IPS Meeting 2018
7 - 9 March

Institute of Physics Singapore

Conference Program

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1 Foreword

Dear fellow Physicists,

this year we are back again to well-known territory with our annual meeting, revisiting the School of Physical and Mathematical Sciences at Nanyang Technologcial University after exploring a new venue with Yale-NUS College last year.

As every year, we aim to give all researchers in physical sciences in Singapore an opportunity to familiarize themselves with the current research landscape in Singapore – for newcomers to learn about who is doing what, who to collaborate with, and for long timers to catch up with new developments on the little red dot, learn about new colleagues and directions, or finally talk to your next-door neighbour about the science they are involved in, and not only about the chores of everyday's routine in our departments.

In this spirit, our six plenary talks this year provide an overview over a very diverse spectrum of outstanding local research activities: Starting with Huanqian Loh from NUS with work on ultracold molecules, over to Shengyuan Yang from SUTD with new developments in theoretical condensed matter physics and Robert Simpson, also SUTD, on chalcogenide material applications for electronics and photonics, we highlight currently hot academic research topics. Then, Koh Wee Shing from the Institute for High Performance Computing, a long time supporter and organizer for the IPS meetings, takes us on a tour out of the academic ivory tower and shows us where physics research has a very direct impact on the quality of our lives in an urban environment. Touching on our physicist's trade mission to go beyond the known in nature, Cheong Siew Ann from the Complexity Institute at NTU will then reflect on how physicists perceived and tried to shape the world around us over time. And while we all share the excitement on the way of thinking as a physicist, it is important to pass this excitement on to the next generation: therefore, Subramaniam Ramanathan from the National Institute of Education will therefore share is insights of being successful at that important task, and conclude this year's selection of plenary talks.

Traditionally, we feature a wealthy set of 19 technical sessions with 89 invited and contributed talks this year.

As important as technical talks are, we feel that interaction is often easier in a relaxed atmosphere, so we put a stron emphasis on a serious poster session with some 66 posters. By now as a tradition, we continue the poster pitch session, where poster presenters can volunteer to give an ultrashort teaser to the whole of the IPS conference audience. So the poster session in the middle of the meeting on Thursday afternoon is really a central part of this event, and as usual, transitions into a networking event with Pizza and Drinks to provide a proper setting.

As in the previous years, our colleagues at the Ministry of Education organized a few events on Friday afternoon where we welcome this year's winners of the Physics Olympiad to our community. If you can, find some time to engage with these newcomers, and perhaps join the panel discussion to learn about the questions the next generation of researchers in physical sciences may have. Be prepared to be chased during the conference to participate in this event, and share your views with the students on Friday afternoon!

Perhaps a short remark on how we prepare this program: often, the choice of the program committee of what becomes an invited talk, or what is selected as a poster or talk where the authors suggest both options is not easy - we aim to base the decision on the importance we seem to find in an abstract, but this is of course subjective. We do rely on your input and participation, so if you have good ideas how to make this a conference more useful to physicists in Singapore – do let us know, and join this community effort.

As always, we owe a big thank you to everyone who helped to make this event happen, especially the helpful hands and location support we get from SPMS at NTU.

We are also very grateful for our institutional supporters, the Department of Physics at NUS and the School of Physics and Applied Physics at NTU, the Graduate Studies Program at SUTD, and, as large research-active centers, the Centre for Advanced 2-Dimensional Materials and the Centre for Quantum Technologies at NUS.

Last but not least, let's thank our exhibitors, who again help with their generous sponsorship to make this conference possible!

With this, we wish you an inspiring conference, a refreshing look up from your daily work, new ideas, new contacts, new collaborations for a successful new year of research in physical sciences ahead!

Your organizing team of the IPS meeting 2018

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2 Schedule

Wednesday, 7 March

8.30 AM	Registration (MAS Atrium)			
9.00 AM	Opening Address (LT1)			
9.30 AM	Plenary talk 1: Huanqian LOH (LT 1)			
10.15 AM	Plenary talk 2: Shengyuan YANG (LT1)			
11.00 AM	Coffee/Tea Break + Exhibition (MAS Atrium)			
11.30 AM	Technical Sessions			
	T1 (LT2) Terahertz physics	T2 (LT3) Post deadline session followed by TC (LT3) Commercial session	T3 (LT4) Plasmonics and Metamaterials	T4 (LT5) Perovskites
12.45 PM	Lunch + Exhibition (MAS Atrium)			
1.30 PM	Technical Sessions			
	T5 (LT2) Physics in 2D Materials	T6 (LT3) Quantum Information	T7 (LT4) Biophysics	
3.00 PM	Coffee/Tea Break + Exhibition (MAS Atrium)			
3.30 PM	Technical Sessions			
	T9 (LT2) Magnetism and Spintronics	T10 (LT3) Quantum optics	T11 (LT4) Complexity and Statistical Physics	T12 (LT5) Quantum Plasmonics
5.00 PM	End of Wednesday sessions			

Thursday, 8 March

9:00 PM	Registration
9.30 AM	Plenary talk 3: Robert E. SIMPSON (LT1)
10.15 AM	Plenary talk 4 KOH Wee Shing (LT1)
11.00 AM	Coffee/Tea Break + Exhibition + Poster mounting (MAS Atrium)
11.30 AM	PO1: Rapid Fire poster Pitch session (LT1)
12.30 PM	Lunch + Posters + Exhibition (MAS Atrium)
1.30 PM	Technical Sessions T13 (LT2) Topological effects 1 T14 (LT3) Atomic Physics T15 (LT4) Spectroscopy
3.30 PM	PO2: Poster session (MAS Atrium) + Exhibition
5.30 PM	Poster awards + Pizza + Drinks (MAS Atrium)
6.30 PM++	End of Thursday sessions

Friday, 8 March

8.30 PM	Registration (MAS Atrium)
9.00 AM	Plenary talk 5: Siew Ann CHEONG (LT1)
9.45 AM	Plenary talk 6: Subramaniam RAMANATHAN (LT1)
10.30 AM	Coffee/Tea Break + Exhibition (MAS Atrium)
11.00 AM	Technical Sessions T16 (LT2) Topological effects 2 T17 (LT3) Applied Quantum Physics T18 (LT4) Many-body Physics T19 (LT5) Physics Demonstrations and Applications
12.30 PM	Lunch (tentative)
1.30 PM	Registration for Physics Olympiade award winners (MAS Atrium)
2.00 PM	Welcome (LT1)
2.15 PM	O1: Keynote address by Emeritus Professor Bernard Tan Tiong Gie (LT1)
2.45 PM	O2: Panel discussion “Promises (and Perils) Physics” (LT1)
3.45 PM	O3: Prize presentations (LT1)
4.00 PM	Refreshments and networking (MAS Atrium)
5.00 PM	End of Conference

3 Plenary sessions

We have several distinguished plenary speakers this year – with a nice overview of recent activities in physical sciences in Singapore. Some of the topics are not really our daily bussines, but we hope you can sit back and enjoy the wide scope of toics physicists are working on!

P1: Quantum Control of Ultracold Dipolar Molecules

Asst. Prof. Huanqian Loh, Centre for Quantum Technologies
Department of Physics, National University of Singapore
Email: phylohh@nus.edu.sg

Wednesday, 7 March, 9:30am, Venue: LT1

Abstract

Polar molecules offer long-range anisotropic interactions, which are fundamental to a wide variety of phenomena, from ferrofluid behavior to the folding of proteins. Recent demonstrations of cooling and trapping polar molecules have made it possible to study these particles in the quantum regime, making them highly attractive for applications such as quantum information storage and exploring novel condensed matter phases. In this talk, I will discuss the creation and quantum control of dipolar fermionic NaK molecules in the ground rovibronic state and at ultracold temperatures as low as 300 nK. Using microwaves, we have coherently manipulated not only the rotational states of the molecules, but also the nuclear spin degree of freedom. I will present our observation of nuclear spin coherence times on the scale of 1 second, and discuss its implications for quantum memory and probing new physics via Hertz-level precision spectroscopy.

P2: 2D and 3D Nonsymmorphic Topological Metals

Asst. Prof. Shengyuan Yang, Engineering Product Development
Singapore University of Technology and Design
Email: shengyuan_yang@sutd.edu.sg

Wednesday, 7 March, 10:15am, Venue: LT1

Abstract

Nonsymmorphic symmetries, i.e. symmetry operations involving fractional lattice translations, can produce nontrivial band-crossings in the band structure. Importantly, these crossings could Hourbe intrinsically stable under spin-orbit coupling (SOC). For example, the previously discussed Dirac points in 2D systems, such as in graphene, are all vulnerable against SOC. In contrast, nonsymmorphic symmetries may give rise to 2D spin-orbit Dirac points, which are truly stable under SOC. We identify the first realistic material example (2D HfGeTe family) that hosts such points at Fermi level, and we show that it is also the first identified 2D Z2 topological metal. We also discuss nonsymmorphic-symmetry-protected hourglass Dirac loops, which are fourfold degenerate and robust against SOC. These loops each enclose a pair of drumhead surface bands on the sample surface. Connecting two such loops can make an extended Dirac chain in the momentum space. We propose for the first time such hourglass Dirac chain metal phase, and find its realization in ReO_2.

P3: Active electronic and photonic materials by nanostructural design

Asst. Prof. Robert E. Simpson, Engineering Product Development
Singapore University of Technology and Design
Email: robert_simpson@sutd.edu.sg

Thursday, 8 March 9:30am, Venue: LT1

Abstract

Francis Crick famously remarked ”If you want to understand function, study structure”. The properties and functions of all materials result from their atomic arrangements. Here I will discuss new ways to design the nanostructure of chalcogenide materials to achieve bespoke functional properties. The properties of chalcogenides are often optimised by inefficient Edison-style methodologies, where interesting attributes are occasional serendipitous discoveries rather than designed to specification. In contrast, a generalisable approach to optimise the design of materials for application in data storage, photonics, and electronics will be discussed. In particular, strain engineering and evolutionary approaches will be used to optimise chalcogenide superlattices. I will show how these methods have allowed us to introduce atomic switching into van der Waals heterostructure superlattices that are composed of two different two-dimensional chalcogenide crystals. Finally I will demonstrate that when ”designed” phase change materials are incorporated into prototype memory cells, the memory characteristics exhibit substantial improvements over unstructured alloys of the same composition.

P4: Environmental Modelling for Urban Cities

Assoc. Prof KOH Wee Shing, Institute of High Performance Computing
Agency for Science, Technology and Research (A*STAR)
and Department of Physics, National University of Singapore
Email: phykws@nus.edu.sg

Thursday, 8 March, 10:15am Venue: LT1

Abstract

Urbanization has resulted to an increasing population density in many cities similar to Singapore. An increasing amount of forested land is converted to public housing to cater for the demands from the residents and industries as economic activities pick up. Therefore, in the place of forested land, are more and more concrete surfaces that trap heat in the urban environment by day and dissipate heat much more slowly at night. This results in the urban heat island (UHI) effect, where the ambient temperature of an urban town can be as high as 30 °oC even at high. Another issue with high density living is the annoyance due to noise. Noise can come from many different sources, but the most prevalent noise source in many places including Singapore is traffic noise. Therefore, the liveability of the city is greatly dependent on (1) how much lesser solar energy can the city absorb; (2) how to maximize passive ventilation or natural wind flow to take heat away; (3) how to reduce the noise to the residents? Before addressing needs to improve city's liveability, we must be able to model the physics with real virtual geometries of the city so that our urban planners can design a better environment for all. In this talk, I will briefly present an integrated environmental modeller (IEM) to simulate the solar radiation, wind and noise in the urban cities. The physics involved will be discussed. Some simulation results involving common urban features will be illustrated.

P5: From the Knowledge of Physics to the Physics of Knowledge

Assoc. Prof. Cheong Siew Ann, Complexity institute,
School of Physical and Mathematical Sciences,
Nanyang Technological University

Friday, 9 March, 9:00am, Venue: LT1

Abstract

We physicists pride ourselves as the pioneers of human knowledge. Indeed, starting with Gallileo, Newton, and Maxwell in the 16th, 17th, and 18th centuries, we have amassed a vast knowledge of physics that is unthinkable in the times of Newton. We now understand pretty well the birth of our universe, the elementary particles, nucleosynthesis in stars, nuclei, atoms, and molecules, and condensed matter. But do we know how our knowledge of physics grows and evolves?

Reflecting on the scientific enterprise, Karl Popper clarified the logic behind coming up with hypotheses, design experiments to test these hypotheses, refine our hypotheses, and test again. In Popper's view, scientific progress is incremental, and the nature of our knowledge is tentative. Studying the birth of special relativity and quantum physics, Thomas Kuhn believed that scientific truth is a social construct born of consensus between scientists. Whenever scientists change their mind, dropping an old theory for a new one, we see a paradigm shift. In this talk, I will describe our attempts to better understand knowledge evolution, by mining the American Physical Society publication data sets, which consists of about 500,000 publications between 1893 and 2013. For each year, we construct a bibliographic coupling network (BCN), and perform community detection. We show that the BCN communities represent research topics that can be treated as mesoscopic units of knowledge. We then visualize how these knowledge units evolve from year to year, to show that this time evolution is a Popperian process dominated by weak mixing between topics. However, we also see strongly-mixing Kuhnian processes where two or more knowledge units merge to become one, or where one knowledge unit split into two or more knowledge units. We show that these Kuhnian processes strongly impact our knowledge of the topics involved, and so these can be considered paradigm shifts at scales smaller than the special relativity or quantum physics revolutions.

Finally, I will describe ongoing work to combine bibliographic analysis with linguistic analysis of the APS publication data, to understand how scientific concepts evolve through Popperian and Kuhnian changes in the citation structure. Another ongoing work involves identifying features in the citation structure that allow us to most accuratey predict Kuhnian processes. Ultimately, we hope to understand knowledge evolution itself as a physical process as well.

[1] W. Liu, A. Nanetti, and S. A. Cheong: *Knowledge evolution in physics research: An analysis of bibliographic coupling networks*, PLoS ONE **12**, 0184821 (2017).

P6: Making the teaching of physics fun and interesting

Assoc. Prof. Subramaniam Ramanathan, National Institute of Education
Nanyang Technological University Email: subramaniam.r@nie.edu.sg

Friday, 9 March, 9:45am, Venue: LT1

Abstract

Research has shown that physics is a difficult subject for students. A number of concepts in physics is counter-intuitive to real life experience, and this makes the subject especially prone to misconceptions. Creating a fun and interesting learning environment can make the subject more appealing and engaging for students. Some of these approaches include the use of demonstrations, thinking questions, everyday contexts, and class-based enrichment activities. These and other approaches are discussed during this presentation.

4 Poster Sessions

PO1: Rapid fire poster pitch competition

As previously, we have a full session (Thursday before lunch) with no parallel technical sessions where all IPS participants get your audience for a supershort (3 minutes) presentation on a poster if the authors want to participate. In order to encourage authors to participate, we will choose the Best Poster Award this year form those submissions where there was short presentation in this session.

For this, we just project your poster on the screen in the lecture hall (please provide us with a PDF file for that purpose). You can email this to us via posters@ipsmeeting.org, or leave it with the reception desk.

IPS Best Poster Award

During the conference the program committee will select the three best poster presentations for the IPS Best Poster Award. The award will be handed over to the winners at the Pizza session after the end of PO2 on Thursday evening, probably around 5.30pm-6.30pm.

PO2: General poster presentation

Timing

Posters are presented during the whole conference; perhaps you can make sure that the posters are up as soon as you can. We encourage everyone to browse around during coffe breaks and lunchtime (catered lunch is nearby). We would recommend that the best time for the poster presenters to be around at the poster is the Thursday afternoon session that will be followed by food and drinks. Please take down the posters by latest at the end of the conference, i.e., on Friday after lunch.

Format

The poster walls fit a A1 sized poster (portrait orientation).

Poster Abstracts

Below, we show a list of abstracts submitted by the authors. You can locate the poster of your interest via the easychair number from the poster submission, they are sorted and labelled by these numbers.

PO.4 Period doubling in period-1 steady states

Bo Xing*, Reuben Wang*, Gabriel Carlo*, Dario Poletti* (Singapore University of Technology and Design)

Nonlinear classical dissipative systems present a rich phenomenology in their "route to chaos", including period doubling, i.e. the system evolves with a period which is twice that of the driving. However, typically the attractor of a periodically driven quantum open system evolves with a period which exactly matches that of the driving. Here we analyze a periodically driven manybody open quantum system whose classical correspondent presents period doubling. We show that by studying the dynamical correlations, it is possible to show the occurrence of period doubling in the quantum (period-1) steady state. We also discuss that such systems are natural candidates for clean and intrinsically robust Floquet time crystals.

PO.7 Elastomeric quantum optics system sampled with a single-pixel camera

Filip Auksztol*, James Grieve, Kian Fong Ng, Neo Ho, Jose Viana-Gomes, Alexander Ling (Centre for Quantum Technologies)

Our recent research has shown that waveguides defined in soft polymer polydimethylsiloxane (PDMS) can be used to implement a robust, tuneable platform for quantum optics, allowing rapidly reproducible devices with feature sizes in the micrometer range.

Using this platform, we propose to implement a random walk of a correlated photon pair in an array of evanescently coupled waveguides. Time evolution of the system is simulated by stretching the PDMS structure and measuring the output face of the waveguides at varying intervals.

Closely spaced waveguide outputs with variable pitch present a challenge to traditional methods of read-out. Considering this, we are using a single-pixel camera setup, with the output face of the waveguide chip sampled with a digital micro-mirror device (DMD) and selectively projected onto the active area of a single photon detector.

In order to counter optical inefficiencies introduced by the single-pixel camera, a compressed sensing scheme may be implemented. By under-sampling the scene in a sparse basis we will be able to reconstruct the joint photon spatial distribution on experimentally feasible timescales.

PO.11 Controlled distillation of quantum entanglement via interferometry

Chithrabhanu Perumangatt*, Alexander Ling (National University of Singapore)

Extracting highly entangled photon pairs from a less entangled source is of primary interest for quantum communication. Entanglement distillation is the process which we distill lesser number of high quality entangled photons from a non-maximally entangled photon source with relatively larger photon number. This can be done with locally filtering out the photons which are not entangled. We employ a modified polarizing Mach-Zehnder interferometer for implementing the distillation. Compared to previous implementations, our method offer better control and can distill any non-maximally entangled states. We measure the Bell parameter before and after the interferometer to ensure the distillation.

PO.12 2D Monte Carlo simulation of CMOS-compatible waveguide-based single-photon avalanche diode for visible wavelengths

Salih Yanikgonul*, Jun Rong Ong, Victor Leong, Leonid Krivitsky (Nanyang Technological University)

Integrated photonics platforms are a potential key factor in enabling the scalable implementation of photonic quantum technologies, but many such applications still rely on external bulk photodetectors. We report the design and simulation of a waveguide-based single-photon avalanche diode (SPAD) for visible wavelengths. The SPAD consists of a PN junction implemented in a doped silicon waveguide, which is end-fire coupled to an input silicon nitride waveguide. We develop a 2D Monte Carlo model to simulate the avalanche multiplication process of charge carriers following the absorption of an input photon, and calculate the photon detection efficiency η and timing jitter Δt_j of the SPAD. We investigate the SPAD performance at 640 nm for different device dimensions and device doping configurations. For our simulated parameters, we obtain a maximum efficiency of $\eta = 0.45\%$ with a breakdown voltage of 25 V, and typical timing jitter values of $\Delta t_j < 4$ ps.

PO.14 Light-Cone and Diffusive Propagation of Correlations in a Many-Body Dissipative System

Ryan Tan*, Jean-Sébastien Bernier, Lars Bonnes, Chu Guo, Dario Poletti, Corinna Kollath (Singapore University of Technology and Design)

We analyze the propagation of correlations after a sudden interaction change in a strongly interacting quantum system in contact with an environment. In particular, we consider an interaction quench in the Bose-Hubbard model, deep within the Mott-insulating phase, under the effect of dephasing. We observe that dissipation effectively speeds up the propagation of single-particle correlations while reducing their coherence. In contrast, for two-point density correlations, the initial ballistic propagation regime gives way to diffusion at intermediate times. Numerical simulations, based on a time-dependent matrix product state algorithm, are supplemented by a quantitatively accurate fermionic quasiparticle approach providing an intuitive description of the initial dynamics in terms of holon and doublon excitations.

PO.15 Interplay of interaction and disorder in the steady state of an open quantum system

Xiansong Xu, Chu Guo, Dario Poletti* (Singapore University of Technology and Design)

Many types of dissipative processes can be found in nature or be engineered, and their interplay with a system can give rise to interesting phases of matter. Here we study the interplay between interaction, tunneling, and disorder in the steady state of a spin chain coupled to a tailored bath. We consider a dissipation which, in contrast to disorder, tends to generate a homogeneously polarized steady state. We find that the steady state can be highly sensitive even to weak disorder. We also establish that in the presence of such dissipation, even in the absence of interaction, a finite amount of disorder is needed for localization. Last, we show that for strong disorder the system reveals signatures of localization. In this case, small to intermediate interaction can weaken localization while strong interaction can enhance it.

PO.16 Interfacial Damage in Phase Change Materials Tuned Optical Structures

Li Tian Chew*, Li Lu*, Robert Simpson* (Singapore University Technology and Design)

We study the diffusion of metal atoms into phase change chalcogenides. Phase change chalcogenides exhibit stable amorphous and crystalline states at room temperature with a substantial difference in their optical and electrical properties between states. These important materials are used in rewritable optical data storage and are now being applied to non-volatile random-access memory devices. Recently, phase change materials have been investigated for active photonics applications. They have been applied in tuneable polarisation-independent perfect absorbers at visible and mid-infrared wavelengths, optical imaging devices, nano-displays, active nano-photonics, and reconfigurable optical circuits. However, many recent publications do not consider reactions and diffusion at the interface between the metal and chalcogenide layers, which may occur. The diffusion influences the properties of the phase change layer, such as the crystallisation kinetics and optical constants. Here, we study the interface between the phase change material, $Ge_2Sb_2Te_5$, and different metal layers using X-ray reflectivity (XRR) and reflectometry of metal/phase change chalcogenide stacks. We find that a diffusion barrier layer, such as Si_3N_4, can help to prevent the interfacial diffusion of the metal and $Ge_2Sb_2Te_5$ layers.

PO.19 Single atoms coupled to near-concentric cavity

Chi Huan Nguyen, Adrian Nugraha Utama*, Matthias Steiner, Christian Kurtsiefer (Centre for Quantum Technologies)

Until recently, strong atom-photon coupling in Cavity Quantum Electrodynamics (CQED) systems have usually been achieved with high finesse mirrors and small mode volumes [1]. We present here an alternative approach by employing a physically large, near-concentric cavity design with strong focusing modes [2]. This proof of concept experiment utilized a 11 mm long near-concentric cavity with a finesse of 140, stabilised to 1.65um shorter than the concentric point. We observed normal-mode splitting in the cavity spectrum under the presence of trapped single ^{87}Rb atoms, and the CQED parameters are estimated to be $(g, \kappa, \gamma) = 2\pi(5, 45, 3)$ MHz [3]. By upgrading the mirror finesse to a modest value of 1000 or operating even closer to concentric, it would be able to achieve strong coupling in upcoming experiments. Strong coupling in near-concentric, low finesse systems presents an attractive pathway in exploring the field of multimode CQED [4] and might facilitate scaling up of quantum networks.

[1] A. Reiserer and G. Rempe, Rev. Mod. Phys. 87, 1379 (2015) [2] K. Durak et al., New Journal of Physics 16, 103002 (2014) [3] C. H. Nguyen et al., Phys. Rev. A 96, 031802(R) (2017) [4] A. Wickenbrock et al., Phys. Rev A 87, 043817 (2013)

PO.20 Coherent transfer of singlet-triplet qubit states in an architecture of triple quantum dots

Chang Jian Kwong, Mengke Feng*, Teck Seng Koh, Leong Chuan Kwek (Nanyang Technological University)

We propose two schemes to coherently transfer arbitrary quantum states of the two-electron singlet-triplet qubit across an empty chain of 3 quantum dots. The schemes are based on electrical control over the detuning energy of the quantum dots. The first is a pulse gated scheme, requiring dc pulses and engineering of inter- and intra-dot Coulomb energies. The second scheme is based on the adiabatic theorem, requiring time-dependent linear control of the detuning energy through avoided crossings at a rate that the system remains in the ground state. We simulate the transfer fidelity for 3 dots using typical experimental parameters for silicon quantum dots. Our results give state transfer fidelities between $94{:}3\% < F < 99{:}5\%$ at sub-nanosecond time-scales for the pulse gated scheme and between $16{:}1\% < F < 99{:}2\%$ at tens of nanosecond time scales for the adiabatic scheme. Taking into account dephasing through charge noise, we obtain state transfer fidelities between $94{:}0\% < F < 99{:}2\%$ for the pulse gated scheme and between $54{:}0\% < F < 93{:}7\%$ for the adiabatic scheme.

PO.21 Towards a Quantum Nanophotonics Platform with Nanodiamonds Embedded in Silicon Nitride Ring Resonators

Victor Leong*, Sumin Choi, Dmitry Kalashnikov, Gandhi Alagappan, Junrong Ong, Ting Hu, Doris K.T. Ng, Leonid Krivitskiy (Data Storage Institute, A*STAR)

Quantum photonics platforms are a promising avenue towards implementing scalable quantum networks. We report on the progress of integrating silicon vacancy (SiV) centres in nanodiamond crystals with a photonic circuit based on silicon nitride waveguides. To enhance the interaction with the quantum emitters, the nanodiamonds are to be buried within a ring resonator structure, which is then coupled to a bus waveguide. We characterise the resonance properties of fabricated waveguide devices and consider the Purcell enhancement of interaction strength with the SiV centres. The single-photon nature of the emitted light can be verified by an on-chip Hanbury-Brown Twiss (HBT) interferometer. As a stepping stone towards practical quantum networking, we will also discuss the application of pairs of ring resonator devices to perform on-chip Hong-Ou-Mandel (HOM) interference experiments.

PO.24 Generation of Ultrashort Dark Pulses via Coherent Perfect Absorption in Plasmonic Metamaterial

Venkatram Nalla*, João Valente, Handong Sun, Nikolay I. Zheludev* (Nanyang Technological University, University of Southampton)

We demonstrate generation of the shortest reported 11fs dark pulses using the coherent absorption process on a plasmonic absorber with a gating pulse. The dark pulses appear as a power dip on the envelope of a long carrier pulse and are characterized using the cross-correlation technique. The principal difference and advantage of our approach in comparison with previously developed laser sources of dark pulses is that, in principle, it allows transferring arbitrary pattern of bright pulses into a pattern of dark pulses in another optical signal channel.

PO.29 Towards quantum-enhanced inference algorithms for modelling stochastic processes

Matthew Ho*, Mile Gu, Thomas Elliot (Nanyang Technological University, School of Physical and Mathematical Sciences)

Stochastic processes are central to the statistical sciences. Their ubiquitous presence makes understanding such processes essential, and critical to this task is our ability to model them. For complex systems, such simulation models can be heavily resource intensive, motivating entire fields that seek methods to simplify their simulation. A recent cross-disciplinary approach to this task has employed tools from complexity science and quantum information theory, realising that quantum models constructed generically require tracking of less information (i.e. less memory) than even the best classical models. This blossoming field, quantum computational mechanics, is producing many interesting and fruitful results. However, currently lacking are inference algorithms for constructing models directly from raw data that properly exploit quantum effects. At present, inference is first achieved through classical algorithms. Here, we seek to develop such quantum-enhanced inference algorithms.

Underpinning these efforts is a recent observation that quantum memory states can be constructed that 'self- assemble' an architecture for quantum models exhibiting sub-classical memory requirements. We demonstrate how patterns and structure in data may be identified with our algorithm, and how a quantum simulator of the stochastic process underlying the data may be inferred. We will also discuss further developments towards optimising these simulators, in order to establish their feasibility with current and near-future quantum technologies.

PO.32 Memory capacity of quantum thermodynamic resources

Jiajun Ma, Varun Narasimhachar*, Jayne Thompson, Gilad Gour, Mile Gu* (School of Mathematical and Physical Sciences, Nanyang Technological University)

The deep connections between thermodynamics and information theory are epitomized by such thought experiments as Maxwell's Demon and Szilard's engine. In this work, we focus our attention on a particular informational aspect of thermodynamics, namely the relation between a quantum system's thermodynamic properties (e.g. free energies) and its usefulness as a memory device. To this end, we formalize the concept of a "thermally passive memory": a memory on which information can be encoded only through thermalizing interactions. We find that the capacity of such a passive memory correlates with the degree of thermodynamic non-equilibrium in its initial state. We show that the capacity scales as the state's Gibbs free energy in the thermodynamic limit (of many i.i.d. copies of the memory). We also compute the single-shot classical capacity of a two-level (qubit) memory, and show that it depends on both the departure of the energy-level populations from their equilibrium values and on quantum coherence relative to the energy basis. We also propose an experimental implementation of the encoding scheme that achieves the optimal capacity.

(Paper in preparation)

PO.35 Surface Energy Balance Modelling for Industrial Areas

Shah Faisal*, B. Sunthar, W. S. Koh (National University of Singapore)

An Urban Heat Island (UHI) describes the phenomena where an urban area has a higher temperature than the surrounding rural areas. The main cause of an UHI is urban development. Vegetation and open areas are replaced with buildings and roads. Materials used in the construction of urban areas have very different thermal properties such as thermal emissivity and solar reflectance which is also known as albedo. Albedo values of urban materials are generally lower than that of vegetation, hence they will reflect less energy from the sun back to the atmosphere. This allows more energy to be stored, raising surface temperatures which contributes to the formation of an UHI. UHIs can bring about negative impacts such as increasing energy usage and reducing the quality of life. Hence, many heat reducing strategies have been employed to mitigate these adverse effects.

In order to study the phenomena of UHI, the energy balance between the Sun and the surface of the Earth must be understood. One of the ways to do so is through the use of the Surface Energy Balance System (SEBS). In SEBS, remote sensing data is used to obtain various parameters such as albedo, surface temperature and fractional vegetation coverage from a certain area of land and using these values, the energy balance for that area of land can be understood. Since SEBS is applied in the macro scale level, it does not take into account the finer details, such as differentiating the roads, pavements and buildings since they have different thermal properties.

There are two objectives in this study. The first objective is to determine the relationship between solar irradiance and surface temperature of different materials. The second objective is to determine the effectiveness of UHI management. To do so, two key areas in Singapore have been identified. They are Ayer Rajah Industrial Estate and CleanTech Park. Both of these areas are industrial estates. However, CleanTech Park employs the "green building" concept in order to reduce the UHI effect while there is no such system in place for Ayer Rajah Industrial Estate. To obtain data, a pyranometer and an air temperature sensor to obtain data on solar irradiance and air temperature respectively was deployed on the rooftop of a single building in each industrial estate. In addition, thermal imagers were used to obtain the surface temperature of various surfaces in the area, such as roads, grass patches and pavement surrounding the buildings as well as the faces of the building. From the data obtained, a UHI model will be constructed for each area, which will then be compared with each other in order to determine the effectiveness of the "green building" concept.

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PO.36 Optimisation of phase change van der Waals structures by statistical design of experiments

Jitendra Kumar Behera*, Xilin Zhou, Alok Ranjan, Robert Edwardsimpson* (Singapore University of Technology and Design)

Two-dimensional van der walls (vdW) bonded layered chalcogenides materials such as Sb_2Te_3, Bi_2Te_3, Bi2Se3, and iPCM superlattice structures have recently gained attention for their applications in photonics, plasmonics, and electronic memory devices. The growth procedure of these two-dimensional vdW layered structures involves a large number of growth deposition parameters, which significantly alter the materials functional properties. Therefore, growing single crystals or highly oriented films on a large scale has always been challenging. Often simple trial and error methods to grow the two-dimensional chalcogenides are simply too consuming and labour intensive. In this poster, we demonstrate the usefulness of design of experiment (DoE) for optimising the crystal quality of chalcogenide van der Waals layered crystals. We investigate and statistically analyse the impact of the growth parameters for highly c-axis oriented Sb_2Te_3 crystals and Sb_2Te_3-GeTe phase change vdW heterostructure superlattices. The statistical significance of the growth parameters of temperature, pressure, power, buffer materials, and buffer layer thickness are optimised using fractional factorial design and response surface analysis methods. We found that the quality of the crystal strongly depends on temperature, pressure, power, and their second order interactions, whilst buffer thickness has an insignificant effect. Additionally, using tungsten rather than molybdenum for the buffer layer significantly enhances the crystal quality of vdW epitaxially grown chalcogenides crystals. The DoE-optimised GeTe/Sb_2Te_3 layered chalcogenide superlattice film shows highly oriented (0 0 L) crystals of grain size greater than 300 nm. These results establish a systematic methodology to grow highly textured two-dimensional structures on a large scale by sputtering, which is desired for mass production in a wide range of industrial applications.

PO.37 Solar Heat Gain Modelling for Urban Environments

B. Sunthar*, Shah Faisal*, W. S. Koh (National University of Singapore)

Daylight is an essential source of light and heat in an urban environment especially in buildings. The luminous spectrum of daylight provides a greater feeling of well-being and comfort for the occupants, positively affecting production and concentration, thus being preferable over artificial lighting and cooling systems. Five minutes of direct sunlight can lead the occupants to close the curtains and unnecessarily turn on the lights and air conditioners for hours which leads the occupants to ignore the principle of energy saving and efficiency (Anderson, 2014). Hence, knowing the available daylight allows designing of spaces that provide greater comfort for the occupants and energy savings on artificial lights and cooling systems.

The luminous spectrum of daylight depends on the luminance distribution of the sky. The very first luminance distribution of the sky was proposed by the Commission Internationale de l′Éclairage (CIE) and is now known as the Standard CIE Sky model in which 3 categories of skies were introduced. They are mainly CIE clear, CIE intermediate and CIE overcast skies. However, actual sky luminance distribution data are available only in handful of locations and sky modelling is complex as it requires detail ray-tracing of light. As a result, the Perez sky model was introduced and developed to estimate the skylight distribution from routine and readily available measurements such as solar irradiance. In doing so, the Perez sky model further categorises the sky into 8 different categories and also introduces an insolation condition known as sky brightness which overall improves the accuracy of the model (Perez, 1993).

The primary objective of this study is to derive a relationship between incident solar irradiance on a surface at different tilt angles and its surface temperature. To do so, a more accurate and considerably simpler version of the Perez diffuse irradiance model (1990), that utilises the 8 categories of sky and sky brightness, was used to estimate short time step irradiance on tilted planes. To obtain data, the tilt angle of the vertical plane was fixed at 90o and the surface temperature of the vertical plane and a horizontal plane (ground) was measured at intervals of 20 minutes. Additionally, the incident global irradiance on the vertical plane and the horizontal plane was also measured at intervals of 1 minute and 10 minutes respectively. From this data, the performance of the Perez diffuse irradiance model (1990) will be evaluated in its simplified circumsolar forms by determining and presenting the coefficients of the model. Lastly, the relationship between incident solar irradiance on a surface at different tilt angles and its surface temperature will be determined and presented.

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PO.38 Digital Signatures Using Multi-Party QKD

Aswin Eapen*, Soe Moe Thar, James Grieve, Aitor Villar, Alex Lohrmann, Peiyu Amelia Tan, Christian Kurtsiefer, Alexander Ling* (CQT)

Digital signatures are used to verify identity of the sender in activities like digital transactions and software distribution. They must satisfy two security assumptions: non-forgeability and non-repudiation. Conventionally, public key cryptography has been used to achieve this. We propose to use multi-party QKD to establish secret keys among three parties, with these keys used to sign messages. In the distribution stage of the protocol, Alice sends two different parts of the signature to Bob and Charlie. They randomly select some signature elements and forward to the other party along the QKD encrypted channel, symmetrizing the key. This helps to achieve non-repudiation. In the messaging stage, Alice sends a message along with appended tags, which can later be used to verify the signature

PO.39 Novel chalcogenide as a material platform for tunable nanoantenna arrays in the visible and near infrared spectrum

Li Lu*, Ramon Paniagua-Dominguez, Vytautas Valuckas, Arseniy I. Kuznetsov, Robert E. Simpson* (Singapore University of Technology and Design)

Nanostructures made of dielectric materials can have analogous properties to plasmonic structures for manipulation of light, with the advantage of having lower dissipative losses [1]. Wide bandgap phase change chalcogenides may be tailored to have a large refractive index with a low absorption in the visible and near infrared spectrum, and thus they are a promising platform for tunable metasurfaces in this spectral ranges. For one of the most commonly used chalcogenides, $Ge_2Sb_2Te_5$ (GST), the refractive index at 840nm is rather large, approximately 4.5 for the amorphous state and 5.5 for the crystalline state. However, the extinction coefficient of GST at 840nm is around 1.5 and 3.6 for the amorphous and crystalline states respectively, which renders it very lossy and, therefore, impractical for realistic applications. In comparison, the properly designed wide bandgap phase change chalcogenide, which is used herein, has a refractive index of approximately 3.0 and 3.5 for the amorphous and crystalline states at 840nm, with an extinction coefficient near 0 at 840nm for both states, thus meeting the high index and low loss requirements for high efficiency devices. We designed nanoantenna arrays metasurfaces based on a wide bandgap chalcogenide for the visible and near infrared spectrum. The device operates in transmission mode and allows manipulation of the phase of the transmitted wave, and is tunable through structural phase transitions in the chalcogenide material. The proposed device exploits both the refractive index change in chalcogenide and the concept of Huygens’ metasurface [2] to exhibit a very high transmission ($>80\%$) with full angular 2π phase control. Based on the structural phase change property of the chalcogenide, we designed a gradient metasurface using two different mechanisms: geometrical tuning and partial crystallization. Both designs allow dynamic control of the transmitted light at a wavelength of 840nm. The transmitted beam deflection could be tuned by adjusting the individual crystallization levels of the wide bandgap phase change material, with overall efficiencies exceeding 40% with respect to the incident power. In conclusion, both simulations and experimental results will be presented that demonstrate nanoantenna array metasurfaces, which are based on a wide bandgap phase change materials, and can achieve tunable control of light beams in the visible and near infrared spectrum. These results suggest that phase change materials have a further application beyond data storage in high-speed spatial light modulator and phase arrays, with potential applications in dynamic holography. Li Lu acknowledges his scholarship from Singapore Ministry of Education (MOE). [1] Kuznetsov, Arseniy I., et al. "Optically resonant dielectric nanostructures." Science 354.6314 (2016): aag2472. [2] Yu, Ye Feng, et al. "High–transmission dielectric metasurface with 2π phase control at visible wavelengths." Laser & Photonics Reviews 9.4 (2015): 412-418.

PO.41 Towards Continuous Variables Quantum Computing with ions

Jaren Gan*, Gleb Maslennikov*, Roland Hablutzel*, Beicheng Lou*, Ko-Wei Tseng*, Dzmitry Matsukevich* (Centre for Quantum Technologies, Natl. Uinv. of Singapore)

The commonly employed paradigm of encoding quantum information in the spin states of atomic-like systems suffers from scalability issue – it becomes increasingly challenging to control a larger number of particles while running the computation. An alternate approach would be to encode qubits using large Hilbert space provided by the quantum harmonic oscillator, which is also known as continuous variables quantum computing (CVQC). The universal CVQC toolbox consists of single and two-mode operations such as rotations, beamsplitters and squeezers operating on the states. The nonlinearity required for some operations is provided by either coupling some spin degree of freedom to motion, or by the anharmonicity of the trapping potential.

Here we use a system of trapped $^{171}Yb^{+}$ ions confined in a linear Paul trap to realize some of the gates that make up the toolbox of CVQC. In particular, we have realized the beamsplitter operation between the Fock states prepared in two motional modes and demostrate the coherence of this operation by observing Hong-Ou-Mandel effect for phonons. We further elaborate on the possibility of implementing a beamsplitter operation that is conditioned on the internal state of the ions and report on the progress in this direction.

PO.49 Electrical, optical and thermal properties of Sb_2Te_3 and related materials

Jing Ning*, Robert Simpson, Yee Kan Koh (Singapore University of Technology and Design)

Sb_2Te_3 is an important material for phase change data storage, thermoelectrics, and topological insulators. Recently, other phase change materials, which are built around Sb_2Te_3 were shown to exhibit a metal insulator transition when heated above 250 °C [1]. Until now, similar metal insulator transitions in Sb_2Te_3 have not been reported. At the same time, the relationship between the thermal conductivity and electrical conductivity of Sb_2Te_3 and $Ge_2Sb_2Te_5$ above and below the metal-insulator transition has not been explored. In this poster we review these properties based on sputtered Sb_2Te_3 and identify future research avenues.

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PO.53 Single and two photon spectroscopy of ultracold dipolar ^{6}Li-^{40}K molecules

Anbang Yang*, Sambit Pal*, Mark Lam, Andrew Laugharn, Sofia Botsi, Sunil Kumar, Kai Dieckmann* (National University of Singapore)

Ultracold heteronuclear dimers of ^{6}Li-^{40}K, in their deeply-bound ro-vibronic states possess a large electric dipole moment. This makes them a suitable candidate for investigating long-range anisotropic dipole-dipole interactions. Starting from a sympathetically-cooled, quantum-degenerate mixture of ^{6}Li and ^{40}K, we create weakly-bound ^{6}Li-^{40}K molecules via a magnetic-Feshbach association with a sole singlet admixture. High-resolution laser spectroscopy of the electronically-excited $B1\Pi$ and $A1\Sigma$ potentials of ^{6}Li-^{40}K Feshbach molecules is performed to identify intermediate vibrational states suitable for coherent Raman transfer to the electronic ground state. Subsequently, Autler-Townes spectroscopy is performed to investigate the deeply-bound ro-vibrational levels of the electronic ground state of ^{6}Li-^{40}K molecules. Results of the single and two-photon molecular spectroscopy are presented in this poster.

PO.55 Efficient implementation of a gray optical molasses for sub-Doppler laser cooling of lithium-6 atoms

Christine Satter*, Senmao Tan, Kai Dieckmann* (Centre for Quantum Technologies)

Alkali-metal atoms are prime candidates for studies of degenerate quantum gases and standard magneto-optical trapping and cooling of these elements to the Doppler limit is conventionally done on the D2 transition. However, standard sub-Doppler cooling techniques are not effective for lithium because of this species' unresolved hyperfine structure in the excited state. In our experiment, a gray optical molasses operating on the D1 atomic transition is applied to cool a cloud of lithium-6 atoms to sub-Doppler temperatures. A new laser set-up was constructed to produce the light on the D1 wavelength. For convenient integration into the pre-existing laser system, a scheme is used where D2- and D1-frequency light beams rapidly take turns injection seeding the same diode laser. A beat system is set up that allows us to monitor the correct seeding of the diode laser during the different stages of the experimental sequence, in a fast, time-resolved manner. We observe cooling of the atoms from 380 to 32 microkelvin. A characterization of the gray molasses is presented and the results are compared to those previously reported in gray molasses experiments, and to results obtained in our group using narrow-line cooling on a UV transition. Finally, we discuss the efficacy of atomic transfer from the molasses into a two-beam crossed optical dipole trap for transport of the atoms to a glass science cell and evaporative cooling to quantum degeneracy.

PO.57 Continuous motional sensing with highly dispersive medium

Pei Chen Kuan*, Chang Huang*, Shau-Yu Lan (Nanyang Technological University)

Current state-of-the-art atoms-based motional sensors rely on measuring the first-order Doppler shift of the atomic transition of single-particles. By using Doppler-sensitive detection methods, the population of atomic states and, therefore, the velocity of atoms can be measured precisely. On the contrary, here, we demonstrate a novel method of measuring the center-of-mass motion of an atomic ensemble using the collective interference of light passing through the ensemble under the condition of electromagnetically-induced-transparency (EIT). With the large enhancement of the dispersion in the EIT medium, we realize an atom-based velocimeter that has a sensitivity two orders of magnitude higher than the velocity width of the atomic medium used. This method has the advantages of high data rate and convenient detection of the interference phase of light over the conventional method of detecting the florescence of atoms and could lead to a new design of compact atoms-based motional sensors.

PO.61 Molecular electronic plasmon sources: the role of the tunnel barrier shape and electrostatic potential profile

Wei Du, Xiaoping Chen, Harshini V. Annadata, Tao Wang, Christian A. Nijhuis* (CA2DM)

By combining molecular electronics with plasmonics, molecular electronic control over plasmons offers a promising route for on-chip integrated molecular-plasmonic devices for information processing and computing [1-7]. To move beyond the currently available technologies, and to miniaturize the plasmonic devices, molecular electronic plasmon sources are needed. Recently, electrically-driven light emission from molecular tunnel junctions containing no chromophores has been reported by us [1,2] and others [3-5], and the origin of the light emission is explained as the radiative decay of surface plasmons excited by tunneling electrons. Here, by introducing halogenated molecules (SC12X, X = F, Cl, Br or I) with polarizable terminal atoms as the tunnel barriers, we demonstrated molecular control over both the plasmon excitation intensity and energy at the atomic level. As the polarizability of the terminal atom increases, the tunnel barrier height decreases, resulting in an increase of the tunneling current and the plasmon intensity. The plasmon energy is controlled by the electrostatic potential drop at the molecule-electrode interface which depends on the polarizability of the terminal atom and the metal electrode material. Our results also suggest that plasmon excitation can be useful for insitu characterization of electrical properties (such as tunnel barriers or interface energetics) of the molecular tunnel junctions.

PO.68 Systematic Corrections to the Thomas-Fermi Approximation Without a Gradient Expansion

Jun Hao Hue*, Thanh Tri Chau, Martin-Isbjoern Trappe, Berthold-Georg Englert (Centre for Quantum Technologies, NUS Graduate School for Integrative Science and Engineering)

We improve on the Thomas-Fermi approximation for the single-particle density of fermions by introducing inhomogeneity corrections. Rather than invoking a gradient expansion, we relate the density to the unitary evolution operator for the given effective potential energy and approximate this operator by a Suzuki-Trotter factorization. This yields a hierarchy of approximations, one for each approximate factorization. For the purpose of a first benchmarking, we examine the approximate densities for a few cases with known exact densities and observe a very satisfactory, and encouraging, performance. As a bonus, we also obtain a simple fourth-order leapfrog algorithm for the symplectic integration of classical equations of motion.

PO.69 Abstract for 2018 IPS meeting

Rui Zhang* (SUTD)

The investigation on nonequilibrium matter has been put forward by artificially engineered quantum matter such as an atomic Bose-Einstein condensate, since it is thermally isolated from the environment and easily taken out of equilibrium. Of many nonequilibrium phenomena in quantum physics, dynamical quantum phase transition can be different from the traditional quantum phase transitions in that they are not driven by external factors such as magnetic field but by internal changes in a nonequilibrium quantum systems as the system evolves in time. Dynamical quantum phase transitions could be easily understood by the analogy between the role of time in the evolution of a thermally isolated quantum system and that of the inverse of the temperature in a system in thermal equilibrium. Rainer Blatt from Austrian Academy of Sciences and the colleagues have observed the above phenomenon successfully in a quantum many body spin system. A one dimensional transverse-field Ising model will undergo dynamical phase transitions at certain critical times after a quench. Under thermally isolate conditions, the system is subjected to a quench when the values of its parameters are suddenly changed from the parameters indicating the ordered phase to those of the disordered phase. Experimentally, starting from an ordered spin state, the group made the system to evolve freely in time by suddenly switching on the interactions among the spins. By studying the time evolution of the probability that all the spins pointed in the same original direction, theorists could predict the singular point at certain time as a consequence of dynamical phase transitions. The experimental study of nonequilibrium phenomena will open new eyes on the investigations of the nonequilibrium matter.

PO.71 Device-independent Self-testing Analysis on Finite Data

Zhi Xian Lee, Koon Tong Goh*, Valerio Scarani (National University of Singapore)

Device-independent self-testing allows the user to verify the measured quantum state and the measurements up to a local isometry based solely on the observed statistics. Such analysis only assumes the validity of quantum theory and no-signalling. No assumptions are needed about the underlying mechanism of the device itself. However, in experiments, the probability of an occurrence is estimated by its relative frequency. Such estimates may not be not be meaningful as the no-signalling constraint may not be met due to statistical fluctuations. This obstacle can be circumvented by projecting the point estimator into the approximate set of quantum statistics. Self-testing of such projected point estimators would provide a valid lower bound of the fidelity between the measured state to the ideal quantum state. In recent works, self-testing of multiple singlet states in parallel is shown to be possible. However, it is unknown how the state-of-the-art experimental implementations would fare in the stringent assessment of self-testing.

In our work, we obtain and study the behaviour of the lower bound on the fidelity to the Singlet state using simulated data of an ideal CHSH experiment with different data size. The next step of our work is to extend our work for two CHSH experiments in parallel and apply the analysis on experimental data. We hope to show that with current experimental implementations, one can obtain non-trivial lower bounds on the fidelity using device-independent analysis.

PO.72 Coherence transportation of Rubidium Atom in an Optical Waveguide

Wui Seng Leong*, Mingjie Xin*, Zilong Chen*, Shau-Yu Lan* (Nanyang Technological University)

Coherence interactions between electromagnetic and matter waves lie at the heart of quantum science and technology. In many experiments such as atom interferometry and qubit manipulation, long atomic coherence time with long coherence transportation distance are always favorite properties. In this presentation, I will show the details of cold ($\sim 20\mu K$) Rb^{85} atoms loaded into a hollow-core photonic crystal fiber, with the aid of a 1 mK deep intra-HCF dipole trap.

Rabi flopping, Ramsey fringes, and spin echo signal using both microwave antenna and Raman beams are also demonstrated. Finally, we have achieve a long coherence time of 160 ms and transportation distance in centimeter scale.

PO.77 Photon triplets from a cold atomic ensemble

Mathias Seidler*, Boon Long Ng, Alessandro Cere, Christian Kurtsiefer (Centre for Quantum Technologies, NUS)

Narrowband correlated photon pairs are useful tools to study the interaction between light and atoms [1]. One way to obtain them is via four-wave mixing in a cold atomic ensemble [2]. We want to extend this scheme and generate three-photon states, where photon frequencies and bandwidths are compatible with other atomic systems. To achieve this we propose a six-wave mixing scheme in ^{87}Rb, with three independent pump beams and the spontaneous emission of three photons. We choose a non-collinear geometry with the pump beams counter-propagating to efficiently separate the generate photons from the spectrally similar pump beams. We will report on the latest progress of this work. References [1] V. Leong, M.A. Seidler, M. Steiner, A. Cere, and C. Kurtsiefer, Nature Communications 7 (2016), arXiv:1604.08020 [2] B. Srivathsan, G. K. Gulati, B. Chng, G. Maslennikov, D. N. Matsukevich, and C. Kurtsiefer, PRL 111, 123602 (2013)

PO.79 Investigation of light-induced atomic desorption (LIAD) on the loading rate of Rb-87 MOT

Thien Tran* (Hwa Chong Institution)

The main topic of this project is to investigate the intensity and wavelength dependence of light-induced atom desorption (LIAD) effect on the loading rate of a typical magneto-optical trap (MOT) of Rubidium-87. Saturated spectroscopy of a Rubidium gas sample gives an accurate reference resonance frequency of Rubidium-87. By locking the laser at the frequency slightly lower than the resonance frequency, only atoms moving out of the trap will absorb the incoming photon, due to Doppler's effect, and have lower momentum, resulting in the MOT of Rubidium-87. The loading curve of the MOT is obtained by directly imaging the trap on a photodiode using a lens element. We fit the loading curve with the solution to the MOT dynamics differential equation, and obtain various parameters of the loading curve, including the initial loading rate. By varying the input current into the LED, we measure the dependence of LIAD effect on light intensity. Wavelength dependence of LIAD is investigated by using different types of LED. We attempt to explain the trend observed in the experimental data and conclude based on experimental results.

PO.80 Polidispersity induced re-entrant melting and hexatic phases of hard disks

Pablo Sampedro Ruiz*, Ran Ni (SCBE (NTU))

The phase behaviour of hard-disk systems has been a subject of intense discussion since the formulation of the KTHNY theory. Recently, it appears to be settled that the monodisperse hard-disk system exhibits two subsequent phase transitions, a first order transition from liquid to hexatic phase followed by a continuous hexatic-solid transition with a narrow stable region of hexatic phase about 0.2% in packing fraction [1]. This suggests the experimental observation of stable hexatic phase in colloidal systems to be highly challenging, while surprisingly recent experiments indeed reported the existence of stable hexatic phase within a packing fraction range of 3% [2]. This motivates us to investigate the effect of polydispersity on the hard-disk systems, which remains unclear. By using Monte Carlo simulations, we calculate the phase diagram of hard-disk systems with various polydispersity. With increasing the polydispersity of hard disks, we find that the first order fluid-hexatic transition becomes weaker and switches to a continuous transition at the polydispersity higher than 7%, which accompanies with a significantly enlarged packing fraction range for stable hexatic phase. More surprisingly, we also observe a re-entrant melting transition in polydisperse hard-disk systems, which was proven never existing in 3D polydisperse hard-sphere systems because of the strong fractionation [3]. Our results implies the fundamental difference between phase transitions in polydisperse hard-sphere system in 3D and 2D, and explains the experimental observation of hexatic phase in polydisperse hard-disk systems.

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PO.81 quantum gears

Zheng Liu*, Stefan Nimmrichter, Valerio Scarani (Centre for Quantum Technologies)

With the advance of nanotechnology and the engineering of mechanical devices at the molecular and atomic scale, it is vital to understand how quantum effects influence the behavior of such devices and their components. One ubiquitous component in mechanical engines and thermal machines are gears, which transmit and synchronize motion through the device. We study the transmission of motion in a system of two 'soft' quantum gears, which are coupled by a finite interaction potential, and where one of them is driven by an external control agent. The coupling of the two gears then transmits energy from the externally driven gear to the other. By evaluating and comparing the transmission efficiency to the equivalent classical case, we can single out genuine quantum signatures such as tunneling and angular momentum quantization.

PO.83 Goos-Hanchen and Imbert Federov shift of Weyl modes

Udvas Chattopadhyay*, Yidong Chong (Nanyang Technological University)

Three-dimensional (3D) photonic crystals can exhibit band degeneracies governed by Weyl-type hamiltonians with a sub-lattice degree of freedom (DoF) acting as an effective pseudospin. Modes near such points can show exotic optical phenomena like Klein tunneling, Goos-Hanchen shifts and Imbert-Federov shifts. Here we report our results on the study of light beams in a Weyl medium reflecting off a domain with a photonic band gap.

PO.84 Three body problems in evolutionary game dynamics: Convergence, Periodicity and Limit Cycles

Sai Ganesh Nagarajan*, Sameh Mohammed*, Georgios Piliouras* (SUTD)

We study the asymptotic behavior of replicator dynamics in settings of network interaction. We focus on three agent graphical games where each edge/game is either a 2x2 zero-sum or a 2x2 partnership game. Using tools from dynamical systems such as Lyapunov functions and invariant functions we establish that this simple family of games can exhibit an interesting range of behaviors such as global convergence, periodicity for all initial conditions as well as limit cycles. In contrast, we do not observe more complex behavior such as toroids or chaos whilst it is possible to reproduce them in slightly more complicated settings.

PO.88 Multilevel optical properties in phase change materials

Yun Meng, Jitendra Behera, Yujie Ke, Litian Chew, Yang Wang, Yi Long, Robert Simpson*
(Singapore University of Technology and Design)

In this poster we demonstrate multilevel optical tuning of phase change materials and their nanostructures. Phase change materials exhibit a substantial change to their optical properties when their structure is changed between two or more states. Typically, for the most famous phase change materials, which exist along the Sb_2Te_3-GeTe pseudobinary tie line, the amorphous and crystalline states are used to form a binary switch between high and low refractive index. However, many new applications in photonics require continuously tuneable optical properties. In this poster discuss two different mechanisms that provide a step toward multilevel and continuously tuneable optical constants.

PO.95 Plasma Assisted core-shell Architectures for Energy Storage Devices

Bo Ouyang, Yongqi Zhang, Hongjin Fan, Singh Rawat Rajdeep* (NTU)

Various carbon-based materials with advantages of cost-effectiveness, chemical inertness and large abundance, have become most popular building blocks for energy storage devices. Currently, various approaches have been used for synthesizing carbon-based nano-architecture. However, conventional strategies are far less efficient in fabricating carbon-based frameworks for satisfactory performance. Hence, plasma-based approaches have received considerable attentions owing to their high efficiency, large scalability, and low expenses. For carbon-based nano-structures, plasma can achieve carbon species with specific frameworks and favorable features. Here, we specifically concentrate on the graphitic carbon coating, for developing high-performance energy storage devices with lower consumption. The plasma provides a facile strategy to not only create uniform carbon shell but also functionalize material surface for enhanced electrochemical performance. We have concentrated our efforts on plasma-based synthesis and processing to achieve carbon-based nano-composite for the application in lithium ion batteries.

PO.100 Understanding photon sideband statistics and correlation for determining phonon coherence

Ding Ding*, Xiaobo Yin, Baowen Li (SIMTech)

Generating and detecting coherent high-frequency heat-carrying phonons have been topics of great interest in recent years. Although there have been successful attempts in generating and observing coherent phonons, rigorous techniques to characterize and detect phonon coherence in a crystalline material have been lagging compared to what has been achieved for photons. One main challenge is a lack of detailed understanding of how detection signals for phonons can be related to coherence. The quantum theory of photoelectric detection has greatly advanced the ability to characterize photon coherence in the past century, and a similar theory for phonon detection is necessary. Here, we reexamine the optical sideband fluorescence technique that has been used to detect high-frequency phonons in materials with optically active defects.We propose a quantum theory of phonon detection using the sideband technique and found that there are distinct differences in sideband counting statistics between thermal and coherent phonons. We further propose a second-order correlation function unique to sideband signals that allows for a rigorous distinction between thermal and coherent phonons. Our theory is relevant to a correlation measurement with nontrivial response functions at the quantum level and can potentially bridge the gap of experimentally determining phonon coherence to be on par with that of photons.

PO.102 A portable image-based cytometer for rapid malaria detection and quantification

Gowtham Subramanian*, Yang Dahou, Ye Ai*, Rajesh Chandramohanadas* (Singapore University of Technology and Design)

Increasing resistance by malaria parasites to currently used antimalarials across the developing world warrants timely detection and classification so that appropriate drug combinations can be administered before clinical complications arise. However, this is often challenged by low levels of infection (referred to as parasitemia) and presence of predominantly young parasitic forms in the patients' peripheral blood. Herein, we developed a simple, inexpensive and portable image-based cytometer that detects and numerically counts Plasmodium falciparum infected red blood cells (iRBCs) from Giemsa-stained smears derived from infected blood. Our cytometer is able to classify all parasitic subpopulations by quantifying the area occupied by the parasites within iRBCs, with high specificity, sensitivity and negligible false positives (0.0025%). Moreover, we demonstrate the application of our image-based cytometer in testing anti-malarial efficacy against a commercial flow cytometer and demonstrate comparable results between the two methods. Collectively, these results highlight the possibility to use our image-based cytometer as a cheap, rapid and accurate alternative for antimalarial testing without compromising on efficiency and minimal processing time. With appropriate filters applied into the algorithm, to rule out leukocytes and reticulocytes, our cytometer may also be used for field diagnosis of malaria.

PO.105 Synchronization of a Self-Sustained Cold Atom Oscillator

Hermanni Heimonen*, Leong Chuan Kwek, Robin Kaiser, Guillaume Labeyrie (Centre for Quantum Technologies)

Nonlinear oscillations and synchronisation phenomena are ubiquitous in nature. We study the synchronization of self oscillating magneto-optically trapped cold atoms to a weak external driving. The oscillations arise from a dynamical instability due the competition between the screened magneto-optical trapping force and the inter-atomic repulsion due to multiple scattering of light. A weak modulation of the trapping force allows the oscillations of the cloud to synchronize to the driving. The synchronization frequency range increases with the forcing amplitude. The corresponding Arnold tongue is experimentally measured and compared to theoretical predictions. Phase-locking between the oscillator and drive is also observed.

PO.108 Spin-1 Heisenberg chain in a helical magnetic field

Ernest Ong*, Pinaki Sengupta (Nanyang Technological University)

We study the spin-1 Antiferromagnetic Heisenberg chain under the effects of a helical magnetic field. By varying the strength and helicity of the magnetic field, we identify several ground state phases. We use the density matrix renormalization group method to calculate the energy gaps, the string order parameter and the entanglement spectrum to characterise the different phases. Our preliminary results show that the topologically ordered Haldane phase at zero field is quenched by the magnetic field through closing of the energy gap and transition to a topologically trivial state. This gap closing is dependent on magnetic field strength and the helicity of the field. Interestingly, beyond a certain critical angle, the Haldane phase is destroyed without a gap closing.

PO.110 Synthesis and electrochemical properties of $Li_4Ti_5O_{12}$ as anode material for Lithium Ion Batteries

Yih Herng Ignatius Choong* (Catholic Junior College/NUS Physics Department)

This project aims to determine which method of synthesis is best for producing Lithium Titanate (LTO) batteries. It also aims to investigate the effects fluorine doping on LTO. 9 batches of LTO were synthesized, 1 using ball milling, 3 using the Solid-State method and 4 using Molten Salt synthesis. For the 9th batch of LTO, fluorine doping of the LTO prepared through ball milling was done. The morphology, crystal structure and electrochemical properties of each batch of LTO were analysed. The ball milling method using Li_2CO_3 and TiO_2 and the solid-state method using Li(Acetate) and TiO_2 are the best methods to use for synthesizing LTO. Both methods yielded LTO with high purity, good morphology, and superior electrochemical performance. This can be attributed to the use of ball milling or grinding. The molten salt method also produced LTO with good electrochemical properties. However, the use of TiO_2 is more favourable than using $TiOSO_4$. Using LiOH and only slight excess of salt was also found to produce LTO with better electrochemical performance as well. Fluorine doping was successfully done using a facile method. However, it adversely impacted LTO's electrochemical properties, as it increases the surface area to volume ratio of LTO particles.

PO.112 Optimal Error Regions in Quantum Process Estimation

Jun Yan Sim*, Hui Khoon Ng*, Berge Englert* (CQT)

Quantum process estimation is the procedure of reconstructing an unknown quantum channel from observed data. In this work, we construct optimal error regions for quantum process estimation as a supplement for the maximum-likelihood estimator. To construct the optimal error regions, we employ the Hamiltonian Monte Carlo method to generate random samples of quantum channel. We developed a parametrization of quantum channel which is essential in the Hamiltonian Monte Carlo method. We illustrate our methods with examples on single qubit channel.

PO.114 The Role of Phosphorus Diffusion in Solar Cell Efficiency

Tham Kai Wen*, Chow Jia Qi (Hwa Chong Institution)

By analysing the effects of phosphorus doping on various parameters through 39 dopant profiles and 35 cell samples, the efficiency and losses of the solar cells are computed respectively. From this, the parameters of the solar cell are optimised to achieve greater efficiency and the losses computed could be used to improve both the simulation to more accurately portray the performance of the solar cell from its dopant profile as well as the doping process to minimise sources of significant losses.

For this research project, we looked at the macro-parameters of the solar cell. PC1D and Griddler2.5Pro are used to compute the short circuit current, open circuit voltage and maximum power point, allowing us to plot an IV graph for each set of profile and parameters. From this we calculated the efficiency of the solar cell under a range of parameter values, arriving at a set of values for the maximum efficiency for each solar cell profile. For the experiment, we looked at the different regions on the solar cell with significantly different free carrier concentrations to quantify the effects of SRH and Auger recombination on the solar cell. From the 385 data points, we did a best fit and loss analysis of the cell samples using SolarEYE.

Overall, the project serves to achieve a greater understanding of the quantitative effects of phosphorus diffusion on the efficiency and losses of solar cells, allowing us to improve the simulations and profiles in the future to work towards greater solar cell efficiency.

PO.115 Feynman Path Integral Approach to Quantum Dynamics

Marcus Pang*, Yeo Ye* (National University of Singapore)

In quantum mechanics, there is an infinite number of possible trajectories for a moving particle to move from point xi at some time ti to point xf at some other time tf. The probability for such an event to occur is the absolute square of the propagator. This propagator is the sum of (complex) contributions of all possible trajectories in the region. Richard P. Feynman postulated that the contributions from each path to be an exponential whose imaginary phase is the classical action in units of $\hbar$ (Feynman 1948). The idea of integrating over all possible trajectories deviates from the standard quantum-mechanical approach. Feynman, fortuitously, managed to derive the same results through a sequential approach. However, he did not directly compute the fluctuation factor of the propagator. Consequently, this report aims to contribute information regarding the Feynman Path Integral, through an approximate calculation of the fluctuation factor in the propagator of any trajectory, and its use in quantum dynamics.

PO.116 Perovskite templating via bathophenanthroline additive for efficient light-emitting devices

Nur Fadilah Jamaludin*, Natalia Yantara, Yan Fong Ng, Annalisa Bruno, Bevita K. Chandran, Xin Yu Chin, Krishnamoorthy Thirumal, Nripan Mathews, Cesare Soci, Subodh Mhaisalkar (Nanyang Technological University)

Offering a wide plethora of unique optoelectronic properties such as low defect densities, long range diffusion lengths and bight photoluminescence, it is unsurprising hybrid halide perovskites have been touted as an emerging candidate for light emission applications. However, despite the effortless transition of perovskites into current organic light-emitting diodes (OLEDs) architectures, misalignment of energy levels at the hole transporting material (HTM) and perovskite interface limits the efficacy of interfacial charge transport. Herein, it is shown that by incorporating a small organic molecule, bathophenanthroline (BPhen), into the $CH_3NH_3PbBr_3$ emitter via a solvent engineering technique, the energy band levels of the perovskite can be tailored and the energy mismatch at the HTM/perovskite interface can be ameliorated through the formation of a graded emitter layer and accompanying morphological improvements. With a BPhen concentration of 0.500 mg mL^{-1}, more than ten-fold enhancement of device luminance and efficiency was achieved, thus demonstrating a facile and viable approach for fabricating high-performance perovskite light-emitting diodes (PeLEDs).

PO.117 Synthesis and characterization of AB_2O_4 spinels for Lithium Batteries

Yeshuai Yang*, Hyunmin Cho, Brian Lim Hoe Ray, Shi Hern Lim, M.V. Reddy* (NUS Physics)

AB_2O_4 based oxides (A= Co,Fe,Mg,Mn,Ni,Zn, B= Co) have been used as anode materials for lithium ion batteries because of their high capacity and safety. Electrochemical properties vary depending on preparation method, initial reactants such as the salts used. The objective of this experiment is to report on the structural and electrochemical properties of the different Co based spinel compounds. In this project, Co based spinels were successfully prepared using the urea combustion method using Cobalt Hydroxide, Urea, Ammonium nitrate, Nitric acid and the corresponding metal salt. The obtained power was then annealed at 600 °C in a furnace for 3 hours. Morphology and Structural analysis were done by scanning electron microscopy (SEM) and X-ray diffraction (XRD). Electrochemical studies were evaluated using Cyclic Voltammetry (CV), Galvanostatic Cycling (GC), and Electrochemical Impedance Spectroscopy (EIS) studies. An average discharge- charge potential of 0.75-2.00V vs. Li was observed from the CV study. GC studies showed the reversible capacity are in the 600-800mAh/g for all AB_2O_4 compounds and we will discuss in detail physical and electrochemical properties by various techniques.

PO.118 Emergence of topological magnons in $SrCu_2(BO_3)_2$

Dhiman Bhowmick*, Pinaki Sengupta* (NANYANG TECHNOLOGICAL UNVERSITY)

We investigate the emergence of and properties of topological phases of magnons/triplons in geometrically frustrated quantum magnets with competing Heisenberg and Dzyaloshinskii-Moriya(DM) interactions using the bond operator formalism. The interplay between geometric frustration, strong interactions and external magnetic fields results in low-lying magnetic excitations (magnons/triplons) with non-trivial topological character. We have demonstrated it on Shastry-Sutherland lattice for S=1/2 spins.

PO.119 Bare and Doped $LiMn_2O_4$ and its Energy Storage Properties

Tam Keng Hong, M.V. Reddy* (National University of Singapore)

$LiMn_2O_4$ is a promising alternative cathode material for energy storage purposes. It has great potential for use in Hybrid Electric Vehicles (HEV) and Electric Vehicles (EV). Cation doping is implemented to improve on the electrochemical performance of the battery. Bare $LiMn_2O_4$ and doped $LiMn_2O_4$ were prepared using sol-gel method. The doped compounds are: $LiCo_{1/6}Mn_{11/6}O_4$, $LiCo_{1/12}Cr_{1/12}Mn_{11/6}O_4$, $LiCo_{1/12}$Al1/12$Mn_{11/6}O_4$. The effects of Mn salts on the crystal structure, morphology, and electrochemical properties of the compounds were studied. Three batches were made, 1st batch with all the compounds using Mn sulphate, 2nd batch with $LiMn_2O_4$, $LiCo_{1/6}Mn_{11/6}O_4$ made using Mn nitrate, and 3rd batch with all the compounds using Mn acetate. X-Ray Diffraction (XRD) was performed on the compounds to analyse the crystal structure of the compounds and to determine their phase purity. Scanning

Electron Microscopy (SEM) was done to analyse the morphology of the compounds. Galvanostatic Charge/Discharge Cycling (GC) was done to determine the charge and discharge capacities of the compounds and their capacity retention after 50 cycles. Cyclic Voltammetry (CV) tests were done to analyse the reaction processes occurring during charge and discharge. Compounds made using Mn sulphate have highly impure phases, poor morphology and poor electrochemical performance. $LiCo_{1/6}Mn_{11/6}O_4$ (made using Mn acetate) had the best electrochemical performance, with an initial discharge capacity of 84mAh/g, 50th cycle discharge capacity of 80mAh/g, and capacity retention of 96% after 50 cycles.

PO.124 Optical Manipulation of Vortex Traps and Hybrid Atom Chip

Francesca Tosto*, Phyo Baw Swe, Tin Nghia Nguyen, Rainer Helmut Dumke (Centre for Quantum Technologies, NUS)

We investigate the dynamics of superconductors with ultra-cold ^{87}Rb atoms to study the magnetic properties of superconductors and the interaction between atoms and vortices. Superconducting atom chips allow a new generation of fundamental experiments and applications, such as novel trapping geometries with the induced persistent currents and the realization of hybrid quantum systems (superconducting LC circuits or SQUIDs interacting with atoms). Combining electric, magnetic and optical fields, atoms can be trapped close to the chip surface following different schemes and patterns. We propose a versatile method for trapping ultra-cold atoms in the vortices of a high-temperature superconductor (HTS) atom chip by using a high-power laser and a DMD (digital micromirrors device). We can generate different trapping potential (ring, square, lattices) by programming our DMD with the chosen pattern, sending the laser light on it and transferring that pattern on the chip. We then exploit the heating effect of the laser light hitting the chip surface and the critical temperature of the superconductor to destroy and manipulate the vortices. This can be done in two different ways: we first load the vortices everywhere and we change the trap at the end by turning on the laser light or we send the laser light first and we let the vortices create only in the allowed regions. This leads to different trapping geometries and a different vortices distribution in the superconductor, paving the way to tunable traps for ultra-cold atoms, on-chip interferometers and new hybrid quantum devices.

PO.125 Microsecond dark-exciton valley polarization memory in two-dimensional heterostructures

Chongyun Jiang, Weigao Xu, Abdullah Rasmita, Zumeng Huang, Ke Li, Qihua Xiong*, Wei-Bo Gao* (Nanyang Technological University)

Transition metal dichalcogenides have valley degree of freedom, which features optical selection rule and spin-valley locking, making them promising for valleytronics devices and quantum computation. For either application, a long valley polarization lifetime is crucial. Previous results showed that it is around picosecond in monolayer excitons, nanosecond for local excitons and tens of nanosecond for interlayer excitons. Here we show that the dark excitons in two-dimensional heterostructures provide a microsecond valley polarization memory thanks to the magnetic field induced suppression of valley mixing. The lifetime of the dark excitons shows magnetic field and temperature dependence. The long lifetime and valley polarization lifetime of the dark exciton in two-dimensional heterostructures make them promising for long-distance exciton transport and macroscopic quantum state generations.

PO.129 Hybrid Quantum Systems of Atoms and Superconductors

Alessandro Landra*, Chin Chean Lim, Kevin Gregory, Christoph Hufnagel, Deshui Yu, Rainer Dumke (Centre for Quantum Technologies)

Hybrid Quantum Systems combine two or more quantum systems in order to use their complementary capabilities. In particular, hybridization of atomic and solid state systems could offer a feasible way to reliably process, store and transmit quantum states in one device [R.Dumke et al J. Opt. 18, 093001 (2016)]. In our experiment we work towards the coupling between ultracold atoms and superconducting circuits. Rb87 atoms are firstly trapped in a Magneto Optical Trap and subsequently transported, with a magnetic conveyor belt, into a dilution refrigerator with optical access. We plan to move the cloud inside a microwave cavity using a wire guide in an Ioffe configuration. Here the atoms can be excited to Rydberg state where we can take advantage of the large electric dipole moment and measure the coupling between the cavity and the cloud. Moreover the cavity can host a superconducting qubit. The presence of the Rydberg atoms changes the dielectric media and can shift resonance of the transmon qubit. This coupling will allow us to perform combined gates between atoms and superconducting circuits [D. Yu et al Phys. Rev. A 93, 042329 (2016)].

PO.130 Kelvin probe force microscopy investigation on the local surface potential of zinc oxide nanowires

Wei Fuhua, Lim Kim Yong, Sow Chorng Haur* (National University of Singapore)

Zinc oxide nanowires (ZnO NWs) grown by chemical vapor deposition (CVD) exhibit multiple color emissions under ultraviolet excitation. It is known that the emissions in the visible range are caused by defects, however, the exact type of defects that gives rise to these emissions are currently unknown. Kelvin probe force microscopy (KPFM) and density functional theory (DFT) simulation were utilized to study the work function of different defects in ZnO NWs. KPFM measurements correlate difference in work functions to the variable emission wavelengths in various ZnO NWs. As different type of defects have been primarily identified via DFT calculations to give rise to work functions difference, it is possible to narrow down the dominant defect pertaining to each color emission amidst the list of possible defects determined from the calculations. This allows us to determine the defect states from which each of these emissions originate. In addition, these results are consistent with Photoluminescence (PL) measurements.

PO.133 Efficient Up-conversion Photoluminescence in All-Inorganic Perovskite Colloidal Semiconductor Nanocrystals

T. Thu Ha Do*, Andres Granados Del Aguila, Jun Xing, Wen Jie Jee, Lulu Zhang, Qihua Xiong* (Nanyang Technological University)

Semiconducting colloidal nanocrystals exhibit very efficient light emission that can be tuned in wavelength by varying their size and composition. The use of direct band-gap lead halide perovskite semiconductors has considerably enlarged this tunability. Their emission wavelength can be modified from near-ultraviolet to near-infrared regions, by varying the chemical constituents or by alloying the halide elements [1]. Particularly relevance to potential applications is the access to deep-blue and green regions of the electromagnetic spectrum where traditional II-VI nanocrystals, such as the prototypical CdSe, hardly accesses and undergoes rapid degradation.

We have investigated the optical properties of all-inorganic $CsPbX_3$ (X = Cl, Br, I, BrI and ClBr) perovskite nanocrystals. In particular, we focus on the ability of these nanomaterials to convert low-energy into high-energy photons, so-called up-conversion photoluminescence (UCPL) [2,3]. Overall, all investigated nanocrystals exhibit robust and efficient UCPL, characterized as the function of temperature, excitation energy and laser power. In these high-quality perovskite nanostructures, the UCPL phenomenon takes place in two distinguishable ways: (i) multiphoton absorption and (ii) one-photon with the subsequent lattice vibrational (phonons) absorption. While the former can produce significant UCPL signal even if being excited at 1100 meV below the electronic level, the latter requires the absorption of up to 200 meV from the thermal energy bath of the nanocrystals [4]. Our finding reveals the potential of high-quality $CsPbX_3$ perovskite nanocrystals in several applications such as bioimaging, photovoltaic light-energy harvesting and optical refrigerators.

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PO.134 Indirect Permeability Measurements using a ‘Strip-coil’ for $Co_{0.6}Zn_{0.4}Fe_{1.7}Mn_{0.3}O_4$

Ushnish Chaudhuri*, Mukesh Kumari, Ramanathan Mahendiran (Physics Department, NUS)

Cobalt ferrite ($CoFe_2O_4$, CFO) is a well-known room temperature ferromagnet insulator with high magnetic anisotropy and large coercivity. It is reported in literature that an optimal substitution of Fe by Mn and Co by Zn in CFO ($Co_{0.6}Zn_{0.4}Fe_{1.7}Mn_{0.3}O_4$,CZFMO), reduces both anisotropy and coercive field along with a significant improvement in the resistivity. A sample with low anisotropy, large resistivity and low eddy current losses can be an ideal candidate for high frequency devices. Keeping this in mind, we choose CZFMO to measure magnetic field dependence of electrical impedance, i.e. magneto-impedance (MI) in this work. Previous methods to measure MI involve passing a high frequency current through the sample and probing the permeability up to a skin depth $\delta(=\sqrt{(2\rho)/(2\pi f\mu_o\mu_r)})$ from the sample surface. The skin depth defines the region where electromagnetic waves propagate, perpendicular to the surface of the sample and depends on resistivity (ρ), relative permeability of the material (μ_r), AC frequency (f) and permeability in vacuum (μ_o). For insulating samples like CZFMO, we are unable to pass a current through the sample and hence indirect methods are needed to measure permeability. An indirect method using a strip-coil is used to measure MI using a single port impedance analyzer E4199A which directly measures the impedance of the coil surrounding the sample using RF-VI technique. Variations in MI arises due to the changes in permeability of the sample. MI measurements were taken with the DC magnetic field (H_{DC}) perpendicular to the high frequency AC magnetic field (h_{rf}). We report (ΔR/R0)%=(Δμ”/μ0”)% and (ΔX/X0)%=(Δμ’/μ0’)% for CZFMO from 500MHz to 2.2GHz and observe a percentage change of 108% for $\Delta\mu''/\mu_0''$ and 2639% for $\Delta\mu'/\mu_0'$ on applying a DC magnetic field of 1888 Oe and 2943 Oe respectively at 2.2GHz. Such large changes in sub-tesla fields can be implemented for sensor applications and magnetic microwave devices.

PO.135 Programmable cell death mediated by configurable magnetic fields

De Wei Wong, Wei Liang Gan, Yuan Kai Teo, Wen Siang Lew* (Nanyang Technological University)

Remote activation of mechanosensitive ion channels to induce cell apoptosis or physical rupture of the cell membrane to cause necrosis has been successfully achieved by magneto-actuation of magnetic nanoparticles (MNPs). In this work, we demonstrate a highly efficient method to induce cancer cell death using a biaxial pulsed magnetic field configuration, which maximizes the induced magnetic torque. The cylindrical NiFe MNPs were synthesized via template-assisted pulsed electrodeposition and differential chemical etching technique. The magnetic torque was experimentally observed through the light transmissivity dynamics of a suspension of MNPs, which revealed that MNPs can be actuated with high responsiveness over a wide range of frequencies by a biaxial magnetic field. This is attributed to the orthogonal fields that eliminates the need for the misalignment of MNPs caused by random rotational Brownian motion. The larger magnetic torque translated into a larger magneto-actuated force at low fields with 12% higher efficacy in cell death.

PO.136 Towards quantum simulation by a BEC in tailored optical potentials

Koon Siang Gan, Wenhua Yan, Nghia Nguyen, Rainer Dumke* (Center for Quantum Technologies, National University of Singapore)

We use an ultracold atom source (superfluidity of a BEC) and various tunable optical potentials (optical ring lattices) to form an Atomtronics SQUID to simulate the electric current and a superconducting ring interrupted by one or more Josephson junctions in a traditional SQUID. Such analogy allows us to explore the effective quantum dynamics of the system in a pure quantum phase dynamics range[1][2]. The experimental setup mainly contains a cold atom source generation part the tunable optical potentials part. We use RF evaporation and optical evaporation in a hybrid trap, formed by a magnetic quadruple trap and optical cross dipole trap, to cool down atoms to condensation phase. We use spatial light modulators (SLM) and digital micromirror devices (DMD) to create the tunable optical potentials. Currently we are proceeding to the final phase to achieve a BEC and the integration of atom source and optical ring lattice setup.

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PO.139 Measuring radon level in Singapore

Wee Lin Joyce Ang*, Boon Kin Pong*, Keng Yeow Chung* (Singapore Nuclear Research and Safety Initiative, NUS)

Radon, a radioactive noble gas, is extensively researched upon in many countries due to the danger of increased risk in lung cancer. Based on World Health Organisation (WHO), radon is estimated to cause between 3–14% of all lung cancers. Its main isotope, ^{222}Rn gas is part of the decay chain of ^{238}U. This isotope is exhaled from the ground which contains trace amounts of ^{238}U. Compared to the inert radon, her progenies (^{218}Po and ^{214}Po) are more likely to be lodged into the lung tissues. In addition, while radon have a relatively long half-life of 3.8232 days, her progenies have much shorter half-lives. Hence, the decay progenies have the potential of undergoing alpha decay in the lungs before it is breathed out, increasing the risk of lung cancer. In spite of these dangers, there are no published data on radon levels in Singapore. Using RAD7, an instrument capable of resolving the energies of alpha particles emitted by the radon progenies, we performed the first study to measure the time variation of radon level in various residential homes and workplaces in Singapore. Here we show some preliminary results of this study. From the results, we observe that air exchanges is an important factor in radon level in the indoors. Air exchanges which facilitate ventilation could drastically reduce the radon level in a room. From the preliminary results, we intend to evaluate other factors which could potentially affect the radon level.

PO.140 Optical Properties on MoS_2 quantum dots: A novel colloidal nanocrystal system

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Transition metal dichalcogenides (TMDs), such as MoS_2, express unique optoelectronic properties based on their atomic layered-structure. They show distinctive photophysical phenomena that originates from the valley and layer degrees of freedom [1]. When comparing the bulk to monolayer form, MoS_2 transforms from an indirect to direct bandgap semiconductor. While the phenomenon of spatial-quantum confinement in the vertical direction (i.e., layer number) is rather well understood in van der Waals bonded solids [2-3], there is currently a lack of understanding regarding the effects of spatial confinement in the lateral direction. When considering the large binding energy of the tightly bound excitons in MoS_2 monolayers , strong in-plane quantum confinement effects are expected to be observed, only, when the lateral size is reduced well below 5 nm. Due to the difficulty to reach this size via undeveloped fabrication methods, uniform and highly optical quality MoS_2 semiconductor colloidal nanocrystals (NC) have yet been realized [4].

Here, we report a systematic investigation of the optical properties of diluted ensembles of colloidal MoS_2 NCs with typically few layer thickness and lateral sizes of about 2nm. Our NCs are fabricated via a novel top-down approach as reported in ref. [4]. We observe well-defined luminescence approximately 500 meV above the excitonic recombination in the monolayer, which is indicative of strong in-plane quantum confinement. At room temperature, the photoluminescence spectrum exhibits a linewidth comparable to that of the monolayer (approximately 80 meV), while at low-temperature (T = 10K) it drastically decreases to around 7 meV, a linewidth which is much lower than traditional II-VI NC ensembles[5] and is comparable to high-quality monolayer samples produced on hexagonal boron nitride (h-BN) substrates [6].

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PO.142 Diamond photonics : silicon vacancy centres in nanodiamonds and the inverse taper effect in diamond tips

Sumin Choi*, Gandhi Alagappan, Jun Rong Ong, Dmitry A. Kalashnikov, Victor Leong, Hu Ting, Doris Ng, Valery Davydov, Leonid A. Krivitskiy (DSI, A-STAR)

Diamond-based photonics is a promising candidate for practical quantum information applications. The silicon vacancy (SiV) centre in diamond posseses attractive properties as a quantum emitter, including high brightness, nearly lifetime-limited optical linewidths, and insenstivity to environmental electrical noise. However, controlling the synthesis of nanodiamonds containing SiV centres is still not well understood. Here, we study several nanodiamond samples hosting SiV centres produced by a high-pressure high-temperature method without catalyst metals, and relate the nanodiamond size distributions and SiV optical properties to their growth conditions. Our results show that nanodiamond growth can be controlled and optimized for targeted different applications. Moreover, we study the emission from SiV centres in a pyramidal diamond tip structure, and observe an enhancement in fluorescence collection through the tip due its tapered gemoetry. This finding can aid the design of quantum systems based on colour centres in diamond, including nanoscale quantum sensors and single-photon sources.

PO.144 Quinoidal Tetraphenyldipyranylidene as an Efficient Hole Transporting Material for Stable Perovskite Solar Cells

Marc Courte*, Chao Shen, Denis Fichou (Nanyang Technological University)

Organic-inorganic lead halide perovskites have shown promise as high-performance light absorbers in mesoscopic solar cells. Within 4 years of research PCE of 22.1% has been obtained. The hole transport materials (HTM) are currently the bottleneck for the realization of cost effective and stable devices. Spiro-OMeTAD is the most commonly used HTM in perovskite solar cells. However spiro-OMeTAD are generally used in combination of additives in order to increase the mobility which are suspected to cause device degradation via moisture absorption and also the large synthesis and purification is expensive and tedious which encourage the development of new alternative HTM. In this we report a of 2,2',6,6'-tetraphenyldipyranylidene (DIPO-Ph4), a large quinoid planar π-conjugated heterocycle, as a dopant-free hole-transporting material (HTM) perovskite solar cells (PSCs). Electrical property of DIPO-Ph4 thin film measured in field effect transistors show a high hole transport mobility. $CH_3NH_3PbI_3$ perovskite solar cells using pristine DIPO-Ph4 showed a higher PCE than the standard non-doped Spiro-OMETAD. The presented results will demonstrate that dipyranylidene could be an excellent building block for high mobility dopant-free HTMs for perovskite solar cells.

PO.147 Ionic Transport through Few Nanometer High Graphene Nanochannels

Kittipitch Yooprasertchuti*, Massimo Spina, Slaven Garaj* (National University of Singapore)

Nanofluidic properties of graphene-derived surfaces – extremely high slip length and atomically smooth, charge-free surface – have attracted huge interest within the last year: Our study explores the possibilities of modeling ionic transport in nanoscale confinement using continuum mechanics of hydrodynamic, electrostatic and chemical transport with 2D finite element model. Although the scale of our confinement is comparable to molecular sizes and the range of hydration forces, we are able to match the experimental result quite well, by renormalizing the hydrodynamic properties of the channel and the ions, in a consistent manner. The measured ionic mobility is order of magnitude larger than then expected from bulk solution properties. We explore the possibility of variable slip-length, ionic mobilities and protonizable charge site density. The comparison to 1D first-order approximation is also done, where the difference is shown through the entrance effect that occurred due to merging of electrical double layer from the edge groups. This work, in combination with outgoing experimental results, contributes to understating of the behavior of ions in confinement comparable to their hydration radius – a significant question for biological, energy and membrane applications.

PO.149 Efficient lattice mode coupling to THz Fano metamaterial with line-narrowing effect

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Metamaterials (MMs) are structures engineered to have unique light interaction properties not found in natural materials. Due to this periodic nature of the metamaterial array, diffraction also occurs and one of the diffraction modes results in surface waves being trapped in the interface of the metal-dielectric medium. This trapped surface waves, also known as Wood's anomaly or lattice modes can be used to couple to metamaterial resonance and enhance its field confinement.

PO.150 Influence of magnetic field and hydrostatic pressure on low temperature structural transition in two distinct classes of ferromagnet $Pr_{0.6}Sr_{0.4}BO_3$ [B= Mn and Co]

Amit Chanda, Ramanathan Mahendiran* (National University of Singapore)

We studied magnetization in ambient pressure as well as under hydrostatic pressure, P =1.16 GPa and thermal expansion in zero and non-zero magnetic fields in two distinct classes of ferromagnet $Pr_{0.6}Sr_{0.4}BO_3$ [B= Mn and Co]. $Pr_{0.6}Sr_{0.4}MnO_3$ is a double exchange ferromagnet with ferromagnetic (FM) transition at TC = 305 K, whereas, $Pr_{0.6}Sr_{0.4}CoO_3$ is an itinerant electron type ferromagnet with a TC of 214 K. Magnetization of both the compounds show anomalies at low temperatures TS = 89 K and 69 K for B = Mn and Co, respectively. Linear thermal expansion in zero field also shows abrupt decrease at TS of both the compounds supporting the occurrence of structural transitions within the FM phase, namely, Pnma to I2/a for $Pr_{0.6}Sr_{0.4}MnO_3$ and, Imma to I4/mcm for $Pr_{0.6}Sr_{0.4}CoO_3$ while cooling. Under the application of 7T magnetic field TS is not shifted for either of the compounds. While, a magnetic field induced structural switching from the monoclinic I2/a phase to a new phase with higher cell volume coexisting with the Pnma phase occurs below TS for $Pr_{0.6}Sr_{0.4}MnO_3$, the cell volume increases for both the phases above and below TS for $Pr_{0.6}Sr_{0.4}CoO_3$. On the other hand, application of hydrostatic pressure shifts the TS towards high temperature (Δ_{TS} = 27 K and 15 K for B = Mn and Co, respectively) which is more remarkable compared to the shift in the TC. The pressure induced huge upshift in TS for $Pr_{0.6}Sr_{0.4}MnO_3$ has been attributed to the uniaxial compression of the MnO_6 octahedra along y-axis in the Pnma phase, whereas, compression of the Co-O bond length along b direction and concomitant enhancement in the Co-O-Co bond angle along the c direction of the orthogonal unit cell are responsible for the upshift in TS for $Pr_{0.6}Sr_{0.4}CoO_3$ under hydrostatic pressure.

PO.151 Signature of non-Abelian gauge field from an expanding atomic cloud

Hasan Mehedi*, Chang Chi Kwong, David Wilkowski (Nanyang Technological University)

We will discuss the dynamics of a quantum gas in the presence of non-Abelian gauge field for different temperature-scales. The expansion of the cloud has asymmetric nature, for both pseudo-spins, due to the moment-dependent eigenstates. The expanding gas below the recoil temperature expands at a faster rate due to the presence of momentum transfer mediated by gauge field, compared to the free-particle expansion rate. This provides a new tool to experimentally detect the signature of non-Abelian gauge field. All the results will be discussed analytical and physical perspectives.

PO.153 Revisiting a Novel Approach to Investigating the Thermal Properties of Materials Using Michelson Interferometer

Ivan Lim*, Sum Hung Yee* (Hwa Chong Institution)

Thermal expansion is a phenomenon observed on a daily basis and has resulted in the need for expansion joints on bridges, pavements and other surfaces on a hot day. The coefficient of linear thermal expansion of a specific material gauges how much the length of the material changes with respect to a change in temperature.

Michelson Interferometers are commonly used to do precise and accurate measurements. The objective of the project is to investigate the coefficient of thermal expansion of copper and aluminium using a Michelson Interferometer, comparing the results with other literature values of copper and aluminium.

Fringe shifts, that were observed due to the expansion of material used, were recorded with a video camera. Temperature changes were recorded using a temperature probe. The change in temperature was achieved using a heat tape. Knowledge of the wavelength of the laser used and of the initial length of the tube used was also necessary for calculation of coefficient of linear thermal expansion.

Using the Michelson Interferometer, we were able to obtain values for the coefficient of linear thermal expansion that were close to literature values and within experimental uncertainty of literature values for the aluminium tube. Unfortunately, we were unable to obtain similarly close values for the copper tube due to structural damage.

PO.156 The Aharonov-Bohm effect in mesoscopic Bose-Einstein condensates

Tobias Haug*, Hermanni Heimonen, Rainer Dumke, Leong-Chuan Kwek, Luigi Amico (Centre for Quantum Technologies)

The Aharonov-Bohm, and its dual, the Aharonov-Casher effects have been extremely fruitful in physics and, nowadays, they are of central importance for quantum technologies. Here, we study the Aharonov-Bohm effect for a Bose-Einstein condensate propagating out of equilibrium along a mesoscopic ring-shaped laser light potential, pierced by an effective magnetic flux. We found how the system experiences a subtle crossover between physical regimes dominated by pronounced interference patterns and others in which the Aharonov-Bohm effect is effectively washed out. We propose various applications for this system.

5 Technical Sessions

T1: Terahertz physics

Time: Wednesday 7 Mar, 11:30am; Venue: LT2; Chair: Marco Battiato
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T1.10 Semiconductor quantum well irradiated by a two-mode electromagnetic field as a terahertz emitter

Subhaskar Mandal*, Timothy Liew, Oleg Kibis (Nanyang Technological University)
11:30am – 11:45am

In recent time, lasers are used to exploit the electronic properties of various quantum systems. When the laser field is not too large, one can use perturbation theory to describe the effect of the field, but when the laser field is intense, it can not be treated as a small perturbation and to take the effects into account one must consider "electron+field" as a whole. This kind of electron, which is bound with a photon is called a dressed electron. Due to the influence of the intense laser field, the energy spectrum of the dressed electron gets modified, and due to the interaction energy gaps $\Delta\varepsilon$ open symmetrically at the resonance point within the energy band of the solid.

In this work, we have performed a theoretical study to investigate the electromagnetic properties of a quantum well driven by a two-mode field using a semiclassical model. When a dressed quantum well is irradiated by another weak electromagnetic wave we have noticed a Bloch oscillation kind of behavior from the photon coupled electron. We have examined the radiation coming out from the quantum well due to this oscillation using the dipole approximation. The restricted motion of the electron results in the generation of a series of harmonics which leads to the creation of a Terahertz comb. We have also described the multielectron dynamics using the single electron model. In the multielectron model due to the contribution of a large number of electrons, we have achieved up to µW Terahertz radiation across a significant no of frequencies.

T1.91 All-optical active THz metasurfaces for ultrafast polarization switching and dynamic beam splitting

Longqing Cong*, Yogesh Srivastava, Ranjan Singh (NTU SPMS)
11:45am – 12:00pm

Miniaturized ultrafast switchable optical components would be the core of next generation all-optical devices with an extremely compact size and faster response instead of traditional integrated circuit which is approaching the bottleneck of Moore's Law. Metasurfaces, logically distributed resonator array, have emerged as fascinating subwavelength flat optical components and devices for light focusing and holography applications, but they are still limited by a passive response. Here, we introduce an active hybrid metasurface integrated with patterned semiconductor inclusions for all-optical active control of terahertz waves. Ultrafast switching and modulation of polarization states and beam splitting ratio are experimentally demonstrated on a time scale of 667 picoseconds. This scheme of hybrid metasurface could also be extended into designing various all-optical active free-space devices such as varifocus planar lenses, switchable vector beam generators, and holography for components in ultrafast imaging, display, and high-fidelity photonic communication systems.

T1.141 Dual Channel Ultrafast Superconductor Metaswitch

Yogesh Kumar Srivastava, Manukumara Manjappa, Harish Natarajan Swaha Krishnamoorthy, Ranjan Singh* (Nanyang Technological University)
12:00pm – 12:15pm

Ultrafast response observed in the charge carrier dynamics upon photoexcitation of the high-transition-temperature cuprate superconductors is widely explored to understand the underlying physics and the mechanism which leads to Cooper pair formation. However, the peculiar features brought about by these dynamical processes to the metamaterial/plasmonic devices remains least explored. In this work, we experimentally demonstrate optical control and switching of Fano resonances excited in asymmetric split ring resonators made of high-temperature YBCO superconductors. Upon photoexcitation, we observed dual dissociation-relaxation dynamics within a single cycle of superconductivity restoration. The presence of dual dissociation-relaxation dynamics establishes the existence of dual switching windows within few picoseconds. We explored the pathways to engineer the switching channels by changing the properties of the substrate. Our results manifest new ways to realize ultrafast dual channel switchable devices.

T1.148 Color sensitive ultrafast optical modulation and switching of terahertz plasmonic devices

Abhishek Kumar, Yogesh Kumar Srivastava, Manukumara Manjappa, Ranjan Singh* (Nanyang Technological University)
12:15pm – 12:30pm

Two-dimensional metallic films with hole arrays have attracted great interest in the field of photonics and nonlinear optics due to their high field confinement and other promising feature like the extraordinary transmission. Here, we demonstrate color sensitive based active modulation of extraordinary transmission of terahertz waves through two-dimensional hole arrays patterned on silicon on sapphire substrate at ultrafast time scale (few ns). Pumping the silicon with 400 and 800 nm optical pump beam with identical fluences exhibits significantly (75% and 63% respectively) different modulation levels. The color dependent sensitivity and control of terahertz modulation provides an extra degree of freedom which opens up new opportunities for future applications in optics, optoelectronics and terahertz photonic devices.

T2: Post deadline session

Time: Wednesday 7 Mar, 11:30am; Venue: LT3; Chair: Koh Wee Shing
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T2.155 Towards Understanding and Engineering the Properties of Perovskites by High Pressure

Tingting Yin, Jiaxu Yan, Zexiang Shen* (Nanyang Technological University)
11:30am – 11:45am

Hybrid organic-inorganic perovskites are of great interest as promising materials for potential applications in solar cells and LEDs, due to their high carrier mobility, tunable spectral absorption range and easy processing. New crystal structures and physical properties of this class materials can be readily developed under high pressure, providing significant insights into pressure-induced structural mechanism and engineering.

In this presentation, the novel optical properties and structures are achieved under high pressure technique.

T2.157 Realization of multi-level states in phase-change thin films by very short laser pulse irradiation

Xinxing Sun*, Martin Ehrhardt, Andriy Lotnyk, Jürgen W. Gerlach*, Bernd Rauschenbach (Leibniz Institute of Surface Modification)
11:45am – 12:00pm

Multi-level storage techniques are promising for increasing storage density and for reducing energy consumption in the application of phase-change materials based memory devices. However, accurately controlling the phase transitions as well as understanding the underlying switching mechanisms are still unsolved. In this study, non-volatile optical multi-level switching in single-layer GeTe phase-change films prepared by laser ablation are demonstrated to be feasible and accurately controllable at a timescale of nanoseconds. For this purpose, an ns UV laser pump-probe setup was adapted for the investigations. This system is capable to vary the laser parameters with broad ranges. Moreover, the optical switching process and the phase transformation are correlated on the microscopic scale for understanding of the fast phase transition mechanism. It is found that each 20 ns laser pulse (wavelength: 248 nm) with a fluence of 26 mJ/cm2 excitation induced a partial crystallization, and complete crystallization was achieved by a succession of 5 such pulses. In the reverse process, a single pulse excitation at a fluence of 112 mJ/cm2 leads to re-amorphization of the film. These results are useful for the further understanding of the fast phase transition mechanism and for the design of multi-level phase-change memory cells.

TC: Commercial session

Time: Wednesday 7 Mar, 12:00pm; Venue: LT3; Chair: Koh Wee Shing
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

TC.159 Recent advances in ARPES & HAXPES Photoelectron spectroscopy

Markus Lundwall*, Susanna Eriksson* (Portsdown Science)
12:00pm – 12:15pm

The development of the ARPES (Angular Resolved Photoelecton Spectroscopy) field has made big leaps forward with the introduction of new, more efficient technology, where the first major breakthrough was the introduction of the Scienta SES200 with the 2D detector for parallel imaging of angles. The next revolution came in 2014 with the introduction of the Scienta Omicron DA30 analyser featuring angular scanning, for higher precision measurements. For all of these advances, achieving state of the art results has demanded home built systems and students working many years to complete the build. Scienta Omicron now has system and software capabilities, and strategic partnerships, to offer complete ARPES solutions with state of the art performance in every aspect.

The new Extreme 5-axis Closed Cycle Cryo Manipulator, developed in collaboration with Fermion Instruments and Omnivac, achieves guaranteed temperatures lower than 5K, including counter-heating capability. This base temperature yields minimal broadening of 1.5 meV, complementing the high energy resolution of the DA30 analyser series. In combination with the ultra-narrow bandwidths of the VUV 5k and VUV Laser sources offered by Scienta Omicron, new levels of energy resolution are now accessible to ARPES Lab users with unparalleled speed to result.

During the last decades, monochromated Al Kα based X-ray sources have dominated the marked for lab based X-ray photoemission spectroscopy (XPS). The fairly low energy for these X-rays leads to surface sensitive measurements. With HAXPES (hard X-ray photoelectron spectroscopy) the field of photoemission opens up a window to the bulk, allowing studies of pure bulk properties of solids, applicable e.g. to the studies of highly correlated systems, nanophysics, solar cells, etc. The activities on HAXPES began in Uppsala, Sweden, by Siegbahn and co-workers using a Cu based source. Today, however, the use of HAXPES is concentrated to different synchrotrons around the world.

We have developed a unique HAXPES lab system, utilizing a 9.25 keV monochromated X-ray source utilizing a Ga-metal jet technique allowing for analysis in the full kinetic energy range up to 9.25 keV. The high photon energy opens up new possibilities for bulk measurements with a mean free path of emitted photoelectrons substantially greater than of photoelectrons emitted by Al Kα radiation. Using energies of several keV will increase the probing depth to over 100 Angstrom.

T3: Plasmonics and Metamaterials

Time: Wednesday 7 Mar, 11:30am; Venue: LT4; Chair: Robert E. Simpson
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T3.26 (INVITED) Photonic doping of epsilon-near-zero media and its extension

Youming Zhang*, Baile Zhang* (Nanyang Technological University)
11:30am – 11:50am

It has been recently pointed out that epsilon-near-zero (ENZ) media have a striking property: by including impurities into their bodies, they can exhibit an arbitrary magnetic permeability, including even a zero value that can render the ENZ media fully transparent to electromagnetic waves. This approach is very similar to the "doping" concept in semiconductor industry. Here we further extend this approach by incorporating anisotropic realization of ENZ media and demonstrate some interesting new phenomena.

T3.63 Metamaterial Super-oscillatory Lens

Guanghui Yuan*, Nikolay I. Zheludev (Nanyang Technological University)
11:50am – 12:05pm

The next disruptive step in nanoscale imaging since the invention of the acclaimed stimulated emission depletion and single-molecule microscopies will be the development of a far-field super-resolution label-free technique. In this work, using the phenomenon of super-oscillations, we propose and demonstrate a new type of far-field metamaterial super-oscillatory which beats the Abbe-Rayleigh diffraction limit without engaging the evanescent wave contributions. Hotspots as small as 0.33λ corresponding to an effective numerical aperture of 1.52 are resolutely confirmed in air, compared with a conventional lens with the same diameter and focal distance giving diffraction limited hotspot size of 0.55λ.

T3.104 Unconventional Plasmons in Cuprates: First Principle Calculations

Muhammad Avicenna Naradipa, Paolo Emilio Trevisanutto, Teguh Citra Asmara, Muhammad Aziz Majidi, Andrivo Rusydi* (National University of Singapore)
12:05pm – 12:20pm

Unconventional plasmons have been shown to exist in SrNbO3.x. In this work, we calculate the electronic structure and complex dielectric and loss function of La_2CuO_4 in its insulating and an- tiferromagnetic phase through first principle calculation. Interestingly, we find strong evidence of unconventional plasmons in the existence of orthorhombic distortion and antiferromagnetic order- ing. The addition of Hubbard interaction through DFT+U dramatically changes the spectra, shifts the plasmonic excitations, and annihilates the unconventional plasmons. Our results show the un- conventional plasmons are generated through exchange-correlation and antiferromagnetic ordering.

T3.138 Active Switching of Toroidal Resonances in Planar Metasurface

Manoj Gupta, Yogesh Kumar Srivastava, Ranjan Singh* (Nanyang Technological University)
12:20pm – 12:35pm

Switching between various multipole excitations, ranging from non-radiating to strongly radiating, is an innovative approach of implementing more than one electromagnetic features in a single device. An optical metamaterial switch that supports dynamic transition from nearly non-radiative toroidal configuration to electric or magnetic dipole excitations facilitates switching between different states of electromagnetic resonance. Such multifaceted featured device would certainly have a key role in designing resonance-based sensing, lasing and ultrafast switching devices.

T4: Perovskites

Time: Wednesday 7 Mar, 11:30am; Venue: LT5; Chair: Guglielmo Lanzani
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T4.107 Small Molecule and Hybrid Perovskites Light Harvesting Capacitors

Gaia Bondelli*, Francesco Maddalena*, Cesare Soci*, Paolo Grilli*, Guglielmo Lanzani* (Politecnico di Milano)
11:30am – 11:45am

Presented for the first time in 2012 [Nanoscale 4, 1728 (2012)], the Light Harvesting Capacitor (LHC) is a novel energy harvesting device concept in which photovoltaic energy conversion is based on the generation of nano-dipoles at donor-acceptor interfaces. Upon variable illumination, the mutual orientation of the nano-dipoles results in a collective macroscopic polarization and a potential difference across the bi-layer heterojunction, inducing a circulating current in the external circuit that can be used to generate power through a load resistance. Since LHCs convert light energy into electrical energy without relying on charge carrier transport through the active layer, they are unaffected by the typical charge injection, recombination and mobility issues of organic semiconductors. Here we report preliminary results on LHCs based on small organic molecules or hybrid perovskites active layers, an appealing opportunity for transportless photovoltaic devices and noiseless photodetectors.

T4.17 Highly efficient colloidal lead-halide perovskite nanocrystal light-emitting diodes

Jun Xing*, Jun Xing* (NTU-SPMS)
11:45am – 12:00pm

Organometal halide perovskite has recently emerged as a very promising family of materials with augmented performance in electronic and optoelectronic applications including photovoltaic devices, photodetectors and light-emitting diodes. Herein we propose and demonstrate facile solution synthesis of a series of colloidal organometal halide perovskite $CH_3NH_3PbX_3$ (X = halides) nanoparticles, which exhibit high quantum yield and tunable emission from ultraviolet to near infrared. The photoluminescence properties of the perovskite nanoparticles were studied in detail. High-efficiency green light-emitting diodes based on $CH_3NH_3PbBr_3$ nanoparticles were demonstrated. These devices reach a record high maximum external quantum efficiency of 12.9% reported to date and an unprecedentedly high power efficiency of 30.3 $\mathrm{lm\,W^{-1}}$ at luminance levels above 1000 $\mathrm{cd\,m^{-2}}$ as required for various applications. These findings suggest that, with feasible levels of device performance, the PeNCs hold great promise for their use in LED lighting and displays.

T4.127 Thermally Stable and Efficient Mixed Dimensional Methyl and Naphthalenemethylammonium based Perovskite Solar Cells

Bhumika Chaudhary*, Teck Ming Koh, Benny Febriansyah, Annalisa Bruno, Nripan Mathews, Subodh Mhaisalkar, Cesare Soci* (Nanyang Technological University)
12:00pm – 12:15pm

The emergence of inorganic-organic lead halide perovskite solar cell (PSC) has re-energized solution-processed photovoltaic's research with materials properties rivaling that of crystalline semiconductors and device efficiencies comparable to that of multi-crystalline silicon. Although methylammonium lead perovskite solar cell ($MAPbI_3$) is the most promising material for solar cells, it still needs to overcome the challenges of durability, thermal instability, due to temperature and moisture-induced degradation. Indeed, in $MAPbI_3$-breakdown of the perovskite crystal structure into its non-photoactive components (CH3NH3I and PbI2) under thermal stress directly downgrades its solar cell's efficiency and long-term stability. Possible strategies to overcome these problems will include the use of multidimensional perovskites (responding to the general formula (M)2(CH3NH3)n-1PbnX3n+1, with M=longer/bulky alkylammonium cation, n=integer), which have gained attention recently due to their stable nature against moisture. In this work, we have combined the bulky naphthalene methylammonium (NMA) and methylammonium (MA) to form mixed dimensional (NMA)2(MA)n-1PbnI3n+1 perovskite and have analyzed the impact on thermal stability. The effects of the thermal aging process on absorption, crystal structure, morphology, vibrational properties (chemical bonding), charge carrier lifetime of the perovskite films and on device performance have been investigated. The higher order n=60, 40 NMA-MA-based perovskites have demonstrated the improved thermal stability, not only at standard 85°C but even at an elevated temperature of 150°C, as compared to the pure $n=\infty$ perovskite, along with the improved PCE 17%. These results provide a useful insight for stability improvement of multidimensional (2D-3D) perovskites material under heat stress.

T4.122 Inhibited Ionic Motion in Mixed-Cation Solar Cells

Annalisa Bruno*, Guifang Han, Wang Hao, Francesco Maddalena, Subodh Mhaisalkar, Cesare Soci (Energy Research Institute @ Nanyang Technological University(ERI @ NTU))
12:15pm – 12:30pm

Despite their excellent power conversion efficiency, hybrid organic-inorganic perovskite (HOIP) solar cells (SC) exhibit operation instabilities that hinder reliable device operation [1,2]. In this work we show how differently ionic motion is affecting charge transport and charge transfer in pure $MAPbI_3$ and in mixed cation HOIP SC, by studying temperature and electrical poling effects on SC performance. Identifying the contribution of the different species to the ionic motion within the HOIP and at TiO_2/HOIP interfaces is critical to develop effective strategies to mitigate operational instability of HOIP SC. In $MAPbI_3$ the initial decrease of power conversion efficiency observed while lowering the operating temperature is completely recovered, and even enhanced up to 20% of its original value, under electrical poling below 160 K, Figure 1b. This behavior has been attributed to the charge accumulation at TiO_2/HOIP interface, leading to the reduction of the electron extraction barrier [3]. Very differently to $MAPbI_3$ SC, triple cation [4] SC, shows an impressive stability in the wide range of temperatures from 350 to 77 K, where Jsc remain constant. The power conversion efficiency, is just slightly affected by the temperature reduction, and under electrical poling, can be just marginally enhanced, Figure 1c. These results confirm that MA+ is the main specie screening the charges' dynamic within the HOIP. The introduction of FA+ and CS+ not only helps to improve the efficiency and to reduce the hysteresis, but it also enhances SC temperature and electrical stability.

References [1]D. A. Egger, A. M. Rappe, L. Kronik, Accounts of Chemical Research (2016), 49, 573. [2]Y. Yuan, J. Huang, Accounts of Chemical Research (2016), 49, 286. [3]A. Bruno et al, Advanced Energy Materials (2017), 7, 1700265. [4]M. Saliba et al. Energy Environmental Science (2016), 9, 1989.

T5: Physics in 2D materials

Time: Wednesday 7 Mar, 1:30pm; Venue: LT2; Chair: Yang Shengyuan
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T5.59 (INVITED) Theory of photoexcited and thermionic emission across a two-dimensional graphene-semiconductor Schottky junction

Maxim Trushin* (Centre for Advanced 2D Materials, National University of Singapore)
1:30pm – 01:50pm

We find that intrinsic graphene provides efficient photocarrier transport across a two-dimensional graphene-semiconductor Schottky junction as a linear response to monochromatic light with excitation energy well below the semiconductor bandgap. The operation mechanism relies both on zero-bias photoexcited and thermionic emission contributing to photoresponsivity, enabled by the extended photocarrier thermalization time in intrinsic graphene. The photoresponsivity rapidly increases with excitation wavelength making graphene-semiconductor junctions attractive for photodetection at the telecommunication frequency.

T5.98 (INVITED) Giant Magnetoresistance in Graphene/Black Phosphorous Heterostructures

Yanpeng Liu* (Centre for Advanced 2D Materials)
01:50pm – 02:10pm

There is a huge demand for magnetoresistance (MR) sensors with high sensitivity, low energy consumption and room temperature operation. It is well known that spatial charge inhomogeneity due to impurities or defects introduce mobility fluctuations in monolayer graphene and give rise to magnetoresistance (MR) in the presence of an externally applied magnetic field. However, to realize a MR sensor based on this effect is hampered by the difficulty in controlling the spatial distribution of impurities and the weak magnetoresistance effect at the monolayer regime. Here, we fabricate a highly stable monolayer graphene-on-black phosphorous (G/BP) heterostructure device that exhibits a giant MR of 775% at 9 T magnetic field and 300 K, exceeding by far the MR effects from devices made from either monolayer graphene or few-layer BP alone. The positive MR of the G/BP device decreases when the temperature is lowered, indicating a phonon-mediated process in addition to scattering by charge impurities. Moreover, a non-local MR of $>$10000% is achieved for the G/BP device at room temperature due to an enhanced flavor Hall effect induced by the BP channel. Our results show that electron-phonon coupling between 2D material and a suitable substrate can be exploited to create giant MR effects in Dirac semimetals.

T5.145 Optical Properties of Excitons in MoS_2 Semiconductor Colloidal Nanocrystals

Andres Granados Del Aguila*, Sean Krupp, Sheng Liu, Zhuangchai Lai, Thu Ha Tran, Hua Zhang, Qihua Xiong* (Nanyang Technological University (SPMS-NTU))
02:10pm – 02:25pm

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Layered transition metal dichalcogenides (TMDs), such as MoS_2, exhibit unique optoelectronic properties and exotic physical phenomena that originate from the valley and layer degrees of freedom [1]. From bulk to monolayer form, MoS_2 transforms from indirect to direct bandgap semiconductor. While the underlying physical properties of MoS_2 are fairly well understood as a function of layer number [2,3], in-plane quantum confinement effects are sparsely investigated. Due to the large exciton binding energy, strong quantum effects are expected to occur with lateral sizes well below 5 nm that, along with the underdeveloped fabrication methods, imposes serious challenges to achieve well-defined atomically thin colloidal semiconductor nanocrystals (NCs).

Here, we have systematically investigated the optical properties of MoS_2 colloidal NCs. The genuine MoS_2 nanostructures have been fabricated by a top-down approach, as described in detail in ref. [4], with typical lateral sizes of 2 nm and thicknesses varying from one to four layers. We have used Raman, time-resolved photoluminescence (trPL) and photoluminescence excitation (PLE) spectroscopy to characterize diluted ensembles of MoS_2 NCs. The results are directly compared with mono- and few-layer MoS_2. We show that the low-temperature (T = 10 K) optical emission takes place at ≈ 2.5 eV (≈ 485 nm in wavelength), which is around 500 meV higher than the exciton luminescence in MoS_2 monolayers (see Fig. 1). The PL spectrum is composed of an unusually narrow zero-phonon-line in colloidal quantum dots [5], which has a linewidth of about 3 meV, on top of a broader line that is identified as a phonon pedestal. Time-resolved PL experiments reveal the transient decay of the luminescence within the first few nanoseconds after pulse excitation. We, therefore, identify the phonon-assisted zero-phonon line in MoS_2 NCs to originate from radiative recombination of laterally-confined bright excitons.

Our optical spectroscopic results in high-quality MoS_2 NCs clearly demonstrate pronounced in-plane quantum confinement effects in atomically thin semiconductors and present themselves as a novel colloidal nanocrystal system, being complementary to TMD monolayers.

References

[1] K. F. Mak et. al., Nat. Nanotech. 7, 494 (2012); [2] A. Splendiani et al., Nano Lett. 10, 1271 (2010) [3] K. F. Mak et al., Phys. Rev. Lett. 105, 136805 (2010); [4] X. Zhang, et al., Angew. Chem. 127, 5515 (2015); [5] A.Granados del Aguila, et al., ACS Nano, 8, 5921 (2014).

T5.90 A New Ohmic Contacting Metal to MoS_2 at Low Temperature

Zhonghan Cao, Jens Martin* (National University of Singapore)
02:25pm – 02:40pm

MoS_2 has been attracting many studies since discovery of 2D materials. Due to its strong spin-orbit coupling, sizable bandgap and theoretically high mobility, many novel properties emerge. However, as a semiconductor the formation of Schottky barriers is always a challenge for electronic transport measurements with MoS_2, especially at low temperature. People strived to achieve ohmic contacts to MoS_2, via use of low work-function metals such as scandium and nickel or by employing van der Waals heterostructures like graphene and Co/h-BN. Here, I describe a new process of fabricating ohmic contact devices with MoS_2. In my experiments, Sn was deposited as electrodes forming ohmic contacts to exfoliated multi and monolayer MoS_2 from room temperature down to 5K. FET-mobilities higher than 100 cm^2 V^{-1} s^{-1} were obtained in all devices. Although Schottky barrier were observed at low charge carrier density, ohmic contact can be realized using Si/SiO_2 gating with moderate voltage. With such a cheap metal and easy process, I wish my finding may promote further research and applications of MoS_2.

T5.46 Broadband negative refraction of highly squeezed hyperbolic graphene plasmons

Jing Jiang, Xiao Lin, Baile Zhang* (Nanyang Technological University)
02:40pm – 02:55pm

Negative refraction effect is essential for many nanophotonic applications such as deep-subwavelength imaging and superlens. 2D materials provides an ideal platform for ultrathin hyperbolic polaritons, allowing strong light-matter interactions with extreme field confinement compared to conventional bulk hyperbolic materials. Here, to achieve negative refraction of highly squeezed polaritons in a broad bandwidth, we propose a graphene nanoribbon structure which enable control over the propagation of light at extreme nanoscale that the wavelength can be squeezed by a factor over 100. We demonstrate negative refraction effects based on dipole source excitation and plane wave excitation, and shows that combination of tunability enables tailoring of the refraction angle.

T6: Quantum Information

Time: Wednesday 7 Mar, 1:30pm; Venue: LT3; Chair: Tomek Paterek
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T6.50 (INVITED) Simulating complex stochastic processes on a quantum computer

Felix Binder*, Jayne Thompson, Mile Gu (Nanyang Technological University)
1:30pm – 01:50pm

Stochastic processes are observed and studied in most scientific disciplines. Manifest in economic markets, biological evolution, the weather, crystal formation, and numerous other phenomena, they are ubiquitous in nature but often hard to simulate and predict. Recently it has been shown how quantum logic can reduce the complexity associated with discrete-time, stochastic processes. Indeed, there are processes whose simulation may be achieved with a fixed number of memory qubits while the number of classical bits required for the same simulation can become unbounded. Building on these results we here give a constructive description of a unitary quantum simulator for stochastic processes. It avoids unnecessary information loss during the simulation and opens up the possibility of practical implementation on a quantum computer.

T6.78 Randomness extraction from Bell violation with continuous parametric down-conversion source

Lijiong Shen*, Jianwei Lee, Thinh Le Phuc, Jean-Daniel Bancal, Alessandro Cerè, Valerio Scarani, Christian Kurtsiefer (Centre for Quantum Technologies, NUS and Department of Physics, NUS)
01:50pm – 02:05pm

Quantum entanglement provides sources of randomness that can be certified as being uncorrelated to any outside process or variable. Certified private randomness can be extracted by a system that shows a violation of a Bell inequality. The randomness extraction rate depends on the observed violation and on the repetition rate of the Bell test. Photonic systems generally show a small violation, but thanks to their high repetition rate it is possible to obtain high randomness generation rate.

In this work, polarization-entangled photon pair generated by spontaneous parametric down-conversion(SPDC), together with near-unit detection efficiency transition-edge sensors are used to demonstrate a detection loophole-free Bell violation. We pump the source continuously and organize detection events in uniform time bins. We demonstrate that the observed violation and randomness generation rates depend on the time bin length.We calculated a randomness generation rates are in the order of hundreds of random bits per second.

T6.62 Computing on quantum shared secrets

Yingkai Ouyang*, Si-Hui Tan, Liming Zhao, Joseph Fitzsimons (Singapore University of Technology and Design)

02:05pm – 02:20pm

A (k,n)-threshold secret-sharing scheme allows for a string to be split into n shares in such a way that any subset of at least k shares suffices to recover the secret string, but such that any subset of at most $k-1$ shares contains no information about the secret. Quantum secret-sharing schemes extend this idea to the sharing of quantum states. Here we propose a method of performing computation securely on quantum shared secrets. We introduce a (n,n)-quantum secret sharing scheme together with a set of algorithms that allow quantum circuits to be evaluated securely on the shared secret without the need to decode the secret. We consider a multipartite setting, with each participant holding a share of the secret. We show that if there exists at least one honest participant, no group of dishonest participants can recover any information about the shared secret, independent of their deviations from the algorithm.

T6.23 Provably unbounded memory advantage in stochastic simulation using quantum mechanics

Liu Qing*, Andrew Garner*, Mile Gu*, Jayne Thompson, Vlatko Vedral (School of Mathematical and Physical Sciences, Nanyang Technological University)

02:20pm – 02:35pm

Simulating the stochastic evolution of real quantities on a digital computer requires a trade-off between the precision to which these quantities are approximated, and the memory required to store them. The statistical accuracy of the simulation is thus generally limited by the internal memory available to the simulator. Here, using tools from computational mechanics, we show that quantum processors with a fixed finite memory can simulate stochastic processes of real variables to arbitrarily high precision. This demonstrates a provable, unbounded memory advantage that a quantum simulator can exhibit over its best possible classical counterpart.

T6.22 Charged string encodings of quantum information

Alex Wozniakowski*, Arthur Jaffe, Zhengwei Liu (Nanyang Technological University)

02:35pm – 02:50pm

In recent years quantum information science has emerged, developed, and popularized; and its techniques and ideas have been widely applied in physics, mathematics, computer science, technology, etc. Pictures appear throughout mathematical and scientific history and their role in quantum information is immense. In this talk we will review the history and usage of pictures in quantum information, such as the widely employed quantum circuit diagrams. Moreover, we will introduce a new pictorial program for quantum information based upon charged string encodings of quantum information. This new approach describes many phenomena in quantum information in an elementary way, which earlier diagrammatic approaches to quantum information did not capture naturally. As an application of the charged string encodings, we will study a new methodology for quantum protocol design. In addition some open problems will be discussed.

T7: Biophysics

Time: Wednesday 7 Mar, 1:30pm; Venue: LT4; Chair: Massimo Pica Ciamarra
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T7.27 (INVITED) The Photophysics of Geneless Opto Stimulation

Guglielmo Lanzani* (Italian Institute of Technology Politecnico di Milano)
1:30pm – 01:50pm

Organic semiconductors in different shapes and composition can be interfaced with living cells. This provides a new, exciting route towards optical control of physiological functions or the restoring of natural functions, e.g. vision. In this talk I will present a number of experiments that show the effective abiotic-biotic coupling of organic semiconductors with cells and small animals, suggesting the potential of organic light actuators for geneless opto stimulation. Investigated systems are all based on polythiophene as photoactive layer, in planar films, nanostructured layers or nanoparticles. Spectroscopy, photo-electrochemistry and photo-electrophysiology are exploited to carry out the experimental investigations. While the mechanism explaining such coupling is still unknown, it is appering that thermal, capacitive, faradaic or chemical coupling are all options to be carefully evaluated.

T7.137 Probing quantum features of photosynthetic organisms

Tanjung Krisnanda*, Chiara Marletto, Vlatko Vedral, Mauro Paternostro, Tomasz Paterek (Nanyang Technological University)
01:50pm – 02:05pm

Recent experiments have demonstrated strong coupling between living bacteria and light. Here we propose a scheme capable of revealing non-classical features of the bacteria (quantum discord of light-bacteria correlations) without exact modelling of the organisms and their interactions with external world. The scheme puts bacteria in a role of mediators of quantum entanglement between otherwise non-interacting probing light modes. We then propose a plausible model of this experiment, using recently achieved parameters, demonstrating feasibility of the scheme. Within this model we find that the steady state entanglement between the probes, which does not dependent on the initial conditions, is accompanied by entanglement between probes and bacteria, and provides independent evidence of the strong coupling between them.

T7.101 Two-dimensional transition metal dichalcogenides based long range surface plasmon resonance biosensors

Yi Xu*, Chang-Yu Hsieh, Lin Wu, Lay-Kee Ang* (SUTD)
02:05pm – 02:20pm

Two-dimensional transition metal dichalcogenides (TMDCs), as promising alternative plasmonics supporting materials to graphene, exhibit potential applications in sensing. Here, we propose a TMDC-mediated long range surface plasmon resonance (LRSPR) imaging biosensor, which shows tremendous improvements in both imaging sensitivity and detection accuracy as compared to conventional surface plasmon resonance (cSPR) biosensor. It is found that the imaging sensitivity of the proposed LRSPR biosensor can be enhanced by the integration of TMDC layers, which is different from the previously reported graphene-mediated cSPR imaging sensor whose imaging sensitivity decreases with the number of graphene layers. The sensitivity enhancement effect for the proposed chalcogenide-cytop-gold-TMDCs based biosensor depends on the thickness of gold thin film and cytop layer. The proposed TMDCs-mediated LRSPR imaging sensor could provide potential applications in chemical sensing and biosensing.

T7.67 Two-dimensional melting of deformable particles in a model of biological tissues

Yanwei Li*, Massimo Pica Ciamarra* (NTU-SPMS)
02:20pm – 02:35pm

Biological cells and polymeric particles such as star polymers, dendrimers and microgels change volume and shape when compressed by their neighbors at high density. In this regime the energy of a particle depends on its shape, which is fixed by its close neighbors, so that particles interact via a many-body potential. Here we investigate the equilibrium melting transition in a model of biological tissues. We show that the zero temperature ground state transient from the solid, to hexatic and the liquid phase through two continuous transition as in the Kosterlitz, Thouless, Halperin, Nelson, and Young scenario. On increasing the temperature, the solid melts either via a one-step first-order transition or via a two-step process with a continuous solid-hexatic transition and a consecutive first-order hexatic-liquid transition, reminiscent of the two-step epithelial-to-mesenchymal transition.

T7.66 A numerical study of the role of reproduction and mobility in bacteria colony expansion

Pin Nie, Massimo Pica Ciamarra* (School of Physical and Mathematical Science)
02:35pm – 02:50pm

Through repeated reproduction, bacteria are able to colonize a surface, and then to grow into a biofilm. Recent experiments have observed a competition in the colonization process of two mutants, that have different motility properties. Based on this observation, we developed a model of bacteria with controllable reproduction rate and mobility properties. We do observe that the slow mutants grow into a compact cluster, while the fast one grow into a less dense cluster. The interplay between reproduction rate and diffusivity of the mobility sets a critical scale above which a bacteria colony jam, as the bacterial become constrained by their neighbors. When the bacteria with different motility coexist, we observe fast bacteria to disrupt the colony formed by the slower ones.

T7.65 Entropy Stabilizes Floppy Crystals of Mobile DNA-Coated Colloids

Hao Hu*, Pablo Sampedro Ruiz*, Ran Ni* (Nanyang Technological University)
02:50pm – 03:05pm

Grafting linkers with open ends of complementary single-stranded DNA makes a flexible tool to tune interactions between colloids, which facilitates the design of complex self-assembly structures. Recently, it has been proposed to coat colloids with mobile DNA linkers, which alleviates kinetic barriers without high-density grafting, and also allows the design of valency without patches. However, the self-assembly mechanism of this novel system is poorly understood. Using a combination of theory and simulation, we obtain phase diagrams for the system in both two and three dimensional spaces, and find stable floppy square and CsCl crystals when the binding strength is strong, even in the infinite binding strength limit. We demonstrate that these floppy phases are stabilized by vibrational entropy, and “floppy” modes play an important role in stabilizing the floppy phases for the infinite binding strength limit. This special entropic effect in the self-assembly of mobile DNA-coated colloids is very different from conventional molecular self-assembly, and it offers a new axis to help design novel functional materials using mobile DNA-coated colloids.

T9: Magnetism and Spintronics

Time: Wednesday 7 Mar, 3:30pm; Venue: LT2; Chair: Jens Martin
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T9.92 (INVITED) Magnetic-anisotropy-field modulation by spin pumping in FeNi/Cu/FePt trilayers

Rohit Medwal*, Surbhi Gupta, S Annapoorni, Y Fukuma, Rajdeep Rawat (Nanyang Technological University)
3:30pm – 03:50pm

Pure spin current induced transfer torque in magnetic multilayer structures offers an efficient control of the magnetization in spintronics devices. To study the effect of the spin torque on the non-local Gilbert damping and magnetic anisotropy, spin pumping study was performed on $Fe_{20}Ni_{80}/Cu/Fe_{50}Pt_{50}$ multilayered structure. The fabricated layered structure with two different magnetic materials $Fe_{20}Ni_{80}$ and $Fe_{50}Pt_{50}$ bargains distinct resonant spectra. Spin pumping study shows an enhanced Gilbert damping when two ferromagnets are precessing at different resonance fields. However, when two ferromagnets are precessing together, the resonance field gets locked and a sharp decrease in the linewidth of the spectra is observed. The anisotropy field in both magnetic layers is also modulated. These results offer advance ways of controlling the magnetization by the pure spin current for futuristic spintronic devices via spin pumping.

T9.126 (INVITED) Towards THz spintronics: generation and transport of subpicosecond spin current pulses

Marco Battiato* (Nanyang Technological University)
03:50pm – 04:10pm

The origin of the ultrafast demagnetisation has been a mystery for a long time. I proposed an approach based on spin dependent electron superdiffusion.[1- 3] A number of experimental works have confirmed the importance and the amplitude of the superdiffusive spin transport for ultrafast magnetisation dynamics.[4-7] In particular the spin superdiffusion model predicted the transfer of magnetisation in the non-magnetic substrate and the possibility of increasing the magnetisation: both phenomena were experimentally confirmed.[4-5] The discovery of the possibility of, not only manipulating the magnetisation in the sub-picosecond regime, but of transporting it is a critical step forwards, since it proves the possibility of constructing all the components of ultrafast spintronics: a huge improvement compared to merely ultrafast storage, the only electronics application that an ultrafast, but purely local, manipulation of magnetisation could have achieved. However, in order to achieve this goal, all the basic electronics elements, like diodes and transistors, have to be redeveloped. The very same wiring needs to be redesigned. The ultrashort spin currents propagate poorly in metals, due to the high number of scatterings. Semiconductors are much better candidates, but that requires the ultrashort spin pulses to be injected in them from the ferromagnetic metal where they are generated. However, it is well known that the injection of spin from a ferromagnet into semiconductor is a formidable challenge facing a series seemingly insurmountable obstacles, chiefly the problem of impedance mismatch.

We predict the possibility of injecting ultrashort (sub-picosecond) spin current pulses from a ferromagnetic metallic layer undergoing ultrafast demagnetisation into a semiconducting substrate. [8-9] After laser excitation, energetic carriers can overcome the semiconductor bandgap. We address the complex interplay of spin diffusion, the formation of high electric fields at the metal/semiconductor interface, and the concomitant thermalisation of the laser excited carriers by state-of-the-art numerical techniques. We show that spin currents pulses hundreds of femtoseconds long are injected in the semiconductor and present a record spin polarisation. Such current pulses have the possibility to become the carriers of information in future spintronics running at unprecedented frequencies above the THz regime.

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T9.8 Valley polarizer and valley analyzer in bilayer graphene

Hao Chen, Pinjia Zhou, Jens Martin*, Fanrong Lin (CA2DM, NUS)

04:10pm – 04:25pm

The inequivalent valleys K and K' in momentum space of a 2D-hexagonal lattice offer a new degree of freedom, valley (isospin), which can be controlled much like the role played by electron spin. Valleytronics thus become promising for new generation electronics. In 2D systems with broken inversion symmetry, such as an electrically gated bilayer graphene, the Berry curvature Ω has the opposite sign in either valley. A sign reversal of Ω across two oppositely gated regions will give rise to counter-propagating 1D-conducting channels with opposite valley indices. These channels are valley-locked and but not topologically protected from intervalley scattering. Local gating of bilayer graphene is an approach to provide an electrically controlled framework for valleytronics, such as valley valves and valley filter, yet it is technically challenging to build such a nanoscale system. Here, we fabricate hBN-BLG-hBN heterostructures with four arrays of dual-split gate. Initial experiments show conductance contrast for normal E-field state and twisted E-field state, indicating on/off of the channels. Further optimizations are in process to achieve a highly clean system. Ultimately, we aim for an off/on-conductance ration to be at least 100. While a single pair of gates can be employed as a valley polarizer, the second pair could detect the valley polarization and serve as a valley analyzer.

T9.99 The spectrum of the Heisenberg ferromagnet from geometric considerations

Yingkai Ouyang* (Singapore University of Technology and Design)

04:25pm – 04:40pm

The Heisenberg model is a well-established model of quantum magnetism, and accurate models a wide range of physical systems that either naturally arise or are specifically engineered. However, the complete solution of its Hamiltonian's energy eigenvalues for interactions of arbitrary dimensions remains elusive. Departing from Bethe's ansatz which applies specifically for one-dimensional systems, we utilize the Heisenberg model's connections with the symmetric product of graphs to obtain various bounds on the spectral gap and the energy eigenvalues of the Heisenberg model. We exactly solve the spectral problem for the mean-field Heisenberg ferromagnet through a connection with association schemes, and we show that mean-field Heisenberg ferromagnets and D-dimensional Heisenberg ferromagnets with sufficiently strong long range interactions have energy gaps between the ground state and the first excited state that grow with the number of spins in the system. Moreover, well-connected infinite dimensional Heisenberg models have Hamiltonians with constant sized energy gaps between the ground state and the first excited state. When the Heisenberg ferromagnet has an arbitrary geometry, isoperimetric properties and generalized diameters of its associated graphs associated provide lower and upper bounds on many of the Heisenberg Hamiltonian's eigenvalues.

T9.143 Domain wall motion driven by voltage controlled magnetic anisotropy effect

Funan Tan*, Wei Liang Gan, Calvin Ang, Wen Siang Lew* (Nanyang Technological University)

04:40pm – 04:55pm

We propose using voltage controlled magnetic anisotropy (VCMA) effect through a series of electrodes to drive domain walls (DWs) along a magnetic nanowire. The voltage applied on the electrodes propagates in a set of three, with positive voltage, zero voltage and negative voltage corresponding to a high, medium and low anisotropy region of the nanowire affected by the electrode. The dynamics of the DW motion were studied using a micromagnetic simulation model, mumax3. The shapes of these electrodes were chosen to ensure that the DW experience an anisotropy gradient at any point along the nanowire. The anisotropy gradient causes the DW to move to the region with lower anisotropy and this process is repeated to drive DWs. The DWs driven in this study can reach velocities of ¿300m/s, which is typical of DWs driven by the spin transfer torque or any other current based methods requiring significantly higher power consumption. Hence, this model of using the VCMA effect to drive DWs is viable for future energy efficient DW based spintronic devices.

T10: Quantum Optics

Time: Wednesday 7 Mar, 3:30pm; Venue: LT3; Chair: Valerio Scarani
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T10.2 (INVITED) Strong photon-atom coupling with 4Pi microscopy

Yue Sum Chin*, Matthias Steiner, Christian Kurtsiefer (Centre for Quantum Technologies)
3:30pm – 03:50pm

Strongly interacting photons constitute a novel platform to study many-body physics and enable building blocks for quantum technologies. Photon-photon interaction being negligible in free space requires a medium to facilitate interactions. A single atom can absorb only one photon at a time and is therefore, in principle, well suited to couple simultaneously impinging photons. However, interactions between atoms and photons in the nonlinear regime at the single-photon level have been demonstrated only in the context of cavity quantum electrodynamics and Rydberg quantum optics.

Here we follow a conceptually simpler approach by tightly focusing the light field onto a single atom. Our implementation uses a 4Pi-microscopy configuration: A single atom is placed between two lenses in a confocal arrangement. The incident beam is split, and the atom is coherently excited by two counter propagating parts of the field simultaneously. We observe 36% extinction of the incident field, and a modified photon statistics of the transmitted field – indicating nonlinear atom-photon interaction. Our results suggest, with 4Pi arrangement, free space implementation of atom-light interaction is strong enough to enter the regime of quantum nonlinear optics.

T10.70 (INVITED) Quantum Absorption Refrigerator at Strong Coupling

Stella Seah*, Stefan Nimmrichter*, Valerio Scarani* (National University of Singapore)
03:50pm – 04:10pm

We investigate the quantum absorption refrigerator with three qubits in the strong and ultra-strong coupling regime. Making use of a refined master equation model, we identify the modified conditions for refrigeration and the optimal coupling strength above which the cooling efficiency deteriorates. Simpler models based on the rotating wave approximation and a local thermalization channel for each spin do not predict this maximum. The optimal cooling power is limited by both the qubit energies and the bath temperatures, ultimately halting the refrigeration effect close to the ground state.

T10.58 Unambiguous path discrimination in a two-path interferometer

Yink Loong Len*, Jibo Dai*, Berge Englert, Leonid Krivitsky (Data Storage Institute)
04:10pm – 04:25pm

When a photon is detected after passing through an interferometer one might wonder which path it took, and a meaningful answer can only be given if one has the means of monitoring the photon's whereabouts. We report the realization of a single-photon experiment for a two-path interferometer with path marking. In this experiment, the path of a photon ("signal") through a

Mach-Zehnder interferometer becomes known by unambiguous discrimination between the two paths. We encode the signal path in the polarization state of a partner photon ("idler") whose polarization is examined by a three-outcome measurement: one outcome each for the two signal paths plus an inconclusive outcome. Our results agree fully with the theoretical predictions from a common-sense analysis of what can be said about the past of a quantum particle: The signals for which we get the inconclusive result have full interference strength, as their paths through the interferometer cannot be known; and every photon that emerges from the dark output port of the balanced interferometer has a known path.

T10.103 Entanglement gain via measurements with unknown results

Marek Miller*, Ray Ganardi*, Tomasz Paterek, Margherita Zuppardo (Nanyang Technological University)
04:25pm – 04:40pm

The task is to study whether it is possible for quantum entanglement to grow as a result of a perfect von Neumann measurement. A state of the system undergoes a transformation in a perfect von Neumann measurement device, whose inner workings are unknown (a black box), along a measurement basis specified in advance. After the measurement, no single basis state is selected for. We attempt at finding optimal examples of the state and the measurement basis such that the entanglement gain is maximized.

The optimal measurement basis need not be a basis of maximally entangled states. For any given pure state that is not maximally entangled there is a basis that provides the gain of entanglement. For any given basis that doesn't consist of only pure product states, or only maximally entangled states, we provide an example of a state for which the entanglement strictly increases.

We give examples of open quantum systems and their irreversible dynamics that result in quantum projective measurement along a basis optimal for the entanglement gain. We observe that for a Markovian dynamics the measurement can be performed only approximately. Following the Araki-Zurek approach, we provide a simple model of decoherence of the system of two qubits that gain entanglement through interacting with its environment.

T10.45 Superior memory efficiency of quantum devices for the simulation of continuous-time stochastic processes

Thomas Elliott*, Mile Gu* (Nanyang Technological University)
04:40pm – 04:55pm

Continuous-time stochastic processes are omniprescent across the sciences. They are used to model a rich and diverse range of systems, such as financial time-series and biological processes. Given their broad applicability, our ability to study, simulate, and make predictions using such models is of great import. However, simulations of such models can become highly resource-intensive, in part due to their continuous nature. In particular, the information that must be tracked about the past of the process typically diverges with increased precision.

Quantum technologies promise enhanced computations by exploiting the fascinating quirks of quantum physics. These enhancements can be characterised and quantified by information-theoretic notions of complexity. Recently, a new type of quantum advantage has been discovered, wherein quantum devices can track and simulate stochastic processes whilst retaining less past information than even the optimal classical models. We extend these results into the continuous-time domain [1], providing a systematic construction for such quantum models of continuous-time processes. We show that the memory savings can be unbounded, allowing quantum simulators of continuous-time processes to achieve arbitrarily fine precision with finite memory, sidestepping the limitations suffered by their classical counterparts.

[1] Elliott, T. J. & Gu, M. arXiv preprint arXiv:1704.04231 [to appear in npj:Quantum Information]

T11: Complexity and Statistical Physics

Time: Wednesday 7 Mar, 3:30pm; Venue: LT4; Chair: TBD
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T11.64 (INVITED) Multiplicative Weights Update with Constant Step-Size in Congestion Games: Convergence, Limit Cycles and Chaos

Gerasimos Palaiopanos, Ioannis Panageas, Georgios Piliouras* (Singapore University of Technology and Design)
3:30pm – 03:50pm

The Multiplicative Weights Update (MWU) method is a ubiquitous meta-algorithm that works as follows: A distribution is maintained on a certain set, and at each step the probability assigned to element γ is multiplied by $(1 - \epsilon C(\gamma)) > 0$ where $C(\gamma)$ is the "cost" of element γ and then rescaled to ensure that the new values form a distribution. We analyze MWU in congestion games where agents use arbitrary admissible constants as learning rates ε and prove convergence to exact Nash equilibria. Our proof leverages a novel connection between MWU and the Baum-Welch algorithm, the standard instantiation of the Expectation-Maximization (EM) algorithm for hidden Markov models (HMM). Interestingly, this convergence result does not carry over to the nearly homologous MWU variant where at each step the probability assigned to element γ is multiplied by $(1 - \epsilon)^{C(\gamma)}$ even for the most innocuous case of two-agent, two-strategy load balancing games, where such dynamics can provably lead to limit cycles or even chaotic behavior. The second behavioral model corresponds to Boltzmann/Gibbs distributions over the accumulated costs of each strategy. Our results reveal a new "route to chaos" phenomenon and raise several open questions.

T11.33 (INVITED) Matrix product state methods for inferring simple predictive models of complex stochastic processes

Chengran Yang*, Felix Binder*, Varun Narasimhachar*, Mile Gu* (School of Mathematical and Physical Sciences, Nanyang Technological University)
03:50pm – 04:10pm

Stochastic processes are ubiquitous throughout the quantitive sciences. Many of these areas investigate utilizing the minimal amount of memory about the stochastic process's past to predict future. Recent studies have shown that quantum Models can further reduce this memory requirement. However, it remains a challenge to identify what kind of stochastic processes benefit from using quantum resources. In this paper, we connect the best-known quantum Models to matrix product state (MPS) methods – an efficient representation of quantum many-body states in condensed matter. This relation allows us to identify the benefits of using quantum Models. Specifically, we construct a large entangled 1D quantum state, the measurement of which generates a given stochastic process. We present the MPS representation of such 1D quantum state. We use MPS methods to show that the amount of quantum memory equals to the entanglement of the 1D quantum state. Furthermore, we propose a more efficient way to construct the best-known quantum Model using MPS methods.

T11.18 Force percolation transition of jammed granular systems

Sudhir Narayan Pathak* (Nanyang Technological University)
04:10pm – 04:25pm

The mechanical and transport properties of jammed materials originate from an underlying percolating network of contact forces between the grains. Using extensive simulations we investigate the force-percolation transition of this network, where two particles are considered as linked if their interparticle force overcomes a threshold. We show that this transition belongs to the random percolation universality class, thus ruling out the existence of long-range correlations between the forces. Through a combined size and pressure scaling for the percolative quantities, we show that the continuous force percolation transition evolves into the discontinuous jamming transition in the zero pressure limit, as the size of the critical region scales with the pressure.

T11.86 Effect of barrier steepness on glassy dynamics

Joyjit Chattoraj*, Massimo Pica Ciamarra (Nanyang Technological University)
04:25pm – 04:40pm

When a liquid undergoes rapid cooling the viscosity increases dramatically, and eventually, it enters the glassy regime where the material behaves as a disordered solid. We study the effect of interparticle attraction on the dynamics of a simple liquid in the viscous regime using molecular dynamics simulations. We use a Lennard-Jones type pair potential where the attraction-tail can be tuned, and thus the barrier steepness gets modified. It is already known that the barrier steepness alters the mechanical response of a glass: A brittle to ductile transition can be captured by decreasing the steepness. Here we find that the effect of barrier steepness on glassy relaxation process is weak. With decreasing the steepness the system becomes more mobile, however, we show quantitatively that this is a mere effect, the relaxation process remains essentially the same.

T11.42 Correlated Opinion Dynamics in a Model of Observational Learning with Expert Advice

Thiparat Chotibut, Tushar Vaidya*, Georgios Piliouras (SUTD)
04:40pm – 04:55pm

Formation of correlated opinions in a network of interacting agents is a ubiquitous social phenomenon. In a financial market, for instance, traders' opinions of private information such as a stock price oftentimes tend to be correlated, despite the complexity of opinion exchange mechanisms. Here, we introduce a minimal model of opinion dynamics that naturally exhibits formation of correlated opinions. In this model, each agent (trader) learns an estimate of private information (a stock price) from an expert (broker) while also updating its opinion by taking a weighted average of other opinions. When an expert can at best provide only an estimate of private information, typified by the truth masked with Gaussian white noise, the opinion dynamics is described by Langevin's dynamics driven by one-dimensional noise. In this case, a stationary Gaussian distribution centered around the truth is developed, and correlated opinions emerge naturally with the correlations encoded in the stationary distribution. In addition, when agents learn from the expert at different rates, the dynamics violates detailed balance. We study in detail the non-equilibrium steady state associated with the correlated opinion dynamics of 2 agents. The case of 3 and higher number of agents is also discussed.

T12: Photonic Crystals

Time: Wednesday 7 Mar, 1:30pm; Venue: LT5; Chair: TBD
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T12.123 (INVITED) Optoplasmonic whispering-gallery-mode microtube cavities

Yin Yin* (Nanyang Technological University)
1:30pm – 01:50pm

Optical whispering-gallery-mode (WGM) microcavities, which are of importance for the study of light-matter interactions and applications such as optical sensing and communications, have gained considerable interest in recent years [1]. Combination of the dielectric WGM microcavities with noble metal layers, consists the optoplasmonic cavities, giving rise to the coupling between resonant light and surface plasmons [2, 3]. In contrast to the pure photonic modes in WGM microcavities, hybrid photon-plasmon modes in optoplasmonic microcavities preserve the high-quality resonances and possess enhanced plasmon-type field localized at the metal layer which are promising for the enhanced light-matter interactions and sensing applications.

To push the light-plasmon coupling to a limit, the microtube cavities fabricated by rolled-up tech are the suitable platforms which benefit from the strong evanescent field supported by the ultra-thin cavity wall [4]. In this presentation, the hybrid modes with different plasmon-types of evanescent field in the optoplasmonic microtube cavities are firstly discussed [5]. The basic physical mechanism for the generation of plasmon-type field is comprehensively investigated based on an effective potential approach. In particular, when the cavity wall becomes ultra-thin, the plasmon-type field can be greatly enhanced, and the hybrid modes are identified as strong photon-plasmon hybrid modes which are experimentally demonstrated in the metal-coated rolled-up-microtube cavities [6]. By designing a metal nanocap onto the rolled-up-microtube cavities, angle-dependent tuning of hybrid photon-plasmon modes are realized, in which transverse electric (TE) and transverse magnetic (TM) polarized modes exhibit inverse tuning trends due to the polarization match/mismatch [7]. And a novel sensing scheme is proposed relying on the intensity ratio change of TE and TM modes instead of conventionally used mode shift. In addition, localized surface plasmon resonances coupled to resonant light is explored by designing a vertical metal nanogap on rolled-up-microtube cavities. Selective coupling of high-order axial modes is demonstrated depending on spatial-location of the metal nanogap [8]. A modified quasi-potential well model based on perturbation theory is developed to explain the selective coupling mechanism.

These researches systematically explore the design of optoplasmonic microtube cavities and the mechanism of photon-plasmon coupling therein, providing a novel platform for the study of both fundamental and applied physics such as the enhanced light-matter interactions, topology optics and label-free sensing [9, 10].

[1] K. J. Vahala, Nature 424, 839 (2003) [2] B. Min et al., Nature 457, 455 (2009) [3] Y-F. Xiao et al., Phys. Rev. Lett. 105, 153902 (2010) [4] O. G. Schmidt et al., Nature 410, 168 (2001) [5] Y. Yin et al., Phys. Rev. A 94, 013832 (2016) [6] Y. Yin et al., Phys. Rev. B 92, 241403(R) (2015) [7] Y. Yin et. al., ACS Photonics 4, 736 (2017) [8] Y. Yin et. al., Phys. Rev.

Lett. 116, 253904 (2016) [9] Y. Yin et. al., Laser Photon. Rev. 11, 1600219 (2017) [10] L. B. Ma et. al., Nat. Commun. 7, 10983 (2016)

T12.31 Near-zero index magneto-optical medium realized with an unpaired Dirac point

Xin Zhou*, Daniel Leykam, Alexander Khanikaev, Yidong Chong* (Nanyang Technological University)

01:50pm – 02:05pm

We realize an unpaired Dirac cone at the center of the first Brillouin zone, using a gyromagnetic photonic crystal with broken square sub-lattice symmetry and broken time reversal symmetry. The behavior of the Dirac modes can be described by a gyromagnetic effective medium model with near-zero refractive index, and giant effective magneto-optical (Voigt) parameter approaching unity. When two domains are subjected to opposite magnetic biases, there exist unidirectional edge states along the domain wall; near the Dirac frequency, these edge states are robust against scattering and can propagate around corners.

T12.25 Transition radiation from 2D materials and photonic crystals

Xiao Lin*, Baile Zhang* (Nanyang Technological University)

02:05pm – 02:20pm

We study transition radiation in 2D materials and photonic crystals, and reveal new phenomena. First, we predict a jet-like rise of excessive charge concentration that delays the generation of 2D plasmons in EELS, exhibiting an analog to the hydrodynamic Rayleight jet in a splashing phenomenon before the lauching of plasmonic ripples [1]. Second, we develop the theory of resonance transition radiation from photonic crystals, and propose this mechanism being able to flexibly control the effective Cherenkov angle [2]. Photonic crystals thus provide a promising versatile platform for Cherenkov radiation detectors, especially well-suited for high-energy particle identification with enhanced sensitivity.

T12.44 Multi-photon transport in nonlinear photonic lattices

Tian Feng See*, Dimitris Angelakis (Centre for Quantum Technologies, NUS)

02:20pm – 02:35pm

We investigate multi-photon transport in many-body photonic systems to explore a range of many-body phenomena. Merging methods traditionally used in quantum optics and condensed matter physics such as input-output and Green's functions formalism — we are able to develop a diagrammatic approach to calculate the statistics of outgoing photons in a multiphoton scattering experiment. Using this tool, we study spectral signatures of many-body phenomena such as Mott to superfluid transition and many-body localisation in the presence of disorder and interactions. Our method paves the way towards a novel many-body spectroscopy approach in open many-body systems.

T12.30 Surface-wave band-gap crystal

Zhen Gao, Baile Zhang* (Nanyang Technological University)
02:35pm – 02:50pm

Guiding surface electromagnetic waves around sharp corners without scattering and reflection is in great demand for modern photonic and plasmonic devices, but is fundamentally difficult to realize because of the dramatic momentum mismatch of surface electromagnetic waves before and after passing the sharp corner in an extremely compact space. Here, we experimentally demonstrate that the bottleneck can be overcomed. We introduce a class of surface-wave band-gap crystal implemented on a single metal surface capable of routing surface-wave pulse around multiple sharp corners along an arbitrary path with no perceptible deterioration. Moreover, based on this platform we further extend the applicability of valley photonic crystals to surface electromagnetic waves and experimentally demonstrate a valley surface-wave photonic crystal as a photonic duplicate of MoS_2. Both the bulk transport and the edge transport are directly mapped with a near-field microwave imaging system.

T12.52 Self-Assembled Chiral Photonic Crystals From Colloidal Helices Racemate

Qunli Lei*, Ran Ni, Yuqiang Ma (Nanyang Technological University)
02:50pm – 03:05pm

Chiral photonic crystals consisting of micro-helices have unique optical properties. In this work, using computer simulation, we investigate a bottom-up self-assembly route to build up helical crystals from the nematic monolayer of colloidal helices racemate. With increasing the density, we find the system undergoes the entropy-driven co-crystallization by forming crystals of various symmetries with different helical shapes. In particular, we identify two crystals of helices arranged in the binary honeycomb and square lattices, which are essentially composed by two sets of opposite-handed chiral crystal. Photonic calculations show that these chiral structures can have large complete photonic bandgaps. In addition, in the self-assembled chiral square crystal, we also find dual polarization bandgaps that selectively forbid the propagation of circularly polarized lights of a specific handedness along the helical axis direction within different frequency gaps. This suggests a possible way to self-assemble photonic crystals with both 3D photonic bandgaps and polarization gaps in the visible region, which have many applications in photonic devices.

T13: Topological effects 1

Time: Thursday 8 Mar, 1:30pm; Venue: LT2; Chair: Cesare Soci
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T13.1 (INVITED) Photoinduced 1/2 e^2/h and 3/2 e^2/h conductance plateaus in topological insulator-superconductor heterostructures

Han Hoe Yap*, Longwen Zhou, Ching Hua Lee, Jiangbin Gong (National University of Singapore)
1:30pm – 01:50pm

The past few years have witnessed increased attention to the quest for Majorana-like excitations in the condensed matter community. As a promising candidate in this race, the one-dimensional chiral Majorana edge mode (CMEM) in topological insulator-superconductor heterostructures has gathered renewed interests during recent months after an experimental breakthrough. In this paper, we study the quantum transport of topological insulator-superconductor hybrid devices subject to light-matter interaction or general time-periodic modulation. We report half-integer quantized conductance plateaus at 1/2 e^2/h and 3/2 e^2/h upon applying the so-called sum rule in the theory of quantum transport in Floquet topological matter. In particular, in a photoinduced topological superconductor sandwiched between two Floquet Chern insulators, it is found that for each Floquet sideband, the CMEM admits equal probability for normal transmission and local Andreev reflection over a wide range of parameter regimes, yielding half-integer quantized plateaus that resist static and time-periodic disorder. The 3/2 e^2/h plateau has not yet been computationally or experimentally observed in any other superconducting system, and indicates the possibility to simultaneously create and manipulate multiple pairs of CMEMs by light. The robust half-quantized conductance plateaus, due to CMEMs at quasienergies zero or half the driving frequency, are both fascinating and subtle because they only emerge after a summation over contributions from all Floquet sidebands. Such a distinctive transport signature can thus serve as a hallmark of photoinduced CMEMs in topological insulator-superconductor junctions.

T13.94 Coexistence of four-band nodal rings and triply degenerate nodal points in centrosymmetric metal diborides

Xiaoming Zhang, Shengyuan Yang* (Singapore University of Technology and Design)
01:50pm – 02:05pm

Topological metals with protected band-crossing points have been attracting great interest. Here we report topological band features in a family of metal diboride materials. Using first-principles calculations, we show that these materials are metallic, and close to Fermi level, there appears coexistence of one pair of nodal rings and one pair of triply degenerate nodal points (TNPs). The nodal ring here is distinct from the previously studied ones in that its formation requires four entangled bands, not just two as in previous cases, hence it is termed as a four-band nodal ring (FNR). Remarkably, we show that FNR features Dirac-cone-like surface states, in contrast to the usual drumhead surface states for two-band nodal rings. Due to the presence of inversion symmetry, the TNP here is also different from those discussed previously in inversion-asymmetric systems. Especially, when spin-orbit coupling is included, the TNP here transforms into a novel Dirac point that is close to the borderline between the type-I and type-II Dirac point categories. We discuss their respective symmetry protections, and construct effective models for their characterization. The large linear energy range ($> 2\,\mathrm{eV}$) in these materials should facilitate the experimental detection of the signatures of these nontrivial band crossings.

T13.48 Strain-induced Landau Levels in an Acoustic System

Yahui Yang, Zhaoju Yang, Baile Zhang* (Nanyang Technological University)
02:05pm – 02:20pm

Sound waves are longitudinal waves, which do not respond to external magnetic fields and carry no intrinsic spins. In the past few years, topological acoustics based on designed gauge fields which explores magnetic effects for sound is emerging as an active field in fundamental and applied research. However, Landau quantization have never been realized for air-borne sound waves because previous approaches to construct gauge fields relied on a periodic system, which is unable to form a uniform effective magnetic field. It has been shown that strain engineering is an effective method to induce a uniform and effective 'pseudomagnetic field' in graphene. This method has been transferred to photonic systems and quantized momentum levels have been demonstrated. Here we introduce the same strain engineering into a graphene-like acoustic system and construct a uniform effective magnetic field. We show theoretically and experimentally that the induced gauge field enables the emergence of Landau energy levels separated by significant gaps. Additionally, we directly observe the sound confinement within the gaps through sound field mapping. Our work offers a path to previously inaccessible magnetic-like effects in traditional periodic acoustic structures, which can be used in many areas such as sound enhancement and sound sensing.

T13.47 Topologically protected refraction of robust kink states in valley photonic crystals

Fei Gao, Haoran Xue*, Zhaoju Yang, Kueifu Lai, Yang Yu, Xiao Lin, Yidong Chong, Gennady Shvets, Baile Zhang (Nanyang Technological University)
02:20pm – 02:35pm

Valley photonic crystals possess many unusual properties arising from their nontrivial topology. Of the utmost interest to optical communications is the existence of robust kink states at the interface between two topologically distinguished domains. We experimentally demonstrate these states with polarization multiplexing in VPCs designed from a spin-compatible four-band model. More interestingly, When the valley pseudospin is conserved, we show that the kink states exhibit nearly perfect out-coupling efficiency into directional beams, through the intersection between the internal domain wall and the external edge separating the VPCs from ambient space.

T13.120 Linear coefficients of thermal expansion of antimony sulfide and molybdenum disulfide using a Gruneisen approach

Chee Kwan Gan* (Institute of High Performance Computing)
02:35pm – 02:50pm

We present an ab-initio study of the coefficients of thermal expansion of two systems: the orthorhombic antimony sulfide[1] and the hexagonal molybdenum disulfide[2]. Extensive search in the lattice parameter space is not necessary in our approach. We first calculate the Gruneisen parameter (GPs) to treat antimony sulfide (three lattice parameters) and molybdenum disulfide (two lattice parameters) crystals. To calculate coefficients of thermal expansion, we define and calculate the GPs by applying different deformations to the crystal and performing phonon calculations as implemented in a density-functional theory code. We outline how the coefficients of thermal expansion can be determined within the Gruneisen formalism, which involves evaluation of quantities such as GPs and heat capacity. For a better analysis, we define the density of GPs and the density of lattice vibrational states weighted by the GPs to account for the absence of negative expansion despite the existence of negative GPs. We present the first theoretical prediction on antimony sulfide where the coefficients of thermal expansion in the b direction is the largest compared to that in the other two directions. This demonstrates a large thermal expansion coefficient anisotropy for antimony disulfide. For the case of molybdenum disulfide, deformations that preserve the space group of the crystal can be used keep the number of calculations to a minimum. The high-temperature coefficients of thermal expansion of molybdenum disulfide show that the 'c' direction is about three times larger than that in the 'a' direction, in good agreement with experiment.

[1] C. K. Gan, J. R. Soh, and Y. Liu, Phys. Rev. B 92 (2015) 235202.
[2] C. K. Gan and Y. Y. F. Liu, Phys. Rev. B 94 (2016) 134303.

T14: Atomic Physics

Time: Thursday 8 Mar, 1:30pm; Venue: LT3; Chair: LAN Shau-Yu
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T14.131 (INVITED) Symmetry-protected collisions between strongly interacting photons

Travis Nicholson*, Jeff Thompson, Qi-Yu Liang, Sergio Cantu, Aditya Venkatramani, Soonwon Choi, Daniel Viscor, Thomas Pohl, Mikhail Lukin, Vladan Vuletic (Centre for Quantum Technologies)
1:30pm – 01:50pm

Realizing robust quantum phenomena in strongly interacting systems is one of the central challenges in modern physical science. Here, using coherent coupling between light and Rydberg excitations in an ultracold atomic gas, we demonstrate a controlled and coherent state exchange collision between two strongly interacting photons. The collision is accompanied by a $\pi/2$ phase shift, which is robust in that the value of the shift is determined by the interaction symmetry rather than the precise experimental parameters, and in that it occurs under conditions where photon absorption is minimal. The measured phase shift of $0.48(3)\pi$ is in excellent agreement with a theoretical model. These observations open a route to realizing robust single-photon switches and all-optical quantum logic gates, and to exploring novel quantum many-body phenomena with strongly interacting photons.

T14.73 Coherence Properties and Quantum State Transportation of Rubidium Atoms inside an Optical Waveguide

Mingjie Xin*, Wui Seng Leong, Zilong Chen, Shau-Yu Lan* (Nanyang Technological University)
01:50pm – 02:05pm

Coherent interactions between electromagnetic and matter waves lie at the heart of quantum science and technology. Here, we optically trap cold ^{85}Rb atoms in a hollow-core photonic crystal fiber and use the waveguide fields as matter-wave beam splitter and mirror pulses to demonstrate that the coherence of a quantum superposition state of atoms can be preserved and interrogated by the optical guided mode to form an interferometer sensitive to the gravity. We also experimentally study the ground state coherence properties of rubidium atoms in the optical fiber. We find that, the coherence time of atoms is mainly due to the inhomogeneous broadening of differential ac stark shift between atomic states from the optical dipole beam. Then we cancel the differential ac stark shift by vector light shift and archive a long coherence time of T=160ms. And we are able to control the coherence quantum state transportation over centimeter distance along the optical fiber. The integration of phase coherent photonic and quantum systems here shows great promise to the advance capability of atom interferometers and optical fiber quantum network.

T14.109 (INVITED) Differential polarizabilities and the blackbody radiation shift in a ^{176}Lu^{+} optical atomic clock

Rattakorn Kaewuam*, Kyle Arnold, Tan Ting Rei, Murray Barrett* (Centre for Quantum Technologies)

02:05pm – 02:25pm

Singly ionized lutetium ^{176}Lu^{+} has multiple potential clock transitions. Notably, the highly forbidden M1 transition $1S_0 - 3D_1$ and the spin forbidden E2 transition $1S_0 - 3D_2$. Initial theoretical estimates indicated a small and potentially negative differential scalar polarizability for these transitions. The small size makes the clock insensitive to the blackbody radiation (BBR) which is one of the crucial technical hurdle for most optical atomic clocks. A negative value would allow micromotion shifts to be cancelled providing a potential pathway to a multi-ion clock. We report recent experimental progress in determining the differential scalar polarizabilities on the two clock transitions. Notably, the room temperature BBR shift evaluated for the $1S_0 - 3D_1$ transition is the lowest among all clock candidates under active consideration. Additionally the $1S_0 - 3D_2$ transition has the desired sign and has the lowest BBR shift of all ions with this property.

T14.82 A dipole forbidden atomic transition close to surfaces

Eng Aik Chan*, Syed Abdullah Aljunid*, Giorgio Adamo*, Nikolay Zheludev, Martial Ducloy*, David Wilkowski* (SPMS/NTU, CQT, MajuLab, CNRS-UNS-NUS-NTU International Joint Research Unit UMI 3654)

02:25pm – 02:40pm

We study the dipole-forbidden electric quadrupole (E2) transition of Caesium at 685nm ($6S_{1/2}$ - $5D_{5/2}$), close to an interface, via Selective Reflection (SR) spectroscopy. Two different studies are performed, one with metamaterials resonant at 685nm, and one on a sapphire substrate. For metamaterials, we report on a pump-probe technique, pumping on the E2 transition and probing on the D2 line, to observe the symmetry-breaking effect of the metamaterials on the atoms. We also perform simulation studies of the effect of metamaterials on the E2 transition of hot atoms to compare with the experiments. With the sapphire substrate we perform a direct frequency modulation SR spectroscopy experiment to measure surface and collision effects on the hot Caesium vapour.

T14.76 Coherent and efficient microwave-to-optical conversion via six-wave mixing in Rydberg atoms

Thibault Vogt*, Christian Gross, Wenhui Li (cqt)

02:40pm – 02:55pm

Interconversion of microwave and optical fields is essential for connecting superconducting qubits and optical photons in future quantum information networks. In order to achieve the transfer of quantum states between microwave and optical photons, coherent, effcient, and broadband conversion will be required. In this talk, I will present a new experimental scheme for coherent microwave-to-optical conversion based on frequency mixing in Rydberg atoms [1]. In contrast to other physical systems being explored, this scheme is demonstrated in freee-space and allows for broadband conversion due to the strong coupling of microwaves to Rydberg transitions. Moreover, using electromagnetically induced transparency strongly enhances the effciency of this process. The results obtained in the experiment are in excellent agreement with theoretical predictions based on Maxwell-Bloch equations and indicate that this approach, with optimized geometry and energy level configuration, will lead to a near-unity photon conversion effciency.

[1] J. Han, T. Vogt, Ch. Gross, D. Jaksch, M. Kiffner, and W. Li, arXiv:1701.07969v2, accepted for publication in Phys. Rev. Lett.

T15: Spectroscopy

Time: Thursday 8 Mar, 1:30pm; Venue: LT4; Chair: Timothy Liew
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T15.154 (INVITED) Highly-confined and tunable surface phonon polaritons in few-nm thin semiconductors

Alexander M. Dubrovkin*, Bo Qiang, Harish N. S. Krishnamoorthy, Nikolay I. Zheludev, Qi Jie Wang (Nanyang Technological University)
1:30pm – 01:50pm

Improvements in device performance and density in photonic circuits can only be achieved with interconnects exploiting highly confined and tunable states of light. Recently this brought interests to highly confined plasmon and phonon polaritons. Surface phonon polaritons (SPhPs) in few-nm thin dielectrics or semiconductors on polar substrates open new opportunities in this direction. The unique dispersion of these modes allows efficient tuning of the polariton wavelength by small varying of the material thickness and operation frequency of the device. While plasmonic structures have been extensively studied, the ultimate limits of phonon polaritons squeezing, in particular enabling the confinement (the ratio between the excitation and polariton wavelengths) exceeding 102 is yet to be explored. Exploiting unique structure of 2D materials, we demonstrate that atomically-thin van der Waals dielectrics (e.g. transition metal dichalcogenides) on silicon carbide substrate demonstrate experimentally record-breaking propagating phonon polaritons confinement resulting in 190-times squeezed surface waves. The strongly dispersive confinement can be potentially tuned to greater than 103 near the phonon resonance of the substrate, and it scales with number of van der Waals layers. Furthermore, we show continuous tuning of SPhPs wavelength in CMOS-compatible conventional semiconductors, demonstrating angstrom-scale sensitivity of the polaritonic modes to the device composition. The results may find applications in tunable highly-integrated photonics and opto-electronics, and would benefit for all-optical material inspection for few-nm semiconductor technology. The concept can be potentially applied to number of technologically important semiconductor and dielectric compounds.

T15.9 Realization of Hofstadter's butterfly and one-way edge mode in polaritonic system

Rimi Banerjee*, Timothy Liew, Oleksandr Kyriienko (Nanyang Technological University)
01:50pm – 02:05pm

Electrons in a periodic potential give rise to the Bloch bands. In contrast, in the presence of perpendicular uniform magnetic field, the spectrum splits into highly degenerate Landau levels. It was predicted that in the interplay with a periodic potential in the presence of a perpendicular uniform magnetic field, a self similar fractal energy spectrum emerges in the two dimensional electron gas, known as Hofstadter's butterfly. It is the plot of the allowed and the forbidden energies as a function of magnetic flux. For rational value of the normalized magnetic flux $\beta = p/q$ (where p and q are co-prime integers) each Bloch band splits into q subbands. These bands deformed into Bloch bands only after closing the gap between them which admit a topological characterization in the system. In other words, the edge states arising in the system are robust against disorder which ensures that the signals can be transported unidirectionally along the edges with minimum energy consumption. To access this regime, we have to break the time reversal symmetry of the system. But due to the charge neutrality of the polaritons, it is not easy to affect the orbital motion significantly and to break the time reversal symmetry directly by applying magnetic field. So in order to mimic the effect, one can synthesize the artificial magnetic field in the system. We propose a scheme by considering a system of exciton polariton micropillars with polarization splitting, which generate an artificial gauge field in the system. This field breaks the time reversal symmetry in the system and enables us to achieve Hofstadter's butterfly and one way edge mode. This unidirectional edge mode has a privilege in the optical technology.

T15.132 Intrinsic Excitonic Properties of High-Quality Lead Halide Perovskite Crystals

T. Thu-Ha Do*, Andres Granados Del Aguila, Chao Cui, Jun Xing, Zhijun Ning, Qihua Xiong*
(Nanyang Technological University)
02:05pm – 02:20pm

Lead halide perovskite semiconductors have received tremendous attention in recent years as potential candidates for low-cost yet efficient devices such as solar cells and light-emitting diodes (LEDs) [1,2]. In contrast to considerable improvement on perovskite-based applications, the underlying fundamental physics has not been well understood yet. Specifically, there is lack of agreement on the electronic band structures and on the electrostatic interaction between electrons and holes to finally form excitons. In this work, we systematically perform temperature-dependent reflectance and photoluminescence measurements on high-quality organic ($CH_3NH_3PbBr_3$, $CH_3NH_3PbI_3$) and inorganic perovskite (CsPbBr3) crystals. In all compounds, we find rich and complex optical spectra with multiple excitonic resonances in both reflectance and photoluminescence experiments. Taking $CH_3NH_3PbBr_3$ as an example, we report two distinct classes of excitons that respond oppositely to temperature and have very different binding energies [3]. More intriguingly, in contrast to conventional semiconductors, the luminescence is dominated by the direct recombination of the high-energy exciton. We attribute this counter-intuitive behaviour to the long relaxation time among levels and the favourable generation of excitons at the high-energy bands [3]. Our study opens access to the intrinsic excitonic properties of perovskite semiconductors that are crucial for the performance of perovskite optoelectronic devices.

References [1] A. Kojima et al., J. Am. Chem. Soc., 131, 6050 (2009). [2] Z. K. Tan et al., Nat. Nanotechnol., 9, 687 (2014). [3] T. T. H. Do, A. Granados del Aguila, et al., Phys. Rev. B, 96, 075308 (2017).

T15.60 Optical response of chalcogenide phase-change materials

Jose Martinez*, Weiling Dong, Robert Simpson (singapore university of technology and design)

02:20pm – 02:35pm

Chalcogenides glasses like arsenic trisulfide (As2S3) strongly absorb in the near and middle infrared.1 Current chalcogenide phase change materials of the Ge-Sb-Te family absorb in the visible range.2 This new attribute bodes well for photonic applications.3 Using a popular parametrization of the dielectric function,4 which we derive and elucidate, we trace this circumstance to the interplay between the spin-orbit interaction and crystal field in the environment of the cation valence electrons.5 This interplay also has implications for the crystalline-amorphous phase transition of these glasses which are useful for understanding the underlying physics and utilizing them in future applications. On this basis, we propose an application in the optical regime. 1. J. A. Savage, Optical properties of chalcogenide glasses, J. Non-crystalline solids 47, 101 (1982) 2. W. Wełnic, et al. Origin of the optical contrast in phase-change materials. Phys. Rev. Lett. 98, 236403 (2007). 3. Tian, X. & Li, Z. Visible-near infrared ultra-broadband polarization-independent metamaterial perfect absorber involving phase-change materials. Photon. Res. 4(4), 146–152 (2016).
4. J. M. Gonzalez-Leal, The Wemple-DiDomenico model as a tool to probe the building blocks conforming a glass, Phys. Status Solidi B 250, 1044 (2013) 5. C-X Liu, X-L Qi, H Zhang, X Dai, Z Fang and S-C Zhang, Model Hamiltonian for topological insulators, Phys. Rev. B 82, 045122 (2010)

T15.28 High modulation index frequency modulation spectroscopy

Chang Chi Kwong*, Syed Abdullah Aljunid, Eng Aik Chan, Rustem Shakhmuratov, David Wilkowski* (MajuLab, CNRS-Universit´e de Nice-NUS-NTU International Joint Research Unit UMI 3654)

02:35pm – 02:50pm

Conventional frequency modulation (FM) spectroscopy works at low modulation index. With large modulation frequency, one finds that the optimal optical depth for the sensitivity of this spectroscopic technique is 2. Large optical thickness increases the absorption of the carrier frequency component, and decreases the sensitivity of the measurement. We present a new FM spectroscopic technique that can be applied to a medium of much larger optical depth. To overcome the large absorption in the carrier, the modulation index is set at a large value of 2.4, where the carrier component is suppressed. With large modulation index, this technique is essentially Doppler free, since the sidebands probe the Lorentzian tails of the absorption window. The large optical depth of the medium leads also to a faster response timescale. This is useful in frequency locking, where one can increase the bandwidth of the lock, beyond the natural linewidth of a single resonator the system. We demonstrate this technique by performing the high modulation index FM spectroscopy on the transmission through the D2 line of a hot cesium vapour.

T15.54 Investigation of Plasma Dynamics using Fast Gated Imaging

Joseph Vas*, Mayank Mishra, Paul Lee, Rajdeep Rawat* (Nanyang Technological University)
02:50pm – 03:05pm

Plasma Focus device are receiving attention in the field of plasma nanotechnology since they are a good source of high energy ionic species which can be tailored for different kind of nanomaterials. For attaining the appropriate ion energy, the operating pressure has to be controlled. This might result in a large quantity of material getting deposition which may not be appropriate for some applications. To limit the amount of material deposited, it might be necessary to dilute the gaseous environment with inert gases like He, Ne or Ar. This might indirectly affect the pinch phenomenon inside the plasma focus device. Thus the effect of mixture on gases on the pinch phenomenon needs to be studied for attaining appropriate ion density and the ionization states. In the present study, different diagnostics of the plasma focus device is employed to understand the pinch phenomenon occurring while operating with Methane gas mixed with Neon and Argon gases. The electrical characterization is done using the voltage probe and the rogowski coil. Optical imaging is used to see the compression of the gas in the pinch phase. Different ionic species produced is characterized by visible spectroscopy.

T16: Topological effects 2

Time: Friday 9 Mar, 11:00am; Venue: LT2; Chair: Zhang Baile
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T16.97 (INVITED) Nodal surface semimetals: Theory and material realization

Weikang Wu*, Ying Liu, Si Li, Chengyong Zhong, Zhi-Ming Yu, Xian-Lei Sheng, Y. X. Zhao, Shengyuan Yang (Singapore University of Technology and Design)
11:00am – 11:20am

We theoretically study the three-dimensional topological semimetals with nodal surfaces protected by crystalline symmetries. Different from the well-known nodal-point and nodal-line semimetals, in these materials, the conduction and valence bands cross on closed nodal surfaces in the Brillouin zone. We propose different classes of nodal surfaces, both in the absence and in the presence of spin-orbit coupling (SOC). In the absence of SOC, a class of nodal surfaces can be protected by spacetime inversion symmetry and sublattice symmetry, and characterized by a $\mathbb{Z}2$ index, while another class of nodal surfaces are guaranteed by a combination of non-symmorphic two-fold screw-rotational symmetry and time-reversal symmetry. We show that the inclusion of SOC will destroy the former class of nodal surfaces but may preserve the latter provided that the inversion symmetry is broken. We further generalize the result to magnetically ordered systems and show that protected nodal surfaces can also exist in magnetic materials without and with SOC, given that certain magnetic group symmetry requirements are satisfied. Several concrete nodal-surface material examples are predicted via the first-principles calculations. The possibility of multi-nodal-surface materials are discussed.

T16.93 Unconventional Pairing Induced Anomalous Transverse Shift in Andreev Reflection

Zhi-Ming Yu*, Ying Liu, Yugui Yao, Shengyuan Yang (Singapore University of Technology and Design)
11:20am – 11:35am

Superconductors with unconventional pairings have been a fascinating subject of research, for which a central issue is to explore effects that can be used to characterize the pairing. The process of Andreev reflection—-the reflection of an electron as a hole at a normal-mental-superconductor interface by transferring a Cooper pair into the superconductor—-offers a basic mechanism to probe the pairing through transport. Here we predict that in Andreev reflection from unconventional superconductors, the reflected hole acquires an anomalous spatial shift normal to the plane of incidence, arising from the unconventional pairing. The transverse shift is sensitive to the superconducting gap structure, exhibiting characteristic features for each pairing type, and can be detected as voltage signals. Our work not only unveils a fundamentally new effect but also suggests a powerful new technique capable of probing the structure of unconventional pairings.

T16.74 Topological Insulator Metamaterials

Harish N. S. Krishnamoorthy*, Giorgio Adamo, Felix Hütt, Harald Giessen, Nikolay I Zheludev, Cesare Soci* (Center for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University)

11:35am – 11:50am

We study the optical properties of various Bi-based topological insulator crystals by means of ellipsometry and FTIR measurements. We then fabricate nanoslit metamaterial arrays in these crystals using focused ion beam milling. We could observe strong optical resonances over a wide spectral range from the visible to the mid-infrared arising as a result of the nanostructuring. We study the nature of the resonances including the quality factors, their dependence on the composition of the crystal and, how they evolve as the resonance wavelength is moved from the plasmonic regime to the dielectric regime. Our studies are important especially due to the fact that topological insulator materials are being looked as attractive candidates for realizing low-loss nanophotonic devices owing to the presence of topologically protected surface states.

T16.43 Stroboscopic braiding of Majorana modes

Raditya Bomantara*, Jiangbin Gong (National University of Singapore)

11:50am – 12:05pm

In the quest for developing fault-tolerant quantum computation, the study of topological quantum computation has received considerable attention in recent years due to its protection against errors at the hardware level. As the name suggests, topological quantum computation relies on the creation, braiding, and annihilation of topological objects to encode and manipulate qubits. One example of such topological objects is Majorana zero mode (MZM), which can be found at the edge of one dimensional p-wave superconducting wire. However, performing Majorana-based quantum computation in such a system is not a trivial task since typically a single wire can only admit a pair of MZMs, while a minimum of four MZMs is needed to encode a single qubit. As a result, many existing proposals usually involve intricate structures such as T or Y junctions to perform quantum computation through braiding of MZMs. We propose that by considering a time-periodic superconducting system, additional Majorana modes may appear at the edge, which allows us to encode and manipulate qubits using less resources. To support this claim, we have also devised a scheme to braid these Majorana modes stroboscopically in the simplest one dimensional wire setup, which can therefore be straightforwardly scaled to carry out more complicated quantum computational tasks.

T16.96 Triple Point Topological Metals

Ziming Zhu* (SUTD)

12:05pm – 12:20pm

Topologically protected fermionic quasiparticles appear in metals, where band degeneracies occur at the Fermi level, dictated by the band structure topology. While in some metals these quasiparticles are direct analogues of elementary fermionic particles of the relativistic quantum field theory, other metals can have symmetries that give rise to quasiparticles, fundamentally different from those known in high-energy physics. Here, we report on a new type of topological quasiparticles—triple point fermions—realized in metals with symmorphic crystal structure, which host crossings of three bands in the vicinity of the Fermi level protected by point group symmetries. We find two topologically different types of triple point fermions, both distinct from any other topological quasiparticles reported to date. We provide examples of existing materials that host triple point fermions of both types and discuss a variety of physical phenomena associated with these quasiparticles, such as the occurrence of topological surface Fermi arcs, transport anomalies, and topological Lifshitz transitions.

T17: Applied Quantum Physics

Time: Friday 9 Mar, 11:00am; Venue: LT3; Chair: Alessandro Cere
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T17.5 (INVITED) Elastomer waveguides: tunable devices for quantum optics

James Grieve*, Kian Fong Ng, Manuel Rodrigues, Filip Auksztol, José Viana-Gomes, Alexander Ling (Centre for Quantum Technologies)
11:00am – 11:20am

In recent years the quantum optics community has become well acquainted with the advantages offered by an integrated, waveguide-based approach to optical circuits, with many prominent experimental results enabled by the interferometric stability and favourable scaling properties supported by these systems. In most cases however, the waveguide platforms in use lack good options for tunability, or constrain the polarization and wavelength of propagating light. In response to these limitations, we have developed an approach based on the soft polymer polydimethyl siloxane (PDMS). Our platform supports polarization insensitive guiding and allows a novel form of tuning via mechanical deformation of the optical circuit. In this contribution I will discuss some unique features of this platform, and highlight experimental results in the form of a broadband tunable beamsplitter and a series of tunable quantum random walks. I will also outline the current direction of our research, with prospects for tunable entangled photon random walks and the inclusion of optical nonlinearity.

T17.106 (INVITED) Infrared metrology using visible photons

Anna Paterova*, Hongzni Yang, Chengwu An, Dmitry Kalashnikov, Leonid Krivitsky (DSI A*STAR)
11:20am – 11:40am

We propose a new scheme of IR measurements using detection of visible photons. The method is based on the nonlinear interference of correlated photons produced via spontaneous parametric down conversion (SPDC), where One photon is generated in the visible range, another in the IR range. The interference fringes for the visible photons depend on the properties of the IR photons, which is used to probe properties of the medium under study. We realized the scheme of a nonlinear Michelson interferometer and study properties of the media in the IR range, when the actual measurements are performed in visible.

T17.87 Secure Quantum Clock Synchronization

Jianwei Lee*, Lijiong Shen, Alessandro Cerè, James Troupe, Antia Lamas-Linares, Christian Kurtsiefer (Centre for Quantum Technologies)
11:40am – 11:55am

The ability to synchronize remote clocks plays an important role in our infrastructure, from maintaining coherence in the electrical grid to allowing precise positioning and navigation.

However, the signals used to transfer timing information can be spoofed by an adversary with classical time sychronisation protocols.

Here we propose a protocol that builds on techniques from quantum communication to provide a verified and secure time synchronization protocol.

The absolute offset between two clocks can also be determined without assuming any knowledge about the propagation time of the signal used for synchronization. We present initial experimental data that demonstrates this aspect of the protocol.

T17.40 Parallel-aligned crystal entangled-photon source (PACES) for entanglement-based applications

Aitor Villar*, Arian Stolk*, Alexander Lohrmann*, Alexander Ling* (Centre for Quantum Technologies)

11:55am – 12:10pm

Pair generation rate (or brightness) in entangled-photon sources is a key parameter in entanglement-based applications. For instance, when implementing Quantum Key Distribution (QKD) networks, the length of the QKD link is directly associated with the signal level generated from the source and it ultimately limits the secure key rate.

In terms of brightness, sources based on non-critically phase matched (NCPM) crystals lead the way, while critically phase matched sources (CPM) typically exhibit one order of magnitude lower pair rates. However, when implementing entangled-photon sources via Spontaneous Parametric Down-Conversion in reduced and harsh environments (e.g., nanosatellites in space), the temperature stability requirement for NCPM sources (± 0.1°C) that is needed to perform optimally cannot always be met. On the other hand, CPM sources (in which the optimal working requirements are met by angle-tuning the nonlinear crystals with respect to the laser pump), are a more cost-effective option.

Traditionally, in CPM sources the crossed-crystal configuration has reported the highest brightness. It utilizes two nonlinear crystals with the optical axis rotated 90 degrees with respect to each other (horizontally and vertically polarized pairs of photons are generated in the first and second crystal, respectively). However, due its crossed orientation, the pump power has to be split into two polarization components, thus effectively using only one half of the pump power to down-convert in each crystal.

Here we present a new optical design based on CPM approach. This optical setup uses two crystals (beta-Barium Borate, BBO) oriented in a parallel configuration, allowing the full pump power to down-convert in both crystals. With the parallel configuration, we report an improvement of 2.4 times in generation rates when compared to traditional setups using single-mode fibers in the collection. Additionally, this crystal configuration allows for multi-mode fiber and high-fidelity collection ($>96\%$), increasing the generation rates one order of magnitude above the single-mode fiber case.

T17.121 Nanophotonic Quantum Devices Realized in Fibers and on Chips

Ruixiang Guo*, Anton N. Vetlugin, Mikhail V. Shestakov, Salih Yanıkgönül, Venkatram Nalla, Cesare Soci, Nikolay I. Zheludev* (1. CDPT, NTU 2. ORC, University of Southampton)

12:10pm – 12:25pm

The most perspective approach for practical realization of quantum computing and communication technologies requires implementation of integrated optical devices, operating at the single photon level, on silicon chips and in optical fibers. This technological advancement will play a crucial role for performance enhancement, scalability and miniaturization of single photon emitters, detectors, interferometers and other quantum devices. In our quantum optics group the research is oriented towards creating a quantum toolkit for photon generation, detection, manipulation and switching in fibers and on chips. We have already demonstrated a fiberized version of a coherent perfect absorption interferometric setup and measured single channel visibility as high as 90%. Recently, we have shifted towards development of actively phase controlled fiberized interferometer for the realization of in-fibre single photon metamaterial switches and exploration of new routes for embedding single photon emitter (NV– center in nanodiamonds) and metamaterials device in fibers for generation of quantum states of light.

T18: Many-body Physics

Time: Friday 9 Mar, 11:00am; Venue: LT4; Chair: Christian Miniatura
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T18.51 Noncollinear magnetic ordering in the Shastry-Sutherland Kondo lattice model: Insulating regime and the role of Dzyaloshinskii-Moriya interaction

Munir Shahzad*, Pinaki Sengupta (SPMS NTU)
11:00am – 11:15am

We investigate the necessary conditions for the emergence of complex, noncoplanar magnetic configurations in a Kondo lattice model with classical local moments on the geometrically frustrated Shastry-Sutherland lattice and their evolution in an external magnetic field. We demonstrate that topologically nontrivial spin textures, including a new canted flux state, with nonzero scalar chirality arise dynamically from realistic short-range interactions. Our results establish that a finite Dzyaloshinskii-Moriya (DM) interaction is necessary for the emergence of these novel magnetic states when the system is at half filling, for which the ground state is insulating. We identify the minimal set of DM vectors that are necessary for the stabilization of chiral magnetic phases. The noncoplanarity of such structures can be tuned continually by applying an external magnetic field. Our results are crucial in understanding the magnetic and electronic properties of the rare-earth tetraboride family of frustrated magnets with separate spin and charge degrees of freedom.

T18.89 Electron-electron contribution to graphene conductivity

Indra Yudhistira*, Derek Y. H. Ho*, Shaffique Adam* (Yale-NUS College)
11:15am – 11:30am

In this theoretical work, starting from a microscopic treatment within the Random Phase Approximation, we calculate the conductivity of graphene due to electron-electron and electron-impurity interactions. We demonstrate that both mechanisms have distinct temperature dependence and hence should provide an unambiguous signature for hydrodynamic transport in graphene. We predict a hydrodynamic window to observe such signature in experiment.

T18.34 Mott transition in the pyrochlore oxides.

Nyayabanta Swain*, Pinaki Majumdar (Nanyang Technological University)
11:30am – 11:45am

We study the interplay of electron correlation and geometric frustration in the context of the Mott transition in the pyrochlore lattice. We formulate the single band Hubbard model on this lattice in terms of electrons coupled to auxiliary local magnetic moments, and treat the resulting 'fermion-spin' problem through a real space Monte Carlo technique. While the ground states we obtain are equivalent to unrestricted Hartree-Fock, the presence of the crucial low energy fluctuations in our approach, and their coupling to the electrons, allows us to establish the temperature dependence of transport and spectral features across the Mott transition. Our study shows the pyrochlore lattice has no long-range ordered state. In the vicinity of the Mott transition the local moments become small and the coupling of electrons to these leads to an anomalous resistive state. We further attempted to model the more complex and experimentally relevant pyrochlore molybdates and iridates by including Hund's and spin-orbit coupling respectively. We have thoroughly studied the model problems and have obtained the overall phase diagrams capturing the details of the Mott transition observed in the pyrochlore molybdates and iridates.

T18.113 Dynamical quantum phase transitions in non-Hermitian lattices

Longwen Zhou*, Qinghai Wang, Hailong Wang, Jiangbin Gong* (NUS)
11:45am – 12:00pm

In closed quantum systems, a dynamical phase transition is identified by nonanalytic behaviors of the return rate as a function of time. In this work, we study the nonunitary dynamics following quenches across exceptional points in a non-Hermitian lattice realizable by optical resonators. Dynamical quantum phase transitions with topological signatures are found when an isolated exceptional point is crossed during the quench. A winding number defined by a real, noncyclic geometric phase is introduced, whose value features quantized jumps at critical times of these phase transitions and remains constant elsewhere, playing the role of a topological order parameter. This work provides a simple framework to study dynamical and topological quantum phase transitions in non-Hermitian systems.

T18.56 Orbital-free density potential functional theory: Applications to quantum gases and materials

Martin-Isbjoern Trappe*, Tri Chau Thanh, Jun Hao Hue, Berthold-Georg Englert, Derek Ho, Shaffique Adam (Centre for Quantum Technologies)
12:00pm – 12:15pm

We propose a versatile variant of orbital-free density functional theory, density-potential functional theory (DPFT), for calculating various properties of systems in one, two, and three dimensions. Interacting many-body systems with large particle numbers like quantum gases or solid states with long-range interactions in various dimensions pose formidable challenges even to state-of-the-art theoretical methods. We establish systematic semiclassical approximations of energies and particle densities for interacting fermion systems. The position-space formulation of DPFT yields self-consistent interacting particle densities in a spirit similar to the Kohn-Sham scheme, but cirumvents the need for orbitals. By design these single-particle densities can be improved systematically beyond the Thomas-Fermi approximation and can be used for efficiently addressing inhomogeneous interacting systems that span from few-body problems and quantum gases to electron-hole puddles in disordered heterostructures. DPFT also has the potential to tackle a variety of open problems in momentum space. Here, the prime targets are quantum-corrected momentum distributions and dispersion relations. The latter are self-consistently obtained from the corresponding noninteracting dispersion for any choice of interaction and thus offer an alternative route to interacting band structures and band gap renormalization. We present data for Hooke's atom, fermion gases, correlations of electron-hole puddles in double-layer structures, and preliminaries on band structure renormalization.

T18.3 Perfect diode in quantum spin chains

Vinitha Balachandran*, Giuliano Benenti, Emmanuel Pereira, Giulio Casati, Dario Poletti (Singapore University of Technology and Design)

12:15pm – 12:30pm

Understanding and controlling transport properties at the nano scale can lead to important technological advances. For instance, many-body nonlinear dynamics might be exploited to design nonlinear devices like heat diodes and transistor. In this work, we study the rectification of spin current in XXZ chains segmented in two parts, each with a different anisotropy parameter. Using exact diagonalization and a matrix product states algorithm we find that a large rectification can be obtained, when one half of the chain is gapless while the other has a large enough anisotropy. We present evidence of diffusive transport when the current is driven in one direction and of a nonequilibrium phase transition to an insulating behavior of the system when driven in the opposite direction, leading to a perfect diode in the thermodynamic limit. The above results are explained in terms of matching of spectrum of magnon excitations between the two halves of the chain.

T19: Physics Demonstrations and Applications

Time: Friday 9 Mar, 11:00am; Venue: LT5; Chair: Subramaniam RAMANATHAN
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T19.111 (INVITED) Sparking Curiosity and Sustaining Interest in Physics Through Demonstrations

Erkan Polatdemir* (Hwa Chong Institution)
11:00am – 11:20am

Live demonstrations, in general, serve as successful triggers in sparking curiosity and piquing students' interest. In order to ride on students' aroused interest in learning a new concept, their attention should be sustained with tasks that require them to regularly think, reason and provide explanations about what they observe. However, creating such a sustainable thinking routine during demonstrations is a challenging task due to various reasons such as insufficient scaffolds, large class size, limited interaction with teacher, ineffective questioning etc. We propose a framework which was, to a certain extent, successfully sparked and sustained students' interest for concepts in optics and quantum physics. In this framework, students' deeply-held assumptions and beliefs are challenged through questions which probe their understanding. Students were provided with scaffolds to support their learning experience and also given opportunities to test their hypothesis. Students' feedback on these lessons will be shared.

T19.13 (INVITED) Stress Induced Domain Wall Motion and its application in Energy Harvesting

S.N. Piramanayagam*, Xiaoxi Liu, Sabpreet Bhatti* (NTU)
11:20am – 11:40am

Energy harvesting is a research topic that is gaining significant interest due to the energy crisis. In small device applications, emergence of internet-of-things (IoT) devices and their requirement of self-generation of power is a stimuli. To harvest energy, several researchers have been investigating ferroelectric materials for voltage generation. However, ferroelectric materials suffer from the problem of having a high resistance at low frequencies, which reduces the output power.

Magnetic methods of power generation are typically done using dynamos with rotating magnets. Vibration based power generation in magnetism is not well studied. One way to achieve vibration based power generation is to use domain wall propagation in ferromagnetic materials, arising from vibrations. A voltage induced by stress-induced domain wall motions can be picked up using coils. This has been investigated as an alternate form of energy harvesting by a few researchers. However, such studies were reported only in multiferroic structures where a voltage is applied to induce the stress, which defeats the purpose of self-power generation.

We have shown that power can be generated from mechanical vibrations in purely ferromagnetic structures. We achieved these results by showing that the domain walls can be moved entirely by stress in a trilayer stack of ferromagnetic microwires. The use of flexible substrates with low Young's modulus and the special magnetic stack enabled us to achieve significant magnetization rotation or domain wall motion even from ambient vibrations. We have exploited the changes in the magnetization angle or domain wall motion to induce voltages in the pickup coils. These results make the observed phenomenon and the proposed technique suitable for power generation in IoT devices. The presentation will describe the underlying physics and the recent developments.

T19.75 Continuous Motional Sensing of High Dispersive Medium

Chang Huang*, Pei Chen Kuan*, Shau-Yu Lan (Nanyang Technological University)
11:40am – 11:55am

Current state-of-the-art atoms-based motional sensors rely on measuring the first-order Doppler shift of the atomic transition of single-particles. By using Doppler-sensitive detection methods, the population of atomic states and, therefore, the velocity of atoms can be measured precisely. On the contrary, here, we demonstrate a novel method of measuring the center-of-mass motion of an atomic ensemble using the collective interference of light passing through the ensemble under the condition of electromagnetically-induced-transparency (EIT). With the large enhancement of the dispersion in the EIT medium, we realize an atom-based velocimeter that has a sensitivity two orders of magnitude higher than the velocity width of the atomic medium used. This method has the advantages of high data rate and convenient detection of the interference phase of light over the conventional method of detecting the florescence of atoms and could lead to a new design of compact atoms-based motional sensors.

T19.146 Single-Crystal Growth of Organic Semicondutcors for Field-Effect Transistors and Some Potential Applications

Hui Jiang*, Denis Fichou* (Nanyang Technological University)
11:55am – 12:10pm

Organic single crystals have been widely investigated in recent years due to the widespread expectation that the transport properties measured on single crystals present the intrinsic properties of organic semiconductors. The single-crystal growth methods of organic semiconductors are discussed in our studies. Organic small molecules, such as anthracene, tetracene, pentacene, rubrene, perylene, fluorinated metal phthalocyanine, etc., are selected for crystal growth. Organic single crystals charge transfer compounds with forms of one-dimensional micro-/nanowires, two-dimensional platelets and three-dimensional cubes are also synthesized by both solution method and physical vapor transport method. Field-effect transistors (FETs) based on organic single crystals are fabricated and high mobility of up to 1 $cm^2V^{-1}s^{-1}$ can be obtained. Some potential applications like phototransistors and gas sensor devices based on organic single crystal FETs are also introduced.

T19.6 Atomic layer deposited electrolyte membranes for Lithium sulfur batteries

R Prasada Rao*, Stefan Adams (NUS)
12:10pm – 12:25pm

Development of solid state electrolytes (SSE) is considered as breakthrough for technologies towards development of safe, new high power and energy density batteries for electronics with low processing cost. The organic electrolytes in current commercial rechargeable Li-ion batteries (LiBs) are flammable, toxic and have limited electrochemical potential window. All-solid-state batteries technology suggests improved safety, cycling performance, electrochemical stability and possibility to device miniaturization. Besides, solid electrolytes would enhance the energy density by enabling metallic Li anodes. In the past decades, a large number of inorganic materials with both crystalline and amorphous structures as well as the composite structures have been investigated experimentally and theoretically as the potential solid electrolyte candidates including LISICONs-like and NASICONs-like compounds, garnets, argyrodites, $Li_7P_2S_{11}$, $Li_{10}GeP_2S_{12}$, Li nitrides, halides and hydrides, LIPONs etc [1-5]. However, limited current density remains a major impediment in these electrolyte systems. Argyrodites form a class of chalcogenide structures related to the mineral Ag_8GeS_6, which includes various fast Ag+ or Cu+ ion conductors such as A_7PS_5X (A = Ag+, Cu+). ^{7}Li-NMR relaxation and impedance experiments find an intrinsic local lithium mobility of the Li-argyrodite crystals as high as 10^{-2}–10^{-3} S/cm at room temperature close to the mobility in liquid electrolytes comprising of $LiPF_6$ salt in various carbonates. But the batteries prepared using these solid electrolytes suffer major capacity fading due to the electrode electrolyte interface resistance after few cycles. In-order to reduce interfacial resistance and increase stability, we coated Lithium Tantalate on SSE at 200 $^\circ$C substrate temperature. SEM and EDX studies of the ALD coated sample indicated the formation of a Ta_2O_3 layer covering the surface uniformly. Impedance analysis of uncoated argyrodite exhibited an ion conductivity of 3.5×10^{-4} S/cm and 6 $\times10^{-4}$ S/cm at 30 $^\circ$C. We demonstrated the enhancement of Li-S semi flow batteries by coating lithium tantalate on two sulphide-based SSE using ALD. Batteries with a $Li_{10}GeP_2S_{12}$ solid electrolyte membrane showed an initial discharge capacity of 1220 mAh g^{-1} and retained 580 mAh g^{-1}, i.e. 41% of the initial capacity at the end of the 50th cycle, while the capacity of the analogous system based on uncoated LGPS had had dropped to ca. 400 mAh g^{-1} after only 20 cycles. Besides this enhancement of the cycle life, ALD coating also significantly raises the cost and energy-efficiency of the battery: Without the coating costly In-Li alloy had to be used as anode. With the $LiTaO_3$ coating the solid electrolyte becomes compatible with Li metal reduce the cost and dead weight of Indium and increasing the cell voltage by about 0.6 V.

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6 Physics Olympiad Events

The 30th Singapore Physics Olympiad 2017 was held in October and November 2017, with more than 200 Junior College students from various schools in Singapore participating. As is tradition, the Awards Ceremony for the Olympiad as well as the announcing of some special prizes will be part of annual meeting of the Institute of Physics, Singapore. All teachers in charge are warmly invited to attend, even if your students have not won anything this time. All student winners (medallists and honourable mentions) are invited to receive their awards.

In addition to the Awards Ceremony, there will be a networking session and a special panel discussion about all things physics, where students can ask questions on topics ranging from the frontier research topics in physics, curriculum of undergraduate programs, opportunities for research and career prospects for physics graduates.

Friday afternoon, 9 March schedule

1.30 PM	Registration for award winners (MAS Atrium) W2
2.00 PM	Welcome (LT1)
2.15 PM	O1: Keynote address by Emeritus Professor Bernard Tan Tiong Gie (LT1)
2.45 PM	O2: Panel discussion “Promises (and Perils) of Physics” (LT1)
3.45 PM	O3: Prize presentation (LT1)
4.00 PM	Refreshments and networking (MAS Atrium)

7 Committees

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Special thanks for help with logistics to the technical support staff, particularly Ms. Sruthi Varier and Mrs. Won Lai Chun, Rebecca, and many students at NTU!

Physics Olympiade Event and School relationship

Darren TAN, MoE

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