13th China-Singapore Joint Symposium on Research Frontiers in Physics

7-9 December 2017

Department of Physics

National University of Singapore

Schedule (venue: S11 02-07 Physics Conference Room)

Session: Thursday morning 7 Dec 2017 (chair: Chorng Haur Sow)		
8:50 – 9:00 opening		
9:00 – 9:40	Chao TANG (*cell type transformation*)	Biological physics
9:40 – 10:20	Jie YAN (*proteins under force*)	
break		
10:40 – 11:20	Dongping ZHONG (*DNA repair*)	
11:20 – 12:00	Zhisong WANG (*DNA motors*)	
12:00 – 12:40	Ee Hou YONG (*egg shape*)	

Session: Thursday afternoon 7 Dec 2017 (chair: Ze Xiang Shen)		
2:00 – 2:40	Andrew WEE (*MoS_2/substrate*)	Nanostructure physics, 2D materials
2:40 – 3:20	Tian YU (*nanotube/magneto transport*)	
3:20 – 4:00	Ting YU (*light matter interaction*)	
break		
4:20 – 5:00	Dacheng WEI (*graphene growth*)	
5:00 – 5:40	Barbaros ÖZYILMAZ (*spin transport*)	
5:40 – 6:20	Xuesen WANG (*Sb & Bi films*)	

Session: Friday morning 8 Dec 2017 (chair: Jian-Sheng Wang)		
9:00 – 9:40	Yuan Ping FENG (*DFT genome*)	Computational physics/ materials
9:40 – 10:20	Xiaozhong ZHANG (*spin logic*)	
break		
10:40 – 11:20	Jing-Tao LÜ (*p-orbital lattice*)	
11:20 – 12:00	Baile ZHANG (*plasmonic waves*)	
12:00 – 12:40	Xiangang WAN (*Rarita-Schwinger quasiparticles*)	

Session: Friday afternoon 8 Dec 2017 (chair: Xuesen Wang)		
2:00 – 2:40	Yue ZHAO (*graphene resonator/magnetic field*)	Transport, optics, oxides
2:40 – 3:20	Wei CHEN (*phosphorene*)	
3:20 – 4:00	Wei JI (*nonlinear optics*)	
break		
4:20 – 5:00	Ze Xiang SHEN (*Raman spectra*)	
5:00 – 5:40	Ramanathan MAHENDIRAN (*oxides* $EuTiO_3$)	
5:40 – 6:20	Handong SUN (perovskite)	
Banquet		

Session: Saturday morning 9 Dec 2017 (chair: Jiangbin Gong)		
9:00 – 9:40	Lock Yue CHEW (*social dynamics*)	Quantum information physics, novel topological materials, complex systems
9:40 – 10:20	Weibo GAO (*quantum information*)	
break		
10:40 – 11:20	Yan CHEN (*quantum Hall*)	
11:20 – 12:00	Xi CHEN (*adiabaticity/cold atoms*)	

Waddington landscape, nonlinear dynamics and stem cells

Chao Tang

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There are hundreds of different cell types (skin, neuron, muscle, etc.) in human body, all derived from the stem cell and all have the same genetic information. About 60 years ago, Waddington speculated that the different cell types correspond to different minima in a landscape emerged from genetic interactions. Recently, biologists succeeded in transforming one cell type to another by perturbing the genetic interactions in a cell. I will discuss the experiments and a mathematical model of a set of such cell type transformations in mice, in which we can see an actual example of the Waddington landscape and ways to alter it to facilitate cell type transformation – in particular, to reprogram a differentiated cell back into a stem cell.

Structural-elastic determination of the lifetime of biomolecules under force

Jie Yan

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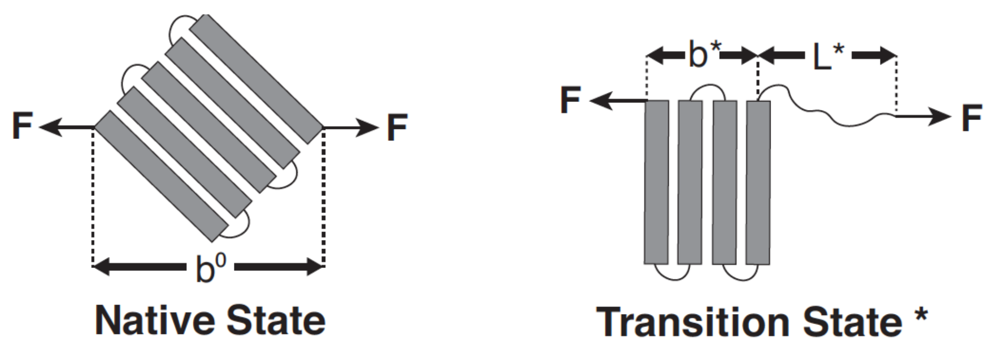
Several recent experiments have suggested that the structural-elastic properties of the native and the transition states of biomolecules are a key determinant of their mechanical stability. However, most of the current theoretical models were not derived based on the structural-elastic properties of the molecules. Here, based on the Arrhenius law and taking into consideration of the structural-elastic properties of the native state and the transition state, we derived a simple analytical expression for the force-dependent lifetime of the native state of the molecules. We show that this model is able to fit a wide scope of experiments, and explain a variety of complex force-dependent transition kinetics observed in recent experiments. The results highlight a previously largely unrecognized structural-elastic determinant of the lifetime of biomolecules under force, and provide a new theoretical framework that can inform us the structural-elastic properties of the molecules.



Sketch of the structure of a protein domain in the native and transition states.

Dynamics and mechanism of DNA repair by photolyases

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Photolyase is a photoenzyme using blue light to repair UV-induced DNA lesions in three life kingdoms. Although earlier studies on microbial photolyases revealed a critical electron-tunneling pathway for the repair mechanism, it is unknown if such electron superexchange can also operate in distant eukaryotic photolyases. Here, using femtosecond spectroscopy we show our systematic dissection of the repair process with seven electron-transfer reactions among ten elementary steps on various photolyases in all life branches. We found a new, unified electron-transfer strategy for all photolyases with bifurcated routes through a conserved structural configuration. Both pathways are operative in repair depending on the relative reduction potentials and converged at damaged-DNA site for efficient repair. From lower microbes to higher eukaryotes, the electron exploits from mainly direct tunneling along one route to dominant two-step hopping on the other path with the same conserved active-site structure through evolution.

THU 11:20 - 12:00

Molecular motors and the 2nd law of thermodynamics

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Molecular motors from biology and nanotechnology often operate on chemical energy of fuel molecules in an isothermal environment, unlike macroscopic heat engines that draw energy from a heat flow between two temperatures. Nevertheless, isothermal molecular motors are still subject to the 2nd law of thermodynamics in a fundamental way: their directional motion must cost a finite amount of energy other than the environmental heat even though no work is done; otherwise the 2nd law would be violated. Hence the 2nd law requires a finite energy price for pure direction of molecular motors. But what is the lowest price of direction allowed by the 2nd law? And how does the 2nd law-decreed price of direction limit performance of molecular motors? In the talk, I shall discuss our quest for answers to these questions on basis of the accumulated biomotor phenomenology, and also briefly introduce our experimental efforts to develop rationally designed DNA bipedal nanomotors following the bioinspired mechanistic guidelines.

Morphometry, evolution & physics of avian egg shape

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Questions such as “what is the shape of an egg?” or “why is an egg shaped the way it is?” - are discussed but not answered in the century-old classic by D’Arcy Thompson “On growth and form.” Hypotheses for egg shape variation generally relate to differences in life history traits, such as clutch size, nest location or diet. However, previous support for these explanations is weak, and we still know very little about the function of egg shape or the mechanism by which it is produced. Our synthetic approach aims to answer these questions by addressing the natural history of egg shape across the largest clade of terrestrial vertebrates, bridging perspectives from morphology, ecology, evolution and development.

The 2D transition metal dichalcogenide interface

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We have previously shown that the electronic properties of graphene can be controllably tuned via molecular functionalization and other surface modifications [1]. In this talk, I will focus on our recent work on semiconducting 2D transition metal dichalcogenides (TMDs) with layer-dependent tunable direct bandgaps, thereby making them suitable for optoelectronic device applications [2-4]. We use high resolution scanning tunneling microscopy/spectroscopy (STM/STS) to study the atomic structure and local electronic properties of 2D MoS_2 and WSe_2 layers on HOPG substrates, and show that the electronic bandgaps can be tuned by strain at grain boundaries and dislocations [5,6]. Using PTCDA as a prototype semiconductor organic molecule, we show that a monolayer TMD can effectively screen an organic-inorganic heterointerface [7]. We demonstrate the fabrication and unravel the electronic properties of a lateral doped/intrinsic heterojunction in 2D WSe_2, partially covered with a molecular acceptor $C_{60}F_{48}$ [8].

In the second part of the talk, I will present our recent work on the opening of an inverted optical gap in monolayer MoS_2 on a gold substrate, as predicted by theory [9]. This is attributed to a phase transformation to 1T' MoS_2, which is triggered by annealing at a specific temperature window. We also demonstrate that gold plasmonic hybrid structures can induce giant photoluminescence enhancement in 2D WSe_2 [10]. Finally, we shed light on how adsorption and desorption of oxygen by monolayer MoS_2 can be employed to modify its electronic and optical properties to suit different applications [11].

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THU 2:40 - 3:20

Structure, magnetic and magnetotransport properties of spin non-trivial carbon nanotube

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Owing to its unique chemical properties and novel electric transport features, carbon nanotube (CNT) is considered as one of the most attractive carbon materials. Recently, CNT with foreign material encapsulated in its cavity has attracted much attention. The possibility of encapsulating various type of materials, including metals, oxides and semiconductors within the CNT cavity provides a new approach to study these materials in nano-scale. By encapsulating magnetic species inside its cavity, spin non-trivial carbon nanotube with highly ordered structure and millimeter-length has been successfully grown. The structure, magnetic, electrical, and spin dependent transport properties of these hybrid-structured CNTs were investigated. It is found that the magnetotransport depends on magnetization states of the encapsulated ferromagnetic materials rather than the applied external magnetic field, which strongly evidences that spin dependent transport is at the origin of observed negative magnetoresistance. Moreover, the observation of magnetoresistance up to room temperature in millimeter-long CNT bundle indicates a weak temperature dependence of spin-flip scattering and large spin diffused length, which makes the spin non-trivial CNTs a promising candidate for spintronic applications.

Acknowledgment

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Optical investigation of strong light-matter interactions in 2D materials

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Two-dimensional (2D) materials, such as graphene and monolayer transitional-metal-dichalcogenides (TMDs), have aroused great attention due to the underlying fundamental physics and the promising atomically-thin optoelectronic applications. Optical properties of these 2D materials are fundamentally interesting such as magneto-phonon resonance in graphene and strong excitonic emission in monolayer WS_2. Meanwhile, development of practical optoelectronics based on 2D materials is very promising, which opens many opportunities for the next-generation light-emitting applications such as valley light-emitting diodes and on-chip vertical-cavity surface-emitting lasers (VCSELs). Here, we report observations of magneto-phonon coupling effects in graphene layers, wealthy excitonic emission states of monolayer WS_2, and 2D semiconductor lasing from monolayer WS_2 embedded VCSELs. In particular, the triple G-mode splitting in graphene on graphite and the magnetic oscillations of the G-mode phonons in ABA- and ABC-stacked trilayer graphene samples have been probed by custom-designed micro-magneto Raman spectroscopy. By electrostatic and optical doping, tunable excitonic emission has been achieved due to interplay of various excitonic states. Meanwhile, the doping dependences of excitons, trions, biexcitons and diverse bound excitons associated with impurities and structural defects have been discussed. Furthermore, we realize room-temperature low-threshold lasing from monolayer WS_2 activated VCSELs under continuous-wave optical pumping, which are intrinsically compatible with the prevailing monolithic integration technology. Overall, our studies provide many new understandings on fundamental light-matter interactions in atomically thin materials and pave ways to develop industrially attractive light-emitting applications based on 2D semiconductors.

Catalyst-free growth of two-dimensional crystals on dielectrics at low temperature for devices

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One of the largest problems, which result in little success of applying two-dimensional materials (2D) in practical application, is the lack of a low-cost, reliable, and controllable method to produce ultra-clean high-quality 2D materials directly on dielectric substrates at low temperature, which can directly be used in various applications. Here, we developed a plasma-enhanced chemical vapor deposition (PECVD) method, which realizes catalyst-free growth of ultra-clean high-quality graphene films, graphene quantum dots and h-BN films directly on dielectric substrate. The growth temperature is as low as 400 °C, which is among the lowest temperature for growing these materials. After growth, these materials are directly used in field effect transistors, surface enhanced Raman scattering, dielectric layers without post-growth transfer, indicating the great potential of PECVD method as a general growth method for future applications of 2D materials.

Spin transport and spin orbit coupling engineering in graphene and black phosphorus

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Electric field control of spin transport is crucial for many novel device concepts. In contrast to bulk materials, two-dimensional material are inherently thin and thus, can sufficiently minimize electric screening. They are also ideal to induce complementary properties by means of the proximity effect. For example, the combination of Rashba interaction, magnetic moments and electric field control of the density, is akin to dilute magnetic semiconductors. In a Dirac material this opens a route toward electric field control of magnetism and engineering topological magnetic states.

In this talk I will discuss efforts in inducing a large spin orbit coupling in graphene. Pristine graphene has negligible spin-orbit coupling (SOC). However, strong SOC can be induced, e.g. by hybridization with heavy metals. I will discuss experiments where this has been achieved with Au intercalated van der Waals heterostructures of graphene and hexagonal boron nitride [1]. We observe spin-splitting of the graphene bands observed in quantum oscillation. The Rashba interaction is large (25 meV) for samples intercalated with 0.1 monolayers of Au. It is modulated by modest electric fields, thereby highlighting the requirement of hybridization with spin-split Au d-electrons.

In the second part of the talk I will show that the SOC in pristine black phosphorus is equally weak. In conjunction with its semiconducting nature, this makes it ideal for both proximity effect studies and spin transport studies. Based on measurements in the non-local spin valves geometry with pure spin currents, we show that the spin relaxation times can be as high as ~ 4ns with spin relaxation lengths exceeding 6 μm [2]. These values are an order of magnitude higher than what has been measured in graphene.

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Self-assembled Sb and Bi few-atomic-layer nanostructures

Xuesen Wang

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Few-atomic-layer nanostructures of Bi and Sb are 2D semiconductors or semimetals, which potentially can be excellent thermoelectric materials or topological insulators useful in spintronics. On graphite and MoS_2 with physical vapor deposition, we observed the self-assembly of several types of Sb and Bi nanostructures, including ultrathin films and nanobelts. Systematic STM-based investigation reveals the crucial roles of diffusion and dissociation of deposited species, as well as the surface stress of the nanostructures in determining the types of nanostructures observed. In particular, at thickness < 8 ML, Bi and Sb ultrathin films appear to start as compressed highly isotropic square-phase nuclei. In a later growth stage, the nuclei undergo a symmetry-breaking transition to form elongated nanobelt as strain relaxation occurs. The compressive-state of the nuclei and nanobelts is attributed to an enormous Laplace pressure induced by surface and edge stress in a nanostructure. The lattice parameters deviate significantly from that of 3D bulk Bi or Sb crystals. This lattice structural deviation is expected to generate change in the electronic structures. Based on our understandings in the nucleation, growth and relaxation mechanisms, certain morphological control of Sb and Bi nanostructures self-assembled on inert substrates has been accomplished, making it possible to fabricate the few-atomic-layer nanostructures of Bi and Sb with certain desirable electronic properties.

Materials prediction from first-principles

Yuan Ping Feng

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I will give a brief presentation on research activities in our group which focuses on first-principles studies of materials for advanced technologies and prediction of new materials. Various types of new materials are urgently needed to solve problems in future energy, environment, security etc. First-principles method based on density functional theory has become an indispensable tool in exploration of new materials. In recent years, we have explored various types of materials such as materials for spintronics applications using first-principles method. Many of these works have been carried out in close collaboration with experimentalists. Recently, we have expanded our study to materials prediction using high throughput first-principles calculations and materials genome approach. A genome for two-dimensional (2D) materials has been developed with close to 2,000 candidates for 2D materials. The database is open to researchers and we welcome collaboration.

Silicon based magnetoresistance and spin logic combined with memory writing

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We developed a silicon based magnetoresistance (MR) device which combines the nonlinear property of diode and Hall Effect of semiconductor. The device can achieve a large MR at a few tens mT [1,2]. We further developed a silicon based magnetic logic device which can do reconfigurable four Boolean logic functions of AND, OR, NAND and NOR. [3]. As all these pure silicon devices have a disadvantage that they cannot work at low magnetic field of ~mT, we propose an alternative route to improve MR performance by coupling nonlinear transport effect of semiconductor and anomalous Hall effect of magnetic material of CoFeB in one device. This device has MR of >20000 % with ~1 mT, the largest MR value at low magnetic field of mT [4].

We further proposed a spin logic-memory device by coupling anomalous Hall Effect in magnetic material and negative differential resistance phenomena in semiconductor [5]. All four basic Boolean logic operations could be programmed by magnetic bit at room temperature with high output ratio (> 1000 %) and low magnetic field (~5 mT). This device demonstrated that non-volatile information reading, processing and writing could be realized in one step and one device. Hence, logic and non-volatile memory could be closely integrated in one chip. The time and energy used in the processes of information transformation and transfer could be saved. Moreover, this device was comparable with the function of neuron cell in brain that also combined memory and information process in one unit. A network with these highly parallel logic-memory devices could perform massively parallel non-volatile computing and might offer a possible route to approach brain-like artificial intelligence beyond traditional CMOS route.

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FRI 10:40 - 11:20

Orbital degrees of freedom in artificial electron lattices on metal surfaces

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Orbital degree of freedom plays a fundamental role in condensed matter physics. Recently, a new kind of artificial electron lattice has been realized in experiments by confining the metal surface electrons with adsorbed molecular lattice. A most recent example is the Lieb lattice realized by CO adsorption on Cu(111) surface [M. R. Slot, et al., Nat. Phys. 13, 672 (2017)]. The Lieb lattice is of special interest due to its flat band physics. Here, by first-principles calculations, muffin-tin potential model and tight binding model, we demonstrate that, the high energy states observed in the experiment actually correspond to the artificial p-orbitals of the electron lattice. Our numerical results, together with the experimental observation, show that artificial p-orbital fermionic lattice has already been realized in solid state system. This opens a new avenue to investigate the orbital degree of freedom in a controllable way.

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Novel plasmonic waves on graphene

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We predict some novel 2D plasmonic waves on the platform of graphene that are excited by swift sources such as charges and dipoles. These include plasmonic splashing, V-shaped ship-wakes, and the possibility of inverse Doppler shift.

Massive relativistic spin-3/2 Rarita-Schwinger quasiparticle in condensed matter systems

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We study the possibility to realize the massive relativistic spin-3/2 Rarita-Schwinger (RS) quasiparticles in condensed matter systems (CMS). The main obstacle to be jumped is the nontrivial constraints that eliminate the redundant degrees of freedom in the representation of the Poincaré group. We propose a generic method to construct a Hamiltonian which automatically contains the RS constraints, and prove that the RS modes always exist and can be separated from the other non-RS ones. Focusing on the two dimensions (2D), we find a novel property for this RS quasiparticle: Due to the nontrivial constraints, although the intrinsic orbital magnetic moment of an energy band is formally like its Berry curvature under symmetry operations, the former is exactly zero-valued in this case despite the latter is finite. Through symmetry considerations, we show that the 2D massive RS quasiparticle can emerge in several trigonal and hexagonal lattices. Based on ab initio calculations, we predict that the thin film of CaLiX (X=Ge and Si) are the candidates.

Whispering galleries in circular graphene resonators and their evolutions under magnetic field

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Graphene provides an ideal platform for electron optics due to its light-like dispersion. Due to Klein tunneling, highly transparent pn junctions can be created by electron static gating. Electron reflection and transmissions at the boundaries can be manipulated by gate potential, enabling the quantum interference of electron waves. In analogy with optical wave propagations, Fabry-Perot interferences and Veselago lensing of carriers in graphene can be achieved in linear pn junctions. In circular geometries, the localized Dirac fermions can induce whispering gallery modes (WGM), similar to acoustic whispering galleries. In this talk, I will discuss the whispering galleries in our circular graphene resonators created by a local STM probe, as well as how the WGM states evolve as magnetic field increases. Under a critical magnetic field, a giant and discontinuous change in the energy of time reversed angular momentum states emerges, corresponding to a berry phase switch in the circular graphene resonators. I will also show that modified Landau levels can be observed due to the STM probe potential when the magnetic field is much larger than the critical magnetic field.

FRI 2:40 - 3:20

Interface engineering for 2D phosphorene based optoelectronic devices

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Black phosphorus (BP), as a fast-emerging two-dimensional (2D) material, stands out from other members in 2D family such as graphene and transition metal dichalcogenides (TMDs), and attracts substantial research interests attributed to its remarkably unique fundamental properties and versatile device applications. In this talk, I will summarize and discuss our recent work for interface engineered 2D materials phosphorene based field-effect-transistors (FETs) and photo-transistors, through the combination of in-situ FET device evaluation and photoelectron spectroscopy investigation. We will particularly emphasize on the electron and hole doping effect on the transport properties and optoelectronic response of phosphorene devices.

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Two-dimensional excitonics for nonlinear optics

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As materials are exposed to intense light, their optical susceptibilities can be expressed in a nonlinear way. The imaginary parts of the nonlinear-optical susceptibilities, such as third-order, and higher odd-order ones, can be utilized to describe multi-photon absorption processes, in which materials absorb more than one photon simultaneously to excite an electron to an excited energy state. Materials capable of simultaneously absorbing multi-photons and subsequently generating photoluminescence or photocurrents have great potential for applications in multi-photon microscopy and light frequency up-conversion. Photocurrents in semiconductors induced by Two-Photon Absorption (2PA) and Three-Photon Absorption (3PA) can also be applied to autocorrelation, optical signal processing, sub-band photodetectors, quantum detectors, coherent control, and others.

Physics of 2PA and 3PA in three-dimensional semiconductors has been well-established. On the contrary, both 2PA and 3PA in two-dimensional semiconductors has hardly been explored. With the emerging of one-layer transition metal dichalcogenides (1L-TMDs), it provides a playground for researchers to explore this new frontier. It has been known that two-dimensional excitons strongly manifest themselves in 1L-TMDs. To take advantage of it, we have investigated a two-dimensional-exciton-enhanced 2PA and 3PA in 1L-TMDs [1,2]. In this talk, we present our systematical study through a quantum theoretical modeling on monolayers of MoS2, MoSe2, WS2, and WSe2; and a measurement on their photocurrents. These theoretical and experimental knowledges (or called as two-dimensional excitonics) should lay a solid foundation for developing sensitive infrared 1L-TMD-based multiphoton subband detection in nano-photonics. It should be emphasized that such multiphoton detectors are totally different from one-photon-induced photocurrent detectors, which have been commonly reported. Multiphoton detectors are highly desirable in many technologies, such as quantum information and sensitive infrared detection.

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Tuning the properties of 2D materials by stacking configuration and its application in 2D homo-junctions

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It is well-known that the optical and electronic structures of two dimensional transition metal dichalcogenide (2D TMD) materials and perovskite often show very strong layer-dependent properties. It is less well-known however is that the properties can also be tuned by stacking order, which allows us to build electro and optical devices with the same material and the same thickness. Detailed understanding of the inter-layer interaction will help greatly in tailoring the properties of 2D TMD materials for applications, e.g. in pn junction, transistors, solar cells and LEDs. Raman/Photoluminescence (PL) spectroscopy and imaging have been extensively used in the study of nano-materials and nano-devices. They provide critical information for the characterization of the materials such as electronic structure, optical property, phonon structure, defects, doping and stacking sequence.

In this talk, we use Raman and PL techniques and electric measurements, as well as simulation to study 2- and 3-layer 2D TMD samples. The Raman and PL spectra also show clear correlation with layer-thickness and stacking sequence. Electrical experiments and ab initio calculations reveal that difference in the electronic structures mainly arises from competition between spin-orbit coupling and interlayer coupling in different structural configurations.

Doped $EuTiO_3$: a new class of magnetoresistance, magnetocaloric and thermoelectric oxides

Km Rubi, A. Midya, and R. Mahendiran

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The two-decade old discovery of colossal magnetoresistance (CMR) in Mn-based perovskite oxides (manganites) revived interest in exploring magnetoresistance in other transition metal oxides of the general formula ABO_3 (A= Rare earth or Alkaline earth ion, B = Transition metal ions) However, none of the other transition metal oxides showed CMR over a wide temperature or doping level comparable manganites ($RMnO_3$). Rare-earth titanates ($RTiO_3$) are classic examples of the Mott-Hubbard insulators. Since they are highly resistive at low temperatures, magnetoresistance has been rarely studied in $RTiO_3$ compounds. Here, we show the occurrence of CMR in the titanate $EuTiO_3$ and its derivatives for the first time. The magnetoresistance is as large as 99% in a field of 5 kOe at 2 K. Further, $EuTiO_3$ and its derivatives ($Eu_{1-x}Ba_xTiO_3$, Nb doped $Eu_{1-x}Ba_xTiO_3$) show very large magnetic entropy change and thermoelectric power, which will be useful for magnetic cooling and waste energy harvest. We will highlight some important results in these compounds.

1. Km Rubi and R. Mahendiran, Euro Phys. Lett. 118, 57008 (2017)

2. A. Midya, P. Mandal, Km Rubi, R. Mahendiran, R. Wang, J.S. Wang, and M. Evangillisti, Phys. Rev. B 93, 094422 (2016).

Inorganic metal lead halide perovskite based nanostructures for solution processable lasers

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I will present the optical gain and lasing properties in the colloidal all-inorganic cesium lead halide perovskite quantum dots ($CsPbX_3$, X = Cl, Br, I) will be presented. Our results indicate that such material system show combined merits of both colloidal quantum dots and halide perovskites. Low-threshold and ultrastable stimulated emission was demonstrated under atmospheric conditions. The gain mechanism is attributed to biexcitonic recombination. The nonlinear optical properties including the multi-photon absorption and resultant photoluminescence of the $CsPbX_3$ nanocrystals were investigated. Moreover, we report the breakthrough in realizing the challenging while practically desirable vertical cavity surface emitting lasers (VCSELs) based on the $CsPbX_3$ inorganic perovskite nanocrystals. These laser devices exhibit low threshold (9 $\mu J/cm^2$), unidirectional output (beam divergence of ~3.6º) and superb stability. We show that both single-mode and multimode lasing operation are achievable in the device.

Social cooperation and disharmony in communities mediated through common pool resource exploitation

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It was theorized that when a society exploits a shared resource, the system can undergo extreme phase transition from full cooperation in abiding by a social agreement, to full defection from it. This was shown to happen in an integrated society with complex social relationships. However, real-world agents tend to segregate into communities whose interactions contain features of the associated community structure. We found that such social segregation softens the abrupt extreme transition through the emergence of multiple intermediate phases composing of communities of cooperators and defectors. Phase transitions thus now occur through these intermediate phases which avert the instantaneous collapse of social cooperation within a society. While this is beneficial to society, it nonetheless costs society in two ways. First, the return to full cooperation from full defection at the phase transition is no longer immediate. Community linkages have rendered greater societal inertia such that the switch back is now typically step-wise rather than a single change. Second, there is a drastic increase in social disharmony within the society due to the greater tension in relationship between segregated communities of defectors and cooperators. Intriguingly, these results on multiple phases with its associated phenomenon of social disharmony are found to characterize the level of cooperation within a society of Balinese farmers who exploit water for rice production.

Spin-photon interface in wide-band gap material and 2D layered materials

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Quantum defects in wide bandgap material provide promising platform for quantum information sciences with their prospects for spin-photon interface and chip-level integration. To realize true quantum register, a system must be coherently driven and exhibit Rabi oscillations. In this talk, I will talk about the scalable coherent emitter generation from Silicon vacancy, germanium vacancy in diamond and SiC. These optical emitters are stable and coherent, which can be potentially used in building quantum network and quantum information processing. In the second part, I will talk about a recently discovered potential candidate for quantum communications, which is a room temperature single photon source in the telecom range. Lastly, I will talk about spin-valley-layer locking and a long lifetime of valley polarization, which can be used potentially in quantum gate and quantum memory construction.

SAT 10:40 - 11:20

Exploring novel quantum states in interacting two-component Bosonic systems

Yan Chen (陈焱)

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Interacting two-component bosonic systems host rich physics including both exotic quantum states as well as elementary excitations. In the following, I will present our two recent theoretical studies in this field. In the first part, we study a two-component Bose-Hubbard model with additional pair hopping term which could be realized in ultracold atoms in optical lattices via Floquet engineering. Novel non-integer Mott insulating state and molecular condensate state may serve as its ground state. More interestingly, the emergence of molecular condensate may result in an elementary excitation with square-root energy-momentum dispersion at finite momentum. In the second part, we investigate anomalous bosonic integer quantum Hall (BIQH) states on square lattice. The model contains a correlated hopping term with staggered magnetic flux. Using a coupled-wire bosonization approach, we analytically show this model exhibits a BIQH state at total charge half filling. These results are confirmed by using the infinite DMRG simulation. Numerical evidences include: (i) a quantized Hall conductance $\sigma_{xy} = \pm 2$, and (ii) two counter-propagating gapless edge modes. Our model is an analog of the Haldane model for free fermions and serves as a guide to extend the analogy between fermionic and BIQH states.

SAT 11:20 - 12:00

Shortcuts to adiabatic control with cold atoms

Xi Chen

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In this talk I will review the shortcuts to adiabaticity proposed in recent years, to speed up the slow adiabatic progresses but without final excitation. I will introduce the concept of shortcuts to adiabaticity and experimental progress. Different examples including atom cooling, transport, control of matter wave soliton, and spin dynamics are illustrated showing the advantages and their physical implementations. Finally, my talk will end up with some applications in quantum information processing, atom interferometry, and quantum thermodynamics.

LIST OF PARTICIPANTS

Overseas:

Yan CHEN – Fudan Univ

Xi CHEN – Shanghai Univ

Jingtao LÜ – Huazhong Univ Sci Tech

Chao TANG – Peking Univ

Xiangang WAN – Nanjing Univ

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SOW Chorng Haur

GONG Jiangbin

WANG Jian-Sheng

PAST "CHINA-SINGAPORE-JOINT SYMPOSIUM" SERIES

1st - Singapore-Sino Joint Symposium on Research Frontiers in Physics, 28-30 August 2005, NUS.

2nd - China-Singapore Joint Symposium on Research Frontiers in Physics, 19-21 May 2006, Hangzhou.

3rd - The Third China-Singapore Joint Symposium on Research Frontiers in Physics, 25–27 May 2007, Xiamen University.

4th - The 4th China-Singapore Joint Symposium on Research Frontiers in Physics, held at the Physics Department of Suzhou University, 23 – 25 Sept, 2008.

5th - NUS, 2009.

6th - The 6th Singapore-China Joint Symposium on Research Frontiers in Physics, held at Xi'an Jiaotong University in Xi'an, China, September 21-23, 2010.

7th- The 7th Singapore-China Joint Symposium on Research Frontiers in Physics, held in School of Physics, Huazhong University of Science and Technology University, Wuhan, September 21-23, 2011,

8th - The 8th Singapore-China Joint Symposium on Research Frontiers in Physics, held at Zhong Shan University in Guangzhou, China, September 23-25, 2012.

9th - NTU, 2013.

10th - The 10th China-Singapore Joint Symposium on Research Frontiers in Physics, 21 - 23 September, 2014, School of Physical Science and Technology, Lanzhou University.

11th - The 11th Singapore-China Joint Symposium on Research Frontiers in Physics, Southwest Jiaotong University, Chengdu, China, from 19th-21th, Sep. 2015.

12th – the 12th China-Singapore Joint Symposium on Research Frontiers in Physics, USTC, Hefei, China, 22-24 Sep 2016.

BRIEF INFORMATION

A) Conference venue is at Physics Conference Room S11-02-07, Department of Physics, NUS.

B) Overseas speakers will be staying at Park Avenue Rochester Hotel (31 Rochester Drive, Singapore 138637, T: +65 6808 8600) from 6 to 9 December 2017. It includes daily breakfast and internet access.

Please refer to this website http://parkavenueintl.com/parkavenuerochester/location/ for information on the hotel and the direction from Singapore Airport to the hotel.

By Taxi
If you are taking a taxi from the airport to Park Avenue Rochester, it will cost approximately SGD25-30 and take approximately 45-60 minutes, depending on traffic conditions. Taxis are available at the taxi stands at the Arrival levels of each Terminal at the Airport.

By MRT
From Changi Airport MRT Station (CG2), take the MRT to Tanah Merah MRT Station (EW4) then change to the westbound train to Buona Vista MRT Station (EW21 / CC22).

C) Daily two-way transfer will be provided from the hotel to NUS and vice versa for the conference period. Please refer to the attached schedule and map.

D) On campus, “eduroam” is available for WiFi.

E) Contacts:
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Transfer between Park Avenue Rochester Hotel and NUS Campus:

Date	Transfer	Departure time	Pick Up Points	Drop Off Points
Thu 7 Dec	From Hotel to NUS	8:15 am	Hotel Lobby	Science Drive 3 (Carpark 6), NUS
	From NUS to Hotel	7:30 pm	Science Drive 3 (Carpark 6), NUS	Hotel Lobby
Fri 8 Dec	From Hotel to NUS	8:30 am	Hotel Lobby	Science Drive 3 (Carpark 6), NUS
	From NUS to Hotel	6:30 pm	Science Drive 3 (Carpark 6), NUS	Hotel Lobby
Sat 9 Dec	From Hotel to NUS	8:30 am	Hotel Lobby	Science Drive 3 (Carpark 6), NUS
	From NUS to Hotel	2:00 pm	Science Drive 3 (Carpark 6), NUS	Hotel Lobby

Map: