IPS Meeting 2019
13 - 15 March

Institute of Physics Singapore

Conference Program

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Institutional Supporters:

1 Foreword

Dear fellow Physicists,

now already for the second time we have our annual meeting in the wild east of Singapore, on the campus of the Singapore University for Technology and Design.

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 neighbor about the science they are involved in, and not only about the chores of everyday's routine in our departments.

As in previous years, we try to highlight outstanding research activities in Singapore and beyond with six plenary talks. Starting from foundational aspects of quantum physics with Tomasz Paterek from NTU over to the foundations of PT symmetry by Carl M. Bender visiting us from Washington University St. Louis in Missouri, US, we get an insight in theoretical work in Singapore on 2D materials by Vitor M. Pereira from the Centre for Advanced 2D Materials at NUS, followed up by an overview over more preparational aspects from SUTD's local Yang Hui Ying. The plenaries on Friday offer an overview over quantum sensing with single ions my Manas Mukherjee from the Centre for Quantum Technologies at NUS, and leave us with an outlook to Artificial life and neuromorhic computing by Timothy Liew from NTU – look forward to the connection of these unusual topics with more traditional physics!

This year, we have a more compact set of 14 technical sessions with 71 invited and contributed talks.

As important as technical talks are, we feel that interaction is often easier in a relaxed atmosphere, so we put a strong emphasis on a serious poster session with some 55 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 an event lineup Thursday afternoon where we welcome this year's winners of the Physics Olympiad to our community. If you can, engage with these newcomers of the next generation of researchers in physical sciences.

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 also try to put together sessions that have a coherent content in a given time constraint. We really would appreciate to have your views on this selection, 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, this time from the team at SUTD.

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 support to make this conference possible. Without their help, we would not be able to put up this conference – so do spend some time and visit their booths to see what products or services they can offer for your research.

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!

Following the main conference, we are also happy to host a satellite meeting on visions for the many aspects of quantum technologies and siences in Singapore on Friday afternoon. This is an attempt to actively shape the future in the Singapore research landscape in the light of very rapid global developments. Target audience for this are Principal investigators or senior scientists in this field.

Your organizing team of the IPS meeting 2019

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2 Schedule

Wednesday, 13 March

8.45 AM	Registration (Central Bridge)		
9.15 AM	Opening Address (LT2)		
9.30 AM	Plenary talk 1: Tomasz Paterek (LT2)		
10.15 AM	Plenary talk 2: Carl M. Bender (LT2)		
11.00 AM	Coffee/Tea Break + Exhibition (Central Bridge)		
11.30 AM	Technical Sessions		
	T1 (location: tt7) Atomic Physics I	T2 (location: tt9/10) Physics of Perovskites	T3 (location: tt8) Valleytronics
12.30 PM	Lunch + Exhibition (Central Bridge)		
2.00 PM	Technical Sessions		
	T4 (location: tt7) Quantum Communication	T5 (location: tt9/10) Metamaterials and Photonics	T6 (location: tt8) Many-Body Physics
3.00 PM	Coffee/Tea Break + Exhibition (Central Bridge)		
3.30 PM	Technical Sessions		
	T7 (location: tt7) Classical and Quantum Optics	T8 (location:tt9/10) Optical Materials	
5.00 PM	End of Wednesday sessions		

Thursday, 14 March

9:00 PM	Registration (Central Bridge)
9.30 AM	Plenary talk 3: Vitor M. Pereira (LT2)
10.15 AM	Plenary talk 4: YANG Hui Ying (LT2)
11.00 AM	Coffee/Tea Break + Exhibition + Poster mounting (LT2)
11.30 AM	PO1: Rapid Fire poster Pitch session (LT2)
12.45 PM	Lunch + Posters + Exhibition (Central Bridge)
2.00 PM	Technical Sessions T9 (location: tt9/10) Physics in 2D Materials T10 (location: tt7) Quantum Information T11 (location: tt8) Biophysics and Microfluidics
3.30 PM 4.00 PM	Coffee/Tea Break + Exhibition + Poster mounting (Central Bridge) PO2: Poster session (Central Bridge) + Exhibition
5.30 PM	Poster awards + Pizza + Drinks (Central Bridge)
6.30 PM++	End of Thursday sessions

Friday, 15 March

9:00 PM	Registration
9.30 AM	Plenary talk 3: Manas Mukherjee (LT2)
10.15 AM	Plenary talk 4: Timothy LIEW (LT2)
11.00 AM 11.30 AM	Coffee/Tea Break (Central Bridge) Technical Sessions T12 (location: tt7) Topological effects in Materials T13 (location: tt8) Atomic Physics II T14 (location: tt9/10) Statistical Physics and Complexity
12.30 PM	End of main Conference)
2.00 PM -5.00 PM	Singapore 3rd Quantum Vision meeting (Location: think tank 21, level 3)

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 business, but we hope you can sit back and enjoy the wide scope of topics physicists are working on!

P1: Non-classicality of uncharacterised objects and processes

Asst. Prof. Tomasz Paterek
School of Physical and Mathematical Sciences,
Nanyang Technological University
Email: tomasz.paterek@ntu.edu.sg

Wednesday, 13 March, 9:30am, Venue: LT2

Abstract

When two quantum objects are coupled via mediator their dynamics has traces of non-classical properties of the mediator and of interaction Hamiltonians. I will show how these traces lead to methods revealing non-classical features of objects and processes that remain uncharacterised throughout the assessment. A few applications will be discussed: in opto-mechanics, quantum biology and to probe quantumness of gravity.

P2: PT symmetry

Prof. Carl M. Bender, Konneker Distinguished Professor of Physics
Washington University in St. Louis, Missouri, USA

Wednesday, 13 March, 10:15am, Venue: LT2

Abstract

By using complex-variable methods one can extend conventional Hermitian quantum theories into the complex domain. The result is a huge and exciting new class of parity-time-symmetric (PT-symmetric) theories whose remarkable physical properties are currently under intense study by theorists and experimentalists. Many theoretical predictions have been verified in recent beautiful laboratory experiments.

P3: Charge density wave and superconducting order in $TiSe_2$ driven by excitonic condensation and its fluctuations

Asst. Prof. Vitor M. Pereira, Centre for Advanced 2D Materials[1]
National University of Singapore

Thursday, 14 March 9:30am, Venue: LT2

Abstract

The interplay of charge-density wave (CDW) order and superconductivity (SC) is of perennial interest in condensed matter since the underlying physics might unlock the promise of high-temperature SC. I will present an encompassing theoretical framework that describes how an excitonic instability in two-dimensional $TiSe_2$ likely underpins the entirety of this compound's experimental phase diagram. In addition to these excitonic degrees of freedom describing extremely well the CDW phase, their fluctuations are shown to induce electronic pairing capable of stabilizing a dome-shaped SC phase at finite doping, as seen experimentally. This work is an important theoretical counterpart to recent experiments in establishing $TiSe_2$ as an example of the elusive correlated excitonic insulator.

P4: Advanced Two-dimensional Nanomaterials: Synthesis to Applications

Assoc. Prof YANG Hui Ying, Engineering Product Development
Singapore University of Technology and Design

Thursday, 14 March, 10:15am Venue: LT2

Abstract

Advanced two-dimensional (2D) materials have attracted significant interest due to their extraordinary physical and chemical properties over the past decade. Understanding and controlling the growth of novel 2D crystal materials is central for the performance of various applications, spanning from electronics to energy storage. Chemical vapor deposition (CVD) method is a key technology we used to develop exceptional nanomaterials and explore their applications in effective energy storage devices as well as scalable water purification. One of the greatest challenges besetting the development of battery technologies is fast charging, especially within flexible or compact designs. We discuss how the design of low dimensional nanostructure can correlate with the ion transportation efficiency, the activity of electrochemical reaction and energy storage based on chemical transformation. We have also studied the prospects of fast prototyping and scalability for 2D materials based devices.

[1] Work done in collaboration with Chuan Chen, Lei Su, Bahadur Singh, Antonio H. Castro Neto, and Hsin Lin

P5: Sensing and simulation with a single ion

Asst. Prof. Manas Mukherjee, Centre for Quantum Technologies
and Department of Physics,
National University of Singapore

Friday, 15 March, 9:30am, Venue: LT2

Abstract

Ion trap technology is a forerunner in quantum computing, simulation, sensing and clocks. The versatile application of ion trap setups stem from their ability to control and manipulate single or multiple ions in a near isolated environment with negligible kinetic energy. Two such applications related to fundamental physics [1] and thermodynamics [2] at the quantum scale have been recently demonstrated in our setup. These two applications will be discussed in detail. In the first application we demonstrate that by proper feedback or noise filtering it is possible to preform frequency measurement with precision beyond the Heisenberg limit. The second experiment deals with understanding thermodynamics at the quantum limit. Both the experiments have been carried out using barium ion in a linear Paul trap using protocols engineered for each tasks.

[1] T. Dutta and M. Mukherjee: *Axion dark matter search - an application of quantum metrology*, arXiv:1803.01724 (2018).

[2] N. Van Horne, D. Yum, T. Dutta, G. Jiangbin, P. Hanggi, D. Poletti and M. Mukherjee: *Single atom energy-conversion device with a quantum load*, http://arxiv.org/abs/1812.01303 (2018).

P6: Artificial life and neuromorphic computing based on exciton-polariton lattices

Asst. Prof. Liew Chi Hin Timothy
School of Physical and Mathematical Sciences,
Nanyang Technological University

Friday, 15 March, 10:30am, Venue: LT2

Abstract

Exciton-polaritons are hybrid states of light and matter existing in semiconductor heterostructures. They have been typically studied in planar microcavities containing quantum wells, exhibiting spin-sensitive phenomena such as the optical spin Hall effect and nonlinear effects such as solitons and bistability. More recently, there has been a growing interest in studying exciton-polaritons in patterned lattices, where the interplay of spin-orbit interaction with magnetic field was shown to give rise to topological physics. Furthermore, as we will show, nonlinear interactions in such systems demonstrate complex phenomena, realizing artificial life and artificial neural networks.

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.2 Low Frequency Noise Attenuation in Acoustic Panels Using Locally Resonant Sonic Crystal

Preeti Gulia*, Arpan Gupta (Indian Institute of Technology Mandi, Himachal Pradesh, India-175001)

Acoustic panels are broadly used for noise attenuation at various places. Multiple panels with certain air gap act more efficiently due to multiple reflections in the air cavity. Different type of absorbing blankets has been used between the panels from last few decades to increase the noise attenuation. However, it does not help to attenuate the noise at low frequencies. This work aims to increase the noise attenuation at low frequencies in the double panel using a locally resonant sonic crystal (LRSC) and absorbing wool. Sonic crystal (SC) is a periodic structure in which circular or rectangular scatterers are arranged periodically in a homogeneous material. Sonic crystal has the ability to attenuate noise in a particular band gap which is centered at Bragg's resonance frequency. In this work, first, SC along with absorbing wool is used as filler between the panels. Sound transmission loss of resulting structure is computed using finite element method. The result shows that filling the air gap with SC along with absorbing wool between the panels increases the sound transmission loss in a band gap (2100 Hz – 5000 Hz) centered at Bragg's resonance frequency. To shift the resonance at low frequency, SC is replaced by LRSC which is made of periodically arranged C-type scatterers. C-type scatterer acts as a Helmhotlz resonator and creates local resonance at a frequency lower than the Bragg's frequency. The result shows that insertion of LRSC along with absorbing wool between the panels increase the sound transmission loss at low frequencies as well as at high frequencies. The combined structure of a double panel with LRSC and absorbing wool as filler provides an average increment of 15 dB at low frequencies range from 600 Hz to 1800 Hz and of 17 dB at high frequencies ranges from 2100 Hz to 5000 Hz.

PO.3 Limitations and modifications of Newton's laws of motion

Amritpal Singh Nafria* (Lovely Professional University)

Newton's laws of motion are three physical laws that laid the foundation for classical mechanics. They describe the relationship between a body and the forces acting upon it, and its motion in response to those forces. Newton's first law states that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. The second law states that force is directly proportional to mass and acceleration (F=ma) and the third law states that for every action (force) in nature there is an equal and opposite reaction. This paper shows 'F=ma' is not a universal equation, as the role of gravity is missing in the given convention. Moreover, 'F=mga' is a formula of Inertia (I=wa), i.e. Newton's first law of motion. Formula of force is 'F=w(v–u)' or 'F=wv'. It is also explained how to calculate force numerically when it is applied on wall/stationary objects and on objects moving with constant velocity. In third law, action and reaction are not exactly explained that makes confusion among students. This paper explains action and reaction act simultaneously till stick together and are always opposite but equal when both stay stationary/don't cause movement; whereas if both bodies cause movement in the same direction, action and reaction get unequal till stick together. It explains that the direction of movement shows which body applies more force, whereas velocity shows how large force is applied by one body on to another body. It is illustrated that the stationary bodies are not capable of applying force on other bodies but these bodies can just hold a specific amount of force w.r.t. its limit of tolerance.

PO.9 Processing quantum states with a quantum reservoir processor

Sanjib Ghosh* (Nanyang Technological University)

We introduce quantum reservoir processing that is a platform for quantum information processing developed on the principle of reservoir computing which is a form of artificial neural network. A quantum reservoir processor can efficiently perform tasks on quantum states, like recognising an entangled state or estimating von Neumann entropy, purity and negativity. As a general structure of this platform, it uses a network (known as reservoir) of quantum objects as the central processor. While this architecture can be used as a software, it is more specifically suitable for hardware implementation. As hardwares, quantum reservoir processors can be realized in a variety of systems, e.g., arrays of semiconductor quantum dots, superconducting qubits, exciton-polaritons in semiconducting microcavities, trapped cold atoms and NV centres in diamond.

PO.12 Simplified Surface Temperature Modelling

Jun Hao Koh* (A*star)

Thermal load on buildings is the net accumulation of heat from the Sun, sky and surrounding surfaces in the built environment. A simplified 1D heat balance model was developed to provide an overview on the variation in surface temperature of conventional and high performance façade. The model demonstrates good agreement with the overall trend of the measured surface temperatures throughout a day for two different industrial buildings. Virtual thermal performance evaluation of different façade materials is carried out to provide an insight on the effect of the potential retrofit of the existing building with high performance facade. An accurate prediction of the surface temperature will enable an accurate prediction of thermal comfort metric, such as mean radiant temperature, and expected impact of radiative thermal loading for different façade technologies in the tropical outdoor environment.

PO.13 MoS_2-mediated long range surface plasmon resonance biosensors

Yi Xu*, Changyu Hsieh, Lin Wu, Lay-Kee Ang* (Singapore University of Technology and Design)

Molybdenum disulphide (MoS_2), as a promising alternative plasmon supporting material to graphene, exhibit potential applications in sensing. Here, we propose a MoS_2-mediated long range surface plasmon resonance (LRSPR) imaging biosensor based on the structure of chalcogenide(2S2G)/cytop/Au/MoS_2/analyte , which shows tremendous improvements in both imaging sensitivity ($> \times 2$) and detection accuracy ($> \times 10$) as compared to conventional surface plasmon resonance (cSPR) biosensor (2S2G /Au/MoS_2/analyte). It is found that the imaging sensitivity of the LRSPR biosensor can be enhanced by the integration of MoS_2 layers, which is different from the previously reported graphene-integrated cSPR imaging sensor whose imaging sensitivity decreases with the number of graphene layers.

By tuning the thickness of gold film and cytop layer, it is possible to achieve optimized imaging sensitivity for LRSPR sensor with any known integrated number of MoS_2 layers and the analyte refractive index. The proposed MoS_2-mediated LRSPR sensor could provide potential applications in chemical sensing and biosensing applications.

PO.15 Towards creation and manipulation of ultracold single molecules

Swarup Das*, Billy Jun Ming Lim, Mohammad Mujahid Aliyu, Krishna Chaitanya Yellapragada, Xiu Quan Quek, Tianli Lee, Huanqian Loh* (CQT, NUS)

Molecular systems at ultracold temperatures, thanks to their rich internal and external degrees of freedom, offer promising opportunities to study quantum many-body systems and others. To date, people have successfully created ultracold molecules by first cooling atoms to ultracold temperatures and then associating them. However, creating ultracold molecules with single-molecule resolution and full quantum state control has not yet been realized. Here we present our experimental progress towards creating ultracold molecules with single-molecule control with the help of optical tweezer traps.

PO.17 Graphene-based thermionic solar cells

Xin Zhang, Jincan Chen*, L. K. Ang* (Singapore University of Technology and Design)

A model of the graphene-based thermionic solar cell (TSC) consisting of a concentrator, an absorber, and a thermionic emission device configured with graphene-based cathode is proposed, where the radiation and reflection losses from the absorber to the environment, the thermal radiation between the cathode and the anode electrodes, and the heat losses from the anode to the environment are considered. The performance characteristics of the TSC are analyzed by numerical calculations. It is found that the maximum efficiency can reach 21% when the area ratio is 0.24 and the voltage output is 2.01V. In addition, the maximum efficiencies of the TSC under different concentrations and the optimal values of some key parameters are determined, and consequently, the corresponding optimally operating conditions are obtained. The results obtained here may provide guidance for the appropriate selection of electrode materials and the optimum design of practical TSC devices.

PO.18 2D Monte Carlo Study of p-n+ and p-i-n+ Silicon Waveguide-based Single-photon Avalanche Diodes for Visible Wavelengths

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

Integrated photonic platforms are promising candidates for the development and implementation of scalable quantum information and networking schemes. However, many state-of-the-art photonic platforms still require the coupling of light to external photodetectors. On-chip silicon single-photon avalanche diodes (SPAD) are a viable option as they can be fabricated at scale and can be operated near room temperature with high efficiencies. We design silicon waveguide-based SPADs for visible wavelengths and use a 2D Monte Carlo model to simulate the avalanche multiplication process of charge carriers following the absorption of an input photon. We study two device families with different doping configurations: p-n+ and p-i-n+, and study their photon detection efficiency (PDE) and the timing jitter. In p-n+ SPADs, we investigate the effect of junction position with respect to the photon absorption region, whereas we vary the intrinsic region width in p-i-n+ SPADs. The device performance is simulated at a wavelength of 640 nm and temperature of 243K. We obtain a maximum PDE of 55% with a breakdown voltage of 34V, and typical timing jitter values remain less than 7 ps for all simulated parameters.

PO.19 Non-linear optical response and HHG in 3D Dirac semimetals

Jeremy Lim*, Yee Sin Ang*, Liang Jie Wong, Ricky Ang (SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN)

Attosecond-duration pulses of extreme ultraviolet to X-ray light, generated via high harmonic generation (HHG), have proven to be highly useful tools in the study of the smallest and quickest fundamental phenomena. The study of HHG in condensed matter systems has attracted much interest due to its potential to realize novel solid-state optical technologies, as well as greater brightnesses compared to gas-phase HHG. We will present results on high harmonic generation in 3D Dirac semimetals, which exhibit strong, non-linear response to incident fields, implying efficient generation of odd harmonics. We consider the massless Dirac quasiparticle limit, previously used to predict the harmonic spectra of 2D graphene due to its simplicity and physical transparency, and extend it to 3D Dirac semimetals. We study its non-linear response due to incident fields, and predict its harmonic spectra. A comparison of our results with graphene as well as potential novel photonic applications will be discussed.

PO.24 Correlated phases and electron localizations in twisted bilayer graphene

Evan Laksono*, Alexander Reaves, Manraaj Singh, Xingyu Gu, Jia Ning Leaw, Nimisha Raghuvanshi, Shaffique Adam* (Yale-NUS College)

Recent experimental works on magic-angle twisted bilayer graphene have pointed to the existence of insulating and superconducting phases when the flat bands are half-filled. In this work, we use our recently developed theory for the non-interacting band structures to understand the emergence of correlated phases within weak coupling limits [1, 2]. Our model suggests that a strong nesting can be present when twisted bilayer graphene is doped close to the van Hove singularities, leading to the formation of density wave and superconductivity. We also incorporate strains into our model which give rise to sharper AB/BA domains at small twist angles, and discuss their effects on the local density of states which can be detected under scanning tunneling microscopes.

Acknowledgement This research is funded by Singapore Ministry of Education AcRF Tier 2 (MOE2017-T2-2-140).

References [1] M. Yankowitz, J. Jung, E. Laksono, N. Leconte, B. L. Chittari, K. Watanabe, T. Taniguchi, S. Adam, D. Graf, C. R. Dean, Nature 557, 404-408 (2018) [2] E. Laksono, J. N. Leaw, A. Reaves, M. Singh, X. Wang, S. Adam, X. Gu, Solid State Commun. 282 38-44 (2018)

PO.29 Electrifying Properties of Scintillating Zinc Oxide Ensconced in a Carbon Nanoforest

Valerie Tan Yi Jie*, Isaac Kwek Zhong Wei* (Dunman High School)

This paper discusses the modification of a Zinc Oxide-Carbon Nanotube (ZnOCNT) nanohybrid via laser pruning. A change in the fluorescence colour of ZnOCNT under UV light was observed from black in pristine ZnOCNT to blue, blue and green, and green in ZnOCNT cut using a 532nm laser with laser power of 7mW, 9mW and 11mW respectively, implying that the nanohybrid has undergone a chemical change. Further characterisation was carried out for pristine ZnOCNT as well as the ZnOCNT with blue, blue and green, and green fluorescence to understand their properties in greater depth. A direct correlation was observed between the intensity of the green emission and the laser power, which is attributed to an increase in the concentration of singly charged oxygen vacancies and oxygen vacancy-zinc interstitial clusters within the nanohybrid. The blue emission is attributed to the ZnO with lattice defects. Since both ZnO and CNT are known field emitters, further studies were conducted to study the field emission properties of pristine and laser-cut ZnOCNT. ZnOCNT with green fluorescence and both blue and green fluorescence exhibited the best field emission properties. The change in the colour of the fluorescence with temperature points to the potential for use of the nanohybrid as a temperature sensor with colour-changing optical displays.

PO.31 The CQT group III machine

Xianquan Yu, Jinchao Mo, Rui Wang, Travis Nicholson* (Centre for Quantum Technologies)

An ultracold gas of group III atoms could enable highly accurate atomic clocks, new tests of fundamental physics, and novel quantum many body states; however, no group III atom has been cooled to ultracold temperatures. In this presentation, we describe our apparatus for cooling group III atoms to the ultracold regime.

PO.32 Enhancing Optical Readout from Diamond AFM Tips for Quantum Nanosensing

Victor Xu Heng Leong*, Sumin Choi, Gandhi Alagappan, Leonid Krivitsky (Institute of Materials Research and Engineering, A*STAR)

Color centers in diamond are promising candidates for quantum nanosensing applications, where the efficient collection of the optical signal is essential to achieving high sensitivity and resolution. Embedding the color centers in diamond microstructures can enhance the collection efficiency, but often requires challenging fabrication and integration. Here, we investigate the photoluminescence (PL) of silicon-vacancy (SiV) centers in commercially available atomic force microscope (AFM) diamond pyramid (DP) tips. We find that the DP geometry efficiently channels PL emitted at the DP apex towards the base, where we experimentally demonstrate an enhanced PL collection of up to 8 times higher compared to other directions. Our experimental observations are in good agreement with numerical simulations using a finite-difference time-domain (FDTD) method. Our results indicate that AFM tips could be an economical, efficient and straightforward way of implementing color-center-based nanosensing as they provide enhanced sensitivity and easy integration with existing AFM platforms.

PO.34 Many-body open quantum systems beyond Lindblad master equations

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

Many-body quantum systems present a rich phenomenology which can be significantly altered when they are in contact with an environment. In order to study such setups, a number of approximations are usually performed, either concerning the system, the environment, or both. A typical approach for large quantum interacting systems is to use master equations which are local, Markovian, and in Lindblad form. Here, we present an implementation of the Redfield master equation using matrix product states and operators. We show that this allows us to explore parameter regimes of the many-body quantum system and the environment which could not be probed with previous approaches based on local Lindblad master equations. We also show the validity of our results by comparing with the numerical exact thermofield-based chain-mapping approach.

PO.36 Polarization entangled photon pair source based on position correlation.

Chithrabhanu Perumangatt*, Alexander Lohrmann, Alexander Ling (Centre for Quantum Technologies)

The photon pairs generated by parametric down conversion of a laser beam have inherent position and momentum correlations. Even though this can be used to generate higher dimensional entanglement, the detection of the same requires special settings and often difficult to use in a practical quantum communication scenario. We convert the inherent position correlation of the photon pairs produced by spontaneous parametric down conversion into polarization entanglement. The generated polarization entangled photon pairs exhibit strong quantum correlations and high brightness. Furthermore, a compact pre-compensated entanglement source design based of position correlation is implemented which can be used for practical quantum key distribution.

PO.39 Disorder Enhanced Spin Transport in XXZ Spin Systems

Kang Hao Lee*, Dario Poletti* (SUTD)

The formation of ferromagnetic domains in spin transport leads to negative differential conductance in an interacting many-body system. It is also known that disorder disrupts ferromagnetic domains. However, it not yet clear how the interplay of interaction and disorder affects spin transport in the regime of negative differential conductance. Here, the question is addressed by studying the spin transport properties of a boundary driven XXZ spin chain with different disorder distributions. We discover transport enhancement due to disorder in the strong driving regime. A distribution of dichotomous disorder revealed a resonant nature of conductance against disorder strengths. The mechanism of this transport enhancement can be understood from the energy level crossings of the basis states when the system is subjected to disorder.

PO.40 Frequency modulation spectroscopy at the large optical depth regime

Chang Chi Kwong*, Eng Aik Chan, Syed Abdullah Aljunid, Rustem Shakhmuratov, David Wilkowski (Nanyang Technological University)

In this work, we present a frequency modulation (FM) spectroscopic technique that works in the large optical depth (OD) regime. Conventional band-resolved FM spectroscopy [1] works well for a medium with small OD, but loses its sensitivity at large OD, due to the exponential absorption of the carrier component. Our technique overcomes this limitation by suppressing the carrier component at a higher modulation index of 2.4. This technique leads to a frequency sensitivity at large OD, that is comparable to the band-resolved FM spectroscopy. Additionally, the sidebands probe the homogeneous tails of the resonance. Thus, one has Doppler-free spectroscopy with a single laser beam. We tested this technique on the D2 line of cesium vapor, finding good agreement with our theoretical prediction. In future, this technique could be used to study cooperative effects, or to measure collisional broadening in an optically thick and dense medium.

[1] G. C. Bjorklund, Opt. Lett. 5, 15-17 (1980).

PO.41 Effect of strong system-bath coupling for a single-site Bose-Hubbard model

Tianqi Chen*, Dario Poletti* (Singapore University of Technology and Design)

We investigate the non-equilibrium transport properties in a single-site Bose-Hubbard model coupled to a bath at finite temperature for different coupling strengths. The effect of the bath can be modeled as two decoupled chains of harmonic oscillators using a thermofield-based transformation and star-to-chain mapping. We numerically explore the effect of on-site interactions, the chemical potential as well as the strong system-bath couplings on the system properties using matrix product states (MPS). Our numerical method provides an exact analysis of the system in the strong system-bath coupling regime unlike most master equation approaches.

PO.43 Weyl-loop half metal in $Li_3(FeO_3)_2$

Cong Chen*, Xian-Lei Sheng, Shengyuan Yang (Beihang University, Singapore University of Technology and Design)

Nodal-line metals and semimetals, as interesting topological states of matter, have been mostly studied in nonmagnetic materials. Here, based on first-principles calculations and symmetry analysis, we predict that fully spin-polarized Weyl loops can be realized in the half metal state for the three-dimensional material $Li_3(FeO_3)_2$. We show that this material has a ferromagnetic ground state, and it is a half metal with only a single spin channel present near the Fermi level. The spin- up bands form two separate Weyl loops close to the Fermi level, which arise from band inversions and are protected by the glide mirror symmetry. One loop is of type-I, whereas the other loop is of hybrid type. Corresponding to these two loops in the bulk, on the (100) surface, there exist two fully spin-polarized drumheads of surface states within the surface projections of the loops. The effects of the electron correlation and the spin-orbit coupling, as well as the possible hourglass Weyl chains in the nonmagnetic state have been discussed. The realization of fully spin-polarized Weyl-loop fermions in the bulk and drumhead fermions on the surface for a half metal may generate promising applications in spintronics.

PO.44 Three-dimensional honeycomb carbon: Junction line distortion and novel emergent fermions

Junping Hu*, Weikang Wu*, Chengyong Zhong, Ning Liu, Chuying Ouyang, Hui Ying Yang*, Shengyuan A. Yang* (Singapore University of Technology and Design)

Carbon enjoys a vast number of allotropic forms, each possessing unique properties determined by the lattice structures and bonding characters. Here, based on first-principles calculations, we propose a new three-dimensional carbon allotrope—hC28. We show that hC28 possesses excellent energetic, dynamical, thermal, and mechanical stability. It is energetically more stable than most other synthesized or proposed carbon allotropes. The material has a relatively small bulk modulus, but is thermally stable at temperatures as high as 2000 K. The structural, mechanical, X-ray diffraction, and electronic properties are systematically investigated. Particularly, we show that its low-energy band structure hosts multiple unconventional emergent fermions, including the quadratic-contact-point fermions, the birefringent Dirac fermions, and the triple-point fermions. We construct effective models to characterize each kind of fermions. Our work not only discovers a new carbon allotropic form, it also reveals remarkable mechanical and electronic properties for this new material, which may pave the way towards both fundamental studies as well as practical applications.

PO.48 Tunable psudocapacitive properties of TiO_2@ carbon nanoparticles derived from metal-organic frameworks for membrane capacitive deionization

Meng Ding, Shuang Fan, Hui Ying Yang* (Singapore University of Technology and Design)

Titanium dioxide (TiO_2) composites have been considered as the promising candidates of the electrode materials for capacitive deionization (CDI). However, its pseudocapacitive potential for further enhancement of salt adsorption capacity is a significant and challenge. In this work, we report a series of TiO_2/porous carbon composites (TiO_2@PC) with tunable pseudocapacitance for high-efficient membrane CDI (MCDI). The TiO_2@PC samples were derived from the titanium-based metal-organic framework (MOF) under different pyrolysis conditions. By controlling the pyrolysis temperature, the crystalline degree and specific surface areas of TiO_2@PC are able to be optimized to have an adjustable pseudocapacitance in desalination processes. A synergistic effort of high pseudocapacitance and good oxidation resistant endows TiO_2@PC (treated at 600 °C) with an improved salt adsorption capacity of 46.7 $\mathrm{mg\,g^{-1}}$.

PO.50 Evolution of the static structure factor of a dissipative Bose-Hubbard chain

Ryan Tan*, Dario Poletti, Corinna Kollath (Singapore University of Technology and Design)

We study the time evolution of a one-dimensional extended hardcore Bose-Hubbard chain subjected to a generic heating mechanism, effectively described as dephasing in Lindblad form. In particular, we look at the static structure factor, which previous theoretical studies have shown to display a crossover momentum, one that separates a low momentum non-equilibrium regime from a high momentum thermal regime. The crossover momentum is predicted to scale as $\approx t^{4/5}$. We tackle this problem numerically using a Matrix Product States based algorithm and also investigate the effect of interactions and different fillings on the structure factor. We find that the presence of interactions affects the time at which the crossover scale emerges. While the presence of an algebraic scaling is evident for the range of parameters in consideration, the precise value of the power-law is yet to determined due to finite-size effect.

PO.51 Rapid Exosome Detection and Enrichment by Using Microfluidic Hydrodynamic Trapping

Mahnoush Tayebi*, Ye Ai (Singapore university of technology and design)

Exosomes are nano-sized (50-150 nm) membrane-bound extracellular vesicles (EVs) that contain lipids, proteins, microRNAs and mRNAs originating from their parental cells. Exosomes are invaluable biomarkers in cancer diagnostic assessments due to their essential functions not only in cell-cell communication but in causing the tumor proliferation. Probing exosome compositions and functions can be used as a powerful diagnosis, prognosis, and therapy tool. It is therefore crucial to selectively isolate them based on their composition before any molecular characterization. In this work, we aim to isolate and visualize the nanovesicles (NVs) by combining an affinity-based method and hydrodynamic microfluidic particle trapping. Microbeads with 20 μm diameter, first are functionalized with streptavidin and biotinylated antibody, then we immobilize NVs on the surface of the beads by using antigen-antibody affinity binding. We designed a microarray system to efficiently trap 20 μm functionalized microbeads by applying the particle parking principle. We propose this approach to provide a rapid and straightforward capturing and quantification method to analyze EVs based on the target biological application.

PO.57 Surface Molecular Doping of All-Inorganic Perovskite Using Zethrenes Molecules

Arramel*, Hu Pan, Xie Aozhen, Songyan Hou, Yin Xinmao, Chi Sin Tang, Nguyen T. Hoa, Muhammad Danang Birowosuto, Hong Wang, Cuong Dang*, Andrivo Rusydi, Andrew T. S. Wee, Wu Jishan* (National University of Singapore)

We present an optical and photoelectron spectroscopic study to elucidate the interfacial electronic properties of organic-inorganic semiconductor heterojunctions formed in a kinetically blocked heptazethrene (HZ-TIPS) and its homologue, octazethrene (OZ-TIPS) on an all-inorganic perovskite cesium lead bromide (CsPbBr3) surface. Photoemission spectroscopy of the physisorbed HZ-TIPS shows chemical shift, which indicates electron transfer from HZ-TIPS molecules to the CsPbBr3 perovskite single crystal. In contrast, the adsorbed OZ-TIPS molecular layer on CsPbBr3 demonstrates the opposite trend indicating a hole transfer process. The average molecular orientation as determined by near edge x-ray absorption fine structure (NEXAFS) suggests that the HZ-TIPS molecular plane is generally lifted with respect to the perovskite surface. We suggest that the nature of the closed-shell electronic ground state of HZ-TIPS could contribute to the formation of interfacial dipole at the molecule/perovskite interface.

PO.59 Topological Magnon Bands in AFM limit of Shastry-Sutherland Lattice

Dhiman Bhowmick*, Pinaki Sengupta* (Nanyang Technological University)

We studied the topology of the magnon band structure of Shastry-Sutherland lattice(SS-lattice)

in anti-ferromagnetic limit in presence of Dzyaloshinskii-Moriya(DM) interaction and Zeeman field. DM-interaction plays a critical role to give rise the topological feature of the magnon bands. The important result of our study is that, topology of the magnon bands vary widely with the change in different DM-interactions present in the Shastry-Sutherland lattice. Topological magnon bands give rise to magnon-hall effect. Our proposal is that by distorting a Shastry-Sutherland lattice and changing magnetic field, we can get different topological character of magnon Hall effect.

PO.61 Bell nonlocality in the Universes permitting closed timelike curves

Jianlong Lu* (National University of Singapore)

In this paper I focus on Bell nonlocality in the Universes which permit the existence of closed timelike curves. In quantum mechanics and quantum information, Bell nonlocality is an important notion and quantum entanglement provides nontrivial ways for realizing the violation of corresponding Bell inequalities. However, in this paper I would like to argue that, in specific region of the Universes permitting closed timelike curves, the violation of Bell inequalities can be trivial and quantum entanglement is not a necessity for its realization. Here trivialness means the violation of Bell inequalities does not require any known communication channel or quantum entanglement.

PO.63 Quadratic and Cubic Nodal Lines Stabilized by Crystalline Symmetry

Zhi-Ming Yu, Weikang Wu, Xian-Lei Sheng, Y. X. Zhao*, Shengyuan A. Yang* (Singapore University of Technology and Design)

In electronic band structures, nodal lines may arise when two (or more) bands contact and form a one-dimensional manifold of degeneracy in the Brillouin zone. Around a nodal line, the dispersion for the energy difference between the bands is typically linear in any plane transverse to the line. Here, we explore the possibility of higher-order nodal lines, i.e., lines with higher-order dispersions, that can be stabilized in solid state systems. We reveal the existence of quadratic and cubic nodal lines, and we show that these are the only possibilities (besides the linear nodal line) that can be protected by crystalline symmetry. We derive effective Hamiltonians to characterize the novel low-energy fermionic excitations for the quadratic and cubic nodal lines, and explicitly construct minimal lattice models to further demonstrate their existence. Their signatures can manifest in a variety of physical properties such as the (joint) density of states, magneto-response, transport behavior, and topological surface states. Using ab-initio calculations, we also identify possible material candidates that realize these exotic nodal lines.

PO.64 Antimony recovery via nitrogen doped graphene adsorbents for energy storage

Lu Guo, Hui Ying Yang* (Singapore University ofTechnology and Design)

Antimony and its compounds are widely applied in flame retardants, catalysts, pigments and batteries. Yet the pollution of the Sb wastes and the scarcity of Sb resources in nature are two great challenges to humankind. Therefore, we hereby propose an efficient adsorbent nitrogen-doped graphene (NGO) for antimony removal and recovery in wastewater simultaneously. The nitrogen doped graphene is synthesized with a simple hydrothermal method. And chemical bonding between the Sb species and NGO is formed at ambient environment. The chemical bonding facilitates the Sb removal performance and the stability of the post-adsorbents, which in turn improves the energy storage performance of the as-prepared electrodes. This work has provided a promising solution to the scarcity and pollution of antimony species.

PO.70 Quantum State Transportation of Rubidium Atoms inside a Photonic Waveguide

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

Coherent interactions between electromagnetic and matter waves lie at the heart of quantum science and technology. We optically trap cold ^{85}Rb atoms in a hollow-core photonic crystal ber and use the waveguide fields as matter-wave beam splitter and mirror pulses to demonstrate a Mach-Zehnder interferometer. The results suggest that the coherence of a quantum superposition state of atoms can be coherently interrogated by the optical guided mode inside the hollow core fiber. We also experimentally study the ground state coherence properties of ^{85}Rb atoms inside the hollow-core fiber. We find that, the dephasing of atomic ground states is mainly due to the inhomogeneous broadening of differential ac stark shift between the ground states introduced by the optical dipole beams. In order to cancel the differential ac stark shift, we introduce vector light shift by applying an external magnetic field and adjusting polarization of the dipole beams. After the cancellation, we achieve a long coherence time of T=250 ms, and able to maintain the coherence of a quantum superposition state over one centimeter distance of transportation along the optical fiber. The integration of phase coherent photonic and quantum systems here shows great promise to the advance capability of atom interferometers, compact atomic clock, quantum memory and optical fiber quantum network.

PO.75 Quantum Gates with Trapped Ions

Ko-Wei Tseng*, Chi Huan Nguyen*, Jaren Gan*, Gleb Maslennikov*, Dzmitry Matsukevich* (National University of Singapore)

We report on the recent progress in implementation of quantum gates in a system of trapped Ytterbium ions. In the first series of experiment we demonstrate the feasibility of using the motional state of the ions as the information carriers. In particular, we realize a gate that swaps the populations of the two motional modes of the single trapped ion conditioned on ion's internal state. This gate was utilized to prepare the maximally entangled (NOON) state with up to 4 phonons in the motional modes, to perform single shot measurement of a Wigner function and to measure an overlap between two quantum states. We also discuss the applicability of this gate for the universal quantum computing with continuous variables.

In the second series of experiments we demonstrate high fidelity (F=98.1(5)%) entanglement between internal states of two ions using Molmer-Sorensen gate. We discuss the engineering effort needed to scale the system up to many qubits.

PO.76 Effects of Precursor Pre-treatment on the Vapor Deposition of WS_2 Monolayer

Mei Er Pam, Lay Kee Ang, Hui Ying Yang* (Singapore University of Technology and Design)

Transition metal oxide powders have been widely used as the growth precursors for monolayer transition metal dichalcogenides (TMDCs) in chemical vapor deposition (CVD). It has been proposed that metal oxide precursors in gas phase undergo a two-step reaction during CVD growth, where transition metal sub-oxides are likely formed first and then the sulfurization of these sub-oxides leads to the formation of TMDCs. However, the effects of stoichiometry of transition metal oxide precursors on the growth of TMDC monolayers have not been studied yet. In this contribution, we report the critical role of WO_3 precursor pre-annealing process on the growth of WS_2 monolayer. Among all the non-stoichiometric WO_3 precursors, the thermal annealed WO_3 powder exhibits the highest oxygen vacancies concentration and produces WS_2 monolayers with significantly improved quality in term of lateral size, density, and crystallinity. Our comprehensive study suggests that the chemical composition of transition metal oxide precursors would be fundamentally critical for the growth of large-area and high-quality WS_2 monolayers, which further pave the way for revealing their intrinsic properties and unique applications.

PO.78 Topological Hall effect in Shastry-Sutherland lattice

Munir Shahzad*, Nyayabanta Swain*, Pinaki Sengupta* (Nanyang Technological University)

We study the classical Heisenberg model on the geometrically frustrated Shastry-Sutherland lattice with additional Dzyaloshinskii-Moriya (DM) interaction. We show that several non-collinear and noncoplanar magnetic states such as flux, all-out, 3in-1out, canted-flux are stabilized over wide range of parametric space in the presence of DM interaction. We discuss the role of different DM vectors in the stabilization of these complex configurations of localized moments. These ordered states not only drive exotic magnetic properties but also anomalous magneto-transport. The spin of itinerant electron moving on the background of these localized spins acquires a Berry phase which manifests itself by contributing an extra term in Hall conductivity known as geometrical or topological Hall effect. We demonstrate this effect by calculating the energy bands and transverse conductivity for conduction electrons hopping on these localized moments. It is shown that transverse conductivity is non-zero for several of these noncoplanar ordered states even in the absence of magnetic field.

PO.82 Multiagent Learning in Network Zero-Sum Games is a Hamiltonian System

James Bailey*, Georgios Piliouras* (Singapore University of Technology and Design)

Zero-sum games are natural, if informal, analogues of closed physical systems where no energy/utility can enter or exit. This analogy can be extended even further if we consider zero-sum network (polymatrix) games where multiple agents interact in a closed economy. Typically, (network) zero-sum games are studied from the perspective of Nash equilibria.

Nevertheless, this comes in contrast with the way we typically think about closed physical systems, e.g., Earth-moon systems which move along recurrent trajectories of constant energy.

We establish a formal and robust connection between these multi-agent systems and Hamiltonian dynamics – the same dynamics that describe conservative systems in physics. Specifically, we show that no matter the size, or network structure of such closed economies, even if agents use different online learning dynamics from the standard class of Follow-the-Regularized-Leader, they yield Hamiltonian dynamics. This approach generalizes the classic connection to Hamiltonians for the special case of replicator dynamics in two agent zero-sum games.

Moreover, our results provide a type of a Rosetta stone that helps to translate results and techniques between online optimization, convex analysis, games theory, and physics.

PO.83 Iron Metal-Metal-Organic frameworks as superior cathode for Sodium-ion batteries

Rui Zhang* (SUTD)

Metal-organic frameworks(MOFs) represent one of the best examples of materials fabricated with high surface areas, tuneable porosity and inherent presence of coordinated metal and heteroatom.The morphology and the structures of the MoF-based materials make them ideal candidates in energy storage and conversion especially in Sodium battery, lithium battery and super capacitors. Here it is demonstrated that modified iron containing Metal-Organic frameworks can be used as a good cathode material for sodium ion batteries. Iron MoF nano particles are synthesised by the hydrothermal process combined with the modification of the MoF nanoparticles, delivering a high reversible capacity compared with the unmodified iron MoFs. The observed good reversible capacity and excellent rate capability of the modified iron MoF crystallines make this material a good candidate for sodium insertion cathode materials. We make this modification based on the fact that modified porous MoF structure makes the ion transport more effectively compared with the performances of ion transport in pristine iron MoF materials.

PO.85 Hands On Quantum Cryptography Session for Pre-University Students

Adrian Nugraha Utama*, Jianwei Lee, Xi Jie Yeo, Chang Hoong Chow, Ting You Tan, Mathias Seidler (Centre for Quantum Technologies)

We develop a quantum key distribution (QKD) hands-on session suitable for pre-university students. This guided experimental workshop provides a concrete implementation of the BB84 (Bennett and Brassard, 1984) key distribution protocol, along with message encryption and decryption. Students are tasked to assemble the opto-mechanical components, set up the transmission and detection circuits, and run pre-written programs to implement the classical and quantum channels similar to the original protocol. However, to allow for simpler assembly and operation of the experiment, particularly by non-experts, the protocol is implemented with signals at macroscopic intensity levels. This inadvertently opens up a 'side-channel attack' where the quantum channel can be eavesdropped without interrupting the protocol, unlike the case where the protocol is implemented at the level of single photons. Another group of students was tasked to exploit this loophole to eavesdrop on the secret message. The demonstrated vulnerability forces the learner to revisit the basic assumption of the protocol - the quantum no-cloning theorem.

PO.86 Optimization of an Entangled Photon Source for Quantum Key Distribution

Kadir Durak*, Şafak Özçimen (özyeğin university)

In this work, optimization of an entangled photon pair source based on type-1 phase matching spontaneous parametric down-conversion (SPDC) phenomenon in collinear geometry is studied to be exploited in quantum communication applications. The relation between nonlinear crystal length and brightness (entangled photon pairs per second per mW pump power) is examined by directly imaging of down-converted photons with a CMOS camera. The collection of signal and idler modes to a single mode fiber (SMF) is quantified by comparing it to the rate of down conversion events. An experimental technique is proposed for this analysis. It has been observed that the brightness has a linear relationship with the crystal length. However, the percentage of the pairs that can be collected (coupled) to a SMF reduces with increasing crystal length due to the dispersion (walk-off) of the pump (and therefore down-converted modes) within the nonlinear crystal. It has also been observed that the aspheric lens has better collection efficiency compared to achromat. Finally we also show that the fidelity is also better with higher collection efficiency.

PO.89 The Emergence of Chaos in a Simple Game-theoretic Model of Traffic Routing

Thiparat Chotibut*, Fryderyk Falniowski, Michał Misiurewicz, Georgios Piliouras* (Singapore University of Technology and Design)

Without a central authority in a complex communication network, how should one strategize traffic routing so that everyone is satisfied? For decades, computer scientists and economists have developed a game-theoretic framework to analyze a set of stable strategies (Nash equilibria) that self-interested agents shall adopt to maximize their own benefits. Although routing games have been exhaustively studied, standard analyses focus on the properties of equilibria, deemphasizing non-equilibrium dynamics. In this talk, we will show that, even in the simplest textbook example of 2-agent, 2-strategy routing game, how agents dynamically learn and update strategies can render a Nash equilibrium inaccessible. In particular, through the widely employed Multiplicative Weight Update learning algorithm, the agents' dynamics are driven away far from the Nash equilibrium; in fact, a period-doubling bifurcation route to chaos naturally emerges as the learning rate increases. Remarkably, even when the agents' dynamic strategies become chaotic, its ergodic (time) average still coincides exactly with the Nash equilibrium. These results highlight the importance of dynamical aspects in game theory, and suggest that the standard equilibrium analysis may only be meaningful in the ergodic average sense. Lastly, the evidence of Feigenbaum's universality in our non-unimodel map, as well as the emergence of chaos in more complicated routing games will also be discussed.

PO.97 Quasiparticle Levels at Large Interface Systems from Many-body Perturbation Theory: the XAF-GW method

Fengyuan Xuan, Yifeng Chen, Su Ying Quek* (National University of Singapore)

Accurate prediction of quasiparticle levels at interface systems remains a challenging problem. GW calculations which are expected to give quantitative predictions of quasiparticle levels, are typically intractable for large interface systems. In this work, we develop a GW-based approach (which we call XAF (eXpand-chi; Add-chi; Full-sigma)-GW) to compute the energy level alignment of large interface systems without strong covalent interactions. Our only assumption is that the polarizability matrix (chi) of the interface system can be approximated by the sum of chi for the individual components. We show that this approximation is sufficiently general to allow cases where the interface wavefunction is a linear combination of wavefunctions from individual components, as well as cases where bonding and antibonding states are formed between the individual components, such as in bilayer black phosphorus. Further, very large, computational savings are obtained by noting that the chi matrices for individual components of the interface can often be computed for much smaller sub-unit cells, and using an expansion procedure to obtain exactly the chi matrices in the actual supercell. Unlike previously developed embedding approaches for GW, use of XAF-GW enables a proper treatment of weakly hybridized systems and even interfaces with charge transfer.

PO.98 Paradoxical consequences of multipath coherence: Perfect interaction-free measurements

Zhuo Zhao*, Spandan Mondal, Marcin Markiewicz, Adam Rutkowski, Borivoje Dakic, Wieslaw Laskowski, Tomasz Paterek (Nanyang Technological University)

Quantum coherence can be used to infer the presence of a detector without triggering it. Here we point out that, according to quantum mechanics, such interaction-free measurements cannot be perfect, i.e., in a single-shot experiment one has strictly positive probability to activate the detector. We formalize the extent to which such measurements are forbidden by deriving a trade-off relation between the probability of activation and the probability of an inconclusive interaction-free measurement. Our description of interaction-free measurements is theory independent and allows derivations of similar relations in models generalizing quantum mechanics.

We provide the trade-off for the density cube formalism, which extends the quantum model by permitting coherence between more than two paths. The trade-off obtained hints at the possibility of perfect interaction-free measurements and indeed we construct their explicit examples. Such measurements open up a paradoxical possibility where we can learn by means of interference about the presence of an object in a given location without ever detecting a probing particle in that location. We therefore propose that absence of perfect interaction-free measurement is a natural postulate expected to hold in all physical theories. As shown, it holds in quantum mechanics and excludes the models with multipath coherence.

PO.99 Topologically Enhanced Harmonic Generation in a Nonlinear Transmission Line Metamaterial

Wang You*, Lang Li-Jun, Lee Ching Hua, Zhang Baile, Chong Yidong* (Nanyang Technological University)

We demonstrate that harmonic generation in a left-handed NLTL can be greatly increased by the presence of a topological edge state. Our NLTL is a nonlinear analogue of the Su-Schrieffer-Heeger (SSH) lattice. Recent studies of nonlinear SSH circuits have investigated the solitonic and self-focusing behaviors of modes at the fundamental harmonic. We find, however, that frequency-mixing processes in an SSH NLTL have important effects that have previously been neglected. The presence of a topological edge mode at the first harmonic can produce strong higher-harmonic signals that propagate into the lattice, acting as an effectively nonlocal cross-phase nonlinearity. We observe maximum third-harmonic signal intensities that are 5 times that of a comparable left-handed NLTL of a conventional design, and a 250-fold intensity contrast between the topologically nontrivial and trivial lattice configurations. Our work may have applications for compact electronic frequency generators, as well as for advancing the fundamental understanding of the effects of nonlinearities on topological states.

PO.103 Quantum Motional Sensing of Electromagnetically Induced Transparent Medium

Chang Huang, Shau-Yu Lan* (NTU)

Current 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, e.g. Raman transition spectra. 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 realise an atom-based velocimeter that has a sensitivity two orders of magnitude higher than the velocity width of the atomic medium used. In this talk, I will show our current progress and future plan of this new sensing system measuring the motion of the cold atomic medium in the free space and the periodic potential.

PO.104 Amorphous GeTe and negative differential resistance

Jose Martinez*, Robert E Simpson* (Singapore University of Technology and Design)

Amorphous germanium telluride (GeTe) is a well-studied phase change material with a plethora of exciting properties. Perhaps one of its least studied properties is the fact that it displays negative differential resistance (NDR), a phenomenon automatically implying a nonlinear current-voltage (I-V) relationship which can have valuable implications in emerging applications such as neuromorphic circuits, tunable nano-device-based oscillators, etc. First, we describe the I-V relation by making use of a modified Zhang-Ielmini formula [1]

$$I = AT^{(3/2)} e^{-\frac{E_C - E_T}{k_B T}} \sinh\left(\frac{qV}{2u_a}\frac{\Delta z}{k_B T}\right)$$

where T is absolute temperature, $E_C - E_T$ is the activation energy, u_a is the amorphous material thickness, Δz is the inter-trap separation. The sinh function comes from taking the reverse current flow between traps into account. The voltage V, of course, drives the current. It is usually true of amorphous material (and this is so for α-GeTe) that a threshold voltage has to be reached before conduction can take place. Temperature effects are important for NDR and we make use of a convenient form of Newton's cooling law [2]

$T = T_{amb} + R_{th}$ I V

where R_{th} is the effective thermal impedance between the electrically-active region and the environment, which is at temperature T_{amb}.

Fig. 1 Typical I-V characteristic for α-GeTe. Starting point is at 11.8 volts. Parameters are: $E_C - E_T$=0.33 eV; Δz= 6 nm; u_a=30 μm; T_{amb}= 300 K

The basic I-V relation for GeTe is shown in Fig. 1(A) above guided by experimental results obtained from Gwin and Coutu [3]. Figs. 1(B) and (C) give the corresponding values for the parameters A and R_{th} while Fig. 1(D) indicates the calculated temperature variation of the GeTe resistor starting from Tamb = 300K. It is noteworthy to observe that a phase transition to crystalline GeTe occurs at around 351 K [4], which is slightly higher than the maximum temperature given in Fig. 1(D). This implies that our sample of GeTe is amorphous throughout the measurement. Comparison of Figs. 1(A) and 1(C) shows that concomitant with NDR is a decrease in Rth with decreasing voltage while current is increasing. This means that during NDR the Joule heat generated by GeTe is more efficiently radiated away from the sample, i.e., during NDR the sample is cooling. Had the sample heated up, it would have crystallized, which does not occur in our case.

The two-level model [5] pictures clusters of atoms in amorphous structures as switching between two distinct energetic levels separated by activation energy WB; thus, spontaneous transitions between the levels gives rise to current fluctuations. See Fig. 2. From the expression for current we can show that GeTe displays a $1/f^{\gamma}$ current noise spectrum, with $\gamma = 1-(k_BT)/E_B$. This two-level model helps us understand the NDR mechanism for GeTe: an electric field drives electrons on either level to hop over traps. As the transition temperature is approached from below, further hopping is energetically costly because of eventual crystallization. Hence the electrons overcome the activation energy WB, and tunnel to the opposite level from where they can hop over succeeding traps. In general, this second level has a lower barrier than the first and this explains why lower voltage gives rise to increase in current. This is just exactly the mechanism for NDR.

Fig. 2 Potential profile between donor traps I and II in the two-level model. Fluctuations in bond lengths and angles means the potential profile switches between the clear and shaded frames. EC and ET denote conduction and trap energy levels. An electron in state I must overcome a barrier EC – ET to transfer to an unoccupied trap state II.

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PO.105 Designing Solid-state Neural Networks with Chalcogenide Phase-change Materials

Ting Yu Teo*, Li Tian Chew*, Robert E. Simpson (Singapore University of Technology and Design)

The search for new computing schemes that address the inefficiencies of implementing neural networks with conventional von Neumann architectures has gained popularity in recent years. One promising solution involves adapting biological neural networks in computing architectures as such a configuration could suggest the possibilities of (a) co-locating the processor and memory and (b) processing parallel streams of input data. In the current state- of- the- art, chalcogenide-based materials are used to develop artificial neural networks (ANNs) as they exhibit useful electrical and optical properties. However, these works focus on the individual components of the neural networks, ranging from single neuron-to-neuron synaptic communication or neuron functionalities. The implementation of neural networks as a whole, which involves combining a multitude of neurons together, has not been explored extensively. Working towards the goal of producing the next generation of computers, we review the current state- of- the- art and propose a novel solid-state neural network design made of chalcogenide materials.

PO.106 Understanding the chemical enhancement mechanism of graphene-enhanced Raman Spectroscopy – A first principles study.

Kanchan Ajit Ulman*, Su Ying Quek* (National University of Singapore)

Surface-enhanced Raman spectroscopy (SERS), involving the enhancement of Raman signals for molecules on metal substrates, is a well-established field that has enabled the detection of trace concentrations of molecules. In recent years, graphene was found to be a candidate substrate for SERS, giving rise to a rapidly expanding field of graphene-enhanced Raman spectroscopy (GERS), and opening doors for other two-dimensional materials to be used for SERS. In conventional SERS, the Raman signal is enhanced by a combination of the dominant electromagnetic enhancement effect, and the smaller chemical enhancement effect, which stems from electron-phonon coupling in the system. The latter chemical enhancement effect is thought to play a dominating role in GERS, thus enabling detailed studies of electron-phonon coupling effects for organic-graphene interfaces. Yet, the details of the chemical enhancement effect in

GERS are not well understood. Using first principles calculations, we study the GERS chemical enhancement mechanism using typical probe molecules such as pyridine adsorbed on graphene. We uncover a novel ground state enhancement mechanism that is distinct from the typical ground state charge transfer mechanism in conventional SERS.

PO.107 Optically tailored trapping geometries for ultracold atoms on a type-II superconducting chip

Francesca Tosto*, Phyo B. Swe*, Rainer Dumke* (Nanyang Technological University)

Superconducting atom chips have very significant advantages in realizing trapping structures for ultracold atoms compared to conventional atom chips. We extend these advantages further by developing the ability to dynamically tailor the superconducting trap architecture. Heating the chosen parts of a superconducting film by transferring optical images onto its surface we are able to modify the current density distribution and create desired trapping potentials. This method enables us to change the shape and structure of magnetic traps, enabling versatile applications in atomtronics.

PO.108 Tailored Optical Potentials with Bose-Einstein Condensates for Quantum Simulation

Koon Siang Gan*, Wenhua Yan* (Nanyang Technological University)

We use an ultracold atom source and various tunable optical potentials 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 an analogy allows us to explore the effective quantum dynamics of the system in a pure quantum phase dynamics range. 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. We have achieved a B and the integration of atom source and optical ring lattice setup.

PO.109 Microstructuring NbN Superconductor using Pulsed Laser

Manikandan Esakkimuthu*, Sreeja B S, Radha S (SSN COLLEGE OF ENGINEERING)

Superconducting materials are of importance in making highly efficient terahertz components for space applications. The creation of microstructure using laser ablation process was provided. A nanosecond pulsed Nd: YAG laser with the maximum energy of 0.6J was utilized to make microscale features in NbN superconducting material. The material was ablated at different energy levels and the corresponding spectrums were captured with spectrometer through fibre optic cable. The exact energy required to ablate the NbN material was obtained experimentally. The experimental part utilizes 1064nm ns-pulsed laser as a source for ablation. The same process has been repeated in high-pressure conditions of 4atm and 8at in a vacuum chamber. The ablation rate was decreased as the pressure level in the vacuum chamber has been increased; solidification of molten material was observed under high-pressure conditions. The effects of laser intensity and scanning speed in the ablation rate of NbN material have been experimentally verified. The poor thermal conductivity of the NbN makes the nanosecond laser ablation as an effective process for micromachining with minimal heat affected area. The morphological properties of the ablated structure were evaluated using optical microscopic images.

PO.110 Femtosecond Laser Micromachined Terahertz Frequency Selective Surface

Sasi Princy S, Sreeja B S, Manikandan Esakkimuthu* (SSN COLLEGE OF ENGINEERING)

The purpose of this paper is focusing the frequency selective surface (FSS) filter structure which exhibits broadband frequency response operating in the THz frequency regime. The achievement of broadband frequency response is been accomplished by means of only invoking the FSS structure excluding the presence of ground plane and also excluding the multilayered FSS technique. The FSS filter is simulated using CST Microwave Studio. The simulation is been carried out using Teflon as the substrate which is a dielectric over which the conductive material gold of 2µm thickness is coated in which the FSS Filter structure is designed with periodic hexagonal aperture unit cells. The structure of the proposed frequency selective surface filter achieves a broadband frequency response of 300GHz bandwidth centered at 0.36THz. The designed FSS structure is a bandpass filter and it exhibits the most imperative properties of angle resolvability and polarization insensitivity. The fabrication of the same has been done using laser micromachining process.

PO.112 Construction of a Portable Atomic Gravimeter

Fong En Oon*, Rainer Dumke* (Centre for Quantum Technologies)

We are constructing an absolute atomic gravimeter (Rubidium) with the aim to be deployed in remote locations, such as volcanic site to measure gravity changes due to magma flow. The system is designed to be portable and is capable of fully controlled by computer remotely after an initial set-up. We have finished constructed the control system, laser system, spectroscopy system and the main vacuum chamber. We expect to be able to fully assemble the whole systems in the coming one year.

PO.114 Review of electrostatic effects on chalcogenide phase change materials

Meena Rajendran*, Jose Martinez*, Robert E. Simpson* (SUTD)

Electrostatic field induced phase transitions in phase change materials have the potential to improve the efficiency of Phase Change Random Access Memory (PCRAM) devices. Thermally driven PCRAM have recently commercialized by Micron, Samsung, and Intel. However, these devices exploit thermally driven structural transitions. Since heat is the lowest quality form of energy and the phase transitions are induced by joule heating, these devices are accompanied by entropic losses, which limits their switching efficiency. We propose to electrostatically drive phase transitions in PCRAM devices. In this poster, we review electrostatic field induced structural transitions in chalcogenide materials.

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https://www.samsung.com/semiconductor/insights/tech-leadership/the-new-norm-for-escalating-pc-memory-demand

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3. Intel and Numonyx Achieve Research Milestone with Stacked, Cross Point Phase Change Memory Technology

https://newsroom.intel.com/news-releases/intel-and-numonyx-achieve-research-milestone-with-stacked-cross-point-phase-change-memory-technology/#gs.mZQjcaI1

PO.115 Giant streaming currents in 2D nanopores

Yanwen Yuan, Kittipitch Yooprasertchuti, Slaven Garaj* (National University of Singapore)

A nanopore is a pore in a membrane whose radius is comparable to some relevant physical quantities (screening length, hydration radius, molecule size…) leading to qualitatively different behaviors then expected from bulk fluidics and ionics. We explored a new class of nanopores, 2D pores made in atomically thin 2D materials, whose channel length is much smaller than their radius, leading to emergence of new phenomenon. We will present observations of the pressure-driven ionic currents for different ions and physical parameters. The observed streaming currents show giant enhancement, and qualitatively different behaviors, compared to the nanochannels. Finally, we will present theoretical model and discuss different applications of this new phenomenon.

PO.118 Dielectric Screening by 2D Substrates

Keian Noori*, Nicholas Lin Quan Cheng, Fengyuan Xuan, Su Ying Quek* (National University of Singapore)

Two-dimensional (2D) materials are increasingly being used as active components in nanoscale devices. Many interesting properties of 2D materials stem from the reduced and highly non-local electronic screening in two dimensions. While electronic screening within 2D materials has been studied extensively, the question still remains of how 2D substrates screen charge perturbations or electronic excitations adjacent to them. Thickness-dependent dielectric screening properties have recently been studied using electrostatic force microscopy (EFM) experiments. However, it was suggested that some of the thickness-dependent trends were due to extrinsic effects. Similarly, Kelvin probe measurements (KPM) indicate that charge fluctuations are reduced when BN slabs are placed on SiO_2, but it is unclear if this effect is due to intrinsic screening from BN. In this work, we use first principles calculations to study the fully non-local dielectric screening properties of 2D material substrates. Our simulations give results in good qualitative agreement with those from EFM experiments, for hexagonal boron nitride (BN), graphene and MoS_2, indicating that the experimentally observed thickness-dependent screening effects are intrinsic to the 2D materials. We further investigate explicitly the role of BN in lowering charge potential fluctuations arising from charge impurities on an underlying SiO_2 substrate, as observed in the KPM experiments. 2D material substrates can also dramatically change the HOMO-LUMO gaps of adsorbates, especially for small molecules, such as benzene. We propose a reliable and very quick method to predict the HOMO-LUMO gap of small physisorbed molecules on 2D and 3D substrates, using only the quasiparticle gap of the substrate and the gas phase gap of the molecule.

PO.126 Fabrication of Microfluidic Device for Cell Separation using Laser Ablation

Indhu R*, Radha S, Manikandan Esakkimuthu*, Sreeja B S (SSN College of Engineering)

The main objective of the work is to develop a low cost Microfluidic device for cancer cell separation. The Microfluidic device consists of array of holes with 9 µm diameters and a microchannel placed at inlet and outlet with 10µm diameter with 1µm depth. An analysis is made by varying the number of microchannel at inlet and outlet for effective separation of cancer cells along the Microfluidic device. As, the Microfluidic device consists of single inlet and outlet, double inlet and outlet, three inlet and outlet. A physical method of cell trapping is followed here. Cancer cells of 11µm is mixed in a buffer solution and made to pass through. A study is made by analysing the cell separation with the flow of buffer solution through the single, double and three channels in a device.

PO.127 Large time-bandwidth photonic waveguide coupled light storage.

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

Integrating light storage or optical delay line in an optical fibre is an attractive component in connecting long distance optical communication networks. Although silica-core optical fibres are excellent in transmitting broadband optical signals, it is challenging to tailor its dispersive property for long light storage time. Coupling tunable dispersive medium with an optical fibre is promising in supporting high performance optical delay line memory while transmitting the light with small loss. Here, we load cold Rb atomic vapour in an optical trap inside a hollow-core fibre and demonstrate light storage using electromagnetically-induced-transparency (EIT). We achieve over 20 ms of the storage time with 1 MHz bandwidth of the pulse. The storage time-bandwidth product exceeds 10^4. Our long memory built-in optical fibre could be used for buffering and regulating classical and quantum information flow between remote networks.

PO.128 Femtosecond Mid-Infrared Spectroscopy of Polaron Dynamics in a 3D Hybrid Perovskite

Klara Stallhofer*, Matthias Nuber, Walter Wong Pei De, Daniele Cortecchia, Annalisa Bruno, Cesare Soci*, Hristo Iglev (Nanyang Technological University)

The detailed understanding of charge carrier dynamics in materials for next generation solar cells - such as conjugated polymers or perovskites, is essential for engineering and optimizing material characteristics and architecture of the resulting devices. Generation, recombination and dissociation of charged species on time scales from picoseconds down to femtoseconds can be accessed by time resolved visible-pump/infrared-probe spectroscopy. The interplay of vibrational dynamics and electronic excitation in the form of polarons is of special interest in perovskites, where both ‘small’ and ‘large’ polarons - involving the organic cations, have been stipulated. Here we focus on vibrational signatures in the polaron bands of the 3D methylammonium lead iodide (MAPI) perovskite and infer polaron characteristics similar to prototypical conjugated polymers, in which the vibrational modes in the ‘fingerprint’ spectral region allow distinguishing between different polaronic species and observing their distinct dynamics. In MAPI, we find the coexistence of polaron bands with distinct dynamics, pointing to a possible role of traps in polaron localization.

5 Technical Sessions

T1: Atomic Physics I

Time: Wednesday 13 Mar, 11:30am; Venue: tt7; Chair: Alex Ling
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.

T1.74 Continuous Variables Quantum Computing with Trapped Ions

Jaren Gan*, Gleb Maslennikov*, Ko-Wei Tseng*, Chi Huan Nguyen*, Dzmitry Matsukevich* (Centre for Quantum Technologies, Natl. Univ. of Singapore)
11:30am – 11:45am

The current paradigm of employing spin states in atomic-like systems for quantum information encoding suffers from the issue of scalability. For example, it becomes very challenging to control a large number of trapped atomic ions, with each ion representing a physical qubit. An alternative approach would be to exploit the large Hilbert space provided by a harmonic trapping potential, by encoding information in the oscillator states. One would then require gate operations on the oscillator states in order to carry out quantum information processing.

By using sideband-resolved addressing of motional states in a single trapped 171Yb+ ion, we realize a conditional beam splitter (CBS) gate. The CBS Hamiltonian $|e\rangle\langle e|(a^\dagger b + ab^\dagger)$ swaps the quantum states between two motional modes of a trapped ion, conditioned on the ion's internal state. This allows the implementation of a conditional-SWAP gate operation between the encoded states. With the CBS gate, we demonstrate swap tests, implement single shot parity measurements, and generate maximally entangled NOON states. Furthermore, by considering the addition of a single ancilla vacuum mode, the CBS gate can be used to construct a universal exponential-SWAP gate which is used for manipulation of logical qubits encoded in motional modes.

T1.102 Quantum Motional Sensing with Electromagnetically Induced Transparent Medium

Chang Huang, Shau-Yu Lan* (NTU)
11:45am – 12:00pm

Current 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, e.g. Raman transition spectra. 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 realise an atom-based velocimeter that has a sensitivity two orders of magnitude higher than the velocity width of the atomic medium used. In this talk, I will show our current progress and future plan of this new sensing system measuring the motion of the cold atomic medium in the free space and the periodic potential.

T1.119 Hybrid Quantum Systems of Atoms and Superconductors

Long Nguyen*, Christoph Hufnagel*, Alessandro Landra*, Yung Szen Yap*, Thomas Weigner*, Shruti Shirol, Rainer Dumke* (National University of Singapore)

12:00pm – 12:15pm

Quantum computing is at the brink of becoming viable. However still many challenges exist. An efficient platform for quantum computing has to be build on qubit realizations following the DiVincenzo criteria like long coherence times, scalability, high performance gate operations as well as low error readout. One prominent candidate to fulfill this demand are qubits based on superconducting circuits. However compare to other potential candidates like neutral atoms, the coherence time is short. In our experiment, we work towards merging the benefits of superconducting quantum circuits with ultra cold atoms. We store 5×10^8 ^{87}Rb atoms for up to 790s in a cryogenic environment with a base temperature reaching 15mK. On the mK Platform we have installed a superconducting 3D cavity which is able to magnetically store atoms as well as house a in house developed transmon qubit. Based on this setup we have proposed previously a protocol to transfer the state of a superconducting qubit to an neutral atom.

T1.121 Progress on multi-ion optical clock with lutetium ions

Ting Rei Tan*, Rattakorn Kaewuam, Kyle Arnold, Ranjita Sapam, Murray Barrett (National University of Singapore)

12:15pm – 12:30pm

The stability of the current generation of ion-based optical clocks is limited due to the restriction to single-ion operation. Multi-ion operation is complicated by inhomogenous magnetic fields, micromotion-related shifts induced by the trapping radio-frequency field, and electric quadrupole shifts arising from the Coulomb fields of neighboring ions. The $^1S_0$-to-$^3D_1$ clock transition of lutetium ion (^{176}Lu$^+$) has favorable features for multi-ion operation, e.g. low sensitivity to magnetic field, low differential static scalar polarizability, and the quadrupole shifts can be suppressed by appropriate orientation of the applied magnetic field. Here, we report progress on establishing clock operation on a small linear Coulomb crystal of lutetium ions.

T2: Physics of Perovskites

Time: Wednesday 13 Mar, 11:30am; Venue: tt9/10; 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.

T2.80 (INVITED) Perovskites: Ideal Platform for Light Upconversion

Thu Ha Do, Andres Granados del Aguila, Jun Xing, Wen Jie Jee, Lulu Zhang, Qihua Xiong* (Nanyang Technological University)
11:30am – 11:50am

Upconversion photoluminescence refers to the fundamental process where low-energy photons are converted into high-energy ones via consecutive interactions inside a medium. The phenomenon takes place in two distinguishable ways: (i) multiple-photon absorption and (ii) one-photon with the subsequent lattice vibrational (phonon) absorption. So far, photon upconversion has been demonstrated in many semiconductor systems. Especially, lead halide semiconductors with a perovskite lattice have been demonstrated to be an ideal platform for frequency upconverted lasing [2] and optical refrigerators [3]. The underlying mechanisms, however, have not been well understood.

Here, we chose all-inorganic lead halide perovskite nanocrystals as representatives to investigate the light upconversion mechanisms. Specifically, we focus on the ability to provide their own internal thermal energy (phonon) to upconvert light. We find that the phonon-assisted upconversion can occur by extracting an energy of up to 200 meV from the thermal bath, which is equivalent to the total energy of more than ten optical phonons in these materials and highly exceed the maximum ability of direct electron-phonon interaction. Our statistical probability model reveals that after the first few consecutive phonon-absorption steps, the finite optical phonon population would become deficient, leading to a decrease of upconversion luminescence efficiency. In this talk, we will discuss different pathways leading to such extraordinary light upconversion in perovskite semiconductors, which requires not only strong light-matter but also matter-matter interactions.

[1] Y. Xu et al., J. Am. Chem. Soc., 138(11), 3761-3768 (2016). [2] S. T. Ha et al., Nat. Photon. 10, 115 (2015).

T2.90 Thermally Evaporated Perovskite Solar Cells

Annalisa Bruno*, Jia Li, Kurt Vergeer, Xin Yu Chin, Herlina Dewi, Hao Wang, Cesare Soci, Nripan Mathews, Subodh Mhaisalkar (Energy Research Institute @Nanyang Technological Universtity, Singapore)
11:50am – 12:05pm

Metal-halide perovskites are one of the most promising active materials for photovoltaic and light-emitting technologies, due to their excellent optoelectronics properties and easiness/versatility of thin films fabrication. Despite the ever improving in the efficiency[1] and stability [2,3], the scalability and reproducibility of perovskite technology remains the major challenges to be tackled before its' introduction to the existing photovoltaic market.

Here we demonstrate high efficient, large area, planar architecture perovskite solar cells with uniform MAPbI3 perovskite active layer deposited by thermal co-evaporation of PbI2 and MAI. The co-evaporated perovskite thin films are of high quality, pinhole-free and highly uniform, as demonstrated by the large grain sizes, low surface roughness and the long carrier lifetime. The high quality of the perovskite thin films translates to small area ($0.16 cm^2$) solar cell devices with power conversion efficiency above 19 % and high reproducibility. Furthermore the uniformity of the coated perovskite film allows us to demonstrate the first mini-modules with active area larger than 20 cm^2 and geometrical fill factor above 91%, with efficiency exceeding 16%. Our work represent an important step towards the development of high quality and reproducible large area thin films, the main requirements the commercialization of the technology.

[1] https://www.nrel.gov/pv/. [2] G. Grancini et al., Nat. Communications, 8, 15684 (2017) [3] L. Meng et al., Nat. Communications, 9, 5265 (2018)

T2.123 Anisotropy of Photoluminescence Energy and Raman Scatering in Two-Dimensional Hybrid Perovskite

Yulia Lekina*, Jiaxu Yan*, Zexiang Shen* (NTU)
12:05pm – 12:20pm

Two-dimensional (2D) hybrid organic-inorganic perovskites have recently attracted a lot of attention due to their unique optical properties and higher moisture stability in comparison with the three-dimensional (3D) ones. 2D perovskites seem to be promising materials for perovskite LED (PeLEDs) in terms of quantum efficiency, showing EQE up to 11.7% for multiple quantum well structures [1]; solar cells, based on heterostructures of 3D-2D perovskites, exhibit PCEs up to 17-19% [2].

In this talk the properties of recently synthesised 2D imidasolium ethyl ammonium lead iodide ($ImEAPbI_4$) are presented. The material exhibits strong intrinsic in-plane anisotropy due to a folds-like structure, formed by $\langle 110 \rangle$ oriented perovskite folds. Such properties has been previously found in black phosphorous [3,4] and some low symmetry transition metal dichalcogenides [5,6]; detailed analysis of the anisotropy in a 2D perovskite is presented by us here.

To analyze structural anisotropy, angle-resolved Raman spectroscopy was conducted. This method allows to determin the crystal orientation instantly. Besides, in contrast to the normal optical anisotropy where the intensity of the photoluminescence (PL) peak show periodic change with the angle between incident laser polarization and crystallographic axis, we observed periodic variation in the PL peak energy. The phenomenon makes $ImEAPbI_4$ a possible candidate to be used in novel devices, based on anisotropic properties.

References

[1] N. Wang, L. Cheng, R. Ge, S. Zhang, Y. Miao, et al., Nat. Photonics (2016), 10, 699.
[2] Z. Wang, Q. Lin, F., Chmiel, N. Sakai, L. Herz, et al., Nat. Energy, (2017), 6, 17135.
[3] F. Xia, H. Wang, and Y. Jia, Nat. Commun. (2014), 5, 1.
[4] X. Ling, S. Huang, E. H. Hasdeo, L. Liang, et al., Nano Lett. (2016), 16, 2260.
[5] Z. Zhou, B. Wei, C. He, Y. Min, C. Chen, et al., Appl. Surf. Sci. (2017), 404, 276.
[6] Q. Song, H. Wang, X. Pan, X. Xu, Y. Wang, et al., Sci. Rep. (2017) 7, 1.

T3: Valleytronics

Time: Wednesday 13 Mar, 11:30am; Venue: tt8
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.

T3.28 Towards reversible valleytronic computer using two-dimensional Dirac semimetal

Yee Sin Ang*, Shengyuan A. Yang, Zhongshui Ma, Chao Zhang, Lay Kee Ang* (Singapore University of Technology and Design)
11:30am – 11:45am

Due to logical irreverisbility, the energy efficiency of classical Boolean logic gates is fundamentally capped by the Landauer's limit. Here we show that valley degree of freedom in two-dimensional (2D) material can be harnessed to resurrect the logical reversibility of classical two-input Boolean logic gates. The valley index manifests macroscopically in the electrical current as three distinct polarization states: two opposite valley polarizations plus one null state. These triplet of valley polarization states can be used to encode additional information, thus removing all ambiguity and recovering logical reversibility in Boolean logic gates. We use 2D Dirac semimetal as a toy model to demonstrate three fundamental valleytronic building blocks: valley filter, valve, and logic gates. We show that the all-important universal reversible gate, such as the NAND gate, can be realized using this valleytronic approach. Our findings provide a Beyond CMOS valleytronic-route towards ultimately energy-efficient classical reversible computing.

*This work is supported by A*STAR IRG (A1783c0011) and AFOSR AOARD (FA2386-17-1-4020).

T3.65 Electron transport on magnetic skyrmion backgrounds in two-dimensional chiral magnets.

Nyayabanta Swain*, Munir Shahzad, Pinaki Sengupta (Nanyang Technological University)
11:45am – 12:00pm

Magnetic skyrmions are observed in bulk samples of several chiral-lattice magnets with the Dzyaloshinskii-Moriya (DM) interaction. Recent experiments on thin films of such magnets confirm the enhanced stability of the skyrmion phase in two-dimensional (2D) systems. Inspired by this, we study classical spins on 2D lattices with ferromagnetic exchange and DM interaction under an external magnetic field with Monte Carlo simulations. We find a rich phase diagram containing helical and skyrmion phases, which turn into a polarised ferromagnetic phase under strong magnetic field. We then look into the electron transport on these backgrounds by coupling the local moments to the conduction electrons. The skyrmion phase has a nonzero spin chirality, and acts as an emergent magnetic field giving rise to anomalous Hall conductivity. With our calculation, we establish the detailed thermal dependence of the Hall conductivity on the skyrmion phase.

T3.79 Optical spin control in reduced-dimensional chiral perovskite

Guankui Long, Weibo Gao*, Qihua Xiong*, Edward H. Sargent* (University of Toronto)
12:00pm – 12:15pm

Hybrid organic-inorganic perovskites exhibit strong spin-orbit coupling, spin-dependent optical selection rules, and large Rashba splitting. These characteristics make them promising candidates for spintronic devices with photonic interfaces. Here we report that spin polarization in perovskites can be controlled through chemical design as well as magnetic field. We obtain both spin-polarized photon absorption and spin-polarized photoluminescence in reduced-dimensional chiral perovskites through combined strategies of chirality transfer and energy funneling. A 3% spin-polarized photoluminescence is observed even in the absence of an applied external magnetic field owing to the different emission rates of sigma+ and sigma-polarized photoluminescene.[1] Three-dimensional perovskites achieve a comparable degree of photoluminescence polarization only under an external magnetic field of 5 T.[2] Our findings pave the way for chiral perovskites as powerful spintronic materials.

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[2] C. Zhang, D. Sun, C. X. Sheng, Y. X. Zhai, K. Mielczarek, A. Zakhidov and Z. V. Vardeny, Nature Physics 2015, 11, 427.

T3.92 Measurement geometry and light polarization dependence of photocurrent in 2D semiconductors

Mustafa Eginligil* (Nanjing Tech University)
12:15pm – 12:30pm

Photocurrent (PC) measurements of 2D semiconductors can be performed in two different geometries: two-probe (with light field parallel or perpendicular to the electrodes) and four-probe Hall bar configuration. Polarized light can lead to several PC contributions in two-probe geometry depending on light field being perpendicular (longitudinal) or parallel (transverse) to the electrode. An elliptically polarized light can have circularly polarized state or linearly polarized state. For circularly polarized light excitation in transverse geometry with an oblique incidence, the PC can be mainly due to the circular photogalvanic effect (CPGE); while in longitudinal geometry, the PC is due to the linear PGE or linear photon drag effect. For the Hall bar configuration the optical field is perpendicular to the sample plane and light induced Hall PC can be observed by both linearly and circularly polarized excitations. In a monolayer semiconductor, MoS_2 has a direct band gap in the visible range in K valley, broken inversion symmetry and strong spin orbit coupling. In two-probe transverse geometry, the CPGE current is expected to be as a result of giant spin-valley coupling which can be controlled by circularly polarized light and global back-gating. In this work, we discuss the CPGE current polarization observed for excitation on–resonance with exciton as well as a large on-off ratio of CPGE current as a function of carrier density. Also we present our recent PC measurements in the Hall bar geometry in doped monolayer MoS_2.

T4: Quantum Communication

Time: Wednesday 13 Mar, 2:00pm; Venue: tt7; Chair: Shau Yi Lan
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.

T4.6 Symmetrical clock synchronization with time-correlated photon pairs

Jianwei Lee*, Lijiong Shen, Alessandro Cerè, James Troupe, Antia Lamas-Linares, Christian Kurtsiefer (Centre for Quantum Technologies)
2:00pm – 02:15pm

We demonstrate a point-to-point clock synchronization protocol based on bidirectionally exchanging photons produced in spontaneous parametric down conversion (SPDC). The technique exploits tight timing correlations between photon pairs to achieve a precision of 51 ps in 100 s with count rates of order 200 per second. The protocol is distance independent, secure against symmetric delay attacks and provides a natural complement to techniques based on Global Navigation Satellite Systems (GNSS). The protocol works with mobile parties and can be augmented to provide authentication of the timing signal via a Bell inequality check.

T4.14 Nonlocal dispersion compensation over buried telecommunications fiber

James A Grieve*, Yicheng Shi, Hou Shun Poh, Christian Kurtsiefer, Alexander Ling (Centre for Quantum Technologies)
02:15pm – 02:30pm

Photon pairs produced by spontaneous parametric downconversion (SPDC) can experience nonlocal compensation of chromatic dispersion when each photon experiences dispersion of opposite sign. This is a direct consequence of the energy anticorrelation of photons entangled in the time-energy basis.

Both positive and negative dispersion coefficients are present in the O-band of standard single-mode telecommunications fiber, on either side of the zero dispersion wavelength (ZDW). When broadband photon pairs are engineered to be degenerate about this point, they experience dispersion compensation without the need for specialized dispersive elements.

We show that this effect can even be observed when photons are propagated over fiber loops deployed in a metropolitan environment. These fibers comprise multiple segments with varying ZDW, and compensation is observed without active tuning of the SPDC source. Techniques such as these will help guide engineering decisions as we transition quantum optics from the laboratory to real-world applications.

T4.22 Coherent fibre network stabilized with single-photons

Salih Yanikgonul*, Ruixiang Guo, Anton N. Vetlugin, Angelos Xomalis, Giorgio Adamo, Cesare Soci, Nikolay I. Zheludev (Nanyang Technological University)
02:30pm – 02:45pm

Development of in-fibre networks operating at the single-photon level is a key step towards robust long-distance quantum communication. The major parts of such networks are quantum light source, fiber-integrated optical elements, single-photon detectors and correlation measurement which imposes stringent requirements on phase stability of the network. Here, we report on a novel phase stabilization technique based on single-photon counting available in these networks. Compared to the conventional stabilization methods our approach requires no additional optical elements and equipment for feedback signal, and hence it allows significant simplification of the optical setup and increased overall scheme efficiency. A phase stability of 0.07 radian is demonstrated in a Mach-Zehnder single-photon interferometer with the length of each interferometer arm of around 20 meters, which implies that the optical path length fluctuation is maintained as small as about 9 nm between interfering arms. As an application example of the proposed stabilization technique, we demonstrate all-optical single-photon switch in a fiberized quantum network by exploiting quantum coherent perfect absorption phenomenon.

T4.96 Almost-tight and versatile security analysis of measurement-device-independent quantum key distribution

Ignatius William Primaatmaja*, Emilien Lavie, Koon Tong Goh, Chao Wang, Charles Ci Wen Lim (Centre for Quantum Technologies)
02:45pm – 03:00pm

Measurement-device-independent quantum key distribution (MDI-QKD) is the only known QKD scheme that can completely overcome the problem of detection side-channel attacks. Yet, despite its practical importance, there is no standard approach towards computing the security of MDI-QKD. Here, we present a simple numerical method that can efficiently compute almost-tight security bounds for any discretely modulated MDI-QKD protocol. To demonstrate the broad utility of our method, we use it to analyze the security of coherent-state MDI-QKD, decoy-state MDI-QKD with leaky sources, and a variant of twin-field QKD called phase-matching QKD. In all of the numerical simulations (using realistic detection models) we find that our method gives significantly higher secret key rates than those obtained with current security proof techniques. Interestingly, we also find that phase-matching QKD using only two coherent test states is enough to overcome the fundamental rate-distance limit of QKD. Taken together, these findings suggest that our security proof method enables a versatile, fast, and possibly optimal approach towards the security validation of practical MDI-QKD systems.

T4.84 Designing a Quantum Cryptography Workshop for Junior College Students

Adrian Nugraha Utama, Jianwei Lee*, Mathias Seidler (Center for Quantum Technologies)
03:00pm – 03:15pm

We designed a 3 hour experimental workshop exploring quantum key distribution (QKD) based on the BB84 protocol. During the workshop, participants were guided to assemble the hardware and run pre-written programs, and were tasked to operate both the classical and quantum channel to send a secret message to another party. Participants were equipped with the basic knowledge for building the system from scratch, allowing them to achieve a better understanding of cryptographic concepts. Our hands-on approach made learning fun and was well received by junior college students.

T5: Metamaterials and Photonics

Time: Wednesday 13 Mar, 2:00pm; Venue: tt9/10
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.

T5.20 Terahertz-optical intensity grating for creating high-charge, attosecond electron bunches.

Jeremy Lim*, Chong Yidong*, Wong Liang Jie* (SINGAPORE INSTITUTE OF MANUFACTURING TECHNOLOGY, A*STAR)
2:00pm – 02:15pm

Ultrashort electron bunches are useful for applications like ultrafast imaging, coherent radiation production, and compact sources of accelerated electrons. Currently, however, the shortest achievable bunches, at attosecond time scales, have only been realized in the single or very few electron regime, limited by Coulomb repulsion and electron energy spread. We will present ab initio simulation results and theoretical analysis which show that highly-charged bunches are achievable by subjecting moderately-relativistic (few MeV-scale) electrons to a superposition of terahertz and optical pulses. Using realistic electron bunches and laser pulse parameters which are within the reach of current compact setups, we provide two detailed examples: one with final bunches of $\sim$1 fC contained within sub-400 as durations and 8 micron radii, and one with bunches of $>$25 electrons contained within 20 as durations and 15 micron radii. Our results reveal a route to achieve such extreme combinations of high charge and attosecond pulse durations with existing technology.

T5.52 Selection of Ag nanocubes for plasmonic enhancement applications: A simulation study

Mohammad Tavakkoliyaraki*, Bin Liu, Yen Nee Tan (Department of Chemical and Biomolecular Engineering, National University of Singapore(NUS))
02:15pm – 02:30pm

Plasmonic engineering the optical properties of a molecule located in the vicinity of a metal nanoparticle could lead to several-fold enhancement in either fluorescence, singlet oxygen generation or Raman scattering of the molecule. Developing colloidal metal-enhanced fluorescence (MEF), metal-enhanced singlet oxygen generation (ME-SOG) and surface-enhanced Raman scattering (SERS) systems based on anisotropic silver nanoparticles, e.g., silver nanocubes, is of importance for various bioapplications. Among the effective factors on the efficiency of the applications above, the size and interparticle gap distance of metal nanoparticle strongly influence the enhancement factor, which must be optimized for each fluorophore/photosensitizer. Here, we systematically studied the optical properties of single silver nanocubes and silver nanocube dimers as a function of their size and size/gap distance, respectively to create a benchmark to select the best parameters that maximize the enhancement factor. Based on the multipole expansion of the extinction spectra and the simulated electric field data, the maximum enhanced electric field in single silver nanocubes is mainly determined by electric quadrupole mode. This study provides the understanding for the design and application of Ag nanocubes for the enhancement of near-field phenomena such as MEF, ME-SOG, and SERS with minimum experimental work to achieve the maximum enhancement factor for each application.

T5.73 Electrically programmable terahertz diatomic metamolecules for chiral optical control

Longqing Cong*, Prakash Pitchappa, Nan Wang, Ranjan Singh (Nanyang Technological University)

02:30pm – 02:45pm

Optical chirality is central to many industrial photonic technologies including enantiomer identification, ellipsometry-based tomography and spin multiplexing in optical communications. However, a substantial chiral response requires a three-dimensional constituent, thereby making the morphology highly complex to realize structural reconfiguration. Moreover, an active reconfiguration demands intense dosage of external stimuli that pose a major limitation for on-chip integration. Here, we report a low bias, electrically programmable synthetic chiral paradigm with a remarkable reconfiguration among levorotatory, dextrorotatory, achiral, and racemic conformations. The switchable optical activity induced by the chiral conformations enables a transmission-type duplex spatial light modulator for terahertz single pixel imaging. The prototype delivers a new strategy towards reconfigurable stereoselective photonic applications, and opens up avenues for on-chip programmable chiral devices with tremendous applications in biology, medicine, chemistry, and photonics.

T5.95 Multi-level security devices based on gap plasmons in native alumnium oxide

Ray Jia Hong Ng*, Joel K. W. Yang*, Ravikumar Venkat Krishnan, Jinfa Ho, Zhaogang Dong, Qifeng Ruan, Hailong Liu, Kin Leong Pey (Singapore University of Technology and Design)

02:45pm – 03:00pm

Visible security prints are useful for many applications, such as anti-counterfeiting, authentication and encoding product information. To enhance the complexity of such prints and to encode multiple sets of information, they can be extended to be observable under other wavelength regions and illumination conditions. Here, we developed aluminium (Al) metal-insulator-metal (MIM) nanostructures with resonances spanning the ultraviolet (UV) to infrared (IR) spectra for use in micro-tags with varying colours of similar brightness, and containing up to three sets of information in the visible bright field, visible dark field and IR.

The insulator in the MIM structures consist of native Al_2O_3 on Al films measured to be $\sim$4–7 nm thick. This thin oxide layer enables gap plasmon resonances to be supported by Al disks with diameters merely $\sim$1/6th of the wavelength at the fundamental mode. Larger disks can also support third- and fifth-order resonances that occur at visible wavelengths, while the fundamental mode occurs at near-infrared wavelengths. When viewed under dark field illumination, the disks also have distinct colours that are dependent on both the periodicity and size of the disks.

Using accurate modelling of the nanostructures and high-resolution electron-beam lithography, we designed and fabricated a printed micro-tag on silicon consisting of two pairs of disk diameters and periodicities. This micro-tag requires image processing to extract a quick response (QR) code in the visible, and 1.2 µm IR illumination (or visible light dark field imaging) to extract a covert barcode. A third distinct image can also be produced by incorporating an additional pair of disk diameters and periodicities.

T5.122 Scalable Selective Nanophotonics with Subwavelength Gratings and Metal Hole Arrays

Ding Ding*, Mohamed Asbahi, Wei He, Hong Xie (IMRE, A*STAR)
03:00pm – 03:15pm

Sub-wavelength photonics can manipulate light in unconventional and interesting ways. Photonic designs with periodic hole arrays and subwavelength gratings are structurally simple, making them some of the earliest designs to be studied. At the same time, both types of structures have exhibited novel physics involving optical interference. For hole arrays, selective transmission is a result of extraordinary transmission. For subwavelength gratings, selective transmission is a result of coupled-mode theory. Here, we design and fabricate both metallic hole arrays and all-dielectric subwavelength grating structures with simulation and experiment. Scalable manufacturing of designs are taken into account and interesting physics were discovered at the same time . Our work paves way for future work in scalable all-metallic and all-dielectric based photonic structures.

T5.124 Tellurium Metamaterials

Robert Edward Simpson*, Li Lu*, Weiling Dong* (Singapore University of Technology and Design)
03:15pm – 03:30pm

Chalcogenide materials are being explored for tuning both dielectric and plasmonic metamaterials, however there are no reports of elemental chalcogen metamaterials. Here we show that metamaterials with resonance in the visible spectrum can be designed from elemental Tellurium. Visible metamaterials typically exploit noble metals, which tend to have plasmon resonances in the visible or near infrared. It is interesting, therefore, that the dielectric function of elemental Te appears to have resonant features in the visible spectrum. Indeed, its complex dielectric function shows a negative real component at visible frequencies, whilst the imaginary component is positive. We have designed, fabricated, and characterized a pure Te metamaterial which has resonates in the visible spectrum. These results will be discussed in this presentation.

T6: Many-Body Physics

Time: Wednesday 13 Mar, 2:00pm; Venue: tt8; Chair: Justin Song
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.

T6.10 Unidirectional propagation of exciton-polaritons in exciton-polariton lattice

Subhaskar Mandal*, Timothy C. H. Liew*, Ge Rongchun (Nanyang Technological University)
2:00pm – 02:15pm

Nontrivial topology ensures the existence of chiral edge states, which propagate in opposite directions and eliminate backscattering [1]. Even though the field of topological physics has advanced significantly, due to the presence of counter-propagating edge states the control over the flow of information (charge/spin) from one side to the other side of a device has remained a challenge. This problem can be overcome if both the edge states propagate in the same direction.

Under resonant excitation we consider exciton-polariton honeycomb lattice ribbon structure with zigzag edge. The system can be described by the driven dissipative Gross-Pitaevskii equation [2]. By choosing the pump profile we can drive the system to a stationary state (mean field) of our choice. Then we consider the Bogoliubov fluctuations over the mean filed. From the Bogoliubov spectrum we find that the two Dirac points are shifted in energy and connected by two edge states, as a result both the edge states gain a same effective group velocity, i.e. both edge modes propagate in the same direction. Since the edge states are spatially separated from the bulk modes, we therefore expect the back-scattering of the edge modes to be strongly suppressed. We believe our work paves the way for new optoelectronic devices exploiting the one way characteristic for more efficient transport of information.

References

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[2] C. E. Bardyn, T. Karzig, G. Refeal, and T. C. H. Liew, Phys. Rev. B. 93, 020502(R) (2016).

T6.38 Heat current rectification and mobility edges

Vinitha Balachandran*, Stephen R. Clark, John Goold, Dario Poletti (Singapore University of Technology and Design)
02:15pm – 02:30pm

Controlling heat transport at nano-scale is key to design of chips and thermoelectric applications. We investigate how the presence of a single-particle mobility edge in a system can generate strong heat current rectification. Specifically, we study a quadratic bosonic chain subject to a quasiperiodic potential and coupled at its boundaries to spin baths of differing temperature. We find that rectification increases by orders of magnitude depending on the spatial position in the chain of localized eigenstates above the mobility edge. The largest enhancements occur when the coupling of one bath to the system is dominated by a localized eigenstate, while the other bath couples to numerous delocalized eigenstates. By tuning the parameters of the quasiperiodic potential it is thus possible to vary the amplitude, and even invert the direction, of the rectification.

T6.56 Numerical Simulations of Quantum Boltzmann Transport Equation using Discontinuous Galerkin Method

Satyvir Singh*, Marco Battiato* (Nanyang Technological University)
02:30pm – 02:45pm

The present work deals with the numerical simulations for Quantum Boltzmann transport equation in the context of electron transport at nanoscales under strongly out-of-equilibrium conditions. Quantum Boltzmann transport equation describes the incoherent time evolution of a quantum system consisting of a large number of quasiparticles (for instance electrons, phonons, excitons) and their interactions. Due to the high number of dimensions (six dimensions in phase space and one dimension in time) and their intrinsic physical properties (in particular the non-parabolicity of the momentum-energy dispersion), the construction of numerical method represents a challenge and requires a careful balance between accuracy and computational complexity.

Among traditional high-order methods, the discontinuous Galerkin methods have received increasing attention as a numerical technique for predicting the flow behavior of gas dynamics problems. In this present work, we proposed an explicit modal discontinuous Galerkin method for solving the Quantum-Boltzmann transport equation. The transport equations are discretized in space, momentum and time for one-dimensional systems and applied to the description of electron transport in single-walled carbon nanotubes and non-linear dynamic conductivity. The method presented herein is generalizable to higher dimensions, and heterogeneous devices.

T6.93 Density-potential functional theory for atoms, molecules, solids, and quantum gases

Martin-Isbjoern Trappe*, Jun Hao Hue, Tri Chau Thanh, Derek Ho, Shaffique Adam, Sergei Manzhos, Berthold-Georg Englert (Centre for Quantum Technologies)
02:45pm – 03:00pm

We apply a versatile variant of orbital-free density functional theory, density-potential functional theory (DPFT), to atoms, molecules, solids, and quantum gases. 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 use recently developed systematic semiclassical approximations of energies and particle densities to describe concrete interacting fermion systems. By design the single-particle densities employed here can be improved systematically beyond the Thomas-Fermi approximation and can be used for efficiently addressing inhomogeneous interacting systems due to the favorable quasi-linear (even sub-linear for some systems) scaling of DPFT with particle number. DPFT yields self-consistent interacting particle densities in a spirit similar to the Kohn-Sham scheme, but circumvents the need for orbitals and does not require an explicit density functional for the kinetic energy. These features put DPFT in the position to become a real alternative to established many-body techniques, and here we showcase a number of its real-world applications.

T6.94 Phase diagram of strongly interacting electron-phonon systems in one and two dimensions

George Batrouni* (Majulab, INPHYNI, University of Nice and CQT)
03:00pm – 03:15pm

We use quantum Monte Carlo (QMC) methods to study the phase diagrams of one- and two-dimensional models of strongly interacting electron-phonon systems at half filling. The electrons are governed by the Hubbard Hamiltonian while their interaction with the phonon field can be short or long ranged. In the one dimensional case, we also study the effect of electron-electron interaction. In one dimension, we find the system to exhibit charge density waves (CDW) and metallic phases as well as phase separation; in two dimensions, we only find CDW and phase separation.

T7: Classical and Quantum Optics

Time: Wednesday 13 Mar, 4:00pm; Venue: tt7
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.

T7.55 (INVITED) Superlight inverse Doppler effect

Baile Zhang* (Nanyang Technological University)
4:00pm – 04:20pm

The Doppler effect is one of the most fundamental mechanisms in physics and has vast applications in fields as varied as weather and aircraft radars, satellite global positioning systems, blood flow measurement in unborn fetal vessels, laser vibrometry, and the detection of extrasolar planets. There is a century-old tenet that the inverse Doppler frequency shift of light is impossible in homogeneous materials with a positive refractive index. We break this long-held tenet by predicting a new kind of inverse Doppler effect of light, which occurs as long as the radiation source moves with a velocity larger than twice the phase velocity of light. We denote this as the superlight (i.e., superluminal) inverse Doppler effect. We further extend this phenomenon into negative refractive index materials. Since inverse Doppler effect and inverse Cherenkov radiation were both predicted in negative refractive index materials, it is interesting to find their combination in the newly studied phenomenon.

T7.16 Sampling an integrated quantum optics chip with a single pixel camera

James A Grieve*, Filip Auksztol, Kian Fong Ng, Paul Thrane, Li Xi, Yi Wei Ho, José Viana-Gomes, Alexander Ling (Centre for Quantum Technologies)
04:20pm – 04:35pm

Integrated photonic devices have been used successfully in a number of large-scale quantum optics experiments involving the propagation of single photons and photon pairs through evanescently coupled waveguides. While chip packaging techniques can be used to efficiently read out these devices, the typical chip contains a large number of closely spaced output modes that can prove challenging for conventional fiber-coupling techniques.

We have developed an approach based on single-pixel camera technology, in which the output plane of the waveguide device is imaged onto either one or two single photon detectors via a digital micromirror device (DMD). In this scheme, the DMD acts as a computer-controlled mask, allowing us to reconstruct the photons' spatial distribution in the focal plane using computational imaging techniques. We demonstrate our approach by imaging the output of a linearly coupled waveguide array, utilizing compressed sensing schemes to mitigate the losses inherent to this approach.

T7.23 Metamaterial absorber for dual-rail photonic qubit filtering

Anton Vetlugin*, Salih Yanıkgonul*, Ruixiang Guo*, Angelos Xomalis*, Giorgio Adamo*, Cesare Soci*, Nikolay Zheludev* (University of Southampton)
04:35pm – 04:50pm

We demonstrate manipulation of a photonic qubit, encoded in a dual-rail basis, by a plasmonic metamaterial absorber. The metamaterial is designed in a way to transmit a single photon, occupying anti-symmetric superposition of two spatial modes, without losses and to absorb its symmetric superposition completely. Thus, whatever the input state of the dual-rail photon, it can leave the absorber in anti-symmetric state only. Probability to pass through the absorber is defined by the amplitude of the anti-symmetric part in the input photon state. To verify this phenomenon, we assembled actively stabilized in-fibre quantum network containing fully-fiberized metamaterial package. By altering the input state of the photon propagating in the network and passing through metamaterial, we measure the output state of the photon and show that it is coherent and does not depend on the input state of the photon. By varying the input state, we also affect the probability of the photon to pass through the absorber. All the results are in a good agreement with the above discussion. We notice, that absorber can be designed in an opposite way: to transmit symmetric state and to absorb anti-symmetric one. Proposed devices can be employed in quantum computation schemes with dual-rail encoding as well as in other protocols of quantum information, operating with single photons or weak coherent states.

T7.26 Polarization effects in the nonlinear interference of biphotons

Anna Paterova*, Hongzhi Yang, Chengwu An, Dmitry Kalashnikov, Leonid Krivitsky (Institute of Materials Research and Engineering A*STAR)
04:50pm – 05:05pm

Nonlinear interference of spontaneous parametric down-conversion photons (SPDC) has been studied over the last few decades, and has been demonstrated to have applications in the infrared (IR) spectroscopy, IR imaging and IR optical coherence tomography. In this work we study polarization effects of the nonlinear interference of biphotons. It is shown that due to the effect of induced coherence, the interference pattern for the signal SPDC photons dependents on the polarization rotation of idler SPDC photons. Based on this concept, we realize two new methods for a measurement of sample's retardation in the IR range by using well-developed and inexpensive components for visible light. The developed IR polarimetry technique is relevant to material research, optical inspection, and quality control.

T7.33 Spectral Compression of Narrowband Single Photons with a Near Resonant Cavity

Mathias Seidler*, Xi Jie Yeo, Alessandro Cerè*, Christian Kurtsiefer* (Centre for Quantum Technologies, NUS and Department of Physics, NUS)
05:05pm – 05:20pm

We compress the spectrum of narrowband heralded single photons generated by four-wave mixing in cold ^{87}Rb atoms [1] using a near-resonant cavity as a dispersion medium, without reducing the brightness and almost matching the atomic linewidth.

Efficient atom-light interaction at the single quantum level requires matching the bandwidth of the traveling photon with the atomic absorption linewidth. A common way to match the two bandwidths is to narrow the single photon spectrum with a filter, with the unavoidable consequence of reducing the brightness. Inspired by techniques to compress ultra-fast pulses [2, 3] we developed a method to compress the bandwidth of already narrowband photons using an asymmetric cavity as dispersion medium without, in principle, reducing the brightness.

1. B. Srivathsan, G. K. Gulati, B. Chng, G. Maslennikov, D. Matsukevich, and C. Kurtsiefer, Narrow Band Source of Transform-Limited Photon Pairs via Four-Wave Mixing in a Cold Atomic Ensemble," Phys. Rev. Lett. 111, 123602 (2013).

2. J. Lavoie, J. M. Donohue, L. G. Wright, A. Fedrizzi, and K. J. Resch, Spectral compression of single photons," Nature Photonics 7, 363 EP – (2013).

3. M. Karpinski, M. Jachura, L. J. Wright, and B. J. Smith, Bandwidth manipulation of quantum light by an electro-optic time lens," Nature Photonics 11, 53–57 (2017).

T8: Optical Materials

Time: Wednesday 13 Mar, 4:00pm; Venue: tt9/10
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.

T8.117 (INVITED) Application of phase change materials in photonic devices

Weiling Dong*, Robert Simpson* (Singapore University of Technology and Design)
4:00pm – 04:20pm

Controlling light-matter interactions has applications ranging from sensing, imaging, lighting and communications. Metamaterials, for example, provide a tailorable route to manipulating light-matter interactions. However, their optical response is usually fixed after the structure is formed. To modulate these responses, it is necessary to either mechanically change the configuration of the metamaterial's nanostructures or use materials with a changeable refractive index. Chalcogenide phase change materials (PCMs) can exhibit tuneable optical constants, and are, therefore, promising candidate materials for active photonics. In particular certain PCMs exhibit high optical contrast, fast switching speed, good cyclicality, as well as non-volatile switching. We have demonstrated a tunable phase change metamaterial enabled by $Ge_2Sb_2Te_5$ that can be tuned over a broad frequency band in the mid-infrared (M-IR) from 3 to 6 µm. We engineered the peak transmission wavelength by controlling the geometry of the metamaterial's features. In addition, by actively switching the structural state of the $Ge_2Sb_2Te_5$, the metamaterial's response can be tuned post-fabrication.[1] This tuneable metamaterial configuration is well suited to the M-IR spectrum, but the main issue with this metamaterial is that it strongly absorbs light in the visible spectrum. Therefore, we have also developed tuneable optical structures based on Sb_2S_3. Sb_2S_3 has a wide optical band gap and exhibits a large ΔRe(n) at visible frequencies. We have shown that by using Sb_2S_3 in a simple optical resonator, the resonant frequency can be easily tuned by inducing a phase transition in Sb_2S_3.[2] The maximum resonance shift was 110 nm.[2] We invoked the phase transition by both optical and electrical heating.[2] We, therefore, conclude that $Ge_2Sb_2Te_5$ is an excellent choice for tuning non-volatile photonic devices in the infrared, whereas Sb_2S_3 is more suitable for tuning visible photonics.

T8.71 Hourglass Weyl Loops in Two-dimensional GaTeI Family Materials

Weikang Wu*, Yalong Jiao, Bo Tai, Si Li, Xian-Lei Sheng, Zhi-Ming Yu, Shengyuan A. Yang (Singapore University of Technology and Design)
04:20pm – 04:35pm

Nodal loops in two-dimensional (2D) systems are typically vulnerable against spin-orbit coupling (SOC). Here, we explore 2D systems with a type of doubly degenerate nodal loops that are robust under SOC and feature an hourglass type dispersion, which may be termed as hourglass Weyl loops. We present symmetry conditions for realizing such loops, which involves the presence of a nonsymmorphic glide mirror symmetry. For two types of mirrors, we find hourglass Weyl loops with two different topologies in the BZ. Based on first-principles calculations, we identify the monolayer GaTeI-family materials as a realistic material platform to study the hourglass Weyl loops. Interestingly, besides one hourglass Weyl loop circling around a high-symmetry point, these materials also possess a spin-orbit Dirac point enabled by an additional screw axis. We show that the Weyl loop and the Dirac point are robust under a variety of applied strains. By breaking the screw axis, the Dirac point can be transformed into a second Weyl loop. Furthermore, by breaking the glide mirror, the hourglass Weyl loop and the spin-orbit Dirac point can both be transformed into a pair of spin-orbit Weyl points. Our work offers guidance and realistic material candidates for exploring fascinating physics of several novel 2D emergent fermions.

T8.72 d-Orbital Topological Materials

Xian-Lei Sheng*, Zhi-Ming Yu, Shengyuan Yang* (Singapore University of Technology and Design)
04:35pm – 04:50pm

It is well known that zinc blende HgTe is a zero gap topological semimetal. Its low energy states are dominated by Te-p orbitals. After including spin-orbit coupling (SOC), the p orbitals split into doublet j=1/2 states and quartet j=3/2 states, with the later at higher energy. The Fermi level crosses the j=3/2 states exactly by half filling. If the sign of SOC were changed, the double j=3/2 states would have higher energy and the system would become a topological insulator. In this talk, we will show the sign change of SOC induced topological phase transition in materials with zinc blende, antifluorite and wurtzite structures. It is found that Cu2S with antifluorite structure is a topological insulator with negative SOC [1]. Cu2Se and CuAgSe are topological semimetals with positive SOC similar to HgTe. By applying uniaxial strain, CuAgSe becomes a idea Weyl semimetal with four pairs of Weyl nodes. Contrasting spin helicities and hybrid surface states were discovered in these materials. For wurtzite structure materials, TlN is a TI with negative SOC [2], while CaAgBi is Dirac semimetal with positive SOC. Moreover, we found hybrid Dirac-type dispersions in CaAgBi with positive SOC, including essential and accidental, type-I and type-II Dirac fermions [3]. For magnetic materials, we will report a two-dimensional intrinsic quantum anomalous Hall insulator in a monolayer 5d transition metal trichloride OsCl3, with Chern number of -1, band gap of 67 meV opened by negative SOC, and the estimated Curie temperature of anisotropic planar rotator ferromagnet Tc $\sim$ 350 K [4]. Finally, we will report a new topological phase Hourglass Dirac Nodal Chain Metal and its materials realization in ReO2, where both nonsymmorphic symmetry and large SOC in d-orbitals play important roles to form such nodal chain phase [5].

Reference:

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T8.88 Chalcogenide Topological Insulators, a Broadband Platform for Metamaterials in the Infrared

Harish Krishnamoorthy*, Giorgio Adamo*, Nikolay Zheludev*, Cesare Soci* (Center for Disruptive Photonic Technologies, Nanyang Technological University)

04:50pm – 05:05pm

We show that chalcogenide based topological insulator crystals are an attractive material platform for photonics in the mid-infrared owing to factors such as high refractive index of the bulk, optical conductivity arising from the topological surface states, and compositionally tunable optical response.

By using a combination of ellipsometry and infrared spectroscopy measurements, we determine the dielectric function of topological insulator crystals of various compositions belonging to the $Bi_{2x}Sb_{2(1-x)}Te_{3y}Se_{3(1-y)}$ family, and extract separately, the contribution of bulk and surface to the overall optical response. The plasmonic response arising from surface carriers is quite significant in the mid-infrared region wherein suitable spectral windows with low optical losses from surface and bulk are identified for potential applications.

Slit arrays fabricated by focused ion beam milling in exfoliated topological insulator crystals of Bi_2Te_3 show resonances over a broad spectral range, from the visible to the mid-infrared, beyond the bulk band gap without the need for any change of design. By carrying out COMSOL FEM simulations, we show that the depth of modulation of these resonances is larger than those from slits arrays in Si and Ge which are typical materials of choice for dielectric metamaterials, alluding to the suitability of these materials systems for dielectric metamaterial architectures.

We argue that chalcogenide topological insulators form a unique material platform for infrared photonic metamaterials, wherein the nature of resonances can be modulated from predominantly plasmonic due to the surface conductivity (for thin films) to dielectric (for thicker films). This may also be accomplished in a dynamic fashion by using external stimuli such as an applied voltage that moves the Fermi level and changes the relative optical conductivity of bulk and surface.

T8.113 Sb_2S_3 phase change tuneable photonics

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

05:05pm – 05:20pm

In recent years, phase change materials (PCMs) have attracted attention for tuneable photonic applications [1]. Comparing to other materials with tuneable optical properties, such as liquid crystals and electrochromics, PCMs can have a larger optical contrast between states and the switching speed can be substantially faster, on a sub-ns scale [2]. Moreover, the phase transition in PCMs is a non-volatile process, which means it retains the switched optical properties without a continuous energy supply. The most commonly used PCM, $Ge_2Sb_2Te_5$ (GST), has a large refractive index in the near infrared (NIR) spectrum and exhibits a large contrast between its amorphous and crystalline structural states. However, it is extremely lossy for wavelengths shorter than 2000 nm. This renders the material impractical for many photonics applications in the visible and NIR spectrum. In comparison, we introduce a wide band gap phase change material, Sb_2S_3, which has a refractive index of approximately 3.0 and 3.5 at NIR frequencies for the amorphous and crystalline states respectively. The band gap is 2.0 eV for amorphous state and 1.7 eV for crystalline state [3]. Thus, the extinction coefficient is near 0 for wavelengths beyond 600 nm in the amorphous state and beyond 800 nm in the crystalline state. Also, this material is capable of reversible switching and crystallization in 70 ns [3]. Thus, Sb_2S_3 has the potential for tuneable visible and NIR photonics applications. In this talk, two different types of Sb_2S_3 reprogrammable photonics devices will be introduced. Firstly, I will discuss all dielectric Sb_2S_3 nanoantenna arrays based on a Huygens' metasurface [4] for visible and NIR spectrum. This device operates in transmission mode and can dynamically bend the transmitted light at a wavelength of 840 nm by an angle of 10 $^\circ$. Secondly, I will show how this same material can be used to programmable route 1550 nm light through InP on-chip waveguides. These two demonstrations suggest that PCMs have further applications beyond data storage for reprogrammable visible and NIR light routers and beam steerers. Reference [1] Wuttig, M., H. Bhaskaran, and T. Taubner. ”Phase-change materials for non-volatile photonic applications.” Nature Photonics 11.8 (2017): 465. [2] Waldecker, Lutz, et al. ”Time-domain separation of optical properties from structural transitions in resonantly bonded materials.” Nature materials 14.10 (2015): 991. [3] Dong, Weiling, et al. ”Wide Bandgap Phase Change Material Tuned Visible Photonics.” Advanced Functional Materials (2018): 1806181. [4] Yu, Ye Feng, et al. ”High–transmission dielectric metasurface with 2π phase control at visible wavelengths.” Laser & Photonics Reviews 9.4 (2015): 412-418.

T9: Physics in 2D Materials

Time: Thursday 14 Mar, 2:00pm; Venue: tt9/10
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.

T9.5 (INVITED) 2D Material-based Electro-optic Modulation and Photodetection

Volker Sorger*, Rishi Maiti, Rohit Hemnani, Chandraman Patil, Mario Miscuglio (The George Washington University)
2:00pm – 02:20pm

Here we demonstrate the first TMD-based electro-optic modulator and photodetector, both heterogeneously integrated into a silicon photonics microcavity operating at telecommunication frequencies. The modulator shows a modulation extinction ratio of 2 dB at 4V, and the photodetector a responsivity of 20 mA/W.

Efficient electro-optic modulation and light detection is important in order to reduce the power consumption for data communication interconnects, but also for emerging photonic algorithms such as neuromorphic photonic computing. Heterogeneous integration of emerging materials such as TMDs allows to take advantage of the low losses of Si/SiN waveguides and cavities, and combines this with efficient electro-optic responses of low-dimensional materials showing stronger responses to electric field stimuli due to the reduced dimension and thus lower coulomb screening than bulk materials. Here we report on two novel optoelectronic devices, namely an electro-optic modulator (EOM) and a photodetector (PD) based on heterogeneous integration of TMDs onto a silicon photonics microring resonator (MRR). To our knowledge this is the first time that either device is demonstrated in such a platform. The EOM is realized in a two-terminal in-plane electrode configuration where 2D hBN flakes are used as gate dielectric, and MoS_2 as the actively gated material. Given the wavelength of 1550nm, we are far away form the exciton resonance of the TMD. Since $dn/d\lambda$ decays slower than $d\kappa/d\lambda$, find a basically unchanged Q-factor with bias. The device shows a $\sim$2dB modulation for 4V of applied bias. The top electrode is placed inside the MRR in such a way to not overlap with the MRR; thus the optical mode of the device is photonic, and not plasmonic. The electric field lines, are therefore horizontal (parallel) to the substrate surface and thus in-plane with the TMD matching the polarization of the waveguide. This ensures an optimized overlap of the applied gate voltage with the optical mode inside the silicon waveguide of the MRR. The index change of the effective optical mode is proportional to the mode-overlap, and thus ensures efficient modulation. We secondly demonstrate a few-layer $MoTe_2$-based photodetector also integrated on MRR. The device is realized in a two-terminal in-plane electrode configuration without applying external gating, showing a responsivity of ($\sim$15 mA/W) depending on band edge transmission. Together, these two initial demonstrations of integrating TMDs into silicon photonics resonators show promising results for functional heterogeneous integration strategies.

T9.7 Gauge phonon dominated resistivity in twisted bilayer graphene near magic angle

Nilotpal Chakraborty*, Indra Yudhistira, Giovanni Vignale, Shaffique Adam (Yale-NUS College)

02:20pm – 02:35pm

Recent experiments on twisted bilayer graphene (tBG) close to magic angle show that a small relative rotation in a van der Waals heterostructure greatly alters its electronic properties. We consider various scattering mechanisms and show that the carrier transport in tBG is dominated by a combination of charged impurities and acoustic gauge phonons*. Charged impurities still dominate at low temperature and densities because of the inability of Dirac fermions to screen long-range Coulomb potentials at charge neutrality; however, the gauge phonons dominate for most of the experimental regime because although they couple to current, they do not induce charge and are therefore unscreened by the large density of states close to magic angle. We show that the resistivity has a strong monotonically decreasing carrier density dependence at low temperature due to charged impurity scattering, and weak density dependence at high temperature due to gauge phonons. Away from charge neutrality, the resistivity increases with temperature, while it does the opposite close to the Dirac point. A non-monotonic temperature dependence observed only at low temperature and carrier density is a signature of our theory that can be tested in experimentally available samples.

* Gauge phonon dominated resistivity in Twisted Bilayer Graphene near magic angle: arXiv:1902.01405 - I.Yudhistira*, N.Chakraborty*, G.Sharma, D.Y.H Ho, E. Laksono, G.Vignale, O.P.Sushkov, S.Adam

T9.21 Dimer-mediated antiferromagnetic coupling in bilayer system

Jia Ning Leaw, Ho-Kin Tang, Pinaki Sengupta, Shaffique Adam* (National University of Singapore, Yale-NUS)

02:35pm – 02:50pm

Bilayer Heisenberg models on perfectly-stacked lattices with interlayer coupling much stronger than the intralayer coupling have been shown to exhibit the dimer phase which kills the long-range Néel order [1]. However, in systems with free sites which are not coupled to any sites on the other layer, the antiferromagnetic order may be hosted on these sites. In this work [2], we consider a bipartite bilayer Hubbard model, where in each layer, the free sites form one sublattice of the bipartite system, and the dimer sites form the other. In the strong-interacting limit with large interlayer coupling, and perturbing the system with intralayer hopping up to the forth-order, we find that the dimer sites mediate an antiferromagnetic Heisenberg coupling between the free sites on different layer, and ferromagnetic coupling between the free sites on the same layer. We complement our analysis with exact diagonalization and mean-field calculation on a four-site system, as well as quantum Monte-Carlo simulation on a Bernal-stacked bilayer honeycomb lattice.

[1] R. Ganesh, Sergei V. Isakov and Arun Paramekanti, Phys. Rev. B 84, 214412 (2011). [2] Jia Ning Leaw, Ho-Kin Tang, Pinaki Sengupta, Fakher F. Assaad, Igor F. Herbut, Oleg Sushkov and Shaffique Adam, (in preparation).

T9.27 Universal scaling laws of electron emission in two-dimensional-material-based electrical contacts

Yee Sin Ang*, Hui Ying Yang*, Lay Kee Ang* (Singapore University of Technology and Design)

02:50pm – 03:05pm

Electrically contacting two-dimensional (2D) material using metal or semiconductor often leads to the formation of an interfacial Schottky barrier. Charge injection across such barrier is commonly analysed using the classic Richardson-Dushman (thermionic emission) and Fowler-Nordheim (field emission) models despite the fact that the assumptions underlying such models are often inconsistent with the physical properties of most 2D materials [1,2]. In this work [3], we formulate a generalized model of electron injection across 2D material Schottky heterostructures. We show that the thermionic charge injection across a 2D material Schottky contact is universally governed by universal scaling laws broadly applicable for wide array of 2D materials. The quantum mechanical tunneling injection of electrons across 2D material vertical heterostructure is also studied. Our models signal the breakdown of classic electron emission models in the 2D Flatland. These findings shall provide a theoretical avenue for the better understanding of contact engineering in 2D-material-based devices.

[1] Y.S. Ang, S.-J. Liang, and L. K. Ang, MRS Bull 42, 505 (2017).
[2] Y.S. Ang, and L. K. Ang, Phys Rev Appl 6, 034013 (2016).
[3] Y.S. Ang, H. Y. Yang, and L. K. Ang, Phys Rev Lett 121, 056802 (2018).

T9.46 Dielectric breakdown in hexagonal boron nitride (h-BN) 2D layered thin films

Alok Ranjan*, Nagarajan Raghavan*, Sean O'Shea*, Kin Leong Pey* (Singapore University of Technology and Design)

03:05pm – 03:20pm

Hexagonal boron nitride (h-BN) has gained interest among CMOS dielectric community as a suitable dielectric for graphene-based 2-D nano-electronic devices. Reliability of h-BN has attracted attention in recent times as fabrication of high-quality crystalline h-BN over large area has shown positive results. The work would focus on understanding physics and physical mechanism of defect generation, degradation and dielectric breakdown mechanisms under different electrical stress conditions.

T9.54 Monolayer Mg_2C : Negative Poisson's ratio and unconventional two-dimensional emergent fermions

Shanshan Wang* (Singapore University of Technology and Design)

03:20pm – 03:35pm

Two-dimensional (2D) emergent fermions and negative Poisson's ratio in 2D materials are fascinating subjects of research. Here, based on first-principles calculations and theoretical analysis, we predict that the hexacoordinated Mg_2C monolayer hosts both exotic properties. We analyze its phonon spectrum, reveal the Raman-active modes, and show that it has small in-plane stiffness constants. Particularly, under the tensile strain in the zigzag direction, the Mg_2C monolayer shows an intrinsic negative Poisson's ratio of 0.023, stemming from its unique puckered hinge structure. The material is metallic at its equilibrium state. A moderate biaxial strain can induce a metal-semimetal-semiconductor phase transition, during which several types of 2D unconventional fermions emerge, including the anisotropic Dirac fermions around 12 tilted Dirac points in the metallic phase, the 2D double Weyl fermions in the semimetal phase where the conduction and valence bands touch quadratically at a single Fermi point, and the 2D pseudospin-1 fermions at the critical point of the semimetal-semiconductor phase transition where three bands cross at a single point on the Fermi level. In addition, uniaxial strains along the high-symmetry directions break the threefold rotational symmetry and reduce the number of Dirac points. Interestingly, it also generates 2D type-II Dirac points. We construct effective models to characterize the properties of these fermions. Our result reveals Mg_2C monolayer as an intriguing platform for the study of 2D unconventional fermions, and also suggests its great potential for nanoscale device applications.

T10: Quantum Information

Time: Thursday 14 Mar, 2:00pm; Venue: tt7; Chair: Dagomir Kaszlikowski
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.

T10.125 (INVITED) Upper Bound on the Duration of Quantum Jumps

Mathias Seidler*, Ricardo Gutierrez-Jauregui, Alessandro Cerè, Rocio Jauregui, Christian Kurtsiefer (CQT)
2:00pm – 02:20pm

Since the original formulation of the quantum theory[1], there is no satisfactory description of the transition between discrete energy states of atoms, or quantum jumps. The established technique for observing quantum jumps, based on shelving configuration[2], has an intrinsically limited time resolution because it relies on a null measurement [3].In this presentation [4] we consider an alternative configuration for the observation of quantum jumps in atomic systems: a monitored cascade three-level system. The second order time correlation of the generated photon pair shows an exponential decay, associated with spontaneous decay, and a sharp rise, associated with the quantum jump. We realize this experimentally by four-wave mixing [5] in cold ^{87}Rb atoms. After taking into account the photodetector response, we find an upper bound for the duration of a quantum jump of 21 ± 11 ps.

[1] N.Bohr, I. on the constitution of atoms and molecules", The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science 26, 1–25 (1913). [2] W. M. Itano, J. C. Bergquist, and D. J. Wineland, Early observations of macroscopic quantum jumps in single atoms", International Journal of Mass Spectrometry 377, 403–409 (2015). [3] D. T. Pegg, Wave-function collapse time", Physics Letters A 153, 263–264 (1991). [4] M. A. Seidler, R. Gutiérrez-Jáuregui, A. Cerè, R. Jáuregui, and C. Kurtsiefer, Upper bound on the duration of quantum jumps", arXiv:1812.00129 (2018). [5] B. Srivathsan, G. K. Gulati, B. Chng, G. Maslennikov, D. Matsukevich, and C. Kurtsiefer, Narrow Band Source of Transform-Limited Photon Pairs via Four-Wave Mixing in a Cold Atomic Ensemble," Phys. Rev. Lett. 111, 123602 (2013).

T10.37 Nonequilibrium Dynamics with Finite-Time Repeated Interactions

Stella Seah*, Stefan Nimmrichter, Valerio Scarani (National University of Singapore)
02:20pm – 02:35pm

We study quantum dynamics in the framework of repeated interactions between a system and a stream of identical probes. We present a coarse-grained master equation that captures the system's dynamics in the natural regime where interactions with different probes do not overlap, but is otherwise valid for arbitrary values of the interaction strength and mean interaction time. We then apply it to some specific examples. For probes prepared in Gibbs states, such channels have been used to describe thermalisation: while this is the case for many choices of parameters, for others one finds out-of-equilibrium states including inverted Gibbs and maximally mixed states. Gapless probes can be interpreted as performing an indirect measurement, and we study the energy transfer associated with this measurement.

T10.66 Quantum entanglement due to gravity in back-to-back optomechanical system

Tanjung Krisnanda*, Guo Yao Tham, Mauro Paternostro, Tomasz Paterek (Nanyang Technological University)
02:35pm – 02:50pm

No experiment to date provided evidence for quantum features of gravitational interaction. Recently proposed tests suggest looking for generation of quantum entanglement between massive objects. Motivated by advances in optical cooling of macroscopic mirrors here we study entanglement dynamics between two mechanical oscillators coupled gravitationally. We derive a figure of merit that characterises generated entanglement and entangling time, and show that squeezing of the initial state of the mirrors significantly improves the entanglement. We then provide numerical analysis of realistic situation where the mirrors are interacting with their thermal and electromagnetic environments. This leads to a range of experimental parameters required for observation of the gravitationally-induced entanglement. It turns out that the mirrors of the LIGO interferometer come close to the required mass and frequency, and sets clear goals for the other parameters. Finally, we discuss conclusions that can be drawn from this experiment regarding the nature of the gravitational coupling and propose research programme aimed at independent verification that gravitational interaction was mediated.

T10.35 Thermalization with detailed-balanced two-site Lindblad dissipators

Mikel Palmero*, Xiansong Xu, Chu Guo, Dario Poletti* (Singapore University of Technology and Design)
02:50pm – 03:05pm

The use of two-site Lindblad dissipator to generate thermal states and study heat transport raised to prominence since [J. Stat. Mech. (2009) P02035] by Prosen and Znidaric. Here we propose a variant of this method based on detailed balance of internal levels of the two site Hamiltonian and characterize its performance. We study the thermalization profile in the chain, the effective temperatures achieved by different single and two-site observables, and we also investigate the decay of two-time correlations. We find that at a large enough temperature the steady state approaches closely a thermal state, with a relative error below 1% for the inverse temperature estimated from different observables.

T10.67 Nondecomposability of time evolution and extreme gain of correlations

Tanjung Krisnanda*, Ray Ganardi, Su-Yong Lee, Jaewan Kim, Tomasz Paterek (Nanyang Technological University)
03:05pm – 03:20pm

Noncommutativity is one of the most elementary nonclassical features of quantum observables. Here we propose a method to detect noncommutativity of interaction Hamiltonians of two probe objects coupled via a mediator. If these objects are open to their local environments, our method reveals nondecomposability of temporal evolution into a sequence of interactions between each probe and the mediator. The Hamiltonians or Lindblad operators can remain unknown throughout the assessment, we only require knowledge of the dimension of the mediator. Furthermore, no operations on the mediator are necessary. Technically, under the assumption of decomposable evolution, we derive upper bounds on correlations between the probes and then demonstrate that these bounds can be violated with correlation dynamics generated by noncommuting Hamiltonians, e.g., Jaynes-Cummings coupling. An intuitive explanation is provided in terms of multiple exchanges of a virtual particle which lead to the excessive accumulation of correlations. A plethora of correlation quantifiers are helpful in our method, e.g., quantum entanglement, discord, mutual information, and even classical correlation. Finally, we discuss exemplary applications of the method in quantum information: the distribution of correlations and witnessing dimension of an object.

T11: Biophysics and Microfluidics

Time: Thursday 14 Mar, 2:00pm; Venue: tt8; Chair: Johan R.C. van der Maarel
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.

T11.100 (INVITED) Light actuators for cell stimulation

Guglielmo Lanzani* (Istituto Italiano di Tecnologia Politecnico di Milano)
2:00pm – 02:20pm

Intramembrane probes have being engineered in order to behave as mechanical stimulator of living cells. A photochromic moiety is functionalized in order to become amphiphillic. This bestow a characteristic membrane affinity that leads to a successful partition of the photo-switch in the cell membrane. The molecule is photoactive in DMSO, but fully locked in water. We study molecular dynamics with pump probe to understand the origin of the freezing effect and show the beneficial role of the lipid membrane in screening the molecule to allow photoisomerization.

T11.47 Photoexcitation Induced Twisted Intramolecular Charge Shuttle (TICS)

Weijie Chi, Qinglong Qiao, Richmond Lee, Wenjuan Liu, Yock Siong Teo, Danning Gu, Matthew J. Lang, Young-Tae Chang*, Zhaochao Xu*, Xiaogang Liu* (Singapore University of Technology and Design)
02:20pm – 02:35pm

Charge transfer and separation are important processes governing numerous chemical reactions. Fundamental understanding of these processes and the underlying mechanism is critical for photochemistry. Herein we reported the discovery of a new charge transfer and separation process, namely twisted intramolecular charge shuttle (TICS). In TICS systems, the donor and acceptor moieties dynamically switch roles in the excited state as a result of $\sim$90° intramolecular twisting, thus exhibit a charge shuttle" phenomenon. We showed that TICS existed in several chemical families of fluorophores (such as coumarin, BODIPY, and oxygen/carbon/silicon-rhodamine), and its environmental sensitivity could be utilized to construct functional fluorescent probes (i.e., viscosity or pH sensors). The discovery of the TICS process expands the current perspectives of charge transfer processes and will inspire future applications.

T11.58 Submicron particle focusing and exosome sorting by wavy microchannel structures within viscoelastic fluids

Yinning Zhou, Zhichao Ma, Mahnoush Tayebi, Ye Ai* (Singapore University of Technology and Design)
02:35pm – 02:50pm

Exosomes, submicron membrane vesicles (30-200 nm) secreted by almost all cells, containing significant information such as proteins, microRNAs and DNAs, are closely associated with disease diagnostic and prognostic test for liquid biopsy in clinical practice. However, their inherently small size lead to great challenges for isolating from complex body fluids with high-throughput and high-purity process. In this work, a reverse wavy channel structures using viscoelastic fluids with the addition of biocompatible polymer was presented for elasto-inertial focusing and sorting of submicron particles and exosomes. The microfluidic periodically reversed Dean secondary flow generated by repeated wavy channel structures could facilitate particle focusing compared with traditional straight channels. Four differently sized fluorescent submicron spheres (1 µm, 500 nm, 300 nm and 100 nm) were used to study the focusing behavior under various conditions. We have achieved simple, high-throughput and label-free sorting of exosomes with purity higher than 92% and recovery higher than 81%. This developed elasto-inertial exosome sorting technique may provide a promising platform in various exosome-related biological research and pharmaceutical applications.

T11.116 Tunable interaction between graphene and a DNA molecule

Milan Blaskovic*, Slaven Garaj* (Centre for Advanced 2D Materials)
02:50pm – 03:05pm

CVD grown monolayer graphene has shown significant potential in bio-sensing and single-molecule detection applications due to its atomic thinness, mechanical robustness, excellent electronic properties, and functionalization possibilities. However, rational implementation of monolayer graphene has been hampered by the lack of understanding of the nature of its interactions with different biomolecules. We investigated interaction of individual single-stranded DNA oligomers with the CVD grown monolayer graphene supported on SiO_2/Si surface, in a wide range chemical and physical liquid environments; and we fully identified and quantified all the relevant forces contributing to the total interactions. Using atomic force microscopy (AFM), we measured force vs. distance curves for the interaction between a DNA tethered on a AFM tip and a graphene surface in aqueous environment. We observed characteristic plateaus in the curves, which are associated with unzipping of the DNA molecule from the surface. The single-molecule forces were measured at room temperature in a range of solutions with varying concentration of salts and various pH values. Lack of significant variation of the molecular forces in these solutions indicated that there is no electrostatic contribution to the force. Further experiments in aqueous solution with inclusion of methanol, and experiments with varying temperature, demonstrated that hydrophobic hydration has dominating contribution to the overall force. With addition of an aromatic solvent (phenol) into the solution, we observe clear decrease in the overall interaction, due to disruption of pi-pi stacking interactions between graphene and aromatic DNA nucleobases. The experiments identified that the overall DNA-graphene interaction is the combination of hydrophobic and pi-pi stacking forces. To understand the experiments, we proposed an elastic polymer chain model, which helped us quantifies all the relevant contributions to the force: pi-pi stacking interactions contribute around 20%; entopic-elastic forces contribute around 10%; and hydration (hydrophobic) forces contribute around 70% to total interaction. The insight obtained from our experiments can be used to modulate DNA-graphene interaction and possibly control to movement of individual biomolecule; to completely eliminate interactions for nanopore-based DNA sequencing; or to limit fouling of graphene membranes in desalination applications.

T11.111 Development of Paper based Microfluidic Channel using Laser Ablation

Muthulakshmi L, Suryasankarar R P, Manikandan Esakkimuthu*, Karthigeyan K A, Sreeja B S (SSN COLLEGE OF ENGINEERING)
03:05pm – 03:20pm

This paper presents the development of a low-cost paper-based microfluidic channel using a pulsed laser ablation process. The cellulose/silver nanocomposite is prepared using in situ generation method. The prepared composite is confirmed by using Fourier transform infrared spectroscopy and surface morphology analysis using scanning electron microscopy. The prepared nanocomposite materials are degradable within 24 hours. This low cost and eco-friendly nanocomposite material is a suitable material for developing microfluidic components.

T11.120 Ionic mobility engineering in graphitic nanochannels

Massimo Spina*, Kittipitch Yooprasertchuti, Nathan Ronceray, Mordjann Souilamas, Slaven Garaj (National University of Singapore)
03:20pm – 03:35pm

Nanochannels based on carbon materials have been intensively studied in the last decade because of their promising application in nanofiltration [1, 2] and the novel physical phenomena arising between graphitic surfaces at the nanoscale [3–6]. More recently, atomically-smooth graphitic channels with sub-nm heights have been fabricated and used to investigate the physics of ions and water molecules in slits comparable to the smallest ion sizes. It has been shown that water flows very fast inside those channels [3], while ionic mobilities are influenced by the distortion of their hydration shells within the narrow channels [4].

In this work, we investigated ionic flow in atomically-smooth graphitic channels with height ranging from 7Å to 3nm. We show that the mobilities of ions in such confinements do not scale with hydration shell in a simple fashion, and we further explored the role of the surface charge, physical confinement and chemical interactions. Engineering ionic mobilities within the graphitic channels, we could induce strong current driven by the salinity gradient. Such osmotic power generators – driven by mobility engineering, rather than surface charge – are more resilient on the variation of chemical environment and show orders of magnitude increase in osmotic power density compared to commercial membranes.

1. S. Hong et al., Nano Lett. 17, 728–732 (2017).
2. J. Abraham et al., Nat. Nanotechnol. 12, 546–550 (2017).
3. B. Radha et al., Nature. 538, 222–225 (2016).
4. A. Esfandiar et al., Science. 358, 511–513 (2017).
5. E. Secchi, A. Niguès, L. Jubin, A. Siria, L. Bocquet, Phys. Rev. Lett. 116, 154501 (2016).
6. Q. Xie et al., Nat. Nanotechnol. 13, 238–245 (2018)

T12: Topological effects in Materials

Time: Friday 15 Mar, 11:30am; Venue: tt7
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.

T12.25 Fermi surface folding of interacting anisotropic 2D Dirac fermions

Girish Sharma* (CA2DM, NUS)
11:30am – 11:45am

We investigate interacting anisotropic two-dimensional massless Dirac fermions within the Hartree-Fock mean-field approximation. The interplay between chirality and electron-electron interaction results in a Fermi surface folding, which is especially remarkable for strong anisotropy. The folding leads to the density of states enhancement as well as to the peculiar non-monotonic Fermi velocity vs. azimuthal angle dependence . Our results could be useful for experimentalists working with graphene, topological insulators, and composite fermions.

Reference: Girish Sharma, Shaffique Adam, Maxim Trushin (in preparation).

T12.42 Transverse shift in crossed Andreev reflection

Ying Liu*, Zhi-Ming Yu, Shengyuan Yang (Singapore University of Technology and Design)
11:45am – 12:00pm

Crossed Andreev reflection (CAR) is an intriguing effect that occurs in a normal-superconductor-normal junction. In CAR, an incoming electron from one terminal is coherently scattered as an outgoing hole into the other terminal. Here, we reveal that there exists a transverse spatial shift in CAR, i.e., the plane of CAR for the outgoing hole may have a sizable transverse shift from the plane of incidence for the incoming electron. We explicitly demonstrate the effect in a model system based on Weyl semimetals. We further show that the effect is quite general and exists when the terminals have sizable spin-orbit coupling. In addition, we find that the corresponding shift in the elastic co-tunneling process shows different behaviors, and it vanishes when the two terminals are identical. Based on these findings, we suggest possible experimental setups for detecting the effect, which may also offer an alternative method for probing CAR.

Ref: Phys. Rev. B 98, 195141(2018).

T12.49 Non-Hermiticity and the breakdown of topological bulk-boundary correspondence

Chinghua Lee* (Institute of High Performance Computing)
12:00pm – 12:15pm

The topological bulk-boundary correspondence is one of the most cherished results in contemporary condensed matter physics. It provides a one-to-one correspondence between bulk topology and boundary states. Yet, recent studies have demonstrated that it no longer strictly holds in the presence of generic non-reciprocal non-Hermiticity. In this talk, I shall introduce how that gives rise to the non-Hermitian skin effect which fundamentally alters the spectrum in the presence of boundaries, and describe a new formalism for treating various non-Hermitian bandstructures on equal footing with the Hermitian ones. With that, I shall discuss the new physics that govern non-Hermitian analogs of known topological systems, such as the enigmatic skin effect-induced discontinuity in the Berry curvature. Culminating in these ideas is a new marine analogy that provides a transparent geometric interpretation of non-Hermitian 3D nodal structures. Lastly, I will discuss the unique experimental signatures of such non-Hermitian phenomena in electric circuits.

T12.77 Near-filed mapping of valley Hall topological guiding at telecom frequency

Alexander M. Dubrovkin*, Udvas Chattopadhyay, Bo Qiang, Qi Jie Wang, Yidong Chong, Nikolay I. Zheludev (Nanyang Technological University)
12:15pm – 12:30pm

Topologically protected states of light allow for robust wave-guiding in appropriately-designed photonic systems. This has attracted tremendous attention in the past decade and stimulated a number of practical applications. In microwave experiments, topological states of light have been demonstrated and accurately mapped in real space. At visible and infrared frequencies, however, nanoimaging of topologically protected states remains a significant challenge. In this work, we present the first demonstration of direct near-field imaging of a valley Hall photonic waveguide at telecommunication frequency. Launching and guiding of optical modes along straight boundary and defects between opposite valley-Chern-index domains is experimentally observed in real space and supported by theoretical simulations.

In experiment, we use scattering-type scanning near-field optical microscopy to directly map the mode of the topological photonic waveguide operating at 1.55 μm wavelength. The valley Hall waveguide is based on a triangular air-hole motif with broken inversion symmetry, realized on a suspended high-index semiconductor slab. This photonic crystal device supports a topological gap in the transverse magnetic spectrum. Near-field mapping provides optical information on the waveguide field distribution with 10-20 nm spatial resolution – remarkably higher than allowed by reported far-field techniques. Moreover, our approach provides the first demonstration of the nanoscale optical phase acquisition – fundamentally important quantity in topologically-nontrivial systems. We directly observe launching of the valley Hall mode when the light travels from the unpatterned slab medium to the topological waveguide. The observed decay of the optical field away from the boundary between topologically distinct opposite valley-Chern-index domains is a typical feature of a wave-guide mode, and agrees with theoretical calculations. Our results provide insight into the design and use of topological protection for optical-to-infrared regime waveguiding applications.

T12.81 Topological BEC of magnons

Abhinava Chatterjee*, Dhiman Bhowmick, Prasanta K. Panigrahi, Pinaki Sengupta (Nanyang Technological University; Indian Institute of Science Education and Research Kolkata)
12:30pm – 12:45pm

We study the topological properties of magnon excitations in a S=1/2 Heisenberg antiferromagnet on a bilayer honeycomb lattice with strong interlayer coupling complemented by layer restricted Dzyaloshinskii-Moriya (DM) interactions. Our goal is to investigate the BEC of field-induced triplon excitations on the ground state. The presence of the DM term in the Hamiltonian breaks the axial U(1) symmetry associated with the lattice, which inherently leads to a BEC crossover. We calculate the topological number associated with the triplon bands and calculate their effects on physical observables.

T12.101 Fermi arc induced vortex structure in Weyl beam shifts

Udvas Chattopadhyay*, Li-Kun Shi*, Baile Zhang*, Justin C. W. Song*, Yidong Chong* (Nanyang Technological University)

12:45pm – 01:00pm

In periodic media, despite the close relationship between geometrical effects in the bulk and topological surface states, the two are typically probed separately. We have recently discovered that when beams in a Weyl medium reflect off an interface with a gapped medium, the trajectory is influenced by both bulk geometrical effects and the presence of Fermi arc surface states. The reflected beam experiences a displacement, analogous to the Goos-Hänchen or Imbert-Fedorov shifts, that forms a half-vortex in the two-dimensional surface momentum space. The half-vortex structure is centered at the point where the Fermi arc of the reflecting surface touches the Weyl cone, and the magnitude of the shift scales as the inverse square root of distance from the touching-point, and diverges at the touching-point. This striking feature provides a way to use bulk transport to probe the topological characteristics of a Weyl medium.

T13: Atomic Physics II

Time: Friday 15 Mar, 11:30am; Venue: tt8; Chair: Huanqian Loh
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.

T13.30 Ultracold group III atoms

Travis Nicholson* (Centre for Quantum Technologies)
11:30am – 11:45am

Most ultracold experiments to date have been performed with atoms in groups I and II of the periodic table. Meanwhile other main group elements remain largely unexplored in the ultracold regime. If group III atoms could be cooled to ultracold temperatures, they could enable highly accurate atomic clocks, new tests of fundamental physics, and novel quantum many body states. Here we report on our progress cooling a group III atom to the ultracold regime.

T13.45 Plasmono-Atomic Interactions on a Fiber Tip

Eng Aik Chan*, Giorgio Adamo, Syed Abdullah Aljunid, Martial Ducloy, Nikolay Zheludev, David Wilkowski (Nanyang Technological University)
11:45am – 12:00pm

Plasmono-atomic interaction affecting hyperfine structure of atomic lines can be detected at the end of optical fiber bearing metamaterial nanostructures. This paves the way for a new type of ultra-compact fiberized atoms-metamaterial devices. Integration of atomic-like hybrid systems in fiberized setups is an important milestone in realizing practical application in an integrated network. Here we present the first experimental demonstration of phase modulated spectroscopy of an atomic vapor with plasmonic metamaterial on the tip of an optical fiber. We observe complete modifications of hyperfine spectra with plasmonic metamaterial on the tip of the optical fiber with respect to a bare optical fiber due to coupling between the plasmonic and atomic modes. We will also discuss how the coupling between the two modes modify the Casimir-Polder potential exerted by the fiberized surface on the atoms.

T13.68 Large time-bandwidth photonic waveguide coupled light storage

Wui Seng Leong, Mingjie Xin, Zilong Chen, Shau-Yu Lan*, Yu Wang (Nanyang Technological University)
12:00pm – 12:15pm

Integrating light storage or optical delay line in an optical fibre is an attractive component in connecting long distance optical communication networks. Although silica-core optical fibres are excellent in transmitting broadband optical signals, it is challenging to tailor its dispersive property for long light storage time. Coupling tunable dispersive medium with an optical fibre is promising in supporting high performance optical delay line memory while transmitting the light with small loss. Here, we load cold Rb atomic vapour in an optical trap inside a hollow-core fibre and demonstrate light storage using electromagnetically-induced-transparency (EIT). We achieve over 20 ms of the storage time with 1 MHz bandwidth of the pulse. The storage time-bandwidth product exceeds 10^4. Our long memory built-in optical fibre could be used for buffering and regulating classical and quantum information flow between remote networks.

T13.91 The Dipolar Ground State of Ultracold LiK Molecules

Sunil Kumar*, Anbang Yang*, Sofia Botsi*, Kai Dieckmann* (Centre for Quantum Technologies,Department of Physics, National University of Singapore)
12:15pm – 12:30pm

Ultracold polar molecules are an ideal tool for the quantum simulation of a large class of many-body effects, for quantum information processing, controlled ultracold chemistry, and quantum metrological applications. We report on our experiments that identified the ground state of bosonic heteronuclear dimers of ^{6}Li and ^{40}K. In the ground state, these molecules possess a large permanent electric dipole moment of 3.6 Debye, which makes them a suitable candidate for a quantum gas with long-range anisotropic dipole interaction. Starting from closed channel dominated Feshbach molecules, we describe a new spectroscopy route to the ground state that is different from schemes previously used for other alkali heteronuclear dimers. Only strong transitions between molecular spin singlet states are involved, avoiding the need to identify suitable perturbed triplet states. We demonstrate how only a sole hyperfine component can be addressed, even if the hyperfine structure is not resolved. Effectively creating a three-level system, the resulting scheme is the most straight forward to date and takes full advantage of the closed molecular channel that can be discussed by means of the simple asymptotic bound state model for our case. Further, we present results from rotational spectroscopy that facilitates to exploit the high electric dipole moment for use of the molecules as a quantum bit.

T13.69 Transporting long-lived quantum spin coherence in a photonic crystal fiber

Mingjie Xin*, Wui-Seng Leong, Zilong Chen, Yu Wang, Shau-Yu Lan (Nanyang Technological University)
12:30pm – 12:45pm

Confining particles in hollow-core photonic crystal fibers has opened up new prospects to scale up the distance and time over which particles can be made to interact with light. However, maintaining long-lived quantum spin coherence and/or transporting it over macroscopic distances in a waveguide remain challenging. Here, we demonstrate coherent guiding of ground-state superpositions of ^{85}Rb atoms over a centimeter range and hundreds of milliseconds inside a hollow-core photonic crystal fiber. The decoherence is mainly due to dephasing from residual differential light shift (DLS) from the optical trap and the inhomogeneity of ambient magnetic field. Our experiment establishes an important step towards a versatile platform that can lead to applications in quantum information networks and matter wave circuit for quantum sensing.

T13.62 Dynamics of Quantum Gas in Non-Abelian Gauge Field

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

12:45pm – 01:00pm

In this talk, I will present the study of laser-cooled strontium-87. The experimental realization of SU(2)-symmetric system with the tripod scheme, by cycling the relative phases of the tripod laser-beams, reveals the non-Abelian nature of the synthetic gauge field. First, the study of gauge field-mediated internal-state dynamics will be delineated. This dynamics leads to a new thermometric scheme that exploits the interferometric-displacement of atoms, in the tripod beams. Afterwards, the coupling of internal (spin) and external (momentum) degrees of freedoms of atoms – spin-orbit interaction – in a non-Abelian gauge field, will be discussed based on theoretical calculations. The dynamics of external degrees of freedom of the gas is shown to carry the signature of the non-Abelian gauge field. This spin-orbit-coupled gas breaks the Galilean invariance and modifies the usual reflection-law, owing to its inherent peculiar dispersion relation.

T14: Statistical Physics and Complexity

Time: Friday 15 Mar, 11:30am; Venue: tt9/10; Chair: Hou Khoon Ng
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.

T14.53 (INVITED) Local structure can identify and quantify influential global spreaders in large scale social networks

Yanqing Hu, Shenggong Ji, Yuliang Jin, Ling Feng*, H. Eugene Stanley, Shlomo Havlin (National University of Singapore)
11:30am – 11:50am

Measuring and optimizing the influence of nodes in big-data online social networks are important for many practical applications, such as the viral marketing and the adoption of new products. As the viral spreading on a social network is a global process, it is commonly believed that measuring the influence of nodes inevitably requires the knowledge of the entire network. Using percolation theory, we show that the spreading process displays a nucleation behavior: Once a piece of information spreads from the seeds to more than a small characteristic number of nodes, it reaches a point of no return and will quickly reach the percolation cluster, regardless of the entire network structure; otherwise the spreading will be contained locally. Thus, we find that, without the knowledge of the entire network, any node's global influence can be accurately measured using this characteristic number, which is independent of the network size. This motivates an efficient algorithm with constant time complexity on the longstanding problem of best seed spreaders selection, with performance remarkably close to the true optimum.

The paper was recently published in Proceedings of the National Academy of Sciences (PNAS), 115(29), 2018.

T14.1 Melting and re-entrant melting of polydisperse hard disks

Pablo Sampedro Ruiz*, Lei Qunli*, Ran Ni* (Nanyang Technological University)
11:50am – 12:05pm

Since the celebrated Kosterlitz-Thouless-Halperin-Nelson-Young (KTHNY) theory for topological solids, there has been a significant interest in the study of melting of two-dimensional solids. Surprisingly, its application to the seemingly simple hard-disk system has been proven problematic due to the possibility of alternative melting mechanisms, such as grain boundaries induced melting [1], that have hindered the establishment of the equation of state. However, recent theoretical results [2] appear to have settled that the system present a continuous solid-hexatic transition, followed closely by a first-order hexatic fluid transition, with a stability range for the hexatic phase of just 0.2-0.3% in packing fraction. These results for the perfect monodisperse planar system have encouraged the study of how experimental conditions, such as particle pinning[3], out of plane motion[4], etc, can alter the nature of melting.

In this fashion, we studied the effect of particle size polydispersity on the melting in two dimensions, and we find new and intriguing physical behavior by performing large scale Event Chain Monte Carlo simulations. The resulting phase diagram shows that for implementations with high enough polydispersity (over 7%), the melting transition undergoes the celebrated

KTHNY scenario, with the melting occurring through two consecutive continuous transitions. For these cases we also find a significant increase in the hexatic packing fraction stability range, by up to one order of magnitude. These results are justified and explained by topological dislocation analysis, and are found to be robust against changes in the particle size distribution function. Finally, we find that for polydispersities larger than 8% the formed hexatic and crystal phases show counter-intuitive re-entrant melting at high enough pressure, similar to the re-entrant melting of soft-sphere systems in 2D[5].

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T14.11 Solitons and pattern formation with Exciton-polariton lattices

Rimi Banerjee*, Timothy Liew* (Nanyang Technological University)
12:05pm – 12:20pm

The study of exciton polaritons in lattices has revealed a number of intriguing phenomena in recent years such as spin-ordered phases [1], simulators [2], and topological states [3].

There is a huge interest in studying spatiotemporal polariton structures, namely, solitons and patterns because it is conjectured that solitons and patterns are useful for information processing.

Here we introduce the concept and show theoretically that when subjected to a series of laser pulses a lattice of exciton-polaritons behaves as a lifelike cellular automaton, that is, a form of artificial life. A polariton cellular automaton allows access to all of these structures, including stable, oscillating or moving solitons, and more, simultaneously.

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T14.8 Data-Driven Inference, Reconstruction, and Observational Completeness of Quantum Devices

Michele Dall'Arno*, Francesco Buscemi, Alessandro Bisio, Alessandro Tosini (National University of Singapore)
12:20pm – 12:35pm

The range of a quantum measurement is the set of output probability distributions that can be produced by varying the input state. We introduce data-driven inference as a protocol that, given a set of experimental data as a collection of output distributions, infers the quantum measurement which is, i) consistent with the data, in the sense that its range contains all the distributions observed, and, ii) maximally noncommittal, in the sense that its range is of minimum volume in the space of output distributions. We show that data-driven inference is able to return a measurement up to symmetries of the state space (as it is solely based on observed distributions) and that such limit accuracy is achieved for any data set if and only if the inference adopts a (hyper)-spherical state space (for example, the classical or the quantum bit).

When using data-driven inference as a protocol to reconstruct an unknown quantum measurement, we show that a crucial property to consider is that of observational completeness, which is defined, in analogy to the property of informational completeness in quantum tomography, as the property of any set of states that, when fed into any given measurement, produces a set of output distributions allowing for the correct reconstruction of the measurement via data-driven inference. We show that observational completeness is strictly stronger than informational completeness, in the sense that not all informationally complete sets are also observationally complete. Moreover, we show that for systems with a (hyper)-spherical state space, the only observationally complete simplex is the regular one, namely, the symmetric informationally complete set.

T14.60 Inferring the complexity of efficient quantum modelling

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

12:35pm – 12:50pm

Complex, stochastic processes underpin quantitative science. It is therefore of paramount importance to study and understand the behaviour of such processes for the crucial twin purposes of modelling and prediction. These tasks are typically resource-intensive, motivating the need for methods that ameliorate these requirements. A promising recent development to this end [1,2], using a cross-disciplinary blend of tools from quantum and complexity science, has highlighted that quantum simulators can operate with much smaller memories than the minimal possible classical models [3,4], while providing equally accurate predictions.

Presently, these efficient quantum models are designed with prior knowledge of the minimal classical model, necessitating the use of classical model inference algorithms when applied to real data. Here, we introduce a new inference protocol specifically designed for constructing quantum models, circumventing certain drawbacks of the classical approach that need not manifest in the quantum domain [5]. Crucially, our protocol can be used to both blindly infer efficient quantum models of a given pattern or time series, and bounds on the associated structural complexity. We show that our protocol is robust to statistical imperfections arising from finite data, and does not require any smoothing of probabilities typically associated with classical algorithms. Our results form a key step in the application of this emerging field to real world systems.

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6 Physics Olympiad Events

The 31th Singapore Physics Olympiad was held in late 2018, 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.

We also invite the students and teachers to join the poster session of the IPS meeting, and researchers to interact with the students of the next generation of physicists!

Thursday afternoon, 14 March schedule

1.34 PM	Registration for award winners
2.00 PM	Opening Remarks (LT2)
2.15 PM	Awards Presentation (LT2)
3.00 PM	Panel discussion (LT2)
4.00 PM	Refreshments and networking

(notes)

7 Committees

Program Committee

Dario Poletti, SUTD

Cesare SOCI, SPMS, NTU

KOH Wee Shing, IHPC, A*STAR

Shaffique ADAM, Yale-NUS College and CA2DM, NUS

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Special thanks for help with logistics to the technical support staff and many students at SUTD: Yang Shengyuan, Jiao Yalong, Vinitha Balachandran, Mikel Palmero, Lee Kang Hao, Ryan Tan, Chen Tianqi, Xu Xiansong, Xing Bo, Ting Yu Teo, Chua Xue Li, Rina Rin Binte Sodar!

Physics Olympiade Event and School relationship

Darren TAN, MoE

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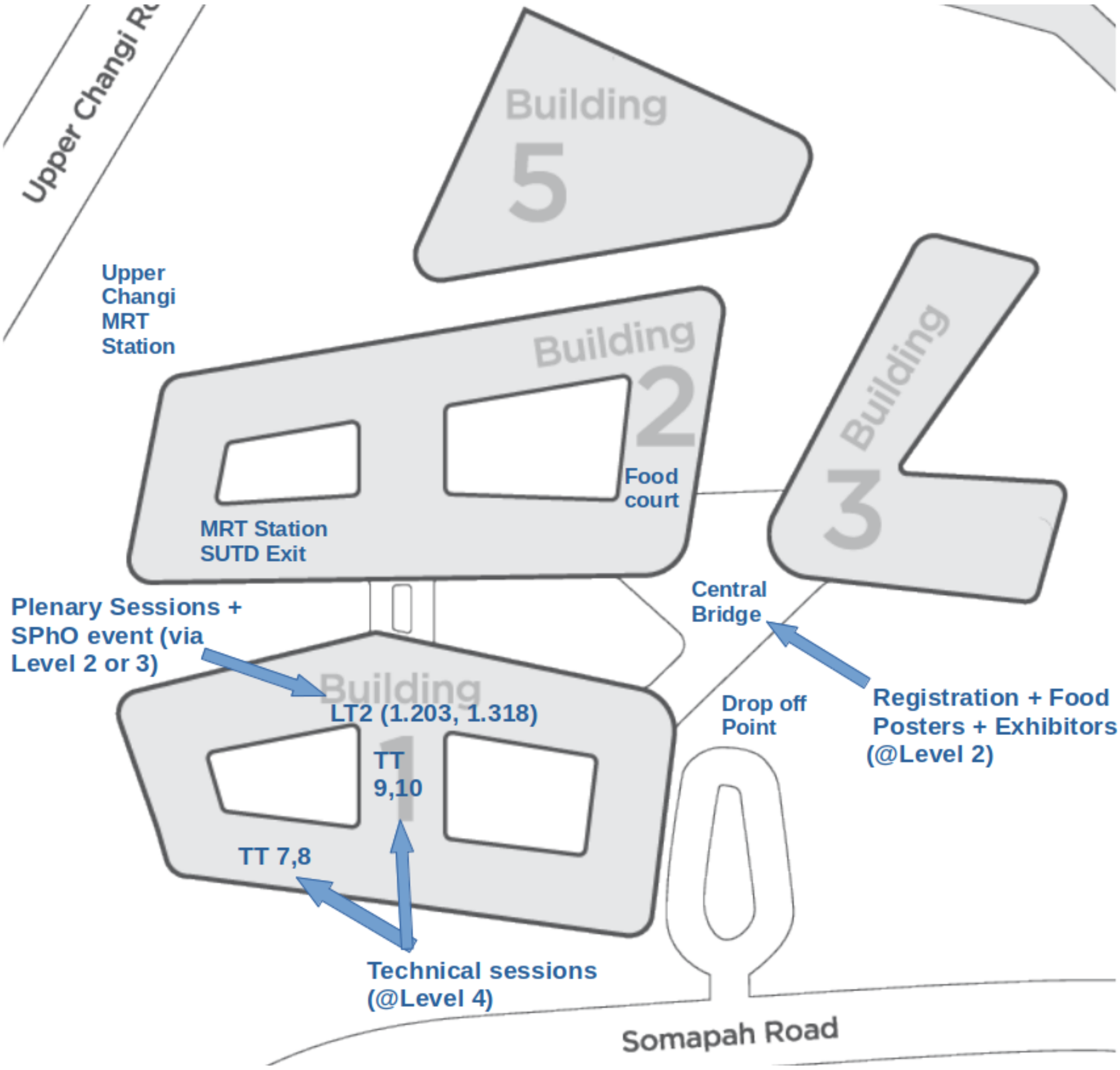
(notes)

8 Location Map

Most events take place either at the Central Bridge, lecture hall LT2, or in the Think Tanks at level 4 in Building 1.



The big lecture theater "LT2" in building is for plenary sessions, posterpitch presentations and the SPhO event.

Please follow local signs to find the respective rooms.