BAS (Physics, Astronomy, Chemistry, Math, Stat and Other Basic Sciences)
Summary
With the current worldwide development of rare isotope accelerators such as the Korea Rare Isotope Accelerator (KoRIA) and the Facility for Rare Isotope Beams (FRIB), it is timely to review the forefront of the nuclear physics that can analyze the data from these accelerators and provide the deeper understanding on the physics of nuclei and the nuclear astrophysics. In this presentation, we discuss the frontiers of current nuclear physics that can address the fundamental issues in the physics of nuclei and the nuclear astrophysics. Relevance of these physics to rare isotope accelerators, in particular KoRIA, will be discussed.

I. INTRODUCTION
Basic Science Institute (BSI) has been planned to establish a world-class institute for the basic science research as the main research institute of the International Science and Business Belt (ISBB) at Daejeon Metropolitan City in Korea. In particular, the Korea Rare Isotope Accelerator (KoRIA) will be constructed at BSI to explore the physics of 10^{-15}m scale, which is much smaller than the size of an atom, through collision of accelerated particles with matter. This development along with the Facility for Rare Isotope Beams (FRIB) planned at Michigan State University in US will allow production of a wide range of new designer isotopes which are necessary for an accurate modeling of atomic nuclei, tests of fundamental symmetries and the study of chemical history and mechanisms of stellar explosions. We would like to address frontier physics questions that can be pursued by KoRIA and FRIB in the area of Particle, Nuclear and Astrophysics: i.e.
• What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes?
• What is the origin of simple patterns in complex nuclei?
• What is the nature of neutron stars and dense nuclear matter?
• What is the origin of the elements in the cosmos?
• What are the nuclear reactions that drive stars and stellar explosions?

These questions touch upon the forefront of the topics in quantum chromodynamics (QCD) and hadrons, fundamental symmetries and neutrinos, physics of nuclei and nuclear astrophysics. We will discuss the frontiers of current nuclear physics theories that can address these fundamental issues such as the nature of the nuclear force, the origin of simple patterns in complex nuclei, the nature of dense nuclear matter (e.g. neutron stars), the mechanism of the nucleosynthesis (e.g. nuclear reactions that drive stars and stellar explosions).

II. CRITICAL CHALLENGES
As the challenge of nuclear science is the microscopic understanding of macroscopic objects and phenomena, the road map from the fundamental theory of strong interactions, i.e. the quantum chromodynamics (QCD), to the effective theory development for comprehensive description of many-body nuclear physics should be unambiguously established. We may benefit from the concrete road map established in the atomic physics: e.g. the link between the quantum electrodynamics (QED) and the phenomenological atomic model. In this development of the road map, fundamental symmetries are crucial to link between the fundamental theory and the effective theory as it has been shown in the development of the chiral perturbation theory from QCD. In this respect, the utility of KoRIA is anticipated to go beyond the physics of nuclei and the nuclear astrophysics and make a forefront impact on the fundamental theory of strong interactions: QCD and hadron physics.

III. CONCLUSION
In this presentation, I will first summarize some of the frontier physics of nuclei and nuclear astrophysics that will be carried out with the new generation of rare isotope beam facilities. I will then discuss the possible road map for the nuclear physics with rare isotope accelerators.

REFERENCES
Determination of Gravitational Constant $G$
Using a Superconducting Differential Accelerometer

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SUMMARY
The University of Maryland (UM) and the Korea Research Institute of Standards and Science (KRISS) are preparing a joint cryogenic experiment to determine the gravitational constant $G$ to one part in $10^8$. The source and levitated test masses will be configured to form a planetary system, in which the gravitational force on the test masses is balanced by centrifugal acceleration and the superconducting differential accelerometer formed by the two test masses is used a null detector.

I. INTRODUCTION
The best resolution of the gravitational inverse-square law, exceeding one part in $10^8$ at $10^7 \sim 10^9$ km, comes from the orbital motions of the Moon and LAGEOS satellites [1]. Such resolution is possible because, in a planetary system, the gravitational field is exactly balanced by centrifugal acceleration:

$$GM_E/R^2 = R\omega^2,$$  \hspace{1cm} (1)

and $R$ and $\omega$ of the orbit can be determined very precisely. This yields a value of $GM_E$ accurate to better than one part in $10^8$. Unfortunately, $G$ cannot be determined from this since the mass of the Earth $M_E$ cannot be measured independently.

A “planetary system” could be constructed in the laboratory by using levitated superconducting test masses at 4.2 K orbiting around a large source mass [2]. Such an experiment would take all the advantages of a real planetary system and the source mass can be measured independently, leading to the possibility of determining $G$ to an unprecedented accuracy of 1 ppm.

II. EXPERIMENTAL PRINCIPLE AND DESIGN
In early 1990’s, Moody and Paik [3] performed a null test of Newton’s law using a superconducting differential accelerometer, setting the best limit at 1-m distance: two parts in $10^6$. This instrument had mechanically suspended test masses, which limited its sensitivity to $2 \times 10^{-3}$ E Hz$^{-1/2}$ (1 E $= 10^{-9}$ s$^{-2}$) [2]. Magnetically levitated test masses could improve the sensitivity by two orders of magnitude.

Figure 1: Schematic of the experiment

Figure 1 shows a top view of the experiment. Each pair of magnetically levitated test masses are coupled by a superconducting circuit to form a sensitive differential accelerometer [3]. The entire apparatus is rotated about the vertical to precisely balance the gravitational field with the centrifugal acceleration. This brings in numerous benefits: (1) the differential accelerometer is used as a null detector, alleviating the need for its calibration, and (2) $\omega$ can be calibrated to high precision by measuring the time it takes to make a complete turn. The absolute distance $R$ can be measured to a few parts in $10^7$ by using optical interferometry. An error analysis indicates that this experiment could yield $G$ to a 1-ppm accuracy.

REFERENCES
Nuclear Science with rare isotope beams

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Summary

The study of atomic nuclei is a core contribution to the goal of understanding matter in the universe. Our view of the landscape of atomic nuclei is severely limited. Models developed based on data from nuclei at or near the region of stability have been seen to fail when applied outside these narrow confines. The Facility for Rare Isotope Beams FRIB, to be constructed on the campus of Michigan State University, will remove much of that limitation. FRIB will offer unique opportunities for rare isotope research. It will provide a wide variety of high-quality beams of unstable isotopes at unprecedented intensities, opening exciting research perspectives with fast, stopped, and reaccelerated beams. Rare isotopes are different from stable nuclei, and provide new and unique insights into the nuclear many-body problem. With the wide variety of high-quality beams of unstable isotopes provided by FRIB at unprecedented intensities, we will be able to study the physics of weakly-bound quantum systems, get access to entirely new nuclear topologies (for example neutron skins), study the role of the proton-neutron imbalance in nuclei with extreme ratios of N/Z, and much more. This insight, coupled with dramatic improvements in nuclear theory and computational power, promises to lead to a quantitative description of nuclei. A comprehensive description of nuclear structure is important to the understanding of the origin of the elements and for the use of nuclei as laboratories for probing fundamental symmetries. This talk will provide an overview of the science that is driving the development of FRIB.
Quantum effects in the solar energy conversion dynamics of soft molecules

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SUMMARY
Nature’s solar energy conversion systems and plastic photovoltaic devices have one thing in common. The constituting molecules are soft. However, the discrepancy in their efficiencies is striking. Recent experimental and theoretical studies suggest that the secret of Nature’s success may be revealed if it is understood how they exploit quantum coherence in order to minimize the loss of energy due to relaxation and disorder. Answering this question requires theoretical means to provide quantitative description of energy flow dynamics in such soft photovoltaic systems. While there are well known theories of energy transfer that have been employed to describe experimental data for many decades, recent experimental results show that such theories are inadequate for describing the energy transfer processes in soft and multichromophoric photovoltaic systems. One of the major issues is that conformational fluctuations and vibrational relaxations need to be treated on the same quantum mechanical footing as the energy transfer dynamics. The other issue is moderate or strong electronic coupling between energy donor and acceptor, which makes the simple rate picture of energy transfer invalid. This talk presents new theories addressing these issues and the application of the theories to natural photosynthetic systems and organic pi-conjugated systems. These elucidate the sensitivity of quantum coherence on details of how electronic excitations are coupled among themselves and to their environments, and suggest ways to utilize them for enhancing the efficiency of energy flow dynamics.

REFERENCES


Here, we present fast magnetosonic waves propagating across solar radial magnetic fields. STEREO COR1 and EUVI observations showed coronal disturbances associated with flares/CMEs and they propagate in the low solar corona in the form of EIT waves and in the high solar corona (above 1.5 Rs) in the form of density compressions along radial magnetic field lines above EIT wave fronts. It turns out that the coronal disturbances pass through streamers which contain a magnetic separatrix. The wave energy appears to be trapped by the streamers and this leads to stationary fronts at the footpoints of the streamers. Our results suggest that the coronal disturbances associated with flares/CMEs are fast magnetosonic waves propagating with local fast magnetosonic speeds and passing through magnetic separatrices. Moreover, we conclude that EIT waves are ‘real’ fast magnetosonic waves. The speeds of the coronal disturbances are 475 ± 14, 926 ± 19, 1217 ± 24, 1734 ± 48, and 1928 ± 42 km/s at 1.0, 1.6, 2.0, 2.5, and 3.0 Rs, respectively. Using coronal seismology, we estimated magnetic field strengths corresponding to these speeds at the heights and they are 1.81 ± 0.06, 0.98 ± 0.02, 0.70 ± 0.01, 0.55 ± 0.02, and 0.39 ± 0.01 G, respectively.
A New Program of Radioactive Beam Studies at the Texas A&M University Cyclotron Institute

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SUMMARY
An upgrade of the accelerator facility at the Texas A&M University Cyclotron Institute is nearing completion and will provide accelerated radioactive beams at energies up to 50 A-MeV. The status of the project and the new science that it will open up will be reviewed in this talk.

I. INTRODUCTION
Beginning in January, 2005, the Department of Energy partnered with Texas A&M University (TAMU) and the R.A. Welch Foundation to upgrade the accelerator facilities at the Cyclotron Institute to produce accelerated radioactive beams. During the course of the project, a K150 (88") cyclotron has been refurbished to produce high intensity beams. The beams will be used to produce secondary reaction products that will be stopped in ion-guide gas catchers and then fed into a charge-breeding Electron Cyclotron Resonance (ECR) ion source where they will be stripped to high charge states before they are reaccelerated in the K500 superconducting cyclotron. The project is nearing completion and should be producing the first radioactive ion beams by the fall of 2012.

Below, an overview of the ion-guide systems is presented. Details will be given during the presentation.

II. Ion-Guide Systems
Two types of ion-guides are being prepared for use in the upgraded facility. One of these is a light-ion guide that is similar to the IGISOL facility at the University of Jyväskylä [1]. The TAMU system is based on stopping recoil ions in pure helium gas that are knocked out of a target from reactions that are induced by a light-ion beam. The recoils are left at 1⁺ ions in the helium. They are extracted from the production chamber by a combination of helium gas flow and acceleration by an electric field. High intensity light-ion beams such as protons or deuterons from the K150 cyclotron will be used to produce the recoils from the target. A sextupole ion guide will transport the stopped ions to a charge-breeding ECR ion source where they will be boosted to high charge states before being transported to the K500 cyclotron for acceleration.

The second type of ion-guide that will be used is an Argonne National Laboratory type linear gas-cell [2]. This ion guide is designed to stop heavy-ions up to about 5 A-MeV that are produced in collisions of stable heavy-ion beams from the K150 cyclotron with stable targets. A large bore superconducting solenoid will be used to collect the recoils and help direct them into the linear gas cell. The stopping gas is once again pure helium, which produces 1⁺ ions from the linear cell. An RFQ device will be used to transport the ions from the linear cell to the charge-breeding ECR source. The path for the highly charged ions out of the ECR source is the same as for those produced by the light-ion guide.

III. Present Status
The present status of the upgrade project will be reviewed during the presentation. This will be followed by a brief description of the initial science program that we plan to carry out with the upgraded facility.

REFERENCES
Heterogeneous Nanostructures: Fast Electrochemistry, from Electrochromics to High Power Energy Storage

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SUMMARY
The presentation will discuss both the electrochemical and electrostatic supercapacitors as high-to-ultrahigh power energy devices, a newly emerging research area in energy storage research field. The electrochemical growth of the conductive polymer nanotubes and the heterogeneous metal oxide composite nanowires will be mainly described for ultrafast electrochromic display and high power energy storage applications. Fast electrochemistry of nanotube-structured materials enables us to design extremely fast charge transport devices due to thin nature of nanotube wall and well-aligned array structure. The fast electrochromics will be discussed and demonstrated as a proof of the fast redox reaction and for display application. The same concept of fast redox reaction can be applied to high power energy storage device such as supercapacitor and high-power battery. Again, nanostructured materials, as noted above, offer vast gains in power density by increasing surface area and reducing path lengths for electron and ion transport. Heterogenous nanostructured materials separate the multiple functionalities (large energy storage, rapid ion transport, high electrical conductivity, high mechanical stability) to different materials, realizing a combined material structure with much higher synergistic performance. This presentation will also give an overview on four strategic themes in roles of nanostructures and their heterogeneous structures for electrochemical energy storage systems, research activities under the NEES Energy Frontier Research Center at the University of Maryland with 6 participating institutes.

REFERENCES
Spin liquid and spin glass states in frustrated magnets

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One of the things that we do for living as scientists is to observe and classify phenomena and to come up with models and theories to get a better understanding and predictability of the phenomena. For example, we categorize things in everyday life into three different categories; gas, liquid and solid. In gas and liquid, particles (or atoms) can move past one another, and flow easily. Their difference is that gas is compressible at moderate forces while liquid is. On the other hand, in solid, atoms cannot move past one another and it is uncompressible at moderate forces. For a quantitative microscopic understanding, we can introduce a physical quantity called the atom-atom correlation function that can be experimentally measured. The correlation function will behave differently for the different states; it has a static component for a solid while it does not for a liquid and a gas. The static atom-atom correlation function appears as sharp peaks in momentum space, which reflects the long range ordering of the atoms in the real space in a solid. Liquid and gas do not yield static correlation functions. For liquid, dynamic correlation function exists and it is broad in the momentum space, reflecting the dynamic short-range order of the constituent particles. Glass is a peculiar state. For a glass, the static correlation function is not zero, but it is broad in the momentum space, which is due to the static short-range order. Thus, solids can be further categorized into two: crystalline solid and amorphous solid (glass).

In this talk, we show that a similar categorization can be applied to magnetic materials; spin solid, spin liquid, and spin glass. We will discuss what are the microscopic origin and characteristics of each state by considering a few model materials for those states. We show that a spin liquid state becomes the ground state for a system where the relevant spin degrees of freedom are disordered, the ground state is macroscopically degenerate and local zero-energy excitations among the ground states exist. On the other hand, a spin glass can be the ground state for a quasi-two-dimensional frustrated magnet where ordered and disordered degrees of freedom coexist, and while the ground state is still degenerate but the zero-energy excitations are not local. Due to the unique properties of the ground state, a spin glass can become the ground state for the quasi-two-dimensional frustrated magnet.

REFERENCES
SUMMARY
The dynamics of energy transfer between exciton and dopant state, charge carrier transfer and trapping processes in Mn-doped semiconductor nanocrystals and their correlation to the structure are investigated using time-resolved spectroscopy. The structural controllability of the dynamics of energy and charge transfer processes will be important in the photonics application of doped semiconductor nanocrystals.

I. INTRODUCTION
Semiconductor nanocrystals doped with transition metal ions, e.g., Mn\(^{2+}\) and Cu\(^{+}\), exhibit unique photophysical properties, such as the sensitized dopant luminescence and magneto-optic effects that bear practical importance in photonics and spintronics applications. Many of these properties are strongly affected by the competition of the several dynamic processes including energy and charge transfer, which can be tuned by structural control of the wavefunctions of exciton and dopant. Here, we discuss the dynamics of exciton-dopant energy transfer and the charge carrier trapping as a function of several key structural parameters of the doped nanocrystals.

II. RESULTS and CONCLUSIONS
The structurally-correlated exciton-Mn energy transfer is studied in Mn-doped CdS/ZnS core/shell nanocrystals (NCs) where the radial doping location (\(d\)) is varied (Figure 1). Samples with three doping densities (\(n_{\text{Mn}}\)) are prepared for each value of \(d\). The energy transfer is expected to be faster with larger exciton-Mn wavefunction overlap, i.e., close doping of Mn to the center of NCs. Energy transfer time (\(\tau_{\text{ET}}\)) is measured from the comparison of the dynamics of the bleach recovery of exciton at the band edge in doped and undoped CdS/ZnS NCs. The faster exciton relaxation in the doped NCs is due to the energy transfer from exciton to Mn, as summarized in Figure 1. \(1/\tau_{\text{ET}}\) is proportional to \(n_{\text{Mn}}\) at a given \(d\), and increases when Mn\(^{2+}\) ions are closer to the core of NC. Depending on the doping location and density, \(\tau_{\text{ET}}\) can be as short as a few ps in our sample. In the energy transfer process of doped nanocrystals, charge carrier trapping is the major competing process. Between the electron trapping and hole trapping, hole trapping is the dominant process that competes with the energy transfer. In our structure, hole trapping occurs on the times scale of 50-100 ps, which is much slower than the energy transfer time.

In conclusion, exciton-Mn energy transfer rate and charge carrier trapping were studied in Mn-doped CdS/ZnS nanocrystals of controlled doping location and density. Knowledge obtained in this study will provide a valuable insight into the structural control of the photophysical properties of doped semiconductor nanocrystals.

REFERENCES
In-situ Impedance Measurement Of Gold Nano-Island Assembly and Polymer Thermolysis in Self-Assembled Multilayer Film

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SUMMARY

In-situ impedance measurements during thermolysis are performed to monitor the formation of nano-islands from a self-assembled Au-314 multilayer film. These measurements provide an insight to the thermolysis process of the polymers and the formation of nano-islands.

I. INTRODUCTION

Gold nano-islands are very sensitive to any plasmon changes on their surface boundary, offering chemical and bio-sensing applications.

Polymer-mediated self-assembly is a low-cost alternative to evaporation or sputtering for depositing gold on a substrate [1,2]. Gold nanoparticles may be functionalized by organic molecules and deposited layer by layer using self-assembly to create layers predictably.

Nano-islands are formed by thermolysis of the organic molecules at high temperatures, and subsequently annealing the resulting gold film at a temperature between 600°C to 650°C.

II. PROCEDURE

A pre-patterned inter-digitated electrode (IDE) glass substrate was dipped to a solution of Au-314 nano-particles functionalized with organic ligands to form a monolayer. Between layers, the electrode was dipped in poly(allyl amine) hydrochloride (PAH), which bonds to an additional layer of functionalized Au-314. Eight layers were assembled by this layer-by-layer method.

The sample impedance was measured in situ during the high temperature heating and cooling by a four-point measurement at 1kHz frequency.

III. RESULTS

Compared to the bare IDE substrate, the self-assembled gold sample shows several distinct features while heating. The most notable feature is a sharp decrease in impedance at 560°C, reaching less than 100 Ω at 570°C. Above 620°C the resistance increases sharply.

Figure: Resistance versus temperature is plotted for a multilayer sample (black) and for a bare IDE (blue). The arrows indicate the direction of the temperature changes during the measurement.

The sharp decrease in resistance around 560°C suggests the structural integrity of polymers is compromised and the gold nano-particles start forming the conductive percolative network. The increased resistance at 625°C indicates the formation of nano-islands through the aggregation and embedding of nano-islands on the glass. We will present experimental evidences to support our conclusions.

We would like to thank Prof. Shon and his group for the samples and other support.

REFERENCES
High Energy Cosmic Rays

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SUMMARY
Direct measurements of cosmic rays with satellite or balloon-borne detectors are used for understanding cosmic ray origin, acceleration and propagation, exploring the supernova acceleration limit, and searching for exotic sources such as dark matter. Their energy reach is currently limited to $\sim 10^{15}$ eV by the detector size and exposure time, but incident particles are identified element-by-element with excellent charge resolution. A challenge of balloon-borne and space-based experiments is that the detectors must be large enough to collect adequate statistics, yet stay within the weight limit for available space flight. Innovative approaches now promise high quality measurements over an energy range that was not previously possible. Recent measurement results and their implications will be reviewed. The outlook for existing and future experiments will also be discussed, along with opportunities for US-Korea cooperation.

I. INTRODUCTION
Cosmic rays consist of the nuclei of all atomic elements in the periodic table plus subatomic particles. They reach Earth from far outside the solar system with enormous energies providing a direct sample of matter from outside the solar system. Their interactions with galactic matter and fields are the source of much of the diffuse gamma ray, x-ray, and radio emissions. Cosmic ray research lies at the intersection of particle physics, cosmology, and astronomy. It focuses on highly relativistic particles produced in the most extreme non-equilibrium environments in nature, e.g., supernova explosions, gamma-ray bursts, or active galactic nuclei.

II. CURRENT RESULTS
Over the past decade several investigations were initiated to look for evidence of a limit to supernova acceleration in cosmic-ray chemical composition at high energies. Example results include an unexpected surplus of high-energy cosmic ray electrons reported by the balloon borne experiment Advanced Thin Ionization Calorimeter (ATIC). Annihilation of exotic particles postulated to explain dark matter is among other explanations proposed. Another notable example is spectral hardening reported by the Cosmic Ray Energetics And Mass (CREAM) experiment, which has achieved a record-breaking cumulative exposure of $\sim 161$ days in six successful flights over Antarctica. This result contradicts the traditional view that a simple power law can represent cosmic rays without deviations below the “knee” around $3 \times 10^{15}$ eV. It provides important constraints on cosmic ray acceleration and propagation models, and it must be accounted for in explanations of the electron anomaly and mysterious cosmic ray “knee.”

III. CONCLUSIONS
Scientific ballooning provides low cost and quick access to near space, while the International Space Station provides an excellent platform to reach for cosmic ray energies higher than previously possible through an order of magnitude increase in the exposure. This is a very exciting time in the history of the field. While the current data might provide some information about the nature of dark matter, its final analysis requires better understanding of the astrophysical and instrumental backgrounds. Improved results from current and upcoming direct and indirect searches will continue to shed light on these puzzles.

REFERENCES
Alkanethiolate-Capped Palladium Nanoparticles as Highly Selective and Recyclable Catalysts

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SUMMARY
This paper shows that controlling the particle size and the surface ligand density of alkanethiolate-capped palladium nanoparticles (cPdNP) leads to the optimization of catalytic activity and selectivity for various organic transformations (i.e. isomerization of allyl alcohols, tandem semi-hydrogenation and isomerization of propargyl alcohols, and isomerization of terminal alkenes). A high stability of cPdNP is also demonstrated.

I. INTRODUCTION
Evaluation of metal catalysts functionalized with well-defined and well-ordered alkanethiolate ligands can be potentially important, because such systems can provide a spatial control in the reactivity and selectivity of catalysts. Despite popular research interests in cPdNP, however, these nanoparticles have generally not been recognized as efficient catalytic materials.

Recently, our group discovered a synthetic method utilizing Bunte salts to generate catalytically active Pd nanoparticles capped with a low density of alkanethiolate ligands.1,2 This discovery is significant because it shows for the first time that altering the density of surface alkanethiolate ligands on metal nanoparticles changes the catalytic activity and, more importantly, the selectivity of nanoparticle catalysts.

II. RESULTS AND DISCUSSION
The current work focuses on the examination of various factors such as the molar equivalencies of sodium S-dodecylthiosulfate (capping ligand), tetra-n-octylammonium bromide (surfactant/phase transfer reagent), and sodium borohydride (reducing agent) and reaction temperature in the synthetic process of cPdNP. The results show that an increase in reaction temperature and a decrease in the concentration of tetra-n-octylammonium bromide result in particles with higher surface ligand density and smaller average particle size, while a decrease in the concentration of Bunte salts results in particles with lower surface ligand density and larger size. The amount of reducing agent, sodium borohydride, is also found to influence the size of PdNP, producing smaller particles with higher borohydride concentration. The catalysis studies show that the surface ligand density and particle size dramatically change the catalytic property of cPdNP. The optimized cPdNP catalyzes the isomerization of allyl alcohols, transformation of propargyl alcohols to saturated carbonyls, and isomerization of terminal alkenes. Lastly, the high stability of homogeneous nanocatalysts is also demonstrated by recycling cPdNP fourteen times for the isomerization of allyl alcohol.

Scheme 1: Synthesis of cPdNP with different core size and surface ligand density

REFERENCES
Low-energy Compton scattering using HIFROST at TUNL/Duke

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SUMMARY
HIFROST (HiγS frozen spin target system) is basically a dilution refrigerator operating in frozen spin mode and operating using dynamic nuclear polarization. Subsystems of HIFROST are cryostat (~50mK in a target), 70 GHz microwave system, NMR system, 2.5-T polarizing magnet and 0.5-T holding magnet system, and proton/deuteron targets. We have been developing/constructing HIFROST and progress has been recently made in parallel at UVa and at TUNL/Duke. I will talk about the physics program using HIFROST with upgraded gamma beam at HiγS and the status of developing/constructing HIFROST.

I. INTRODUCTION
The program to investigate the structure of hadrons using Compton scattering at HiγS is well-aligned with the vision of the nuclear physics community outlined in the Nuclear Science Advisory Committee (2007). Polarizability measurements will provide stringent tests of the link between effective low-energy descriptions of nucleons to QCD. The heart of this program is HIFROST, which makes double polarization experiments, in conjunction with either circularly or linearly polarized gamma beams, possible.

II. HIFROST
A. Overview of HIFROST
HIFROST is a system that maintains spins of a target in a frozen-spin mode. We use dynamic nuclear polarization (DNP), which polarize nucleon spin through spin-exchange with electron spin. We expect polarization to be >95% for proton and >90% for deuteron in HIFROST.

B. Status of HIFROST
Two pumping systems for 3He and 4He flows are constructed at TUNL and tested. The 30 mmol/s Cryostat has been warm-leak-tested at UVa and will be cooled down soon. Diverse versions of proton and deuteron of polarizable materials are available. Microwave system was tested. Three working Q-meters for proton and deuteron for NMR system has been tested and Labview-based DAQ is in progress to develop. 2.5-T polarizing magnet was field-mapped and a longitudinal holding magnet was also mapped. A transverse holding magnet was built at TUNL Gas (3He/4He) control system is currently in progress. We plan to commission HIFROST for the beam in September 2012 and perform the first Compton scattering experiment with a deuteron target in December 2012.

Overview of HIFROST is shown in Fig. 1. A target is cooled by a 3He-4He dilution refrigerator with 3He/4He cryo-pumping system. A paramagnetic dopant in hydrogen-rich or deuterium-rich material serves uppaired or quasi-free electron for electron polarization in 2.5-T magnetic field by introducing 70 GHz-microwave. Polarization is monitored by LRC-resonance circuit NMR system.

Figure 1: Overview of HIFROST
Mesoporous metal oxide materials have been extensively studied due to their potential applications in photoelectrochemical solar cell fabrications, biosensors, and electrooptical devices where transparent conducting oxides (TCOs) such as antimony-doped tin oxide (ATO), play a critical role.

As a part of the collaborative effort in the Energy Frontier Research Center for Bio-Inspired Solar Fuel Production at Arizona State University, we have developed a scalable synthetic method for highly transparent mesoporous ATO coating materials which can be utilized as a high surface-area electrode. The electrode materials will serve as conductors of charge and also as supports for photoelectrochemically active bio-nanostructures.

In the new synthetic procedure, the highly mesoporous ATO “bulk” material is produced by creating, drying and calcining inorganic-polymer composite gels that exhibit a 3D interpenetrating network structures. Mesoporous ATO “films” were synthesized on fluorine-doped tin oxide coated glass slides (FTO) through the same procedure but by first doctor-blading the precursor solution on the slides. The final products show a good crystallinity and have high surface areas up to 100 m²/g (or ~200 m²/cm³) and high porosities up to 69 %. The materials exhibited low resistivities (>0.14 Ω-cm) for a mesoporous ATO material. Figure 1a shows that the mesoporous ATO films appear uniform and transparent, which is in agreement with the UV-Vis reflectance spectra of the bulk materials. In Figure 1b, the top surface of the ATO film shows a smooth but porous structure, in contrast to more corrugated polycrystalline structure of the FTO substrate (Figure 1c).

By employing two different mesoporous ATO with different average pore sizes (7 and 14 nm), we have recently demonstrated that the size-specific incorporation of 3D DNA nanocages into their pores is possible without affecting the physical integrity of the DNA nanostructure (a self-assembled tetrahedron with an edge length of ~7 nm).

Furthermore, a successful application of the mesoporous ATO films as a high-surface area substrate has been demonstrated more recently by employing two redox proteins, cytC and azurin. Some important conclusions are (a) the protein coverage was approximately two orders of magnitude greater than would be expected on a flat surface, (b) the excellent transparency of the porous ATO films allowed easy detection of the characteristic Soret band (409 nm for cytC) and the Q-band (circa 530 nm for cytC) (c) the structure of the proteins was largely intact on the surface, (d) the observed electrochemical signal arises from a fast, fully reversible, adsorbed redox couple (e) the amount of electroactive cytC protein on the electrode surface was at least four times higher than any previously reported for value cytC adsorbed to an electrode, and (f) almost all the adsorbed protein is able to exchange electrons directly with the material.

REFERENCES
SUMMARY

We review intense, broadband electromagnetic (EM) wave generation at terahertz (THz) and infrared (IR) frequencies in two-color, femtosecond laser filamentation.

INTRODUCTION/ABSTRACT

When ultrashort intense laser pulses are focused in air, they often produce long plasma filaments due to a dynamic balance between self-focusing and defocusing in plasma. The resulting filament can range from a few centimeters to hundreds of meters depending on the laser parameters and focusing geometry. One of the most intriguing phenomena that can occur in the filamentation process, particularly with multiple pulses, is the generation of intense terahertz (THz) radiation when an ultrashort pulsed laser’s fundamental and second harmonic fields are mixed to ionize a gas [1-4]. Depending on the relative phase between two-color pulses, symmetry can be broken to produce a sub-picosecond electron current, producing THz radiation at the far-field (see Fig. 1). This plasma current model, first proposed by Kim et al. [2], is now widely adopted in the community.

Aside from the generation mechanism, this process is quite attractive in producing intense THz radiation, and much of the current research in our lab is focused in that direction. Recently, we showed that such coherent radiation is extremely broad and may cover the entire infrared (IR) bandwidth (4~3000 μm) [3]. For example, Figure 1(c) shows a simulation result showing the existence of extremely broad THz radiation almost covering the mid-infrared (MIR) regime. In particular, in the case of near-atmospheric air, the radiation extends up to ~75 THz (corresponding to ~4 μm) [3].

In detecting and characterizing supercontinuum IR, we have investigated three approaches—(i) conventional grating-based NIR spectrometry, (ii) Fourier transform interferometry combined with pyroelectric detection, and (iii) electric-field induced second harmonic (EFISH) generation. We review all these methods.

REFERENCES

SUMMARY

The thermal expansion coefficient (TEC) of single-layer graphene is estimated with temperature-dependent Raman spectroscopy in the temperature range between 200 and 400 K. It is found to be strongly dependent on temperature but remains negative in the whole temperature range with a room temperature value of \((-0.8 \pm 0.7) \times 10^{-6}\) K\(^{-1}\). The strain caused by the TEC mismatch between graphene and the substrate plays a crucial role in determining the physical properties of graphene, and hence its effect must be accounted for in the interpretation of experimental data taken at cryogenic or elevated temperatures.

I. INTRODUCTION

Graphene is attracting much interest due to potential applications as a next generation electronic material as well as its unique physical properties. For such applications, knowledge of the TEC as a function of temperature is crucial. In order to determine the TEC of graphene directly, it would be necessary to measure a free-standing graphene sample. However, since most graphene samples are fabricated on substrates or over a trench held at the edges, such a direct measurement would be extremely challenging, if not impossible. Here, we demonstrate that the TEC can be estimated by monitoring the strain caused by the TEC mismatch between the graphene sample and the substrate whose TEC is known.

II. EXPERIMENTS

Graphene samples used in this work were prepared on silicon substrates covered with a 300 nm thick SiO\(_2\) layer by mechanical exfoliation of natural graphite flakes. Temperature-dependent Raman spectra of graphene and graphite were obtained while cooling and heating the samples in a microscope cryostat where the temperature could be controlled between 4.2 and 475 K.

III. RESULTS and Discussion

TEC of graphene in the temperature range of 200-400 K was obtained by analyzing the temperature-dependent shift of the Raman G band of single-layer graphene on SiO\(_2\) and by careful exclusions of the substrate effects. Below 200 K or above 400 K, the effects depending on the materials properties of the substrate such as buckling or slipping of graphene occur obscuring a clear determination of TEC of SLG. Our work calls for careful considerations on the TEC matching between graphene and the substrate in determining various intrinsic physical properties of graphene over a wide temperature range.

Figure 1: Raman frequency shifts of single-layer graphene (circle), bilayer graphene (diamond), and graphite (triangle) as a function of temperature.

REFERENCES

Unusual electron self-energy in graphene

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SUMMARY

The electron-Electron interaction is one of the key concepts in the study of a material, as it bears information on a variety of fundamental properties such as electron effect mass, conductivity, and charge mobility, which ultimately are crucial quantities for any device fabrication [1]. By using angle-resolved photoemission spectroscopy, we study unusual electron self-energy in graphene induced by the electron-electron interactions. The observed electron self-energy is clearly distinguished from that of an ordinary Fermi liquid, resulting in the deformation on the electron band structure as shown in Figure 1. Our findings provide a new venue toward the engineering of electronic properties of two-dimensional electron systems and may open the way to potential applications in electronic devices with variable charge mobility.

Figure 1: The deformation of electron band structure of graphene from the linear spectra (left) to the curved spectra (right) due to strong electron-electron interactions

REFERENCES

Bond Strengths of New “Universal” Dental Adhesives

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SUMMARY
The purpose of this study is to compare the bond strength of two new universal dental adhesives (total-etch/self-etch). The two “Universal Adhesives” tested in this study had statistically same bond strengths with exceptions for enamel, use with self-cured resin cements, and accelerated aging.

I. METHODS
Human dentin and enamel were polished by 320-grit paper and half of them were etched with H₃PO₄-etchant. Zirconia, Alumina, Stainless Steel, RexIII, SureFireA, and Gold were lightly sandblasted. Lithium Disilicate and Porcelain were etched by HF-porcelain etchant. According to the manufacturer’s instructions, the substrates were treated with All-Bond Universal (Bisco), or ScotchBond Universal (3M ESPE). When cemented with dual-cure resin cements, ScotchBond Universal was mixed with its dual-cure activator (ScotchBond Universal DCA) before application per manufacturer’s instruction. Shear bond strength was tested using the ultradent jig method (n=6-8), bonded with resin composites/cements, light-cured (40sec/500mW/cm²) except where indicated, stored in de-ionized water for 24hours/37°C (except where indicated), and tested by Instron tester (1mm/min). The data were analyzed statistically by one-way ANOVA and Tukey Tests (p<0.05).

II. RESULTS
Mean bond strength, MPa(standard deviation). For each row, means with different letters are statistically different (p<0.05).

III. CONCLUSIONS
For all direct and indirect substrates, the two new “Universal Adhesives” tested in this study had statistically same bond strengths except All-Bond Universal had higher bond strength(p<0.05) 1) for enamel (both etched and unetched), and etched lithium disilicate/porcelain; 2) when use with self-cured resin cements; or 3) after accelerated aging.
Hyperspectral Imaging of Plasmonic Dimer for the Single Molecule Structure Analysis and Tracking in Living Single Cells

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The intracellular detection of single molecules in nanoscale is promising new venues of research about the exact mechanisms of molecular interactions. To this end, intracellular molecule detection has been studied using a variety of methods with various labels for visualization, but single molecule imaging in living single cells have not been demonstrated due to the lack of both the appropriate imaging technique and the sensitive single molecule probe without bio-toxicity and blinking/photobleaching phenomena. Herein, we propose a new approach of a single molecule imaging method by a multispectral measurement technique, accompanied with the designed plasmonic nanoparticle probe. Among many different techniques, the hyperspectral imaging system (HSI) stands out as a method that can measure the full spectrum of each point in the sample image with the high sensitivity of single gold nanoparticle detection. We utilized HSI as a single molecule imaging tool by employing engineered gold nanoparticle probes targeting specific single molecules inside the living single cells or on the cell membrane.

In this study, the hyperspectral imaging system (HSI) use designed and installed to detect various target molecules with multiplexing ability. Multiplexing ability of the HSI due to characteristic spectra of different materials and their structures is proposed to dynamically monitor the nanoscale processes and the change of environmental conditions, such as temperature and refractive index. Raman spectroscopy and Dark-field spectroscopy are mainly used for different purposes: Raman spectra can be used as a powerful tool especially for multiplexing detection and chemical identification with well-defined resolution[1], and Dark-field spectrum is good for motion tracking of dimer interaction in the range of distance from a few nanometers to tens of nm. Many different nanomaterials with spectral features in their response to the optical excitation have been employed as nanoprobes for HSI applications. This study particularly focuses on the gold nanoparticle and the control of its surface plasmon resonance by forming a regulated structure, especially about the dimer. The application of cell membrane marker detection[2] and intracellular single molecule mRNA[3] will be presented.

![Image: In this study, the hyperspectral imaging system (HSI) use designed and installed to detect various target molecules with multiplexing ability. Multiplexing ability of the HSI due to characteristic spectra of different materials and their structures is proposed to dynamically monitor the nanoscale processes and the change of environmental conditions, such as temperature and refractive index. Raman spectroscopy and Dark-field spectroscopy are mainly used for different purposes: Raman spectra can be used as a powerful tool especially for multiplexing detection and chemical identification with well-defined resolution[1], and Dark-field spectrum is good for motion tracking of dimer interaction in the range of distance from a few nanometers to tens of nm. Many different nanomaterials with spectral features in their response to the optical excitation have been employed as nanoprobes for HSI applications. This study particularly focuses on the gold nanoparticle and the control of its surface plasmon resonance by forming a regulated structure, especially about the dimer. The application of cell membrane marker detection[2] and intracellular single molecule mRNA[3] will be presented.](image-url)

REFERENCES

Investigating Warm and Dense States of Matter with an X-ray Free Electron Laser

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SUMMARY

The first experimental study of warm and dense plasmas created by X-ray free electron laser (FEL) is presented. The K-alpha spectroscopy provides the detailed interaction processes of intense X-ray pulse with a solid density system. Solid density matter at temperature over a million degree is created, and X-ray – matter interactions channels with multiphoton and resonant processes are unveiled that are inaccessible with conventional X-ray sources.

I. INTRODUCTION

The recent advent of X-ray FEL makes it possible to deliver for the first time ultra intense pulses of X-ray radiation, an increase of nine orders of magnitude in spectra brightness of synchrotron. It affords the possibility to create a unique state of matter, which is at solid density in a short-lived state that is highly ionized yet crystalline. It is highly relevant to planetary science, astrophysics and inertial confinement fusion research.

II. EXPERIMENT

The experiment was performed at Linac Coherent Light Source (LCLS) at SLAC. Intense 80 fs X-ray pulses at $10^{17}$ W/cm$^2$ with photon energy of 1480 ~ 1700 eV, were incident on a 1 μm thick Al foil. The K-alpha x-ray emission spectra were observed with a crystal spectrometer utilizing an ADP (101) crystal and an in-vacuum x-ray CCD.

III. RESULTS

In Figure 1, the spectrally resolved K-alpha X-ray emissions for a range of excitation energies are plotted. In between 1560 eV and 1700 eV, the spectra show the non-resonant emissions, i.e. the main K-alpha peak at 1486 eV, followed by a series of peaks corresponding to K-alpha emission from higher charge states due to a growing number of L-shell holes. The major ionization process is a sequential direct K-shell photoionization in particular ions if the photon energy lies above that ion's K-edge, resulting in the creation of a solid-density plasma at temperature over 100 eV [1].

Along the line of FEL and emission photon energies are the same, the resonant emissions from various configurations of charge state are observed. Below the K-edge of neutral Al (1560 eV), the resonances between atomic inner-shells are inaccessible with a single photon, but cracked open via multi-photon processes [2]. In the regime of 1600 ~ 1700 eV, resonances involving hollow ions, which has double K-holes with L-electrons are clearly observed.

REFERENCES

The h-p Version of Stochastic Galerkin FEM for Stochastic Optimal Control Problems

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SUMMARY
In the last decade, people in the scientific computing community have taken great interest in the stochastic partial differential equations (SPDE) and its solver called the Stochastic Galerkin Method (SGM) [1, 2]. In this paper, we study the p-h version of stochastic Galerkin finite element approximations for an optimal control problem constrained by stochastic elliptic PDE.

I. Introduction
SGM has been created and developed to analyze a stochastic problem in the following sense. Suppose that we have a deterministic partial differential equation (PDE) that models some natural phenomenon; for instance, pollutant transportation in groundwater. To improve this deterministic mathematical model, we assume that we replace some deterministic quantities in the PDE with stochastic input data. For instance, there may be lack of knowledge about some materials such as rocks and soils for groundwater. For these unknown properties of rocks and/or soils, we would like to use the concept of randomness in the model so that a new mathematical model with additional random terms can represent better the natural phenomenon. If there are inputs that are random, then the solution to the new model problem should also be including randomness. We then need a stochastic domain, and need to use probability theories to analyze the solution to the new model problem. Now the remaining question is how we apply or modify a typical method such as the Galerkin Method to analyze the new stochastic problem derived from a deterministic problem. SGM actually answers this question, and it turns out to be an excellent method that gives us good results in terms of accuracy and cost.

II. Numerical Experiment
As we can see from the above figures, by using the stochastic Galerkin Finite element methods, we obtain the expected value of the optimal solution $E(u^h)$ that is near to the given target solution $U = \sin(\pi x) + \sin(2\pi x)$ on the interval $[-1, 1]$.

III. Conclusion
We estimate the error for the solution of the stochastic optimal control problem constrained by SPDE using the h-p version of stochastic Galerkin methods and give the comparison between analytical and numerical solutions.

REFERENCES
SUMMARY

Surface plasmon polaritons (SPP) are electromagnetic waves propagating along the interface between a dielectric and a metal, evanescently confined in the perpendicular directions to the interface. These electromagnetic surface waves arise via the coupling of the electromagnetic radiations to the collective plasmon oscillations of free electrons in the metal.\(^1\) We combine femtosecond laser pump-probe interferometry with photoemission electron microscopy (PEEM) to image ultrafast SPP phenomena in nanostructured metal films. The interferometric time-resolved PEEM technique enables us to record movies of ultrafast electric polarization field and electron dynamics with <100 nm spatial resolution and ~330 attosecond pump-probe time interval. In this presentation, I'll discuss our PEEM study of two simple SPP structures, a nano slit and a plasmonic lens, lithographically fabricated in an 80 nm thick Ag film deposited on a Si substrate.

I. NANO SLIT

Nonlinear two-photon PEEM is used to image SPP wave packets excited by an obliquely incident laser pulse (~10 fs) at a single slit fabricated in a thin silver film. We image the forward propagating polarization grating formed by the coherent superposition of the external excitation pulse and the SPP wave packet fields. By systematically varying the coupling slit width from sub- to multiple-wavelength scale, we observed a modulated increase and a long range oscillation of the polarization grating intensity, which is phenomenologically accounted for by distinct contributions to the coupling efficiency from the incident field to the SPP waves.\(^2\)

II. PLASMONIC LENS

Coupling structures can be fabricated for SPP guiding, interfering and focusing, et al. We observed that the oblique incidence excitation geometry of the PEEM experimental setup causes aberration in SPP focusing with a circular arc shaped lens. The aberration can be corrected by adjusting the lens shape, taking into consideration of the underline excitation geometry. A PEEM movie of the modified plasmonic lens structure demonstrates the focusing of the SPP field in both space and time (Figure 1).

![Figure 1. Tuning the focus of a plasmonic lens](image-url)

REFERENCES

Skyrmions with quadratic band touching fermions: 
A way to achieve charge $4e$ superconductivity

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ABSTRACT
We study Skyrmion quantum numbers, charge and statistics, in (2+1) dimension induced by quadratic band touching fermions. It is shown that induced charge of Skyrmions is twice bigger than corresponding Dirac particles' and their statistics are always bosonic. Applying it to the Bernal stacking bi-layer graphene, we show that Skyrmions of quantum spin Hall(QSH) are charge 4e bosons, so their condensation realizes charge 4e superconductivity(SC). The phase transition could be a second order, and one candidate theory of the transition is O(5) non linear sigma model(NLSM) with non-zero Wess-Zumino-Witten(WZW) term. We calculate renormalization group beta function of the model perturbatively and propose a possible phase diagram. We also discuss how QBT fermions are different from two copies of Dirac particles.

SUMMARY
In this paper, we showed how Skyrmions interacting with quadratic band touching(QBT) fermions obtains their quantum numbers. Applying the mechanism to bi-layer graphene, we also showed that QSH Skyrmions in bi-layer graphene are charge 4e bosons. By condensing the Skyrmions, it is possible to achieve charge 4e superconductivity. Such mechanism is far different from the general BCS-like description, and we argue that it might be described by the deconfined quantum criticality. We propose the O(5) non-linear sigma model with the WZW term at the critical level as a critical theory. Figure 1 illustrates both possible beta function behaviors in terms of renormalization group flow and the phase diagram at the critical level.

REFERENCES
Functional Nanostructured Materials for Enhancing Charge Collecting and Light Harvesting Properties in Dye-sensitized Solar Cells

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SUMMARY

Photoelectrochemical solar cells such as dye-sensitized cells (DSSCs), which exhibit high performance and are cost-effective, provide an alternative to conventional p-n junction photovoltaic devices. However, the efficiency of such cells plateaus at 11-12%, in contrast to their theoretical value of 33%. The majority of research has focused on improving energy conversion efficiency of DSSC by controlling nanostructure and exploiting new materials in photoelectrode consisting of semiconducting oxide nanoparticles and a transparent conducting oxide electrode (TCO). [1-6] In this presentation, inverse opal-based scattering layers containing highly crystalline anatase nanoparticles are introduced and their feasibility for use as bi-functional light scattering layer is discussed in terms of optical reflectance and charge generation properties as a function of optical wavelength. Also, new nanostructured TCO material and preferred oriented TiO₂ nanotube material for DSSC is going to be discussed in terms of charge collecting characteristics.

REFERENCES


Figure 1: Inverse opals and ITO nanowires for improving light harvesting and charge collecting properties in DSSCs
Compartmentalization is an important strategy for regulating biochemical activity in nature. Subcellular compartmentalization is often achieved using supramolecular protein assemblies. Examples include viruses and ferritin for the storage of nucleic acids and metals, respectively, chaperones for protein folding, and bacterial microcompartments (such as the carboxysome, the propanediol utilization compartment, and the ethanolamine utilization compartment) for securing metabolic reactions. Bacterial microcompartments are particularly noteworthy because they act as cellular nanoreactors by encapsulating enzymes. The advantages of enzyme encapsulation include preventing loss of labile intermediates in the encapsulated pathway, and activity regulation by controlling diffusion of substrates into the microcompartment via gated pores. The capsid formed by *Aquifex aeolicus* lumazine synthase (AaLS) is a good starting point for engineering bio-inspired nanoreactors. As a proof of principle, we have performed the *in vivo* encapsulation of an esterase bearing a positively charged deca-arginine tag (Est55-R$_{10}$) in a negatively charged AaLS variant (AaLS-13) [Figure 1]. Kinetic measurements with the substrate p-nitrophenyl acetate show that AaLS capsids bearing Est55-R$_{10}$ have 64-fold higher specific esterase activity than the empty capsids. This indicates that the esterase remains active when encapsulated, and the capsid is sufficiently porous to allow entry of small substrates. Further studies with larger substrates will better define capsid porosity, which should aid the design of more sophisticated nanoreactors for biotechnology or synthetic applications.
SUMMARY
A new therapy for cancer treatment called nanoparticle-self lighting photodynamic therapy (PDT) is introduced in which no external light is needed for activation. This new method enables PDT not only for skin cancer treatment but also for deep cancer treatment.

I. INTRODUCTION
Photodynamic therapy has been designated as a “promising new modality in the treatment of cancer” since the early 1980s. This can be partially attributed to the attractive basic concept of PDT—the combination of two therapeutic agents: a photosensitizing drug and light. Both the light and the photosensitizing agent are relatively harmless by themselves but, combined in the presence of oxygen, can result in selective tumor destruction. The three key components required for PDT are oxygen, photosensitizer, and light. It is commonly accepted that singlet oxygen is the predominant cytotoxic agent produced during PDT. Therefore, PDT efficiency is largely determined by the production efficiency of singlet oxygen, which is a product of photosensitizer efficacy, light characteristics (intensity and wavelength), and oxygen concentration. Light must be delivered to the photosensitizers to activate PDT and this limit PDT treatment for skin cancer because light cannot penetrate deeply into tissue. To solve the problem of light penetration and to enable the PDT treatment for deep cancers, a new PDT system is proposed in which the light is generated by afterglow nanoparticles with attached photosensitizers. When the nanoparticle-photosensitizer conjugates are targeted to tumor, the light from afterglow nanoparticles will activate the photosensitizers for photodynamic therapy. Therefore, no external light is required for the treatment. More importantly, it can be used to treat deep cancers because the light source is attached to the photosensitizers and are delivered to the tumor cells together.

II. RESULTS AND DISCUSSION
Currently, we are developing afterglow nanoparticles for PDT activation and the afterglow nanoparticles can be activated by radiation beam such X-ray or Gamma-ray. In this way, we can easily combine photodynamic therapy with radiotherapy for cancer treatment, which would reduce the radiation dose for cancer treatment and this is critically important to reduce the side-effects of radiation treatment.

The above concept has been proved in our pilot studies. For example, after a 24 hours incubation with nanoparticles and a subsequent irradiation with 5 G X-ray, MCF-7 cells were stained simultaneously with DAPI, propidium iodide (PI) and JC1. The bright green granules indicate that LaF$_3$:Ce$^{3+}$/porphyrin/PLGA nanoparticles were uptaken into the cytoplasm. While healthy cells are supposed to show blue nuclei and red cytoplasm, these treated cells with red nuclei and green cytoplasm indicate damage of cell membranes and decreased membrane potential of mitochondria. These results indicate that X-ray activated LaF$_3$:Ce$^{3+}$/porphyrin/PLGA nanoparticles have a toxic effect for both nuclei and mitochondria as shown in Figure 1.

Figure 1. Breast cancers treated with LaF$_3$:Ce$^{3+}$/porphyrin-PLGA nanoparticles (right) in comparison with the control (left) that was treated with X-ray but no nanoparticle-porphyrin conjugates. The X-ray dose is 3 Grays.

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**Giving back to the community: short term missions abroad.**

I have been fortunate and blessed in my life. I can’t even count how many hands were involved for me to get here. It is easily forgotten that we did not get to this place by ourselves. I think one of the problems in the Korea and many places are caused by privileged people not giving back to the community where they received all of their educations, wealth and everything from.

Therefore, giving back to the community is not an option, but it’s a must. I believe that there are many ways we can give back to the community. I just want to give few ways to give back to the community, or where to learn ways to give back to the community through my experiences.

I have been involved in short term abroad mission trips from church and habitats. It really opened my eyes to learn how many needy people are there in the world, and my education and work should not solely go to accumulate my wealth or reputations.

I served as a case worker for refugees in the United States. It helped me to know that things just do not happen abroad, but it’s our neighbors who are needy.

However, giving back to the community is not just limited to go devote your time and money to go abroad or full time job. It can happen as little as in your office and at your work.

All of these experiences helped me to be inspired in my career. My research, studies and work should have these people in my mind.

Instead of chasing after money or reputation, I believe that we should be light and salt in this world. And I believe that people in this conference are one of the brightest and privileged people in this world, and I firmly believe changes made among us can make a difference.
Exciton-Polariton Quantum Simulators

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SUMMARY
We demonstrate phase-coherent high-orbital exciton-polariton condensates in a two-dimensional lattice. The orbital symmetry of the condensates can be selected by a pump rate. This polariton-lattice system can be a promising candidate towards solid-state quantum emulators.

I. INTRODUCTION
Microcavity exciton-polaritons emerge from the strong coupling between cavity photons and quantum well (QW) excitons in a semiconductor-based microcavity structure. As quantum bosons, exciton-polaritons are dynamically condensed at high temperatures [1,2], exhibiting spontaneous long-range spatial coherence. Here we introduce a simple but scalable method to produce in-plane square lattice potentials by depositing a thin metal film [3]. We demonstrate that exciton-polariton condensates are formed at metastable $p$- and $d$-orbital states [4].

II. EXPERIMENTAL RESULT
Our GaAs device consists of 12 GaAs quantum wells separated by AlAs barriers embedded at the antinodes of a $\lambda/2$ cavity with the strength of exciton-polariton coupling ~14 meV. We deposit a thin Au/Ti (25/3 nm) film on a 2D square lithographic pattern whose lattice constant is 4 $\mu$m. The created lattice potential strength is 200 OeV.

We characterized our 2D polariton-lattice device via time-integrated far-field spectroscopy and images with a mode-locked Ti:sapphire laser in a pulsed scheme at 4 K. Figure 1 presents the observed polariton distributions in momentum space at various optical pump powers. Above quantum degeneracy thresholds, the intense sharp peaks develop at the vertices of the first Brillouin zone (BZ), where $d$-wave condensate states reside. As the pump power increases, the condensates relax into the edges of the first BZ, exhibiting $p$-wave orbital symmetry. The dynamical properties of exciton-polariton condensates are determined by the competition between radiative decay through a cavity mirror and thermal relaxation process towards the ground state.

Figure 1. Pump power dependent lower polariton population distributions in momentum space. Pump power varies from $P/P_{\text{th}} \sim 0.3, 1, 1.7, 4.3, 14$ from left to the right and $P_{\text{th}} \sim 7$ mW.

III. CONCLUSION
We have observed the $p$- and $d$-wave condensation of microcavity exciton-polaritons in a 2D square lattice. The dynamical nature of exciton-polariton condensates allows us to selectively prepare for phase-coherence high-orbital condensates by varying pumping powers. The realization of phase orders in multi-orbital bands will be a stepping stone towards a solid-state quantum emulator for investigating macroscopic orbital orders in real condensed matter materials.

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Excitation Studies of the Th-229 Isomer at Jefferson FEL Facility

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Experimental gamma-ray spectroscopy measurements have revealed the presence of an isomeric excited state in Th-229 only 3.5±1.0 eV above the ground state [1,2]. Such a low-lying nuclear level is of interest as it is a rare case in which the nuclear excitation energy is on the order of atomic energies. In particular it is lower than the ionization potential of 6.08 eV for neutral Th, and so the usual internal conversion of the nuclear level cannot occur. Theoretical considerations suggest that the isomeric excited state should decay via interactions with the atomic electrons of the Th atom, a so-called “electronic bridge” mechanism. Strizhov and Tkalya [3] suggested that the isomeric level would decay by exciting a 6d to 7p transition in the Th atom, with an energy change of 1.28 eV. Therefore red shifted photons of energy 3.5 eV – 1.28 eV = 2.22 eV should be observable. This prompted Irwin and Kim [4] to search for optical photons in this energy range emitted from sources of U-233, which populates the isomeric level in Th-229 approximately 2% of the time. In two samples studied optical photons in this range were indeed observed around 2.3 eV, along with emission in the ultraviolet. Richardson et. al. [5] observed similar optical emission spectra from a liquid source. It was later determined that the ultraviolet emission in both cases was due to fluorescence of nitrogen molecules in air, and it was suggested that the emission near 2.2 eV was probably also due to non-nuclear effects [6,7]. However, recent theoretical calculations [8] have predicted that the main emission expected from the decay of the isomeric level should be in the range 2.3-2.4 eV, in agreement with the experimental results in references 4 and 5.

References:

Hard X-ray from betatron oscillations of a wakefield-accelerated electron beam by asymmetric laser pulses

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SUMMARY  
We investigated the hard X-ray generation from betatron oscillations of electron beams in the laser wakefield acceleration (LFWA) by using temporally asymmetric laser pulses.

I. INTRODUCTION  
Laser wakefield acceleration (LWFA) scheme utilizes large-amplitude plasma waves for accelerating electrons to relativistic energies over an extremely short distance. Therefore, this scheme is promising as a new technology that could lead to downsizing future high-energy accelerators.

As the electron bunch is accelerated along the bubble, it experiences a transverse force, which leads to betatron oscillations, emitting synchrotron radiation in the forward direction. Hence, a laser wakefield accelerator itself can serve as an extremely compact synchrotron light source.

II. RESULTS OF SIMULATIONS  
We used the fully relativistic 2D particle-in-cell (PIC) code. As shown in Fig. 1, the symmetric laser pulse with a Gaussian shape has a pulse duration (FWHM) of 35 fs and the asymmetric pulse has several different ratios of rising and falling times.

This temporally asymmetric laser pulse can be used for laser wakefield acceleration with self-injection and the tail part of the laser beam can interact strongly with the electron beam. This can lead to a large transverse electron oscillation due to the resonance, which can provide a good method for generation of ultrashort (fs) coherent radiations covering tens of kiloelectronvolts in photon energy (Hard X-ray).

The proposed scheme can be realized in a fairly simple experimental setup as temporally asymmetric laser pulses are easily produced by detuning the compressor gratings in a CPA (chirped-pulse amplification) laser system.

FIG. 1. Schematic of the density profile of a plasma slab and an asymmetric laser pulse. The density of the first plateau is \( n_1 = 1 \times 10^{16} \text{ cm}^{-3} \) with a length of 100 \( \mu \text{m} \), and the second plateau is \( n_2 = 5 \times 10^{18} \text{ cm}^{-3} \) with a length of 2.3 mm. The ramp scale lengths from 0 to \( n_1 \) and from \( n_1 \) to \( n_2 \) are 100 \( \mu \text{m} \) and 30 \( \mu \text{m} \), respectively.

REFERENCES  
Ultra-Small Plasmonic Crystal Defect Nanolasers

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SUMMARY
We demonstrate the surface-plasmon-polariton based photonic crystal defect nanolasers, the so-called plasmonic crystal defect nanolasers. Using conventional III-V semiconductors, we achieve lasing in a mode volumes as small as $V_{\text{eff}} = 0.3(\lambda_d/\pi)^3$ at $\lambda_d = 1342$ nm, which is 10 times smaller than similar modes in photonic crystals of the same size. This demonstration is expected to pave the way for achieving engineered nanolasers with deep-subwavelength mode volumes.

I. INTRODUCTION
Nanoscale light sources have become increasingly interesting due to their many applications and the fundamental studies. Here, we present a laser based on a one-dimensional plasmonic crystal, which has the potential to attain mode volumes much smaller than photonic crystals, where plasmons are engineered into subwavelength mode volumes with precise control of radiation implied by the design of such crystals.

II. CAVITY DESIGN
The cavity was designed by creating a one-dimensional photonic crystal structure out of InGaAsP on the gold substrate, as shown in Fig. 1(a,b). This device confines the surface-plasmon-polariton (SPP) mode inside the defect region [1]. The cavity defect mode has a simulated quality factor $Q = 100$ in a three-hole defect and an approximate mode-volume $V_n \sim 0.3(\lambda/2n)^3$.

III. EXPERIMENTS
The cavity was fabricated with electron-beam metal evaporation, flip-chip bonding, substrate removal, electron-beam patterning of the nanocavity, and subsequent semiconductor etching [2]. Using micro-photoluminescence, we verify that the band edge modes appear brightest when the edge of the device is optically pumped, whereas the defect mode only lases when the center of the device is pumped, as shown in Fig. 1(c) and (d). The laser threshold pumping power was found to be $\sim 100$ kW/cm$^2$, and the spontaneous emission factor ($\beta$) was measured to be 0.12, as shown in Fig. 1(e) and (f).

REFERENCES
I. INTRODUCTION

Density-functional theory has been one of the most successful approaches ever to address the electronic-structure problem; nevertheless, since its implementations are by necessity approximate, they can suffer from a number of fundamental qualitative shortcomings, often rooted in the remnant electronic self-interaction present in the approximate energy functionals adopted. Functionals that strive to correct for such self-interaction errors, such as those obtained by imposing the Perdew-Zunger self-interaction correction [1] or the generalized Koopmans’ condition [2], become orbital dependent or orbital-density dependent, and provide a very promising avenue to go beyond density-functional theory, especially when studying electronic, optical and dielectric properties, charge-transfer excitations, and molecular dissociations. Unlike conventional density functionals, these functionals are not invariant under unitary transformations of occupied electronic states, which leave the total charge density intact, and this added complexity has greatly inhibited both their development and their practical applicability.

II. METHODS

Here, we first recast the minimization problem for non-unitary invariant energy functionals into the language of ensemble density-functional theory [3], decoupling the variational search into an inner loop of unitary transformations that minimize the energy at fixed orbital subspace, and an outer-loop evolution of the orbitals in the space orthogonal to the occupied manifold. Then, we show that the potential energy surface in the inner loop is far from convex parabolic in the early stages of the minimization and hence minimization schemes based on these assumptions are unstable, and present an approach to overcome such difficulty.

II. RESULTS AND DISCUSSION

The overall formulation allows for a stable, robust, and efficient variational minimization of non-unitary-invariant functionals, essential to study complex materials and molecules, and to investigate the bulk thermodynamic limit, where orbitals converge typically to localized Wannier functions. In particular, using maximally localized Wannier functions as an initial guess can greatly lower the initial value of the total energy; however, the effect on the convergence efficiency depends on the kind of self-interaction correction.

REFERENCES

Semiclassical approach to single impurity bound state

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I. INTRODUCTION

The presence of impurities in system induces impurity bound state and raises modifications of bulk band structure near the impurity sites. Because actual fabrications of any materials cannot prevent from the inclusion of impurities, the understanding of system with impurities is important issue. Not only limited to the practical reason, but interesting physical phenomena have been discovered in the presence of impurities such as Anderson localization, quantum Hall effect, Kondo effect, etc. which captured the imagination of many in the physics community. T-matrix method and exact diagonalization are powerful computational tool to study the physics of impurities. In this work, we develop semiclassical view point derived from the T-matrix formulation, providing physical picture of bound state in terms of a few damping plane waves around an impurity.

II. Abstract

A localized state near single impurity on a gapped 2-dimensional lattice model is studied in the continuum limit, and semiclassical method making use of a finite number of plane waves is developed as a further approximation of continuum model. The lattice version Bernevig-Hughes-Zhang (BHZ) model is employed to calculate a bound energy of localized state for different potential strength, and it is found that a bound energy is always placed within energy gap at strong potential limit in topological phase. The continuum limit of lattice model is studied near isotropic Dirac cone m=0 and near anisotropic Dirac cone m=4A²/B. The semiclassical method is then applied and examined its limitation.

REFERENCES

Calibration of instrumental polarization crosstalk for the New Solar Telescope at Big Bear Solar Observatory

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SUMMARY
We developed a new technique to correct polarization error caused by optical depolarization effect.

I. INTRODUCTION

The Sun consists of many magnetic fragments and their formation and development are key factor for many local events – flares, eruptions, solar winds, etc. Since the analysis of the solar magnetism is the best way to understand the underlying mechanisms of many solar activities, the data of magnetic field structure on the solar atmosphere, magnetogram, is the most commonly used data.

II. DETAIL

Among many methods of modulation to record magnetic field structure of the Sun, mechanically rotating modulators are the most widely used type.

Here, we describe a method to cope with modulation without synchronization to the detector. We used the InfraRed Imaging Magnetograph (IRIM) installed at the New Solar Telescope, Big Bear Solar Observatory. This uses a rotating birefringent polymer as modulator, and two Wollaston prisms as analyzer. The exposure time of the camera is matched with the revolution rate of the modulator, but the phase between the two does not match. The amount of phase offset is random, and this introduces artificial instrumental crosstalk among Stokes parameters. These additional errors can be corrected by multiplying correction matrix and applying weight factors. In addition, we would like to report how the calibration for the IRIM data has been done so far.

REFERENCES
SUMMARY

Investment casting is a widely employed industrial process for manufacturing of metal parts. Due to its heavy weight and shape distortion during storing, the wax pattern is being replaced by polymer foam materials that have many advantages; less expansion on heating, facilitated pattern removal, lower material cost, ease of handling, possibility of rapid prototyping, etc. In this research, different polymer materials were evaluated as the low-density pattern for investment casting application. The physicochemical properties of pattern material such as density, elastic modulus, expansion coefficient, thermal degradation behavior, etc. were experimentally investigated for their effect on the casting quality. Pattern removal process from the shell was examined by thermal gravimetric analysis (TGA) to arrive at a kinetic model that best represents the actual casting process by employing experimental data and empirical functions. In order to help predict and improve the casting process, the simulation of casting process was conducted while considering the degradation of the foam pattern, the counter pressure in the gap and the venting through the shell into the surrounding sand mold.

INTRODUCTION

Investment casting, also known as lost-wax casting, is a widely employed for manufacturing of precision metal components used in the automobile, aerospace and biomedical industries because of its ability to produce accurate and complicated shape castings. During the investment casting process, a wax pattern is coated with ceramic slurry to form the investment shell, and then placed in an autoclave to melt/burn out the wax to create cavity. Molten metal is poured into this investment mold and cooled until solidified. Finally, the ceramic shell is destroyed to release the metal casting. There are some limitations of using wax pattern; shape distortion during storing and difficulty in handling due to its heavy weight and brittleness. Therefore, the wax pattern is being replaced by polymer foam materials because of their advantages; less expansion on heating, facilitated pattern removal, lower material cost, ease of handling, possibility of rapid prototyping, etc. The objective of current study was to explore the specific property issues affecting the application of different low-density polymer patterns in investment casting processing.

METHODS AND RESULTS

The properties which affect the applicability of low-density polymer materials used in investment casting were experimentally investigated. The materials studied included EPS foam, FOPAT foam with different densities and SLA patterns with internal honeycomb structure produced by stereolithography. Comparing these materials to a wax pattern, density is much lower, which makes the handling much easier for larger castings. Varying conditions need to be considered when different polymer patterns are used in investment casting. Because of low elastic modulus of EPS foam, the trees for EPS need pattern to be designed with stabilizing bars to prevent deformation during the dipping process in slurry. Based on the thermal decomposition results, high firing temperature (700°C or higher) and excess oxygen is necessary in furnace to minimize the residue during FOPAT pattern removal. It is also recommended that FOPAT pattern should be removed using flash firing to prevent the shell cracking. Heavier shells or more layers may be needed with FOPAT patterns to prevent cracking due to the higher elastic modulus. The honeycomb core orientation in SLA pattern should be considered if the shell cracking occurs. The elastic modulus of SLA pattern at Z direction is much higher than that at X and Y directions.

Figure 1: Thermal degradation behaviors of FOPAT pattern materials
Direct Visualization of Antibiotic-induced Pores in Phospholipid Vesicles by Cryo Electron Microscope

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SUMMARY
Utilizing cryo-electron microscopy, we have directly observed magainin, an antibiotic peptide, interacting with synthetic membranes. Cryo-EM offers direct-imaging of systems in configurations closely related to in vivo conditions. We demonstrated that magainin-induced pores in lipid vesicles have a mean diameter of ~85 Å. This also demonstrates that computed power spectra from windowed out regions of cryo-EM images can be compared to neutron scattering data.

INTRODUCTION
Cytolytic peptides, such as Magainin, Melittin, and Alamethicin are ubiquitously present within the animal kingdom as a part of the host-defense system. Magainin-2 lyses a wide range of both gram-negative and gram-positive bacteria and a range of cancer cells. Unlike most commercial antibiotics, which interact with specific protein targets, Magainin 2 and other peptides in this class have been shown to interact directly with the lipid bilayer; therefore, it is believed that bacteria will be largely unable to develop resistance to this class of antibiotics. It is believed to initially interact with acidic lipids in the bacterial membranes through electrostatic interactions, forming an amphiphilic helix, followed by hydrophobic interactions inducing pore formation, but the issue remains controversial. A number of methods have been used to study the structure of possible pores; however, none of those methods could directly observe the pores themselves. We present a new method for studying peptide/lipid interactions, which employs cryo-EM to directly image Magainin-induced pores in phospholipid vesicles. Images of DMPC/DMPG lipid vesicles with Magainin showed both perturbed and unperturbed vesicles, while vesicles without Magainin were unperturbed: perturbed vesicles exhibited power spectra similar to neutron scattering experiments in the presence of Magainin. To estimate pore size, we completed a set of simulations with randomly distributed pores on spherical vesicles. The mean pore size obtained by simulation was ~83Å, which is compatible with prior neutron scattering data. In addition, since the vesicle images are projections, we performed cryo-electron tomography experiments to reconstruct the 3-D structure of the pores. For the first time, we were able to visualize antibiotic peptide-induced pores on phospholipids vesicles, and the pore size is consistent with the simulation result.

Figure 1: Fitting CTF-corrected simulation curve to the experimental data. Pore size, pore size variation, and pore density are allowed to vary in simulation to yield the best matching power spectra to the experimental data, with CTF correction performed. The best fitting parameter gives a mean pore size of 80 ± 2 Å and the pore size variation 12 Å.

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iINTEGRATED Space Weather Analysis System Application to Space Weather Analysis and RBE model validation

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SUMMARY

As the maximum of solar cycle 24 come near, the demand on the space weather information is increased. NASA/GSFC-CCMC developed the iINTEGRATED Space Weather Analysis (hereinafter iSWA) system on 2009. The iSWA is the web-based dissemination system for NASA-relevant space weather information. Here we introduce iSWA as a tool for space weather analysis and present Fok's RBE model evaluation results using iSWA.

I. iSWA as tools for Space Weather Analysis Platform

The iSWA had been developed on 2009 for NASA-relevant space weather operation including around 300 products of modeling results and comprehensive sets of ground and space based observational data covering from the Sun to near Earth. It's the tool which introduces space weather-relevant physical concepts like CME impact estimation with WSA-ENLIL model products, single event upset effect on spacecraft and aircraft, radiation storm due to energetic electrons, solar origin of space weather induced communication and navigation problems and solar magnetic connectivity to Earth (1). Figure 1 shows one example of the iSWA layout. The iSWA can be easily accessed through web browser and configure the layout by user.

II. RBE model evaluation

Radiation belt electrons play key role in the processes in the Earth’s space environment change, which has the significant impact on the satellites on Geostationary orbit. We evaluate the real-time operation performance of RBE model (2) by comparing its energetic flux output (E > 0.6 MeV) with what is measured by GOES-11 (E > 0.6 MeV), GOES-13 (E > 0.8 MeV) and GOES-15 (E > 0.8 MeV) satellite using the iSWA archived data.

It is shown that real-time RBE model well describe the physical signature with space environment change, in general. However, the flux increase during post-storm period is not shown during the operation period. To improve the accuracy during the post-storm period, the updated version of model with the wave-particle interaction is considered.

III. Conclusion

The iSWA provides a comprehensive suite of real-time and historical space environment data products for science, education, space weather forecasting and public outreach. Here we introduce iSWA as a tool of integrated space weather analysis system with high accessibility and provide the model evaluation results using iSWA system.

REFERENCES

High-harmonic generation for attosecond science in the soft X-ray range

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SUMMARY
We present the recent progress on the soft-X-ray attosecond light sources based on long-wavelength-driven high-harmonic generation at MIT. Underlying physics and enabling technologies, such as optical parametric amplifiers and picosecond pump laser technology, will be discussed.

High-harmonic generation (HHG) is a strong-field phenomenon, where a valence electron is tunnel ionized by strong femtosecond light field and then recombinates to the parent atom after acquiring high kinetic energy from the acceleration by the electric field. The photon energy emitted in the HHG process is given by the ionization potential plus the kinetic energy of electron, which corresponds to the extremely ultraviolet (EUV) and soft X-ray range. Since the HHG process happens every half cycle of the driving laser field which is typically 1-2 fs, the pulse duration of generated high-harmonic pulses can easily reach down to attosecond regime. Moreover, few-cycle-duration driver pulse can limit the number of attosecond pulse generation event to only a few and eventually makes it possible to generate an isolated attosecond pulse with the help of proper gating techniques.

Over last decade the high-harmonic attosecond pulses have been studied in the EUV range (<100 eV) using high-power Ti:sapphire lasers at 800 nm. On the other hand, long-wavelength (mid-IR) drivers can extend the harmonic cutoff to keV region by accelerating the ionized electron with much higher kinetic energy. To explore the attosecond science at high photon energy with high flux, we have developed a kHz-repetition-rate, mJ-level, optical parametric chirped pulse amplifier (OPCPA) [1,2] operating at 2.1 μm wavelength, which is pumped by a novel picosecond cryogenic Yb:YAG amplifier.

We performed the HHG experiments using 32-fs, carrier-envelope-phase stable pulses from the 2.1 μm OPCPA. Figure 1 shows the obtained high harmonic spectra from Xe, Kr, and Ar, where we obtained \(10^9-10^{10}\) conversion efficiencies per harmonic at the cutoff. We will discuss the high-harmonic spectroscopy using these spectra revealing the orbital structure of atoms and present the pulse propagation effect on high-harmonic spectroscopy.

![Fig. 1 HHG spectrum driven by the kHz, 2.1-μm OPCPA using Xe (a), Kr (b), and Ar (c) gas jets.](image)

In addition, the coherent wavelength multiplexing technique of OPCPAs [3] for high-energy sub-cycle waveform synthesis and isolated attosecond pulse generation will be presented.

REFERENCES
SUMMARY
A negatively-charged Nitrogen-Vacancy (NV) center is a solid-state candidate for study of spin-based phenomena and quantum information processing. The nuclear spin of the NV center can be polarized by optical pumping. We discuss the effect of spin-mixing and fast phonon mediated transitions on the dynamics of the NV centers, and dynamic nuclear polarization dependence on applied magnetic field.

I. INTRODUCTION
A negatively-charged Nitrogen-Vacancy (NV) center is a defect, formed by a carbon vacancy adjacent to a substitutional nitrogen atom in diamond. A room temperature read-out of a single nuclear spin by coherent mapping onto the electronic spin states, and long-live spin coherence, among many properties, make the NV centers an attractive solid-state system for application in quantum information science. Understanding of dynamical nuclear polarization of the NV centers is an important step toward this development.

II. THEORY
Optical illumination of an NV center makes transitions between the ground ($^3A_2$) and the excited ($^3E$) states in Fig. 1. Both the states $^3A_2$ and $^3E$ are electronic spin-triplet states. The optical transitions between $^3A_2$ and $^3E$ conserve the electronic spin projection (zero phonon line: 1.945eV), which allows optical initialization of the NV center. Hyperfine interaction flips the nuclear spin of the NV center via electronic/nuclear spin-flip, which can be used to dynamically polarize nuclear spin as a function of applied magnetic field.

Strain in diamond and a spin-orbit coupling of the NV center induce electronic spin-mixing in the excited states. These make nuclear spin-flip processes more complex during optical cycling. These necessitate studies to address the dynamics of the NV centers.

We take into account the effect of the above considerations in the level structure in Fig. 1 with help of Redfield theory, and analyze the dynamics of the NV center. We show that spin-mixing, phonon-assisted transitions have substantial effects on dynamical nuclear polarization of the NV center.

III. ILLUSTRATIONS

Figure 1: Electronic levels of NV centers

A. Electronic level structure based on group theory
- $^3A_2$: ground state
- $^3E$: excited state ($E_X/E_Y$: upper/lower branch)
- $^1A_1$: intersystem state

B. Transitions (arrows in Fig. 1) between levels
- a. Optical transitions between $^3A_2$ and $^3E$
- b. Phonon transitions $R$ between $E_X$ and $E_Y$
- c. Spin-selective transitions through $^1A_1$

REFERENCES
Interaction-induced ordered states in multilayer graphene systems

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SUMMARY
In this talk, I propose new types of interaction-driven ordered states in multilayer graphene systems that arise due to their peculiar electronic structure. Two examples of such states are pseudospin magnets, which show spontaneous charge transfer between the two layers, and excitonic superfluids, which could have remarkably high transition temperatures.

I. INTRODUCTION
Multilayer graphene[1] has recently attracted considerable attention because of the presence of additional layer degrees of freedom, its chiral electronic structure which is sensitive to stacking sequences, and its possible use as the basis of new electronic devices. In combination with the chiral band structure and electron-electron interactions, exotic ordered states can occur in graphene systems which could be very useful for future electronic device applications.

II. PSEUDOSPIN MAGNETISM

Figure 1 In-plane pseudospin orientation of a broken symmetry state for a neutral, unbiased bilayer graphene.

First, we show that neutral graphene bilayers are pseudospin magnets[2,3], in which the charge density contribution from each spin and valley spontaneously shifts to one of the two layers (Figure 1). Pseudospin magnetism in graphene systems could potentially lead to very appealing electrical analogs of ferromagnetism suggesting the possibility of a new electronic device scheme based on the collective behavior of many electrons.

III. EXCITON CONDENSATION

Figure 2 Normal to exciton condensation phase diagram showing the dependence of the critical temperature $T_c$ on the distance between layers $d$ and external bias electric field $E_{ext}$.

Next, we demonstrate that room-temperature exciton condensation is possible in decoupled graphene double layers[4]. Graphene is a particularly attractive candidate for high temperature bilayer exciton condensation because it is gapless so that more carriers can be induced by external electric fields, because its 2D massless Dirac-band structure implies nearly perfect particle-hole symmetry, and because it is atomically thin eliminating the layer thickness effects that substantially weaken Coulomb interaction (Figure 2).

REFERENCES
Hyperbolic Metamaterials for Tuning the Radioactive Decay Rate of Dye Molecules

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SUMMARY

We demonstrated an improved radiative decay rate of dye molecules when they are near to the designed multilayer hyperbolic metamaterials (HMMs). Due to the interaction with the designed HMM layers, the radiative decay rate for Rhodamine 800 (Rh800) becomes higher. Also, we demonstrated the higher quantum yield of Rh800 with the HMM layer comparing to the measurement with other control layers by changing layer materials, thickness, and the distance from the structures. Finally, we validated the effective control HMM by showing that multilayer hyperbolic metamaterials provide an extraordinary high radiative decay rate relative to those from monolayer thin or thick gold films. Our study provides the quantitative platform for the studying about tuning of the optical property of the molecules both experimentally and theoretically.

INTRODUCTION

It has been reported about the lifetime change of a molecules in excited states due to the interaction with HMMs [1-2]. However, it should be separately studied about the radiative decay rate to clarify the effect of HMM to the molecules’ optical properties. In this work, we took the bottom-up approach to demonstrate the increase in the radiative decay rate of a Rhodamine 800 dye layer near to HMM structure by separately measuring the quantum yield, absorption, emission, reflection, and lifetime of the dye molecules. We evaluate the material and structure effect of HMM by comparing it with the measurement of the radiative decay rate with control samples, namely thin and thick gold films. We also changed the distance between the dye molecules and the substrates to show that both our gold-film control samples as well as our experimental samples can be theoretically explained by broad hyperbolic dispersion. Briefly, our result agrees the surface plasmon polariton theory, which occurs at the metal (m) and dielectric (d) interface, namely Re(εm) < 0 and Re(εd) > 0 . Our results show that all the metal-dielectric layers can elucidate the directional emission as a result of the excitation of an SPP. Our approach provides the method of designing the effective HMM for tuning the optical properties of molecules, demonstrating that structure containing metal-dielectric layers can be considered as a single layer with hyperbolic dispersion, as we demonstrate in this work.

Table 1: Quantum yields for the various samples

<table>
<thead>
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<th>Sample</th>
<th>Quantum Yield 89 nm</th>
<th>Quantum Yield 21 nm</th>
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<tr>
<td>HMM</td>
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REFERENCES

In this talk, I will describe effects of various external mechanical perturbations on physical and chemical properties of graphene systems and their consequences in various spectroscopic signals. First, an ideal strength of single layer graphene will be re-examined by considering unique interplays between electrons and phonons in the system when equibiaxial strain is applied. Various channels to weaken the integrity of hexagonal network of carbon atoms will be introduced and the ideal strength of single layer graphene is determined [1,2]. Second, when inhomogeneous strains or shears are applied to bilayer graphene, a possible energy gap generation [3] is demonstrated and an occurrence of electronic topological transition [4] will be discussed. I will also discuss the several spectroscopic consequences of such external mechanical perturbations in graphene systems [5,6,7]. Finally, a couple of applications such as doped and corrugated graphene for oxygen reduction reaction will be discussed [8].

REFERENCES
SUMMARY

Using transmission electron microscopy (TEM), we investigate one-dimensional structural defects in chemical vapor deposited (CVD) graphene. Diffraction and atomic-resolution TEM analysis reveal various defective structures which include grain boundaries and double fold structures in suspended graphene membranes.

ABSTRACT

Chemical vapor deposition (CVD) synthesis of graphene on copper foils has been advanced as a scalable route to produce high-quality monolayer graphene. However, synthesis-related structural defects still exist in CVD graphene, which can limit graphene’s various performances in many applications. Understanding defect formation mechanisms and implications to graphene’s properties will be of a critical issue.

Transmission electron microscopy (TEM) is a very powerful tool to study suspended graphene membranes at micrometer and atomic scales. Using atomic-resolution TEM and diffraction analysis, we perform structural investigations of suspended monolayer graphene membranes and find various one-dimensional defective structures in graphene.

First, we study the grain and grain boundary (GB) structures in CVD graphene. TEM analysis confirms that the CVD graphene is polycrystalline with grain sizes about a few micrometers [1]. Global grain and GB mapping can be performed using electron diffraction in scanning transmission electron microscopy (STEM) or using dark-field imaging in conventional TEM. Additionally, we utilize aberration-corrected TEM to extract direct images of the local atomic arrangements of graphene GBs, which reveal the alternating pentagon-heptagon structure along high-angle GBs.

We also observe double-folded structures in graphene membrane [2]. These structures are also prevalent in transferred CVD graphene. The double folds (or pleat folds) exhibit band-shape features with two straight folding edges. Their widths range from a few nanometers to several hundred nanometers and lengths often extends tens of micrometers. Nano-beam diffraction and atomic-resolution TEM analysis confirm that double folding produces localized triple layers between two folding axis in graphene. We also present effective ways of controlling folding formations by introducing anisotropic curvatures during graphene synthesis or transfer processes. The folded structures have important implications in graphene’s electronic, optical, and mechanical properties.

REFERENCES

Is the indoor environment safe for children?

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SUMMARY

Levels of di(ethylhexyl)phthalate (DEHP) in indoor floor dust from residential houses in Korea are the highest in the world, generally 10 to 30-folds higher than those of other countries. DEHP in all samples from Korea exceeded US Environmental Protection Agency risk-based screening level, implying elevated probabilities of health risk especially to younger children.

I. INTRODUCTION

Indoor dust contains elevated levels of various endocrine disrupting chemicals, including plastic additives (e.g., phthalates, flame retardants), pesticides, and trace metals. Due to behavioral and physiological characteristics, children are exposed to these toxic chemicals through inadvertent ingestion that significantly increases the health risk in children.

II. METHODS

To assess exposure of children to endocrine disrupting chemicals through inadvertent ingestion, floor dust samples were collected from household vacuum clear bags donated by about 78 and 82 homes in Korea and California, respectively. Upon arrival at the laboratory, dust samples were sieved with 100 um stainless sieve. About 0.5g of the sieved dust samples were extracted using dichloromethane, and analyzed using a gas chromatograph-mass spectrometer.

III. Results and Discussion

Concentrations of Di(ethylhexyl)phthalate (DEHP) in dust from Korea were 10 to 100-folds higher than those of other countries, probably due to PVC containing plastic flooring that is very commonly used in most Korean houses. DEHP in all samples from Korea and more than 50% of the samples from California exceeded the US Environmental Protection Agency risk-based screening level, implying elevated probabilities of health risk especially to younger children. Penta-brominated diphenyl ethers (BDEs), which are most toxic BDEs among polybrominated diphenyl ethers (PBDEs), in dust from CA homes were much higher than other countries because the US and Canada consumed about 95% of world penta-BDE production.

Recent epidemiological studies and animal studies showed that DEHP might be linked to recent fast increases of autism and atopic dermatitis in children. Additional studies are required to investigate whether the highly elevated levels of DEHP in Korean houses might be one of the reasons for the prevalence of atopic dermatitis in Korea.

Simple changes we can make to minimize the exposure of children to endocrine disrupting chemicals include

1. frequent floor vacuuming and ventilation  
2. use of bates instead of sprays and foggers for indoor pest control  
3. use of products containing no or less PVC, penta-BEDs, and bisphenol A.

Figure 1: Concentrations of Di(ethylhexyl)phthalate (DEHP) in indoor floor dust from Korea and other countries.
High-Performance Inverted Polymer Solar Cells Introducing Novel Functional Interlayers

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SUMMARY
We report high-efficiency inverted polymer solar cells using ‘ionic self-assembly’ of nonconjugated polyelectrolytes as an ideal interfacial layer.

ABSTRACT
Inverted polymer solar cells (I-PSCs), consisting of a conjugated polymer:fullerene bulkheterojunction (BHJ) photoactive layer between indium tin oxide (ITO) as a bottom cathode and a high work function (WF) metal (Ag or Au) as a top anode, have been attracted as a promising device structure because of long-term device lifetime and low-cost processability [1,2]. Because the high work function of the bottom ITO cathode is difficult to collect electrons photogenerated from the active layer, it is crucial to develop novel interface materials that induce ohmic contacts with the lowest unoccupied molecular orbital level (LUMO) of fullerene acceptor and form high built-in fields inside I-PSCs.

In our work, by incorporating the electrostatically self-assembled nonconjugated polyelectrolytes (NPEs) as an ideal interfacial layer into I-PSCs, we have successfully demonstrated UV-independent high-efficiency I-PSCs with power conversion efficiencies approaching 6.3 %. The NPE layers were solution-processed on ITO at a low annealing temperature (80 °C). Due to dipole formation between NPE and ITO, the WF of ITO was significantly reduced from 4.8 eV to 4.0 eV, which results in an ohmic contact with the LUMO level of the fullerene and high built-in fields inside of the I-PSCs.

REFERENCES
Climatic Classification over East Asia during the Middle Holocene Climatic Optimum

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SUMMARY
The reconstructed winter (summer) surface air temperature at 6 kyr BP was 0.85 °C (0.21 °C) lower (higher) than PD over East Asia. The seasonal variation and heating differences of land and ocean in summer at 6 kyr BP might be much larger than PD. The winter (summer) precipitation of 6 kyr BP is 0.067 (0.017) mm/day larger than PD over East Asia. The Class B climate at 6 kyr BP decreased 17% compared to PD, but the Class D climate increased 7% over East Asia. Comparison between the results from the model simulation and published paleo-proxy record well agrees within the limited sparse paleo-proxy record data.

I. INTRODUCTION
This study focuses on the simulation of climatic features during the middle Holocene climatic optimum, and Köppen climate classification over East Asia with PMIP models. For comparison of model outputs, paleoenvironmental proxy data was used. This study may provide not only for a chance to simulate climate features during the middle Holocene climatic optimum and climate classification over East Asia but also for a chance to examine the impacts of orbital forcing on global warming climate change.

II. METHOD
We used a climate classification devised by the Russian-born German climatologist Wladimir Köppen. As a tool for representing the general world pattern of climates, the Köppen classification has been the best-known and most widely used system (Lutgens and Tarbuck, 2001). It uses only easily obtained monthly and annual mean values of temperature and precipitation. Furthermore, the criteria are unambiguous, relatively simple to apply, and realistic dividing the world into climate regions. We used BIOME 6000 to evaluate the model simulations of the 6 kyr BP over East Asia with a realistic paleoclimate record (Prentice et al., 1992; Harrison et al., 2001). Based on the paleo-proxy data of pollen during 6 kyr BP and PD, BIOME gives a global distribution of the vegetation between 6 kyr BP and PD. Some species which are sensitive to climate change have been studied in lake and coastal areas during the mid-Holocene over East Asia including China and Japan.

III. RESULTS
The reconstructed climate at 6 kyr BP over Japan and the southern part of China were similar to the modern climate. The observed tree distributions at 6 kyr BP over Japan were rather similar to PD (Takahara et al., 2002). Therefore we suggest that the changes in the climate and bioclimate of Japan and southern part of China have been small since the mid-Holocene. The reconstructed climate at 6 kyr BP over the Korean Peninsula shows that Class Dfa climate occupied central and northern regions in the Korean Peninsula, but Class Cfa dominated southern regions in the Korean Peninsula. Choi (2001) studied pollen at the southeastern part of the Korean Peninsula. His results also indicate that the cool-temperate central / montane forest existed during the mid-Holocene in the eastern area. Because biomass distributions in the Korean Peninsula were different from Japan at 6 kyr BP, climate and bioclimate between the Korean Peninsula and Japan have been different since at least 6 kyr BP.
Recent Progress in Organic Bulk Heterojunction Solar Cells

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SUMMARY

Substantial improvement in energy conversion efficiency has been demonstrated lately in organic semiconductor based solar cells. Utilization of newly synthesized materials and improved understanding on distinctive photovoltaic processes in organic semiconductors have been the main driver of this late innovation. In this talk, I will provide an overview on photovoltaic energy conversion processes in organic solar cells and recent advancements in the field. Despite the rapid development of high performing devices, lack of fundamental understanding on some of key photovoltaic and material parameters is conspicuous, and I will try to frame the discussion around this issue.
Based Fundamental Groups and the Knot Group [Survey Article]

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SUMMARY
The knot group of some knot K is the based fundamental group of the space left when K is removed from $\mathbb{R}^3$, and it serves as a knot invariant. It also arises other interesting properties of knots.

I. OVERVIEW
In this paper we will be exploring knot groups. We will define knot groups by first defining a loop on a space, and then homotopy classes between loops. From there we will build a definition of the based fundamental group; a special case of which will be the knot group of a knot in $\mathbb{R}^3$.

The importance of the knot group is that it is a knot invariant, which we will prove by looking at ambient isotopies between knots.

We will then compute the knot group of the unknot by considering it embedded in the three-sphere. Further, we will use the Seifert-van Kampen Theorem to determine the knot group for any (p,q) torus knot since (p,q) torus knots are relatively easy to visualize compared to other types of knots.

Finally, we will determing the abelianization for the knot group of the (p,q) torus knots, and find examples of knots which share the same knot group but are not ambient isotopic, showing that the knot group is not a complete invariant.

II. FUTURE IN KNOT THEORY
Knot theory is relatively a new and still growing field of mathematics. Back in the days, mathematicians were interested in searching for a complete knot invariant, classifying different types of knots, and finding connections between knot theory and mathematical methods in statistical mechanics and quantum field theory.

Recently knot theory has been applied in real life situations as scientists became interested in and found more applications of knot theory. For example, studying knots helps in determining whether a molecule is chiral or not, studying tangles helps studying the action of topoisomerase on DNA, and studying braid groups played crucial role in the construction of theories in quantum computing.

REFERENCES
Quantum superresolution with entangled photons

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SUMMARY
Spatial resolution enhancement with entangled photons was experimentally achieved by optical centroid method with higher detection efficiency than well-known quantum lithography.

I. INTRODUCTION
Quantum lithography (QL) using the quantum N00N states and an N-photon absorption material can beat the classical Rayleigh resolution limit, but its realization has yet been achieved due to low multi-photon absorption (MPA) efficiency.

We report an experimental demonstration of a new approach, referred to as the optical centroid measurement (OCM), to enhance the spatial resolution as much as the QL method with much higher detection efficiency.

II. N00N states and Quantum lithography
The N00N states represent the quantum superposition states of N photons in path a and no photon in path b or vice versa as given by:

\[ |\Psi_{N00N}\rangle = \left( |N\rangle_a |0\rangle_b + e^{i\phi} |0\rangle_a |N\rangle_b \right) / \sqrt{2} \]

where \( \phi \) is the phase difference between two paths a and b. Quantum mechanically, the probability of MPA event with the N00N states will be a function of \( 1 + \cos(N\phi)/2 \), and quantum lithography can achieve N-fold enhanced resolution of its fringe pattern.

III. Optical centroid measurement
Multi-photon absorption occurs with very low efficiency, so the realization of QL is extremely difficult. Instead of using MPA detectors, an array of single-photon detectors followed by postprocessing to find the optical centroid position of entangled N photons is used in the OCM method in quantum imaging. The histogram of the optical centroid positions shows resolution enhancement identical to that of the QL method. In addition, if the pixel size of the detector array is smaller than the correlation area of the entangled photons, the efficiency of MPA becomes extremely small, but the OCM efficiency does not change. In this case, the detection efficiency of the OCM method is much higher than that of the QL method.

III. Experimental results
We performed a proof-of-principle experiment of the OCM method. Fig. 1(a) & (b) are the interference patterns against position by the classical method and the QL method, respectively. The QL fringe exhibits two-fold enhanced resolution compared to the classical fringe. The OCM method also enhanced the fringe resolution identical to the QL method, but it has much higher efficiency as shown in Fig. 1(c).

![Figure 1: Interference patterns by (a) the classical method, (b) the QL method, and (c) the OCM method versus position.](image)

REFERENCES
Random Walks in a Sparse Random Environment

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SUMMARY

We consider random walks on Z in a sparse random environment. Our main goal is to prove Sinai-type limit laws for recurrent random walks in a sparse (non-stationary) random environment.

I. THE MODEL

In the usual model of random walks in a random environment (RWRE) on Z, the environment is defined as an i.i.d. sequence of jump kernels \( p(n) \) associated with each site \( n \) of the integer lattice [4]. The random walk is assumed to be the nearest-neighbor, so the jump kernel \( p(n) \) can be considered as a pair \( \{1-w(n), w(n)\} \), where \( w(n) \) specifies the probability of a jump from the site \( n \) to \( n+1 \), while \( 1-w(n) \) is the probability of a jump from the site \( n \) to \( n-1 \).

A corresponding sparse environment model is defined as follows. Some of the sites of the lattice are marked at random, in such a way that the distances between two successive marked sites form an i.i.d. sequence and the origin is marked with probability one. Let \( \{a(n): n \geq 0\} \) be the sequence of marked sites. Then the transition kernel of the random walk at site \( a(n) \) is \( p(n) \), where \( \{p(n)\} \) is the random environment introduced above.

We assume that in non-marked sites, the probability of moving one step to the right and to the left are both equal to one-half.

II. THE RESULTS

The random walk in a sparse random environment (RWSRE) can be thought as a perturbation of the simple nearest-neighbor random walk obtained by introducing a sequence of marked (“corrupted”) sites with unusual transition probabilities. Indeed, if the expected value of the i.i.d. distances \( a(n)-a(n-1) \) is infinite, the sequence of marked sites is a sparse subsequence of \( Z \), and hence one can expect that at least in this case the RWSRE would exhibit basic features of both simple random walk and RWRE.

It however turns out that even though such RWSRE is recurrent regardless the properties of the random environment \( \{p(n)\} \), the asymptotic behavior of the random walk resembles that of the regular recurrent RWRE. The latter satisfies so called Sinai's limit law, and in particular \( X(n) \) (which is the location of the random walk at time \( n \)) turns out to have the order of magnitude \((\log n)^{1/2} \) [1,2,3]. Thus a recurrent RWRE is considerably slower than the usual simple random walk, for which the order of magnitude of \( X(n) \) is known to be square root of \( n \).

Our main result is a Sinai-type limit law for RWSRE in the case \( E[a(n)-a(n-1)]=+\infty \). We show that if the distribution of the “marked spots” increments belongs to the domain of the attraction of a stable law of index \( 0<\alpha<1 \), then \( X(n) \) scales asymptotically to a power of \( \log n \), which can be computed as an explicit function of the parameter \( \alpha \).

The proof of our main result rests on an extension of the original argument of Sinai [3] which shows that the random walk spends almost all it time in the deepest values of a suitably defined random potential associated with the environment.

In addition to the limit law for the recurrent case, we obtain recurrence-transience criteria and the law of large numbers for our model.

REFERENCES

Physicochemical and textural properties of rice starches separated from different cultivars

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Starches separated from 13 different rice cultivars in Korea, China and USA were compared in their physicochemical properties, such as morphological, thermal and pasting properties. Comparing to corn and wheat starches, rice starches contained much smaller granules, but no difference in morphological appearance was observed among the starches from 13 cultivars. Starch from Koami 3 (high amylose type) showed the highest gelatinization temperature of 67.2, 74.4, and 83.7°C for T_o (onset), T_p (peak) and T_c (conclusion), respectively, among the Korea rice starches. Starches from US and China rice cultivars showed even higher gelatinization temperatures but lower gelatinization enthalpy than the starches isolated from Korea rice cultivars. The all rice starches, except Koami 3, showed the higher peak viscosity and lower pasting temperature than corn and wheat starches. In addition, starches from US and China rice cultivars showed lower pasting viscosity and higher pasting temperature as compared to starches from Korea rice cultivar. The textural properties of rice starch gels were different from those of corn and wheat starches, showing the higher values in springiness and cohesiveness. Especially, Koami 3 starch showed the highest chewiness, gumminess and hardness: 666, 736 and 811 g forces, respectively, among the rice starches tested.
Experimental Facility Design of Rare Isotope Science Project in Korea

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SUMMARY
According to the users’ requirement in the various fields, the Rare Isotope Science Project (RISP) has proposed research programs and is now designing the experimental facilities for basic and applied sciences with the neutron-rich rare isotopes (RIs) and stable heavy ion beams.

I. INTRODUCTION
In order to carry out the technical design and the construction of the accelerator complex, the RISP was established in December 2011, in the Institute for Basic Science. The complex consists of a 400 kW heavy ion linear accelerator as the driver for the IF(Flight Neutron Separation) system, a proton cyclotron as the driver for the 70kW ISOL(Isotope Separation On Line) system and a post-accelerator for the ISOL system.

II. RESEARCH PROGRAM & REQUIRED BEAMS

A. Research Program
The research program of the RISP includes nuclear science, atomic & molecular science, material science, and bio & medical sciences. The high priority research subjects will be introduced in the presentation.

B. Beam Requirements
The RISP facility can produce both proton-rich and neutron-rich exotic RI beams and has a unique operation mode that nobody has tried before. It will give researchers more opportunities about the nuclei near the drip-line by using more exotic RI beams. The required beams include $^{60}$Ni, $^{76}$Fe, $^{132}$Sn, and $^{144}$Xe with the intensity of more than $10^8$ pps. (Table 1)

III. EXPERIMENTAL FACILITY DESIGN
The ISOL system has been designed to produce neutron-rich intense RI beams from the fission reaction of $^{238}$U by 70 MeV protons. The basic elements of ISOL system are the driver cyclotron, the production target coupled to the ion source, the RF beam cooler, the High Resolution Mass Separator (HRMS), the charge breeder, the beam transport system, and the post-accelerator. According to the experimental requirements, a HRMS with 45,000 resolving power is considered as a part of the transport system.

Various experimental facilities have been designed for the possible research subjects, which are Korea Recoil Separator (KRS), Large Acceptance Multi-Purpose Spectrometer (LAMPS), Precise Isotope Mass Measurement Trap, Atomic Spectroscopy System, β-NMR, μSR, etc. The status of design process will be presented.

Table 1: Selected RI beam requirements for RISP

<table>
<thead>
<tr>
<th>RI Beam species</th>
<th>Energy Range</th>
<th>Desired Intensity [ particles / sec ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{60}$Ni, $^{76}$Fe, $^{132}$Sn, $^{144}$Xe</td>
<td>&gt; 100 A MeV</td>
<td>&gt; $10^8$</td>
</tr>
<tr>
<td>$^{60}$Ni, $^{76}$Fe, $^{132}$Sn, $^{144}$Xe</td>
<td>5-20 A MeV</td>
<td>&gt; $10^8$</td>
</tr>
<tr>
<td>$^{15}$O, $^{14}$O</td>
<td>&lt; 10 A MeV</td>
<td>&gt; $10^{10-11}$</td>
</tr>
<tr>
<td>$^{45}$Al</td>
<td>5-20 A MeV</td>
<td>&gt; $10^7$</td>
</tr>
<tr>
<td>$^{45}$V</td>
<td>0.613-2.25 A MeV</td>
<td>&gt; $10^7$ - $10^9$</td>
</tr>
<tr>
<td>$^{35}$Si, $^{36}$Mg</td>
<td>5-10 A MeV</td>
<td>&gt; $10^7$</td>
</tr>
<tr>
<td>$^{60}$Ni, $^{110}$Sn, $^{132}$Sn</td>
<td>10-250 A MeV</td>
<td>&gt; $10^3$</td>
</tr>
<tr>
<td>$^{6,8}$He, $^{12}$Be, $^{24,30}$O</td>
<td>50-100 A MeV</td>
<td>&gt; $10^3$</td>
</tr>
<tr>
<td>$^{17}$N, $^{18}$B, $^{35,32}$Al, $^{34}$K</td>
<td>50-100 A MeV</td>
<td>&gt; $10^3$</td>
</tr>
<tr>
<td>$^{9}$Li, $^{11}$Be, $^{17}$Ne</td>
<td>&lt; 30 keV</td>
<td>&gt; $10^9$</td>
</tr>
<tr>
<td>$^{132}$Sn</td>
<td>&lt; 60 keV</td>
<td>&gt; 1</td>
</tr>
<tr>
<td>$^{8}$B, $^{9,11}$C, $^{15}$O</td>
<td>≥ 400 A MeV</td>
<td>&gt;$10^7$ - $10^9$</td>
</tr>
</tbody>
</table>

REFERENCE
1. RISP, “Baseline Design Summary”, to be published.
Summary
Combined mathematics and economics are being offered by more and more colleges increasingly. The curriculum of economics and mathematics are very similar and closely related in many respects. Combined mathematics and economics provides a basic understanding in economic theory, mathematical methods, probability, and statistics.

I. OVERVIEW
The merger of economics and mathematics is a competent combination. The questions from everyday life that economics provides can be solved more accurately with the analytic methods that mathematics provides.

The importance of mathematical knowledge in economics has increased tremendously. Recently, economics are being more dependent on mathematical methods that are more sophisticated than before.

Economists has become to be mathematically competent to be successful in economic industry. Even graduate programs in economics require certain level of mathematics that is higher than some engineering programs in graduate schools.

II. INDUSTRY PROSPECTS
The mathematical methods can be applied to the development of economic theory, models, and analysis. Economics relies on mathematical analysis while mathematics provides solutions to optimization and control problems posed by economists. Especially in recent decades, economic theory has come to use more and more mathematics and empirical research in economics has turned to sophisticated statistical techniques. As a result, Government and companies has become to prefer to recruit mathematical economists who can do both jobs altogether.

III. CAREERS IN THE COMBINED MATH/ECON INDUSTRY
Careers in Math/Econ industry are very broad since it opens career opportunities not available in just one of these two fields. Careers that interest combined mathematics and economics majors include accountant, budget analyst, credit analyst, teacher, financial analyst, and statistician to name just a few.

Salaries in this industry differ broadly by the job title, degree, experience, and achieved certificates. The well known certificates include CFA and CPA.
SUMMARY
Understanding the fundamental physics of matter in extreme conditions is of paramount importance to laboratory astrophysics, high pressure community, high energy density, and development of energy technologies. With the recent advent of a high peak brightness x-ray free electron laser source, the Linac Coherent Light Source (LCLS), we are constructing the Matter in Extreme conditions (MEC) instrument that will cover a wide range of the extreme conditions in phase space. Here, we present the overview of the LCLS, MEC instrument, and related experiments.

I. INTRODUCTION
Understanding the thermodynamic response of matter at extreme conditions is an important element of contemporary research in physics and materials science. Especially, matter whose energy density corresponds to pressures above millions atmospheres (or Mbars) responds differently from the known material states and signals the underlying structure and dynamics providing insight into new phenomena.

The area of warm dense matter (WDM) refers to the part of the density-temperature phase space where are from liquid to greater than solid density with temperatures comparable to the Fermi energy. It is the region where the temperature of a solid nears or exceeds the Fermi temperature indicating the failure of standard condensed matter approaches and the region where is too dense and/or too cold to admit to standard solutions used in plasma physics. The study of high energy density matter has been severely dependent on the laser-based techniques since such extraordinary conditions can be created by thermal pressure, internal energy of material constituents, intense fields, or a combination of those.

II. The LCLS and MEC Instrument

The Linac produces a high current 5-15 GeV electron beam that is bunched into 100 fs slices with a 120 Hz repetition rate. The emitted coherent x-rays have unprecedented brightness with an order of $10^{12}$ photons/pulse in a 0.2% energy bandwidth and unprecedented short pulse duration of 50-200 fs, operating in the 500-9,500 eV energy range. Two general concepts of experiments are proposed for the LCLS. One consists of experiments where the LCLS beam is used to probe the sample, as is done in most experiments at current synchrotron sources and the other one is to use the LCLS beam to induce non-linear photo processes or matter in extreme conditions. The characteristics of short pulse duration and high peak brightness in tunable X-ray photon energy open the opportunities to exploit the dependence of the photo-absorption cross section and ionization potential change in WDM.

MEC instrument is designed for the study of material under extreme conditions. The particular strength of the MEC instrument is to combine the unique LCLS beam with high power optical laser beams, and a suite of dedicated diagnostics tailored for this field of science. The key scientific areas include WDM physics, high pressure studies, shock physics, and high energy density physics.
POSTER ABSTRACT

Recent activities and physics outputs of the Korea-CMS Collaboration are summarized. Korean physicists have been participating in the CMS Collaboration, one of the biggest international scientific collaborations for the LHC Physics, since late 1990, and they now work as a federation team. Korea-CMS team has made several important contributions in various ways in many of CMS achievements reported recently, such as combined results on the Standard Model Higgs boson search.

LHC is now producing 8TeV proton-proton collisions and mostly likely a conclusion on the existence of the SM Higgs boson will be made by this year. Korea-CMS will also strongly participate in the CMS Upgrade activity from this year.

I. INTRODUCTION

Korea-CMS (KCMS) has three major Physics data analysis sub-groups, and detector R&D teams, as well as a CMS Tier2 center. KCMS consists of 7 universities and about 70 physicists and students are working together as a team inside CMS.

II. KCMS Physics Analysis Groups (PAG)

A. Higgs and New Particle Search
   - Doubly charged Higgs boson search
   - W' particle search
   - SUSY particle search
   - Extra-D RS Graviton search

B. Top and Standard Model Precision Measurement
   - Precision measurement of Top production cross-section
   - Top mass measurement
   - QCD Jet Physics

C. Heavy Ion Physics
   - Quarkonia productions at LHC
   - Flow measurement
   - QCD in hot & dense nuclear matter
   - Quark-Gluon-Plasma

III. KCMS Detector & Computing activities

Korea-CMS detector R&D activities and the CMS Tier2 center at KNU will also be introduced in the poster.
Nanocone-based three dimensional thin film silicon solar cells

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ABSTRACT

Three-dimensional (3D) solar cells have attracted great attention over conventional two-dimensional planar solar cells because of their potential output efficiency improvement through enhanced light absorption and collection efficiency. We introduce a litho-free method of forming size tunable arrays of glass nanocones via self-assembled/self-forming Tin (Sn) nanosphere masks. Etching through self-assembled Sn nanospheres with a broad size range from 20 nm to 2 μm allows for patterning glass substrates into glass nanocones with various dimensions. Output efficiency of ~8% was obtained upon deposition of 150nm thick a-Si:H solar cell p-i-n stacks on the glass nanocones mainly due to 50% enhanced short circuit current compared to planar solar cells [1].

REFERENCES

The formation and the temporal evolution of a bipolar moving magnetic feature (MMF) was studied with high spatial and temporal resolution. The photometric properties were observed with the New Solar Telescope at Big Bear Solar Observatory using a broadband TiO filter (705.7 nm), while the magnetic field was analyzed using the spectropolarimetric data obtained by Hinode. For the first time, we observed a bipolar MMF simultaneously in intensity images and magnetic field data, and studied the details of its structure. The vector magnetic field and the Doppler velocity of the MMF were also studied. A bipolar MMF having its positive polarity closer to the negative penumbra formed being accompanied by a bright, filamentary structure in the TiO data connecting the MMF and a dark penumbral filament. A fast downflow (<2km/s) was detected at the positive polarity. The vector magnetic field obtained from the full Stokes inversion revealed that a bipolar MMF has a U-shaped magnetic field configuration. Our observations provide a clear intensity counterpart of the observed MMF in the photosphere, and strong evidence of the connection between the MMF and the penumbral filament as a serpentine field.
Understanding the dynamics of DNA looping

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SUMMARY

Bending of double-stranded DNA is associated with fundamental biological processes such as genome packaging and gene regulation. During these processes, DNA has to bend sharply in a timely manner with or without the aid of other factors. Therefore, studying sequence-dependent dsDNA bending in the time domain is a key to understanding biological impact of DNA sequence beyond the genetic code. A large body of work has focused on the behavior of long double stranded DNA under stress or in static equilibrium, but studies on intrinsic dynamics are rare, especially at small length scales where sequence heterogeneity of dsDNA cannot be averaged out. Here we present a framework to study sequence-dependent bending of short DNA duplexes through looping dynamics, which combines single-molecule FRET (Förster resonance energy transfer), gel electrophoresis, a semi-analytical model, and coarse-grained simulations. We find that the looping kinetics of DNA correlates more with curvature (the static persistence length) than flexibility (the dynamic persistence length) at ~180 base pair length scale. We argue that our measured looping kinetics can be directly related to the end-to-end distance probability distribution and show that our experimental data are in excellent agreement with Monte Carlo simulations.

Figure 1: A 100-200 base pair (bp) long (34-68 nm) double-stranded DNA molecule of any given sequence is modified near the ends to incorporate single-stranded overhangs (~10-bp) that are complementary to each other. When DNA loops due to thermal excitation, these two “sticky” ends of the DNA can base pair and stabilize the DNA in the looped state. The stiffness of the DNA then exerts restoring force on the base paired ends and shears them apart (denaturation).
Antiferromagnetic exchange coupling between GaMnAs layers separated by a nonmagnetic GaAs:Be spacer

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ABSTRACT

Recently Chung et al. reported the existence of antiferromagnetic (AF) coupling between GaMnAs layers in a superlattice comprised of GaMnAs layers separated by non-magnetic Be-doped GaAs spacers [1]. This exciting finding has spurred recent theoretical work by Szalowski and Balcerzak [2], who point out that the carrier-mediated inter-layer exchange coupling (IEC) between magnetic layers of a superlattice should be different from that between magnetic layers of a GaMnAs/GaAs:Be/GaMnAs trilayer due to drastically different boundary conditions. Ref. [2] further suggests that the trilayer structure provides a simpler, more fundamental system for understanding the basic exchange mechanisms between GaMnAs layers.

Here we report a systematic experimental study of IEC in trilayers comprised of two Ga$_{0.95}$Mn$_{0.05}$As layers separated by a Be-doped GaAs spacer. The experiments were carried out by SQUID magnetization, magnetotransport, and polarized neutron reflectometry (PNR). All these measurements independently indicate the presence of robust AF IEC when the GaAs spacer is sufficiently thin and highly doped. We argue that the observed behavior arises from competition between the interlayer exchange field and the magnetocrystalline anisotropy fields intrinsic to the GaMnAs layers. By carrying out the SQUID measurements at different field strengths and different field orientations, we are able to estimate the magnitude of the IEC field and the rate at which the IEC field decays with increasing temperature. The PNR experiment provides a direct measure of the magnetic depth profile (i.e., the values of the individual layer magnetizations within the trilayer), which shows excellent agreement with the SQUID data taken when these layers are in the ferromagnetic or the antiferromagnetic alignments. Systematic magnetoresistance and planar Hall effect measurements taken at different field orientations and temperatures provide independent confirmation of the presence of AF IEC in the trilayer system. These results taken together offer a clear and detailed picture of magnetization interactions in GaMnAs/GaAs:Be/GaMnAs trilayers under different conditions.

REFERENCES

SUMMARY
People interact with one another in multiple ways, via multiple spheres of social relationships and via online and offline modes of communication. We show that this multiplicity of kinds of interaction facilitates the spread of ideas, product adoption, etc., in a simple, mathematical model.

I. INTRODUCTION
Viral marketing, instant fads, the spread of bank defaults—these cascades of changes in people, companies and financial institutions increasingly pervade modern life, with important and sometimes dire consequences. This has motivated the study of simple models of cascades in a network of individuals connected to one another. A commonly studied rule (the so-called Watts model) is that people buy a new product, say, if a sufficiently large fraction of their friends have (because friends recommend it and because its utility increases as more people use the product). By considering lending rather than friendships, this model can also describe spreading default among banks.

Most studies so far consider just one kind of interaction among the system’s constituents, such as friendships in a social network. But often people, banks, countries and others interact in many different ways. For instance, friends and work colleagues exhibit different influence on a person’s decision to buy a new smartphone app. Banks also interact in many ways—through balance sheet claims, derivatives contracts and reliance on common credit lines—which collectively cause cascades. This motivates studying multiple kinds of interactions.

II. RESULTS
On an NSF EAPSI fellowship in Seoul, South Korea, in collaboration with Prof. Kwang-Il Goh and his PhD student Kyu-Min Lee at Korea University, we generalized the Watts model to multiple kinds of interactions. Namely, we studied the rule that a person joins a growing movement, say, if a sufficiently large fraction of friends in any of her social spheres have joined it.

What we found is that considering multiple kinds of interactions facilitates cascades—and in nontrivial ways. It is easier to get an enormous cascade when people (or banks) interact in multiple ways. What this suggests is that advertising may become more effective with every new medium, while banks may grow more vulnerable with every new lending mechanism.

REFERENCES
Novel Force Spectroscopy and its application to Nano-Liquid Physics

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SUMMARY

In this contribution we present a novel technique for dynamic/static force spectroscopy by combining a quartz tuning-fork based NC-AFM with a micromechanical force sensor (MEMS). The technique, applied here to measure the visco-elastic properties of nanoscale water, has the advantage of being able to simultaneously make direct measurements of the tensile strength of nanoscale liquids, by performing a static force balance measurement, while also measuring the force gradient, determined by the dynamic AM-AFM measurement. A schematic of the setup is shown in the figure below. The AFM is composed of a sharp tip glued to a quartz tuning fork. The QTF has a spring constant on the order of 1500 N/m, while the MEMS, composed of a polysilicon plate suspended above a detection electrode by four springs, has a design specific spring constant, typical between 1 – 100 N/m. This means while the QTF is fixed, the MEMS can be displaced. The MEMS is placed on top of a PZT allowing for the controlled approach of the MEMS surface to the tip of the AFM. We tested our system by performing measurements on nanoscale water columns. The water columns were formed between the tip of the AFM and the surface of the MEMS by capillary condensation. Previous works [1] have predicted that the visco-elastic properties of the water column can be measured from the changes in amplitude and phase of the QTF. By comparing these values to the force measurements made using the MEMS it is possible to compare the values made in two independent ways. We find good agreement between the approaches indicating that the not only is the AFM suitable for investigating the visco-elastic properties of liquids, but our approach is also feasible. The inclusion of the MEMS, which doubles as an actuator, opens up additional means for the study and manipulation of nano-scale liquids. An increased understanding of which is necessary as more nanoscale devices are developed.

Figure 1: Schematic of apparatus.

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Anisotropic superconducting gap in NaFe$_{1-x}$Co$_x$As pnictides

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SUMMARY

The superconducting gap structure on single crystals of electron-doped NaFe$_{1-x}$Co$_x$As superconductors were studied by measuring London penetration depth, $\lambda(T)$, using tunnel diode resonator (TDR) technique. The low temperature variation of $\lambda(T)$ analyzed using a power-law fit, $\Delta\lambda = A T^n$, and the corresponding superfluid density reveals that the superconducting gap is highly anisotropic even at the optimal doping. This doping dependent gap evolution can be explained with a recent theory considering a competition of the inter-band attraction and intra-band Coulomb repulsion within extended $s_\pm$ pairing symmetry. [1].

I. INTRODUCTION

Contrary to the cuprate high-Tc superconductors which show robust nodal d-wave superconducting gap for all doping types and levels, the gap structure of newly discovered Fe-based superconductors (FeSCs) is strongly doping dependent varying from isotropic to nodal gap structure. A key question is whether there exists any universal trend among different materials.

So far, the gap structure of both electron-doped Ba(Fe$_{1-x}$T$_x$)$_2$As$_2$ ($T =$ transition metal), hole-doped (Ba$_{1-y}$K$_y$)Fe$_2$As$_2$ shows universal dome-like evolution: isotropic (nodeless) at the optimal doping and highly anisotropic (perhaps nodal) at the dome edges. The only exception is found in isovalent – doped BaFe$_2$(As$_{1-x}$P$_x$)$_2$ where nodal behavior was concluded even at the optimal doping. In this report, we will present the doping dependent gap evolution in NaFe$_{1-x}$Co$_x$As, which shows highly anisotropic gap structure even at the optimal doping.

II. EXPERIMENTAL

Single crystals of Na(Fe$_{1-x}$Co$_x$)As with $x =$ 0, 0.02, 0.025, 0.05, 0.08, and 0.10 were used to measure the London penetration depth using tunnel diode resonator (TDR) technique [2].

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