues/organs, however, often causes various challenges, such as the mechanical fracture in the device under deformations, and discomfort and consequent stress to users. Ultra-flexible and stretchable electronic and/or optoelectronic devices have low system modulus and intrinsic softness and solve these issues. Here, our unique strategies in the synthesis of nanoscale materials such as quantum dots, their seamless patterned integration with ultrathin electronics, and unconventional device designs toward wearable and transparent integrated light emitting devices are presented. These wearable electronic and optoelectronic systems combine recent breakthroughs in unconventional soft electronics to address many unsolved issues.

Keywords:

Quantum dot, Light emitting diode, Wearable display, Ultrathin display, Transparent display

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C11.04

White QLEDs with High Color Quality

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Abstract:

Colloidal quantum dots (QDs) have been widely investigated as one of the efficient light-emitting materials with a narrow emission spectrum. Additionally, the spectral peak wavelength of QDs can be easily tuned by changing the size and the chemical composition of the core during synthesis, which enables to obtain a variety of emission colors. Utilizing this character of QDs, we developed white-emitting QD-based light-emitting didoes (QLEDs) with high color quality by mixing five and six colors of QDs in a single emission layer. The white quality was thoroughly investigated for their potential application to displays and lighting devices.

Keywords:

white QLED, quantum dot

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C12.01

Spontaneous versus interaction-driven burstiness in human dynamics: The case of Wikipedia edit history

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Abstract:

The origin of non-Poissonian or bursty temporal patterns observed in various datasets for human dynamics has been extensively investigated, yet its understanding still remains incomplete. Considering the fact that humans are social beings, a fundamental question arises: Is the bursty human dynamics dominated by individual characteristics or by interaction between individuals? In this talk we address this question by analyzing the Wikipedia edit history to see how spontaneous individual editors are in initiating bursty periods of editing or to what extent individual behaviors are driven by interaction with other editors in those periods. We refer to this question as spontaneous burstiness versus interaction-driven burstiness. After identifying bursty periods from the edit sequence of each Wikipedia article for a given timescale, we quantify the degree of initiative (DOI) of an editor using the statistics of bursty periods containing the editor's edits. Scanning the entire range of timescale in the article, we obtain the DOI curve for the editor, from which the area under the curve (AUC) is calculated. The large (small) value of AUC implies the dominance of spontaneous burstiness (interaction-driven burstiness) over the other type of burstiness. By correlating the AUC value with other measures for temporal and editorial correlations, we find that the AUC values tend to be larger for weaker temporal correlations for the ego and/or stronger editorial correlations in the edit sequences. These empirical findings are successfully confirmed by deriving an analytic form of the DOI curve from a model capturing the essential features of edit sequences. Therefore our approach gives a deeper insight into the origin and underlying mechanisms of bursts in human social dynamics.

Keywords:

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C12.02

Friendly-rivalry solution to the iterated n-person public-goods game

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Abstract:

Repeated interaction promotes cooperation among rational individuals under the shadow of future, but it is hard to maintain cooperation when a large number of error-prone individuals are involved. One way to construct a cooperative Nash equilibrium is to find a `friendly rivalry' strategy, which aims at full cooperation but never allows the co-players to be better off. Recently it has been shown that for the iterated Prisoner's Dilemma in the presence of error, a friendly rival can be designed with the following five rules: Cooperate if everyone did, accept punishment for your own mistake, punish defection, recover cooperation if you find a chance, and defect in all the other circumstances. In this work, we construct such a friendly-rivalry strategy for the iterated n-person public-goods game by generalizing those five rules. The resulting strategy makes a decision with referring to the previous $m=2n-1$ rounds. A friendly-rivalry strategy inherently has evolutionary robustness in the sense that no mutant strategy has higher fixation probability in this population than that of neutral drift, and our evolutionary simulation indeed shows excellent performance of the proposed strategy in a broad range of environmental conditions.

Keywords:

iterated public-goods game, direct reciprocity, evolutionary robustness

C12.03

Photosystem network reveals that diverse chlorophylls facilitate photoprotection

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Abstract:

Photosynthesis is the primary energy production process of ecosystem [1]. It is known that the light-harvesting complex in photosystem II is distinguished by its diverse composition of two different types of chlorophylls a and b [2]. The structure and functional characteristics of the individual chlorophylls have been investigated in the molecular level, but it has yet to be explained clearly that the significance of the coexistence in the photosystem's point of view. Here we present a principled framework for discerning and quantifying the chlorophylls' role during the excited energy transfer. Our approach combines network science [3, 4] and Monte Carlo Markov analysis based on the Förster resonance energy transfer rates [5] between all chlorophylls. We reveal that the coexistence of chlorophylls a and b enables the photosystem to be maintained robust guaranteeing the best use of its photodamage control mechanism. Comparing to other synthetic photosystem models, we show that the natural light harvesting system is the most advantageous to protect itself against photodamage.

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Keywords:

complex systems, network science, photosystem

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C12.04

Betweenness Centrality Distribution of Hypergraphs

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Abstract:

As a central measure of individual influence in social networks, L. Freeman proposed betweenness centrality(BC). This quantity is based on the shortest-path information transport processes. The concept is enlarged to general network structures for diverse applications, such as analyzing loads on the power grid or expressing how severe the traffic jamming is. In recent years, the wide-usage of hypergraphs gives us deep understandings of higher-order interactions. Nevertheless, there is no concrete definition of BC on hypergraphs yet. Here, we consider the BC distributions of two random growing hypergraph models. For the first case, a growing random uniform hypergraph(GRUH) model, hyperedges are constructed by random selection of fixed number of nodes, which have equal probability. The other one, a preferentially growing hypergraph(PGH) model, is founded on the preferential-attachment rules. Also, the model allows that the hyperedges can take diverse sizes to reflect general situations. The BCs on vertices and hyperedges are defined and measured to understand the transport phenomena in the hypergraphs. In this presentation, we confirm that the BC distribution follows the power law at the percolation point though the structural inhomogeneity is weak. Furthermore, we observe that the breakdown of the power-law distribution at the large initial attractiveness for the PGH model. Finally, we find positive correlation between BC and hypergraph degrees of vertices.

Keywords:

Betweenness Centrality, Hypergraph, Higher-order interaction

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C12.05

The stability and feasibility of ecological networks.

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Abstract:

It is important to understand the linear stability of fixed points in dynamical systems defined on the complex network in many various fields. The linear stability of the species abundance in the ecological networks of plants and animals under competition, mutualism, or both have been studied. But there is no unified answer on the relationship between the network structure and linear stability of feasible equilibrium points in ecological dynamical systems and other dynamical properties like feasibility.
We derive the systematic coexistence criterion for which ecological systems are both stable and feasible. We construct a block-structured interaction matrix representing the competition and the mutualism used in the Lotka-Volterra equation. We obtain analytically the inverse of and the largest eigenvalue of the interaction matrix in the uniform and mean-field approximation.
Our results show that mutualism decreases the feasibility and stability of the ecological system. Analyses of the model and 148 real empirical networks are conducted to examine our conclusion. We perform a data collapse for 148 empirical data and find the scaling variables. We identify two phases transitions one from stability to instability and one from feasible to unfeasible. Our study provides an insight into how network structure, notably degrees, influences species stable coexistence.

Keywords:

Ecological network, Stability, Feasibility,Coexistence

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C12.06

인천 버스노선의 복잡계 네트워크적 특성

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Abstract:

교통이란 운송수단을 이용해서 특정 지점에서 다른 지점으로 사람이나 물류를 이동하는 것을 의미하며 이동의 시작과 끝, 그리고 흐름으로 정의할 수 있다. 도시의 버스는 한 정류장에서 다른 정류장으로 승객을 수송하는 역할을 한다. 본 논문은 2018년 인천의 버스정류장을 기반으로 네트워크를 구성하고 복잡계 네트워크적 특성을 알아보았다. 버스 네트워크의 각 노드는 버스정류장이고, 각 정류장을 경유하는 각 버스 노선이 링크를 형성한다. 도시 교통의 중요한 교통수단인 전철이 버스 네트워크에서 어떤 영향을 끼치는지 확인해보았다. 분석한 내용을 토대로 버스정류장 네트워크의 특징 및 발생할 수 있는 문제를 파악하였다.

Keywords:

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C12.07

The spatial transition of urban retail areas in Hongdae revealed through online SNS data: in perspective of complex network.

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Abstract:

Retail areas in a city play essential roles in local economic activities. With the continuous interest on dynamics occurring retail areas for several decades, recently it become more emphasized to understand underlining motives of stakeholders who do major activities. However, for long it has been hard to comprehensively understand the perceptions of these stakeholders toward the retail areas, due to a lack of data availability. Most related previous studies were based on surveys and interviews thus they have a limitation in terms of spatial and temporal scales. Meanwhile, recent growing availability and accessibility to various online big data have provided a new perspective in the understanding of urban changes. It enables us to explore how people perceive and use urban areas for large area and long-term time scale.

This study employs the text mining to collect big text data from SNS (online blogs) and analyzes the data to investigate dynamic spatial transformation and interaction across multiple, adjacent retail areas around Hongdae area, a major commercial hub in Seoul. We also utilize a complex network analysis in order to create co-occurrence networks of the collected text data and to systemically capture representative place images and user experience of the Hongdae area and its neighboring, “spin-off” retail districts.

Our finding is summarized as follow. First, the Hongdae area, which was a small-scale bohemian, hippest neighborhood in Seoul incubating indie culture, has become fully commercialized as a global tourist attraction, with a phenomenon that consumer experience about “food” and “eating” dominates. Identified from the SNS text data, this “food” and “eating” experience has diffused into neighboring districts over time (Sangsu, Hapjeong, Yeonnam, and Mangwon), signaling sequential commercialization of the districts and weakeninig their original place identities at the same time. Second, our text network analysis is effective in illustrating that the dynamic patterns of commercialization throughout the Hongdae’s neighboring districts follow “invasion-succession (IS) process” hypothesized in classical urban ecological view of land use. Third, we find key words signaling gentrification from our text networks, constructed for each “spin-off” commercial district adjacent Hongdae.

The complex network analysis using SNS text data proposes a new way to review and organize consumer perspectives on a retail space. Especially combining with several network analysis methodology, we are able to conceptualize the essence of consumer perception.

This work was supported by the National Research Foundation of Korea(NRF) grants funded by the Korea government (MSIT) (No. 2020R1A2C2008443 and No. 2016R1A2B4013843).

Keywords:

Urban space, Retail area, Gentrification, Complex network, Community detection

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C12.08

Diversity and Stability on an Open Evolving Network Model

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Abstract:

Complex systems such as economic, biological, and ecological systems consist of many individuals interacting with each other. These interactions determine the dynamics of the system as to how many different types of individuals survive and how long they stay in the system. Such diversity and stability have been extensively studied at fixed interaction structures. However, diversity and stability that are found in the system where new types of individuals are constantly emerging have not been well understood yet. We introduce an open evolving network with a competitive Lotka-Volterra type dynamics to examine how diversity and stability are shaped. Particularly, we focus on the role of the interaction strength and the new individual's appearance rate. Our model shows that the weaker interactions and the higher appearance rates it has, the higher diversity it represents. Interestingly, we found that there are two regimes for the low diversity phase. In this phase, above the threshold interaction strength, the majority type occupying most of the population changes all the time while the majority stays forever for smaller strength values.

Keywords:

Complex System, Competitive Lotka-Volterra Type Dynamics, Open Evolving System, Diversity, System

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C14.01

Experimental Transverse Beam Emittance Measurement Using Solenoid Magnet Strength Variation in the AB-BNCT

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Abstract:

Boron neutron capture therapy (BNCT) is one of useful cancer treatment modality other than direct radiation therapy using charged particles such as proton or carbon beam. Accelerator based BNCT (AB-BNCT) is recently attracting treatment modality due to construction in a hospital. Korea Institute of Radiological & Medical Sciences (KIRAMS) constructed the injection system of electrostatic accelerator for AB-BNCT and having been commissioned 30 keV H− and 5 keV D− ion beams. Beam characteristic parameters, Twiss parameters, are important things to be confirmed by experiment and have various methods to be applied. In this study, the linear matrix formalism is used as a technique by varying magnetic field strength of solenoid magnet in the beam line. In order to confirm the validity for varying method of solenoid magnetic field strength, the tracking Monte Carlo simulation was executed and confirmed to be well satisfied with a tool extracting twiss parameters. After verification by MC simulation, the method is adopted on the experiment and accurately obtains the transverse beam emittance within the uncertainty. As one of method extracting the Twiss parameters indirectly, solenoid magnet field strength variation tool is a very useful and convenient method. In case other tools such as quadrupole magnetic field strength are added, the result of the Twiss parameter is expected to be measured with more precise and accurate.

Keywords:

AB-BNCT, solenoid magnet, transverse beam emittance, linear matrix formalism

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C14.02

Development of UNIST EBIT

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Abstract:

For the purpose of studying highly charged ions(HCIs), CHEA(Center of High Energy Astrophysics) is developing an electron beam ion trap(EBIT) in collaboration with Max Planck Institute of Nuclear Physics(MPIK). The EBIT has up to 8 keV energy of electron beam with 0.86 T by permeant magnets to perform the X-ray spectroscopy of the HCIs in a cost-effective and low maintenance way.
The first target is measurement X-ray transition spectroscopy of High charged iron ion (FeXXV) to investigate the formation of the universe by comparison with satellite X-ray observatory data. For this precise measurement, high resolving power X-ray sources are required. The newly built PAL-XFEL(Pohang accelerator laboratory X-ray free-electron laser) facility is our major candidate to achieve our requirements. In this work, the status of UNIST-EBIT and our research plan will be presented.

Keywords:

Electron Beam Ion Trap, Ion, Spectroscopy

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C14.03

Generation of isolated, terawatt, attosecond X-ray free-electron laser pulse by investigating the effect of high slice energy spread of an electron beam

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Abstract:

Attosecond (asec) X-ray free-electron laser (XFEL) has attracted considerable interest over the past years. Nowadays typical XFEL application experiments demand 10^{10}–10^{11} photons per pulse, which corresponds to a peak power of terawatts (TW) in case of asec hard X-ray pulse. To the realization of such TW asec-XFEL pulse, however, the unavoidable increase of slice energy spread (SES) due to laser heater, which is commonly used to mitigate the micro-bunching instability (MBI), would be a major obstacle. To deal with this problem, the effect of such a SES is investigated in this work. The results reveal that (1) SES of a current spike is linearly proportional to the peak current of a current spike in an electron beam, (2) surprisingly, this linearity is independent of the wavelength of an energy modulation driving laser which is used to make a current spike and (3) the gain length of current spike in the undulator is sensitive to the initial SES, so there is an optimal peak current of the current spike for successful FEL lasing process. Utilizing these characteristics, a series of simulations with parameters for Pohang Accelerator Laboratory X-ray Free Electron Laser was carried out to demonstrate that an isolated, TW asec-XFEL pulse can be generated even when the SES is increased due to the usage of laser heater to prevent the MBI in the XFEL. We show that an isolated X-ray pulse with >1 TW and a pulse duration of 73 as (~3×10^{10} photons/pulse at 12.4 keV or 0.1 nm) can be generated by using ten current spikes with optimal peak current. It becomes clear for the first time that the disadvantage from the increased SES can be indeed overcome.

Keywords:

free-electron laser, slice energy spread effect, attosecond, terawatt

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C14.04

Radiation reaction of a charged particle undergoing uniform circular motion

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Abstract:

전자기학에서 한 입자가 느끼는 radiation reaction (RR)은 수학적으로 표현되기에 너무 난해해서 테일러 급수 형태로만 표현될 수 있었다. RR의 초기 항들은 디랙에 의해 얻어졌고, 나머지 항들은 입자의 크기가 0일 것이라는 가정 때문에 무시되었다. 그러나 우리는 최근 연구에서, RR의 나머지 항들을 모두 고려했을 경우, 등가속운동하는 입자의 RR이 자신의 (유효)질량을 변화시킬 수 있다는 것을 발견했다. 이는 기존 이론이 예측했던 "등가속운동에선 RR이 없다"와 상반되는 결과이며, 실제론 RR의 고차항이 고려되어야 한다는 것을 시사한다. 이 발표에서, 우리는 등속원운동 하는 입자의 RR을 완벽하게 계산해본다. 이렇게 계산된 RR은 급수형태가 아닌, 하나의 항으로 간단하게 표현될 수 있음을 증명할 것이다. 또한 이 결과를 통해, 등속원운동에서의 RR이 입자의 질량을 변화시킬 수 있다는 것과, RR의 방향이 retarded time에서의 입자 가속도에 영향을 받는다는 것을 보일 것이다.

Keywords:

radiation reaction, electrodynamics

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C14.05

Simulation study of phase-matched THz emission from an axially modulated magnetized plasma

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Abstract:

We studied and demonstrated the emission of THz wave by the beating of two laser beams in an axially modulated magnetized plasma in the presence of static magnetic field (applied transversely to the direction of propagation of lasers) from two-dimensional particle-in-cell simulation. The ponderomotive-force-induced nonlinear current drives THz radiation with frequency close to the beat frequency ($\Delta\omega=\omega_1-\omega_2$), which propagates in forward direction. Inside the plasma, THz radiation consists of a mixture of linear and radial polarization while linear polarization dominates outside the plasma. The THz field amplitude grows resonantly in time, and it becomes saturated due to the growth of excited higher-order of modes, and its saturation level is about 4 times higher than non-rippled plasma case. The density ripple of suitable wave number also provides the extra momentum to satisfy the phase matching condition $kq=(k_1-k_2)-k_{THz}$. The conversion efficiency reaches around 0.018 for our simulation parameters, which is good resemblance with theoretical results reported on present scheme.

Keywords:

THz radiation, Rippled Plasma

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C14.06

자기유체역학 코드를 이용한 고전압 펄스전원장치의 엑스 핀치(X-pinch) 플라즈마 전산모사
Numerical Study of X pinch plasmas evolution on pulsed power generator using MHD Simulation

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Abstract:

X-pinch plasmas are formed by applying high current pulsed current on X-shape metallic thin wire loads. The current density is increased at the cross point, where the wires are touched each other and a high compression of plasma is produced by increasing the azimuthal magnetic field. Also, a plasma jet is formed from the cross-point to each axial direction. Soft X-ray emitted at the cross-point is usually applied to radiograph on small and fast evolving object, also, jet structures are studied for space jet phenomena in relevant to astrophysics. In this study, simulations of X-pinch plasmas on tungsten wires are performed using a MHD code. The plasma structure and power evolutions in the simulation are compared to the measured X-ray time and magnitude in the Seoul National University pulsed power generator.

Keywords:

X-pinch, magnetohydrodynamics simulation, exploding wires

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C15.01

Non-resonant laser using a light trapping scattering cavity

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Abstract:

Non-resonant lasers (NRLs) are the lasers that does not utilize the optical resonance. This concept, which may seem contradictory at first glance, was proposed in 1966 [1], only seven years after the suggestion of 'optical masers' by Schawlow and Townes [2]. The NRL is usually demonstrated by the introduction of a diffusive or scattering media in the cavity to prevent the closed-loop formation [3]. However, the NRLs have not been studied extensively because of the low power efficiency and beam directionality. Introducing the scattering medium produces inevitable loss that significantly increases the laser threshold and reduces the power efficiency. Even if the sufficient pumping power is provided, the NRLs usually operate in every possible direction due to the diffusive nature of scattering medium. Here, we propose a light trapping scattering cavity that can greatly enhance the energy efficiency and directionality of NRLs. Inspired by fishing trap designs, the proposed cavity effectively traps the lights, and permits the laser emission to the predefined direction. For the first demonstration, we used a porous Nd:YAG ceramic. Directional laser emissions with significant enhancements in the slope efficiency and linewidth is observed. The results are elucidated by a theoretical model based on the cavity geometry and the properties of used scattering gain media. This work suggests NRLs as a good alternative of the conventional lasers, especially for the gain materials that has been hard to be crystallized.

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[2] Schawlow, A.L. and C.H. Townes, Infrared and Optical Masers. Physical Review, 1958. **112**(6): p. 1940-1949.
[3] Cao, H., Lasing in random media. Waves in random media, 2003. **13**(3): p. R1-R39.

Keywords:

non-resonant laser, random laser, scattering medium

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C15.02

3D Stochastic Interferometry

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Abstract:

Light interferometers provide extraordinarily precise measurements, down to a fraction of a wavelength. Though possible designs are very diverse, they all fundamentally measure the same quantity: a relative variation of a 1D optical length. Consequently, they remain unable to probe volumetric perturbations.
Here, together with theory and experiment, we introduce the concept of 3D stochastic interferometry. By using a highly reflective diffusing cavity, we create for the first time a 3D coherent random light field that is sensitive to any perturbation that acts upon the cavity shape or induces fluctuations of the dielectric tensor field inside. We demonstrate a picometer sensitivity to vibrations, and the detection of the motion of nano-objects in solutions at the sub-angstrom level.
Our results demonstrate that optical volumes can now be probed, in a simple interferometer design that does not require precise alignment. We anticipate this work to open the way for the measurement of previously inaccessible volumetric phenomena, with applications in acoustics, seismology, optical rheology, and low-frequency dielectric spectroscopy in material sciences.

Keywords:

Interferometry, Random field, Light scattering, Berry field, Cavity

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C15.03

High-contrast, Intense Single-cycle Pulses from multiple-plates in a Double-stage Configuration

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Abstract:

The key to the interaction between the laser pulse and the matter is that the electrons in the matter react to the incident electric field, i.e. the light–matter interaction depends strongly on the ratio of the pulse duration to the characteristic response time of the medium (polarization response), in addition to the pulse intensity and energy. In a recent, it has been noted that there exists a fundamental characteristic of interaction physics within the single-cycle pulse limit, which does not appear in multi-cycle pulses on the strong-field ionization dynamics. Accordingly, high-contrast, intense single-cycle pulses are highly desirable tools in ultrafast science, enabling highest temporal resolution, pushing matter to extreme conditions, and serving as drivers in petahertz electronics.

Here, we demonstrate the generation of high-contrast, intense single-cycle pulses, using double-stage of multiple-plate supercontinuum generation (MPSC) with a 0.42 mJ/30 fs Ti:sapphire femtosecond laser at 3 kHz. The novelty of this configuration is in the design with controllability of relative contribution between self-phase modulation (SPM) and self-steepening (SS) during spectral broadening by using the well-compressed few-cycle pulses, generated in first stage, as driving sources for second MPSC stage, allowing broader full width at half maximum (FWHM) in spectrum and temporally high-contrast pulses. The resulting pulses are compressed by broadband chirped mirrors and an ammonium dihydrogen phosphate (ADP) crystal down to 2.6 fs measured by dispersion-scan (D-scan) setup, close to the transform limit of 2.55 fs, with an energy of 0.235 mJ. They exhibit an excellent power stability of 0.5% rms over 3 h and a beam profile.

Such high-contrast, intense single-cycle pulses could be utilized on the application of high-resolution time-resolved spectroscopy, attosecond science or high-intensity light-matter experiments. Furthermore, this double MPSC configuration can also be adopted for higher laser power, different repetition rates or wavelength system by adequately adjusting the pulse intensities at each plate, and/or modifying the plate material.

Keywords:

high-contrast, single-cycle pulses, MPSC, SPM

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C15.04

Ultrafast dynamics of electron-phonon coupling in 2H-$MoTe_2$ thin film

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Abstract:

Electron-phonon coupling plays a crucial role in optoelectronic device physics such as carrier mobility and diffusion length. Since electron-phonon coupling in two-dimensional van der Waals materials decay rapidly, time-resolved electron-phonon mechanism in 2D van der Waals materials is unclear. Here, we study excited carrier dynamics and coherent phonon in a photoexcited 2H-$MoTe_2$ thin film via pump-probe spectroscopy with varying pump energy, fluence, polarization, probe energy. Upon photoexcitation at room temperature, we identify a electron-phonon scattering time of ~ 1 ps and coherent longitudinal optical phonon (A_{1g} at 21.3 meV) modes in 2H $MoTe_2$ with a dephasing time of a 5 ps due to Frohlich interaction. While the dephasing time is independent over the pump photon energy, the frequency of A_{1g} phonon modes is decreased. Moreover, at different probe photon energy, we investigate the phase shift of A_{1g} mode and discuss in detail later. Finally, we obtain that the intensity of the A mode is controllable with a polarization direction. These results provide insight of ultrafast phonon dynamics, electron-phonon interaction in layered materials and possibility for optoelectronic applications.

Keywords:

carrier dynamics, carreir-phonon coupling, 2D materials, Ultrafast spectroscopy, Coherent phonon

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C15.05

Development of a SESAM-assisted Kerr-lens mode-locked laser with the SESAM located at the inside of the cavity

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Abstract:

Semiconductor saturable absorber mirrors (SESAMs) are powerful components for generating pulses. In ultrafast solid-state lasers, as one end mirror, they have been frequently used to assist Kerr-lens mode-locking. However, the use of a SESAM causes a prism pair for dispersion compensation to be placed in the cavity arm that has an output coupler as the other end mirror. In such a cavity structure, the angular dispersion of the prism pair results in a spatially chirped output beam. In order to compensate for the spatial chirp, the additional prism pair is generally used, but this leads to unwanted dispersion compensation and an increase in a system size. Here, by relocating the SESAM to the inside of the cavity, We present that the output beam with no spatial chirp can be generated from a SESAM-assisted Kerr-lens mode-locked laser despite the use of a prism pair. The properties of the newly designed laser are analyzed in comparison to those of the conventional laser that has a SESAM at the cavity end.

Keywords:

SESAM, Kerr-lens mode-locking, Ultrafast lasers

C15.06

레이저 유도 X-선 기반 금속 단백질 형광 측정 연구

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Abstract:

레이저 유도 X-선은 레이저 광원의 특성을 지니기에, 짧은 펄스폭과 높은 반복률을 가진다. 이와 같은 특성을 이용해 재료 과학 분야의 원자 수준 구조 변화 관찰, X-선 흡수분광, X-선 회절, 위상차 이미징 등 다양한 분야에 응용이 가능하고, 해당 분야들에서 활발히 연구되고 있다.
본 연구에서, 펨토초 레이저 유도 X-선 소스를 기반으로 금속-단백질 화합물 X-선 형광을 측정하였다. 고반복률 펨토초 Ti:Sapphire 레이저(1 kHz, 40 fs, 800 nm)를 비축 포물 거울로 집속시켜, 알루미늄 테이프 타겟에 조사했다. 집속된 레이저 광원의 세기는 10^{16}W/cm^2 이상이며, 알루미늄 Kα 영역에서 10^7 photon/s·srad 이상, Bremsstrahlung 영역에서 10^7 photon/s·srad 이상 flux 의 X-ray 광원을 발생시켰다. 레이저 유도 Kα 및 Bremsstrahlung X-ray 광원을 특성화 하기 위해 레이저 강도와 펄스 집중 위치를 변경하였다. 동판, 셀레늄 분말, 동결 건조 헤모글로빈, 동결 건조 된 셀레노-메티오닌 으로 X 선 형광 신호를 측정하였으며, 이를 X 선 분광기로 검출하였다. 마이크로그램 단위의 샘플로 X 선 형광을 높은 정확도와 높은 안정성으로 측정 할 수 있다.

Keywords:

laser plasma, high repetition rate, K alpha, X-ray fluorescence, Laser-induced X-ray

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C15.07

Temporal contrast measurement using tunneling ionization

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Abstract:

The development of high-power lasers allows us to study light-matter interaction in the relativistic regime. The intensity of the high-power laser pulse is often strong enough to ionize a target before the arrival of the main pulse, preventing the interaction between the target and the main pulse. Therefore, it is critical to check if the laser pulse has a prepulse. In order to measure the existence of the prepulse, a third-order autocorrelator can be used whose dynamic range reaches up to $\sim 10^{12}$. However, it does not provide information on the temporal profile of the laser pulse. In this work, we investigate the temporal contrast measurement using a new pulse characterization method called TIPTOE (Tunneling ionization with a perturbation for the time-domain observation of an electric field) [1]. TIPTOE is a method that can directly measure the temporal profile of the laser pulse in the time-domain using tunneling ionization. We found that a dynamic range of 10^8 can be achieved using the TIPTOE method. This limitation is caused by the noise of the data acquisition circuit, the power fluctuation of the laser, and the pointing instability. We discuss if the dynamic range of the TIPTOE method can be improved using a differential measurement.

Keywords:

laser pulse measurement

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C15.08

Electrically tunable spatial light complex amplitude modulator

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Abstract:

본 연구는 복굴절 물질 기반으로, 진폭과 위상의 조절이 가능한 일반화된 공간 광 변조기 (SLM) 구조를 제시하고 있으며, Jones matrix 기반의 시뮬레이션을 통하여 입증하였다. 본 구조는 대칭적 director 분포의 복굴절 물질과 특정한 조건의 편광판 조합을 사용하며, 대칭성을 유지하는 수평 및 수직 전계를 사용하는 경우, 복소 진폭의 조절이 가능하다.

본 구조는 일반화된 구조로, 특정 조건을 만족하는 경우 VA (Vertical Alignment)와 IPS (In-Plane Switching)와 같은 대부분의 LC mode 및 복굴절 물질로 구현이 가능하다. 복소 공간 전영역에서 복소 진폭 조절이 가능한 SLM의 경우 기존에는 다수의 SLM을 사용하거나, beam splitter, waveplate, 거울 등 추가적인 광학소자를 이용하여 일종의 super-pixel을 형성하였지만, 본 구조는 하나의 화소를 통한 복소 진폭 조절을 특징으로 한다.

본 연구의 복소 SLM 구조는 홀로그램, 양자광학, 양자컴퓨팅 등 대부분의 광학 및 양자역학 실험과 application에서 큰 역할을 할 것으로 보인다.

Keywords:

Spatial Light Modulator, complex SLM, Birefringence, Liquid Crystal DIsplay

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C17.01

New directions for optoelectronics with a valley degree of freedom

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Abstract:

The emergence of transition metal dichalcogenides (TMD) layers has sparked significant research interest and led to the rapid development of valleytronics. A monolayer of TMD materials has direct bandgaps consisting of two (energy-degenerate) valleys at the corners of the Brillouin zone (K, K'), which provide an opportunity to manipulate the additional degree of freedom, so called the valley degree of freedom. And valley information can be optically addressed and detected using the spin angular momentum of light, due to their valley-dependent optical selection rule. However, the interaction between light and a TMD layer is intrinsically weak due to the huge mismatch between wavelength and the layer thickness (400–1500 nm vs. <1 nm). It is generally believed that additional photonic structures such as external cavity are necessary to increase and control light-matter coupling in a TMD layer. Unfortunately, these additional structures with a linearly polarized optical mode easily spoil valley pseudospin information making it difficult to exploit the full potential of TMD layers.

In this talk, the valley-selective exciton–light coupling in a TMD layer will be discussed. In weak coupling regime, we demonstrated directional emission of valley-polarized exciton into plasmonic eigenstates of a silver nanowire [1]. A plasmonic nanowire provides a high degree of local transverse optical spin, and its handedness is locked to the propagation direction of the mode. As a result, the emission from the two different valleys of TMDs material will couple to the plasmonic modes propagating in opposite directions. In strong coupling regime, we investigated coherent coupling between exciton and photon in a thick TMD layer. We found out that these intrinsic exciton polariton in a TMD layer can carry valley information of exciton [2]. Valley-dependent exciton–light coupling offers a novel platform for realization of valley transport even at room temperature without any magnetic fields. And these results pave the way for exploiting a valley pseudospin in integrated valleytronics devices using nanophotonics structures.

References

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[2] Sung, J., Cho, H., Suh, H., Park, Q.-H., Kuipers, L., Gong S.-H., 2020, submitted.

Keywords:

transition metal dichalcogenides, valley pseudospin, optical spin

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C17.02

Tuning the excitonic properties with semiconductor-based nanocavities

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Abstract:

Semiconductor nanostructures are promising building blocks for coherent light-emitters at the nanoscale, which can be exploited in the fields of nanophotonics, nano-optics and nanobiotechnology. Light-matter interaction between the excitons and the cavity photons could be enhanced in nanostructure geometry because of the enhanced oscillator strength and the reduced mode volume compared to conventional micro-cavities. One of fascinating effects of the light-matter interaction is the low-threshold polariton lasing without the population inversion, resulting from Bose-Einstein condensation of polaritons. Therefore, the polaritons in nanowire cavity could be a key to achieve the low-threshold coherent light-emitters at the nanoscale. The lasing mechanism for various material systems, such as GaAs, CdS, and GaN, has been widely investigated to achieve the polariton lasing from nanowire systems. ZnO nanostructures are one of the best materials for room temperature polariton lasing because of the strong oscillator strength and the large exciton binding energy (60 meV). However, it is still not clear whether the lasing mechanism in ZnO nanostructure at room temperature is attributed to the condensation of polaritons. Also, it is quite difficult to achieve the room temperature polariton lasing in ZnO nanostructures because of several limitations such as the low cavity quality factor and thermal broadening of the exciton resonance at room temperature. In this work, the radial ZnO/MgZnO quantum wells, which could provide the larger oscillator strength and more stable exciton at room temperature, was introduced to achieve the room temperature polariton lasing in ZnO nanorods. The radial quantum well nanorods exhibited the outstanding features, including the thermal stability of polaritons up to the room temperature, ultra-low lasing threshold, and high spectral coherence. The characteristic features of room temperature polariton lasing will be presented.

Keywords:

Exciton-Polariton, Light-Matter Interaction, Semiconductor

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C17.03

Ultrasensitive Plasmon-free Surface-enhanced Raman Spectroscopy with Femtomolar Detection Limit from 2D van der Waals Heterostructure

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Abstract:

Two-dimensional (2D) materials have been promoted as an ideal platform for surface-enhanced Raman spectroscopy (SERS), as they mitigate the drawbacks of noble metal-based SERS substrates. However, the inferior limit of detection has limited the practical applicability of 2D material-based SERS substrates. Here, we synthesize uniform large-area ReO_xS_y thin films via solution-phase deposition without post-treatments, and demonstrate a graphene/ReO_xS_y vertical heterostructure as an ultrasensitive SERS platform. The electronic structure of ReO_xS_y can be modulated by changing the oxygen concentration in the lattice structure, obtaining efficient complementary resonance effects between ReO_xS_y and the probe molecule. In addition, the oxygen atoms in the ReO_xS_y lattice generate a dipole moment on the thin-film surface, which increases the electron transition probability. These synergistic effects outstandingly enhance the Raman effect in the ReO_xS_y thin film. When ReO_xS_y forms a vertical heterostructure on a graphene as the SERS substrate, the enhanced charge-transfer and exciton resonances improve the limit of detection to the femtomolar level, while achieving remarkable flexibility, reproducibility, and operational stability. Our results provide important insights into 2D material-based ultrasensitive SERS based on chemical mechanisms.

Keywords:

charge-transfer resonance, dipole-dipole interaction, heterostructure, Raman enhancement, two-dimensional materials

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C18.01

Multi-level switching mechanism of resistive memory device based on SiO_2 nanoparticle-decorated TiO_x

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Abstract:

The resistive switching device has attracted interest as a promising candidate for next-generation non-volatile memory devices, as it should enable low power consumption, good storage capability, high-speed operation, and stable switching properties. Among the various metal oxide materials, TiO_2 has been widely studied, due to its fast switching speed and promising performance. Recently, scaling down the device size and increasing the structural density of the memory array have been issues of great importance in the field of resistive random access memory device. The considerable attention is the fabrication of a multi-level switching device, which can be store multi-bit data in one cell. In recent, incorporating metal-nanostructures into the matrix of the switching layer is a promising method in switching devices to improve the switching performance. However, the metal nanostructures embedded switching device has a crucial issue for fabricating the transparent switching device due to the inherent opaqueness of metal, which is not feasible for next-generation memory device. Here, we attempt to achieve the fully transparent non-volatile memory devices, as well as multi-level switching characteristics, by using SiO_2 nanoparticles.

In this study, we obtained the multi-level switching device with transparent characteristics by decorating SiO_2 nanoparticle (NP) into TiO_x matrix (structure with ITO/SiO_2 NPs decorated TiO_x/ITO on glass substrate) using solution process. The SiO_2 NPs decorated TiO_x device achieves outstanding switching characteristics, such as high on/off ratio, and distinguishable multi-level, by adjusting the set voltages. To understand the conduction mechanism in each resistance states, the I-V curves is fitted with various mechanisms. The switching mechanism agrees well with the conductive filament model, including the trap-controlled space charge limited conduction mechanism in the low-voltage region. In the high-voltage region, trap-assisted tunneling and Poole–Frenkel emission dominate, which can be explained by the multi-level switching characteristics. This method offers a promising approach for high-performance non-volatile multi-level memory application.

Keywords:

Multi-level switching, Switching mechanism, Resistive switching device, Titanium oxide, Nanoparticle

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C18.02

산화아연 박막트랜지스터 능동어레이를 이용한 초고해상도 유연 압력 센서 제조 및 이를 이용한 로봇집게의 폐루프 제어

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Abstract:

본 초록은 산화아연(ZnO) 박막트랜지스터(TFT)를 이용한 초고해상도 유연 압력센서의 제조 및 이를 이용한 로봇집게의 폐루프 제어를 다룬다. 오늘날 디스플레이에 널리 사용되는 박막트랜지스터 기술을 응용, 압전 특성을 가지는 산화아연을 채널로 사용하여 신호의 스위칭과 외부 힘의 측정이 동시에 가능한 산화아연 박막트랜지스터를 제조하였다. 본 트랜지스터는 힘이 가해질 경우 산화아연 채널 내부에 압전효과로 인한 전하가 생성되며 이 전하가 추가적인 게이트 전압으로 작용, 전류가 변하는 성질을 가지고 있다. 트랜지스터가 센서의 역할을 겸함에 따라 높은 점멸비 및 반응속도를 가지는 액티브 매트릭스(Active-matrix) 구조를 셀 당 한개의 트랜지스터 만으로 제작할 수 있었다. 또한, 산화아연은 저온(200 ºC)에서 증착이 가능하여 유연한 폴리이미드 기판에 제작 후 유연소자 응용이 가능하였다. 특히, 이렇게 제조된 트랜지스터 어레이 위에 특별히 고안된 3차원 구조물을 적용, 수평방향의 전단력 (Shear force)의 정량적 측정 역시 구현할 수 있었다. 본 소자는 반도체 공정을 이용하여 소자 미세화에 용이하였고, 최대 16 x 16 어레이에서 센서간 거리 0.1 mm, 프레임 갱신속도 100 FPS (Frame per second)를 구현할 수 있었다.
이렇게 제조된 소자를 로봇 집게에 결합하고, 소자가 측정한 수직항력 및 전단력을 입력값으로 하여 물체의 미끄러짐을 감지하고 스스로 쥐는 힘을 조절하는 폐루프 제어 알고리즘을 구현하였다. 이는 향후 로봇의 물건을 다루는 능력을 사람 수준 혹은 그 이상으로 향상시키는데 크게 기여하리라 예상된다. 또한 추가적인 응용분야로서 다양한 제스처를 감지하는 햅틱 입력 장치, 소자의 빠른 반응속도, 높은 민감도 및 방수 코팅을 이용하한 맥박 측정과 액체 내 압력 측정 등을 제시하였다. 본 기술에 대한 소개 영상은 다음에서 확인할 수 있다.
Summary video: https://youtu.be/lAtWaMX3jt4
Full presentation video: https://youtu.be/nEwl0riDxTc

Keywords:

ZnO, Piezoelectric, Shear, Closed-Loop, Robotics

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C18.03

Analysis for growth and drug reaction mechanism monitoring of NIH 3T3 cells using impedance biosensor with various frequencies

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Abstract:

Impedance biosensor is manufactured on slide glass using semiconductor process to monitor cell growth and cell-drug reactions. Impedance pattern deposited by using 80 nm thick Platinum for the biocompatibility using sputtering system. After the formation of Pt electrode, PDMS well is attached for cell culture. After sterilization and coating inside of the well with Poly-L-Lysine, NIH 3T3 cells (~10K cells/well) are added in the well and cultured during about 48 hours. Impedance signals are continuously monitored for each 10 minutes during 48 hours with the variations of frequency from 500 Hz to 1 MHz. The capacitance values show gradual change with the increase of NIH 3T3 cells numbers. After 48 hours growth, 6.67 μg/ml Puromycin (Gibco, A11138-03) is injected for the monitoring of cell-drug reaction. At this point, it can be seen that the mechanism is different depending on the low and high frequency. For the low frequency, capacitance tended to decrease as the number of cells increased. However, at high frequency the capacitance also tended to increase as the number of cells increased. Consequently, after the injection of Puromycin, the capacitance is almost fixed during about 10 hours then rapidly increase and decrease within about 9~10 hours in low and high frequency. In this study, we could monitor the state of cells and the cell-drug reactions using the developed impedance biosensor chip by using Electrical Cell-substrate Impedance(ECIS) technique. The developed impedance biosensor could be applied in wide bio-medical area, for example, non-destructive real time cell growth/cell-drug reaction monitoring.

Keywords:

Impedance biosensor, Real-time monitoring, Frequency dependence, Cell growth and drug reaction, Semiconductor process

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C18.04

Optimization of the resolution of microfluidic chip calorimeters for sensing a few mammalian cells

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Abstract:

Measuring the metabolic heat production rate from cellular metabolism can provide information on the physiological state of the cell. However, much information is lost while measuring the metabolic rate from cells in bulk. This paper aims to design, fabricate, and analyze chip calorimeters capable of measuring metabolic heat rates of a few mammalian cells without the need of sample labeling. Vanadium Pentoxide (V_2O_5) was chosen as the thermometer material due to its relatively high sensitivity and long-term stability. The microfluidics and cell handling was done through use of droplet-based microfluidics in parylene microfluidic channels. Parylene was chosen as the main material of microfluidics due to its strong mechanical properties and chemical inertness which made it an optimal material in terms of cellular microfluidic handling. Droplets were made from oil-water emersion to capture few cells at a time and flown into the chip calorimeter along the parylene microfluidic channel. The fluidic channels and thermometers were designed in a way as to reduce the amount of heat lost to the surrounding and temperature resolution was reduced to its optimal range in order to ensure the best power resolution of the chip calorimeter. Characterization of the fabricated device resulted in sub-milliKelvin temperature resolution and thermal conductance of a few μW/K. The chip calorimeter was tested out by measuring the basal metabolic rate of a few T-cells.

Keywords:

Chip Calorimeter, vanadium pentoxide, parylene microfluidics

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D1.01

Fast timing using silicon sensors with intrinsic gain in the CMS upgrade

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Abstract:

A new detector system being designed the high luminosity upgrade of the CMS detector will use silicon sensors with intrinsic gain. This new approach provides precise time measurements with 30 to 50 ps resolution for each charged particle, allowing 4D tracking to resolve the collisions in both space and time. I will describe the motivations for this new detector, its design, and recent progress.

Keywords:

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D1.02

ASIC Development for LGAD-based CMS Endcap Timing Layer (ETL) Upgrade

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Abstract:

The rate of simultaneous proton-proton interactions per bunch crossing (pileup) at HL-LHC is estimated to reach an average of 140 to 200, which can lead to misidentification of tracks. The minimum ionizing particle (MIP) Timing Detector (MTD) for the CMS Phase-2 Upgrade is expected to mitigate the event from pileup by providing precision timing information for the MIP with 30-40 ps resolution. The MTD are divided into BTL (Barrel Timing Layer) and ETL (Endcap Timing Layer). The ETROC (Endcap Timing Readout Chip) is being developed for the LGAD-based ETL. The ETROC is designed to handle a 16 x 16 pixel cell matrix, with each pixel cell being 1.3 mm x 1.3 mm to match the LGAD sensor pixel size. We present the contribution of the Korea CMS group to the ETROC R&D for the MTD project.

Keywords:

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D1.03

Plan for LGAD sensor testing in Korea

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Abstract:

As part of CMS Phase 2 upgrade, MIP Timing Detector is planned to be installed in order to mitigate the impact of pileup that is expected to reach ~200 in HL-LHC. In the endcap region, silicon-based Low Gain Avalanche Detector (LGAD) sensors that allow timing resolution of a few tens of picoseconds are used. The sensor design needs to be optimized considering several factors, including radiation resistance, uniformity of gain, and long-term stability. I will discuss the status and the timeline of sensor testing, and the plan for Korea's participation in this effort.

Keywords:

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D1.04

HPC application for future collider projects

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Abstract:

Development of the high throughput computing such as the Grid system has been led by the High Energy Physics community to analyze the increasing size of the data coming from the Large Hadron Collider. Big data analysis becomes a key idea of the recent breakthrough of the IT and AI industry. Future collider projects will be the next driving force of fast, reliable AI with Big Data to analyze data coming from the future colliders at an extreme rate and complexity,
equipped with new detectors with advanced concepts. High performance computing will play a very important role for the success of the physics programme of the future colliders.

Keywords:

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D2.01

Status and performance of the AMoRE-I detectors

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Abstract:

Advanced Mo-based Rare process Experiment (AMoRE) is an international collaboration project searching for neutrinoless double-beta decay (0νββ) of ^{100}Mo, using molybdenum-based enriched crystals in a cryogenic system. The project aims at operating the detector in zero-background condition to detect this extremely rare decay event. The simultaneous measurement of phonon and photon signals based on the metallic magnetic calorimeter (MMC) read-outs is performed at a few tens mK temperatures to achieve a high resolution and a good background rejection. AMoRE-I, the phase after the successfully completed AMoRE-, has been running in the Yangyang underground laboratory, using thirteen $^{48depleted}Ca^{100}MoO_4$ and five $Li_2{}^{100}MoO_4$ crystals with a total mass of 6.2 kg and the same dilution refrigerator used in the pilot phase. We present the current status of AMoRE-I detectors and the most recent analysis results.

Keywords:

AMoRE, Underground Experiment, Neutrinoless Double Beta Decay

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D2.02

Analysis tools for the AMoRE-I experiment

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Abstract:

The advanced Mo-based rare-process experiment (AMoRE) is an underground cryogenic particle detection experiment to search for the neutrinoless double-beta decay of ^{100}Mo. The experiment uses scintillating crystals composed of enriched ^{100}Mo isotopes as the target material for simultaneous detection of phonon and scintillation signals with MMC readouts at a few tens millikelvin temperatures. After the pilot stage of the project was carried out with six $^{48dep}Ca^{100}MoO_4$ (CMO) crystals with a total mass of 1.9 kg, the AMoRE-I has been operating with thirteen CMO and five $Li_2{}^{100}MoO_4$ crystals with a total mass of 6.2 kg at Yangyang underground laboratory. We present methods to lower the energy threshold using a bandpass filter, to process relatively small photon signals using an optimal filter, and to improve resolution using noise cancellation applicable to multi-channels.

Keywords:

AMoRE, neutrino, double-beta decay, cryogenic, analysis

D2.04

Alpha Background Modeling for AMoRE-Pilot Experiment

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Abstract:

The Advanced Mo-based Rare process Experiment (AMoRE) is an experiment for neutrinoless double-beta decay search of ^{100}Mo using molybdate crystals. AMoRE experiment requires extremely low radioactive background contributions from crystals and detector materials. Alpha radioactive contamination in crystals might be produced naturally from a chemical compound that is used in production phases or introduced during the cleaning process. The other concerns are coming from the surface, impurities that are attached to the exposed surface of the crystal or other detector components. Some of long-lived decay might be implanted inside the surface of the material. In addition to that, surface contamination can produce degraded alphas making continuum energy distribution that extends to double-β energies, obscuring a possible signal of 0νββ. Surface alpha contamination can be originated from the crystal itself and detector component which is directly facing the crystal. To suppress the radioactive background and optimize the crystals in the future, understanding of the background sources and their contributions are important. To investigate those backgrounds, a Monte Carlo simulation was performed. Effects of radioactive isotopes such as ^{238}U, ^{232}Th, and ^{235}U including their daughter isotopes inside crystal and ^{210}Pb inside the reflector were simulated. Additionally, a surface alpha simulation was performed. We found that energy distribution changes sensitively with a variation of surface depths. We compare the MC spectra to the measured data by using the Likelihood Fitting Method. Surface contamination can explain the measurement data well. Details of this study will be presented.

Keywords:

alpha, AMoRE, background modeling, GEANT4, surface alpha

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D2.05

Status of AMoRE-II

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Abstract:

The AMoRE is an experiment to search for the neutrinoless double-beta decay of ^{100}Mo using molybdate scintillation crystals and a cryogenic detection technique. Detection of both thermal and scintillation signals using metallic magnetic calorimeter (MMC) sensors provides high energy resolution and efficient particle discrimination. AMoRE-II, which succeeds AMoRE-pilot and AMoRE-I, is being prepared in the Yemi underground laboratory (Yemilab) in Jeongseon with the aim of commissioning in early 2022 using $Li_2{}^{100}MO_4$ crystal. The AMORE hall was constructed at the Yemilab in August 2020. The cryostat for the low-temperature detectors, the lower shield made of lead and polyethylene, the muon veto detector which consists of extruded plastic scintillator and wavelength shifting fiber with SiPM readout placed outside of the lower shield, and the upper active shield using 70 cm thickness of water as a muon veto detector and a radiation shielding are expected to be installed in 2021.

Keywords:

AMoRE, neutrinoless double-beta decay, Li2100MO4

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D2.06

Neutron and muon-induced background simulations for AMoRE-II shield design

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Abstract:

AMoRE experiment is preparing the next phase (AMoRE-II) to search for neutrinoless double-beta decay of ^{100}Mo isotopes. AMoRE-II detector will be built in a 1000 m deep underground laboratory called Yemilab at Jeongseon. In order to reach the goal of 10^{-5} background events/keV/kg/year, various shield materials and muon veto counters will be constructed. This study is going to estimate the effects of environment neutrons and cosmic muons on the background rate with several configurations of shield design by using Geant4 simulation package. The total muon flux is considered as 8.2 equation.pdf 10^{-8} muons/cm^2/s and the energies of generated neutrons are from 1 to 10 MeV with the neutron flux of 1.5 equation_1.pdf 10^{-2} counts/cm^2/h. Details of the results and discussions will be presented.

Keywords:

AMoRE, Underground experiment, Double-beta decay, Geant4 simulation, Muon-induced background

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D2.07

Status of COSINE-100 experiment

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Abstract:

COSINE-100 experiment aims to detect the dark matter induced recoil interactions in NaI(Tl) crystals to test the DAMA/LIBRA collaboration's claim.
A total of 106 kg of low background NaI(Tl) crystals is installed in the several layers of shielding materials together with a liquid scintillator veto system and muon counters at the Yangyang underground laboratory.
Data taking has been stable for four years from September 2016.
In this talk, we report the status of the COSINE-100 experiment and preparation for the next phase.

Keywords:

COSINE-100, annual modulation, dark matter searches

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D2.08

COSINE-100 annual modulation search

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Abstract:

The annual modulation of low-energy nuclear recoil events reported by the DAMA/LIBRA experiment has been interpreted as being due to the presence of a stationary galactic halo of WIMP dark matter that the Earth moves through during its orbit around the Sun. However, the validity of the DAMA/LIBRA analysis technique has recently been disputed. The COSINE-100 experiment is a direct dark matter search experiment with the primary goal of the testing of the DAMA/LIBRA claim, and has currently accumulated more than three full years of nuclear-recoil data with an energy threshold lowered to 1 keV. In this report, we describe our model-independent annual modulation analysis technique and compare its results with those obtained from the application of an analysis procedure that is as close as possible to the DAMA/LIBRA method to the same (COSINE-100) data.

Keywords:

COSINE-100, annual modulation search, dark matter experiment

D2.09

Search for dark matter with COSINE-100 NaI(Tl) detectors

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Abstract:

The DAMA/LIBRA collaboration has claimed an annual modulation signal which is consistent with that induced by dark matter interactions in NaI(Tl) crystals. COSINE-100 is an experiment searching dark matter to test the claim of DAMA/LIBRA collaboration with the same target material, NaI(Tl). COSINE-100 excluded the DAMA/LIBRA's signal region allowed by dark matter-nucleon interactions in the standard galactic halo model through rate+shape analysis of initial 60-days data. However, there is a significant difference in the quenching factors measured by COSINE-100 and DAMA, and the 60-days data of COSINE-100 cannot fully cover the DAMA/LIBRA's signal if considering this difference. For that, the 1.7-years data of COSINE-100 has been analyzed with the improvement of systematic uncertainty, and we will open the results in this presentation.

Keywords:

dark matter, NaI(Tl) detector, COSINE-100 experiment

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D2.10

Neutron monitoring at Y2L

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Abstract:

The COSINE-100 is a dark matter search experiment, which is running at the Yangyang underground laboratory(Y2L), 700m below the earth's surface with a low cosmic-ray muon background environment. There are arguments about whether the DAMA's annual modulation signal is due to muon-induced neutron signals. Therefore, it is important to understand the neutron rate of COSINE-100 background. In order to monitor the neutron event rates, we have installed liquid scintillator(LS) detectors and a ^{3}He gas detector for the detection of fast and thermal neutron respectively. For the fast neutron monitoring, selection of neutron events was made based on pulse shape discrimination method and time coincidence to identify gamma and alpha events respectively. For the thermal neutron, measurements at a ground lab and the underground lab by the ^{3}He gas detector will be compared. In this presentation, performance and monitoring results of both detectors will be presented.

Keywords:

neutron, darkmatter, COSINE

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D3.01

Heavy flavor measurements and new observables in the future with ALICE

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Abstract:

Many interesting properties of the heavy-flavour production have been studied so far in relativistic heavy-ion collisions. The suppression of D and B mesons follows the hierarchy expected due to the mass dependence of quark energy loss. Besides the collectivity observed vis flow parameters in Pb-Pb collision systems, the elliptic flow of heavy particles in p-Pb collisions give hints at possible effects of collectivity in smaller systems at higher multiplicities, which was previously unexpected. The suppression behavior of D+s , B0s and Λ+c compared with non-strange D and B mesons in heavy-ion collisions suggests the presence of unforeseen hadronization mechanisms such as the recombination of heavy quarks with lighter quarks within the medium. During the second Long Shutdown, the significant upgrades have been made both to the experiments and the accelerator itself, allowing a factor ~10 increase in the recorded luminosity. This will lead to vast improvements in the precision of measurements for the rare heavy-falvour particles, further constraining models, and will allow new channels in this sector to be studied. In this talk, the recent heavy flavor measurement with ALICE will be summarized and the future perspective will be discussed.

Keywords:

CENUM, Heavy flavour, Heavy-ion collisions, ALICE, Quark-Gluon Plasma

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D3.02

Hadron production models in heavy ion collisions

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Abstract:

We discuss hadron production models in heavy ion collisions by focusing on the production of charmed hadrons based on both the statistical and coalescence models. Starting from the investigation on estimated yields of various charmed hadrons in the statistical hadronization model, we consider transverse momentum distributions of those hadrons produced at quark-hadron phase transition in the coalescence model. We also consider the transverse momentum distribution of charmed exotic hadrons such as Tcc and X(3872) mesons, and evaluate transverse momentum distribution ratios between charmed hadrons. We show that the transverse momentum distribution ratios are closely related to kinds and numbers of quarks as well as the interplay between constituent quarks of those hadrons.

Keywords:

statistical model, coalescence model, charmed hadron production

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D3.03

Lattice-QCD projects in CENuM

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Abstract:

In this talk, we introduce the ongoing research projects of CENuM for extreme QCD matter by employing lattice-QCD simulations. To overcome the sign problem for the finite quark chemical potential, the canonical method is explored and tested via effective models. After verifying the validity of the method, we study its natures in SU(2c) lattice simulations. Moreover, in addition to the instanton-vacuum approaches, we develop a theoretical method based on the information generated from the lattice QCD.

Keywords:

Lattice QCD, Nonpertuerbative QCD, Extreme QCD matter, Sign problem, Canonical method

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D3.04

Lambda(1405) as a hadronic molecule

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Abstract:

Hadronic molecules are the new form of matter induced by the strong interaction.
However, identification of the hadronic molecules involves several subtle difficulties such as the model dependence and the interpretation of the resonance wave function.
To overcome these difficulties, we use the compositeness to characterize the internal structure of hadrons, and generalize the weak-binding relation for unstable resonances.
It is quantitatively shown that the structure of the Lambda(1405) resonance is dominated by the molecular state of an antikaon and a nucleon.

Keywords:

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D3.05

Revisiting nuclear symmetry energy with KIDS density functional

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Abstract:

With the KIDS nuclear energy density functional, we determine the symmetry energy parameters J, L and $K_{\rm sym}$ by assuming consistency with both nuclear data of neutron rich nuclei and the state-of-the art observation of neutron stars. We obtain widest ranges of J and L as $30 \le J \le 32$ MeV and $45 \le L \le 65$ MeV, and the correpsponding range of $K_{\rm sym}$ as $-200 \le K_{\rm sym} \le -30$ MeV. On the other hand, J and L values that are in best agreement with the nuclear data and the neutron star observation are reduced to $30 \le J \le 31$ MeV and $50 \le L \le 60$ MeV, respecitvely.

Keywords:

Nuclear symmetry energy, Density functional theory, Neutron star

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D3.06

Quasi-elastic (e; e’p) reaction using various nuclear models

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Abstract:

We calculate the exclusive (e; e’p) reaction using various nuclear models in quasi-elastic region. The wave functions of the bound state are generated with relativistic nuclear models, that are the ← $\sigma - \omega$ model, the non-linear sigma model, the quark-meson-coupling (QMC) model, and the chiral QMC (CQMC) model. To calculate this reaction, the incident electron beam is unpolarized with medium energies (400 MeV ~↑ 2.44 GeV) and stable nuclei like 16O, 40Ca, and 208Pb are used as targets. We compare our theoretical results using spectroscopic factor with the experimental data measured from NIKHEF, Saclay, and JLAB. We nd that the theoretical cross sections obtained from various models are dependent on the target nuclei and the kinematics. The trend is shown to be signi cant with the heavier nuclei.

Keywords:

(e,e'p) reaction, QMC model, non-linear model, CQMC model

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D4.01

Updated preliminary analysis of TAx4 hybrid trigger and events

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Abstract:

Since 2009 the Telescope Array (TA) experiment has observed air showers created by ultra-high energy cosmic rays (UHECRs) using a combination of ground array particle detectors and air-fluorescence induced UV detection telescopes. Making detection area 4 times larger and thus improving UHECR event statistics significantly, we have constructed TAx4 observatory since 2018, which contains a new 500 particle detectors and 3 telescope stations. We have deployed 260 detectors late 2018, and tuned and calibrated them up until now to have all in operation. While the TAx4 surface detector has superior statistics in measurements of the event arrival directions and the energy spectrum, it should be noted that the TAx4 fluorescence detector sees the full longitudinal profiles of the air showers in the atmosphere and therefore determines their energies more accurately than the TAx4 SD. Events seen in common by the TAx4 FD and SD are used for establishing the energy scale of the TAx4 SD. Also, the FD longitudinal profile is used for determining the mass composition of the primary comic ray particles, when the event geometries are well constrained by simultaneous FD and SD measurements. Such events are called "hybrid events", and for this reason, the TA is often referred to as a "hybrid cosmic ray detector" in literature. Despite large differences in their stand-alone performances, both detector types complement each other in measuring important physical quantities. In this presentation I want to talk about updated preliminary analysis of TAx4 hybrid trigger and TAx4 hybrid events.

Keywords:

Astroparticle physics, Telescope Array, TA, TAx4, Cosmic-ray

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D4.02

Preliminary analysis on energies and arrival directions of UHECRs detected by TAx4 Surface Detectors

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Abstract:

The source and acceleration mechanism of Ultra High Energy Cosmic Rays (UHECRs) has been a mystery since its first discovery. Telescope Array (TA) project, detecting UHECRs from hybrid detection of Fluorescence Detectors (FDs) and Surface Detectors (SDs), has studied arrival direction and energy of UHECRs since 2009. To broaden detection area, TAx4 was proposed and we deployed 260 SDs in 2019. We will present the preliminary distribution of energies and arrival directions of UHECRs detected by TAx4 SDs.

Keywords:

UHECR, Cosmic Ray, Telescope Array, TAx4

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D4.03

The study of energy-scale of UHECR with result with air fluoresence measurement using 15 EeV electron shower

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Abstract:

The Air Fluorescence Yield (AFY) is an important parameter to determine the energy scale of ultra high energy cosmic rays (UHECR) (> 1018 eV).
So far, the results of AFY from experiments and theoretical estimation show about 20% spread.
To investigate this, we measured AFY in the so-called “sFLASH” experiment at the Stanford Linear Accelerator Laboratory(SLAC).
The key point of sFLASH is using ~10^18 eV artificial air showers produced by the interaction of the SLAC electron beam and various depth of alumina targets.
We will present the measurement, analysis, and preliminary results of the sFLASH and expectation energy scale of UHECR using our result.

Keywords:

air fluorescence, Ultra High Energy Cosmic Rays, electron accelerator

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D4.04

A search for secluded dark matter with

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Abstract:

The IceCube neutrino observatory is a cubic kilometer volume 3D array of photodetectors installed in the Antarctic ice. It consists of 5,160 photomultiplier-tubes spread among 86 vertical strings. IceCube detects neutrinos via the Cherenkov light charged relativistic particles produced in neutrino interactions produce with the Antarctic ice. IceCube has a particularly high sensitivity to high-energy neutrinos thanks to its size and the spacing of its detector modules. In this presentation i show a search for dark matter annihilating into metastable mediator particles, that can yield standard model particles in subsequent decays, inside the Sun using IceCube data. Such secluded dark matter models can yield an enhanced high-energy neutrino flux compared to models without a mediator. Other models for dark matter produce signals in the Sun form the decay of standard model particles that get strongly atenuated inside of the solar plasma. In the models considered here, the mediator can escape the Sun before producing any neutrinos, thereby avoiding attenuation. Due to its good sensitivity to high-energy neutrino signals IceCube is the ideal tool for this type of search. We present the sensitivities of an analysis of six years of IceCube data looking for dark matter in the Sun considering mediator lifetimes between 1 ms to 10 s and dark matter masses ranging from 100 GeV to multiple ten TeV.

Keywords:

Dark Matter, Neutrino, Sun, IceCube

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D4.05

Sensitivity analysis of SISA experiment and simulation of Stellar intensity interferometer

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Abstract:

The SISA experiment is a new method to detect Gravitational Wave, based on intensity interferometer using spatial coherence of star light, newly proposed by Il H. Park. The experimental system consists of two satellites placed in the L2 orbit and pointing to the same star, each with an independent photon detector and an optical system. Two photon detectors measure the spatial coherence of photons coming from the star, based on a Hanbury Brown and Twiss experiment. When the gravitational wave passes between the star and the detector, the spatial coherence collapses, and the gravitational wave is detected by measuring this coherence. The simulation is first to set with basic environment, which generate photons from a star and observe them with two detectors to check spatial coherence. After then add the effect of gravitational waves on photon propagation and extract the properties of gravitational waves from measured coherence. In addition, we will present an estimated sensitivity curve for our experiment to detect gravitational wave in frequency range of 10^{-7} to 10^{-4} Hz. Characteristic strain of our detectors in targeted frequency range is considered with several effects related to our satellite, including shot noise of detector and acceleration noises induced by interplanetary magnetic field(IMF), temperature variation and other effects.

Keywords:

gravitational wave, stellar interferometer, laser interferometer, spatial coherence, LISA

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D4.06

Investigation on developing new coating materials for Advanced LIGO Plus (A+LIGO) with reduced coating Brownian noise

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Abstract:

100 years since Einstein first predicted the existence of gravitational waves, the Advanced LIGO (aLIGO) detectors succeeded in the first direct detection in 2015. To further improve the sensitivity of the detectors, world-wide collaborations are working on various experimental and modelling research. For the A+LIGO upgrade, the most critical noise source that is limiting the detector's sensitivity at the most sensitive detection band is coating Brownian noise. We are targeting to reduce the room temperature mechanical loss of the coating by a factor of 4, and investigating different options to achieve that goal with a systematic research model. In this talk, a brief introduction of aLIGO coatings work will be presented along with the current status of atomic structure characterization research and future plans.

Keywords:

Gravitational waves, LIGO, Suspension thermal noise, Coating Brownian noise

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D4.07

Identification of Lensed Gravitational Waves with Deep Learning

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Abstract:

The propagation path of gravitational waves is expected to be bent near massive astrophysical objects. The massive object acts as a lens. Similarly to electromagnetic lensing, the lens amplifies gravitational waves' amplitude and can produce multiple gravitational-wave images. Suppose the positions of lens and source of a gravitational wave deviate from the line of sight. In this case, the gravitational-wave images arrive at different times because they have traveled different trajectories around the lens at the same speed. As a consequence, multiple gravitational waves can be detected as repeated, near-identical events, or superposed gravitational waves with characteristic ``beating patterns'' depending on the difference in their arrival times. In particular, when the lens is small, $₩lesssim 10^5 M_₩odot$, the lens produces images with short time delays. The short time delay results in the superposition of the gravitational-wave images and beating patterns. We utilize spectrograms to study the beating patterns. It is known that many state-of-the-art deep learning models are excellent at recognizing foreground images, similar to spectrograms, from background noises. In this work, we study the feasibility of applying deep learning to identify lensing signatures from the spectrogram of gravitational-wave signals detectable by the Advanced LIGO and Virgo detectors. We assume the lens mass is around 10^3 -- $10^5 M_₩odot$, which can produce the order of millisecond time delays between two images of lensed gravitational waves. We discuss the feasibility of two aspects: distinguishing lensed gravitational waves from unlensed ones and estimating the parameters related to not only the lensing factor but also the source binary system and lens. We suggest that deep learning would be of particular interest for microlensed waveforms, for which we do not have accurate waveform templates.

Keywords:

gravitational wave, gravitational lensing, machine learning

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D5.01

Intermediate-excitation single electron source

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Abstract:

The on-demand single electron source (SES) is an essential block for electron quantum optics and electronic flying qubits. In terms of energy scales, high-excitation SESs over 100 meV and low-excitation SESs near the Fermi level have been developed based on dynamic semiconductor quantum dots and mesoscopic capacitor (or voltage pulse) with GaAs heterostructures, respectively. In this study, we introduce another type of SES: an intermediate-excitation SES around ~40 meV, by using the chiral nature of edge states in a quantum Hall regime with a dynamic quantum dot. We will discuss the operation mechanism of the intermediate-excitation SES, comparing with the conventional SESs.

Keywords:

Single electron source, GaAs

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D5.02

Imaging current flow in transport devices using a solid-state spin magnetometer

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Abstract:

Direct imaging of spin and current flow in transport devices with nanometer scale spatial resolution can provide useful insight understanding mesosopic physics in condensed materials and devices. In this talk, I will introduce novel scanning magnetometers based on solid-state spin qubits i.e. nitrogen-vacancy (NV) defect center in diamond. I will also present our recent works on imaging ferromagnetism in 2D materials and imaging current flows in graphene transport devices.

Keywords:

scanning magnetometer, diamond NV center

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D5.03

Graphene-based Josephson junction microwave bolometer

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Abstract:

Sensitive microwave detectors are critical instruments in radioastronomy, dark matter axion searches, and superconducting quantum information science. The conventional strategy towards higher-sensitivity bolometry is to nanofabricate an ever-smaller device to augment the thermal response. However, this direction is increasingly more difficult to obtain efficient photon coupling and maintain the material properties in a device with a large surface-to-volume ratio. Here we advance this concept to an ultimately thin bolometric sensor based on monolayer graphene. To utilize its minute electronic specific heat and thermal conductivity, we develop a superconductor-graphene-superconductor (SGS) Josephson junction bolometer embedded in a microwave resonator of resonance frequency 7.9 GHz with over 99% coupling efficiency. From the dependence of the Josephson switching current on the operating temperature, charge density, input power, and frequency, we demonstrate a noise equivalent power (NEP) of 7×10^{-19} W/Hz$^{1/2}$, corresponding to an energy resolution of one single-photon at 32 GHz and reaching the fundamental limit imposed by the intrinsic thermal fluctuation at 0.19 K.

Keywords:

microwave bolometer, graphene Josephson junction, quantum computer

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D6.01

Emerging New Quantum Phases in $GaTa_4Se_8$ under pressure

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Abstract:

$GaTa_4Se_8$ is the first confirmed example of J_{eff}=3/2 moment residing in a real material [1, 2]. While this exotic magnetic ground state is shown to exist in the Mott phase at ambient pressure, the key remaining question is about its fate under pressure since this material exhibits the insulator-to-metal transition followed by superconducting transition as a function of pressure. In this talk, I will report our recent progress on this issue. First, under moderately high pressure, we found that the J_{eff}=3/2 moment is well maintained in the metallic region and presumably also in the superconducting phase [3]. Our DFT+DMFT (density functional theory + dynamical mean-field theory) calculation and RIXS (resonant inelastic x-ray scattering) experiment coincidentally indicate that the metallic phase of this material is still well identified by J_{eff}=3/2 state. Hereby, we establish that the pressurized $GaTa_4Se_8$ is the first verified example of 'J_{eff}=3/2 metal'. Our result also strongly suggests the unconventional nature of the superconductivity at higher pressure as being closely related to the unusual magnetism. In the second part, I will discuss our discovery of new phases under even higher pressure that has never been reached before in this material. Remarkably, a new metallic and new superconducting state are identified by our experimental characterizations and theoretical calculations [4]. We construct the extended pressure phase diagram for $GaTa_4Se_8$ in which the known Mott transition is followed by J_{eff}=3/2-magnetic to non-magnetic transition and two distinctive superconducting phases appear.

Reference
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Keywords:

Quantum magnetism, spin-orbital entangled state, superconductivity, density functional theory, dynamical mean-field theory

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D6.02

Pressure-induced phase transitions and superconductivity in magnesium carbides

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Abstract:

Crystal structure prediction and in silico physical property observations guide experimental synthesis in high-pressure research. Here, we used magnesium carbides as a representative example of computational high-pressure studies. We predicted various compositions of Mg–C compounds up to 150 GPa and successfully reproduced previous experimental results. Interestingly, our proposed MgC2 at high pressure >7 GPa consists of extended carbon bonds, one-dimensional graphene layers, and Mg atomic layers, which provides a good platform to study superconductivity of metal intercalated graphene nano-ribbons. We found that this new phase of MgC2 could be recovered to ambient pressure and exhibited a strong electron-phonon coupling (EPC) strength of 0.6 whose corresponding superconductivity transition temperature reached 15 K. The EPC originated from the cooperation of the out-of-plane and the in-plane phonon modes. The geometry confinement and the hybridization between the Mg s and c pz orbitals significantly affect the coupling of phonon modes and electrons. These results show the importance of the high-pressure route to the synthesis of novel functional materials, which can promote the search for new phases of carbon-based superconductors.

Keywords:

First principle calculations, electron-phonon coupling, high pressure, graphene nano-ribbon

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D6.03

Extraordinary pressure-induced quantum phase transition from superconducting to charge-density wave state in LuPd2In

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Abstract:

The charge density wave (CDW) is often competing with superconductivity because they originate commonly from the electron-phonon coupling. In typical metallic materials showing the CDW property, the pressure induces the phase transition from CDW to superconducting (SC) state due to the suppression of nesting feature. In this work, we have found the occurrence of intriguing phase transition from SC to CDW state in pressurized cubic-Heusler compound LuPd2In, which is quite unusual in view of that the pressure is detrimental to the CDW state in usual systems. Based on ab initio density functional theory, we have demonstrated that this abnormal transition originates from the extraordinary softened-phonon mode, which first enhances the SC transition temperature, but eventually yields the phonon softening instability so as to bring about the CDW transition. This extraordinary transition originates from the occurrence of phonon softening instability at a special q = M in the Brillouin zone. We have thus proposed that LuPd2In is a quite unique material, in which the CDW quantum critical point is realized under the SC dome by applying the pressure.

Keywords:

charge density wave, superconductivity, quantum critical point

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D6.04

Alloying and pressure effect on Metal-insulator transition of $NiS_{2-x}Se_x$

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Abstract:

In the last decade, there has been remarkable progress in the understanding of the Hund's coupling effect on the correlated systems. The Hund's coupling effect in half-filled multi-band systems, however, is rarely discussed although it is well understood that the Hund's coupling also enhances the correlation strength in the half-filled. For an investigation of the Hund's coupling effect in the half-filled multi-band systems, $NiS_{2-x}Se_x$ is probably the most suitable multi-band system to study. $NiS_{2-x}Se_x$ has long been studied as one of the prototypical half-filled compounds which shows a bandwidth-control Mott Metal-insulator transition (MIT) by doping or pressure.
In the first part, I will discuss the Hund's coupling effect and the energy scale of $NiS_{2-x}Se_x$ system. We observed the kink feature in the low energy dispersion of $NiS_{2-x}Se_x$, which exhibits characteristic evolution with x. The kink originated from the Hund's coupling becomes clear and moves toward to lower energy scale as the system becomes close to the Mott insulating state. This kink behavior can be understood by the suppression of the temperature scale due to Hund's coupling.
In the second part, I will discuss the metal-insulator transition of NiS_2 under pressure. Our DFT+DMFT calculation well describes the experimental phase diagram under pressure. We found abrupt bond length change at the MIT point, which results in the first-order like MIT. The optical conductivity of NiS_2 under pressure will be also discussed to understand Hund's coupling effect.

Keywords:

high pressure, Earth's core, Iron oxides, electron correlation effect

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D7.01

Magnetization dynamics and spin transport in compensated ferrimagnets

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Abstract:

For magnetization dynamics, compensated ferrimagnets combine the best features of antiferromagnets and ferromagnets. Antiferromagnets are of considerable interest because the exchange torques between the two sublattices give a time scale that is much faster than that in ferromagnets and the lack of magnetization and net angular momentum lead to minimal perturbation by stray fields and eased constraints due to angular momentum conservation. A compensated ferrimagnet has all these virtues. At the same time, the lack of symmetry between the two sublattices in a compensated ferrimagnet means that quantities like average spin currents are not zero making the systems potentially easier to manipulate and detect the consequences. We will describe calculations and measurements of domain wall and skyrmion motion at the angular momentum compensation point. At this point with no net spin density, the rotational motion of the magnetic textures (domain walls and skyrmions) is absent. As a result, domain walls move fast (Refs. [1, 2]) since there is no tilting of domain wall angle. For the same reason, the skyrmion Hall effect vanishes (Ref. [3]) and the magnon-photon coupling enhances (Ref. [4]). We will also discuss the increased efficiency of spin torques due to the weakened dephasing in compensated ferrimagnets. Combining experiments with theoretical studies, Refs. [5] and [6] show large torques for ferrimagnetic multilayers and for ferrimagnetic domain walls, respectively.

Reference:

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Keywords:

compensated ferrimagnet, spin current

2020 KPS Fall Meeting
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D7.02

Diffusive transport of orbital angular momentum

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Abstract:

Recent demonstration of orbital Hall effect has attracted the community because of both fundamental interest and possibility for efficient control of magnetism. While previous studies focus on the local generation of orbital current by an external electric field, it is important to examine how the nonequilibrium orbital angular momentum flows in mesoscopic solids for comparison of theory and experiment and further development of relevant devices. Unlike spin angular momentum, nonzero orbital angular momentum originates from quantum coherence, so the semiclassical spin diffusion formalism cannot be directly applied to the orbital angular momentum transport. In this presentation, we present how to effectively describe transport of the quantum coherent state and discuss unique features of orbital transport that are absent in spin transport.

Keywords:

orbital angular momentum, Diffusion formalism, electronic transport

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D7.03

Orbital transport from first-principles

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Abstract:

Over the last few years, we have noticed importance of orbital degree of freedom in many spin-orbitronic phenomena such as spin Hall effect and spin-orbit torque [1,2]. It is exemplified by precedence of orbital dynamics to spin dynamics when the electronic system is driven by an external electric field. Thus, the spin dynamics is governed by the orbital dynamics, which are entangled by the spin-orbit coupling. However, experimental verification of the orbital transport effects are yet to be made. Thus, theoretical prediction of real material systems and comparison with experiments are necessary, in which first-principles calculation based on the density functional theory can play a decisive role. In this talk, I introduce methods for describing orbital transport effects based on the density functional theory calculation and suggest a few material systems that are expected to exhibit significant orbital dynamic effects. As a main method, I show that equations of motion of the spin and orbital angular momentum based on the continuity equation enable systematic tracking of angular momentum flow, not only in space but also between different degrees of freedom [3]. Then I present detailed analysis of real materials by applying the developed formalism: (i) Fe/W(110) and Ni/W(110) [3], (ii) Fe/Pt/Cr(001) [4], and (iii) surface oxidized Cu(111) [5]. In (i), I show that the directions of the spin-orbit torque are opposite between Fe/W(110) and Ni/W(110) as a result of the competition between spin Hall and orbital Hall currents from W. In (ii), I show that insertion of Pt layer between Fe and Cr(001) provides a way to harness gigantic orbital Hall current arising from Cr, leading to sign change of the spin-orbit torque. In contrast to (i) and (ii), where bulk orbital Hall current plays significant role, in (iii), I show that surface oxidization of Cu(111) leads to significantly pronounced orbital polarization of the surface states via orbital Rashba effect. Considering substantial on-going efforts in these materials from the experimental side, I not only compare the calculation with experimental data but also discuss further implications of the theoretical prediction.

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[4] S. Lee, M.-G. Kang, D. Go et al. in preparation.
[5] D. Go et al. in preparation.

Keywords:

spin-orbit coupling, spin-orbit torque, orbital transport, spin transport, spin-orbitronics

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D7.04

Spin-orbit-coupling-enabled topological hydrodynamics

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Abstract:

Spin-orbit coupling that connects a charge current and spin dynamics has been shown to enable hydrodynamics of topological chiral solitons in various materials including magnets and superconductors. In this talk, we will discuss two examples in this exciting direction. The first example is the topological hydrodynamics of magnetic domain walls in easy-plane magnets with additional in-plane anisotropy. We will discuss how we can use spin-orbit coupling to pump domain walls into magnets and, reciprocally, detect a domain-wall current. The second example is spin transport by a vortex liquid in superconductors, in which spin of a magnet is connected to charge of a superconductor via spin-orbit coupling, and the charge of the superconductor is connected to a vortex via charge-vortex relation. We envision that interfaces between two different orders can serve as hosts of a variety of couplings between seemingly non-related physical quantities.

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Keywords:

hydrodynamics, domain wall, spin-orbit coupling, spin-orbit torque, vortex

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D7.05

Berry phase effects and anomaly in Kramers-Weyl semimetals with single Weyl point

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Abstract:

Weyl semimetals have pairs of topological band crossings called Weyl points and exhibit chiral anomaly, which gives rise to negative longitudinal magnetoresistance and planar Hall effect. Here we study Kramers-Weyl semimetals with a single Weyl point and show that they exhibit strange transport properties that are proportional to **E** dot **B** and reminiscent of the chiral anomaly despite the fact that there is only one Weyl point. We introduce the concept of the helical anomaly to capture Berry phase effects. We demonstrate that the strange transport properties can be explained in terms of the helical anomaly. We also study spin currents in the Kramers-Weyl semimetals.

Keywords:

Chiral anomaly, Weyl semimetal, Kramers-Weyl semimetal, Negative longitudinal magnetoresistance

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D8.01

Spin-orbital separation and orbital differentiation in Hund metals

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Abstract:

Hund metals are multiband materials in which strong correlations are driven not only by on-site Coulomb repulsion but also by the Hund's rule of spin maximization. A hallmark of Hund metals is spin-orbital separation: the spin and orbital fluctuations at a lattice site are screened by surrounding electrons at different energy scales. We find that there exists a non-Fermi liquid regime between those two energy scales [1,2], by using the numerical renormalization group (NRG) calculation and conformal field theory argument. Another hallmark is orbital differentiation [3], including orbital-selective Mott transition as its extreme form. Our first-principle dynamical mean-field theory (DMFT) calculation on Sr_2RuO_4, with using NRG as an impurity solver, shows that both spin-orbital separation and orbital differentiation are responsible for very low Fermi-liquid temperature scale of the material.

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Keywords:

Hund metals, Dynamical mean-field theory, Numerical renormalization group, Orbital differentiation, Non-Fermi liquid

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D8.02

Non-Fermi Liquids in Conducting 2D Networks

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Abstract:

We explore the physics of novel fermion liquids emerging from conducting networks, where 1D metallic wires form a periodic 2D superstructure. Such structure naturally appears in marginally-twisted bilayer graphenes, moire transition metal dichalcogenides, and also in some charge-density wave materials. For these network systems, we theoretically show that a remarkably wide variety of new non-Fermi liquids emerge and that these non-Fermi liquids can be classified by the characteristics of the junctions in networks. Using this, we calculate the electric conductivity of the non Fermi liquids as a function of temperature, which show markedly different scaling behaviors than a regular 2D Fermi liquid.

Keywords:

Strongly Correlated Electrons, Non-Fermi Liquid, Emergent Network

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D8.03

Many-body flatband localisation

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Abstract:

We generate translationally invariant systems exhibiting many-body localization from all-bands-flat single-particle lattice Hamiltonians dressed with suitable short-range many-body interactions. This phenomenon, dubbed many-body flatband localization, is based on symmetries of both single-particle and interaction terms in the Hamiltonian, and it holds for any interaction strength. We propose a generator of corresponding Hamiltonians which covers both interacting bosons and fermions for arbitrary lattice dimensions, and we provide explicit examples of such models in one and two lattice dimensions. We also explicitly construct an extensive set of local integrals of motion for this set of models. Our results can be further generalized to long-range interactions as well as to systems lacking translational invariance.

Keywords:

flatbands, localisation, interacitons, many-body localisation, nonergodicity

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D8.04

Emergences of the Fermi liquid and the Gapped phase out of quantum critical point by the symmetry breaking.

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Abstract:

One of the most known character of the strongly correlated material is having a fuzzy or no Fermi surface.
However, we show that both Fermi liquid and gapped phase can appear by symmetry breaking, depending on the sign of the order parameter.
The Fermi surface appears as the boundary localized Jackiw-Rebbi zero mode of the holographic space so that
the energent fermi liquid phase can be considered as a topolological insulator in the holographic spacetime
while the gapped phase can be considered as a topologically trivial insulator. We discuss the the Metal insulator transition between the two phases.

Keywords:

quantum critical point, symmetry breaking., Metal insulator transition, emergent fermi surface, gapped phase

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D8.05

Many-Body Invariants for Chern and Chiral Hinge Insulators

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Abstract:

We construct new many-body invariants for 2d Chern and 3d chiral hinge insulators, which are characterized by quantized pumping of dipole and quadrupole moments. The invariants that we devise are written entirely in terms of many-body ground state wavefunctions on a torus geometry with a set of unitary operators. We provide a number of supporting evidences for our invariants via topological field theory interpretation, adiabatic pumping argument, and direct mapping to free-fermion band indices. We finally confirm our invariants by numerical computations including infinite density matrix renormalization group on a quasi-one-dimensional system. The many-body invariants therefore explicitly encircle several different pillars of theoretical descriptions of topological phases.

Keywords:

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D8.06

Causal projection method for imaginary-time many-body simulations

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Abstract:

In many-body physics, causality frequently refers to negative semidefiniteness of the imaginary part of the real-frequency Green's function. However, most numerical simulations of many-particle systems are conducted in imaginary time, without any explicit condition for causality. In this work, we present a causal projection method which projects an imaginary-time numerical function onto a space of functions satisfying causality. This method allows us to impose causality in imaginary-time many-body calculations. Applying this method to finite and statistical calculations, we show that causality determines intermediate-frequency behaviors smoothly, excluding unphysical statistical errors efficiently. Moreover, we demonstrate that our causal projection method can suppress unphysical branches of the Luttinger-Ward functional. This work was supported by NRF of Korea (Grant No. 2020R1A2C3013673) and KISTI supercomputing center (Project No. KSC-2019-CRE-0195), and the Graduate School of Yonsei University Research Scholarship Grants in 2018.

Keywords:

Causality, Imaginary-time, DMFT, CTQMC, Luttinger-Ward functional

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D8.07

Symmetry Protected Magnetic Weyl Nodal Loops in $5d^{1,2}$ Cubic Double Perovskites

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Abstract:

For last fifteen years, various topological phases in condensed matters have been intensively investigated. Crystalline symmetries and spin-orbit coupling (SOC) play a crucial rule to emerge these topological states. Up to now, there are many theoretical proposals of topological phases, but relatively fewer experimental observations. In order to stimulate applications and experiments, topologically nontrivial states located near the Fermi level and robust under SOC are highly demanded.
Using both first-principles calculations and an effective 3-band model, we investigate the Os- and Re-based cubic double perovskites ($5d^{1,2}$), which show spin-full magnetic Weyl nodal loops (WNLs) and multipole Weyl nodes. In presence of the time-reversal symmetry (TRS), the Dirac nodal lines (DNLs) appear on the mirror planes, when neglecting SOC. Remarkably, for the broken TRS case, magnetic WNLs and multiple Weyl points with the chiral charges of |1| and |2| remain survived due to the combination of mirror symmetry and broken TRS, even when including SOC. Additionally, the strong SOC gives rise to a large anomalous Hall conductivity (AHC) at the energy of WNLs. Besides, our results indicate that the Re compound is an ideal magnetic Weyl half-semimetal, spin-polarized drumhead state at the Fermi energy without any interruption of trivial bulk states. Our findings suggest that cubic double perovskites are a promising platform for studying abundant robust topological phases.

[Acknowledgements]
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Keywords:

magnetic Weyl nodal line, double perovskite, first principles

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D8.08

Nontrivial Topology induced by Magnon-Phonon Hybridization

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Abstract:

We present the topological aspects of the magnon-phonon hybrid excitation in a simple two-dimensional (2D) square-lattice ferromagnet with perpendicular magnetic anisotropy. Several distinguishing features of our model are as follows. Our model is optimized for atomically thin magnetic crystals, i.e., 2D magnets. The recent discovery of magnetism in 2D van der Waals materials opens huge opportunities for investigating unexplored rich physics and future spintronic devices in reduced dimensions. Because we consider the 2D model, we ignore the nonlocal dipolar interaction, which is not a precondition for a finite Berry curvature in 2D magnets. Moreover, the Berry curvature we find does not require a special spin asymmetry such as the DM interaction nor a special lattice symmetry: Our 2D model description is applicable for general thin-film ferromagnets. Therefore, we show in this work that even without such long-range dipolar interaction, DM interaction, or special lattice symmetry, the nontrivial topology of a magnon-phonon hybrid can emerge by taking account of the well-known magnetoelastic interaction driven by Kittel. As Kittel's magnetoelastic interaction originates from the magnetic anisotropy, which is ubiquitous in ferromagnetic thin-film structures, our result does not rely on specific preconditions but is quite generic. Furthermore, we show that the topological structures of the magnon-polaron bands can be manipulated by effective magnetic fields via topological phase transition. We uncover the origin of the nontrivial topological bands by mapping our model to the well-known two-band model for topological insulators, where the Chern numbers are read by counting the number of topological textures, called skyrmions, of a certain vector in momentum space. In this picture, the magnon-phonon hybridization induces the chiral texture of the momentum space vector. As an experimental probe for our theory, we propose the thermal Hall conductivity.

Keywords:

Thermal Hall effect, Magnon polaron

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D9.01

Artificial synapse based on magnetic skyrmions for neuromorphic computing

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Abstract:

Neuromorphic computing, inspired by human brain's nervous system, has significantly attracted attention with great demands for low-power consumption electronic devices. To emulate the synaptic operations, several non-volatile memory technologies, including phase-change[1], resistive memory device[2], and magnetic domain based multilevel spintronic devices[3], have been explored.
Recent simulation studies[4] have reported that magnetic skyrmions are suitable for synaptic devices due to their particle-like behavior leading to multiple skyrmions aggregating within a defined device area. However, experimentally implementation of skyrmion-based synaptic devices remains challenging. In this study, we experimentally demonstrated the skyrmion-based artificial synapse by using such device which electrically induced generation, motion, detection and deletion of skyrmions at room temperature. We find that ferrimagnetic skyrmions formed in [Pt (3 nm)/$Gd_{24}Fe_{66.6}Co_{9.4}$ (9 nm)/MgO (1 nm)]$_{20}$ multilayer stacks, can be accumulated and dissipated within a defined area by controlling with electrical pulses to represent the variations in the synaptic weights. While bi-directional current pulse is applied, the vertical channel fabricated as Hall-bar structure, can be used to read the synaptic weights through anomalous magneto-resistance (AMR) (Fig. 1 (a)). Skyrmions are generated from a source, during potentiation, accumulating several skyrmions within a defined area correspondingly changes the synaptic weights (Fig. 1 (b), (c)). During depression, skyrmions are driven to sink area or annihilated by pinning site, reducing synaptic weights (Fig. 1 (b), (d)). Then, we demonstrated that skyrmion-based artificial synapses could be used for neuromorphic computing tasks such as pattern recognition by using chip-level simulations and artificial neural network (ANN) simulation for pattern recognition with MNIST handwritten pattern data set. Our system achieves a recognition accuracy of ~89%, which is comparable to the accuracy achieved with software-based ideal training (~93%).
Our finding exemplify the promising properties of ferrimagnetic skyrmions for its potential utilization in neuromorphic computing devices.

Keywords:

spintronics, magnetic skyrmion, neuromorphic

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D9.02

Nanoionics: ionic space-charge effect in lead halide perovskites

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Abstract:

$CH_3NH_3PbI_3$ (MAPI) is the archetypal lead halide perovskite material that is currently in the focus of photovoltaic research because of its high conversion efficiencies and many intriguing physical properties. In this study, we investigated equilibrium space charge effects in MAPI and focus on the MAPI/TiO_2 and MAPI/Al_2O_3 contacts, which are significant for perovskite solar cells. Irrespective of polarization phenomena building up under device operation, already the equilibrium situation is dominated by space charge effects (built-in space charge). While such equilibrium space charge effects are usually only considered in terms of electronic charge carrier redistribution, we will apply a generalized nano-ionic picture that discusses not only ionic but also electronic redistribution. This ionic equilibrium space charge effect has not been fully understood in photovoltaic field. Here we applied this nanoionics concept to MAPI for the first time and found that ionic carriers are not only relevant, they even dictate the space charge potential, which the electrons have to follow [1-3]. Our investigation is based on the measurement of electronic and ionic conductivities, a technique that has been successfully applied in solid states ionics. The results give indeed very strong indications of ionically-driven equilibrium space potentials forming at the MAPI/TiO_2 and MAPI/Al_2O_3 contacts [4]. This study may lead to a novel physical understanding of interfacial phenomena in perovskite solar cells.

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Keywords:

Interface, Nanoionics, Lead Halide Perovskite

D9.03

Tailoring optoelectronic properties of two-dimensional materials based heterostructures

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Abstract:

Atomically thin transition metal dichalcogenides (TMDCs) of a new class of two-dimensional (2D) materials have opened new opportunities for the next generation optoelectronics because of their unique layer-dependent electrical and optical properties. The modulation of optical and electrical properties of TMDCs is importance to enable various devices. Therefore, it is important to develop a strategy for implementing high-performance devices. Recently, modulation of the optical and electrical properties of TMDCs by doping, strain, contact engineering and 2Dmaterial-based heterostructures have been reported.
Here, we introduce the modulated optical and electrical properties of heterostructures Based on 2D Materials. We performed Photoluminescence and Raman scattering measurements on various heterostructure to understand interactions in the heterostructure. Also, we measured change of electrical characteristics and demonstrated high performance device of heterostructures based on 2D Materials

Keywords:

TMDCs, Van der Waals heterostructure, Photoluminescence, Raman, Optoelectronic

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D10.01

Optical spectroscopy of magnetic ordering in 2-dimensional materials

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Abstract:

Ferromagnetic and antiferromagnetic ordering in 2-dimensional van der Waals materials is a fascinating topic not only for possible applications in spintronics but also for fundamental understanding of physics in low dimensions. Due to the small sample volume of 2-dimensional materials, magnetic ordering is often difficult, if not impossible, to detect directly. Various optical spectroscopic techniques, including Raman scattering and second harmonic generation have been used to monitor the signatures of magnetic ordering in this class of materials. The coupling of lattice vibration modes with the magnetic ordering often results in modification of the Raman spectrum, which can be used as a signature of magnetic ordering. Similarly, magnetic ordering induced symmetry change results in dramatic change in second harmonic generation efficiency in some of these materials. In this talk, I will review the recent progress in optical spectroscopy of magnetic ordering in both ferromagnetic and antiferromagnetic 2-dimensional materials.

Keywords:

Two Dimension, van der Waals, Raman, Second Harmonic Generation, Magnetic Ordering

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D10.02

Anomalous Hall measurement of 2D ferromagnet-based heterostructures

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Abstract:

The representative 2D materials, graphene, h-BN, and MoS2, have interesting mechanical, electrical and optical properties and have exhibited fascinating physical phenomena so far. However, they mostly lack one important physical property in physics, magnetism. The new 2D materials such as CrSiTe3, CrI3, and FePS3, which began to be studied recently, possess ferro- or antiferro-magentic properties even in atomic level thickness and are expected to reveal deep level of physics in 2-dimensional confinement. In this talk, our recent works on electrical characterization of a 2Dferromagnet(Fe3GeTe2)-based heterostructures and their exotic properties. From the hall measurement, Fe3GeTe2 exhibited the anomalous hall effect due to its intrinsic ferromagnetism[1]. Interestingly, the magnetic properties such as coercivity changed significantly with decreasing thickness changing from weak ferromagnet to strong ferromagnet. In the heterostructure of Fe3GeTe2/Graphite/Fe3GeTe2, Hall measurement showed an exotic 3-states of resistance due to the spin-polarized current at the interfaces[2]. In the Fe3GeTe2/CrPS4 (FM/AFM) heterostructure, exchange bias was observed below the Neel temperature of the AFM layer. The exchange bias was dependent on the thickness variation of the AFM layer, and down to bilayer of AFM layer the exchange bias was maintained. Also, it could be controlled by applying electric potential.

This work was supported by National Research Foundation of Korea (Grant no. 2019R1A2B5B01070477, 2020R1A2C2014687, 2011-0031630) and Samsung Research & Incubation Funding Center of Samsung Electronics under Project Number SRFC-TB1803-04.

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Keywords:

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D10.03

Tunable magnetic and topological properties of iron-based van der Waals magnets

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Abstract:

Discovery of two dimensional (2D) magnets, showing intrinsic ferromagnetic (FM) or antiferromagnetic (AFM) orders, has accelerated development of novel 2D spintronics, in which all the key components are made of van der Waals (vdW) materials and their heterostructures. High-performing spin functionalities have been proposed, often relying on current-driven manipulation and detection of the spin states. In this regard, metallic vdW magnets are expected to have several advantages over the widely-studied insulating counterparts but have not been much explored due to the lack of suitable materials. Here we show that iron-based van der Waals magnets, Fe_3GeTe_2, Fe_4GeTe_2 and $(Fe,Co)_4GeTe_2$ host long-range itinerant magnetism with topological electronic structures. The spin configurations and orientations, together with topological responses, are sensitively controlled by doping, magnetic field, and thickness, which are effectively read out by electrical conduction. These findings manifest strong merits of metallic vdW magnets as an active component of vdW spintronic applications.

Keywords:

van der Waals magnets, Ferromagnetism, Antiferromagnetism, Topological properties

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D10.04

Two-dimensional magnetism in atomically thin chromium trihalides

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Abstract:

The family of two-dimensional (2D) materials has grown rapidly from semimetals and semiconductors to systems exhibiting collective electronic properties. In particular, several 2D magnetic compounds have been recently discovered. Experimental observations of the magnetic ground state in single atomic layers of such materials are not only important for fundamental interest, but also technologically relevant for next-generation spintronic devices. In this talk, I will present studies of atomically thin magnetic semiconductors CrX_3 (X= Cl, Br, and I) as well as their device applications. By sandwiching CrX_3 between few-layer graphene electrodes, we are able to fabricate high-quality van der Waals magnetic tunnel junctions and electrically probe the magnetic properties of the three materials. Moreover, we found that CrI_3 exhibits an extremely large tunnel magnetoresistance (~10^6%) as well as a robust memristive switching behavior that is tunable with magnetic field.

Keywords:

2D magnetism,, interlayer magnetism, intralayer magnetism, tunnel magnetoresistance

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D11.01

Organic Electronics for Wearable Healthcare

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Abstract:

유기반도체는 기존 반도체 기술에 비해 훨씬 더 낮은 온도에서 형성될 수 있어 플라스틱과 같은 다양한 기판위에 전자소자를 구현할 수 있는 장점이 있다. 이로 인해 신체부착형이나 가벼움, 형태변형 가능성 등이 중요한 웨어러블 전자기기에 높은 잠재성을 인정받고 있다. 웨어러블 기기는 피트니스, 메디컬 등 점차 개인화 되고 모바일화 되고 있는 헬스케어 분야에서 중요한 역할을 할 것으로 기대되고 있는데, 본 강연에서는 유기전자 기술이 헬스케어 분야의 웨어러블 소자를 구현하는데 어떤 역할을 할 수 있을지에 대해 논의한다.[1] 특히 관련 사례로서 웨어러블 산소포화도 센서 구현에 관한 연구결과를 소개한다. [2] 초기의 유기 산소포화도 센서 연구가 주로 유기소자의 다양한 폼팩터적 장점에 집중했던 것과 달리, 유기소자의 패턴자유도와 광학적 설계를 잘 활용할 경우 초저전력의 센서 구현도 가능함을 보여준다. 이외에도 인체 부착형 패치형 광 테라피 플랫폼 구현 등에 유용한 스트레쳐블 OLED 기술에 대해서도 소개한다. [3]

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Keywords:

Organic electronics, pulse oximetry, stretchable OLEDs , wearable healthcare

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D11.02

Skin-Inspired Artificial Ion Electronic Skin

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Abstract:

Human skin has different types of tactile receptors that allow distinguishing of mechanical stimuli and temperature. The somatosensory system of human skin has several unique characteristics. The receptors are composed of ion conductors and their operation is based on ion dynamics. A large number of thermoreceptors and mechanoreceptors are spatially distributed in the dermis [1], hence the spatial profiles of strain and temperature on the skin can be perceived distinctively. The viscoelastic deformability of the ionic receptors maintains stable electrical signals under large shear strains [2]. Here, we present a highly-deformable artificial multimodal ionic receptor design that can simultaneously detect thermal and mechanical information without signal coupling [2]. Two variables are derived from the analysis of the ion relaxation dynamics; the charge relaxation time as a strain-insensitive intrinsic variable to measure absolute temperature, and the normalized capacitance as a temperature-insensitive extrinsic variable to measure the strain. We present a pixelated matrix of the multimodal receptors, called Ion-Electronic skin (IE-skin). IE-skin can detect the directions and magnitudes of forces from various tactile motions (shear, pinch, spread, torsion, etc.) while sensing temperature at the same time. This ability is expected to help us understand the tactile sensing mechanisms in human skin.

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Keywords:

Artificial skin, stretchable electronics, ion-electronic skin, electrolyte

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D11.03

Nanoscopically Engineered Organic Semiconducting Materials for Healthcare Sensors

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Abstract:

With the advent of the Internet of Things (IoT), strong demand has grown for flexible and stretchable healthcare sensors. Particularly, sensors based on π-conjugated molecules covering small organic molecules and polymers have recently attracted great interest due to their high potential for use in flexible, low-cost, solution-processable, large-area electronics. Functional properties of organic active layers can be tailored by rational molecular design or surface functionalization to enhance their selectivity and sensitivity. Nanoscopically engineered organic semiconducting materials have recently emerged as promising building blocks for high-performance flexible sensors. In this talk, the development of high-performance organic and polymeric semiconductors will be presented with viable approaches to selectively tune the dominant polarity of charge carriers and achieve efficient charge transport, which embrace the rational design of conjugated backbones, side-chain engineering, microstructural and morphological control. Unconventional organic and polymeric nanomaterials covering single-crystalline nanowires, nanoporous films, core-shell nanomaterials, multiple-patterned plasmonic nanostructures, and chiral supramolecules will be described with their applications in flexible and wearable sensors including photodetectors, chemical and biological sensors, especially focusing on healthcare applications. In addition, the fundamental charge transport and photophysical phenomena of molecule-based active layers will be discussed.

Keywords:

organic electronics, organic semiconductor, flexible electronics, healthcare sensor

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D11.04

A bioinspired ion channel for optoelectronic deformable sensors

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Abstract:

Creating artificial sensory skins that shows the tactile-sensing capability of human skin has been a big challenge in wearable skin electronics. In particular, biomimetics has emerged as a burgeoning area in the field of deformable tactile sensor skins that has led innovations in material designing and device structure manipulation with the aim of imitating sensing mechanism of human skin, intelligently.
In this talk, inspired by the sophisticated physiological ion dynamics of living cells, we describe a uniquely designed deformable ion channel consisting of artificial ions confined into well-designed hybrid interface. Novel bottom-up strategy employed here resulted into supramolecular polymer networks through non-covalent interactions between poroelastic artificial ions and viscoelastic polymer chains or through hydrogen-bonding triggered ion dynamics, which endows effective ion drift under mechanical stimuli, simultaneously. This design allows for high-performance synaptic plasticity as well as ultrasensitive mechano-transduction over a wide spectrum of pressure, which can serve next neuromorphic tactile platform for highly interactive human-machine interface.

Keywords:

bioinspired ion channel, ion trap & release, sensor skin, human-machine interface

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D12.01

Emulating relatedness network using the structural information of the citation

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Abstract:

Scholars frequently use citations to estimate the similarity between two scientific items (e.g., papers, patents, and their authors and institutes). However, necessary citations can be missing for various reasons, such as information overload, search failure, and non-use policy of journals, and one commonly measures indirect relatedness between two items. Such relatedness measures are commonly based on overlapping references (i.e., bibliographic coupling) or citations (i.e., co-citation) and can then be used with cluster analysis to find boundaries between research fields. Unfortunately, calculating a relatedness measure is challenging, especially for a large number of items, because the computational complexity is greater than linear. In this presentation, we propose an alternative method for network construction that uses direct citation inspired by relatedness measures, simply replicating a node into two distinct nodes: a citing node and a cited node. We then apply typical clustering methods to the modified network. Clusters of citing nodes should emulate those from the bibliographic coupling relatedness network, while clusters of cited nodes should act like those from the co-citation relatedness network. For validation tests, our proposed method demonstrated high levels of similarity with conventional relatedness-based methods. We also found that the clustering results of the proposed method outperformed those of conventional relatedness-based measures regarding both similarities with natural language processing--based classification and geographical proximity. In addition to the simple relatedness measures, we also suggest a method emulating hybrid relatedness networks that combines bibliographic coupling, co-citation, and/or direct citation.

Keywords:

citation network, clustering analysis

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D12.02

Win-Stay-Lose-Shift as a self-confirming equilibrium in the iterated prisoner's dilemma

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Abstract:

Evolutionary game theory assumes that players are able to replicate a highly scored player's strategy through genetic inheritance, but in terms of learning, it is often difficult to recognize a strategy just by observing the behavior. In this work, we consider players with memory-one stochastic strategies in the iterated prisoner's dilemma, with an assumption that they cannot directly access each other's strategy but only observe the actual moves for a certain number of rounds. Based on the observation, the players have to infer the resident strategy in a Bayesian way and adjust their own strategies accordingly. By examining the best-response relations, we argue that players can escape from full defection into a cooperative equilibrium supported by Win-Stay-Lose-Shift, provided that the cost of cooperation is low and the observational learning supplies sufficiently large uncertainty.

Keywords:

Evolution of cooperation, Reciprocity, Bayesian inference

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D12.03

The effect of media on opinion formation model

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Abstract:

Our opinions on a social issue can be affected by others' opinions in social networks and by various media we are acquainted with. In a modern society, there are many different media we can choose, and we often choose the one that is close to our own political and cultural tastes. We introduce a simple model in which the opinion of an agent is affected not only by other agents in the system, but also by the media. The effect by the media is tuned by a parameter Hin our model, which can either strengthen (for $H > 0$) or weaken (for $H < 0$) the opinion of the agent. As H is varied, we find that our model exhibits three different states: neutral state, consensus state, and polarized state. We observe that a discontinuous transition occurs between the neutral and consensus states, and examine how the finiteness of the system size affects the transition between the consensus and polarized states.

Keywords:

opinion formation, media, discontinuous transition, finite-size effect

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D12.04

Homological percolation transitions in evolving coauthorship relations

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Abstract:

Graph, composed of nodes and links, is a simple representation for constituents and pairwise interactions, respectively. This simple method was successful for explaining diverse properties of complex systems to some extent. Hypergraph which contains simplicial complex as a subspace is a generalization of graph, which takes into account not just pairwise interactions between multiple nodes but higher order interactions as well. Particularly, in simplicial complex, we extract topological features much easier such as Betti numbers which might hardly be shown in graph level. Here, using the simplicial complex representation based on algebraic topology, we determined the evolutionary stages in the coauthorship relations, a prototypical example of large-scale social relationships, based on empirical datasets in scientific research fields. We used the thresholds of 1st and 2nd Betti numbers in determining evolutionary stages of coauthorship simplicial complex, and found Betti numbers in growing simplicial complex show different properties compared to unimodal behaviors of those in static versions. We also found that the facet degree distribution exhibits power-law decaying along with the graph degree distribution. As a result, we suggest a minimal model, growing simplicial complex, retaining such topological features, non-unimodal behaviors of Betti numbers and power-law decaying of facet degree distribution. Moreover, in the model, we found the infinite-order phase transitional property of growing networks can be also served by Betti numbers of all orders in growing simplicial complexes.

Keywords:

coauthorship relation, simplicial complex, homology

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D12.05

Quantifying and Predicting Synergy in Scientific Collaboration

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Abstract:

Scientists mainly work in teams. Why does collaboration with someone get better outcomes and with someone doesn't? If two scientists publish a highly-cited paper that exceeds the expectation, is it by chance or because synergy exists between them? How can we determine the expectation of two scientists? To answer these questions, we trace the publication histories of both individual scientists and teams. In the so-called Q-model, the individual scientific impact is determined by a multiplicative process of a sustained ability Q of each scientist and a universal fluctuation, luck. We find that the Q-model is valid for teams, implying that shared experience does not guarantee success and that each team has a unique and stable ability Q. To reveal the relationship between Q of a team and individual Qs of its members, we try to predict team Q with the generalized mean of individual Qs and find that the geometric mean shows the best performance, prompting us to propose an additivity rule. However, combining our additivity rule and the luck in the Q-model cannot explain the deviations from the additivity. We consider these deviations as interaction effects that emerge between scientists and classify the interactions into five types: strongly synergistic, weakly synergistic, additive, weakly antagonistic, and strongly antagonistic. We also show that a network inference method can predict the interactions. Furthermore, we collect various types of metadata of individual scientists (e.g., gender, ethnicity, etc.) and investigate the predictive power of metadata.

Keywords:

science of science, science of success, network inference

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D12.06

A Set of Central Words in Korean Language

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Abstract:

When one starts to learn a foreign language, search for the meaning of a word leads to many recursive searches of words in a dictionary.
The process can be described as an epidemic spreading in a lexical network, and one can encounter an outbreak of searches.
As one's knowledge is expanded, meanings of more words are known, and thus search outbreaks can be stopped in the early stage
of the search. Accordingly, the already known words can be mapped to the vaccinated nodes in the network. We define the central word set as the minimal group of vaccinated words preventing the outbreak and discuss some strategies to find them in the Korean language utilizing the Korean Standard Dictionary(표준국어대사전).

Keywords:

network, central word, Korean language

2020 KPS Fall Meeting
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D12.07

Machine learning approaches for the nonlinear dynamics

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Abstract:

With growing interest in the machine learning, recent works on physical systems has demonstrated successful progresses by adopting the machine learning approaches for tasks of classification and generation. In this paper, we perform various machine learning approaches for the Kuramoto system which is basic and simple model for synchronization phenomena and exhibits complicated chaotic behavior. As the system displays rich properties such as synchronization transition and nonlinearity with varying parameters, we applied machine learning for finding the value of the coupling strength and the critical value. Considering the finite size scaling, we confirm that results follow the critical behavior of the Kuramoto system. By focusing on the phase dynamics of all oscillators, we applied the performance of the neural network for predicting future behaviors of all oscillators and detecting underlying network topology. As the Kuramoto model offers support for the application on real-world systems exhibiting synchronization phenomena or nonlinear behaviors, our work has potential for utilizing the machine learning approaches for such systems.

Keywords:

Machine learning, Synchronization, Kuramoto model, Non-linear system, Complex network

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D14.01

Overview of beam-driven wakefield accelerators

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Abstract:

Beam-driven plasma wakefield acceleration (PWFA) could provide novel high-gradient acceleration schemes for high-energy particle physics experiments and future compact light-sources. Here, a driving beam excites strong wakefields in plasma, and a trailing witness beam is accelerated by the wakefields. Hence, the R&D topics of the PWFA can be categorized into two folds: shape control of driver beam and injection optimization of witness beam. In this talk, we go over worldwide research activities on the beam-driven wakefield accelerators and remaining issues for their practical use.

Keywords:

Beam, Wakefield, Accelerator

2020 KPS Fall Meeting
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D14.02

Generation of non-thermal energetic ion beams from a layered target irradiated by an ultraintense laser pulse

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Abstract:

Since 2000, Generation of energetic ion beams from a laser-foil interaction has been attracted due to its potential applications with advanced characteristics such as a high intensity, a short pulse duration, a species-tunability, and a compact size. Many progresses have been made to understnad underlying physical mechanismsand but development of a way to generate high quality ion beams in the sense of energy and energy spread is still far from expectations. In these situations, the authors currently obtained unusual ion beams having non-thermal energy spectra from a layered target irradiated by a high-contrast 100-TW laser pulse. The authors will present efforts for the development of a high quality ion beams.

Keywords:

Laser acceleration, Ion beam, Non-thermal spectrum, Layered target

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D14.03

Two laser pulses-based plasma acceleration for high temporal resolution UED researches

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Abstract:

Ultrafast electron diffration (UED) is one of promising techniques to observe ultrafast dynamics in materials at atomic timescales. Conventional UED instruments have used femtosecond (fs) electron beam produced by RF photocathode gun, and thus they limits temporal resolution to a few tens of fs due to time jitter between pump-probe (laser-electron) pulses by RF jitter and electron bunch length. In laser-plasma electron acceleration (LPA) technique, in contrast, since electron beam has strong correlation with laser pulse for electron generation, no intrinsic time jitter between pump-probe pulses occurs and electron pulse width can be down to sub-10 fs or attosecond (as). Among many LPA schemes, LPA using two laser pulses separated to driving pulse and injection pulse is most efficient method for high quality electron generation. Here, we present new concept to generate high quality electron beam based on simulataneous spatial-temporal focusing (SSTF) method, which decreases Rayleigh length and thus increases localized intensity at focal position.

Keywords:

Laser-plasma acceleration, Ultrafast electron diffraction, Simultaneous spatial-temporal focusing

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D14.04

레이저-플라즈마를 이용한 초고속-광대 THz 광원 개발

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Abstract:

Two-color laser mixing in gas/air has been much attracted due to its capability of producing intense, broadband terahertz (THz) pulse. In this scheme, two-color femtosecond laser pulse (fundamental and its second harmonic pulse) are focused to ionize a gaseous medium and creates a plasma current. Under optimal phase different between two-color laser fields, a directional current can arise on the time scale of the laser pulse duration, which can emit broadband (0.1~100 THz) THz radiation. The plasma current under two-color laser fields obtains a drift velocity that scales linearly with wavelength, like the electron quiver velocity. Thus, the THz energy is expected to scale with the square of wavelength for fixed laser intensity. Previously, the most of THz generation with two-color mixing were conducted at near-infrared (800 nm) laser wavelengths, and the observed THz energy were limited to ~0.1%. In this presentation, we present efficient THz generation from air plasma via two-color, mid-infrared (3.9 um) femtosecond laser pulse. Using an intense long-wavelength pulse, we observe a highly efficient (~1%), coherent THz radiation and investigate the interplay between tunneling ionization and THz with coherent control of two-color laser fields.

Keywords:

Terahertz, plasma

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D15.01

Adiabatic quantum computation with trapped ions

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Abstract:

Quantum computers are expected to provide solutions to various difficult problems that are intractable in classical computers. One challenging problem is to find ground states of a non-trivial Hamiltonian, which is classically demanding because of the exponentially increasing Hilbert-space of the Hamiltonian. Adiabatic method, which begins with a ground-state of a simple Hamiltonian and slowly evolves to the non-trivial Hamiltonian of interest, is one promising way to find the ground state. A few experimental demonstrations of the adiabatic preparation have been reported with a small number of effective spins, in particular, with trapped ions-qubits [1,2]. However, these realizations have not reached to the true ground-state due to couplings of spin-spin interactions to vibrational modes [3,4]. Also the interactions have been limited to near uniform regime [2]. Here, we report the adiabatic preparation of the true ground states of the transverse Ising models with programmable interactions with up to four spins. We adopt the digital realization of the adiabatic evolution to completely decouple the spin-spin interactions to phonons. We also apply the global gate-scheme [5] to generate arbitrary pre-programed interaction-geometry among spins. Our experimental demonstrations can be extended further to a larger number of spin-systems and applied to other computationally complex problems.

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Keywords:

Quantum Computation, Adiabatic evolution, Ising model, Trapped ions

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D15.02

Trapped ions coupled to optical cavities

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Abstract:

We dispersively couple a single trapped ion to an optical cavity to extract information about the cavity photon-number distribution in a nondestructive way. The photon-number-dependent ac Stark shift experienced by the ion is measured via Ramsey spectroscopy. We use these measurements first to obtain the ion-cavity interaction strength. Next, we reconstruct the cavity photon-number distribution for coherent states and for a state with mixed thermal-coherent statistics, finding overlaps above 99% with the calibrated states.

Keywords:

ion trap, cavity QED

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D15.03

Semiconductor spin-photon interfaces for quantum network research

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Abstract:

Well-isolated color centers in semiconductors can be used as isolated atoms with outstanding quantum nature such as indistinguishable photon emission and, long-lived spin states. When efficient and high-fidelity transfer between photonic and spin states is possible, color centers can serve as a spin-to-photon interface which is a building block for modular quantum computing structure, and long-distance quantum repeater network. In this presentation, I will introduce the basic principles about how one can use such color centers as quantum bits and quantum interfaces, and the recent research progress on spin-photon interactions in wide-bandgap semiconductors, e.g. silicon carbide.

Keywords:

quantum repeater, color center

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D15.04

Nanophotonics for Efficient Quantum Interfaces

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Abstract:

신뢰성 있는 광자기반 양자컴퓨터 개발을 위해서는 고효율 양자인테페이스의 구축은 필수적이고, 이를 위해서는 인터페이스에서 발생하는 광자 손실을 최소화하고, 광자의 근본적 발생속도를 높일 수 있는 연구가 필요하다. 본 발표에서는 나노포토닉스를 이용하여 고효율 광자기반 양자인터페이스를 구축할 수 있음을 보이고자 한다. 구체적으로는, 메타렌즈를 이용하여 고체 점결함으로부터 발생하는 광자의 수집 효율을 높일 수 있음을 보이고, 극미세 플라즈모닉 나노안테나를 이용하여 발생속도가 매우 느린 어븀 이온의 광자 발생 속도를 극대화시킬 수 있음을 보이고자 한다.

Keywords:

양자인터페이스, 메타렌즈, 플라즈모닉, 나노안테나, 나노포토닉스

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D16.01

리드버그 원자를 이용한 고감도 광대역 전기장 계측 연구

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Abstract:

최근 원자물리를 기반으로 하는 정밀 계측 연구가 고감도 초정밀 초소형 양자센싱 기술로 활발하게 연구되고 있다. 그 중에서 리드버그 원자를 이용한 전기장 측정 연구는 최근에 무선통신과 이동통신의 발전과 전자파에 민감한 집적도가 높은 회로 등에 산업체의 활용도가 높아지면서 높은 감도와 넓은 주파수 영역, 그리고 공간 분해능이 높은 전자파 측정에 대한 새로운 산업체의 수요가 급증하고 있다. 국제적인 측정표준 연구와 신산업의 수요에 따라 새로운 전자기파 측정 방법에 대한 연구가 절실히 요구된다. 본 발표에서는 원자 증기 셀에 있는 알카리족 원자를 리드버그 상태로 만든 후, 리드버그 상태 사이에 공명하는 RF와 다시 상호작용을 통해서 전기장의 세기를 측정에 관한 실험적인 결과를 발표한다. 리드버그 상태에서 측정되는 전기장의 세기는 Autler-Towns (AT) 분리 정도로 측정하기 때문에 전기장의 세기를 주파수로 측정한다는 점에서 높은 정확도로 측정할 수 있다. 또한 리드버그 원자의 양자상태를 제어하여 수 GHz에서 수백 GHz영역 (W-band) 까지 넓은 주파수 영역을 하나의 측정 시스템에서 측정이 가능하다는 장점을 가질 수 있다.

Keywords:

리드버그 원자, 전자파 측정, 전자기 유도 투과, 양자 센서

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D16.02

Toward high precise, compact, low power gyroscopes: Atom spin gyroscopes

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Abstract:

Atom Spin Gyroscopes (ASGs), often referred to NMR gyros, are sensors that measure the rotation rate based on the Larmor frequency measurement of gaseous noble gas atoms such as Xenon. They have attracted attention as potentially high precise, compact, and low power consumption gyroscopes. We have developed Rb-^{129}Xe/^{131}Xe dual species ASGs that extract the rotation rate and the magnitude of the bias magnetic field from the measured Larmor frequencies. In this talk, we give an overview of ASGs and introduce recent progress on development of ASGs in ADD.

Keywords:

Atom spin gyroscope, NMR gyroscope, Larmor precession

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D16.03

초정밀 이동형 원자중력계 개발

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Abstract:

지난 2~30년간 원자의 물질파 중첩현상을 이용한 원자간섭계를 이용하여 여러가지 물리현상 규명 및 정밀 측정을 위해 많은 연구들이 진행되어 오고 있다. 본 학회에서는 특히 정밀 중력측정을 관한 이동형 원자중력계의 개요 및 현재의 연구 진행 현황을 소개하고 현재 한국표준과학연구원에서 개발중인 원자중력계의 연구 진행현황을 소개한다.

Keywords:

원자간섭계, 원자중력계

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D17.01

High PCE perovskite solar cells with active layer modulation

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Abstract:

One of the most effective methods to achieve high-performance perovskite solar cells has been to include additives to precursor solutions that serve as dopants, crystallization agents, or passivate defect sites. Cl-based additives are among the most prevalent in literature, yet their exact role is still uncertain. In this work, we systematically study the function of methylamine chloride (MACl) additive in formamidinium lead iodide ($FAPbI_3$)-based perovskite thin films. Using density functional theory, we provide a theoretical frame work for understanding the interaction of MACl with a perovskite active layer.We show that MACl successfully induces an intermediate to the pure $FAPbI_3$ α -phase with out annealing, effectively stabilizing this structure only through cationic site substitution. The formation energy for this phase is directly related to the amount o f incorporated MACl. By tuning the incorporation of MACl, the perovskite film quality can be significantly improved, exhibiting a 6x increase in grain size, a 3x increase in phase crystallinity, and a 4.3x increase in photoluminescence lifetime, compared to a native control. The resulting optimized solar cells based on these films achieved a peak-scan efficiency of 24.02%.

Keywords:

perovskite, high PCEs, solar cells, active layer, additive

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D17.02

Cathode interlayers for favorable energy level alignment in inverted organic solar cells

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Abstract:

In recent decades, organic solar cells (OSCs) have attracted significant interest owing to their many advantages including simple fabrication methods, light weight, and mechanical flexibility. In OSCs, an inverted structure shows a longer device lifetime than a conventional structure. To obtain a high power conversion efficiency in inverted OSCs, a sufficient decrease in the work function of a bottom cathode is of great importance. Such electrode engineering forms a favorable energy level alignment for efficient charge extraction from the organic layer to the electrode. In this presentation, various functional interlayers modifying the electronic structure at the cathode interfaces are presented. The origin of improvement in device performance (e.g. interface dipole) is elucidated with determining the energy level alignment using photoelectron spectroscopy and inverse photoelectron spectroscopy measurements.

Keywords:

organic solar cells, cathode interlayer, photoelectron spectroscopy, work function

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Facile conductivity enhancement of PEDOT:PSS with high work-function for transparent electrode application

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Abstract:

In this study, we report a facile electrical conductivity improvement method for poly (3,4-ethylenedioxythiophene):poly (4-styrenesulfonate) (PEDOT:PSS), which is one of the most widely studied conductive polymers and used for many electronic applications. From our study, we successfully demonstrated that simple hydroquinone (HQ) addition to pristine PEDOT:PSS aqueous solution can dramatically increase the conductivity of PEDOT:PSS thin film more than 3-order even without removal of an insulator-like PSS from coated PEDOT:PSS thin film. We demonstrated that this superior conductivity enhancement without PSS removal is originated from promoted phase separation between conductive PEDOT and insulating PSS after HQ addition which acts as a proton (H^+) donor for PEDOT:PSS. Due to our conductivity enhancement method excluding PSS-removal, high work-function property of PEDOT:PSS is also well preserved which is highly crucial for optoelectronic device application of conductive PEDOT:PSS as a transparent electrode.

Keywords:

conductive polymer, PEDOT:PSS, conductivity, work-function, transparent electrode

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D17.04

친환경 컬러 $Cu(In,Ga)Se_2$ 박막 태양전지 기술

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Abstract:

$Cu(In,Ga)Se_2$ (CIGS) 박막 태양전지는 직접적인 전이가 이루어지는 밴드 구조를 갖고 있어 광 흡수율이 큰 장점이 있고, 23% 이상의 매우 높은 광전변환 효율을 보고하고 있다. 일반적으로 유리기판 뿐만 아니라 유연기판에 적용할 경우 구부리거나 휠 수 있어 다양한 형태의 플렉시블 태양전지를 구현할 수 있다. 이처럼 가볍고 휴대성이 매우 뛰어난 플렉시블 태양전지가 상용화되면 모바일 기기, 전기차를 포함하는 운송수단, 아웃도어 용품 등 다양한 산업 분야에서 새로운 가치를 창출할 수 있을 것으로 기대되며, 나아가 건물 일체형 태양광 발전시스템에 적용될 수 있을 것으로 기대된다.
본 논문에서는 CIGS 박막 태양광 기술 동향에 대해 알아보고, 건물적용형 태양전지에 요구되는 친환경적이면서도 심미성이 우수한 태양전지 기술에 대해 논의하고자 한다.

Keywords:

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D18.01

기계적 에너지 수확을위한 마이크로 아키텍처 마찰전기 필름으로 향상된 전기 출력 특성

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Abstract:

일상 생활에서 전기 장치의 사용이 급격히 증가함에 따라 에너지 개념이 증가하고 있다. 따라서 태양, 열, 바람, 파도, 기계 에너지와 같은 재생 가능한 자원에서 에너지를 수확하는 것이 많은 관심을 받고 있다. 여러 에너지원 중에서 기계적 에너지는 다양한 기계적 움직임의 개입으로 인해 일상 생활에서 매우 유용하다. 이와 관련하여 고효율 에너지 변환으로 인해 마찰 전기 나노발전기 (TENG: triboelectric nanogenerator)가 매우 집중되어 왔다. 그러나 기계에서 전기로의 에너지 변환 효율은 재료의 전하와 표면적에 크게 좌우된다. 전자를 잃거나 얻는 경향이 더 높은 마찰전기 재료를 사용하면 표면적의 향상과 함께 전기 출력의 효율성을 높일 수 있다. 본 발표에서는 각각 매우 양전하 및 음전하를 띠는 나일론 및 폴리디메틸 실록산 (PDMS: Polydimethylsiloxane) 마찰전기 필름이 사용되었다. 처음에는 표면을 수정하기 위해 리소그래피 기술로 마이크로 아키텍처 실리콘 몰드를 준비한 다음 이러한 몰드를 사용하여 마찰전기 필름의 표면을 개선했다. 일반적으로 마찰전기 필름의 표면적을 늘리면 필름의 전하 축적이 향상되어 전기 출력이 높아진다. 일반 필름과 마이크로 아키텍처 필름의 전기적 성능을 비교했다.

Keywords:

마찰전기, 나노발전기, 전기적 특성

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D18.02

슈퍼커패시터 응용을 위한 향상된 전기화학적 성능을 갖춘 MnV_2O_6 미세 구조의 제작

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Abstract:

독특한 형태를 가진 마이크로/나노 구조의 혼합 전이금속 산화물은 슈퍼커패시터와 같은 잠재적인 응용 분야로 인해 많은 관심을 받고 있다. 본 발표에서는 MnV_2O_6 미세 구조는 다른 시약을 사용하는 수열합성법으로 준비되었다. 합성된 MnV_2O_6 물질은 전계방출 주사전자현미경, X-선 분말 회절, 고해상도 투과전자현미경 및 X-선 광전자 분광법을 특징으로 한다. 순환 전압 전류법, 정전류 충전/방전 및 전기화학 임피던스 분광법을 사용하여 재료의 전기화학적 특성을 측정했다. 준비된 MnV_2O_6 미세 구조는 이온 수송을 위한 큰 나노스케일 기공 채널을 제공한다. 합성된 MnV_2O_6 물질은 우수한 전기화학적 특성을 나타낸다. 이러한 우수한 성능은 MnV_2O_6 미세 구조가 슈퍼커패시터 응용 분야에서 유망한 전극 재료임을 시사한다.

Keywords:

슈퍼커패시터, 수열합성법, 전기화학적 특성

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D18.03

에너지 저장 장치용 바나듐 통합 금속산화물의 합성 및 특성

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Abstract:

슈퍼커패시터 (SC: supercapacitor)는 수명, 높은 전력 밀도, 손쉬운 작동 및 안전이라는 두드러진 특징으로 인해 새로운 에너지 저장기술중 하나로 매료되었다. 슈퍼커패시터는 전하 저장 메커니즘에 따라 전기이중층 커패시터와 의사 커패시터로 분류된다. 전기이중층 커패시터에서는 생성된 전하가 전극재료/전해질의 계면에 축적된다. 이와 달리, 의사 커패시터는 전하를 비패러데이 방식으로 저장한다. 즉, 산화 환원 반응이 전기화학적 활성 물질의 표면에서 수행된다. 다공성 활성탄, 탄소 나노 튜브, 산화 그래핀 등은 전기이중층 커패시터 거동을 나타내며 이러한 물질은 일반적으로 높은 전력 밀도를 제공한다. 반면, 의사 커패시터 전극재료인 전이금속 수산화물/산화물 및 전도성 고분자는 전기화학적 활성 종의 존재로 인해 전기이중층 커패시터 재료보다 상대적으로 높은 정전용량을 제공하여 높은 에너지 밀도를 제공한다. 그러나, 단일 금속산화물은 각각의 단점으로 인해 전극재료로 제한된다. 다중 금속산화물을 개발하는 것은 이러한 단일 금속산화물의 한계를 완화하기 위한 효율적인 전략이다. 따라서 우리는 바인더를 사용하지 않고 구리 폼에 직접 구리 코발트 바나데이트 복합재를 설계했다. 집전체에 활물질을 직접 준비하면 비전 도성 바인더가 제거되어 빠른 전하 수송이 가능하다. 더욱이, 삼원 금속산화물의 통합은 산화환원 활동뿐만 아니라 전기전도도를 향상시킨다. 개별 금속산화물의 시너지 효과로 인해 제조된 구리 코발트 바나데이트 복합재는 우수한 전기화학적 성능을 보여준다.

Keywords:

슈퍼커패시터, 구리 코발트 바나데이트, 전기화학적 특성

2020 KPS Fall Meeting
2020-11-04 - 2020-11-06

D18.04

Core-shell MnO_2 deposited one-dimensional porous silicon nanowire electrodes for high performance supercapacitors

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Abstract:

Electrochemical energy storage (EES) have attracted considerable interest due to the increasing demand for high energy and power densities for potential applications in many fields. The most important class of EES devices, having higher power than conventional batteries while storing more energy than the dielectric capacitors are supercapacitors. Recently the extensive research has been focused on developing new advanced materials which are structurally robust and electrically conductive with a large surface area for enhanced charge storage capacity and are environmentally friendly. In this study, core-shell manganese oxide (MnO_2)-deposited on plasma assisted vertically aligned silicon nanowires (csMnO_2/pSiNWs) are fabricated for high energy and power density supercapacitors. The fabricated electrode material system exhibits exceptional electrochemical behavior with a specific capacitance reaching 709.54 F/g with 100% coulombic efficiency in non-aqueous PC$LiClO_4$. Furthermore, the electrode material exhibits excellent capacitive retention of about 93.12 % over 6000 galvanostatic charge-discharge (GCD) cycles. To evaluate the practicability, an asymmetric supercapacitor (ASC) is designed using csMnO_2/pSiNWs as positive electrode and activated carbon deposited carbon fabric (C/CF) as negative electrode. The assembled ASC shows a superior power density ranging between 21 W/cm^3 at energy density of about 18 Wh/cm^3 with a large operational potential window (2.4 V) and capacitive retention of 89 % over 10,000 GCD cycles.

Keywords:

one-dimensional SiNWs, MnO2, supercapacitor, asymmetric device, non-aqueous electrolyte

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D18.05

GaN/p-GaN core-shell Nanowire-Based Self-powered Piezoelectric-Pressure Sensor

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Abstract:

Gallium nitride (GaN) is one of the prominent III–V semiconductors and has excellent optical and electrical properties. Here, we report the self-powered, flexible, and stable piezoelectric pressure sensor (PEPS) based on hetero- and homo-junction GaN NWs. The GaN NWs with controlled crystallographic orientation were grown on c-plane GaN thin film (TF) using MOCVD. The demonstrated self-powered PSs based on piezoelectric nanogenerator (PNG) work on the principle of piezoelectricity and require no external power-supply components like batteries, because of the pressure induced piezoelectric effect. The challenging aspect for piezoelectric induced pressure sensors is the measurement of static signals, because, the carrier transportation across the semiconductor-metal interface (referred as junction current screening effect) decays the voltage response significantly. Initially, we demonstrated the PNG based on GaN/V_2O_5 core-shell NWs. The PNG exhibited the enhanced stability, maximum output voltage of 27 V, and maximum current of 850 nA, but still the suppression of junction current screening effect and reduction in leakage current were not up to the level to use it as a piezoelectric PS.
In order to suppress junction current screening effect, GaN/Al_2O_3 core-shell NW structure was utilized because of huge barrier height of Al_2O_3. The Al_2O_3 with optimized shell thickness of 6 nm was conformally deposited on GaN NWs using ALD to fabricate the PS based on PNG. Under the compressive strain, the output voltage exhibited by the PS was ~30 V at 150 g/cm^2 while the maximum current was 100 nA because of the high resistivity of Al_2O_3. The PS still exhibited the 7% decay in voltage response per second. The decay of voltage response observed because of the poor GaN-Al_2O_3 interface quality. For the elimination of decay of voltage response, recently, we fabricated the self-powered PS based on GaN/pGaN core-shell homojunction NWs. The p-GaN shell with controlled resistivity was epitaxially grown on core GaN NWs using MOCVD. To enhance the resistivity of p-GaN, the growth of p-GaN shell was performed in H_2 environment because this helps hydrogen atoms to adsorb into GaN and make Mg-H bond. The post annealing of p-GaN was not performed because Mg-activation increases the p-type conductivity which degrades the piezoelectric performance. The epitaxially grown GaN/p-GaN core-shell NWs exhibited the improved interface quality. For the flexible PS, the core-shell NWs were encapsulated in PDMS and subsequently transferred to the indium-coated PET substrate. The fabricated PS exhibited the maximum current of 55 μA, output voltage of 30 V at 50 g/cm^2, 40 and 45 ms response and recovery time, and stable voltage response. No external power was applied for the signal detection by piezoelectric PS. Because of the fascinating response of aforementioned GaN/p-GaN core-shell NWs; we are in a process to fabricate the flexible electronic skin.

Keywords:

GaN, nanowire, piezoelectric, nanogenerator

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D18.06

리튬 이온 배터리용 NiS_2-CoS_2@MoS_2 음극재의 합성 및 특성

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Abstract:

이종 구조의 NiS_2-CoS_2@MoS_2 나노 결정은 2 단계 합성 공정을 통해 성공적으로 준비되었다. 먼저 공침법으로 NiS_2-CoS_2를 제조 하였다. 둘째, NiS_2-CoS_2는 N 도핑된 그래핀 매트릭스에서 캡슐화된 NiS_2-CoS_2@MoS_2 를 설계하기 위해 용매 열방법을 통해 MoS_2@그래핀과 성공적으로 결합되었다. 제조된 샘플의 상 확인은 분말 X선 회절법을 사용하여 분석하였다. 표면 조성 및 원자가 상태는 X선 광전자 분광법에 의해 추가로 조사되었다. 표면 형태와 미세 구조는 각각 전계 방출 주사 전자 현미경과 투과 전자 현미경으로 관찰하였다. 새롭게 설계된 이종 구조 샘플은 우수한 속도 성능과 우수한 가역성을 나타내는 리튬 이온 배터리의 음극 재료로 조사되었다.

Keywords:

리튬 이온 배터리, 이종 구조, 전기화학적 특성

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D18.07

고성능 슈퍼커패시터를 위한 삼금속 층상이중수산화물의 합성

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Abstract:

최근 에너지 문제가 증가함에 따라 신 재생 에너지 저장 시스템 개발에 초점을 맞추고 있다. 주로 슈퍼커패시터 (supercapacitor)는 급속 충전/방전 안정성, 긴 수명의 사이클링, 높은 전력 밀도 및 안전한 작동이라는 탁월한 특성으로 인해 친환경 에너지 저장 시스템으로 상당한 헌신을 기울였다. 슈퍼커패시터는 일반적으로 전하 저장 메커니즘에 따라 두 가지 유형으로 분류된다. 하나는 전하가 비패러데이 방식으로 저장되는 전기 이중층 커패시터 (예 : 탄소 기반 재료) 이다. 다른 유형은 패러데이 산화 환원 반응을 통해 전하를 저장할 수 있는 의사커패시터이다. MnO_2 및 RuO_2와 같은 전이 금속 산화물은 의사커패시터 유형 재료로 연구된다. 최근 NiCo LDHs (layered double hydroxides), NiMn LDHs, $NiMoO_4$, $Ni(OH)_2$, Co_3O_4, $NiWO_4$, NiCoMo LDHs 등이 배터리 유형 소재로 널리 연구되고 있으며 높은 산화 환원 특성으로 인해 의사커패시터보다 상대적으로 높은 비용량/용량 및 에너지 밀도를 제공 할 수 있다. 그중에서 NiCoMo LDH는 화학적 안정성, 저렴한 비용 및 향상된 전기 화학적 성능으로 인해 효율적인 전극 재료로 간주되고 있다. 본 발표에서는 바인더가 없는 NiCoMo LDH 하이브리드 복합재가 손쉬운 열합성기술을 통해 성공적으로 준비되었다. 합성된 NiCoMo LDH 하이브리드 복합재는 다른 용매로 제조된 다른 전극에 비해 우세한 산화 환원 화학과 더 높은 용량을 나타냈다. 얻은 전기 화학적 특성을 기반으로 NiCoMo LDH 하이브리드 복합재는 슈퍼커패시터 응용 분야에서 효율적인 전극 재료로 사용될 수 있다.

Keywords:

슈퍼커패시터, 층상이중수산화물, 전기화학적 특성

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2020-11-04 - 2020-11-06

D19.01

Role of metal ions in enzyme catalysis

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Abstract:

Carbonic anhydrases (CAs) are zinc metalloenzymes that catalyze the reversible hydration/dehydration of CO_2/HCO_3^-. The zinc ion in CA can be substituted by similar transition metal ions, leading to dramatically different catalytic activity. However, the underlying mechanism is not clearly known. In our study, we studied the intermediate states of four divalent transition-metal ions (Zn^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}) that induce drastic changes in CA II activity (100%, ~ 50%, ~ 2%, and 0%, respectively). The results show that the characteristic metal ion coordination geometries directly modulate the catalytic processes, and that the metal ions have a long-range (~10 Å) electrostatic effect on restructuring the water network at the active site. Our study provides clear evidence that the metal ions in metalloenzymes have a crucial impact on the catalytic mechanism beyond their primary chemical properties.

Keywords:

Metalloenzyme, Catalytic Mechanism, Carbonic Anhydrase

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2020-11-04 - 2020-11-06

D19.02

Development of a hyperspectral endoscopy system for imaging the gastrointestinal tract in clinics

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Abstract:

Hyperspectral imaging (HSI), measuring both morphological and biochemical information of tissue, has shown its potential as disease diagnostic tools. The tissue optical properties, including absorption, scattering, and polarisation, are changed during disease progression due to alterations in structural and biochemical features of abnormal tissue. Therefore, HSI could discriminate healthy and abnormal tissue based on spectral profiles. Many hyperspectral imaging systems have been developed and proposed to diagnose diseases in various tissue types. However, only limited numbers of hyperspectral imaging methods have been practically used in clinics due to challenges encountered during clinical translation, such as poor reproducibility or low clinician/patient acceptance. Besides, there are additional challenges for the instrumentation of a clinically translatable hyperspectral endoscope due to image distortions caused by a flexible optical fibre. In order to overcome these challenges, I have focused on the development of a hyperspectral endoscopy system by exploiting a line-scanning method and computer vision technique. In this talk, I will introduce the hyperspectral endoscopy system for imaging the gastrointestinal tract in clinics. Moreover, I will show the results of the pilot clinical study approved by the FDA.

Keywords:

Biomedical optics, Hyperspectral imaging, Endoscopy, Translational research, Biophysics

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D19.03

High-speed tracking of synaptic protein interactions

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Abstract:

Molecular observations of synaptic proteins provide a unique viewpoint on neurotransmission that complements electrophysiology measurements. In this talk, I will introduce molecular tweezers that can monitor the zippering of a single SNARE complex, a process that drives synaptic vesicle fusion. Using a magnetic particle, the method simultaneously manipulates and probes the structure of a SNARE complex with a millisecond time resolution, revealing partially zippered SNAREs and their interactions with other presynaptic proteins. We found that distinct intermediate forms of a SNARE complex are differentially regulated by associated factors such as complexin and synaptotagmin. Importantly, the addition of Ca2+ ions to the synaptotagmin-1−SNARE complex strongly drives the complete zippering of SNARE proteins, suggesting the critical role for synaptotagmin in synchronous, Ca2+-triggered neurotransmission. I will also discuss how such a force application technique can be employed to address mechanical aspects of molecular neuroscience.

Keywords:

2020 KPS Fall Meeting
2020-11-04 - 2020-11-06

D19.04

프라이머-템플릿에서 DNA 녹는 특이점은 시공간적으로 패밀리-B DNA 중합 효소의 교정 활동을 지휘합니다.

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Abstract:

고-충실도 DNA 중합 효소는 중합 효소 (pol)와 엑소 뉴 클레아 제 (exo)의 두 가지 활동을 시공간적으로 조정하지만 구조적 제어의 지배규칙은 아직 명확하지 않습니다. 여기 우리는 가족 B DNA 중합 효소를 모델로 사용하고 단일 분자 형광 이미징에 의한 교정 활동의 전체 과정을 조사했습니다. 우리는 현재 알려진 것과 달리 DNA 중합 효소가 잘못된 뉴클레오타이드를 통합 한 직후에 수정하지 않고 오히려 뉴클레오타이드를 더 추가한다는 것을 발견했습니다. 그 결과, 일치하지 않는 염기가 프라이머-템플릿 (pt) 접합 뒤의 세 번째 위치로 밀릴 때 열역학적 특이점이 생성됩니다. pt 접합에서 DNA 용융 특이점은 pol에서 exo로의 급격하게 구조적 전환이 발생하도록 해주는 최소 에너지입니다. 우리의 연구는 DNA 중합 효소가 DNA 복제의 높은 충실도를 위해 실수를 열역학적 이익으로 전환하는 방법에 대한 새로운 메커니즘을 제공합니다.

Keywords:

DNA 중합효소, DNA 엑소 뉴클레아제, 교정기능

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D20.01

미래 방사광가속기의 이용 기술과 사이언스

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Abstract:

미래 방사광가속기의 이용 기술과 사이언스

Keywords:

방사광가속기

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D20.02

신규방사광가속기에서의 분광실험 발전 방향

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Abstract:

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Keywords:

방사광가속기

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D20.03

Design of Korean 4GSR and its beam characteristic

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Abstract:

Design of Korean 4GSR and its beam characteristic

Keywords:

방사광가속기

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D20.04

KAERI의 다목적 방사광가속기 구축 인력 리뷰

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Abstract:

KAERI의 다목적 방사광가속기 구축 인력 리뷰

Keywords:

방사광가속기

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E1.01

Overview of EIC and Calorimeter

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Abstract:

EIC is the world's first electron-ion collider. A polarized electron beam is collided with a polarized proton, light ion, or heavy ion beam with high energy and luminosity to perform precise experiments on QCD. In this talk, in addition to the overview, current status and physics of EIC, we will discuss calorimeters as the detectors that the EIC-Japan group is mainly involved in the development of at present. We are especially interested in the development and construction of forward (hadron direction) and the most forward (zero degree) calorimeters.

Keywords:

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E1.02

Opportunity in EIC physics for the control case study of relativistic heavy ion experiments

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Abstract:

The electron ion collider (EIC), which will be built in Brookhaven National Lab, is a particle accelerator that collides a polarized electron with a polarized proton or heavy nuclei at high energy. The primary goal of this new experimental facility is to investigate the internal structure of nuclei in the deepest level with the highest precision ever. It will also allow to measure hard scatterings that will be useful as the control experiment for heavy ion experiments. In this presentation, we will review the physics topics that can be studied by the high energy division and nuclear physics division of KPS. In addition, we will discuss about contributions for manufacturing the machine, particularly focusing on the forward calorimetry.

Keywords:

E1.03

Development of silicon trackers for EIC

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Abstract:

The study of gluon distribution inside the nucleus is one of main subjects at the electron-ion collider. Heavy quarks produced from photon-gluon interaction is an excellent probe to study gluons in the nucleus. A silicon tracker covering a wide kinematic range is a very important detector to achieve precise measurements of heavy quark. Silicon detectors which have been developed for the heavy-ion experiment are good candidates, and there are also efforts to develop a new technology. In this presentation, activities on the silicon detector development for the EIC will be introduced.

Keywords:

E1.04

Nucleon tomography with GPDs at the EIC

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Abstract:

Many questions remain about how the partons, i.e. quarks and gluons, are distributed in space, momentum and spin inside the nucleon. Generalized parton distributions (GPDs) describe the complex internal structure of the nucleon in terms of those partons. Among other aspects, GPDs reveal the correlation between the longitudinal momentum fraction and the transverse spatial distributions of partons inside the nucleon, allowing us to perform nucleon tomography. GPDs can be studied through the measurements of exclusive reactions such as deeply virtual Compton scattering (DVCS). Nucleon tomography is among the main research goals at the future Electron-Ion collider (EIC). Recent results from Jefferson Lab data and future DVCS measurements at the EIC will be discussed.

Keywords:

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E2.01

Emergent Fermi liquid as topological insulator in holographic spacetime.

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Abstract:

For strongly interacting fermion system, the fermi surface is usually fuzzy if it exist at all. However in this paper, we show that a symmetry breaking introduced in such system creates fermion zero modes, which in turn create emergent Fermi surfaces of various types associated with the spectral features such as Dirac cone, Flat band, nodal line or Fermi-sphere.

The fermion zero modes are localized at the boundary of asymptotically AdS space therefore it is the Jackiw-Rebbi solution, therefore when such bulk zero modes are present, the boundary system can be considered as the edge state of a topological matter sitting at the bulk of the AdS. The proof is done by finding the Green functions analytically as well as by constructing the zero mode explicitly.

Keywords:

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E2.02

Magnetsm from rotating black brane

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Abstract:

We investigate magnetism of stongly interacting system using gauge/gravity duality. The study of magnetic properties from gauge/gravity dualisty has been performed by using dyonic black hole geometry for a long time. However, seperating external magentic field from total system is almost impossible for the dyonic black hole. We construct gravity model which can split external field and other magnetic properties. We also study thermodynamic property of the background system.

Keywords:

gauge/gravity duality, strongly interacting system, magnetism

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E2.04

Junctions of mass-deformed nonlinear sigma models on SO(2N)/U(N) and Sp(N)/U(N)

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Abstract:

We study vacua, walls and three-pronged junctions of mass-deformed nonlinear sigma models on SO(2N)/U(N) and Sp(N)/U(N) for generic N. We also discuss the on-shell N=2 nonlinear sigma model on the Grassmann manifold in the N=1 superspace formalism, in the harmonic superspace formalism and in the projective superspace formalism.

Keywords:

BPS, extended supersymmetry

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E2.05

Dyonic Generalisation of Effective One-Body Formalism via Scattering Amplitudes

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Abstract:

In this talk, we perform dyonic generalisation of effective one-body formalism by combining with amplitudes techniques up to second post-Minkowskian (2PM) order. We begin by reviewing the effective one-body formalism with Schwarzschild background as an example. At first post-Minkowskian order, the scattering angle from amplitudes with gravitational electromagnetic rotations matches with that of effective dynamics. However, there is a mismatch at 2PM, which can be traced back to non-exponentiation of eikonal phases in the presence of non-trivial NUT charges. This is a problem of one-loop amplitudes, which will be examined from various unitarity-related perspectives.

Keywords:

Scattering Amplitude, Taub-NUT Spacetime, Dyon Scattering, Effective One-Body Formalism, Post-Minkowskian Expansion

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E2.06

Structure Constants of a Single Trace Operator and Determinant Operators from Hexagon

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Abstract:

We study the structure constant of a single trace operator and two determinant operators in {₩cal N}=4 super Yang-Mills theory. Holographically such a quantity corresponds to the interaction vertex between a closed string and two open strings attached to the spherical DD-branes. Relying on diagrammatic intuition, we conjecture that the structure constant at the finite coupling is nicely written by the hexagon form factors. Precisely we need to prepare two hexagon twist operators and appropriately glue edges together by integrating mirror particles contributions and by contracting boundary states. The gluing generates the worldsheet for a closed string and two open strings attached to the DD-branes. At the weak coupling, the asymptotic expression simply reduces to sum over all possible partitions not only for the edge related to the closed string but also for the edges representing the half of the open string together with reflection effects for the opposite open string edges. We test the conjecture by directly computing various tree level structure constants.

Keywords:

Holography, Integrability

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E2.07

Large N gauge theories with a dense spectrum and the Weak Gravity Conjecutre

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Abstract:

We classify the large N limits of four-dimensional supersymmetric gauge theories with simple gauge groups that flow to superconformal fixed points. We restrict ourselves to the ones without a superpotential and with a fixed flavor symmetry. We find 34 classes in total, with 8 having a dense spectrum of chiral gauge-invariant operators. The central charges a and c for the dense theories grow linearly in N in contrast to the N^2 growth for the theories with a sparse spectrum. We find that there can be multiple bands separated by a gap, or a discrete spectrum above the band. We also find a criterion on the matter content for the fixed point theory to possess either a dense or sparse spectrum. We discover a few curious aspects regarding supersymmetric RG flows and a-maximization along the way. For all the theories with the dense spectrum, the AdS version of the Weak Gravity Conjecture (including the convex hull condition for the cases with multiple U(1)'s) holds for large enough N even though they do not have weakly-coupled gravity duals.

Keywords:

quantum field theory, AdS/CFT correspondence, quantum gravity, supersymmetry

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E2.08

Quantum Simulation for SYK Models

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Abstract:

We investigate SYK models without sign problem. We analyze chaotic properties of those models by using quantum Monte Carlo simulation, exact diagonalization and large N analysis. We will also discuss their holographic duals.

Keywords:

strongly correlated system, quantum Monte Carlo simulation, chaos, random matrix, holography

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E2.09

Holography of T^2 deformation in quantum mechanics

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Abstract:

We study the holographic interpretation of T^2 deformation of 1d quantum mechanical system. The deformation can be thought of as the dimensional reduction of T^2 deformation in 2d, which preserves the trace relation. The 2d gravity theory is Jackiw-Teitelboim gravity, which is a reduction of 3d Einstein gravity.
The variation method of the on-shell action is employed to find the map between deformed and undeformed theory at finite cutoff. The Dirichlet boundary conditions at finite cutoff correspond to mixed boundary conditions at infinity. The parameters of the black hole dual to the deformed theory is related to those of original black hole by the requirement that the two black holes have the same entropy. The trace of the deformed stress tensor in 2d gravity then reproduces the spectrum of the deformed quantum mechanical system such as Schwarzian theory.

Similar holographic interpretation is possible for 1d JT bar deformation. The bulk theory is the JT gravity with a topological field strength term for a gauge field, which has its origin in 3d Einstein gravity with a Chern-Simons term. An example of quantum mechanical system in this case is the charged Schwarzian theory, which is a low energy limit of the charged SYK model.

Keywords:

T2 deformation in 1d, Holography, JT gravity, Schwarzian

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E2.10

Pole-skipping of scalar and vector fields in hyperbolic space: conformal blocks and holography

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Abstract:

Motivated by the recent connection between pole-skipping phenomena of two point functions and four point out-of-time-order correlators (OTOCs), we study the pole structure of thermal two-point functions in d-dimensional conformal field theories (CFTs) in hyperbolic space. We derive the pole-skipping points of two-point functions of scalar and vector fields by three methods (one field theoretic and two holographic methods) and confirm that they agree. We show that the leading pole-skipping point of two point functions is related with the late time behavior of conformal blocks and shadow conformal blocks in four-point OTOCs.

Keywords:

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E3.01

Nuclear transmutation of ^{93}Zr using the low-energy beamline

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Abstract:

Nuclear transmutation is one of the solutions to reprocess long-lived fission products (LLFP). ^{93}Zr, the one of them with a long half-life (1.5 million years), is a candidate of nuclear transmutation in the previous studies. Proton-induced nuclear transmutation experiment on ^{93}Zr was carried out using the OEDO beamline at RIBF, RIKEN. The experiment was a part of the first physics campaign of the OEDO beamline, and we sucessfully obtained the 27-MeV/u ^{93}Zr beam. Thanks to the SHARAQ spectrometer, reaction products were clearly identified and their production cross section of each isotope was determined. In this talk, we will report the experimental details, results including production cross sections for each isotope, and their interpretation based on the theoretical estimation by TALYS.

Keywords:

nuclear transmutation, LLFP, TALYS, production cross section

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E3.02

Neutrino-Deuteron Reactions at Solar Neutrino Energies in Pionless Effective Field Theory with Dibaryon Fields

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Abstract:

We study breakup of the deuteron induced by neutrinos in the neutral $\nu d \to \nu np$, $\bar{\nu} d \to \bar{\nu} np$ and the charged $\bar{\nu} d \to e^+ nn$, $\nu d \to e^- pp$ processes. Pionless effective field theory with dibaryon fields is used to calculate the total cross sections for neutrino energies E_ν from threshold to 20MeV. Amplitudes are expanded up to next-to-leading order, and the partial wave is truncated at P-waves. The Coulomb interaction between two protons is included nonperturbatively in the reaction amplitudes, and an analytic expression of the amplitudes is obtained. The contribution of the next-to-leading order to the total cross section is in the range of 5.2−9.9% in magnitude, and that of the P-wave is 2.4−2.8% at E_ν = 20 MeV. Uncertainty arising from an axial isovector low-energy constant is estimated to be on the order of 1%.

Keywords:

Neutrino-deuteron reactions, Solar neutrino, pionless effective field theory

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E3.03

Development of new Graphic User Interface program for nuclear reaction

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Abstract:

One of the main obstacle for new learner to do a nuclear reaction calculation is inconvenient interface of many old nuclear reaction codes available. To make a nuclear reaction model calculation easier, a new graphic user interface program is under development. The program provides an easy interface for DWBA calculation of elastic, inelastic and transfer reactions with simple structure model assumption. It also contains several utilities for getting kinematic information, global optical potential and double folding potentials.

Keywords:

nuclear reaction, DWBA, GUI

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E3.04

Nuclear structure of neutron-rich Te isotopes beyond the double magic nucleus ^{132}Sn

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Abstract:

In this talk, recent experimental results of neutron-rich Te isotopes will be dicussed. The experiment was performed at the Radioactive Isotope Beam Factory (RIBF) of RIKEN as one of the EUROBALL-RIKEN Cluster Array (EURICA) experiments. Nuclear structure of Te isotopes is important due to their special circumstance with a proton pair over the robustly closed proton shell at Z = 50. In particular, neutron-rich Te isotopes beyond the double magic nucleus ^{132}Sn show a unique symmetric feature in the nuclear structure evolution with respect to the neutron magic number N = 82.
This presentation will focus on the nuclear structure of ^{137}Te and ^{138}Te with newly observed levels from beta decays. These newly observed levels will be described by two different shell model calculations to investigate the physics origin. Further, the brief future plan with new experimental setups will be introduced to extend our knowledge on nature of pairings and interactions in neutron-rich Te isotopes.

Keywords:

Rare-isotope beam, Nuclear structure, Beta decay, Gamma-ray spectroscopy, EURICA

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E3.05

Tensor force in nuclei

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Abstract:

We investigate the role of the pairing correlations due to the tensor force on N = Z sd-shell nuclei by a deformed BCS model with the Brueckner pairing matrix elements (PMEs) derived from the CD Bonn potential. In particular, the isoscalar (IS) correlations in neutron-proton (np) pairing is discussed in relation with the triplet-even tensor force (TF) in the nucleon-nucleon interaction. Detailed analyses of the np pairing and its possible enhancement of IS channel are performed for 12C, 16O, 20Ne and 32S, focusing on the di♂erent roles of attractive spin-triplet even and re-pulsive spin-triplet odd channels of TF.

Keywords:

Tensor force, isoscalar correlation

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E3.06

Structure of ^{100}Sn - present knowledge and research methods

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Abstract:

Many important questions in low-energy nuclear physics and nuclear astrophysics are centered on ^{100}Sn, the self-conjugate doubly-magic nucleus. The robustness of the N = Z = 50 shells, single-particle structure, proton-neutron interaction and the role of ^{100}Sn in the rapid proton capture process (rp-process) have been studied indirectly through various types of experiments on proton-rich nuclei with A ~ 100. ^{100}Sn has also become a key benchmarking nucleus for novel theories based on 3N forces and effective field approaches. A brief summary of the recent and ongoing experimental and theoretical efforts concerning this particular nucleus will be presented.

Keywords:

Nuclear structure, Magic numbers, Decay spectroscopy, Shell model

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E4.01

Measurement of cosmic-ray proton spectrum with the ISS-CREAM experiment

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Abstract:

The Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM) experiment is designed for measurements of energy spectra and elemental composition of cosmic rays. The ISS-CREAM experiment took data successfully until February 12th, 2019 since the launch to the International Space Station (ISS) in August 2017. The ISS-CREAM instrument can measure protons to iron nuclei in the energy range of TeV – PeV. For the elemental identification of cosmic rays, we use the silicon charge detector (SCD) placed at the top of the ISS-CREAM payload. The four-layer SCD consists of 10,752 silicon pixels with an active area of 78.2 cm x 73.6 cm in each layer. Each pixel is 1.57 cm x 1.37 cm x 0.05 cm in dimensions. It is designed to distinguish between backscattered and incident particles using the small pixels. Our preliminary result shows a good performance in measuring the charge for the protons and iron nuclei with charge resolutions of (0.1 – 0.3) e. The energy measurements are made with the calorimeter (a carbon target and twenty layers of tungsten plate and scintillating fibers) which provides the tracks of incident cosmic rays. In this presentation, we will report the current result of the proton spectrum from the ISS-CREAM experiment.

Keywords:

ISS-CREAM, Cosmic ray, proton spectrum

E4.02

Cosmic-ray Heavy Nuclei Spectra from the ISS-CREAM Experiment

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Abstract:

The Cosmic Ray Energetics And Mass for the International Space Stations (ISS-CREAM) instrument is designed for investigating high-energy cosmic-rays. It can measure cosmic rays up to PeV energies. The ISS-CREAM instrument is composed of the silicon charge detector (SCD), calorimeter (CAL) and top/bottom counting detectors (TCD/BCD). The SCD is composed of 4 layers and provides the measurement of cosmic-ray charges with a resolution of ~ 0.2 e. Each SCD layer consists of 56 × 48 silicon pixels, and the dimensions of each are 1.57 cm × 1.37 cm. The CAL consists of 20 tungsten plates and scintillators. The CAL measures energies of the incident cosmic-ray particles and provides a high energy trigger. The TCD/BCD provide a low energy trigger. In this analysis, the charge is determined by requiring consistency between the SCD top two layers. The energy distribution measured by CAL is deconvolved into an incident energy distribution. We will present the preliminary results of deconvolved cosmic-ray heavy nuclei spectra from the ISS-CREAM experiment.

Keywords:

ISS-CREAM, Cosmic-ray, Heavy nuclei

카그라 MCMC 모수 추정 파이프라인을 이용한 블랙홀 쌍성의 물리량 추정

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Abstract:

중력파는 질량의 가속 운동으로 생기는 시공간의 잔물결로 지구 상에서 레이저 간섭계를 이용해 검출할 수 있다. 대표적인 중력파원 중 하나인 밀집 쌍성 병합은 공전 운동을 하는 밀집 쌍성이 서로 가까워지고 마침내 충돌하여 하나의 밀집 쌍성이 되면서 중력파를 방출하는 현상이다. 중력파 신호를 분석하면 중력파원의 질량이나 위치 등 물리량을 추정할 수 있다. KAGRA는 일본 카미오카산에 위치한 최초의 지하 중력파 검출기이다. KAGRA 중력파 자료 분석에 특화된 KAGALI (KAGRA Algorithmic Library)가 개발되고 있다. 이 연구에서는 KAGALI의 모수추정 파이프라인 개발 노력의 일환으로 KAGALI를 사용한 마코브 체인 몬테칼로 중력파 모수 추정 시뮬레이션을 수행하였다. 특히, 쌍성 병합 단계 중에서 두 천체가 멀리 떨어져 있어 점질량으로 근사할 수 있는 나선 접근 단계의 중력파를 모델링하고, 이상적인 가우시안 잡음이 있는 경우와 없는 경우에 대해 모수추정한 결과를 보이고자 한다.

Keywords:

중력파, 블랙홀 쌍성, 모수추정

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E4.04

Gravitational waves generated by a rotating traversable wormhole

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Abstract:

In this talk, the gravitational wave generation by a rotating wormhole with vibrating throat is considered. Two types of rotating wormholes are adopted as the model of the wave generation: the rotating Ellis wormhole and the thin-shell wormhole from two Kerr black holes. We also found the strain amplitude and the power emitted in gravitational wave as well as the wave form.

Keywords:

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E4.05

Observations of Gravitational Waves by Gauge-Invariant Measures of Light

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Abstract:

Gravity influences the light described by a scalar field (phase) and a vector field (polarization). We provide a covariant description of how gravitational waves affect the phase and polarization of light. Unfortunately, perturbations of the phase and the polarization are not gauge invariant, which means that they cannot be measured in the laboratory. Defining various gauge-invariant measures of light perturbation to observe gravitational waves, we explain the working principle of detectors; e.g., Michelson interferometers and pulsar timing arrays. In addition, we explore the possibility of developing a new scheme for gravitational-wave detection by measuring the polarization of light. We expect that our analysis will not only deepen our understanding of gravitational-wave observations, but also be useful in designing new detectors.

Keywords:

Gravitational wave detector, Gravitational perturbation in optics, Stokes parameters

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E4.06

Light in the presence of gravitational waves

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Abstract:

The proper length for a spacelike separation gets streched and shrunken when a gravitational wave passes by. Lights would not have interferences in the Michelson interferometer if the wavelength of light behaves in the same way. Consequently, it is expected that light and free masses should respond to gravitational waves differently. On the other hand, light has to propagate along the null trajectory, e.g., geodesic curve, in the deformed geometry by gravitational waves. We consider the linearized Maxwell equation in a curved spacetime to study the response of light to a gravitational wave.

Keywords:

Light, Gravitational wave

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E5.01

Two-dimensional chiral stacking orders in quasi-one-dimensional charge density waves

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Abstract:

Chirality or handedness manifests in various forms in nature and plays a significant role in all branches of the natural sciences including chemistry, biology, mathematics, and physics. For example, in spin-ordered states, chirality manifests magnetic chiral solitons in chiral magnets, vortexes or skyrmions in thin magnetic layers, and topological monopoles in Weyl semimetals. Such richness is quite natural because of the vector order parameter in spin systems. Although 1T-$TiSe_2$was proposed as the first charge-density wave (CDW) system with a real-space chiral stacking order due to inversion symmetry breaking, a recent work reported that the remaining inversion symmetry with CDW contradicts the proposedexistence of the chiral CDW stacking order. Thus, there is no compelling evidence of the chirality in charge-ordered states due to their scalar order parameters.

Recently, topological solitons with chirality are realized in quasi-one-dimensional (quasi-1D) CDW atomic wires consisting of indium atoms on Si(111). Even though the solitons are found to exhibit unusual topological properties, their CDW groundstates have not been explored in terms of chirality or chiral order. In this work, we have explored the chirality among quasi-1D CDW ground states with scanning tunneling microscopy, symmetry analysis, and density functional theory calculations. We discovered three distinct chiralities emerging in the form of two-dimensional chiral stacking orders composed of degenerate CDW ground states. Such chiral stacking orders correspond to newly introduced chiral winding numbers. Furthermore, we observed that these chiral stacking orders are intertwined with chiral vortexes and chiral domain walls, which play a crucial role in engineering the chiral stacking orders. Our findings suggest that the unexpected chiral stacking orders can open a new way to investigate the chirality in CDW systems, which can lead to diverse phenomena on chirality.

Keywords:

chirality, charge-density waves, scanning tunneling microscopy, chiral staking order, quasi-one-dimensional atomic wires

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E5.02

Atomic and electronic reconstruction in the twisted bilayer graphene

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Abstract:

Controlling the interlayer twist angle in two-dimensional (2-D) van der Waals (vdW) heterostructures offers an experimental route to create moire superlattices. One can realize exotic electronic states by adjusting the width of the electronic band widths with a tunable moire length scale. However, in the small twist angle regime, the interplay between the vdW interaction energy and the elastic energy at the interface can cause significant structural reconfiguration, creating the arrays of commensurate domains and domain boundaries. In this talk, we will discuss the atomic reconstruction at the vdW interface in twisted bilayer graphene and its effect on electronic structure and electrical transport through the topological channels formed along the domain boundaries.

Keywords:

atomic reconstruction, twisted bilayer graphene, transmission electron microscopy

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E5.03

Control of electron-electron interaction in graphene by proximity screening

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Abstract:

Electron-electron (e-e) interactions play a critical role in many condensed matter phenomena, and it is tempting to gain control of them by changing the interactions' strength. One possible approach is to place a studied electronic system in a proximity to a metal, which induces additional screening and hence suppresses electron interactions. So far, however, it was not possible to study experimentally the impact of the screening exerted by metallic or dielectric media on the e-e interaction in a crystal. The main obstacles are surface roughness, impurities, and leakage in thin dielectrics, which hamper quantitative measurements of the e-e scattering length l_{ee} of the material one wants to tune. Fundamental questions remain therefore unanswered: how proximal should the metal be? What is the size of the effect one can achieve? To achieve this goal, we build van der Waals heterostructures with atomically-thin gate dielectrics and atomically-flat metallic gates. Driving the electron system in graphene in the hydrodynamic regime, we can quantitatively access l_{ee} and investigate how screening exerted by such metal gates changes viscous electron flow. The proximity screening is found to enhance l_{ee} and qualitatively changes its dependence on carrier density. Counterintuitively, the screening becomes important only at gate dielectrics' thickness of a few nm, much smaller than a typical separation between electrons. Our theoretical analysis agrees well with the scattering rates extracted from measurements of electron viscosity in monolayer graphene and of umklapp electron-electron scattering in graphene superlattices. The results provide a guidance for future attempts to achieve proximity screening of many-body phenomena in two-dimensional systems.

Keywords:

graphene, electron hydrodynamics, screening effect

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E6.01

메가바 이상의 극한 환경에서의 산화물의 전자-결합구조의 실험적규명

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Abstract:

물질은 원자단위의 배열의 규칙성의 여부에 따라 규칙적인 단위가 반복되는 결정질과 규칙적으로 원자가 배열되지 않고 무질서도를 가지는 비정질로 구분됩니다. 상대적으로 원자구조가 잘 알려진 결정질에 비하여, 비정질의 고압환경 하에서의 원자/전자구조는 잘 알려져 있지 않습니다. 특히 백만기압 [대기압의 100만배의 압력, 메가바(megabar), 혹은 100 기가파스칼(GPa)]이상의 극한적인 고압환경에서 비정질의 원자구조는 1기압이나 상대적으로 낮은 압력 범위 이하에서의 비정질의 구조와 매우 다를 것으로 추정되었으나 전통적인 탄성 산란이나 진동분광분석 방법으로는 규명이 어려우며, 따라서 현대과학의 난제로 남아있습니다. 본 발표에서는 다양한 비정질 산화물의 극한 고압환경에서의 원자구조를 주로 고상 NMR과 비탄성-산란을 이용하여 극한환경에서 획득한 결과들을 소개합니다. 고분해능 고체 NMR 방법론을 이용하여 새롭게 밝힌 비정질 산화물의 극한환경하의 특성들은 산소삼중클러스터(3개의 양이온과 공유결합을 하는 배위수가 3인 산소)의 존재[1], 압력에 의한 네트워크의 위상변화와 이로 인한 엔트로피및 탄성계수의 비정상적 거동[2], 25만기압까지의 양이온 배위수와 영구고밀도화의 관계[3], 그리고 메가바이상에서의 원자핵스핀 화학차폐와 위상의 관계[4]입니다. 입자가속기의 비탄성 x-선 산란방법으로부터 200만기압의 압력에서 산소사중클러스터의 존재[5], 메가바 이상의 압력에서 거시적 밀도와 PDOS의 선형적관계[5,6], 그리고 지구 및 거대지구의 과정을 설명한 일련의 연구결과들을 공유합니다[5,7].

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Keywords:

비정질 산화물의 전자구조, 비탄성 x-선 산란, 고분해능-고체 nmr, 메가바 이상의 극한고압환경

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E6.02

XFEL-Induced Synthesis of ε-Iron Nitride at High Pressures

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Abstract:

The ultrafast synthesis of ε-Fe_3N_{1+x} in a diamond-anvil cell (DAC) from Fe and N_2 under pressure was observed using serial exposures of an X-ray free electron laser (XFEL). When the sample at 5 GPa was irradiated by a pulse train separated by 440 ns, the estimated sample temperature at the delay time was above 1400 K, confirmed by in-situ transformation of α- to γ-iron. Ultimately, the Fe and N_2 reacted uniformly throughout the beam path to form $Fe_3N_{1.33}$, as deduced from its established equation of state (EOS). We thus demonstrate that the activation energy provided by intense X-ray exposures in an XFEL can be coupled with the source time structure to enable exploration of time-dependence of reactions under high pressure conditions. *This abstract represents one of the results emerging from a large collaborative effort to perform the first static high pressure experiments at European XFEL (at a "Community-assisted commissioning" beamtime performed in October, 2019).

Keywords:

XFEL, Synthesis, Iron nitride

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E6.03

Structure and Transport Properties of Potassium Hydrides under High Temperature and Pressure of Hydrogen

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Abstract:

Recent experimental results revealed that forming a metal-polyhydride is a possible route to discover high-transition temperature superconductors (SCs) by enhancing the electron-phonon coupling. DFT calculations suggest that alkali metals are good elements combining hydrogen for increase the transition temperature for SCs. Stable polyhydrides of heavy alkali metals, MHn (where M=K, Rb, Cs, and n>2), have been predicted by theoretical analysis [1,2]. Potassium (K) has been proposed as a promising candidate for pressure-induced SC (~60 K at 166 GPa) [3], but no experimental report on structure and transport properties has been reported. This may due to the experimental difficulties handling the sample at high temperature and pressure without exposing to air.
We reacted potassium with hydrogen at high pressure (~80 GPa) and high temperature exceeding 2000 K using a diamond anvil cell, and investigated the change in the structure of possible polyhydrides. A series of XRD data for potassium under high hydrogen pressure were collected at various beamlines of APS (HPCAT and GSECARS), and PETRA-III (PO.02) after loading a small piece of potassium in a DAC and were analyzed the diffraction data by using a Dioptas software.
Potassium formed a KH at the initial pressure of hydrogen loaded by using a gas-loading system (1.66 GPa) with a lattice constant of 5.54 Å (FCC structure). The structure of the KH sample transformed to BCC at 4.87 GPa. The values of lattice constants changed from 5.54 to 4.04 Å, as increasing the pressure from 1.66 to 24.93 GPa, corresponding the increment of volumetric hydrogen density from 59.71 to 152.98 kgH_2/m^3. The structure of KH was reversible after decreasing pressure to 1 atm. The structure, electrical transport properties of hydrogenated potassium as a function of pressure will be presented.

Reference
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[2] A. Shamp et al., Inorg. Chem. 51, 9333 (2012).
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Keywords:

Potassium hydrides, High Pressure

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E6.04

Enhanced activation energy at a possible hidden antiferromagnetic phase in FeSe under pressure

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Abstract:

The strong coupling among magnetic, structural, and electronic degrees of freedom is the hallmark of Fe-based superconductors. There are few studies of the interplay between those degrees of freedom and superconductivity. In this study, by using transport measurements of FeSe single crystals under hydrostatic pressure, we present how superconducting properties, especially the flux pinning mechanism, are affected by pressure-induced phase transitions. In high magnetic fields, the activation energy (U_0/k_B) goes along with previously reported pressure dependence of critical current density and shows similar pressure dependent behavior of critical temperature (T_c) . Since the overall aspect of the upper critical field ($H_{c2,0}$) follows two-band WHH model, the averaged Fermi velocity can be obtained from the model with respect to pressure and it is almost same with the pressure dependence of T_c. However, for low magnetic fields , we found that U_0/k_B shows drastic increase near the pressure where a possible hidden antiferromagnetic ordering arises in vortex state. Our results are not only consistent with the antiferromagnetic-induced pinning mechanism but also it provides an important step toward a universal description of the superconducting properties of Fe-based superconductors.

Keywords:

Fe based superconductor, pressure, phase diagram, flux pinning

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E7.01

Observation on selective orbtials of 5d IrO_2 epitaxial thin films using resonant inelastic x-ray sacttering

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Abstract:

Rutile IrO_2 has attracted great attention due to scientific interests and possible energy applications, e.g., spin-orbit entangled states and one of highest active energy conversion materials. Although IrO_2 exhibits the state-of-the-art activity for the energy conversion proecess, i.e., oxygen evolution reaction (OER) , understanding of physical origins of the electrocatalytic activity is still unsatisfactory due to limits of experimental tools. To verify the role of orbitals of rutile IrO_2, we introduce the resonant inelastic x-ray scattering (RIXS) studies on 5d IrO_2 epitaxial thin films using Ir L_3-edge combined with scattering geometries. We were able to selectively detect the d-orbitals of epitaxial IrO_2 films grown on TiO_2 (100) and (001) single crystals. In specific, the dx^2-y^2 orbital significantly contributed to the energy loss near 2 eV, closely related to the edge-sharing of octahedra and connected to the OER activity.

Keywords:

RIXS, Iridates

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E7.02

Polarized x-ray resonant scattering from the chiral structures of the electric quadrupole moments

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Abstract:

Transition metal oxides have been actively investigated due to the variety of emergent phases, exhibiting new types of orderings. In particular, the superlattices consisting of two different oxides provide various ways of controlling the materials properties and even inducing a new phase of matter, massing in bulk. $PbTiO_3$/ $SrTiO_3$ superlattices are one of the representing examples of the emergent phase in which the ferroelectric polar vortex was observed[1]. Recently, the circular dichroism effect in x-ray resonant scattering (CDXRS) was observed at Ti L edge, which is unusual from the nature of polar vortex having time-reversal symmetry. It was argued from symmetry analysis that the polar vortex can induce the dichroism by periodic modulation of the charge quadrupole moments [2]. However, there has been no quantitative analysis that explains the unusual Qz dependence of the CDXRS intensities. Based on the resonant scatting theory and first-principles calculations, we investigate the CDXRS intensities considering realistic spatial modulation of the polar vortex. We discuss the Qz-dependent lineshape of CDXRS depending to the periodic structure of polar vortex which may provide the information of the vortex structures

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[2] S. W. Lovesey, and G. van der Laan, Resonant x-ray diffraction from chiral electric polarization structure, Phy. Rev. B **98**, 155410 (2018)

Keywords:

resonant scattering, chiral structure, quadrupole moment

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E7.03

Magnetic skyrmions in heterostructures

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Abstract:

Magnetic skyrmions are cylindrical swirling topological spin structures found in chiral magnetic systems. The topology of a skyrmion determines many of its interesting fundamental and dynamical properties. Moreover, its nanometer size and efficient current-driven manipulation makes it suitable for information storage and logic operations. Magnetic skyrmions have been observed in various material systems which have the Dzyaloshinskii-Moriya Interaction (DMI) due to broken inversion symmetry, such as non-centrosymmetric single crystals, ultrathin epitaxial systems, and magnetic heterostructures. The stability of magnetic skyrmions are determined by the competition between various magnetic interactions, including the DMI, exchange interaction, dipole interaction, magnetic anisotropy, etc. Magnetic heterostructures offer expanded opportunities to tune the complex magnetic interactions by interface engineering, that could result in topological spin textures.

In this work, utilizing x-ray magnetic circular dichroism (XMCD) based x-ray imaging techniques and Lorentz transmission electron microscopy (LTEM), we study the magnetic skyrmions in magnetic heterostructures including van der Waals magnetic materials, and multilayer and superlattice systems.

Keywords:

Magnetic Skyrmions, X-ray imaging

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E7.04

Ferromagnetism and XMCD studies in 2D layered chrome telluride thin films

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Abstract:

Chromium telluride ($Cr_{1-x}Te$) has been known as a layered materials based on $CrTe_2$ structure. It is known as ferromagnetic metal with varied Curie temperatures (T_c = 170 K – 340 K) depending on the x value. Recent report suggested existance of skyrmion phase by showing the topological Hall effect (THE) (Nano Research, 11, 3116 (2017)). Also control of magnetic anisotropy and curie temperature of chromium telluride compounds have been reported. However, the origin of THE as well as the various T_c and magnetic anisotropy among the Cr_2Te_3 phases was not clearly understood yet. Here, we investigate two different types of Cr_2Te_3 ultra-thin films with different T_c via different growth conditions to understand the origin of the various T_c by using X-ray absorption and X-ray magnetic circular dichroism

Keywords:

layered ferromagnet, X-ray magnetic circular dichroism

Sub-nanosecond phase transition dynamics of iron using laser-pump and XFEL-probe

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Abstract:

Iron is one of the most studied chemical elements due to its socio-technological and planetary importance, hence understanding its structural transition dynamics is of vital interest. By combining a short pulse optical laser and an ultra-short free electron laser pulse at PAL-XFEL, we have observed, for the first time, the sub-nanosecond structural dynamics of iron from high quality X-ray diffraction data measured at 50 ps intervals up to 2500 ps. We unequivocally identify a three-wave structure during the initial compression and a two-wave structure during the decaying shock, involving all of the known structural types of iron (α, γ and ε-phases). In the final stage, negative lattice pressures are generated by the propagation of rarefaction waves leading to the formation of expanded phases and the recovery of γ-phase. Our observations demonstrate the unique capability of measuring the atomistic evolution during the entire lattice compression and release processes at unprecedented time and strain rate.

Keywords:

XFEL, Iron, Shock compression

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E7.06

Time-resolved x-ray diffraction study of acoustic and thermal transports across metal-semiconductor interfaces

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Abstract:

We present a time-resolved x-ray diffraction (TRXD) study of acoustic and thermal transports across metal-semiconductor interfaces. TRXD intensities were measured for four different samples of Si(001) and GaAs(001) single-crystal substrates coated with 80-nm and 150-nm thick Cr films. X-ray measurements were performed with 50 ps time intervals and an x-ray energy of 10 keV at the 7-ID beamline at the Advanced Photon Source. The TRXD intensities clearly showed both time-dependent satellite peaks and asymmetric bumps around the (004) single-crystal Bragg peak. The satellite peaks result from an acoustic pulse train propagating with a constant pulse-to-pulse separation, which was generated by an irradiation of a single pulse from a femtosecond-laser and subsequent round trips of its photo-acoustic pulse in the metal film. On the other hand, asymmetric bumps can be explained by extended strains due to temperature diffusion. The TRXD intensities were quantitatively analyzed using the dynamical x-ray diffraction theory. The two kinds of strain profiles in semiconductor crystals were calculated by solving both partial differential equations of elasticity and thermal diffusion. We found from the best fits of all four different samples that the TRXD intensities were explained well with energy diffusion parameters such as the optical penetration depth and the sound velocity of thin Cr films, thermal diffusion conductivity of the semiconductors, and thermal boundary conductance of metal-semiconductor interface.

Keywords:

Phonon Transport, Time-resolved X-ray diffraction, Laser-pump X-ray-probe method, metal transducer

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E8.01

Propagation Control of Octahedral Distortion in $SrRuO_3$ via Atomic-scale Heterostructuring

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Abstract:

Octahedra bonding geometry is a key concept to customizing emergent functional properties of transition metal oxides, such as metal-insulator transitions, spin-phonon coupling, superconductivity, topological phases, and enhanced electrocatalytic activities.[1-3] Conventional approaches include epitaxial strain, thickness, and stoichiometry control, and they inevitably accompany unintended side-effects originating from dissimilar substrates, partial or full strain relaxation, and/or charge transfer across the film/substrate interface.
Here, we propose a strategy to selectively control the octahedral bonding geometries while preserving other parameters that might influence the functional properties.[4] We used atomically designed $SrRuO_3$/$SrTiO_3$ superlattices to validate the octahedral tilt propagation engineering. Especially, the propagation of RuO_6 octahedral tilt within the $SrRuO_3$ layers were systematically controlled by varying the thickness of adjacent $SrTiO_3$ layers. This induces a significant modification in the electromagnetic properties of the $SrRuO_3$ layers.

[1] S. G. Jeong et al., Phys. Rev. Lett. **124**, 026401 (2020).
[2] S. G. Jeong et al., Nanoscale **12**, 13926 (2020).
[3] S. A. Lee et al., Energy Environ. Sci. **10**, 924 (2017).
[4] S. G. Jeong et al., Adv. Sci. **7**, 2001643 (2020).

Keywords:

SrRuO3, Artificial heterostructuring, Structural phase transitions, Octhahedral distortion, Pulsed laser epitaxy

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E8.02

Light control of octahedral rotation in perovskite oxides

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Abstract:

One of the key goals in the research of perovskite transition metal oxides (TMOs) is to design and control their physical properties, for which MO_6 (M=transition metal) octahedron rotation (OR) is considered to be one of the key control parameters. Thus, changing OR at will might be one of the ways to obtain desired physical properties in perovskite materials. In my talk, I will introduce my pump-probe X-ray diffraction result, which shows that OR in $SrRuO_3$ can be controlled with pump-light. As we tune fluence of the pump light, the OR angle is gradually reduced. OR suppression in fast time scale (hundreds of femto-seconds) suggests that the reduction of OR angle is not due to conventional steric effect, but from electronic origin. Our result not only shed light on the mechanism of OR in perovskite materials, but also are an important step towards the design of functional materials through the OR angle variation.

Keywords:

Octahedral rotation, Perovskite oxdie, pump-probe XRD

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E8.03

$LaMnO_3$의 중적외선 전도도 피크들의 기원

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Abstract:

$LaMnO_3$ 라만 실험에서 중적외선에 산란 세기가 약한 peak들이 나타났으며 이것들은 오비톤(orbiton)이라는 새로운 종류의 기본입자로 해석되었다. 그러나 대칭 특성이 반대인 적외선 전도도(conductivity) 스펙트럼에서도 같은 에너지에서 비슷한 모양이 peak들이 관찰되면서 라만과 전도도에서 동시에 나타나는 peak들의 기원에 대한 해석은 미궁에 빠졌다. 이 논문에서는 기존에 우리 연구진이 주장한 phonon-coupled orbiton 모델이 라만과 전도도에 동시에 나타나는 peak를 설명할 수 있음을 발표하고자 한다.

Keywords:

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E8.04

The strong correlation between electric and magnetic properties in the cubic pyrite Co-doped NiS_2 system

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Abstract:

We investigated the physical properties of Co-doped NiS_2 single crystals, $Ni_{1-x}Co_xS_2$ ($0 \leq x \leq 1$), grown by chemical vapor transport (CVT) method. The cubic pyrite $Ni_{1-x}Co_xS_2$ does not undergo any structural transition, whereas it exhibits the phase transition from an antiferromagnetic Mott insulator NiS_2 to a ferromagnetic metal CoS_2, upon doping Co. The insulator-metal transition and magnetic phase transition are strongly related in this system, demonstrated by the resistivity and magnetic susceptibility measurements. In the presentation, I will show the phase diagram depending on the doping parameter.

Keywords:

pyrite, Ni1-xCoxS2, insulator-metal transition, magnetic phase transition

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E8.05

Effect of grain size on the electrical properties of SmB_6 thin films

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Abstract:

Samarium hexaboride (SmB_6) has emerged as a topological Kondo insulator. In simple temperature-dependent resistance measurements, the low-temperature plateau (i.e., resistance saturation) is observed, which is a distinct feature indicative of the emergence of conducting surface states against Kondo insulating bulk states. However, there is still inconsistency in the electrical properties of SmB_6, such as the magnitude of resistance saturation and the thickness of surface states, which is likely due to disorder. Recently, it has been reported that disorder (e.g., defects such as samarium vacancies and boron interstitials) does not influence the bulk activated behavior of SmB_6. Here, we systematically manipulate the grain size of SmB_6 thin films by adjusting thin film growth parameters and investigate their electrical properties. A simple two-channel model (including a top/bottom surface channel and a bulk channel) is adopted to describe the temperature-dependent resistance behavior. We discuss the change in the electrical behavior of SmB_6 thin films depending on grain size with possible scenarios.

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1F1A1070421).

Keywords:

topological Kondo insulators, SmB6, thin films , defects, grain boundaries

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E8.06

Defect engineering of magnetic phase of $EuTiO_3$ epitaxial thin films

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Abstract:

Deliberate control of defect in perovskite transition metal oxides leads to facile tuning of their functionality, including opto-electromagnetic and energy properties. During pulsed laser epitaxy (PLE), various parameters including growth temperature, laser intensity can be used to effectively control the stoichiometry of the thin film. Oxygen partial pressure during growth ($P(O_2)$) and post-annealing also serve as efficient tuning parameters.

The defect creation of $SrTiO_3$ (STO) and $SrRuO_3$ (SRO) thin films with $P(O_2)$ and post-annealing have been conducted, suggesting designating the individual role of cation and oxygen vacancy [1, 2]. The formation of cation and oxygen vacancies plays a crucial role to accompany structural and electronic phase transition in STO and a change magnetic transition temperature in SRO thin film. In perovskite oxides europium titanate ($EuTiO_3$, abbreviated ETO), it could also be a promising candidate for studying the strong coupling with emergence of defects or/and epitaxial strains, since it has exhibited attractive physical properties including structural properties, magnetic phase transition, and optical properties. For instance, theoretical results have been performed to emerge magnetic phase transition from antiferromagnetic to ferromagnetic phase via both compressive and tensile strains and volume increment for ETO thin films [3, 4]. Moreover, the ETO thin films with no strain has a band gap (between Eu 4f and Ti 3d orbital) of 0.93 eV, which electronic structure can be regulated by epitaxial strains. On the other hand, many experimental approaches have also been reported the relation between strain, volume, and magneto-electric phase.

Here, we fabricate ETO thin films on $(LaAlO_3)_{0.3}(Sr_2AlTaO_8)_{0.7}$ (abbreviated LSAT) and STO substrates with controlled stoichiometry via $P(O_2)$ and post-annealing control during PLE. Manipulating Eu and O vacancy concentration has achieved a lattice expansion of c-axis in epitaxial ETO thin films and ferromagnetic phase induced, respectively. These independent roles of cation and oxygen vacancies types can systematically tune various properties to open an opportunity for tailoring properties of ETO thin films.

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Keywords:

EuTiO3 thin film, Defect engineering, volume change, magnetic phase, electronic structure

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E8.07

Infrared observation of the low-energy interband transition in ultraclean $SrVO_3$ film

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Abstract:

We report the optical and density functional theory plus dynamical mean-field theory (DFT + DMFT) studies on a ultraclean $SrVO_3$ film. Optical conductivity spectra $\sigma_1(\omega)$ of the ultraclean $SrVO_3$ film shows a well-resolved peak at about 0.06 eV which is clearly separated from the Drude-like response. In $\sigma_1(\omega)$ of disordered $SrVO_3$ film, the peak merges into the Drude-like response becoming a shoulder-like feature, leading to a typical spectral shape of $\sigma_1(\omega)$ of correlated metals. Memory function analysis further reveals characteristic behavior of the mass renormalization and the scattering rate. However, our DFT + DMFT calculation shows that the low-energy peak in $\sigma_1(\omega)$ originates from interband transitions induced by further nearest neighbor hoppings. Our study demonstrates a profound impact of low-energy interband transitions in charge dynamics of correlated metallic systems.

Keywords:

Correlated metal, Infrared spectroscopy, DFT + DMFT, Low-energy interband transition

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E9.01

Bi-doping induced visible-light optical absorption of wide bandgap semiconductor In_2O_3

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Abstract:

In_2O_3 is a wide-bandgap semiconductor that is used for transparent electrodes mostly in its highly Sn-doped form. It was suggested that adding Bi to In_2O_3 introduces a new valence band, allowing optical absorption of the visible spectrum, according to the density functional calculation [1]. We experimentally found that the strong visible-light absorption occurred from 1.2 eV in the Bi-doped In_2O_3 ceramics synthesized by the solid-state reaction method. We verified that the trivalent Bi is substituted at In site in bixbyite In_2O_3 structure by detailed analysis of X-ray diffraction and X-ray photoelectron spectroscopy. Further, X-ray absorption near edge spectra showed the occupied Bi 6s state with empty state 6p state, implying the hybridization of Bi 6s and O 2p states increases the valence band maximum driving the low-energy interband transition. This result suggests that the Bi-doped In_2O_3 is promising for the light-absorbing layer in the tandem solar-cell applications.

This work is supported in part by NRF-Korea (2018R1D1A1B07045663).

Keywords:

Transparent conducting oxide, Bandgap engineering, Optical transition, Dopant

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E9.02

Local electrical characterizations of nanomaterials and nanodevices

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Abstract:

We have been performing local electrical characterizations of nanomaterials and nanodevices using local probe techniques such as electrostatic force microscopy (EFM), Kelvin probe force microscopy (KPFM), and scanning gate microscopy (SGM), which are all based on an atomic force microscope (AFM).
In this presentation, we will present recent examples of AFM-based local electrical measurements to elucidate electrical and optoelectrical characteristics of nanomaterials and nanodevices based on low-dimensional materials such as graphene and transition metal dichalcogenide (TMDC) materials. The evolution of local conductance can be probed via EFM as it is applied to the study of thermal or chemical reduction of graphene oxide. On the other hand, surface photovoltage measurements on TMDC with KPFM provide information about the re-distribution of photo-excited carriers. Our results demonstrate spatial inhomogeneities and variations of electrical or optoelectrical properties in nanomaterials and nanodevices.

Keywords:

AFM, EFM, KPFM, SGM, nanomaterials

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E9.03

Controlling spin structure of antiferromagnet for the switching of exchange bias effect

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Abstract:

Due to the absence of net magnetization in the antiferromagnet (AFM), magnetic alignment of AFM spins remains insensitive against the externally applied magnetic field. Therefore, uniaxial realignment of spins in AFM usually requires the field-cooling procedure, which involves heating of AFM above Néel temperature to overcome the existing magnetic anisotropy, followed by cooling in a magnetic field to reinstate its anisotropy.
In the present work, controlled realignment of AFM spin structure has been successfully shown without going through conventional field-cooling procedure by applying dc or ac mechanical strains as well as the spin Hall current at room temperature. Exchange coupled antiferromagnet (AFM)/ferromagnet (FM) bilayers grown on the piezoelectric substrates were employed and the exchange bias effect of the bilayers was measured to reflect the controlled spin structures of the antiferromagnet layer.
By the new and efficient routes as presented here avoiding the traditional field cooling procedure, local control of AFM spin structure can be repeatedly applied, thereby enables wider implementations of AFM as well as its exchange bias effect in the spintronics technology.

Keywords:

antiferromagnet, spin structure, exchange bias, mechanical strain

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E10.01

Antisymmetric interlayer exchange coupling in magnetic multilayers

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Abstract:

The exchange interaction governs static and dynamic magnetism. This fundamental interaction comes in two flavors - symmetric and antisymmetric. While the symmetric interaction leads to ferro- and antiferromagnetism, the antisymmetric interaction has attracted significant interest owing to its major role in promoting topologically non-trivial spin textures that promise fast, energy-efficient devices. So far, the antisymmetric exchange interaction has been found to be rather short–ranged and limited to a single magnetic layer. Here, we report a long-range antisymmetric interlayer exchange interaction in perpendicularly magnetized synthetic antiferromagnets with parallel and antiparallel magnetization alignments. Asymmetric hysteresis loops under an in-plane field reveal a unidirectional and chiral nature of this interaction, resulting in canted magnetic structures. We explain our results by considering spin-orbit coupling combined with reduced symmetry in multilayers. Our discovery of a long-range chiral interaction provides an additional handle for engineering magnetic structures and could enable three-dimensional topological structures.

Keywords:

Antisymmetric interlayer exchange, DMI, RKKY interaction

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E10.02

Dynamics of topological defects and their applications

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Abstract:

Topological defects such as magnetic solitons, vortices and skyrmions have started to play an important role in modern magnetism because of their extraordinary stability, which can be exploited in the production of memory and logic devices. Recently, a type of antisymmetric exchange interaction, namely the Dzyaloshinskii–Moriya interaction (DMI), has been uncovered and found to influence the formation of topological defects. Exploring how the DMI affects the dynamics of topological defects is therefore an important task. In this talk, I will briefly review our recent processes on the study of dynamic magnetic solitons and skyrmion. I will also present a new concept of memory and logic devices by utilizing the topological soliton and skyrmion.

Keywords:

topological defect, chiral spin texture, Dzyaloshinskii–Moriya interaction, skyrmion, spin soliton

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E10.03

Magnetic skyrmions in van der Waals ferromagnet-based heterostructures

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Abstract:

Layered van der Waals (vdW) materials have been attracted increasing attention due to their emerging physical properties as results of reduced dimensionality, high quality interfaces (or surfaces) and gating capabilities at the atomic scale. Since the discovery of magnetism in the two-dimensional (2D) vdW materials ($Cr_2Ge_2Te_3$ and CrI_3) in 2017, extensive efforts around the world have south to engineer such 2D magnetic materials, with a view to using them together with other 2D family for novel low-power spintronic applications. In 2D magnetic materials, spin-orbit coupling (SOC) stabilizes perpendicular magnetic anisotropy (PMA). Due to the expected large SOC and the broken inversion symmetry, vdW magnets and their heterostructures could permit the chiral magnetism, leading to the formation of topological magnetic textures such as skyrmions via the Dzyalshinskii-Moriya interaction (DMI). In this talk, we present the observation of Néel-type magnetic skyrmions and their lattice in the layered vdW ferromagnet Fe_3GeTe_2 (FGT). We also demonstrate the current-induced skyrmions motion of individual skyrmions in vdW heterostructure (FGT|h-BN). Using first-principle calculation with corroborating experiments, we envision the possible physical origin of DMI in vdW FGT flakes. Our finding allows us to engineer vdW heterostructures for desired chiral magnetism and opens the door to a new avenue toward 2D magnet-based spintronics.

Keywords:

magnetic skyrmions, van der Waals materials, Heterostructures

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E10.04

Role of in-plane magnetic field in the generation of magnetic skyrmion in Fe/Gd multilayer

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Abstract:

Magnetic skyrmion are topologically non-trivial spin texture, which is characterized by integer skyrmion number [1-3]. Owing to its topological properties, it has high thermal stability despite of tiny size. It has been considered for the future memory bit in the spintronic devices [4, 5]. Here, we will show the generation and manipulation of magnetic skyrmion by chopping stripe domain under a tilted magnetic field using magnetic transmission x-ray microscopy. Our micromagnetic simulation shows that the magnetic skyrmion is generated through the sequential processes of the injection, propagation, and annihilation of the Bloch point when the wall magnetization is antiparallel to the in-plane component of tilted magnetic field. We demonstrated that the in-plane magnetic field leads to the increase of local exchange energy and it decays into the injection of the Bloch point. We believe that our works will provide insight into topological transformation of spin texture and contribute to developing the spintronic devices based on spin textures.

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[5] S. Je et al. ACS Nano **14**(3), 3251-3258 (2020)

Keywords:

Magnetic skyrmion, Topological structure, Micromagnetic simulation, Magnetic Transmission X-ray Microscopy (MTXM), Magnetic bubble

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E11.01

Surface Photovoltage Imaging of Hybrid Perovskite Crystals

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Abstract:

Understanding photogenerated charge separation is the key to gaining further performance gains even though perovskite solar efficiency exceeds 25%. Analysis of surface photovoltage images displays the photo-responses form the localized charge separation which provide insights into the understanding of photovoltaics. Thus, potential distributions differences present the surface band bending. In that point, Kelvin probe force microscopy reveals not only the spectral potential gradient in the surface which is known to be beneficial or harmful to carrier transport and recombination but also the surface photovoltage spatially. We grow halide dependent $CH_3NH_3PbX_3$ (X= I, Br, Cl) single crystals using the low temperature technique which are considered an ideal form without interfacial effects to investigate the surface photovoltage imaging and the spectral surface band bending of perovskite material itself. We examine the surface photovoltage maps and the band bending with and without the external light sources and demonstrate the band structures of each crystal depending on the induced lights. Also, conductive atomic force microscopy is used to show the dark current and photocurrent to explain the carrier movement. Analysis of the current maps reveals the important role of surface band bending in the photovoltaic performance. Those results provide the local optoelectrical properties in the perovskite material which have the direct correlation with the efficient devices.

Keywords:

Hybrid perovskite, Single crystal, Surface photovoltage

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E11.02

Impact of Rashba and Polaronic Effects on the Luminescence Properties of $APbBr_3$ (A=Cs, CH_3NH_3) Perovskite Single Crystals

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Abstract:

Halide perovskites are excellent materials for optoelectronics such as light-emitting applications and photovoltaic solar cells. Numerous progress has been achieved, including high-efficiency solar cells over 25% and high photoluminescence (PL) quantum yield over 90%. Nevertheless, a basic understanding of photophysical properties is still incomplete and controversial. Complex effects in the perovskite structure like structural fluctuation and rotational motions of organic cations can induce many interesting photophysical phenomena such as Rashba splitting and polaronic effects. In this presentation, we report on photophysical properties of typical all-inorganic and organic-inorganic hybrid halide perovskites $APbBr_3$ (A=Cs, CH_3NH_3 (MA)) grown by Bridgman technique and inverse temperature crystallization, respectively. According to ellipsometry and excitation wavelength-dependent PL spectroscopy under front and back scattered geometry, we found that there is an indirect tail state in $CsPbBr_3$ (λ_i ~ 551 nm) and $MAPbBr_3$ (λ_i ~ 566 nm) induced by dynamic Rashba effect slightly below the direct band edge of $CsPbBr_3$ (λ_d ~ 527 nm) and $MAPbBr_3$ (λ_d ~ 538 nm) at 300 K. The indirect tail state in $CsPbBr_3$ vanishes below 50 K, rendering color change from orange to yellow and transparency recovered. However, this effect is much smaller in $MAPbBr_3$. This difference between $CsPbBr_3$ and $MAPbBr_3$ indicates that the A-site cation influences on structural fluctuation; the polar MA cation has a non-spherical shape and lighter than Cs. The polar or non-polar A cation also affects to the low-temperature PL spectra. The PL of $CsPbBr_3$ exhibits the emerging phase of electron hole plasma (EHP) as evidenced by spectral redshift and broadening as the carrier density increases. On the other hand, EHP is absent in $MAPbBr_3$. We believe that the polaronic effect, which is known to be stronger in $MAPbBr_3$, hinders the high-density phase of excitons and/or carriers by short range repulsion. The presence of EHP also influences on exciton-exciton inelastic scattering (P-band emission) by EHP screening. We assigned the origin of each PL peaks at 10K and by using this we extracted the exciton binding energies for $CsPbBr_3$ and $MAPbBr_3$ as 20 (±2) meV and 38 (±3) meV, respectively.

Keywords:

Photoluminescence, Large polaron, Dynamic Rashba, Halide peorvskites

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E11.03

Raman scattering study of structural properties of methylammonium lead chloride single crystals

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Abstract:

Active research is being conducted on organic-inorganic hybrid perovskite, which is widely used as a solar cell absorber material recently. It has a high potential for development, because it shows a higher PCE (power conversion efficiency) growth rate than other material-based devices. For the commercialization of perovskite, study of the structural properties is important and it can be the key to understand an interesting phenomenon such as ion migration etc. We measured temperature- and polarization-dependence of Raman response of methylammonium lead chloride ($CH_3NH_3PbCl_3$) single crystals where obvious structural phase transitions occur from cubic to tetragonal at ~179 K and from tetragonal to orthorhombic at ~172 K. With Raman spectroscopy, we found abrupt changes of intensities and linewidths of certain phonon peaks at phase transition temperatures. Polarization-Raman analyses are being conducted to find out the relevant modes to the phase transitions. We report that Raman scattering spectroscopy is highly effective in monitoring unusual structural behavior in perovskite materials.

Keywords:

Perovskite, Raman, Structural property, MAPbCl3, Organic-inorganic hybrid perovskite

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E11.04

Large size and high quality metal halide perovskite single crystals by inverse temperature crystallization

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Abstract:

There have been increasing interests of the organic–inorganic hybrid perovskite $CH_3NH_3PbX_3$ (X =Cl, Br, I) as a promising candidate for the optoelectronic applications due to their superior potential properties such as high absorption coefficient, direct bandgap, long carrier lifetime, high balanced hole and electron mobility, low cost, facile deposition techniques. Despite of this, most of reported perovskite devices depending on polycrystalline thin films immensely suffer from poor stability and high trap density created by grain boundaries, which limits the performance in device applications. Recently, single crystal structures of perovskite have been investigated in order to realize stable device and reduce the trap density compared to thin film counterpart. Here we present a novel method of growing sizable $CH_3NH_3PbBr_3$ single crystals based on the high solubility behavior of hybrid perovskites at low temperature within inverse temperature crystallization. We compared the crystallinity and charge transport of perovskite single crystal stuructures as a function of melting temperature dependence. New growth technique can provide quick process and high yield of large scaled single crystal growth with high quality. Our advanced growth technique and resulting single crystal structures will contribute to demonstrating its potential in optoelectronic applications.

Keywords:

Perovskite single crystal, CH3NH3PbBr3, Inverse temperature crystallization, Quick process, Low trap density

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E11.05

Nanogap for SERS analytical platform for the detection of explosives

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Abstract:

Attacks utilizing Explosive Devices by terrorist are the major issue of concern due to its energetic and military applications properties which compelled researcher to improve security screening methods for explosive detection. To detect explosives, researcher develop different instruments, techniques and also number of analytical techniques are currently under investigation. Detecting trace amount of explosives from a distance to ensure personal safety is important and it is possible using laser based spectroscopies techniques which distinguish explosives on the basis of their detailed fingerprint signals.

Surface-enhanced Raman Scattering (SERS) is an analytical technique that can detect traces of explosives. In the present work, we investigate SERS of explosives involved either solution or vapor phase. Typically, explosives have low vapor pressure and packaging explosives in a plastic bag makes detection of explosive vapor much more difficult. Our work focus on detection and distinguish different explosives using SERS methods which produce a definite “finger-print” for a molecule on both phase. Nanogap substrate using metals like gold, silver was fabricated and employed for the detection work. Solution phase detection of TNT was possible down to 100 picomolar range with laser power of 108 μW. In addition, we succeed to detect vapor phase at room temperature using a safe, low laser power (0.2 mW) and measurement time of 20 s, using our nanogap substrates. Measurements indicates that our SERS approach are easier, more effective and stable than other methods for the practical explosive detection.

Keywords:

Nanogap, Surface Enhanced Raman Scattering (SERS), Nitro-explosive, Vapor SERS

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E11.06

Gate-tunable interlayer charge transition in graphene/MoS_2 heterostructures

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Abstract:

Two-dimensional (2D) heterostructures exhibit unique optical and electrical properties due to strong Coulomb interaction between electron-hole pair located in different layers. Interlayer charge transition (ICT) has been studied recently as a promising property in 2D heterostructures which can be used to construct novel optoelectronic applications because it enhances interlayer carrier generation. However, with an intensive research for the ICT in 2D heterostructures, the detailed mechanisms and the applications of the phenomena still remain elusive and unaddressed. In this context, we measured photocurrent spectra in graphene/MoS_2 field effect transistors (FET) with gate modulation, induced by ICT. An anomalous behavior of broadband photocurrent was observed with applied gate bias lower than -20 V under excitation energy below the MoS_2 band gap ~1.83 eV. A possible scenario to elucidate the result is either charge transfer from graphene to MoS_2 after excitation in graphene, or the direct excitation via ICT from graphene to MoS_2. To characterize the ICT, we perform carrier dynamics via femtosecond transient absorption (TA) spectroscopy. Detailed analysis will be discussed. The results provide an effective freedom to control charge transfer dynamics in 2D heterostructures and facilitate their future applications in light-harvesting and optoelectronics.

Keywords:

van der Waals heterostructure, field effect transistor, interlayer charge transition, transition metal dichalcogenides, photocurrent spectroscopy

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E11.07

Advanced Manufacturing Process for Defect-Free Microneedle Arrays Based Transdermal Drug Delivery System by Employing Electrostatic and Capillary Actions in Combination with Freeze-drying

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Abstract:

We present a facile defect-free microneedle array fabrication process by exploiting electrostatic (10^6 V/m) and capillary pressures in combination with a freeze-drying method. Conventional mold casting methods suffer from inevitable deformation due to an air pockets present at the tip of the microneedle and high sensitivity to moisture. However, our method allows to remove the air pocket defects by using electrostatic pressure and capillary force. Arrays of carboxymethyl cellulose and hyaluronic acid based microneedles were successfully fabricated by attracting the polarized particles to the anode and extruding the air pockets above the glass transition temperature (typically 50~100℃). Further, microneedles that are sensitive to heat and moisture were subsequently treated using the freeze-drying oven to minimize the deformation of the shape. This method can be used for transdermal drug delivery system (TDDS) and achieved high yield and large-area of microneedle arrays.

Keywords:

Microneedle, Electrostatic Pressure, Transdermal Drug Delivery System

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E12.01

Synchronization in leader-follower switching dynamics

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Abstract:

The features of animal population dynamics, for instance, flocking and migration, are often synchronized for survival under large-scale climate change or perceived threats. These coherent phenomena have been explained using synchronization models. However, such models do not take into account asynchronous and adaptive updating of an individual's status at each time. Here, we modify the Kuramoto model slightly by classifying oscillators as leaders or followers, according to their angular velocity at each time, where individuals interact asymmetrically according to their leader/follower status. As the angular velocities of the oscillators are updated, the leader and follower status may also be reassigned. Owing to this adaptive dynamics, oscillators may cooperate by taking turns acting as a leader or follower. This may result in intriguing patterns of synchronization transitions, including hybrid phase transitions, and produce the leader-follower switching pattern observed in bird migration patterns.

Keywords:

synchronization

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E12.02

Infinite-order phase transitions in growing scale-free simplicial complexes

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Abstract:

Coauthorship complex, a prototypical social complex, grows with time. To investigate the properties of percolation transitions in this system, we propose a growing complex model. A node is added every time step. Moreover a uniform d-dimensional simplicial complex (d-simplex) is added with p. To form a d-simplex, d+1 nodes are selected with the probability proportional to k_i+a, where k_i is the facet degree of each node i and a is initial attractiveness. This preferential attachement rule leads to a scale-free facet degree distribution. Here, we investigate analytically the percolation properties of the growing scale-free simplicial complexes. The order parameter exhibits an infinite-order phase transition with the critical exponent depending on the simplicial dimension d, the attachement probability p and initial attractiveness a. The cluster size disrtibution follows a power-law decay behavior in the subcrtical regime. The exponent tau also depends on d, p and a.

Keywords:

Percolation, Growing simplicial complex, Simplex, Scale-free

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E12.03

Link overlap influence opinion dynamics on multiplex networks: spin model approach

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Abstract:

Suppose that there are two social networks: one is for friendship and the other is for business. Then each individual pair can be connected by one of the three ways: they are connected only via friendship link, or only via colleague link, or via both relationships, i.e. overlapped links. These three types of connections can cause different effects on opinion formation about a certain social issue. Therefore, emerging pattern of opinion formation can be significantly influenced depending on the statistics of the links, e.g. degree distribution, of each type of connections. In the field of multiple-layer-network studies, however, it has not been focused how the emerging pattern, or phase transition (PT) pattern, is affected by the distributions for respective types of links. To quantitatively address this problem, we study a simple spin model, called Ashkin-Teller model, which may be seen as a simple model for opinion formation in a double-layer network. In this model, the degree-distribution exponents $₩lambda_{₩textrm{I}}$ and $₩lambda_{₩textrm{II}}$ for nonoverlapped (singly connected) and overlapped (doubly connected) links, respectively, can be independently varied, thus, we can systematically investigate the effect of the link overlap on the PT pattern for opinion formation. Furthermore, the interaction strength between the two layered networks can be controlled by one parameter x.
With this model, we find that the line along which a first-order PT occurs can be modified by varying λ_{I} and λ_{II}: the first-order PT line goes to left-upper direction as λ_{I} decreasing, and diverse patterns of first-order PT Line in the $x - T^{-1}$ (T^{-1}: inverse temperature) plane emerge as λ_{II} decreasing. Through this controlling, we can design a full PT diagram which includes all the types of PTs such as continuous, discontinuous, double-discontinuous, successive, and hybrid PTs.

Keywords:

Link overlap, phase transition, double-discontinuous phase transition, modified phase diagram

E12.04

Hybrid percolation transition in a self-organized system

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Abstract:

Hybrid percolation transitions are discontinuous transitions, but which also exhibit critical behaviors. The critical behaviors are mainly classified into two categories: the critical avalanche dynamics in cluster pruning process and the critical tug-of war dynamics between growth and suppression of large clusters in cluster merging process. The latter type occurs when the system is partitioned into small and large clusters. Here, we consider a self-organized system, in which tug-of-war dynamics still arises without any partitioning the system and induces a hybrid percolation transition. The order parameter jumps at a transition point and the cluster size distribution follows a power law. Further critical behaviors emerge, which will be discussed.

Keywords:

Percolation, Hybrid phase transition

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E12.05

Accessing the quantum criticality of the transverse-field Ising chain via a neural-network quantum state

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Abstract:

A neural-network quantum state has attracted much attention because of its capability to describe a highly entangled state. In the well-known model system of the transverse-field Ising chain, we benchmark its accuracy to see whether it can be used as a tool for a standard finite-size-scaling (FSS) analysis beyond the limit of the exact diagonalization. We employ the variational Monte Carlo method with a fully-connected neural network as a trial wavefunction to locate the quantum critical point and estimate the critical exponents. The quantities explored, including the order parameter, magnetic susceptibility, spin-spin correlation, quantum fidelity susceptibility, and Renyi entanglement entropy, show an excellent FSS collapse in the tests with various system sizes up to the one with 128 sites, going much beyond the system-size limit of the exact diagonalization. We observe a comparable numerical accuracy in all our benchmark with the exact solution and the density matrix renormalization group.

Keywords:

phase transition, critical phenomena, variational Monte Carlo, neural network

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E12.06

Temperature-Dependent Performance of Erasure Machine in Detecting Interaction Structure of Spin Glasses

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Abstract:

Interaction strengths between spins in the spin glass systems can be estimated by the Maximum Likelihood Estimate (MLE) method from spin configurations, which demands large data sets and huge computational costs. We test the performance of the Erasure Machine, which has been proposed to overcome the drawbacks of MLE, by using Monte Carlo samples of Sherrington-Kirkpatrick model, Edwards-Anderson models in 3D and 4D. We measure the mean square error of predicted parameters of Erasure Machine varying temperature and find that the Erasure Machine shows the best performance for predicting parameters near the critical temperatures of the spin glass systems.

Keywords:

Erasure Machine, spin glass, critical phenomena

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E12.07

Crossover from a quantum to a classical DP transition in dissipative quantum systems

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Abstract:

Phase transitions in dissipative quantum systems are intriguing because they are induced by the interplay between coherent quantum and incoherent classical fluctuations. Here, we investigate the crossover from a quantum to a classical absorbing phase transition arising in the quantum contact process in one dimension (1D-QCP). The Lindblad equation contains two model parameters, $₩omega$ and $₩kappa$, which adjust the contributions of the quantum and classical effects, respectively. We find that there exists a critical line $₩omega_c(₩kappa)$ in the region $0<₩kappa<₩kappa_*$, along which the exponent $₩alpha$ associated with the density of active sites decreases continuously from quantum to the classical directed percolation (DP) value. The neural network machine learning technique is used to identify the critical line and to determine the correlation length exponent. Numerical simulations using the quantum jump Monte Carlo technique and the tensor network method are performed to determine all the other critical exponents of the 1D-QCP. Finally, we discuss a relation between a theoretical parameter and experimental control parameters in ultracold Rydberg atoms.

Keywords:

Open quantum system, Quantum contact process, Machine learning, Tensor network, Quantum jump Monte Carlo

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E14.01

Nonlinear MHD Study on the Dual SPI in KSTAR

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Abstract:

Shattered pellet injection (SPI) is the baseline concept for the disruption mitigation system (DMS) in ITER, in which a cryogenic pellet is shattered into a disrupting plasma to mitigate the consequences of a disruption [1, 2]. SPI has experimentally shown improved disruption mitigation performance compared with other DMS concepts, and numerical studies are being widely conducted to reveal its physical mechanisms [3-6]. To suppress the radiation asymmetry, ITER plans to utilize a symmetric SPI configuration. While it is a general assumption that the symmetric SPI configuration would mitigate the radiation asymmetry, it has been pointed out that the symmetric impurity injection might lead to stronger radiation peaking in the MGI case [7]. Thus the effect of symmetric SPI requires more careful examination before its actual exploration in ITER. To explore the effect of dual symmetric SPI in KSTAR, the nonlinear 3D MHD code JOREK [8] has been applied to one of KSTAR H-mode plasma in which the actual dual SPI experiment had been conducted. Since the asymmetry of the radiation of thermal energy tends to be relaxed in the Current Quench phase, we limit our interest to Thermal Quench in this study.

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Keywords:

KSTAR, Shattered Pellet Injection, Nonlinear MHD, Disruption

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E14.02

A gyrofluid model for the plasma parallel dynamics with poloidally inhomogeneous sources

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Abstract:

We study parallel dynamics of a tokamak plasma in the presence of the poloidally inhomogeneous source, as an effort to develop a two dimensional transport code. Traditional 1.5D transport solvers have neglected this poloidal inhomogeneity effect since the non-zero poloidal modes are to be damped out via Landau damping and ion collisions. We assess how the poloidal uniformity in the tokamak core is valid even in the significant poloidally inhomogeneous external source (e.g. RF waves, NBI or pellet injection). We find the gyrofluid model appropriate to describe all procedures of the poloidal spin up [1], damping of GAM with neoclassical polarization effect [2], and the collisional damping [3]. With this model, we can describe the plasma parallel dynamics in a sequence of each time scales (transit time, bounce time, ion-ion collision time)
At the beginning phase after the inhomogeneous source is introduced, the ExB flow increases due to the Rayleigh-Taylor like instability, as demonstrated in [1]. As the poloidal modes develop, the geodesic acoustic modes (GAM) occur with the frequency of the order of the inverse bounce time. In this oscillation frequency range, the ion Landau damping happens significantly for the non-zero poloidal mode. The zonal mode is coupled with the poloidal mode driven by the source through the magnetic drift and become unstable if the source strength is higher than the threshold. After a few bounce times and ion collision times, such zonal mode is damped by ion collisions, as the flow shear is damped by the neoclassical viscosity.

Keywords:

gyrofluid, poloidally inhomogenous source, parallel dyanmics, zonalflow, damping physics

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E14.03

Effects of SAS-like divertor structure on detachment phenomenon in KSTAR.

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Abstract:

High-performance divertor is essential in long-term operation of nuclear fusion reactor. In the devices such as Advanced Tokamaks like ITER or K-DEMO, suppression of erosion and heat flux load on the divertor surface is very important. In this presentation we report numerical simulations of a SAS-like divertor without carbon impurities in KSTAR. From SOLPS-ITER simulations (without particle drifts), we find that the SAS-like slot divertor, despite its very small depth, drives the neutral particle trajectories to the area near separatrix. Neutral deuterium concentrated near the separatrix leads to detachment onset at considerably lower electron densities at the outer-midplane, along with significantly reduced heat flux and temperature than in the open divertor. Interestingly the detachment is not sensitive to the depth of the slot as long as the facet angles of the slot is preserved. We have verified that the result is not altered qualitatively even by the change in the transport coefficient and the boundary conditions of the simulations. This suggests that the SAS-like structure can act as a seed of detachment for a wide range of Tokamak operation parameters. Furthermore, the improved divertor performance (i.e. detachment onset at lower density) without the aid of carbon impurities (carbon erosion is very low in our simulations) implies that the SAS-like structure can be expected to produce similar effects when the tungsten material is used as PFC in future reactors like K-DEMO and ITER.

Keywords:

SOLPS-ITER, KSTAR, Divertor, SAS, detachment

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E14.04

태양 플라즈마에서 자기장의 증폭을 설명하는 alpha, beta 효과의 직관적 파악과 해석적 유도

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Abstract:

태양과 같은 회전하는 천체 플라즈마 구조에서 관측되는 주기적인 자기장의 변화는 아직 그 메커니즘이 완전히 이해되지는 않고 있다. 특히 적도방향의 자기장(Btor)과 남북극을 향하는 자기장 (Bpol)은 시간적인 위상차가 90도이고 11년 주기의 역전현상과 비주기적인 특이 현상을 동시에 보이고 있다.

현재 Btor에서 Bpol의 변환 과정은 알파효과에 기인한 Parker의 모델과 태양 흑점 효과에 기인한 Babcock-Leighton의 모델로 설명되고 있으나 아직 완전하지 않다. 회전체에 존재하는 부력과 코리올리 힘은 Bpol의 생성에 중요한 역할을 한다(알파 효과). 그러나 이 알파효과는 (- , b : 난류 자기장, u : 난류 속도) 나선형 자기장이 증가함에 따라 감소하여 0으로 수렴하는 것으로 알려져 있으며, 플라즈마 난류 운동에너지에 의한 beta 효과는 자기장을 확산시켜 Bpol의 소멸을 야기한다. 이는 Bpol과 차등회전 효과에 의존하는 Btor의 감쇠로 이어져 결국 태양 자기장의 소실을 의미한다.

이 논문에서는 이러한 이론과 실제간의 모순을 해결하기 위해 alpha, beta 효과가 기존의 이론적 추론처럼 변화하는지 확인해 보았다. 즉 alpha → 0, beta > 0). 그러나 alpha, beta 텐서는 원래 통계적 개념에 의해 추론된 물리량들이다. 비록 해석적으로 유도가 되지만, 여러 비선형 항들을 무시하고 풀어낸 근사식이어서 정확한 수식적 정의를 내리기 어렵다. 따라서 우리는 난류영역의 u, b로 이루어진 기존식 대신, large scale의 자기장 에너지 (B^2)와 자기 헬리시티 (A·B, A : 벡터 포텐셜)를 이용하여 alpha, beta 텐서의 변화를 정의하는 식을 다시 유도했다. 이 식은 시뮬레이션과 관측을 통해 얻을 수 있는 자기장 에너지와 자기 헬리시티만을 사용하기 때문에 추가적인 가정이 필요없고, 추상적인 alpha, beta 계수의 시간에 따른 변화를 직접 관측할 수 있는 장점이 있다.

시뮬레이션 데이터를 이용해 테스트 해본 결과, alpha 계수는 기존 이론처럼 0으로 수렴하지만 그 수렴속도가 훨씬 빨라 자기장의 지속적인 증폭 요인으로서는 부족했다. 또 양의 값을 가져야 할 beta 효과는 마이너스 값을 유지하다가 자기장이 어느 정도 증폭되면 소멸되는 것으로 나타났다. 이는 퓨리어 공간에서 마이너스 값을 갖는 라플라시안과 함께 자기장을 증폭시키고 어느 일정 단계 이후에서는 자기장 증폭을 억제하는 능동적인 역할을 하게 된다. 이 결과는 자기장의 증폭 및 포화와 같은 물리적인 현상을 설명하지만, 기존의 이론과는 대치된다.

우리는 이러한 결과를 설명하기 위해 자기 유도 방정식에 기반한 필드 구조 모델을 이용하여 물리적 근거를 마련하고, beta에 관련된 2차 모멘트항을 다시 유도하여 조사하였다. 새로운 이론적인 풀이에 의하면 토로이달 방향의 속도 utor는 기존 이론대로 양의 자기 확산값을 유도하고, 폴로이달 방향의 속도 upol은 유도된 자기장과 2차 결합하여 자기 헬리시티를 증가시키는 것으로 나타난다. 완전한 등방적 구조는 이러한 분석적인 방법을 쓸 수 없지만, 반사 대칭이 깨진 등방적 구조에서는 가능하며 더 현실적이다.

Keywords:

플라즈마, 자기장, alpha, beta 효과, 태양

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E14.05

Study of plasma dispersion relation and wave stability with fluid closure

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Abstract:

Plasma stability is related to the plasma wave dynamics through the couplings between wave electromagnetic fields and fluid parameters such as density, flow velocity, and temperature. The wave properties are described by dispersion relations in the space of complex wave frequency and wavenumber. For small-amplitude waves, the linear dispersion relation is obtained from the Fourier transforms of Maxwell's equations and fluid equations. In this work, we derive a generalized linear dispersion relation by using a fluid closure scheme for the arbitrary spatial gradient of fluid quantities and arbitrary collision frequencies. We provide analytic formulae in the low collisionality regime that give a finite imaginary frequency indicating plasma stability. The validity of the formula is confirmed by comparing the analysis and numerical calculations.

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Keywords:

fluid plasma dispersion relation, wave stability, fluid closure

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E15.01

First-principles theory of quantum defects in 2D materials

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Abstract:

Optically addressable spin defects in wide-gap semiconductors have recently shown immense promise for use in solid-state quantum applications owing to their robust spin properties, spin-to-photon interfaces, and room-temperature functionality [1]. Furthermore, several vacancy defects in SiC have featured prominently in the search of new and improved solid-state qubits compatible with scalable semiconductor devices and telecommunication technologies. Optically active quantum defects are also gaining prominence in integrated quantum photonics using two-dimensional materials. Hexagonal boron nitride, a wide-band gap insulator among 2-dimensional (2D) van der Waals materials, has gained a great amount of attention due to the discovery of bright single-photon emitters operating at room temperature, and considerable focus has been devoted to the search of optically addressable spin qubits in h-BN. In this talk, we summarize our recent efforts to understand and control quantum point defects in h-BN [2,3,4,5]. We will first present a defect-by-design approach leading to first-principles predictions of carbon dimer defects as a promising spin qubit candidate in h-BN. We find that the defect has a robust $^3A_2$ ground state and ^3E excited state, both of which are isolated from the h-BN bulk states. In addition, we discuss how to model several key structural and optical properties of defect-based single-photon emitters in h-BN from first-principles, which was used to analyze and understand experimental results. Our results represent significant steps towards the realization of individually addressable spin qubits and the controlled generation of single-photon sources in two-dimensional hexagonal boron nitride.

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Keywords:

spin qubits, single photon emitters, quantum sensing, quantum computing, quantum information

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E15.02

Utilizing electronic spin interactions for scalable quantum network

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Abstract:

Solid state defect based qubit system is one of the uprising platforms for quantum information applications. Its composite nature, mainly divided into electronic spin defects and surrounding nuclear spin defects, allows us to optimize the system for building a scalable quantum network; nuclear spins for physical qubits and electronic spins for ancilla/network qubits. By utilizing strong magnetic dipolar coupling between electronic spin defects, we can connect two distant nuclear spin physical qubits via hyperfine couplings between nuclear and electronic spins. In this talk, we show our recent progress on creating strongly coupled electronic spin pairs and generation of entangled states between two electronic spins. Furthermore, we will discuss our recent efforts to improve its scalability using cutting-edge nano-fabrication techniques.

Keywords:

Solid state defect, NV center, Quantum register, Quantum computation

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E15.03

Defects in crystals with efficient optical interfaces

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Abstract:

Optically active defects in crystals such as diamond or SiC have emerged as the most attractive candidates for implementing quantum technologies, including quantum gates, quantum sensors, quantum memories, and quantum light sources. Optical control of these solid-state qubits plays a key role in initialize, manipulate, and read out the quantum state of qubits. However, the poor optical interfaces from high-refractive-index media and standard far-field optical microscope cause a significant loss of information and errors in the processing. In this talk, we present two different methods of efficient optical interfaces. First is microsphere-assisted super-resolution imaging, which overcomes the diffraction limit of conventional optical microscopy. The method enables simple integration of add-on optics for single defect imaging and improves both brightness and resolution of the confocal photoluminescence image. The second is defects in one-dimensional nanowires. Introducing nanostructures effectively extract the single photons from the defects, and we observe unconventional strong zero-phono line emission compared to the defect in bulk medium. Therefore, these improved optical interfaces extend the potential use of defects in crystals for future integrated quantum photonics.

Keywords:

single photons, defect, quantum photonics, diamond, SiC

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E15.04

Effective single-photon detection for quantum nanophotonics

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Abstract:

양자상태의 조작을 통한 양자 정보의 전달이나 처리를 통해 양자컴퓨터와 양자암호통신과 같은 양자기술이 현실에 가깝게 다가오고 있다. 양자상태의 생성과 조작, 그리고 측정은 양자정보기술의 핵심 단계로 다른 매체에 비해 상대적으로 쉽게 만들어지고 조작될 수 있는 광시스템이 양자정보기술의 플랫폼으로써 큰 관심을 받고 있다. 하지만 양자상태를 만들 수 있는 단일광자의 생성과 조작은 다양한 환경에서 쉽게 다뤄지는 반면, 높은 효율로 단일광자를 검출하기는 어렵다. 본 발표에서는 단일광자 검출을 위한 다양한 방법 및 연구결과를 소개하고 광집적소자에 사용 가능한 고효율의 빠른 단일광자 검출기의 연구 진행사항에 대해 다뤄질 것이다.

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Keywords:

Single photon detector, 단일광자 검출기, 양자정보기술, 양자광학, 양자정보통신

2020 KPS Fall Meeting
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E16.01

Chip-Scale Atomic Clock

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Abstract:

초소형 원자시계는 정보, 통신, 방송, 항법 등 다양한 분야에서 중요하게 사용될 수 있다. 본 발표에서는 개발중인 초소형 원자시계의 소개 및 연구 결과들을 다루고자 한다. 초소형 원자시계를 위해 MEMS 기술로 마이크로 분광셀을 제작하고, VCSEL을 광원으로 사용하여 CPT(coherent population trapping) 원자시계를 구성하였다. 제작된 물리부 크기는 1 cm^3 이하이다. 마이크로파 합성기, 주파수안정화 서보회로, 온도안정화 회로 등을 고집적 회로로 제작하여 원자시계의 전체 크기가 25 cm^3 이하가 되도록 하였다. 측정된 원자시계의 주파수안정도는 $<1\times10^{-10}$ (@ 1 s), $<8\times10^{-12}$ (@ 1000 s) 이다.

Keywords:

초소형 원자시계, CPT

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E16.02

Nitrogen-vacancy centers in diamond for magnetometry

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Abstract:

Superconducting quantum interference device (SQUID), atomic magnetometer (AM), and nitrogen-vacancy (NV) centers in diamond are the most sensitive quantum magnetic field sensors so far developed [1-3]. Especially, NV has attracted research interests not only due to its robust magnetic field sensitivity, but also the sensitivity for temperature, strain, and electric field in room temperature with nano-meter scale resolution [3]. For example, its ac-magnetic field sensitivity was reported to be below 1 pT/Hz$^{1/2}$ and the spatial resolution was several nano-meter [4, 5].

In this talk, we will present our research progress at KRISS on NV based wide-field magnetometry and magnetometers. We have obtained dc magnetic field sensitivity down to 20 nT/Hz$^{1/2}$ per micro-meter by adopting lock-in based detection and ^{12}C enriched(>99.99%) diamond layer. The magnetometry can help us to understand how MRI contrast agents works in sub-micrometer spatial resolution. We are improving the sensitivity further to detect T$_1$ or magnetic moment contrast in biological tissue or mesoscopic physics. Additionally, we have obtained dc magnetic field sensitivity down to 70 pT/Hz$^{1/2}$ while the temperature is simultaneously measured with the sensitivity of 20 $\mu K/Hz^{1/2}$. The sensitivities were obtained without adapting ^{12}C enriched diamond and an objective lens. This could be a step forward to an affordable and portable NV-based magnetometer.

[1] McDermott R. et al., Science 295, 2247 (2002)
[2] Kitching, J., Appl. Phys. Rev. 5 (3), 031302(2018)
[3] Barry J. et al., arXiv:1903.08176
[4] Wolf T. et al., Phys. Rev. X 5, 041001(2015)
[5] Balasubramanian G. et al., Nature 455, 648 (2008)

Keywords:

DNV, Magnetometer, Quantum sensing

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E16.03

Atomic sensor based on diamond NV centers

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Abstract:

The nitrogen-vacancy (NV) center in diamond is a quantum point defect having promising potential for highly sensitive atomic sensor. Due to its atomic scale size, long spin coherence times and high field sensitivity, NV centers have been used in sensing and imaging of various field such as magnetic, electric, strain field and etc. In this talk, I will introduce the basic working principles and sensing examples based on diamond NV centers.

Keywords:

diamond NV center, quantum sensing

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E17.01

Understanding tunable photoresponsivity of 2D multilayer phototransistors: Interplay between thickness and carrier mobility

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Abstract:

Phototransistor is a transducer that detects light signals and converts them to electrical signals. Since the wavelength of light to be detected is directly connected to band gap of channel material, the thickness dependent-band gap and high carrier mobility of two-dimensional (2D) van der Waals (vdW) layered materials have gained intensive attention as a promising candidate for photodetector applications. To achieve a high photoresponsivity of 2D vdW materials, numerous approaches have been considered such as material/dielectric engineering and device structure development via 2D heterostructures, however, the effect of interplay between thickness and carrier mobility to photoresponsivity in 2D multilayer system is little known. In this presentation, the distinctive conduction features of a distorted 1T phase (1T¢) multilayer ReS_2 possessing the i) layer-independent direct bandgap, ii) anisotropic in-plane transport, and iii) strong decoupled vdW interaction between adjacent layers will be demonstrated. Next, the gate-tunable photoresponsivity of 2D multilayer ReS_2 will be discussed in terms of the channel thickness (1.7 ~ 27.5 nm) and carrier mobility. On the basis of the analytical photocurrent and photoresponsivity definition, the observed high similarity between the gate bias-dependent photocurrent and transconductance was mainly ascribed to the strong correlation between photocurrent and carrier mobility, allowing us to propose the strategy of how to achieve the ideal photoresponsivity in 2D vdW-based phototransistors. This understanding would be helpful for optimizing the photoresponsivity performance in 2D vdW materials.

Keywords:

Phototransistor, Photoresponsivity, Multilayer system, 2D material, Interlayer resistance

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E17.02

Graphene-mediated non-covalent epitaxy of semiconductor micro-light-emitting diodes for flexible optoelectronics applications

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Abstract:

Conventional covalent epitaxy has yielded high performance light-emitting diodes (LEDs) for full color light emission. Recent progress in fabrications of micro-LEDs is changing the landscape of display technology. The III–V semiconductor is undoubtedly ideal light source materials. For fabricating the micro-LED smaller than 100 micrometers, it is necessary to remove the wafer by using laser lift-off or chemical etching of sacrificial layer, which leave a damage that unwantedly degrades the LED performance. Meanwhile, recent paradigm shift of substrate from single crystal wafers to soft materials has opened the floodgates for flexible electronics. Owing to excellent electrical, optical, mechanical properties, and ease of large-scale single crystal synthesis, graphene would be potentially a good candidate material for the use as a flexible epitaxial substrate. This talk chiefly deals with the use of graphene for semiconductor epitaxy. Specifically, both the van der Waals and remote epitaxy of III–V wire heterostructures on graphene is presented for fabricating miniatured micro-scale lighting source arrays that are flexible and transferable. The use of single-layer graphene and selective-area van der Waals epitaxy are introduced for vertical semiconductor nanowires. We further deal with van der Waals epitaxial semiconductor/graphene/semiconductor double heterostructures. Then, the remote epitaxy that enables the copy-and-paste of crystallographic registration from wafer to overlayer across graphene is presented for homo- and heteroepitaxy with the cases of ZnO on ZnO and GaN, respectively. As the practical device applications via the remote epitaxy, the microrod LEDs on graphene are demonstrated, which are easily transferable and deformable. We also discuss the challenges and opportunities of graphene substrates and epitaxy of microrod toward future flexible optoelectronics and displays technology.

Keywords:

remote epitaxy, van der Waals epitaxy, micro-LEDs, graphene, III-V

E17.03

Epitaxial growth of single-crystal transition metal dichalcogenide monolayers via atomic step surfaces

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Abstract:

Large-area two-dimensional 2D monolayers such as hexagonal boron nitride (hBN) and transition metal dichalcogenide (TMdC) are highly desirable to realize the intrinsic material properties and unprecedent devices for industrial applications. Here, we present the recent progress of single-crystal growth for hBN and TMdCs monolayer films in a wafer scale. Two different growth mechanisms of self-collimation and epitaxial growth on liquid and solid substrate are introduced accordingly [1,2].

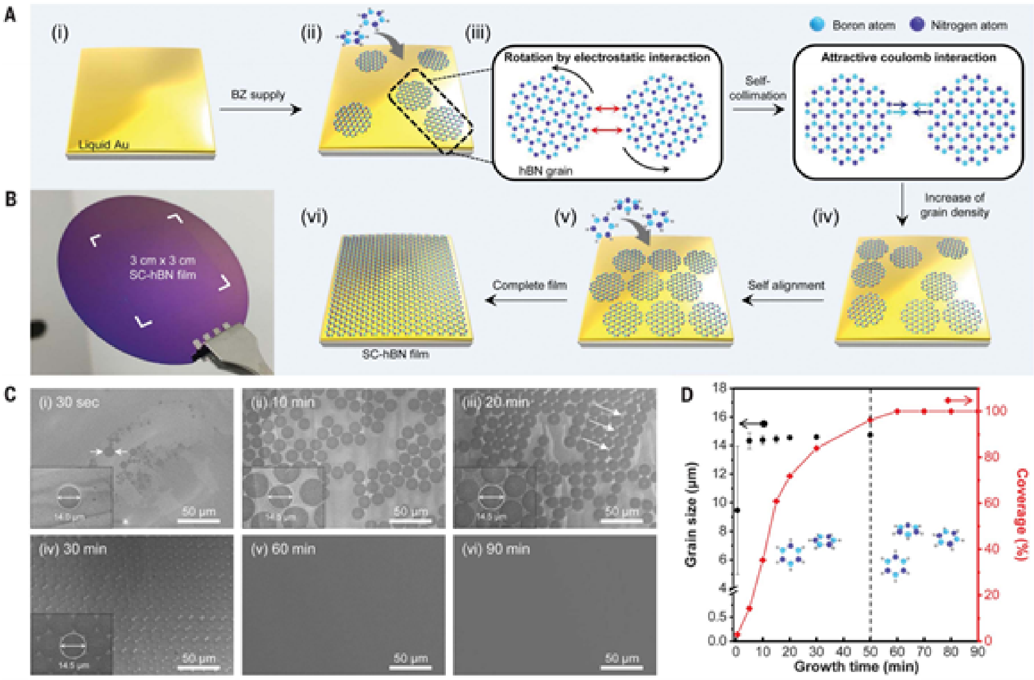

Fig. 1. Synthesis of single-crystal hBN film. (**A**) Schematic illustration for the growth of SC-hBN film by means of self-collimated circular hBN grains with a rotation invoked by the attractive Coulomb interaction of B and N edges between grains (i to vi). BZ, borazine. (**B**) Photograph of a wafer-scale SC-hBN film on a SiO_2-Si wafer. (**C**) Growth evolution of SEM images of hBN film. Single-headed arrows indicate linear alignment of hBN grains. (**D**) Time evolution of hBN grain size and coverage. Full coverage of monolayer hBN film is achieved at 60-min growth time. Error bars indicate the size deviation of hBN grains.

[1] J. S. Lee, Science, 362, p. 817 (2018).
[2] S. H. Choi, Submitted (2020).

Keywords:

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E18.01

Size-dependent electronic transitions and shape anisotropy on optical properties of CdSe quantum dots

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Abstract:

CdSe quantum dots (QDs) capped with fatty acid and phosphine ligand was synthesized by lower temperature reaction. It was found that shape anisotropy and size estimation of CdSe QDs, performed with X-ray diffraction (XRD) and high-resolution transmission electron microscopy. As a result of XRD, diffraction patterns show mixed crystal facet with zinc blende and wurtzite structure in small-sized QDs. The electronic transition energies extracted from differential absorption (DA) spectra are similar to the values calculated with consideration of the energies of the quantum size levels related to band mixing of CdSe QDs with a moderate bandgap. Excitonic absorption peaks are more 'Hidden' with decreasing size of QDs. It is related to crystal structure and crystalline corresponding to diffraction patterns and estimation error from DA spectra using by the calculated level structure model. The results show good agreement with the obtained diffraction patterns and the estimation errors obtained from the DA spectra.

Keywords:

Quantum dots, Anisotropy, Electronic transition, Hidden excitonic feature, Quantum size levels

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E18.02

MoS_2 Layers on Nano-patterned SiO_2/Si Wafers: Broadband Absorption Enhancement

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Abstract:

MoS_2, one of the most representative 2D layered semiconductor materials, has been intensively investigated for optoelectronic device applications. MoS_2 has many attractive physical properties, such as sizable and tunable bandgap energy, high electron mobility, and superior mechanical flexibility. However, the optical absorption needs to be improved, due to the extremely small physical thickness. There have been active research activities to integrate 2D MoS_2 layers on 3D nanostructures. Plasmonic effects and Mie resonance can tailor the optical response of the MoS_2 layers on the metal and high-refractive-index semiconductor nanostructures. In this work, we prepared conformally grown MoS_2 monolayers on SiO_2 nanopillar (NP) array patterns on SiO_2/Si wafers. The NP arrays were fabricated by electron-beam lithography and dry etching of 100- and 320-nm-SiO_2/Si wafers. The period, height, and diameter of the cylindrical NP arrays were 500 nm, 50 nm, and 300 nm, respectively. MoS_2 monolayers could be successfully grown on the SiO_2 NPs using metal organic chemical vapor deposition technique. The Raman intensity from the NP region was larger than that from the flat region, indicating enhanced optical absorption. Numerical calculations suggested that such improved absorption could be attributed to the strong electric field formation at the SiO_2 surface.

Keywords:

MoS2, nanostructure, Absorption

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E18.03

Valley-dependent directional emission of WS_2 layers to a dielectric nanowire

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Abstract:

Abstract:
We demonstrate directional emission of valley-polarized excitons in TMD (transition metal dichalcogenide) layer to a zinc oxide nanowire. A TMD layer is an atomically thin 2D semiconductors. A monolayer of TMD layer has a valley degree of freedom because of the broken inversion symmetry of crystal structure. Due to the valley-dependent optical selection rule, one can easily control valley pseudospin in TMD layers by changing handedness of circularly polarized light. Meanwhile, an evanescent field has a transverse spin angular momentum which handedness is determined by propagation direction of the field. This is so-called spin-momentum locking of transverse optical spins. As a results of exciton coupling to transverse optical spins, direction of emitted light from TMD layers is determined by valley pseudospin of excitons. In a prior study, the valley dependent directional coupling was demonstrated using a plasmonic nanowire [1]. Because of an ohmic loss of metal, however, propagation distances of plasmonic modes are limited. In this work, therefore, we adopt a dielectric waveguide which has a negligible loss. A zinc oxide nanowire which has large bandgap can be utilized as a dielectric waveguide at the wavelength of exciton transition in TMD layers. High valley polarization (~0.65) of WS_2 multilayer enables us to investigate valley-dependent emission at room temperature. We show a high directionality (-0.3-+0.3) of exciton emission to the zinc oxide nanowire. We also demonstrate that valley pseudospin information can be transferred in a long distance using the zinc oxide nanowire. Our study provides a low-loss platform for controlling valley(spin) information of TMD layers using dielectric materials.

Reference

[1] Gong et al., Science 359, 443–447 (2018)

Keywords:

TMDC, dielectric nanowire, valley pseudospin

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E18.04

Stacking dependent Interlayer Coupling of Multi-Layered MoS_2

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Abstract:

Transition metal dichalcogenides (TMDC) heterostructure is an emerging platform to explore low dimensional devices. Especially, stacking dependent interlayer coupling is a significant knob to engineer the physical properties of multi-layered TMDC. We prepared wedding-cake and spiral types of MoS_2 multi-layers on the highly oriented pyrolytic graphite substrate, simultaneously. Accordingly, both wedding-cake and spiral MoS_2 multi-layers' growth and post processes are the same, and interlayer coupling could be the sole control of local electrical properties. Scanning force microscopy study showed stacking-dependent height, friction, surface potential of the MoS_2 multi-layers. Scanning tunneling microscopy examined electrical band structure with respect to the stacking types. We further studied interlayer coupling changes at local heterogeneities such as wrinkles and step edges in the multi-layer system.

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Keywords:

2d materials, , TMDC, MoS2, SPM, STM, interlayer coupling

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E18.05

Effects of Interlayer Coupling and Band Offset on Second Harmonic Generation in Vertical $MoS_2/MoS_{2(1-x)}Se_{2x}$ Structures

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Abstract:

Noncentrosymmetric monolayers (MLs) of transition metal dichalcogenides (TMDCs) and their 3R-type vertical stacks provide an ideal platform for studying atomic-scale nonlinear light–matter interaction in terms of second harmonic generation (SHG). Unlike the case of MLs, SHG from artificial stacks can be nontrivially affected by interlayer coupling and band offset between the constituent MLs, where the latter occurs for band-gap-engineered vertical heterostructures (VHs). In order to study these effects, we produced different sets of 3R-type homobilayers (homo-BLs) and heterobilayers (hetero-BLs) composed of MoS_2 and its ternary alloy $MoS_{2(1-x)}Se_{2x}$. We first investigated the impact of interlayer coupling on the SHG response across the A- and B-exciton resonances in the MoS_2 homo-BLs. The coupling strength was varied by preparing (i) decoupled BLs (SiO_2 intercalated), (ii) weakly coupled BLs (dry transferred), and (iii) strongly coupled BLs (postannealed) and monitored by photoluminescence, Raman, and reflectance difference spectroscopy, and atomic force microscopy. Unlike the decoupled BL, SHG in the coupled BLs cannot be explained by the simple square law in thickness due to coupling-induced band modification. The impact of exciton-resonance offset on SHG was also investigated in the hetero-BLs by controlling the Se concentration in $MoS_{2x}Se_{2(x-1)}$. Although these VHs can significantly broaden the spectral range for efficient SHG by vertically superposing distinct resonances of the constituent MLs, coherent reinforcement of SHG cannot be achieved basically because of the π/2 phase difference between the on-resonance SHG field in one ML and the off-resonance SHG field in the other ML. Upon postannealing, however, the overlapping resonance regime exhibited unexpectedly high SHG enhancement. This may arise from the formation of the strong resonance when the VHs approach ideal 3R-type hetero-BLs. Our approach may be utilized for fully exploiting the TMDC VHs for highly efficient broadband SHG applications.

Keywords:

transition metal dichalcogenides monolayer alloys vertical heterostructures resonantly enhanced second harmonic generation

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E19.01

Development of a label-free interferometric scattering method for characterizing biomolecules and their interactions at a single molecule level

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Abstract:

In biological processes, interactions between biomolecules play critical roles, so their interactions should be dissected for fundamental understanding of biological phenomena. Due to their nanoscopic size, it would be difficult to observe them and their interactions with conventional optical microscopy. One, perhaps most widely used method to detect nano-sized particles would be fluorescence microscopy, which bears several limitation such as photophysical issues and need for dye labelling.

Recently, the iSCAT (interferometric scattering) microscopy has attracted great attention as a non-fluorescent technique due to its superb sensitivity and label-free detection [1]. It has been demonstrated that the technique can be used as an optical method to measure the mass of individual proteins [2]. Here, we report our characterization of non-metallic, nano-sized objects such as polystyrene beads and proteins. We successfully detect those objects in motion without labeling and surface immobilization. Our iSCAT-based technique holds great promise as a non-fluorescent, label-free tool to characterize nano-sized biological molecules such as nucleic acids and proteins.

[1] : Richard W. Taylor and Vahid Sandoghdar, 'Interferometric Scattering Microscopy: Seeing Single Nanoparticles and Molecules via Rayleigh Scattering', Nano Letters **2019** 19 (8), 4827-4835
[2] : Young et al.,"Quantitative mass imaging of single biological macromolecules ", Science 360, 423–427 (2018)

Keywords:

iSCAT, nano particle

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E19.02

Parylene microfluidic calorimeter as a cell-based assay platform

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Abstract:

Cellular metabolic rate can provide information about the response of the cells to external stimuli such as drug. The metabolic rate of cells can be measured with rate of metabolites consumption such as oxygen and glucose, or total heat flux involved in cellular metabolism. Calorimetry is a label-free method that can measure the metabolic heat production in real time. However, low resolution and ineffective sample delivery system have been bottlenecks for applications in cellular metabolic heat measurements. Here, we developed a payrlene microfluidic calorimeter system that can provide robust measurements of cellular metabolic rate. Precise fluidic manipulations are enabled by a thin-film parylene microfluidics integrated with on-chip PDMS valves. In addition, high-resolution vanadium thermistors and thermal engineering facilitates the high resolution heat power measurements. The microfluidic chip calorimeter is contacted with the PID temperature-controlled vacuum chuck that has temperature stability of better than ~100 μK. Metabolic heat changes of cells responding to external stimuli including lysis buffer and norepinephrine were measured with adherent and non-adherent cells. We anticipate the chip calorimeter to be a novel cell-based assay platform that can be utilized in many fields of life science research and pharmaceutical industry.

Keywords:

Parylene microfluidics, Vanadium thermistor, Chip calorimeter, Metabolic heat

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E19.03

Termination Mechanism in Prokaryotic Transcription Determined the Fate of RNA Polymerase

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Abstract:

Factor-dependent transcription termination, comprising 20~50% of Escherichia coli termination sites, is induced by a hexameric helicase Rho. Even though there have been many studies concerning factor Rho, the mechanism of factor-dependent transcription termination still remains elusive. Several models have been suggested to explain how Rho releases RNA from the DNA:RNA hybrid. In the hybrid shearing model, the Rho disrupts DNA:RNA hybrids by exerting a pulling force on the hybrid to make it taut enough. In the hybrid shearing model, the DNA:RNA hybrids are disrupted by translocating Rho, until it becomes taut enough to expert a pulling force on the hybrid. According to the hyper-translocation model, Rho has been thought to exercise a brute force that may cause translocation of RNA polymerase (RNAP) along the DNA without extension of the RNA, bring about the RNA release. We developed single-molecule fluorescence assay to clarify the mechanism of factor-dependent prokaryotic transcription termination. Our assays showed that there were two different pathways, depending on the dissociation of RNAP after RNA release. Our further study showed that the termination mechanism decided the fate of RNAP. The termination pathway caused by hyper-translocation showed RNAP disruption after RNA release, while the other termination pathway induced by hybrid shearing showed RNAP remaining. Moreover, two different pathways are different in termination time, the pathway caused by hybrid-shearing model was faster than that by hyper-translocation model. These findings seem to shed lights on the question how transcription termination in prokaryote happens.

Keywords:

Single Molecule, Factor Rho, Rho-dependent termination, hyper-translocation model, hybrid shearing model

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E19.04

Structural and single-molecule studies reveal the molecular function underlying histone loading of Schizosaccharomyces Pombe AAA+ ATPase Abo1

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Abstract:

Chromatin dynamics is important for genomic stability, gene regulation, and epigenetic inheritance. Chromatin assembly proteins, which form nucleosomes, are crucial factors for chromatin dynamics. Especially, bromodomain-containing AAA+ ATPase family can mediate chromatin assembly-disassembly mechanism. In Saccharomyces cerevisiae, Yta7 is known to disrupt chromatin organization to facilitate transcriptions. Meanwhile, it was recently reported that AboI, a fission yeast homolog of Yta7, contributes to chromatin assembly. However, the biological role and molecular features of AboI remain poorly understood yet. Here we characterize the molecular function of AboI in the structural and biophysical perspectives. The cryo-EM and high speed AFM reveals the structures of AboI. In apo- or ADP-bound state, Abo1 has a symmetric hexameric ring structure whereas ATP-bound Abo1 has open spiral structure. On the other hand, using single-molecule DNA curtain assay, we demonstrate that AboI does not dislodge H3-H4 histones from DNA but deposits the histones onto DNA only when ATP hydrolysis is allowed. In addition, we show that Abo1 does not load H2A-H2B dimer but histone octamer. We also examine the Abo1 and DNA interaction. Interestingly, Abo1 does not bind DNA regardless of ATP and neither histone nor DNA stimulate ATP hydrolysis activity of Abo1. Moreover, we investigate the details about histone deposition onto DNA using single-molecule photobleaching assay. we find that Abo1 requires at least 80 bp long DNA for H3-H4 deposition and deposits more histones as DNA length increases. Based on these findings, we propose allosteric communication model for H3-H4 deposition by AboI, in which ATP hydrolysis changes the configuration of histones to facilitate their deposition to DNA.

Keywords:

AAA+ATPase, Abo1, DNA curtain, Single-molecule, Cryo-EM

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E19.05

TonEBP recognizes R-loops and initiates m6A RNA methylation for R-loop resolution

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Abstract:

R-loop is a hybrid structure consisting of RNA-DNA hybrid and displaced single-stranded DNA. R-loops are induced by inappropriate transcription, transcription-replication collision and DNA damage. Normally R-loops play important roles in many cellular activities, but the abnormal accumulation of R-loops also can cause serious problems such as genomic instability or cancer. To regulate R-loops, methyltransferase-like 3 (METTL3)-mediated m6A RNA methylation resolve it. However, the detailed mechanism by which R-loop is recognized and METTL3 is recruited to R-loop remains unclear. Here, using single-molecule imaging technique DNA curtain and other biochemical assays, we find that tonicity-responsive enhancer binding protein (TonEBP) recognizes R-loops. In DNA curtain assays, we observed that TonEBP binds R-loops via both 1D diffusion and 3D collision. Furthermore, we demonstrate that TonEBP moves along DNA by sliding mechanism without helical rotation from salt-independent diffusion coefficients. Furthermore, we reveal that TonEBP binds the displaced ssDNA strand of R-loop, not RNA-DNA hybrid structure using electrophoretic mobility shift assay. Next, we examine the interaction between TonEBP and METTL3 that catalyzes methylation of A6 in RNA. We observe the colocalization of TonEBP and METTL3 at DNA damage site. Depletion of TonEBP and METTL3 increases R-loops and reduced cell survival. Our study reveals an R-loop resolution pathway by TonEBP and METTL3 and provide new insights into R-loop resolution processes.

Keywords:

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E19.06

Revealing and analyzing the three-dimensional strcture of human mitotoic chromosome

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[2]Photon Science Center, POSTECH
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Abstract:

The human chromatin is compacted about 1000-fold during mitosis. However, its packing mechanism and structure are still unknown mysteries. To find a clue about the structure of mitotic chromosomes, we exploited the cryogenic coherent X-ray technique and obtained 3D electron density images of frozen-hydrated mitotic chromosomes. Regarding the obtained images, in this talk, we present some results obtained from statistical analysis of the data--along with coarse-grained polymer simulation results--and give insight into the packing structure of the mitotic chromosome. Our theoretical analyses suggest that the mitotic chromosome has a disordered character, to some extent, in its structure, which means that the folding mechanism is not fully deterministic. The electron density of the chromosome is heterogeneous, and high-density regions exist like clusters across the whole volume. We visualize these features, providing comparison of the experimental data with the mathematically generated random fields having the same density correlation property. The structure of the clusters is analyzed in terms of the radius of gyration, fractal dimension, and the asphericity.

Keywords:

coherent X-ray, fractal dimension, chromosome structure, mitotic chromosome

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E19.07

In vitro and in vivo PABP count during translation

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Abstract:

Translation is the process of converting genetic information into a specific amino acid chain. During the translation, poly(A) tail in 3′ end of a mRNA is covered with poly(A) binding protein (PABP)s for stabilizing and enhancing the translation through the interaction of eIF4G resulting a closed-loop of mRNA. However, the properties of PABP biding to poly(A) tail of mRNA during translation are poorly understood. We first characterized the number and binding kinetics of mNeonGreen-tagged PABP to various poly(A) tail using single-molecule fluorescence microscopy. We then monitored 5′ cap-bound eIF4E labeled with mScarlet-I and mNeonGreen-PABP associated with 3′ poly(A) tail of mRNA in polysome extracts. The mRNA with PP7 stem-loops in the 3'UTR was tethered to the PEG-biotin-coated quartz glass through the streptavidin-binding peptide (SBP) that contains PP7-coated proteins. The polysome extract experiment provides how many PABPs are involved in translation. Finally, we visualize the number of PABP endogenously labeled with PATagRFP binding to mRNA translating in a cell using PALM technique. We will present the single-molecule studies of PABPs binding to poly(A) tail of mRNA during translation.

Keywords:

Translation, Singlemolecule, Fluorescence imaging, PABP, mRNA

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F1.01

Status of NEOS-II

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Abstract:

The energy spectrum of the reactor electron antineutrino has been measured at 24 m distance from the Hanbit-5 reactor core for about two years. The experimental period includes one full reactor operation cycle and two reactor-off periods before and after. We investigate the possible short baseline neutrino oscillation and the decomposition of the energy spectra of the antineutrinos from uranium-235 and from plutonium-239. The overall status of the experiment is presented

Keywords:

neutrino oscillation, reactor neutrino, sterile neutrino

F1.02

Pulse Shape Discrimination using Convolution Neural Network for NEOS-II

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Abstract:

Pulse Shape Discrimination is a technique to distinguish different types of particles using differences in their waveform shapes. In NEOS experiment, pulse shape discrimination of neutrons from photons does a key role in improving the signal-to-background ratio by removing fast neutrons. Convolution neural network can recognize the features of pulses by scanning the full shapes of waveforms and perform the pulse-shape discrimination of NEOS data. The network provides a strong discriminating power, which is called CNN Score. CNN Score accurately at 99.9% distinguishes most particles that may be neutrons or gammas.

Keywords:

Pulse Shape Discrimination, CNN, Deep Learning

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F1.03

Performance study of a large water Cherenkov neutrino detector in Korea

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Abstract:

A deep underground large water Cherenkov detector in Korea has been proposed to study the beam-neutrino-based physics and multi-messenger astronomy. The detector performance was studied using a GEANT4 based detector simulation package and event reconstruction algorithms with various detector configurations. We present an overview of the preliminary studies on the detector performance and the sensitivity on the CP violation, assuming the neutrino beam from J-PARC in Japan.

Keywords:

water cherenkov detector neutrino korea

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F1.04

Background Study of NEOS-II

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Abstract:

NEOS-II (phase-2) aims to figure out anomalies in the reactor neutrinos and began operation in September 2018. The experimental period includes ~500-days of reactor operation and ~200-days of the reactor-off period. As done in phase-1, the reactor-on data subtracting the reactor-off data is used for the analysis. The phase-2 data includes the whole burn-up cycle while the phase-1 had a relatively short period and the variation of background data was a major systematic uncertainty. For this reason, a comparison of reactor-off data sets before and after the reactor-on period and analysis of reactor-off data has emerged as an important topic. In this presentation, there will be a background modeling of reactor-off data via the possible background sources and a comparison of the two reactor-off data sets through the modeling.

Keywords:

reactor neutrino, background, NEOS experiment

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F1.05

Data Analysis and Simulation for NEOS-II

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Abstract:

NEOS experiment, being carried out in the tendon gallery of the Hanbit reactor unit 5, detects electron anti-neutrinos from the reactor core at 24 m distance to search for sterile neutrinos. The first phase of the NEOS experiment with 180-day data (2015-2016) did not show any strong evidence of active-to-sterile neutrino oscillation. NEOS phase-II (NEOS-II) operating since Sept. 2018 has taken 500 days of reactor-on data until late March covering a whole burnup cycle. In this talk, details of data analysis and simulation for NEOS-II are represented.

Keywords:

Reactor Experiment, Sterile Neutrino, Reactor Anomaly, NEOS Phase-II

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F1.06

Analysis of KAPAE data on Positronium Annihilation Energy and Position for CPT violation studies

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Abstract:

Positronium is the simplest system to study CPT violations in the lepton sector. The KNU Advanced Positronium Annihilation Experiment (KAPAE) has its first goal in that it can accurately measure the extinction of positrons. The annihilation of positronium causes the decay of 2 gammas and 3 gammas into para-positronium (p-Ps) and ortho-positronium (o-Ps), respectively, depending on the spin state. The detector consisting of 200 segmentations BGO scintillator provides energy and position dataset of the gamma signal generated by the annihilation of positronium. In order to study the CPT violation, data analysis on the 3 gammas decay of positronium is necessary. We selectively analyzed the data on the decay of 3 gammas energy. In addition, the positron trigger, which has improved efficiency by direct measurement, can estimate the polarization of the initial positronium by tagging the positron emitted in one direction. we present the results of analyzing preliminary data for CPT violation research using the KAPAE detector.

Keywords:

KAPAE, Positronium, CPT violation

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F1.07

18 T High Temperature Superconducting Magnet for an Axion Haloscope Experiment

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Abstract:

A strong magnetic field solenoid magnet is the most crucial component of the axion dark matter haloscope experiment. We report a detailed performance of an 18T high temperature superconductor (HTS) magnet. The magnet is developed for an axion haloscope experiment and consists of 44 double pancake superconducting coils with a cylindrical cold bore size of 70mm in diameter and 476 mm in height. The magnet dimension is designed to probe dark matter axions in the mass range of 14 μeV or higher which is suggested by prominent inflation models. The 18 T magnet is the strongest solenoid magnet ever used in axion haloscope experiments. In this talk we will report recent progress of CAPP18T experiment.

Keywords:

Axion, Haloscpe, Superconducting Magnet, HTS Magnet

F1.08

Search for invisible axion dark matter with a multiple-cell haloscope

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Abstract:

We present the result of the first axion haloscope experiment using a multiple-cell cavity. This cavity concept offers a very efficient approach to high mass regions through larger detection volume, simpler detector setup, and unique phase matching mechanism compared to the conventional multiple-cavity design. Searches using a double cell cavity excluded axions with a photon coupling greater than 6×10^{-14} GeV^{-1} in the mass range from 13.0 to 13.9 μeV at 90% confidence level. This result demonstrated the concept of the multiple-cell cavity is highly beneficial for high-mass axion searches and thus can make significant contributions to next-generation experiments.

Keywords:

axion, dark matter, haloscope

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F1.09

Status of Neutrino Elastic-scattering Observation with NaI(Tl) (NEON)

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Abstract:

NEON (Neutrino Elastic-scattering Observation with NaI) aims an observation of a coherent elastic neutrino-nucleus scattering (CEvNS) using reactor anti-electron neutrino which has not been measured yet with NaI(Tl) crystal detectors at Hanbit nuclear power plant in Yeounggwang. The observation can provide other new physics such as neutrino magnetic moment and non-standard interactions. The NEON pilot detector which will be installed 24 meters from the reactor core consists of a 15 kg NaI(Tl) target mass with 40 cm liquid scintillator, 10 cm leads, 30 cm HDPE for vetoing background radiations. Before moving to the Hanbit reactor, it was installed in the basement laboratory of IBS headquarter(Daejeon) to measure background and threshold because sensitivity relies on them. The background level of approximately 4 counts/day/kg/keV and threshold study is ongoing. The current status of the NEON experiment will be presented in this talk.

Keywords:

Neutino, Reactor, NaI(Tl)

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F2.01

Readiness of detector mass production and the quality-control procedure for the CMS muon system in the Phase-2 LHC

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Abstract:

In the future PHASE-2 high luminosity runs, the LHC will be operated with an instantaneous luminosity of maximum 7×10^{34} cm^{-2} s^{-1}. The CMS muon system in the PHASE-2 LHC runs will be extended up to η region of 2.4 where only the cathode strip chambers are currently present for the muon measurement. In view of the high background conditions in the HL-LHC runs, we have studied high-sensitive double-gap resistive plate chambers to improve the rate capability and to enhance the detector longevity. A series of intensive and systematic R&Ds with muon beams and gamma-ray sources indicates the choice of the detector technology for the extension of the RPC system is a thin phenolic double-gap model. The RPC detector upgrade for the PHASE-2 will be completed with the installation of the chambers during the Technical Stops at the end of 2022 and 2023.

Keywords:

Resistive Plate Chamber, Compact Muon Solenoid, Hi-Luminosity LHC

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F2.02

Trigger RPCs for SHiP experiments and an Application to Muon Radiography

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Abstract:

We report the current R&D activity for trigger RPCs for the future SHiP experiment and introduce a R&D of RPCs to be applied to cosmic-ray muon radiography. In order to accommodate use of new eco-friendly gas mixtures for the detector operation and to improve the operational characteristics in future, the baseline structure of the RPCs of the SHiP Scattering Neutrino Detector (SND) has been modified. In 2020, we planned construction of small and real sized prototype RPC modules and the dedicated R&Ds. Here, we present the construction of the prototype detectors and the future R&D activity to be performed by the end of 2021.
The present RPC model of the SHiP SND is an excellent candidate of an application to Muon radiography. We propose an application of the present RPC model to the muon radiography for imaging nuclear reactors. The expected angular resolution obtained by a four-layer RPC detectors with 5-mm strip pitches is about 2 mrad, which is amply enough to differentiate the a typical uranium fuel core and surrounding shielding materials composed of water, concrete, and iron. In the presentation, we introduce a proposed detector layout of muon tracking and the structure of the unit detector planned in the present study.

Keywords:

Search for Hidden Particles, Resistive Plate Chambers, Dark Photons, Muon Radiography, Heavy Neutral Leptons

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F2.03

Scattering and Neutrino Detector at the LHC

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Abstract:

The SHiP collaboration proposed a small experiment to study Neutrino physics at LHC in Run 3 by using the Scattering and Neutrino Detector (SND). The detector will measure, for the first time, the process $pp \rightarrow \nu X$ in the pseudo-rapidity region ($7.2 < \eta < 8.7$) where neutrinos are mostly produced from charm decays, and search for feebly interacting particles (FIPs) in an unexplored domain. It will be installed in the decommissioned TI18 tunnel, 480 m away from ATLAS IP (interaction point) and will be off-axis with respect to the IP. In order to identify neutrino interactions of the three flavours and perform searches for neutral massive particles via their scattering on the detector material, we will use a hybrid method combining the nuclear emulsion technology and electronic detectors. The ECC (Emulsion Cloud Chamber) with scintillating fibre tracking layers are used in the target region and a muon identification system is based on scintillating bars that will also play the role of a hadronic calorimeter. This detector is a prototype of the SND of the SHiP experiment. These measurements will also provide important input to the optimization of neutrino detectors for future experiments at the HL-LHC and at a possible CERN Beam Dump Facility. In this talk, we will introduce a conceptual design of the SND detector and physics performance of the proposed experiment.

Keywords:

LHC, Neutrino, SND, SHiP

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F2.04

The measurement status of the aging properties of the Korean tirpple GEM detector for the CMS upgrade.

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Abstract:

The Gas Electron Multiplier (GEM) based detectors are widely adapted in many high energy experiments due to their far more impervious to aging than other gaseous device and their ability to handle hit rate up to a few MHZ/cm^2. The Korean CMS group (KCMS) is involved in the muon spectrometer subsystems upgrade of Compact Muon Solenoid (CMS) experiment initially from GE1/1 to ME0 , GE2/1 regions where will be installed GEM based detectors for the High Luminosity LHC (HL-LHC) era which will run about ten years and will be reached 10 times higher integrated luminosity with respect to current LHC.
KCMS, consortium with a manufacturer (Mecaro), has produced the large size GEM foil using double mask photolithography technique the first time in the world. According to the recent simulation study, ME0, the innermost region of the forward CMS muon system, expects to be reached 7.9 C/cm^2 charge accumulation. Under this harsh radiation environment, the degradation of detector’s performance is foreseen therefore pre-estimating of these aging effects are very important issue to guarantee the detector stability during the whole period of programmed experiment. To ensure in ME0 the GEM detector’s long term stability under an unprecedented radiation environment of HL-LHC era, KCMS GEM team undertakes a long term aging test with Korean manufactured large size Triple-GEM chamber via x-ray exposing. This study will introduce the aging test setting process in detail and the preliminary results.

Keywords:

Aging Test, Triple-GEM, ME0

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F2.05

The Front-end Chip Test Results for the LGAD Based Precision Timing Application in MTD project for CMS Phase-2 Upgrade

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Abstract:

In the high luminosity (HL-LHC) environment, the rate of simultaneous interactions per bunch crossing (pileup) is estimated to reach an average of 140 to 200, which can lead to misidentification of tracks. The primary goal of the CMS Phase-2 upgrade for the HL-LHC is to maintain the current excellent performance of the CMS detector. The minimum ionizing particle (MIP) Timing Detector (MTD), which is planned to be installed in the CMS Phase-2 Upgrade is expected to mitigate the event from pileup by providing precision timing information for the MIP with 30-40 ps resolution. The MIP timing detector (MTD) consists of the Barrel timing layers (BTL) and the Endcap timing layers (ETL). The detector aspects are divided into Crystal scintillators readout with silicon photomultipliers (SiPMs) and Low Gain Avalanche Detector (LGAD) silicon sensors for BTL and ETL respectively. The ETL uses the LGAD sensor and ASIC to readout the signal.The ETL readout ASIC chip (ETROC) is designed to handle a 16×16 pixel cell matrix, each pixel cell being 1.3×1.3 mm^2 to match with the LGAD sensor pixel size. The prototype of ETROC called ETROC0 consists of a single channel with front-end preamplifier and discriminator. The uniformity of the sensor response, efficiency, and timing resolution with different conditions have been measured using 120 GeV proton beams at the Fermilab test beam facility. In this talk, the preamplifier performance of ETROC0 with 120 GeV proton beam at the Fermilab Beam Test Facility is reported.

Keywords:

CMS, Phase-2 Upgrade, MTD

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F2.06

Studies of MET regression with machine learning technique for Phase-2 Upgrade of CMS Level-1 Trigger system

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Abstract:

Collecting the high quality datasets efficiently at High Luminosity LHC (HL-LHC) will be a challenge in the high pileup environment of 200 proton-proton collisions per beam crossing. To deal with the large size of the dataset from the HL-LHC, the Phase-2 Upgrade of the Level-1 (L1) trigger system at the CMS experiment is essential. We will present updated results on the MET regression with machine learning technique for CMS Phase-2 Level-1 trigger. The missing transverse energy (MET) is calculated based on the PF and PUPPI algorithms for the L1 correlator trigger. The goal of the study is to improve the MET based on PF and PUPPI algorithms using the machine learning method. In this talk, the performance of the L1 MET trigger using machine learning techniques based on various training models and loss functions will be presented.

Keywords:

LHC, machine learning

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F2.07

FPGA based firmware implementation of MET algorithm for CMS Phase-2 Level-1 trigger

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Abstract:

The high-luminosity upgrade of the LHC (HL-LHC) will enable a factor of ten increase in the total dataset collected by the CMS Experiment, maximizing the potential for the discovery of new physics. While the increased instantaneous luminosity will bring this significant advantage, it also requires improved capabilities of the CMS detector performance. The CMS Level-1 trigger will be significantly expanded during the Phase-2 upgrade to allow for more efficient data collection. The Level-1 Correlator Trigger (L1CT) will become the main engine of the trigger system, performing particle flow (PF) reconstruction, which reconstructs physics objects by combining signals collected by all sub-detectors. These PF objects are passed to a second-stage FPGA for further processing into higher-level objects. This work describes the firmware implementation of a MET algorithm, developed using Vivado High-level synthesis (HLS), including simulation results with the prototype trigger board.

Keywords:

CMS, L1 trigger, HL-LHC, MET, FPGA

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F2.08

Frontiers in HEP precision measurements through machine learning

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Abstract:

Machine learning (ML) methodologies have gained remarkable popularity in the high energy physics (HEP) community in recent years. This has improved the achieved precision of HEP experimental results. This work presents the study of novel ML techniques which address the problem of classification within experimental data to discriminate physics interesting versus background events. Specifically, it is focused on the combination of a number of individual classifiers through the so-called boosting ensemble algorithms. The novelty of this work resides on the use of a definite strong classifier as a component classifier in an ensemble, that is, support vector machines (SVMs); furthermore, different approaches to build the ensembles are explored. The previous considerations aim to improve the performance of a single SVM as being part of an ensemble and to be competitive with existing ML algorithms used as benchmarks by experimentalists (boosted decision trees and neural networks). The final goal of this effort is to apply the proposed algorithm to HEP measurements and reach precision frontiers. Early results on public available data will be presented.

Keywords:

Support Vector Machine, Boosting, Classification

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F2.09

R-Parity Violating Supersymmetry event classification using Convolutional Neural Network with Large Scale Deep Learning

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Abstract:

Deep Neural Network (DNN) is the most promising tool to explore rare physics phenomena from huge amounts of background at the LHC experiments. Convolutional Neural Network (CNN) is one of the successful Deep Learning (DL) techniques in pattern recognition. We implement the CNN architecture to discriminate R-parity Violating Supersymmetry (RPV-SUSY) events from the quantum chromodynamics (QCD) background. Low-level information of the CMS detector such as tracking system, electromagnetic and hadronic calorimeters are used as 3-channel input images for our CNN model. The model is trained with Monte Carlo samples based on the Delphes fast simulation software with the CMS detector configuration. The benchmark studies are performed to compare with a traditional cut based physics selection in the realistic condition with multiple proton-proton interactions (pileup).
Furthermore, we perform the distributed training based on the Nurion supercomputer at KISTI to demonstrate the DL model can be optimized and scaled effectively on a multi-node HPC system. We report the scalability of this deep learning model on the Nurion HPC architectures.

Keywords:

Deep Learning, CMS, Supercomputer, Convolutional Neural Network, LHC

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F2.10

Permutation independent Deep Learning Algorithm for RPV SUSY event classification

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Abstract:

Deep Learning is a powerful tool to analyze the big data of high energy physics. Typical problems in the high energy hadron collision are classifying events which consist of feature variables of multiple physics objects such as Jet's four-momentum, flavour tagging information. In this study, we adopt an advanced Deep Learning architecture, Graph Neural Network (GNN) to address relations between physics objects in non-Euclidean geometry. GNN can handle events with different lengths of physics objects, but also independent of their permutation.

Keywords:

GNN, Deep Learning, CMS, RPV SUSY

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F3.01

Diquark perspective on hadron structure

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Abstract:

Diquark is a system of correlated two quarks. As diquark has a color charge, it cannot be observed directly, but can be a constituent of hadrons. Among various diquarks, we focus on light diquarks composed of up, down and strange quarks with color antitriplet. It is expected that the light diquarks might develop in heavy hadrons rather in light systems due to mass asymmetry between heavy and light quarks. In this talk we discuss the properties of the light diquarks in several aspects. First of all, we use a phenomenological QCD sum rule with an explicit diquark field [1]. It is interesting to see that this QCD sum rule works for the Lambda, Lambda_c and Lambda_b baryons which have the scalar ud diquark as their constituent. Next, we investigate the Lambda_c baryon in a potential model in which a two-body system of a charm quark and a ud diquark are confined in the Coulomb plus linear potential [2,3]. Although one expects the string tension in the confinement potential should be universal for the triplet-antitriplet systems, the string tension for the charm quark and the ud diquark is demanded to be half of quark and antiquark systems to reproduce the excitation energy of the Lambda_c baryons. Finally we discuss a speculated symmetry between the strange quark and the anti ud diquark [4,5], which have color triplet and a similar size of the mass. We regard a triplet of the s quarks with spin up and down and the ud scalar diquark with spin 0 as a fundamental representation of this symmetry. We introduce possible hadronic representations constructed by the triplets and heavy quarks, and apply for the estimation of the masses of exotic hadrons.

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[5] T. Jimbo, D. Jido, in preparation.

Keywords:

F3.02

Heavy baryon spectroscopy

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Abstract:

We discuss heavy hadron spectroscopy as stimulated by new observations by high energy accelerator facilities. The roles of heavy quarks and light degrees of freedom are investigated. For baryons distinctive features of the lambda and rho modes are emphasized to clarify the origin of various resonances. As a particular example, we in some detail discuss the recently observed states which are considered to be Roper state analogues in various flavor sectors.

Keywords:

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F3.03

Production of multi-quark baryon states with hadron beams

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Abstract:

While three hidden-charm pentaquark states (Pc's) were reported in the Lambda_b decays by the LHCb Collaboration, the existence of multi-quark baryon states in the strangeness sectors still await experimental confirmation with unambiguous evidence. Among them, experiments searching for hexa-quark baryon states are now underway with hadron beams from J-PARC. In this talk, I will review such recent experimental programs envisioned at J-PARC with particular emphasis on the H-dibaryon search with E42.

Keywords:

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F3.04

Isospin mass differences of singly heavy baryons

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Abstract:

We study the isospin mass differences of singly heavy baryons, based on a pion mean-field approach. We consider both the electromagnetic interactions and the hadronic contributions that arise from the mass difference of the up and down quarks. The relevant parameters have been already fixed by the baryon octet. In addition, we introduce the strong hyperfine interactions between the light quarks inside a chiral soliton and the Coulomb interactions between the chiral soliton and a heavy quark. The numerical results are in good agreement with the experimental data. In particular, the results for the neutral mass relations, which contain only the electromagnetic contributions, are in remarkable agreement with the data, which implies that the pion mean field approach provides a good description of the singly heavy baryons.

Keywords:

Heavy baryons, Isospin mass differences, Pion mean fields

2020 KPS Fall Meeting
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F4.01

Gravitational waves from the early universe

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Abstract:

Gravitational waves are useful probe not only for astrophysics of compact objects but also for cosmology of the early universe. There are a number of cosmological gravitational waves which generate stochastic signals in wide range of frequencies. After introducing their features and possible detection methods, I discuss implication of latest observation of NANOGrav collaboration of pulsar timing to inflationary cosmology and cosmic strings.

Keywords:

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F4.02

On Horava-Lifshitz-DeWitt Gravity: An Overview and Future Directions

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Abstract:

About 12 years ago, a renormalizable quantum gravity `a la Horava, Lifshitz, and DeWitt was proposed and it has been developed in diverse directions. I will explain its basic ideas and give a brief overview for some possible tests in astrophysical and cosmological data which would be available near future, as well as the long-standing theoretical issues which have been resolved recently.

Keywords:

Horava-Lifshitz-DeWitt Gravity, Renormalizable Quantum Gravity

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F4.03

Tests of gravity with gravitational waves

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Abstract:

The direct detection of gravitational waves (GWs) from merging binary black holes and neutron stars marks the beginning of a new era in gravitational physics, and it brings forth new opportunities to test theories of gravity in strong and dynamical regimes. To this end, it is crucial to search for anomalous deviations from general relativity in a model-independent way, irrespective of gravity theories. In this presentation, I will talk about recent developments in testing gravity with GWs, focusing on generation, propagation, and polarizations. Also I will show how KAGRA contributes to the joint observation with a global detector network in these tests of gravity.

Keywords:

2020 KPS Fall Meeting
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F4.04

Fuzzy dark matter and mysteries of galaxies

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Abstract:

Recently, there is a growing interest in the fuzzy dark matter model, where dark matter is an ultra-light scalar particle with mass $m = O(10^{-22})eV$. This model has a typical length scale from quantum pressure, which is about the core size of dwarf galaxies and can solve the small scale issues of the cold dark matter model such as the core-cusp problem. We show that the typical acceleration scale of the dark matter can explain many other mysteries of galaxies such as the baryonic Tully-Fisher relation and the MOND-like behaviour of rotation curves.

Keywords:

fuzzy dark matter, galaxy, rotation curves

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F5.01

Quantum Anomalous Hall Effect in Two-Dimensional Topological Magnetic Insulators

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Abstract:

Quantum anomalous Hall (QAH) insulator can be realized in a topological magnetic insulator with non-trivial band topology combined with magnetic order. In principle, QAH insulators could be stable at ambient conditions, but their experimental realizations have been demonstrated only at extremely low temperatures. Several groups reported the QAH effect in intrinsic topological magnetic insulator $MnBi_2Te_4$ [1] and in twisted bilayer graphene aligned to hexagonal boron nitride [2]. These findings signify the presence of the material platforms for the realization of the QAH effect in a broad class of topological materials. In this talk, I will review recent research developments searching for topological magnetic insulators among two-dimensional (2D) materials. Some transition metal chalcogenides and halides have interesting features in their electronic band structure, which lead to novel magnetic interactions and topological characteristics. From density-functional-theory calculations, we demonstrate that a class of 2D transition-metal compounds becomes a ferromagnetic insulator with a non-trivial Chern number. While transition metal atoms are responsible for the ferromagnetic ground state, the band topology depends on the hopping matrix elements through chalcogen atoms. The non-trivial band topology is confirmed to have a nonzero Chern number, quantized Hall conductivity, and chiral edge states by using the Wannier function analysis. We also predict that a two-dimensional metal-organic framework of a single layer of the transition-metal bis-dithiolene complex can become a ferromagnetic insulator with a non-trivial Chern number [3].

[1] Y. Deng et al., Science **367**, 895 (2020).
[2] M. Serlin et al., Science **367**, 900 (2020).
[3] S. Baidya et al. Sci Rep **9,** 13807 (2019).

Keywords:

Quantum Anomalous Hall Effec, Topological Magnetic Insulators

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F5.02

Non-Hermitian Topological Phases

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Abstract:

Whereas Hamiltonian are supposed to be Hermitian in many textbooks, the low-energy effective Hamiltonian for quasiparticles often can be non-Hermitian because of finite lifetime due to interactions with environments or disorders. It has been revealed recently that such non-Hermiticity gives novel topological phases called non-Hermitian topological phases [1]. Importantly, non-Hermiticity enriches gap structures of the systems [2,3], and ramifies fundamental symmetries [2]. Furthermore, novel gapless structures called exceptional points [4,5] and new boundary states called skin modes [6] appear. In this talk, I explain recent progresses on this new trend in topological phases, based on our recent papers.

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Keywords:

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F5.03

Universal behaviors of deconfined fractionalized spin excitations in α-$RuCl_3$

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Abstract:

Searching for a universality class near a quantum critical point, a precarious point of quantum instability between two competing phases, is a fundamental paradigm with emergence of exotic elementary excitations. Ruthenium trichloride, α-$RuCl_3$, is a Kitaev magnetic quantum system presenting both a symmetry breaking antiferromagnetic order and an entangled topological order, and thus could be a candidate for a new universality class involving deconfined fractionalized excitations of the itinerant and Z_2-flux localized majorana ferimions. In this talk, I present an unprecedented crossover behavior of the quantum criticality across the high to low temperature region based on inelastic neutron scattering and specific heat results of α-$RuCl_3$. The results demonstrate that a Wilson-Fisher-Yukawa-type "conventional" quantum criticality in high temperature crosses over to an exotic strong-coupling local quantum criticality in low temperature, which is represented with a scaling function based on the heavy-fermion type critically fluctuating local moment physics. Our findings provide deep insight on how the quantum criticality evolves in fermion-boson coupled topological systems with different types of deconfined fermions.

Keywords:

Qantum spin liquid, Quantum criticality

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F5.04

Experimental signatures of a Kitaev quantum spin liquid in α-$RuCl_3$

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Abstract:

Quantum spin liquids (QSLs) are enigmatic states of matter, in which quantum fluctuations and frustrations prevent spin configurations in a lattice from any solid-like ordered alignments. An exactly solvable model of two-dimensional honeycome lattice proposed by Kitaev, in which the bond-dependent Ising interactions act as an exchange frustration, leads to a QSL ground state characterized by Majorana fermions, whose composites are non-abelian anyons that may be useful for fault-tolerant topological quantum computations. Recent efforts to search the Kitaev QSL states revealed that in an antiferromagnet α-$RuCl_3$ with layered honeycome structure, the zig-zag magnetic order can be suppressed by in-plane magnetic fields, leading to a paramagnetic ground state. In this presentation, I will show our recent results of thermal conductivity and specific heat measurements in the high-field paramagnetic state of Kitaev material α-$RuCl_3$. The field dependence of thermal Hall conductivity shows a plateau behavior with the value close to one half of quantized thermal Hall effect of electron systems [1], whose sign changes with field angle as expected from the Chern number in the Kitaev model [2]. The most recent specific heat measurements provide thermodynamic evidence for field-angle dependent Majorana gap, which demonstrates the bulk-edge correspondence in a Kitaev quantum spin liquid [3].

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[3] O. Tanaka, Y. Mizukami, R. Harasawa, K. Hashimoto, N. Kurita, H. Tanaka, S. Fujimoto, Y. Matsuda, E.-G. Moon, and T. Shibauchi, arXiv:2007.06757.

Keywords:

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F6.01

Chiral edge states along the mass-inverted doamin wall in gapped graphene

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Abstract:

Recently, the emergence of topological domain walls in bilayer graphene has attracted intense interest for understanding fundamental physics of topological matters. In this study, an alternative way of hosting chiral 1D states in single layer graphene with a finite mass gap, by means of mass inversion as a novel route toward making topological line defect. The mass-inverted domain wall indeed hosts chiral and topological edge states with the chiral symmetry. Since the existence of the chiral states are protected by both sublattice symmetry and non-zero valley Chern number, it is shown that the chiral states are preserved even in more realistic situations; asymmetric or continuous mass inversion, and atomic vacancies. Such findings of the robust chiral states in single layer graphene with the non-uniform mass gap may trigger following research on topological phenomena in single layer graphene.

Keywords:

Topological states, Graphene, Chiral states

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F6.02

Spatial structure of two-channel Kondo cloud

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Abstract:

A Kondo cloud is an object formed by conduction electrons to screen a nearby impurity spin. Although the cloud is important to understand Kondo effects and other many-body phenomena, it has been studied mostly for the single-channel Kondo effect. Here we study how a Kondo cloud forms spatially and decays thermally for the two-channel Kondo effect, using the numerical renormalization group and the bosonization methods. The spatial distribution of the cloud is quantified by computing quantum entanglement. We find that the cloud has both Fermi-liquid and non-Fermi-liquid structures, and analyze the dependence of the structures on system parameters.

Keywords:

Kondo effect, Kondo cloud, Entanglement

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F6.03

Universal Thermal Entanglement of the Multi-channel Kondo Effect

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Abstract:

Kondo effect, which happens as a spin-1/2 impurity is entangled with conduction electrons, is an important topic of condensed matter physics. When the impurity is screened by multiple conduction electron channels, the multi-channel Kondo effect occurs. The effect shows a non-Fermi liquid behavior and results in fractional quasi-particles such as a Majorana fermion at the impurity, at low temperature.

In this work, we study the entanglement induced by the impurity in the multi-channel Kondo model at finite temperature. We develop a boundary-conformal-field-theory approach of computing the entanglement negativity for the partition that separates the impurity from the rest. We demonstrate that its temperature dependence has a universal scaling form with the exponent determined by the conformal dimension of a primary boundary operator. This result is consistent with that calculated by using the numerical renormalization group.

Keywords:

Kondo effect, Entanglement, Boundary conformal field theory

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F6.04

Robust Quantum Point Contact via Trench gate Modulation

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Abstract:

Quantum point contacts (QPC) are a primary component in mesoscopic physics and have come to serve various purposes in modern quantum devices. However, fabricating a QPC that operates robustly under extreme conditions, such as high bias or magnetic fields, still remains an important challenge. As a solution, we have analyzed the trench-gated QPC (t-QPC) that has a central gate in addition to the split-gate structure used in conventional QPCs (c-QPC). From simulation and modelling, we predicted that the t-QPC has larger and more even subband spacings over a wider range of transmission when compared to the c-QPC. After an experimental verification, the two QPCs were investigated a quantum Hall regimes as well. At high fields, the maximally available conductance was achievable in the t-QPC due to the local carrier density modulation by the trench gate. Furthermore, the t-QPC presented less anomalies in its DC bias dependence, indicating a possible suppression of impurity effects.

Keywords:

Quantum Point Contact, Quantum Hall

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F6.05

Crystallization of Transition-metal Oxides in Aqueous Solution beyond Ostwald Ripening

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Abstract:

The crystallization mechanism of transition-metal oxides (TMOs) in a solution was examined based on ZnO crystallization using in-situ x-ray absorption fine structure (XAFS) measurements at Zn K edge and semi-empirical quantum chemistry (SEQC) simulations. The XAFS results quantitatively determine the local structural and chemical properties around a zinc atom at successive stages from $Zn(NO_3)_2$ to ZnO in an aqueous solution. The results also show that a zinc atom in $Zn(NO_3)_2$ ions dissolves in a solution and bonds with approximately three oxygen atoms at room temperature (RT). When hexamethylenetetramine ($C_6H_{12}N_4$) is added to the solution at RT, a stable Zn-O complex consisting of six $Zn(OH)_2$s is formed, which is a seed of ZnO crystals. The Zn-O complexes partially and fully form into a wurtzite ZnO at 60^{o}C and 80^{o}C, respectively. Based on the structural properties of Zn-O complexes determined by extended-XAFS (EXAFS), SEQC simulations clarify that Zn-O complexes consecutively develop from a linear structure to a polyhedral complex structure under the assistance of hydroxyls(OH^-s) in an aqueous solution. In a solution with a sufficient concentration of OH^-s, ZnO spontaneously grows through the merging of ZnO seeds ($6Zn(OH)_2$s), reducing the total energy by the reactions of OH^-s. ZnO crystallization suggests that the crystal growth of TMO can only be ascribed to Ostwald ripening when it exactly corresponds to the size growth of TMO particles.

Keywords:

Crystallization, Metal oxide, Growth mechanism, Synthesis, Nano-materials, ZnO, XAFS, EXAFS, Computational physics

2020 KPS Fall Meeting
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F6.06

Particle-antiparticle duality and re-fractionalization of chiral solitons in the extended Su-Schrieffer-Heeger model

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Abstract:

A topological soliton is an extremely stable object that exists in various systems, including but not limited to optical fibers, magnetic materials (skyrmions), and topological insulators (chiral edge state). As one of the famous quantum topological solitons, SSH (Su-Schrieffer-Heeger) solitons exhibit various important concepts including particle-antiparticle (PA) symmetry and fractional charge, there have been only few advances in exploring such properties of topological solitons beyond the SSH model. In this work, by considering a chirally extended double-Peierls-chain model, we demonstrate novel particle-antiparticle duality and fractional charge e/2 of topological chiral solitons even under the dynamical chiral symmetry breaking. This provides a counterexample to the belief that chiral symmetry is necessary for such particle-antiparticle relation and fractionalization of topological solitons in a time-reversal invariant topological system. Furthermore, we generalized the fractionalization concept and found the re-fractionalization of chiral soliton. Each chiral soliton is split into two sub solitons and a quartet of subsolitons is generated during the soliton-antisoliton pair-creation, which has not been observed or even proposed in any physical systems. As a result, such dualities and fractionalizations support the Z_4 algebraic structures. Our work will inspire researchers who are seeking feasible and promising topological systems.

Keywords:

Topological soliton, Extended Su-Schrieffer-Heeger model, Particle-antiparticle symmetry, Fractionalization

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F6.07

Electron spin resonance of a single atom in vector magnetic fields

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Abstract:

Scanning tunneling microscopy in combination with electron spin resonance (ESR) technique [1] enables a direct access to the quantum states of individual magnetic atoms or molecules on surfaces. Here, we investigate ESR of hydrogenated Ti (TiH) atoms adsorbed on bridge binding site of MgO using a two-dimensional vector magnetic field. We find ESR frequency as well as ESR amplitude change as a function of the angle of vector magnetic fields. The resonance frequency varied by different vector magnetic fields indicates an anisotropy of the g-tensor. Furthermore, ESR amplitude is presumably determined by two factors, tunneling magnetoresistance (TMR) effect at the STM junction and the transverse magnetic field to drive ESR. Our results provide deeper understanding on the quantum states of a single atom and thus the direction to engineer and design the spin-based quantum states.

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Keywords:

STM, Scanning Tunneling Microscopy, ESR, Electron spin resonance, ESR-STM

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F6.08

Effects of doping on electronic and magnetic properties of twisted graphene

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Abstract:

Twisted bilayer graphene (TBG) has drawn great attention for its tunable flat bands by the twist angle. Correlated electronic phases have been observed experimentally at different doping concentrations, but the large number of atoms in the moiré supercell has limited theoretical calculations of doping effects on electronic and magnetic properties. Here, we develop an efficient method to calculate electronic and magnetic properties of electron- and hole-doped TBGs based on results of density functional theory calculations of undoped TBG. With this method, we also investigate temperature dependences of electronic and magnetic properties of doped TBGs. We discuss effects of doping on electrostatic screening, low-energy band dispersions, and magnetization of TBG. This work was supported by NRF of Korea (Grant No. 2020R1A2C3013673) and KISTI supercomputing center (Project No. KSC-2019-CRE-0195).

Keywords:

twisted, graphene, doping, magnetism

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F7.01

Ultrafast dynamic phenomena in strongly electron-correlated materials investigated at PAL-XFEL

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Abstract:

X-ray free electron laser (XFEL) is a new generation x-ray source that opens a gateway to ultrafast dynamic phenomena in materials. This source has been exploited for only a decade, but has extensively contributed to emergence of the new science in concert with rapidly developing XFEL experimental techniques based on three key features: 1) higher brightness (>10^8 times), 2) shorter x-ray pulse (<10^{-4} times), and 3) longer coherence length (>10^2 times) than those of the synchrotron x-ray radiation source. The capability of optical laser pump and XFEL probe experiment allows one to access in the time domain intriguing coupled/decoupled nature among physical degrees of freedom (e.g. lattice, spin, orbital, and charge) in strongly electron-correlated materials. I will discuss recent progress of research on the strongly electron-correlated materials at PAL-XFEL.

Keywords:

x-ray free electron laser, ultrafast dynamics, strongly electron-correlated material

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F7.02

ARPES and Time-resolved ARPES studies in epitaxially grown 2D chalcogenide thin films

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Abstract:

Two-dimensional (2D) transition metal dichalcogenides (TMDs) attract huge interest as potential building blocks for innovative electronic and optoelectronic applications. Not only the potential for applications, electronic correlated properties are intensively discussed. By reducing the material thickness and forming a heterostructure, many properties of layer materials change with examples including semiconductivity and charge ordering. 2D TMDs films are epitaxially grown on graphene/SiC (0001) substrate by molecular beam epitaxy. From angle-resolved photoemission spectroscopy (ARPES) measurements in synchrotron, we obtain the electronic band structure of TMDs films. We illustrate the electronic properties of TMDs films to figure out layered properties of TMDs films. We analyze the electronic structure of $ReSe_2$ and VSe_2 films about semiconductivity and charge ordering, respectively. $ReSe_2$ has distinct orbital character as well as lattice distortion and such properties suppress interlayer interaction of material. Interface coupling between VSe_2 and graphene triggers the emergence of a novel metal-insulator transition. In addition, we employ the time-resolve ARPES experiments to discuss the time dependent charge ordering property of VSe_2 films.

Keywords:

ARPES, TR-ARPES, MBE, Syncrotron, 2D-TMDs

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F7.03

Time resolved measurement of topological spin structure by using soft x-ray microscopy

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Abstract:

In any change of the topological charge in a three dimensional (3D) spin configuration such as a vortex core and skyrmion switching, a Bloch point (BP) - a unique topological singularity should be mediated [1-3]. Consequently, it is crucial to know the intrinsic nature of BP and its role in magnetization dynamics for understanding the various dynamical phenomena of spin structures. Since BP is a virtual point at which the local magnetization vanishes among lattice points as well as BP is rarely stabilized in magnetic nanostructures, the intrinsic natures of a BP and its dynamic behaviours have not been verified experimentally.
In this presentation, we demonstrate how to form stable BP in a ferromagnetic patterned nanodisk which can provide a flatform for experimental observation of BP and its dynamic behaviour. We successfully formed a steady-state BP in the middle of elongated magnetic vortex core structures in asymmetrically shaped $Ni_{80}Fe_{20}$ nanodisks [4] . By using the magnetic transmission soft X-ray microscopy (MTXM) at the Advanced Light Source [5], we measured detailed static and dynamic characteristics of BPs. Based on time-resolved nanoscale magnetic X-ray imaging combined with micromagnetic simulations, the role of BP in vortex-core dynamics will be elucidated in this presentation.

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Keywords:

Spin, Time resolved measurement, Bloch point, spin singularity, Magnetic vortex

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F7.04

Observation of Three-dimensional Magnetic Domain Structure by Using Transmission X-ray Microscopy

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Abstract:

Patterned magnetic domain structures play an important role for the operations in future device. Especially magnetic flux closure domain (FCD) structure which is stabilized in ferromagnetic disks has a potential for novel for novel memory device based on the two degrees of freedom : in-plane curling magnetization (chirality) and out-of-plane magnetization direction (polarity). [1,2] Recent advance in imaging technique and micromagnetic simulation enabled to explore the FCD in extended systems. As the system evolves from two-dimensional (2D) to three-dimensional (3D), a complex 3D magnetic structure forms, the asymmetric Bloch wall consisting of Bloch wall in the middle and two Néel-like surface walls of opposite chirality at the top and bottom (two degenerate states exist).[3] Such magnetic structure is qualitatively different physical behaviors compared with previous reports on 2D systems, as well as the enhanced performance. [4,5] The discovery of the additional degree of freedom of ABW can be controllably switched opened up new possibility in developing unique multi-bit memory device. [5] To control the ABW, it has been utilized the asymmetric geometry to break the symmetry of those state. In this presentation, we show their symmetry also can be broken even in the symmetric geometry under the horizontal magnetic field which provides another way for controlling the ABW efficiently using micro magnetic simulation. Furthermore, we successfully verified our method experimentally by using the magnetic transmission soft x-ray microscopy (MTXM).[6]

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Keywords:

magnetic domain walls, ferromagnetic disk, X-ray imaging, Three dimensional magnetic domains

F7.05

Enhancing Vertical Carrier Transport on a Thin Film Polymer Semiconductor via Molecular orientation modification by a femto-second Laser process

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Abstract:

유기 박막의 낮은 전하수송 특성을 극복하고 고효율 유기 광전자공학을 달성하기 위한 방법으로 유기분자 정렬방향과 구조제어가 가장 효과적인 방법 중 하나이다. poly(3-hexylthiophene) (P3HT) 기반 유기반도체 박막에 극초단 (펨토초) 레이저를, 임계값(ablation threshohold) 근처의 그러나 조금 낮은 출력으로, 조사를 하면 박막의 미세구조 변화를 유도할 수 있으며 아울러 전기적 특성을 획기적으로 개선할 수 있다. 레이저 출력을, 임계값을 포함한 다양한 출력 및 펄스폭에서 테스트한 결과, 최적화 조건에서 P3HT 박막의 분자가 face-on 방향으로 재정렬이 되고 수직 방향의 전류흐름이 약 3배정도 개선이 되었다. 이러한 전류흐름의 향상은 분자의 face-on 방향 정렬에 따른 수직방향으로의 π–π 적층 개선에 의한 것이다.
GIWAXS(스침각 광각 X선 산란)와 NEXAFS(근접 가장자리 X선-흡수 미세구조)의 분석을 통해 극초단 레이저 조사가 유기박막의 P3HT 분자를 edge-on 방향에서 face-on 방향으로 효과적으로 재정렬하는 것과 이 face-on 재정렬에 따른 안정성을 확인하였다.
이러한 결과는 박막제조 후 비접촉식 방법을 통하여 유기박막의 특성 개선을 위한 새로운 아이디어를 제시하고 있으며, 향후 유기 전자제품과 하이브리드 장치 등에 활용이 될 가능성을 제시한다.

Keywords:

fs Laser, conjugated polymer, organic semiconductor, molecular orientation, carrier transport, c-AFM

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F7.06

Electronic band structure at the Au/Perovskite interface via photoemission spectroscopies

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Abstract:

The electronic properties of the interface between Au and organometallic triiodide perovskite ($CH_3NH_3PbI_{3-x}Cl_x$) were investigated by ultraviolet photoelectron spectroscopy (UPS) and X-ray photoemission spectroscopy (XPS). $CH_3NH_3PbI_{3-x}Cl_x$ films were prepared on Au surfaces by spin casting with various concentrations to control the film thickness. Their morphology was examined by atomic force microscopy (AFM). $CH_3NH_3PbI_{3-x}Cl_x$ films exhibited a maximum valence band edge of 5.91 eV. The energy levels shifted downward by 0.26 eV with a perovskite coverage of 116.3 nm, indicating that band bending occurs at the interface. The observed energy level shift indicates an interface dipole at the Au/$CH_3NH_3PbI_{3-x}Cl_x$ junction. These findings contribute to the understanding of how perovskite materials function in electronic devices and aid in the design of new perovskite materials.

Keywords:

perovskite, Band bending, Interface, Ultraviolet photoelectron spectroscopy (UPS), X-ray photoemission spectroscopy (XPS)

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F8.01

Off-centered Pb interstitials inducing lattice instability in PbTe

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Abstract:

We revisit the defect properties of intrinsic defects in PbTe using first-principles density-functional calculations. Here, we break the symmetry imposed on on-centered intrinsic defects in PbTe and reveal that the Pb interstitial defects can be off-centered along the [111] direction toward the direction of one of Te nearest neighbors. With multiple degeneracy of ground configurations and their lowered defect formation energy compared to on-centered one, the defect density of Pb interstitials is expected to be ~5.6 times larger than previous predictions when PbTe is synthesized at 900 K. Moreover, the off-centered Pb interstitials in PbTe can exhibit long-range lattice relaxation along [111] direction beyond distance of 1 nm, indicating a potential formation of weak local dipoles. Our results provide the possible explanation of the formation of local-dipole and suggest a possible lattice instability induced by intrinsic defects in PbTe.

Keywords:

PbTe, Pb interstitial, Off-centered

F8.02

Neural network interatomic potential for (B,N)/Pt(111) surface system

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Abstract:

The artificial neural network technology boasts outstanding grades in terms of its performance and efficiency, which is being applied in various fields. In the field of physics, application of artificial intelligence are commonly found as well. However, it is not easy to find instances in the surface systems yet. In this study, we build the artificial neural network potentials (NNPs) for the behaviors of a B atom and a N atom on the Pt(111) surface, which is important in understanding the h-BN synthesis mechanism. The training dataset is made by the randomized atomic-system generator (RAG) [1] method, the molecular dynamics (MD) method, the potential energy surface (PES) method, and the nudged elastic band (NEB) method, in which atomic structures are calculated by the Vienna ab-initio simulation package. Furthermore, the dataset is augmented to six times by the Taylorexpansion approach [2]. The training error was less than 3.0 meV/atom. We check the PES and the NEB by the NNP for a B atom and a N atom on the Pt(111) surface. The diffusion energy barriers of B and N along the surface direction are 0.7 and 0.8 eV, respectively, which is consistent with the DFT calculations result. We propose that the NNP can be the key to the extensive system calculation with speed and accuracy.

[1] Y. Choi and S. Jhi, J. Phys. Chem. B (accepted).
[2] A. M. Cooper, J. Kästner, A. Urban, and N. Artrith, NPJ Comput. Mater. **6**, 54 (2020).

Keywords:

Machine learning, Artifitial neural network potential, Interatomic potential, Pt(111), h-BN

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F8.03

Accurate band gap prediction with tuplewise graph based material representation based on machine learning

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Abstract:

The open-access material databases allowed us to approach scientific questions from a completely new perspective with machine learning methods. Here, based on open-access databases, we focus on the classical band gap problem for predicting accurate the band gap of a crystalline compound using a machine learning approach with newly-developed tuplewise graph neural networks (TGNN), which is devised to automatically generate input representation of crystal structures in tuple types and to exploit crystal-level properties as one of the input features. Our method brings about a highly accurate prediction of the band gaps at hybrid functionals and GW approximation levels for multiple material datasets without heavy computational cost. Furthermore, to demonstrate the applicability of our prediction model, we provide a dataset of GW band gaps for 45,835 materials predicted by TGNN posing higher accuracy than standard density functional theory calculations.

Keywords:

machine learning, band gap, GW

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F8.04

High mobility two-dimensional electron gas in $PbZr_{0.5}Ti_{0.5}O_3/BaSnO_3$ heterostructure

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Abstract:

The two-dimensional electron gas (2DEG) formed at oxide heterointerface between $LaAlO_3$ and $SrTiO_3$ has been attracting fundamental and practical attention due to its novel quantum properties and interfacial conductivity. However, these 2DEGs reside in weakly dispersive Ti-d bands, and the mobility of 2DEG is relatively low at room temperature, which limit its future application. Here, in order to enhance 2DEG mobility, we consider a novel $BaSnO_3$ with highly dispersive Sn-s band. Using the first-principles calculations, we find that the n-type 2DEG can be formed at $PbZr_{0.5}Ti_{0.5}O_3/BaSnO_3$ heterostructure. Our results show that the 2DEG produced by polar field resides within the highly dispersive Sn-5s band and its mobility is expected to be almost 10 times higher than that in LAO/STO.

Keywords:

high mobility two-dimensional electron gas(2DEG), PbZr0.5Ti0.5O3 ,BaSnO3

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F8.05

Partial quantum revivals of localized condensates indistorted lattices

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Abstract:

We report on a peculiar propagation of bosons loadedby a short Laguerre-Gaussian pulse in a nearly flatband of a lattice potential. Taking a system of exciton-polaritons in a kagome lattice as an example, we showthat an initially localized condensate propagates in aspecific direction in space if anisotropy is taken intoaccount. This propagation consists of quantum jumps,collapses, and revivals of the whole compact states, andit persists given any direction of anisotropy. This prop-erty reveals its signatures in the tight-binding modeland, surprisingly, it is much more pronounced in a con-tinuous model. Quantum revivals are robust to the re-pulsive interaction and finite lifetime of the particles.Since no magnetic field or spin-orbit interaction is re-quired, this system provides a new kind of easily im-plementable optical logic.

Keywords:

Compact localized state

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F8.06

First Principles Study of a Phase Change Mechanism of $GeTe/Sb_2Te_3$ Superlattice Structure

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Abstract:

Because of the development of electronic device technologies, we also need to explore the next-generation nonvolatile memory technologies that work not only with low power but also with fast reaction time. Recent studies discovered that phase change memory with a superlattice structure composed of Ge, Sb, and Te elements is a strong candidate for it. In the experiment, the electrical resistivity in the perpendicular direction to the superlattice planes becomes 100 times higher after irradiating the sample with a laser beam. However, the phase change mechanism and even its second stable structure are still controversial. Therefore, we study the physical characteristics of its first and second stable structures, performing first-principles calculations based on the density functional theory, and compared our results to the experimental results. It is found that our calculated XRD peaks of Ge_2Sb_2Te5 match well with those experimentally observed for the sample only in the high-resistance states (HRS). Our results also show that the electrical resistivity of the superlattice gets much higher as the portion of the $Ge_2Sb_2Te_5$ structure increases in the superlattice structure. The differences between XPS peak profiles of the Ge 3d state in HRS and LRS are also discussed. Given that these results correspond to the experimental measurements, we could conclude that the formation of $Ge_2Sb_2Te_5$ is key to understand the phase change process. Finally, we will introduce a few approaches that could enhance the phase transition properties.

Keywords:

GeTe/Sb2Te3, Phase change memory

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F8.07

Deep Convolutional Neural Network for Determining the Unit Cell Structure of Lead Titanate

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Abstract:

Piezoelectric materials change their unit cell structures under external stresses or electric fields. Macroscopic piezoelectric coefficients, rather than the exact locations of the composing atoms, have been measured to understand the materials properties. Figuring out structural information, using x-ray diffraction (XRD) pattern, is very important to understand a material because we can predict other physical properties such as the phase transition and the electrical conductivity from the geometrical structure. Recently deep learning techniques are widely employed in the various analyses of data whose formats are images, voices, or even sequences. Although there are already many applications of deep learning techniques to analysis powder XRD images to classify the types of crystal structures, there were few attempts that are using single crystal XRD image data to classify the atomic unit cell structures.
In this paper, we focus to predict the unit cell structures of Lead Titanate($PbTiO_3$) especially on the comparative z axis locations of O^{2-}(2), O^{2-}(1), and Ti^{4+}, which are sensitive to the external force exerted on the sample. Each relative z axis location is quantized to the 11 levels. The total number of classes to classify is 1331(11×11×11). For each class, 100 samples of images are generated for training and 10 samples of images are generated for testing. The value of each pixel of the XRD images is simulated by taking the value of Patterson function at the corresponding integer Miller index added by the random noise following the Poisson distribution. Through this process, (11, 11, 11) tensor is generated which is used as the input of the Deep Convolutional Neural Network(DCNN). By tuning the hyperparameters of DCNN, 99% of classification accuracy was gained after 3000 epochs.
DCNN structure was selected to visualize the filters for intuitive understanding. The visualization process is in progress. Given a standardized format of experimental data obtained with effective noise reduction, this DCNN structure is proven to be very effective in identifying the unit cell structures of piezoelectric materials at certain circumstances.

Keywords:

Convolutional Neural Network, X-ray Diffraction, Unit Cell Structure, Lead Titanate, Classification

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F9.01

Ab initio study of remote heteroepitaxial growth of GaN on the graphene/Al_2O_3 substrate

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Abstract:

Recently, two-dimensional (2D) materials have been actively studied in various research fields. Among 2D materials, graphene has excellent mechanical, electrical, and optical properties due to the unique electronic structure. Therefore, the study of graphene based heterostructures has been increasingly popular in both academia and industry. In this study, we have investigated the heteroepitaxial growth of GaN on the graphene/Al_2O_3 substrate using density functional theory calculations. Here, we focus on the roles of both graphene and Al_2O_3, forming the graphene/Al_2O_3 substrate on which GaN grows via the remote heteroepitaxy. Especially, we clarify how the heteroepitaxy of GaN on the substrate is made possible through graphene. In addition, it is confirmed that Al_2O_3 affects the GaN growth regardless of the in-plane crystal orientation of graphene.

Keywords:

Ab initio, Graphene, Al2O3, GaN, Remote heteroepitaxial growth

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F9.02

First principles study of $TiCl_4$ adsorption on bare and hydroxyl terminated alpha-phase Al_2O_3 during TiN ALD

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Abstract:

In the fabrication of 3D V-NAND, one of technical issues is formation of W voids due to very deep trench in 128-layer VNAND. During this process, TiN layer is used for W adhesion layer and F diffusion barrier layer between Al2O3 layer and W layer. When depositing TiN layer, it has been found that TiN grow as island form, and researchers empirically found that hydroxyl terminated Al2O3 is good for uniformly depositing TiN layer. To understand the role of –OH in this process, we have studied the effects of hydroxyl termination on alpha-phase Al2O3 on TiCl4 adsorption during TiN atomic layer deposition using density functional theory (DFT) calculation. We selected two surfaces, bare and hydroxyl-terminated alpha-Al2O3 (0001) surface for $TiCl_4$ adsorption for compassion. On bare alpha-Al2O3 (0001) surface, $TiCl_4$ is dissociated and chemisorbed with surface. Ti atom is bonded with three oxygen atoms of Al2O3 surface, and two Cl atoms are bonded with surface Al atoms. This step is exothermic and occurs without energy barrier. The process of moving Cl atom from Ti to surface Al atoms are endothermic and have activation energy of 2.91 eV to 3.28 eV. Charge density difference and bader charge analysis were also used to understand the bonding between Cl atom and surface Al atom. These results show that there are strong bond between surface Al atom and Cl atom, which hinders removal of Cl atom. In contrast, on hydroxyl terminated alpha-Al2O3 surface, there are four –OH on 2X2 supercell, and $TiCl_4$ molecule reacts with one –OH. This step is also exothermic and energetically favorable. After adsorption, Cl atom from TiCl4 and H atom from –OH are removed as HCl with relatively low activation energy of 0.76 eV. This shows that –OH help to remove Cl as a form of HCl gas. According to above results, OH-terminated alpha-Al2O3 (0001) surface helps removing Cl atom from surface, which is half cycle of TiN atomic layer deposition.

Keywords:

: DFT, First principles, ALD, VNAND, TiN, Al2O3

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F9.03

Electrohydrodynamic-Driven Nanostructure Replica Transferred Surface Enhanced Raman Scattering Active Swab for Rapid Detection of Low-Concentrated Substances

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Abstract:

For the detection of a low concentrated (< 10^{-8}M) hazardous material, surface enhanced raman scattering (SERS) can be served as an effective analytical tool. Conventional SERS swabs with various nanostructures have been fabricated via various chemical synthesis routes. Although extensive literature has been documented, they still suffer from poor signal reproducibility and non-uniform intensity due to limited control over forming reproducible structures by chemical method. Herein, we explored the electrohydrodynamic (EHD) replication method in combination with facile pattern transfer of replicated nanostructures to a swab surface to realize SERS swabs with great flexibility enabling to overcome aforementioned limitations. Upon replicating a desirable nanostructure pattern on polymer films by EHD, the patterned replica was then transferred onto swab surface. This allows to remove the defects of swab's hollow structure. In addition, our SERS active swabbing can be exploited to collect low-concentrated analyte on a non-planar and rough surface. This facile SERS active swab preparation method was demonstrated to achieve high enhancement factor of intensity (> 10^7) with low relative standard deviation (RSD) less than 10%.

Keywords:

Electrohydrodynamic-Driven Nanostructure Replica, urface Enhanced Raman Scattering, swab

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F9.04

Laser-induced crystalline-phase transformation for hematite nanorod photoelectrochemical cells

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Abstract:

Solar water splitting that utilizes solar energy as a permanent energy source has been received massive attention as an eco-friendly method to produce hydrogen fuel. Hematite (α-Fe_2O_3), an n-type semiconductor, has been regarded as one of the most promising materials for photoelectrochemical (PEC) water splitting because of its bandgap (~2.1 eV) that is adequate to absorb solar spectrum, chemical stability, non-toxicity, and low cost. Typically, a high-temperature annealing process at more than 700 ˚C is necessary to improve the water splitting performance of the hematite nanorods (NRs) grown on the fluorine-doped tin oxide (FTO) substrates. However, some critical problems can be incurred during the high-temperature annealing process, such as conductivity degradation of the FTO film and deformation of the glass substrate. Herein, we introduce a laser annealing process for the fabrication of hematite NR photoanodes without damage on the substrates. The developed laser-induced phase transformation (LIPT) process yields the hematite NRs with the enhanced physical and electrochemical properties. Owing to the improved properties, the LIPT-processed hematite NR photoanodes exhibit an enhanced PEC performance compared to those processed by the conventional annealing process.

Keywords:

Solar water splitting, Hydrogen, Hematite, Laser processing

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F9.06

Fog Collection Based on Anisotropic Wetting for Secondary Electrohydrodynamic-induced Hybrid Structures

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Abstract:

Taking lessons from plant surfaces such as a rice leaf or a bamboo leaf, extensive effort has been devoted to fabricating the anisotropic arrays of micro-/nanoscale features, to explore anisotropic droplet spreading. Nonetheless, precise engineering of the density and continuity of three-phase contact line (TCL) for anisotropic wetting still remains a great challenge without resorting to chemical modifications and costly procedures. In this work, we investigated secondary electrohydrodynamic instability of low-viscosity polymer film to produce the secondary nanosized pattern formation between the micron-sized grooves by controlling the non-parametric time-scale parameter, $1/\tau_m$, ($> 10^4$). We experimentally demonstrated the facile morphological control over anisotropic wettability. Further, without any chemical modifications, anisotropic hydrophilic surface required for both droplet condensation and removal was fabricated by secondary phase instability of polymer resists, which outperforms the water collection efficiency of conventional (isotropic) hydrophilic surface in water harvesting applications (~150 $mg/cm^2{\cdot}h$) with excellent durability.

Keywords:

Fog Collection, Anisotropic Wetting, Secondary Electrohydrodynamic-induced Hybrid Structures

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F10.01

Raman studies on interlayer vibration and structural phase transition in few-layer 1T′ and T_d $MoTe_2$

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Abstract:

We performed polarized Raman spectroscopy on mechanically exfoliated few-layer $MoTe_2$ samples and observed both 1T′ and T_d phase at room temperature. Few-layer 1T′ and T_d $MoTe_2$ exhibited a significant difference especially in interlayer vibration modes, and they were systematically investigated using the group theory analysis. We also extracted the interlayer coupling strength using the linear chain model and observed the strong in-plane anisotropy in both phases. Furthermore, temperature-dependent Raman measurements showed a peculiar phase transition behavior in few-layer 1T′ $MoTe_2$. In contrast to bulk 1T′ $MoTe_2$ crystals where the phase transition to the T_d phase occurs at ~250 K, few-layer samples exhibited the phase transition at much lower temperatures, mostly below 80 K, and it was completely suppressed in 3L and 4L samples. Noticeably, even in the same thickness, the phase transition behavior and the critical temperature varied dramatically from sample to sample. The intermediate phases, neither 1T′ or T_d phase, were observed with different interlayer vibration modes, and this suggests that several metastable phases exist with similar total energies.

Keywords:

MoTe2, polarized Raman spectroscopy, interlayer vibration modes, group theory analysis, structural phase transition

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F10.02

Quasi-Fermi Level Splitting in Epitaxial Heterobilayers of WS_2 and MoS_2

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Abstract:

Transition metal dichalcogenides (TMDs) have enabled the development of novel high-performance optoelectronic devices. Since type-II van der Waals heterostructures are helpful for the separation of excitons and suppression of their recombination, the heterostructures can exhibit improved optical absorption and carrier transport. Therefore, TMD-heterostructures are considered as candidates to realize high-efficiency photovoltaic devices. In this work, we fabricated not only monolayers of MoS_2 and WS_2 but also heterobilayers of WS_2/MoS_2 and MoS_2/WS_2 on Al_2O_3 substrates using sulfurization of pre-deposited transition metals. The Raman and PL spectroscopy measurements confirmed the epitaxial growth of high-quality TMD layers. In particular, efficient interlayer relaxation of excitons and improved absorption could be observed in the heterobilayers. The surface photovoltage (SPV) characteristics of the samples were studied using Kelvin probe force microscopy. The SPV signals are determined by the splitting of the quasi-Fermi levels in our TMD layers, which corresponds to the upper limit of the output voltage of the TMD-based photovoltaic device. This work demonstrates that the SPV measurements directly reveal light-induced quasi-Fermi level splitting in the TMD layers without any electrode patterning.

Keywords:

Quasi-Fermi level splitting, surface photovoltage, Kelvin probe force microscopy, WS2/MoS2 heterostructure

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F10.04

Atomic-Layer-Confined Multiple Quantum Wells Enabled by Monolithic Bandgap Engineering of Transition Metal Dichalcogenides

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Abstract:

Two-dimensional (2D) semiconducting transition metal dichalcogenides (TMDs) have attracted enormous attention because of exceptional optical properties such as large exciton binding energy, and strong light-matter interaction at the ultimate thickness limit. Such remarkable properties make them promising for high-performance light-emitting devices such as LEDs, LASERs, and single-photon emitters. However, high efficiency in the luminescence of those 2D semiconductors is inherently limited to monolayer regime due to indirect-to-direct bandgap transition and intrinsic high quantum yield should be realized for practical applications. In addition, constructing a quantum well structure with type I band alignment is difficult because most TMDs form the type II heterojunctions. Consequently, securing the large active volume and confining the excitons in 2D semiconductor heterostructures still remain a huge challenge. Here, we demonstrate the novel approach to fabricate atomic-layer-confined multiple quantum wells (MQWs) via monolithic bandgap engineering of TMDs and artificial van der Waals stacking. A fundamental building block of QWs, the WO_X/WSe_2 hetero-bilayer with type-I band alignment, was prepared by monolithic oxidation of the WSe_2 bilayer, followed by stacking the blocks into the MQWs. Unlike the case of stacking monolayers only, the photoluminescence (PL) characteristic was not quenched in this MQWs, and the super-linear increases of PL with the number of QWs were achieved. This is presumably because the WO_X layer acts as a quantum-barrier layer between two adjacent monolayers, allowing to preserve the direct bandgap nature of monolayers even in the staked heterostructure. By examining the band structure of WO_X/WSe_2, we found that the hetero-bilayer WO_X/WSe_2 constitutes the quantum well for efficient exciton confinement and radiative recombination. Furthermore, the quantum-confined radiative recombination in MQWs was verified by a large exciton binding energy of 193 meV and a short exciton lifetime of 170 ps. This work paves the way toward monolithic integration of 2D superlattices for novel quantum optoelectronics.

Keywords:

Two-dimensional materials, Transition Metal Dichalcogenides, Monolithic bandgap engineering, Photoluminescence, Multiple-Quantum-Wells

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F10.05

Surface Photovoltage Spectroscopy Study of MoS_2 Monolayers on Au Nanostructures

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Abstract:

In hybrid systems consisting of transition metal dichalcogenides (TMDs) and metal nanostructures, considerable research efforts have been focused on investigation of the intriguing physical phenomena. We fabricated two different kinds of hybrid systems; MoS_2 monolayer flakes on Au nanodot (ND) and nanohole (NH) arrays. Enhanced PL intensity was observed in the MoS_2 monolayers on both ND and NH arrays, compared with those on SiO_2/Si substrates and planar Au thin films. Angle-resolved reflectance spectra of MoS_2/ND and MoS_2/NH had different angle-dependence which is originated from excitation of propagating surface plasmon polaritons. In this work, we investigated behaviors of photo-generated charge carriers in MoS_2/ND and MoS_2/NH by surface photovoltage (SPV) spectroscopy. Local electromagnetic field maps obtained by finite-difference time-domain (FDTD) method explained the difference of the SPV spectra between MoS_2/ND and MoS_2/NH. Furthermore, surface potential maps, obtained by Kelvin probe force microscopy, suggested the distinct spatial distribution of photo-generated charges in MoS_2/ND and MoS_2/NH under illumination. These findings can be a useful means of optimizing optoelectronic characteristics and improving the performance of MoS_2-plasmonics devices.

Keywords:

MoS2, localized surface plasmon, surface plasmon polariton, photoluminescence, surface photovoltage

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F10.06

Expanding Chemical Enhancement Mechanism of SERS by using WS_2

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Abstract:

Surface enhanced Raman scattering (SERS) is a technique which overcomes a low intensity of Raman scattering by adsorbing molecules on metal or semiconductor substrates. There are two different mechanisms in SERS, one is electromagnetic enhancement (EM) and the other is chemical enhancement (CE) which is related to charge transfer (CT) mechanism. By using the semiconductor as a substrate, we can study CE mechanism by excluding EM mechanism.
In previous non-metallic SERS studies, it was claimed that energy difference between molecular orbitals (HOMO or LUMO) and band edges of semiconductor is important. In our previous study using ZnO and GaN microstructure, we suggested the directionality of CT mechanism. In our experiment, we used WS_2, one of the transition metal dichalcogenides (TMDCs), as a substrate to study the directionality of CT mechanism further. We used an exfoliated WS_2 flake and 3 types of WS_2 nanosheets made under different temperature each of which looks like a flower shape to get a large surface area. We adsorbed Rhodamine 6G (R6G) molecules on WS_2 substrates. By this study, we can again suggest the directionality of CT mechanism, charge transfer from semiconductor's valence band to molecule's LUMO is more dominant for the SERS process than the charge transfer from molecule's HOMO to semiconductor's conduction band.

Keywords:

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F10.07

CO-induced Phase Transition of WS_2 and MoS_2 Nanocrystals: A DFT Study

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Abstract:

Transition metal dichalcogenide (TMD) which is a member of 2D materials has attracted significant attention due to its superb mechanical, electrical, optical, catalytic, and many other properties. Another important feature of TMD is that the different phases of it show distinction in these properties. This difference in material property leads to gap in performance when TMD is applied to several fields. Therefore, controlling the phase of TMD is crucial to accomplish desirable performance.
However, the difference in energy between two phases makes obtaining relatively unstable phase difficult. Hence, many research groups have found the ways to overcome this problem. Those ways include intercalating alkali metal ions between layers of TMD, applying mechanical strain to TMD layer, and formation of S vacancies on TMD layer.
Recently, our colleagues obtained the experimental results that unstable T phase WS_2 and MoS_2 were obtained by annealing with CO/CO_2 gas mixture and observed that T phase WS_2 was obtained in higher annealing temperature and CO mole fraction than the case of MoS_2. To elucidate this difference, we conducted DFT calculations. We calculated the energies for the reaction steps of S vacancy formation by the reaction between CO and S of WS_2 and MoS_2 and S diffusion to the site of T phase. Before calculating the reaction energy, we checked that S vacancy on edge site was formed more easily than that on basal plane in both WS_2 and MoS_2. The results showed that the energy barrier for S vacancy formation on edge site and phase transition to T phase of WS_2 was higher than that of MoS_2. This DFT calculation result corresponds to the experimental result. Consequently, we confirmed that the phase transition of WS_2 and MoS_2 can be achieved by S vacancy formation on edge sites followed by diffusion of S, and the difference in the condition for phase transition to T phase between WS_2 and MoS_2 can be explained by DFT calculations on the reaction energies for S vacancy formation and S diffusion.

Keywords:

DFT, TMD, Phase transition, S vacancy

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F10.08

Effect of stacking order change in 2D MoS_2, WS_2 heterostructure with Raman spectroscopy

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Abstract:

Transition metal dichalcogenide (TMD) is attracting a lot of attention because of its unique properties and various applicability, especially in the electrical and optical field. TMD has graphene-like layered structure and shows distinctive characteristics depending on the number of layers. Interest in heterostructure based on 2D TMD are also increasing with recent advances in TMD material research. It gives adjustable band structure, enhanced photo absorption and high-efficiency charge transfer between materials. In this study, we measure Raman spectra of the CVD-grown monolayer MoS_2, WS_2 and MoS_2/WS_2 and WS_2/MoS_2 heterostructures at 488nm. Raman spectroscopy is an effective research tool that can study lattice vibration. In-plane $E^1{}_{2g}$ and out-of-plane $A^1{}_g$ peak of MoS_2 and WS_2 show different peak shift pattern by controlling the stacking order of the heterostructure. These results could be caused by the difference in the mass of W and Mo atoms affecting the strain between stacking layer and it is estimated that there is also an effect of doping. Our study will not only provide the basic properties of TMD materials, but also explore the possibilities of applications of heterostructure.

Keywords:

MoS2, WS2, Heterostructure, Raman spectroscopy

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F12.01

Emergence of motile structures via symmetry breaking in active fluids

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Abstract:

Living systems maintain their structures and functions by staying far from equilibrium, which they achieve by taking and dissipating energy without any external bias. Active matter, which autonomously converts stored or ambient energy into systematic motion, provides a natural framework for studying the physics of such systems. Unlike the conventional nonequilibrium systems driven by boundary reservoirs or global external fields, active matter is driven out of equilibrium at the level of each particle, which leads to a plethora of novel collective behaviors. In this talk, I will focus on how large-scale motile structures can emerge in a fluid consisting of active matter (“active fluid") only by immersing passive objects in it. While the motion of the latter objects is generally suppressed at equilibrium, in an active fluid, there is a positive feedback mechanism that leads to a sustained motion of the object via spontaneous symmetry breaking. This mechanism can generically be found in a broad range of active fluids, with potential applications to biological transport and colloidal engines.

Keywords:

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F12.02

Langevin dynamics of an active Brownian particle in a viscoelastic polymer environment

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Abstract:

Active particles in a viscoelastic environment are ubiquitous in nature, with examples such as the motion of ATP-consuming molecules attached to a biological polymer, a Janus particle confined to a polymer network, to name a few. Despite a decade-long investigation on the active particle and its out-of-equilibrium properties, it remains a lack of understanding of the dynamics of active particles in a viscoelastic environment. To get an insight into such a viscoelastic active system, we set up a minimal model, where an active Brownian particle (ABP) is cross-linked to a star polymer of functionality f in a viscous fluid. The ABP has self-propelled motion from its own energy consumption, but due to the viscoelastic feedback from the polymer, it attains a strong non-Markovian anomalous motion in general. We have performed extensive Langevin dynamics simulations on this system at various conditions and, also, analytically solved the same system in the simplest case. Our study shows that the dynamics of ABP cross-linker is gaussian and subdiffusive with the scaling $\langle \Delta \mathbf{R}^2(t) \rangle \sim t^\alpha$ with $\alpha \le 1/2$. In the Brownian limit, it is well-known that the motion of a Brownian particle in a Rouse polymer chain follows fractional Brownian motion (FBM) of $\alpha = 1/2$. Our exact theory shows that it occurs a logarithmic growth ($\sim \ln t$) of the mean squared displacement (MSD) because of active random motion in the viscoelastic polymer environment, which turns out to be the origin of the observed subdiffusion of $\alpha < 1/2$. We find that the anomalous diffusion of the active cross-linker is governed by a fractional Langevin equation with two distinct--thermal and athermal--noises.

Keywords:

Active Brownian particle, Langevin dynamics simulation, Viscoelastic feedback, Anomalous diffusion, Rouse model

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F12.03

Fluctuation dissipation theorem for energy eigenstates

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Abstract:

We investigate whether the fluctuation dissipation theorem (FDT) is obeyed by isolated quantum systems in an energy eigenstate. We derive the formal expression for two-time correlation functions in the energy eigenstates. With the help of the eigenstate thermalization hypothesis, the two-time correlation functions are shown to satisfy the Kubo-Martin-Schwinger condition, which is the sufficient and necessary condition for the FDT. With extensive numerical works for the XXZ spin chain model, we confirm our theory for the FDT.

Keywords:

fluctuation dissipation theorem, eigenstate thermalization hypothesis, XXZ spin chain

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F12.04

Motility induced by symmetry breaking in an active fluid

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Abstract:

It is well known that an asymmetric object immersed in an active fluid becomes motile through the rectification of active fluctuations. In this study, we theoretically show that even a symmetric object in an active fluid can gain motility due to a “negative drag force" that applies in the direction of the object’s velocity. This effect leads to spontaneous symmetry-breaking transitions associated with bifurcations of the steady-state velocity of the symmetric object. While previous reports [1,2] of similar effects require the presence of polar or nematic order in the active fluid, our mechanism is more generically applicable even in dilute and disordered fluids. Moreover, the mechanism can induce both discontinuous and continuous transitions in the motility of the object, whose hallmarks are numerically checked.

[1] E. Tjhung, D. Marenduzzo, and M. E. Cates, Proc. Natl. Acad. Sci. **109**, 12381 (2012).
[2] De Magistris et al., Soft Matter **10**, 7826 (2014).

Keywords:

Active matter, Negative motility, Spontaneous symmetry breaking, Phase transition

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F12.05

Membrane fluctuations encapsulating active matters

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Abstract:

A cell body is full of cytoplasm, ribosomes, etc. Not only do such contents make entropic effect in a cell body, but also contain various chemical or enzymatic reactions, which may exert active forces to its membrane. In this study, to describe the influence of inner contents onto the membrane, we encapsulated active matter into GUV (Giant unilamellar vesicle). The degree of activity of encapsulated matters could be controlled by external magnetic field in XY-plane. We measured membrane fluctuation through GUV contour analysis.

Keywords:

GUV, Membrane, fluctuation

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F12.06

Effect of magnetic field on the dream engine condition

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Abstract:

It is important to design an engine with high performance. Thus, people tried to realize an ideal engine with the Carnot efficiency and a finite power simultaneously, referred to as a dream engine. In the frame of the classical thermodynamics, any heat engine can never be a dream engine due to the second law of thermodynamics. However, it was reported that a system with broken Onsager symmetry can operate as a dream engine in the linear response regime [1]. In a study on a concrete example [2], it was turned out that it is the stability condition that prohibits the dream engine. These results imply that the second law is insufficient to prohibit the dream engine when the time-reversal symmetry is broken. In this context, we investigate how magnetic field influences the relation between the second law and the dream engine condition in a system far from the linear response regime. To do this, we study a solvable Brownian engine model with magnetic field. The system obeys the Onsager symmetry, and thus the dream engine condition is always forbidden by the second law in the linear response regime. In the far from equilibrium regime, we find that the system can achieve the dream engine condition when the magnetic field is stronger than a given threshold strength. The result shows that if the degree of broken time-reversal-symmetry is weak, the second law is sufficient to prohibit the dream engine. We also verify that the dream engine is always impossible due to the stability condition. The results extend our understanding of the effect of broken time-reversal symmetry on the relation between the second law and the dream engine beyond the linear response regime.

[1] G. Benenti, K. Saito, and G. Casati, Phys. Rev. Lett. **106**, 230602 (2011).
[2] J. S. Lee, J.-M. Park, H.-M. Chun, J. Um, and H. Park, Phys. Rev. E **101**, 052132 (2020).

Keywords:

heat engine, trade-off relation on power and efficiency, stochastic thermodynamics

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F12.07

Data dependence of the resolution-relevance tradeoff in unsupervised learning

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Abstract:

When creating a generative model with an artificial neural network, one should choose the appropriate size of latent space. Too narrow latent space cannot extract sufficient information from data, while too broad latent space cannot filter out meaningless information. The resolution-relevance tradeoff theory [1] proposes an information-theoretical perspective on this issue. In this study, we apply the theory to the Restricted Boltzmann machine and explore how the statistical features of the data affect the optimal size of latent space. Using artificial patterns with tunable signal-to-noise ratio as well as the 2D Ising spin patterns generated at different temperatures, we check how the fluctuation properties of the data affect the resolution-relevance tradeoff. Then we critically assess how well the output data generated at the tradeoff describes the statistical characteristics of the original data.

[1] R. J. Cubero, J. Jo, M. Marsili, Y. Roudi, and J. Song, J. Stat. Mech. 2019, 063402 (2019).

Keywords:

machine learning, unsupervised learning, restricted boltzmann machine, artificial neural network

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F12.08

Deep reinforcement learning for feedback-controlled flashing ratchets

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Abstract:

A flashing ratchet is a nonequilibrium model that induces a net current of Brownian particles in a spatially periodic asymmetric potential which can be temporally switched on and off. The net current of the particles in this system can be greatly improved by feedback control based on the particle position. There are several hand-designed feedback algorithms for maximizing the current, but they are not the optimal policy for a moderate number of particles and require prior information of the system as well. In this study, we use deep reinforcement learning (RL) for finding the optimal policy, and the result shows that deep RL can outperform the hand-designed policies. Additionally, in a time-delayed feedback situation, we demonstrate that deep RL is also better than the previous hand-designed strategies.

Keywords:

Deep reinforcement learning, Nonequilibrium physics, Flashing ratchets

F13.01

물리교육에서 이론과 실행간 격차에 대한 이해

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Abstract:

물리교사 양성과정에서 예비교사들은 물리학습지도와 관련된 이론, 즉 학습이론과 학습지도모형 및 지도전략 등을 배우고, 임용시험을 통해 물리교사로 활동을 하게 된다. 그러나 최근 연구에서 과학교사들이 알고 있는 교육이론들 중 실제 사용율이 26%에 불과하다는 보고가 있듯, 교육분야에서 이론과 실행간 격차에 대한 보고들이 많이 있어왔다. 본 발표에서는 교육 분야에서 이론과 실제간 격차에 대한 국내외 연구결과들을 살펴보고, 물리교육에서 이론과 실제간 격차를 어떻게 이해해야 하고, 나아가 격차의 해소를 위해 어떠한 노력이 필요한지를 논의하고자 한다. 이를 위해 그러한 노력의 일환으로 본 발표자가 수행했던 교수-교사 협력에 의한 과학(물리)수업 개선 연구를 소개하고, 이 과정에서 이론과 실행간 격차 해소를 위해 이론가로서 대학의 교수들에게 어떠한 인식의 변화가 필요하고, 그러한 변화를 기반으로 교사교육에서 필요한 변화의 방향에 대해서도 논의하고자 한다.

Keywords:

teacher education, theory and practice

F13.02

물리예비교사양성에서 탐구 교육

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Abstract:

탐구는 과학 학습에서 과학이론학습과 함께 가장 중요하게 여겨지는 영역으로 과학을 다른 학문과 구별짓는 요소이다. 따라서 교육과정에서도 탐구를 매우 중요하게 다루고 있고, 국제적인 교육개혁에서도 탐구 교육을 강조하고 있다. 우리나라에서도 2007년 개정 교육과정에서 '자유탐구'를 포함시켰으며, 2015 개정 교육과정에서는 '과학탐구실험' 교과목을 신설하기도 했다. 그러나 과학교사들은 학생들의 탐구를 지도하는데 계속된 어려움을 갖고 있다. 이번 발표에서는 물리예비교사양성에서 탐구교육이 어떻게 이루어지고 있는지 현황을 분석하고, 일부 대학의 사례를 제시하여 예비교사의 탐구지도역량을 강화하기 위한 방안을 논의하고자 한다. 특히 예비교사간의 상호작용을 통해 탐구 수행과 탐구 지도를 체험할 수 있는 교과목 사례를 제시할 것이다.

Keywords:

물리교사, 예비교사, 탐구, 탐구교육

F13.03

물리 교육과정 개정과 교사교육의 방향 탐색: 고등학교 현대물리학 교육의 어려움을 중심으로

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Abstract:

09개정 교육과정 이 후, 고등학교 물리교과서에는 상대성이론과 양자역학이 포함되어오고 있다. 학교현장에서는 현대물리학의 두 가지 핵심 기둥을 가르치는 것에 대한 기대도 있지만, 새로운 내용의 갑작스런 추가로 인한 많은 어려움을 겪어오고 있다. 본 연구에서는 이와 같은 현장의 어려움에 관한 선행연구들을 분석하고, 대학생들이 고등학교 재학 시 경험한 현대물리학(특히, 상대성이론)학습의 어려움을 조사하였다. 그리고 학교 현장에서 경험하고 있는 현대물리학 교육의 어려움을 해소할 수 있는 방안을 제안하였다.

Keywords:

현대물리학 교육의 어려움, 교육과정 개정, 물리교사교육

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F13.04

모든 이를 위한 물리교육에 대한 소고

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Abstract:

내년 2월이면 2015개정 교육과정으로 고등학교 3년의 교육을 받은 학생들이 졸업을 한다. 이들이 대학에 들어가서 혹은 취업을 해서 발휘하는 능력의 일부는 교육과정의 효과로 간주할 수 있을 것이다. 고등학교 교육에서 물리 영역의 일부 내용은 필수교과인 통합과학에 포함이 되었고, 독립적인 교과로는 선택교과로 제공되고 있다. 작년도 선택과목 수강 현황에 따르면 일반선택 교과인 물리학Ⅰ은 전국의 25.2%의 학생이 선택하여 이수하였고, 진로선택인 물리학Ⅱ는 8.9%의 학생이 이수하였다. 교육과정의 구조에 따르면 일반선택인 물리학Ⅰ은 일반인들에게 필요한 기초적인 물리를 다루어야 하고, 물리학 Ⅱ는 이공계 진로를 염두에 둔 학생이 선택하여 이수하는 강좌이다. 본 발표에서는 물리의 저변 확대를 위해 공통교과에 포함될 물리 교육과정의 성격 및 내용에 대한 논의를 하고자 한다. 해외 교육과정과 2015 개정 과학과 교육과정의 물리 교육과정을 간단히 고찰하고, 이공계 진학을 염두에 두지 않은 학생들이 선택할 물리교과목의 교육목표, 교육내용 및 교육방법에 대한 논의를 개진하고자 한다. 이러한 논의를 바탕으로 물리 교과의 일반선택 교과로서의 정당성과 필요성을 고찰하고자 한다.

Keywords:

물리 교육과정

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F14.01

핵융합 코어 플라즈마 붕괴 기작 및 제어 연구

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Abstract:

본 연구센터는 핵융합 코어 플라즈마 붕괴 현상의 기작을 이해하고 제어하는 기술을 확보하여 핵융합로 운전의 신뢰도와 안정성을 높이고자 한다. 붕괴 기작 및 제어 연구를 위해서 기 구축된 VEST 장치에 필요한 진단계를 추가하여 붕괴 특성 실험 데이터를 확보하고, KSTAR 붕괴 데이터를 더해 딥런닝 기반의 붕괴 예측 기술을 개발하고, KSTAR SPI 실험결과를 비선형 MHD 코드로 분석하여 붕괴 완화 기작을 도출하고, 붕괴 시 발생하는 탈출전자를 고속파와의 상호작용을 활용하여 완화하는 연구를 진행하고 있다. 1세부에서는 VEST 장치에서 발생하는 유사 붕괴 현상인 IRE (Internal Reconnection Event)에 초점을 맞추어 MHD 전조현상을 중심으로 IRE의 발생 기작 및 안정화와 관련된 다양한 현상의 진단 및 해석을 진행하고 있다. 자기진단과 톰슨 측정 결과를 활용하여 정확도를 높인 평형 재구성 결과를 Mirnov 신호와 고속 카메라 신호의 스펙트럼을 다양한 방법으로 분석하여 IRE 전후의 MHD 현상을 이해하여 IRE 발생 기작에 대한 연구를 수행하고 IRE 전후의 플라즈마 가열 및 회전 특성 변화를 광진단을 통하여 파악하여 IRE의 안정화에 대한 단초를 얻는 노력을 진행하고 있다. 2세부에서는 KSTAR의 붕괴 데이터를 활용하여 딥런닝 기반의 붕괴 예측 코드를 개발하여 80% 이상의 예측율을 달성하고 VEST IRE 데이터에의 적용을 준비하고 있으며 3D nonlinear MHD code JOREK을 KSTAR H-mode 에 적용하여 KSTAR SPI (Shattered Pellet Injection) 실험 결과를 해석하기 위한 준비를 마쳤다. 3세부에서는 탈출전자와 고속파의 상호 작용을 연구하기 위해 Hard X-ray 진단 시스템을 구축하고 측정된 에너지 스펙트럼과 자장탐침으로 측정된 파동 특성과 비교 연구를 진행하고 있다. 이러한 세 개의 세부과제의 연구 결과가 결합되면 붕괴 현상의 기작에 대한 이해와 더 나아가 이를 제어할 수 있는 방법을 찾을 수 있을 것으로 기대하고 있다.

Keywords:

코어 플라즈마 붕괴, 붕괴 기작 및 제어, 딥런닝 기반 붕괴 예측, 탈출전자와 고속파 상호작용

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F14.02

혁신적 디버터 열속 제어 처리 기술 거점 센터 연구 개발 현황

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Abstract:

Center for Innovative Diverto (CID)는 3개의 세부 그룹, 즉 경계플라즈마 물리 연구를 통하여 디버터로 들어오는 열속을 줄이는 디버터 구조 전산 모사 연구 그룹 (1세부, 총괄), 디버터 표면 안쪽에 hypervapotron 냉각 채널을 적용한 획기적 열속 처리 능력과 안정적 대면체 구조 설계 및 평가를 연구하는 그룹 (3세부), 그리고 디버터 모사 장치를 이용하여 1,3세부의 새로운 디버터의 열속 처리 성능을 검증함과 동시에PFC의 재료 손상을 연구하는 그룹 (2세부)으로 구성되며, 이러한 세 연구 그룹이 유기적으로 연결되어 혁신적으로 열속을 제어 및 처리하는 디버터 시스템 설계를 목표로 한다. 최근 1세부에서는 DIII-D에 사용되는 SAS와 유사한 슬롯 디버터를 KSTAR 에 적용하는 전산 모사 연구를 수행하여 원래 SAS 보다 훨씬 얕은 슬롯에서 탄소 불순물을 사용하지 않고 중수소 중성 입자만의 리사이클링으로부터 디테치먼트가 크게 향상되는 결과를 얻었다. 이는 차후 ITER나 K-DEMO에서 스퍼터링에 의한 불순물 양이 상대적으로 적은 텅스텐 디버터에 슬롯 형태를 약하게 얹는 것만으로도 디버터에 들어오는 열속을 크게 줄일 수 있음을 의미한다. 2세부에서는 열속 7 MWm^{-2}, 입자속 10^{22-23} $m^{-2}s^{-1}$의 실제 핵융합로 디버터와 유사한 수준의 열속/입자속을 내는 Applied-Field MPD thruster 기반 디버터 플라즈마 모사장치 개발을 성공하였다. 또한 12-14 mm 공간 분해능의 랭뮤어 탐침 12채널을 KSTAR의 central divertor에 설치하여 경계 플라즈마 데이터를 수집하고 있다. 3세부에서는 다양한 형태의 냉각 채널 실험을 수행하여, Hypervapotron과Swirl 원형 채널이 높은 임계열유속을 가진다는 것, 이에 더해 Hypervapotron의 열전달계수가 Swirl 원형 채널보다 25 ~ 30% 높고 차압은 1/3배까지 낮은 것을 확인함으로써 Hypervapotron 채널의 열수력학적 우수성을 실험적으로 입증하였다. 또한, Hypervapotron을 적용한 모노블락 플라즈마 대면체 설계 및 구조 해석, 성능 검증을 완료하였다.

Keywords:

디버터,디테치먼트,SOLPS,hypervapotron, MPD thruster, 디버터모사장치,랑뮤어탐침,냉각채널,swirl 원형 채널,임계열유속

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F14.03

플라즈마 불순물 및 경계 열속 연구센터

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Abstract:

본 센터에서는 핵융합 플라즈마의 노심에서 플라즈마 경계에 이르는 전영역에서 나타나는 다양한 불순물 관련 난제들을 해결하기 위해 불순물 관련 다양한 최첨단 진단계와 물리 전산해석 코드의 활용 및 주체적인 개발을 통해 연구를 수행한다. 거점센터의 세부 그룹 간의 유기적인 연구를 통하여 불순물을 보다 능동적으로 활용하여 플라즈마 경계 영역의 최대 난제 중 하나인 내벽 및 디버터 열속 완화의 실질적 구현을 최종 목표로 하고있다. 1세부에서는 KSTAR 플라즈마에서 D_2 연료개스와 N_2 등의 불순물 개스 주입을 통한 디버터-플라즈마 분리 달성 및 운전조건을 확립하였으며, 이를 바탕으로 ITER를 포함한 차세대 토카막 장치에서의 플라즈마-디버터 분리 시나리오를 예측하기 위한 scaling law확립에 기여할 수 있다. 또한 크립톤 개스 불순물 주입 실험을 통하여 ELM 억제, ITB 형성 등 여러 현상을 구현하였으며, 이를 심층적으로 분석하기 위해 플라즈마 회전을 고려한 폴로이달 단면의 비대칭적인 불순물 분포를 모사할 수 있는 KAIST Impurity Modelling (KIM) 코드를 개발하였다. KSTAR 및 ITER의 불순물 이미징 분광진단계의 제한된 시선을 극복하기 위한 토모그래피 알고리즘 개발을 통해 기존 진단계의 한계를 극복하였다. 2세부에서는 SOL 다채널 프로브 진단계의 채널을 기존 16개 에서 32채널로 증대시킴으로써 공간 및 시간 분해능을 향상시켜 KSTAR SOL 영역에서 세밀한 ELM blob의 관측을 가능하게 하였다. 3세부에서는 1세부의 KIM 코드와 연계하여 신고전 수송 전모사(NEO, PERFECT 코드 이용)를 진행하였으며 신고전 수송에 영향을 미치는 다양한 파라미터 분석을 통해 KSTAR 환경에서의 불순물 수송 모사 결과를 검증할 예정이다. 4세부에서는 불순물을 활용한 ELM 억제 및 디버터 열속 완화 구현을 위한 중성종 역할 분석을 위해EMC3-EIRENE 코드 전산해석을 통해 디버터 열속분포를 계산하였으며, APG(ASDEX Pressure Gauge) 진단계의 진공 및 불활성 기체(Ar, He) 내에서 전자방출 특성 확인 및 중성종에 따른 보정수치 실험적 확보하였다. 또한, FAC 원자분자 해석코드를 이용하여 1세부의 크립톤 실험 분석에 필수적인 원자 데이터 계산하여 제공하였으며 스펙트럼 모사를 성공적으로 수행하고 있다.

Keywords:

불순물 수송 해석, 플라즈마-디버터 분리현상, 디버터 열속 완화

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F15.01

Symmetry breaking in integrated photonics

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Abstract:

Symmetry breaking phenomena in the integrated photonics platforms are critically related to unidirectional propagation and bifurcation of optical modes, and therefore can play important roles in a number of areas, such as light source integration, optical mode locking, and optical information storage. In this presentation, we discuss the appearance of exceptional points involving the coalescence of both eigenvalues and eigenfunctions of non-Hermitian Hamiltonian in an open quantum system, such as a photonic resonator-waveguide system as well as a structurally symmetric optical coupler. In particular, asymmetric backscattering from multiple subwavelength-scale scatterers on the perimeter of microdisk resonators results various interesting phenomena, including optical chirality, partial directionality, and unidirectional filtering. We will explore possible applications of symmetry breaking for integrated photonic devices, including microdisk lasers and optical filters/switches.

Keywords:

symmetry breaking, bifurcation, non-Hermitian, integrated photonics

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F15.02

Evolution of photonic topological insulators from triangular lattice to honeycomb lattice

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Abstract:

We examined topological photonic effects in the honeycomb (HC) slab structures composed of two different air holes for breaking inversion symmetry. When two holes in the unit cell are not identical, the Dirac cone at the K-point in the HC lattice disappears and the photonic band-gap (PBG) creates . We systematically investigated the evolution of the Berry curvature from the HC to the triangular (TR) lattice structures which has only one hole in the unit cell. In spite of zero Berry curvature, the TR lattice structure has PTI behavior with the wide PBG. We numerically confirmed that the edge mode can be propagating losslessly and one-directionally along the interface formed by the TR lattice. We believe that this TR lattice structure is suitable for the basic platform of lossless photonic integrated circuits.

Keywords:

photonic topological insulator, honeycomb lattice, triangular lattice, one-directional propagation

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F15.03

Kerr nonlinear nanophotonics in microring resonator

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Abstract:

Integrated photonics plays a central role in modern science and technology, enabling experiments from nonlinear science to quantum information, ultraprecise measurements and sensing, and advanced applications like data communication and signal processing. Optical materials with favorable properties are essential for nanofabrication of integrated-photonics devices. In this presentation, we discuss conventional and new materials for integrated nonlinear photonics from silicon, silicon nitride, silica to aluminum nitride and tantalum pentoxide. Various properties of these materials such as stress, optical loss, nonlinearity, thermo-optic and electro-optic coefficients for applications in Kerr nonlinear photonics are presented.

Keywords:

F15.04

Chiral Plasmonic Nanosensors

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Abstract:

Chiral nanoparticles and nanostructures show interesting polarization effects that are many orders of magnitude stronger than what is observed in biomolecules. They are thus able to amplify small polarization changes which hold tremendous potential in sensing applications.

Here, we show that the shape and the dielectric function of individual chiral nanoparticles can be engineered by physical shadow growth method, termed nanoGLancing Angle Deposition (nanoGLAD). This allows us to achieve record sensitivities in local surface plasmon resonance (LSPR) sensing. Furthermore, through the same technique but with different material combination, we can combine multiple functionalities within our nanocolloids, such as a chiral shape, plasmonic activity, and a magnetic moment. A suspension of these nanocolloids is used for active nanorheology.
A common feature of the chiral spectroscopy for both the LSPR sensing and the nanorheology is that the chirality of the nanoparticle causes the polarization-dependent extinction spectrum with rich spectral features that is background free and thus can be precisely tracked. This makes the chiral nanosensors observable optically even in highly absorbing whole blood at an optical density of OD 3. It is thus possible to perform rheological measurements of the blood serum without the need to separate the blood cells.

In this talk, the fabrication of chiral nanocolloids will be presented and it will be shown how their spectral analysis enables new sensing tasks in complex biological fluids.

Keywords:

Plasmonics, Nanosensor, Glancing angle deposition, Chiral Spectroscopy

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F16.01

Non-Born-Oppenheimer Molecular Dynamics Observed by Coherent Nuclear Wave Packets

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Abstract:

The dynamics of a photophysical or photochemical process is typically described by the potential energy surfaces in terms of nuclear coordinates based on the Born–Oppenheimer (BO) approximation. A strong interaction between electrons and nuclei, conventionally occurring at conical intersections, however, breaks the BO approximation and has major consequences for the efficiency of a photoinitiated process. Despite its importance, related studies into the non-BO dynamics are scarce because the simultaneous electronic and nuclear (vibrational) wavefunctions is not easy.
Here, we investigate the non-BO dynamics of excited-state intramolecular proton transfer (ESIPT) occurring in 10-hydroxybenzo[h]quinoline (HBQ) with a wave packet analysis based on a transient absorption measurement with a time resolution of 11 fs and with a density functional theory-based model calculation. The coherences of the vibronically excited vibrational modes associated with the ESIPT are decoherenced by the reaction. Thus, the coherence vibrational spectrum of the product can be predicted once we know the decoherence dynamics. Two coherent vibrational modes at 237 and 794 cm^{-1} representing molecular dynamics on a diabatic surface in HBQ are identified, where the two modes are strong evidences for the presence of the non-BO characteristics. It is also revealed that the strong Coulomb field effect in HBQ leads to the completion of ESIPT within about two cycles of the OH stretching mode. The work paves the way for time-domain studies of molecular dynamics beyond the BO approximation in other photochemical reactions.

Keywords:

nonlinear spectroscopy, coherence, Born-Oppenheimer approximation, ultrafast dynamics

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F16.02

Dual-frequency operation of unshielded radio-frequency atomic magnetometer

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Abstract:

Abstract: We present an optically pumped radio-frequency atomic magnetometer with two different operating frequencies under unshielded condition. Two identical ^{87}Rb cells are resonant with different radio-frequencies adjusted by different static magnetic fields, which are independently controlled. Another natural Rb cell contains ^{87}Rb and ^{85}Rb together, and two different operation frequencies also can be realized under the same static magnetic field due to different gyromagnetic ratios. We compare the magnetometer sensitivity of those two kinds of dual-frequency operation systems, one with two identical cells and another with a cell containing Rb isotopes, to apply Frequency-shift keying(FSK) communication system in very low frequency (VLF) region.

Acknowledgment: This work was supported by the Institute of Information & communications Technology Planning & Evaluation(IITP) grant funded by the Korea government(MSIT) (No.2019-0-00007, Magnetic Field Communication Technology Based on 10pT Class Magnetic Field for Middle and Long Range)

Keywords:

radio-frequency atomic magnetometer, optically pumped magnetometer(OPM)

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F16.03

Diffusion induced spin relaxation of gaseous ^{129}Xe in the presence of magnetic gradients

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Abstract:

We measure the transverse spin relaxation time(T_2) of ^{129}Xe as a function of magnetic field gradients by using the free induction decay(FID) method. The spin relaxation of ^{129}Xe is induced by magnetic field change resulting from the diffusive motion of ^{129}Xe atoms in the presence of magnetic field gradients.

We find out that the transverse spin relaxation($1/T_2$) is a quadratic function of magnetic field gradients, and is a quartic function of gas cell dimension. We extract the diffusion constant of each atomic gas cell from the result of our experiments.

Keywords:

transverse spin relaxation, magnetic field gradients

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F16.04

Multi-step energy dissipation in a binary superfluid gas by a moving magnetic obstacle

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Abstract:

We present the observation of multi-step energy dissipation in a miscible two-component Bose-Einstein condensate by a moving magnetic obstacle. We confirm a superfluid behavior in spin channel of the condensate against the external spin perturbation, and as the obstacle velocity increases, the two types of energy dissipation are found with certain critical velocities: wave excitation, where spin density waves are generated with long wavelengths, and vortex excitation, where half-quantum vortices (HQVs) are created. In particular, the two-step transition from superfluid to wave excitation to vortex excitation is observed depending on the obstacle velocity and strength, which implies their hierarchy in superfluid systems. We also investigate the initial dynamics of HQV shedding, and find that the magnetic property of the obstacle differentiates the critical velocities for HQVs with the different core magnetization.

Keywords:

Spin superfluidity, Binary superfluid

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F16.05

Spontaneous defect formation in a thermally quenched Bose gas and the statistics of the defect number

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Abstract:

Kibble-Zurek mechanism (KZM) is an universal theory which describes the spontaneous defect formation in a system undergoing a continuous phase transition. The main prediction of KZM is that the number of generated defects shows power-law behavior with the system's quench rate and it has been experimentally tested with many controllable systems such as liquid crystals, trapped ions, and ultracold atomic gases. Recently, a simple model was proposed for describing the full statistics of the defect number in KZM, predicting that the defect number exhibits a binomial distribution characterized with a single probability value. In this talk, we present our experimental investigation on the statistics of the defect number with a Bose gas of rubidium atoms in an oblate trapping potential. We rapidly cooled down the sample across its superfluid critical point with a variable quench rate and measured the number of quantum vortices generated in the system. We observed that the variance of the measured vortex number shows the same scaling behavior with the quench rate as its mean value, supporting the model prediction. We will also describe the saturation behavior of the defect number in the fast quench regime and discuss its underlying mechanism.

Keywords:

Bose-Einstein condensate, Kibble-Zurek mechanism, Quantum vortex, Quench dynamics

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F16.06

Reflection of Helium clusters from two different square-wave gratings

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Abstract:

The reflection of ^{4}He beams from two different square-wave gratings has been interrogated at grazing-incidence conditions. The reflection square-wave gratings are a conventional square-wave grating and a dual-period grating. The conventional square-wave grating is composed of strips of width a = 0.9 mm which are separated with the period d = 1.8 mm. On the other hand, in the dual-period grating, 45 strips, whose width and center-to-center distance are 2.3 and 20 μm, respectively, replace the 0.9-mm wide strip of the conventional grating. From each grating, we scatter a helium beam containing the clusters as well as monomers and observe fully resolved matter-wave diffraction patterns. The reflectivity of dimers and trimers are increased markedly when the flat grating structure is replaced with parallel narrow strips while the reflection of monomers is decreased. Moreover, the qualitative trend of the experiment results from two different square-wave gratings is successfully explained. The behavior of the total reflectivity versus incidence angle is well explained by the relative mole fractions of clusters in the beam and a dominant reflection mechanism. The reflection from the conventional square-wave grating is explained by the quantum reflection theory [1], whereas, the reflection from the dual-period grating mainly follows the theory of the reflection from the periodic array of half planes [2, 3]. Our experiment paves the way for efficient differentiation of dimers and trimers in He beam from optimized dual-period grating. Also, since our data first provide the reflection of dimers from the flat grating structure, this will serve as a test bench for the theoretical models of quantum reflection.

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[3] H. Oberst, D. Kouznetsov, K. Shimizu, J. I. Fujita, and F. Shimizu, Phys. Rev. Lett. **94**, 013203 (2005).

Keywords:

Quantum reflection, Reflection from the periodic array of half planes, Beams of He clusters, Matter-wave, Reflection square-wave grating

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F16.07

Single-site Resolving ^{7}Li Quantum Gas Microscope

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Abstract:

Imaging and addressing individual atom in optical lattices with single-site resolution constitute a new approach to the study of quantum many-body problem. It provides microscopic information of quantum many-body states, such as correlation functions and entanglement entropy, and one can engineer arbitrary density pattern for the study of non-equilibrium quantum dynamics. In this presentation, we introduce a single site-resolved imaging system of 7Li atoms in two-dimensional square optical lattices. The optical lattice is made of 1064 nm light with 750 nm lattice spacing and generated by four-fold interference of retroreflected light. The maximal lattice depth can be reached to 4500 Er with its sideband frequency 1.57 MHz. For imaging and cooling the atoms, we apply Raman sideband cooling, where the scattered photons are collected by a high numerical aperture (NA=0.65) objective lens. The point spread function of our imaging system is 820 nm, 30% larger than the diffraction limit of the imaging system, still enough for having a single-site resolution.

Keywords:

quantum gas microscope, Bose-Einstein condensate, optical lattice

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F17.01

Nanopipette/QTF-AFM-based Nanofabrication and Surface Characterization

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Abstract:

Nanofabrication allows breakthrough on the fabrication process of the semiconductor industry including scientific research, which generally categorized with two ways as a top-down (photolithography, e-beam lithography, physical/chemical vapor deposition, nano-imprint technique, etc) and bottom-up (self-assembly, vapor-liquid-solid growth catalyst, etc) process. Among them, atomic force microscope-based lithography like dip-pen lithography as a bottom-up process has several advantages such as direct patterning, selective positioning (on-demand), and local fixing method. Here, I show the quartz tuning fork-atomic force microscopy-based nanofabrication combining with nanopipette which is one of the useful tool for small volume liquid delivery of micro/nanoscale objects such as micro/nanoscale biomolecules, organic/inorganic materials [1,2] with a guidance of naturally formed nanoscale water meniscus without tip breaking with precise control of tip/sample distance. Additionally, I demonstrate a nanopipette/QTF-AFM-based sorting technology with in situ optical characterization combining Raman spectroscopy.

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Keywords:

Nanofabrication, QTF-AFM, Nanopipette

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F17.02

Investigating Heterogeneous Defects in Two-Dimensional Transition Metal Dichalcogenides via Tip-Enhanced Raman Spectroscopy

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Abstract:

Two-dimensional transition metal dichalcogenides (TMDs) have been emerged as promising materials due to their unique electrical and optical properties. In particular, the monolayer TMDs have attracted much interest because they present the atomically thin thickness and the direct energy band gap in the visible wavelength range. Thus, the monolayer TMD has been in the limelight for (opto-)electronics and valleytronics. In order to apply monolayer TMDs to various applications, understanding basic characteristics is very essential because the physical properties of the TMDs can be easily affected by a number of factors such as defects, structural phases, synthesis methods, and so on. In this regard, tip-enhanced Raman spectroscopy (TERS) is a very powerful technique to investigate the monolayer TMDs, because TERS provides significantly high sensitivity down to a single molecule and high-spatial resolution beyond the diffraction limit. Accordingly, we described TERS studies of monolayer TMDs.
To perform the TERS, we devised the electrochemical etching method and found the condition for obtaining the TERS tip. We significantly increased the reproducibility of tip fabrication by automating the electrochemical etching system. In addition, we optimized the etching conditions for an etchant that comprised a KCl solution to which ethanol was added to overcome the limitations of the acidic etchant. The automated etching system significantly increases the yield rate of tip-fabrication reproducibility from 65 to 95%. The standard deviation of the radius of curvature decreased to 7.3 nm with an average radius of curvature of 30 nm.
On the basis of the optimization of TERS tip fabrication, we conducted the TERS for monolayer WS_2 synthesized on the gold substrate. We unveiled the defect-related Raman mode of monolayer WS_2. Moreover, we demonstrated that the S vacancies induce the red-shifted A_{1g} mode through the density functional theory calculation. Furthermore, using the TERS, we also investigated the single-crystalline hexagonal WS_2 monolayer. We identified that W- and S-edge domains in hexagonal WS_2 monolayer show shifted A_{1g} modes, respectively, with the defect-related Raman mode. Lastly, we also probed the lateral heterostructure MoS_2-WS_2 monolayer through the TERS. In the vicinity of the interface, we observed the defect-related Raman modes of MoS_2 and WS_2. We also identified the MoS_2 Raman modes in the WS_2 region, which indicates that the adlayer defects and the alloy-like interface.

Keywords:

tip-enhanced Raman spectroscopy, transition metal dichalcogenide, defect

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F17.03

Dynamic plasmonic tip-cavity from weak to strong coupling regime

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Abstract:

Plasmonic nano-cavities can enhance and control a range of light-matter interactions at the nanoscale. This manipulation of optical properties through plasmon coupling is allowed even at room temperature with extremely small mode volume. Yet, in most studies, static geometries are used which put constraints on the ability to control coupling strength and induce coupling to different emitters with the same cavity. To achieve the desired dynamic nano-cavity, I present plasmonic tip-cavity which enables reversible control of light-matter interactions from weak to strong coupling regime. The tip-cavity is formed between a plasmonic tip and a metal substrate and the cavity gap is dynamically controlled by atomic force feedback between them. In this talk, I will demonstrate a range of light-matter interactions in low-dimensional quantum materials, which are probed and controlled by plasmonic tip-cavity.

Keywords:

tip-enhanced nano-spectroscopy

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F18.01

전계방출 디스플레이를 위한 적색 Ba_2GdSbO_6: Eu^{3+} 형광체의 제작 및 특성

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Abstract:

전계방출 디스플레이 (FED: field-emission display)는 전통적인 음극선관에 대해 넓은 시야, 빠른 응답 시간, 경량, 자체 방출 및 높은 명암비와 같은 많은 장점을 가진 차세대 평면 패널 디스플레이로 유망한 것으로 여겨지고 있다. 3색 희토류 (rare-earth) 이온 활성화 발광 재료는 높은 발광효율, 오래 지속되는 시간 등의 뛰어난 성능으로 인해 FED에서 많은 주목을 받고 필수 구성 요소가 되었다. 본 발표에서, 새로운 적색 발광 Ba_2GdSbO_6: Eu^{3+} 형광체가 고온에서 간단한 고체반응법에 의해 합성되었다. 결정구조, 원소조성, 형태, 발광특성 및 열 안정성을 자세히 조사했다. Eu3+ 이온의 최적 도핑 농도는 Ba_2GdSbO_6 호스트 격자에서 결정되었으며, 자외선 여기 파장하에서 적색의 좁은 예리한 피크를 방출 하였고, 열 안정성은 매우 우수했다. 또한, 음극발광 (cathodoluminescence) 방출 스펙트럼과 높은 발광강도를 나타내어, 결과적으로 Ba_2GdSbO_6: Eu^{3+} 형광체가 전계방출 디스플레이에 잠재적으로 사용될 수 있음을 나타낸다.

Keywords:

Phosphors, Cathodoluminescence

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F18.02

An Epitaxially Separated GaN Thin Film As An Alternative to A Free-Standing GaN Thick Film

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Abstract:

By adopting polarity-inverted lateral overgrowth, a GaN thin film was grown on an SiO_2–patterned sapphire substrate. The issues associated with this approach were segmentation of GaN domains during epitaxial separation made possible by KOH wet etching and the suppression of GaN nucleation on sapphire during the regrowth. A careful design of experimental procedures allowed us to solve the related issues, and the details of fabrication of a GaN thin film, which is epitaxially separated from but physically attached to a substrate are provided. This type of a GaN thin film, epitaxially separated from but physically attached to a sapphire substrate, can be an interesting platform alternative to a free-standing GaN thick film.

Keywords:

GaN, epitaxial separation

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F18.03

Non-edge-triggered polarity inversion of a GaN thin film from (0001) to (000-1)

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Abstract:

The polarity of c-GaN domains, grown on c-sapphire patterned with an SiO2 mask, was reported to invert from (000-1) to (0001) at the boundary of a mask during epitaxial lateral overgrowth, but the polarity inversion from (0001) to (000-1) has not been reported yet. We, however, report that the polarity of m-facet-exposed c-GaN domains were inverted from (0001) to (000-1) during epitaxial lateral overgrowth. In addition to this intriguing polarity inversion, this polarity inversion occurred not at the edge of an SiO2 mask but on the flat region of mask far from the edge of SiO2 mask. The flow rate of NH3 seems to induce non-edge-triggered polarity inversion.

Keywords:

GaN, polarity inverted lateral overgrowth

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F18.04

Growth of composite TiO_x and $N:TiO_x$ thin films deposited by DC sputtering technique.

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Abstract:

직류 스퍼터링 방법으로 유리 기판위에 산화 티타늄 (TiO_x) 과 질소가 도핑된 산화 티타늄 ($N:TiO_x$) 박막을 성장하였다. 스퍼터링 박막 성장시에 플라즈마 종과 이들의 에너지를 플라즈마 분광법을 사용하여 분석함으로써 물질합성 과정 중 열역학적 요소를 포괄적으로 이해하려 시도 하였다. 특히, 반응 플라즈마 종들에 대한 이해를 바탕으로 박막의 화학 조성중 산소와 질소 량을 세밀하게 조절하므로써, 박막의 광학적 특성을 엔지니어링 하는데 초점을 두어 연구를 진행하였다. 참고로 산화 티타늄 계열의 소재의 에너지 밴드갭이 가시광선 영역에 존재한다면, 이의 환경/에너지 소자 관련 응용성의 확대는 괄목할 만하다. 박막 성장 방법과 특성 평가, 그리고 관련 플라즈마 분석등 자세한 연구 내용과 결과를 프리젠테이션으로 발표하도록 하겠다.

Keywords:

산화 티타늄, 플라즈마 분광법, 질소 도핑

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F18.05

Observation of cavity modes in GaN equilateral triangular structure

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Abstract:

GaN based optical cavities have great potential for various applications in optoelectronics, UV and visible lasers. And bottom-up synthesized cavity structures in GaN have attracted because GaN based cavities suffered significant quality factor spoiling due to etching damage from top-down fabrication process. So, we aimed to growth the GaN equilateral triangular structure without any etching process using MOCVD for high quality cavity. By photoluminescence measurement, we check whether there are modes in the cavity and measure quality factor of each modes.

Keywords:

cavity modes, equilateral triangular structure, MOCVD, photoluminescence measurement

F18.06

Field dependent optical properties for InGaN pyramidal apex quantum structure

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Abstract:

Growing GaN 3D structure by metal organic chemical vapor deposition (MOCVD), using selective area growth, 6-fold symmetric pyramid structures are formed. With self-limited growth, we can control the growth condition of this kind of pyramid structure, we can acquire small width structure at the pyramid apex. At this apex, quantum structure can be grown. By applying field on this quantum structure, we can trap single electron. In this research, with complex 3D fabrication, making contact on GaN 3D structure. Also by taking field dependent PL on the pyramid apex, we can learn the photoluminescence property during changing voltage.

Keywords:

InGaN quantum structure, MOCVD, Self-limited Growth, Field dependent PL

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G1.01

Observation of excess electronic recoil events in XENON1T

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Abstract:

XENON1T is an experiment designed to measure nuclear recoils induced by dark-matter particle interactions in the Milky Way. The detector consist of a dual-phase time projection chamber (TPC) with 2 tons of liquid xenon (LXe) in the target. Due to its large mass and ultra-low background, the physics case of XENON1T is expanded to further rare event searches. In this talk, results from searches for new physics with low-energy electronic recoil data will be presented. The data enables competitive searches for solar axions, an enhanced neutrino magnetic moment using solar neutrinos, and bosonic dark matter. An excess over well-known backgrounds is observed below 7 keV, rising towards lower energies and prominent between 2–3 keV. In this talk, I will discuss the cross-checks performed to the data, additional possible backgrounds and the results for the different searches for new physics.

Keywords:

G1.02

Review of theoretical models explaining the XENON1T excess

TAKAHASHI Fuminobu *1
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Abstract:

In this talk, I will review the theoretical models explaining the electron recoil excess found in XENON1T and introduce some interesting ideas and known constraints on them. Among the models, I will focus on axon-like particle and hidden photon dark matter, and discuss their implications for the early and late universe.

Keywords:

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G1.03

Leptonic new forces for Xe1t anomaly

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Abstract:

We discuss possible interpretations of Xenon1t by considering anomaly free extensions of the Standard model.
We focus on leptonic new forces associated the extended gauge symmetries with and without dark matter contributions.

Keywords:

xenon1t, leptonic new force, dark matter

G1.04

Exothermic Dark Matter for XENON1T Excess

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Abstract:

Motivated by the recent excess in the electron recoil from XENON1T experiment, we consider the possibility of exothermic dark matter, which is composed of two states with mass splitting. The heavier state down-scatters off the electron into the lighter state, making an appropriate recoil energy required for the Xenon excess even for the standard Maxwellian velocity distribution of dark matter. Accordingly, we determine the mass difference between two component states of dark matter to the peak electron recoil energy at about 2.5 keV up to the detector resolution, accounting for the recoil events over ER=2−3 keV, which are most significant. We include the effects of the phase-space enhancement and the atomic excitation factor to calculate the required scattering cross section for the Xenon excess. We discuss the implications of dark matter interactions in the effective theory for exothermic dark matter and a massive Z′ mediator and provide microscopic models realizing the required dark matter and electron couplings to Z′.

Keywords:

Dark matter, Electron recoil, Effective field theory, Light mediators

G1.05

Implications of Dark Matter Interpretation

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Abstract:

The dark matter (DM) interpretation for the recently reported excessive electron recoil events at the XENON1T detector seems challenging because halo DM velocity is not large enough to give rise to recoiling electrons of O(keV), and is in favor of the existence of fast-moving or boosted DM component(s) in the present universe, which may require non-conventional dark matter dynamics. We investigated various cases in which such DM of spin 1/2 and 0 interacts with electrons via the vector, pseudo-scalar, or scalar mediator in the context of the two-component boosted DM model as a concrete example. We find that there exist a set of parameter choices to be compatible with existing bounds as well as to accommodate the anomaly. Our study suggests that the scales of mass and coupling parameters preferred by the excess can be mostly affected by the type of mediator, and that significantly boosted DM can explain the excess with appropriate choices of mediator and its mass. The analysis method proposed in this work is general, and thus readily applicable to the interpretation of observed data in other DM direct detection experiments.

Keywords:

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G2.01

Search for the $B^0 \rightarrow l^+\tau^-$ decays at the Belle experiment

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Abstract:

We study the lepton-flavor-violating rare leptonic decays $B^0 \rightarrow l\ \tau$ (τ to one lepton and 2 neutrinos), using Monte Carlo (MC) based simulation data from Belle detector at KEKB e^+e^- collider. With the full event interpretation algorithm, the one of a B meson from $\Upsilon(4S) \rightarrow B^0\overline{B^0}$ is fully reconstructed to semi-leptonic decay channel with O(1%) of efficiency. Remained particles are used to reconstruct signal B. The Toolkit for MultiVariate Analysis with ROOT(TMVA) is used to improve signal purity.

The estimated signal events are extracted with the distribution of the momentum of primary lepton on center-of-mass frame(p_l*). Expected upper limit is calculated by recursive estimation of p_l^* distribution in signal region. Control sample study with $B^0 \rightarrow D^-\ \pi^+$ are used to calibrate signal mode. Both systematic and statistical uncertainties are studied.

Keywords:

Belle, KEK, B meson

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G2.02

Monte-Carlo study for a search of $B^0 \rightarrow K_S{}^0 K_S{}^0 \gamma$ in the Belle experiment

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Abstract:

The Belle experiment, at KEK in Japan, recorded 711 fb^{-1} data collected at Υ(4S) resonance with an asymmetric-energy e^+e^- collider. $B^0 \rightarrow K_S{}^0 K_S{}^0 \gamma$ is a rare decay mode through $b \rightarrow d\gamma$ transition which is forbidden at the tree level in the Standard Model (SM). This decay has not been measured and might provide an existence of new physics beyond the SM. We aim to search the decay, $B^0 \rightarrow K_S{}^0 K_S{}^0 \gamma$, using the full data sample of pairs collected by the Belle detector. We report Monte Carlo study for the signal and backgrounds in order to estimate signal events withe full data sample.

Keywords:

Belle experiment, Rare decay, Radiative decay, $b \rightarrow d\gamma$

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G2.03

Performance of the Belle II calorimeter trigger system at the SuperKEKB collider

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Abstract:

The Belle II experiment at the SuperKEKB asymmetric energy electron-positron collider in Japan began physics data-taking in April 2018 with an ultimate target of 40 times higher instantaneous luminosity than the KEKB collider, which was 2.1×10^34/cm^2/s. The main goal of Belle II is to search for New Physics beyond the Standard Model in heavy flavor sector. In order to select events of interest efficiently under a much higher luminosity and beam background environment than previous KEKB collider, Electromagnetic Calorimeter (ECL) trigger system has been upgraded and operated well with various trigger logics. In this report, progress of the ECL trigger system operation is outlined and preliminary results from beam collision data is described.

Keywords:

Belle II experiment, Calorimeter trigger system, Heavy flavor physics

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G2.04

Studies of dark sector at Belle & Belle II

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Abstract:

In this talk, we present recent studies of dark sector and related subjects at the Belle and Belle II experiments. In particular, we present light Higgs search in $₩Upsilon$ resonances and search for dark photon in B decays at Belle, and searches for light-mass Z' and axion-like particles at Belle II.

Keywords:

Belle, Belle II, dark sector, dark photon, axion-like particle

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G2.05

Toward first test beam with dual-readout calorimeter R&D for future e+e- collider

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Abstract:

Calorimeters has been the sprit of modern high energy physics experiments since they provide four-vector of both neutral and charged particles. Future lepton collider experiments such as FCC-ee and CEPC are proposed for the higgs factory to understand the origin of mass and its relation to the Higgs mechanism. High-quality energy measurement for these experiment is imperative to study couplings between Higgs and all decay products. The dual-readout calorimeter is regarded (or considered) as a good option to satisfy this requirement. KFC DREAM (Korea Future Collider Dual-REAdout Method) is supposed to have the "test beam" with two prototype modules of dual-readout (DR) calorimeter with pions and protons from SPS at CERN in the end of 202. The goals of the test beam are that the one is to measure the nuclear interaction lengths of pion and proton, and the other is to obtain the resolutions (energy, position, and time) of the prototype DR calorimeter. In this talk, we will present the plan and status for the 2021 test beam.

Keywords:

Calorimeter, dual-readout calorimeter, FCC-ee, CEPC

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G2.06

Study on EM/jet energy resolution with 4π dual-readout calorimeter

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Abstract:

As a novel technology of the calorimeter, the dual-readout calorimeter has been included in the conceptual design report of both FCC-ee and CEPC projects. In this presentation, we will show result of calibration and EM/Jet energy resolution for the dual-readout calorimeter, based on GEANT4 simulation. Calibration of dual-readout calorimeter has been done with 20 GeV electron simulation measuring corresponding energy of a photoelectron for each component. EM energy resolution of the dual-readout calorimeter is measured with various electron energy on the basis of calibration constant. With dual-readout calorimeter, the high precision energy measurement for jets can be accomplished by measuring the electromagnetic shower fraction of hadron showers and correcting their energy event-by-event. The anti-kt algorithm is used to reconstruct jets based on the measured energy with the calorimeter.

Keywords:

Dual-readout, Calorimeter, 4π projective geometry, Energy resolution, Calibration

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G2.07

The simulation of the dual-readout calorimeter for future collider experiments using Key4HEP common software framework

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Abstract:

The Key4HEP is a common software framework proposed by software experts of all future HEP experiments, including ILC, CLIC, FCC and CEPC. It provides software stacks which can be commonly used for various physics and detector studies on top of LCG releases. The simulation of the dual-readout calorimeter has been migrating from standalone GEANT4 toolkit to Key4HEP framework, making a room to collaborate with wider communities, including central software framework of each experiment and detectors. We present recent activities on the simulation of the dual-readout calorimeter using Key4HEP, and future plan for its application to various physics and detector study topics.

Keywords:

Key4HEP, FCC, CEPC, Dual-Readout, DD4HEP

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G2.08

Deep learning implementation for Dual-Readout calorimeter

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Abstract:

The dual-readout calorimeter consists of scintillating and Cerenkov fibers readout together. This design allows both electromagnetic and hadronic showers to be measured with high precision in a single detector. While it's under development for future colliders, deep learning implementation is studied to maximise the physics potential. Image based deep learning model analyzes pixelated data with convolutional neural networks. And raw hits can be applied with a point cloud based deep learning method. This study shows particle identification and jet variables regression using image based and point cloud based deep learning methods to show how deep learning can be implemented to the dual-readout calorimeter.

Keywords:

Dual-readout calorimeter, Deep learning, Jet discrimination

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G2.09

Simulation study on position and angular resolution of the dual-readout calorimeter

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Abstract:

The dual-readout calorimeter is a next-gen detector which offers high-precision measurements for the energies of electromagnetic particles, hadrons and jets as well as for the position of an incident particle.
Its modules, packed with dense arrays of fibers which every single of them is attached to a separate SiPM(Silicon PhotoMultiplier), meticulously compose projective structure. This high-precision high-granularity dual-readout fiber calorimeter is designed to well separate the position and angular distributions in an efficient way.
This presentation will show the predictions for the position and angular resolutions of the dual-readout fiber calorimeter. The position of an incident particle is determined by center-of-gravity method, reconstructing its center of gravity of the energies deposited. Based on the simulation carried out in Geant4, position and angular resolution are obtained by comparing the reconstructed position **to** the MC truth value.

Keywords:

dual-readout, high-precision, calorimeter, position and angular resolutions, simulation

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G3.01

Exclusive photoproduction of φ meson on ^{4}He

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Abstract:

We investigate ϕ-meson photoproduction on the ^{4}He target by employing an effective Lagrangian method. We use the factorization approximation within the multiple scattering theory. The model parameters are fixed from the elementary process $\gamma p \to \phi p$ where abundant data are provided from the CLAS. We then extend to the $\gamma^4 He \to \phi^4 He$ process. The t dependence of the differential cross sections from the LEPS is described quite well. We also consider the effect of the final state interaction by solving the Lippman-Schwinger equation for getting the t-matrix from a potential. The results of the beam-asymmery are presented as a prediction.

Keywords:

effective Lagrangian, Pomeron exchange, exclusive photoproduction

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G3.02

Tribaryons in a constituent quark model

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Abstract:

We calculate the matrix elements of the color-spin interaction for all possible multiquark states of tribaryons in flavor SU(3) broken case. For that purpose, we construct the flavor-color-spin wave functions of the tribaryons, which are taken to be antisymmetric to satisfy the Pauli exclusion principle. Furthermore, we analyze the diquark structure of the tribaryon configurations using the symmetric and antisymmetric basis set of flavor, color and spin states.

Keywords:

Quark model, Tribaryon, Color-spin interaction

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G3.03

Electromagnetic Form Factor Analysis in 1+1 Dimension: Light-front Dynamics vs. Instant Form Dynamics

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Abstract:

We investigate the electromagnetic form factor F(q^2) of the meson by using exactly solvable ₩phi^{3} scalar field theory in 1+1 dimension. As the rotations are absent in 1+1 dimension, the advantage of the light-front dynamics (LFD) with the light-front time ₩tau=t+z/c as the evolution parameter is maximized due to the frame-independence or the boost invariance of the individual ₩tau-ordered amplitudes contributing to F(q^2). In the usual instant form dynamics (IFD) with the ordinary time t as the evolution parameter, the individual t-ordered amplitudes contributing to F(q^2) are not however invariant under the boost, i.e. dependent on the reference frame. Due to the lack of the boost invariance, the charge density defined in the IFD is apparently dependent on the reference frame while the characteristic charge density defined as the slope of F(q^2) at q^2=0 must be frame-independent. We clarify such confusion in defining the charge density in the IFD, analyzing F(q^2) in the LFD. LFD allows to get the exact analytic result which covers not only the spacelike(q^{2}<0) but also timelike region(q^{2}>0). Using the analytic result, we verify that the real and imaginary parts of the form factor satisfy the dispersion relation in the entire q^{2} space. Comparing with (3+1)-calculation, we point out that the anomalous threshold appearing in 3+1 dimension is the characteristic feature of transverse momentum components. We discuss the ramifications of our findings in this analysis with respect to the extraction of F(q^2) from the experimental measurements.

Keywords:

electromagnetic form factor, light-front dynamics, charge density, dispersion relation

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G3.04

Rho-omega mixing and charge-symmetry breaking nuclear forces in chiral perturbation theory

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Abstract:

The rho^0-omega mixing is responsible for the cusp in the pion form-factor.
It also affects the charge-symmetry breaking nuclear interactions.
There has been however debates on the the momentum-dependence of the mixing.
We address this issuse by using chiral perturbation theory with massive vector mesons as well as nucleons and pions.

Keywords:

rho-omega mixing, chiral perturbation theory, charge-symmetry breaking force

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G3.05

Importance of precise mass measurements for ^{65}As and ^{66}Se

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Abstract:

We report on the impacts of mass uncertainties of the ^{65}As and ^{66}Se isotopes on the (p,γ)-(γ,p) established between ^{64}Ge and ^{65}As, effective lifetime of the waiting point ^{64}Ge, and abundance of key isotopes in the rp-process. It was found that the waiting-point potential of ^{64}Ge is still a question because of the current mass uncertainty (Δm = 85 keV) of ^{65}As. A variation up to a few orders of magnitude was observed in the astrophysical rates of the proton capture ^{65}As(p,γ)^{66}Se due to its Q-value uncertainty. Besides, analysis for precise measurements for the concerned isotopes using MR-TOF technique (i.e., at RAON) in near future was also discussed.

Keywords:

mass spectrometer, MR-TOF, proton-rich nuclei, rp-process

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G3.06

The production of ^{53}Mn as a cosmochronometer by neutrino process in core-collapse supernova

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Abstract:

From the protosolar cloud to present solar system formation took about 4.6 billion years. In the early solar system formation, there is an assumption that the elements by supernova explosion flowed into the cloud. One evidence is the existence of short-lived radionuclides (SLRs), which have half-lives less than 10 M years. SLRs can be used as a chronometer of solar system formation and some of them are affected by the neutrino process in the core-collapse supernova. In this study, we perform the nucleosynthesis with SN1987A model and investigate the element 53Mn, which is affected by neutrino reactions.

Keywords:

nucleosynthesis, neutrino process, 53Mn, cosmochronometer

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G3.07

Dynamic screening effects on big bang nucleosynthesis

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Abstract:

We investigate the dynamic screening effects on big bang nucleosynthesis (BBN). Since the moving ion in plasma causes the distorted Coulomb potential, the screening effect for the dynamic ions is distinct from the usual Salpeter formula. To determine the Coulomb potential of the moving ions in plasma, we calculate the dielectric permittivity considering the varying components from electron-positron-ion to electron-ion plasma during BBN epoch. Assuming the unmagnetized Maxwellian plasma, we obtain the thermal averaged reaction rates for the BBN calculation.

Keywords:

Dynamic screening effects, big bang nucleosynthesis, Maxwellian plasma

G4.01

Multimessenger astronomy in Japan: introduction of optical-infrared follow-up observation project

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Abstract:

Optical and infrared observation projects for multimessenger astronomy in Japan are introduced. J-GEM (Japanese collaboration for Gravitational-waves Electro-Magnetic follow-up) consists of Japanese major optical
astronomical facilities including the Subaru Telescope to detect and follow up optical-infrared counterparts of gravitational wave sources. J-GEM successfully conducted follow-up observations of the first neutron star
merger event GW170817 for more than 2 weeks from its early phase (17 hours after the event). An inter-university optical-infrared observation consortium, OISTER (Optical and Infrared Synergetic Telescopes for
Education and Research), is dedicated to follow-up observations of various transient objects including supernovae, novae, AGNs, high-energy neutrino sources, and gravitational wave sources. OISTER detected a flare-up signal from a blazar TXS 0506+056 that resides in the error circle of the neutrino event IceCube-170922A and triggered world-wide follow-up observations for this unique event. J-GEM and OISTER are closely collaborating with each other to promote multi-messenger astronomy in Japan. I talk about the basic concepts and main scientific results of these attempts.

Keywords:

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G4.02

Gravitational Wave, Data Analysis, and Observations

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Abstract:

After the first detection of gravitational wave on September 14, 2015 by LIGO and Virgo collaboration, there has been, and still are, a lot of interest on gravitational waves. The fact that gravitational waves not only open a new window for observing the Universe but also the technical breakthroughs we had to make to detect the weakest signal in nature is what makes gravitational wave so interesting. The gravitational wave is very weak by nature, and it is enormously difficult to detect. Actually it took more than 20 years of development since the conceptual design to make the first observation.
In this talk I want to introduce basics of gravitational wave detection principle using large optical interferometer, how one can extract relevant signal from noisy data and a brief summary of the current observational results.

Keywords:

Gravitationa Wave, Data Analysis

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G4.03

Gravitational-wave EM Counterpart Korean Observatory, GECKO

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Abstract:

Recent detection of optical counterparts for a gravitatational wave source and a high energy neutrino event marked the beginning of multi-messenger astronomy (MMA). With continueds improvedment in sensitivites and new installments of gravitational wave and neutrino detectors, we expect MMA to develop rapidly in near future. As an effort to support MMA, our group in Korea has established a network of optical telescopes, named as the Gravitational-wave EM Counterpart Observatory (GECKO). In this talk, we will introduce GECKO, its scientific highlights, and future prospects. The scientific highlights will include the observation of GW 170817 EM counterpart, a study of host galaxies of compact merger events, and the property of the neutrino emitting blazar, TXS 0506+056. We will also present expected outcome from GECKO.

Keywords:

Multi-messenger Astronomy, Gravitational-wave Astrophysics, Neutrino Astrophysics, Observational Astronomy, Galaxy properties

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G4.04

Multimessenger astronomy and the origin of heavy elements in the Universe

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Abstract:

The first gravitational wave observation from a neutron star merger was successfully made for GW170817. The detection triggered electromagnetic wave observations over the entire wavelength range, which enabled the first identification of an electromagnetic counterpart of a gravitational wave source. In the ultraviolet, optical, and infrared wavelengths, the counterpart shows characteristic properties of "kilonova", electromagnetic emission powered by radioactive decays of newly synthesized heavy elements. In this talk, I introduce basic physics involved in neutron star mergers and summarize what we have learned from the multimessenger observations of GW170817. Then, I highlight open questions and future prospects toward understanding the origin of heavy elements in the Universe.

Keywords:

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G5.01

Dirac fermions coupled with magnetic order and lattice polarization

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Abstract:

Topological Dirac/Weyl semimetals hosting linear energy dispersion of relativistic Dirac/Weyl fermions have received significant attention. Specifically, the coupling of the Dirac/Weyl fermions with the quantum phenomena in solids, such as magnetism, has been intensively investigated, since unconventional transport and optical phenomena were revealed. However, the material variety of the correlated topological materials has been still limited. Here we propose that layered material $AMnX_2$ (A: alkaline and rare earth ions, X: Sb, Bi) is a promising platform for this. $AMnX_2$ consists of the alternative stack of the X^{-} square net layer hosting quasi 2D Dirac fermions and the A^{2+}-Mn^{2+}-X^{3-} magnetic block layer. By systematically substituting the A and X sites, we have demonstrated that the topological electronic state in the former layer can be controlled and even enriched by the coupling with the physical properties of the block layer.
First, we show the Dirac fermions coupled with the magnetic order in $EuMnBi_2$ [1-4], which exhibits large magnetoresistance (by approximately one order of magnitude) by the field-induced change in antiferromagnetic order of the Eu sublattice while keeping the high mobility (~14,000 cm^2/Vs) [1]. Furthermore, the effective g-factor estimated from the quantum oscillation at high fields differs by ~50% between two antiferromagnetic phases, which is firm evidence of the strong exchange coupling of the Dirac bands with the local Eu moments [2].
Second, we show the Dirac fermions coupled with the lattice polarization in $BaMnX_2$ (X=Sb, Bi) [5,6], where the X^{-} square net is slightly distorted to zig-zag chains leading to an in-plane polar structure. In these materials, the spin-valley-coupled Dirac fermion manifest itself owing to the Zeeman-type spin-orbit coupling, which is experimentally supported by the ARPES and high-field transport measurements [5]. Interestingly, the type of spin-valley coupling is largely tunable with chemical substitution of the X site, which would be of great advantage to future device design [6].

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Keywords:

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G5.02

ARPES study of a Multifold Fermionic Semimetal $PdSb_2$

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Abstract:

The experimental confirmation of the Dirac/Weyl fermions in topological semimetals invokes parallelism between particle physics and condensed matter physics. However, condensed matter physics has higher degrees of freedom because it is not limited by the Poincare symmetry. Type-II Dirac/Weyl fermions are the first example that shows such degrees of freedom. Recently, another type of unconventional quasiparticles that shows the flexibility has been proposed in several groups of materials, named multifold fermions. Multifold fermions are also called unconventional quasiparticles with a large Chern number, which have no high-energy counterpart. They are not only conceptually interesting, but also expected to have intriguing physical properties due to their topologically non-trivial nature. In this talk, we will present our recent ARPES data to confirm the multifold fermions in a semimetal PdSb2.

Keywords:

multifold fermion, unconventional quasiparticle, PdSb2, ARPES

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G5.03

Exotic nodal fermions in topological materials studied by ARPES

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Abstract:

Discovery of topological insulator (TI) initiated the search for new types of topological materials. TIs are characterized by the gapless metallic states at the boundary despite insulating bulk. In three-dimensional TIs, such a boundary state is recognized as a Dirac-cone energy band at the surface. Recently, a new type of topological material with a Dirac-cone band in bulk, topological semimetal (TSM), is attracting particular attention. Dirac semimetal, a prototypical TSM, is characterized by the spin-degenerate bulk 3D Dirac-cone band, and shows outstanding physical properties such as extremely high mobility. When spin degeneracy of Dirac semimetal is lifted by breaking space-inversion symmetry or time-reversal symmetry, Weyl semimetal can be realized. While Dirac and Weyl semimetals are characterized by the band crossing at a discrete point in k space, there exist another type of TSM called line-node semimetal whose Dirac points extend one dimensionally in k space. Such a line node is typically protected by specific symmetry of the crystal such as mirror reflection symmetry and nonsymmorphic symmetry, and is currently a target of intensive studies. In this talk, we present our recent angle-resolved photoemission spectroscopy (ARPES) results on various types of topological materials, in particular on line-node semimetals, and discuss how crystal symmetry plays an essential role to characterize nodal fermions. We will focus on the following subjects.

1. Discovery of new chiral fermions in CoSi [1]
2. Line node in MgB_2-related compound [2]
3. Loop node protected by mirror symmetry in CaAgAs [3]
4. Manipulation of Dirac cone in Pb/TI heterostructure [4]
5. Possible axion-insulator phase in $EuIn_2As_2$ [5]

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Keywords:

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G5.04

Extreme Nonlinear Meissner Effect in Superconductors

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Abstract:

Under a strong external magnetic field, superconductors exhibit unusual physical properties due to a suppression of the gap. Such pair-breaking effects manifest themselves in thermodynamic, transport, and optical properties. For example, the London penetration depth acquires a magnetic-field dependence, which leads to a nonlinear Meissner effect. Here, we present our terahertz spectroscopic study of superconducting Nb thin films under a magnetic field, experimentally demonstrating the theoretical predictions. Our results suggest that the field dependence beyond the squared-field law hints at the gapless superconducting state that emerges close to the magnetic breakdown of superconductivity at the thermodynamic upper critical field.

Keywords:

nonlinear Meissner effect, Superconductors, Terahertz spectroscopy

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G6.01

Computational Search for Two-dimensional Iodine-Monofluoride Epitaxially Grown on WSe_2

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Abstract:

Interhalogen compounds (IHCs) are extremely reactive molecules used for halogenation, catalyst, selective etchant, and surface modification. Most of the IHCs are unstable at room temperature especially for the iodine-monofluoride (IF) whose structure is still unknown. Recently, we demonstrated an unambiguous observation of two-dimensional (2D) IF bilayer grown on the surface of WSe_2 by using scanning transmission electron microscopy (STEM) and electron energy loss spectroscopy (EELS). The bilayer IF shows a clear hexagonal lattice and robust epitaxial relationship with the WSe_2substrate. Despite the IF is known to sublimate at -14°C and has never found as a solid form in the ambient condition, but surprisingly it is found stabilized on a suitable substrate. To identify crystal structure and properties of IF bilayer on WSe_2, we carried out density functional theory (DFT) calculations. Evolutionary structure search algorithm was used to identify stable crystal structure and we found that chain-like IF structure the most stable structure. We also studied electronic structure of this structure and interaction between IF bilayer and WSe_2 substrate. This is the first 2D materials of IHC and which is actually a biproduct during a CVD growth of WSe_2 in the presence of alkali metal halides as a growth promotor and requires immediate surface passivation to sustain. This work points out a great possibility to produce novel 2D structures which are unexpected to be crystallized or cannot be obtained by a simple exfoliation, but can be grown only on a certain substrate.

Keywords:

Iodine fluoride, First-principles calculation, Density functional theory, 2D materials

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G6.02

STM study of lattice dynamics in 1T` structure of bilayer VSe_2

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Abstract:

We systematically investigate the lattice dynamics in 1T` structure of bilayer VSe_2 using by time spectroscopy measurement of STM. The vibrational motion of Se atom is well captured by time spectroscopy, which measures the change of tunneling current as a function of time with feedback loop turned off. The time spectroscopy indeed shows random telegraph signals that tunneling current fluctuates between high and low currents. Statistical analysis described by the Markov process provides average residence time (τ) for high and low current states, and transition rate ($R = 1/\tau$). Interestingly, the transition rate as a function of tunneling current (I) follows a power law of $R = I^N$ (N = constant), and the N value is close to 1. This linearity of transition rate indicates that the lattice dynamics are mostly induced by tunneling current. Our result confirms the role of tunneling current that drives the observed lattice dynamics in the bilayer VSe_2.

Keywords:

Scanning Tunneling Microscopy, Lattice dynamics, Transition metal dichalcogenides, Phase transition.

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G6.03

Crystal structure identification of type-II red phosphorus

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Abstract:

Red phosphorus (RP), an allotrope of phosphorus which is usually amorphous, has several types of crystalline phases. The crystal structures of type-IV (fibrous RP) and type-V (Hittorf's phosphorus) have been previously identified by single-crystal X-ray crystallography. However, those of type-II and type-III phases are yet to be identified. Here we identify the crystal structure of type-II red phosphorus by complementary structure characterization techniques via powder X-ray diffraction, 3D electron diffraction, atomic-resolution scanning transmission electron microscopy (STEM). Type-II red phosphorus synthesized by chemical vapor transport method was analyzed by powder X-ray diffraction and Raman spectroscopy, which shows the data consistent with those of crystal known as Type-II. We confirmed that type-II RP has a large triclinic unit cell with approximately 500 phosphorus atoms. Moreover, STEM images clearly revealed the local tubular structure of phosphorus.

Keywords:

Red phosphorus, Crystallography

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G6.04

First-principles study of metal-atom adsorption on black phosphorus

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Abstract:

Growing a single-crystalline metal film on a semiconductor surface can form an ideal metal-semiconductor junction. Black phosphorus (BP) is expected to limit single-crystalline metal film formation on its surface due to its high chemical reactivity and puckered atomic structure. Based on first-principles density-functional calculation, we studied adsorption of metal atoms on the BP surface. First, we calculate the adsorption energy of various metal atoms on the BP surface as a function of in-plane coordinates. Through this, we investigate adsorption sites with maximal binding energy, and energy barriers for diffusion along zigzag and armchair directions for each metal atom. Based on these results, we discuss conditions for single-crystalline metal film formation on BP surface. This work was supported by NRF of Korea (Grant No. 2020R1A2C3013673) and KISTI supercomputing center (Project No. KSC-2019-CRE-0195).

Keywords:

Black phosphorus, metal-semiconductor junction

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G6.05

Pseudospin Tunneling in Two-Dimensional Black Phosphorus Junctions

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Abstract:

Two-dimensional black phosphorus (BP) has attracted enormous attention because of its unique electronic structure and outstanding properties for high-performance electronic devices. Notably, recent BP-based tunneling field effect transistors have shown record-high tunneling current with record-low subthreshold swing. However, the microscopic origins of such superb performances are yet to be fully understood. In this talk, we review pseudospin structure of BP and investigate its implications on the tunneling properties of BP junctions. We calculate interband tunneling properties across BP junctions along armchair and zigzag direction. We show that the interband transmission is completely different depending on the crystal directions because of the anisotropic pseudospin structure. Our work provides insights into the mechanism of tunneling-based transport devices with pseudospins.

This work was supported by NRF of Korea (Grant No. 2020R1A2C3013673) and KISTI supercomputing center (Project No. KSC-2019-CRE-0195). Y.W.C. acknowledges support from NRF of Korea (Global Ph.D. Fellowship Program NRF-2017H1A2A1042152).

Keywords:

black phosphorus, pseudospin,tunneling

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G6.08

Studies of non-volatile single atom magnet using ESR-STM technique

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Abstract:

Single atom magnet without a magnetic field promises to miniaturize memory devices at atomic scale. A conventional electron spin resonance (ESR) technique with a spin-polarized STM enables us to coherently drive spins of individual atoms and molecules on surfaces with improved energy resolution. We use the ESR-STM technique to investigate 4f Dy atoms. By measuring the magnetic coupling between Fe and Dy atom, we found that we can write and read the spin state of individual Dy atoms, which are even stable without any magnetic field. This work suggests that individual Dy atoms can be the smallest non-volatile memory bit.

Keywords:

STM, single atom magnet, non-volatile memory, ESR

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G7.01

X-ray holography based on a speckle-correlation scattering matrix

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Abstract:

High-resolution X-ray imaging is a longstanding challenge. Due to the intrinsic low refractive index differences in X-ray, unfortunately, the X-ray refractive lenses are not as efficient as in the visible regime. Even though the diffractive lenses such as zoneplates are frequently utilized as an alternative, the imaging resolution is still limited by the resolution of lithography techniques. In order to overcome such practical insufficiencies, various X-ray holographic techniques has been studied extensively. Since the holographic technique measures the complex amplitude of light (the amplitude and phase), a perfect X-ray lens that does not exist in nature can be numerically applied.
In X-ray holography, because the phase information cannot be measured directly, a proper phase retrieval algorithm must be introduced to successfully estimate the sample phase. Unfortunately, this is an infamous ill-posed problem, so-called phase problem, has been studied in the vast subfield of physics and mathematics. In order to circumvent the issue, additional a priori information is generally required to specify the correct phase solution. For example, in coherent diffraction imaging (CDI) techniques, sparse sample assumptions and boundary constrains are frequently utilized. Recently, ptychographic techniques has been developed, which solve the phase ambiguity from the multiple measurements. However, regarding that another practical resolution limit of X-ray imaging is sample destruction, an assumption-less, high-resolution, and single-shot X-ray holographic technique is still demanding.
Here, we propose a speckle-correlation scattering matrix (SSM) technique as a solution. The SSM technique is a phase retrieval technique utilizing statistical characteristics of coherent speckle patterns, which is first proposed and demonstrated in the visible regime by the same authors recently. Unlike the other phase retrieval algorithms, the SSM method does not require any assumptions or constraints on sample, while the measured image should be a speckle pattern that presents the random distribution in space. In order to produce the X-ray speckle pattern, we introduced a designed X-ray diffuser after the sample, and make the sample field be scrambled again by the diffuser. From the X-ray speckle pattern single-shot, we successfully reconstruct the hologram of the sample. We demonstrated down to 21.4 nm image resolution of calibration target with 5.456 keV source. The experiments were conducted at the coherent X-ray scattering (CXS) beamline of the Pohang Accelerator Laboratory.

Keywords:

X-ray holography, X-ray imaging, spekcle pattern, coherent imaging, speckle-correlation scattering matrix

G7.02

Comparative study of hard x-ray undulator beamline performance in 4GSR-Korea and PLS-II

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Abstract:

A new light source based on the electron storage ring, dubbed the "diffraction-limited storage ring" (DLSR) to keep the full intrinsic wave nature of x-ray has been proposed since the early stage of storage ring history and finally developed sucessefully, and now chosen in the worldwide synchrtron facilites as both an upgrade and a new construction program. A newly-coined term aiming at the same direction, the so-called "4th generation storage ring" (4GSR) was decided to construct in Korea, and the 4GSR-Korea is expected to be 10-100 times brighter than Pohang Light Source (PLS-II). The hard x-ray undulator beamlines would benefit from the 4GSR due to its low emittance value approaching the diffraction limit. In PLS-II, more than 10 hard x-ray undulator beamlines are currenly in operation. We pesent a comparative study of the representative hard x-ray undulator beamlines performing the cutting-edge diffraction-spectroscopy techniques in PLS-II and the 4GSR for better understanding the upcoming light source in Korea. The figure-of-merits of specific experimental techniques, the resonant inelastic x-ray scattering (RIXS) is discussed for comparison in the two light sources. Both RIXS is sometimes referred as a "renaissance" in x-ray science and therefore strongly expected to be adopted in the 4GSR beamlines.

Keywords:

Diffraction limited storage ring, 4th generation storage ring, resonant inelastic x-ray scattering

2020 KPS Fall Meeting
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G7.03

X-ray-induced photo-current of non-stoichiometric Ga_2O_{3-X} Thin Films grown by powder sputtering method

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Abstract:

Ga_2O_3 has been investigated for applications in high-power electronics and solar blind photodetectors due to its outstanding properties such as its high breakdown field of 8 MV/cm d wide bandgap of 4.9 eV. Recently, Ga_2O_3 has also been applied to be used as an x-ray photodetector, and its performance has been reported, where the in-house X-ray source was usually used as radiation source. In this study, we report on X-ray induced photocurrent of Ga_2O_3/sapphire(0001) thin films synthesized by powder sputtering method. The experiments were performed using the synchrotron X-ray micro-beam. The X-ray energy of 10 keV were focused using K-B mirrors to be approximately10 ´ 30 mm^2. Non-stoichiometric Ga_2O_{3-X} thin films epitaxially grown on sapphire (0001) substrates were examined as X-ray photo-detectors. When X-rays irradiated on the samples, the changes in electrical conductance were monitored via a four-point probe. With varying the input voltages from 1 to 5 V, the sensing properties were measured repeatedly. By using a simple photo-induced sensing model, the relaxation time-scale on raising and decay modes was estimated. Detailed results on X-ray photo-current measurements will be presented.

Keywords:

Ga2O3 thin film, X-ray photo-current

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G7.04

In situ heating X-ray diffraction of VO_2 $(020)_{M1}$ & $(011)_{M1}$ on $Al_2O_3(006)$ analyzed with 3D reciprocal space map(RSM).

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Abstract:

We present In situ-heating xrd on $(020)_{M1}$ & $(011)_{M1}$ on $Al_2O_3(006)$.
VO_2 thin films were prepared by means of RF magnetron sputtering using a VO_2 target.
During the film depositions, the working pressure and RF sputtering power were kept constant at 0.7 Pa and 80 W, respectively.
The characteristics of VO2 were confirmed through rapid drop (up to three orders of magnitude) in resistance (electrical property) through R-T hysteresis, change in reflectance(up to 20% decrease) through He-ne laser (632.8nm) ,and Raman spectroscopy (structural change).
Based on this, We measured 2D diffraction signals for several rocking_curves to obtain a 3D reciprocal space map.
Through this, it was confirmed that VO2 is arranged from $(020)_{M1}$ to $(200)_T$ & $(011)_{M1}$ to $(110)_T$ on $Al_2O_3(006)$,respectively.
Also we found how the domains behave according to temperature.

Keywords:

Vanadium dioxide, 3D-Reciprocal space mapping, In-situ heating X-ray diffraction

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G7.05

V_2O_3 tetrahedron grown on sapphire (0001) substrates using thermal chemical vapor deposition method under hydrogen-reducing atmosphere

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Abstract:

Vanadium oxides such as V_2O_3, VO_2, and V_2O_5 have been extensively investigated due to their distinct physical properties such as metal-insulator-transition (MIT). Among them, V_2O_3 is a well-known strongly correlated material system that exhibits MIT as well as magnetic phase transition from low-temperature antiferromagnetic to high-temperature paramagnetic phases at temperature of ~150 K. Crystallographic symmetry is also transformed from low-temperature monoclinic to high-temperature rhombohedral. So far, most studies have experimentally reported the properties of V_2O_3 thin films and compared them with theoretical models. Recently, the growth of the V_2O_3 nano-structures has been attempted and the results have been reported. For example, the magnetic transition of V_2O_3 nanocrystals, estimated from the change in magnetic susceptibility, decreased to less than 100 K. In this study, we report on the V_2O_3 tetrahedron grown on sapphire (0001) substrates using thermal chemical vapor deposition method under hydrogen-reducing atmosphere. Based on the results of high-resolution synchrotron X-ray diffraction and transmission electron microscopy, we proposed a crystallographic model of rhombohedral V_2O_3 tetrahedron epitaxially grown on sapphire (0001) substrates. Initially, triangular disks are formed, and as growth proceeds further, they evolutes into tetrahedrons. This might be attributed to the low surface energy of the (-1012) facet planes. In this presentation, detailed results and future works will be discussed.

Keywords:

V2O3, Thermal Chemical Vapor Deposition, Tetrahedron, Faceting, Reducing Atmosphere

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G7.06

Feedforward compensation for hysteresis and dynamic behaviors of a high-speed atomic force microscope scanner

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Abstract:

Piezoelectric actuators (PEAs) suffer from an inherent creep, hysteretic non-linearity, and mechanical resonances. Creep is more dominant in low speed applications; hysteresis is affected by the dynamic behavior of the PEA. A compensation for the weaknesses of PEAs is required to improve the precision of PEA-based nano-positioning stages. This work presents a feedforward compensation method for a high-speed atomic force microscope (HS-AFM) XY-scanner to mitigate the combined effects of hysteresis and scanner dynamics. Hysteresis is compensated by using an inverse Bouc-Wen model while the system dynamics are compensated by using an inverse model identified using MATLAB's system identification toolbox. The compensated scanner is then used to acquire images of the data tracks of a Blu-ray disk in order to demonstrate the efficacy of the adopted approach.

Keywords:

Atomic force microscopy, feedforward compensation

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G8.01

Hybrid density functional theory calculation for high-throughput studies

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Abstract:

The recent advancement of computational physics enabled high-throughput density functional theory (DFT) calculation to find new materials for specific applications. In line with this advancement, big databases of the calculations were constructed and opened to the public. However, in order to build these databases, calculations were performed using semi-local functionals, which is well known to underestimate the electronic band gap of semiconductors.

To overcome this problem and make the high-throughput calculation more valuable, a highly accurate method with less computational cost than hybrid functional should be developed. In this talk, we discuss how to reduce the size of the hybrid DFT calculation without losing accuracy [1]. First, the physical properties of a material can be calculated using two different k-point meshes, one for the Hartree-Fock exchange potential and the other one for the remaining exchange-correlation potentials. Second, if the electronic structure is the only concern, the non-self-consistent field calculation can be performed. We believe that the combination of these two calculation methods will promote the high-throughput calculations.

[1] Ji-Sang Park, Current Applied Physics 20, 379-383 (2020).

Keywords:

non-self-consistent field, hybrid density functional theory, high-throughput

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G8.02

Stabilization of metastable TiS_2 via alloying

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Abstract:

Alloying is one of the efficient methods to control the physical properties of the transition metal dichalcogenides (TMDs). The most common type of TMDCs alloys has been mixed from stable phases. Here, beyond conventional alloying strategies, we investigated the stability and the electronic properties of the 1T-$Ti_{1-x}Nb_xS_2$ (1T-TNS) via alloying the metastable 1T-TiS_2 with stable 1T-NbS_2. We find that the 1T-TNS alloys exhibit metallic properties for all concentrations, which is similar to the charge doping of 1T-phase materials. From the Raman spectroscopy calculations, we reveal that the stability in 1T-TiS_2 originates from the strong interaction between Nb and Ti cations and severe lattice distortions.

Keywords:

Unstable TiS2, Stable NbS2, Stable 1T-Ti1-xNbxS2 alloys, DFT

2020 KPS Fall Meeting
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G8.03

High-harmonic spectroscopy in 3D topological insulators

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Abstract:

Probably the next technological revolution in the production of **ultrafast electronic devices** underlies in our capability to **control the transistor speeds** by using quantum materials which might still follow **Moore's law**. However, I believe, this is yet an extremely interesting technological challenge. Surprising, **topological states** of matter, recently, promise a novel avenue to the modernization of electronic devices. This is so since the underlying **topological conducting surface states** and **isolating bulk states** are topologically protected by **the time-reversal symmetry** - making topological insulators (TIs) robust against dissipation and perturbations, and more importantly attractive to the ultrafast optimization of our daily use of electronic devices. In spite of this promise, the control of topological states of matter remains yet in its infancy not only because of the TI material production but also because its characterization. Here, we investigate an alternative to **explore topological surface states** with respect to the bulk bands by means of studying the optical nonlinear responses from Bi2Se3 subjected to strong lasers. We produce high-order harmonic generation (HHG) from Bi2Se3 driven by elliptically polarized lasers. Particularly, our experimental results suggest an **atypical HHG enhancement** while the TI is driven by a **circularly** polarized laser-beam in comparison to a **linearly polarized laser-field**. This experimental observation is fully supported by our theoretical treatment in which we split the bulk contribution from the surface one. Our theory shows that this atypical enhancement can be attributed to the emission from the topological surface states. We find theoretical evidences to show that the main mechanism behind that **atypical/anomalous enhancement** lies in the **dipole vortex** and the **spin-orbit coupling** (SOC) strength structure, mostly present at the TI surface states rather than at the bulk states. Those SOC in and out of plane at the surface are indispensable pieces in our understanding of the anomalous enhancement of the emitted radiation.

This work opens exciting new opportunities to explore how the charge and spin currents can be controlled by strong lasers at PHz regimes and also how the laser can assist topological phases and transitions in quantum materials.

Keywords:

Topological material, Topological surface state

G8.04

Spin and charge correlations across the metal-to-insulator crossover in the half-filled 2D Hubbard model

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Abstract:

The 2D Hubbard model with nearest-neighbour hopping on the square lattice and an average of one electron per site is known to undergo an extended crossover from metallic to insulating behavior driven by proliferating antiferromagnetic correlations. We study signatures of this crossover in spin and charge correlation functions and present results obtained with controlled accuracy using diagrammatic Monte Carlo in the range of parameters amenable to experimental verification with ultracold atoms in optical lattices. The qualitative changes in charge and spin correlations associated with the crossover are observed at well-separated temperature scales, which encase the intermediary regime of non-Fermi-liquid character, where local magnetic moments are formed and non-local fluctuations in both channels are essential.

Keywords:

Diagrammatic Monte Carlo method, 2D Hubbard Model

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G8.05

Atomistic study of the interfacial oxide layer effect on the stabilization of orthorhombic HfO_2

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Abstract:

Using the first-priciples density functional theory calculations, we find that the interfacial oxide layers formed at the HfO_2/TiN interface stabilize the ferroelectric orthombic phase in hafnia. For the abrupt HfO_2/TiN interface, monoclinic phase becomes the preferred phase at the interface. In contrast, the highly oriented ferroelectric orthombic phase is strongly stabilized once we introuce the interfacial TiO_2 oxide layer at the HfO_2/TiO_2/TiN interface. From the the surface reaction simuation of tetrakis(ethylmethylamino)hafnium (TEMAHf) precursor with TiN and TiO_2, we find that TEMAHf precursors are spontaneously adsorbed on TiO2 oxide layer and form the 2-fold oxygen environment around the Hf metal cations, and then the ferroelectric orthombic phase is stabilized. Our results indicate that interface enginnering is a critical approach to stabilize and maintain the energetcally unfavorable metastable phases.

Keywords:

HfO2, density functional theory, ferroelectricity

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G8.06

Variaitonal Quantum-Classical Simlulations for Quantum Phase Transitions of Spin Chains

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Abstract:

We investigate quantum spin chains by using the variational quantum-classical simulation with the quantum approximate optimization algorithm. Ground and first excited states of quantum spin models are obtained and compared with other numerical methods such as exact diagronalization and density-matrix-renomalization group methods. Good agreements are obtained by increasing depths of quantum circuits. We also discuss intrinsic properties of the quantum approximate optimization algorithm, which may be used for quantum simulations in near-term quantum computation.

Keywords:

quantum spin chain, quantum phase transitions, quantum-classical hybrid

2020 KPS Fall Meeting
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G8.07

Circular dichroism in high-order harmonic generation: Heralding topological phases and transitions in Chern insulators

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Abstract:

Topological materials are of interest to both fundamental science and advanced technologies, because topological states are robust with respect to perturbations and dissipation. Experimental detection of topological invariants is thus in great demand, but it remains extremely challenging. Ultrafast laser-matter interactions, and in particular high-harmonic generation (HHG), meanwhile, were proposed several years ago as tools to explore the structural and dynamical properties of various matter targets. Here we show that the high-harmonic emission signal produced by a circularly-polarized laser contains signatures of the topological phase transition in the paradigmatic Haldane model. In addition to clear shifts of the overall emissivity and harmonic cutoff, the high-harmonic emission shows a unique circular dichroism, which exhibits clear changes in behavior at the topological phase boundary. Our findings pave the way to understand fundamental questions about the ultrafast electron-hole pair dynamics in topological materials via non-linear high-harmonic generation spectroscopy.

Keywords:

Topological material, Chern insulator, Haldane model, Laser-matter interaction

G9.01

Principles and Laws in Ferroelectricity

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Abstract:

Principles and laws are compared in terms of their definition and characteristics. Principles are inherently featured by exactness and rigorousness, whereas laws allow variety, flexibility and approximation. Their characteristics are reviewed in physical science and human history. Human prefers principles to laws in intellectual history while fundamentalism yields pragmatism. On the verge of artificial intellegence, hyperconnectivity and complexity in human society and matters can be treated by the artificial intelligence. On the 100th anniversary of ferroelectricity, the questions, "What is the principle of ferroelectricity? How can ferroelectricity treated by artificial intelligence" are raised in this presentation.

Keywords:

principles, ferroelectricity, ferroelectricity, artificial intelligence

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G9.02

Nanogenerators for energy harvesting based on piezoelectric nanostructures

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Abstract:

Pierre Curie and his brother Jacques first discovered the piezoelectricity phenomenon in quartz and Rochelle salt in 1880 and named the effect piezoelectricity (from Greek piezein, "to press"). And then 40 years later, Joseph Valasek presented his first paper on "Piezoelectric and allied Phenomena in Rochelle salt" at the meeting of the American Physical Society in Washington in April 1920. He stated: "... the dielectric displacement D, electric intensity E, and polarisation P ... are analogous to B, H and I in case of magnetism." The full version of his presentation was submitted to Physical Review in December 1920. Now ferroelectric materials have a wide range of applications owing to their anisotropic physical properties such as a high dielectric constant, pyroelectricity, and piezoelectricity. The high piezoelectric properties (d_{33}) of $Pb(Zr,Ti)O_3$ (PZT) make it one of the most widely used ferroelectric materials. Ferroelectric nanostructures are considered highly promising in many applications such as actuators, transducers, and energy harvesters. Here I am going to talk about a brief history of ferroelectricity and recent results on piezoelectric nanogenerators.

Keywords:

Ferroelectricity, Piezoelectricity, Nanogenerators

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G9.03

Flexo-electronics: achievement and future

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Abstract:

Flexoelectricity describes the generation of electric polarization by strain gradients in every dielectric. This universal effect is inversely proportional to the length scale, thereby promising novel, enhanced functionalities at the nanoscale. In particular, a scanning probe microscope (SPM) tip-induced flexoelectric effect has recently proved great potential for scientific and technological endeavors. The SPM tip-induced flexoelectric internal field could be large enough to allow the electrical-state switching in dielectrics and semiconductors. Therefore, the scope of electric control in solids, such as dielectrics and semiconductors, could be extended to explore unconventional electronic phenomena under strong static fields via flexoelectricity. In this talk, we will discuss further opportunities and challenges for advancing the SPM tip-based flexo-electronic applications.

Keywords:

flexoelectric, strain gradient, scanning probe microscope

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G9.04

Can the negative capacitance of ferroelectrics be useful?

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Abstract:

The emergence of ferroelectricity in doped HfO_2 and $(Hf,Zr)O_2$ (HZO) thin film with a typical thickness ~10 nm brings back the great interest in ferroelectric (FE) memories including the conventional ferroelectric random access memory, ferroelectric field-effect transistors (FEFET), and more recent negative capacitance (NC) field-effect transistors, in not only academia but also memory industry. Among these diverse applications, NC-effect appears to be the most appealing for low power devices, while still controversial. From the physical point of view of the well-established ferroelectric theory, the intrinsic instability-induced NC effect is highly improbable due to the feasible evolution of the domain structure. Nonetheless, the involvement of domain structure does not necessarily exclude the possible observation of some of the characteristic features of the NC effect, such as internal voltage boosting. This is because the mismatch between the rapid ferroelectric switching being accompanied by the charge dissipation and the charge injection through other circuit components, such as a series resistor or a dielectric capacitor, can incur temporal voltage effects, which appears to indicate the NC effect. Understanding the subtle correlation between the ferroelectric switching and charge transport through the involved circuit elements is the crucial factor for the precise understanding of the seemingly NC effects. Such a temporal voltage effect can be useful for some applications, but others are not.
In this work, a simplified and straightforward view on the various voltage effects due to the limited charge compensation in response to the ferroelectric switching is provided. The quantitative correlation between the availability of the compensating charges and apparent voltage effects are discussed. The usefulness and limitation of the charge-injection induced device performances are finally discussed.

Keywords:

negative capacitance, HfO2

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G10.01

Epitaxial Growth of Single-Crystalline Metal Films on Black Phosphorus

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Abstract:

The properties of metal-semiconductor junctions are often unpredictable because of non-ideal interfacial structures, such as interfacial defects or chemical reactions introduced at junctions. Black phosphorus (BP), an elemental two-dimensional (2D) semiconducting crystal, possesses the puckered atomic structure with high chemical reactivity. Establishing a realistic atomic-scale picture of BP's interface toward metallic contact is of great importance but has remained elusive. Here we examine the interfacial structures and properties of physically-deposited metals of various kinds on BP. We find that Au, Ag, and Bi form single-crystalline films with (110) orientation through guided van der Waals epitaxy. Transmission electron microscopy and X-ray photoelectron spectroscopy confirm that atomically sharp van der Waals metal-BP interfaces forms with exceptional rotational alignment. Under a weak metal-BP interaction regime, the BP's puckered structure play an essential role in the adatom assembly process and can lead to the formation of a single crystal, which is supported by our theoretical analysis and calculations. The experimental survey also demonstrates that the BP-metal junctions can exhibit various types of interfacial structures depending on metals, such as the formation of polycrystalline microstructure or metal-phosphides. This study provides a guideline for obtaining a realistic view on metal-2D semiconductor interfacial structures, especially for 2D crystals with high chemical reactivity.

This work was mainly supported by the Basic Science Research Program at the National Research Foundation of Korea (NRF-2017R1A5A1014862 and NRF-2019R1C1C1003643) and by the Institute for Basic Science (IBS-R026-D1).

Keywords:

Black phosphorus, van der Waals epitaxy, single-crystalline metallic film, metal-semiconductor interface, Two-dimensional crystals

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G10.02

Nonvolatile tuning of the spin-orbit coupling in graphene by a ferroelectric dipole

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Abstract:

Spin-orbit coupling (SOC) offers an alternative technique for generating pure spin currents in non-magnetic materials as well as controlling spin precessions for spin-field effect transistors. In addition, introducing SOC into graphene cause pristine graphene to evolve into a new condensed matter phase, such as topological insulator state (quantum spin Hall state). Thus, the control of SOC in graphene is essential for its functional spin-orbitronic applications. Here, we report the nonvolatile tuning of SOC in graphene through the proximity effect from a ferroelectric substrate, $Pb(Zr_{52},Ti_{48})O_3$ (PZT). Ferroelectric poling by applying a gate voltage induces a change in the SOC strength in addition to shifting the charge neutral point in graphene. The variations in SOC were extracted from weak localization within the quantum interference theory of graphene. Our analyses show that the dipole moments from the PZT polarization significantly enhance the $z \rightarrow -z$ asymmetric and symmetric SOCs of graphene. Unlike the impurity doping and/or gating, our methodology leads to the nonvolatile electrical control of SOC, thereby paving the way for versatile spin-orbitronic applications of graphene.

Keywords:

Ferroelectric, Spin-orbit coupling, Graphene, Weak localization

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G10.03

High thermoelectric performance of two-dimensional α-GeTe bilayer

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Abstract:

The thermoelectric energy conversion has been growing as an important alternative sustainable and ecological source of energy. However, the optimum temperature appears at rather high temperature (~ 1000 K) and this high ZT value is only found in a very narrow temperature range because the high ZT is very rapidly decreases if the temperature deviates from the optimum temperature. Recently, some theoretical studies suggest that 2D materials can show high ZT (~ 2) at high temperature[1, 2]. Nonetheless, the optimal thermoelectric conversion was still operating at high temperature within a very narrow range and restricted to specific carrier type and concentration. In these studies, the more tricky issue is that the Wiedemann-Franz law is employed to estimate the electronic contribution to the thermal conductivity because the Wiedemann-Franz law seems underestimate electrical thermal conductivity. Thus, we explored the temperature dependence of the thermoelectric property of the recently exfoliated 2D α-GeTe layer [3]by applying the Boltzmann transport theory and also used the semi-empirical Wiedemann–Franz law method. We found that the electronic thermal conductivity from the Wiedemann–Franz law was substantially smaller than that found from the Boltzmann transport theory. Thus, from the Boltzmann transport theory, we obtained a maximum ZT of 0.95 in the bilayer structure. The 2D α-GeTe bilayer system exhibited an anomalous temperature and carrier type dependencies. For instance, both n- and p-type systems displayed high ZT of 0.8 ~ 0.95 and this ZT value was unchanged in a wide range of temperatures 100 ~ 600 K. Overall, the TE efficiency of the bilayer system was insensitive to the wide range of temperature and carrier concentration and also carrier type. Thus, the 2D bilayer α- GeTe may show superior TE property, not found in any other 2D materials.

Keywords:

α-GeTe bilayer, thermoelectric property

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G10.05

Out of plane growth of Bi_2O_2Se thin film for constructing functional van der Waals heterostructures

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Abstract:

As an emerging ultrathin semiconductor material, Bi_2O_2Se exhibits prominent performances in electronics, optoelectronics, ultrafast optics, etc. However, till now the in-plane growth of Bi_2O_2Se thin films is mostly fulfilled on atomically flat mica substrates, with interfacial electrostatic forces setting obstacles for Bi_2O_2Se transferring to fabricate functional van der Waals heterostructures. We propose controlled growth of out of plane Bi_2O_2Se thin films and with apparently reduced interfacial contact areas upon mica flakes, the transfer of out of plane Bi_2O_2Se could be facile. We fabricate back-gated Bi_2O_2Se field effect transistors on SiO_2/Si by post transfer out of grown Bi_2O_2Se, featuring high mobility of ~$200cm^2V^{-1}s^{-1}$, outperforming previously reported in-plane Bi_2O_2Se devices. Furthermore, we propose probe tip assisted transfer to fabricate 2D heterostructures without assistance of acid or polymers. Bi_2O_2Se/graphene heterostructure phototransistor fabricated by probe tip-assisted out of plane Bi_2O_2Se transfer exhibiting highly efficient photoresponses. The results in this work pave the way for prospective van der Waals heterostructures building up incorporating Bi_2O_2Se thin films.

Keywords:

Bi2O2Se, out of plane growth, clean transfer, van der Waals heterostructures

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G10.06

Mass prediction of materials using artificial intelligence in noisy environment

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Abstract:

In measuring devices made of low-dimensional materials, noise is one of the main factors that interfere with the device's intrinsic properties. Especially, if the noise included in the frequency is larger than the mass of the substance to be measured, the accuracy of the data is degraded due to the noise in an experiment in which the mass is confirmed through frequency measurement. Noise originates from a variety of sources. We first calculated the noise generated by the device itself and confirmed the limit of predictable mass in a noisy environment using an artificial intelligence algorithm. The algorithms we used are largely divided into machine learning algorithms and deep learning algorithms. Using the various algorithm models included in each, the range of predictable masses was confirmed. Also, we considered what needs to be improved to increase the reliability of the measurement results in actual experiments.

Keywords:

noise, artificial intelligence(AI), mass, frequency, prediction

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G10.07

Valley acoustoelectric effect in two dimensional Dirac materials exposed to Rayleigh surface acoustic waves.

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Abstract:

Two dimensional (2D) Dirac materials have been attracting a great deal of attention in both theoretical and experimental research in the recent years. There have been numerous studies related to interaction of 2D Dirac materials with electromagnetic fields, but studies related to interaction phenomena with acoustic waves are still at a nascent stage. In this work, we study the acoustoelectric effect in two-dimensional Dirac materials like transition metal dichalcogenide monolayers located on an isotropic substrate and exposed to Rayleigh surface acoustic waves. We discuss the mechanism of interaction of electrons with Rayleigh surface acoustic waves via deformation potential mechanism and calculate the acoustoelectric current. We investigate the behavior of this resulting current, with special focus on the Hall component of the electric current density which appears due to the trigonal warping of the valleys in k-space and study its dependence on the electron effective lifetime and electron density in the sample.

Keywords:

Acoustoelectric effect, Rayleigh surface acoustic waves, transition metal dichalcogenides

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G10.08

Improving shielding effectiveness by designing of multiple porous thin metal layers at X-band frequency wave.

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Abstract:

We propose calculation method of shielding effectiveness of a meta-film as multiple porous thin-metal layers in X-band frequency range. Applying the transfer matrix method, we found that shielding effectiveness is effected by porosity in a meta-film. Taking this advantage of its porous structure, a metal-film shielding effectiveness can be controlled by porosity, so that shielding effectiveness of a metal layer, 10 um thickness and 4665.1 S/cm^2 conductivity, improved around 30dB by making porosity.

Keywords:

shielding effectiveness, porosity, muliti-layer, transfer matrix method

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G12.01

Layering Transition and Novel Topological Defects of Chiral Nematic Liquid Crystals Confined in a Cylinder

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Abstract:

Chiral nematic liquid crystals (LCs) have been investigated actively because of their usefulness as materials for applications such as temperature-responsive coating and optical cavity for liquid crystal lasers. They also serve as intriguing model systems to study the geometry and topology of condensed matter. The chiral nematic ordering under confinement often leads to frustrated configurations and gives rise to exotic topological defects such as skyrmions.
Chiral nematic phases of lyotropic chromonic LCs (LCLCs) have become a new member of this exciting class of materials. Namely, because of the unusual elastic and surface-anchoring properties of LCLCs, i.e., giant elastic anisotropy, large saddle-splay modulus, and weak azimuthal anchoring, chiral LCLCs provide an excellent platform to study confined chiral nematic LCs. To our interest, we find a twist angle of chiral LCLC's double-twist (DT) configuration in a cylinder with a degenerate planar anchoring increases discontinuously as the dopant concentration increases. This "step-like" phenomenon, called layering transition, results from local minima in the energy landscape and new ground state's appearance according to the dopant concentration. Consequently, meta-stable configurations corresponding to each local minimum can coexist and accompany topological defects between them. Lastly, we observe that meta-stable domains are protected from their annihilation by a unique topological layer number invariant.

The authors acknowledge the support from the Korean National Research Foundation through NRF-2018R1C1B6002811.

Keywords:

Chiral liquid crystals, Layering transition, Topological defect

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G12.02

Solvent Isotopic Effect on the Phase Transition of Lyotropic Chromonic Liquid Crystals: Possible Roles of Electrostatic Interactions

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Abstract:

In lyotropic chromonic liquid crystal (LCLC), charged disk-like molecules in water (H_2O) self-assemble via non-covalent attractions to form aggregates by face-to-face stacking, and these rod-like aggregates align to exhibit liquid crystal phases. It is vital to understand the roles of lyotropic LCs' solvent because it governs the viscoelasticity and phase behavior of the mesophases. We report how the phase behavior of LCLC is affected by heavy water (D_2O) solvent, which is physicochemically similar to H_2O. D_2O-LCLCs exhibit higher nematic-to-isotropic phase transition temperatures than H_2O-LCLCs. X-ray scattering also reveals considerably longer inter-aggregate correlation lengths in D_2O-LCLCs, while the other microstructural properties, such as inter-aggregate and inter-molecular distances and intra-aggregate correlation length, are comparable. To explain this isotopic effect, we propose a hypothesis that the strength of electrostatic interactions between aggregates in H_2O and D_2O is different. The strong repulsive force between charged aggregates tends to destabilize the alignment, hence lower the nematic-to-isotropic phase transition temperature; The aggregates would want to twist to each other to alleviate the high electrostatic energy. The repulsive force is affected by multiple factors: dielectric constant of the solvent, charge density of the aggregates, and amount of electrolyte in the solution. We find that the pD of D_2O-LCLCs is greater than the pH of H_2O-LCLCs, meaning fewer deuterons (D^+) than protons (H^+). Additionally, ^{23}Na-NMR measurements disclose that more counterions are bound to the aggregates of D_2O-LCLC. Considering the longer screening length and lower charge density of the aggregates in D_2O-LCLC, we explain the isotopic effect in LCLCs' nematic phase.
The authors acknowledge the support from the Korean National Research Foundation through NRF-2018R1C1B6002811.

Keywords:

Liquid crystal, Electrostatic interaction, Isotopic effect

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G12.03

Pair Potential between Topological Defects of Spontaneously Twisted Liquid Crystals in a Cylindrical Cavity

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Abstract:

Symmetry breaking from isotropic to ordered phase accompanies topological defect formations. We use a double-twist (DT) director configuration of lyotropic chromonic liquid crystals (LCLC) as a model system to study the interaction between a pair of topological defects. The domain-wall-like defect forms when two domains of opposite twist handedness are adjacent; The left- and right-handed domains are equally favorable in the DT configuration of our achiral LCLC. Because there is a large deformation in the vicinity of the defect, causing an energy penalty, the minimization of the elastic free energy drives the merging and annihilation of two nearby defects. Here, we investigate the merging process of a pair of defects by measuring the separating distance as a function of time. Making an analogy with a system of particles lying in 1D and utilizing a dimensional analysis, we propose a model where the pair-potential is a power-law potential, and the viscous force is dominant over the inertial force. Fitting our experimental data to this model, we find two distinct regimes of different power-law exponents depending on defects separation. Understanding the interactions between defects would help us elucidate the time evolution of domains via merging and annihilation.

The authors acknowledge the support from the Korean National Research Foundation through NRF-2018R1C1B6002811.

Keywords:

Topological defect, Liquid crystals, Confinement

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G12.04

Diabetes prediction with KoGES data using Machine Learning

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Abstract:

Diabetes is one of the most prominent diseases in the 21st century. Not only are there statistical surveys with prevalence rates of around 10% in the world and in Korea [1, 2], 11.3% of the world's mortality rates are due to diabetes [1]. In Korea, the prevalence rate of people aged 70 and over is 26.5%, higher than the global average. Although the cause of diabetes has been identified to some extent, it is a chronic disease, and it causes various adult diseases and complications, as well as its prevalence is very high and it is on an increasing trend, so many related studies are steadily underway worldwide [3, 4]. Research on diabetes prediction and cause analysis using machine learning is ongoing worldwide [3]. Various machine learning techniques have been applied to a variety of data, and although there are some differences, the accuracies of diabetes prediction are about 90%. Although attempts have been made to predict the Korean type diabetes model applied to Korean data, relatively recent machine learning techniques like ensemble method or deep learning have not yet been applied [5, 6]. We study about a diabetes prediction model that applies machine learning to KoGES (Korean Genome and Epidemiology Study) data. It is an ongoing project in the early stages, but we would like to share our preliminary results.

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Keywords:

diabetes, prediction, KoGES, machine learning

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G12.05

Effect of various recoding of granule cells on Pavlovian eyeblink conditioning in a cerebellar network

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Abstract:

We consider the Pavlovian eyeblink conditioning (EBC) via repeated presentation of paired conditioned stimulus (tone) and unconditioned stimulus (airpuff). The effect of various temporal recoding of granule cells on the EBC is investigated in a cerebellar network where the connection probability p_c from Golgi to granule cells is changed. In an optimal case of p_c^* (=0.029), individual granule cells show various well- and ill-matched firing patterns relative to the unconditioned stimulus. Then, these variously-recoded signals are fed into the Purkinje cells (PCs) through parallel-fibers (PFs), and the instructor climbing-fiber (CF) signals from the inferior olive depress them effectively. In the case of well-matched PF-PC synapses, their synaptic weights are strongly depressed through strong long-term depression (LTD). On the other hand, practically no LTD occurs for the ill-matched PF-PC synapses. This type of "effective" depression at the PF-PC synapses coordinates firings of PCs effectively, which then make effective inhibitory coordination on cerebellar nucleus neuron [which elicits conditioned response (CR; eyeblink)]. When the learning trial passes a threshold, acquisition of CR begins. In this case, the timing degree $\mathcal{T}_d$ of CR becomes good due to presence of the ill-matched firing group which plays a role of protection barrier for the timing. With further increase in the trial, strength $\mathcal{S}$ of CR (corresponding to the amplitude of eyelid closure) increases due to strong LTD in the well-matched firing group, while its timing degree $\mathcal{T}_d$ decreases. In this way, the well- and the ill-matched firing groups play their own roles for the strength and the timing of CR, respectively. Thus, with increasing the learning trial, the (overall) learning efficiency degree $\mathcal{L}_e$ (taking into consideration both timing and strength of CR) for the CR is increased, and eventually it becomes saturated. By changing p_c from p_c^*, we also investigate the influence of various temporal recoding on the EBC. It is thus found that, the more various in temporal recoding, the more effective in learning for the Pavlovian EBC.

Keywords:

Eyeblink conditioning, Effective learning, Various temporal recoding, Synaptic plasticity

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G12.06

Human blood glucose modulation via insulin secretion adjustment

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Abstract:

Insulin, an important hormone that regulates blood sugar level in the human body, acts on the liver or peripheral tissues to regulate the consumption and production of blood sugar. When human organs become resistant to the action of insulin, blood sugar level rises. Because the sensitivity to insulin in the body varies from person to person, the insulin levels, required to maintain normal blood glucose level, are different depending the personal characteristics. Therefore, in this study, we define how insulin secretion function can change when insulin resistance or sensitivity varies from person to person, and introduce mathematical models and its simulation results for the process of blood glucose regulation.

Keywords:

Insulin, Glucose, mathematical model

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G12.07

Two kinds of stochastic resonance in an ecological community

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Abstract:

Periodic environmental changes are commonly observed in nature from the amount of daylight to seasonal temperature. These changes usually affect individuals' death or birth rates, dragging the system from its previous stable states. When the fluctuation of abundance is amplified due to such changes, the extinction may be accelerated. To study the effect of such periodic environmental changes, we investigate a population system wherein two types of species coexist together. We implement an ecological system based on three rules–birth, death from competition, and spontaneous death. Periodic environmental changes in our model are implemented as the modulation of the competition death rates between species. As the strength of competition rates is varied, we observe the resonance behaviour in both fluctuations of abundances and mean time to extinction. Our result suggests that neither too high nor too low competition rates make the system more susceptible to the environmental changes, which results in the faster extinction of species.

Keywords:

stochastic resonance, population dynamics, ecological system

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G12.08

Competition between cells in a hierarchical tissue can suppress the accumulation of mutations

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Abstract:

A hierarchical structure of cells in tissue has been recognized for a long time; the stem cells become mature cells through several differentiation steps. Previous studies have shown that such structures could reduce cancer risk by suppressing the accumulation of mutations, suggesting the hierarchical structure could be an evolutionary outcome. However a huge volume of model studies has ignored the interaction between cells that is an essential ingredient of the frequency-dependent evolution. Here we introduce competition between cells and develop a minimal model to study the role of interaction. The results show that competition can enhance wildtype cells even without no competition advantage for wildtype cells. The key underlying mechanism is that the benefit of wildtype cells can be effectively larger for smaller population size.

Keywords:

hierarchical tissue organization, evolution

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G13.01

IT 융합과 STEM 기반 물리교육의 확대

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Abstract:

20세기의 우리나라 중등물리교육은 주로 물리학의 기본 개념을 학생들이 이해하도록 지도하는 형태로 이루어졌다. 이는 기본 개념을 이해하고 있으면 이를 바탕으로 연관된 분야에 응용이 가능하다는 '연역적 학습 전이'의 전제에서 수행가능한 것이다. 그러나 실제로는 대부분의 학습 내용이 추상적 개념에 대한 수학적 문제 풀이 중심으로 이루어졌고, 이 때문에 많은 학생들은 물리 학습에 흥미나 가치를 느끼지 못하고, 심지어 수학과 물리를 구별하지 못하는 경우도 나타난다. 21세기의 발달된 IT환경에서 물리학의 활용은 다양하게 요구되지만 학생들에게는 이러한 기회가 잘 제공되지 못하여, 물리학이 적용되고 있는 정보통신, 그래픽, 디스플레이, 로봇 등 다양한 분야의 활용을 생각할 수 없는 것이 현실이다. 따라서 이제는 연역적 학습 전이가 아닌, 각 활용 영역의 주요 대상들이 어떻게 물리학과 연관되는지 이해하게 하는 STEM적 '귀납적 학습 전이'가 필요하다. 본 연구에서는 이러한 방법과 의미에 대하여 논의한다.

Keywords:

STEM, IT 융합, 귀납적 접근

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G13.02

마이크로비트를 이용한 무센센서네트워크 구축 및 과학탐구활동에의 활용방안 탐색

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Abstract:

블록코딩 기반 피지컬 컴퓨팅은 배우기 쉽고, 다양한 방식으로 활용될 수 있다는 점에서 과학교육에서 주목할 가치가 있다. 본 연구에서는 마이크로비트를 활용하여 무선센서네트워크(Wireless Sensor Network, WSN)를 구축하였다. 무선센서네트워크는 무선 링크를 통해 정보를 주고 받을 수 있는 기기들의 집합을 의미한다. 본 연구에서는 학생들의 과학탐구에서 활용도가 높을 두가지 기본 네트워크 유형을 선정하여 개발하였다. 첫째 유형은 다수의 말단 센서에서 중앙 수신장치로 정보를 보내는 것이다. 둘째 유형은 한 말단 센서에서 중계기를 거쳐 중앙 수신장치로 정보를 보내는 것이다. 이러한 무선센서네트워크를 기반으로, 탐사체에 센서를 부착하여 데이터를 수집하고 원격 전송한 후 중앙 수신장치에서 데이터를 모아서 분석하는 방식의 과학탐가 저비용으로 가능하다. 이러한 무선센서네트워크 구축을 통해 가능한 과학탐구활동도 예시적으로 논의할 것이다.

Keywords:

피지컬 컴퓨팅, 마이크로비트, 무선센서테트워크, 과학탐구

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G13.03

가상/증강 현실을 활용한 교육의 현황과 성과

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Abstract:

최근 들어 ICT기술 발달과 함께 코로나19라는 판데믹에 의해 원격 교육의 중요성이 강조되고 있다. 1990년대 말부터 물리교육에서는 Java Applet이나 Java Script를 활용한 시뮬레이션 등이 개발되었고 최근에는 가상현실 또는 증강현실을 기반으로 한 실험 실습 교육이 활용되고 있다. 이에 본 발표에서는 최근 일어나고 있는 가상/증강현실의 활용 사례와 함께 이러한 도구와 시스템의 활용이 실제 교육적 성과로는 어떻게 이어지는지 살펴보고 미래 이를 위한 교육의 방향에 대한 시사점을 제공하고자 한다.

Keywords:

미래교육, 에듀테크, 증강현실, 가상현실

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G14.01

MHD-stabilized reactor-relevant fusion plasmas (with full integration of edge, divertor and core)

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Abstract:

Since 2013, the UNIST Fusion center has been studying the fusion plasma stability and confinement, while spearheading advanced imaging diagnostics [1]. This led us to directly measure the nonlinear interaction between resonant magnetic perturbation (RMP) and turbulent eddies during RMP-driven, edge-localized-mode (ELM) crash suppression, clarifying the role of the ExB rotation shear [2, 3]. Currently, we are conducting a comprehensive investigation to realize MHD-stabilized conditions in a fully integrated manner at edge, divertor and core areas, essential for fusion reactor. Specifically, three research focuses are grouped in terms of 1) "Control", 2) "Advanced Diagnostics" and 3) "Numerical Simulation" respectively. In the area of "Control", the main emphasis is given to the physics mechanism of RMP-driven, ELM-crash-suppression, as well as that of divertor heat flux broadening under RMP, while securing its compatibility with core plasmas even in a long pulse. To further advance the imaging diagnostic capability, a next-generation receiver of electron cyclotron emission imaging (ECEI) diagnostic is being developed. In the area of "Advanced Diagnostics", we continue to explore the possibilities of advanced diagnostics for reactor-relevant fusion plasma through full utilization of ECEI and high-speed RF systems on KSTAR, leading to localized measurement of high frequency electromagnetic fluctuations [4], and semi-automated images of MHD and turbulence fluctuations. In the area of "Numerical Simulation", we have launched a gyro-kinetic simulation study about the interaction between plasma turbulence and Neoclassical Tearing Mode (NTM) that could degrade the performance of magnetic confinement, as well as a numerical prediction of NTM creation and its behavior. This talk will not only introduce the progress in each area, but also outline the latest research highlights. For example, recent KSTAR experiments helped us discover a strong up-down asymmetric dependence of RMP on ELM-crash-suppression [5]. Also, in view of divertor heat fluxes, the RMP-drivenELM mitigation appears slightly more favorable than RMP-driven, ELM suppression [5]. Meanwhile, the multi-year long ECEI improvements led us to expedite the post-processing of turbulence images via machine learning [6]. Preliminary GENE simulation results show non-monotonic temperature profiles inside magnetic island, whose aspect ratio dependence has been systematically addressed [7]. The details are to be presented in various conferences, as well as to be published.

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Keywords:

resonant magnetic perturbation (RMP), RMP-driven, edge-localized-mode (ELM) crash suppression, electron cyclotron emission imaging (ECEI) diagnostic, high-speed RF system on KSTAR, gyro-kinetic simulation study

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G14.02

핵융합 재료-플라즈마 반응 연구센터 소개 (Center for Interaction of Materials with Plasmas: cimpl)

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Abstract:

핵융합 재료-플라즈마 반응 연구센터는 ITER/KSTAR와 같은 핵융합로의 벽면(wall) 및 디버터(divertor) 재료와 플라즈마와 상호작용을 연구한다. 벽면 재료에 입사되는 핵융합 플라즈마와 재료 (텅스텐) 표면 에서의 반응을 이해하고, 재료 물성 변화에 의한 재료의 내 플라즈마 특성 성질 이해 및 생성 티끌에 의한 입사 플라즈마의 열속 감쇄능의 플라즈마-재료 상호 반응 (plasma-material mutual interaction) 특성 연구한다. 핵융합 연료가스인 수소동위원소 및 ash 가스인 He의 입자의 저밀도 조건(디버터 dome 근방의 조건 모사, ECR plasma 장치)과 고밀도 조건(디버터 vertical plate 근방 모사, DiPS-2 장치)을 모사하여 연구한다.
1차년도 연구 결과로 (1) 고열속 정상상태 플라즈마에 노출된 텅스텐 표면의 변형 (Recrystallization) 분석; (2) 천이열속 (ELM 조건 모사 : Laser)를 통한 재료의 손상 (Dust formation); (3) 플라즈마에 의해 전달되는 열속 (heat flux)과 입자속 (particle flux)에 해석; (4) 고온-고압 환경에서의 텅스텐에 수소 및 중수소 흡수에 따른 표면 분석; (5) 플라즈마 경계면에서 전파되는 고주파 모드의 집단적 행동과 전자 및 이온 온도의 영향; (6) 다양한 각도에서 중수소 이온 조사를 통한 재료 표면에 변형 (Blister formation) 기전 해석; (7) 입사각에 따른 중수소 흡착량의 영향 분석 및 모델링 (8) 천이열속 (Plasma Torch)를 통한 재료의 손상 이온; (9) 디버터 텅스텐의 dpa 평가 통해 실험적인 모사(experimental simulation) 자료를 확보하였다.
2차년도 연구 수행 내용으로 (1) 장시간 고열속 정상상태 플라즈마에 노출된 텅스텐 표면의 변형 (Hole formation, recrystallization) 분석; (2) 천이열속 (ELM 조건 모사 : Laser, Target bias)를 통한 재료의 손상 (Erosion, dust formation, or crack); (3) 흡수/취하에 따른 표면 구조 및 중수소 방출 특성 분석; (4) 텅스텐-전자의 충돌 단면적 모델 개발; (5) 열속/이온속 복합 조사 평가용 열속 손상 텅스텐 시편 확보 및 표면 손상 결과 DB 구축; (6) 열속 손상 텅스텐의 이온속 조사 조건 표면 변형 특성 및 중수소 흡착 특성 변동 기전 해석; (7) 텅스텐 중성자 손상 및 중수소 흡착 특성 해석을 위한 전산 모사 체계 구축 (VASP, LAMMPS, 동역학적 몬테카를로)을 통해 디버터에서의 재료 변화 및 플라즈마 변동의 요인과 특성에 대한 연구를 수행 중이다.
본 발표에서는 cimpl센터 소개와 함께, 1차년도 연구결과와 2차년도 연구 수행 내용 및 성과를 발표할 예정이다.

Keywords:

Divertor, Tungsten, Transient HHF, Material-Plasma-Interaction, ELM

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G15.01

Mechano-optic devices for large-scale photonic integration

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Abstract:

Integrated photonics technology has shown remarkable advances in last decade. By using high index optical materials (e.g. Si, SiN), optical mode is confined in area less than μm^2, and therefore be able to integrate high performance optical systems (e.g. optical processing units, vision sensors, chem/bio sensors, transceivers) on chips. However, majority of the systems operates based on thermo- or electro-optic effects which consume large amount of power. For example, one optical phase shifter unit, a fundamental building block of integrated photonics, consumes tens of milliwatts. In addition, they exhibit large optical insertion loss and crosstalk due to weak optical effect (i.e. small refractive index change). As a result, integration densities of integrated photonic systems are far less than that of fabrication capabilities.

In this presentation, we start by explaining principles of mechano-optic devices. Then we present devices based on mechano-optic effect and their applications. Mechano-optic effect enables us to have integrated systems exhibit few orders of magnitude less power consumption/insertion loss/crosstalk than thermo- or electro-optic effects. In particular, we will show experimental demonstrations of large-scale silicon photonic switches, and ultra-low power optical phase shifters.

Keywords:

mechano-optics, large-scale integration, low power consumption, low optical insertion loss

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G15.02

Monolithic integration of efficient InAs quantum dot laser onto Si by direct epitaxy

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Abstract:

I talk about integration methods of various III-V compound semiconductor materials onto Si. Then, silicon photonics will be discussed as a disruptive technology for data center and telecom applications. III-V lasers grown on Si using quantum dot structure will be presented, which shows promising integration approach for efficient and reliable light source onto silicon. The quantum dot lasers on silicon show a very low threshold current, temperature-insensitivity, and extrapolated device lifetimes more than 1 million hours. As a next step, I present a possible way to integrate quantum dot laser source onto Si waveguide via epitaxial integration. Simulation shows that reducing GaAs buffer thickness for evanescent coupling is necessary. I also discuss challenges and promises of the wafer bonding-free laser integration using quantum dots.

Keywords:

quantum dot laser, silicon photonics, epitaxial integration, evanescence coupling

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G15.03

Extreme nanophotonics based on surface polaritons in 2D materials

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Abstract:

Two-dimensional (2D) materials have been the focus of intense research due to their potential for a wide range of nanophotonic applications, including photodetectors, metasurfaces, and sensors. So far, the performances of nanophotonic devices based on 2D materials have been largely limited by weak light–matter interactions in 2D materials. Surface polaritons in 2D materials are one of promising candidates to overcome such challenge since they can confine light to a sub-diffractional length scale around a 2D material layer. However, the unprecedented level of the field confinement enabled by the surface polaritons leads to the extreme momentum mismatch with incident radiation, which in turn limits the coupling efficiency to the surface polaritons.
In this presentation, we present how this fundamental trade-off between the field confinement and the coupling efficiency can be overcome. Based on the understanding on coupling mechanism, we have demonstrated polaritonic resonators that can simultaneously achieve extreme field confinement and near-unity coupling efficiency.

Keywords:

2D materials, surface polaritons, graphene plasmonics, hyperbolic phonon polaritons

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G16.01

광통신 대역에 맞는 광자 생성을 위한 사광파 혼합

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Abstract:

본 연구는 루비듐 원자의 사다리 구도 전이선에서 사광파 혼합에 대하여 실험적으로 조사하였다. 사광파 혼합의 파장은 각각 780nm, 1529nm로 이러한 연구를 통하여 광통신에 사용할 수 있는 광자쌍 생성 광원에 대해 이해한다면 궁극적으로 장거리 통신에 이용할 수 있는 양자리피터를 구현할 수 있을 것이다.

루비듐 원자를 이용하여 빛이 가진 정보를 저장하거나 상관관계가 높은 광자쌍을 이용한 얽힘 현상에 대한 연구 등이 활발하게 이루어지고 있다. 양자 정보 통신에 있어 광원의 정보를 매우 멀리 떨어진 곳까지 전달하는 것은 아주 중요한 문제이다. 이를 실현시켜줄 장치를 양자리피터라 한다. 양자리피터는 이전에 전송된 빛의 정보를 왜곡이나 손실없이 그대로 광원의 형태로 방출하여 아주 멀리까지 보낼 수 있는 장치를 말한다.

본 연구는 이에 관하여 루비듐의 5S-5P-4D 에너지 전이선 구도에서 사광파 혼합에 대하여 조사하였다. 자발적 사광파 혼합(Spontaneous Four-wave Mixing)은 높은 상관관계를 갖는 광자쌍을 생성하는 것으로 잘 알려져있다. 여기서 발생한 광자는 원자와 쉽게 상호작용할 수 있을 정도로 낮은 대역폭을 가진다. 루비듐의 5S-5P-4D 에너지 전이선 구도는 각각 780nm, 1529nm의 파장 간격을 가지고 있다. 특히 1529nm는 광섬유에서 손실이 낮아 광통신에 사용되는 파장 대역에 있다. 그리고 780nm 파장의 빛은 루비듐 원자와의 상호작용을 통해 정보 저장 등의 용도로 사용될 수 있다. 따라서 이 에너지 구도에서 자발적 사광파 혼합에 의한 광자쌍 생성이 많은 광자쌍을 만들어 낼 수 있다면 광자의 정보를 아주 먼 거리까지도 손실 없이 전달할 수 있을 것이고 이는 장거리에서 사용할 수 있는 양자 리피터 개발로 이어질 수 있을 것이다.

실험 구성은 각각 780nm, 1529nm의 펌프레이저를 87Rb 원자 증기셀에 서로 마주보는 방향으로 보낸 후 파장이 동일한 또 다른 각각의 시드레이저를 특정 각도로 넣어주어 사광파 혼합 신호를 측정하였다. 사광파 혼합 신호는 세 레이저의 방향과 관련하여 위상 정합 조건(phase-matching condition)에 맞는 특정 각도로 나온다. 본 연구에서는 이를 이론적으로 계산하여 1.5um의 시드레이저가 1.5도로 입사할 때 780nm의 FWM신호가 펌프신호에 대하여 1.1도 틀어져서 나올 것이라 예측하였다.

사광파 혼합 신호의 경향성을 각각의 레이저 세기 및 주파수를 바꿔가며 측정하여 사광파 혼합에 관한 비선형 효과의 메커니즘을 이해하고자 하였다.

Keywords:

Spontaneous Four-wave Mixing, Quantum Repeater

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G16.02

마이크로 세슘 증기 셀에서 사광파조합

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Abstract:

양자광학 실험을 위한 첫번째 단계는 적합한 광원을 갖는 것이고 실험의 목적에 따라 다양한 방법으로 만들어진 광원을 사용한다. 선폭이 좁고 얽힘을 가지는 단일-광자 광원을 만드는 대표적인 방법으로는 증기셀에서 SpFWM(Spontaneous Four Wave Mixing)과정을 통하여 얻는 방법이 있다 [1-2]. 하지만 광원을 만들기위해 사용되는 기존의 원자 증기셀을 비롯한 광학장비들의 부피가 커서 다른 실험과의 연계를 위한 접근성, 공간적인 설계에 제약이 존재한다는 문제가 있다.
본 연구에서는 기존에 사용되던 세슘 증기셀과 마이크로 사이즈의 세슘 증기 셀의 OD(Optical Density)를 비교하였으며, 마이크로 세슘 증기 셀에서 사광파조합 신호를 관측하였다. 광자 생성에 사용된 레이저들의 출력 및 주파수들을 변화시키며 얻은 신호들을 통해 마이크로 셀이 갖는 특성을 분석하였고, 마이크로 셀이 기존의 셀을 대체하여 선폭이 좁고 소형화가능한 단일-광자 광원을 만들 수 있다는 가능성을 확인하였다.

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Keywords:

사광파조합(FWM, Four-wave mixing), 양자광원, 마이크로 세슘 증기 셀

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G16.03

Simulation and fabrication of a linear Paul trap with segmented blades(분할된 날을 이용한 선형 폴 이온트랩의 개발)

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Abstract:

분할된 날(segmented blade)을 이용한 이온트랩 디자인과 개발 과정에 대해 보고한다. 본 연구에서는 171Yb+ 이온에 대해, 분할된 금속날 포획의 3차원 시뮬레이션을 수행하여 이온의 포획 주파수 (trap frequency)가 횡방향 3 MHz, 종방향 1 MHz인 조건을 찾았다. 또한 알루미나 세라믹을 이용한 레이저 미세가공을 수행하여 5개로 분할된 날 제작에 성공하였고 이에 대한 주사전자현미경(scanning electron microscope) 사진을 보인다. 이러한 이온트랩 실험 장치를 설치하기 위한 진공 챔버와 Yb 원자빔 제작에 대해 보고한다. 고충실도(high fidelity) 2큐빗 게이트가 수행 가능한 5큐빗 양자컴퓨터 개발을 진행할 계획이다.
*홍정수와 김명훈의 이 일에 대한 기여도는 같음.

Keywords:

Segmented Blade, Ion trap, 171 Ytterbium Ion, UHV, Vacuum Chamber

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G16.04

Genuinely tripartite Bell inequality using a quasi-distance

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Abstract:

It is shown that information-theoretical distances are powerful tool to investigate various non-classical phenomena for qubits, for examples Bell inequalities, contextuality, monogamies and so on. However, a generalization to many quDits is non-trivial problems as quantum correlations for qudits reveal their properties in a way different from qubits. We here introduce a quasi-distance that is a metric sans symmetry. It enables to derive Svetlichny-Zohren-Gill type Bell inequalities for d-dimensional tripartite systems. We will show that our Bell inequalities are genuinely tripartite ones and discuss quantum violations and measurement settings. We also discuss their monogamous natures.

Keywords:

Bell inequalities, monogamy, qudit, quasi-distance

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G16.05

Rydberg-atom quantum simulator measures quantum-Ising eigenspectra of non-isomorphic graphs of up to six qubits

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Abstract:

Here we report experimentally measured conformation eigenspectra of quantum-Ising Hamiltonian systems. In our Rydberg-atom quantum simulator, all possible non-isomorphic graphs of N=3 and 4 qubits and bi-layer antiprism graphs of N=6 qubits, and their geometric imtermediates, are constructed, in which vertices and links represent atoms and Rydberg blockade couplings, respectively. Their eigenenergy changes are measured with Fourier transform spectroscopy, in particular, during their topological transformations. With the coherence time of 0.01 ms, improved by locking the laser frequencies to ULE reference cavities, spectroscopic resolution (dE/E) less than 10% is achieved. The measured energy level changes are in good agreement with the model few-body quantum-Ising Hamiltonian. It is hoped that programmable high-dimensional qubit connectivities demonstrated in this work shall be useful for quantum simulator applications.

Keywords:

Rydberg atom, quantum simulation

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G16.06

Development of asymmetric optical cavity in strong atom-cavity coupling regime
원자-공진기 강결합 영역에서 비대칭 공진기의 개발

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Abstract:

다양한 양자네트워크 플랫폼 중 원자-공진기 기반의 양자노드는 많은 발전을 보여왔다. 본 연구에서는 효율적인 양자인터페이스를 위한 공진기 개발과 특성 조사에 대해 보고한다. 여기서 사용된 공진기는 780 nm 근처에서 약 20,000 이상의 휘도(finesse)를 가지고, 두 개의 비대칭적인 반사율을 가진 거울로 구성되어 한 쪽 거울로만 80% 이상의 광자가 빠져나가는 효율적인 광자 추출이 가능하다. 780 nm 다이오드 레이저를 이용하여 공진기 길이, 휘도, 복굴절(birefringence) 정도, 기계 진동수(mechanical resonance)를 측정하였고, 795 nm에서 공진기 특성 역시 조사되었다. 본 공진기에 단일 루비듐 원자를 결합하여 양자광학, 양자네트워크 실험을 진행할 계획이다.

Keywords:

Cavity QED, High Finesse Fabry-Perot Optical Cavity

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G16.07

원자 앙상블을 이용한 4-광자 Greenberger-Horne-Zeilinger(GHZ) 상태 구현과 특성 분석

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Abstract:

본 연구에서는 도플러 선폭 확대된 87Rb 원자 앙상블을 이용한 두 개의 독립적인 편광 얽힘 광원으로부터 4-광자 Greenberger-Horne-Zeilinger (GHZ) 상태를 구현하고 특성을 분석하였다. 편광-얽힘 광원은 ^{87}Rb 원자의 $5S_{1/2} - 5P_{2/3} - 5D_{5/2}$ 전이선에서 이-광자 결맞음 효과로 인한 자발적 사-광파 조화 과정을 통하여 생성된 광자-쌍을 사냑 간섭계에서 중첩 시켜 얻었다.

각각의 편광-얽힘 광원은 $|\psi\rangle = \frac{1}{\sqrt{2}}(|H_sH_i\rangle + |V_sV_i\rangle)$ 상태로 형성되어 있다. 여기서 H, V 는 수평과 수직 편광된 광자 상태를 의미하여 아래 첨자 s, i 는 780 nm 파장의 시그널 (signal) 광자와 776 nm 파장의 아이들러 (idler) 광자를 의미한다. 두 광원으로부터 아이들러 광자를 가져와 편광 빔 분할기로 입사시키면 다음과 같은 4-광자 GHZ 상태를 얻을 수 있다.
$|GHZ\rangle = \frac{1}{\sqrt{2}}(|H_1H_2H_3H_4\rangle + |V_1V_2V_3V_4\rangle)$ 이렇게 생성된 GHZ 상태의 신뢰도를 얻기 위해 편광 기반 측정을 통한 얽힘 증거 (Entanglement witness)와 양자 상태 단층촬영 (Quantum state tomography) 두 가지 방법을 수행하였다.

Keywords:

원자 앙상블, 양자얽힘, GHZ 상태

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G17.01

Nanoscale Hyperspectral Mapping by using Photo-induced Force Microscopy

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Abstract:

The nanoscopic resolution provided by atomic force microscopy (AFM) yields topographic images with exquisite detail, enabling visualization of individual atoms and intermolecular bonds under optimized conditions. Yet, it has proven difficult to relate the local interaction forces on which the contrast is based to chemically selective information. In this regard, recent developments in combining photo-induced molecular excitations with mechanical force detection, photo-induced force microscopy (PiFM), are of particular interest, as these approaches seek to add chemical selectivity to force microscopy. The photo-induced forces, strongly localized by the tip-enhanced field, depend on the local response of the media, which covers from induced dipole interaction to thermal expansion, can be probed with a spatial resolution of a few nanometers.

Exploiting the photoinduced force under the mid-infrared light, the so-called molecular “fingerprint” response of a monolayer ligand-functionalized single nanoparticle is investigated by obtaining the nanoscale hyperspectral images with a 10 nm spatial resolution. We extend our study to the diagnosis of nanoscale heterogeneous chemical contaminants which come from a particle functionalization process but are undetectable in conventional ensemble-averaged imaging technique. High sensitivity and high spatial resolution are achieved via the strongly localized tip-enhanced force at the junction between the gold coated tip and the functionalized nanoparticle, which far exceeds the capability of the conventional methods. The present study paves a new way to directly detect heterogeneous chemicals at the single component level, which is necessary to evaluate nanomaterial safety in biomedical applications.

Keywords:

Nano-IR, Spectroscopic imaging, Photo-induced Force Microscopy, Chemical imaging

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G17.02

THz near-field spectroscopy of single coaxial aperture

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Abstract:

We experimentally demonstrated a single coaxial aperture as a practical platform for THz absorption spectroscopy. THz tip-probe near-field measurement system is used to investigate the electric field distribution in a single coaxial aperture and the near-field image clearly shows that the electric field is strongly confined at the gap. Near-Field transmissions at the gap as a function of the distance of the THz probe from the sample also show that the field enhancement inside the gap dramatically increases. After inserting lactose in the gap, we can couple the intense optical fields of the single annular gap into the vibrational modes of lactose molecules. We observed high contrast THz absorbance signals drastically suppressing of the transmitted light. This result indicates that the single annular aperture can be used as a platform that is promising avenues toward future drastic miniaturization of THz devices and sensors..

Keywords:

THz near-field spectroscopy

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G17.03

Investigation of Chemical Origin of White-Light Emission in Two-Dimensional $(C_4H_9NH_3)_2PbBr_4$ via Infrared Nanoscopy

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Abstract:

The broadband light emission in low-dimensional organic lead halide perovskites (OHPs) is a fascinating property for white light-emitting diodes (LEDs). However, unique emission has been observed in highly distorted low-dimensional OHPs such as (110) and (111) perovskites. Herein, we report the first observation of white-light emission under ambient conditions in a rectangular microsheet of $(C_4H_9NH_3)_2PbBr_4$, a (100) perovskite. The origin of white-light emission in $(C_4H_9NH_3)_2PbBr_4$ was revealed as defect-assisted radiative recombination via excitation power-dependent photoluminescence measurement. Additionally, the origin of the defect was confirmed to be organic cation vacancies formed by intercalated water molecules via infrared nanoscopy.

Keywords:

organic lead halide perovskite, 2D perovskite, IR Nanoscopy, White-light emission, Defects

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G18.01

이중 페로브스카이트 Mn^{4+} 첨가된 Ba_2YTaO_6 형광체의 합성 및 특성

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Abstract:

3가 희토류 이온 활성화 산화물 형광체는 고체조명 응용 분야에서 광범위하게 연구되고 사용되고 있다. 그러나 희토류 재료의 부족으로 인해 경제 및 대체 재료가 필수적입니다. 현재 이용 가능한 원료, 특히 효율이 우수한 희토류 비활성화 적색 형광체가 더 적합하다. 오늘날, 비교적 온화한 조건에서 제조될 수 있는 환경 친화적인 희토류가 없는 적색 인광체를 위한 Mn^{4+} 활성 산화물계 호스트 재료는 많은 관심을 끌고 있다. 본 발표에서는, Mn^{4+} 활성화된 Ba_2YTaO_6 형광체는 기존의 고체반응법에 의해 합성되었다. 소자의 상 식별, 입자 표면 구조 및 산화 상태를 상세하게 연구하였다. Ba_2YTaO_6: Mn^{4+} 형광체의 발광 거동은 광 발광 (PL: photoluminescence) 스펙트럼 및 온도 의존성 PL 측정으로 조사되었다. 얻어진 실험 결과는 Ba_2YTaO_6:Mn^{4+} 형광체가 고체조명 응용에서 적색-발광 형광체로서 사용될 것임을 나타낸다.

Keywords:

Phosphors, Solid-state reaction, Luminescence

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G18.02

Drain Induced Fermi Energy Shift in ReS_2 Multilayers

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Abstract:

Strong vertical gate bias-dependent interlayer tunneling barrier (E_{int}) and Thomas-Fermi charge screening effects play a critical role in carrier transport of two-dimensional (2D) multilayer system such as channel migration along the c-axis. However, since E_{int} varies considerably with a drain bias (V_D) either, the effective contribution of each layer to the total current would differ as a function of V_D, causing a shift of flat band voltage (V_{FB}). Herein, we demonstrate a drain induced barrier increasing (DIBI) in 2D multilayer rhenium disulfide (ReS_2), which is a reverse drain induced barrier lowering (DIBL). The layer-independent electronic band structure and much higher interlayer resistivity of ReS_2 than that of other 2D materials allow us to observe DIBI clearly. As V_D becomes higher, the amplitude of E_{int} decreases, consequently leading to i) increase of off-current, ii) enhancement of field-effect mobility, and iii) positive shift of V_{FB}, but which is in sharp contrast to what reported previously in a short channel bulk-Si devices in the presence of DIBL. We attribute this contradiction to the inefficient Fermi level tunability arising from the channel migration from bottom- to top-surface of ReS_2. The V_D-dependent Coulomb scattering parameter probed via a low-frequency noise analysis further supports the channel migration inside a multilayer ReS_2. Our findings pave the way for the fundamental charge transport mechanism in a 2D multilayer system.

Keywords:

Drain induced barrier increasing, multilayer materials, interlayer tunneling barrier, rhenium disulfide, carrier transport.

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G18.03

Coherent polarization of micro-photoluminescence in an anisotropic single quantum ring

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Abstract:

Polarization dependence of micro-photoluminescence(micro-PL) spectrum was studied in order to investigate the localized states in an anisotropic single GaAs/AlGaAs quantum ring. With a pair of perpendicularly polarized spectrum, we observed polarization dependent micro-PL intensity and a small energy difference (~0.1 meV) . When the polarized spectrum was also analyzed in terms of four Stokes parameters, we found that a significantly large ratio of incoherent PL (~25%) is involved in the crescent-like localized state. This result was attributed to elastic charge scattering of different fine levels in the same quantum ring. Additionally, coherent polarizaions of spectrum were calulated without incoherent light from Poincare sphere.

Keywords:

quantum ring, Coherent Polarization, Stokes parameter

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G18.04

InAs/AlSb 초격자 구조의 광학적 특성 연구

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Abstract:

GaSb 기판 위에 도핑 하지 않은 GaSb buffer layer 위에 InAs 7 monolayer (ML)과 AlSb 7 ML을 1주기로 사용하여 InAs/AlSb 초격자를 p-i-n 구조로 성장시켰다. 808 nm laser를 사용하여 파워 의존성과 온도의존성 Photoluminescence (PL)를 실험하였다. 파워 의존성 PL 에서는 파워가 약해질수록 높은 에너지 쪽으로 이동하였으며 총 3개의 피크가 약 0.674 eV에서 0.81 eV에서 관측되었다. 가장 낮은 에너지 피크는 GaSb defect 신호, 중간 영역 피크는 InAs/AlSb SL 신호 그리고 가장 높은 영역의 피크는 GaSb 신호로 추정되어진다. 온도 의존성 PL 실험에서는 온도가 높아질수록 저 에너지 영역으로 피크들이 이동하며 220 K 이상에서는 약 0.72 eV에서 날카로운 피크가 추가적으로 관측되어졌다.

Keywords:

InAs/AlSb superlattice, Photoluminescence

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G18.05

The optical properties of PIN-AlGaAsSb Random alloy and Digital alloy on InP by Photoluminescence and Photoreflectance Spectroscopy

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Abstract:

MBE를 이용해서 성장시킨 PIN 구조의 AlGaAsSb Random alloy(RA) 방식과 Digital alloy(DA)방식을 이용하여 성장한 샘플의 광학적 특성을 Photoluminescence와 Photoreflectance를 이용하여 분석하였다. 샘플은 InP위에 n++-$In_{0.53}Ga_{0.47}As$ 500nm, n+-$Al_{0.85}Ga_{0.15}As_{0.56}Sb_{0.44}$ 100nm, RA UID-$Al_{0.85}Ga_{0.15}As_{0.56}Sb_{0.44}$ 1000nm, p+-$Al_{0.85}Ga_{0.15}As_{0.56}Sb_{0.44}$ 300nm, p++- $In_{0.53}Ga_{0.47}As$ 20nm와 DA $Al_{0.85}Ga_{0.15}As$와 $Al_{0.85}Ga_{0.15}Sb$를 교차 적층 구조의 UID-AlGaAsSb를 각각 성장하여 비교하였다. 여기 광원으로 532nm 레이저를 이용하여 PL과 PR을 측정하였다. PL은 1.5eV, 1.4eV 영역대에서 각각의 스펙트럼이 관찰되었으며, 온도에 따른 S-shape 곡선이 관찰되었다. PR에서는 0.731eV영역에서 InP의 신호를 관찰하였으며, RA와 DA의 스펙트럼의 shift를 관찰하였다. 이는 DA의 격자 불일치의 영향으로 사료된다.

Keywords:

Photoluminescence, photoreflectance

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G18.06

Evaluation of the electric field of $In_{0.25}Ga_{0.75}As_{0.3}Sb_{0.7}$ nBn detector by using the photoreflectance spectroscopy.

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Abstract:

The temperature dependences of the electric fields have been investigated for a $In_{0.25}Ga_{0.75}As_{0.3}Sb_{0.7}$ nBn detector by using photoreflectance (PR) spectroscopy. The $In_{0.25}Ga_{0.75}As_{0.3}Sb_{0.7}$ nBn detector grown by using molecular beam epitaxy(MBE) method. The electric field strength was examined through the Franz-Keldysh oscillation (FKO) analyses with respect to temperature in the range from 200 to 300 K. In photoreflectance (PR) spectrum, the signals related to the $In_{0.25}Ga_{0.75}As_{0.3}Sb_{0.7}$ absorption and $Al_{0.35}$ $Ga_{0.65}$ Sb barrier layer were observed at 0.62 and 1.15 eV, respectively. Above the band gap, the FFT methods are used to examine the strength of the electric field. The results show that the strength of the electric field decreased with decreasing temperature in the $In_{0.25}Ga_{0.75}As_{0.3}Sb_{0.7}$ absorption layer. Also, we showed that a similar PR signal fitted by PR functions in the FKO oscillation period. And the theoretically and experimental spectra are similar. A decrement of the temperature makes the decrement of the density of electron and holes carriers due to decreasing the density of states, which increases the number of photo-generated excess carriers. We also demonstrate that PR spectroscopy is a good method for investigating the optical properties in the nbn detectors.

Keywords:

nbn detector,photoreflectance spectroscopy, FKO oscillation

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G18.07

Improving the optical properties of droplet-epitaxy-grown GaAs/AlGaAs quantum dots by thermal annealing

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Abstract:

Intermediate band solar cells (IBSCs) have been suggested as a next-generation approach to overcome Shockley-Queisser (SQ) efficiency limits through sub-bandgap interband photon absorption [1]. The maximum efficiency of an IBSC is calculated to be 63.2% under full concentration (46200 suns), which is much higher than the SQ limit of 40.7% for a conventional single-gap solar cell [2]. In this work, we report the effects of the annealing temperature for the GaAs/AlGaAs quantum dot heterostructures on their optical properties. GaAs quantum dots were grown on a GaAs (001) substrate by droplet epitaxy in a molecular beam epitaxy system and were in-situ annealed at 650, 700, and 750℃ for 1 hour after capping with $Al_{0.3}Ga_{0.7}As$. Figure 1 shows the low-temperature (20 K) photoluminescence (PL) spectra of the three annealed samples. The PL peak energy is blueshifted with increasing the annealing temperature, possibly due to the size reduction of GaAs quantum dots. The crystal quality of GaAs quantum dots is significantly improved with higher annealing temperature, evidenced by the stronger PL peak intensity. These experimental results indicate that optimal thermal annealing enhances the optical properties of droplet-epitaxy-grown GaAs/AlGaAs quantum dots with high crystallinity, which can be applied as a superior sub-bandgap photon absorber in IBSCs.

Keywords:

quantumdot, annealling

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G19.01

The packaging process of a DNA into a viral capsid determines how the DNA exits the capsid

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Abstract:

There are a tremendous number of bacteriophages about 10^{31} on earth. It usually takes about minutes to days for each bacteriophage to undergo replication. Therefore, packaging polymeric materials such as DNAs into a small confinement of a viral capsid and ejecting the DNA from the capsid occur almost all the time ubiqutously in nature. Packaging and ejecting a long macromolecule via a small confinement is an important topic in various industrial applications, too. Under the local equilibrium approximation, the ejection process of the DNA has been usually considered irrelevant to how the DNA was packaged in the first place. It has been accepted that the DNA conformation would reach an equilibrium one at the conformational free energy minima after the packaging was complete. This suggests that the ejection process would be independent of the history of the packaging process. According to recent studies, however, DNAs are often jammed in non-equilibrium states with various conformations inside the viral capsid due to a high density. In this talk, I present Langevin dynamics simulation results to investigate the packaging and ejection process of a semi-flexible chain in a confinement. I will show that the ejection process should depend significantly on how the chain was packaged. The ejection can be categorized into three regimes depending on how the packaging was completed: (1) knot dominant, (2) non-equilibrium conformation dominant and (3) intermediate regimes. In case the packaging was sufficiently slow, the chain forms a complex knot readily such that the ejection slows down (the knot dominant regime). On the other hand, when the packaging occurred quickly, the knots are less likely to form but the chain is jammed in non-equilibrium conformational states, which slows down the ejection (non-equilibrium dominant regime). For a moderate packaging rate, the polymer chain may relax its conformation readily with a low chance of knot formation, thus leading to a facilitated ejection (the intermediate regime).

Keywords:

DNA, Packaging, Ejection, Knot, Langevin dynamics, Non-equilibrium

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G19.02

Super-accuracy molecular dynamics simulations of proteins

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Abstract:

Through the decades-long developments, the molecular dynamics (MD) simulation became one of the most promising techniques to characterize the folding-unfolding energetics and diffusive dynamics of proteins at unprecedented resolutions in space, time, and energy. However, recent extensive validations of the state-of-the-art MD techniques turned out rather disappointing. Even for small model proteins such as Trpcage, the folding-unfolding energetics and the physical size of unfolded conformations disagree with the experiments by more than 5 kT and a factor of two, respectively. For DNA clamps, the diffusion coefficient shows an order of magnitude discrepancy with experiments. By closely examining the fundamental molecular forces, we reveal that the current MD models significantly overestimate the strengths of hydrogen bonds and charge-charge interactions, resulting in the discrepancies with experiments. Further, we propose newly revised interaction models that can achieve accuracies of folding-unfolding energetics within a kT level and diffusion coefficients within a standard error.

Keywords:

Molecular dynamics, Protein folding, Diffusion

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G19.03

New trends in computational biophysics

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Abstract:

Since the first emergence of biomolecule (bovine pancreatic trypsin inhibitor) simulation by Martin Karplus et al in 1977, computational biophysics has played an essential role in modern biology, medicine and pharmaceuticals. In particular, statistical mechanics, quantum chemistry/mechanics, and polymer physics made great contribution to the establishment of robust concepts in computational biophysics over the last 50 decades. Physics-based concepts led to the platform development of molecular dynamics simulation and quantum simulation packages for biomolecule simulation based on large–scale computer calculations, one of the efficient tools in computational biophysics. In this presentation, we discuss of recent research trends in computational biophysics based on statistical mechanics, quantum chemistry/mechanics. And we also discuss the new emergence and potential of artificial intelligence in computational biophysics.

Network theory
Non-receptor tyrosine kinase c-Src plays a critical role in numerous cellular signaling pathways. Activation of c-Src involves a change from its inactive to its active state accompanied by large-scale conformational change depending on the phosphorylation state of two major phosphorylation sites, Tyr416 and Tyr527. A detailed mechanism for the entire conformational transition of c-Src via phosphorylation control of Tyr416 and Tyr527 is still elusive. We investigated the inactive to active conformational transition pathway based on network analysis.

Quantum mechanics
We investigate the dinuclear manganese, Mn(II)–Mn(II), active site of human cytosolic X-propyl aminopeptidase (XPNPEP1) by employing the QM/MM method. The optimized structure supports two manganese atoms at the active site and excludes the possibility of a single Mn(II) atom or another combination of divalent metal ions, Ca(II), Fe(II), and Mg(II). A broken-symmetry solution verifies an antiferromagnetically coupled state between the Mn(II)–Mn(II) pair, which is the ground state. From the energy difference between the high spin state (HS) and the broken-symmetry state (BS), we estimate the exchange coupling constant, J.

Artificial Intelligence
The prediction of a native fold for an unknown protein remains challenging, especially if the amino acid sequence is particularly unique. We discuss of innovate techniques used in the prediction of distinct protein folds through the application of deep learning and statistical physics based on decades of accumulated knowledge and theory centered around the protein folding theory.

Keywords:

computational biophysics, statistical physics, qunatum mechanics, Artificial Intelligence

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G19.04

Θ-chain in confined space and its implication to biopolymers

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Abstract:

When compressed in a slit of width D, a theta-chain whose size (R_0) scales as $R_0 \sim aN^{1/2}$, expands in the lateral direction as $R_{||} \sim aN^{\nu}(a/D)^{2\nu-1}$. Provided that the theta condition is strictly maintained throughout the compression, the well-known scaling exponent of Θ-chain in two dimensions, ν = 4/7, is anticipated upon a perfect confinement. However, numerics shows that upon increasing compression, the exponent ν gradually deviates from ν = 1/2 and plateaus at ν = 3/4, the exponent associated with the self-avoiding walk in two dimensions. Using both theoretical considerations and numerics, we argue that it is highly nontrivial to maintain the Θ condition under confinement because of two major effects. First, as the dimension is reduced from three to two dimensions, the contributions of higher order virial terms, which can be ignored in three dimensions at large N, become significant, making the perturbative expansion used in Flory-type approach inherently problematic. Second and more importantly, the geometrical confinement, which is regarded as an applied external field, alters the second virial coefficient (B_2) changes from $B_2 = 0$ (Θ condition) in free space to $B_2 > 0$ (good-solvent condition) in confinement. Our study offers better understanding of the confinement effect on the conformation of a single biopolymer chain.

Keywords:

Theta-chain, 2-dimension, confinement, Polymer

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H1.01

Development of low threshold detector to search for light dark matter

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Abstract:

Most studies have focused on searching for dark matter with masses of 10GeV/c^2, but recently an increasing interest points towards models involving lighter particles. So we started an experiment to detect light dark matter using a low threshold detector. Detector module consists of CaF_2 crystal and MMC (Metallic Magnetic Calorimeter) sensor. MMC is a sensor that can measure temperature changes and measures the phonon signal generated by the crystal. In this presentation, we will present the results of the low threshold experiment.

Keywords:

MMC, SQUID, CaF2

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H1.02

Background modeling and Threshold study for Neutrino Elastic-scattering Observation with NaI(Tl)(NEON) experiment

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Abstract:

NEON (Neutrino Elastic-scattering Observation with NaI) aims an observation of a coherent elastic neutrino-nucleus scattering (CEvNS) using reactor anti-electron neutrino which has not been measured yet with NaI(Tl) crystal detectors at Hanbit nuclear power plant in Yeounggwang. Now it has been installed in the IBS headquarters(Daejeon) to measure background and threshold. The background level of approximately 4 counts/day/kg/keV and the background modeling study is ongoing using Monte Carlo simulation. Threshold study is also ongoing using machine learning methods to go under energy range for 1-0.5 keV target. The details of the experimental analysis will be presented here.

Keywords:

Neutrino, NEON, NaI(Tl)

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H1.03

NaI(Tl) temperature-dependent responses measurement at -35℃

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Abstract:

NaI(Tl) detector has many uses including rare event searches. Since it is known that the light yield of NaI(Tl) is increased at temperature around -35℃, we measured responses of high-light-yield NaI(Tl) crystal detector at two different temperatures of -35℃ and 22℃. Temperature dependence on the light yield, neutron and gamma pulse shape discrimination power, and neutron quenching of NaI(Tl) will be reported in this presentation.

Keywords:

NaI(Tl), Low temperature, Light yield, Pulse shape discrimination

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H1.04

Improved intensities for the gamma transitions with E_γ> 3 MeV from ^{208}Tl decay

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Abstract:

The background study from the decay of 208Tl is one of the important issues for the neutrinoless double-beta decay search experiments because this decay has high Q-value (5 MeV) and can produce background signals at regions of interest(ROI) in their experiments.
Most gamma transitions from the 232Th decay chain were studied well, however, the gamma transitions with E_γ> 3 MeV from decays of ^{208}Tl, have not been observed and their transition intensities were known only as upper limit values. The simulation study for the AMoRE experiment suggested that these high gamma transitions can produce non-negligible internal background signals in the ROI if current upper limits for intensities as real numbers are used. Therefore, we measured a ThO_2 powder using a100% HPGe (High Purity Germanium) detector to obtain more accurate intensity values of the 3198keV, 3475 keV, and 3708 keV transitions from ^{208}Tl decay.
From this measurement, we improved upper limits for intensities of the 3198 keV, 3475 keV, and 3708 keV gamma transitions as < 1.2×10^{-4}%, < 1.6×10^{-4}, and < 1.0×10^{-4}%, respectively. These upper limits are at least a factor of 20 better than the previous results.

Keywords:

HPGe detector, 208Tl decay, Neutrinoless double-beta decay, background study

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H1.05

Measurement of cosmogenic Li/He production rate at RENO

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Abstract:

A high energy cosmic muon produces various spallation isotopes in the RENO detector. Among them, unstable isotopes of 9Li and 8He can mimic reactor neutrino candidate events and become one of the most serious backgrounds in precise determination of the neutrino mixing angle theta13. The cosmogenic 9Li/8He production rate is measured using the time correlation relative to their preceding muon and the spectral shape of their decay products. The fraction of 8He is also measured from the energy spectrum of 9Li/8He decay products. In this talk, we present the measured production rate of cosmogenic 9Li/8He isotopes in the RENO detector.

Keywords:

RENO, 9Li, 8He

H1.06

Updated RENO results on reactor antineutrino oscillation amplitude and frequency

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Abstract:

The RENO experiment has precisely measured the amplitude and frequency of reactor antineutrino oscillation near the Hanbit Nuclear Power Plant since Aug. 2011. The results published in 2018 were based on ~2200 days of data. We have collected and analyzed additional ~900 days of data with improvements. The additional data are taken in a period of only one or two reactors in operation to provide rather minimal reactor thermal powers. In this presentation, we report updated measurements of reactor antineutrino oscillation amplitude and frequency using ~3100 days of data.

Keywords:

RENO, neutrino oscillation

Measurement of reactor neutrino flux and spectrum at RENO

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Abstract:

The RENO experiment reports measured flux and energy spectrum of reactor electron antineutrinos from the six reactors at Hanbit Nuclear Power Plant. The measurement uses 2900 days of data taken from August 2011 to March 2020. The inverse beta decay (IBD) yield measured in the near detector is reported with the corresponding ratio to the prediction by the Huber and Mueller (HM) model. A reactor antineutrino spectrum is obtained by unfolding a measured IBD prompt spectrum. The measured neutrino (prompt) spectrum shows a clear excess around 6 (5) MeV of neutrino (prompt) energy relative to the HM prediction. A correlation between the fraction of this excess and a fission fraction of a certain fissile isotope is shown. The measured reactor antineutrino spectrum will be useful in understanding unknown neutrino properties and reactor models. The potential application of this model-independent antineutrino spectrum also will be presented.

Keywords:

reactor antineutrino, neutrino oscillation, RENO

Study of accidental background using machine learning at RENO

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Abstract:

The RENO's first measurement of the mixing angle of theta13 using reactor neutrino events with neutron capture on hydrogen is published in early 2020, based on 1500 live days of data. The reactor neutrino candidate sample suffers from a high accidental background due to random coincidence between prompt and delayed candidate events. The high rate of ambient gamma-rays causes an overwhelming background against the delayed signal of 2.2 MeV gamma-rays coming from neutron capture on hydrogen. In order to reduce the accidental background rate and uncertainty, we employ a multivariate analysis of TMVA(the toolkit for multivariate data analysis) that can be integrated into the analysis framework ROOT. We also use the gradient Boosted Decision Tree algorithm to classify the signal events and accidental backgrounds. In this talk, we present efforts on accidental background reduction in 2200 days of RENO reactor candidate sample accompanied with a delayed signal of neutron capture on hydrogen.

Keywords:

RENO, Machine Learning, Hydrogen

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H2.01

Current status of JSNS^2 experiment

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Abstract:

The JSNS^2 (J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source) experiment will search for neutrino oscillations over a short 24 m baseline with delta m square near 1 eV square at the J-PARC Materials and Life Science Experimental Facility. The JSNS^2 detector will be filled with 17 tons of gadolinium-loaded liquid scintillator (LS) with an additional 31 tons of unloaded LS in the intermediate gamma-catcher and outer veto. A 1 MW proton beam (3 GeV) incident on a mercury target produces an intense neutrino beam from muon decay-at-rest. The experiment will search for muon antineutrino to electron antineutrino oscillations, detected via the inverse beta decay reaction (electron antineutrino + proton -> positron + neutron), which is then tagged by the distinctive gammas from neutron capture on gadolinium. JSNS2 is expected to provide the ultimate test of the LSND anomaly by replicating nearly identical conditions with a much better S/N ratio. In June 2020, JSNS^2 took the first 10 days of physics data after scintillator filling and extracted the scintillator for the summer maintenance of the MLF. In this talk, we will summarize the detector operation and subsystems including scintillator filling and extraction procedure, data acquisition system, and preliminary data analysis status.

Keywords:

JSNS2, sterile neutrino

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H2.02

Background study status of JSNS2 experiment

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Abstract:

The goal of the JSNS2 (J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source) experiment is searching for neutrino oscillations with Δm2 ~ 1 eV2 at the J-PARC MLF (Materials and Life Science Experimental Facility), over a short baseline (24m). The JSNS2 detector is filled with 17 tons of gadolinium-loaded liquid scintillator (LS) in the target, and additional 31 tons of LS in the gamma-catcher & veto. A 3 GeV 1 MW proton beam incident on a mercury target at the MLF produces an intense neutrino beam from muon decay at rest (mu-DAR). This experiment will search for anti-muon neutrino to anti-electron neutrino oscillations, detected via the inverse beta decay (IBD) reaction which is tagged by gammas from neutron capture on Gadolinium. JSNS2 is the experiment which can be the direct test of LSND anomaly with very similar conditions, but much better S/N ratio. In June 2020, JSNS2 took the 10 days of physics data. And in this presentation, we will show the overall summary for the background study status, using these 10 days of data.

Keywords:

JSNS2, Background, Sterile Neutrino

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H2.03

The slow control and monitor system of JSNS^2 Experiment

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Abstract:

The hunting for sterile neutrinos is one of the most interesting topics in neutrino physics. The JSNS^2 experiment is aimed to search for the existence of neutrino oscillation with $\triangle m^2$ near eV^2 based on electron antineutrinos appearance at the J-PARC materials and Life Science Experimental Facility(MLF). The JSNS^2 expects an ultimate direct test of the LSND results at lower backgrounds utilizing a pulsed proton beam and a better neutrino detector with gadolinium loaded liquid scintillator. The JSNS^2 detector will be filled with 17 tons of gadolinium-loaded liquid scintillator (LS) with an additional 31 tons of unloaded LS in the intermediate gamma-catcher and outer veto. The slow control and monitor system has been installed to control systematic effects. In this presentation, I introduce the slow control and monitor system.

Keywords:

Sterile neutrino, J-PARC, Slow control and monitor system

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H2.04

PSD study of Gd-loaded liquid scintillator with DIN

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Abstract:

In the JSNS2 (J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source) experiment, pulse shape discrimination (PSD) is used to reduce the neutron background. Generally, DIN-based liquid scintillator (LS) make to improve PSD performance compare to LAB based LS. In order to reduce neutron background, we plan to add DIN to the Gd-LS. In this presentation, we summarize the measurement result of PSD performance for GdLS with DIN.

Keywords:

JSNS2, Neutrino, PSD, LS, DIN

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H2.05

Progress and plans of DUNE

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Abstract:

DUNE is building detectors for muon neutrino oscillation over 1300-km long baseline and the observation of neutrinos from cosmic rays, sun, and supernovae, etc. As the construction of far detectors in South Dakota and the design of near detectors in Illinois, USA are taking stages, the sensitivities of mixing angles and CP phase are updated along with the expected timeline for physics targets. This talk shares the overall status of DUNE construction, detector R&D, and broad possibilities for new physics.

Keywords:

long-baseline neutrino oscillation, high-intensity proton beam, Leptonic CP violation

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H2.06

The DUNE Near Detector

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Abstract:

The Deep Underground Neutrino Experiment (DUNE) will host the Near Detector (ND) facility near the Fermilab site. Main physics goals in DUNE including the Charge-Parity violation measurement heavily rely on precise understanding of the neutrino beam flux and the cross section with various targets which can be done efficiently at the DUNE-ND facility. To achieve this, DUNE-ND applies two approaches by including movable liquid and gas Ar detectors (time projection chambers) and a fixed scintillator tracker (fine-grained plastic scintillator array). I will go over the overall concept of DUNE-ND and discuss the scintillator tracker system in more detail.

Keywords:

DUNE, Neutrino, CP violation, Neutrino Cross section

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H2.07

Neutron detection of 3DST in the DUNE near detector

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Abstract:

The 3-Dimensional Projection Scintillator Tracker (3DST) is a detector in the Near Detector complex of the Deep Underground Neutrino Experiment (DUNE). It is surrounded by a low-density tracker, an ECAL and a Magnet used for the KLOE experiment. This system aims at detecting all final-state particles including neutrons from neutrino charged-current interaction, thus providing a full reconstruction of each individual interaction channel. Such a measurement can constrain the neutrino interaction and flux uncertainty for each exclusive neutrino interaction channel.

Keywords:

DUNE

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H2.08

Search for sub-millicharged particles at J-PARC

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Abstract:

A new experiment sensitive to millicharged particles produced at the 30 GeV proton fixed-target collisions at J-PARC is discussed. The detector is based on long scintillators that allow the particles with small electric charge to produce photons by ionization energy loss. With the number of protons on target of 10^22, the experiment is sensitivie to particles with electric charge 3 × 10^−4 e for mass less than 0.2 GeV/c^2 and 1.5 × 10^−3 e for mass less than 1.6 GeV/c^2.

Keywords:

millicharged particles, J-PARC, scintillator, dark matter, PMT

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H2.09

Data analysis on axion EDM experiment at COSY

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Abstract:

Due to the axion-gluon coupling, the electric dipole moment (EDM) of nucleons can be a time-varying quantity oscillating at axion mass frequency. The time-varying EDM can be detected using the storage ring method, which was introduced by IBS/CAPP. In 2019, the first axion EDM experiment was carried out at COSY (Juelich, Germany), where IBS/CAPP has played a leadership role. The experimental method is discussed and the first results from the data analysis is presented in this talk.

Keywords:

Storage ring, EDM, Axion, Data analysis

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H2.10

The status of the GBAR experiment

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Abstract:

The GBAR experiment is an experiment to measure the gravitational acceleration of anti-hydrogen atoms at the terrestrial gravitational field. The ultra-cold anti-hydrogen atom can be produced by trapping and cooling procedure to anti-hydrogen ion generated by double charge exchange reactions between an anti-proton and positroniums. The anti-hydrogen ion production as a first milestone has been prepared for the beam time after LS2 shutdown at CERN. I present the status of the GBAR experiment based on anti-hydrogen ion production preparation.

Keywords:

anti-hydrogen, gravity

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H2.11

Dark Photon Search at Yemilab, Korea

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Abstract:

Dark photons are well motivated hypothetical dark sector particles that could account for observations that cannot be explained by the standard model of particle physics. A search for dark photons that are produced by an electron beam striking a thick tungsten target and subsequently interact in a 3~kiloton-scale neutrino detector in Yemilab, a new underground lab in Korea, is proposed. Dark photons can be produced by ``darkstrahlung'' or by oscillations from ordinary photons produced in the target and detected by their visible decays, ``absorption'' or by their oscillation to ordinary photons.

By detecting the absorption process or the oscillation-produced photons, a world's best sensitivity for measurements of the dark-photon kinetic mixing parameter of $₩epsilon^2 > 1.5 ₩times 10^{-13} (4.6 ₩times 10^{-13})$ at the 95₩% confidence level (C.L.) could be obtained for dark photon masses between 80~eV and 1~MeV in a year-long exposure to a 100~MeV electron beam with 100~kW (10~kW) beam power. In parallel, the detection of e^+e^- pairs from decays of dark photons with mass between 1~MeV and $₩sim$80~MeV would have sensitivities of $₩epsilon^2 > ₩mathcal{O}(10^{-17})$ at the 95₩% C.L., which are comparable to those of the Super-K experiment.

Keywords:

Dark photon, Dark universe, Kinetic mixing, Yemilab, dark photon oscillation

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H9.01

Miscroscopic structrue and roles of defects and impurities in perovskite ferroelectric oxides

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Abstract:

The ferroelectrics in the TiO6-based perovskite oxides are important functional materials with the spontaneous polarization which is generated due to the lattice instability in Ti-O chains. Defects can have negative effects on the function of polarization, leading to the fatigue and aging phenomena. In this talk, two kinds of defect physics will be discussed based on the first-principles DFT calculations. i) the physics of the interactions between the defects and the long-range ferroelectric polarization and the lattice instabilty around defects will be discussed. ii) The role of wide-band-gap in the formation energetics in defects and impurity states in ternary oxides will be discussed based on the first-principles density functional theory calculations.

Keywords:

Defect, ferroelectrics, Impurity, Perovskite, Calculation

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H9.02

Atomistic visualization of ferroelectricity via Scanning Transmission Electron Microscopy

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Abstract:

Over the past decades, the ferroelectricity has been regarded as one of the most fascinating material phenomena. The insights into the fundamentals of ferroelectric phenomena such as polarization, domain wall dynamics, and domain switching have been conventionally uncerstood by the synergy of macroscopic measurements, neutron/X-ray scattering technique, and piezoresponse force microscopy (PFM). On the other hand, in terms of the atomistic characterization in the field of ferroelectric materials, the ferroelectric mechanisms on an atomic scale have remained poorly understood until the last decade, when the spatial resolution in scanning transmission electron microscopy (STEM) techniques have allowed (i) the mapping of the electric field derived from the phases of the electron beam; and (ii) the mapping of structural distortions within the unit cells. Firstly, it is possible to visualize the electric field in the ferroelectric materials by identifying the deflecting order of the exit electron via the differential phase contrast (DPC)-STEM or ptychography STEM technique. To this end, it is prerequisite to utilize the segmented STEM detectors or the pixelated CCD detector so that it can be achieved by the hardware modification into STEM. Secondly, it has been realized to derive the polarization from the atomic positions of all atoms within a unit cell and their effective Born charges. Thus, these derived polarization fields can be used as a qualitative, atomistic measure of ferroelectricity. Beyond the qualitative description, the local polarization distributions in the vicinity of surfaces, interfaces, or topological defects can be understood, which are actually crucial to unveil lots of ferroelectricity based on the nonequilibrium state. To this end, the machine learning / artificial intelligence in the ferroelectric materials has been tried to be applied in the field of condensed matter physics. In this talk, I inform the recent trend in terms of atomistic analytical methodologies in the ferroelectric materials and further I will introduce the relevant achievements that came from $CaTiO_3$ and WO_3 thin films.

Keywords:

Atomic structure, scanning transmission electron microscopy, deep machine learning, differential phase contrast, ptychography

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H9.03

Unit-cell-scale ferroelectricity : Flat band breaks the 100-years myth of necessitating domains

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Abstract:

Since ferroelectricity is a collective phenomenon necessitating thousands' atoms' simultaneous displacement, it's been believed since it's discovery in 1920 that at least finite-sized domains (10~100nm) are required to stabilize and switch the ferroelectric dipole moments. Here, we show that we can break the 100-years myth if we introduce flat-band theory in the history of ferroelectricity [1]. As flat band has been known to induce intrinsic local states and to cause very unusual phenomena such as graphene superconductivity and electron lattices, we, for the first time, show that flat band in ferroelectricity induces intrinsic local dipoles of unit-cell scale of a few angstroms [2]. These intrinsic local dipoles are individually stable and switchable, now one does not need the formation of the conventional domains for the dipole switching. We can directly switch the unit-cell-scale dipoles and finally pave a way to achieve ultimate-density ferroelectric devices.

[1] Noheda et al., Science **369**, 1300 (2020)
[2] Lee et al., Science **369**, 1343 (2020)

Keywords:

Flat band, unit-cell-scale ferroelectricity

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H9.04

Beginning of ferroelectric thin film researches in Korea and the following developments

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Abstract:

Since the first discovery of ferroelectricity in 1920, there have been lots of attention in this intriguing phenomenon. Most of the initial research efforts up to the late 1980s had been concentrated on bulk ferroelectric (FE) materials. Several basic mechanisms had been elucidated and emergent phenomena coming from the inversion symmetry breaking had been intensively studied. In the early 1990s, FE thin films started to attract attention worldwide due to potential application to nonvolatile memories. Korean science communities were quite fortunate to initiate FE thin film researches in the early 1990s and have played important roles in the international FE communities.

In this talk, I will first talk about how Korean researchers started to perform FE thin film researches in the early 1990s. Then I will introduce several important research activities done by Koreans, including FE memory, high-κ dielectric, piezoelectric device applications, nanoscale domain switching dynamics, and flexoelectricity. Finally, I will discuss the possible future development by generating artificial ferroelectricity and controlling novel functionalities in oxide heterostructures.

Keywords:

ferroelectricity, thin film, oxide heterostructure

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H12.01

하드포크 그 이후: 비트코인과 비트코인 파생 코인들 간의 정보 흐름 실증 분석

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Abstract:

이 연구는 비트코인 분할 후 생성된 새 코인과 스플릿 코인 사이의 정보 흐름을 실증하고자 한다. 정보 이론적 접근을 통해 비트코인과 비트코인 캐쉬 간의 Transfer Entropy를 추정한 결과, Symbolic Time Series Analysis 에서 비트코인에서 비트코인 캐쉬로 흐르는 비대칭 정보 흐름이 발견되었다. 우리는 이러한 현상의 원인을 시장 유동성에서 기인하는 정보 발견 역할에서 찾는다. 이를 통해 우리는 (i) 비트코인 캐쉬 시장의 투자자가 비트코인 가격의 상승-하락 패턴을 이용하여 비트코인의 가격 변동을 예측할 수 있음을 밝힌다. (ii) 정책 입안자는 시장 왜곡과 규제를 이용한 차익 거래를 방지하기 위해 두 시장 간의 정보 흐름을 면밀히 모니터링 해야 함을 밝힌다.

Keywords:

비트코인, 비트코인 캐쉬, 그레인저 인과관계, Symbolic Time Series Analysis, Transfer Entropy

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H12.02

보이는 것이 다가 아니다: 비트코인과 비트코인 캐시 시장 사례 분석 연구

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Abstract:

본 연구는 비트코인과 비트코인 캐시 시장에 대해 약형 효율적 시장 가설을 검증하고자 하였다. 이를 위해 우리는 양자 조화 진동자 모델을 활용하여, 비트코인 하드 포크 이후 두 개의 갈라진 블록체인의 로그수익률 데이터를 분석하였다. 분석 결과, 유동성 및 변동성과 같은 시장 특성에 기반한 일반적 기대와 달리 비트코인 캐시 시장이 비트코인 시장 대비 보다 효율적인 것으로 나타났다. 우리는 이러한 결과가 비트코인 시장 내 가격 조작 및 투기적 거래로 유발된 비효율성에 기인하는 것으로 추론하였다.

Keywords:

양자 조화 진동자, 효율적 시장 가설, 하드 포크

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H12.03

신종 코로나바이러스(COVID-19) 국면의 유가 폭락 예측 : 시장 속성을 중심으로

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Abstract:

본 연구는 신종 코로나바이러스(COVID-19)로 촉발된 2020년의 역사적인 수준의 유가 폭락 예측 가능성을 통계물리학에서 소개되어 금융시장의 버블 진단과 붕괴 예측에 널리 사용되는 Log-periodic power law (LPPL)모델을 적용하여 검증하였다. 또한, 예측 결과의 원인을 원유시장 기저의 투자자들의 집단현상 및 시장효율성 측면에서 설명하고자 각각 Power-law 지수와 Hurst 지수를 활용하여 2008년 금융위기 시기의 유가 폭락과 비교하여 분석하였다. 연구 결과, COVID-19 시기의 유가 폭락은 예측 가능하나 정확도는 제한적이며, 그 원인은 원유시장의 속성으로 설명할 수 있었다. 이는 유가 급변에 대한 예측에 있어 내생적 버블에 기반한 예측 모델을 활용할 수 있으나, 투자자들의 행태와 시장 속성에 대한 종합적인 고려가 필요함을 시사한다.

Keywords:

신종 코로나바이러스(COVID-19), 유가 폭락, 집단현상, 시장효율성

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H13.01

과학 교사의 제안에서 시작된 과정중심평가 기반 수업 및 평가 실행 분석

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Abstract:

본 연구는 외부 연구자와의 협업을 통해 본인의 수업을 개선하려는 교사의 요청에서 시작되었다. 이를 위해 교사의 요구에 적합한 연구를 계획하고 실행하는 것이 필요하였다. 이러한 맥락에서 이 연구는 다음과 같은 절차를 통해 진행하였다. 우선 연구자-교사의 협의를 통해 연구 주제 및 연구 질문을 구체화하고, 수집 자료 범위 설정과 요청 자료 결정하였다, 이후 연구자가 분석한 자료를 공유하고 그에 대한 교사의 의견을 반영하여 분석에 추가하였다. 결론은 교사와 합의한 결과에 기반하여 도출하였다. 이 연구에서 초점을 둔 연구 주제는 과학 교사가 실천에서 중요성을 인식하고 어려움을 토로했던 과정중심평가에 기반한 평가 설계와 수업 실천이다. 이를 위해 연구자는 교사에게 평가 설계 준거틀을 제시하고, 제시된 분석틀을 이용하여 교사가 자신의 평가 설계 과정을 분석하여 그 과정에서 나타난 교사의 고민과 어려움을 분석하였다. 이후 평가 설계와 실행에 대한 교사의 분석 결과를 연구자가 해석하여 교사에게 제공하였다. 마지막으로 연구자의 산출물이 자신의 수업 실천에 가져온 영향에 대한 교사의 인식을 분석하였다. 본 연구는 교사와 연구자의 연구 수행이라는 쌍방향 상호작용의 의미를 논의하고, 이러한 연구 수행이 교과 교육학 연구에 주는 시사점을 제시할 것이다.

Keywords:

과학 교사의 연구 요청, 과정중심평가, 평가 설계와 실천

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H13.02

Bra-Ket Representation of Inertia Tensor

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Abstract:

We employ the Dirac's bra-ket notation to define the inertia tensor operator that is independent of the choice of bases or coordinate system. The principal axes and the corresponding principal values for the elliptic plate are determined only based on the geometry. By making use of a general symmetric tensor operator, we develop the method of diagonalization which is convenient and intuitive in determining the eigenvector. We demonstrate that the bra-ket approach greatly simplifies the computation of the inertia tensor with an example of N-dimensional ellipsoid. The exploitation of the bra-ket notation to compute the inertia tensor in classical mechanics should provide undergraduate students with the strong background to deal with abstract quantum mechanical problems.

Keywords:

Classical Mechanics, Inertia Tensor, Bra-ket notation, Diagonalization, Hyperellipsoid

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H13.03

Relativistic Analogue Hidden in a Projectile Motion

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Abstract:

We present a four-vector analogue $mathscr{U}^muequiv(mathscr{U}^0,bm{mathscr{U}})=(|bm{V}'|,bm{V}) $ that can be directly constructed from the velocity of a projectile motion. Here, $bm{V}$ and $bm{V}'$ are the velocities of a projectile at heights $h+H$ and h, respectively. In the non-relativistic regime, the mathematical structure of this four-vector analogue has an exact correspondence to the relativistic counterpart four-velocity $u^mu=gamma(1,bm{beta})c$ of a massive particle. Based on this observation, we illustrate the design of an introductory laboratory experiment to investigate the Lorentz invariance and its covariant nature by measuring the velocity of a projectile. The experiment may help students to acquire a concrete perspective of Lorentz covariance through their own measurements and analyses of a free-fall motion.

Keywords:

Special relativity, Lorentz transformation, Four-velocity, Free falling

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H13.04

Understanding the Theory of Special Relativity Based on Einstein's Exploration Process for Science Education

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Abstract:

The purpose of the study is to explore the elements, assumptions (based on a model), and both the epistemic value and predictive power involved in the construction of theory through such assumptions. as a first step, adheres to Galileo's opinion that Einstein's first axiom does not exist in any way to test absolute motion in any way. and the second axiom follows Maxwell's equations and experimental facts that say that light is always moving at a constant speed in a vacuum no matter how the sender (source of light) or the receiver moves. In the second step, we're just following Einstein's search for results with these two postulates. First, Einstein's hypothesis is that the speed of light has neither special space nor special time. Second, it shows coherence between the constructed theories, much like how a raft is held together. Time and space, as well as mass and energy, are connected in one row. The process of leading the equation is by no means complicated or eccentric. Third, attaching any special condition to the theory of special relativity (i.e. the condition of low speed), yields Newtonian dynamics, but no special relativity principle is brought about when any condition is attached to Newtonian mechanics. Therefore, the theory of special relativity encompasses Newtonian mechanics, but Newtonian mechanics does not encompass special relativity. Fourth, since time and space depend on the motion of matter, the metaphysics of the absoluteness of time and space has collapsed, while the dialectical view of the relativity of time and space has been established. Absolute space is always the same and stationary in its own nature, regardless of anything outside of it. Time is also absolute, and flows steadily from the past to the present to the future without any connection to the material world. It has its own fullness, and thus does not rely on anything. Einstein introduced the concept of time-space continuity and claimed the equivalence of energy and matter, While Cartesian and Newton distinguished time and space, and energy and matter.

Keywords:

theory of Special relativity , aesthetic value of theory

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H15.01

Atomically flat single-crystalline copper films for plasmonics

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Abstract:

We report on the use of large-area atomically flat copper films grown epitaxially on sapphire substrates in combination with focused ion beam milling to pattern plasmonic nanostructures with superior quality. The copper surfaces prepared using a single-crystalline copper sputtering target exhibit a very low surface roughness without any grain boundaries for varying film thicknesses and a strong resistance to oxidation, in contrast to the conventional polycrystalline copper films. Surface plasmon resonance measurements show that improved dielectric constants with higher conductivity, lower absorption and greater durability can be achieved using the single-crystalline copper films. In addition, a stronger field enhancement is found in the single-crystalline nanohole arrays compared to the nanohole arrays made from the polycrystalline copper films. This is attributed to reduced propagation loss of surface plasmon polaritons in the nanoholes due to their well-defined and smooth features. Our study opens an alternative pathway to the practical use of single-crystalline copper films in plasmonic and nanophotonic devices as well as integrated nanocircuits in the industry.

Keywords:

Single-crystalline films , Polycrystalline films , Copper, Surface plasmon resonances , Extraordinary optical transmission

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H15.02

Emerging unnatural optical magnetism from DNA-guided metamolecules

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Abstract:

광학메타물질의 구현에서 가장 큰 걸림돌은 물질에 들어가는 전자기파에 의해 자기장의 반응을 잘 유도해내는 것이 어렵다는 것이다. 자연계의 대부분의 광학적 물질은 전기장에는 반응을 하지만 자기장에는 반응을 잘 하지 않기 때문에 인공적으로 자기장의 반응을 유도하는 구조체를 만드는 것이 광학메타물질 분야의 중요한 이슈이다. 나노 스케일에서의 자기장 유도는 고감도의 원형 이색성 (Circular dichroism) 및 방향성 산란, 음굴절률과 같은 매우 독특한 광학 현상을 발현하기 때문에 메타물질 또는 플라즈모닉스 분야에서 자기장을 유도하고자 하는 시도는 오늘날까지 계속되고 있다. 본 연구에서는 자연계의 방향족 분자에서 비편재화 전자의 공진에 의해 발생하는 자기 공명현상에 착안하여 단파장 영역인 가시광 영역에서 자기장을 유도해 내는 나노구조체를 구현해 내는데 성공하였다. 방향족 분자를 모사한 이 메타분자는 DNA 종이접기기술이 도입되어 복잡한 자기 구조를 형성하는 NP의 분자 자기 조립을 실현하였고 반 강자성, 순수 자기 기반 Fano 공명 및 자기 표면 플라즈몬 폴라리톤을 포함한 새로운 특성을 확인하였다. 이는 메타물질 분야의 파장 영역을 가시광 영역으로 가져올 수 있는 기반 기술이 될 수 있을 것으로 기대되며 자기공명 플라즈몬을 유도할 뿐만 아니라 자기공명 플라즈몬을 마치 회로처럼 디자인하여 차세대 광학메타물질 개발의 활로을 열 수 있는 가능성을 제시한다.

Keywords:

metamterial, metamolecule, DNA origami, plasmonic nanoparticle, optical magnetism

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H15.03

Transformable gratings for seamless and large-scale integration of multiple diffractive optical elements

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Abstract:

Diffractive optical elements (DOE) have been considered as a foundation for the augmented reality (AR) and virtual reality (VR) technologies. For transformative AR/VR applications, field-of-view (FOV) from DOE needs to be as large as possible; toward this end, the seamless integration of multiples gratings (with various periodicities and grating vectors) into a single and large-scale composite has been considered as a promising approach. However, unfortunately, this technological demand was not so addressed from conventional lithographic methods such as photolithography, electron-beam lithography, and focused-ion-beam lithography.

In this talk, I'll briefly introduce soft gratings, which can be transformed merely via one-shot light illumination (a.k.a. transformer gratings). Particularly, our transformer grating is readily reconfigured according to the grating vectors and periodicity of post-illuminated interference pattern (without any developing, heat, and etching process). By benefitting from this exotic advantage, we successfully integrate multiple gratings into a single surface over the large-scale (at least cm-scale) within a few tens of minute; holographic 3D image with wide FOV is successfully re-generated. This generic type of gratings, we believe, could offer a platform for facilitating the practical use of AR/VR technologies.

Keywords:

Hologram, Diffractive optics, DOE

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H15.04

루비듐 원자에서 생성된 안정된 편광 얽힘 양자광원

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Abstract:

Abstract : 본 연구에서는 주파수 안정화된 DBR 레이저를 사용하여 높은 장기 안정도를 가진 상태에서 루비듐 원자 증기 셀에서 높은 장기 안정도를 가진 양자얽힘 양자광원을 생성하였다. 원자와 광자의 비선형 상호작용을 통해 얻은 광자쌍 큐비트는 양자통신, 양자컴퓨터, 양자반복기 등 다양한 분야에 사용된다 [1-2]. 다양한 분야에 응용하기 위해서 장시간동안 얽힘이 유지되는 광원을 만들어야 한다. 이를 위해 지속적으로 일정한 전이선에서 원자와 레이저가 공진해야 한다. 기존 실험에 사용된 외부 공진형 다이오드 레이저는 외부 충격에 민감하여 장기 안정도를 보장할 수 없는 반면, 이번 연구에서는 DBR 레이저를 사용하여 장기 안정도를 확보하였다. 장시간 동안 안정적으로 편광 얽힘 광원을 생성을 함에 따라, 추후 주파수 얽힘 및 GHZ 상태에 대해서도 장기간 안정화된 광원을 얻을 수 있을 것으로 기대하고 있다.

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Keywords:

자발사광파조합(SFWM, Spontaneous four-wave mixing), 편광 양자얽힘, 원자결맞음, 양자광원

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H15.05

Sum frequency generation using fiber mode-locked pulse laser and CW laser diode

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Abstract:

본 연구에서는 모드 잠금된 광섬유 레이저와 연속 발진하는 좁은 선폭의 반도체 레이저를 이용하여 periodically poled lithium niobate (PPLN) 결정에서 합주파수 생성 연구를 수행하였다. 모드 잠금된 광섬유 레이저는 중심 파장 1560 nm이고 스펙트럼의 폭 약 1.5 nm이며, 연속 발진 반도체 레이저는 중심 파장 1552 nm이고 스펙트럼의 폭은 약 10 MHz로 동작한다. 두 레이저를 PPLN 결정에 동시에 입사시켜 중심 파장이 778 nm인 합주파수 생성을 성공적으로 수행하였다. 본 연구 결과는 주파수 제어가 가능한 광주파수 빗 (optical frequency comb)을 이용한 광주파수 측정 및 고분해 레이저 분광 연구 등 다양하게 응용될 수 있을 것으로 기대된다.

Keywords:

Nonlinear optical effect, Sum-frequency generation, fiber mode-locked laser

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H15.06

Simultaneous multi-particle tracking by dynamic holographic 3D imaging

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Abstract:

Tracking micro-scale particles in an optical microscope is a high-interest topic in physics, biology, chemistry, and engineering [1]. For example, the movement of living cells or the dynamics of molecules occurs in three-dimensional space in general. However, the measurable range of axial positions is limited by the depth of field of an optical system, making a 3D microscope resort to time-consuming tomography. Recently, we have developed the dynamic holographic 3D imaging method applying the principle of holography for simultaneously monitoring of 3D distributions of single atoms [2]. In this work, we further develop this method to trace 3D particles in motion. In experiments, we devised a variable multi-focus holographic apparatus with a real-time tracking algorithm and used micrometer-scale fluorescence beads in water. Axially-dispersed particles are simultaneously imaged beyond each of the depth of fields by the holographic device that implemented computer-programmed micro-lense patches.

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Keywords:

Holographic technique, Particle tracking

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H15.07

딥러닝 기법을 이용한 레이저 공간 모드의 고분해능 인식
High-resolution recognition of laser spatial modes using deep-learning technique

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Abstract:

궤도 각운동량을 포함한 레이저 공간 모드는 정보 인코딩을 위한 추가적인 광 자유도로써 고전 및 양자 통신 분야에서 주목받고 있다. 특히, 이론적으로 임의의 정수 모드가 가능한 궤도 각운동량은 다가오는 통신 용량의 한계를 극복할 수 있는 해결책으로 여겨졌다. 그러나 기대와 달리, 물리적으로 제한된 광학 시스템의 공간 대역폭과 궤도 각운동량의 정수 양자화로 인해 통신 용량을 효과적으로 증가시키는데 어려움이 있다. 이러한 이유로 분수 간격으로 분리된 궤도 각운동량 모드를 이용한 정보 전송이 제안되었고 이에 대한 검증이 필요한 상황이다. 본 연구에서는 이에 대한 기반 연구로써 딥러닝 기법을 이용한 레이저 공간 모드의 고분해능 인식에 대해 연구하였다. 5개의 합성곱 계층과 2개의 완전 연결 계층으로 이루어진 합성곱 신경망을 설계하였고 학습을 통해 0.03의 모드 분리를 갖는 궤도 각운동량 상태를 높은 정확도로 인식할 수 있음을 확인하였다. 또한, 베셀-가우스 빔의 지름 및 방위 모드를 이용한 실험을 통해 추가적인 광학 요소 없이 서로 독립적인 공간 모드에 대해 동시에 분류 가능함을 검증하였다.

Keywords:

structured light, orbital angular momentum, deep-learning, optical communication

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H15.08

THz 메타구조를 이용한 페로브스카이트 포논-폴래리톤 관측

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Abstract:

납황화물 페로브스카이트는 차세대 고효율 태양전지 물질로 크게 각광받고 있으며, 고품질의 결정을 스핀코팅법과 간단한 열처리로 구현할 수 있기 때문에 다양한 광전소자로의 응용가능성이 높다. 본 연구에서는 테라헤르츠파(THz) 영역에서 포논모드를 가지는 페로브스카이트를 메타물질에 도포하여 포논-폴래리톤을 구현하고, 박막 결정 의존성을 연구하였다. 페로브스카이트의 포논에너지를 메타물질의 공명주파수와 일치시켜 포논-폴래리톤을 구현하였으며, 연속적인 공명주파수를 지니는 32개의 메타물질을 제작하여 폴래리톤 분산곡선을 성공적으로 관측하였다. 특히, 실시간 THz 측정을 통해, 열처리 과정에 따른 Rabi 주파수 변화추이를 관측하였는데, 페로브스카이트 박막의 결정도가 증가함에 따라 Rabi 주파수가 커지는 것을 확인하였다. 흥미롭게도, Rabi 주파수가 나노결정의 성장차원에 크게 의존함을 확인하였는데, 국소적인 전자기파 증대효과의 차원의존성을 통해 성공적으로 규명하였다.

Keywords:

페로브스카이트, 포논-폴래리톤, THz, 메타물질

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H19.01

Higher-order chromatin structure in gene regulation

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Abstract:

Linear DNA sequences encode genetic information. However, its interpretation requires an understanding of the three-dimensional structure of chromosomes since distant DNA sequences can be juxtaposed by highly condensed chromatin packing in the nuclear space to precisely control gene expression. Recent technological innovations in exploring higher-order chromatin structures such as Hi-C have uncovered its organizational principles and various biological implications. In this talk, I will present our recent study on the higher-order chromatin structure of colorectal cancer. Here, we generated Hi-C contact maps of 40 colon tumors and 10 matched normal colons for the first time with the largest cohort. Using this valuable resource, we first report various forms of disorganization on 3D chromatin structure, including complex rearrangements and multi-TAD spanning TAD fusions. We also revealed that such rearrangements often mediate super-enhancers and promoter interactions, leading to oncogenic gene activation. Our study highlights the utility of 3D chromatin structure to account for patient-specific oncogene activation and provide a new mechanistic insight in understanding abnormal gene regulation underlying various human diseases.

Keywords:

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H19.02

The Stickers and Spacers Framework: Understanding Biomolecular Phase Separation Behaviors

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Abstract:

Many biomolecular condensates appear to form via spontaneous or driven processes that have the hallmarks of intracellular phase transitions. This suggests that a common underlying physical framework might govern the formation of functionally and compositionally unrelated biomolecular condensates. I will summarize a recent work that leverages the so-called stickers-and-spacers framework adapted from the field of associative polymers for understanding how multivalent protein and RNA molecules drive phase transitions that give rise to biomolecular condensates. I will present an analytical mean-field model of the framework, and demonstrate how this model explains the phase separation behaviors of FUS family proteins, both quantitatively and qualitatively. Further extension and applications of the framework will also be discussed.

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Keywords:

biomolecular condensates, Stickers and Spacers

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H19.03

Nuclear Mechanobiology: Biological interpretation of subcellular nuclear mechanics

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Abstract:

Accumulating evidence suggests that the three-dimensional organization of the nucleus regulates gene expression through lamina-chromosome interactions. While alterations in nuclear morphology correlate with a variety of human diseases, however, the mechanics and forces that shape the nucleus are not well understood. The nuclear lamina is a thin filamentous meshwork that provides mechanical support to the nucleus and regulates essential cellular processes such as DNA replication, chromatin organization, cell division, and differentiation. Here we show that both A-type lamins and transcriptionally active chromatins are vertically polarized by the tension exercised by the perinuclear actin cap that is composed of highly contractile actomyosin fibers organized at the apical surface of the nucleus. Furthermore, we first demonstrate that the nucleus undergoes a large volumetric reduction accompanied by a morphological transition from an almost smooth to a heavily folded surface. A mathematical model that systematically analyzes the evolution of nuclear shape and volume suggests that the pressure difference across the nuclear envelope is a major factor determining nuclear morphology. Our results show that physical and chemical properties of the extracellular microenvironment directly influence nuclear morphology and suggest that there is a direct link between the environment and gene regulation. These findings broaden our understanding of 3D nuclear architecture and provide new prospects in laminopathies and cellular mechanotransduction.

Keywords:

Mechanobiology, Nuclear mechanics, Laminpathy

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H20.01

Quantum chaos and black holes

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Abstract:

Quantum chaos and black holes

Keywords:

Quantum chaos, black hole

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H20.02

Towards room-temperature T_c in Van der Waals layered magnetic semiconductors

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Abstract:

Towards room-temperature T_c in Van der Waals layered magnetic semiconductors

Keywords:

Van der Waals, magnetic semiconductor

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H20.03

Recent advances with neutrino program in Korea

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Abstract:

Recent advances with neutrino program in Korea

Keywords:

neutrino

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H20.04

Emergent electromagnetic phenomena from topological magnets

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Abstract:

Emergent electromagnetic phenomena from topological magnets

Keywords:

topological magnet

PL1.01

The Fascinating Quantum World of Atomically Thin Two-dimensional Materials

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Abstract:

Many fascinating phenomena in nature owe their emergence from the interactions of large number of particles. In particular, symmetry, interaction and topological effects dominate many of the quantum properties of reduced-dimensional systems. These effects often lead to manifestation of counter-intuitive concepts and phenomena that may not be so prominent or have not been seen in the bulk. In this talk, I present some fascinating quantum phenomena discovered in recent studies of atomically thin one- and two-dimensional materials. A number of interesting and unexpected behaviors have been found – e.g., strongly bound excitons (electron-hole pairs) with unusual energy level structures; tunable magnetism and plasmonic properties; novel topological phases; correlated 3- and 4-particle excitations; etc. – adding to the promise of these materials for exploration of new science and valuable applications.

Keywords:

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T1.01

Dark energy or Dark delusion?: Evidence for a decelerating universe from supernova cosmology

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Abstract:

Supernova (SN) cosmology is based on the assumption that the corrected luminosity of SN Ia would not evolve with redshift. Recently, our age dating of early-type host galaxies (ETGs) from high-quality spectra has shown that this key assumption is most likely in error. It has been argued though that the age-Hubble residual (HR) correlation from ETGs is not confirmed from the age datasets measured from multi-band optical photometry of host galaxies of all morphological types. We find, however, that the statistical analysis involved is affected by "regression dilution bias", severely underestimating both the slope and significance of the age-HR correlation. Remarkably, when we apply regression analysis with a standard posterior sampling method to this dataset comprising a large sample of host galaxies, very significant (4.3 sigma) correlation is obtained between the population age and HR with the slope highly consistent with our previous spectroscopic result from ETGs. We also show that the light curve parameters (x1 & c) of high-redshift SNe are consistent with those of SNe from young progenitors. This confirms that the systematic bias with redshift (luminosity evolution) is inevitable due to an over-correction in standardization. The corresponding luminosity evolution is significant enough to fully explain the observed dimming of SN with redshift without the dark energy. When the luminosity evolution is properly taken into account, SN data now strongly support a decelerating cosmic expansion! Since the SN cosmology has long been considered as the most direct evidence for the accelerating universe, an important avenue of future investigations would be to see how this new result from SNe can be reconciled with other cosmological probes.

Keywords:

Cosmology, Cosmic Expansion, Supernova

T2.01

Fundamentals of Raman scattering spectroscopy

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Abstract:

Raman scattering refers to inelastic scattering of light. In this tutorial, I will briefly introduce basics of Raman scattering spectroscopy that utilizes inelastic scattering phenomena due to inhomogeneity inside materials induced by various elementary excitations. Focus will be given for scattering by phonons among the elementary excitations and brief introduction to applying symmetry selection rules to Raman spectroscopic measurements will also be presented. As applications of Raman scattering spectroscopy, I will present results especially on low dimensional systems such as 1D and 2D materials. Through the examples, I will show that Raman scattering spectroscopy can provide a very useful mean to study basic characteristics such as optical properties and structural properties of various materials systems. In addition, I will introduce methodology that spectroscopically "focusing and controlling" light below the diffraction limit by applying techniques from SERS (surface enhanced Raman scattering).

Keywords:

Raman scattering, Spectroscopy, Elementary excitations

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T3.01

First-principles modeling : Bridging fundamentals to edge-cutting technology

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Abstract:

When the Physicist R. Feynmann was asked to think of a single sentence that would convey the most important scientific knowledge we possess, he answered “Everything made of atoms”. First-principles modeling is one of the most crucial methods to directly deal with arrangement of atoms and their unexpected physical consequences. Combined with our physics knowledge, this method can make great synergy in inventing ground-breaking technology. First, I will teach how to understand the basics principles of first-principles approach based on density-functional theory. Then, I will teach how to apply this method to understand and define the various setbacks to the technological breakthrough and to solve the problems for the renovations in various fields such as semiconductor and energy industry. I will end up with showing our recent successful examples of the real-life fairy tale [1] in densest ferroelectric memories [2], topological superconductor [3], solar cells [4], batteries [5], and hydrogen-catalysts [6].

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[2] Lee et al., Science **369**, 1343 (2020)
[3] Lee et al., **4**, 034202, Phys. Rev. Mater 4, 034202 (2020)
[4] Min et al., Science **366**, 749 (2019)
[5] Ryu et al., Nat. Comms. **10**, 2351 (2019)
[6] Seo et al., Appl. Catal. B **260**, 118186 (2019)

Keywords:

First principles, ferroelectric, densest memory, topological superconductor, solar cell, hydrogen catalyst, battery

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T4.01

A moment approach to plasma fluid/kinetic theory

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Abstract:

A system of exact fluid equations always involves more unknowns than equations. This is called the closure problem. An important aspect of obtaining quantitative closures is an accurate account of collisional effects. In this talk, I introduce how to convert the kinetic equation into an equivalent set of moment equations with exact collisional moments. Then I present how to solve the moment equations to obtain (1) fluid closures for collision-dominated plasmas with short mean free paths and (2) parallel closures for magnetized plasmas with arbitrary mean free paths. In particular, I highlight the effect of long mean free path on parallel heat transport.

Keywords:

포스터발표논문

Poster session abstract

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P1-ap.102

Experimental band structure of group-IV monochalcogenides

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Abstract:

Two-dimensional (2D) van der Waals crystals have attracted considerable interest not only for the study of fundamental physical properties, but also for their potential for application in devices. Black phosphorus has a honeycomb network like graphene, but it is regularly modulated to form a so-called puckered honeycomb structure. This structural anisotropy of black phosphorus results in interesting consequences in the band structure of black phosphorus [1] and its electronic and optical properties [2]. The puckered honeycomb structure is not unique to black phosphorus, but common in other 2D van der Waals crystals, such as GeS, GeSe, SnS, SnSe. In this work, we systematically measure the band structure of GeS, GeSe, SnS, SnSe by means of angle-resolved photoemission spectroscopy (ARPES). We discuss similarities and differences in the electronic band structure of these materials, which are in good agreement with theoretical band calculations.

Keywords:

Puckered honeycomb crystal, ARPES

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P1-ap.103

Observation of the Dirac nodal surface in black phosphorus

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Abstract:

Dirac semimetals in which band crossings are protected by time-reversal symmetry and crystalline symmetries have been widely studied. In this kind of materials, band crossings can be classified based on their dimensionalities as a point (0D), a line (1D), and a plane (2D). Dirac nodal points or Dirac nodal lines are experimentally observed in various materials, whereas the Dirac nodal surface have rarely studied. In this work, we study the low-energy band structure of black phosphorus by means of angle-resolved photoemission spectroscopy (ARPES). We find the Dirac nodal surface at the zone boundary in the armchair direction if the spin-orbit coupling of black phosphorus less than 10meV is not respected. The symmetry origin of the Dirac nodal surface is discussed based on tight-binding band calculation and symmetry analysis.

Keywords:

Dirac semimetal, Dirac nodal surface, ARPES, Black phosphorus

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P1-ap.105

용액 공정 기반으로 합성된 $W_xMo_{1-x}S_2$ 합금 박막의 열분해 성장 온도에 따른 구조적 특성 분석

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Abstract:

그래핀은 소자 내의 높은 전하 이동도를 가지고 있지만, 밴드갭(bandgap)이 없기 때문에 반도체 소자 응용의 한계를 지닌다. 이러한 문제를 해결하기 위하여 도핑, 원자 치환, 나노 패턴 등을 통해 그래핀의 밴드갭을 생성하는 연구들이 진행되었지만 이러한 방법은 이동도가 떨어진다는 단점이 있다. 2차원 전이 금속 칼코겐 화합물(2D Transition metal dichalcogenides, TMDs)중 이황화 몰리브덴(MoS_2)과 이황화 텅스텐(WS_2)은 밴드갭(1-2 eV)이 존재하며, 층상 구조를 가지고 있고, 투명하고 유연한 물성을 가지고 있어 그래핀의 대체제로 응용하기 위해 많은 연구가 진행되고 있다. MoS_2는 층수에 따라 밴드갭을 조절할 수 있고 광 검출기(photodetector)와 트랜지스터(transistor, TFT)소자에 응용할 수 있는 잠재력이 있다. 그러나, 합성 방법에 따라 전하이동도의 차이가 크고 산업적 대량 생산에는 아직 어려움이 있다. 최근, $W_xMo_{1-x}S_2$ 합금 박막을 원자 층 증착법 (Atomic Layer Deposition, ALD)을 이용하여 제작하였고, 감광성 (photoresponsivity)을 측정했을 때, MoS_2 와 WS_2 단일 소자들의 특성보다 3~4 배 향상된 광 전류가 검출되는 것을 보고하였다[1]. 하지만, ALD를 통한 합성 방법은 고 진공의 환경이 필요하고 시료 제작 시간이 오래 걸린다는 단점이 있다. 우리는 본 실험에서 두 전구체 $(NH_4)_2MoS_4$와 $(NH_4)_2WS_4$ 를 유기 용매와 섞어 용액 형태로 제작한 후, 두 단계의 열분해 과정 중 첫번째 열분해 과정을 280^oC로 고정시킨 후, 두 번째 열분해 온도 (600, 650, 700 ^oC)를 조절하여 실험을 진행하였다. 합성된 $W_xMo_{1-x}S_2$ 합금 박막의 화학 조성비, 결정성, 결합 형태 등의 구조적 분석을 하기 위해 엑스선 광전자 분광법(X-ray photoelectron spectroscopy, XPS)과 라만 분광법(Raman spectroscopy)으로 조사하였다. 엑스선 광전자 분광법을 통해서 텅스텐(W), 몰리브덴(Mo), 황(S) 원소의 개별 스펙트럼 피크 세기의 적분 된 값을 통해 원자의 상대적 비율을 계산하여 성장 온도가 증가함에 따라 전체 분자 구조에서 황의 비율이 감소하는 것을 확인하였다. 또한 W의 코어 레벨 스펙트럼을 통해 성장 온도가 600^oC에 가까울 수록, MoS_2 관련 피크의 세기가 지배적으로 나타나며, 산화된 W 관련 피크가 관측되는 것을 확인하였다. 라만 분광법을 통해 A_{1g} 피크가 400-419 cm^{-1} 사이에서 넓게 관측되었으며, 이를 통해 제작된 $W_xMo_{1-x}S_2$ 가 합금 형태로 합성 이 된 것을 확인하였다. 이러한 분석 결과, 성장 온도를 조절하여 황 공격자(vacancy)가 최소가 되고 화학조성비가 맞는 $W_xMo_{1-x}S_2$ 합금의 성장 조건을 최적화하였다. 이를 통해 용액 공정을 기반으로 화학조성비가 맞는 $W_xMo_{1-x}S_2$ 박막을 제작한 뒤, $W_xMo_{1-x}S_2$ 박막 기반의 광 검출기의 성능이 향상되었음을 확인 하였다.

[1] Nat. Commun. 6, 7817 (2015)

Keywords:

2D materials, TMDs, Photodetector

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P1-ap.106

다층 a-MoO_3 기반 전계 효과 트랜지스터의 산소 결함 유도에 의한 전도도 특성 향상 및 게이트 전압 의존 특성 연구

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Abstract:

본 연구에서 3.2 eV의 넓은 밴드 갭을 가지는 층간 물질 a-MoO_3에 의도적으로 산소 결함을 발생시켜 전자 이동도와 저항 변화를 관찰하였다. 기계적 박리를 통해 확보한 얇은 층의 a-MoO_3에 수소를 흘려주는 Rapid Thermal Anneal (RTA) 공정으로 수소와 산소의 결합을 통한 산소 결함을 유도하여 a-MoO_{3-X}의 구조를 만든 뒤 전자빔 리쏘그래피 및 금속 증착 공정으로 수 마이크로 사이즈의 전극을 형성하여 a-MoO_{3-X} 전계 효과 트랜지스터(Field-effect Transistor, FET)를 제작하였다. 제작된 각각 다른 두께의 a-MoO_{3-X} FET는 공기 중의 산소 결합을 최소화하는 진공 챔버 내에서 IV 측정을 진행하였고, 채널 내부의 산소 결함으로 전도 특성이 발생하는 것을 확인할 수 있었다. 하지만 Si/SiO_2 (300 nm) 기판을 통해 인가된 back gate 전압에 대한 의존성은 나타나지 않았다. 이를 극복하기 위해 비교적 산소 결함의 분포가 큰 a-MoO_{3-X}의 표면에 절연 층간 물질인 h-BN을 전사하여 게이트 전압을 인가할 수 있는 top gate 구조의 a-MoO_{3-X}를 제작하여 비교하였다. 캐리어 농도가 낮아 본연의 상태에서는 전자 장치에 적합하지 않은 절연 특성의 intrinsic a-MoO_3의 두께 조절과 산소 결함 생성, 소자적 구조 변화를 통해 명확한 스위칭 효과와 높은 전계 효과 이동도를 충족하는 a-MoO_{3-X}의 전기적 특성의 연구는 차세대 반도체 물질로서 다양한 응용을 기대할 수 있으며 또한 작아진 밴드 갭을 통해 광학적 특성의 변화 또한 기대할 수 있다.

Keywords:

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P1-ap.107

Graphene nano-electro-mechanical resonator arrays; physical properties and application to radio

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Abstract:

We have fabricated a graphene nano-electro-mechanical resonator and studied its electromechanical properties, especially focused on its RF applications. A drum-like trench substrate was prepared and the suspended graphene on trench substrates was transferred. The resonance frequency of the graphene electromechanical resonator was measured by a laser interferometry technique. The radio frequency near the resonance frequency of the graphene drum was modulated and transmitted to the resonator. The amplitude of the transmitted radio signal was modulated by mixing a sound source and the radio frequency signal. The graphene resonator demodulated amplitude and reproduced the sound output through the speaker. The sound from the speaker could be easily recognized through ears. The resonance frequency of graphene radio has shown in the megahertz range, which can be tuned by applying electrostatically induced strain to the resonator. The duffing like nonlinear resonance behavior was utilized to detect a small amount of mechanical resonance frequency change. Graphene nano-electro-mechanical drum radio represents the possibility of approaching highly sensitive mass resolutions of several daltons by measuring the resonance frequency.

Keywords:

Nano-Electro-Mechanical-Systems, Graphene, Resonator, NEMS, Graphene Resonator

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P1-ap.108

Monolithic Interface Contact Engineering to Boost Optoelectronic Performances of 2D Semiconductor Photovoltaic Heterojunctions

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Abstract:

In optoelectronic devices based on two-dimensional (2D) semiconductor heterojunctions, the charge transport across the interface is a critical factor to determine the device performances as photo-excited carriers should be efficiently extracted from the active semiconductor to the electrode. Even though much effort has been recently made to improve generation and dissociation of excitons in 2D semiconductors, effective strategies that can enhance charge extraction at the contact interface have rarely been explored. Here, we report an unexplored approach to boost the optoelectronic device performances of the WSe_2-MoS_2 p-n heterojunctions via the phase-transition-induced modulation of the interface band alignment. In the proposed device, the atomically thin WO_x layer, which is monolithically formed by layer-by-layer oxidation of WSe_2, is used as a charge transport layer for promoting hole extraction. The use of the ultrathin oxide layer significantly enhanced the photoresponsivity of the WSe_2-MoS_2 p-n junction devices. When the WO_x interlayer was introduced at the semiconductor/electrode interface, the power conversion efficiency increased by about an order of magnitudes, from 0.7 to 5.0%, maintaining the response time. The enhanced characteristics can be understood by the formation of the low Schottky barrier and favorable interface band alignment resulting from the monolithic phase transition, as confirmed by band alignment analyses and supported by first-principle calculations. Our work suggests a new route to achieve band-structure engineering in the heterostructures toward realizing high-performance 2D optoelectronics.

Keywords:

2D semiconductors, Transition metal dichalcogenides, Heterostructures,Optoelectronics, Band engineering

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P1-ap.109

Experimental Band Structure of Black-arsenic Studied by Angle-resolved Photoemission Spectroscopy

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Abstract:

After graphene was discovered, it studied various kinds of 2D semiconductors such as TMDC and Black phosphorus as next-generation materials. Black phosphorus, among others, is in the spotlight due to its anisotropic structure, unique electronic and optical properties. Black arsenic is a family of black phosphorus which has similar structure, electronic and optical properties. In addition, black arsenic has better air stability [1] and more anisotropy [2] than black phosphorus. For example, it is found that the band gap of black arsenic depends strongly on its thickness. The bulk black arsenic has a direct band gap of 0.39eV. Its band gap increases up to 1.4 eV at the monolayer limit because of the quantum confinement effect [3]. The interlayer interaction produces an upward dispersion of the highest valence band and a downward dispersion of the lowest conduction band along the Γ-Z line. Therefore, it is important to understand that black arsenic's out-of-plane band dispersion. We present the angle-resolved photoemission (ARPES) study of black arsenic using synchrotron radiation and discuss the out-of-plane dispersion of black arsenic in comparison with the theoretical calculation.

References:
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[2] Y. Chen et al., Adv. Mater. 2018, 30, 1800754
[3] Z. Zhang et al., Appl. Phys. Express 8, 055201 (2015)

Keywords:

2D, black arsenic, anisotropy

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P1-ap.111

Electrical and optical properties of large-area MoS_2 layers synthesized on silicon substrates

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Abstract:

Two-dimensional (2D) layered materials such as molybdenum disulfide (MoS_2) which is a family of transition metal dichalcogenides, are widely investigated because of their excellent electrical and optical properties for the device applications such as field-effect transistors and photodetectors. For example, the bulk MoS_2 has an indirect bandgap of 1.2 eV, whereas single-layer MoS_2 has a direct bandgap of 1.8 eV. However, not many researches have been studied satisfying both large-area and high-quality diode structures. In this study, we present a large-area synthesized n-MoS_2/p-Si heterojunction structures by using sulfurization process for MoO_x films, which are thermally evaporated on p-type silicon substrates. The n-MoS_2/p-Si heterojunction structure possess excellent diode characteristics such as ideality factor of 1.77 and rectification ratio exceed 10^4. Photoresponsivity of the diode showed wide range photo detecting properties from the visible to near-infrared range up to 475 mA/W and detectivity up to 6.5×10^{11} Jones. The device shows the maximum external quantum efficiency of 72 %. These results suggest that the 2D materials can be applicable to next-generation electronic and optoelectronic devices.

Keywords:

Transition metal dichalcogenides, MoS2, Heterojunction, Photodiode

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P1-ap.114

Enhanced Raman spectra in WS_2/ReS_2 heterostructure

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Abstract:

Transition-metal dichalcogenides (TMDs) are known as layered materials and have been studied actively because of their novel properties such as strong light-matter interactions [1]. Tungsten disulfide (WS_2) and Rhenium disulfide (ReS_2) are two types of layered materials showing different dependence on the polarization angle of the incident light due to the different structure. The interactions between the two monolayers of WS_2 and ReS_2 and the polarization dependence of the heterostructure are not understood fully.
We stacked a monolayer WS_2 on another monolayer ReS_2 to fabricate heterostructures using the dry-transfer method [2]. Atomic force microscopy (AFM) and low-frequency polarized Raman measurements are conducted to inspect the quality of the heterostructure. Then, we compared the polarization dependence of the Raman modes from the heterostructure to those of the monolayers of WS_2 and ReS_2. The interlayer vibration mode shows weak anisotropy which may be induced from anisotropy of ReS_2. Moreover, excitation energy-dependent Raman measurement is conducted for several samples which have different stacking angle between the armchair direction of WS_2 and b-axis (Re-chain) of ReS_2, and the enhancement of specific Raman modes is analyzed.

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Keywords:

Transition-metal dichalcogenides (TMDs), Raman spectroscopy, Heterostructure

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P1-ap.115

화학기상증착법의 제어를 통한 그래핀 일함수의 조절 (Direct tuning of graphene work function via chemical vapor deposition control)

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Abstract:

그래핀의 일함수 (work function)는 그래핀 기반 전자소자 제작에 있어서 매우 중요한 요소이며, 많은 종류의 전자 및 광전자 장치에서 그래핀 일함수의 적절한 조절이 요구되고 있다. 그래핀 일함수 조절을 위해 많이 이용되는 접근법으로, 도핑이나 분자 흡착 등에 의해 유도되는 일함수 조절에 관한 연구가 광범위하게 진행되어 왔지만, 이와 같은 방법들은 추가적인 공정 과정의 도입에 따른 공정 시간과 비용의 증가를 야기한다.
본 연구에서는, 기존의 화학기상증착법 (chemical vapor deposition, CVD)에서의 CH_4/H_2 비율을 적절한 제어함으로써 그래핀의 일함수를 조절할 수 있었으며, 이와 같은 그래핀 일함수 조절 결과는 켈빈 탐침 현미경(Kelvin probe force microscopy, KPFM) 및 횡력 현미경(lateral force micoroscopy, LFM)을 이용하여 확인될 수 있었다.

Keywords:

CVD, Graphene, Work function, KPFM, LFM

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P1-ap.117

Optical spectroscopy of van der Waals material Nb_3I_8

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Abstract:

We conducted absorption spectroscopy experiment on single-crystal Nb_3I_8 with a Kagome lattice. We obtained the absorption spectra in the UV, visible, and terahertz regions. The bandgap of Nb_3I_8 is about 4.4 eV at room temperature, and about 0.49 eV at 5 K. Also, three peaks were observed near the bandgap. In the terahertz region, two sharp peaks were observed. These two peaks hardly changed in width and position with temperature.

Keywords:

Terahertz spectoscopy, UV-Vis spectroscopy, van der Waals material

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X-ray Spectroscopy Study of Atomic-Layer-Deposited MoS_2 Monolayer on SiO_2

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Abstract:

The electronic structure of the atomic-layer-deposited MoS_2 monolayer (ML) on SiO_2 was investigated by using X-ray absorption spectroscopy (XAS) and X-ray photoelectron spectroscopy (XPS). The angle-dependent evolution of the XAS spectra and the photon-energy-dependent evolution of the XPS spectra are analyzed in detail. The experimental spectra exhibit distinct features from those of ideal ML, which can be interpreted as a consequence of S–O van der Waals (vdW) interactions. This suggests that the vdW interaction between MoS_2 and adjacent SiO_2 layers can influence the electronic structure of the system, manifesting the substantial electronic interaction at the MoS_2–SiO_2 interface.

Keywords:

MoS2, Van der Waals, X-ray spectroscopy

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Intra-layer exciton energy shifts in TMD heterostructure

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Abstract:

Recently, heterostructures of transition metal dichalcogenides (TMDs) have attracted much interest owing to their unique physical properties. One of the most interesting characteristics is the large exciton energy of TMDs. As the electronic band structures of TMD materials are highly dependent on the number of layers, the interlayer interaction between constituent layers in the heterostructure also affects the band structure [1]. Therefore, understanding the changes of exciton states is important to revealing the band structure of the TMD heterostructure. In this study, we fabricated MoS_2/WSe_2 heterostructures by the stamping method using exfoliated monolayer MoS_2 and WSe_2. The Raman measurements were carried out to determine the quality of interface in the heterostructures. Especially, the interlayer breathing mode from low-frequency Raman measurements confirmed the existence of interlayer interaction between the constituent layers [2]. Furthermore, using the reflectance difference contrast spectroscopy, we observed a shift of the exciton energy in the heterostructure compared to those in individual constituent layers.

[1] M. M. Ugeda et al., Nat. Mater. **13**, 1091 (2014).
[2] C. H. Lui et al., Phys. Rev. B **91**, 165403 (2015).

Keywords:

TMD heterostructure, Raman spectroscopy, Reflectance contrast difference spectroscopy, 2D materials, Exciton

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Piezo/triboelectric energy harvester using two-dimensional In_2Se_3 flakes

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Abstract:

Recently, research on energy harvesting as one of solutions to energy depletion and environmental problems caused by the use of fossil fuels has attracted much attention. Energy harvesting is a renewable energy technology that converts thermal, solar or mechanical energy wasted in the surrounding environment into electrical energy. Among these various energy harvesting technologies, nanogenerators based on piezoelectric and triboelectric phenomena can generate electrical energy based on mechanical energy sources, and recently, two-dimensional (2D) materials have been selected for piezo/triboelectric nanogenerator implementation. Unlike conventional methods, 2D piezoelectric materials have a large piezoelectric coefficient and flexibility in the plane direction, which is very important as a material for developing energy harvesters for wearable devices. However, large-area processing of 2D materials and control of the number of layers have been pointed out as problems. Therefore, we propose a simple process of inserting the 2D indium selenide (In_2Se_2) flakes, which has recently been reported for multidirection piezoelectricity in mono and multilayered, into a flexible polymer layer (such as polydimethylsiloxane (PDMS) and polyvinylidene fluoride (PVDF)).
In this study, piezoelectric and triboelectric energy harvesters were fabricated by forming a piezoelectric layer by spin-coating PDMS and PVDF mixed with In_2Se_3 flakes. In order to measure the output signals, a piezo/triboelectric generator device in the form of a PVDF or PDMS layer deposited on a flexible indium tin oxide (ITO)/polyethylene terephtalate (PET) substrate was fabricated. The output power of PVDF and PDMS layers composited with 2D In_2Se_2 flakes used in piezoelectric and triboelectric energy harvesters tends to improve. Based on these results, we will investigate and discuss changes in structure and electrical properties in order to find out the correlation with the increase in output power due to the In_2Se_3 flakes.

Keywords:

Nanogenerators, 2D materials, In2Se3 flakes, Piezoelectric

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Interlayer Vibration Modes of Monolayer-Bilayer MoS_2/WSe_2 Heterostructure

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Abstract:

Two-dimensional-material-based heterostructures produce novel phenomena due to distinctive interactions between the stacked layers. For MoS_2 and WSe_2, several studies have been done for their monolayer-monolayer heterostructures [1]. However, there are only few studies on monolayer-multilayer or multilayer-multilayer structures. As a first step, we tried to investigate monolayer-bilayer heterostructures.
We fabricated 2L-MoS_2/1L-WSe_2 and 1L-MoS_2/2L-WSe_2 heterostructures using the dry-transfer method [2]. The twist angles of these heterostructures were determined using polarization dependent second harmonic generation. When the interlayer interaction between the constituent layers existed, we found that new low-frequency Raman modes appeared in addition to the breathing and shear modes of bilayer MoS_2 and WSe_2. Using circularly polarized Raman spectroscopy, we assigned the peaks as breathing- and shear-like interlayer vibrational modes. For breathing-like modes, 3 or more peaks were observed, although only 2 normal modes can exist in a material with 3 layers. We also observed that these new modes vary with the twist angle of the samples. In 2L-MoS_2/1L-WSe_2 heterostructures, more than two breathing-like modes were observed only in the samples with relatively small angles (<10°). On the other hand, for 1L-MoS_2/2L-WSe_2 heterostructures, more than two breathing-like modes were observed in almost all the samples, not only in the samples with relatively small angles (<10°).

[1] Ming-Hui Chiu, ACS Nano. 8, 9649–9656 (2014)
[2] A. Castellanos-Gomez et al., 2D Mater. 1, 011002 (2014).

Keywords:

polarized Raman spectroscopy, Transition Metal Dichalcogenides, TMD heterostructure, interlayer vibrational modes

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P1-ap.123

Domain structure and birefringence of few-layer ReS_2

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Abstract:

Rhenium disulfide (ReS_2), one of the transition metal dichalcogenides (TMDs), is a semiconducting material which has a direct band-gap from monolayer to bulk. ReS_2 has an anisotropic crystal structure (1T', distorted tetragonal) unlike hexagonal MoS_2 and WS_2, because Re has one more electron, which makes a Re-chain. Furthermore, opposite vertical orientations of ReS_2 are not equivalent. Due to the in-plane anisotropic structure, its physical properties such as electrical transport and optical response are anisotropic [1]. The direction of the Re-chain and the direction of the c-axis of ReS_2 can be determined by polarized Raman spectroscopy [2, 3].

We made a few-layer ReS_2 sample by mechanical exfoliation and found that same samples have several domains in one flake. Polarized Raman spectroscopy is used to identify opposite vertical orientations [3, 4]. The direction of the Re-chain in each domain is also determined by polarization dependence of the Raman mode at 212 cm^{-1} [2, 3] and SAED patterns. The grain boundary between the two domains is observed by Raman mapping for two different polarization angles and dark field images. Furthermore, the grain boundary can also be observed by angle-resolved polarized optical microscopy (ARPOM) [5]. We found that the directions of the Re-chain in neighboring domains are exactly aligned. Moreover, we studied the birefringence in the ReS_2 samples with several domains by ARPOM and SAED patterns. So we found the relation between the optical axis and the Re-chain of ReS_2 samples.

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[1] E. Liu et al., Nature comm. **6** 6991 (2015).
[2] D. A. Chenet et al., Nano Lett. **15** 5667 (2015).
[3] Y. Choi et al., Nanoscale Horiz. **5** 308-315 (2020).
[4] S. Zhang et al., ACS Nano. **11** 10366-10372 (2017).
[5] X. Li et al., Adv. Funct. Mater. **29** 1906385 (2019).

Keywords:

ReS2, Raman spectroscopy, Grain boundary, Domain structure, Birefringence

Electrical Characteristics of Field Effect Transistors Based on MoS2 Monolayer Grown by Chemical Vapor Deposition

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Abstract:

Transition metal dichalcogenides (TMDs) are layered two-dimensional (2D) semiconductors and have received significant attention for their potential application in field effect transistors (FETs), owing to their inherent characteristics. Among the various reported 2D TMD materials, monolayer (ML) molybdenum disulfide (MoS_2) is being considered as a promising channel material for the fabrication of future transistors with gate lengths as small as ~1 nm. In this work, we present chemical vapor deposition-grown triangular ML MoS_2 with a lateral size of ~22 μm and surface coverage of ~47%, as well as a PMMA-based wet transfer process for depositing the as-grown triangular ML MoS_2 flakes onto a SiO_2 (~100 nm)/p ++-Si substrate. Additionally, we demonstrate the fabrication of an n-type MoS_2 -based FET device and study its electrical characteristics as a function of the gate voltage. Our FET device shows an excellent on/off ratio of ~106 , an off-state leakage current of less than 10−12 A, and a field effect mobility of ~10.4 cm2 /Vs at 300 K.

Keywords:

Transition Metal Dichalcogenides (TMDs), Field Effect Transistor (FET), Molybdenum Disulfur (MoS2), Chemical Vapor Deposition (CVD)

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Interlayer modes in 2H-$MoTe_2$/hBN heterostructure

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Abstract:

2H-$MoTe_2$ is a semiconductor belonging to group VI – transition metal dichalcogenides with an indirect (~1 eV) and a direct (1.1 eV) bandgap in bulk and monolayer, respectively. Hexagonal BN (hBN) is an insulator with a large bandgap (~6 eV). Heterostructures based on van der Waals materials have been studied intensely because of their new physical properties which cannot be observed in a single material such as interlayer excitons and the moire pattern [1]. Through the phenomena, the origin of interlayer interactions in heterostructure are revealed and understood. Recently, the unusual low-frequency Raman peaks ascribed to interlayer interactions appeared in hBN/WS_2 heterostructures due to cross-dimensional electron-phonon coupling [2].
In this report, we fabricated heterostrucures based on 2H-$MoTe_2$ and hBN by mechanical exfoliation and the dry transfer method. The thicknesses of 2H-$MoTe_2$ and hBN are from 1 to 5 layers and several nanometers, respectively. The low-frequency Raman measurements were performed to observe interlayer vibrational modes in the heterostructures. The new modes in the low-frequency region appeared, and the peak positions of the interlayer vibrational modes in 2H-$MoTe_2$ were changed. These behaviors of the Raman modes in the heterostructures suggest that interlayer interactions depend on the thickness of samples and the contribution of the twist angle between 2H-$MoTe_2$ and hBN is negligible.

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[1] Pasqual Rivera et al., Nature nanotechnology **13**, 1004–1015(2018).
[2] Miao-Ling Lin et al., Nature communications **10**, 2419(2019).

Keywords:

Heterostructures, 2H-MoTe2, hBN, Raman spectroscopy

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Photoinduced topological phase transition and optical conductivity of black phosphorene

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Abstract:

We theoretically study the photoinduced topological phase transition of black phosphorene induced by laser light with moderate intensity, which can satisfy the experimentally realistic requirement to preserve the quality of the sample. By deriving the effective Floquet Hamiltonian in terms of pseudospin $S = 1/2$ degrees of freedom, we calculate the Chern number and the optical conductivity of the system with varying laser frequency Ω. As one can expect from the photon-assisted transport, the longitudinal optical conductivity has a threshold frequency at $\Delta = \Omega/\hbar$, with Δ being the band gap of black phosphorene. Unlike the longitudinal optical conductivity, the optical Hall conductivity sharply increases when $\Omega\hbar$ goes beyond one-half of the band gap $\Delta/2$. We also show that the Chern number changes from trivial to nontrivial upon increasing frequency Ω beyond $\Omega\hbar = \Delta/2$.

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Keywords:

Topological phase transition, Black phosphorene, Floquet theory

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Scanning Probe Microscopy Studies of Photon-Plasmon-Exciton Coupling in MoS_2/Au-Nanogratings

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Abstract:

We fabricated MoS_2 monolayers on plasmonic Au nanogratings (AG) using electron beam lithography to investigate the photon-plasmon-exciton coupling phenomena. Periodic grating structures with period of 500 nm support propagating surface plasmon polariton (SPP) modes when incoming photon has appropriate energy, polarization, and incident angle. The angle resolved reflectance spectra of MoS_2/AG depended on the light polarization, indicating the coupling between photons and SPPs. Wavelength and polarization dependent photoluminescence and optical simulation results showed the SPP-mediated enhanced light-matter interaction in MoS_2/AG. Scanning probe microscopy measurements were carried out to investigate surface morphology and contact potential difference (CPD) of the samples with atomic force microscopy and Kelvin probe force microscopy modes, respectively. The CPD change of the MoS_2 monolayers in dark and under illumination was compared while varying the wavelength and polarization of incident light. The morphology of the suspended MoS_2 region could reveal the light-induced heating effect in MoS_2/AG. All the results show that interplay of photons, plasmons, and excitons could influence the physical properties of 2D MoS_2 monolayers on plasmonic 3D AG.

Keywords:

MoS2, Grating, surface plasmon polariton, Kelvin probe force microscopy

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Spin Seebeck Effect in the 2D Ferromagnetic $CrPbTe_3$

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Abstract:

The thermoelectric semiconductor materials have attracted enormous attention from the scientists and industrial areas for both environmental and economic reasons. Indeed, the conventional Seebeck effect was discovered long time ago, but the spin Seebeck effect (SSE) was observed a decade ago. The SSE is based on the heat/spin current conversion owing to thermal gradient and represents one of the key factors in the spin caloritronics.[1-3]. Mostly in the previous experimental and theoretical reports, bulk type magnetic materials have been investigated. However, the SSE efficiency is still insufficient compared with the conventional Seebeck effect, and only a few μV/K has been generated. Recently, few 2D magnetic have been synthesized although their Curie temperatures are lower than the room temperature. For instance the 2D material $CrGeTe_3$ has a Curie temperature of 30 K. Interestingly, we have found that the critical temperature can be increased to 110 K if the Ge is replaced by Pb [4]. Thus, we have investigated the SSE of the 2D $CrPbTe_{3.}$ Note that most of previous reports for thermal transport study employ the Landauer–Büttiker approach assuming ballistic transport. However, this approach requires some particular conditions, and is limited in the actual experimental conditions. Therefore, we apply the Boltzmann transport approach to be more realistic in this report. We have found that the $CrPbTe_3$ monolayer displays large SSE ~ 1300 μV/K. This is substantially enhanced value compared with that found in bulk magnetic materials. This finding may imply that the 2D can be a potential material for the thermoelectric device applications.

Keywords:

Spin seebeck effect, CrPbTe3

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P1-ap.201

그래핀과 강유전체 물질을 이용한 FET 소자의 전기적 특성 분석 및 개선

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Abstract:

분극 반전, 잔류 분극 등 다양한 성질을 가진 강유전체 물질들과 밴드 갭이 없는 2차원 물질인 그래핀의 이종접합을 통한 소자의 구현은 많은 관심을 받아왔다. 이전의 몇몇 실험들에서 graphene ferroelectric FET (GFeFET) 소자를 제작하였으나, 기대와 달리 전하 trapping, 기판 물질의 표면 결함 등의 이유로 그래핀의 I-V 곡선이 anti-hysteresis 특성을 보였다.

위에 언급한 소자 특성 개선을 위해 본 연구에서 사용한 GFeFET 소자는 강유전성을 띄는 물질인 Pb(Mg1/3Nb2/3)O3–PbTiO3 (PMN-PT)를 게이트 물질로 하고, 그래핀을 채널 물질로 하였다. 이렇게 제작한 소자를 3단자 측정을 통해 PMN-PT의 분극반전이 그래핀 채널에 어떠한 영향을 미치는지 연구하였다.

우리는 첫 번째로 대표적인 원인인 전하 trapping을 해결하기 위해 강유전체 물질의 상전이을 이용한다. 강유전체 물질이 curie 온도 이상의 고온에 놓이게 되면 상유전체 물질로 상전이하게 되는데, 이 경우 분극이 없어지기 때문에 표면에 붙어있던 이온들이 감소하여 그래핀과 맞닿는 부분인 표면을 깨끗하게 할 수 있다. 본 실험에서 이용한 PMN-PT의 경우 curie 온도가 약 150~200℃ 이고, 이러한 고온 상태의 PMN-PT에 stamping 방법을 이용해 그래핀을 전사하게 되면, 이온이나 다른 화합물이 존재하지 않는 깨끗한 계면을 얻을 수 있다.

시료들의 성장 조건에 따라 표면에 생기는 결함의 정도가 달라지는데, 이 연구에서 이용한 PMN-PT 역시 표면에 수 nm 수준의 결함들이 존재했다. 우리는 두 번째 표면 결함에 대한 분석을 위해 atomic force microscopy (AFM)를 이용하여 PMN-PT의 표면 상태를 확인하고, defect이 많은 영역과 적은 영역으로 나누어 실험을 진행했다. 이를 통해 계면 영역의 결함들이 FET 소자에 어떠한 영향을 미치는지 알 수 있었다.

본 연구와 같은 anti-hysteresis 등의 문제를 해결하기 위한 연구들이 2D 물질들과 강유전체 물질들을 결합한 다양한 소자 제작이 큰 힘이 될 수 있을 것이다.

Keywords:

PMN-PT, Graphene, 2D materials, anti-hysteresis, interface

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P1-ap.202

다공성 실리콘을 감지부로 이용한 정전형 센서의 습도 감응 특성

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Abstract:

본 연구에서는 다공성 실리콘을 감지부로 적용한 정전형 센서의 습도 감응특성을 조사하였다. 다공성 실리콘의 공명진동수들은 10 – 80 %의 습도 변화에 대해 낮은 진동수 또는 높은 진동수 쪽으로 이동되는 현상이 관찰되었다. 이 특성을 더 구체적으로 관찰하기 위해 제작 조건이 다른 다공성 실리콘의 열처리에 따른 진동수 응답의 특성을 조사하였다. 실험 결과 다공성 실리콘을 감지부로 이용한 정전형 센서는 습도에 대한 명확한 감응 특성이 존재한다. 그러므로 후속 연구를 통해 그 감응특성의 민감도와 정확도, 감응 반복성 등에 대한 특성 조사가 요구된다.

Keywords:

정전형 센서, 다공성 실리콘, 공명진동수, 습도

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Double-layer Deposition Method for Enhancement Surface and Magnetic Properties of Amorphous $CoFe_2O_4$ Thin Film

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Abstract:

본 연구에서 우리는 기판의 종류에 상관없이 표면 거칠기는 줄이고 자기 특성은 유지하는 $CoFe_2O_4$ 박막 성장을 위한 'double-layer deposition method'를 제안한다. $CoFe_2O_4$는 ferrimagnetic 물질로 magnetization과 coercive field가 큰 물질로 알려져 있다. 하지만 RF magnetron sputter를 이용한 증착 과정에서 기판의 종류와 물질의 두께 등의 원인으로 표면의 거칠기가 달라져 $CoFe_2O_4$ 본연의 물리적 특성 혹은 그래핀과 같은 이차원 물질과의 상호작용 연구에 어려움이 있다. Amorphous 구조인 SiO2에 성장시킨 $CoFe_2O_4$ 박막은 결정성을 가지지 않고 증착 온도에 따라 표면의 거칠기가 다르게 나타난다. 500C에서 성장시킨 경우 증착 온도가 낮아짐에 따라 표면 거칠기 또한 낮아지지만 magnetization과 coercive field 특성 또한 저하된다. 이를 해결하기 위해 우리는 'double-layer deposition method'를 이용하였고, 500C에서 double-layer deposition method로 성장시킨 $CoFe_2O_4$ 박막의 표면 거칠기는 AFM 분석을 통해 약 1.1nm로 기존의 증착 방법에 비해 74% 감소하였음을 확인하였고, 기존 성장법과는 달리 자기 특성은 유지하여 그래핀과 같은 이차원 물질과의 이종 접합 구조에 유리한 박막임을 입증하였다.

Keywords:

CoFe2O4, thin film, surface roughness

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P1-ap.204

Spontaneous van der Waals epitaxy of chalcogenide thin film by pulsed laser deposition

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Abstract:

Recently, layer structured chalcogenides have been received much attention due to the exotic physical properties, such as thermoelectricity, superior carrier mobility, ultrafast charge transfer, topological insulator, and superconductivity. The extensive demands on high-quality chalcogenide films for device applications are increasing since such properties inherited from their unique crystal structure and crystal quality. However, the difficulties in controlling epitaxy with defect density, the lack of suitable substrate, and the limited understanding of growth mechanism for chalcogenide film have been major problems for the further advances of these materials. We demonstrate facile method enabling the van der Waals epitaxy (vdWE) of 2D chalcogenide epitaxial film on conventional 3D substrate. We demonstrate that highly-oriented binary chalcogenide films can be epitaxially grown on sapphire substrates by pulsed laser deposition via spontaneous vdWE utilizing the natural surface reaction of the substrate with chalcogen. It was verified that this unusual vdWE renders chalcogenide epitaxial film with the strong structural correlation between overlayer and substrate, high carrier mobility, and low defect density.

Keywords:

Spontaneous van der Waals epitaxy, pulsed laser deposition, chalcogenide thin-film, 2D epitaxy, epitaxial thin film

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P1-ap.205

음향 센서를 이용한 DED 방식 금속 3D 프린팅의 공정 모니터링

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Abstract:

금속 3D 프린터 중 DED(Directed Energy Deposition) 방식은 생산성 및 출력물의 강도와 충격치가 높은 장점을 가지고 있으며 합금 및 이종 물질 적층이 가능하고 기존 제품을 보수할 수 있어 현재뿐만 아니라 향후 활용 가능성도 매우 큰 금속 3D 프린팅 방식이다. DED 방식 금속 3D 프린터의 활용성을 높이기 위해서는 출력물의 균일성 및 반복재현성을 높여야 하는데 이러한 특성을 개선하기 위해서는 공정 모니터링이 필수적으로 필요하다. 기존에는 공정을 모니터링 하기 위해서 멜트풀(Melt pool)에서 발생하는 광량을 포토다이오드로 측정하거나 열화상 카메라를 이용하여 멜트풀 온도 및 형상을 측정하였는데 이러한 방식만으로는 공정 모니터링에 대한 한계를 가지고 있어 본 연구에서는 DED 방식에서의 공정 모니터링을 하는데 있어 음향 센서를 적용하여 공정 조건에 따른 음향 특성을 분석하였다.
DED 방식은 고출력 레이저 빔을 조사하면서 동시에 금속 분말도 공급하여 멜트풀(Melt pool)을 형성하면서 실시간으로 적층하는 방식으로 금속 분말이 주입할 때와 레이저가 금속표면에 조사될 때 등 공정 중에 발생할 수 있는 다양한 음향원이 존재한다. 공정 중에 발생하는 음향원을 음향 센서와 Acoustic spectrum analyzer(Virtins Technology, RTA 168A)를 사용하여 음향 특성을 분석하였다. 다양한 공정 조건 중 금속 분말 주입량, 레이저 출력, DED 헤드와 표면의 거리의 공정조건에서 발생하는 음향에 대해 주파수 영역에서 변화를 측정하였고 음향 특성 분석이 DED 금속 3D 프린터의 공정모니터링에 대한 적용가능성을 확인할 수 있었고 이에 대한 결과를 발표할 계획이다.

Keywords:

금속 3D 프린터, DED(Directed Energy Deposition), 음향 스펙트럼, 모니터링, 음향 센서

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Chemical growth of PbS directly on large-area graphene for photovoltaic infrared high performance photo-detectors

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Abstract:

Based on high transmission in the infrared region, high electrical conductivity, excellent optoelectronic and atomic lattice structure properties of graphene, enormous attention from the scientific community has been focused on graphene due to the broad applications for industrial purposes. The increasing interest in the need for bendable, flexible and high performance optoelectronic devices has led to various functional materials/graphene hybridized materials [1-2]. Great efforts on the achievement of high-performance graphene-based photodetectors have been concentrated on the development of graphene (G) hybrid structure such as G-semiconductors, G-quantum dots (QD) and G-polymer. Studies have also been conducted to form epitaxial junctions by directly depositing various functional materials on large area CVD-graphene [3].
We fabricated vertical photovoltaic type G/PbS/Ti device by taking advantage of Ti/PbS Schottky junction and discussed the photocurrent transient behavior. Lead sulfide (PbS) was deposited directly on post-annealed large-area CVD (Chemical vapor deposition) graphene by CBD (Chemical bath deposition). Using a metal mask and an e-beam evaporator, we deposited Ti on glass/G/PbS. Temperature dependent photocurrent spectra of our G/PbS/Ti photovoltaic devices were measured by a Fourier transformed infrared (FTIR) set-up. Post-annealing was important for the adhesion of PbS films on G/glass. As the bandgap energy of PbS decreases with decreasing temperature, the cut-off wavelength increases to longer wavelength, as temperature decreases.

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Keywords:

CVD-graphene, Infrared, Photovoltaic, Photocurrent transient, FTIR

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P1-ap.207

Surface Raman enhancement of Vertically-Oriented WS_2 nanosheets with a few layers

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Abstract:

Surface enhanced Raman scattering (SERS) for Raman signal amplification has been studied and its various application possibilities have been suggested. Recently, transition metal dichalcogenide (TMD) materials have been used as SERS substrates due to its electronic, chemical and optical properties in visible range.
In this study, we have investigated the chemical enhancement effect of SERS from R6G molecules adsorbed on vertically-oriented WS_2 in the visible wavelength range. Vertically-oriented WS_2 nanosheets were CVD-grown at different temperatures and were used as SERS substrates. Each sample showed different properties that led to different enhancement behavior from which we could suggest optimum growth temperature for maximum enhancement. Through comparison with the SERS results in exfoliated monolayer WS_2, we found that the vertically-oriented WS_2 nanosheets are more effective than exfoliated flakes for SERS measurements. The FDTD simulation results also support our experimental results.

Keywords:

Surface Enhanced Raman spectroscopy (SERS), WS2

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Charge transport study of lead halide perovskite and oxide layer interface

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Abstract:

In the field of photovoltaics, lead halide perovskite has emerged as a promising light absorber due to its high power conversion efficiency and various intriguing physical-chemical properties. Methylammonium lead iodide ($MAPbI_3$) is the archetypal lead halide perovskite and a mixed electronic and ionic conductor. This material has high ionic charge carrier concentrations (iodine vacancy)[1]. From the perovskite solar cell structure, SnO_2 layer is used as an electron transport material according to its low-temperature process and excellent electrical and optical properties. In this presentation, we discuss the interface effect on MAPI/SnO_2 and see electronic and ionic transport in it. In a previous study, experimental proof identifies that in MAPI/TiO_2, ions are responsible for the equilibrium space charge potential due to ion adsorption at the contact between MAPI and oxide layers[2]. To observe a similar tendency at MAPI/SnO_2 interface such as TiO_2, we control the contact area between MAPI and SnO_2 and investigate the ionic space charge effect. We also observe the adsorption behavior of SnO_2 and measure the electron and ion conductivity in MAPI/SnO_2 thin films. After that, we will study how the interface effect contributes to charge extraction and recombination in perovskite solar cells. This work will provide a better physical understanding of perovskite solar cell systems.

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Keywords:

charge transport, interface, perovskite

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P1-ap.210

Identification and Classification of Defects in STEM images of MoS_2 using Deep Learning

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Abstract:

Advances in transmission electron microscopy (TEM) have led to increases in the quantity and quality of visual data available for material characterization. Consequently, the need to develop image analysis techniques that can effectively process massive amounts of high resolution electron microscopy images has never been greater. The application of deep learning-based image processing has shown to be effective in this regard, extracting features of interest for quick and accurate identification and classification of different types of defects with less human intervention than traditional techniques. Here we use a deep learning model employing a ResUNet architecture to automate the detection and categorization of sulfur vacancies in molybdenum disulfide (MoS_2). Images of CVD-grown 2H-MoS_2 were acquired with high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM). Based on the experimental images, 2H-MoS_2 images were simulated and used to train the ResUNet model to identify two different types of sulfur vacancies. Our results suggest that deep learning can be used to efficiently identify and classify defects in two-dimensional materials with sufficient accuracy.

Keywords:

STEM, Deep learning, MoS2, TMDC

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Improving thermoelectric performance of silicon nanowires by heat dissipation and energy filtering through gold nanoparticles

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Abstract:

열전 발전은 물질의 양단 온도차이를 전기 에너지로 바꾸는 발전을 말한다. 열전 발전의 효율을 평가하는 요소로는 열 전도도, 전기 전도도, 그리고 제백 계수가 있으며, 이 3개의 요소는 상호작용하여 열전 발전의 효율을 올리기 어렵다고 알려져 있다. 학계에서 연구되는 해결 방안으로는 복잡한 구조를 활용한 열 전도도 조절, 전하 농도 조절로 제백 계수와 전기전도도 조절, 나노 입자를 활용한 열 전도도와 제백 계수의 조절 등이 있다.

본 연구는 MACE 방식으로 제작한 150~ 200 nm 직경의 Si nanowire 다발에 반지름 5 nm 이하의 금 입자를 흡착시켜 열전 효과 상승을 확인했다. 금 입자 흡착 후에는 Si nanowire의 전기 전도도가 감소하지만, 열전도도의 감소폭과 제백 계수의 증가폭이 더 크게 나와 ZT와 PF가 향상되는 결과를 얻었다. 열전 효율 관련 3개 요소를 범밀도함수 계산과 Wannier90 프로그램을 활용하여 확인했으며, 전기전도도의 감소와 제백 계수의 증가를 비슷한 증감 폭으로 확인할 수 있었다. 열 전도도의 감소를 확인하기 위해 유한요소법 계산을 했으며, 그 결과 금 입자를 따라 열 에너지들이 Si nanowire에서 공기 중으로 빠져나가는 것을 확인하였다. 또한 금속-반금속 접합시의 공핍층 계산을 이용하여 금 입자 흡착시 Si nanowire의 공핍층이 nanowire 직경을 다 뒤덮는 것을 확인했으며 이에 따라 energy filtering 효과가 더 크게 나타난 것이라 유추해낼 수 있었다.

Keywords:

thermoelectric, gold nanoparticle, silicon nanowire, heat dissipation, energy filtering

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Nanostructure CuO application for hydrogen gas sensor

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Abstract:

수소 가스는 풍부하며 환경 친화적인 특성으로 인해 식품, 우주, 의학, 산업, 철강 제조와 같은 분야에 재생 가능한 에너지 원으로 각광 받고 있다.
수소는 무색, 무독성으로 부식성이 높고 인화성이 높은 특성을 가지고 있기 때문에 이를 제어하고 감지하기 위한 센서의 개발이 대두되고 있다.
낮은 작동 온도의 초기 단계에서 높은 가스 반응과 낮은 가스 농도 감지를 보여줄 수 있는 고급 수소 센서 재료의 개발이 필수적이다.
SnO2, ZnO, WO3, NiO, CuO 등의 금속 산화물 나노구조는 각각 물질의 크기, 모양 및 활성 표면으로 인하여 가스 센서 성능 향상을 위한 물질로서 연구되어지고 있다. P형 반도체 센서 재료는 상대적으로 연구가 적고 습도 의존성이 낮은 산소 흡착 특성을 가지고 있어 고성능 가스 센서를 제작하기 위한 p형 반도체 금속 산화물 재료의 개발이 주목받는다. 그 중 CuO는 작은 직접천이형 밴드갭, 높은 촉매 활성도, 우수한 열 안정성, 저렴한 합성비용으로 인한 장점으로 인하여 각광받고 있는 후보 물질이다.
본 연구에서 수소 가스 센서는 화학적으로 합성된 나노구조의 CuO 물질을 적용하여 제작되었으며, CuO는 화학적 및 광학적 방법을 통하여 분석되었다. 나노 사이즈 CuO를 적용한 센서는 동작 온도 200도에서 100ppm의 수소에 대해 150초의 반응 시간을 보였으며, 175%의 최고 가스 응답을 보였다. 2ppm의 낮은 수소 가스 농도에서 5%의 응답을 확인하여 수소가스의 CuO 센서에 대한 반응과 안정성을 확인 하였다.

Keywords:

CuO, Gas sensor, H2

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P1-ap.213

수성 폴리우레탄 아크릴레이트와 BNNT 충진 복합재의 성능향상에 효율적인 BNNT의 함유량 연구

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Abstract:

수성 폴리우레탄 아크릴레이트(WPUA)는 잉크, 페인트 혹은 섬유, 가죽, 종이, 목재, 등의 접착 및 코팅의 소재로써 많이 사용되며, 용매가 물이기 때문에 친환경적인 면에서도 유리하다. 하지만 기존의 코팅 소재에 비해 기계적, 화학적 특성과 내수, 내열성이 상대적으로 취약한데 이를 보완하기 위해서 충진재(Filler)를 활용하여 성능을 개선이 가능하다. 우리는 충진재 중에서도 우주 항공 분야에서 많이 사용되는 BN을 BNNT의 형태의 충진재를 양을 달리하여 WPUA와 복합하고 어떠한 물성이 나타나는지 연구하였다.

우리는 WPUA와 BNNT 필러를 각각 1.25 %, 2.5 %, 5 %로 혼합하여 접촉각이 64.1 ^{o}에서 최대 86 ^{o}까지 향상하는 것을 확인하였으며, 물의 흡수는 29.9 %에서 14.4 %까지 줄어들어 내수의 향상을 나타냈고, 기계적 강도에서 Young's Modulus가 12.0 GPa에서 16.4 GPa로 증가함을 확인하였다. 또한, DMA를 사용하여 열 변형이 가장 크게 일어나는 온도가 62.3 °C에서 98.5 °C까지 증가하는 결과를 얻었다. 함량 대비 성능의 향상율에서 2.5 %의 비율이 최대가 되어 적절한 함량으로 조사되었다.

Keywords:

WPUA, BNNT

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Laser Scribed Carbon Nanomaterials for Gas Sensor based on Polyimide-Copper composite

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Abstract:

탄소나노재료는 우수한 물리적 · 화학적 특성을 가지고 있어 폭넓은 산업에 응용되는 핵심 물질로 각광받고 있으며, 특히 매우 높은 비표면적으로 인한 분자 흡착 거동 및 전도성으로 인해 가스센서 분야에서의 응용도 기대할 수 있다. 그러나 기존에 일반적으로 사용하는 열처리 기반의 탄화 방법은 약 1000 ℃에 해당하는 고온 처리가 수반되며 이에 따른 가열과 냉각에 많은 시간이 소요되는 등 비용과 공정 시간의 측면에서 단점을 가지고 있다. 이에 반해 레이저 스크라이빙 방법은 초 단위의 매우 짧은 시간으로 합성 가능하고 원하는 형태의 패턴으로 탄화가 가능하다는 장점이 있어 많은 응용이 기대되고 있다. 한편, 폴리이미드(Polyimide)는 이미드 고리를 가지는 고분자 물질로서 질소 원자를 가지고 있기 때문에 N-doping 된 탄소재료를 합성하는 전구체로 활용될 수 있다. 이러한 이종 원소가 치환된 도핑 카본 형태는 표면 극성의 변화와 전자이동성의 변화로 보다 우수한 성능의 가스 센서 재료로 활용 가능하다.

본 연구에서는 가스 센서용 탄소나노재료를 합성하기 위해, 스핀 코팅의 방법으로 quartz 기판 위에 폴리이미드 박막 필름을 제작한 후 LASER assisted CVD를 활용한 레이저 스크라이빙 공정을 통해 탄소 재료로 합성하여, 공정 시간과 에너지 소모를 절감시킴과 동시에 탄소 재료를 원하는 위치와 모양으로 패턴 합성하는 연구를 수행하였다. 이때, 스핀 코팅된 폴리이미드 박막은 흡광도가 매우 낮아 대부분의 레이저를 투과시키기 때문에, Cu 입자를 혼합하여 폴리이미드의 레이저 흡수성을 향상시키고 탄화과정에서 촉매 역할을 하게 하여 성공적으로 우수한 성질의 탄소나노재료를 패터닝 할 수 있었다. 합성된 재료는 Raman spectroscopy, XPS analysis, 광학 및 전자현미경 이미지분석을 통해 화학적 · 형태적 특성을 평가하였고, 가스센서 측정을 위한 챔버와 LabVIEW 프로그래밍 인터페이싱을 통해 이산화질소 및 암모니아에 대한 센서 성능을 평가하였다.

Keywords:

Gas sensor, Laser scribing, Nano carbon materials, Carbon sensor, polyimide

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P1-ap.215

Dynamic modification changes on graphene surface observed by in-situ TEM

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Abstract:

We investigated dynamic modification changes of graphene using in-situ scanning transmission electron microscope (STEM) observation. A suspended graphene was prepared on the SiN membrane substrate with gold electrodes. The STEM observation was performed on mono/bi-layer graphene surface and edge as well as on nano hole area. We observed graphitization by e-beam irradiation at the holes of the mono layer graphene section and at the boundary section between mono and bi-layer graphene. A donut shape graphene growth was observed at the hole area during e-beam irradiation. In-situ STEM observation on graphene was also conducted while temperature of graphene was increased by Joule-heating process during the e-beam irradiation. A graphene was torn, and crack was formed along armchair direction when a bias voltage for Joule-heating was applied up to 2.3 V. During the Joule-heating process we observed that small carbon contaminations were rotated. In this presentation, various interesting changes and movements of molecules observed on graphene surface are demonstrated.

Keywords:

TEM observation, Graphene

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P1-ap.217

Plasma-synthesized gold nanoparticles for optical sensing applications

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Abstract:

Gold nanoparticles (Au NPs) belong to the most prominent nanomaterials for optical sensing applications due to their optical confinement effects and biological affinity.[1] In this research, we investigate the sensing properties of biomaterials based on AuNPs prepared by a simple plasma-assisted method. The interaction between plasma-induced reactive species and liquid medium can induce the synthesis of AuNPs without using reductants, thus reducing the consumption of harsh chemicals, as well as shortening the reaction time.[2] The plasma-synthesized AuNPs were functionalized with antibodies for selective detection of analytes.[3] This study will provide new insight into the development and applications of plasma-synthesized nanomaterials.

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Keywords:

Plasma-liquid interactions, Gold nanoparticles, Optical sensing

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P1-ap.218

Magneto-Plasmonic Nanoparticles assembly on Nickel metasurface for Terahertz sensing.

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Abstract:

Terahertz (THz) wave lie between microwave band and infrared band of frequencies in the electromagnetic spectrum. With unique spectral properties, THz radiation promises many cutting-edge applications, including molecular exploration, identification and sensing, nondestructive evaluation and imaging. THz, which has a wide range of applications, is able to interact effectively with metamaterials. Metamaterials, as a novel type of compositional periodic artificial materials, are suitable for THz biosensing applications, as metamaterials with special specifications like size and shape can stimulate spoof surface plasmons and effectively interact with THz radiation. Metasurface is a two-dimensional structure of metamaterials. Magneto-Plasmonic (MagPlas) nanoparticles (NPs), Ag@Fe_3O_4 NPs, are assembled on the metasurface to enhance the THz resonance. The nickel patterned on the metasurface is magnetized by magnet, and then the MagPlas NPs are assembled by magnetic property.

Keywords:

Terahertz, metasurface, Plasmonics, magnetic nanoparticles

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P1-ap.219

ReS_2 based pn Heterojunction Device

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Abstract:

Two-dimensional transition metal dichalcogenides (TMDs) have attracted a great amount of attention in the fields of flexible electronics and optoelectronics owing to their excellent electrical properties as well as the advantage of a substantial band gap. Recently, researches have also been conducted to create more special devices like heterostructures through the combination of two-dimensional materials. TMDs heterostructures have appeared as a fascinating research topic for both fundamental science and applied physics. Pn heterojunctions consist of TMDs semiconductors have been used to demonstrate photodetectors and photovoltaic devices. However, the development of band gap to enhance photo generation in devices made from two-dimensional materials with high light absorption is a promising field that has not been studied much yet. Of the varieties of TMDs, Rhenium disulfide (ReS_2) reveals a distinct property as an n-type semiconductor. We are going to analyse its electrical properties through an experiment, and furthermore measure photoelectric current due to its application to a photodetector. In conclusion, the final goal is to make the multifunctional few-layer ReS_2/GeSe heterostructure and ReS_2/MoS_2 QDs device which is technologically promising for next-generation optoelectronics.

Keywords:

quantum dot, heterojunction, 2D material

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P1-ap.220

Correlation between magnetothermopower and magnetoresistance in topological insulator

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Abstract:

Topological-insulator (TI) nanowires (NWs) represent an unusual phase of quantum matters with an insulating bulk gap and gapless surface state, indicating that electrons can only move along the surface of the material. Based on the surface-state property, the Aharonov–Bohm (AB) oscillation of magnetoresistance has been observed with axial magnetic fields at a cryogenic temperature. In this study, we have used the magnetothermopower to observe the topological nature. We present preliminary results about the correlation between the magnetothermopower and magnetoresistance in terms of AB oscillations in Sb doped Bi_2Se_3 NWs.

Keywords:

Topological-insulator, Aharonov–Bohm oscillation

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P1-ap.221

Analysis of electromagnetic field distribution around metal nanostructures based on finite difference time domain method

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Abstract:

The enhancement of electromagnetic fields in nanoscale metallic objects has been considered a major topic in nano-optical phenomena because of its variety of applications such as sensitive molecular detection, ultra-high spatial resolution imaging, and ultrafast field emission. The understanding of electromagnetic interaction between metallic nanoparticles is critical, especially when analyzing the mechanism of Surface Enhancement Raman Spectroscopy (SERS). Previous studies have revealed that the determination factor for the field enhancement are the size and shape of the particles, because those parameter determines the strength of the resonant excitation of the localized surface plasmon (LSP). In addition, the manner of the distribution of those nanoparticle is also important, because the interaction between those LSPs introduces much larger enhancement than that observed in the individual nanoparticles. In this report, we have performed a simulation based on a Finite Difference Time Domain (FDTD) method to demonstrate a huge field enhancement in arrays of octahedral gold nanoparticle, which is recently synthesized chemically. These particles were highlighted because of their outmost performances as an effective SERS substrates showing ultrasensitive detection power with uniform hotspot generation.
In this simulation, we prepared seven identical octahedral metallic nanoparticles having vertical dimension of 62.2 nm and horizontal dimension of 61.3 nm, forming array with the gap size of 10, 5, 4.5, 4 and 2.5 nm (see Fig. 1(a)). The plane wave light source (plane wave) was placed at the bottom of the particles with a distance of 300 nm, having two different polarization (see Fig. 1(a)). To observe the field profiles at the near field and their evolution, several monitors are places as depicted in Fig. 1(a). By integrating the electric field measured at those monitors while varying the wavelength of the light source, we have obtained electric field spectrum radiating through the far-field and field enhancement spectrum simultaneously, as depicted in Fig. 2(a). Here, distinct peaks are observed which is related to the LSP excitation with different modes. In addition, the peak splitting with increasing gap distance strongly suggest that the coupling between these LSP modes are responsible for additional increase of the field enhancement factor.

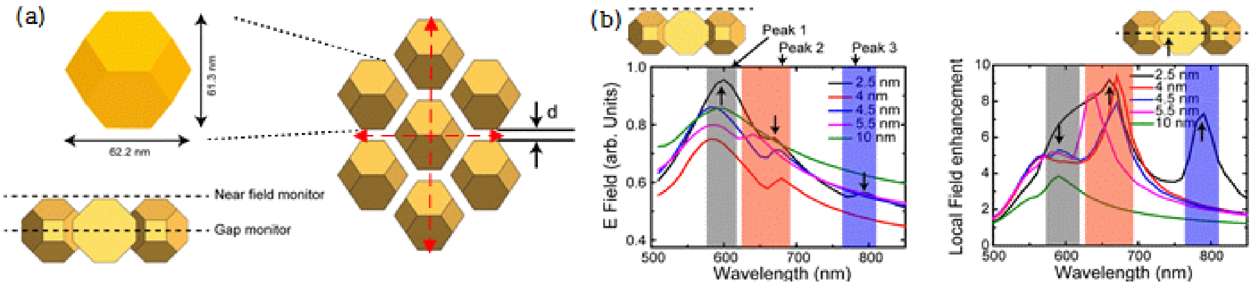

Figure 1.(a) it shows the size of the octahedral metal nanoparticles and the location of the monitors, d is the gap size, the red line indicates the polarization direction. (b) Spectrum of both monitors.

Keywords: SERS, LSP, FDTD

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P1-ap.222

Research of near-field distribution and transmission properties of single metal nanoplasmon structures

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Abstract:

The surface plasmon excitation of metal nanoparticles is one or the physical origin of the hotspot generation, where the huge enhancement and the accumulation of the electromagnetic field. Such hotspots are often generated in narrow gaps or junctions of metallic nanostructures in nanometer scale, where hugely enhanced electric field enables ultrahigh sensitive molecular detection, i.e. Surface Enhanced Raman Scattering (SERS). Traditionally, those SERS substrates are fabricated by dispersing metallic nanostructures to generate hotspots, however, the inability to control the location of the gaps is the biggest problem. Therefore, it was suggested to produces such nanoparticles where gaps already exist for alternative SERS substrate recently, and highly efficient SERS signal generation has been reported [1]. Here, the various geometry of nanoring structures were utilized, where surface plasmon excitation and field enhancement between the rims of the rings were expected.

In this report, we confirmed the surface plasmon excitation in the film of the dispersed nanoring with various geometry by performing transmission spectroscopy. In addition, we verified that the hot spots were created in the nanostructures by demonstrating the exact location and the strength of the field enhancement, using the Finite Different Time Domain (FDTD) method. By performing the FDTD simulation with different sizes and thickness of the double ring nanostructure, we suggest the optimal shape and geometry for achieving more effective hotspot generation.

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Keywords:

Near-field distribution, Transmission properties, Single metal nanoplasmon structures, Surface plasmon, Surface Enhanced Raman Scattering

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P1-ap.301

Parametric spin wave modes in rectangular-shaped permalloy building block

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Abstract:

Parallel parametric pumping is a nonlinear wave phenomenon and a promising technique for electronic devices based on spin wave, so-called “magnonics”. As the magnonic devices become miniaturized, the study of spin wave excitation in nano-scale magnetic elements becomes increasingly important where the exchange interaction would be dominant in the spin wave together with the dipole interaction. Parametric pumping in a sub-micron rectangular-shaped magnetic block is investigated to identify the quantized spin waves and their threshold characteristics using micro-Brillouin light scattering (μ-BLS). The parametric spin wave mode selectivity according to the microwave power **P** was confirmed by obtaining experimental spatial mode profiles. The obtained profiles show the direct experimental evidence of the mode transitions from fundamental mode to high-**k** quantized mode, which is well corresponding to analytical dispersion relation. Our results give significant insights for parametric mode selectivity in nano-scale building block.

Keywords:

Parallel parametric pumping, parametric spin wave, magnonics, spin wave mode selectivity, micro-Brillouin light scattering

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P1-ap.302

Residual stress effect on the Ni_xFe_{1-x} thin film

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Abstract:

Flexible electronics has been widely studied for the future applications, such as rollable display, wearable health care devices and electronic skin for robots [1-2]. In particular, the stress effect on the material is very important to develop key element of those applications. In terms of the magnetism, most of ferromagnetic materials have very sensitive magnetostriction effect. On the other hand, a $Ni_{80}Fe_{20}$ (permalloy) is the well-known candidate for the flexible applications due to its zero magnetostriction effect under a tensile or compressive stress [3].

In this study, we have been measured the residual stress effect on the thin film of Ni_xFe_{1-x} alloy, when the composition of Ni varies under the tensile and compressive stress along the magnetic field direction. The residual magnetization changes after bending up to 200 times of the alloy thin films. Due to the deformation after bending, the magnetostriction effect still affects the net magnetization at the zero field. However, the residual stress effect of the alloy films is suppressed when the composition of Ni closed to 80. The conventional magnetic hysteresis curves of the alloy thin films are measured using a vibrating sample magnetometer (VSM). The films were deposited using conventional Ni-Fe co-sputtering technique on the polypropylene flexible substrates. We will discuss the details of the residual stress effect of the Ni_xFe_{1-x} thin films under tensile and compressive stress along the external magnetic field and its possible device applications.

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Keywords:

ferromagnetic material, magnetostriction effect, permalloy, magnetic thin film

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P1-ap.303

Charge-to-spin conversion in HM/FM/perovskite trilayers

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Abstract:

Charge-to-spin (CS) conversion phenomenon in various systems composed of a ferromagnet (FM) and a non-magnet (NM) has been intensively studied for last a decade [1][2]. The phenomenon leads spin current within a transverse direction to charge current flowing in a system, thereby spin accumulation at the interface. Consequently, such accumulation generates the angular momentum dissipation, giving rise to spin-torque to the magnetization of the FM. That is to say, we can control the magnetization using the phenomena. The CS conversion has two origins; spin-Hall effect and Rashba effect. [4][5] Various metallic systems, such as Pt/FM, W/FM and topological insulator/FM, have been reported to have large CS conversion. [6]

However, not many oxides which is expected to have strong Rashba effect with FM layers has been studied in spite of its importance to develop energy-efficient spin-based devices. In this work, we present CS conversion in a HM/FM/perovskite trilayer nano-device observed by unidirectional spin Hall magnetoresistance[USMR] and Spin-Orbit torque[SOT] using a harmonic measurement technique which is used in a structure having in-plane magnetic anisotropy. As a result of the experiment, USMR become larger, with NNO layer, than reference. In order to eliminate the distortion of the signal due to joule heating, we also checked thermal gradient using harmonic measurement. Interestingly, we observed the change of USMR sign with NNO layer 7 u.c and 10 u.c device. To interpret this interesting trend, we need to more discuss about our experiment.

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Keywords:

Charge-to Spin conversion, SOT, Nickelate, USMR, Perovskite

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P1-ap.304

Enhanced Magnon-Photon Coupling at the Angular Momentum Compensation Point of Ferrimagnets

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Abstract:

Spin ensembles, or magnons, have shown their own role in the field of quantum information processing, especially for storage and transduction of quantum bits [1]. The magnons need to be strongly coupled to other quantum information carrier such as photons in a cavity, to prevent the loss of quantum information during the quantum process. Additionally, a higher characteristic frequency of magnons on which the coupling occurs could extend the applicability of the magnon based quantum device.
Most studies on magnon-photon coupling have focused on ferromagnets (FMs) [2] or ferromagnetic behavior of ferrimagnets (FIMs). A recent study suggests that magnons in antiferromagnets (AFMs) can couple to photons [3], offering a way to increase frequency ranges of a magnon-photon coupled system based on the high resonance frequencies of AFM. However, the coupling strength of AFM is limited, because the magnon-photon coupling is mediated by the Zeeman interaction between magnetic moment and magnetic field part of electromagnetic waves, but the magnetization of AFM is tiny.
In this study, we theoretically investigate the magnon-photon coupling in antiferromagnetically coupled rare earth-transition metal (RE-TM) FIM. Because of the different Landé-g factors of RE and TM elements, the net spin density vanishes at the angular momentum compensation point T_A, while the net magnetic moment is finite at T_A [4]. We finally show that the effective coupling is enhanced at T_A and that compensated FIM combines the best features of FM and AFM for the magnon-photon coupling.

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Keywords:

magnon-photon coupling, angular momentum compensation point, ferrimagnet

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P1-ap.305

Role of orbital hybridization in anisotropic magnetoresistance

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Abstract:

The spin-orbit interaction has enriched the spintronics with fascinating phenomena such as the interconversion between charge and spin currents, the dependence of electrical resistance on the direction of magnetization, and so forth. Among these effects, recent studies[1,2] clarified the exact origin of intrinsic spin Hall effect as the orbital Hall effect which preexists in a system regardless of the spin-orbit interaction. In other words, some features in the spin system is a concomitant result of precedent physics in the orbital system, demanding thorough research on the orbital origin of spin-related phenomena. In this work, we theoretically and numerically investigate the longitudinal orbital currents in ferromagnets. Interestingly, the longitudinal orbital currents depend on the direction of magnetization due to the effective correlation between the orbital and magnetization via concerted action of spin-orbit interaction and exchange interaction. This anisotropic behavior of orbital currents contributes to the anisotropic magnetoresistance (AMR) and we call this orbital contribution as the orbital anisotropic magnetoresistance (OAMR). The OAMR arises from the momentum-dependent orbital splitting, which is universal characteristic of the multiorbital systems achieved through the orbital anisotropy[3] and the orbital hybridization. We illustrate the significance of orbital hybridization as the newly found origin of AMR and also as the common origin of OAMR and orbital Hall effect[1,2]. We also predict that the OAMR appears even in non-magnetic metals through the Zeeman coupling.

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Keywords:

Anisotropic magnetoresistance, Atomic orbital, Spin-orbit coupling

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P1-ap.306

Controlling threshold current of auto -oscillation using cobalt co-sputtering in nano-wire structure.

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Abstract:

In magnonics, SHNO is promising candidate to generate spin wave then STNO. Since STNO uses charge current which pass multilayer, SHNO has advantage over Stability of device and simple structure thus easier fabrication process. However, SHNO has lower out-put power. Also SHNO generally need more current which pass through heavy metal layer to create pure spin current exerting torque on ferromagnetic layer. Thus there are studies to increase output power density and to reduce threshold current for on-set of auto-oscillation. Co show low increase of gilbert damping constant when it Co-sputtered with NiFe Compared with the other transition metals. Also Co layer is used interface layer as that increase spin hall transparency. In conclusion,We observed enhancement of spin wave excitation on NiFe-Co nano wire structure using Co-sputtering fabrication method. We measured enhancement of thermal fluctuation via BLS and confirm lowering of threshold current.

Keywords:

spintronics, magnonics, spin-torque oscillator

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P1-ap.307

Observation of the spin-Seebeck effect in a WS_2/NiFe bilayer by the inverse spin Hall effect.

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Abstract:

We have studied the spin Seebeck effect in a WS_2/NiFe bilayer as detected by the inverse spin Hall effect (ISHE) of platinum (Pt) strips on top. We used a 10 nm-thick WS_2 covering the whole NiFe film of 20 nm thickness deposited on SiO_2/Si substrate of 5×5 mm in size. The top Pt electrodes were placed at each given temperature region spaced along the temperature gradient. The spin Seebeck signal detected from the electrode at the coldest end is about 0.55 μV when temperature difference of 30 K is maintained over a distance of 4 mm at room temperature. The Spin Seebeck coefficient we have calculated is 0.45 μV/K, which is comparable to the values reported in articles published before. However, we have observed a linear dependence of the signal on both the temperature difference and the position along the temperature gradient, in contrast to the result published in [ACS Applied Materials & Interfaces **11**, 48533 (2019)] where a nonlinear dependence on the temperature difference was reported for thinner layers of WS_2. Our result is consistent with the one-dimensional temperature profile used in the experiment, an important and mandatory factor to confirm a pure spin Seebeck effect.

Keywords:

Spin-Seebeck effect, Inverse Spin Hall Effect, Transverse Spin-Seebeck Effect, Nernst Effect.

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UV-Ozone Treated Growth of Highly Conducting SnO_2 Thin Films for Various Device Applications

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Abstract:

The metal oxide semiconductor (MOS) such as SnO_2, ZnO and TiO_2 have been used as potential materials for applications in thin film transistors, memory devices and solar cells. Especially tin based oxide plays an important role of solar cell transport layers. Cleaning MOS thin films is the most important and basic process as a fabrication of devices. Ultraviolet ozone (UVO) treatment is one of the effective methods to remove surfaces defects as organic contaminants on electrical semiconductor. Furthermore, UVO treatment can enhance the surface polymer residue can be removed. It is very useful to remove the organic, polymer contaminants. But there are not any studies of UVO treated metal oxide. Herein, we conducted UVO treatment on SnO_2 surface as an excellent device behavior. We determined the electrical properties of UVO treated SnO_2 thin film. The band structure and the carrier transport mechanism interface were explained by conductive atomic force microscopy, Kelvin probe force microscopy. UVO treatment has been found to eliminate severe current leakage inside the device, reducing interface defects and hysteresis.

Keywords:

Metal oxide semiconductor, UV ozone treatment, SnO2

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Collective electromigration offers an alternative method for determining ionic conductivity

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Abstract:

An oxygen vacancy plays a role of control parameter to modulate emergent function in oxide system such as a metal-insulator transition [1], a magnetic property [2] and local ferroelectricity [3]. The motion of oxygen vacancies is required to study for applying emergent functionalities in future devices. Most of studies on oxygen ion transport have been performed generally using an AC impedance spectroscopy to measure ionic conductivity. However, we need to make an ionic-dominant oxide system and design a proper equivalent circuit model to analyze ionic conductivity. Recently, we have conducted a real-time visualization of oxygen vacancy transport in Ca 30% doped bismuth ferrite (BCFO30) using an optical microscope [4, 5]. In this work, we measured the ionic conductivity of BCFO30 films on $SrTiO_3$ (110) substrate using both methods, AC impedance spectroscopy and optical visualization. We first investigate a crystal structure of a BCFO30 film on $SrTiO_3$ (110) substrate using X-ray diffraction. To suppress the electronic contribution to the conductivity, we anneal the BCFO30 films in a N_2 gas environment at elevated temperatures before measuring the AC impedance spectroscopy. The ionic conductivities from both methods, the optical microscope and AC impedance spectroscopy surprisingly show almost similar value. We also explored the ionic conductivity depending on its film orientation and analyzed oxygen vacancy flow by combining the crystal structure. This work provides a useful insight on measuring the ionic conductivities in solids.

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[4] J. S. Lim et al., NPG Asia Materials **10**, 943-955 (2018)
[5] J. S. Lim et al., Science Advances (in press).

Keywords:

AC impedance spectroscopy, Ca-doped bismuth ferrite, oxygen vacancy, ionic conductivity, collective electromigration

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The relationship between Al and the unnatural negative Threshold voltage shift of solution processed Induim Gallium Zinc Oxide TFTs

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Abstract:

Induim Galium Zinc oxide(IGZO)는 기존의 thin-film transistors(TFTs) 물질인 Amorphous Silicon (a-si) 보다 높은 전자이동도, Low Temperature Polysilicon (LTPS)보다 좋은 균일도로 차세대 TFTs의 채널 물질로 각광받고 있는 대표적인 물질이다. 하지만 상업적 응용을 위해서 소자의 문턱전압(Threshold voltage, Vth) 안정성이 요구되고, 이를 극복하기 위해 문턱 전압 이동의 원인 규명 및 조절에 대한 선행연구가 진행되고 있다. 본 연구에서는 TFT소자의 채널 길이 별 전기적 특성 결과에서 문턱전압의 비정상적인 negative shift 현상을 확인하였고, Time-of-Flight Secondary Ion Mass Spectrometry(SIMS)와 X-ray photoelectron spectroscopy(XPS) 분석을 통해 전극 증착 과정 중 유입된 Al이 문턱전압의 negative shift 현상에 지배적인 영향을 미치는 것을 알 수 있었다. 또한 IGZO TFT의 열처리 및 PMMA passivation 과정으로 문턱전압 이동을 제어하였고, 공정 전/후의 전기적 특성 및 XPS 분석으로 효율적인 해결 방안임을 입증하였다. 문턱 전압 이동에 대한 Al의 영향 및 제어에 대한 열처리 및 PMMA passivation 메커니즘 규명은 향후 공정과정 개선 및 문턱전압 조절에 기여를 할 수 있을 것이라고 기대된다.

Keywords:

InGaZnO, Threshold voltage, Al electrode

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테이프캐스팅을 이용한 Flexible YSZ Thin film 제조 연구

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Abstract:

테이프 캐스팅은 두께가 얇고 균일한 대면적 세라믹 필름을 제조할 수 있는 공법이다. 세라믹 분말을 용매와 섞어 슬러리를 만들어 필름을 제조하며, 성형된 시트의 밀도, 두께 등이 시트의 성능을 발현하는 요소이다. 한편, 이트리아 안정화 지르코니아는 산소 빈자리 (Oxygen vacancy)를 통해 이온 전도도가 높아지고, 화학적 및 열적으로 안정하여 연료전지 전해질, 산소 센서 등으로 사용된다. 그러나 전해질로 사용시, 주기적인 구동으로 인해 생기는 열 충격, 열화 현상 등이 기계적 변형 및 균열 형성을 유발하고 이는 구동 수명 단축의 원인이 된다. 본 연구는 물질의 유연성을 높임으로써, 기계적 변형 및 균열 형성을 줄이는데 초점을 두고 있다.
기존 연구에 따르면 Flexibility를 항복 응력과 영률의 비를 두께로 나눈 값으로 나타내었다. 본 연구에서는 얇은 필름 제조를 위해 바인더, 용매, 계면 활성제 등을 정밀하게 조절한 세라믹 슬러리를 이용해서 테이프 캐스팅을 진행하였고, 평평한 평면에서 주조 한 후 건조시킨 후 소결 공정을 통해 제조하였다. 제조한 필름의 경우 최소 5 마이크로미터까지 두께를 줄일 수 있었으며, 이중 굽힘까지 가능한 것을 확인할 수 있었다. Flexibility가 향상된 필름은 높은 온도에서 구동되는 연료 전지, 웨어러블 디바이스 등의 응용분야에 적용이 될 수 있다

Keywords:

Zirconia Oxide, YSZ, Flexible Oxide

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Local magnetization control through reduction of CoO_X thin films

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Abstract:

Magnetic nanoscale patterning is one of the most important technology for high density of magnetic recording media. It is also essential in developing spin logic devices or spintronic devices. It has been reported that when the magnetic oxide is reduced by proton irradiation, not only the local phase control, but also anisotropy of the magnetic thin film can be controlled depending on the degree of reduction. In particular, such proton irradiation has advantage for the non-destructive nano patterning. In this presentation, we demonstrate that such local phase control of the transition metal oxide, CoO_X for this study, can be done with He ion irradiation. Use of He ions also has advantage for the non-destructive nano patterning due to light mass. The reduction mechanism is also discussed based on the molecular dynamics study with ab initio calculation.

Keywords:

ion irradiation, nanoscale patterning, reduction, magnetic recording media, ab initio calculation

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P1-ap.314

Achieving atomically flat and single-terminated layered perovskite substrate surfaces

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Abstract:

Over the past decades, perovskite oxides have been extensively studied with their affluent physical properties providing platforms for electronic device applications. Among them, the layered perovskite has attracted a great deal of attention with advantageous physical properties such as high temperature superconductivity, colossal magnetoresistance, and significantly suppressed dielectric loss.[1-3] However, high-quality growth of epitaxial A_2BO_4 thin films has often been disturbed by extended structural defects, arising from the structural difference with conventional ABO_3 substrates.[4] Since these planar defects hamper functionality and device applications seriously, atomically flat and single-terminated layered perovskite substrate has been highly required to suppress the structural defects.[5] The most common material that is used as layered perovskite substrates is $LaSrAlO_4$ substrate (tetragonal, I4/mmm, a = b= 3.75 Å and c =12.63 Å). $LaSrAlO_4$ substrates has been frequently employed for growing high T_c superconductors and other functional oxide thin films. Nevertheless, there have been little reports of single-terminated and well-defined step-and-terrace surfaces.
In this study, we demonstrated the surface treatment method for the layered perovskite $LaSrAlO_4$ substrate. After chemical and thermal annealing, we realized atomically flat and single-terminated surface of $LaSrAlO_4$ substrates with well-defined step-and-terrace structure. Our study suggests a wider opportunity to develop novel functional devices based on the layered perovskites.

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[2] Y. Moritomo et al., Nature **380**, 141 (1996).
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[5] M. A. Zurbuchen et al., J. Mater. Res. **22**, 1439 (2007).

Keywords:

Layered perovskite, Substrate treatment, LaSrAlO4, Oxide heterostructure

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Enhancement of Output Performance in relaxor ferroelectric $Bi_{0.5}(Na_{1-x}K_x)_{0.5}TiO_3$ piezoelectric nanogenerator

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Abstract:

The piezoelectric nanogenerators (PENGs) are devices that can transfer the small mechanical movement to the electrical energy. Many researchers have been studied on enhancement of output performance in piezoelectric nanogenerators (PENGs) for various application. Up to now, the output performances of PENGs have been reached to 250V and 320 uA, respectively [1,2]. However, their high performances were resulted from the lead-based materials with large piezoelectric coefficient (d_{33}). Because of environmental issue of lead-based materials, they need to be replaced to a lead-free substitute. Also, PENGs based on the lead-free substitute should show the high performance. Generally, the output performance of PENGs is higher if materials have a larger d33. Instead of using materials with a high inherent coefficient, there are several controlling methods to enhance piezoelectric coefficient (d_{33}) such as crystallization, anisotropy, doping, and morphotropic phase boundary (MPB). In relaxor ferroelectric system, however, it is applied to a morphotropic relaxor boundary (MRB), which is a boundary of different local polar symmetries with different polar nanoregions (PNRs), but the same macroscopic symmetry. It is different with MPB applied to a general ferroelectrics (FEs). Recently, it is experimentally revealed that electrostrain and permittivity increase at the MRB resulting in high inverse piezoelectric coefficient (d_{33}^*) [3]. Therefore, the MRBs may become an effective strategy of enhancement of the output performance of RFE PENGs based on the field-induced large electrostrain, not of general FE PENGs based on d_{33}. Herein, we selected $Bi_{0.5}(Na_{1-x}K_x)_{0.5}TiO_3$ (BNKT) at x=0.08–0.12 known as the regions shown large d_{33}* and then fabricated PENGs. To understand the effect of REFs, structure analysis and measurement of output signals for PENGs were performed by X-ray diffraction and bending machines. Experimentally, we confirmed that the structural phases coexist together, but slightly shift rhombohedral to tetragonal phase. The maximum voltage is 14V at x=0.10. It is 3.5 times higher than at x=0.08. This result shows the same trend to ceramics with 1.3 times higher d_{33}* comparing at same composition. Consequently, this study presents that the PENGs based on RFEs can be affected to electrostrain resulting in d_{33}* unlike the PENGs based on general FEs affected to d_{33}.

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[2] Nat. Commun. 11, 1030 (2020)
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Keywords:

Ferroelectrics, Nanogenerator

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Photogenerated characteristic of Na passivated $Cu_2ZnSn(S,Se)_4$ thin-film solar cells by Kelvin probe force microscopy

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Abstract:

$Cu_2ZnSn(S,Se)_4$ (CZTSSe) thin film solar cell is considered as promising substitute for $Cu(In,Ga)(S,Se)_2$ (CIGS) so numbers of research have been done to enhance its performance. Positive effects of Na incorporation such as grain size growth and increasement of hole concentration are well known in CZTSSe as well as in CIGS thin film solar cell. Especially, illumination-induced properties in photovoltaic device is important for practical performance however, less studies have been done so far in CZTSSe thin film solar cell. Herein, four samples
with different Na concentration on CZTSSe absorber layer surface were prepared to examine the effect of Na incorporation on optoelectronic properties. The amount of Na atoms remained on CZTSSe absorber layer surface was confirmed by X-ray photoelectron spectroscopy (XPS). To investigate illumination-induced change in electrical properties, Kelvin probe force microscopy (KPFM) was utilized. Surface potential was obtained both under darkness and illumination condition (405, 532, and 640 nm wavelength) and work function was calculated. In Na deficient sample, no work function change was observed under illumination implying carrier excitation and formation of surface photovoltage (SPV) was limited. In contrast, Na-rich samples showed noticeable work function shift with maximum 0.05 eV. As a result, higher Na concentration on CZTSSe absorber surface prevent the photogenerated carrier recombination and form larger SPV. We suggest that the formation of surface photovoltage was attributed to Na atoms, and further investigation of Na effect on photogenerated carrier transport is needed.

Keywords:

Kelvin probe force microscopy (KPFM), surface photovoltage, Na passivation, Cu2ZnSn(S,Se)4 (CZTSSe) thin film solar cell

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A membraneless nonenzymatic fiber-shaped glucose fuel cell based on multiwall carbon nanotube yarn electrode

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Abstract:

Recently, glucose fuel cells become interesting not only because they use glucose as abundance, environmental-friendly fuel but also they can generate a considerable power output. Redox enzymes are the most common catalysts for glucose fuel cells but they suffer from a fragile durability for practical applications. Micro-size fiber-shaped membraneless fuel cell has been received much attention nowadays which is desirable for lightweight, flexible electronic devices. Here, we introduce a membraneless nonenzymatic fiber-shaped glucose fuel cell using a flexible multiwall carbon nanotube yarn with a support of Mxene thin layer as a high conductive current collector when combining with nickel cobalt layered hydroxides as a catalyst. This fuel cell can offer an electrical output in glucose-alkaline electrolyte and also in glucose-containing phosphate buffered saline electrolyte an open circuit voltage and a maximum power density of 0.35 V, 61 μW cm^{-2} and 0.36 V, 35 μW cm^{-2}, respectively. Our membraneless nonenzymatic fiber-shaped fuel cell can be applied in an alkaline fuel cell as well as a medical biofuel cell for glucose energy harvesting.

Keywords:

Multiwall carbon nanotube yarn; Fiber-shaped fuel cell; Membraneless nonenzymatic glucose fuel cell

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메타소재 기반의 THz 투과체 및 조절장치

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Abstract:

우리는 이동통신의 급격한 발전으로 4G 세대를 넘어 5G 세대를 살고 있다. 이동통신은 10년주기로 급격한 단계적 기술발전이 이뤄졌으며, 세대가 진화할 때마다 사용하는 주파수와 데이터 통신양도 급격히 향상되었다. 5세대 이동통신에서는 28GHz 대역의 주파수를 사용하여 예상되는 데이터 속도는 20Gbps 로써 기존 4세대 대비 30배 정도 큰 값이다. 5세대 이동통신을 넘어서는 차세대 이동통신은 28GHz 보다 높은 주파수 대역에서 작동이 되어야 하는데, 해당 주파수는 THz 대역에 해당된다. 현재 6세대 또는 semi-6세대 이동통신 개발을 하기 위해 많은 연구자들이 고효율, 고전압, 고주파수 및 낮은 손실의 소자들을 개발하고 있는 단계이다. THz 이동통신을 상용화하기 위해서는 몇 가지 소자 또는 장비들에 대한 기초적인 연구가 필요한데, 대표적인 것은 해당 주파수에서의 투과체, 흡수체 및 반사체이다.
우리는 메타소재 기반의 THz 대역 투과에 대한 연구를 진행하였다. 본 연구에서 제안하는 메타구조는 유전체 기판을 사이에 두고 앞뒤에 동일한 패턴을 입힌 구조로써 전체적인 두께는 1 mm 이하이다. 본 연구에서 제안하는 메타소재는 THz 대역에서 전자기파의 손실이 거의 없이 100% 에 가까운 완전한 투과 특성을 나타낸다. 앞뒤의 메타패턴이 정렬을 정확하게 한 경우 또는 정렬이 틀어진 경우에도 0.975 THz 부근에서 완전한 투과가 발생한다. 특이한 현상은 1.546 THz 부근에서 메타패턴이 정렬을 정확하게 한 경우에는 투과율이 0에 가까우나 메타패턴이 정렬이 틀어짐에 따라 1.546 THz 부근에서 특이한 투과 피크가 형성되는 것을 확인하였다. 특이 투과 피크에 대한 근원을 확인하기 위해 시뮬레이션을 통해 분석을 진행하였다.

Keywords:

메타물질, 이동통신, THz communication

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유기물 반도체 TMTSF의 전하수송 특성 연구

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Abstract:

본 연구에서는 유기물 반도체에서의 전하 수송 특성을 연구하기 위해 TMTSF(tetramethyl-tetraselenafulvalene)를 활성층으로 사용하는 전계 효과 트랜지스터를 제작하였다. 본질적인 전하 수송 특성을 연구하기 위해, 측정 및 분석에 영향을 미치는 외부 요인들(접촉저항, 단 채널 효과 , 쇼트키 컨택 등)을 고려해야만 한다. 전기적 특성을 저하 시키는 grain boundary 영향을 단결정 TMTSF를 사용하여 제거하였다. 동일한 공정으로 제작된 두 가지 패턴을 통해 2-탐침과 4-탐침 측정 결과를 분석하여 접촉저항을 정량화 하였다. 반도체와 금속 컨택의 전기적 특성에 다라 내재적으로 결정되는 쇼트키 장벽(금속의 일함수와 반도체의 이온화 전위의 차)의 크기는 다양한 온도영역에서의 열전자 방출로 인한 전류 특성 분석을 통해 얻었다. 본 발표에서는 TMTSF 반도체의 내재적인 전기적 특성과 여러 외적인 요인에 의한 영향에 대해 논의할 것이다.

Keywords:

TMTSF, organic semiconductor, 유기물, Contact resistance

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P1-ap.402

The tunability of energy levels in the highly ordered conjugated polymer system

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Abstract:

Organic semiconductors have received the great deal of attention for their advantageous properties to be applied in electronic devices such as low-cost, flexibility and ease of large-area production. The performance of the organic semiconductor devices highly depend on their energy levels, i.e. the ionization energy, electron affinity and work function, because the charge transfer properties of the device is determined by the energy level alignment at the interfaces. Recently, the controlling the orientations of organic semiconductor has been highlighted as an effective method to fine tune the their energy level alignment. However, up to now, almost all studies has been only concentrated on small molecule systems, even though the polymers occupy a large part in the field of organic semiconductor.
In this study, we controlled the orientation of Poly(3-hexylthiophene) (P3HT), a most widely used conjugated polymer, with two different deposition methods, spin-coating and vacuum electrospray. The significantly different orientation of P3HT, so called edge-on and face-on, are proven by grazing incidence wide angle x-ray scattering. The energy levels of orientation controlled P3HT films were examined by ultraviolet photoelectron spectroscopy and showed significant different their energy level. The obtained experimental results were compared with first-principles calculations were in full consistency and support our claim.

Keywords:

Energy level, P3HT, Organic

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P1-ap.403

Optoelectronic Responses in $CH_3NH_3PbCl_3$ Perovskite Crystals with of Excitonic Behavior

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Abstract:

Hybrid perovskites are promising optoelectronic materials with its attractive optical and electronical properties. Understanding and controlling the intrinsic properties of this material is important for solving the unsettled questions and advancing the performance of the diverse optoelectronic applications. Determining the excitonic behavior is still unexplored despite being able to predict the optoelectronic properties in semiconductors. At this point, we focused on the investigation of $CH_3NH_3PbCl_3$ perovskite single crystals which are considered an ideal form without having interfacial effects. We verified the structural properties by using the temperature dependence photoluminescence and transmission spectra. We observed the unusual excitonic behaviors near band edge region through the comparing both. In addition, we determined the surface potential distribution with/without the external light source via Kelvin probe force microscopy. Depending on the various light source, we presented the electronic band structures of perovskite crystal which reveal the semiconducting nature of the materials by consolidating the result values of the band gap energy, the work function, and surface photovoltage. We could suggest the identified perovskite structure and possibility to apply to many optoelectronic devices.

Keywords:

Hybrid perovskite, Signle crystal, Exciton

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P1-ap.404

Increasing electrical efficiency of MFC with synechococcus sp.

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Abstract:

Microorganisms that use solar energy and water to generate the energy needed for cell survival produce bioenergy with high quantum efficiency of 100%. However, the method of extracting based on a mediator from microorganisms currently used in the electrochemical field shows a low efficiency of around 10%. In this study, a photosynthesis-based microbial energy device was developed using Synechococcus cells capable of high-efficiency energy extraction. Using Synechococcus cells produced by the algae phenomenon, we created a hydrogel-based photosynthetic microbial fuel cell (PMCM) and analyzed the diffusion phenomenon mechanism of mass transfer to realize high-efficiency energy harvesting. Photocurrent characteristics can be analyzed through the current characteristics of the cell's energy patch with and without light. Microbial energy can be used as a new form of renewable energy to accumulate and supply energy to display devices.

Keywords:

MFC, Microbial. Synechococcus, Microorganism,Bioenergy

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P1-ap.405

Study on the charge transfer characteristics of organic semiconductor devices with controlled crystal properties by heat and nanoparticles

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Abstract:

In this study, the charge transfer characteristics of an organic semiconductor device are controlled by changing the crystal characteristics of the organic semiconductor layer. After integrating the organic nanoparticles, cellulose nanowhisker (CNW), into the TIPS-Pentacene organic semiconductor layer, the temperature of the fabrication substrate was changed to change the crystal shape of the organic semiconductor layer. The crystals of the organic semiconductor layer changed depending on the heat of the substrate and the presence or absence of organic nanoparticles, which affected the charge transfer and charge accumulation mechanism of the organic semiconductor device. I-V, C-V and C-F electrical measurements were performed to analyze the charge mechanism of organic semiconductor devices and to investigate the relationship between the crystal properties of organic semiconductor layers and charge transfer.

Keywords:

Cellulose nanowhisker, TIPS-Pentacene, Organic semiconductor device

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P1-ap.406

Effect of temperature during stirring of P3HT:PCBM solution on organic photovoltaics

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Abstract:

In bulk heterojunction organic photovoltaics (OPVs), a phase separation of donor and acceptor materials significantly affects the device performance. When depositing a light-absorbing layer by a solution process, the temperature during stirring of a solution changes the phase of donor-acceptor mixture. In particular, in OPVs with a poly(3-hexylthiophene-2,5-diyl) (P3HT) donor and [6,6]-phenyl-C_{61}-butyric acid methyl ester (PCBM) acceptor, PCBM tends to be aggregated if supersaturated. Hence, to establish an efficient process in device fabrication, an understanding of phase separation and its effect on charge dissociation is highly important.

In this study, we investigated the changes in electrical and electronic properties in OPVs by temperature during stirring of a P3HT:PCBM solution. The significant changes in morphology and crystallinity with different stirring temperature of P3HT and PCBM were observed through optical microscope and X-ray diffraction (XRD) measurements. Accordingly, the power conversion efficiency of OPVs was remarkably varied. To figure out the origin of difference in device performance, photoluminescence spectroscopy, UV-visible spectroscopy, and X-ray photoelectron spectroscopy measurements were performed. The exciton and charge transport mechanisms were discussed based on the measured film properties.

Keywords:

organic photovoltaics, PCBM aggregation, PL, XPS

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P1-ap.407

Variation in optical and electronic properties of polymeric thin films by ultraviolet-ozone treatment

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Abstract:

Organic semiconductors have been intensely investigated because of their unique properties, including mechanical flexibility and solution-processability. Hence, it has been used in various optoelectronic devices, including organic solar cells (OSCs) and organic light-emitting diodes (OLEDs). However, a short lifetime has been regarded as a critical factor that hinders their commercialization. In this regard, a fundamental understanding of degradation of polymers is necessary.

In this study, we investigated the effect of ultraviolet-ozone (UVO) treatment on the electronic structures of poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT) and poly(9,9-di-n-octylfluorenyl-2,7-diyl) (PFO) films. To analyze the optical properties of the polymeric thin films according to the UVO treatment time, we performed UV-vis and photoluminescence (PL) spectroscopies. Also, the electronic structure of thin films were studied by using X-ray photoelectron spectroscopy (XPS). The significant oxidation and decrease in thickness were observed. This study provides a useful information on the surface modification of polymeric films.

Keywords:

F8BT, PFO, UVO treatment, electronic structure, XPS

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P1-ap.408

Structural and Optical Characterization of Mechanochemically Synthesized Cs-based Perovskites

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Abstract:

Over the past decade, lead halide perovskites (LHPs) have gained significant interest due to their attractive optoelectronic properties with photoconversion efficiency (PCE) exhibiting ca. 22% in perovskite solar-cell (PSC) technologies. Generally, solvent based synthesis has been utilized as a synthetic method of LHPs. Recently, mechanochemical synthesis (MCS) has emerged as an appealing alternative due to many distinctive advantages such as its solvent-free nature of the process. Even though precise mechanisms involved in MCS have not yet been fully elucidated, MCS enables a well-controlled environment where intermediate phases can be analyzed. In this study, we investigated the time-dependent behavior in the synthesis of Cs_4PbBr_6 (referred to as "0D perovskite") by ball milling of stoichiometric precursor mixtures. During the synthesis process, we could identify the coexisting two additional phases: $CsPb_2Br_5$ and $CsPbBr_3$, referred to as 2D and 3D phases, respectively, and derived the weight fraction of each phase from Rietveld refinement and NMR analysis. In addition, the peak photoluminescence (PL) intensity centered at 523 nm was observed to vary depending on the duration time of the synthesis and reached the maximum at around 3 hours of ball milling. The phase fraction analysis of the 0D powders with the maximum PL intensity indicates the presence of a finite amount of 3D phase, which agrees well with previous reports that proposed $CsPbBr_3$ nanocrystals embedded in solution-synthesized Cs_4PbBr_6 microcrystals as the origin of a highly efficient green light with a PLQY of 90%. Our results provide a controllable synthetic methodology for acquiring 0D Cs-based perovskites with an efficient green emission through MCS and paves the way for developing high performance perovskite light emitting devices in the future.

Keywords:

Ball milling, Mechanochemical synthesis, Time-dependence, Cesium lead halide perovskite, Photoluminescence

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P1-ap.409

Improving electron injection with nucleoside cytidine in organic light-emitting diode

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Abstract:

In organic light-emitting diodes (OLEDs), an efficient charge injection is one of the most important requirements to obtain the high device performance. In this regard, nucleoside cytidine can be used as an efficient electron injection layer in OLEDs because of its low work function and solution processability. In addition, cytidine is soluble in nontoxic water allowing environmental-friendly device fabrication and can be obtained from the nature without the complex synthesis process.

In this study, we fabricated inverted OLEDs with a cytidine electron injection layer. The current density-voltage-luminance characteristics of OLEDs with various thicknesses of a cytidine layer were measured to find the optimum thickness. The morphology and electronic structure of a cytidine layer were investigated using atomic force microscopy and photoelectron spectroscopy. The origin of the enhancement in device performance was demonstrated based on the measured film properties.

Keywords:

cytidine, electron injection layer, organic light-emitting diode.

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P1-ap.410

Antisolvent-mixed perovskite precursor for high-performance perovskite solar cells

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Abstract:

In this work, we develop a method to enhance photovoltaic performance of perovskite film by directly mixing an anti-solvent, chlorobenzene, into the perovskite precursor. Using precursor with 30% chlorobenze, the power conversion efficiency of the champion device is improved from 15.24 to 18.48% because of a thicker perovskite film with enlarged grain size. In addition, the chlorobenzene-used device shows much less degradation in normalized power conversion efficiency after 120 h strorage in ambient air without encapsulation. Because we obtain thicker perovskite film by adding anti-solvent in precursor solvent, less material is wasted, benefiting the commercialization of the perovskite devices.

Keywords:

Perovskite solar cell, anti-solvent, chlorobenzene

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P1-ap.411

development of a single device-based organic tactile synapse for artificial learning skin applications

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Abstract:

Recently, research on wearable intelligent electronics that detects, remembers, and learns external stimuli in real-time is receiving great interest. And a tactile synaptic device studies have emerged because they have the potential for human-interactive neuromorphic applications capable of large-scale parallel processing. However, the artificial tactile synaptic devices reported so far have complex physical connections between the sensor unit and the memory unit, which are inevitably not suitable for the wearable and patchable device due to the complex and costly manufacturing steps. Here, we demonstrate an artificial orgnic tactile synaptic device based on the integrated single device that enables the sensing, storing, and learning of a variety of tactile information. The synaptic device is able to be programmed with various tactile input pressures, by using a ferroelectric field-effect transistor structure with a pressure-sensitive ball-shaped top gate electrode. The synaptic device reliably and stably operates with high tactile reception sensitivity of 88 KPa^{-1} under bending conditions. And it was confirmed that synaptic plasticity was stably implemented for 10,000 inputs by various electrical/tactile stimuli, which allows for precise and robust tactile perception learning. Furthermore, we demonstrated that an integrated 4 x 4 tactile synaptic array allows for 2-dimensional tactile learning and proof-of-concept recognition simulations for diverse handwriting patterns with an outstanding error tolerance. As a result, This study proposes the novel platform for a single, integrated tactile neuromorphic system, which can simultaneously sense and learn a variety of external information.

Keywords:

organic tactile synapse, wearable neuromorphic system

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P1-ap.412

Fiber-shaped multi-synapses based on the organic ferroelectric transistor for wearable neuromorphic applications

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Abstract:

A wearable neuromorphic electronic system, that can learn and interpret the non-structural biometric information at extremely low-power, has been brought great attention because of its applicability as the intelligent device that can easily attach onto the human body or any rough surface [1-3]. With this reason, organic-based artificial synaptic devices have been proposed as a potential candidate for wearable neuromorphic applications due to its inherent mechanical flexibility and the material (or device form) variability for the desired functionalities [2,3]. In this study, we designed 1D fiber-shaped multi-synapses comprising ferroelectric organic transistors fabricated on a 100 mm Ag wire and utilized them as multi-synaptic channels in an e-textile neural network for wearable neuromorphic applications [4]. The device mimics diverse synaptic functions, including short- and long-term plasticity with 80 states and spike rate- and timing-dependent plasticity. It exhibited excellent reliability even under 6,000 repeated input stimuli and mechanical bending stress. Various NOR-type textile arrays are formed simply by cross-pointing 1D synapses with Ag wires, where each output from individual synapse can be integrated and propagated without undesired leakage. Notably, the 1D multi-synapses achieved up to ~90% and ~70% recognition accuracy for MNIST and electrocardiogram patterns, respectively, even in a single-layer neural network, and almost maintained regardless the bending conditions.

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Keywords:

wearable device, artificial synapse, neuromorphic

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P1-ap.413

Highly Tunable Molecular Rectifier Realized by Interfacial Design in Molecular Heterojunction with Two-Dimensional Materials

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Abstract:

Until now, a specifically designed functional molecular species has been recognized as an absolute necessity for realizing the diode's behavior in molecular electronic junctions.[1-4] However, even non-functional molecules can be served for the implementation of molecular diode with employing appropriate energy band alignment in heterostructure molecular junctions. Here, we suggest a facile approach for the implementation of a tailored diode in a molecular junction based on non-functionalized alkyl and conjugated molecular monolayers.[5] A two-dimensional (2D) semiconductor (MoS_2 and WSe_2) was used as a rectifying designer at the alkyl or conjugated molecule/Au interface. From the adjustment of band alignment at molecules/2D semiconductor interface that can activate different transport pathways depending on the voltage polarity, the rectifying characteristics can be implemented and controlled. To demonstrate the molecular tunneling in positive bias region and Schottky emission in negative bias region, we performed temperature-dependent measurements of the solid-state devices composed of Gr/N_L-MoS_2/OPT2/Au junctions. The rectification ratio could be widely tuned from 1.24 to 1.83×10^4 by changing the molecular species and type and the number of layers of the 2D semiconductors in the heterostructure molecular junction. Our work sets a design rule for implementing tailored-diode function in a molecular heterojunction structure with non-functionalized molecular systems.

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Keywords:

Molecular electronics, 2D semiconductors, Molecular heterojunction, Molecular-Scale Rectifier

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P1-ap.414

Realization of Sub-2nm Molecular Selector for Next-generation Memory Application

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Abstract:

Diverse types of molecules such as a donor-s-acceptor molecules and ferrocenyl alkanethiol have been suggested as potential candidates for the electronic component of a molecular rectifier.[1,2] Recently, we demonstrated a novel strategy and design rule for realizing molecular-scale diode features based on the energy band engineering between simple alkanethiol or conjugated molecules and two-dimensional (2D) semiconductors.[3] Here, we firstly suggest a molecular-scale (sub-2nm) selector where is based on a heterojunction structure with a non-functional molecule(1-octanethiol, tridecafluoro-1-octanethiol) and two-dimensional semiconductor(MoS_2, WSe_2), which can be utilized to prevent the crosstalk signal in the crossbar memory array. According to direction of molecular dipole moment, the type of 2D semiconductors (1_L-MoS_2 of n-type), and the metal work function (Au and Pt), we found the nonlinearity at 1/2 V_r scheme can be significantly varied, e.x., 1.2 ± 10^1 for Au/C8/1_L-MoS_2/Au and 3.5 ± 10^2 for Au/F6H2/1_L-MoS_2/Pt. This phenomenon can be understood based on the interfacial energy band adjustment of 2D semiconductor in molecular heterojunction according to the direction of molecular dipole moment. The maximum non-linearity value is found to be 2.7 ± 10^3 for the case of Au/F6H2/1_L-MoS_2/Pt, which never been demonstrated in the molecular-scale junction so far. With this non-linearity, the suggested molecular selector enables to extend the array size up to ~ 9Gbit crossbar array. This firstly suggested molecular-scale selector concept will give novel idea for the data storage application for the future technology in data storage application.

[1] Díez-Pérez, I. et al. Rectification and stability of a single molecular diode with controlled orientation. Nat. Chem. **1**, 635 (2009).
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Keywords:

Molecualr Selector, Molecular Heterojunction, Molecular Dipole moment, 2D semiconductor

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P1-ap.501

Structural phase transition behavior of methylammonium lead halide perovskite single crystals studied by Raman scattering spectroscopy

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Abstract:

Over the decades, tremendous amount of research effort has been done to improve the efficiency of photovoltaic devices. This study focuses on understanding the temperature dependence of structural characteristics, particularly the phase transition behavior of methylammonium (MA) lead halide perovskite materials. Raman responses from single crystalline $MAPbCl_3$ samples were measured as a function of temperature and polarization, and abrupt changes were observed near the phase transition temperatures. Our results show that the contributions of each atomic/molecular vibration to phase transition are determined by the type of vibrations. Especially, driving force for the phase transitions are associated with hydrogen bonding involving halogen element. From our results, we claim that Raman scattering spectroscopy is a very effective research tool to sensitively monitor structural phase transition by observing small changes in phonon spectra reflecting the microscopic environment.

Keywords:

Perovskite, Phase transition, CH3NH3PbCl3, Raman spectroscopy

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P1-ap.502

PEDOT:PSS mixed with inorganic V_2O_5 as hole injection layer for efficient quantum-dot light-emitting diodes

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Abstract:

Poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) is a material commonly used for hole injection layer (HIL) in quantum-dot light-emitting diodes (QLEDs). In this study, we report the high-performance QLED by mixing PEDOT:PSS with vanadium oxide (V_2O_5), which is transition-metal oxide (TMO). PEDOT:PSS mixed with V_2O_5 at 10:1 volume ratio showed the best hole injection and device performances. The effective hole injection characteristic of V_2O_5 mixed PEDOT:PSS HIL was confirmed by the hole-only-devices (HODs). The source of enhanced hole injection properties was analyzed using ultraviolet and X-ray photoelectron spectroscopy. We noticed that the density of state (DOS) near the E_F of V_2O_5 mixed PEDOT:PSS was slightly increased than that of simple PEDOT:PSS, and found that it was due to the mixing of V_2O_5. The QLED with PEDOT:PSS showed maximum luminance and current efficiency of 26,577 cd/m^2 and 4.6 cd/A, respectively. On the other hand, the device with V_2O_5 mixed PEDOT:PSS (10:1 V/V) showed maximum luminance and current efficiency of 36,198 cd/m^2 and 13.9 cd/A, respectively. More importantly, the stability of the devices was increased due to the mixture of inorganic V_2O_5. The operating lifetime (T_{50}) is 300 hours at the initial luminance of 100 cd/m^2, which is more than 10 times that of the control device. These results demonstrate that transition-metal oxide mixed PEDOT:PSS is an alternative to simple organic HIL for high efficiency and stable QLEDs.

Keywords:

Quantum dots, Stable, PEDOT:PSS, Transition-metal oxides, Quantum-dot light-emitting diodes

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P1-ap.504

근적외선 영역에서의 광섬유 기반 선형 위상 제어
Fiber-based Linear Phase Change in the Near-Infrared Range

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Abstract:

광섬유 내부의 굴절률 변화를 외부 펌프광을 통해 제어할 수 있는 기법은 기계적인 변위를 이용하는 방법의 단점을 극복하면서도 광학적으로 정교하게 제어가 가능한 위상 제어 방법이다. 이를 이용하면 샘플의 3차원 단차 특성을 복원하는데 있어서 기존 방법을 대치하는 대안 기술로의 활용이 가능하다[1]. 이 때 적용된 광원의 중심파장은 630 nm로써 광영상 기법에서 주로 이용하는 근적외선 파장 대역과는 다른 영역이다. 이러한 광원을 근적외선 광원의 중심파장 대역인 850 nm 부근의 파장대역으로 이동시켜 적용함으로써 보다 다양한 광영상 기법에 광섬유 기반 위상 천이 기법의 적용 가능성이 예상된다. 광섬유 기반의 위상 천이 방법은 파장에 의존성이 없이 인가 전류의 값을 조정함으로써 적절한 위상 천이가 가능한 장점을 가질 수 있다. 또한 펌프광의 세기에 따른 굴절률 변화 및 위상 변화 특성이 선형성을 가지고 있으며 특정 펌프광의 세기 이상에서는 위상 변화가 일정해 지는 특징도 보고되었다[2]. 이러한 위상 천이의 특징을 근적외선 대역에서 활용하기 위해서 본 실험에서는 이터븀 특수 광섬유를 이용한 위상 이동 간섭계에서 830 nm 의 신호광의 위상 변화 특성을 계산해 보았다. 시뮬레이션 결과를 바탕으로 선형적인 위상 제어에 필요한 특수 광섬유의 길이와 펌프광의 세기를 결정하고 제어 조건에 따른 위상 변화 특성을 실험적으로 측정하여 비교 분석하였다. 중심파장에 해당하는 위상 변화를 고려함으로써 최적 제어 조건을 확보함으로써 근적외선 영역에서 동작하는 3차원 단층 영상 시스템에서의 가능성을 확인하고자 하였다.

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[2] Arkwright, John W., et al. Journal of lightwave technology 16.5 798 (1998).

Keywords:

광섬유 위상 이동 간섭계, 선형 위상 제어, 이터븀 첨가 특수 광섬유

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P1-ap.506

Color-tuning behavior of $K_3YB_6O_{12}$:Er^{3+}, Tm^{3+}, Eu^{3+} phosphor for each activator ions various concentrations

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Abstract:

Full-color emission fluorescence materials are of imperious demand in information storage, graphics imaging, and anti-counterfeiting fields. Recently, white light-emitting diodes (WLEDs) have become research hotspots because of their excellent luminescence behavior, low cost, and stable performance.

In this work, the luminescence properties of $K_3YB_6O_{12}$:Er^{3+}, Tm^{3+}, Eu^{3+} were investigated by solvothermal method. Their crystalline structures, surface morphologies and luminescent characteristics were investigated for the samples prepared at various annealing processes by using X-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence (PL), respectively. The purpose of this study is analysis the luminescence properties of $K_3YB_6O_{12}$:Er^{3+}, Tm^{3+}, Eu^{3+} phosphor with the energy transfer between Er^{3+}, Tm^{3+} and Eu^{3+} ions for each activator ions concentrations, and confirmed by analyzing the photoluminescence spectra and CIE coordinate positions.

Keywords:

phosphor, color-tuning

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P1-ap.508

Fast synthesis of carbon dots by using coffee residue

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Abstract:

Recently, carbon dots have been subject of extensive research to achieve potential applications such as optical device, photocatalysis, sensing, and solar cell because of their property (optical stability, cheap raw materials, facile synthesis process, and low toxicity). Therefore, carbon dots seem to be promising alternatives to rare earth ion and quantum dots.

In this work, the carbon dots using coffee residue were synthesized by using fast and facile method without heat. The size of synthesized carbon dots is about 6 nm have strong cyan emission centered at 440 nm under 360 nm excitation. Then, we represent the characterization of prepared carbon dots such as XPS, FT-IR, and Raman spectrum. The results show that the prepared carbon dots can be effectively applied to several applications.

Keywords:

carbon dot

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P1-ap.509

Microwave synthesis and latent fingerprint detection of $Ca_2MgSi_2O_7$: Eu^{2+} phosphor

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Abstract:

Rare-earth based inorganic phosphors are applied various field, such as solid-state lighting, bio-imaging, thermos-sensing, anti-counterfeiting, forensic science, etc. In particular, the phosphor can be applied to identify a suspect, by detecting a latent fingerprint which is visualization of invisible or barely visible fingerprint. The latent fingerprint on rigid surface of evidence are generally obtained by using a powdering method. In general, the regular powder for latent fingerprint detection is regular, metallic.

Recently, powdering the inorganic phosphors have been paid attention due to their strong luminescence, small particle size, high contrast. Among the various rare-earth based inorganic phosphors, the latent fingerprint detection of calcium magnesium silicate phosphor have not been studied.

According to past research, Eu^{2+} doped $Ca_2MgSi_2O_7$ ($Ca_2MgSi_2O_7$: Eu^{2+}) phosphor emits green light centered at 521 nm, which is highly sensitive in human eye. Also, their excellent durability for UV excitation, high chemical and physical stability are favorable advantages for latent fingerprint detection.

In this study, we synthesize a $Ca_2MgSi_2O_7$: Eu^{2+} phosphor using a microwave irradiation. The effect of Eu^{2+} concentration on structural, morphological and luminescent properties of the phosphor are analyzed. Based on the analysis, we developed a latent fingerprint detection of $Ca_2MgSi_2O_7$: Eu^{2+} phosphor.

Keywords:

phosphor, microwave synthesis

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P1-ap.510

Effect of mistracked principal state of polarization on measurement of optical signal to noise ratio using optical power

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Abstract:

Future fiber optic networks are envisaged to be dynamically restructured to switch and control traffic based on optical cross connects and reconfigurable optical add drop multiplexers. In these networks, each of different wavelength channels may have different optical signal to noise ratio (OSNR) owing to different route each passes, which necessitates OSNR measurement by channel. Meanwhile, polarization mode dispersion in optical fiber link makes this channel OSNR hard to exactly measure. Recently, a method of monitoring OSNR based on optical power and tracking of principal state of polarization (PSP) was reported to solve this problem. In this work, the influence of mistraced PSP on the OSNR measurement by the reported method is theoretically simulated and analyzed.

Keywords:

Optical signal to noise ratio, polarization mode dispersion, optical fiber communication

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P1-ap.511

Responsivity of arranged fiber optic sensors using Sagnac interferometers

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Abstract:

Fiber optic Sagnac interferometers, inherently path balanced, can be used as sensors for detecting a variety of environmental phenomena, such as rotation, acceleration, electric and magnetic fields, seismic wave, temperature, pressure, strain, and vibration. Their commercial and military applications involve microphone, earthquake sensor, oil exploration, security sensor, hydrophone for antisubmarine or underwater terrain mapping. In this work, optical fiber sensors based on the Sagnac interferometer are arranged and the vibrational signal responsivity for the different configurations are theoretically and simulatively investigated and discussed.

Keywords:

Sagnac interferometer, optical fiber sensor, interferometer

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P1-ap.512

Structural and Optical Properties of Tris- (8-hydroxyquinoline) Aluminum Doped ZnO Nanoparticle for Organic Light Emitting Diode Applications

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Abstract:

The interest in Organic light emitting Diodes and transistors have rapidly increased in display panel technologies due to their outstanding characteristics such as homogenous emission over a large area, high luminance, tunable wavelength emission, high mechanical flexibility, low cost, the ease to fabrication, and they are environmentally friendly. Amongst those complexes, Tris(8-quinolinolate) Al (III) (AlQ3) considered as a promising material because of it is outstanding electrical transport properties as well as emission properties making them a suitable choice to work as emissive layer as well as electron transparent layer in OLED and OLET devices.In the present study Tris(8-quinolinolate) Al -ZnO nanocomposites were synthesized with different weight percentage (2,6,10) of ZnO NPs in Alq3. The nanocomposites were characterized by X- Ray Diffraction (XRD), Fourier-Transform Infrared spectroscopy (FTIR), Field Emission Scanning Electron Microscopy (FE-SEM), Ultraviolet Visible (UV-Vis) Absorption, and the effect of ZnO nanoparticles on luminescence properties of the samples were studied by photoluminescence (PL) spectra.

Keywords:

Alq3-ZnO nanocomposites, OLED, OLET

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P1-ap.513

Hybrid quantum system employing a nano-mechanical oscillator and a superconducting microwave resonator

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Abstract:

As various platforms are being developed in quantum information science, measures to interconnect disparate quantum systems are necessary. Superconducting qubits for quantum computation operate at gigahertz frequencies and heavily depend on microwave technologies. On the other hand, quantum communications are realized with optical techniques utilizing visible and infrared lasers. In order to connect quantum computers and construct a quantum network, intermediate systems that convert quantum states between microwave and optical frequencies are required.
Recently, optomechanical systems have attracted great attention as potential applications for coherent quantum conversion. A mechanical oscillator with a high quality factor can couple to both microwave and optical fields simultaneously and mediate coherent conversions between them. As a first step, we focus on coupling a nanoscale silicon-nitride membrane with a superconducting microwave resonator. Physically, two heterogeneous resonators interact each other by the small capacitance formed between them. Constructing the combined circuit requires a multistep fabrication process and precise alignment.
The integrated system can be simplified as coupled harmonic oscillators and described by number operators with a coupling constant. The hybrid device provides an excellent opportunity to study quantum electrodynamics involving acoustics.

Keywords:

Microwave-to-optics conversion, Superconducting microwave resonator

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P1-ap.514

Low noise telecom-band single-photon detector via frequency up-conversion

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Abstract:

In quantum communication applications, the InGaAs/InP-based single-photon counting detectors (SPDs) are typically exploited to detect telecom-wavelength photons. These detectors, however, suffer from large dark count (DC) rates (~1 kHz at 10 % quantum efficiency (QE) in free-running mode), the main causes of which are thermally-induced noise and afterpulsing effect noise. To suppress the large DC rates, the detectors are operated in gated mode and the long dead time (~10 μs). However, these constraints limit the detection speed (~10 kHz), which is unsuitable for applications such as the high-speed clocked QKD system.

In recent studies, a frequency up-conversion single photon detector (UCSPD) has been developed, and its main idea is to use a sum frequency generation (SFG) process with well-developed Si-based SPDs for NIR-wavelength photons. The Si-based SPDs have much better performance (short dead time ~30 ns and high QE ~70 % at 700nm with low DC rates ~100 Hz) than the InGaAs/InP-based SPDs, but it is operated only at NIR-wavelength range. Therefore, a special technique is required here, which is the SFG process. The SFG is a χ(2)-based nonlinear process based on the annihilation of two input photons (1550 & 1800 nm) while, simultaneously, one photon (836 nm) is generated. Then, the NIR-wavelength signal photons converted from telecom-wavelength photons can be detected with the advantages of Si SPDs.

In this work, by extension, we demonstrate the wavelength-adaptable UCSPD which can be widely-applicable in quantum communication. Compared with the previous UCSPDs which are specific to optimized wavelengths, our UCSPD is capable of measuring the signals over a wide wavelength range from 1520 nm to 1580 nm by adopting a widely-tunable pump laser.

We observed the highest conversion up to 11.2 % of total photon detection efficiency and the background noise coming from nonlinear waveguide effects (Raman noise, pump SHG tail, etc.), and the result show noise is less than 200 Hz except for SPD's DC rates.

Therefore, we think our wavelength-adaptable UCSPD will be widely used in optical research where low DC rates are required, such as quantum communication.

Keywords:

single photon detector, quantum communication, sum frequency generation

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P1-ap.515

Observation of second-order interference beyond the coherence time with true thermal photons

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Abstract:

The coherence time usually defines the temporal extent within which interference can occur. Contradictory to this common understanding of temporal coherence, second-order interference beyond the coherence time has been observed with a pair of correlated pseudo thermal light beams [PRL 119, 263603 (2017)]. However, as the pseudo-thermal beam itself was originated from a long-coherence laser (and by using a rotating ground disk), there exists the possibility of a classical theoretical model to account for second-order interference beyond the coherence time on the long coherence time of the original laser beam. In this work, we experimentally demonstrate the counter-intuitive second-order interference, in which the interference visibility is completely irrespective of the path length differences, with a true thermal photon source generated via quantum thermalization, i.e., obtaining a mixed state from a pure two-photon entangled state. The thermal (mixed) state of the photon was obtained by tracing out one subsystem of a pure two-photon entangled state generated via the atomic spontaneous four-wave mixing process. This experiment not only clarifies the unique second-order coherence properties of true thermal (mixed state) photons but may also open up remote metrology applications based on such properties, i.e., coherence-time-insensitive and turbulence-robust second-order interference of thermal photons.

Keywords:

Optical interference

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P1-as.001

A cosmic cloud system for the ISS-CREAM data analysis

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Abstract:

The Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM) experiment is designed for direct measurements of high-energy cosmic rays on the ISS. A cosmic cloud system is being developed using PHP and MySQL to efficiently manage ISS-CREAM data collected from August 2017 to February 2019. The cloud system has some advantages of easy access to multiple versions of data, fast I/O speed for large files, parallel processing with multiple servers, and security, etc. Using Simple Query Language (SQL) statements, processing speed can be high because variables can be quickly found, compared and combined. The ISS-CREAM Level 0 and Level 1 data have been processed using Data View generated with a SQL statement with relations. Correlated variables in Data View can be easily accessed repeatedly. Visualization tools for the web interface and C++ API will be developed to make data analysis more efficient. We will report on the status of the cosmic cloud system and discuss possible applications for the scientific data analysis.

Keywords:

ISS-CREAM, Cloud system, Data analysis

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P1-as.002

Properties of AdS black hole in dilatonic Einstein-Gauss-Bonnet theory

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Abstract:

We study a hairy AdS black hole solution in the dilationic Einstein-Gauss-Bonnet theory in which the Gauss-Bonnet term is nonminimally coupled to the dilaton field. We construct a black hole solution in AdS space and check properties of the solution numerically. There exists the lower bound for the dilaton black hole mass. We examine the behavior of the lower bound in terms of the parameter γ.

Keywords:

Dilatonic Einstein-Gauss-Bonnet, AdS Black Hole

천구기준계와 지구기준계에서의 지구자전축의 섭동에 대한 분석

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Abstract:

지구자전(Earth Rotation)은 지구상의 위치와 천구상의 위치를 연계하여 준다. 지구의 자전은 대체로 균일하다고 간주되지만, 그의 변화양상은 미세하며 다양하다. 천구기준계(Celestial Reference Frame)에서의 세차장동은 매우 정밀하게 모델화되어 있고, 지표면에서의 극의 위치변동도 그다지 크지 않다(연중 수 미터). 그렇지만 천구상에서의 지구의 자전축의 실제 위치는 세차장동모델과 약간의 차이를 보여주는바, 이 섭동의 주성분은 자유핵장동(free core nutation)으로 믿어지고 있는데, 그 주기와 진폭이 일정하지않고 모두 변화가 많음이 확인되었다. 지구상의 위치는 경도/위도/고도로 나타내는 바, 이 좌표의 기준인 지구기준계(Terrestrial Reference Frame)를 정의하는 데에 또한 지구자전이 필수적이다(현재 경위도의 기준이 되는 북극점은 1900년의 자전축). 한편 지표면에서의 극의 위치의 섭동의 주성분은 찬들러워블과 일년주기적운동이며, 이외에도 여러가지 다른 요인에 의한 섭동이 발견되고 있다. 본 연구에서는 최근 40년간의 자료를 분석한 결과를 보고한다. (Keywords: 지구자전, 천구기준계, 지구기준계)

Keywords:

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P1-at.001

Comparison of Polarization Spectroscopy on Pump Beam Intensity and Cell Temperature for the ^{85}Rb F_g=3 →F_e=4 and ^{87}Rb F_g=2 →F_e=3

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Abstract:

We investigate the dependence of polarization spectroscopy signal on the pump beam intensity and vapor cell temperature around the $F_g = 3 \rightarrow F_e = 4$ closed transition line of ^{85}Rb and the $F_g = 2 \rightarrow F_e = 3$ closed transition line of ^{87}Rb, and analyze the amplitude of those signals. We observe that the temperature dependency of the polarizaton spectroscopy signal around the closed transition lines of ^{85}Rb and ^{87}Rb shows a different tendency each other, and the temperature dependence affects the change of the polarizaton spectroscopy signal on the pump beam intensity. We also calculate temperature dependence of the PS amplitude for the $F_g = 3 \rightarrow F_e = 4$ closed transition line of ^{85}Rb and the $F_g = 2 \rightarrow F_e = 3$ closed transition line of ^{87}Rb.

Keywords:

polarization spectroscopy

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P1-at.002

Polarization dependence of sub-Doppler spectral resolution for four-level coherent medium in ^{85}Rb

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Abstract:

We report the polarization dependence of sub-Doppler spectral resolution in a Doppler-broaden four-level atomic medium interacting with three laser. The EIT & EIA-like spectrum is observed and changed depending on the Intensities of the two coupling fields, and we investigate the polarization dependence of EIT & EIA-like signals by changing the polarizations of the probe and two coupling fields. The four-level N system is transformed into three-level V type and Λ type configurations depending on the polarization configuration of three fields. We analyze the peak amplitude and width of EIT & EIA-like signals under various polarization configurations of three fields.

Keywords:

sub-Doppler spectral resolution, Doppler-broaden four-level atomic medium

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P1-at.003

Detection of the ion pair channels for collision of 4 kev hydrocarbon ion beam with helium atom

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Abstract:

The dissociation of accelerated hydrocarbon ion by helium collision has been investigated using the ion-ion coincidence time-of-flight method. We have found the ion pair channels in the collision of CH_2^+ and CH^+ with helium. However, no ion pair channels were found in the collision of CH_3^+ with helium. The count rate of the ion pair channels of CH^+ was about 7 times higher than that of CH_2^+.

Keywords:

collision, ion pair, time-of-flight, hydrocarbon, Helium

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P1-at.004

MTS를 이용한 양자중력계용 다이오드 레이저의 주파수 고안정화

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Abstract:

본 연구팀에서는 고감도 양자중력계를 위한 고안정 레이저시스템을 개발하고 있다. 사용된 레이저의 주파수 안정도가 양자중력계의 안정도에 직접적으로 영향을 미치기 때문에 높은 안정도의 레이저시스템 개발이 필요하다. 이전 연구에서 MTS(Modulation Transfer Spectroscopy) 분광시스템을 이용하여 레이저의 주파수를 안정화하여 1×10^{-11}@1s 이하의 안정도를 얻었다. 본 연구에서는 MTS 분광시스템 개선 및 EOM(Electro-Optic Modulator)에 의한 RAM(Residual Amplitude Modulation) 효과를 최소화하여 레이저의 주파수 안정도를 개선하였다. 두 외부공진기 다이오드 레이저의 맥놀이 주파수 측정으로 얻어진 레이저의 상대주파수 단기안정도는 τ = 1 s 에서 1.4×10^{-13} 에 도달하였고, 1 s ~ 1 d 전영역에서의 장기안정도는 5×10^{-12} 이하인 결과를 얻었다.

Keywords:

양자중력계, ECDL, MTS, 주파수안정화

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P1-at.005

Single-site Resolving ^{7}Li Quantum Gas Microscope

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Abstract:

Imaging and addressing individual atom in optical lattices with single-site resolution constitute a new approach to the study of quantum many-body problem. It provides microscopic information of quantum many-body states, such as correlation functions and entanglement entropy, and one can engineer arbitrary density pattern for the study of non-equilibrium quantum dynamics. In this presentation, we introduce a single site-resolved imaging system of 7Li atoms in two-dimensional square optical lattices. The optical lattice is made of 1064 nm light with 750 nm lattice spacing and generated by four-fold interference of retroreflected light. The maximal lattice depth can be reached to 4500 Er with its sideband frequency 1.57 MHz. For imaging and cooling the atoms, we apply Raman sideband cooling, where the scattered photons are collected by a high numerical aperture (NA=0.65) objective lens. The point spread function of our imaging system is 820 nm, 30% larger than the diffraction limit of the imaging system, still enough for having a single-site resolution.

Keywords:

Bose-Einstein condensate, quantum gas microscope, optical lattice

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P1-at.006

Mechanism of HHG from solids based on Houston states

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Abstract:

Since the observation of high-order harmonic generation (HHG) from a bulk crystal [1], the mechanism of HHG from solids have been studied intensively. Similarly with the real space three-step model in the gas-phase HHG, to explain the mechanism of HHG from solids, the three-step model in the momentum k-space is suggested [2,3], based on that the electron from a lower band to an upper band transits through the minimum band gaps. We use the Houston states [4] to investigate at what time the transition from the lower band to the upper band most occurs. Based on this investigation, the mechanism of HHG process in solids is examined.

[1] S. Ghimire, A. D. DiChiara, E. Sistrunk, P. Agostini, L. F. DiMauro, and D. A. Reis, Nat. Phys. 7, 138 (2011).
[2] T.-Y. Du and X.-B. Bian, Opt. Express 25, 151 (2017).
[3] M. Wu, D. A. Browne, K. J. Schafer, and M. B. Gaarde, Phys. Rev. A 94, 063403 (2016).
[4] J. B. Krieger and G. J. Iafrate, Phys. Rev. B 33, 5494 (1986).

Keywords:

Houston states, three-step model, high-order harmonic generation, HHG from solids

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P1-at.007

Test of quantum search algorithm

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Abstract:

Recently Ambainis et al. [1] suggested a quantum walk algorithm that can find a marked vertex in any graph quadratically faster than the corresponding classical random walk, remaining the proof as an open problem. Shortly thereafter, Apers et al. [2] showed that the algorithm really works by introducing the quantum fast-forwarding technique and unifying the electrical network framework with the hitting time framework. In this poster we present results of numerical test for correctness of the algorithm by using classical computers and summarize the essential features of the algorithm.

[1] A. Ambainis, A. Gilyén, S. Jeffery, and M. Kokainis, Quadratic speedup for finding marked vertices by quantum walks. arXiv: 1903.07493 (2019).
[2] S. Apers, A. Gilyen, S. Jeffery, A Unified Framework of Quantum Walk Search, arXiv: 1912.04233v1 (2019).

Keywords:

quantum search, quantum walk, quantum fast-forwarding

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P1-at.008

Higher order multiphoton frequency mixing effects on coherent electromagnetically induced absorption spectra of ^{85}Rb atoms

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Abstract:

We have investigated multiphoton frequency mixing effects on coherent electromagnetically induced absorption (EIA) spectra of ^{85}Rb atoms using two orthogonal linear polarizations of the strong pump and weak probe beams theoretically and experimentally with respect to an applied longitudinal magnetic field and pump powers. The genuine coherent spectral shapes are observed with a single laser combined with two AOMs, where the spectral resolution is limited due to the decoherence rate between Zeeman sublevels in the ground state from transit-time relaxation. We confirm for the first time that more than five-photons oscillations in solving the time-dependent density-matrix of a degenerate two-level system of $\boldsymbol{F_g = 3 \rightarrow F_e = 4}$ of ^{85}Rb atoms in the case with the quantum axis as the propagation field direction should be required to explain experimentally observed coherent EIA spectra with strong pump and weak probe beams.

Keywords:

EIA, 85Rb atom, frequency mixing

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P1-at.009

Development of helical resonator for trapping ytterbium ions
Yb 이온 포획을 위한 나선형 공진기의 개발

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Abstract:

이온트랩 기반의 양자컴퓨터에서는 이온들을 안정적으로 포획할 수 있도록 깊은 포텐셜 우물이 필요하다. 이를 위해 이온트랩 전극에 RF 주파수로 진동하는 고전압을 가할 수 있어야 한다. 본 발표에서는 약 500 V 정도의 전압 공급이 가능한 나선형 공진기(helical resonator)의 설계 및 제작 과정에 대해 보고한다. 우리는 171Yb+ 이온을 사용하며, 공진기의 목표 공진 주파수는 22.5 MHz이다. 산화막이 존재하는 구리, 담금질(annealing)된 구리, 니켈, 은, 금 도금 등으로 구리 산화막을 피해 교류 전류가 흐르도록 제작된 공진기에서 주파수와 휘도를 측정할 계획이다. 본 연구에서 개발된 나선형 공진기는 이온에 가해지는 운동 모드(motional modes) 대역의 잡음을 줄여주는 역할도 하게 되어 안정적인 이온 포획을 가능하게 할 것으로 기대된다.

Keywords:

나선형 공진기

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P1-at.010

Entropic nonclassicality and quantum non-Gaussianity tests using homodyne detection with beam splitting operation

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Abstract:

We here propose experimentally feasible nonclassicality and quantum non-Gaussianity tests using the entropy of quadrature distributions [1]. Our approach relies on the fact that the entropy of a quadrature distribution is non-increasing via a loss channel for the case of a classical state. We show that our test is strictly stronger than the variance-based squeezing condition. It can also be extended to detect quantum non-Gaussianity in conjunction with phase randomization. Furthermore, we address how our criteria can be useful to identify single-mode resource states to generate two-mode states demonstrating the Einstein–Podolsky–Rosen (EPR) paradox, i.e., quantum steering, via beam-splitter setting. Our finding shows that quantum non-Gaussian states can be more feasible for activating quantum steering from a phase-randomized single-mode state by a beam-splitter. It supports why we need strong quantum non-Gaussian states for continuous-variable quantum information protocols.

[1] J. Park, J. Lee, and H. Nha, Sci. Rep. **9**, 17835 (2019).

Keywords:

entropy, nonclassicality, quantum non-Gaussianity, homodyne detection, beam splitter

2020 KPS Fall Meeting
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P1-bp.001

A model of artificial chaotic 1/f noise generation

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Abstract:

A novel model of artificial 1/f time series generation is presented. The motivation of this study is to provide an idea about the origin of 1/f-type signals found in biological systems. We employed a cellular automata system which consists of masses of self-replicating and mutually competing loops. Our self-replicating system is an advanced version of Chou & Reggia's system (Physica D 110, 252-276). Development of complex self-replicating CA loops was performed using a novel construction scheme. We introduced a unique activity measure of CA to simulate biological characteristics. By the summation of the global loop activities and observing its time evolution, we obtained the artificial biological time series. The power spectrum of the resulting time series shows the exact 1/f^{alpha} scaling behavior. The exponent {alpha} in the 1/f^{alpha} power spectrum of the unconstrained self-replicating system was {alpha} =~ 1.5 . Further, the {alpha} value was lowered to {alpha} =~ 1.1 with no growth condition. The larger scale destruction in the CA rules produced the lowered {alpha} in the generated 1/f^{alpha} time series. From the calculation of nonlinear measures (correlation dimension and largest Lyapunov exponent), the chaotic behavior of the time series was observed. This study proposes another explanation regarding the origin of 1/f^{alpha} -type scaling behavior in biological signals (e.g. electroencephalogram).

Keywords:

time series, 1/f noise, self-replication, power law, cellular automata

2020 KPS Fall Meeting
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P1-bp.002

A database of behavioral phenotypes of C. elegans

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Abstract:

Charcot-Marie-Tooth disease (CMT) is a disease in which motor and sensory nerves are damaged by mutations in specific genes causing sensory loss and anomalous sensation. While human genome analysis and studies with transgenic mice have been most successful in understanding the disease, here we sought to employ C. elegans as a CMT-disease model. We examined worms carrying mutations for the orthologs of the CMT-causing genes, and quantified their behavioral phenotypes along with those of the wild type. To do so, we designed an imaging system to record movement and body posture of multiple worms for 10 minutes and extracted various features from the acquired images based on previous studies. By inspecting over 5,000 individuals covering 26 different C. elegans strains, we compiled a database of behavioural phenotypes of C. elegans mutants associated with CMT disease. The database will be beneficial to those who are considering C. elegans model for CMT disease.

Keywords:

Behavior, Model Organism, Disease Model

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2020-11-04 - 2020-11-06

P1-bp.003

A simple, scalable imaging platform for behavioral analysis of C. elegans

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Abstract:

Probing motor behaviors of C. elegans, a powerful nematode model equipped with ample genetic and imaging tools, is a simple yet powerful experimental approach for neurogenetics, because locomotion and body posture of worms are coordinated by the nervous system. Real time recordings of their motor behaviors also offer a valuable opportunity to study the mechanistic model of their movements. Here, we made a simple platform for imaging the behaviors of the worms, based on previous studies. Although our setup is very simple, we can still track the movement and the body posture of 10 individual worms every 0.5 seconds, which allows us to extract various features such as speed, acceleration, dwelling/roaming state, reversal, bending angles, amplitude of its undulation, and more. Our platform is also very affordable and compact, which enables scaling up experiments with ease. As a proof of the scalability, we demonstrated simultaneous operation of 8 microscopes to monitor various worm strains that exhibit different behavioral phenotypes. We anticipate that this simple, scalable imaging platform could be useful for the search of C. elegans peripheral neuropathy models.

Keywords:

Behavior, Model Organism, Custom Microscope

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P1-bp.004

Recovery of fatty acid monolayers by divalent salts investigated by sum-frequency generation spectroscopy

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Abstract:

Langmuir monolayers consisting of fatty acids having relatively short alkyl chains ($C_{14}H_{29}COOH$ (pentadecanoic acid, PDA), $C_{15}H_{31}COOH$ (palmitic acid, PA)) are stable at neutral pH, but become unstable at high pH (pH ~ 11). Further addition of small amount of divalent salt in water was found to recover the monolayer, presumably binding of the divalent cation to the carboxylic headgroup makes the molecule more stable against dissolution into subphase water. Revival of the monolayer was readily seen by pressure-area isotherm measurement or by sum-frequency generation spectrum in the CH_x range at much lower concentration for Mg^{2+} as compared to Ca^{2+}. This showed that the binding affinity of Mg^{2+} to $R\text{-}COO^-$ was stronger than that of Ca^{2+}. Fatty acids monolayer could possibly be used to detect trace amount of divalent cations in water.

Keywords:

fatty acid monolayers, Deprotonation, Sum-frequency generation spectroscopy, divalent salt

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P1-bp.005

Optimization of osteoblasts culture in PLCL scaffolds through electrical stimulation

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Abstract:

As we enter an aging society, there is growing interest in treatments that regenerate bone damage. In general, biological tissue engineering to treat bone damage uses methods that utilize bone substitution to promote bone tissue regeneration. Bone substitutes need to have a certain level of mechanical strength or higher, and are required to have physical properties and biodegradable properties to adapt to the attachment and proliferation of osteoblasts. In this study, CaP (skeletal component) and alendronate, which is used as a therapeutic agent for osteoporosis, are added by adjusting the synthesis rate of PLCL material to create a bone substitute material with excellent mechanical properties and biodegradability developed.

In addition, electrical stimulation was applied to the PLCL scaffolds to efficiently control the culture of osteoblasts. A current was applied to the PLCL scaffolds to efficiently promote cell culture and analyze the intensity and duration of electrical stimulation. It was confirmed that the growth surface of cells appeared differently based on the electrical condition, and the effect of promoting cell culture at a specific current and time was confirmed. The cell culture time before transplantation to the scaffolds could be effectively shortened via electrical stimulation, and it can be utilized in a feasible method of bone substitute.

Keywords:

PLCL scaffolds,CaP, Alendronate ,osteoblast (MG63), electrical stimulation

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P1-bp.006

Nondestructive tumor monitoring using radiation-guided targeting system

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Abstract:

To increase bioavailability of nano-drug in mouse brain tumor model, nondestructive tumor monitoring system was establish using radiation-guided targeting technique. HVGGSSV peptide was used as the drug delivery carrier. TIP-1 is a molecular target which enables the selective binding of the HVGGSSV peptide in irradiated mouse brain tumors. TIP-1 is a radiation-inducible antigen on the surface of tumor cells that can bind peptide ligand HVGGSSV. An IVIS optical imaging study was conducted to determine whether targeting the nanoradiosensitizer to radiation-inducible receptors could improve tumor-specific drug delivery. Fluorescence images were acquired and Ce6 dye signals were measured to verify drug delivery to the tumor. Irradiated tumor models showed greater radiance compared to untreated control. Nondestructive tumor monitoring using radiation-guided targeting system can be effectively applied to define the tumor growth.

Keywords:

Nondestructive tumor monitoring, nano-particle, radiation-guided targeting

2020 KPS Fall Meeting
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P1-bp.008

Single molecule biophysical studies of chromatin-targeting anti-cancer agent Curaxin

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Abstract:

Curaxin has attracted considerable attention as an anti-cancer agent that acts on chromatin without DNA damage. Interestingly, from circular dichroism (CD) spectra of Curaxin-bound DNA, we found that a DNA molecule undergoes a considerable conformational change from B-form to A-form-like state upon binding to Curaxin. To understand the effect of Curaxin binding on DNA, we have investigated the physical properties of the Curaxin-DNA complex using magnetic tweezers. Curaxin appears to associate with DNA as an intercalator, lengthening and unwinding DNA. For quantitative analysis, we characterized the helicity and extension of Curaxin-bound DNA. From the systematic measurement, we estimated the size of Curaxin binding site and the binding constant of Curaxin to DNA using the McGhee-von Hippel model and thus determined the elongation length and unwinding angle of DNA per bound Curaxin molecule.
All taken together, we conclude that Curaxin is a chemical agent that induces dramatic conformational change in DNA without permanent damage to DNA, which is likely responsible for its novel chemotherapeutic effect.

Keywords:

magnetic tweezer, Curaxin

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P1-bp.009

Exonuclease-independent mismatch repair in a cell free system

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Abstract:

DNA mismatch repair (MMR) has fundamental role in maintaining genomic stability of cells by correcting the mismatched base mainly generated during DNA replication. Therefore, deficiency of MMR function causes various genetic disease like Lynch syndrome, as well as sporadic colorectal, ovarian, endometrial cancer. During MMR process, removal of mismatched base is carefully controlled but the details are still ambiguous. Exonuclease I (ExoI) is a 5′ to 3′ exonuclease which is participated in DNA repair process, but it is assumed that mismatch removal process will take place in two pathways; ExoI-dependent or ExoI-independent pathway. In our work, to monitor the removal of mismatch, we constructed the circular DNA probe which has mismatched base and donor-acceptor fluorescence pair for single-molecule FRET by using CRISPR/Cas9 nickase based method. When the mismatch is removed from the nick on the opposite strand of the fluorescence pair, the DNA becomes a single-stranded form and the distance between the donor-acceptor fluorescence is closer, which increases FRET efficiency. From the Biochemical experiment, we confirmed that Exo I could not pass fluorescence of DNA, and mismatch removal by EXOI was blocked, so this circular DNA probe can selectively monitor ExoI-independent DNA mismatch removal. We monitored DNA mismatch removal process with purified MMR protein by single molecule FRET. Then, we monitored the FRET efficiency change in cell nuclear extract. We propose a single-molecule technique to monitor DNA mismatch removal of cells.

Keywords:

DNA mismatch repair (MMR), single-molecule FRET, CRISPR/Cas9, Exonuclease-independent mismatch repair

P1-bp.010

Single-molecule visualization of mismatch repair components using DNA skybridge

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Abstract:

The mechanism of how mismatch-recognized MutS interacts with MutL was a long- standing controversial issue in DNA mismatch repair. Single-molecule localization and tracking has been successfully used to interpret characteristics of nucleic acid binding proteins. To study the dynamics of MutS homolog (MSH) and MutL homolog(MLH) on mismatched DNA in human cells, we used DNA skybridge that is surface-condition independent and high-throughput single-molecule fluorescence imaging platform [1]. We will introduce the diffusion mechanics of MSH and MLH during human DNA mismatch repair.

[1] D. Kim, F. Rashid, Y. Cho, M.S. Zaher, I.H. Cho, S.M. Hamdan, C. Jeong, J.-B. Lee, “DNA skybridge: 3D structure producing a light sheet for high-throughput single-molecule imaging”, Nucleic Acids Research, 47, e10 (2019)

Keywords:

DNA skybridge, Single-molecule fluorescence imaging, Human Mismatch Repair

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P1-bp.011

Single-molecule cryo-fluorescence microscopy

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Abstract:

Super-resolution fluorescence microscopy, such as PALM and STORM, plays an important role in understanding cellular ultrastructure with 20-30 nm resolution. Under cryogenic conditions, the brightness of most fluorophores increases, and native ultrastructure is preserved much better than chemical fixation. Therefore, we can have better spatial resolution and fine cellular structures in cells under cryogenic conditions. However, for single-molecule imaging, high numerical aperture (NA) objective (>1.0) is required. We achieved NA=1.8 without an immersion medium using a solid immersion lens [1]. We will demonstrate the solid immersion microscopy capable of resolving single fluorophores in cryo-immobilized mammalian cells under the cryogenic condition.

References:
[1] Wang et al., 2019, Nature Communications Biology.

Keywords:

Single-molecule imaging, Cryo-fluorescence microscopy, Solid immersion lens, Cryo-immobilized mammalian cells

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P1-bp.012

The role of beta-actin mRNA localization in single dendritic spines studied by two-photon glutamate uncaging

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Abstract:

mRNA localization in neurons is required to synthesize proteins in dendrites and axons. Long-term potentiation (LTP) is an important form of synaptic plasticity underlying learning and memory. To investigate the physiological role of beta-actin mRNA localization in dendritic spines, we employed two-photon glutamate uncaging to stimulate single dendrite spines with or without beta-actin mRNA localization. Hippocampal neurons cultured from the MCP ´ MBS knock-in mice in which all endogenous beta-actin mRNAs are fluorescently labeled were used for live-cell imaging of beta-actin mRNA. The activity of all neurons was blocked by applying tetrodotoxin (TTX), which is an inhibitor of sodium channels. Two-photon uncaging of glutamate was carried out to stimulate only a single dendritic spine. The structural LTP was assessed by measuring the changes in the volume of dendritic spines. Our results suggest that localization of beta-actin mRNA has a strong correlation with structural LTP process. We treated cycloheximide (CHX) and custom ordered beta-actin mRNA targeted morpholino (MO) to exclude the effect actin proteins around a single spine. This study sheds a light on the implication of beta-actin mRNA localization and local translation for LTP in neurons and their role in long-term memory formation.

Keywords:

sLTP, beta-actin, mRNA, translation, localization

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P1-bp.013

Transcription of Arc mRNA induced by electrical burst stimulation

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Abstract:

Immediate early genes (IEGs) are genes that are rapidly induced by neural activity. The expression of IEGs such as Arc, c-fos, and Egr1 has been used to investigate the relation among external stimuli, neural activity, and memory formation. Inside cells, there exist signaling pathways where the chain reaction of enzymes leads to the gene expression and regulation. These pathways can be driven by external stimuli such as heat, chemicals, growth factors, and electrical stimulation. In this research, we investigated the effect of electrical stimulation on the expression of Arc in hippocampal neurons cultured from the Arc-PBS ´ PCP-GFP mice. Among various frequency range of brain waves, 4~8 Hz (5~10 Hz for rodents) is called theta frequency. The theta frequency wave is observed during rapid eye movement (REM) sleep and known to be involved in memory formation. Particularly, the theta burst stimulation (series of high-frequency bursts given at theta frequency) is known to induce long-term potentiation (long-lasting increase in synaptic responses). We focused on the effect of the burst stimulation and tested various time intervals between the bursts to find the optimal burst frequency for induction of Arc transcription. Live-cell imaging of Arc-PBS ´ PCP-GFP neurons allowed us to observe real-time response of Arc transcription. We found that theta burst stimulation induced Arc transcription in ~45% of neurons, which were significantly higher than the percentage of neurons activated by other frequency range. These results will shed light on the relation between Arc transcription and LTP-inducing electrical stimulation.

Keywords:

immediate early gene, Arc, electrical stimulation, theta burst stimulation

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P1-bp.014

Fluctuation analysis of transcription in live mammalian cells

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Abstract:

- Transcription is the initial step of gene expression, in which the genetic information in DNA is copied into RNA by RNA polymerase. In eukaryotic cells, RNA polymerase II (PolII) and its associated factors transcribe all protein coding genes and a number of noncoding RNA. Yet it is not well known how the complex transcriptional machinery control transcriptional dynamics through the initiation, elongation, and termination of RNA synthesis in mammalian cells. To address this question, we directly monitored the transcriptional output in live cells using a transgenic mouse that expresses fluorescently labeled Arc and ActB mRNA. By imaging transcription sites (TS) in live mouse embryonic fibroblasts (MEF) cultured from the mouse model, we collected the fluctuation data of the transcriptional events. By fitting the autocorrelation function and declince curves of fluorescence intensity fluctuation from the TS, we measured the initiation, elongation, and termination rates of Arc mRNA. We also simulated the transcription model using a simple computational method to determine the contribution of the three stages. This study will allow us to compare the simulation and the actual observations, which will shed a light on the complex regulation of mRNA synthesis in live mammalian cells.

Keywords:

transcription, stem-loop, mRNA

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P1-co.102

Finding the electron-boson spectral density functions with machine learning

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Abstract:

The electron-boson spectral density functions ($I^2\chi$) can be obtained from the optical scattering rates data at normal state using the Shulga's formula [1]. There are several methods for getting $I^2\chi$ from the optical scattering rate ($1/\tau^{op}(\omega)$) such as maximum entropy and least square methods [2,3]. Here we introduce a new method using machine learning for obtaining $I^2\chi$ from $1/\tau^{op}(\omega)$. We use modern methods such as the convolution neural network (CNN) and the bi-directional long short-term memory model (Bi-LSTM) for training and the stochastic gradient descent optimizer for optimizing. The training data set is $1/\tau^{op}(\omega)$ at 100 K generated from model $I^2\chi$, which consists of a Gaussian peak, a sharp mode and an MMP mode. We include random noises in $1/\tau^{op}(\omega)$ to make them more realistic. After training, we tested the machine learning with other remaining $1/\tau^{op}(\omega)$. For verifying our machine learning, we apply it to existing measured optical scattering rates at 100 K of one optimally doped and two overdoped $Bi_2Sr_2CaCuO_{8+\delta}$ (Bi2212) samples with $T_c = 60K$, $T_c = 82K$, and $T_c = 96K$, respectively. Reconstructed optical scattering rates are consistent with the measured ones. From this study, we learned that our method is strongly model ($I^2\chi$) dependent. We need to improve this method to develop a more generalized model-independent one.

Keywords:

electron-boson spectral density function, optical scattering rate, machine learning

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P1-co.103

Analysis of magnetic properties in GdBCO rings with narrow paths

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Abstract:

In this study, we analyzed global magnetic properties of GdBCO ring with narrow paths. The measurement of magnetization of GdBCO coated conductors were measured by using Magnetic Property Measurement System (MPMS XL 7). We patterned specimens by maskless photolithography using a UV-laser. The specimens were made of ring-shaped samples with different numbers and widths of narrow paths, respectively. Since the outer diameters of the rings are all the same, the virgin state was the same in all specimens at an external magnetic field which is lower than the full penetration field H_p. At a higher external magnetic field, the global magnetization indicated a large difference according to the geometry of the narrow paths. We analyzed this study focused on the difference in the total volume of GdBCO and magnetization of the specimens, which decrease by the narrow paths.

Keywords:

GdBCO, MPMS, Ring, Narrow path, Magnetization

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P1-co.104

Interval and stacking number dependence of AC loss in GdBCO coated conductor

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Abstract:

A 2G HTS coated conductor with large aspect ratio has a large AC loss for a perpendicular external magnetic field. Therefor reduction of AC loss in 2G HTS C.C is an important issue. Stacking HTS C.C increase full penetration field Hp and behave like infinity slab. The AC loss for maximum applied magnetic field H_m below H_p affected by interval D and staking number n, whereas AC loss for Hm above Hp, unaffected by D and n. In this study, we stacked 1~3 square GdBCO coated conductors which have the same geometry with regular D . We measured magnetization of the stacked samples in 83 K (low H_m approximation) and 89 K (high H_m approximation) using MPMS. The AC losses obtained by calculation of measurement results and we compared AC losses in the stacked samples with the single layer sample. We investigated the dependence for D and n of AC loss.

Keywords:

Superconductivity, GdBCO, AC loss, Stacked coated conductor

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P1-co.105

Linear Proportionality of Creep Scaling Constant on Co-Layer Thickness

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Abstract:

Despite apparently different phenomena, many of systems often follow unifed dynamics laws such as fluid invasion of porous media, vortex lattices, charge-density waves, and contact lines during wetting of solids by liquids. Among these various disordered systems, magnetic multilayer systems provide test body to analyze the disordered media with their dynamics, especially through the behavior of magnetic domain wall motion under application of external field. Here we report the relation between the creep scaling constant α and the ferromagnetic layer thickness t_{Co} in various tri-layer magnetic systems. For this study, we prepared a series of magnetic ultrathin films using DC magnetron sputtering. The detailed layer structure is Ta (5 nm) / X (2.5 nm) / Co (t_{Co}) / Pt (1.5 nm) on Si (525 μm) / SiO_X (100 nm) substrates, with different heavy metals X (=Au, Pd, and Pt) over the t_{Co} ranges (0.3~0.9 nm) with 0.1 increments. And then, creep scaling law $v=v_0\exp(-\alpha H^{-\mu})$ of elastic interfaces, where v_0 is the characteristic speed and μ (=0.25) is the creep exponent. Figure 1 plots α and t_{Co} irrespective of different X. This clear linear proportionality provides us a way to predict the effective ferromagnetic layer thickness in ultrathin perpendicular magnetic anisotropy thin films.

Keywords:

Creep scaling law, Scaling constant, Ferromagnatic layer thickness

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P1-co.106

Domain-wall-roughness-based determination scheme for Dzyaloshinskii-Moriya interaction

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Abstract:

Stabilization of chiral domain-walls (DWs) is a key issue to achieve high performance spintronic applications such as memory and data storage devices with high speed and high durability [1]. Such stabilization can be achieved by the Dzyaloshinskii-Moriya interaction (DMI) in structural inversion asymmetry systems [2-4]. It is therefore important to analyze the strength of DMI accurately and thus, there have been also numerous efforts devoted to quantifying the DMI [5-6]. However, many of the DMI measurement schemes have a trouble with severe artefact caused by additional asymmetries such as the chiral damping [7]. Here, we propose a new scheme to measure the strength of the DMI-induced effective field HDMI, based on the DW roughness. The present scheme was then applied to determine HDMI's in Pt/Co/Pt ultrathin films, which exhibit both sizable DMI strength and strong perpendicular magneto anisotropy. To check the validity, HDMI's were again measured by other independent measurement schemes based on the DW velocity vDW [5]. Figure 1 shows the plots of (a) wDW and (b) vDW with respect to Hx. It is clear from the plots that both experimental schemes show the same strength of HDMI and therefore, we confirmed the validity of our present DMI measurement scheme based on the DW roughness.

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Keywords:

DMI,Domain Wall,PMA,Roughness

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P1-co.107

Cr 기반의 이종박막 내에서 발생하는 스핀-홀 자기저항에 대한 연구

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Abstract:

정보화 시대가 열린 오늘날, 하루에도 수백 ZB의 데이터가 새롭게 발생한다. 이를 저장할 때 발생하는 에너지의 소모량이 급속도로 증가하고 있다. 이러한 문제를 해결하기 위해 스핀전류을 이용하는 차세대 메모리 소자 개발이 활발하게 진행되고 있다. 그러나 기존에 연구가 진행되고 있는 W 및 Ta과 같은 중금속들은 많은 스핀전류을 생성함에도 불구하고 전기 전도도 값이 작아, 결과적으로 소자로 사용하기에는 효율이 떨어진다는 단점이 있다. 이에 우리는 큰 전기 전도도 값을 가지면서도 충분히 자화를 제어할 수 있는 스핀전류를 발생시키는 Cr에 대해서 연구를 진행하였다.
본 연구에서는 스퍼터링 공정을 이용하여 강자성체인 CoFeB과 경금속인 Cr 이중 박막 구조 사이에 중금속(HM)인 Pt 혹은 W을 삽입한 3층박막 시편을 제작하였고 션팅효과 등을 제거하기 위해 전류의 경로를 나노 공정을 이용한 패터닝 작업을 진행하였다. 우리는 해당 시편에서 스핀-홀 자기저항(이하 SMR)을 측정함으로써 Cr층에서 발생하는 스핀-수송 현상을 이해하고자 한다. 이를 위하여 Cr/HM/CoFeB에서 HM층을 스핀-홀 각도가 서로 다르다고 알려진 Pt와 W을 사용하여 중금속의 두께 변화에 따른 SMR의 변화 경향성을 살펴보았다.
이후 해당 소자에서 측정한 SMR 값을 이용하여 각 층에서의 1)스핀-홀 각, 2)스핀 생존시간, 3)스핀 혼합 전도도에 대해 계산을 진행했고, 이를 통하여 Cr층에서 발생하는 스핀-수송에 대해 연구를 진행하였다.

Acknowledgments This work was supported by the Brain Korea 21 Plus Program (Human Resource Center for Novel Materials Research Experts) through the National Research Foundation of Korea (No. F19SR21D1101) and the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. NRF-2018R1A4A1020696, 2017R1A2B3002621 and 2019R1C1C1010345).

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Keywords:

Cr, 스핀-홀 자기저항, 스핀-홀 각, 스핀 생존시간, 스핀 혼합 전도도

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P1-co.108

Thickness dependent magnetic transition in vdW layered $MnPS_3$

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Abstract:

Transition metal phosphorus trisulfides ($TMPS_3$) are a new family of antiferromagnetic van der Waals (vdW) layered materials. Magnetic ordering in a Heisenberg-type system should not exist in the monolayer limit according to the Mermin-Wagner theorem, and Néel temperature (T_N) is expected to approach 0 K rapidly as the thickness is reduced. We tried to investigate the T_N of the Heisenberg-type 2D magnetic vdW material $MnPS_3$ as a function of the number of layers.

We exfoliated $MnPS_3$ samples from monolayer to bulk on SiO_2/Si substrates. We cooled the samples in a micro-cryostat to 22 K using liquid He. Raman spectroscopy was performed to identify the antiferromagnetic transition, and the broadening and abrupt redshift of a phonon peak at 155 cm^{-1} were observed near T_N, which is an indicator of the antiferromagnetic transition [1]. By monitoring this change for samples with different thicknesses, we found that T_N decreases only slightly from ~78 K for bulk to ~ 66 K for 3L. This small reduction of T_N in few-layer $MnPS_3$ approaching the 2D limit implies that the interlayer interaction is playing a crucial role in stabilizing magnetic ordering in vdW layered magnetic materials.

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Keywords:

Transition metal phosphorus trisulfides , Magnetic transition, MnPS3, TMPS3, vdW magnetic material

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P1-co.109

Two-dimensional Fe_3GeTe_2: strain effect on magneto-crystalline anisotropy

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Abstract:

In recent years, two-dimensional (2D) Fe_3GeTe_2 (FGT) is intensively studied [1], whose moment reaches around 2.06 μB/Fe1 and 1.04 μB/Fe2 . Using density-functional theory, magneto-crystalline anisotropy (MCA) is studied for strain (η) from -5% to 5%. Monolayer FGT exhibits perpendicular MCA for all η , which has an advantage for high bit density, thermal stability, and low critical current in spintronics. On the other hand, bilayer shows perpendicular MCA for most of η but in-plane MCA for η = - 5%. Without strain (η=0%) , bilayer FGT of A-type antiferromagnetic (A-AFM) energetically favors over ferromagnetic (FM) (Δ E=15.96 meV). Besides, A-AFM to FM transition occurs at strain (η) of + 4.16%.

Reference

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Keywords:

2D magnetic material, Density-functional theory, Magneto-crystalline anisotropy, Strain

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P1-co.111

Non-vanishing Anomalous Hall Effect in nearly Compensated Ferrimagnet Mn_3Al

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Abstract:

In the absence of total magnetization, anomalous Hall effect (AHE) is not anticipated. But in recent studies show that AHE can emerge in various situations such as non-collinear antiferromagnets [1, 2], collinear antiferromagnets [3], and compensated ferrimagnets [4].
In this work, density functional theory is used to investigate AHE in Mn_3Al, whose total magnetization is nearly compensated, where magnetic moments of two inequivalent Mn sites are compensated but Al has small moment. The goal is to investigate volume-dependent anomalous Hall effect, more specifically anomalous Hall conductivity and Berry curvature associated with electronic structures.

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Keywords:

Spintronics, Anomalous Hall effect, Berry curvature, DFT

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P1-co.112

Unidirectional spin Hall magnetoresistance현상에서 마그논 기여에 관한 연구

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Abstract:

Unidirectional spin Hall magnetoresistance(USMR)는 최근 새로 발견된 자기저항으로 강자성체와 비자성체인 중금속의 이중층 구조에서 스핀 홀 효과(Spin Hall effect)로 형성된 스핀전류에 의해 발생한다. USMR은 가해진 전류와 외부 자기장의 방향에 따라 비대칭성을 가지기 때문에 시스템에서 스핀전류의 스핀신호와 전하-스핀 변환정도를 쉽게 정량화 할 수 있어 스핀전류 생성의 정량적 분석에 이용될 수 있다. 그러나 USMR이 스핀전류에 의해 발생한다는 것은 잘 알려져 있지만, 여전히 그 메커니즘에 관해서는 연구의 여지가 남아있다. CO Avci는 처음 USMR을 보고하면서 스핀 축적에 관한 매커니즘을 통해 이 현상을 설명했다.[1] 그러나 후속된 연구에 따르면 전자-마그논 산란 또한 중요한 매커니즘으로 고려되어야 한다고 보고되고 있다. [2,3]
GMR에서 사용된 two current model에서 착안하여[4], 해당모델의 접근을 USMR에 적용시켜본 결과 전자-마그논 산란 또한 고려한 분석모델을 유도할 수 있었다. 분석모델에서 마그논 기여는 자성층의 두께와 자성층 내의 active layer의 두께가 연관되어 있음을 알 수 있다. 따라서 본 연구에서는 중금속(Pt or Ta)/Co이중층 구조에서 자성층인 Co의 두께에 따른 USMR을 다양한 온도에서 측정하였다. 그리고 측정한 USMR의 두께 및 온도 의존성 실험 결과에 two current model모델을 이용하여 분석함으로써 USMR에서 마그논 기여를 살펴보았다.

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Keywords:

Unidirectional spin Hall magetoresistance, electron-magnon scattering, two current model, spin accumulation

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P1-co.113

Temperature-dependent ARPES Study of CeRhAs

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Abstract:

In a recent theoretical study, it has been reported that Kondo materials (CeNiSn, CeRhSb, and CeIrSb), having non-symmorphic glide and screw-axis symmetries, can become Möbius Kondo Insulators (MKI's) with Möbius-twisted topological surface states (TSS's) [1]. However, the features of MKI for CeNiSn and CeRhSb have not been experimentally confirmed so far. Another recent theoretical study predicted that hourglass-type bulk bands crossings exist around the k=S point in CeNiSn and CeRhX (X=As, Sb) [2]. CeRhAs has the same crystal structure as CeRhSb and CeNiSn, but has a large energy gap [3]. So CeRhAs might be a more appropriate system for exploring Möbius-twisted TSS's. In order to understand the topological Kondo insulators, it is very important to investigate the temperature (T)-dependent behavior of the electronic states near the Fermi level. We have performed T-dependent angle-resolved photoemission spectroscopy (ARPES) studies for CeRhAs. We measured the Fermi surfaces and band structures for three orthogonal planes of (100), (010) and (001). T-dependent ARPES measurements reveal that the coherent Ce 4f states persist to remain above 200 K, which agrees with the high Kondo temperature of CeRhAs.

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Keywords:

Topological Insulator, Möbius Kondo insulator, ARPES

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P1-co.114

Successive magnetic transitions in the trimer-based triangular lattice $Ba_4NbMn_3O_{12}$

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Abstract:

We present comprehensive studies of the trimer-based triangular lattice $Ba_4NbMn_3O_{12}$, using muon spin relaxation rotation (μSR) and neutron scattering techniques. The μSR experiments reveal the multistage magnetic transitions at T_C=42K, T*=21K, and T**=10K, consistent with the anomaly indicated by the first derivative of magnetic susceptibility. However, the neutron powder diffraction results show the development of magnetic Bragg peaks along k=[0.5 0.5 0] below T_C without any evidence for multistage phase transitions. This suggests that the subsequent phase transitions below T_C are related to the onset of intertrimer exchange interactions rather than the local symmetry lowering. The inelastic neutron scattering measurements unveil the coexistence of the discrete higher-energy magnetic cluster excitations and the diffusive lower-energy excitations below T_C. The observed successive magnetic transitions and the dichotomic nature of magnetic excitations will be discussed in terms of complex exchange interaction hierarchy.

Keywords:

Spin trimer, Triangular lattice, Muon spin relaxation, Neutron powder diffraction, Inelastic neutron scattering

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P1-co.115

Giant and highly anisotropic magnetocaloric effects in single crystals of disordered-perovskite $RCr_{0.5}Fe_{0.5}O_3$ (R= Gd, Er)

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Abstract:

We have synthesized disordered-perovskite $RCr_{0.5}Fe_{0.5}O_3$ (R=Gd, Er) single crystals and investigated the influences of magnetic anisotropy and additional ordering of rare-earth moments on the cryogenic magnetocaloric properties. Both $GdCr_{0.5}Fe_{0.5}O_3$ (GCFO) and $ErCr_{0.5}Fe_{0.5}O_3$ (ECFO) crystallize in an orthorhombic Pbnm structure with randomly distributed Cr^{3+} and Fe^{3+} ions. In GCFO, the long-range order of Gd^{3+} moments emerges at T_{Gd} = 11 K. The relatively isotropic nature of large Gd^{3+} moment originating from zero orbital angular momentum exhibits giant and almost isotropic magnetocaloric effect with a maximum magnetic entropy change as $\Delta S_M \approx 50.0$ J/kg·K. On the contrary, in ECFO, the Er^{3+} moments tend to align along the c-axis below T_{Er} = 12 K. The highly anisotropic magnetizations lead to a giant rotating magnetocaloric effect demonstrated by a rotating magnetic entropy change ΔS_R = 21.8 J/kg·K. Due to the disordered characteristic of Cr^{3+} and Fe^{3+} ions in these compounds, the magnetocaloric properties appear to be determined principally by the magnetic anisotropy of rare-earth magnetic moments. Our results enrich fundamental and applied research on magnetic materials in view of the distinct magnetic aspects of disordered perovskites.

Keywords:

magnetocaloric effect, single crystal, magnetism, rare-earth, disordered-perovskite

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P1-co.116

Anisotropic and nonlinear magnetodielectric effects in orthoferrite $ErFeO_3$ single crystals

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Abstract:

In rare-earth orthoferrites, strongly correlated order parameters have been thoroughly investigated, which aims to find multiple functionalities such as multiferroic or magnetoelectric properties. We have discovered highly anisotropic and nonlinear magnetodielectric effects from detailed measurements of magnetoelectric properties in single-crystalline orthoferrite, $ErFeO_3$. Isothermal dielectric constant varies in shapes and signs depending on the relative orientations between the external electric and magnetic fields, which may be ascribed to the spin-phonon couplings. In addition, a dielectric constant with both electric and magnetic fields along the c axis exhibits two symmetric sharp anomalies, which are closely relevant to the spin-flop transition, below the ordering temperature of Er^{3+} spins, T_{Er} = 3.4 K. We speculate that the magnetostriction from the exchange couplings between Er^{3+} and Fe^{3+} magnetic moments would be responsible for this relationship between electric and magnetic properties. Our results present significant characteristics of the orthoferrite compounds and offer a crucial guide for exploring suitable materials for magnetoelectric functional applications.

Keywords:

Magnetodielectric, Orthoferrite

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P1-co.117

Oxygen Vacancy Engineering for Highly Tunable Ferromagnetic Properties: A Case of $SrRuO_3$ Ultrathin Film with a $SrTiO_3$ Capping Layer

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Abstract:

Oxide heterostructures have great potential for spintronics applications due to their well-defined heterointerfaces and vast functionalities. To integrate such compelling features into practical spintronics devices, effective control of the magnetic switching behavior is key. Here, continuous control of the magnetic coercive field in $SrTiO_3$/$SrRuO_3$ ultrathin heterostructures is achieved by oxygen vacancy (V_O) engineering. Pulsed laser deposition of an oxygen-deficient $SrTiO_3$ capping layer can trigger V_O migration into the $SrRuO_3$ layer while avoiding the formation of Ru vacancies. Moreover, by varying the thickness and growth conditions of the $SrTiO_3$ capping layer, the value of the coercive field (H_C) in the ferromagnetic $SrRuO_3$ layer can be continuously tuned. The maximum enhancement of H_C at 5 K is 3.2 T. Such a wide-range tunability of H_C may originate from a V_O-induced enhancement of perpendicular magnetic anisotropy and domain wall pinning. This study offers effective approaches for controlling physical properties of oxide heterostructures via V_O engineering, which may facilitate the development of oxide-based functional devices.

Keywords:

oxygen vacancies, oxide heterostructures, SrRuO3 thin films, coercive field, perpendicular magnetic anisotropy

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P1-co.118

Coupling magnon modes with microwave-cavity modes at low temperature below 20 mK

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Abstract:

Ferromagnetic materials are widely used in microwave technologies. As microwave techniques are accelerating the progress in quantum information sciences, ferromagnetic spin systems are being introduced and utilized in quantum techniques.
Ferromagnetic insulator yttrium iron garnet(YIG) is known to exhibit robust spin-wave properties. When the wavelength of a magnon mode is equivalent to the sample size, the contribution from the short-range interaction becomes negligible and the system is dominated by the Zeeman interaction. Then, static spin-wave modes are formed over the entire sample and their resonance frequencies linearly depend on the external magnetic field. We have measured the magnetostatic mode of a YIG sphere in a microwave cavity at a low temperature. The magnon mode can be tuned to match with the microwave cavity mode by adjusting the external field intensity. When the two resonance frequencies coincide, the system forms two hybrid modes indistinguishable from each other. At temperature below 20 mK, thermal noise is suppressed, and the hybrid modes can be measured in their low energy states with the mean photon number of unity.
The ferromagnetic material in a microwave cavity provides an opportunity to study quantum electrodynamics together with spin dynamics. The magnetostatic mode coupled to more than one electromagnetic mode can be applied to the frequency conversion of quantum signals. We will study the possibility of quantum conversion using the YIG-cavity system at low temperatures.

Keywords:

Magnon, Microwave

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P1-co.119

Torque magnetometry using circuit change of membrane-type surface stress sensor

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Abstract:

We present a new method for torque measurement by using a membrane type surface stress sensor (MSS). This sensor has a silicon membrane supported by four beams with integrated piezoresistive paths. we modified the on chip aluminum interconnect on the MSS to obtain more magnetic information and used it for torque measurments.
We verified the angle dependent magnetic torque measurement of magnetic material by rotating the device with a respect to the applied magnetic field. Instead of the existing one wheatstone bridge, on-chip aluminum interconnects have been modified to have two wheatstone bridges. Using this experimental setup, it was possible to simultaneously investigate magnetic responses along different crystallographic directions in a two- dimensional plane.

Keywords:

Torque magnetometery

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P1-co.203

Electronic structures and magnetic properties of ruthenate thin films

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Abstract:

Transition metal oxides with strong hybridization give rise to a variety of functionalities associated with their structural, electrical, magnetic, and chemical properties. Among them, perovskite ruthenates ($ARuO_3$, A = Ca, Sr, and Ba) are rare metallic oxide materials that can be used as a conducting buffer layer or an electrode for electronic device applications. The modification of the A-site element of perovskite ruthenates can result in different magnetic properties, even though they have the same B-site element with the same valence state of Ru^{4+}. In this study, perovskite ruthenate thin films was epitaxially stabilized on $SrTiO_3$ (001) substrate via pulsed laser deposition (PLD). In particular, 3C-$BaRuO_3$ epitaxial thin film was prepared having four-fold symmetry indicating a cubic perovskite structure. We investigate the correlation between electronic structure and magnetic property depending on A-site element in perovskite ruthenates, systematically. It is verified that the electronic structure of the 3C-$BaRuO_3$ is significantly different from that of 9R-$BaRuO_3$ thin film but shows a similarity to its structural analogues ($SrRuO_3$ and $CaRuO_3$), suggesting the importance of the lattice structure determining the electronic structure. The electrical transport properties of 3C-$BaRuO_3$ thin film shows a similar metallic behavior to $CaRuO_3$ thin film with non-Fermi liquid phase. Also, the ferromagnetic transition temperature of 3C-$BaRuO_3$ thin film is ~50 K, lower than that of SRO thin film (~150 K).

Keywords:

ruthenate thin films, perovskite, Electronic structure

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P1-co.204

Observation of Kondo hybridization with an orbital-selective Mott phase in 4d $Ca_{2-x}Sr_xRuO_4$

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Abstract:

The heavy fermion state with Kondo-hybridization (KH), usually manifested in f-electron systems with lanthanide or actinide elements, was recently discovered in several 3d transition metal compounds without f-electrons. However, KH has not yet been observed in 4d/5d transition metal compounds, since more extended 4d/5d orbitals do not usually form flat bands that supply localized electrons appropriate for Kondo pairing. Here, we report a doping- and temperature-dependent angle-resolved photoemission study on 4d $Ca_{2-x}Sr_xRuO_4$, which shows the signature of KH. We observed a spectral weight transfer in the γ-band, reminiscent of an orbital-selective Mott phase (OSMP). The Mott localized γ-band induces the KH with an itinerant β-band, resulting in spectral weight suppression around the Fermi level. Our work is the first to demonstrate the evolution of the OSMP with possible KH among 4d electrons, and thereby expands the material boundary of Kondo physics to 4d multi-orbital systems.

Keywords:

orbital-selective Mott transition, 4d multi orbital system, Kondo hybridization

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P1-co.205

Variety of resistance properties and lattice parameters of $SrIrO_3$ films according to growth conditions

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Abstract:

The temperature dependent resistivity behavior of $SrIrO_3$ films grown on $SrTiO_3$ substrate was found to be “insulator-like”, “intermediate” and “metal-like” depending on the $SrIrO_3$ lattice structure. Herein, we measure the resistivity behavior of the $SrIrO_3$ film that changes with changing the growth condition. $SrIrO_3$ film was grown on the $SrTiO_3$ substrate using the PLD (Pulsed Laser Deposition) method, Samples of a different thicknesses were prepared. With increasing the growth temperature, the resistivity behavior of the $SrIrO_3$ film changed to “insulator-like” property, and with increasing the laser fluence, it also changed to “insulator-like” property. And the lattice parameter was calculated by measuring XRD (X-Ray Deposition). Through this, it was confirmed that the lattice parameter has different values according to the state of the $SrIrO_3$ film.

Keywords:

SrIrO3, growth condition, Pulsed laser deposition, SrTiO3

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P1-co.207

Observation of Kondo lattice behavior in an antiferromagnetic metal FeTe

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Abstract:

In a classical picture, Kondo lattice and antiferromagnetism competes each other, making them barely overlap in the phase diagram since localized moments are screened by itinerant electrons upon forming Kondo singlet. This classical picture assumes the Kondo interaction is on-site. If the Kondo interaction is off-site, itinerant electrons are not able to screen localized moments. As a result, Kondo lattice and magnetism can coexist if the Kondo interaction if off-site. Here, we report the emergence of Kondo lattice behavior in an antiferromagnetic metal, FeTe. We observed Kondo hybridization between localized Fe 3dxy and Te 5pz bands by using angle-resolved photoemission spectroscopy (ARPES) below Néel temperature. Our work shows the first observation of Kondo p-d hybridization, and cooperation of Kondo lattice and antiferromagnetism.

Keywords:

Iron-based superconductors, Kondo lattice

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P1-co.208

Temperature dependent anomalous Hall effect in (Co, Ni)S_2 single crystals

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Abstract:

Pyrite cubic CoS_2 is an itinerant ferromagnet which can be engineered by chemical doping. We have measured magnetoresistance(MR) and anomalous Hall effect(AHE) of pristine CoS_2 and Ni doped CoS_2 single crystals. CoS_2 shows a large positive MR at low temperature, which is suppressed as soon as the Ni doping level increases. We found that the (Co, Ni)S_2 single crystals exhibit negative coefficients of ordinary Hall effect and positive saturation values of anomalous Hall resistivity at low temperature. Both values change the sign on a pristine sample as the temperature increases. Ni-doped samples have almost temperature-independent ordinary Hall coefficients below ferromagnetic transition temperature, T_c, and a maximum saturation value of anomalous Hall resistivity at slightly lower than T_c. At last, we compare the Hall angle and Hall factor of (Co, Ni)S_2 with previously reported data for other AHE materials.

Keywords:

CoS2, AHE

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P1-co.209

Control of Photothermoelectric Effect in Topological Insulator

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Abstract:

Three-dimensional (3D) topological insulators (TIs) exhibit intriguing properties which are derived from the coexistence of the gapless topological surface states (TSS) and the insulating bulk states [1]. It has been revealed that there exists spin-polarized current on the topological insulator with incident light, derived from the spin-momentum locking property of electrons on TSS [2]. However, unwanted thermoelectric current in the bulk states induced by the incident light interferes with generating high spin polarization on TI [3]. In order to solve the problem, we measured the photothermoelectric current by scanning photocurrent microscopy to clarify the thermoelectric mechanism which occurs in the bulk states and control the effect.
In this work, we fabricated a thermoelectric device (Fig. 1(a)) composed of the topological insulator $Bi_{1.1}Sb_{0.9}Te_2S$ (BSTS) with top and bottom gates to induce p-n junction at the interface of p-type and n-type regions in bulk states of the TI. Our measurement system utilized 532nm continuous-wave (CW) laser as the light source of the photocurrent microscopy system, and two x and y translation stages for accurate space resolved measurement.
Figure 1(b) shows the measurement of the photocurrent of the topological insulator BSTS by means of the space resolved photocurrent microscopy system. We confirmed photothermoelectric current and its flip of the sign at the edge of the top gate. It can be described in Mott relation of I_{PT} = (S_2-$S_{1)}$ ΔT where S is thermoelectric power in the gate regions and ΔT laser-induced temperature gradient. In Fig. 1(c), the resistance of the induced current flip area varies with two gate voltages. This result means applying bottom and top gate voltage can control the photothermoelectric effect, reaching the charge neutrality point (CNP).
In conclusion, we have measured the photocurrent of topological insulator BSTS with space resolved method. The generated photocurrent and its mapping make it possible to figure out the photothermoelectric effect in the bulk states. Controlling the effect by gate tuning, the result makes it helpful to investigate the pure spin dynamics on TSS by excluding or controlling thermoelectric current, as well as to figure out the mechanism in the bulk states.

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Keywords:

Topological insulator, Photothermoelectric current, scanning photocurrent microscopy

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P1-co.210

Electronic band structure of Cu3TeO6 via visible-UV Spectroscopy

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Abstract:

Cu3TeO6 is an antiferromagnetic spin-web lattice material. Using visible-UV spectroscopy, we measured optical absorption of Cu3TeO6 and studied the temperature dependence in the 0.5 – 3 eV energy range. Around 2 eV range, there is a striking peak on transmittance and a fluctuation in reflectance. From transmittance and reflectance, we derived spectral functions and studied the band structure of Cu3TeO6.

Keywords:

Antiferromagnet, Cu3TeO6, Spectroscopy, Band structure

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P1-co.211

Growth optimization and characterization of ferroelectric properties in Bi_2WO_6 thin films

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Abstract:

Aurivillius family is known to display excellent ferroelectric properties like high Curie temperature and strong spontaneous polarization. Bi_2WO_6 (BWO) is the simplest member of the Aurivillius family, with each Bi_2O_2 layers are sandwitched WO_6 octahedron layers. It has high Curie temperature and spontaneous polarization (950^{o}C, 50 μC/cm^2) [1]. More interesting property about this material is that its ferroelectric domains are aligned along only the in-plane (IP) direction. This means we can expect there will be no depolarizing field and critical thickness will be decreased or disappear. Also, ferroelctric domains of BWO can be switched with low energy cost than other ferroelectric materials like $PbTiO_3$. This property is effective for realizing electric device with low energy demand [2].
Although BWO has such advantages, a systematic study focusing on the growth condition optimization is missing. Moreover, although BWO is theoretically expected that it's ferroelectricity is coming from W cations displacement, there is no direct experimental proof.
Here, using the pulsed laser deposition (PLD) technique, we have grown epitaxial BWO thin films on (001)-oriented $SrTiO_3$ substrates and $SrRuO_3$ buffer layers. The crystalline quality is confirmed by the X-ray diffraction, atomic force microscopy and transmission electron microscopy. We show the atomic displacemet of W cations in BWO thin film by Scanning Tranmission Eelectron Microscopy technique and ferroelectric property by Piezoresponse Force Microscope technique. We will also present grwoth phase diragram which shows the systematic optimization of BWO films grown under various PLD conditions.

[1] H. Djani, et al., Phys. Rev. B 86, 054107 (2012).
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Keywords:

Bi2WO6, Ferroelectricity, STEM

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P1-co.212

Temperature Dependent Raman Spectroscopic Study of Lead Halide Perovskite $MAPbCl_3$ Single Crystals

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Abstract:

Lead halide perovskites have been an emerging class of materials specially in the field of photovoltaics. Perovskite solar cells have been able to achieve a photovoltaic efficiency of 25.2% [1]. Raman spectroscopy has been widely used for assigning symmetry of vibrational modes of crystals which gives a better understanding of material properties. In this research, we have studied the temperature dependent Raman scattering spectrum of methylammonium lead chloride ($MAPbCl_3$) single crystals from room temperature to -196°C by using a micro-Raman spectrometer at a backscattering geometry. The full width at half maximum (FWHM) and Raman shifts of all vibrational modes have been obtained over a wide frequency range from 10 ~ 3500 cm^{-1} by using a peak fitting software. Nearly all modes show clear and abrupt anomalies in the FWHM and Raman shifts near the phase transition temperatures of -112°C and -106°C. In this work, the change in behavior of vibrational modes upon phase transitions has been reported based on Raman scattering and will be compared to previous reports [2-4].

* This study was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea Government (MSIP, NRF- 2019R1H1A2079858).

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Keywords:

Raman Spectroscopy , Lead Halide Perovskites, MAPbCl3

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P1-co.213

Optical and electrical properties of $La_{1-x}Sr_xVO_3$ films and Schottky diodes of $La_{1-x}Sr_xVO_3$ /$SrVO_3$ (x≤0.15)

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Abstract:

Transparent metal oxides (TMOs) with suitable electrical, optical, and mechanical properties are desired for next generation photovoltaics. High-quality perovskite oxide (ABO_3) thin films have significant potential for electronic devices with multifunctional properties.

p-$La_{1-x}Sr_xVO_3$ films were grown on either TiO_2-buffer-layered Si substrates or LSAT substrates using RF magnetron co-sputtering deposition with a commercial $SrVO_3$ and $LaVO_3$ targets at 500 °C with a mixed gas of H_2 and Ar. We used field emission scanning electron microscopy, X-ray diffraction spectrometry, X-ray photoemission spectroscopy, and spectroscopic ellipsometry to investigate the structural and optical properties. We found that the apparent resistivities of $La_{1-x}Sr_xVO_3$ films grown on LSAT substrates (LSVO_L) were similar to those grown on TiO_2/Si substrates (LSVO_T) for 0.6≥x≥0.338, whereas the resistivities of LSVO_L were much larger than LSVO_T for 0.282≥x≥0.15. We found that LSVO_L were fully strained and LSVO_T were fully relaxed. Metal-insulator (MI) transition appears to occur near x = 0.2 for LSVO_T and near 0.3 for LSVO_L. near 0.3 for LSVO_L. MI transition near x = 0.3 for LSVO_L is corroborated in the dielectric function spectra using Drude tails. MI transition was reported to occur at x = 0.178 for bulk LSVO single crystals [1]. We investigated the Schotty diodes of p-$La_{1-x}Sr_xVO_3$ /n-$SrVO_3$ for x = 0 and 0.1 and determined the ideality factor n.

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Keywords:

p-type La2/3Sr1/3VO3 film, Strong correlation, Schottky diode, Ellipsometry

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P1-co.214

Chemical control of dielectric permittivity in Ni-doped $BaTiO_3$ ceramics

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Abstract:

We chemically controlled dielectric dispersion properties in Ni-doped $BaTiO_3$ ceramics. We identified that a low-frequency dielectric permittivity strongly depended on chemical environments and it was reversibly tunable via a reset process by external stimulus. For the as-sintered state, the initial dielectric constant in the doped $BaTiO_3$ ceramics was low (~ 10^3, named as an off state). After various chemical treatments during a particular time, it changed to an extremely high value (~ 10^6, named as an on state). We also found that the ultrahigh dielectric permittivity in the on state went back to the original value in the off state via thermal annealing. It is highly likely that oxygen vacancy migration driven by chemical adsorption on the sample surface is closely related with the reversible change of dielectric responses. Conceptually, our work is of potential interest for realizing sensing devices of greenhouse gases like CO_2.

Keywords:

Ceramic, Dielectric permittivity, Chemical absorption, Oxygen vacancy

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P1-co.215

Impact of growth temperatures on ferroelectric hysteresis in epitaxial $Bi_{1/2}(Na_{0.82}K_{0.18})_{1/2}TiO_3$ thin films

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Abstract:

We demonstrate an effect of a growth temperature on ferroelectric hysteretic properties in epitaxial $Bi_{1/2}(Na_{0.82}K_{0.18})_{1/2}TiO_3$ thin films grown by pulsed laser deposition. We identified that the polarization-electric field hysteresis loops varied depending on the film deposition temperature. In a film grown at a low temperature, the corresponding hysteresis loop was single with a monodomain state (i.e., c domain), as previously reported in the conventional ferroelectric materials. On the contrary, for a film deposited at a high temperature, a double hysteresis characteristic was observed with the mixed state of c and a domain. In the as-grown film with the multi domain state, we also found screw dislocations on the film surface, which can act as a pinning center in polarization switching leading to the pinched hysteresis loop. The temperature-dependent formation of vacancy defects and thereby, a difference in the resulting misfit strain would induce this discrepancy in the ferroelectric hysteresis and domain configurations. Conceptually, our work is of potential interest for realizing electrostrictive and energy-storage devices with high performance.

Keywords:

ferroelectric, hysteresis, pulsed laser deposition, thin film

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P1-co.301

Superconducting proximity effect and Aharonov-Bohm oscillations in Josephson junctions made of topological insulator nanoribbons.

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Abstract:

Realization of one-dimensional (1D) topological superconductor hosting Majorana bound state (MBS) is still a challenging project for developing topological quantum information devices. Topological insulator nanoribbon (TI NR) provides a promising platform to form MBS via the superconducting proximity effect. The number of 1D subbands of the surface state in TI NR can be modulated by the external magnetic flux through the cross section of NR, exhibiting Aharonov-Bohm oscillations. The helical 1D surface mode in TI NR is theoretically expected to occur under the condition of half-integer magnetic flux quantum, h/2e. Since the small cross-sectional area of TI NR requires large magnetic field to meet the half flux quantum criteria, the induced superconductivity in TI NR needs to be durable under the application of such high magnetic field. Here we report the fabrication and quantum electrical transport properties of Josephson junctions based on Sb-doped Bi_2Se_3 TI NR contacted with Nb superconducting electrodes. Our experimental observations would be useful to explore topological superconductivity and MBS in TI NR.

Keywords:

Topological insulator nanoribbon, Josephson junction, Aharonov-Bohm oscillations, Majorana bound state

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P1-co.303

Ab initio study of electric field effect on p-n junctions based on 2D van der Waals heterostructures

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Abstract:

The p-n junction has become an essential component in modern electronics and optoelectronics. It is created by contacting two different types of doped semiconductors, which makes the depletion of free charge carriers at the interface of the junction. In conventional p-n junctions, three-dimensional semiconductor materials have been used for making p-n junctions, so there have been some limitations in reducing the size of a p-n junction. Nowadays, many scientists have paid attention to two-dimensional van der Waals (2D vdW) p-n junctions because they are only one unit cell thick and have the superior efficiency of electron-hole separation. In this study, we investigate the electronic structure of p-n junctions with 2D vdW heterostructures using density functional theory calculations. Especially, we focus on the change in the electronic structure at the interfaces of doped 2D semiconductors when electric fields are applied. Details in electronic structure are analyzed in terms of orbital projected band structure and partial charge density.

Keywords:

p-n junction, van der Waals heterostructures, density functional theory, two-dimensional, electronic structure

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P1-co.304

Theoretical study of adsorption of acetonitrile molecules on Si(111)-(7x7)

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Abstract:

We have investigated the adsorption of acetonitrile molecules on Si(111)-(7x7) using density functional theory calculations. In order to understand the multimolecular adsorption, we consider possible site-by-site and step-by-step adsorption mechanisms. From theoretical simulations, we find energetically most stable structures, which are compared with experimental observations obtained by the scanning tunneling microscopy (STM) measurement. For most stable structures, we determine chemical or physical bonding structures between acetonitrile molecules and topmost Si atoms of the substrate. Details are analyzed in terms of partial density of states and charge density difference.

Keywords:

Silicon, Si(111)-(7x7), Acetonitrile, STM, Density of state

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P1-co.306

Revivable vertical graphene resistive strain sensor for in vivo biocompatible application

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Abstract:

Stretchable resistive strain sensor (RSS) with ultrasensitivity has been investigated for widespread applications. However, due to physical/mechanical limits, the development of mechanosensors satisfying the prerequisite of stability and durability remains a challenge. Also, in-depth toxicology in in vivo system is imperative because of in direct contact with skin, even applied to organs, yet has not been reported for RSS. Here, we demonstrate that vertical graphene (VG) RSS can serve in vivo biocompatible sensor, and show remarkable sensitivity (gauge factor of 5,000) with revivable status even after broken current path. Three-dimensional tufted VG network structure allowed charge transport depending on crack geometry. We further showed that the signals from rat heartbeat depend on the direction of VG sensor directly attached to the heart, enabling to distinguish the cardiac contractility through its ventricle and atrium. Our finding provides new insight for controllable and permanent mechanosensing system, making VG promising option for long-term in vivo biocompatible platform.

Keywords:

Vertical graphene, strain sensor, in vivo test, biocompatibility, timbre recognition

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P1-co.307

The Morphological Characterization Study of Proton Exchange Membrane through Local Charge Density Measurement by EFM

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Abstract:

The proton exchange membranes are a crucial component of proton exchange membrane fuel cell because is work such as a gas separator, electrode insulator, and proton passage. Thus, understanding of the morphology of the proton exchange membranes, which is connected with its work, is important to improve proton exchange membrane fuel cell's performance. However, the characterization of its morphology is extremely difficult because of its nanoscopic heterogeneous structure and morphological change in environment. In this work, the morphological understanding of proton exchange membrane through numerical approach of the local charge density and dielectric constant is studied by using electrostatic microscopy, which maps the surface charge distribution of the sample by measuring the electrostatic force between a tip and the sample surface. The study is done by a several steps. First, the electrostatic force variation model between a tip and proton exchange membrane surface is derived by assuming nano sized parallel capacitor such as a tip/membrane/sample holder. Second, dry and wet proton exchange membranes are prepared and each membrane is measured under different bios voltage. Third, the surface morphology of each membrane is analyzed by the electrostatic force variation model. From the study, a few remarkable facts are discovered. The local surface charge density, which is directly connected with ionic domain is calculated by applying the electrostatic force variation model. Also, the local dielectric constant which is related to morphological variation is calculated by applying the electrostatic force variation model.

Keywords:

Proton Exchange Membrane , Electrostatic Force Microscopy , Local Charge Density, Local Dielectric Constant

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P1-co.308

Effect of the sample work function on alkali metal dosing induced electronic structure change

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Abstract:

Alkali metal dosing (AMD) has been widely used as as a way to dope electrons to the sample without disorder. This technique, in combination with angle resolved photoemission spectroscopy (ARPES), often provides an opportunity to observe unexpected phenomena. However, how much charge it transfers varies significantly depending on which system one studies. Here, we report systematic study on the correlation between the sample work function and alkali metal induced electronic structure change for three iron-based superconductors: FeSe, $Ba(Fe_{1.94}Co_{0.06})_2As_2$ and NaFeAs. Electronic structure change upon AMD and the sample work function were measured using high resolution ARPES. Our results show that the degree of electronic structure change is proportional to the difference between the work function of the sample and the electronegativity of the deposited alkali metal. This finding provides a possible way to estimate the AMD induced electronic structure change.

Keywords:

Alkali metal dosing, Angle resolved photoemission spectroscopy, Work function

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P1-co.309

Bimodal switching current distribution and fractional Josephson effect in topological Josephson junctions

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Abstract:

Topological insulators (TIs) contain a spin helical topological surface state (TSS), exhibiting spin-polarized current or Aharonov-Bohm oscillations. Contacted with superconducting electrodes, TIs provide a useful platform to host Majorana bound state (MBS), which would be essential for fault-tolerant quantum computation technology. Here, we report experimental observations of bimodal switching current distribution below T = 0.3 K in topological Josephson junctions made of Sb-doped Bi_2Se_3 micro-flakes and PbIn superconducting electrodes. The co-existence of 2π- and 4π-periodic (current-phase relation) CPRs splits the distribution as a consequence of MBSs formed in the junction. At higher temperatures, the two stochastic distributions merge into one and is fitted well with thermal activation and phase diffusion models, depending on temperatures. Irradiated with microwaves, unconventional Shapiro steps with missing the first one are observed at T = 7 mK, which is attributed to the 4π-periodic CPR. The first-step-missing behavior is enhanced with increasing temperatures up to T = 300 mK due to the mixing of 2π- and 4π-periodic CPRs. Our observations indicate the coexistence of topological and trivial supercurrent in TIs contacted with superconducting electrodes.

Keywords:

topological Josephson junction, Majorana bound state, switching current distribution, Shapiro step, current-phase relation

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Semiclassical Broadening in Quantum Dot Thermometry

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Abstract:

전자의 양자역학적 거동에 관한 연구에서는 열적요동을 최소화하기 위한 저온 실험 환경이 중요하다. 이러한 극저온을 구현하기 위해서 주로 희석식 냉동기를 사용하지만 대부분의 경우 시료내부에서 실제로 전기적 수송에 관여하는 전자 온도는 냉각장치 보다 높은 온도를 가지게 된다. 본 연구는 전자온도를 효과적으로 낮추는 방법 이전에, 근본적으로 정확한 전자온도 측정에 초점을 맞추고 있다. 2차원 전자계에서 구현된 양자점을 이용한 전도도 측정은 전자온도 측정에 유용하게 사용되는 방법이다. 양자점은 Source, Drain과 터널링 결합으로 이루어진 소자이고, 터널링 결합의 정도에 따라 전자온도의 측정 감도가 결정되게 된다. 또한, 외부 노이즈에 따라서 측정의 불확도가 크게 영향을 받을 수 있다. 본 연구에서는 Source, Drain과의 결합 정도에 따른 양자점 기반의 온도 측정 방식을 분석하고, 1.5% 이내의 에러를 가지는 근사함수를 제안하였다. 이 함수를 이용하면 손쉽게 전자온도를 분석할 수 있다. 또한 외부의 노이즈가 전자온도 측정에 미치는 영향을 분석하고, 단계별 주파수 filter를 효과적으로 사용하는 셋업에 대해 고찰하였다. 이는 전자소자를 연구하는 대부분의 극저온 시스템에 광범위하게 적용될 수 있을 것이다.

Keywords:

Quantum Dot, Electron Temperature

P1-co.401

Magnetism of Heusler Compound $Mn_{3-x}Co_xGa$ (0≤ x ≤1) in Cubic and Tetragonal Phases

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Abstract:

Mn-based Heusler compounds are prominent materials for spin transfer torque applications because of various properties such as low magnetic moment, high Curie temperature, and high spin polarization [1]. In Mn-based Heusler compounds, two inequivalent Mn sites couple ferrimagnetically, offering ability to tune there total magnetic moment with suitable substitutions [2,3]. In this study, a detailed investigation of magnetism of $Mn_{3-x}Co_xGa$ (0≤ x ≤1) in cubic and tetragonal phases are presented using first-principles calculations. Interestingly, Co magnetism possesses different behaviors in two different phases. In tetragonal (cubic) phase, Co magnetic moment is almost zero (about 1 μ_B), whereas Mn magnetic moment changes not much. In tetragonal phase, total magnetic moment reduces, while in cubic phase it enhances with x. Magnetic exchange coefficient (J_{ij}) in Heisenberg model is used to clarify the puzzling Co magnetism. In tetragonal phase, vanishing Co magnetic moment can be explained by weak Co-Mn(I) J_{ij}, which is five times less than cubic one.

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Keywords:

Heusler compound; magnetic exchange coefficient; first-principles calculations

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P1-co.402

First-principles study of two-dimensional Gd_2C electride

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Abstract:

Electrides are ionic crystals in which electrons act as anions. Recently, two-dimensional (2d) electrides with weak interlayer bonding strength have been synthesized, and their surface properties have been studied. We investigate the electronic properties of few-layer Gd_2C that is one of the 2d electrides. We focus on anionic electrons at the interstitial space. In this study, we employ the Vienna Ab Initio Simulation Package (VASP). The wave functions were expanded using a plane-wave basis set. We also do the scanning tunneling microscopy simulation. We also calculate the work functions of the few-layer Gd_2C structures to investigate the layer dependence. The monolayer and the pentalayer have the work functions of 3.426 and 3.350 eV, respectively. Interestingly, the Gd_2C has a lower work function than Y_2C. This tendency of the work function seems to be related to the localization of the electrons in the interstitial space between layers. In other words, the anionic electron density in the interstitial space of Gd_2C is more delocalized than the case of Y_2C. We conjecture that a more delocalized anionic electron density in the interstitial space can result in a smaller work function. Finally, we study the response of Gd_2C to the applied uniform electric field.

Keywords:

DFT, Electride, 2D materials, Layer dependence

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P1-co.403

Variations in Electronic Properties due to Defects in Monolayer GeS

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Abstract:

Two dimensional (2D) materials have recently attracted great attention in the fields of electronic devices due to their unique electrical and optical properties. Among 2D materials, graphene, black phosphorus (BP), and transition metal dichalcogenides (TMDs) have been actively studied in various ways. Along with such attention, germanium sulfide (GeS) has also received attention as it has a similar structure to BP. Furthermore, it is worthwhile to note that defects in 2D materials play a fundamental role in variation of their material properties because they can be donor or acceptor.
In this study, the effects of vacancies and substitutional atoms in monolayer GeS are investigated using density function theory calculations. We choose group IV or chalcogen atoms as substitutional ones which substitute for Ge or S in GeS. It is found that the band gap of GeS with substitutional atoms is close to that of pristine GeS, while the band gap of GeS with Ge or S vacancies is smaller than that of pristine GeS. In terms of formation energy, monolayer GeS with Ge vacancies is more stable than that with S vacancies. Details are analyzed using the orbital projected band structure, partial density of states, and charge density difference.

Keywords:

first principles, vacancy, DFT, GeS, substutitutional atom

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P1-co.404

Emergence of anomalous Hall effect from a compensated collinear ferrimagnetism

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Abstract:

It has long been believed that the anomalous Hall effects can only be observed in ferromagnetic materials. It is clear, however, that any magnetic material can exhibit the anomalous Hall effects because the time-reversal symmetry is absent in those systems. In this work, we investigate the compensated collinear ferrimagnetic material Mn_3Al with the magnetization along z axis. We found that the Hall conductivity σ_{xy} only survives under the constraint of the magnetic symmetry and the explicit first-principles calculations reveal that σ_{xy} has a quite large value about $300\,(\Omega\,\mathrm{cm})^{-1}$.

Keywords:

Mn3Al, Anomalous Hall effect, Magnetic symmetry, Magnetic space group

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P1-co.405

Very Strong Lithium-Polysulfide Anchoring Effect of Amorphous Carbon for Lithium-Sulfur Batteries

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Abstract:

Solving the shuttle effect caused by the dissolution of lithium polysulfides (LPSs) into the electrolyte is very important for practical application of lithium-sulfur (Li-S) batteries. The chemical anchoring of LPSs to conductive carbon combined with the sulfur cathode is one of the main methods to suppress the shuttle effect. The present first-principles study is the first to report that amorphous carbon offers the best ability to anchor the LPSs among the carbon materials reported so far. The calculated adsorption energies of LPSs (6.38-8.75 eV) on the amorphous carbon surface are higher by at least six times than those on graphene and also higher by at least two times than those on pyridinic-N doped graphene, which is one of the most efficient anchoring materials. The adsorbed LPSs on the amorphous carbon surface undergo significant molecular distortion and/or partial dissociation due to the S-to-C electron transfer of 1.2-1.8 e per molecule and the formation of strong bonds of both the Li and S atoms with reactive sp- and sp^2-site C atoms. We propose as an anchoring material for Li-S batteries the graphite-amorphous carbon hybrid structure, where the graphite core can act as an electron channel, and the amorphous carbon shell can strongly capture the LPSs.

Keywords:

Lithium_Sulfur Batteries, Amorphous Carbon, Lithium_polysulfide, Density Funtional Thoery

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P1-co.406

First Principle Study of the groove smoothing mechanism on a Cu(111) surface

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Abstract:

Growing high-quality graphene over a large area is greatly demanded not only for fundamental research but also for practical applications. It has been known that such high-quality graphene can be grown on a single domain of Cu (111) surface, whose domain size determines the size of graphene. It is, therefore, important to prepare a single domain and a large area of Cu (111) surface, for which one should remove grain boundaries to combine small domains. Our experimental colleagues found a way to expand the domain size by removing grain boundaries or surface grooves by the cyclic heat treatment (CHT). To understand the fundamental mechanism of removing grain boundaries by CHT, we combined the density functional theory with a Monte Carlo method. Firstly, we explore the hopping behavior of an extra Cu atom on a perfect Cu (111) surface by evaluating its diffusion behaviors based on the binding energies of the extra Cu atom on different adsorption sites. Its diffusion barrier was evaluated to be 76 meV. Secondly, we investigated the escaping process of an edge Cu atom attached to a grain boundary or a surface groove. It has to overcome our estimated barrier of 0.96 eV to escape on to the surface. Using these values of diffusion and escaping barriers, we performed Monte Carlo simulations using the hopping and escaping probabilities obtained from the Boltzman distribution at a given temperature. We consequently evaluated certain conditions of the surface density of freely-moving surface Cu atoms and the linear density of dangling Cu atoms at the grain boundaries explaining the experimental observation by the CHT.

Keywords:

DFT, Cu(111) surface, CHT, Monte Carlo method

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P1-co.407

Hydrogen evolution reaction of AgTe

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Abstract:

We study hydrogen evolution reaction (HER) of AgTe using density functional theory calculations. Using the Vienna Ab initio Simulation Package, we calculate the model systems with a plane wave basis set. For the exchange correlation term of the Hamiltonian, we used generalized gradient approximation. The convergence threshold on forces was 10^{-3} eV/Å, and the energy tolerance was set to 10^{-6} eV. To understand the HER performances of AgTe, we investigated the electronic structures and the Gibbs free energy difference (ΔG_H) of hydrogen adsorption on a 2 nm-thick AgTe (001) slab. Our computational results show that the AgTe slab is metallic while bulk has a small bandgap of ~ 0.35 eV. We consider six different binding sites for a hydrogen atom. ΔG_H varies from -0.005 eV to 0.33 eV for our six configurations. Since the value close to zero implies high performance of HER, we conclude that the AgTe surface possesses highly active catalytic sites for HER. Besides, we find that the atomic geometries at the surface affect orbital hybridization, which leads to the differences in ΔG_H.

Keywords:

AgTe, Hydrogen evolution reaction

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P1-co.501

Double-well potential of hydrogen bonds revealed by NMR

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Abstract:

We investigate the microscopic structure of hydrogen double-well potentials in a hydrogen-bonded ferroelectric system exposed to radioactive particles of hydrogen-ion beams. The hydrogen-bonded system is ubiquitous, forming the base of organic-inorganic materials and the double-helix structure of DNA inside biological materials. In order to determine the difference of microscopic environments, an atomic-scale level analysis of solid-state ^{1}H high-resolution nuclear magnetic resonance (NMR) spectra was performed. The hydrogen environments of inorganic systems represent the Morse potentials and wave function of the eigen state and eigen-state energy derived from the Schrödinger equation. The wave functions for the real space of the localized hydrogen derived from the approximated solutions in view of the atomic scale by using quantum mechanics are manifested by a difference in the chargedensity distribution.

Keywords:

Hydrogen-bonded ferroelectrics, Nuclear Magnetic Resonance (NMR), Magic angle spinning (MAS), Schrodinger’s equation, First-principle density functional theory (DFT)

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P1-co.503

Design of frequency conversion device using ‘membrane-in-the-middle’ cavity optomechanics

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Abstract:

It is hard to mediate quantum information between two different frequency bands of electromagnetic (EM) waves. For example, radio frequency (RF) EM waves in GHz band and infrared (IR) optical photons in THz band, in general, do not directly interact with each other. Here, we use ‘membrane-in-the-middle’ cavity optomechanics devices to mediate interaction between RF and IR photons. It consists of a thin membrane-type high Q mechanical oscillator that is located inside a high finesse Fabry-Perot optical cavity. The mechanical motion of the membrane can be coupled to not only optical cavity photons via radiation pressure force, but also superconducting RF circuits via capacitive coupling. Since the same mechanical motion can coherently interact with the two different frequencies of photons, in principle, this device can mediate information even in quantum level. In this poster, we show our design and initial test of the device in the optical domain. Detail characterization of the Fabry-Perot cavity and mechanical oscillator will be discussed. Afterward, we will discuss our future plan of combining this setup with the superconducting circuit which has been separately developed by our collaborators in Korea Research Institute of Standards and Science.

Keywords:

Optomechanics, Frequency conversion, Optical cavity, Membrane

P1-co.504

각분해 광전자 분광학을 이용한 PdSb2 전자구조 연구

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Abstract:

각분해 광전자 분광학(Angle-Resolved Photoemission Spectroscopy; ARPES)은 직접적으로 전자 구조를 관측할 수 있는 실험 방법 중 하나이다. 이를 이용하여 응집물질물리 분야에서 주목받고 있는 위상 물질 중 디락/바일 준금속을 넘어서 multifold fermion이 존재하는 것으로 예측된 PdSb2의 전자 구조를 확인하는 것은 매우 중요하다. 디락/바일 준금속은 페르미 에너지 근처에서 전도띠와 원자가띠가 만나는 점(디락점)이 존재하는데 예측된 PdSb2의 전자 구조는 역격자 공간의 R 점 근방, 페르미 에너지 근처에서 6중 축퇴를 형성하고 있고 이를 각분해 광전자 분광학을 이용하여 실험적으로 직접 확인하였다.

Keywords:

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P1-nu.001

Detailed study of string shoving model in PYTHIA8

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Abstract:

In the collisions of heavy nuclei at relativistic energies, a hot and dense matter called Quark-Gluon Plasma (QGP) is created. Intriguingly, collective motion of the generated particles, which is thought to be a strong evidence of the formation of QGP, is also seen in small systems like pp collisions. The string shoving model implemented in PYTHIA8 Monte Carlo event generator can reproduce the long-range two-particle correlation shown in the pp data at the LHC. In order to have a quantitative study, we compare associated yield and elliptic flow between the experimental data and the model, and it shows a large disagreement. This difference results from the modification of jet shape in the shoving model which is not expected in the experimental data. An additional analysis to take into account the jet shape modification has been performed. In this poster, the detailed study of two-particle correlation in pp collisions with the string shoving model will be presented.

Keywords:

PYTHIA8, string shoving, particle correlation

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P1-nu.002

Development of the prototype of Active Target Time Projection Chamber

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Abstract:

The active-target time projection chamber (AT-TPC) is a novel detector designed to study nuclear reactions at a low-intensity target experiment. The principal difference from an ordinary TPC in collider experiments, such as STAR or ALICE, is that the drift gas is used for the target as well. For this reason, the active volume can be extended to the entire space of the chamber including the collisional vertex. We propose to use a new cylindrical AT-TPC for low-energy experiments at RAON, the Rare Isotope Accelerator which will be built in Daejeon, South Korea. We plane to exploit the AT-TPC as the main component to measure the scattering of alpha particles and heavy ions, in particular, associated with the formation of alpha-cluster resonance. In this poster, we present the progress of R&D for an AT-TPC prototype. The assembly of hardware, construction of a data acquisition system, and the test using cosmic muon are eported in detail.

Keywords:

attpc, tpc, lamps, raon

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P1-nu.003

Status report of a prototype BDC for the LAMPS system at the RAON

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Abstract:

The Large Acceptance Multi-Purpose Spectrometer (LAMPS) is a detector system to study rare isotope collisions and the nuclear symmetry energy at supra-saturation densities at the RAON accelerator facility. To detect the nuclides of isotopes and their trajectories, Beam Drift Chamber (BDC) will be installed in the front of the LAMPS. We will report the current status of BDC in this presentation.

Keywords:

Beam drift chamber, RAON, LAMPS, Isotope collision, Nuclear symmetry

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P1-nu.004

The Data aquastion development of LAMPS starting counter

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Abstract:

Starting counter 란 입자 출동 실험을 진행 할 때 입사 입자의 기준 시간을 정해주는 검출기이다. 두 입자 간의 충돌 이후 여러 방향으로 산란되는 파편 입자는 시간 투영 챔버(TPC)나 중성자 검출기 같이 다른 검출기들을 통하여 입자를 식별 할 수 있다. 이러한 입자 식별 과정에서 필수적인 정보가 바로 기준 시간이다. 현재 LAMPS 에서는 중이온 입자 빔(Beam)을 통하여 충돌 실험을 진행 할 예정이다. 입자 빔 내의 각각의 개별 입자의 기준 시간을 파악하기 위해서는 좋은 시간 분해능(Timing resolution)을 갖는 Starting counter를 만드는 것이 중요하다.

본 연구에서는 EJ-230 scintillator로부터 온 데이터를 NIM 모듈과 VME 모듈을 통해 분석을 진행하였다. VME 모듈중 TDC, QDC와 FADC를 사용해 들어온 신호의 total charge, time difference, pulse shape의 정보를 얻을 수 있었다. 각 정보들의 correlation 분석을 통하여 Starting counter의 timing resolution을 얻을 수 있다.

Keywords:

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P1-nu.005

Comparison of radio-photoluminescence with silver doped phosphate glass with different composition

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Abstract:

Silver-doped phosphate glass has been used as a promising solid-state radio-photoluminescence (RPL) dosimeter. RPL has a promising property such as RPL intensity linearity for irradiation dose and repeatability of measurement. In this study, we synthesize silver-doped phosphate glass with different composition (NaCl, Na_2CO_3, NaBr) at laboratory for performance optimization and compare their RPL properties with a commercial glass GD-352M. The absorption, emission and excitation were measured before and after x-ray irradiation for optimizing their properties

Keywords:

Dosimeter, Radio-Photoluminescence, X-ray irradiation

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P1-nu.006

Crystal Structure and Luminescence Study of Lithium Scandium Borate ($Li_3Sc(BO_3)_2$) Phosphors

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Abstract:

Borate crystals are potential candidate for thermal neutron scintillation and imaging. Lithium orthoborates containing Gd, Y, Lu etc. have been studied extensively for different purposes of applications. However, introducing scandium (Sc) instead of Y, Gd or lanthanides will reduce the density and effective atomic weight that make the compound more attractive for thermal neutron detection in high gamma radiation background. In present experiment, $Li_3Sc(BO_3)_2$ polycrystalline powder has been synthesized with solid state reaction method. The crystal structure of the prepared powder has been verified with powder XRD measurement and reitveld refinement technique. The compound will be doped with different rare earths and other luminescence providing elements. The radio and photoluminescence as well as decay time will be measured to optimize the doping element and concentration. Czochralski technique will be applied to grow pure and doped single crystals.

Keywords:

Li3Sc(BO3)2 , Phosphor, X-ray Diffraction, X-ray Luminescence

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P1-nu.007

Investigation of ^{22}Mg levels by resonant scattering of ^{18}Ne+α

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Abstract:

An α resonant scattering on ^{18}Ne was measured in inverse kinematics in order to study the energy levels of ^{22}Mg nuclide. ^{18}Ne rare isotope beam was produced at the Center for Nuclear Study radioactive ion beam separator (CRIB) of the University of Tokyo. Recoiling α particles were measured by the silicon detector telescope. The excitation function of ^{22}Mg was obtained for the energy region of E_x = 11 – 16 MeV. R-matrix analysis using SAMMY8 code was performed to investigate the energy level properties of ^{22}Mg. Spins and parities of newly observed levels were constrained for the first time. Details of the preliminary results will be discussed in this presentation.

Keywords:

22Mg levels, resonant scattering, rare isotope beam

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P1-nu.008

Simulation study for quasi-mono energetic neutron source based on p+^{9}Be/C using the GEANT4

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Abstract:

A quasi-mono energetic neutron source based on the ^{9}Be(p,xn) reaction was developed using the GEANT4 program for activation experiment. We present the simulation results of quasi-mono energetic neutron flux of various thickness for Be/C target with 30, 35, and 45 MeV proton energies. Neutron target assembly was designed and optimized to produce a quasi-mono energetic neutron field for 30, 35, and 45 MeV proton beam.

Keywords:

Geant4

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P1-nu.009

Measurement of Gamma-ray Energy Spectrum of ^{176}Re and ^{180}Re isotopes produced from ^{nat}W(p,x) Reaction by 100-MeV Proton Accelerator

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Abstract:

The delayed gamma ray energy spectrum of ^{176}Re and ^{180}Re isotopes were measured from ^{nat}W(p,x) nuclear reaction with the high-intensity 100-MeV proton linac facility (the Korea Multi-Purpose Accelerator Complex, KOMAC). The gamma-rays from the isotopes were measured by gamma-spectroscopy system with HPGe detector. In the current study, we observed that ^{nat}W(p,xn)$^{177, 178, 179}$Re nuclear reactions were generated between the tungsten target and the high energy proton beam.
However, these isotopes of ^{176}Re(5.3 min) and ^{180}Re(2.4 min) have relatively very short half-life compare than other isotopes produced by ^{nat}W(p,x) reaction. In the present study, the 240.2 and 902.8 keV gamma-rays from ^{176}Re and the ^{180}Re were measured successfully. From delayed gamma-ray generated in the produced nucleus, it has been compared the gamma-ray peak intensity to distinguish the decay series. This result is expected to be useful in calculating the half-life and proton spallation cross-section of ^{176}Re and ^{180}Re isotopes in the future.

Acknowledgement
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Keywords:

natW(p,xn), delayed gamma-ray, 100-MeV proton beam, 176Re, 180Re

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P1-nu.012

The Comparison Study of Dose Distribution for 6He and 4He Ion Beams

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Abstract:

In this study, we evaluated the dose distribution of ^{4}He and ^{6}He ion beams under the same irradiation setting by using the Monte Carlo method. For simulation, the water phantom that includes three normal regions and one target region for measuring the dose deposition in various regions is defined. In addition, the ^{6}He and ^{4}He ion beams with specified parameters are defined. Then, the distribution of doses and tracks of ion beams are obtained, and the dose values deposited in each region are calculated. The calculation results shows that the dose of ^{4}He ion beam in the proximal volume, lateral volume, distal volume, and target volume are 82.30%, 17.28%, 66.85%, and 107.50% of the dose of ^{6}He ion beams in each volume. Therefore it can be said that for the aspect of physical dose distribution, the ^{4}He ion beam is more ideal comparing to the ^{6}He ion beam. To more objectively evaluate the therapy effect of ^{4}He and ^{6}He ion beams, the experimental study about the biological effects of ^{4}He and ^{6}He ion beams will be taken in the next study.

Keywords:

Monte Carlo simulation

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P1-nu.013

$Na_2(Mo_{1-x}W_x)_2O_7$ scintillation crystal: Crystal growth, luminescence and scintillation properties

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Abstract:

Disodium dimolybdate $Na_2Mo_2O_7$ has found to be one of the effective cryogenic scintillation detectors for the rare event search experiments, especially for the neutrinoless double beta decay. Mo-based crystals contain ^{100}Mo isotope which is the promising candidate for this task due to its high transition energy, ability to enrich, and high natural abundance in comparison with other candidate isotopes. So far, many molybdate crystal scintillators have been developed and tested for the neutrinoless double beta decay search around the world, especially AMoRE collaboration. Until now, the light cation Mo-based scintillator $Na_2Mo_2O_7$ has been considered and improved. However, the disadvantages of $Na_2Mo_2O_7$ is the low light yield and the appearance of cleavage planes during growth. To eliminate these issues, a small amount of $Na_2W_2O_7$ was mixed with $Na_2Mo_2O_7$ crystal since the intrinsic scintillation crystal $Na_2W_2O_7$ has high light yield, stable chemical-physical properties, and the suitable structure for mixing. Therefore, in this work, the disodium-ditungstate-mixed disodium dimolybdate ($Na_2(Mo_{1-x}W_x)_2O_7$) has been grown and studied. The polycrystalline compound of $Na_2(Mo_{1-x}W_x)_2O_7$ was synthesized by the solid-state reaction and the crystal was grown by using the Czochralski method. The luminescence and scintillation properties at low temperatures have been measured and the results will be presented.

Keywords:

Neutrinoless double beta decay, Czochralski crystal growth, Na2Mo2O7, Na2W2O7, mixed crystal

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P1-nu.014

Calculation of beam quality correction factor for different depths of SOBP using Monte Carlo simulations

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Abstract:

In proton radiotherapy, the k_Q factor is a quantity that compensates for the difference between the reference beam quality used in the correction of the ionization chamber and the beam quality used in patient treatment to calculate the correct dose. The beam quality correction factor currently recommended by the TRS-398 protocol is calculated based on the center of the SOBP (Spread Out Bragg Peak) of the proton beam. The k_Q factor calculated by using such method is applied equally to all depths of the proton beam to calculate the absorbed dose. In this study, we aim to verify the validity of this calculation method by using Monte Carlo simulations. We used TOPAS to perform simulations of the beam nozzle of the National Cancer Center and a proton beam with a 15-cm range and a 15-cm modulation range. We simulated the absorbed dose in water and the measured value of the ionization chamber, and thus calculated the k_Q factor at the reference depth of 7.5 g/cm^2 suggested by TRS-398, but also at 4 g/cm^2 and 13 g/cm^2.

Keywords:

Proton therapy, Monte Carlo simulations, kQ factor

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P1-nu.015

Synthesis and luminescence properties of Ce^{3+} doped $CsBaYB_6O_{12}$ phosphor

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Abstract:

In recent decades, there have been many research interests of borate compounds due to their attractive optical properties and wide practical applications. In particular, the borate compounds, un-doped and doped with rare-earth and transition elements, are very promising materials for nonlinear optics, quantum electronics, scintillations, photolithography and laser technology etc. We have synthesized powder samples of pure and Ce^{3+} doped $CsBaYB_6O_{12}$ polycrystalline compounds using standard solid-state reaction technique. Powder X-ray diffraction (PXRD) analysis, thermoluminescence (TL), X-ray luminescence, photoluminescence (PL) were used to investigate structural and luminescence properties of Ce^{3+} doped borate phosphors. PXRD pattern confirms that the synthesized compounds crystallize in a single phase without any additional impurity peaks, which is in good agreement with previously reported result. The X-ray emission spectra of the pure sample shows the two obvious intrinsic luminescence bands originated from the host compound. Impurity ion Ce^{3+} doping improves the intrinsic luminescence and the optimal concentration of the dopant was studied about 2 mol%. The PL emission spectra of the doped samples found to be produced the same emission bands with two different excitation bands. The peak positions of PL spectra are well match with the X-ray emission bands. TL glow peak was observed with the heating rate of 5 K/s followed by the X-ray irradiation. The study of luminescence and other TL kinetic parameters such as activation energy (E), frequency factor (s) will be calculated and discussed in more detail

Keywords:

Borate;Phosphor; Solid-state reaction; Optical properties; Luminescence

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P1-nu.016

외기빔 PIXE 시스템을 이용한 대기 시료 내 중금속 분석 실증 연구

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Abstract:

한국원자력연구원 양성자과학연구단에서는 1.7 MV 탄뎀가속기 기반 외기빔 PIXE (Proton-Induced X-ray Spectrometry) 시스템을 구축하였으며, 이를 이용하여 문화재 시료 분석 등 다양한 시료의 물질 분석에 활용 중에 있다. 본 연구에서는 구축된 외기빔 PIXE 을 이용한 대기중 중금속 성분 농도 분석에의 활용에 대해 발표하고자 한다. 미세먼지 등에 결합된 형태로 호흡 등을 통해 인체 내로 유입된 중금속은 폐, 기관지와 같은 호흡기에 악영향을 미치는 것으로 알려져 있다. 외기빔 PIXE는 극미량의 원소 성분의 정밀 분석이 가능해 미세먼지 필터 내 중금속 원소의 존재량에 대한 측정 및 분석이 가능하다. 대기 중 먼지 표준시료와 실제 공기 중에서 포집된 미세먼지 필터 시료에 대한 분석결과를 살펴보고 향후 대기 중 중금속 농도 분포에의 외기빔 PIXE 시스템의 적용 가능성을 논하고자 한다.

Keywords:

이온빔 분석, 탄뎀가속기, 중금속, 대기환경, PIXE

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P1-nu.017

Development and Calibration of a BC501A Liquid Scintillator for Neutron Detection

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Abstract:

BC501A organic liquid scintillators have been widely used for neutron detection due to its high light output and excellent pulse shape discrimination capability. In this study, we have designed and constructed a 0.5L scintillator detector for background neutron detection using BC501A liquid. Detail specification of the detector will be presented. In addition, we have characterized the detector with different gamma and neutron sources to determine the resolution function, energy calibration parameters and the PSD capability. Monte-Carlo simulation has been used to support and verify the experimental results. Background neutron in our laboratory has been measured using this calibration.

Keywords:

BC501A liquid scintillator, neutron detection, detector resolution, energy calibration, Monte-Carlo simulation.

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P1-op.001

LED 광원을 이용한 항공장애등 프레넬 렌즈설계
(Design of Fresnel Lens for Aircraft Warning Light Using LED Light Source)

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Abstract:

본 논문는 국토교통부에서 고시한 A-type 항공기 경고등용 중 조도 광학계를 설계하고 분석하였다.
LED 광원 모듈 과 Fresnel Lens, 국토 교통부에서 제시 한 수직앙각 별 중심 광도 20,000 cd와 주변 광도를 만족시키기 위해 Collimator용 Fresnel lens를 해석학적으로 설계하고 분석하였다.
이 초기 설계 자료를 기본으로 하여 LED 광원의 위치와 광학계를 최적화하여 국토교통부에서 제시한 광도분포와 배광곡선 특성을 만족하도록 최적의 광학계를 설계하고 분석하였다.

Keywords:

항공기 경고등, LED 광원, Fresnel Lens, 광학설계

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P1-op.002

온도측정을 위한 적외선 광학계 설계에 관한 연구
(InfraRed Optical System Design for Temperature Measurements)

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Abstract:

최근 들어 COVID-19 관련 비접촉식 체온측정용 광학계는 주변에서 흔히 볼 수 있는 적외선 응용 분야의 증가가 급속히 이루어지고 있는 광학장치중 하나가 되었다. 특히 초점면 배열 검출방식 열상센서 및 시스템 설계 기술 개발이 지속적으로 이루어짐에 따라 고분해능 고감도를 실현하는 비구면(aspherical surface) 광학계 및 회절광학(diffractive optics) 소자의 가공이 일반화됨에 따라 이들을 적외선 광학계에 적용하고 있으며, 적외선 영역에서 사용할 수 있는 재질의 제한적인 요인을 극복함으로서 성능향상이 급속도로 이루어지고 있다.
본 논문에서는 비냉각식 비주사식 CMOS 방식을 이용한 적외선 검출소자로서 25um*25um 픽셀 피치를 갖는 검출기에 적합한 적외선 광학렌즈를 설계 구성하였으며, 기본설계한 광학계를 최적화하여 광학적 한계 분해능을 만족하도록 하였으며, 그 성능을 MTF 곡선으로 표시하였다.

Keywords:

IR Lens, IR Opticsl System, 적외선 광학계, 광학설계

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P1-op.003

Few-femtosecond nanoplasmonic near-field dynamics studied by interferometric time- and energy-resolved photoemission electron microscopy

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Abstract:

We report a time-resolved normal-incidence photoemission electron microscope with an imaging time-of-flight detector using ~7-fs near-infrared laser pulses and an actively phase-stabilized interferometer for studying ultrafast nanoplasmonic near-field dynamics by nonlinear photoemission from metallic nanostructures. The Mach-Zehnder interferometer's stability of 35±6 as root-mean-square (from 0.2 Hz to 40 kHz) allows precise sub-cycle sampling via the autocorrelation method as well as on-line characterization of the driving laser field using the second output of the interferometer, which is a requirement for nanoplasmonic near-field reconstruction. We observed strong field enhancement and few-femtosecond localized surface plasmon lifetimes at a monolayer of self-assembled gold nanospheres with ~40 nm diameter and ~2 nm inter-particle distance. A wide range of plasmon resonance frequencies could be simultaneously observed in the time domain at different nanospheres, which are distinguishable already within the first optical cycle or as close as about ±1 fs around time-zero in the nonlinear autocorrelation trace. These results provide a clear path towards complete temporal reconstruction of optically excited nanoplasmonic near-fields at sub-100-nm spatial resolution. In addition, energy-resolved imaging (microspectroscopy) revealed spectral broadening of the photoelectrons due to strong-field or space charge effects, making this instrument a versatile tool for ultrafast strong-field physics on the nanoscale.

Keywords:

Ultrafast optics, Photoemission electron microscopy, Surface plasmons, Electron spectroscopy, Nonlinear autocorrelation

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P1-op.004

Temperature dependence of vermilion pigments in the terahertz region

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Abstract:

Terahertz pulses can be used to nondestructively analyze artworks. We study vermilion pigments over the temperature range of 2-300K in the THz region. The two overlapping peaks around 1.2 THz are distinguished by performing time-domain spectral measurements of vermilion pellets at low temperature and at high resolution. Vermilion exhibits strong absorption at approximately 38, 42 and 88 cm^{-1}. Our experimental data show redshift in the absorption peak with increasing temperature.

Keywords:

Terahertz spectroscopy, Pigments, Vermilion

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P1-op.005

Quantitative analysis of vermilion pigments using terahertz time-domain spectroscopy

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Abstract:

We studied vermilion pigments (HgS) and investigated its absorbance in the 8-100cm^{-1} range. Three sharp absorption peaks are found at 1.1, 1.2 and 2.6 THz. Since the vermilion absorption is rather large, polyethylene having a low absorption in the terahertz region was used as mixing matrix. We compared the data measured with different ratios of vermilion pigment and polyethylene. This study of historical pigments will help to identify counterfeit artworks by fingerprint spectral absorption features.

Keywords:

Terahertz spectroscopy, HgS

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P1-op.006

Angle-insensitive reflective structural color filters creating additive colors

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Abstract:

Recently, structural color filters which rely on thin-film multilayers, photonic crystals, plasmonic nanostructures, and metamaterials have drawn tremendous attention for their extraordinary features such as high stability, high efficiency, and high color purity. Although various reflective structural color filters that can create subtractive cyan (C), magenta (M), and yellow (Y) colors have been proposed, the structural color filters generating additive red (R), green (G), and blue (B) colors in reflection have remained unstudied, which can be applied to diverse applications such as reflective displays and automotive surface coatings. Moreover, grating-based structural color filters present the angle-sensitive performance due to the momentum matching condition, which can impede their practical applications. Hence, there is a critical demand to develop a novel approach that allows additive reflection colors to be created with high purity and high angular tolerance.
In this work, we present RGB additive color-mixing reflective structural color filters based on dual Fabry-Perot cavities. Each cavity absorbs different wavelength ranges, which enables the broadband absorption and thus additive reflection color generation. A highly reflecting material is selected for a bottom mirror, while a lossy metal is chosen for an upper mirror to attain the absorption over a broad range of wavelengths. Reflection spectra at normal incidence exhibit pretty high reflection efficiency at resonant wavelengths and almost zero reflections at non-resonant wavelengths, which suggests that the resulting reflective colors are greatly pure with high brightness. In addition, employing the medium with high refractive index as a cavity leads to the angle-invariant property up to 50˚. The scheme described in this study could offer the distinct potential to numerous applications, such as reflective displays, e-book displays, and colorful decorations.

Keywords:

Fabry-Perot cavity, Multilayer interference, Filter

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고출력 백색광원용 세라믹 형광체 플레이트의 기공 크기에 따른 발광 분포 및 효율 분석

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Abstract:

일반적으로 백색광원을 구현하는 방법은 GaN 계열 청색 발광 다이오드에 황색 형광체를 도포하는것이다. 저출력 백색광원에서는 문제가 없으나 자동차 헤드라이트, 스포트라이트, 서치라이트와 같은 고출력 백색광원에는 많은 열이 발생하고, 도포된 형광체가 열에의해 손상되어 제품의 성능이 떨어지는 문제가 존재한다. 이를 해결하기 위해 고온에서 견딜수 있게 하기 위해서 나노 파우더를 사용하여 고온 고압으로 압축하여 세라믹 형광체 플레이트를 사용한다. 세라믹 형광체 플레이트는 제작하는 과정에 내부에 기공이 생성된다. 이 기공은 세라믹 형광체 플레이트의 성능에 큰 영향을 미친다.
본 논문에서는 서로 다른 두 나노파우더로 제작한 세라믹 형광체 플레이트의 기공의 크기를 측정하고 전면입사, 후면입사를 통해 PL과 투과율 측정하여 비교하였다. 또한 기공의 크기가 크고 많은 세라믹 형광체 플레이트를 연마하여 두께에 따른 PL의 차이를 통해 기공이 세라믹 형광체 플레이트의 성능에 미치는 영향을 분석하였다.

Keywords:

phosphor, nano powder, ceramic phosphor plate

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P1-op.008

DED 방식 금속 3D 프린팅 공정에서의 멜트풀 파장 특성 분석

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Abstract:

금속 3D 프린팅은 크게 PBF(Powder Bed Fusion)와 DED(Directed Energy Deposition) 방식으로 나눌 수 있는데 DED 방식은 PBF 방식에 비해 생산성이 비교적 높고 반복재현성이 우수하며 강도와 충격치가 높은 장점을 가진다. 이러한 DED 방식은 고출력 레이저 빔을 조사하면서 동시에 금속 분말도 공급하여 멜트풀(Melt pool)을 형성하면서 실시간으로 적층하는 방식으로 멜트풀에 대한 정밀한 모니터링 및 제어가 적층 품질에 매우 큰 영향을 미친다. 기존에는 공정을 모니터링 하기 위해서 멜트풀에서 발생하는 광량을 포토다이오드로 측정하거나 열화상 카메라를 이용하여 온도 및 형상을 측정하여 공정을 모니터링 하였다.

본 연구에서는 DED 방식의 멜트풀을 모니터링 하기 위해 Spectrometer(Ocean Optics, USB2000+)를 사용하여 멜트풀에서 발생하는 빛의 파장 특성을 분석하였다. DED 헤드 이송 속도, 금속 분말 주입량, 레이저 출력, DED 헤드와 표면의 거리 등 다양한 공정 조건에서 멜트풀에서 발생하는 파장 특성을 분석하였고 공정 조건에 따라 파장 스펙트럼의 세기와 폭의 변화를 분석하였다. DED 방식에 있어 최적의 공정조건을 찾거나 공정에 대한 오류를 모니터링하는데 있어 파장 분석은 좋은 도구가 될 수 있음을 확인할 수 있었고 이러한 결과를 발표할 계획이다.

Keywords:

금속 3D 프린팅, 분광계, 모니터링, DED(Directed Energy Deposition), 파장 스펙트럼

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P1-pa.101

Search for Darck Sector with Belle Experiment

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Abstract:

In this presentation, we are looking for Dark Sector particle with Belle experiment. One is axion like particle search with B to K a' decay channel, and the other is dark photon search with B to K A' A' decay channel.
We used 10 stream of BB, 6 stream of qq 50 stream of rareB and 20 stream of ulna to evaluate this result. Each stream is corresponds to 711fb^-1 full Y(4S) Belle Montecarlo samples that equivalent to 772M BB pairs.

Keywords:

Belle, KEKB, ALP, Dark Photon, B meson

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DAQ Archiver management for Belle II Detector Operation

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Abstract:

The Belle II experiment is a high-energy physics experiment using the SuperKEKB electron-positron collider.
With Belle II data, high precision measurement of rare decays and CP-violation in heavy quarks and leptons will be made to probe New Physics.
In this presentation, we present the archiver system to monitor the Belle II detector, and discuss how we maintain the system that archives he monitoring process variables of the subdetectors.
For stable data taking, it is essential to collect and archive these variables.
To ensure variables are sent from the subdetector and other systems, we regularly check variable availability and consistency.
By checking the stored status of the variable, we ensure the archiver operation. To cope with a possible hardware failure, we prepared a backup archiver that is synchronized with the main archiver..

Keywords:

Belle II, Archiver

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P1-pa.103

Shielding configuration to reduce beam-related gamma backgrounds at JSNS^2

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Abstract:

The purpose of the JSNS^2 experiment is to search for sterile neutrinos with Δm^2 near 1eV^2. A 3 GeV J-PARC proton beam incident on a mercury target produces an intense neutrino beam from muon decay at rest which oscillates to anti-electron neutrinos. The JSNS^2 detector is located at 24 m baseline from the target. The detector has a fiducial volume of 17 tons filled with GdLS, that efficiently can detect electron antineutrinos via the inverse beta decay reaction followed by a gamma signal from the captured neutron on Gd. It is essential to
shield external gamma backgrounds caused by proton beam in order to discern inverse beta decay signals. Lead blocks and iron plates were placed on the floor to reduce this beam related gamma backgrounds for the data-taking period of June, 2020. Due to larger gamma backgrounds than expected, additional shielding configurations are studied to reduce the gamma backgrounds further using MC simulations. Based on the results of the studies,
we present the shielding configuration which will be used for the next JSNS^2 run.

Keywords:

Beam, Simulation, Background, JSNS2

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P1-pa.104

Report on an LED run of the JSNS2 experiment

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Abstract:

The JSNS2 experiment aims to search for the existence of sterile neutrino at J-PARC. A 1 MW beam of 3 GeV protons incident on a spallation neutron target produces an intense neutrino beam from muon decay at rest. The experiment will search for muon anti-neutrino to electron anti-neutrino oscillations which are detected by the inverse beta decay interaction, followed by gammas from neutron capture on Gd. After filling liquid scintillator (LS), an LED run was performed in order to understand the JSNS2 detector and the effect of the LS. In this presentation, the JSNS2 LED system and the LED run in June are reviewed. Also, several analyses performed using the LED data samples, such as PMT gain measurement and signal timing calibration, are covered.

Keywords:

JSNS2, sterile neutrino, neutrino oscillation, JPARC, MLF

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P1-pa.105

A study of Dark Matter at e+ e- collider using MadGraph

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Abstract:

Using MadGraph5 as a simulation tool kit, we have studied cross section according to various parameters such as center of mass (CM) energy, dark photon (A') mass and coupling constant. We have studied the decays of e+ e- → mu+ mu- A'. The signal process is dark photon which couples only to heavy leptons. We focus on the case in which dark photon decays into two muons. Therefore, this is four muon final state. The imported theoretical model in MadGraph is the Simplified Model which covers SM particles, dark matter and dark photon particles. The invariance masses of dark photon have been reconstructed at the various e+ e- collider energies. We have studied background using the SM of e+ e- → mu+ mu- mu+ mu-. This result will be helpful for searching for dark matter at e+ e- collider of experiments such as Belle II, CEPC and ILC.

Keywords:

Dark matter, Dark photon, e+ e- collider, MadGraph

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P1-pa.106

Cosmic gamma Background study at the $JSNS^2$

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Abstract:

The J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source (JSNS2) experiment has started the search for neutrino oscillations with $\Delta m^2 \sim 1$ eV^2 from anti-muon neutrino to Anti-electron neutron detected via the inverse beta decay (IBD) reaction which is tagged via gammas from neutron capture on Gadolinium. A 3 GeV 1 MW proton beam incident on a mercury target at the MLF at J-PARC produces an intense neutrino flux from muon decay at rest (mu-DAR). The JSNS2 experiment consists of a 50 tons liquid scintillator detector, that is already completed and located at a distance of 24m from the neutrino source. JSNS2 is the only experiment that can directly test the LSND anomaly without having to rely on theoretical scaling assumptions. The JSNS2 experiment successfully collected 10 days of data from the first physics run. In this poster, I will describe the cosmic gamma background, which can give rise to a two independent IBD event signal. We have studied this accidental background using physics run data.

Keywords:

JSNS2 Experiment, Sterile neutrino, neutrino, Particle Physics

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P1-pa.107

A Study on the Way to Build an Affordable Storage System in the Big Data Age with the Experience of Operating the WLCG CMS Tier-2/3 Center

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Abstract:

There's been an increasing number of studies in recent years that require large research facilities. These huge experiments have to deal with massive amounts of data that are difficult to process on a personal computer or workstation. In order to handle this data, the big experimenters also have access to computing resources and provide them to users, but individual research groups must have a computing environment to respond to, in order to keep up with the competition.

We, KISTI-GSDC, have been providing services for users of these huge experiments for many years. We run a regional computing center for domestic CMS researchers. Through a distributed storage program developed by CERN called XRootD. In addition, we also operate a CMS tier-2 international cooperation computing center(WLCG) to support the international collaborative research. The storage system of our CMS Tier-2 Center was developed by the DESY Institute under a program called dCache. Similarly, although the system is mainly used in high-energy physics research.

We compared the pros and cons of various programs used in high-energy physics research and those frequently used in the IT field based on operational experience.

Keywords:

Data Center, WLCG, Google API, XRootD, dCache

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P1-pa.108

Study of MET Significance for the Phase-2 Upgrade of the CMS Level-1 Trigger

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Abstract:

The High-Luminosity LHC (HL-LHC) will provide a new window to understand the nature of the universe with information-rich datasets, helping the precision measurement of the Standard Model and maximizing the search potential for new physics. The upgrade of the HL-LHC also entails a harsh pileup environment of up to 200 proton-proton interactions per bunch crossing, therefore collecting datasets efficiently is one of the main challenges for the CMS Phase-2 upgrade In order to achieve this goal, a new system, named the correlator trigger (CT) for Level-1 (L1) trigger is proposed in CMS. The traditional L1 trigger is vulnerable to a large pileup environment since it exclusively uses calorimeter information while reconstructing the jet and the missing transverse energy (MET). To address the traditional problem, the L1 CT collects information from all sub-detectors and selects pure events by using Particle-Flow (PF) and PileUp Per Particle Identification (PUPPI) algorithms which are best for performing reconstruction and pileup mitigation techniques respectively. Previously we have studied MET reconstruction based on the PF+PUPPI algorithm at Level-1, presenting expected resolutions and trigger rates. Building on this past work, we incorporate per-jet energy resolution information to define and study the performance of a MET significance trigger, which aims to reduce the contribution of fake MET from mis-measured multi-jet events.

Keywords:

CMS Phase-2 Upgrade, LHC, Level-1 trigger, Missing Transverse Energy, Jet

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P1-pa.109

CMS RPC offline software development and quality monitoring

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Abstract:

Offline software of the CMS experiment has been evolving by many physicists for more than 10 years. The CMS collaboration has solved issues of the software quality control by comparing output of full chains of simulations and data processing between software releases, referred as the release validation. In this poster, we review the release validation procedure for the CMS RPC offline software and issues we have encountered during the Run 2. We also present recent developments to improve RPC release validation to be ready for the Run 3 and the phase2 upgrade.

Keywords:

CMS, RPC

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P1-pa.110

Sipm design optimization by TCAD simulation for the dual-readout calorimeter

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Abstract:

Silicon Photomultiplier (SiPM) are state-of-the-art semiconductor photodetectors based on the pixel arrays of avalanche photodiodes which operate beyond breakdown voltage. The dual-readout method is a novel calorimetry technique that allows the simultaneous measurement of both electromagnetic and hadronic particles at high precision. The excellent position and energy resolution which can be gained by combining the dual-readout calorimeter and SiPM are essential for future lepton collider experiments including FCC-ee and CEPC.For this purpose, the SiPM design is optimized using TCAD Sentaurus. In this presentation, the ideal concept and its simulation results are reported.

Keywords:

Dual-readout calorimeter, SiPM, process simulation, CEPC, FCC-ee

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P1-pa.111

Unfolding Weyl invariants

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Abstract:

The Weyl anomalies play important roles in physics, especially in AdS/CFT correspondence, string theory, black hole physics and so on. So far, they are classified up to dimension six. The Weyl invariant scalar densities are closely related to Weyl anomalies and classified up to dimension eight. Our aim is the classification of the Weyl invariants in higher dimensions, hopefully in general dimensions.

To achieve this goal, we consider the Weyl gravity as the gauge theory of the conformal group, and use the unfolding scheme which reformulates the dynamics of a system into an equivalent system with auxiliary fields. To begin with, we study the linearized case and compare our result with the spin-2 off-shell Weyl tensor module (the spin-2 Fradkin-Tseytlin module).

Keywords:

Weyl invariants, Unfolding scheme.

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P1-pa.112

Asymptotic Symmetries of Conformal Gravity

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Abstract:

The 3d gravity theory is particularly interesting due to its simplicity and direct relation to the Chern-Simons formulation. It is important to see the asymptotic symmetry when we considering holography of 3d gravity theory. 3d conformal gravity also admits Chenr-Simons formulation, and we can consider its asymptotic symmetry on the asymptotically AdS background. This consideration is analyzed several years ago under the certain boundary condition. In this research, we revisit this analysis by considering more general boundary condition.

Keywords:

3d Conformal Gravity, Asymptotic Symmetry, Asymptotically AdS background, Chern-Simons gravity, Boundary Condition

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P1-pa.113

The higher spin operator product expansion in the N=3 Kazama-Suzuki Model

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Abstract:

The N = 3 Kazama-Suzuki model at the 'critical' level has been found by Creutzig, Hikida and Ronne. We describe the higher spin-3/2 and 2 currents, and obtain the OPE between the higher spin-3/2 current and itself.

Keywords:

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P1-pa.114

Higgs inflation as non-linear sigma models and its UV completion

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Abstract:

The simplicity of Higgs inflation makes it an attractive candidate for an inflationary model.
However, Higgs inflation has the unitarity problem at a low cutoff scale, which can be best understood from the equivalent description in a nonlinear sigma model (NLSM).
We rewrite the Higgs inflation as a NLSM in a basis-independent way and discuss new linear sigma models including the scalaron field as a UV completion of Higgs inflation. We also address the implications of the new sigma models for inflationary dynamics.

Keywords:

Higgs inflation, NLSM, UV completion

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P1-pa.115

Light mediators for dark matter beyond Z_2 parity

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Abstract:

We consider a dark matter model with Z_3 symmetry, containing light dark Z' boson and dark Higgs boson in a UV completion. In this model, we calculate the Sommerfeld-enhanced cross section of dark matter self scattering with light mediators and determine the relic density of dark matter by freeze-out mechanism.

Keywords:

Dark matter, Z3 Symmetry, Sommerfeld Effect

Four-form flux bridging between Higgs boson and dark matter

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Abstract:

We consider the relaxation of the Higgs mass and the reheating process in the presence of a four-form flux.
In this scenario, we discuss the mechanism for dark matter production from four-form couplings and propose ways to test at indirect and direct experiments for dark matter.

Keywords:

Four-form flux, Dark Matter Production, Hierarchy problem, Reheating

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P1-pa.202

Deep Learning For Low Energy Noise Rejection From COSINE-100 Data

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Abstract:

COSINE-100 is a dark matter search experiment with NaI(Tl) scintillation crystal detectors. It has been in operation since 2016 with the main purpose of testing DAMA/LIBRA experiments. The DAMA/LIBRA data showed model-independent dark matter signatures with 9.5 sigma significance with an energy threshold of 1 keV. Therefore, high signal efficiency at low energy is important in direct comparison with DAMA/LIBRA. Several manual algorithms and binary decision tree techniques have been applied so far, but signal efficiency at near 1 keV was still less than or around 80%. In this study, a deep learning approach, known to be powerful when given large amounts of data, was tried for noise rejection and event selection.

Keywords:

Dark Matter, Deep Learning, Event Selection, COSINE-100, DAMA

P1-pa.203

The Camera System for the IceCube Upgrade

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Abstract:

Abstract:
The IceCube Neutrino Observatory is the first gigaton detector that observes Cherenkov light emissions from charged particles that are produced in neutrino interactions inside or close to the detector volume. The IceCube detector is located at the South pole. The in-ice components of IceCube consist of 5,160 digital optical modules(DOMs) attached to 86 vertical strings. Each DOM contains one Photomultiplier Tube(PMT). The IceCube Upgrade is scheduled to be constructed between 2022 and 2023, adding seven new strings with novel multi-PMT optical sensor modules and calibration devices. Korea has a role in designing and manufacturing a camera system which will be installed into each new DOM.
The camera system will study the bulk ice surrounding the strings and monitor the ice in the drill holes containing the strings. The IceCube Upgrade is expected to enhance the detection and reconstruction of neutrino events. SKKU NeutrinoAstroparticlephysics laboratory(NAPPL) group has started the mass production of camera systems. A few adjustments have been applied to the test procedure for the second batch of 900 cameras. We will present a summary of test results and improvements for the 150 cameras from the first batch and the 900 new cameras.

Keywords:

IceCube, IceCube Upgrade, Camera System

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P1-pa.205

Design of target and background study for a magnetic monopole experiment

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Abstract:

KoreA Experiment on Magnetic Monopole (KAEM) searches magnetic monopoles which has been a long-time puzzle of Electromagnetism for last 150 years. In this experiment, we search low-mass and low-charge magnetic monopoles. It consists of an aluminum target, LYSO crystals, high-field resistive electromagnets and vacuum chambers. LYSO crystals are located in both ends of cylindrical vacuum chambers and the target in the center. We designed a magnetic mirror to achieve a reasonable interaction probability between positrons from sodium-22 and electrons in the target. In addition, the main background of this experiment is studied with this experimental configuration. In this poster, we present the design of magnetic mirror and results of the background study performed with GEANT4.

Keywords:

Monopole, GEANT4

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P1-pa.206

Photon propagation simulation in the crystal scintillator

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Abstract:

Increase in the light collection from a crystal scintillator is important in dark matter and neutrino experiments because it provides an improved sensitivity at their low detector threshold region.
In order to obtain an optimized detector configuration in lieu of the high light collection, we are required to find out how an individual photon generated within a specific crystal geometry propagates until it is detected by a photo sensor. Using photon simulation tools, hundreds of individual photons are tracked within a crystal detector and thus, the ratio of detected ones to generated as an efficiency is obtained. The results and methods will be reported in the conference.

Keywords:

Photon Simulation, Chroma

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P1-pa.207

A way to reduce the aging of a solid state scintillator

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Abstract:

A solid state scintillator is used commonly in the high energy particle and nuclear physics experiments. Because the high energy physics experiments are executed for a long time, the aging of scintillator affects the experiment efficient. Main reason of aging come from the photon, the chemicals in a scintillator itself, the chemicals in laboratory, etc. Among those reasons, we will focus to the aging from chemicals in the air and to study of reducing the aging by that chemicals. At the end of study, we will suggest the way to reduce the aging of scintillator.

Keywords:

Scintillator, anti-aging

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P1-pa.208

Photon simulations for AMoRE-Pilot experiment

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Abstract:

Monte Carlo simulations are widely used in particle physics. In particular, simulations can help to estimate the detector's response and improve its design. Geant4 model has been extensively used for the AMoRE-Pilot experiment consisting of six $^{48dep}Ca^{100}MoO_4$ crystals located at the Yangyang underground laboratory. Until recently, energy deposits in the crystals were considered in the simulations. To improve our understanding of photon collection and the detector design, ^{238}U full decay chain simulations are done including the generation of optical photons.
Scintillation process, refraction and reflection at medium boundaries, and bulk absorption are considered. The main challenge in these simulations is the tuning of optical properties of detector materials, which sometimes are not known precisely. Also, the optical photon simulations are computationally heavy and consequently time-consuming. To validate our simulations, we conducted a light detector study to estimate the unknown optical properties of the detectors. To overcome the difficulties related to the time-consuming nature of the photon simulations, we explored recently developed GPU-based simulation tools.

Keywords:

AMoRE, Underground experiment, Monte Carlo simulations, Light detector

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P1-pa.209

Energy resolution study for AMoRE-Pilot experiment

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Abstract:

AMoRE-Pilot, a neutrinoless double-beta decay experiment with six $^{48dep}Ca^{100}MoO_4$ crystals and located at Yangyang underground laboratory, collected data in 2015-2018. We have used calibration run and physics run data to study the energy resolution of each crystal. ^{232}Th radioactive source was used in the calibration run, while the physics run observed natural gamma-ray background. Background subtracted spectra were calculated taking into account the DAQ lifetime of each crystal. Prominent peaks were identified in the spectra at the energy range (0.2 – 3) MeV. Each peak was fit by Exponentially Modified Gaussian function. Full Width at Half Maximum (FWHM) and standard deviation were estimated as characteristics of energy resolution for each peak. Having the energy resolution for each peak, the energy resolution function was estimated for each crystal. The calculated energy resolution function is used in analyzing AMoRE-Pilot background simulation results. Data and simulation are in good agreement overall.

Keywords:

AMoRE, Underground experiment, Energy calibration, Radioactive source

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P1-pa.210

Rock gamma simulation for AMoRE

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Abstract:

Amore (Advanced Mo-based Rare process Experiment) is an underground experiment, with the goal of observing the neutrinoris double-beta decay phenomenon to measure the absolute mass of neutrinos. The neutrinoris double-beta decay is a very rare phenomenon and requires a zero background in the region of interest (ROI). To lower the background, you need to understand the background of the underground rock. However, too much system resources are consumed to study the background radiation of a rock layer with a simple computational simulation.
In this study, various methods were used to reduce system consumption and will be presented. And we will present the background results simulated using the above method.

Keywords:

Neutrino, Geant4, Simulation, Rock, background

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P1-pa.211

Simulation study of calibration system for AMoRE-II experiment

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Abstract:

AMoRE-II (AMoRE phase-II) is next phase of the AMoRE searching for neutrinoless double-beta decay of ^{100}Mo isotopes using ~200 kg of molybdenum containing cryogenic detectors. The AMoRE detector consists of ~500 CMO crystals in a refrigerator and the identification of candidate events can be done through a precise measurement of their energies. In order to establish the absolute energy response, each crystal needs to be calibrated by using gamma sources. This study is going to find the most suitable activity of the gamma source for the calibration system. We performed a Geant4 simulation to estimate the event rates of the crystals and the ratio of innermost to outermost arrays. The details of the study will be presented.

Keywords:

Underground experiment, Geant4 simulation, Calibration, AMoRE, gamma radioactive source

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P1-pa.212

Novel Silicon Photomultiplier Tube (SiPMT) for KNO

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Abstract:

Photomultiplier tube (PMT) is the conventional photodetector that has been used in many neutrino observatories as well as in high energy and nuclear physics experiment. Finally, after so many years a new photosensor called silicon photomultiplier (SiPM) emerges which is a good alternative to PMT due to its excellent photon counting capability, insensitive to a magnetic field, low voltage, compact, and robust. Our idea is to put SiPM in a vacuum tube along with the scintillator with a large photosensitive area so that it can be used in neutrino observatories. We named this kind of novel design as SiPMT. In this novel design, the complex dynodes structure of PMT is replaced by SiPM along with a scintillator. In SiPMT the light incident on the photocathode will generate photoelectrons that will be guided to the scintillator crystal by an electric field generated by anode at the high voltage. The scintillator absorbs photo-electrons and produces scintillation light, which can be in turn detected by SiPM. The gain of SiPMT will be higher than any other photosensor like PMT and SiPM itself. The additional gain comes from the scintillator. We have designed a new demonstrator with feed-through connections which improve the vacuum level, therefore, enables us to apply high voltage to the anode. The results obtained from this new demonstrator will be presented.

Keywords:

Scintillator, Photocathode, Photodetectors

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P1-pa.213

Development of vertex reconstruction and particle identification tool for KNO

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Abstract:

The Korea Neutrino Observatory (KNO) has been proposed as a next generation neutrino experiment and is expected to contribute significantly to the field of neutrino physics and multi-messenger astronomy. The KNO detector is planned as a large water Cherenkov detector inside which PMTs collect Cherenkov photons generated through the interaction of neutrinos with water. The detector simulation package of KNO is currently being developed to study and to optimize the performance of the detector. The key part of the detector simulation is how well neutrino properties such as energy, type, and interaction positions are reconstructed from the electric signals of PMT. In this presentation, we present preliminary results on vertex reconstruction and lepton identification of the KNO reconstruction software.

Keywords:

neutrino, KNO, reconstruction, water cherenkov

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P1-pa.214

Reconstruction of neutrino energy in the KNO detector

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Abstract:

The next-generation water Cherenkov detector in Korea (KNO: Korean Neutrino Observatory) has been proposed to measure leptonic CP violation and detect neutrinos of astronomical origin. The performance of the KNO detector is being studied using GEANT 4 based detector simulation and self-developed reconstruction package. For simplicity, only charged current quasi-elastic scattering (CCQE) process is considered in this simulation. In this presentation, we show preliminary results on the neutrino energy reconstruction for various KNO configurations and the effects on physics sensitivities.

Keywords:

KNO, neutrino, water Cherenkov detector, CP violation, simulation

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P1-pa.215

Kovar Alloy Oxidation and Baking System for the Fabrication of the Photocathode and SiPMT Assembly.

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Abstract:

We have been developing a photodetector called SiPMT which consists of a photocathode, an electrode, a scintillator, and a silicon photomultiplier in a vacuum tube. This type of photodetector with a large area of photocathode could be utilized in the photo-detector array for neutrino detection at Korean Neutrino Observatory (KNO). It is necessary to make glass-metal sealing for electrical and vacuum-pump connections. We chose the Kovar alloy and borosilicate glass for the glass-metal sealing due to the similar thermal expansion coefficient. We oxidized the Kovar alloy to enhance the glass-metal sealing. Prior to the fabrication of the photocathode, the vacuum tube with the completed glass-metal sealing should go through the baking process which removes elements outgassed from the inner surfaces of the tube as well as from materials within the tube. We will present the glass-metal sealing process and the design and production of the baking system that will be used for the fabrication of bi- or multi-alkali photocathodes and SiPMT assembly.

Keywords:

Kovar oxidation, glass-metal sealing, photocathode, SiPMT, bakinng system

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Optimization of external quadrupole field in free-electron laser

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Abstract:

External quadrupole field가 포함된 3차원 자유전자레이저 시뮬레이션 코드를 개발하였다. 개발된 코드를 이용하여 exteral quadrupole field에 따른 패스 수와 디튜닝에 대한 방출되는 방사광의 증폭에 대해 연구하였고, external quadrupole field와 빔 파라미터의 최적화 조건에 대해 연구하였다.

Keywords:

External quadrupole field, Free-electron laser

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P1-pl.102

레이저유도형광 진단을 이용한 홀추력기 플라즈마 내 Xe II 이온의 2 차원 거동 연구

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Abstract:

홀추력기는 플라즈마가 발생되는 방전채널 내에 외부 자기장과 전기장을 인가하여 축방향의 전자의 전기전도도를 감소시킴으로써 전기장 영역을 형성하고, 이 전기장으로 이온을 가속시켜 추력을 얻는 플라즈마 장치이다. 이온가속에 필요한 전기장을 결정짓는 중요한 요소인 전자의 거동은 자기장에 의해 지배되는데, 홀추력기의 방전채널 내에는 자기장과 전기장이 위치에 따라 다르게 존재하므로 전기장에 의해 가속되는 이온속도의 크기와 방향도 위치마다 다르게 나타난다. 전기장을 실험적으로 진단하기 위해서는 이온의 속도를 측정하는 방법 또는 플라즈마 전위를 측정하는 방법이 있는데, 본 연구에서는 비침습적 진단법인 레이저유도형광 진단을 이용하여 홀추력기 플라즈마 내에서 $5d^2F_{7/2}$ 에 머무르는 Xe II 이온의 속도분포를 측정하였다. 방전채널 직경과 깊이가 50 mm와 24 mm로 동일한 고리형 홀추력기와 원통형 홀추력기를 사용하여, 양극전압을 300 V로 동일하게 인가하여 방전채널 안에서부터 바깥까지 이온속도분포를 측정하였다. 두 추력기 모두에서 방전채널에 가까워질수록 이온의 반경방향 속도가 커지는 것을 확인할 수 있었으며, 방전채널 내 자기장의 형상과 크기 변화가 큰 원통형 홀추력기에서는 반경방향 위치에 따라 달라지는 가속지점을 확인할 수 있었다. 본 발표에서는 이온속도의 벡터 지도 및 색상 지도와 결과해석 내용이 소개될 예정이다

Keywords:

홀추력기, 레이저유도형광, 이온속도분포

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P1-pl.103

Characterization of the plasma dipole oscillation in strongly magnetized plasmas

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Abstract:

Generation of plasma dipoles oscillation (PDO) in strongly magnetized plasmas is investigated by particle in cell (PIC) simulations. The spectrum of the magnetized PDO has upper hybrid frequency (H) and right (R)-, left (L)- cutoff frequencies of X-mode. The electron bunch in PDO moves along the trajectory repeatedly appears star shape with one focal point and two focal points. The emitted radiation spectra show that the spectral peaks at R and L cutoffs are dominant, whereas the peak at H is relatively weak. The polarization of the radiation along the magnetic field is circular, while it is linear for the perpendicular radiation.

Keywords:

plasma dipoles oscillation (PDO), magnetized PDO, X-mode, polarization, electron bunch

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P1-pl.104

KOMAC 양성자가속기의 200 MeV 업그레이드를 위한 극저온 시스템 기초 설계 연구

KIM Han Sung *[1], KWON Hyeok Jung [1], DANG Jeong Jeung [1], LEE Seung Hyun [1], KIM Kyung Hyun [1], JUNG Won Hyeok [1], CHO Yong Sub [1]
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Abstract:

한국원자력연구원 양성자과학연구단에서는 대기/우주 방사선 영향시험 플랫폼 구축의 일환으로, 현재 운영 중인 100 MeV 양성자가속기의 에너지를 200 MeV로 업그레이드 하는 계획을 추진 중에 있으며, 이를 위한 가속관으로는 초전도 Half-wave Resonator (HWR)을 기반으로 가속기의 설계가 진행 중이다. HWR 가속 공동의 설계 운전온도는 2 K 이며, 저온모듈의 열차폐체 설계 운전온도는 35 K ~ 55 K 영역이다. 4개의 350 MHz HWR을 포함하는 총 9 대의 저온 모듈로 구성된 초전도 가속기의 정적 열부하, 동적 열부하 및 설계 마진을 종합적으로 고려하면, 초전도 가속기의 안정적 운전을 위해 4.5 K 환산 냉각용량 3 kW 급의 저온 플랜트가 요구된다. 본 연구에서는 200 MeV 초전도 가속기의 극저온 시스템에 대한 기초설계 연구에 대해서 발표한다.

본 연구는 과학기술정보통신부 연구비 지원을 받았음.

Keywords:

양성자가속기, 초전도 가속기, 극저온 시스템, Half-wave resonator

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P1-pl.105

Numerical Study on the residual gas molecules in KOMAC LEBT using Molflow+

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Abstract:

Space charge neutralization greatly affects beam dynamics in a low energy high intensity beam transport line (LEBT). To understand and favorably utilize the space charge compensation, residual gas molecules were quantitatively analyzed. The existing vacuum system of KOMAC LEBT was modeled on Molflow+ as a numerical simulation code. Neutralization gas injection system and differential pumping system were newly designed to improve the beam emittance and beam-matching quality. The design and simulation results will be presented.

Keywords:

KOMAC LEBT, Molflow+, Space Charge Neutralization, Residual Gas Molecules, Beam Emittance

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P1-pl.106

A new configuration for helium atmospheric pressure plasma jet

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Abstract:

Atmospheric pressure plasma jets (APPJs) have received much attention due to their plenty of applications in surface modification, biological decontamination and environmental protection. In our experiment, a novel configuration of a helium APPJ based on dielectric barrier discharge was assembled by using a quartz tube and three metal electrodes. The first is the tip-shape electrode was placed inside the quartz tube. The second is the ring-shape electrode was covered outside the quartz tube. The third electrode was placed outside far from the quartz tube. Helium plasma was generated by applying an AC voltage to the second and third electrodes at the frequency of 5kHz and the amplitude of 12kVp.p. A DC bias was applied a to the tip-shape electrode to enhance the plasma emission light intensity. Plasma spectra were measured along the APPJ by using a portable spectrometer. Spectra of hydroxyl radical (OH), atomic oxygen (O), hydrogen (H), helium (He), molecular helium (He_2), nitrogen molecular (N_2) and molecular nitrogen ion (N_2^+) were observed in plasma spectra. Plasma emission light intensity in the region outside the quartz tube was different when we applied negative and positive voltage DC bias. The behavior of plasma spectra was discussed when DC bias amplitude was changed.

Keywords:

Atmospheric pressure plasma jet, dielectric barrier discharge, helium plasma

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P1-pl.107

Design and First Experimental Results of a Beam Extraction system of 2.45 GHz Electron Cyclotron Resonance Ion Source for Compact Neutron Generator

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Abstract:

We present recent study on the development of a 2.45 GHz electron cyclotron resonance ion source for high yield compact D-D neutron generator. The ion source has been based on compact permanent magnet ECR ion source [1]. The source uses permanent magnets and the microwave is coupled to 100 mm (diameter) x 90 mm (length) plasma chamber through ridge waveguide [2]. Double ECR zones for plasma heating are located both near the plasma window and beam extraction entrance. Extraction system is composed of 3 electrodes with water cooling system. The gaps between inner grids are optimized for the lowest extraction RMS divergence angle using IGUN code. A shielding plate is positioned in order to reduce fringe field which avoid Penning discharges to occur inside the accelerating column. A mild steel plate for adjusting the position of the ECR zone near the beam entrance is also located at the downstream side of the plasma grid. A hydrogen beam of over 30 mA at 50 keV has been extracted from a single 5 mm diameter aperture. The required equivalent hydrogen beam current density of 150 mA/cm^2 was extracted at a microwave power of about 600 W with an optimized magnetic field. This presentation describes the design of the ECR ion source and first beam characterization experiments.

Keywords:

ECR ion source, Neutron Source, Beam Extraction System, Neutron Generator

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P1-pl.108

Gas cell development for laser plasma acceleration by using fs-laser machining

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Abstract:

A plasma source is a vitally important part in laser plasma acceleration and a gas cell is a very good plasma source for stable acceleration. We developed a fs-laser machining system for development of gas cells, which can be used for the laser wakefield acceleration (LWFA) research. The micro-machining system is based on the Ti:sapphire regenerative amplifier in our laboratory, which operates at 1 kHz. By using the fs-laser micro-machining system, a few different types of capillary gas cells were fabricated and their operation characteristics were measured. In this presentation, the fs-laser micro-machining system and the experimental results are introduced.

Keywords:

machining, gas cell, fs-laser, plasma, laser wakefield acceleration

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유전장벽형 유연 플라즈마 파우치 개발 및 특성 조사

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Abstract:

COVID-19 유행병의 전세계적인 확산으로 인해, 의료 및 보건 분야의 플라즈마 기술 활용에 대한 사회적 요구가 올해 들어 급속도로 증가하였다. 플라즈마는 하전입자, 고 에너지 원자 및 분자, 반응성 화학종, 자외선 등으로 구성된 복잡한 혼합물이다. 이러한 복잡성에서 기인한 다양한 효과로 인해 플라즈마의 산업적 활용도도 급증하고 있다. 특히 대기압 약전리 플라즈마는 개방된 공간에서 생성이 가능하고 열역학적 비평형 상태를 가지는 특성으로 산업적 이점을 가진다. 약전리 플라즈마의 응용을 위해 다양한 형태의 플라즈마 발생기가 개발되어 왔는데, 최근에는 필름 형태의 유연 플라즈마 발생기의 가능성과 유용성이 활발히 논의되고 있다. 유연 플라즈마 발생기는 인체와 같은 고차원 물체에 효율적인 플라즈마 처리를 가능하게 하여, 플라즈마 처리 면적 극대화 및 플라즈마와 처리 표면의 직접적인 상호작용을 가능하게 한다. 본 연구는 잉크젯 프린팅을 이용한 유전장벽형 유연 플라즈마 발생기(FXDBD: Flexible Dielectric Barrier Discharge)의 제작부터 개선, 특성 평가 및 적용 모델 실증에 이르는 일련의 과정을 고찰한다. FXDBD는 다양한 모양에서도 안정적인 플라즈마 생성이 가능하여 종이접기와 같은 방식으로 다양한 형태에 적응할 수 있다. 전극구조 개선과 전극과 플라즈마의 공간적 분리를 통해 플라즈마에 의한 물리화학적 스트레스의 영향을 최소화하였으며, 소모전력의 변화에 따라 오존 및 질소산화물의 발생 경향의 변화를 확인하였다. 마지막으로, 제작된 FXDBD의 실제 적용 타당성 조사의 일환으로 파우치 형 플라즈마 소스를 구현, 파우치 내에 저장된 블루베리의 품질유지 기간 연장 효과를 확인했다.

Keywords:

COVID-19, Flexible DBD, Plasma pouch

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Measuring electric fields between two conducting parallel plates using a linear electro-optic effect applicable to a plasma assisted combustion system

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Abstract:

With aims of manipulating flames and flammability limits, many studies on plasma assisted combustion systems have been reported where plasmas are generated via various shapes (frequency, duty cycle, magnitude and direction) of externally applied electric fields to a pair of parallel conducting plates. Existing results demonstrate undoubtable correlations between the shapes of applied electric fields and flame characteristics, indicating that plasmas (or charged particles) within the flames affect their characteristics. We utilize an electro-optic crystal whose refractive index changes in response to the externally applied electric field to measure the field strength in free space. We measure a change of polarization state of incident laser beam before and after passing through the electro-optic crystal, from which we can infer the change of refractive index and thus the electric field. We present a measurement system based on a BBO (beta-barium borate) electro-optic crystal as a sensing part and provide measurement results obtained in between a pair of parallel conducting plates similar to a plasma assisted combustion system. Electric fields are applied to the plates up to ~10^5 V/m.

Keywords:

plasma flame, linear electro-optic effect, electric field measurement

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P1-pl.111

Generation of laser induced helium plasma at atmospheric pressure

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Abstract:

Laser-induced plasma (LIP), which use a high energy laser beam as the vaporization, atomization, and excitation source, is a high sensitive and fast technique for diagnostics of atoms and ions in the generated plasma. In this experiment, we developed LIP system for measuring the LIP signal of the helium plasma. Nanosecond Nd:YAG pulse laser at 532 nm was used as the excitation source. The laser beam was delivered and focused in the helium chamber. The emission light from the plasma was collected by a lens system and an optical fiber. A portable spectrometer was used for detecting the plasma spectra. We produced the laser induced helium plasma at atmospheric pressure. The emission spectra were measured and analyzed with the ambient gas pressure adjusted from 200-760 Torr.

Keywords:

Laser-induced plasma, helium plasma, atmospheric pressure

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Single Crystal Dispersion Interferometer 데이터의 베이지안 기반 해석을 위한 forward model 개발

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Abstract:

단일 결정 분산 간섭계(Single Crystal Dispersion Interferometer; SCDI)는 새롭게 개발되어 KSTAR에 설치된 분산 간섭계이다. 두 개의 비선형 결정을 사용하는 기존의 분산 간섭계와 달리 단일 결정 분산 간섭계는 비선형 결정을 하나만 사용하여 광경로를 보다 쉽게 정렬할 수 있으며, 두 개의 비선형 결정을 통과하여 발생하는 레이저 출력 감소 등의 문제점을 해결할 수 있다는 장점을 가지고 있다. 베이지안 통계 이론에 기반한 SCDI 데이터 해석은 이로부터 유추된 선적분 플라즈마 밀도와 측정된 데이터 간의 일관성(consistency)을 수월하게 유지하게 한다. 본 연구는 KSTAR에 설치된 SCDI 시스템의 forward model을 개발하여, 이를 베이지안 통계이론에 필요한 우도(likelihood) 계산에 활용하는 것을 목적으로 한다. 개발된 forward model은 SCDI 진단계에 사용되는 비선형 결정 및 AOM(acousto-opcic modulator) 등을 포함한 모든 광학부품들의 투과 계수를 포함한다. 또한, forward model은 전자장비에서 발생하는 노이즈를 가우시안 분포를 따르는 확률 변수로, 광자 노이즈를 푸아송 분포를 따르는 확률 변수로 포함한다. 따라서, forward model은 확률 분포의 형태로 선적분 플라즈마 밀도에 의해 발생하는 위상 변화를 보여주며, 데이터 해석에 활용되는 것뿐 아니라 단일 결정 분산 간섭계 디자인에도 활용 가능하다.

Keywords:

Plasma diagnostics, Data analysis, Interferometry, Statistical analysis

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P1-pl.113

Design and Evaluation of Impedance Transformer to Improve 2.45 GHz Microwave Coupling into Plasmas in Electron Cyclotron Resonance Ion Source (ECRIS)

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Abstract:

Electron Cyclotron Resonance Ion Source (ECRIS) operated at 2.45 GHz has been widely used as a high intensity light ion source in the past 30 years. Since the Taylor source (1991) which is still a prototype of the 2.45 GHz ECRIS, an impedance transformer has significantly enhanced microwave coupling efficiency and consequent plasma density by matching the impedance between transmission waveguide and plasmas. Many ECRIS devices have adopted a four-step ridged waveguide as the impedance transformer with widely known design procedures. Typical design procedures merely assumed plasma impedance around 100 ohm without any consideration of plasma density and magnetic field strength which determine dielectric constant of plasmas. In this presentation, plasma medium is modelled with the cold plasma dielectric tensor by using COMSOL Multiphysics® and calculation of reflection coefficient with respect to the plasma density is included in the design procedures. Two impedance transformers are fabricated according to the simulation results. Extracted beam current and plasma efficiency are compared with and without impedance transformers in order to evaluate performance of the impedance transformers.

Keywords:

electron cyclotron resonance ion source (ECRIS), impedance transformer, 2.45 GHz microwave, four-step ridged waveguide

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Preliminary study of high energy beam transport for 200 MeV energy upgrade of KOMAC proton linac

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Abstract:

Korea Multitpurpose Accelerator Complex (KOMAC) proposes an energy upgrade plan of the existing 100 MeV proton linac. The design of the extended linac is based on superconducting RF cavities. It consists of a beam matching section of high energy beam transport (HEBT) and cryomodules containing 4 Half Wave Resonator cavities with doublet focusing lattice structure. HEBT is to efficiently match the 100 MeV linac output beam profile to a matched beam profile of the SRF linac with quadrupole doublet for each cryomodule. In this work, we report the study of the HEBT design for the 200 MeV superconducting linac carried out at KOMAC.

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Keywords:

proton linac

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KOMAC 200 MeV 에너지 업그레이드를 위한 HWR 극저온 모듈 제작 일정 계획

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Abstract:

KOMAC 100 MeV 양성자 가속기를 200 MeV로 에너지 업그레이드하기 위해서는 4개의 HWR(Half Wave Resonator) 초전도 가속공동이 들어간 극저온 모듈 9 개가 가속기 터널 내에 설치되어야 한다. 이 극저온 모듈을 제작하기 위해서는 먼저 니오븀 가속공동을 만들고, 표면 처리를 한 후 , 극저온 냉각 시험을 통해 고주파 및 기계적/열적 성능을 확인한다. 가속공동의 성능이 확인된 후 크린룸에서 4개의 가속공동을 일렬로 조립하고, 이후 조립장에서 기계 조립, 가속공동 정렬, 극저온 배관, 자기장 차폐 및 열 차폐 설치 등 과정을 거쳐 극저온 모듈이 완성된다. 완성된 극저온 모듈은 극저온 냉각 시험을 통해 최종 성능이 확인되면, 가속기 터널에 설치되는 과정을 거치게 된다. KOMAC 200 MeV 에너지 업그레이드 계획 수립을 위해 9개 극저온 모듈의 제작 과정을 어떻게 진행하는 것이 합리적인지, 어느 정도 기간이 소요되는지 추정할 필요가 있다. 본 발표에서는 외국의 사례를 참고하여 KOMAC HWR 극저온 모듈 제작을 위한 일정 계획을 제시하고자 한다.

Keywords:

KOMAC, 에너지 업그레이드, HWR, 극저온모듈, 제작일정

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50 W급 저전력 홀추력기의 자기장 형상에 따른 성능 및 이온빔 특성 연구

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Abstract:

홀추력기는 플라즈마가 발생하는 방전채널 내부에서 중성입자 이온화를 통해 생성된 이온의 가속으로 추진력을 얻는 전기추력기의 일종으로, 인가 전력 대비 비추력이 높아 다양한 우주임무에 활용되고 있다. 최근 100 kg 이하의 초소형위성 혹은 큐브샛 활용 증가로, 100 W급 이하의 저전력 홀추력기의 연구개발 중요성 역시 크게 증가하고 있다. 저전력 홀추력기는 고전력 추력기와 비교해서 채널지름을 작게 만들므로 채널벽으로의 입자손실과 열 발생이 증가하고 성능이 감소하여 연구개발 난이도가 매우 높다. 따라서, 저전력 홀추력기에서는 이러한 난제를 완화하기 위해 자기장 형상에 따른 방전특성 분석을 통한 최적 자기장 세기 및 형상 설계가 필수적이다. 본 연구에서는 100 W급 이하의 저전력 홀추력기의 자기장 제어 전후에 따른 성능 및 방전특성을 측정하고 분석하였다. 특히, 자기장에 따른 채널 벽과 플라즈마 간 상호작용 차이에 따른 특성분석을 위해, 양극방향으로 오목하게 제어된 자기장과 일반적인 홀추력기와 동일한 채널 평면과 평행한 자기장에서 각각 방전시험을 진행하였다. 제작된 홀추력기 방전은 자기장 제어 전후에 따라 제논유량 4.3 sccm에서 양극전압 160 – 280 V 및 양극전력 30 – 70 W 범위에서 수행되었다. 이때 자기장 제어 전후 홀추력기는 각각 64 W의 동일 방전전력에서 추력은 3.6 mN와 4.1 mN, 양극효율은 25%와 31%, 비추력은 860 s 및 1000 s으로 측정되어, 자기장 제어 시 더 높은 추력성능을 확인하였다. 패러데이 탐침 및 전위지연탐침 분석 결과, 해당 전력에서 자기장 제어된 홀추력기는 제어 전에 비해 이온전류가 10%정도 더 낮았으나, 빔분사각은 제어 후의 경우가 37% 더 낮아 추력성능 향상에 기여한 것으로 판단된다. 본 발표에서는 자기장 제어 전후 홀추력기 성능변화를 야기하는 채널 내외 플라즈마 특성에 대해 상세하게 논의한다.

Keywords:

전기추력기, 저전력 홀추력기, 자기장 제어, 플라즈마 진단

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제한된 시선을 가진 ITER 분광계 시스템의 토카막 토모그래피 기법 개발

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Abstract:

핵융합 플라즈마에서 불순물을 제어하는 것은 안정적인 플라즈마 운전에 있어 중요한 문제이다. ITER와 같은 미래 핵융합 장치에서는 고온 플라즈마에 의한 높은 열속을 견디기 위해 텅스텐 등의 대면재를 사용한다. 하지만 텅스텐과 같은 높은 원자번호를 가진 불순물은 플라즈마 내에서 강한 제동복사와 선방사선을 방출하기 때문에 심각한 방사냉각을 유발하며, 이는 플라즈마 감금 성능 저하와 플라즈마 붕괴현상을 일으킨다. 따라서 안정적인 플라즈마 운용을 위해서는 이러한 불순물의 분포 변화를 진단하여 플라즈마의 불순물을 제어할 필요가 있다. 진공 자외선(VUV) 및 극진공 자외선(EUV) 분광계는 다양한 불순물 측정에 중요한 진단계로 여러 토카막 장치에서 활발하게 이용되고 있으며, ITER에서는 디버터 영역, 플라즈마 가장자리 영역 및 중심 영역을 지나는 VUV 분광 시스템이 설치될 예정이다 [1]. 이 분광 시스템은 공간적으로 제한된 시선 영역을 가지고 있기 때문에 국소적인 플라즈마 이미징에는 부적합하다 [2]. 따라서 분광계의 공간분해능을 최대한으로 활용하기 위해서는 새로운 토모그래피 기법 연구가 필요하다. 본 연구는 자기평형에 기초해 원심력에 의한 비대칭성 효과를 포함한 예측된 불순물 분포를 추가적인 정보로 이용하여 Philips-Tikhonov 정규화에 기초한 토모그래피 방법의 정확성을 개선하였다. 또한 ITER 환경에서 예측된 텅스텐의 가상 폴로이달 분포들을 이용하여 ITER 디버터 분광계에 적용된 토모그래피 기법의 효과를 검증하였다. 재구성된 텅스텐 분포는 높은 신뢰성을 보여 다양한 불순물 분포에서도 본 토모그래피 기법이 유효하다는 것을 입증하였다. 또한 높은 중성자속에 의해 예상되는 진단계 노이즈에도 불구하고 높은 재구성 신뢰도를 보임을 확인하였다. ITER는 반경이 약 6 m 정도로 크고 최대 약 360 km/sec의 회전속도를 가질 것이라고 예상되기 때문에 [3] 높은 원자번호를 가진 불순물들의 폴로이달 비대칭성을 기대할 수 있다. 개선된 토모그래피 기법은 제한된 시선을 가진 ITER 분광계 시스템에서 불순물 분포를 국소적으로 이미징하여 정확하게 진단하는데 유용하게 사용될 것이라고 기대된다.

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Keywords:

ITER 분광계, 토모그래피

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하이브리드 Particle-In-Cell 전산모사를 통한 100 W급 이하 저전력 홀추력기의 채널 내외 플라즈마 특성 연구

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Abstract:

홀추력기는 방전채널 내 인가된 자기장에 의해 채널 내부에 전자가 구속되어 이온화가 일어나며, 생성된 이온들은 전기장을 통해 가속되어 높은 비추력을 얻는 전기추력기의 한 종류이다. 최근 심우주탐사를 포함한 다양한 임무에 초소형위성 활용이 증가하고 있으며, 100 W급 이하 저전력 홀추력기의 연구개발의 중요성이 부각되고 있다. 그러나, 저전력 홀추력기는 kW급 홀추력기에 비해 채널크기가 작아 부피대비 표면적 비율이 커서 입자손실을 통한 성능악화를 야기한다. 따라서 채널 내외부 플라즈마 특성분석을 통한 성능향상이 필수적이나, 채널크기가 작아 플라즈마 특성 진단의 난이도가 매우 높아 전산모사를 통한 플라즈마 특성 분석이 필수적이다. 본 연구에서는 기존에 개발된 100 W급 이하 저전력 홀추력기 방전조건을 활용하여, 채널 축방향의 일차원 공간에 따른 채널내외 플라즈마 특성을 전산모사하고 분석하였다. 특히, 본 계산에서 제논이온 및 중성입자는 Particle-In-Cell(PIC) 기법으로, 전자는 유체로 계산하는 하이브리드 기법을 활용하여, 양극전압 200 V 및 양극유량 0.42 mg/s의 방전을 구현하였다. 특히 전자유체는 전하량 보존 법칙 및 일반화된 옴의 법칙을 적용했으며, 전자와 중성입자간 충돌, 변칙충돌주파수, 그리고 벽면충돌이 고려되었다. 전산모사의 시간간격은 20 ns로, 총 2.0 ms의 시간에 대해 계산을 진행하였다. 결과적으로, 69 W 조건에서 추력은 3.9 mN 및 방전전류는 0.402 A 로 계산되었으며, 이는 측정한 추력 4.0 mN 및 측정 방전전류 0.345 A에 비해 추력은 5% 이내, 방전전류는 20% 이내 정확도이다. 또한, 측정된 이온 속도분포를 계산결과와 비교 시, 채널 출구로부터 축방향 거리 0 - 30 mm에서 축방향 속력1 km/s 이내의 오차로 값이 유사함을 확인하였다. 본 발표에서는 개발된 일차원 하이브리드 PIC 전산모사 기법 및 실험결과와 비교 검증을 통한 채널 내외의 상세한 플라즈마 특성에 대해 논의하고자 한다.

Keywords:

전기추력기, 저전력 홀추력기, 플라즈마 전산모사

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저주파에서 발생되는 대기압 플라즈마 젯의 기초 진단 및 액체 내 활성 종들의 변화

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Abstract:

대기압 플라즈마는 식품, 농업, 환경 분야뿐만 아니라 생의학적 응용에서도 활성 종의 생성을 조절할 수 있는 매개물로서 많은 관심을 받고 있다. 저주파에서 발생시킨 대기압 플라즈마의 경우, 고주파의 경우보다 활성 산소 및 질소 종들의 생성이 더 풍부한 것으로 보여 진다. 이를 확인하기 위해 50 kHz에서 동작하는 단일 젯 형태의 플라즈마 젯에 pulsed DC 전압을 가하여 헬륨 플라즈마를 발생시켜 그 특성을 알아보고, 액체에 처리하여 활성 종들의 변화를 정량적으로 분석하였다. 특히, 방전 조건 중 duty ratio를 8~50%로 조절함에 따라 달라지는 플라즈마 형태와 전류-전압 특성, 광 방출 특성을 알아보았다. 플라즈마 처리된 증류수(deionized water, DW)에서 pH는 3.6 까지 낮아졌고, 전기전도도는 약 70 uS/cm까지 측정되었다. 또한, UV-Vis spectrophotometer를 통해 액체 내 O_3, NO_2^-, NO_3^-, H_2O_2의 양을 측정해 본 결과, 0.06-0.2 mg/L, 10-16 mg/L, 4-8.5 mg/L, 2.6-6.5 mg/L로 측정되어졌다. 방전 조건 중 인가전압이 증가함에 따라 액체 내 생성되는 활성종의 양이 증가되었고, duty ratio 8%일 경우가 전체적으로 높게 측정되었다. 이전에 연구했던 고주파 플라즈마 발생장치로 정량화되어진 활성 종의 양을 비교하였을 때, 저주파의 경우에 더 많은 NO_3^-, H_2O_2의 양이 생성되는 것을 확인하였다.

Keywords:

대기압 플라즈마, 활성 산소 및 질소 종, 플라즈마 처리 수

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지구 저궤도 플라즈마 환경모사를 위한 링-커스프 자기장 기반의 플라즈마 발생장치 개발 및 플라즈마 특성 조사

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Abstract:

저궤도 위성이 운용되는 200 - 2000 km 상공에는 밀도 10^{4-7} cm^{-3}, 전자온도 1 eV 수준의 플라즈마가 존재한다. 저궤도 플라즈마는 통신 및 지구 환경 이해에 있어서 과학적 가치가 있지만, 전기적 성질로 인하여 위성 전자장비에 복구 불가능한 손상을 초래하기도 한다. 따라서 위성 운용에서의 위험방지 및 대응방안을 위해서는 위성과 플라즈마 사이의 상호작용 예측을 위한 플라즈마 진단이 필수적이다. 위성에 탑재될 진단장비 검증 및 시험을 위해서는 넓은 범위의 저궤도 환경의 모사가 가능한 플라즈마 발생장치가 반드시 필요하다. 따라서 본 연구에서는 진단장비 지상시험용 저 전자 밀도 및 온도 발생을 목적으로 하는 반지름 100 mm, 길이 300 mm 의 원통형 플라즈마 발생장치를 개발하였다. 장치 내부에는 플라즈마를 가두기 위하여 장치 상단과 중단, 그리고 하단에 각각 15, 20, 10개의 영구자석을 배치함과 함께, 강자성 물질로 링-커스프 자기장 형상을 마련하였다. 이 자기장 형상은 원통 경계로부터 약 60 mm까지 30 - 40 G 수준의 자기장을 생성하여 원통 중앙 축으로부터 반지름 약 30 mm 크기의 전자 구속 영역을 만든다. 이때 본 연구실에서 개발한 전자 공급용 저전류 할로우 음극으로 플라즈마 방전을 개시 및 유지하였으며, 전자와 달리 자화되지 않는 소수의 이온만이 마련된 자기장을 통과하여 장치 외부로 빠져나갈 수 있도록 설계하였다. 생성된 플라즈마는 원형 평면 랭뮤어 탐침과 쉬스의 영향을 최소화 하기 위한 가드링 원형 평면 랭뮤어 탐침을 각각 사용하였고, 장치 입구로부터 57 cm떨어진 곳에서 이온밀도 10^{6-7} cm^{-3}와 전자온도 3-6 eV 수준의 플라즈마가 측정 되었다. 본 발표에서는 저궤도 플라즈마 환경모사를 위해 개발된 장치의 상세 구동 원리 및 구성과 장치 운전변수에 따른 플라즈마 특성 변화, 그리고 랭뮤어 탐침의 가드링 유무에 따른 플라즈마 측정치 변화를 살펴본다.

Keywords:

전리층, 플라즈마, 랭뮤어 탐침

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200 MeV 에너지 업그레이드를 위한 초전도 저온용기의 자기차폐 설계 기초연구

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Abstract:

한국원자력연구원 양성자과학연구단에서는 현재 운영중인 100 MeV 양성자가속기의 에너지를 200 MeV 로 업그레이드 하는 계획을 추진중에 있다. 초전도 기반 Half-wave Resonator (HWR)을 가속관으로 고려하고 있으며, 4개의 HWR을 1개의 저온용기에 설치하는 설계를 수행하고 있다. HWR의 설계 운전온도는 2 K 이며, 초전도 상전이시 구속된 자기장에 의한 표면저항을 3 nohm 이하로 하기 위해서는 운전 주파수인 350 MHz에서 자기장을 15 mGauss 이하로 제한하여야 한다. 본 연구에서는 HWR 주변의 자기장을 HWR 운전 조건에 맞도록 줄여주는 자기차폐에 대한 기초설계 연구에 대해서 발표한다.

Keywords:

양성자가속기

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Development of thin-foil based infrared bolometer system in KSTAR

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Abstract:

Plasma disruption – sudden loss of stored energy with the formation of runaway electrons (REs) and high electromagnetic loading – is an important issue affecting the safe operation of magnetically confined high-temperature plasma devices. The Shattered Pellet Injection (SPI) system installed on the KSTAR tokamak aims to mitigate the damages from the plasma disruption. To examine the performance of the SPI, we have developed a thin-foil based infrared (IR) bolometry system as a companion to a filtered AXUV bolometer system and a fast IR camera. When the radiation from plasma is absorbed by a carbon-coated thin platinum foil (platinum ~1.5 μm, carbon coating ~100 nm), the heated foil emits the black body radiation in the IR region, which is then measured by an IR sensor. We have performed modulated laser experiments and 3D heat transport simulations to measure the response time scale of the thin foil. Both the experimental and numerical results show that the characteristic time scale of the bolometer system is of the order of 100 ms. The thin-foil bolometer signals will be used to calibrate the companion AXUV signals. In addition, we adopt a pile-up signal analysis to extract faster response in the foil signals.
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Keywords:

plasma disruption, shattered pellet injector, infrared bolometer system, heat transport equation

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유도 결합 플라즈마에서 He 2^3S 준 안정 상태 원자 밀도에 따른 E-H 모드 전이에 관한 연구

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Abstract:

유도 결합 플라즈마는 에칭, 증착, 결정 성장 등 다양한 산업분야에서 활용되고 있다. 유도결합 플라즈마는 상대적으로 낮은 RF 파워와 낮은 플라즈마 밀도로 동작하는 E 모드와 상대적으로 높은 플라즈마 밀도를 가지는 H 모드로 동작할 수 있다고 알려져 있다. 유도 결합 플라즈마를 발생시키기 위해 Right-helical 타입의 RF 안테나를 사용하였다. 전원으로는 13.56MHz RF 전원을 사용하였으며, RF 전원의 최대 RF power는 1.5kW였다. RF 파워를 조절하며 방출광 스펙트럼을 측정하였으며, 방출광 스펙트럼의 세기를 이용하여 E 모드와 H 모드를 확인하였다. 1083nm의 파장 가변 레이저를 이용해서 2^3S-2^3P전이의 흡수 스펙트럼을 측정하였으며, 흡수 스펙트럼을 이용하여 모드 전환이 발생할 때의 헬륨 2^3S 준위의 밀도를 측정하였다. 측정한 헬륨 2^3S 준위 밀도는 방출광 세기 변화와 비교하여 분석하였다. 2^3S 준위 밀도는 방출광 스펙트럼과 유사한 hysterisis특성을 나타내었다.

Keywords:

inductively coupled plasma, laser absorption spectroscopy, mode transition, metastable state

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P1-pl.202

제트 플라즈마 전산모사를 통한 전기풍(Electric wind) 발생 연구

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Abstract:

전기풍이란 플라즈마 방전 시에 발생하는 중성기체의 흐름으로, 전기장에 의해 가속된 전자, 이온 등 하전입자와 충돌하며 운동량이 교환되는 과정에서 기체입자에 가해진 전기역학적 힘으로 인해 발생한다. 이 현상은 대기 내의 약이온화된 기체에서도 나타나 여러 자연현상의 발생 원인으로 주목받아 왔으며, 현상에 대한 연구를 위해 실험과 이론, 그리고 전산모사 등을 통해 다각도로 연구가 진행되어 왔다. 본 연구에서는 방전기체를 헬륨으로 사용하는 제트 플라즈마를 모사하는 2차원 전산모델을 개발하였으며, 함께 주입한 방전기체의 유속 외에 플라즈마에 의해 추가적으로 발생한 전기풍의 원인 등의 특성을 정량적으로 분석하였다. 3 kV 크기의 펄스 전압을 제트 전극의 입구 부분에 인가하였을 때 방전시작 시점부터 나노초 단위에서의 전자와 이온 밀도, 전하밀도와 전기장 세기 변화를 계산하였고, 계산된 변수를 바탕으로 펄스 전압이 주기적으로 인가된다고 가정하였을 때 플라즈마에 의해 추가적으로 발생되는 전기풍을 정량적으로 계산하였다. 전산모사를 통해 방전 이후 수백 나노초 동안의 전하밀도, 전기장 세기 등의 플라즈마 특성 변수의 시공간적 변화를 확인하였으며, 전자나 질소, 산소 이온보다 방전기체로부터 이온화된 헬륨 이온이 전기풍의 생성에 큰 영향을 미치는 것을 확인하였다. 이 연구를 통해 전기풍의 발생 원인 및 각 이온들이 미치는 영향을 정량적으로 분석할 수 있는 전산모델을 개발하였고, 이를 기반으로 다양한 형태의 각종 제트 플라즈마의 특성 분석과 동시에 전기풍 발생 원인을 분석할 수 있을 것으로 기대된다.

Keywords:

전기풍, 전산모사, 제트 플라즈마

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P1-pl.203

Al Hugoniot from model calculations including semicore electrons based on density functional theory

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Abstract:

We present Al Hugoniot from model calculations based on density functional theory. We improved previous two step calculations employing molecular dynamics simulations with an ambient electronic temperature and electronic structure calculations of the Al crystal with desired high electronic temperatures and with the ambient electronic temperature. We treated semicore electrons as valence electrons only for the electronic structure calculations of the Al crystal. We employed VASP program to perform density functional theory calculations for Al Hugoniot. Our result is in better agreement with available experimental data and theoretical calculations in the literature than our previous density functional theory calculations with three valence electrons.

This work was supported by the Defense Research Laboratory Program of the Defense Acquisition Program Administration and the Agency for Defense Development of Republic of Korea.

Keywords:

Al, Hugoniot, Density functional thoery, Molecular dynamics

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P1-pl.204

Development of one dimensional full wave spectral code for the ICRF H&CD of a nuclear fusion reactor

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Abstract:

A full wave spectral code has been developed for the analysis of Ion Cyclotron Range of Frequency (ICRF) H&CD (Heating and Current Drive) and the design of the ICRF antenna launcher. The final object is to develop 2D full wave spectral code to include poloidal propagation and absorption reflecting more realistic tokamak geometry. As an intermediate step, one dimensional full wave code is developed to make sure the validity of the spectral algorithm and identify the probable problems in the course of 2D code development such as calculation time or code errors. The governing equation is Maxwell-Vlasov equation and the boundary condition is a perfect conductor. The code is composed of three main calculation parts and a post processing part. Main three parts are initialization, matrix construction, and solving part. The input data is imported, and mesh-plasma-wave parameters are initialized in the initialization part. A conductivity tensor is calculated at each mesh point and a matrix equation is made of Maxwell-Vlasov equation of Fourier mode in the matrix construction part. Finally, the matrix is solved and the Fourier mode solution is saved in the solving part. In the post processing part, electro-magnetic field, power flow and absorption are calculated and plotted. As a test for the developed 1D code, the heating and power flow of ICRH is calculated for the KSTAR hydrogen minority D(H)plasma. It turns out that the most ICRF power is absorbed by the hydrogen minority as expected and the power flow is consistent with the power absorption. The detailed code development status and test calculation result will be presented in the meeting.

Keywords:

hot plasmas, ICRF, full wave, spectral, code

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P1-pl.205

Experimental Observations of Interaction between Runaway Electrons and Fast Waves in Versatile Experiment Spherical Torus (VEST)

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Abstract:

Relativistic runaway electron (RE) causes severe damage to tokamak device. The runaway avalanche increases exponentially with pre-disruption plasma current and expected damage for ITER or fusion reactor is inestimable. To resolve these concerns, most of the effort has been focused on RE mitigation schemes utilizing massive gas injection and pellet injection. However, these schemes have inherent limitation of expecting energy loss of ‘runaway’ electrons via collisions. Recently, theoretical and experimental researches on collisionless wave-particle interaction between REs and fast waves have been actively studied as a possible RE mitigation scheme after pioneering results in DIII-D. In this presentation, recent results on measurement of hard x-ray and fast waves in Versatile Experiment Spherical Torus (VEST) experiments are presented. Energy spectrum from hard x-ray detection and spectrogram from wave measurements are discussed in relation to the wave-particle interaction between the REs and fast waves.

Keywords:

runaway electron, fast wave, wave-particle interaction, VEST

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P1-pl.206

인공신경망을 이용한 토카막 플라즈마 내 불순물 수송 코드 백워드 모델 개발

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Abstract:

토카막 플라즈마 내에 존재하는 높은 질량의 불순물은 노심 내에 축적되면 높은 방사냉각을 발생시킬 뿐만 아니라 연료이온의 농도를 희석시켜 감금성능에 치명적인 영향을 미친다. 따라서, 불순물 수송현상 분석을 통해 노심 내 불순물의 농도를 제어하는 것은 필수적이다. 기존에는 토카막 내 불순물의 수송 분석을 위해 KAIST Impurity Modeling (KIM) [1] 코드를 기반으로 한 포워드 모델을 사용하여 Compact Advanced EUV Spectrometer (CAES) [2] 와 VUV 진단시스템에서 측정된 실제 진단데이터와 비교를 반복 수행함으로써 허용오차 내의 불순물 입자의 수송계수를 휴리스틱하게 도출한다. 본 연구는 불순물 수송계수의 도출과정을 효율적으로 개선하고자 KIM 코드를 기반으로 인공신경망을 활용한 백워드 모델을 개발하여 불순물 입자의 수송계수를 자동적으로 도출하는 것을 목표로 한다. 백워드 모델은 각 시간대의 불순물의 프로파일 정보와 플라즈마 진단데이터를 포함하고 있는 행렬이 입력값으로, 대응하는 수송계수를 출력값으로 설정하여 학습이 진행된다. 후처리 된 EUV 영역의 공간분해된 스펙트럼을 바탕으로 계산된 불순물 분포를 KIM코드로부터 계산된 결과값과 인공신경망으로부터 도출된 결과를 비교하여 개발된 알고리즘의 유효성을 검증한다.

참고문헌:

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Keywords:

인공신경망, 불순물 수송, KSTAR

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P1-pl.207

Development of 2D Plasma/Neutral Transport Simulation System from Core to Wall in KSTAR

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Abstract:

Interactions between the plasma and the tokamak wall are getting more attention because of the importance of reducing the wall damage from the core plasma and the effect of impurity transport from the wall to the core plasma in long time-scale operations [1, 2]. Due to the open magnetic field line and the complex geometry of the tokamak structure, the two-dimensional modelling should be considered to describe those interactions. Here, the reliable grid generation, as well as the coupled core-edge-SOL simulations, are very important. In this presentation, we focus on the development of two-dimensional plasma transport simulation system in the region from the first wall to the tokamak core composed of VEGA2.0 [3, 4], a grid generator and C2 [5], a 2D plasma transport code. The computational domain was modified by applying a mapping method to VEGA2.0. And the heat flux contribution was improved in the region where the magnetic surface and the grid is misaligned due to the open field lines by considering the cross-diffusion in C2.
In order to validate this simulation system, some KSTAR discharge was reproduced with the theory based transport model in the core and Braginskii's model in the SOL region. The results of core plasma were benchmarked one-dimensionally with that of ASTRA [6], 1D plasma transport code. The divertor heat flux was calculated and compared with the experimental data, and the distribution of the particle flux was investigated on the wall.

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Keywords:

Plasma simulation, Plasma wall interaction, Plasma transport, Integrated Simulation

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P1-pl.208

Disruption prediction in KSTAR using Neural Network

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Abstract:

A plasma disruption occurred by plasma instabilities during high performance Tokamak plasma operations can form a large amount of heat flux on the wall of the device, causing fatal damage. For future ITER or other nuclear fusion reactor plasma operations, controlling plasma disruption is essential. Recently, with development of machine learning and deep learning, neural network is applied in many tokamak problems, including the real time control system [1], modelling of transport phenomena [2], transport simulations [3], and predicting plasma disruption in JET and DIII-D [4]. In this research, neural network is applied for predicting plasma disruption using KSTAR disruption database and checking effects of plasma parameters in disruption with RNN(Recurrent Neural Network), to predict disruption with time-series data.

References**:**
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[2] O. Meneghini et al., Physics of Plasmas 21, 060702 (2014)
[3] O. Meneghini et al., Nucl. Fusion 57, 086034 (2017)
[4] Julian Kates-Harbeck et al., Nature 568, 526-531 (2019)

Keywords:

Disruption, tokamak, KSTAR, Neural Network, Recurrent Neural Network

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P1-pl.209

The Cs-free Negative Hydrogen Ion Source Project at KAERI for Future N-NBI Systems

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Abstract:

Due to reliability issues in using cesium (Cs) for efficient hydrogen negative ion production in ion sources for negative ion based neutral beam injection (N-NBI) systems in fusion research, many researchers have explored Cs-free alternatives to Cs for a future DEMOnstration power station (DEMO) NBI system. The Korea Atomic Energy Research Institute (KAERI) recently launched a new project in collaboration with Seoul National University (SNU) in order to identify an efficient Cs-free negative ion source based on the volume production mechanism, for fusion application. In this project, we attempt to improve efficiency of the volume negative ion source by introducing plasma pulsing. The plasma pulsing, which is also called temporal filter, refers to a method of modulating power that sustains the plasma and consequently the electron energy. Supplying negative ions at high densities by the pulsing is, however, inherently transient and its duration is short. In view of a future DEMO, a significant drawback of the pulsing is being unable to continuously supply the negative ions to an extraction system. To remedy the drawback, and consequently to develop a novel promising Cs-free alternative, we devised a multi-pulsed ion source. The multi-pulsed ion source included more than two plasma sources and magnetic filters operates with an alternating pulsing sequence of the plasma sources. The temporal and magnetic filters named spatiotemporal filters may enable this ion source to continuously supplying the negative ions, leading to the development of the efficient Cs-free negative ion source. In this presentation, the overview of the Cs-free negative hydrogen ion source project at KAERI, the new ion source concept, and its preliminary experimental results will be presented and discussed in detail.

Keywords:

Ion source, Pulsed plasma, Hydrogen plasma, Neutral beam injection, Negative ion

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P1-pl.210

Comparison of KSTAR impurity measurements with neoclassical impurity transport theory

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Abstract:

Sputtered impurities from plasma facing components (PFC) of tokamaks can be problematic when they transport to the center of plasmas and accumulate. To address these issues, we analyzes the results of tungsten impurity injection experiment of KSTAR tokamak using neoclassical transport theory. In a KSTAR experiment (#16958), the injected tungsten impurity are observed to be highly collisional and high rotational, but very it has a low impurity density (trace limit) with various charge states. Because of the high charge number (Z>20), it is likely to be analyzed by the neoclassical transport theory, especially in Pfirsch-Schluter regime [1-5]. We simulate two neoclassical transport codes NEO [6] and PERFECT [7] to interpret the experimental results, by which, the density of many charge states are calculated using emission line diagnostics and a novel topology algorithms in a code, KIM [8]. We found that the particle fluxes of the neoclassical codes are comparable to the estimated values in KIM, but the radial profiles are different depending on many parameters affecting the particle flux; (1) main ion pressure and temperature gradients, (2) various charge state and its different density gradients, (3) impurity toroidal flow (Mach number), and (4) local or global assumptions. Additionally, we study the charge reduced method [1,4,5] to interpret the many charge state as a single effective charge, and show its validity and limitation for the highly rotational impurities of the KSTAR experiments. These theoretical analysis will be useful in estimating the high-Z impurity behaviors of the ITER like walls.

Keywords:

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P1-pl.211

Study of Hydrogen-isotope permeation in Tungsten for fusion applications

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Abstract:

The permeation behavior of hydrogen isotopes in tungsten was experimentally for fusion applications. The tungsten sample was fabricated into disks 20 mm in diameter, 0.2 mm in thickness. Detailed results are presented, and our results are also compared with those previously reported by other authors.

Keywords:

Tungsten, Deuterium, Transport, Permeation

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P1-pl.212

Investigation of the n=0 MHD resistive wall mode in a tokamak with the effects of a negative triangular plasma shape

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Abstract:

The n=0 MHD resistive wall mode (RWM) is the dominant mode initializing the vertical instabilities, which determine the maximum elongation of a tokamak. In our previous study [1], we used the feedback capacity parameter of a system to optimize several plasma parameters of the shape and profiles for the maximum elongation against the n=0 RWM mode. Recently, some beneficial effects of a negative triangularity has been observed experimentally and theoretically. The electron heat transport is shown to be decrease in the negative triangularity in the shape of TCV tokamak [2], and a specific plasma profile is theoretically found to increase the normalized beta by reducing localized Mercier/ballooning modes and interchange modes [3]. However, the n=0 MHD resistive wall mode has not been extensively studied except the recent report [4] for the negative triangularity, in which the vertical instability can be problematic. For this study, we investigate the effects of the negative triangularity on the n=0 resistive wall mode. We used a fixed wall boundary that is close to the DIII-D wall shape with various plasma profiles of poloidal beta and internal inductance. Unlike the positive triangularity, the negative one has a big different in a shape with the wall boundary. Therefore, there is a large distance between the plasma and the wall over most poloidal positions. The effects of the increased instability due to the gap distance are quantitatively evaluated in our simulations for the negative triangularity.
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[3] S. Y. Medvedev et. al., Nuclear Fusion 55 (2015) 6
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Keywords:

Negative triangularity

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P1-pl.213

Geometric effect on profile flattening of magnetic island in Tokamak

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Abstract:

Magnetic island is manifestation of magnetic field reconnection by tearing mode, particularly, neoclassical tearing mode in tokamaks. Considering that neoclassical tearing mode has been observed to degrade plasma confinement and even cause plasma disruption, understanding its physics is getting more and more important in moving toward stable operation of Tokamak. In this research we carried out electrostatic gyrokinetic turbulence simulations with fixed magnetic island using GENE (Gyrokinetic Electromagnetic Numerical Experiment). We present effect of geometric parameters on profile flattening inside the magnetic island and discuss its implication and underlying physics.
This work has been supported by National Research Foundation under basic research program of nuclear fusion, NRF-2019M1A7A1A03088462 and NRF-2017M1A7A03072766.

Keywords:

nuclear fusion, tearing mode, magnetic island, gyrokinetic

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P1-pl.214

KSTAR H-mode 플라즈마에서 D_2 연료개스 및 Ne 개스 주입에 의한 경계 플라즈마 물성 변화 분석

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Abstract:

ITER 및 DEMO와 같은 미래 핵융합 장치들에서 노심 플라즈마로부터 벽면 및 디버터로 전달되는 막대한 열속 및 입자속을 제어하는 일은 지속 가능한 장치운전을 위해서 반드시 해결되어야 할 과제이다. 이 문제의 해결책의 하나로, D_2 연료개스 또는 불순물 개스를 주입하고 하전입자와 중성입자들 간의 상호작용 및 에너지 방사를 통해 디버터 타겟에 도달하는 열속을 줄이는 디버터-플라즈마 분리에 대한 연구가 전세계적으로 활발히 진행되고 있다. 본 연구에서는 경계 플라즈마 해석 코드인 SOLPS-ITER를 이용하여 KSTAR H-mode 플라즈마에서 D_2 연료개스 및 Ne 개스를 주입하였을 때 디버터 타겟의 열속 및 입자속을 포함한 경계 플라즈마의 물성 변화를 분석하였다. 다양한 가열 파워 및 플라즈마 전류 조건(3.0-4.0 MW, 0.5-0.7 MA)에서 D_2 연료개스 주입 실험을 수행하였으며 각각에 대하여 디버터-플라즈마 분리가 일어나는 개스 주입량 및 노심 전자밀도값을 알아내었다. 예측되었던 바와 같이, 가열 파워와 플라즈마 전류가 커질수록 높은 노심 전자밀도가 요구되었으며, 플라즈마 전류와 디버터-플라즈마 분리 달성에 필요한 노심 전자밀도의 관계를 열속 감쇠 길이(λ_q)의 변화와 연관지어 설명하였다. Ne 개스 주입 실험의 경우 D_2 연료개스 주입 실험보다 높은 노심 플라즈마 가둠성능을 유지하면서 디버터-플라즈마 분리 달성이 가능할 것으로 예상되었으나, 경계 플라즈마에 거의 영향을 주지 않고 노심 가장자리에 축적되어 붕괴를 일으켰다. Ne 개스의 수송 기작 및 pedestal 변화와 함께 그 원인을 분석해 볼 예정이다. SOLPS-ITER 전산모사를 통해 방사파워 형상 등의 실험결과를 정성적으로 재현하였으며, 더 나아가 정량적으로 재현하는 것에 목표를 두고 있다. 본 연구는 미래 토카막들의 디버터-플라즈마 분리 달성 조건을 예측하는 scaling law 개발에 기여할 것이며, SOLPS-ITER와 같은 전산코드에 사용되고 있는 경계 플라즈마 모델을 보완하고 검증하는데 기여할 것으로 예상된다.

Keywords:

KSTAR, H-mode, 디버터-플라즈마 분리, SOLPS-ITER

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P1-pl.215

Development of a full-orbit plasma particle trajectory code for the wave-particle resonance of energetic ions in a tokamak

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Abstract:

The topology of the particle orbits in the inhomogeneous background magnetic fields of a tokamak is important to determine the wave-particle interactions especially for the energetic ions due to its large orbit width. The wave -particle interactions can be seen a diffusive process in a velocity space or in a configuration space, which makes the distribution function somewhat flat or the radial profile flat, respectively. In this study, to calculate the realistic phase space diffusion of the energetic ions in the electromagnetic field, we develop a full particle trajectory code using the Boris algorism in a Boozer coordinate. This code can be applicable to the perturbed electromagnetic wave fields of tokamaks such as Toroidal Alfvén eigenmode (TAE) and ICRF waves with considering both effects of gyro-orbits and banana orbits, which may be important for the energetic particles. For the reliability of the code calculating in a long particle orbit, Boozer coordinate which makes magnetic field line straight is essential and we construct field line that fits the realistic poloidal geometry of a tokamak by using the MHD equilibrium code, ECOM [1]. With the code, we examine the change of particle energy, magnetic moment, and canonical toroidal angular momentum by the resonant interactions in the particle trajectory including gyromotion and banana motions.

[1] J. P. Lee, A Cerfon, Computer Physics Communications 190, 72 (2015)

Keywords:

Particle code, Plasma, Magnetic field, ECOM, Boozer coordinate

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P1-pl.216

토카막 플라즈마 진단에 활용되는 분산간섭계의 광정렬 문제를 개선하는 Single Crystal Dispersion Interferometer(SCDI)의 개발 및 설치

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Abstract:

분산간섭계는 기계적 진동으로 인한 소음을 감쇄시키는 장점을 가지며 다양한 핵융합 연구시설에서 플라즈마 밀도 변화 측정에 활용되고 있다. 10.6um의 파장을 사용하는 기존의 분산간섭계와는 달리, KSTAR에서는 1,064nm 파장의 Nd:YAG 레이저를 사용하여 shattered pellet injection(SPI)으로 발생되는 급격한 플라즈마 밀도 변화를 진단할 수 있도록 하였다. 이 과정에서 기존의 분산간섭계처럼 비선형 결정을 2개 사용할 경우 25m에 달하는 광경로를 정렬하기 어렵다는 문제점을 발견하고, 이를 개선하는 새로운 분산간섭계 시스템인 Single Crystal Dispersion Interferometer (SCDI)를 개발하였다. SCDI 시스템은 비선형 결정을 1개 사용하되, frequency doubler(RF소자의 일종)를 사용하여 기계적 진동으로 인한 소음을 감쇄한다. 이를 통해 기존의 분산간섭계보다 쉽게 간섭계를 구성할 수 있게 하였다. 본 발표에서는 KSTAR 플라즈마 밀도 변환 측정을 위한 SCDI의 개발 및 설치 내용과 측정된 초기 데이터를 소개한다.

Keywords:

Interferometer, Dispersion Interferometer, Nuclear Fusion, Plasma, KSTAR

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P1-pl.217

Introducing unstructured mesh support to a developing gyrokinetic code, gKPSP2

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Abstract:

To solve governing differential equations over complex geometry, it is imperative to create and utilize unstructured mesh, in general. National Fusion Research Institute started developing a gyrokinetic simulation code, gKPSP2, to aim at a whole device modeling for real geometry of Tokamaks such as KSTAR, ITER and K-DEMO. Handling the entire domain of Tokamak is expected to require high performance parallel computation over more than 1M real space elements in addition to velocity space elements for each real space element.

In this presentation, we introduce the code development in the mesh perspective and show how unstructured mesh is created for realistic Tokamak geometry and what functionalities are required to support the unstructured mesh in parallel use for gKPSP2.

* This research was supported by R&D Program of "Study of an efficient SOL discretization algorithm for global ITER burning plasma simulation (code No. IN2004-6)" through the National Fusion Research Institute of Korea (NFRI) funded by the Government funds.

Keywords:

Unstructured mesh, Whole device modeling, Gyrokinetic code, High performance computing

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P1-pl.218

Development of a Fokker-Planck code with Rosenbluth potentials using MFEM library

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Abstract:

Through various studies so far, Fokker-Planck equation is solved numerically to analyze the kinetic effects of plasmas in a tokamak. However, in some cases, the application of the numerical solver is limited because the equation is linearized or the solver uses the spectral mesh grid (e.g. Legendre polynomial). Thus, it is necessary to solve the nonlinear Fokker-Planck equation in a more flexible grid in a velocity space for analyzing the self-collisions of majority ions or implementing energy source or sink models.

We are developing a code, which solves the nonlinear Fokker-Planck equation with Rosenbluth potentials for a non-relativistic problem by using finite element method (FEM). The mesh domain used in calculation are discretized in 2-D velocity space, as we assume a axially symmetric cylindrical coordinate. The code is based on the MFEM [1], which is a finite element discretization library developed at CASC and LLNL, and opened to the public. By using the well-established FEM package, we can obtain a better accuracy of the solution and more flexible options to be parallelized easily and have different types of mesh and basis. We verify the suitability and the numerical conservation of our code by comparison with the E. Hirvijoki`s paper [2].

[1] Robert Anderson et. Al., LLNL, MFEM: A Modular Finite Element Methods Library (2018)
[2] E. Hirvijoki and M. F. Adams, Phys. Plasmas 24, 032121 (2017)

Keywords:

Plasma, Fokker-Planck equation, Rosenbluth potentials, Finite element method, MFEM

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P1-pl.219

Effects of target materials on the heat flux at divertors in KSTAR

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Abstract:

The effects of target materials on the heat flux load on divertors are investigated in two different divertor geometries of KSTAR: current KSTAR design and PFC upgrade design. Using the SOLPS-ITER code, we compare the recycling of neutral particles in the divertor region for carbon and tungsten as the divertor materials. The heating power is set to 24 MW, which is very high and compatible with the KSTAR upgrade plan of NBI and ECH. We find that the temperature and heat flux near the divertor are affected by divertor materials, as the particle and energy reflection coefficients change depending on the material. For both the current KSTAR design and the PFC upgrade design, the tungsten divertor shows significantly lower electron temperature and slightly lower heat flux load than the carbon at the inner target, whereas opposite behaviors are observed at the outer target. The analysis of simulation data shows that the change in the density distributions of D and D_2 , depending on the materials, are related with those results.

Keywords:

Divertor, Target materials, SOLPS-ITER

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P1-pl.220

KSTAR 플라즈마에 주입한 크립톤 밀도에 따른 ELM 완화 및 내부수송장벽 생성 현상 연구

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Abstract:

토카막 핵융합장치의 노심 플라즈마로부터 방출되는 높은 열속으로부터 내벽을 보호하는 것은 장치의 안정적인 운전을 위한 중요한 과제이며, 불순물 개스 주입은 이를 달성하기 위한 효과적인 방법 중 하나로 여겨지고 있다. 본 연구에서는 KSTAR에서 다양한 조건의 크립톤 주입 실험을 통하여 플라즈마 내의 크립톤 밀도에 따른 현상을 분석하였다. 분석에 주로 활용된 진단계는 적외선 이미징 볼로미터(IRVB) 로, 전자온도 및 밀도에 따른 방사냉각계수를 활용하여 크립톤의 밀도분포를 계산하였다. 전자밀도 대비 크립톤 밀도의 피크 값이 작을 때에는 플라즈마 변수 및 ELM의 변화가 없었으나, 중간 수준(코어 전자밀도 대비 약0.10%)에서는 전자밀도, 노심 전자온도 및 플라즈마 축적에너지가 약간 감소되나 ELM이 완화되는 것을 관찰하였다. 크립톤 주입량을 더 증가시켰을 때에는 ELM이 완전히 억제되었으며 피크 크립톤 밀도 역시 증가함을 확인하였다. 또한 충분히 높은 크립톤 주입실험을 통해ELM 완화 이후 내부수송장벽(ITB)의 형성에 성공하였다. 이 실험에서 플라즈마 중심부 영역에서 이온 및 전자 온도, 토로이달 회전속도의 급격한 상승이 관찰되었고, 또한 디버터로의 열속 및 입자속이 상당히 감소함을 확인하였다. 위 실험들을 바탕으로 크립톤 밀도에 따른 ELM 완화 및 내부수송장벽 생성에 미치는 기작 이해를 위한 해석이 진행되고 있으며, 불순물 scaling law 확립에 기여할 것으로 기대한다.

Keywords:

#Tokamak plasma, Impurity, KSTAR

P1-se.101

Magnetic field controlling of the thermoelectric efficiency under spin density waves

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Abstract:

The thermoelectric efficiency is given by the dimensionless figure of merit ZT. The ZT is characterized by the ZT = $\sigma S^2 T/\kappa$, where S, σ, T, and κ are the Seebeck coefficient, electrical conductivity, absolute temperature, and thermal conductivity, respectively. Here adopting minimal two band model, we calculated the thermoelectric properties by the Kubo formula for the isotropic momentum spin density wave (SDW) order. Our results show that SDW gap dramatically enhance the electric thermoelectric properties. Turning on the magnetic field, it reduces the SDW gap and acts as Lorentz's force in the transport process. In this study, we consider Pauli-limit for the SDW gap renormalization and keep only the linear dependence of the vector potential in the transport process. The calculated magnetic field dependent transport coefficients and thermoelectric efficiency will be presented and discussed about its applications.

Keywords:

thermoelectricity, spin density wave, magentic field, transport

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P1-se.102

에너지 수확을 위해 마찰전기 폴리머에 내장된 ZnO 나노 플레이크의 합성 및 특성

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Abstract:

마찰전기 나노발전소자는 간편하고 비용 효율적이며 친환경적인 장치 구조와 다양한 응용 분야로 인해 더 많은 연구 관심을 얻고 있다. 마찰전기 나노발전소자는 마찰 전기 및 정전기 유도를 기반으로 작은 기계적 에너지를 전기 에너지로 변환한다. 그러나, 나노발전소자의 전기적 출력은 마찰전기 물질의 유전 상수에 크게 의존한다. 따라서, 마찰전기 필름의 유전 상수를 증가시키면 전하 전위가 향상되어 전기 출력이 향상될 수 있다. 본 발표에서는 ZnO 나노 플레이크를 합성하여 다른 중량비로 나일론 폴리머에 로딩하여 다양한 유전체 필름을 형성하였다. 합성된 양의 성향을 갖는 다양한 유전막을 이용하여 아치형 나노발전소자를 제작하고, 외부 기계적 힘을 가하여 반대로 대전된 마찰 전층에 대해 작동시켰다. 소자의 전기적 성능은 나일론 필름의 ZnO 농도가 증가함에 따라 증가했다. V_{OC}, I_{SC}, 전하 밀도 및 전력 밀도 값들이 측정되었다. 최적화된 ZnO 나노 플레이크기반 마찰전기 나노발전소자에서 생성된 전기는 다양한 휴대용 전자 제품에 전력을 공급하고 일상 생활에서 기계 에너지를 수확하는 데 사용될 수 있다.

Keywords:

마찰전지, 나노발전소자, ZnO

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P1-se.103

A Highly Efficient Soot Based Bilayer Solar Vapor Generator

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Abstract:

Solar driven vapor generation has the potential to address the global challenges in terms of water scarcity and energy crisis. In recent years, various strategies have been adopted to enhance the solar vapor generation efficiency. Herein, we demonstrated the vapor generation capability of a bilayer solar vapor generator (BSVG), which is comprised of a candle soot collected over a filter paper (FP), yielding a hydrophobic(soot)/hydrophilic(FP) interface that naturally enables the BSVG to float. BSVG possesses high photothermal conversion owing to the broadband solar absorption and heat localization considering low thermal conductivity offered by the soot. In addition, the hydrophilic nature of the FP endows BSVG with the effective capillary actions essential for the rapid water transport to the evaporation surface. Benefitting from synergetic effect of these characteristics, we attained a high evaporation rate ~1.45 kg m^{-2} h^{-1} with a vapor generation efficiency of 95.67% under one sun irradiation. Besides, BSVG shows a high stability over 12 repeated cycles. Finally, the low cost, facile fabrication, working durability and easy recyclability of BSVG endows it with the capability to be applicable on large scale.

Keywords:

solar vapor generation, broadband solar absorption, capillary actions, heat localization.

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P1-se.104

Simple and Facile Fabrication of Anion Vacancy Induced MoO_{3-x} Catalysts for Enhanced Hydrogen Evolution Activity

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Abstract:

Advanced catalysts for clean hydrogen generation and storage offer attractive possibility of developing a sustainable and eco-friendly future energy system. Especially, transition metal oxides (TMO) are appealing candidates to be largely considered as electrode catalysts. However, for practical applications, there are still challenges that the intrinsic catalytic properties of TMOs should be further improved and those TMOs should be synthesized by practical routes for cost-effective and scalable production of catalysts. Therefore, to this end, finding promising ways to efficiently produce highly active TMOs with outstanding electrochemical performance is important to signify the virtue of hydrogen evolution catalysts. Herein, we present the direct and facile synthetic approach to successfully provide highly efficient MoO_{3-X} catalysts with electrochemically active oxygen vacancies through the one-step thermal activation process on a Mo metal mesh. Variations in the oxidation states of molybdenum oxides can significantly increase the active sites of the catalysts and improve the electrochemical activity, making these oxide compounds suitable for HER. [U1] [u2] Comparing to the bare Mo mesh and fully oxidized Mo (MoO_3) electrodes, the fabricated MoO_{3-X} electrode exhibits the better electrochemical performance in terms of the overpotentials and Tafel slope as well as the electrochemical 1,000 cycling stability, confirming the improved HER performance of MoO_{3-X}. Our finding provides new insight into the simple-procedure suitable for the large-production supply.

Acknowledgments
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Keywords:

Oxygen vacancy, Anion deficient molybdenum trioxide (MoO3-X), Hydrogen Evolution Reaction

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P1-se.105

Electron beam engineered monolayer MoS_2 for an efficient hydrogen evolution reaction electrocatalyst

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Abstract:

Among the electrocatalytic water splitting hydrogen evolution reaction (HER) research, numerous studies have been currently carried out on the two-dimensional materials to an alternative for the non-precious catalysts, in which monolayer (ML) MoS_2 has been considered to be an ideal candidate. On the other hand, thermal-dynamically stable 2H phase MoS_2 have a limit HER performance because of low density of active edge sites and poor conductivity. However, the engineering MoS_2 from semiconductor 2H to metallic 1T phase could improve fundamentally the HER performance due to favorable conductivity and enhancing active sites density. In this work, we have adopted the electron beam to induce the phase transition for ML MoS_2 confirmed through photoluminescence and Raman scattering. The pristine ML 2H MoS_2 was synthesized by the metal-organic chemical vapor deposition. The linear sweep curve and corresponding Tafel plot shows an strong improving HER performance for obtained 1T phase sample, as its overpotential and Tafel slope much lower than that of 2H phase sample. Our research shows that the electron beam treatment is an effective route to changing MoS_2 phase and hence enhancing significantly electrocatalytic HER activity

Keywords:

hydrogen evolution reaction, 1T & 2H phase, MoS2, electron beam

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리튬 이온 배터리용 음극재로 Fe_2VO_4 나노 구 구조의 합성 및 특성

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Abstract:

나노 크기의 전극 재료의 수집을 피하는 것은 고용량의 이점을 효과적으로 활용하기 위한 중요한 점이다. 본 발표에서는 Fe_2VO_4@rGO 복합재를 제조하기 위해 질소 도핑된 환원 그래핀 옥사이드 (rGO: reduced graphene oxide) 나노 시트에 캡슐화된 철 바나데이트 (Fe2VO4) 다공성 나노 구를 준비하기 위해 간단한 용매 열 처리가 개발되었다. Fe_2VO_4@rGO 복합재는 리튬 이온 배터리의 음극 재료로 사용된다. 제작된 Fe_2VO_4@rGO 복합 양극은 부피 변화를 크게 능가하고 운동 전달 특성을 향상시킬 수 있다. Fe_2VO_4@rGO 복합 음극은 우수한 전기화학특성을 나타냈다. 따라서, Fe_2VO_4@rGO 복합재는 차세대 리튬 이온 배터리의 고급 음극 소재로 유망하다.

Keywords:

리튬 이온 배터리, 복합재, 전기화학적 특성

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P1-se.107

리튬 이온 배터리의 음극으로 바인더가 없는 3차원 Co_3O_4/Ni 복합 구조의 합성 및 특성

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Abstract:

바인더가 없는 전극의 손쉬운 제작은 고성능 리튬 이온 배터리에 대한 상당한 관심을 끌어왔다. 반면에, 에너지 저장 응용 분야를 위한 복잡한 마이크로/나노 구조 재료를 제작하는 것은 중요하다. 특히, 잘 조직된 형태를 가진 다공성 3차원 구조의 형성은 다양한 구조적 특성으로 인해 에너지 저장 연구 분야에서 주목할만하다. 본 발표에서는 다공성 2 차원 육각형 Co_3O_4 미세 구조를 3차원 니켈 폼위에 성공적으로 증착하여 간단하고 비용 효율적인 수열합성법을 통해 3차원 Co_3O_4/Ni 복합 구조를 제작했다. 이러한 복합재는 리튬 이온 배터리용 바인더가 없는 음극 재료로 정확하게 조사될 수 있다. 바인더가 없는 3차원 Co_3O_4/Ni 복합 전극은 더 나은 가역성과 안정적인 속도 성능을 나타냈다. 이러한 3차원 Co_3O_4/Ni 복합 전극의 우수한 전기화학적 성능을 획득하여 고성능 리튬 이온 배터리의 잠재적인 음극 재료로 가능성이 크다.

Keywords:

리튬 이온 배터리, 수열합성법, 3차원 복합 구조, 전기화학적 특성

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Cubic CdS 단결정 박막의 엘립소메트리 및 투과 측정

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Abstract:

Cubic CdS는 II-VI족 화합물 반도체로서 에너지갭은 약 2.50 eV 정도를 가지며, 직접천이형 반도체로서 자외선과 가시광선 영역에서 효과적으로 활용할 수 있는 광전도 전지나 광전자 장치에 널리 사용되어지고 있다. 박막들은 열벽적층성장법 (Hot-Wall Epitaxy; HWE)으로 GaAs(100) 기판위에 성장시켰다. 성장된 박막들의 결정구조와 결정성을 알아보기 위하여 XRD 패턴과 HRXRD 스펙트럼의 반치폭을 이용하였고, 표면상태를 확인하기 위하여 Nomarski 간섭현미경과 SEM-EDS을 사용하였다. 또한 광학적 특성을 알아보기 위하여 분광학적 엘립소미트리을 이용하여 측정하였고, 측정된 박막의 데이터들은 복소유사유전함수인 $\langle\varepsilon\rangle=\langle\varepsilon_1\rangle+i\langle\varepsilon_2\rangle$를 실온에서 2.0-8.5 eV의 포톤에너지 범위에서 얻을 수 있었다. 광학적 유사유전함수의 결과로부터 반사율(R), 굴절지수(n), 소광계수(k) 흡수계수(α) 등을 얻을 수 있었다. 타원편광분석법을 이용하여 획득된 데이터의 이계도함수를 이용하여 E0, E1, E2 그리고 두개의 E0’, E1’ 로 표현되는 임계점 피크를 구하였다.

Keywords:

Cubic CdS , 엘립소메트리 , 투과 측정, 열벽적층성장법, 유사유전함수

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Characteristics of Ga2O3 solar-blind photodetector fabricated by pulsed laser deposition

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Abstract:

Ultraviolet light in 200 to 280nm wavelength band is mostly absorbed into the atmosphere and is called solar-blind. Because the solar-blind photodetectors (PDs) are not significantly affected by the sun's radiation, they have various applications such as missile guidance sensor, detecting ozone holes, etc. Wide-bandgap semiconductors such as SiC (2.3-3.2 eV), GaN (~3.4 eV), ZnMgO (~3.7 eV) and Ga2O3 (4.4-5.3 eV) can be used for the solar-blind PDs. However, Ga2O3 has many advantages for the solar-blind PDs over other wide-bandgap materials due to its excellent cut-off edge of 280 nm and low fabrication cost. In this work, we fabricated Ga2O3 based solar-blind PD by using pulsed laser deposition (PLD). Ga2O3 films were deposited on quartz substrates at room temperature for 1 hour by PLD with 30m torr oxygen pressures. After the PLD deposition, Ga2O3 films were post-annealed at temperature ranges from 450 to 600 ℃ for 30 minutes. The Ga2O3 photodetector with Au interdigitate pattern showed the highest photoresponsivity of 0.5 AW-1, and the fastest response speed of 0.1s at 500℃. This work will be discussed further on the effect of annealing temperature for high-quality solar-blind PDs.

Keywords:

Ga2O3, Solar-blind photodetector, Wide band gap semiconductor, Pulsed laser deposition, Furnace annealing

Effect of internal electric field according to the strain of InAsSb/GaSb interface

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Abstract:

In this study, InAsSb/GaSb grown by the molecular beam epitaxy (MBE) method was grown to investigate the interface. The modified zinc-blende semiconductor heterostructure grown with InAsSb/GaSb is greatly influenced by the internal region generated by the piezoelectric effect. The electric field generated by this deformation changes the properties of InAsSbd and GaSb, and this change in properties is caused by electricity. It appears as an optical effect. Using these characteristics, this study intends to investigate the change of the interface between GaSb and InAsSb by growing InAsSb/GaSb at different growth temperatures and the ratio of As and Sb with MBE equipment. The composition ratio of InAsSb was grown at less than 3%, which is a range where the composition ratio of InAsSb did not change significantly, and we will discuss the change of the interface according to the strain change resulting from the growth temperature and x-ray diffraction (XRD) measurement results. The change of the interface was investigated through the photoreflectance (PR) of the change of the internal electric field. The internal electric field of the sample was investigated by Photoreflectance (PR). When the strain between InAsSb and GaSb decreases the strain rate at the InAsSb peak position from tensile 1465 arcsec to 736 arcsec, the direct bandgap of GaSb increases from 0.758 eV to 0.785 eV. Through this change, the higher the growth temperature and the higher the As/Sb ratio, the lower the deformation of the internal interface.

Keywords:

InAsSb/GaSb, hetero junction, Internal electric field, strain, MBE

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P1-se.111

건식공정으로 합성한 MAPbI3 페로브스카이트 박막의 전기적 및 광학적 물성

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Abstract:

본 연구에서는 두께 조절 및 대면적 공정에 유리한 건식공정을 사용하여 $MAPbI_3$ 페로브스카이트 박막을 제조하고, 이들에 대한 전기적 및 광학적 물성을 연구하였다. $MAPbI_3$ 박막은 먼저 PbI_2 박막을 RF 마그네트론 스퍼터로 증착한 다음 MAI vapor를 사용하여 합성하였다. PbI_2 박막을 스퍼터링법으로 증착하기 위해 PbI_2 분말을 압축성형한 타겟을 사용하였고, 공정압력은 Ar 및 소량의 요오드 가스를 사용하여 10 mTorr로 유지하고 타겟에 인가한 RF 파워는 20W이다. $MAPbI_3$ 박막 합성을 위해 MAI vapor 생성온도는 190 ℃, 반응 압력은 N2 캐리어 가스를 사용하여 10 Torr로 고정한 후 PbI_2 박막의 온도를 120-150 ℃로 변화시켰고, 합성된 $MAPbI_3$ 박막의 두께는 약 1.2 μm이다. 합성된 박막의 구조적 및 광학적 물성은 X-ray diffraction 측정 및 PL 측정으로 각각 분석하였다. 또한, 박막의 운반자 농도 및 결함상태 분석을 위해 C-V 및 DLTS (deep level transient spectroscopy) 측정을 수행하였다. 합성조건에 따라 Ec-0.60 eV, Ec-0.36 eV, Ev+0.66, Ev+0.63 eV의 결함상태들이 나타났다. 또한, 합성박막의 광전소사 응용성 분석을 위해 photosensitivity 측정하였고, 이들 실험결과들을 토대로 광전소자 응용을 위한 최적의 시료합성 조건을 논의하였다.

Keywords:

Perovskite, Sputtering, DLTS, Defect State, PL

P1-se.112

디지털 합금 InGaAlAs 다중 양자 우물의 열처리 온도에 따른 광학적 특성 연구

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Abstract:

디지털 합금 (digital alloy) InGaAlAs 다중 양자 우물 (multiple quantum wells : MQWs) 구조의 열처리 (rapid thermal annealing : RTA) 온도에 따른 광학적 특성을 광발광 분광법 (photoluminescence : PL) 와 광반사 분광법 (photoreflectance : PR)를 통해 분석하였다. 본 실험에서 사용된 시료의 MQWs의 우물 (well)과 장벽 (barrier)은 각각 $(InGaAs)_{0.8}(InAlAs)_{0.8}$ SPS (short - period superlattice)와 $(InGaAs)_{0.4}$-$(InAlAs)_{0.6}$ SPS로 성장하였다. 또한, MQWs 성장하기 전과 후에 각각 50 nm 두께의 $(InGaAs)_{0.4}$-$(InAlAs)_{0.6}$ (30 pairs) SCH (separate – confinement heterostructure)를 성장하였다. PL 실험에서 MQWs 신호를 확인하였으며, 열처리 온도가 올라감에 따라 MQWs PL 신호가 청색편이를 하였다. PR실험에서는 PL실험에서 관측한 MQWs 신호 뿐만 아니라 InP 버퍼층, InAlAs 클래딩층, $(InGaAs)_{0.4}$ $(InAlAs)_{0.6}$ (30 pairs) SCH 신호를 관측하였다.

Keywords:

digital alloy, InGaAlAs, photoreflectance

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P1-se.113

Wafer-scale homogenous growth of high quality tungsten disulfides via surfactant-assisted metal-organic chemical vapor deposition

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Abstract:

Two-dimensional semiconducting transition metal dichalcogenides (TMDs) have recently emerged as a promising material candidate for next-generation electronics and optoelectronics owing to their exceptional electrical and optical properties. For practical device applications, it is very crucial to achieve the large-area growth of TMDs films with high quality and good uniformity. Here, we will present the wafer-scale homogenous growth of monolayer tungsten disulfides (WS_2) using surfactant-assisted metal-organic chemical vapor deposition (MOCVD). By optimizing the growth conditions such as temperature, pressure, and molar ratio of precursors, the WS_2 monolayer film was grown continuously on a 2-inch SiO_2/Si wafer. The MOCVD-grown films exhibited uniform optical properties over the entire wafer area as characterized with photoluminescence (PL) and Raman spectroscopy, whos optical quality comparable to that of the exfoliated single crystal counterpart. the quality of WS_2 films was further improved by introducing sodium chloride (NaCl) nanoparticles spin-coated on the wafer as a surfactant during the MOCVD growth. The average grain size of the WS_2 monolayer film increased by an order of magnitude, from several tens of nanometers up to a micrometer, resulting in much improved optical characteristics than those of normally-grown films. These phenomena, generally observed for other TMDs, can be understood by suppressed nucleation and promoted lateral crystal growth aided by the surfactant. The detailed growth mechanism and the role of alkali metal will be further discussed.

Keywords:

MOCVD, TMDs, Wafer-Scale, Tungsten Disulfides

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P1-se.114

Optical and magnetic properties in Mn-doped layered 2D n-butylammonium bromide single crystals

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Abstract:

Layered lead halide perovskites such as n-butylammonium lead bromide (BA_2PbBr_4) posses a multiple quantum well structure, which is expected to enhance the interaction between the excitons and Mn dopants. We report the one-pot synthesis of centimeter-sized differ Mn-doped BA_2PbBr_4 single crystals of different Mn doping ratio, to study the relation between exciton and biexciton and optical and magnetic propetries.

Keywords:

layered lead halied perovskites, 2D perovskites, optical property, magnetic property

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P1-se.115

Amplified spontaneous emission from a bulk CsPbBr3 single crystal at Room temperature

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Abstract:

Lead halide perovskites have received intense interest over the years for their promising photovoltaic and optoelectronic properties. One of those properties is high optical gain required for a laser gain medium. Amplified spontaneous emission (ASE) has been reported for both all-inorganic and hybrid perovskites in various forms including quantum dots, nanorods, nanocrystals, etc. Despite these recent progress, exact mechanism that provokes ASE is still in debate. In this presentation, we report on ASE from a bulk CsPbBr3 single crystal at room temperature where the corresponding ASE threshold intensity is only 60MW/cm2. Strangely, however, this room-temperature ASE was found to occur only at specific positions at the crystal. In order to investigate this position-dependent ASE mechanism, we employed both micro-photoluminescence and micro- Raman spectroscopy, together with microscopic imaging. We found that the ASE-active sites of a typical size (20~100um) are embedded randomly over our single crystal, which can be readily identified by clear optical contrast. Although this specific region does not exhibit any difference in Raman response, we confirmed that it yields clear distinct photoluminescence spectra. This implies that difference in their optical difference arise from different levels of reabsorption effect. We believe that CsPbBr3 can be an excellent laser gain medium if the crystals can be engineered to reduce reabsorption.

Keywords:

Halide perovskite, ASE

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P1-se.116

광섬유 통신용 파장의 단광자 생성을 위한 양자점 성장

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Abstract:

양자 통신의 광범위한 사용을 위해서 기존 광섬유 통신망 사용은 필수적이다. 이러한 광섬유 통신망을 이용하기 위해서는 광섬유에서 손실이 적은 1550nm 파장(C-BAND)의 단광자를 생성하는 광원이 필요하다. 이러한 단광자 광원을 현실화 하기 위해서 여러가지 방법 중에 양자점은 매우 우수한 후보로 꼽힌다.
기존에 사용 되는 양자점 들은 GaAs 기판위에 InAs를 증착시켜 두 개의 물질간의 격자 상수 차이를 이용하여 성장한다. 이러한 양자점들은 높은 품질에도 불구하고 양자점의 크기 제약과 격자상수 차이로 인한 응력에 의해 방출되는 광자는 900-1200nm의 파장으로 제한된다. 이러한 이유로 1550nm의 광자를 생성하는 양자점을 성장하기 위해서는 양자점의 크기와 응력의 제어가 필요하다..
우리는 이러한 양자점의 성장을 위한 접근법을 제시하고자 한다.

Keywords:

단광자 광원, 양자점, 양자통신

P1-se.117

Far-field Fluorescence Mapping Using a Home-made Single Laser Cantilever-type Near-field Scanning Optical Microscope

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Abstract:

Different types of probes have been used for implementation of near-field scanning optical microscope (NSOM) ever since its conception. Development of a special type of cantilever probes with an aperture at the apex has made the NSOM concept less complex to implement. The ability to use atomic force microscopy (AFM) control techniques in this cantilever-type NSOM makes their control more easy and stable. Normally two lasers are used; one for topography detection and the other one for near-field excitation of the sample [1].
In this work, we present our effort to implement NSOM concept using one laser beam to perform both topography detection, using optical beam deflection technique to monitor the cantilever deflection, and to perform near-field fluorescence excitation of the sample. We focus a 405 nm laser at the apex of the cantilever probe, where a small part of this incident beam is confined through the tiny aperture to cause local excitation of the sample [2]. The other part of the beam is used for optical beam deflection technique to generate the feedback control signal that is used for obtaining the topography image. We used a silicon avalanche photodetector for far-field detection of the fluorescence emissions from the sample. The mapping obtained from this data shows an orientation of the particles that correlates very well with the topography image.

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Keywords:

Near-field excitation, Far-field detection, Fluorescence, NSOM

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P1-se.118

전력소자용 GaN on Si 과 SiC on SiC 반도체의 ex-situ 깊이 의존성 변형률 분포에 대한 분석

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Abstract:

최근 데이터 처리속도가 중요한 IT분야와 전기 자동차 등 모빌리티 분야에서 전력반도체의 중요성이 매우 커지고 있는 추세이다. GaN계열 질화물 반도체와 SiC는 기존의 전력 소자보다 더 높은 전기적 안정성을 가지고 있어 미래 전력소자제작에 유망성을 보이는 반도체 재료이다. 특히 전력소자로 사용되기에 SiC(실리콘 카바이드)는 절연 파괴 전계 강도가 Si보다 10배 크고, 밴드갭 에너지가 3.26 eV로 Si보다 약 3배정도 큰 특징을 가지고 있다. 또한, 도핑을 통한 P, N형 반도체의 제작이 가능하기 때문에 기존의 SI의 한계를 넘는 전력 소자로 적용되기 우수하다는 평가를 받는 물질이다. 하지만 아직 SiC의 기술은 기존의 SI에 비해 높은 공정 비용문제와 구현이 어렵다는 문제를 보이고 있다
현재 SIC와 GaN공정에서 성장 과정중에 재료의 열팽창 계수 차이 및 격자상수 차이에 의해 발생하는 변형률이 소자의 성능에 영향을 주는 이슈가 있다. 이러한 변형률은 현재 성장과정에서 1000도에 임박한 고온의 환경에서 실시간으로 측정되는데 이때 재료간 서로 다른 열 팽창 계수의 차이에 의해 두께에 따른 정확한 변형률 분포를 분석하기에 한계가 있다. 또한 이미 완성된 소자에 대해서는 변형률을 분석할 수 있는 방법이 알려져 있지 않다. 따라서 우리는 성장이후의 완성된 소자에 대하여 두께에 따른 변형률을 분석할 수 있는 방법을 제시하였다.
본 연구에서는 Surface-plasmon enhanced raman spectroscopy(SERS)와 사선연마 기술을 이용하여 소자의 두께에 따른 불균일한 변형률 분포를 분석할 수 있었다.

Keywords:

power devices, SERS, SiC, GaN

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P1-se.119

Optical Characterization of InGaAsP/InGaAs tandem solar cells with excitation wavelength.

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Abstract:

This study investigated the optical characterization of InGaAsP/InGaAs tandem solar cell capable of absorbing energy bands of 1.1 eV and 0.74 eV by using photo-luminescence (PL) and photo-reflectance (PR). Figure 1. shows the structure of a tandem solar cell. The wavelengths of excitation light were investigated at 532, 975, 1300 nm to study the change luminescence characteristics with different penetration depth. As the wavelength of excitation light increased, the signal of athe lower InGaAs (emitter) layer increases more than that of the upper InGaAs (contact) layer signal. Quantum efficiency was obtained from PL and PR results according to penetration depth and the characteristics of tunnel junction was evaluated.

Keywords:

tandem solar cell, photoluminescence, photoreflectance, InGaAsP/InGaAs, tunnel junction

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P1-se.120

Role of organic surfactant decomposition via O_2 pre-annealing in CVD-grown hexagonal WS_2

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Abstract:

Monolayer two-dimensional (2D) transition metal dichalcogenides (TMDs) grown by chemical vapor deposition (CVD) have attracted attention due to extraordinary semiconducting properties and various potential applications. In the liquid-precursor-based CVD, the use of a surfactant (OptiPrep; $C_{35}H_{44}I_6N_6O_{15}$) is crucial for uniform and large flakes. However, incompletely decomposed surfactants during the CVD process act as barriers for large scale growth. Here, we study the role of surfactant decomposition by introducing O_2 pre-annealing in the growth process of hexagonal WS_2. At lower temperatures of O_2 pre-annealing than 300 ^oC, incompletely decomposed organic residues act as hurdles for crystal growth. In contrast, above 300 ^oC for O_2 pre-annealing, residual carbons decomposed from the organic surfactant are drastically reduced, resulting in large size growth of hexagonal WS_2 flakes. These are characterized via confocal photoluminescence and Raman spectroscopy as well as x-ray photoemission spectroscopy for each condition. Our results pave a way for the shape control of CVD-grown WS_2 by introducing the optimized O_2 pre-annealing process.

Keywords:

O2 pre-annealing, organic surfactant, liquid metal precursor, hexagonal WS2, chemical vapor deposition

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P1-se.121

Nonlinear optical properties of β-Ga_2O_3 as probed by wavelength-dependent optical excitation spectroscopy

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Abstract:

β-Ga_2O_3 is an emerging semiconductor for a deep ultraviolet emitter owing to its wide bandgap, which significantly varies in the range of 4.49 eV to 4.74 eV due to its optical trirefringence in the monoclinic crystal structure (C_{2h}). While linear properties of β-Ga_2O_3 such as ellipsometry, and depth-resolved cathodoluminescence spectroscopy have been reported, there are only a few report on precise quantification of its nonlinear optical properties. In this presentation, we report on the linear and nonlinear PL response of β-Ga_2O_3 under one-photon absorption, two-photon absorption, and three-photon absorption, respectively, by tuning the excitation wavelength from 240 nm to 550 nm. A broad set of optical properties of this semiconductor will be discussed in terms of nonlinear excitation power dependence, polarization dependence, and 2PA depth scan. Moreover, the 2PA and 3PA coefficients are determined at 460 nm and 550 nm.

Keywords:

β-Ga2O3, nonlinear spectroscopy, three-phton absorption, selection rule, wide-bandgap semiconductor

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P1-se.122

Enhancement of surface morphology and electrical properties of Cd_3As_2 via photo-assisted molecular beam epitaxy

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Abstract:

The topological semimetal is a new class of matter which presents high electron mobilities, low thermal conductivity, as well as variety of unique physics due to its band-touching nodes at a crossing points of two non-degenerated bands. Beside its properties, the topological semimetal is also distinguished from graphene due to its presence in a three-dimensional bulk material, thus, the topological semimetal is much straightforward to the future electronic applications utilizing conventional CMOS-compatible process.
Among a number of topological semimetals such as Na_3Bi, TaAs, and Cd_3As_2 etc., Cd_3As_2 is a material of a chemically stable in the atmosphere and possesses a high carrier mobility nature at room temperature as comparted to the others. Thus, the Cd_3As_2 can be regarded as the most attractive for the device realization.
Due to its importance, the Cd_3As_2 is grown and/or synthesized in a various methods and forms across many research groups, and has allowed us to explore its physical nature. The Cd_3As_2 in a high-quality and an epitaxial layer form on a substrate is a must for the future advances. It is true that there are some reports on an epitaxial growth of Cd_3As_2 with molecular beam epitaxy (MBE). However, the epitaxial Cd_3As_2 is grown with an expensive Cd_3As_2 compound source, thus can be hardly used for fabrication into devices.
Herein, we report the MBE growth of Cd_3As_2 using photo-assisted growth technique with Cd and As elemental sources at a low temperature (<200°C). As compared to the Cd_3As_2 grown without photo irradiation, our results clearly show that the photo-assisted grown Cd_3As_2 has an improved surface morphology by coalescence of clear triangular Cd_3As_2. The sample also presents enhanced Hall mobility and carrier concentration by twice at room temperature. The high-resolution X-ray diffraction pattern exhibits the enhancements of the photo-assisted grown Cd_3As_2 is due to the enhanced crystallinity which induced by enhanced adatom desorption thus modified surface kinetics with the help of the in-situ photo irradiation during growth.

Keywords:

Cd3As2, Photo-assisted epitaxy, MBE, Topological semimetal, MBE

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P1-se.123

Dissimilarity in similarities between GaN nanorods grown on Si (111) and Si (100) substrates

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Abstract:

Monolithic integration of two dissimilar semiconductors into a single platform via epitaxy has been addressed for decades to outperform beyond intrinsic limit and/or to cut down the fabrication cost of the semiconductor devices. However, the integration highly depends on physical parameters such as lattice constant, thermal expansion coefficient and crystal structure, thus gets failure whenever deviations of the physical parameters excess their acceptable limit by forming unwanted crystalline imperfections. However, when it comes to nanowires or nanorods, the mismatches can be relieved through lateral elastic relaxation due to their one-dimensional nature. In this regard, a large number of combinations between lattice mismatched nanorods (or nanowires) and substrate, as well as core and shells in nanowires were addressed for decades throughout many different growth methods across various materials systems.
Gallium nitride (GaN) nanorod is one of the key components that enables the integration of wide band gap semiconductors into Si-based narrow band gap platform with free of strain and misfit defects that could propagate into the nanorods grown above. Among the various advantages of GaN nanorods grown on Si platform, accessibility to a commercial production utility and low-cost Si substrates are the key features that GaN nanorods can take.
Herein, we investigate the structure and optical properties of GaN nanorods grown on Si (100) and Si (111) substrates. Our results show that the two sets of GaN nanorods are identical and exhibit no clear difference in surface morphologies, atomic structure, optical properties and THz reflection spectra. However, we observed clear difference in THz radiation between the two sets of GaN nanorods when probed with incident optical pulses. The GaN nanorods grown on Si (111) substrate exhibit significant THz radiation in the range up to 3 THz and nearly linear peak amplitude changes as a function of excitation power. On the other hands, the GaN nanorods grown on Si (100) substrate emit no THz radiation regardless of excitation power. The THz radiation inactivity is due to the loss of crystal symmetry and birefringence in macroscopic clusters of GaN nanorods owing to the co-existence of two types of GaN nanorods rotated 30° around [0001] with respect to each other.

Keywords:

MBE, GaN, Nanorod, THz spectroscopy

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P1-se.124

Unusual optical phonon behaviors in $Ge_{1-x}Sn_x$ layers

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Abstract:

Ge 완충층 위에 에피 성장된 $Ge_{1-x}Sn_x$ ($0 \le x \le 0.09$) 박막에 대한 편광 및 공간 분해된 라만 산란 연구 결과를 보고한다. GeSn 박막 윗면에서 수행한 편광 라만 산란으로부터 Sn 함량이 증가할수록 Ge-Ge LO 포논 에너지가 감소하는 것을 확인하였다. 이를 분석한 결과 Sn 함량 증가에 따른 에너지 감소가 예측과 달리 부분적으로 일어남을 알 수 있었으며 이는 에피 성장된 박막 층에 여전히 압축 변형이 남아 있음을 나타낸다. 이를 보다 명확히 알아보기 위해서 샘플 측면으로부터 공간 분해된 라만 산란 실험을 수행하였다. 그 결과, GeSn/Ge 계면으로부터 GeSn 박막 윗면까지의 Ge-Ge TO 포논 에너지의 변화를 통해 압축 변형이 완전히 풀리지 않았음을 알 수 있었을 뿐만 아니라, 포논 에너지 분포가 에피 성장에 따른 이축 인장 변형 모델에서도 어긋나 있음을 알 수 있었다. 특히, 수소 유도 결합 플라즈마 처리가 된 샘플에 대한 공간 분해된 라만 산란 실험을 통해 박막 내부의 이러한 변형 상태를 보다 더 균질적으로 제어할 수 있음을 확인하였다. [이 성과는 2019년도 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임 (No. 2019R1A2C1003366)]

Keywords:

germanium tin, optical phonon, polarized Raman spectroscopy, strain, stress

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P1-se.125

Population dynamics of excitons and biexcitons in a 2D halide perovskite single crystal

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Abstract:

Halide perovskites have attracted significant attention owing to their excellent optical properties. In the case of 2D Ruddlesden-Popper series, $(A')_m(A)_{n-1}Pb_nX_{3n-1}$ (A', A = organic cations and X = halogen anion with n = 1 ~ ∞), the A' cations acts as an insulating barrier that strongly confines charge carriers in the 2D perovskite layer. This specific arrangement of alternating organic-inorganic layers generates a 2D quantum-well structure, under the quantum and dielectric confinement effects. These properties give rise to large Coulomb interaction, leading to the formation of excitons and biexcitons with large binding energies. In this work, we prepared a single crystal of PEA_2PbI_4 ($PEA=C_6H_5(CH_2)_2NH_3$) and investigated the population dynamics of excitons and biexcitons as a function of input photon flux and temperature as well. We found that biexcitons are stable when temperature is cold enough (< 100 K) based on the time-integrated photoluminescence spectroscopy. The measured biexciton binding energy is about 40±5 meV , which is consistent with the recent publication. For the first time, we experimentally determined the exciton-exciton capture coefficient $C \cong 6.72\times10^{-19}\ ns^{-1}cm^3$ to form a biexciton at 10 K under both one-photon absorption (1PA) and two-photon absorption (2PA) by analyzing the simultaneous rate equations for the exciton-biexciton dynamics in the steady-state regime. Our next goal is to find the temperature-dependent C and lifetimes of excitons and biexcitons in this important material.

Keywords:

2D peroskite, Low temperature, exciton, biexciton, rate equation

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P1-se.126

Anomalous photoluminescence of CVD-grown $MoSe_2$ monolayer: role of residual promoters and surfactants

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Abstract:

Synthesis of atomically thin transition metal dichalcogenides via chemical vapor deposition (CVD) has attracted attention because of unique physical properties for electronics and photonics. Improving crystallinity of CVD-$MoSe_2$ is important for potential applications such as light emitting devices because $MoSe_2$ monolayers exhibit higher quantum efficiency. During CVD process, un-wanted residues arising from liquid-solution are remained on $MoSe_2$. In this reason, a transfer process is necessary for removing un-wanted residue. While the transferred $MoSe_2$ exhibits normal spectra of photoluminescence (PL), as-grown samples revealed anomalous PL spectra. Furthermore, peak intensities of $MoSe_2$ are prominently modulated by transfer and post-annealing processes. By using Atomic Force Microscopy (AFM), Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XPS), we investigate surface properties as well as interactions between $MoSe_2$ and substrates. For as-grown $MoSe_2$, residual sodium and carbon compounds resulting in strain and doping effects are attributed to the anomalous PL spectra for CVD-$MoSe_2$. In contrast, such residue effects are relieved by the transfer and post-annealing processes.

Keywords:

Anomalous photoluminescence, MoSe2, Residual promoters, Residual surfactants, Chemical vapor deposition

P1-se.127

Rashba and polaron effects in optical transitions ofMAPbX$_3$ (X=Cl, Br, and I) under pulsed Magnetic fields

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Abstract:

We have investigated photoluminescence (PL) transitions of MAPbX$_3$ (X = I, Br and Cl) organic-inorganic hybrid perovskite single crystals in magnetic fields to 60 T. At low temperature (4.2 K), sharp free exciton transition peaks emerged. In the presence of strong magnetic fields, free exciton PL transitions of three different halogen elements show dramatic differences. For MAPbCl$_3$ crystal, the free exciton transitions undergo negative energy shifts and MAPbBr$_3$ crystal free excitons show normal diamagnetic shifts. For MAPbI$_3$, the energy shifts of the free exciton for both s$^+$$₩sigma^+$ and s$^-$ transitions exhibit B$^{1/2}$ below 20 T and linear in B afterward. Such peculiar magnetic field effect on different halogen elements can be understood as the strong spin-orbit coupling in conjunction with a strength of the polar nature of lattice bonding varied by the electronegativity of each element.

Keywords:

organic-inorganic hybrid perovskite, photoluminescence, Rashba effect, polaron, magnetic field

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P1-se.201

Analysis of spin Hall effect of sputtered W3Ta thin film in a W3Ta/Co20Fe60B20/MgO structure

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Abstract:

최근에 인공지능과 자율주행이 각광받으면서 다량의 데이터를 처리할 새로운 초고속, 초저전력인 차세대 반도체가 중요하게 되었다. Spin-transfer-torque magnetic random-access-memory (STT-MRAM)은 27.3μs retention time 기준으로 DRAM에 비해 전력은 약 68%, 동작속도는 92.6%만큼 절감이 가능한 초고속 초저전력 소자로 각광받고 있다 [1]. 하지만 STT-MRAM보다 spin-orbit-torque magnetic random-access-memory (SOT-MRAM)을 선택하는 경우에 Write access latency가 16KB기준 약 5배 빠르고, 전력소모는 3배 적어질 수 있다. STT 기술은 write/read 할 때 current path가 같은 반면, SOT 기술은 STT와 같은 read mechanism에서 write할 때 전류가 storage layer plane으로 주입되어 더 높은 endurance를 보장한다 [2]. 따라서 높은 spin Hall angle (SHA)를 갖는 물질에 대한 연구가 앞서 Ta(Θ=0.15), Pt(0.08), W(0.30) 등에서 진행되고 있었다 [3]. 그 중에서 A15 구조의 W4-xTax 물질이 x=1에서 β-W보다 최대 20% 높은 spin Hall conductivity(SHC) 갖는 first calculation 결과가 있었다 [4]. 이 물질은 sputter로 증착이 가능하면서도 비용이 낮아 실제 상용화되기에 가장 적합한 비자성 giant spin Hall effect (GSHE) solid layer의 가능성이 있어, 이 연구에서는 12-inch ultra-high vacuum (1×108 torr) sputter를 이용하여 공정 하여 다음과 같은 특성을 확인하였다. X-ray diffraction (XRD)를 통해 A15 구조 결정성을 입증하고, vibrating sample magnetometer (VSM)을 통해 Si/SiO2sub/W3Ta/Co20Fe60B20/MgO/Ta 박막의 static magnetic behavior를 분석하고 standard Hall-bar 구조를 제작하여 W3Ta의 spin Hall effect를 분석하였다.

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Keywords:

SOT-MRAM, Spin Hall Effect , Spin Hall Angle

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P1-se.202

Dependence of Forming-free $GeSe_x$ based Conductive-Bridging Random-Access-Memory Characteristics on Thicknesses and Chemical Composition Ratio of $GeSe_x$

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Abstract:

Conductive-bridge resistive-access-memory (CBRAM) has attracted attention as an emerging high-density nonvolatile memory device due to its simple structure, high switching speed and low power consumption. The CBRAM cell requires a forming process, which is highly undesirable since it caused an extra burden for initializing memory-cells and degraded the write and erase endurance cycles. Thus, in this work, we developed $GeSe_x$ based CBRAM cell with a thickness of 10 nm to achieve a forming-free process by using deposition power of 30 W. Prior to fabricating the memory cell, it was confirmed that the crystallinity of $GeSe_x$ film was observed at its thickness of thicker than 10 nm by XRD analysis. We investigated the dependency of non-volatile memory (NVM) characteristics on chemical composition ratio and thickness of $GeSe_x$. The CBRAM cells were fabricated with the structure of $Pt/Cu/GeSe_x/W$, where Cu and $GeSe_x$ was used as a source layer and switching layer. A chemical composition ratio and thickness of $GeSe_x$ play an important role in NVM characteristics, such as forming voltage and high resistance state (HRS) current. It was found that as the deposition power for $GeSe_x$ increased from 15 to 60 W, the forming voltage increased from 0.25 to 0.8 V, while the HRS current at 0.1 V decreased from 2.8×10^{-8} to 2.8×10^{-11} A. This result indicates that the chemical composition ratio of $GeSe_x$ was changed with varying the deposition power. In addition, it was found that as the thickness of the $GeSe_x$ increased from 5 to 10 nm, the forming voltage decreased from 0.65 to 0.3 V, resulting from the thickness of $GeSe_x$ thinner than 10 nm was amorphous. On the contrary, when the thickness of the $GeSe_x$ increased from 10 to 30 nm, the forming voltage increased from 0.3 to 0.7 V, resulting from the thickness of $GeSe_x$ thicker than 10 nm was crystallinity. In our study, we present how much the composition ratio and thickness of $GeSe_x$ affect non-volatile memory characteristics of CBRAM to achieve the forming-free and stable memory characteristics.

Keywords:

Conductive-bridge resistive-access-memory, Forming-free, Cu, Filament, GeSex

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P1-se.203

Dependency of Current Voltage Characteristics of IGZO TFT on 8-mercaptooctanoic acid Solution Concentration for Sensing Breast Cancer

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Abstract:

Cancer is one of the most dangerous disease in human life. It is very important to detect cancer in early stage, however, there are many difficulties to diagnose caner such as time consuming, high cost and limit sensitivity. [1] Some researchers studied to overcome these difficulties by using electro chemical reaction methods such as carbon nanotube field-effective transistor, AlGaN/GaN HEMT, graphene oxide TFT, Si nanowire FET, PEDOT:PSS conducting paper, and ZnO nano-rods. We proposed Indium-Gallium-Zinc-oxide (IGZO) thin film transistor (TFT) to detect breast cancer cell and investigate the dependency of current voltage characteristics of IGZO TFT on 8-mercaptooctanoic acid (8-MOA) solution concentration via culturing breast cancer cell line. It was confirmed that when the concentration of 8-MOA was 10, 20, 30 and 40 mM, and the variation ratio of drain current ($\Delta I_{drain}/I_{drain}$) of IGZO TFT was 0.10891, 0.20803, 0.26437, 0.35507, respectively, i.e. $\Delta I_{drain}/I_{drain}$ of IGZO TFT increased with 8-MOA concentration. Finally, we present how much 8-MOA solution concentration affects current voltage characteristics of IGZO TFT to sense breast cancer.

Keywords:

Indium-Gallium-Zinc-Oxide, Cancer cell, 8-Mercaptooctanoic acid, Thin-Film-Transistor

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P1-se.204

Relaxation Frequency Variation in Blue Organic Light-Emitting Diodes

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Abstract:

Numerous advantages of organic light emitting diodes (OLEDs) such as a wide viewing angle, high color contrast ratio, quick response time, thin and scalable fabrication recently have provided a great opportunity for them to be employed in a wide range of displays. To further extend their versatility with long lifetime and high uniformity, various approaches have been introduced so far, however, primary degradation parameters and relating unresolved operation mechanism of OLEDs are still unknown clearly. Besides, its complex device structure of OLEDs hampers an accurate lifetime prediction and device parameter extraction of OLEDs, respectively. In this presentation, to have a deeper insight for degradation mechanism of a blue OLED, the stress time-dependent Nyquist plot, relaxation frequency, contact resistance, and trap energy are presented, respectively. The obtained relaxation frequency (f_r) determined at a charge-balancing voltage reduced gradually with the stress time. We attributed this f_r reduction to the degradation of transport layer (TPL) interface rather than that of emission layer interface, which is further rationalized by the increased both contact resistance and characteristic trap energy after the stress. This strong correlation between f_r and TPL interfaces consequently renders f_r a powerful degradation indicator for the TPL interface. Our finding will pave the way toward highly reliable blue OLEDs technologies with long life-time for the coming future.

Keywords:

Organic light-emitting diode, relaxation frequency, impedance spectroscopy, electrical degradation

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P1-se.205

Highly Reliable Contact Resistance and Characteristic Trap Energy Extraction Methods in Blue Organic Light-Emitting Diodes

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Abstract:

Enormous technology progress in organic light-emitting diodes (OLEDs) industry has demonstrated recently large-area display, high colour contrast ratio, wide viewing-angle, and light-weight with flexibility. However, the limited life-time and unclear degradation mechanism of blue OLEDs still remain as unresolved issues, requiring thorough understanding of the electrical property degradation in blue OLEDs. In addition, an accurate method for contact resistance (R_{CT}) and characteristic trap energy (E_T) extraction is still lacking in OLED devices mainly because of the complex device architecture, which further makes this problem much difficult. Herein, we propose a simple but highly reliable R_{CT} and E_T determination methodology by taking the trap-charge-limited-current (TCLC) model into account. To demonstrate the validity of our approach, the extracted R_{CT} and E_T are directly compared by connecting a bias-independent commercial resistor of 100 Ω, 1 kΩ, 9.8 kΩ to blue OLED in series. Besides, to further investigate on the electrical current degradation mechanism of the blue OLED, the current cycle-dependent R_{CT} and E_T of blue OLEDs are presented in addition to various electrical parameters such as ideality factor and turn-on voltage at the current injection regime. This study will provide a deep and wide understanding for the electrical degradation in blue OLED to realize a highly reliable OLED device with long lifetime.

Keywords:

Organic light emitting-diodes (OLEDs), Contact resistance, Characteristic trap energy, degradation

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P1-se.206

PbS 광전압 소자에서 광전류 과도 현상(transient)의 입사광 세기 의존성

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Abstract:

lead sulfide, fluorine doped tin oxide(FTO), Ti를 이용하여 수직, 수평 구조의 두 가지 소자를 제작하였다. 증착한 lead sulfide의 특성을 확인하기 위해 x-ray diffraction XRD 스펙트럼 측정과 scanning electron microscope SEM 이미지 촬영을 통해 PbS의 결정성을 확인하였다. photocurrent 측정 결과 수직 구조 소자에서는 전자가 Ti 쪽으로 이동한 다는 것을 확인하였고, 레이저 조사시 광전류의 빠른 증가과 함께 나타나는 스파이크 형태의 과도현상을 관측하였다. 수평 구조 소자에서도 수직 구조 소자 에서와 마찬가지로 광전류의 빠른 증가와 스파이크 형태의 과도 현상을 관측하였다. 또한 레이저 빛을 가릴 때 천천히 감소하는 과도현상이 나타나는 것을 확인하였다.

Keywords:

PbS, FTO, Transient

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P1-se.207

Investigation of charge transport properties in a ZnO nanowire field effect transistor

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Abstract:

Zinc dioxide (ZnO) has been regarded as a promising material over the past few decades, which has direct wide bandgap (~3.37eV) and a large exciton binding energy (60 meV). Recently, ZnO nanostructures have attracted much attention to the fields of nanoscale electronic and optoelectronic devices, such as sensors, solar cells, energy harvesting devices, light-emitting diodes, and especially field effect transistor (FETs).

It is important to understand charge transport behaviors in nanowire-based transistors because the FET using nanowires is one of the essential constituents in nanoelectronic applications. The electrical properties in nanowire-based FET devices are significantly affected by their geometrical size and shape, impurities and surface defects. Furthermore, the contacts between the nanowire and metal electrodes are widely regarded as an important factor of the charge transport properties of the nanowire-based FETs due to their large surface-to-volume ratio. Lord et al. previously reported that the electrical transport behavior of nanocontacts between ZnO nanowires and gold metals. He et al. and Jo et al. showed the effect of the contact resistance on the electrical properties in ZnO nanowires and In_2O_3, respectively.

In this work, we report the effect of applied gate and drain voltages on the charge transport properties in a ZnO nanowire FET with a back-gated configuration. We find that the threshold voltage shifts to a negative gate bias direction. To fabricate ZnO nanowires FETs, ZnO nanowires are transferred onto a highly-doped silicon wafer with 100 nm-thick silicon dioxide by dropping and drying a liquid suspension of ZnO nanowires, which are vertically grown on Au-coated c-plane sapphire substrates using a vapor transport method. In order to demonstrate the structural characterization of the ZnO nanowires, we performed field emission scanning electron microscope (FESEM) and transmission electron microscope (TEM). Moreover, we show the temperature-dependent I-V measurements which is believed to show the transport behavior of the ZnO nanowire FET.

This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (2019R1A2C1007883), and by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2016R1A6A1A03012877).

Keywords:

ZnO, nanowire, charge transport, field effect transistor, conduction mechansim

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P1-se.208

Vacuum deposition of organic-inorganic hybrid perovskite for the realization of red, green and blue light emitting diode

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Abstract:

The application of organic-inorganic hybrid halide perovskites to light emitting diode has been widely studied within the last several years. They have shown great potential for light emitting diode (LED) with their narrow FWHM exceeding quantum dot emitter. Moreover, the emission color of perovskite LED could be delicately altered by substituting halide species. Through vacuum deposition, the composition of perovskite, as well as emission color, could be finely tuned regardless of environment and the thickness could also be controlled.

Here we made perovskite film by vacuum co-deposition technique. The deposition of organohalide, which is reported to be the main hurdle for vacuum deposition, was controlled with new crucible design. The film quality was evaluated in terms of film crystallinity, morphology, topography, stoichiometry and electronic structure. We have also fabricated light emitting diode whose structure is ITO/PEDOT/NPB/Perovskite/TPBi/Yb/Al. We here report R, G, B perovskite light emitting diode using MA^+ as A site cation being fabricated through single chamber.

Keywords:

Perovskite, light emitting diode, vacuum deposition, halide substitution

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P1-se.209

CdSe 양자점 / PbS 양자점 photodiode pixel array

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Abstract:

Colloidal 양자점은 높은 광흡수율과 밴드갭 조절이 쉽다는 점, 용액상으로 공정할 수 있기에 저비용 공정이 가능하다는 이점을 가지고 있어서 광센서로서의 응용이 활발하게 연구되고 있다. 본 연구는 colloidal 양자점을 이용하여 가시광과 근적외선을 동시에 감지하는 광센서 array를 만드는 방법에 대해 연구한 것이다. Photolithography 공정을 통해 colloidal 양자점 광센서를 픽셀화 하여 CdSe/ZnS (core/shell) 양자점 픽셀과 PbS 양자점 픽셀을 동시에 갖는 광소자를 구현하는 방법에 대해 논의 하고자 한다.

Keywords:

Quantum dots, CdSe/ZnS, PbS, photodiode

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P1-se.210

Structure, optical and magnetic properties of yttrium iron garnet doped with erbium

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Abstract:

A series of yttrium iron garnet polycrystals doped with erbium (Er;YIG) has been synthesized using conventional solid state reaction. For the synthesis of polycrystalline Er;YIG, the stoichiometric powder mixture of Y_2O_3, Fe_2O_3 and Er_2O_3 were calcinated at 850 ^{o}C and, then, sintered at 1300-1500 °C in air. We studied the crystal structure, optical and magnetic properties using x-ray diffractometer (XRD), FT-IR spectrometer, a vibrating sample magnetometer (VSM), and differential scanning calorimetry (DSC). The XRD patterns show that Er;YIG exhibits a single phase of cubic structure overall the content of Er dopant. The optical properties in the range of the near-infrared region were obtained by FT-IR measurements and their optical transparency seems to depend on the chemical state of Er dopant in YIG system. The magnetic hysteresis curves of Er:YIG were obtained at room temperature and the Curie temperatures were checked by DSC measurements.

Keywords:

yttrium iron garnet, Ferrimagnet

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P1-se.211

Noise analysis and optimization of vanadium pentoxide (V_2O_5)-based highly sensitive thermistor

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Abstract:

Highly sensitive thermometer is a very crucial element in many MEMS sensors such as microfluidic chip calorimeters. Because the power resolution of the calorimeter is directly related to the performance of the thermometer, careful choice and optimization of thermometer is required. Vanadium pentoxide (V_2O_5) is widely used as a thermistor material due to its high temperature coefficient of resistance (TCR) over -3 %/K and low 1/f noise. We fabricated thin-film V_2O_5 thermistors by sputter deposition and photolithography. The noise levels of the V_2O_5 thermistors were analyzed with gold (Au) interdigitated electrodes (IDE) as design parameters; noise performance was characterized while total resistance, gap and width of the Au IDE were varied. Scanning electron microscope and lock-in amplifier were used to investigate grain boundaries of deposited V_2O_5 and to measure electrical noise signal of the thermistor circuit respectively. We found the electrical noise was strongly related to the thickness of the V_2O_5 and the gap of the Au IDE. We expect this finding provide a guideline to design optimal Au IDE for a highly sensitive thermometer.

Keywords:

Vanadium pentoxide, thermistor, noise

P1-se.212

Resonant tunneling current in a SrRuO3/SrTiO3 superlattice

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Abstract:

Resonant tunneling[RT] which is a quantum mechanical process has been attracting both scientific and technological attention because of its interesting physics and application for high-speed electronics. This phenomenon accompanies negative differential resistance in current-voltage characteristics and has various physical properties that are used in many electronic circuits such as multi-level logic devices. But oxide-based RT study encounters difficulty because of sample instability and lack of evidence for a mechanism.
Here for systematical studying of RT in oxide material, we deliberately designed SrRuO3/SrTiO3[SRO/STO] superlattice exhibits RT with negative differential resistance. We fabricate 4 kinds of SRO/STO superlattice sample using pulsed laser epitaxy with atomic-scale precision on Nb: STO substrate. The thickness of the SRO layer is fixed as a 6-unit cell. And we changed the thickness of STO, acts as an insulator barrier, 2,4,6, and 8-unit cell. Apart from the STO 2-unit cell sample, all SRO/STO superlattices show negative differential resistance coming from the discrete state of SRO between the STO barrier. As an STO thickness increases, negative differential resistance peak positions increase.

Keywords:

Resonant tunneling current, Superlattice, Oxide

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P1-se.213

Environmental effects on optical properties and carrier dynamics of $CsPbBr_3$ nanocrystals with different reaction times

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Abstract:

In the recent years, organic-inorganic perovskites (OIP) have attracted much attention due to their excellent photophysical properties such as small exciton binding energies, large tunable photoluminescence, and narrow band emission. However stability of OIP has always been main obstacle significantly hindering the device performance. Compared with OIP, the all-inorganic perovskite feature much enhanced stability against atmospheric factors. Therefore all-inorganic perovskite garnered tremendous interest in the field of photovoltaics and light emitting diodes. Despite of recent progress, the understanding of fundamental photophysics of materials such as phase-transition and atmospheric condition effect remains elusive. In this work, we used hot-injection technique and the reaction was terminated at different time to obtain samples with various phases, and then exposed to air to investigate how the atmospheric condition affect optical properties and carrier dynamics of the $CsPbBr_3$ perovskite nanocrystals (PNCs). It is found that the photoluminescence (PL) intensity of $CsPbBr_3$ PNCs can be boosted by ~7 times than that of pristine and average PL lifetime is increased by exposing the $CsPbBr_3$ PNCs to ambient air.

Keywords:

All inorganic perovskite, CsPbBr3, Atmospheric effect, Optical properties, Carrier dynamics

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P1-se.214

MoS_2 전자 수송층을 이용한 페로브스카이트 광 다이오드/태양전지 나노 시스템 연구

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Abstract:

페로브스카이트 물질과 MoS_2와 같은 2차원 재료들로 이루어진 유무기 하이브리드 구조들은 다양한 광전자 소자에 적용이 가능할 것으로 기대되고 있다. 최근에 페로브스카이트 기반 하이브리드 다이오드 구조에서 광기전력의 발생뿐만 아니라 발광까지 두가지 기능을 동시에 수행할 수 있다는 연구결과가 발표되고 나서 더욱 많은 관심을 받고 있다. 일반적으로 페로브스카이트에 사용되는 투명산화물기반 전극들은 구부리거나 휘어지는 소자에 적용시 굽힘 테스트 동안 균열에 의한 성능저하가 일어난다. 또한, TiO_2와 ZnO와 같은 금속 산화물이 전자 전달층(electron transport layer, ETL)으로 보편적으로 사용되어 왔는데, ETL과 활성층 사이의 계면에서 전하 운반자의 축적/재결합에 의해 소자 성능이 저하된다. 본 연구에서는 이러한 문제를 해결하기 위해, triethylentetramine이 도핑된 n형 그래핀 전극과 MoS_2 ETL를 포함하는 n형 그래핀/MoS_2 ETL/$CH_3NH_3PbI_3$/PTAA/Au 구조를 갖는 n-i-p 형 페로브스카이트 광 다이오드-태양전지 나노시스템(perovskite photodiode-solar cell nanosystem, PPSN)을 제작하였다. PPSN은 광 다이오드 모드에서 0.42 AW^{-1}의 광 반응도(responsivity), 75%의 외부양자효율, 1.1 × 10^{10} cm $Hz^{1/2}$ W^{-1}의 광검출능, 112 dB의 선형 동작 범위, 0.98 μs의 응답시간을 보였다. 태양전지 모드에서는 광전변환효율이 14.27%였다. PPSN의 안정성 및 유연성 테스트 결과 대기 중에서 30일 동안 광반응도가 ~22 % 감소하였으며, 4 mm 곡률반경에서 1000회 반복적인 굽힘 시험 후에도 20 % 감소만을 보였다. 이러한 실험적인 결과들을 토대로 n형 그래핀과 MoS_2 ETL의 구조적 및 광학적 특성과 PPSN의 성능과의 상호관계를 논의하고자 한다.

Keywords:

photodiode-solar cell nanosystem, 그래핀, MoS2, 페로브스카이트, electron-transport layer

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P1-se.215

MoS_2를 중간층으로 사용한 그래핀/다공성 실리콘 태양전지의 효율 향상

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Abstract:

본 연구에서는 화학기상증착법으로 성장된 MoS_2박막을 1, 2, 4, 8층으로 조절하여 bis(trifluoromethanesulfonyl)-amide (TFSA)가 도핑된 그래핀 투명 전극 (TFSA-그래핀) 과 다공성 실리콘 사이의 중간층으로 사용하여 TFSA-그래핀/MoS_2/다공성 실리콘 태양전지를 제작하였다. MoS_2를 중간층으로 사용할 경우, 그래핀과 다공성 실리콘 사이의 밴드 불일치를 완화시킬 수가 있어서 전하의 수집/분리 기능을 향상시켜 광전변환효율을 향상시킬 수 있다. 특히, 광전변환효율은 TFSA 도핑 농도와 MoS_2의 층수에 크게 의존하였으며, TFSA의 도핑농도가 20mM이고 MoS_2의 층수가 4 일 때 12.09%로서 최대값을 나타내었다. 이와 더불어, 태양전지의 후면에서 일어날 수 있는 전하의 재결합 손실을 감소시키기 위해 TiO_x를 후면 passivation 층으로 사용하여 광전효율을 최대 13.18%까지 더 증가시킬 수 있었다. 또한, 온도와 습도가 각각20~22℃와 40%일때 태양전지의 안정성을 30일간 측정한 결과, 광전효율이 85% 이상으로 유지됨으로써 기존의 연구결과에 비해서 괄목할 만하게 장기 안정성이 향상되었음을 확인하였다.

Keywords:

MoS2, 다공성 실리콘, 태양전지, 중간층, 그래핀

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P1-se.216

Influence of dopant concentration on optical properties of Mn-doped ZnSe quantum dots

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Abstract:

Colloidal semiconductor quantum dots (QDs) have attracted a great deal of interest for investigations of fundamental physics and their promising potential applications in optoelectronic devices. However, the intrinsic toxicity of cadmium limits immediate application in various fields. To overcome this problem, doped ZnSe QDs are being explored as viable alternatives to undoped QDs with additional advantages such as larger Stokes shift to avoid strong self-quenching, enhanced thermal and environmental stabilities, and minimized toxicity. Furthermore, doping different transition metal ions into ZnSe QDs can extend QD emission window from violet blue to the red end of the visible spectrum. Therefore, it is important to investigate the effects of dopant concentration on optical properties of Mn-doped ZnSe QDs. In this work, we investigated the optical properties of Mn-doped ZnSe QDs with different dopant concentrations using nucleation-doping strategy. Absorption and fluorescence measurements were carried out for the optical properties of the Mn-doped ZnSe QDs with various dopant concentrations.

Keywords:

ZnSe, Mn-doped quantum dots, Nucleation-doping, Dopant concentration, Optical properties

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Biaxial strain engineering for exciton-polaritons in transition metal dichalcogenides

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Abstract:

Atomically thin materials, especially layered two-dimensional (2D) transition metal dichalcogenides(TMDCs), are emerging as a new platform for exploring 2D semiconductor physics due to their remarkable physical properties. Because of reduced dimensionality and broken crystal inversion symmetry, 2D TMDCs have exceptionally strong exciton binding energies (i.e., huge oscillation strength of excitons) and a valley degree of freedom[1, 2]. Recently, valley-polarized exciton polaritons in TMDCs materials have been successfully demonstrated with various optical cavities, which has shown valley-dependent physics such as circularly polarized emission or optical valley Hall effect[3]. Valley-polarized exciton-polaritons open the possibility of exploring polariton-based valleytronics in two-dimensional materials. Meanwhile, it has been recently turned out that, even without an optical cavity structure, the formation of exciton-polaritons in a bare two-dimensional TMDCs is possible due to the strong exciton coupling strength with light[4, 5, 6].
Here, we demonstrate strain-induced tunability of exciton-polaritons in bare TMDCs layers[7]. We performed the strain transfer from thermally expanded or compressed polypropylene(PP) substrate to WS_2 layers. A PP substrate has a large enough thermal expansion coefficient (α_L ~136 ± 15 (10^{-6}·1/K)) to be utilized in thermal-expansion-induced strain engineering[8]. In order to investigate the strain-induced optical properties of WS2 layers, we measured photoluminescence from bare TMDCs layers using a micro-photoluminescence spectroscopy set-up. We used a 594 nm CW diode laser to excite excitons in few-layers TMDCs on a PP substrate or a Si/SiO_2 wafer. Because exciton polaritons in TMDCs layers are non-radiative modes, their spectra were obtained mainly at sample edges. Using the PP substrate, we observed a redshift in optical spectra of both excitons and polaritons as increasing temperature (in other words, increasing tensile strain). Strain-induced bandgap tuning makes it possible to modify the polariton dispersion curve in TMDCs layer. We believe that our demonstration paves a way to tune optoelectronic properties of TMDCs in a reproducible way.

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Keywords:

Exciton, Exciton-polariton, Hall effect, Berry curvature, Strain engineering

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P1-se.218

Simultaneous Raman and photoluminescence studies of chemically doped two-dimensional MoS_2 layers

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Abstract:

이차원 MoS_2 다중층을 TFSI를 이용하여 화학적으로 처리하고 이와 관련된 도핑 및 결함 치유에 관한 정량적인 정보를 얻기 위하여 라만 산란과 광 발광 이미징 실험을 샘플의 같은 영역에 대해서 진행하였다. TFSI 처리 전과 후의 라만 산란 스펙트럼의 차이를 비교 분석한 결과 E ′ 포논 에너지는 감소하였지만 A_1' 포논 에너지는 증가하였음을 알 수 있었다. 이는 황 공극 결함이 치유되면서 인장 변형이 생겼으며 이에 따라서 p-도핑 효과가 일어난 것으로 생각된다. E ′ 포논과 A_1' 포논 에너지의 상관관계 분석을 통해서 도핑 농도의 변화를 계산하였고, 이를 통해 단층보다 이중층 영역에서 전자 밀도가 더 많이 감소되었음을 알 수 있었다. 도핑 농도의 변화는 트라이온과 엑시톤의 광 발광 세기 비율을 분석함으로써도 얻어질 수 있는데 그 결과는 라만 분석 결과와 일치하였다. 결과적으로, 라만 산란과 광 발광 실험 방법은 상호 보완적이며 같은 샘플 영역에 함께 적용될 경우 도핑 효과에 대한 보다 포괄적인 정보를 취득할 수 있는 장점이 있다는 것을 알게 되었다. [이 성과는 2019년도 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임 (No. 2019R1A2C1003366)]

Keywords:

molybdenum disulfide, optical phonon, exciton, strain, doping

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P1-se.220

Study on Magnetoconductance of Monolayer MoS_2

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Abstract:

We discuss the magnetoconductance of electrons in a monolayer MoS_2 nanoribbon. KWANT which is a Python package for numerical calculation based on the tight-binding method is implemented to compute the spin-dependent electron transmission and energy dispersions. In these calculation, we consider hopping processes between the nearest-neighbor Mo-S, the next nearest-neighbor Mo-Mo (in plane) and S-S (out of plane). The result of energy dispersions has good agreement with the result of DFT calculation. External magnetic fields are applied perpendicular to the plane of the pristine zig-zag edged nanoribbon and magnetoconductance is studied with changing the magnitude of magnetic fields and the width of the applied magnetic field region. The magnetoconductance is more affected by the modulation of magnetic fields in high incident energy regime than in low incident energy regime

Keywords:

MoS2, Nanoribbon, KWANT, Magnetic modulation, Magnetoconductance

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P1-se.221

Observation of circularly polarized polariton mode in WS_2 layers

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Abstract:

Recently, 2D layered transition metal dichalcogenides (TMDs) have been widely studied because of its numerous attractive natures such as strong excitonic transitions at direct bandgaps or valley-dependent phenomena (Valley-dependent optical selection rules, Valley-Hall effects, etc.). Here, we report a novel mode of exciton-polariton in 2D WS_2 flakes. The exciton polaritons are guided modes propagating along the WS_2 flakes and their eigenstates are circularly polarized. For experimental demonstration of circularly polarized polariton modes, WS_2 flakes were prepared by exfoliating WS_2 crystal on a glass substrate. And thicknesses of flakes were measured by Atomic Force Microscopy (AFM). Circularly polarized laser was irradiated on an edge of flakes to resonantly excite exciton polariton modes, and we observed the degree of circular polarization (DOCP) of scattering light on the other side of edge to find out whether the handedness of light can be maintained after traveling along the flake. Surprisingly, we noticed that the measured handedness of guided light shows a high DOCP (up to ~0.7) with the same handedness as the excitation laser. Furthermore, we found that the spectrum of scattered light also shows interference peaks. By investigating these interference peaks, we could obtain dispersion curves of exciton polaritons in WS_2 flakes. These results not only demonstrate a fundamental characteristic of exciton polaritons in 2D TMDs layers but also suggest a new way to control light in a 2D layered material.

Keywords:

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P1-se.222

Atomic-layer Multiple Quantum Wells Structure Fabricated by Layer-by-layer Oxidation of MoS_2

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Abstract:

The thickness control of two dimensional transition metal dichalcogenides (TMDs) is one of the most important issues because of their varying properties depending on the number of layers. Plasma etching is one of many efforts to fabricate monolayer TMDs. Since monolayer TMDs are promising for optical and optoelectronic application because of strong photoluminescence, exfoliated flakes are highly utilized for the investigation. Among various applications, TMD-based quantum well structures are demonstrated for novel devices by stacking monolayer TMDs and thick hBN alternatively. However, reliable oxide layers with TMDs can be achieved by oxidation of TMDs, which also can reduce the step of repeated stacking process. Here we demonstrate atomic-layer quantum wells structures of $MoO_x/MoS_2/MoO_x/MoS_2$, consisting of two MoS_2 monolayers separated by oxidized layers of MoO_x. We first oxidized top layer of bilayer MoS_2 by applying oxygen plasma treatment to fabricate MoO_x-passivated 1L-MoS_2. MoO_x/MoS_2 heterostructure shows enhanced photoluminescence intensity and suppression of defect-induced and charged exciton-related light emission. Another bilayer MoS_2 was transferred onto this stack, followed by subsequent oxidation of top-most layer. The final quantum well structure shows high photoluminescence from two decoupled MoS_2 monolayers.

Keywords:

Molybdenum disulfide, Layer-by-layer oxidation, Atomic-layer multiple quantum wells, Oxygen plasma, Molybdenum oxide

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P1-se.223

Nanoscale investigation of hydrogen-free carbon nanocrystal film: tailoring the electrical and physical performance by tuning the sp^2-sp^3 configuration

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Abstract:

We synthesized carbon films on a silicate glass at room temperature by sputtering a graphite target in Ar atmosphere at various sputter power (15 kW to 30 kW). The following Raman and photoemission spectroscopy shows that, at low power regime, carbon films consisting of sp^3 bonds was dominant. In contrary, as the sputtering power increased, the sp^2 carbon ordering replace them. The results can be attributed to the sublantation model of incoming carbon ions at the low energy and the thermal relaxation caused by excessive kinetic energy of carbon ions at the high energy, respectively. Thus, strong correlation between properties and sputter power was observed by using atomic force microscopy. While friction, adhesion, and energy dissipation tends to decrease for the increasing sputter power, conductivity rapidly increase, in spite of negligible topographical variations. Although modulus presented a little upward-convex behavior for the increment of sputter power, it still remains good enough even at the highest power condition. The growth of sp^2 ordering facilitated the enhancement of conductivity as well as tribological performance. We utilized the sp^2-sp^3 tuning features of the sputtered carbon film in the triboelectric nanogenerator (TENG). The high durability and performance of carbon film was achieved by virtue of its dual role as a triboelectric as well as an anti-friction layer.

Keywords:

amorphous carbon, sputter power, sp2, sp3, triboelectric

광촉매 정수 응용을 위한 gC-CuO-ZnO 나노 구조의 합성 및 특성

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Abstract:

다기능성 나노 물질은 다양한 응용 분야에서 잠재적인 물질로 부상하고 있다. 본 발표에서는 광촉매 정수 및 물 소독의 응용을 위해 gC (graphitic carbon)-CuO-ZnO 나노 복합체의 손쉬운 합성을 보고한다. 제작된 나노 복합체는 직사광선하에서 약제 학적 화합물인 amoxicillin and clavulanate potassium tablet (Drug), industrial effluent (IF), methylene blue dye (MB)에 대해 우수한 광촉매 분해 효율을 보였다. 주로 싱크로트론 소프트 X-선 흡수 분광법이 수행되었다. 제작된 gC-CuO-ZnO 나노 복합체의 에너지 밴드갭은 UV-Vis 흡광도 스펙트럼을 사용하여 Tauc 플롯에서 2.97 eV로 추정되었다.

Keywords:

나노 물질, 광촉매

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P1-se.225

Facile and Universal Growth of Monolayer Transition Metal Dichalcogenides by Liquid-Phase Deposition

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Abstract:

In the chemical vapor deposition (CVD) process using solid-phase precursor, the large-scale growth of transition metal dichalcogenides (TMDs) thin films with good uniformity is quite challenging since the nucleation density and growth behavior of TMDs become highly irregular on the growth substrate under the influence of non-uniform precursor vapor pressure distribution. Recently, the CVD process based on the liquid-phase precursor has emerged as a compatible synthesis approach for synthesizing uniform large-area TMDs thin films. Therein, the homogenous coverage of transition metal precursors onto the growth substrate with controllable concentrations can offer highly reliable and reproducible growth. Herein, we successfully synthesized monolayer 2H phase TMDs including molybdenum disulfide, molybdenum diselenide, tungsten disulfide, and tungsten diselenide on sapphire substrate via liquid-phase deposition process based on a homogeneously mixed solution containing transition metal precursor. The broad universality of the proposed liquid-phase deposition methodology was also demonstrated in other phase TMDs families including distorted 1T phase rhenium disulfide and rhenium diselenide. This proposed CVD approach provides better insight into the uniform synthesis of TMDs and sheds light on their practical applications in electronics and optoelectronics.

Keywords:

liquid-phase deposition, monolayer, transition metal dichalcogenides, universal growth

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P1-st.001

Invasion of a simple population dynamics with Allee effect on one-dimensional patch

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Abstract:

We look at the invasion of population dynamics in a one-dimensional lattice considering the Allee effect. The simple population dynamics, expressed by the logistic equation, can increase the population even at the very low number of populations. Therefore, in this system, the invasion rate of species is linearly proportional to the dispersal rate. However, when the Allee effect is applied, the system has a minimum condition to increase the number of populations, so the population is not maintained and extinct in the low density of population. The population does not invade and is pinned at the low dispersal rate, but the invasion is occurring and shows the depinning state above the critical dispersal rate.
We obtained a phase diagram of pinning-depinning transition according to the population growth rate and the strength of the Allee effect.

Keywords:

population dynamics, invasion rate, Allee effect, pinning, phase diagram

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P1-st.002

Yang-Lee Edge Singularity of the Ising Ferromagnet in an External Magnetic Field

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Abstract:

Yang and Lee proposed a mathematical mechanism for the occurrence of phase transitions in the thermodynamic limit, and yielded an insight into the unsolved problem of the ferromagnetic Ising model as a function of temperature in an external magnetic field by introducing the theory of the zeros of the grand partition function in the complex magnetic-field plane. The zeros of the grand partition function in the complex magnetic-field plane are simply called Yang-Lee zeros. SInce then, the theory of partition function zeros has played an important role in diverse fields of physics. The Yang-Lee edge singularity is one of the important properties of partition function zeros. It is explained in detail for the infinite-range Ising ferromagnet in an external magnetic field. Also, the unknown properties of the Yang-Lee edge singularity for the Ising ferromagnet on a square lattice in an external magnetic field are discussed.

Keywords:

Yang-Lee edge singularity, Partition function zeros

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P1-st.003

Free energy measurements by the generalized fluctuation theorems: theory and numerical study of a model filament.

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Abstract:

We measure the free energy of a model filament, which undergoes deformations and structural transitions, as a function of its extension, in silico. We perform Brownian Dynamics (BD) simulations of pulling experiments at various speeds, following a protocol close to experimental ones. The results from the fluctuation theorems are compared with the estimates from Monte Carlo (MC) simulation, where the rugged free energy landscape is produced by the density of states method. The fluctuation theorems (FT) give accurate estimates of the free energy up to moderate pulling speeds. At higher pulling speeds, the work distributions do not efficiently sample the domain of small work and FT slightly overestimates free energy. In order to comprehend the differences, we analyze the work distributions from the BD simulations in the framework of trajectory thermodynamics and propose the generalized fluctuation theorems that take into account the information (relative entropy) evaluated in the expanded phase space. The measured work - free energy relation is consistent with the results obtained from the generalized fluctuation theorems. We discuss operational methods to improve the estimates at high pulling speed.

Keywords:

non-equilibrium, free energy, Jarzynski equality, Crooks fluctuation theorem, helical filament

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P1-st.004

Effects of the self-propulsion parity on the fuel efficiency of an active heat engine

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Abstract:

Recent experiments have reported that, by utilizing active particles as working substance, colloidal heat engines can enhance their power and efficiency. But we still lack a precise thermodynamic picture of how such engines operate far from equilibrium. In particular, there has been much debate on how the sign (parity) of the self-propulsion force under time reversal affects the performance of the engine. To systemetically address these issues, we introduce a simple, thermodynamically consistent model heat engine consisting of a dimer whose activity is driven by fuel consumption and self-propulsion force can have any parity. Through cyclic changes in the temperature and the confining potential, work can be extracted from the engine. We find that the fuel efficiency of the engine, defined as fuel-to-work conversion rate, exhibits drastically different behaviors depending on the parity of the self-propulsion force. If the parity is even, the engine is fuel efficient when the period of each cycle and the persistent time of the active particle are comparable. In contrast, if the parity is odd, the engine is full efficient when the persistent time of the active particle is much shorter than the period of each cycle. Based on these observations, we discuss design principles which optimize the engine's performance under prescribed spatiotemporal scale and self-propulsion mechanism.

Keywords:

active matter, stochastic thermodynamics, efficiency, heat engine

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P1-st.005

Initial growth pattern of Parylene-C film on the liquid surface

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Abstract:

화학 기상 증착을 통해 글리세롤과 이온성 액체, 실리콘 오일 표면에서 성장한 Parylene-C 박막의 표면 구조를 원자력 현미경(AFM)을 이용하여 측정하였고, 이를 동력학적 스케일링 이론을 적용하여 박막의 성장 메커니즘을 연구하였다. 접촉각 측정을 통해 얻은 각 표면에서 parylene-C의 퍼짐계수(spreading coefficient)는 글리세롤: -4.07 mN/m, 이온성 액체 EMIM BF4: -2.02 mN/m, 실리콘오일 Pmx200: -41.42 mN/m 로 얻어졌다. 글리세롤 표면에서 Parylene-C 분자는 초기에 매우 얇은 네트워크 형태를 기반으로 성장함을 보였다. 이는 Parylene-C 분자가 액체 표면에 단일층을 형성하였고, 그 과정에서 grain 간 경계에 Parylene-C의 작용기가 밀집되었기 때문이다. 표면이 충분히 형성된 이후 나타나는 연속성장 영역에서는 거칠계수(roughness exponent) $\alpha = 1 \pm 0.1$, 성장계수(growth exponent) $\beta = 0.19 \pm 0.02$, 동적계수(dynamic exponent) $1/z = 0.2 \pm 0.02$로 고체 표면과 동일한 동력학적 특성을 보였고 이는 동력학적 스케일링 특성 중 초거칠(super rough) 성장모델에 해당한다. 이는 유사한 성장조건에서 길러진 박막의 동력학적 특성과 동일하다. 패럴린이 충분이 증착된 연속성장영역(d > 100 nm)에서는 표면의 구조, 상태에 관계없이 동일한 표면구조를 얻을 수 있었다. 이는 Parylene-C 단량체의 작용기 간 결합력에 의해 형성되는 화학적 결합력에 의한 응집 (CRLA)에 의한 특성이다.

Keywords:

AFM, Dynamic Scaling Theory, linear chain polymer, Vapor deposition, Parylene-C

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P1-st.006

Rank-unbounded evolving hypergraph model

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Abstract:

There has been increasing interests on group interaction and how to introduce it into networks. A network has been represented by a graph consisting of vertices and edges connecting two vertices and this depiction is restricted to pairwise interaction. Hypergraph is one of the extensions of a graph which include higher-order interactions, consisting of vertices and hyperedges where any number of vetices could be contained. In this scheme, a hyperdegee means how many hyepredges a vertice is included in and hyperedge size means how many vertices a hyperedge contains.

Several models have been proposed [1-3] and studied considering higher-order interaction. However, those are coming with limited hyperedge size while it is not always in real world. Rank-unbounded hypergraph evolving rule is suggested acordingly and compared with real network. The model hypergraph is designed to have power-law hyperedge size distribution and unbiased correlations in between graph degree and hyperdegree as real world network. It seemed as graph degree and hyperdegree have different power-law exponent in real world system. However, this difference in exponents is concluded as finite-size effect since it disappears in Monte carlo simulation with large number of nodes and ensembles. Hyperdegree exponent from simulation is supported by numerical estimation

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Keywords:

hypergraph, evolving, rank-unbounded

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P1-st.007

Urban scaling and transition in Korean economy

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Abstract:

Urban scaling, a nonlinear relation of population and indicators across different cities, has explained economic characteristics of many different countries as superlinear scaling for cognitive industries and sublinear scaling for manual industries. Despite an increasing number of studies on urban scaling, we still lack understanding of scaling properties in the Korean economy. Using a dataset of real estate prices and employment in all industry sectors, we present the scaling properties of the Korean economy and its critical population size of transition from small-city to large-city economies. As a result, we observe prevalence of superlinear scaling in real estate prices and most industries with the highest scaling exponent at the real estate industry. According to these scaling relations, the economic structure shows a transition into cognitive economies at a city population around 500,000 in consistent with the transition in the US economy. These findings highlight stronger concentration of the labor market and the real estate market in large cities compared to other countries.

Keywords:

urban scaling, Korean economy, economic transition

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P1-st.008

Explaining the varying exponent of gravity model on urban landscapes

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Abstract:

Human mobility in cities has been a crucial part in urban dynamics, and the gravity model has described the deterrence of travels with distance in mobility patterns and general human interactions inside cities. However, the mechanism for determining the exponent of the gravity model in cities is still far from understanding. In this study, we show how spatial urban landscapes shape the deterrence of the gravity model. Using the travel data in three different cities, i.e., Beijing, Shenzhen, and Chicago, we measure the exponents of travels between areas of different population sizes to find the link between the exponents and urban landscapes. As a result, a common pattern emerges in three cities, which displays large exponents between intermediate-populated areas. We explain how this travel pattern is related with centralized structures of cities. Our findings give insights into urban travels for the better prediction and optimization.

Keywords:

Gravity model, Human mobility, Population landscape

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P1-st.009

Evolutionary game dynamics with chain-reaction death on networks

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Abstract:

We study the evolutionary game dynamics on structured populations with the chain-reaction death process of the Bak-Sneppen model using mean-field theory and Monte Carlo method. Interaction between members is mimicked by a donation prisoner's dilemma game with a memoryless stochastic strategy. The fitness of each individual is determined by the total payoffs π of the games with its neighbors. The population evolves with two-types of death processes, fitness dependent death and chain-reaction death. In the former, the death probability is proportional to $1/f = e^{-\beta\pi}$ with selection intensity β. The neighbors of the death site also die with a probability R through the chain-reaction process invoked by the abrupt change of the interaction environment. When a cooperator is exploited by defectors, the cooperator is likely to die due to its low payoff, but the neighboring defectors also tend to disappear through the chain-reaction death, giving rise to an assortment of cooperators. Owing to this assortment, cooperation can emerge for a wider range of R values than the mean-field theory predicts. For the small cost-to-benefit ratio, the emergence of cooperation through the assortment is more prominent on heterogeneous networks since the defective hubs disappear due to the chain-reaction death process. However, when the cost-to-benefit ratio is relatively large, close to one, we observe that the cooperative region of R on heterogeneous networks becomes narrower than on regular networks in the strong selection limits. This is because cooperative hubs are prone to die out due to their large fluctuations in payoffs. Our observation implies that the chain-reaction death process provides a robust way for the evolution of cooperation for a large range of parameter values, but the exact condition for the cooperation may strongly depend on the structures of populations.

Keywords:

Evolutionary game theory, Emergence of cooperation, Prisoner's dilemma, Bak-Sneppen model

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P1-st.010

랜덤워크 기반 모형을 통한 서울시 편의 시설 및 지하철 분포 분석

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Abstract:

서울을 포함한 수도권의 주민등록상 인구는 2020년 6월 현재 2천600만으로 대한민국 총 인구의 약 50%가 넘는다. 주요 대중 교통수단은 서울 도시철도인데, 자하철 1-9호선 및 서울 경전철 노선들의 총거리는 약 350km에 해당된다. 서울에는 병원, 식당 등 다양한 편의 시설이 복잡하게 분포(복잡계)되어 있으며, 이들은 교통 접근성이 좋은 각 지하철역을 중심으로 위치지어져 있다. 본 연구에서는 서울 공공 지방행정 인허가 데이터개방 (www.localdata.kr) 웹사이트에 공개되어 있는 서울시 편의시설의 분포(예: 지하철역 위치, 병원 및 식당 위치 등)를 데이터 기반 분석을 통해 고찰하였다. 나아가 이러한 데이터 분석 결과를 랜덤워크에 기반한 수리적 모델로 단순화 하여 컴퓨터 시늉내기를 통해 재현하였다.

Keywords:

랜덤워크, 복잡계, 데이터 기반

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P1-st.011

The cover time on networks of random walks with stochastic revisiting

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Abstract:

The random search process in complex networks is closely related to various real-world problems, e.g., surfing the Internet to obtain the information, finding someone on Facebook, and transmitting data packets to any target computer. In human or animal movements in physical space and cyberspace, it is frequently observed that a walker revisits previously visited nodes using their long-term memory. In this study, we investigate the effect of revisit strategy on random search performance with our model; a walker randomly revisits one of the previously visited nodes at a constant rate. We apply our model to synthetic and real networks and measure the cover time, which is the time needed to visit every node in a network. We numerically observe some optimal revisit rates to minimize the cover time on a network 1) with a line-like structure and 2) with inaccessible nodes in both synthetic and various real-world networks.

Keywords:

Random walk, Cover time, Stochastic revisiting, Complex networks

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P1-st.012

Network Analysis of scientific collaboration and knowledge flow

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Abstract:

Social network analysis has become an active research area in recent years in order to understand the social impact and grouping of people or groups. Collaboration networks have also been studied in the past few years, such as Newman's work on the structure of scientific collaboration networks and Barabasi's work on the study of dynamics of scientific collaboration networks.

While the papers so far have focused on the individual scientists' level, in our presentation, we analyze the network by focusing on the group level to which the scientists belong. We studied the collaboration networks of academic fields at the institution level and particularly focused on QS top 200-ranked universities. We will discuss the knowledge flow of universities through the network topology values obtained from collaboration networks in our analysis.

Keywords:

Social network analysis, scientific collaboration, knowledge flow

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P1-st.013

Time evolution of political polarization in the National Assembly of Republic of Korea

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Abstract:

We study the time evolution of political polarization in the National Assembly of Republic of Korea based on co-sponsorship among lawmakers for the past 70 years. By projecting the data onto the first principal axis, we observe a high degree of polarization from the early 1960's to the late 1980's, and since then polarization has tended to decrease but with large fluctuations. We discuss this observation in relation to the median-voter theorem.

Keywords:

political polarization, principal-component analysis, co-sponsorship, median-voter theorem

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P1-st.014

Mean-field model for real epidemic spreading

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Abstract:

2019년말부터 최근까지 대유행 중인 코로나 바이러스(Covid-19)는 강력한 전파력을 가지고 있으며, 특히 무증상 전파 사례가 보고되고 있다. 본 연구는 이러한 Covid-19의 질병 전파 양상을 설명하기 위해, 평균장 형태의 질병전파모델인 SEIR 모델에 무증상 감염자(non-confirmed Infection)를 추가한 새로운 모형을 제시한다. 각 국가별 Covid-19 감염자 데이터를 가장 잘 설명 할 수 있는 모형의 매개변수를 Bayesian optimization 및 least square fit을 통하여 구하였다. 추정된 파라미터들을 이용하여 질병 전파 양상을 논의해 본다.

Keywords:

Complex system, Epidemic

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P1-st.015

Deep learning of chaos classification

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Abstract:

We train an artificial neural network which distinguishes chaotic and regular dynamics of the two-dimensional Chirikov standard map. We use finite length trajectories and compare the performance with traditional numerical methods which need to evaluate the Lyapunov exponent. The neural network has superior performance for short periods with length down to 10 Lyapunov times on which the traditional Lyapunov exponent computation is far from converging. We show the robustness of the neural network to varying control parameters, in particular we train with one set of control parameters, and successfully test in a complementary set. Furthermore, we use the neural network to successfully test the dynamics of discrete maps in different dimensions, e.g. the one-dimensional logistic map and a three-dimensional discrete version of the Lorenz system. Our results demonstrate that a convolutional neural network can be used as an excellent chaos indicator.

Keywords:

Machine Learning, Chaotic Dynamics, Deep learning, Chirikov standard map

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P1-st.016

Lumped permutation entropy: A robust complexity measure on noisy time series under state transitions.

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Abstract:

Measuring complexity from non-stationary time series provides an important clue to the understanding of dynamic patterns of a given dynamical system. One of the widely used complexity measures is the permutation entropy, which quantifies the entropy of the symbolic patterns of the observed time series.
In this study, we propose the lumped permutation entropy (LPE) which provides a robust complexity measure that helps to overcome some limitations of previous algorithms under noisy environments. LPE allows a joint rank on the pattern formation, enhancing the robustness over strong background noise. The performance of LPE is demonstrated for chaotic time series from some dynamical models and empirical electroencephalogram (EEG) data from anesthetic studies. In particular, our results show that LPE of the EEG complexity is anti-correlated with the concentration of anesthetics throughout the anesthesia phase, allowing the quantitative monitoring of the state transitions of the brain through the entropic complexity of EEG patterns.
In summary, the lumped permutation entropy (LPE) can be useful for measuring and monitoring the complexity of dynamical systems under strong noise such as EEGs with continuous state transitions.

Keywords:

Complexity, Time Series, EEG, Anesthesia

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P1-st.017

Microbial groups as evolutionary units: variance of group traits

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Abstract:

Holobiont unit is a recently developed concept, indicating a host with many other species within or around it. However, holobiont as an evolutionary unit is in a huge debate due to the lack of theoretical studies. As a first step of understanding the evolution of holobiont, we focus on the microbial groups prepared in the serial dilution experiments and their growth rates as group traits. Microbial groups grow in a fixed time and then are diluted. Repeating this protocol, we trace the variance of group traits in time as a fundamental ingredient of evolution. Results show that the variance increases in time when the population size is large and the dilution time interval is short. The stochastic differential equation for the group traits is derived to confirm our result in the same limit.

Keywords:

Population Genetics, Multilevel selection

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P1-te.001

동영상에 기록된 정보의 해석을 통해 살펴보는 법과학에서 사용되는 기초 물리학

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Abstract:

법과학이라는 용어는 범죄수사를 하는 과정에 사용되는 과학적 방법을 통칭하여 사용되는 말이다. 법적인 것과 관련한 법정과 관련한 과학이라는 의미로 널리 알려져 있고, 포렌식(Forensic)이라는 단어와 혼용해서 사용되고 있다. 법과학 영역에서 물리학의 사용범위는 물성의 분석으로부터 규모가 있는 사고의 재구성과 관련한 해석까지 매우 넓다할 수 있다.
본 논문은 대학 전공자가 아니라 할지라도 실생활에서 피부에 와 닿는 물리학적 접근으로 과학을 전공하지 않은 대중이 단지 물리학이라는 단어가 갖는 무게감을 좀 더 가볍게 느꼈으면 하는 바람을 담아 매우 간결한 기초 물리학 지식을 기반으로 실제 범죄 수사를 해석하는 과정에 적용한 사례를 소개하고자 한다.
범죄수사에 대한 과학적 해석은 이미 잘 알려진 기술이나 완성된 이론을 적용하여 그 과정을 유추해 나가는 것으로 법정에서 다툼이 이루어지는 요소는 유추해 낸 결과의 타당성, 증명력을 가질 수 있는 가에 대한 논의라 할 것이다[1]. 이러한 논의가 최신 기술과 이론을 알아서 적용하고 있는가에 초점을 맞추고 있는 것이 아니라, 과학적 시험법으로 알고 있는 체계성을 갖추고 있는지에 대한 것이 중심이 된다[2].
과학자는 새로운 현상을 확인하여 가설을 설정하고 이에 대한 증명을 해 나가는 과정으로 이루어진 이론을 바탕으로 다양한 가능성을 제시할 수 있다. 다만, 법과학자의 경우 한 개인의 인생에 영향을 미칠 수 있으므로, 미소한 가능성만을 기반으로 한 의견 제시는 신중해야 한다[3].
특히나 상당수의 범죄는 인간의 의지가 포함되어 있는 결과이기 때문에, 매개변수를 정의할 수 없거나, 정의할 수 있는 경우에는 가능한 범위를 정하여 분석이 이루어지게 된다.
본 논문에서 소개하고자 하는 사례는 실생활에서 많이 일어나는 차량의 이동에 따른 상호작용을 차량용 주행 영상 기록장치를 활용한 해석한 사례로부터 기초 물리학이 어떻게 적용되었는지에 대한 것이다.
영상을 촬영하는 장치인 카메라는 동영상을 기록하게 되는 경우, 일정시간 간격으로 영상을 획득하고, 이를 통합하여 기록할 수 있도록 되어 있다. 법과학에서는 영상정보가 목격자로서 그 활용도가 높으며, 기록되어 있는 피사체의 거동을 확인하고 이를 해석하여 사고 해결의 실마리를 찾기도 한다. 최근에는 블랙박스로 일컫는 차량용 주행 영상 기록장치가 널리 보급되어, 차량사고는 물론 주행 중 녹화 기능으로 사설 CCTV의 역할까지 해 내고 있다. 차량의 주행과정에 촬영된 주요 피사체의 위치를 기준으로 한 거리 계측, 동영상을 구성하는 개별 영상을 활용한 시간 측정과 이를 활용한 속력 측정 사례와 영상에 기록된 차량의 다중충돌사고에서 음파의 세기를 활용하여 충돌 순서를 재구성한 사례이다.

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Keywords:

법과학

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P1-te.002

Actual Experiment of Radiation in Primary School Science

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Abstract:

In the 6th ~ 9th section of Science 5-2 [Temperature and Heat] title in primary school, it introduces conduction and convection from solid, liquid and gas to heat transfer. The content of radiation, one of the methods of heat transfer, is not included in the current curriculum. The exploratory activity at the elementary school level are proposed to perform the radiation experiments with simple tools. In the radiation experiments, sun and incandescent lamps were used as radiant light sources, and white cans and black cans were used as target objects. The temperature of water in a container according to time are measured under the various variables of lamp power, distance between lamp and object, surface color of objects, volume of water and so one. The temperatures of waters in the white and black cans under sun radiation were affected on the natural conditions of cloud, wind and so on. Using incandescent lamps, it is convenient to control the variables that can conduct experiments in a class time, regardless of natural conditions.

Keywords:

Radiation

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The dependence of tilting of wooden board on various variables

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Abstract:

In the section of How do you compare the weight of an object? of Science 4-1 [Weight of Objects] title in primary school, the wooden board level is kept level. Must the wooden board be kept level? Is it wrong if the wooden board is tilted? What is the difference between tilting and horizontal? If there is a difference in the two cases, what is the cause? The answer to these questions implies the principle of lever. The tilting factor of the wooden board depends on the weight of the object, the distances and heights between the load, force and fulcrum points, and the mass and the physical size of the wooden board. A simulation program was created for variables that affect the tilt of wooden boards, and the dependence of tilt on these variables was performed.

Keywords:

lever

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공간을 전파하는 음파의 횡적 파형 측정

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Abstract:

자유공간에서 음파의 골과 마루의 위치를 측정하는 음파위상측정기(SWPM, sound wave phase meter)를 개발하였다.
본 연구에서는 개발된 SWPM을 이용하여 자유공간에서 음파의 횡적 파형을 측정하는 실험을 진행하였다. 이를 위해 점파원에서 음파가 발생되도록 SWPM과 음원 사이에 단일슬릿을 설치하고 SWPM을 앞뒤로 이동시키며 음파의 횡적 파형을 측정하였다. 그 결과 임의의 시간 t에서 공간에 형성되는 음파의 횡적 파형을 성공적으로 검출하였다. 따라서 SWPM은 교육용 실험 장치로 활용이 가능할 것으로 기대된다.

Keywords:

음파위상측정기, 음파, SWPM, 횡파, 교육용 실험장치

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지구온난화에 의한 영구동토층 융해에 따른 온실기체 배출 실험 모델

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Abstract:

영구 동토층 아래에 매장된 메탄가스 등의 온실기체가 지구온난화로 인해 동토층이 녹으면서 대기로 급격히 방출되고 있다.
본 연구에서는 지구온난화에 의한 영구동토층 융해에 따른 온실기체 배출에 대한 실험 모델을 구상하였다. 이를 위해 드라이아이스를 물 안에 넣으면 드라이아이스 표면에 얼음 층이 형성되는데, 이때 물은 지구의 대기, 얼음 층은 영구동토층, 드라이아이스는 온실기체라고 대치한다. 그러면 지구온난화의 효과를 물의 온도증가로, 영구동토층의 융해를 얼음층의 융해로, 온실기체의 배출을 이산화탄소의 배출로 간주할 수 있을 것 이다.
이러한 실험모델을 구체적으로 실험한다면 영구동토층이 모두 녹는데 필요한 지구 평균 대기온도의 상승치를 구할 수 있을 것으로 판단된다.

Keywords:

영구동토층, 지구온난화, 메탄가스, 드라이아이스, 온실기체