IPS Meeting 2017
22 - 24 February

Institute of Physics Singapore

Conference Program

The IPS Meeting 2017 thanks its sponsors
for their generous support

ROHDE&SCHWARZ

PI

FEI™

LASER21

AceXon
ACEXON TECHNOLOGIES PTE LTD

Quantum Design
Singapore

genetron

CST

Institutional Sponsors:

NUS National University of Singapore

CQT Centre for Quantum Technologies

SUTD SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN
Established in collaboration with MIT

NUS National University of Singapore | Centre for Advanced 2D Materials

NANYANG TECHNOLOGICAL UNIVERSITY

YaleNUSCollege

1 Foreword

Dear fellow Physicists,

after visiting the new campus of the Singapore University of Technology and Design last year, we are are yet again visiting a new venue, the campus of the Yale-NUS College for our annual gathering of physicists active in research.

With this meeting, we aim to maintain a good mix of overview presentations from internationally established scientists, and provide a platform of exchange and networking for every active researcher in physical sciences here in Singapore. The scope is deliberately wide, just to make sure that we don't only meet the colleagues we hang out with in specialized workshops all the time anyway.

This year, we have six plenary talks, grouped in three themes: the first one Wednesday morning on the very hot topic of topological materials and their applications, with Michael Fuhrer from Australia and Justin Song from NTU as speakers. A second theme is around new effects and powerful observation techniques for surface physics, with Stephen Pennycook from the Material Science Department at NUS, and Christos Panagopoulos from NTU as plenary speakers. The third theme is about fancy facilities taming extreme light sources – an overview of the Singapore Synchrotron Light Source by its director, Mark Breese, and one on light emitted by cosmic explosions by the Zwicky Transient Facility, brought to us by Astrophysicist Bryan Penprase from our host institution this year, Yale-NUS College.

Apart from the Plenary overviews, we feature 17 technical sessions with 86 talks, of which the IPS meeting program committee selected 31 as invited talks. We are again happy to see a wide spectrum of research activities present in this year's IPS meeting.

As always, technical talks can be demanding to follow, so we have again a strong poster session with some 57 posters, including contributions from some Junior College students participating in university research. As in the last few years, we have a poster pitch session, where poster presenters can volunteer to give an ultrashort teaser to the whole of the IPS conference audience. And, also as it proved a very workable concept, the poster session in the middle of the meeting on Thursday afternoon is followed by a Pizza and Drink event, to provide a proper setting for networking between physicists here in Singapore.

Last but not least, our colleagues at the Ministry of Education set up a track on Friday afternoon, where we honor the successful participants of the Physics Olympiad with an award ceremony, and a panel discussion to provide the potentially next generation of researchers with a perspective on what physicists do. Be prepared to be chased during the conference to participate in this event, and share your views with the students on Friday afternoon!

This leaves me to say a big thanks to all helpful hands especially at Yale-NUS, and students form several research groups across the island.

We are also happy again to acknowledge our institutional supporters, the Department of Physics at NUS and the School of Physics and Applied Physics at NTU, the Yale-NUS College, the Graduate Studies Program at SUTD, and, as research-active centers, the Centre for Quantum Technologies and the Centre for Advanced 2-Dimensional Materials.

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

With this, we hope this conference gets you out of your comfort zone a little bit, and inspires you with new ideas, new contacts, new collaborations for a successful new year of research in physical sciences ahead!

Your organizing team of the IPS meeting 2017

Contents

2 Schedule

Wednesday, 22 February

8.30 AM	Registration (Foyer of Performance Hall, W2)			
9.00 AM 9.15 AM	Opening Address (Performance Hall, W2) Plenary talk 1 (Performance Hall, W2)			
10.00 AM	Plenary talk 2 (Performance Hall, W2)			
10.45 AM	Coffee/Tea Break + Exhibition (Foyer of Performance Hall, W2)			
11.15 AM	Technical Sessions			
	T1 (EC3) Novel 2D Phenomena	T2 (E4) Energy Storage	T3 (E3) Open Quantum Systems	T4 (E1) Optical Computing
12.45 PM	Lunch + Exhibition (Foyer of Performance Hall, W2)			
1.30 PM	Technical Sessions			
	T5 (EC3) Topological Phenomena	T6 (E4) Biophysics	T7 (E3) Quantum Information	
3.00 PM	Coffee/Tea Break + Exhibition (Foyer of Performance Hall, W2)			
3.30 PM	Technical Sessions			
	T9 (EC3) General Theory 1	T10 (E4) Meta-materials	T11 (E3) Quantum Simulation and Computation	
5.00 PM	End of Wednesday sessions			

Thursday, 23 February

8.30 PM	Registration
9.00 AM	Plenary talk 3 (Performance Hall, W2)
9.45 AM	Plenary talk 4 (Performance Hall, W2)
10.30 AM	Coffee/Tea Break + Exhibition (W2) + Poster mounting (E2)
11.00 AM	Technical Sessions T13 (EC3) Disordered 2D Materials T14 (E4) Devices T15 (E3) Techniques in Photonics T16 (E1) General Theory 2
12.30 PM	Lunch + Posters + Exhibition (Foyer of Performance Hall, W2)
1.30 PM	PO1: Rapid Fire poster Pitch session (Performance Hall, W2)
2.30 PM	Coffee/Tea Break + Exhibition
3.00 PM	PO2: Poster session (Multipurpose Hall E2) + Exhibition
5.30 PM	Poster awards + Pizza + Drinks (Oculus, near Performance Hall W2)
6.30 PM	End of Thursday sessions

Friday, 24 February

8.30 PM	Registration (Foyer of Performance Hall, W2)
9.00 AM	Plenary talk 5 (Performance Hall, W2)
9.45 AM	Plenary talk 6 (Performance Hall, W2)
10.30 AM	Coffee/Tea Break + Exhibition (W2)
11.00 AM	Technical Sessions T17 (EC3) Theory of 2D systems T18 (E4) Acoustics and Nanomechanics T19 (E3) Photonics
12.30 PM	Lunch + Exhibition
1.30 PM	Registration for Physics Olympiade award winners (Outside Performance Hall, W2)
2.00 PM	O1: Physics Olympiad award ceremony (Performance Hall, W2)
3.00 PM	O2: Panel discussion "Personal Perspectives on Physics" (Performance Hall, W2)
4.30 PM	Refreshments and networking (Oculus)
5.30 PM	End of Conference

3 Plenary sessions

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

P1: Topological Electronics

Prof. Michael S. Fuhrer, ARC Centre of Excellence in Future Low Energy Electronics Technologies
School of Physics and Astronomy, and Monash Centre for Atomically Thin Materials, Monash University, Monash 3800 Victoria, Australia
Email: michael.fuhrer@monash.edu

Wednesday, 22 February, 9:15am, Venue: Performance Hall

Abstract

Energy consumption in the information and communications technology (ICT) sector already accounts for about 5% of global electrical energy consumption, and is doubling every decade. There is an identified need for a new computing technology with vastly lower energy consumed per operation, but no clear technological solution at present. The discovery in the last decade of topological phases of matter offers a new route to low-energy computation devices. Topological insulators differ from conventional insulators in that the former are guaranteed to have conducting states on their boundaries i.e. edges in two dimensions (2D), or surfaces in three dimensions (3D). These conducting states are generically protected from backscattering and cannot be localized, and, in the case of edge modes of 2D topological insulators, may even conduct current without dissipation. Topological transistors, in which electric or magnetic fields tune a material from conventional insulator to topological insulator, may require less energy for switching than their conventional counterparts, field effect transistors in which an insulator (semiconductor) is tuned to conduction by adding charge. I will discuss how topological insulators arise from basic physical considerations, give some examples of real topological materials being studied today, and give an outlook on what is needed to realise topological electronics.

About the Speaker

Michael S. Fuhrer directs the Australian Research Council Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET). Fuhrer received his B.S. in Physics from the University of Texas at Austin in 1990, and Ph.D. in Physics from the University of California at Berkeley in 1998. After postdoctoral research at Berkeley, Fuhrer joined the University of Maryland as an Assistant Professor in 2000, and from 2009-2012 was Professor, and Director of the Center for Nanophysics and Advanced Materials. In 2012 Fuhrer was awarded an ARC Laureate Fellowship, and moved to Monash University as Professor of Physics in 2013, where he founded the Monash Centre for Atomically Thin Materials. Fuhrer studies the electronic properties of low-dimensional systems, including carbon nanotubes, graphene, atomically thin semiconductors, and the surface states of topological insulators. His works have been cited over 17,000 times. Fuhrer is a Fellow of the American Physical Society and the American Association for the Advancement of Science.

P2: Anomalous opto-electronics in topological semimetals

Justin Song, Nanyang Assistant Professor of Physics, School of Mathematical and Physical Sciences, Nanyang Technological University
and National Research Foundation Fellow

Wednesday, 22 February, 10:00am, Venue: Performance Hall

Abstract

The "twisting" of electron wavefunctions in crystals, as encoded by Bloch band Berry curvature or band topology, yield anomalous electronic properties that characterize topological materials. In the presence of electron interactions, a rich array of topological phases and behaviors are expected to manifest.

I will detail how the combined action of Berry curvature and band topology can dramatically enrich the range of opto-electronic properties found in topological materials. One striking example are a new class of collective excitations – Berry plasmons - that manifest in anomalous Hall metals. Berry plasmons manifest as chiral propagating plasmonic modes, which are confined to system boundaries, and appear even in the absence of magnetic field or topological edge states. A second example are collective modes of Fermi-arc carriers in time reversal broken Weyl semimetals. These chiral fermi arc plasmons possess dispersion relations that are open, featuring hyperbolic constant frequency contours. As a result, a large range of surface plasmon wave vectors can be supported at a given frequency, with corresponding group velocity vectors directed along a few specific collimated directions. Both Berry plasmons and Fermi-arc plasmons can be probed via nanophotonic methods, and are parts of an increasingly rich new tool box to manipulate light in topological matter.

About the Speaker

Dr. Song's research focuses on unveiling new emergent phenomena in quantum systems. Recently discovered quantum materials provide a ripe venue for this exploration, e.g., Weyl and Dirac materials, van der Waals heterostructures, topological insulators, as well as driven systems such as those realized in cold atom optical lattices. In many of these, the unique winding of Bloch wavefunctions, electron correlations, intimate coupling between several layers in heterostructures, external drives that push a system away from equilibrium, or indeed the interplay of any and all of the above can yield qualitatively new phenomena. His research uncovers how these can manifest in transport, optical, and/or opto-electronic response signatures that may be probed in experiment.

An area of current interest are topological materials, where the winding of Bloch wavefunctions changes the motion of electrons in an essential way. For example, charge carriers in materials are often described as particles similar to free electrons but characterized by effective quantities such as an effective mass. However, electrons in topological materials defy this description; they acquire an additional quantum mechanical property - Berry curvature - that radically alters their dynamics. Much as a spinning baseball allows a pitcher to start a wide variety of plays -

e.g., fastballs, curveballs, changeups - Berry curvature (a kind angular momentum that is engineered into a crystal) may yield a plethora of non-intuitive, and as yet undiscovered, electronic behavior.

P3: Materials under the microscope: the atomic origin of functionality

Prof. Stephen J. Pennycook, Department for Material Science & Engineering, National University of Singapore

Thursday, 23 February, 9:00am, Venue: Performance Hall

Abstract

The aberration-corrected scanning transmission electron microscope (STEM) provides real space imaging and spectroscopy with single atom sensitivity. Coupled with first-principles theory, we can now unravel what controls the functionality of surfaces and interfaces, the key to the design of new materials with improved properties. For example, in Nb@C catalysts, we find that single atoms are the active sites, not the numerous nanocrystals that are also present [1]. In $BiFeO_3$ films grown on $La_{0.5}Sr_{0.5}MnO_{3-x}$ the precise interface termination determines ferroelectric properties [2], and in CdTe solar cells, grain boundaries, long supposed detrimental to properties, are actually found to be beneficial [3]. We can understand the origin of colossal ionic conductivity in strained yttria-stabilized zirconia [4], and the formation of flexible metallic nanowires by electron beam sculpting [5]. In the future we may even be able to determine materials structure and bonding at atomic resolution in three dimensions [6].

[1] X. Zhang et al.: *Catalytically active single-atom niobium in graphitic layers*, Nature Communications **4**, 1924–1927 (2013).

[2] Y.-M. Kim et al.: *Interplay of Octahedral Tilts and Polar Order in $BiFeO_3$ Film*, Advanced Materials **25**, 2497–2504 (2013).

[3] Li et al.: *Grain-Boundary-Enhanced Carrier Collection in CdTe Solar Cells*, Phys. Rev. Lett. **112**, 156103 (2014).

[4] T. J. Pennycook et al.: *Origin of Colossal Ionic Conductivity in Oxide Multilayers: Interface Induced Sublattice Disorder*, Phys. Rev. Lett. **104**, 115901 (2010).

[5] J. Lin et al.: *Flexible metallic nanowires with self-adaptive contacts to semiconducting transition-metal dichalcogenide monolayers*, Nature Nanotechnology **9**, 436–442 (2014).

[6] R. Ishikawa, S.J. Pennycook, A.R. Lupini, S.D. Findlay, N. Shibata, and Y. Ikuhara: *Single atom visibility in STEM optical depth sectioning*, Applied Physics Letters **109**, 163102 (2016).

About the Speaker

Stephen J. Pennycook obtained his B.A. degree in natural sciences from the University of Cambridge, England, in 1975, and his M.A. and Ph.D. degrees in physics from the same institution in 1978. He then continued at the University of Cambridge Cavendish Laboratory in postdoctoral positions until moving to the ORNL Solid State Division in 1982, where became leader of the Electron Microscopy Group. Since 2014, he is Professor at Department of Materials Science and Engineering at the University of Tennessee, USA, and Professor at the Dept. of Materials Science and Engineering at the National University of Singapore.

His main research interest is the study of materials through the technique of Z-contrast scanning transmission electron microscopy (STEM). This technique provides a directly interpretable image of materials at the atomic scale, in which higher atomic numbers (Z) show brighter. It overcomes the phase problem associated with conventional electron microscopy and diffraction techniques by establishing incoherent imaging conditions, the electron equivalent of incoherent imaging in the optical microscope first described by Lord Rayleigh in 1895.

P4: Spin orbit coupling phenomena at surfaces and interfaces

Prof. Christos Panagopoulos, Division of Physics & Applied Physics School of Physical & Mathematical Sciences, Nanyang Technological University Thursday, 23. February, 9:45, Venue: Performance Hall

Abstract

Recent advances in thin film growth techniques and in calculation capabilities in condensed matter physics have enabled the synthesis of atomically flat surfaces and heterostructures, and the prediction of their electronic properties. A prototype laboratory infrastructure and an integrated network of techniques enable us to study tailor-made materials architectures including magneto-electrics, ultrathin magnets, superconductors, quantum Archimedean lattices, and atomic scale spin valves.

A common thread across several architectures of interest, especially heavy metal compounds and multilayers is that the spin orbit coupling strength at surfaces and interfaces is comparable to the other relevant energy scales, and thus plays a pivotal role. Novel spin-charge phenomena emerge often robust to disorder and thermal fluctuations, with much promise for room temperature applications.

I will discuss the notable progress made on Rashba interfaces, symmetry protected states, non-collinear spin textures, and techniques to generate, stabilize and manipulate them in devices. Using particle-like spin structures as a paradigm, I will demonstrate that the states induced by spin orbit coupling and inversion symmetry breaking open a broad perspective with significant impact in the practical technology of spin topology.

About the Speaker

Prof. Christos Panagopoulos is currently in the School of Physical and Mathematical Sciences since 2008. He received his Bachelor's of Science (Honours) degree in Physics from La Trobe University, Master's of Science from Kyushu University and Ph.D. from the University of Cambridge. His research interests include phase control in smart materials operations, quantum magnetism and superconductivity, and electron motion through materials at their quantum limits. He has been the group leader of a European excellence team and has served as a visiting professor or scientist at a number of institutions, including the Chinese Academy of Sciences and the Universities of British Columbia, Tohoku and Kyoto. Author of more than 50 research papers published in refereed journals, Panagopoulos has delivered more than 100 invited lectures at international meetings and universities. Honours accorded Panagopoulos include the European Young Investigators Award, the European Excellence Grant and his election as Research Fellow of Trinity College, Cambridge and University Research Fellow of The Royal Society, UK.

Driven primarily by innovations in materials science and engineering, his research focuses on condensed matter systems with spontaneous tendencies toward complex electronic pattern formation. The materials investigated in his laboratory include spin and charge memory devices, magneto-electrics and high-temperature superconductors. These are part of a larger class of prime examples of frontier technology for the 21st century, displaying novel behaviours that do not conform to the quantum theory of solids developed over the past 70 years. Panagopoulos develops an international coordinated effort on the science and applications of emergent complex phases in modern materials. Understanding and controlling these spontaneous tendencies will enable the design and development of highly sensitive micro- and nano-scale devices where we tune electronic matter to the widest possible range, starting from an insulator to a high temperature superconductor.

P5: The Singapore Synchrotron Light Source

Prof. Mark Breese, Department of Physics, NUS
Director, Singapore Synchrotron Light Source (SSLS)
Director, Nanoscience and Nanotechnology Initiative (NUSNNI)
5 Research Link, National University of Singapore, Singapore 117603 Friday, 24. February, 9:00am, Venue: Performance Hall

Abstract

Synchrotron radiation is a powerful tool for analytical purposes and for advanced fabrication, which has become indispensable in many disciplines such as the life sciences, materials science, environmental analysis, and micro/nano fabrication. Synchrotron radiation enables us to look into living organisms, man-made materials and advanced engineering components, in vivo, almost non-destructively, in situ, and with spatial and time resolution, revealing detailed structural, chemical, electronic, and magnetic properties. Our superconducting storage ring uses a 700 MeV electron energy and 4.5 Tesla magnetic field to produce synchrotron radiation with a characteristic photon energy of 1.47 keV and characteristic wavelength of 0.845 nm. We have seven Synchrotron beam lines covering the full spectrum of radiated photon energies, from infrared to X-rays of about 10 keV. This presentation will give an overview of SSLS, covering the accelerator, beam lines and range of applications.

About the Speaker

Prof. Mark Breese obtained his Phd in 1990 from the University of Salford, UK, followed by prestigeous Postdoctoral fellowships from Oxford and the University of Melburne. In 1996, he became a E.C. Professor at the Physics Department, University of Lisbon, Portugal, moved on as a Lecturer in Physics, University of Surrey, UK in 1998, before he joined the Department of Physics at NUS as an Associate Professor in 2002. He was elected a Fellow of the Institute of Physics in UK and Singapore in 2005, and served as a Deputy Head of the Physics Department at NUS from 2006 tto 2010. He currently is Director of the Singapore Synchrotron Light Source (SSLS), as well as the Nanoscience and Nanotechnology Initiative (NUSNNI), both at the National University of Singapore.

Prof. Breese's ion beam research activities are centred around the use of focused high-energy beams of charged particles as a means of imaging the structure and crystallinity of materials and to modify their properties. This work includes areas such as porous silicon formation, electrochemistry, ion optics, and ion channelling, accelerator physics. Much of the current work is on the use of silicon micromachining to fabricate micro- and nanoscale components for silicon photonics. His Synchrotron research activities include X-ray lithography, X-ray optics, accelerator physics, soft X-ray scattering.

P6: Chasing Cosmic Explosions: ZTF and Time-domain astrophysics

Prof. Bryan E. Penprase
Professor of Science and Director, Centre for Teaching and Learning at Yale-NUS college
Visiting Associate, California Institute of Technology
Research Professor, Pomona College
16 College Avenue West, #01-220 Singapore 138527 Friday, 24. February, 9:45am, Venue: Performance Hall

Abstract

Prof. Penprase will discuss the most luminous sources of radiation in the universe: quasars, supernovae, gamma ray bursts, and merging neutron stars, in the context of his collaboration with astrophysicists at Caltech and worldwide on the "Zwicky Transient Facility" – or ZTF. He will also give an overview of these cosmic explosions, and the technologies on earth and space used to discover and characterize these transient events. With the discovery of gravitational waves from LIGO and an emerging global telescope network, opportunities exist for entirely new types of astronomy and he will explain this new dynamic type of astrophysics that allows astronomers to "chase" these cosmic explosions before they fade away, and what new types of astrophysics they are revealing. The research on such transients has discovered new types of supernovae, new gamma-ray bursts, and gravitational lensing sources. With a global network of telescopes known as GROWTH the time-evolution of the "explosions" is revealing new information about the astrophysics of compact objects, the formation of the elements, and the last moments of stars as they collapse. The new ZTF facility is opening in summer of 2017, and the talk will review some of the capabilities of ZTF and the latest research ongoing with the GROWTH network, and plans for the new research with ZTF.

About the Speaker

Dr. Bryan Penprase is a Professor of Science at Yale-NUS College, and for 20 years was the Frank P. Brackett Professor of Astronomy at Pomona College. Bryan received both a BS in Physics and an MS in Applied Physics from Stanford University in 1985, and a PhD from the University of Chicago in Astronomy and Astrophysics in 1992. Bryan's research includes nearly all aspects of observational astrophysics, from photometric observations of nearby asteroids to spectroscopic studies of element formation in the Early Universe, using telescopes such as the Hubble Space Telescope and the Keck Telescope in Hawaii. He is the author of "The Power of Stars – How Celestial Observations Have Shaped Civilization," published by Springer, Inc., and has authored or co-authored over 50 peer-reviewed articles, in the Astrophysical Journal, Astronomical Journal, and in Nature and Science. He has served on numerous NSF and NASA review panels, including the Hubble Space Telescope Time Allocation Committee and the NASA/Keck Time Allocation Committee, and has participated in the external review of the Five College Astronomy Program. His most recent research program is a collaboration with Caltech to develop the Zwicky Transient Facility (ZTF) and a Global Relay of Observatories known as GROWTH for studying gamma ray bursts, new supernovae, and the electromagnetic counterparts of gravitational wave sources.

4 Poster Sessions

PO1: Rapid fire poster pitch student competition

As in the last two years, we have a full session (Thursday after 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 postersipsmeeting.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 at (Venue: near W2).

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.

Location

The poster area will be in the multipurpose hall in E3. Each poster is assigned a panel which corresponds to the easychair number. We will provide Velcro strips to mount the posters on the wall, please see the reception desk for this.

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 Point Defects in CVD-grown Monolayer WSe_2 studied by STM/STS and DFT Modeling

Yujie Zheng*, Andrew Wee, Su Ying Quek (NUS)

An intensive study of intrinsic point defects of CVD-grown monolayer tungsten diselenide (WSe_2) on graphite is performed via scanning tunneling microscopy/spectroscopy (STM/S) and density functional theory (DFT) modeling. We find that possible candidates for the dominant defects are O substitution and O insertion for our CVD-grown WSe_2, which is different from CVD-grown MoS_2 where sulphur vacancies are dominant. From the STS results, we find that the electronic properties of WSe_2 are preserved at the defect sites. Our first principles calculations show that O substitution and O insertion defects can considerably improve the chemical activity of WSe_2. The atomic scale study of the native point defects provides fundamental insights and paves the way for defect engineering in WSe_2.

PO.5 Dual-functional N dopants in MoS_2 nanosheets towards efficient hydrogen evolution

Wen Xiao, Yuan Ping Feng, Daqiang Gao*, Jun Ding* (National University of Singapore)

Green production of hydrogen (H_2) via electrolysis of water is widely regarded as a promising route for energy conversion and storage, which triggers enormous interest to design efficient and economical hydrogen evolution reaction (HER) electrocatalysts. Herein, we perform a combined first-principles and experimental study to investigate the dual-functions of N dopants in molybdenum disulfide (MoS_2) nanosheets towards efficient hydrogen evolution. Firstly, systematic first-principles calculations reveal that N dopants activate the HER catalytic activity of MoS_2 S-edge and explicitly identify the S site opposite to the N dopant in the S-edge as the new active HER site due to the weakened H-S bond. Secondly, N dopants in MoS_2 basal plane induce uniformly distributed conducting charges over the material because of the strong Mo 3d–S 2p–N 2p hybridizations at Fermi level, which promote rapid charge transfer and enhance the conductivity of the electrocatalyst. Furthermore, comprehensive experimental study proves that both the amount of active HER sites and the conductivity of N-doped MoS_2 increase with the increasing concentration of N dopants. Finally, we achieve the most efficient MoS_2-based HER catalyst of N-doped MoS_2 nanosheets, possessing an onset overpotential of 35 mV, an overpotential of 121 mV at 100 mA/cm^2 and a Tafel slope of 41 mV/dec. Our findings will stimulate further development on nonmetal-doped MoS_2 systems as high-performance electrocatalysts for efficient hydrogen production via electrolytic water splitting.

PO.7 Pseudocapacitive Na-Ion Storage Boosts High-Rate and Areal Capacity of Self-Branched 2D Layered Metal Chalcogenide Nanoarrays

Dongliang Chao, Ze Xiang Shen* (School of Physical & Mathematical Sciences)

The abundant reservation and low cost of sodium have provoked tremendous evolution of Na-ion batteries (SIBs) in the past few years, but their performances were still limited either by the specific capacity or rate capability. Attempts to pursuit high-rate ability with maintained high-capacity in a single electrode remains even more challenging. Here, an elaborate self-branched 2D SnS_2 (B-SnS_2) nanoarrays electrode is designed by a facile hot bath method for Na storage. This interesting electrode exhibits unprecedented areal reversible capacity of ca. 3.7 mAh cm^{-2} (900 mAh g^{-1}), and rate capability of 1.6 mAh cm^{-2} (400 mAh g^{-1}) at 40 mA cm^{-2} (10 A g^{-1}). Improved extrinsic pseudocapacitive contribution is demonstrated as the origin of fast kinetics of alloying-based SnS_2 electrode. Sodiation dynamics analysis based on first-principle calculations, ex-situ HRTEM, in-situ impedance, and in-situ Raman technologies verify the S-edge effect to the fast Na+ migration, reversible and sensitive structure evolution during high-rate charge/discharge. The excellent alloying-based pseudocapacitance and unsaturated edge-effect enabled by self-branched surface nanoengineering could be a promising strategy for promoting development of SIBs with both high capacity and rate response.

PO.9 Sulfur synchronously electrodeposited onto exfoliated graphene sheets as cathode material for advanced lithium-sulfur batteries

Liyuan Zhang*, Hong Jin Fan* (Nanyang Technological University)

Lithium-sulfur batteries show fascinating potential applications for the rapid-growing electric vehicles and grid-level energy storage due to low cost and high energy density. Up to date, various carbon hosts have been utilized to confine sulfur for improving Li-S battery performance. However, the adopted sulfur storage techniques are post-carbon-synthesis involving complex processes. It remains a great challenge for the ideal configuration of carbon-sulfur composite with uniform dispersion and high sulfur loading. Herein, we report a novel synthesis of graphene-sulfur composite (GSC) by electrolytic exfoliation of graphite coupled with in situ sulfur electrodeposition. The sample delivers an initial discharge capacity of 1080 mAh g^{-1} at 0.1 A g^{-1} and retains above 900 mAh g^{-1} over 60 cycles. This strategy via. electrochemical exfoliation/deposition synchronous reactions can provide strong sulfur chemical interaction with the graphene host, achieving advanced cathode materials for Li-S batteries.

PO.20 Fano resonances mediated by various multipoles in two-dimensional metamaterials

Longqing Cong*, Yogesh Srivastava, Ranjan Singh (Nanyang Technological University)

The interaction between microscopic particles has always been a fascinating and intriguing area of science. Similar interactions are reproduced in the dynamic electromagnetic system which would provide an avenue to explore and interpret the microscopic phenomena. Metamaterials provide the freedom to artificially tailor light-matter interaction and the interaction between unit cells in the array. Here, the static spin of a particle is mimicked by an electromagnetic excited Fano resonance in a meta-molecule that is induced a dynamic magnetic dipole. We discuss the dynamic interactions of meta-molecules in the array in terms of multipoles by selectively configuring the spin orientation distributions. Various multipoles featured Fano resonances are individually induced in arrays composed of symmetrically distributed spin orientations, and they are simultaneously excited in a single spectrum in arrays of asymmetrically distributed spin orientations. This multi-Fano resonances spectrum provides a multispectral sensing platform for applications in imaging and biosensing. The dynamic approach to reproduce the static interaction between microscopic particles would enable more profound significance in exploring the unknown physical world by the macroscopic analogues.

PO.21 Negative differential resistance in MoS_2/BN/MoS_2 heterostructure

Shoujun Zheng*, Fucai Liu, Hongjin Fan (Nanyang Technological University)

Resonant tunneling diode based on graphene/BN/graphene heterostructure has been reported by L. Britnell et al. The peak-to-valley ratio of negative differential resistance (NDR) is about 4 at 6 K. It was predicted that the peak-to-valley ratio based on 2-dimensional transitional metal chalcogenides is much higher than the one based on graphene. Here, we fabricated a MoS_2/BN/MoS_2 heterostructure and observed NDR in this device at room temperature. The peak position of the NDR is gate-tunable. However, the peak-to-valley ration is quite small, which may result from n-type MoS_2 and twist of different layers.

PO.30 Mn-based Oxides As Anodes for Li-Ion Batteries

Shen Kai Yeo, Min Shi Justin Tan, Yi Quan Matthias Liau, M.V. Reddy* (Department of Physics, National University of Singapore)

MnO2 nanopowders with different morphology were synthesised using the molten salt method, by firing LiNO3 and LiOH with different starting manganese reagents, namely Mn(NO3)2, MnSO4 and MnCO3. The powders were analysed with the Brunauer–Emmett–Teller (BET), X-ray photoelectron spectroscopy (XPS), X-Ray Diffraction (XRD) and Transmission Electron microscope (TEM). The 3 different powders were made into separate anodes with and without graphene oxide (GO), resulting in a grand total of 6 batches of anodes. Each anode was constructed into a battery cell and underwent characterisation tests, such as Galvanostatic Cycling (GC), Cyclic Voltammetry (CV), and Electrochemical Impedance Spectroscopy (EIS). Results from GC indicates that amongst all the batteries, the cell with anode made from MnSO4 boasts the lowest capacity fading of around 15% from the 2nd to 40th cycle, with a reversible capacity of 550 mAh/g, which is higher than the theoretical capacity of graphite, 372 mAh/g. Impedance studies showed that the best performing samples had lower impedance. It was also shown that the addition of graphene oxide generally lowers the cell capacity and increases capacity fading.

Yeo Shen Kai(1), Justin Tan Min Shi(1), Matthias Liau Yi Quan(1), M.V. Reddy(2)

(1)NUS High School of Math and Science, 20 Clementi Avenue 1, Singapore 129957 (2)Department of Physics, National University of Singapore, Singapore 117542

PO.31 Optical Isolation with Nonlinear Topological Photonics

Xin Zhou, You Wang, Daniel Leykam, Yidong Chong* (Nanyang Technological University)

We perform a theoretical study of self-induced topological edge states in nonlinear photonic topological insulators, and show that the phenomenon be used to implement nonlinear optical isolators. Compared to conventional nonlinear optical isolator designs, which are not based on topological photonics, our proposed system can achieve large isolation ratios while being robust to lattice defects. Our results are based on simulations of coupled-waveguide lattices as well as ring resonator lattices, both of which are experimentally realizable.

PO.32 Electronic and optical properties of black phosphorous based van der Waals heterostructures

Yifeng Chen, Su Ying Quek* (Centre for Advanced 2D Materials and Department of Physics, National University of Singapore)

Black phosphorous (BP) is an emerging 2D material for novel electronic and optoelectronic applications. In particular, the broadband tunable and anisotropic optical response of atomically thick BP layers are very intriguing and promising. Van der Waals heterostructures of atomically thin 2D materials have been proven to be an important route towards device functionalizations of these system. Here we investigate BP based heterostructures both with isoelectronic GeS layers and with hexagonal boron nitride (hBN) layers. First principle many body perturbation theory based GW method was used to study their quasiparticle excitation properties, while the Bethe-Salpeter equation was solved upon the GW result (GW-BSE formalism) to obtain the optical absorption spectrum. We find that the direct band gap of monolayer BP is preserved in these vertical heterostructures, while the optical spectra are influenced differently due to different dielectric environment. Our work provides important understandings and insights about BP based heterostructures, and paves the way for further sophisticated studies and possible device utilizations.

PO.34 High quality multi-functional silicon nitride thin films fabricated by low energy inductively coupled plasma assisted chemical vapour deposition for photovoltaic applications

Christian Yudhistira, Jian Wei Mark Lim*, Shuyan Xu (Plasma Sources and Applications Centre, National Institute of Education, Nanyang Technological University)

Crystalline silicon based photovoltaic (PV) cells dominates the market as the main type of device used to harvest solar energy. However, despite being researched on extensively, efficiencies of silicon-based solar cells still remain low. A silicon nitride layer can significantly improve efficiency of a silicon-based solar cell in three ways: reducing the amount optical losses by serving as an anti-reflection coating (ARC), increasing the minority carrier lifetime by passivation of dangling bonds at the wafer surface, and reducing surface recombination velocity by inducing positive static charges resulting from development of K+ centres in the structure. In this work, optical simulations were carried out to determine optimized film thicknesses of the ARC based on the refractive indices of the material interfaces. Inductively coupled plasma-chemical vapour deposition (ICP-CVD) is then used to deposit silicon nitride layers on top of various substrates with varied power and nitrogen flow rates. Coupled with plasma diagnostics, it is possible to derive how process parameters affect plasma parameters which in turn result in different chemical compositions which ultimately impact minority carrier lifetime, deposition rate, reflectance and refractive index. The results show changes in nitrogen content significantly influence the optoelectronic properties of the film while power and temperature mainly affect deposition rate of silicon nitride layer. With improved understanding on how these variables affect the film, it is possible to implement silicon nitride film on commercially available cells to further increase efficiency.

PO.35 Light-dragging effect in a moving electromagnetically induced transparent medium

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

As one of influential experiments on the development of modern physics, the phenomenon of light dragging in a moving medium has been discussed and observed extensively in different types of systems. In order to get a larger dragging effect, a long duration of light travelling in the medium is preferred. We therefore demonstrate a light-dragging experiment in an electromagnetically induced transparent cold atomic ensemble to enhance the dragging effect by at least three orders of magnitude compared with the previous experiments. With a large enhancement of the dragging effect, we realize an atom-based velocimeter that has a sensitivity two orders of magnitude higher than the velocity width of the atomic medium used. The result suggests the possibility of making a motional sensor using the collective state of atoms in a room temperature vapour cell or solid state material in the future.

PO.36 Center-of-mass motion in three-level Raman transitions

Luyao Ye*, Englert Berthold-Georg (Centre for Quantum Technologies)

Abstract Theoretical and experimental values of the fidelities of two-qubit neutral-atom gates suffers significant disagreement. This suggests a more thorough analysis on the possible errors in the implementation of the gates. In general, the experimental implementation of neural-atom gates consists of three major steps. First, the atoms carrying quantum information are cooled and trapped in the extrema of optical potentials produced by laser beams. Second, the trapping lasers are switched off when short pulses of light field are sent to interact with the atoms and drive the atomic transitions for the gate operation. Third, after the sequence of light pulse has been implemented, the trapping lasers are switched on to recapture and trap the atoms. These trapped atoms are not stationary. They have a center-of-mass (CM) motion and a corresponding momentum distribution depending on the geometry, depth, and other properties of the trap. Such CM motion has two major effect: • The change of CM wave function by the laser pulses can lead to mis-capturing the atoms after trapping lasers are turned back on again. This probability of mis-capturing the atom due to CM motion should be well below 1%. • The atom-light interaction entangles the CM motion to the atomic levels due to photon recoils. This is often treated approximately with Doppler shifts. In this poster, we give a more rigorous analysis of the CM motion in two-level and three-level Raman transitions taking into full account of the CM wave functions.

PO.37 Charge transport properties of 2,2',6,6'-tetraphenyldipyranylidene thin films

Marc Courte, Sandeep Surya, Ramesh Thamankar, Chao Shen, V. Ramgopal Rao, Subodh Mhaisalkar, Denis Fichou* (NTU - NANYANG TECHNOLOGICAL UNIVERSITY)

The charge transport properties of 2,2',6,6'-tetraphenyldipyranylidene (DIPO-Ph4), a large planar quinoïdal pi-conjugated heterocycle, are investigated in field-effect transistor (FET) configuration and by conductive atomic force microscopy (c-AFM). The field-effect transistor properties show a clear p-type behavior with a hole mobility up to 2×10-2 cm^2/V.s. The transfer characteristics Id/Vg present a clear hysteresis typical of a resistive memory effect. This memory effect is confirmed by means of c-AFM in lateral mode using a nearby gold top-contact as the counter-electrode. The c-AFM current response recorded between the AFM tip and the top electrode shows a resistive switching behavior in the low-voltage 0.0–3.0 V region. Repeated "write-read-erase-read" cycles performed at low frequency reveal a non-volatile memory effect in the form of high-resistance and low-resistance states.

PO.38 Deterministic nanoscale modification of p-type silicon surfaces through plasma diagnostics of inductively coupled Ar + H_2 plasma discharges

Yvette Lim Yu, Jian Wei Mark Lim*, Shiyong Huang, Shuyan Xu (Plasma Sources and Applications Centre, National Institute of Education, Nanyang Technological University)

There are various published research articles detailing the process and results of Ar+H_2 plasma treatment of p-type silicon wafers. These articles show that variations of the Ar:H_2 ratio, pressure and discharge power yield significant changes in the material properties of the processed substrates. These include significant reduction in material reflectance, formation of a p-n junction leading to a measurable open-circuit voltage (Voc) across, and uniform production of nanotextures as seen through the scanning electron microscope (SEM). However, little correlation between the discharge processes, parameters and material properties has been made so far, which greatly impedes the reconstruction of the appropriate experimental environment to achieve desired results. In this work, plasma diagnostics of an Ar + H_2 discharge were performed with the aid of a Langmuir probe and an optical emission spectrometer to yield information on the electron density (ne), electron temperature (Te), electron energy distribution function (EEDF) and the density of reactive species present in the bulk discharge. The variation in discharge parameters resulted in a wide range of obtained Voc's in the excess of 480 mV, and a broad range of reflectivities from 5.67 – 27.3 %. This work uncovers the underlying discharge mechanisms based on the derived plasma parameters and reveals information on the plasma and surface chemistry resulting in the material properties obtained as well as the etch profiles seen through SEM. This offers huge promise for single step processing of ultra-low reflectivity photovoltaic cells as recipes can be transferred from different fabrication facilities with varied geometries based on their plasma parameters as opposed to process parameters, improving reliability and reproducibility with potential for rapid upscaling.

PO.39 Building a sub-nanometre resolution grating monochromator

Zheng Yang Choong* (Hwa Chong Institution)

In this work, we build and demonstrate a grating monochromator calibrated to the HeNe 632.8 nm laser line. The predicted resolution limit for a multi-mode beam is close to 2 nm. We observe spectral peaks at 632.8 ± 0.1 nm and 633.9 ± 0.2 nm, with a FWHM of 2.1 ± 0.1 nm, in agreement with the theoretical prediction. Having demonstrated the grating monochromator, we then produce and observe breakdown flash, performing timing correlation measurements on photo-events from a pair of APDs; we obtain two correlation peaks, indicating the detection of breakdown flash, with a signal-to-noise ratio of 10.2 ± 0.5.

Silicon Avalanche Photodiodes (APDs) are commonly used for their high sensitivity and quantum efficiency in the visible to near-infrared regime. However, during avalanche breakdown, APDs emit some visible light in what is known as breakdown flash. This can compromise the security of quantum key distribution implementations, providing an eavesdropper with information on photo-detection events. We thus intend to extend this technical capability to characterise the spectrum of breakdown flash at the single-photon level using a technique called photon coincidence spectrometry, resolving the spectrum of breakdown flash at a sub-nanometre resolution.

PO.43 Nanostructured $VSbO_4$ as a anode material for Lithium ion batteries

Jia Yao*, M.V. Reddy* (NUS Department of Physics)

This project aimed to test the Li cycling properties of $VSbO_4$ in Lithium ion batteries. The samples created through solid state method and solution method were characterised by X-ray diffraction, X-ray photoelectron spectroscopy and BET surface area methods. Cycling properties were studied by galvanostatic charge-discharge cycling with lithium as the counter electrode. Based on the galvanostatic cycling plots and capacity vs. cycle number profiles, $VSbO_4$-I ($VSbO_4$ sample prepared through solid state method) performs better but with capacity-fading that does not appear to stabilise within 50 cycles while $VSbO_4$-II (solution method) has lower but stable capacities.

PO.44 Mathematical theory of the modified Gross-Pitaevskii equation

Xinran Ruan*, Weizhu Bao, Yongyong Cai (National University of Singapore)

The Gross-Pitaevskii equation (GPE) is the mean-field approximation for the Bose-Einstein condensation, where the interaction between particles is approximated by the two-body Fermi contact interaction. However, such approximation is only valid under the low energy and low density assumption. If the assumption is violated, correction terms should be included for better description. And a higher order interaction (HOI) correction to the pseudopotential approximation gives the modified GPE (MGPE).

We aim to study the MGPE mathematically both in theory and in numerical computation. Classical problems, like the dimension reduction problem, existence and computation of the ground state, Thomas-Fermi (TF) approximations and energy asymptotics, will be studied. New phenomenons of the MGPE compared to the classical GPE will be shown. It turns out that the HOI term does introduce something nontrivial and may affect the solution significantly in some situations. Numerical simulations for the dynamics of the MGPE will be provided in the end.

PO.45 Synchronization of a Self-Sustained Quantum Oscillator

Hermanni Heimonen* (Centre For Quantum Technologies)

Synchronization of oscillators is a vast topic of interest for fundamental physics and technologies. Self-sustained oscillations of a cloud of ultra-cold atoms in a magneto-optical trap have been observed [1], providing the necessary conditions for observing synchronization phenomena in the quantum regime. We theoretically explore the feasibility of studying the synchronization properties of this cloud of atoms with respect to an external drive.

[1] Labeyrie, G., Michaud, F., & Kaiser, R. (2006). Self-sustained oscillations in a large magneto-optical trap. Physical review letters, 96(2), 023003.

PO.47 Nitrogen based high-density plasma immersion ion implantation for eco-friendly fabrication of high quality junctions in crystalline silicon photovoltaic cells

Loh Yong Xin, Jian Wei Mark Lim*, Chia Sern Chan, Luxiang Xu, Shuyan Xu (Plasma Sources and Applications Centre, National Institute of Education, Nanyang Technological University)

Plasma Immersion Ion Implantation (PIII) is a versatile process technology with its vast applications in materials engineering. PIII is used to implant energetic ions from plasma of desired species onto the target which is properly insulated in a vacuum chamber. This technique is well-known for its uniform dose rate with good conformity and its cost saving properties. In this work, a plasma discharge utilizing nitrogen feedstock was employed for shallow surface substitutional doping of p-type crystalline silicon wafers, resulting in the formation of high quality p-n junctions. The primary aim of this work is to obtain reliable information of the effect of bias and discharge pressure on plasma parameters, such as the electron density (ne), electron temperature (Te) and density of excited species, as well as the resulting material properties of the processed samples. It is observed that under the conditions of, -300 V applied DC bias on substrate, 2500 W of supplied RF power, with the discharge held at a pressure of 3 Pa, at 250 ℃ for 30 minutes, processed samples yield the highest open circuit voltages (Voc). This is in good agreement with Langmuir probe and optical emission spectrometry measurements which gives insights on dissociation and fragmentation mechanisms during the discharge and how they vary accordingly with the change in process parameters. Correlation of plasma parameters with material properties enable transfer of processing conditions to scaled reactors of enhanced geometries to yield rapid uniform processing over large areas which is a key benefit of inductively coupled plasma discharges. Feedstocks used are green and non-toxic which answers the growing need for an environmentally friendly source of renewable energy.

PO.50 Highly doped p-type uc-Si through remote inductively coupled plasma assisted chemical vapour deposition for photovoltaic passivation applications

Jian Wei Mark Lim*, Yingnan Guo, Shiyong Huang, Luxiang Xu, Shuyan Xu (Plasma Sources and Applications Centre, National Institute of Education, Nanyang Technological University)

Inductively coupled plasma assisted chemical vapour deposition (ICP-CVD) is widely used in industries for fabrication of thin films for a myriad of applications in semiconductor devices. Advantages of processing through ICP-CVD include high throughput for fabrication, enhanced uniformity over large areas, and ability to precisely manipulate optoelectronic material properties through variation of discharge parameters. However, film deposition with ICP sources incurs high energy ion bombardment on the surface of substrates which result in damaged thin films of poor quality. In this work, highly doped p-type microcrystalline silicon thin films are grown through ICP-CVD utilizing SiH_4, H_2 and B_2H_6 as feedstock gases. A remotely configured ICP-CVD system was employed to clearly segregate 3 phases of this process into different regimes in the reactor, namely, the plasma generation phase, the radical and ion transport phase, and the surface reaction phase. Films obtained were determined through Raman spectroscopy to be highly crystalline reaching 90% in crystallinity (xc). Films were also heavily doped, with hall effect measurements indicating bulk concentrations to be approximately 1021 cm^{-3} which correlated well with the redshift of the transverse optical mode (510 cm^{-1}) corresponding to the crystalline phase of silicon from the Raman scattering spectra with the increase in dopants incorporated in the film. This is understood to be due to contributions from phonon confinement effects (PCE) and added tensile strain resulting from the densely packed film containing exceedingly large amounts of dopants. The highly crystalline films exhibit excellent electronic properties which has potential for implementation in photovoltaic cells to provide a back surface field for enhanced passivation effects.

PO.52 Electrospinning of Polymers for Water Purification Applications

Thuy Dung Tran* (Hwa Chong Institution)

In this project, we studied the effects of 3 different materials (Polyvinylidene Fluoride PVDF, Polycaprolactone PCL and Polyvinyl Alcohol PVA), and 3 different parameters (potential difference, solution concentration and standoff distance) on electrospun fibre diameters and morphology by varying the parameter values in an electrospinning setup with all other physical quantities being kept constant inside a fume hood. After characterising all the samples under light and electron scanning microscopes, we tabulated and plotted the data for diameter and morphology of fibres. The results showed that ultrafine fibres of diameters to nanometers can be created for all 3 polymers at high voltages. Concentration of the polymer solution also determined whether there are beads in the fibres. We were also able to create very thick fibres up to 100μm at standoff distance less than 1.7cm for all 3 polymers. These results can be very useful for making 2-dimensional water filtration membranes or 3-dimensional sponges for chemical absorption purposes.

PO.59 Mach-Zehnder atom interferometer inside an optical fiber.

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

Precision measurement with light-pulse grating atom interferometry in free space have been used in the study of fundamental physics and applications in inertial sensing. Recent development of photonic band-gap fibers allows light for traveling in hollow region while preserving its fundamental Gaussian mode. The fibers could provide a very promising platform to transfer cold atoms. Optically guided matter waves inside a hollow-core photonic band-gap fiber can mitigate diffraction limit problem and has the potential to bring research in the field of atomic sensing and precision measurement to the next level of compactness and accuracy. Here, we will show our experimental progress towards an atom interferometer in optical fibers. We designed an atom trapping scheme inside a hollow-core photonic band-gap fiber to create an optical guided matter waves system, and studied the coherence properties of Rubidium atoms in this optical guided system. We also demonstrate a Mach-Zehnder atom interferometer in the optical waveguide. This interferometer is promising for precision measurements and designs of mobile atomic sensors.

PO.62 Cavity quantum electrodynamics with a nearly concentric optical cavity

Huan C. Nguyen*, Adrian Utama, Christian Kurtsiefer (Center for Quantum Technologies)

We demonstrate a new cavity quantum electrodynamics system with trapped neutral Rb atoms coupled to the field of a nearly concentric optical cavity with strong focused mode, relatively low finesse (100) and large physical volume. The atoms are directly loaded from a magneto optical trap formed inside the cavity and stored in a red detuned intracavity dipole trap. The transmission spectrum of the composite atom-cavity system is observed to exhibit two resolved normal modes.

PO.63 Novel nanocrystalline anodes for Lithium ion batteries

Yan Yuh Tan, Mv Reddy* (NUS Physics Department)

This project presents the synthesis of nanocrystalline $Li_2ZnSn_3O_8$ and $Li_2Zn(VSbSn)O_8$ and evaluation of the phase as an anode material for lithium ion batteries. The compounds are prepared using the sol-gel method and the physical characteristics of the material is characterized by Powder X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), electron microscopy techniques and Brunauer-Emmett-Teller (BET) analysis. The electrochemical properties of the materials vs. lithium metal are analysed by galvanostatic cycling, cyclic voltammetry and impedance spectroscopy studies under two voltage ranges, 0.005-1.2V and 0.005-3.0V. The electrochemical effects of doping $Li_2ZnSn_3O_8$ with additive graphene oxide (GO) is explored. Sol-gel method of $Li_2ZnSn_3O_8$ leads to the formation of 80nm particles. Galvanostatic cycling studies, conducted with a current density of 60 mAh g^{-1}, shows that the nano phase material exhibits a reversible capacity of 459 mAh g^{-1} between 0.005-1.2 V, with a capacity retention of 65.0% after 35 cycles and 547 mAh g^{-1} between 0.005-3.0V with a capacity retention of 42.4%. Graphene oxide has shown to significantly improve the electrochemical performance of $Li_2ZnSn_3O_8$ in terms of both reversible capacity and capacity retention. $Li_2Zn(VSbSn)O_8$ was observed to possess a sub-micon morphology constructed by nanoflakes. It showed a reversible capacity of 301 mAh g^{-1} in the voltage range of 0.005V-1.2V, but with superior capacity retention of 86%. Cyclic voltammetry and impedance spectroscopy results agree well with that from galvanostatic cycling. The current observations suggest that the nanocrystalline anodes prepared using the sol-gel method can have good electrochemical performance in terms of both capacity and capacity retention.

PO.66 Parity-preserving light-matter system mediates effective two-body interactions

Thi Ha Kyaw*, Sebastian Allende, Leong-Chuan Kwek*, Guillermo Romero (Centre for Quantum Technologies)

We study the equilibrium and non-equilibrium physics of two qubits interacting through an ultrastrong coupled qubit-cavity system. By tuning the qubits energy gap while keeping the ultrastrong coupling system to its ground state energy, we demonstrate a fast two-qubit entangling gate as well as an enhanced excitation transfer between the two qubits. Our proposal has twofold implications. It might pave a way for multipurpose parity-protected quantum information tasks in superconducting circuits, and it might constitute a building block for the ultrastrong coupled cavity-enhanced exciton transport in disordered media.

PO.75 100 THz bandwidth optical modulators via cohorent absorption of metamaterial

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

All-optical signal processing is one of the rising fields to eliminate the disadvantages of optical –electrical – optical conversion and continuing advances in terabits per second communications for high-performance computing. All-optical modulation via Coherent Perfect Absorption is the control of the phase or intensity of one light beam by another. A device based on coherent absorption has the advantage of being compact, fast, and intrinsically low power while demonstrating large modulations of light. Using femtosecond laser with variable pulse duration we probe the limits of switching that exploits coherent absorption in nanostructured gold and diamond metamaterials. Higher switching contrast ratios and modulation bandwidth exceeding 100 THz has been observed.

PO.76 High-Q Toroidal Resonances in Metamaterials

Manoj Gupta, Ranjan Singh* (NTU)

Toroidal dipole and anapole resonances enhance quality factor and figure of merit values of the asymmetric line shape resonances. Excitation of toroidal dipole mode provides an edge over to traditional Fano resonances in planar metasurface.

PO.78 Transverse scattering of light by a moving atom in presence of magnetic field: Quantum mechanics in special relativity context.

Chang Chi Kwong*, Bart van Tiggelen, David Wilkowski* (MajuLab, CNRS-Universite de Nice-NUS-NTU International Joint Research Unit UMI 3654, Singapore)

We study the transverse scattering of light by an atom moving with a velocity v. We consider an incident light that is propagating opposite to the motion of the atom. A magnetic field B, perpendicular to the both the light polarization and the light propagation directions, is applied. This leads to an imbalance in the fluorescence emitted in the direction of v x B due to special relativity correction. The atom further experiences a transverse force due to this imbalance. A detection at the level of $v/c \approx 10^{-6}$ is required to observe this imbalance. We will explain the physics behind this effect and describe the progress in tackling the challenge of experimentally detecting the small imbalance on an atomic beam.

PO.80 Quantum error correction in the presence of a small bath

Yink Loong Len*, Yicong Zheng, Hui Khoon Ng (Centre for Quantum Technologies, NUS)

For the implementation of a realistic quantum computer, an important element is quantum error correction (QEC), in which one actively detects and corrects errors that occur in the physical system. Traditionally, the efficacy of QEC is assessed using a quantum channel, or equivalently, a completely positive (CP) description of the noise. This, however, neglects memory effects that can significantly change the nature of the noise seen by the system. In this work, we report on a more realistic analysis of QEC, where we treat the noise as coming from the interaction with a few most relevant bath degrees of freedom, i.e. a small bath, that plays the role of a memory for information to flow in and out of the system. Specifically, we describe the discrete-time dynamics of the system and small bath by a quantum channel. One can justify this by approximating the continuous-time dynamics of the system and small bath by a Lindblad master equation, with dissipation into a large bath in mind. Here, we show the conditions for perfect and approximate QEC under such a noise model. We present also an analysis on the system-only dynamics and find that the CP-divisible nature of the system-only dynamics is correlated with the strength of the noise, but not, rather surprisingly, with its entangling capabilities, or its ability to generate discord between the system and the bath.

PO.83 Imperfect Optical Pumping due to Dipole-Dipole Interactions

Ewan Munro*, Lc Kwek, Darrick Chang (CQT)

Optical pumping is a widely used technique in atomic physics for manipulating the internal states of atoms. It finds application in a number of important contexts, including in laser construction, measurements of atomic lifetimes and energy level splittings, atomic clocks, state initialisation for quantum information, and even the enhancement of MRI scanning in the medical domain. In spite of all its successes, little is known about how efficient the method is in dense ensembles of atoms where multiple scattering events can occur, i.e. where photons can by emitted and re-absorbed by different atoms. In particular, as a result of the dipolar emission pattern of the atoms when they scatter light, the incident field polarisation is generally not maintained, giving rise to new field components which then couple to unwanted atomic transitions. We show that under certain conditions this can lead to a significant degree of error in the optical pumping process.

PO.87 Applications of the trilinear Hamiltonian with three trapped ions

Roland Hablutzel*, Gleb Maslennikov*, Jaren Gan*, Shiqian Ding*, Stefan Nimmrichter*, Jibo Dai*, Alexandre Roulet*, Valerio Scarani*, Dzmitry Matsukevich* (Centre for Quantum Technologies, Natl. Uinv. of Singapore)

The trilinear Hamiltonian $a^\dagger bc + ab^\dagger c^\dagger$, which describes a nonlinear interaction between harmonic oscillators, can be implemented to study different phenomena ranging from simple quantum models to quantum thermodynamics. We engineer this coupling between three modes of motion of three trapped $^{171}\mathrm{Yb}^+$ ions, where the interaction arises naturally from their mutual (anharmonic) Coulomb repulsion. By tuning our trapping parameters we are able to turn on / off resonant exchange of energy between the modes on demand. Here, we present applications of this Hamiltonian for simulations of the parametric down conversion process in the regime of depleted pump, a simple model of Hawking radiation, and the Tavis-Cummings model. We also discuss the implementation of the quantum absorption refrigerator in such system and experimentally study effects of quantum coherence on its performance.

PO.90 The Effects of Noise on a Quantum Spin Coupled to an Intermediate Bath Spin

Jiayun Wang*, Vanessa Koh, Yicong Zheng, Yink Loong Len, Hui Khoon Ng (Yale-NUS College)

In this work, we study the effects of noise on a (central) quantum spin, i.e., decoherence arising from interactions with a large bath of uncontrollable spins. Conventionally, such a central spin model can be solved with a fully quantum-mechanical treatment, or with an effective field approximation for the large bath. However, they are limited by either the expensive cost of computation or ignore detailed features like the effects of initial spin-bath correlations. To overcome these problems, we consider an intermediate spin model, where the central spin is coupled to an (intermediate) bath spin, which is itself coupled to a time-dependent classical field. Such an intermediate spin model has been found to be relevant for many realistic physical systems, e.g. noise in superconducting circuits, where only very few spins in the bath are coupled strongly to the central spin because of proximity or resonance conditions, for instance, while the rest of the bath spins act as a fluctuating background field to the intermediate spin. We perform numerical simulation for such model, examining the fidelity of the information stored in a system spin exposed to such noise. We find that the fidelity level is not sensitive to frequency changes of the field beyond a certain point.

PO.92 Semi-device-independent randomness expansion with partially free random sources

Yuqian Zhou*, Fei Gao (Center of Quantum Technology, National University of Singapore.)

By proposing device-independent protocols, Pironio et al. [Nature (London) 464, 1021 (2010)] and Colbeck et al. [Nat. Phys. 8, 450 (2012)] proved that new randomness can be generated by using perfectly free random sources or partially free ones as seed. Subsequently, Li et al. [Phys. Rev. A 84, 034301 (2011)] studied this topic in the framework of semi-device-independent and proved that new randomness can be obtained from perfectly free random sources. Here we discuss whether and how partially free random sources bring us new randomness in a semi-device-independent scenario. We propose a semi-device-independent randomness expansion protocol with partially free random sources and obtain the condition that the partially free random sources should 2 satisfy to generate new randomness. In the process of analysis, we acquire a two-dimensional quantum witness. Furthermore, we get the analytic relationship between the generated randomness and the two-dimensional quantum witness violation.

PO.93 Semi-Device-Independent Quantification of Entanglement for given Hilbert Space Dimension using Experimental Data

Benjamin Goh*, Koon Tong Goh, Valerio Scarani (National University of Singapore)

Some entanglement witnesses in the literature rely on the assumptions of state tomography – the complete knowledge of the measurement device characteristics as well as the Hilbert space dimension of the systems being measured. On the other extreme end are the Device-Independent (DI) entanglement witnesses, which rely only on the observed correlations to certify the presence of entanglement without any further assumptions. However, DI entanglement witnesses give pessimistic bounds on the amount of certifiable entanglement, and is restricted to correlations that violate a Bell inequality.

There are also schemes which are considered “semi-device independent” which keep some of the assumptions of state tomography while relaxing others. One such relaxation involves only assuming the dimension of the Hilbert space of the systems, and has been tested with ideal statistics [1], certifying entanglement for correlations that do not violate a Bell inequality and thus cannot be certified in a DI fashion. This project addresses the question of quantifying the amount of entanglement given experimental correlations and only the knowledge of the Hilbert space dimension, accounting for the experimental fluctuations arising from non-ideal detectors as well as finite sample size.

[1] New J. Phys. 18, 045022.

PO.95 Self-calibrating Quantum State Estimation

Jun Yan Sim*, Jiangwei Shang, Hui Khoon Ng, Berge Englert (Centre for Quantum Technologies)

Self-calibrating quantum state estimation is the procedure of reconstructing the quantum state and certain properties of the measurement devices from the same data. We apply self-calibration procedure to the double-crosshair measurement of the BB84 scenario in quantum cryptography for reconstructing the state and detector efficiencies simultaneously. When we perform maximum likelihood estimation, we observe multiple maxima in the likelihood function even when the state parameters and detector efficiencies are uniquely determined by detection probabilities. This problem disappears when prior knowledge of the ratios of detector efficiencies is taken into account. Finally, the point estimators are endowed with error regions to express the uncertainties associated with the point estimators.

PO.98 Semiclassical Particle Density for Many-Fermion Systems

Jun Hao Hue*, Thanh Tri Chau, Martin-Isbjoern Trappe, Berthold-Georg Englert (Centre for Quantum Technologies)

We present a mixed density-potential-functional reformulation of standard orbital-free density functional theory (DFT). This approach offers an alternative to other self-consistent schemes such as Kohn-Sham or Hartree-Fock to describe interacting many-fermion systems for arbitrarily large particle numbers. The Thomas-Fermi (TF) model, which erroneously predicts vanishing densities in the classicallly forbidden region, can be improved, for example, by gradient corrections or enhanced WKB methods like those discussed in [1]. Ribeiro et al.'s remarkably accurate one-dimensional particle density cannot be generalized to higher dimensions as the wave function has to be manually patched. We tackle this problem and aim for similarly accurate particle densities, expressed in terms of the propagator, by using Suzuki-Trotter decompositions. Thereby, we construct semiclassical densities, which are exact for the constant-force potential and are consistent with the leading-order gradient corrections. The densities resulting from the propagator, valid for any dimensions, require no patching and are ready to enter the self-consistent scheme to include interactions. To benchmark our density approximations, we present preliminary results for the analytically accessible Hooke atom of two harmonically confined spin-1/2 fermions, interacting via Coulomb's potential.

[1]: R. F. Ribeiro et al., Phys Rev. Lett. 114, 050401 (2015)

PO.100 Accessing the High-Q Fano Resonances in Superconductor Metasurfaces

Yogesh Kumar Srivastava, Manukumara Manjappa, Harish N. S. Krishnamoorthy, Ranjan Singh* (NTU)

Superconducting metamaterials at terahertz frequencies provides a platform for realizing switchable, low-loss, narrow-band plasmonic metamaterial devices. We used high-Tc superconductor YBCO to access the low asymmetry regime of the Fano resonators to excite extremely sharp resonances, which is inaccessible with the identical metallic Fano resonators at terahertz frequencies. The observation of high quality factor Fano resonances clearly establishes the superiority of superconductors over conventional metals in designing lower loss metamaterials.

PO.101 Binary Bose-Bose Mixtures in the Imbalanced Honeycomb Lattice

Zhe Wei Kho* (Centre for Quantum Technologies)

Ultracold gases trapped within optical lattices constitute a promising and powerful new toolbox for the study of strongly-correlated quantum many-body systems. These highly versatile and tunable systems can potentially be engineered to realise novel quantum many-body systems. In particular, binary Bose-Bose mixtures have received considerable attention in recent years, owing to the possibility of admitting rich quantum phases beyond that of the single-species Bose-Hubbard model, such as demixed phases, paired superfluidity and super-counter-fluidity. They also lend themselves naturally to a magnetic representation that may prove useful for implementing quantum Hamiltonians in adiabatic computation schemes. Motivated by these results, we explore the properties of the two-component Bose-Hubbard model on the topologically non-trivial honeycomb optical lattice with imbalanced hopping amplitudes via both extended mean-field and Quantum Monte Carlo approaches, where the interplay between the bipartite nature of the lattice and the interspecies interactions is expected to yield interesting features.

PO.102 Fourier Transform Spectroscopy of Helium-Neon laser to nanometer precision

Junhui Yang*, Xiaorun Wu* (Hwa Chong Institution)

We aim to build a Fourier spectrometer whose resolution is on par with, or even higher than the current commercial products like Ocean Optics USB2000+, whose optical resolution, dependent on configuration, is in the range of 0.1-10.0 nm (Full width at half maximum, or FWHM).

In this work, the spectrum of a He-Ne laser is measured. The intensity of interference pattern against optical path difference between the transmission and reflective arms of a Michelson interferometer which uses a Helium-Neon (He-Ne) laser as its light source is measured. An interferogram is then obtained and Fourier transformed to find the mean wavelength and line-width of the He-Ne laser.

PO.105 Measurement of Gouy phase with cold ^{88}Sr atoms

Mehedi Hasan*, Vincent Mancois, Chang Chi Kwong, Rebhi Riadh, David Wilkowski (Nanyang Technological University)

The transverse confinement of light beam leads to a shift in the expectation value of axial propagation constant known as Gouy phase shift which is an ubiquitous feature of any focused laser beam. There have been numerous proposals and realizations, for the measurement of Gouy phase in different contexts, e.g., electron wave, plasmon etc. Till dates, there is no report of measuring Gouy phase in the context of cold atom system where incredible precision can be achieved in frequency measurement. In this work, we will delineate our approach towards the measurement of Gouy phase with ultra-cold ^{88}Sr atom. First, we show the theoretical calculations that suggest that Gouy phase shift can be directly measured with cold ^{88}Sr atom via Doppler shift introduced by Gouy phase on the narrow intercombination line. Hence, the geometric phase shift introduced by Gouy phase is directly mapped to the frequency-shift of the spectroscopic measurement, thus it provides a robust avenue to precisely measure the phase. Secondly, we will present our progress of the on-going experiment to realize the theoretical predictions.

PO.107 Non-Abelian Geometric Operations on an Ultra-Cold Gas

Riadh Rebhi*, Frederic Leroux, David Wilkowski, Kanhaiya Pandey (CQT)

Non-Abelian gauge field is an active research subject in condensed matter physic and also in ultracold gases. In our experiments, we use a cold thermal gas of Fermionic strontium atoms to perform operations of quantum computation on a single geometrical qubit composed of the two dark states issued from the light-matter interaction by tuning the phases of two lasers. We show the Non-Abelian nature of those transformations and their purely geometrical origin. Finally we explore the role of the thermal averaging showing that precise thermometry of the gas can be performed.

PO.114 Temperature and Electrical Poling Effects in Hybrid Perovskite Solar Cells

Annalisa Bruno*, Daniele Cortecchia, Chin Xin Yu, Francesco Maddalena, Subodh Mhaisalkar, Cesare Soci (Energy Research Institute @ NTU (ERI@N))

Despite their excellent power conversion efficiency, hybrid organic-inorganic perovskite (HOIP) solar cells exhibit strong hysteresis effects that hinder reliable device operation [1]. In this work, we show that ionic motion is the dominant mechanism underlying hysteresis in pure $MAPbI_3$ and in mixed HOIP (e.g.: mixed MA+, Cs+ and FA+ and mixed I-/Br-) solar cells by studying temperature and electrical poling effects on solar cell performance. We observe that the hysteresis in the I-V curves is completely suppressed below 160 K and at the same time the effects of electrical poling are strongly temperature dependent. The initial decrease of power conversion efficiency observed while lowering the operating temperature is completely recovered, and even enhanced up to 20% of its original value, when electrical poling is performed at temperatures below 160 K. This behavior is consistent with temperature activated diffusion of halide anions and/or the motion of the cations that drive charge accumulation at TiO_2/HOIP interface, leading to the reduction of the electron extraction barrier. Studying HOIP solar cells with different contents of MA+ and FA+ and Br- and I- allows discriminating the contribution of specific ions and cations to the ionic motion within the HOIP and at the TiO_2/HOIP interfaces. This is particularly important to develop effective strategies to mitigate operational instability of HOIP solar cells.

[1] D. A. Egger, A. M. Rappe, L. Kronik, Accounts of chemical research 2016, 49, 573; Y. Yuan, J. Huang, Accounts of chemical research 2016, 49, 286.

PO.115 Towards atom-metamaterial interaction on fibre tips

Eng Aik Chan*, Syed Abdullah Aljunid*, Giorgio Adamo, Martial Ducloy, David Wilkowski*, Nikolay Zheludev (CQT/NTU)

Atoms have been demonstrated as a good resource for quantum information processing. This resource can be manipulated by atom-surface interactions due to nearby metasurfaces, emitters etc.

Having shown modification of the atom-metamaterial interaction by tuning the plasmonic resonance through selective reflection spectroscopy on hot vapour atoms, we now attempt to realise this plasmon mediated interaction on the surface-tip of a fiber. We will present our results for a large mode area fiber that is large enough for the atoms to have reasonable interaction time with the electromagnetic field.

PO.116 Tuning Charge Transfer Property of MoS_2 via Focused Laser Beam Based Technique

Kleon Ang*, Carina Lim*, Rachel Pong* (Dunman High School)

Molybdenum disulfide (MoS_2), a transition metal dichalcogenide (TMDC), displays high potential in optoelectronics due to its strong absorption of visible light. Through the use of focused laser beams (FLB), the conductivity and photoresponsivity of MoS_2 can be tuned. FLB allows for precise and controlled modification of MoS_2, enabling fine tuning of charge transfer properties specifically for selected areas, essential for applications such as creating distinct p-doped and n-doped regions in p-n junctions for use in modern silicon chips. As-grown TMDCs reportedly contain a high density of chalcogen vacancies, reducing its electron mobility. We found that this can be countered by using FLB to atomically heal MoS_2, improving its conductivity and photoresponsivity. Au nanoparticles (NPs) sputtered on MoS_2 have been proven to demonstrate plasmonic enhancement of photocurrent of MoS_2 while improving its absorption of light. However, we found that while Au NPs decorated via FLB technique increases MoS_2's light absorption as predicted, it decreases its current and photoresponsivity. Past studies have also shown potential for increased conductivity and photoresponsivity of MoS_2 through amine-doping, prompting our investigation of the effect of urea, deposited via FLB technique, on MoS_2. The observed decrease in the dark current of MoS_2 after addition of urea disagrees with our hypothesis that n-doping occurs when urea was deposited on MoS_2. Additionally, effects of different metals used as electrodes on the conductivity of our samples were also investigated. Our results show that MoS_2 devices with Au/Cr electrodes sputtered on displayed greater ohmic behaviour than those with Al electrodes.

PO.119 Hybrid Atom - Superconductor Quantum System

Chin Chean Lim, Alessandro Landra, Christoph Hufnagel*, Rainer Helmut Dumke (Centre for Quantum Technologies)

Quantum technology, the engineering of quantum states for practical applications, has seen much progress over the last decades. Today, scientists are able to create, control and manipulate quantum states at an extraordinary level, opening the way to many applications , such as quantum information processing, secure communication, quantum enhanced sensors and quantum simulation. Experimentally, quantum states have been implemented in many systems, ranging from microscopic states, like ions, atoms and photons to meso(macro-)scopic states, like nanomechanical and superconducting devices. Unfortunately none of these systems can universally be applied to all quantum applications. Microscopic systems like atoms are typically well isolated from the environment, thus they show long coherence times and are therefore well suited for storing quantum states rather than processing them. On the other hand macroscopic systems like superconductors show strong coupling to the environment. This allows to rapidly process them, while their coherence time is short, making them suitable for fast processing. In order to implement devices that are capable of storing, processing and transmitting quantum states, it is favorable to combine several implementations in one, thus benefiting from their corresponding advantages. These combined implementations go by the name of Hybrid Quantum Systems. In our work we are concerned with building hybrid quantum systems made out of neutral atoms and superconductors. We will present an experiment that is feasible to couple neutral atoms and superconducting circuits on one platform. Allowing us in future to transfer states between the microscopic and macroscopic quantum states, as well as establishing entanglement between these systems.

PO.120 White Cathodoluminescence Enabled by the Field Emission from Zinc Oxide Nanowires

Anqi Chen*, Zheng Yong Ang* (Hwa Chong Institution)

Modern-day light-emitting diodes (LEDs) operate at voltages of 1.8V-3.3V, and currents of 10mA-30mA. This research aims to produce LEDs with simpler design, thus reducing the production cost of LEDs by about 30%. Thermal oxidation of brass wire mesh was carried out to form zinc oxide (ZnO) nanowires on the surface of the wires. These nanowires are desired over commercial samples due to their greater density and lengths, which is desired for better cathodoluminescence effect. Cathodoluminescence (CL) is the phenomenon whereby electrons strike on a luminescent material, causing emission of photons. The wire mesh containing ZnO nanowires is placed near a layer of white phosphor, in vacuum. When a potential difference of 1kV-10kV is applied across the wires, an electric field is produced between the wires and the phosphor layer. This causes electrons travelling through the wires to bombard the phosphor after leaving the tips of the nanowires, resulting in cathodoluminescence. SEM results indicate that at higher oxidation temperatures, the lengths of ZnO nanowires increase, which is preferred because the distance between the nanowires' tips and the phosphor is reduced. Thus, electrons lose less energy as they travel a shorter distance in vacuum, because they are less likely to strike into air molecules. Therefore, more electrons will have sufficient energy to bombard onto the phosphor, hence causing the intensity of light produced to be greater. Through this process, light of similar intensity as modern-day LEDs could be produced by a device that has a lower production cost than modern LEDs.

PO.122 superconducting circuit-neutral atom hybrid quantum systems

Deshui Yu*, Maria Martinez Valado, Christoph Hufnagel, Alessandro Landra, Leong Chuan Kwek, Luigi Amico, Rainer Dumke (Centre for Quantum Technologies, National University of Singapore)

Hybridizing different quantum systems may be a promising way to inherit the advantages of each component and compensate the weaknesses with each other. A superconducting circuit-neutral atom hybrid structure possesses the potential of transmitting information between two distinct quantum realizations, leading to the rapid processing and long-term storage of quantum states. Different hybrid systems, where the superconducting qubits and resonator strongly interact with a single Rydberg atom, are proposed. The potential applications including the preparation of different entangled states and quantum logic gates are investigated in detail.

PO.123 Superconducting vortex lattices for ultracold atoms experiments

Phyo Baw Swe, Francesca Tosto, Nghia Tin Nguyen, Maria M. Valado*, Rainer Dumke (Centre for Quantum Technologies, National University of Singapore)

We propose the realization of a magnetic vortex lattice for ultracold atoms in a thin film type-II superconducting square. In our experiments, ultracold ^{87}Rb atoms are trapped close to the film surface in a magnetic trap formed entirely by persistent supercurrents induced in the thin film after applying a magnetic field pulse perpendicular to its surface [1]. To generate the lattice, we implemented a thermal switch consisting in a focused IR laser beam in combination with a DMD (digital micromirror device). Hence, by heating the film surface we obtain an on/off switch of the superconducting properties of the square (or of a specific area), allowing us to tune the parameters of the vortex lattice. Our work paves the way to the realization of a quantum Hubbard simulator [2], or the implementation of a guided atom interferometer based on a superconducting atom chip [3].

[1] M. Siercke et al., PRA 85, 041403 (2012). [2] O. Romero-Isart et al., PRL 111, 145304 (2013). [3]Müller et al., New Journal of Physics 10 073006 (2008).

PO.127 Solvent Engineering: A route towards high efficiency Perovskite-based Light-Emitting Devices

Nur Fadilah Jamaludin* (NTU)

Metal halide perovskites have gained widespread attention owing to a plethora of optoelectronic properties. One of their main advantages is the ease of solution-based processing. The facile and inexpensive route of film deposition offered by the spin coating process enables the formation of crystalline perovskite film aided by solvent evaporation and convective self-assembly. However, growth of smooth, compact and uniform film is still limited with conventional spin coating process. One way of circumventing this is through the introduction of an anti-solvent, midway during the spin coating process. Otherwise known as solvent engineering, this process facilitates crystallization by inducing rapid supersaturation of the precursor solution. This study entails exploring the effect of solvent engineering on film morphology and properties, as well as the correlation with fabricated light-emitting devices.

PO.132 Ultrafast Dynamics of Self-trapped Carriers in Two-dimensional Hybrid Perovskites

Shu-Zee A. Lo*, Daniele Cortecchia, Annalisa Bruno, Cesare Soci* (Centre for Disruptive Photonic Technologies, The Photonics Institute, Nanyang Technological University 637371)

Two dimensional perovskites have recently gained scientific interest for potential application as efficient broadband white light source. Recent investigations suggested that small polarons confined within the inorganic lattice act as emissive colour centres with wide energy distribution [1-3]. Here we investigate a series of three two-dimensional perovskites with significantly different emission properties by femtosecond time-resolved transient absorption (TR-TA) measurements. These were synthetized, ad hoc, using different templating cations such as n-butylamine (NBT), 1-(3- Aminopropyl)imidazole (API) and 2,2-(ethylenedioxy)bis(ethylammonium) (EDBE). Despite the similarities in absorption spectra, steady-state photoluminescence (PL) measurements show dramatically different emission spectra. For $(NBT)_2PbBr_4$, a narrowband emission is detected at 410 nm, while doubled emission peaks centred at 400 and 610 nm are detected in $(API)PbBr_4$. Lastly, an ultra-broadband white light emission centred at 520 nm is found in $(EDBE)PbBr_4$. Comparison among these samples would provide information on the origin of self-trapped polaron.Using global analysis fitting, we have separated the time-evolved spectra for the three samples at three different time scales under excitation wavelength of 370 nm (on resonance with the excitonic absorption) and 266 nm (above resonance). Weaker broadband photoinduced absorption features in $(NBT)_2PbBr_4$ shows the lack of self-trapping polaron which in turn confirms narrow emission spectrum in steady state photoluminescence. The result of these measurements provides key information on time evolution of self-trapping mechanisms responsible to emission and absorption in low dimensional hybrid perovskite in relation with their structural properties. [1] D. Cortecchia, J. Yin, A. Bruno, S.-Z, A. Lo, G. G. Gurzadyan, S. Mhaisalkar, J.-L. Brédas, C. Soci, Polaron Self-localization in White-light Emitting Hybrid Perovskites, arXiv:1603.01284 [2] J. Yin, H. Li, D. Cortecchia, C. Soci, J.-L. Brédas, Excitonic and Polaronic Properties of 2D Hybrid Organic-Inorganic Perovskites, ACS Energy Letters, accepted [3] D. Cortecchia, S. Neutzner, A. R. S. Kandada, E. Mosconi, D. Meggiolaro, F. De Angelis, C. Soci, A. Petrozza, Broadband Emission in Two-Dimensional Hybrid Perovskites: The Role of Structural Deformation, J. Am. Chem. Soc. 2016, DOI: 10.1021/jacs.6b10390

PO.133 Black Phase Stabilization of Formamidinium and Cesium lead Halide Perovskites by Incorporation of Long Chain Alkyl Amines

Bhumika Chaudhary*, Teck Ming Koh, Subodh Mhaisalkar, Cesare Soci* (Division of Physics and Applied Physics Nanyang Technological University 21Nanyang Link Singapore 637371)

The emergence of inorganic-organic lead halide perovskite solar cell (PSC) has re-energized solution-processed photovoltaic's research with materials properties rivaling that of crystalline semiconductors and device efficiencies comparable to that of multi-crystalline silicon. Albeit methyl ammonium lead perovskite solar cell ($MAPbI_3$)1 is the materials of choice, it is still needs to overcome the challenges of durability, thermal instability, and degradation due to the environment and moisture. Formamidinium (FA) and Cesium (Cs) lead perovskite solar cells are promising cation substituent's to $MAPbI_3$ which enable perovskites to perform better under thermal excursions and humid conditions. At room temperature, FA and Cs based perovskites have the tendency to experience the phase transition and rapidly covert into their unwanted non-perovskite phases2. Here, we perform transform the 3D $FAPbI_3$ and $CsPbI_3$ perovskites structures into mixed 2D-3D hybrid perovskites by incorporating long-chain alkyl amine cations that stabilizes the black phase of these materials, thus rendering them more stable under the stresses of humidity and temperature. The perovskite films of $FAPbI_3$ thus obtained showed the excellent stability for more than 20 days under ambient atmospheres. Reference: 1.Kojima, A.; Teshima, K.; Shirai, Y.; Miyasaka, T. Journal of the American Chemical Society 2009, 131, 6050. 2.Lee, J. W.; Kim, D. H.; Kim, H. S.; Seo, S. W.; Cho, S. M.; Park, N. G., Formamidinium and Cesium Hybridization for Photo–and Moisture–Stable Perovskite Solar Cell. Advanced Energy Materials 2015, 5 (20).

PO.134 Integration of color centers in nanodiamonds with a silicon nitride ring resonator

Sumin Choi*, Gandhi Alagappan, Jun Rong Ong, Dmitry Kalashnikov, Victor Leong, Mingbin Yu, Valery Davydov, Leonid Krivitskiy (Data Storage Institute, Agency for Science, Technology and Research)

Quantum photonic platforms are a promising avenue towards implementing scalable quantum networks. We report on the progress of integrating colour centres in nanodiamond crystals with a photonic circuit based on silicon nitride (Si_3N_4) waveguides. To enhance the interaction with the quantum emitters, the nanodiamonds are buried within a ring resonator structure (4 - 6 µm radius), which is then coupled to a bus waveguide. Our simulations using a finite-difference time-domain method (FTDT) yield a set of optimised parameters compatible with our CMOS microfabrication capabilities, for which we calculate a cavity-enhanced interaction with a Purcell factor of 12.3. We also optically characterize the silicon vacancy (SiV) centres in samples of isolated nanodiamonds ($<$100 nm in size), which show a stable zero phonon line (ZPL) emission at 738 nm, and a SiV concentration of as low as 4 centres per nanodiamond crystal.

PO.136 Tailored Optical Potentials for Atomtronics

Koon Siang Gan*, Nghia Nguyen* (Nanyang Technological University)

Bose-Einstein Condensate (BECs) in a ring structure is a simple configuration which contains a rich amount of physics, especially in the field of atomtronics. Various methods have been applied successfully to create ring-like structures to simulate devices like a Superconducting Quantum Interference Device (SQUID). Here we work towards a versatile method of producing different structures, specifically a ring lattice with a weak link, utilising a Spatial Light Modulator (SLM). A stable flux qubit can be created by inducing a flow in a BEC ring lattice. Coupling 2 stacks of BEC in a ring lattice produces a 2-ring qubit. Different complex structures can be also simulated and investigated using this method.

PO.138 Iron Oxides as Anodes for Lithium-ion Batteries

Lisa Shannon Goh, M V Reddy* (National University of Singapore)

The aim of this project is to investigate the electrochemical performance of iron oxides as anode material for lithium-ion batteries. FeO and α-Fe_2O_3 were synthesized via carbothermal reduction method and thermal decomposition method respectively whereas Fe_3O_4 was a commercial sample. They were characterized using X-ray Diffraction (XRD), X-ray Photoelectron Spectroscopy (XPS), Scanning Electron Microscopy (SEM) and Brunauer–Emmett–Teller (BET). Their electrochemical performances are evaluated using Galvanostatic Cycling (GC), Cyclic Voltammetry (CV) as well as Electrochemical Impedance Spectroscopy (EIS). All 3 samples were proven to be pure, and their lattice structures were identified. FeO was observed to display the best potential as anode material with high initial charge capacity of 842 mAh/g and negligible capacity fade over 40 cycles. Both Fe_2O_3 and Fe_3O_4 were reported to have initial charge capacities of 864 mAh/g and 427 mAh/g respectively, but suffer from poor capacity retention of 46.2% and 48.4 % respectively. This is attributed to the effect of particle morphology and exposed surface area on electrochemical properties which was identified by SEM and BET. The synthesis method of FeO has managed reduced particle size to nanoscale and increased surface area (7.8 m^2/g), as well as provided a slight carbonaceous framework, thus enhancing electrochemical performance. However, the synthesis method of Fe_2O_3 has resulted in particle agglomeration and irregular particle morphology, resulting in poor surface area (6.7 m^2/g) and the Fe_3O_4 commercial sample has been characterized and electrochemically tested to be a poor anode material.

PO.139 Free-space microwave-to-optical conversion via six-wave mixing in Rydberg atoms

Thibault Vogt*, Jingshan Han, Christian Gross, Dieter Jaksch, Martin Kiffner, Wenhui Li (Centre for Quantum Technologies, Majulab)

Efficient and coherent interconversion of millimeter waves and optical fields is critical for classical and quantum technologies. To achieve this, the challenge resides in the design of a device that interacts strongly with both frequency bands, microwave and optical. In this poster, we report an experimental demonstration of a new scheme based on six-wave mixing in Rydberg atoms [1]. Our scheme utilizes the strong coupling of millimeter waves to Rydberg atoms as well as electromagnetically induced transparency that greatly enhances the non-linearity for the conversion process. The microwave-to-optical conversion that is demonstrated here is free-space, broadband and has the potential to reach near-unity photon conversion efficiency upon modification of the geometry of our setup. Our results indicate the tremendous potential of Rydberg atoms for the efficient conversion between microwave and optical fields, and thus paves the way to many applications.

[1] J. Han, T. Vogt, Ch. Gross, D. Jaksch, M. Kiffner, and W. Li, arXiv:1701.07969.

PO.140 Polaron formation and transport dynamics in $MAPbI_3$

Walter P.D. Wong, Daniele Cortecchia, Yin Jun, Xin Yu Chin, Cesare Soci*, Andrew C. Grimsdale* (Nanyang Technological University)

Hybrid organic-inorganic perovskites (HOIP) are a class of materials that has generated tremendous interest in recent years for photovoltaic applications. However, to date there is no clear understanding on the nature of charge transport leading to high carrier mobility and diffusion length. Recent studies have proposed that electron-phonon coupling in hybrid perovskites contributes to the formation of polaronic species which would be contributing to the observed properties. In this study, we utilise measurements of infrared photoinduced absorption and fast photocurrent to prove the ultrafast generation of charge species and the relaxation dynamics, consistent with signature of polarons. This is further supported by first principles computational studies of charge localization in large molucular clusters. Overall, this study highlights the importance of polaronic transport to understand and optimize the performance of solar cell and light emitting HOIP devices.

PO.146 Emergent Properties from WS_2 Empowered by Laser Sculpting and Au Nanoparticles Landscaping

Belle Sow*, Chorng Haur Sow, Junpeng Lu (NUS High School)

Monolayer Transition Metal Dichalcogenides (TMDs) are exciting systems to engineer its properties en route to future optoelectronic applications. Growing WS_2, a kind of TMDs using the Chemical Vapour Deposition method tends to yield bulk layer instead of monolayer WS_2. It would be useful if we could modify bulk layer WS_2 to obtain photoluminescence (PL) similar to monolayer WS_2 for use. Gold nanoparticles (Au NPs) can then be added to see if there is an increase in PL intensity of the modified bulk layer. In this work, Au NPs were deposited on WS_2 after laser modification to explore the effects of the deposition on the PL intensity and the changes to Au NP deposition morphology after successful decoration. Results have shown that laser modification of bulk layer causes Au NPs to deposit at much higher densities, suggesting that laser modification creates defects, sulfur vacancies and more nucleation sites for gold deposition. Modifying the material in helium is much harder than in ambience, and Au NPs deposit at higher densities in ambient-modified regions. This suggests that oxygen takes part in the laser modification process and facilitates the modification of the bulk layer. Au NPs have the ability to sharpen the PL emission by amplifying the neutral exciton peak, suggesting Au NPs increase the fluorescence of the sample through both plasmonic coupling and reducing the electron cloud shielding between electron-hole pairs. Monolayer WS_2- Au NP is a good Surface Enhanced Raman Substrate to detect aromatic molecules such as R6G.Bulk layer WS_2- Au NPs can also be used as a substrate after laser modification. As a whole, we have created a hybrid device with tunable morphology, functionality and properties as we have better control over Au NPs deposition.

5 Technical Sessions

T1: Novel 2D Phenomena

Time: Wednesday 22 Feb, 11:15am; Venue: EC3; Chair: Shaffique ADAM
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.

T1.4 (INVITED) Charge Density Waves and the Hidden Nesting of Purple Bronze KMo_6O_{17}

Lei Su*, Vitor Pereira* (Centre for Advanced 2D Materials, Department of Physics)
11:15am – 11:40am

The layered purple bronze KMo_6O_{17}, with its robust triple CDW phase up to high temperatures, became the emblematic example of the "hidden nesting" concept. Recent experiments suggest that, on the surface layers, its CDW phase can be stabilized at much higher temperatures, and with a tenfold increase in the electronic gap in comparison with the bulk. Despite such interesting fermiology and properties, the K and Na purple bronzes remain largely unexplored systems, most particularly so at the theoretical level. We introduce the first multi-orbital effective tight-binding model to describe the effect of electron-electron interactions in this system. Upon fixing all the effective hopping parameters in the normal state against an ab-initio band structure, and with only the overall scale of the interactions as sole adjustable parameter, we find that a self-consistent Hartree-Fock solution reproduces extremely well the experimental behavior of the charge density wave (CDW) order parameter in the full range $0 < T < T_c$, as well as the precise reciprocal space locations of the partial gap opening and Fermi arc development. The interaction strengths extracted from fitting to the experimental CDW gap are consistent with those derived from an independent Stoner-type analysis.

T1.65 (INVITED) Theoretical study of the criteria and consequences of hydrodynamic electron flow in graphene

Indra Yudhistira*, Derek Ho, Nilotpal Chakraborty, Shaffique Adam* (Yale-NUS College)
11:40am – 12:05pm

Experiments on graphene electrons have succeeded in entering the hydrodynamic regime, as demonstrated by successful observations of Wiedemann-Franz law violations [J. Crossno et al. Science 351, 1058 (2016)], and evidence for electron vortices [D. A. Badurin et al. Science 351, 1055 (2016)]. The hydrodynamic regime is expected to occur when electron-electron interactions dominate over all other electron collision mechanisms. We calculate the electron-electron, electron-impurity and electron-phonon scattering rates as a function of temperature, charge doping and disorder (charge puddle) strength. We find that there exists a window in parameter space where electron-electron scattering dominates and hydrodynamic effects become observable. However, we also find that disorder induced carrier density inhomogeneity continues to play an important role in the vicinity of charge neutrality, even in the strongly interacting hydrodynamic regime. For example, although the ratio of thermal conductivity and electrical conductivity show a violation of the Wiedemann-Franz law in the aforementioned experiment, the electrical conductivity as a function of temperature still follows a disorder-driven universal scaling theory first predicted in Adam and Stiles, Phys. Rev. B 82, 075423 (2010). This work was supported by the National Research Foundation of Singapore (NRF-NRFF2012-01).

T1.137 Anomalous Nonlocal Resistance and Spin-charge Conversion Mechanisms in Two-Dimensional Metals

Chun Li Huang*, Chong Yidong, Miguel Cazalilla (NTU)
12:05pm – 12:20pm

We uncover two anomalous features in nonlocal transport behavior that can be used to identify the dominant spin-charge conversion mechanisms in two dimensional metallic materials with spin orbit coupling. Firstly, the nonlocal resistance can have negative values and oscillate with distance, even in the absence of a magnetic field. Secondly, the oscillations of the nonlocal resistance under an applied in-plane magnetic field (Hanle effect) can be asymmetric under field reversal. Both features lie outside the scope of previous spin diffusion theories of nonlocal transport. These effects should be observable in adatom-functionalized graphene, and may provide the reason for discrepancies in recent nonlocal transport experiments in graphene.

T1.55 Excitonic Enhanced Multiphoton absorption in 1L-TMDC

Feng Zhou*, Wei Ji (National University of Singapore)
12:20pm – 12:35pm

Exploring fundamental mechanisms for strong and fast optical nonlinearities in nanoscale materials are of paramount importance in both physics and engineering. Multiphoton absorption, as a typical nonlinearity mechanism, is well-studied in bulk crystals and semiconductor quantum dots. It has been implemented to various applications such as vivo-imaging, solar cell and photo-detection. Here, we report considerable enhancement of degenerate two-photon absorption (2PA) and three-photon absorption (3PA) through excitonic effects in single-layer molybdenum disulfide (1L-MoS_2), Since the excitonic energy levels are formed within the bandgap in 1L-MoS_2, they can be utilized for intermediate and final states in 2PA and 3PA processes and this unique electronic structure is believed to induce one near-resonant transition and one intra-excitonic transition at least. Our model reveals values of 2PA and 3PA coefficients are on the order of 0.01 cm/MW and 0.1 cm3/GW2, respectively. As compared with those of bulk semiconductors, 2PA and 3PA coefficients of 1L-MoS_2 are enhanced by 10-1000 times in the near-infrared (NIR). Our theoretical prediction is validated by measuring photocurrents induced by 2PA or 3PA in a 1L-MoS_2 photo-detector at room temperature. The measured 2PA or 3PA coefficient is consistent with our model within one-order-of-magnitude experimental errors. This finding lays theoretical foundation and provides experimental evidence for developing sensitive infrared TMDC-based multiphoton detectors for nano-photonics.

T2: Energy Storage

Time: Wednesday 22 Feb, 11:15am; Venue: E4; Chair: YANG Hui Ying
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.

T2.22 (INVITED) Overview of advanced energy storage materials for Li-ion Batteries

M V Reddy* (National University of Singapore)
11:15am – 11:40am

Lithium ion batteries (LIBs) are extensively used in the present-day portable electronic devices and high-power applications like back-up power supplies and electric/hybrid electric vehicles. The commercial LIBs consists of layer-type lithium cobalt oxide, spinel $LiMn_2O_4$ or $LiFePO_4$ as the cathode and graphite or Li4Ti5O12 as the anode material, and a non-aqueous Li- ion conducting solution or immobilized gel-polymer are used as an electrolyte. LIBs need to satisfy several additional criteria, such as safety, toxicity, low cost and long cycle life. In my presentation, will summarize our group studies on nano/submicron sized functional anode and cathode materials synthesis by molten salt synthesis, graphenothermal reduction and other facile chemical methods on various oxide materials. Namely MO (M= Co, Ni, Fe, Mn and Cu), nano MO_2 (M= Sn, Ti, Mo), thin and bulk metal nitrides and $(M_{1/2}Sb_{1/2}Sn)O_4$ (M=V, Fe, In) and ternary oxides nano-MCo_2O_4 (M= Mn, Cu, Mg, Zn) and few novel metal organic frame work cathode materials will be discussed. The functional materials characterized by Rietveld refinement X-ray diffraction, X-ray absorption fine structure, X-ray photoelectron spectroscopy, SEM, TEM, density and BET surface area methods, and cyclic voltammetry, galvanostatic cycling and electrochemical impedance spectroscopy techniques. I will discuss the advantages of morphology, nano/submicron size, matrix elements on capacity values and average charge-discharge voltages, and its electrochemical performances and reaction mechanisms.

Key words: Lithium ion batteries; Nanomaterials Synthesis; Cathodes; Anodes; characterization techniques.

References [1] M.V. Reddy, G.V. Subba Rao, B.V. R. Chowdari Chemical Reviews 113(2013)5364-5457 (Impact factor : 37, 1100 citations) [2] M.V. Reddy, M. Rajesh, S. Adams, B.V.R. Chowdari, ACS Sustainable Chemistry and Engineering, 4 (2016) 3076-3086. [3] A.S. Hameed, M.V. Reddy, M. Nagarathinam, T. Runčevski, R.E. Dinnebier, S. Adams, B.V.R. Chowdari, J.J. Vittal, Scientific Reports, 5 (2015) 1670. [4] my other publications are listed here.

T2.15 (INVITED) High Rate All-Solid-State Na-ion Batteries $Na_{2+2\delta}Fe_{2-\delta}(SO_4)_3$—$Na_{3+x}M_xP_{1-x}S_4$—$Na_2Ti_3O_7$

Prasada Rao Rayavarapu*, Haomin Chen, Lee Loong Wong, Stefan Adams (National University of Singapore)
11:40am – 12:05pm

Electrolytes in current Na-ion batteries are mostly based on the same fundamental chemistry as those in Li-ion batteries – a mixture of flammable liquid cyclic and linear organic carbonates leading to the same safety concerns especially during fast charging. All-solid-state

Na-ion rechargeable batteries utilizing non-flammable ceramic Na superionic conductor electrolytes are a promising alternative. Among the known sodium conducting electrolytes cubic Na_3PS_4 phase has relatively high sodium ion conductivity exceeding 10^{-4} S cm^{-1} at room temperature. Here we systematically study the doping of Na_3PS_4 with Ge^{4+}, Ti^{4+}, Sn^{4+} and optimise the processing of these phases. A maximum ionic conductivity of 2.5×10^{-4} S cm^{-1} is achieved for $Na_{3.1}Sn_{0.1}P_{0.9}S_4$. Utilising this fast Na^+ ion conductor, a new class of all-solid-state $Na_{2+2\delta}Fe_{2-\delta}(SO_4)_3$ — $Na_{3+x}M_xP_{1-x}S_4$ (M = Ge^{4+}, Ti^{4+}, Sn^{4+}) (x = 0, 0.1) — $Na_2Ti_3O_7$ sodium-ion secondary batteries is demonstrated that is based on earth-abundant safe materials and features a high rate capability even at room temperature. All-solid-state $Na_{2+2\delta}Fe_{2-\delta}(SO_4)_3$ — $Na_{3+x}M_xP_{1-x}S_4$ — $Na_2Ti_3O_7$ cells with the newly prepared electrolyte exhibited charge–discharge cycles at room temperature between 1.5 V to 4.0 V. At low rates the initial capacity matches the theoretical capacity of ca. 113 mAh/g. At 2C rate the first discharge capacity at room temperature is still 83 mAh per gram of $Na_{2+2\delta}Fe_{2-\delta}(SO_4)_3$ and at 80 °C it rises to 109 mAh per gram with 80% capacity retention over 100 cycles.

T2.64 Facile synthesis of LiV_3O_8 Nano-structures for Lithium ion Batteries and their Physical, Structural and Electrochemical Properties

Benjamin Lee Hong Rui, M V Reddy*, K P Abhilash* (National University of Singapore)
12:05pm – 12:20pm

LiV_3O_8 is an extremely promising cathode material for Lithium-ion batteries due to its low cost, high discharge capacity and good safety characteristics, compared to commercial cathode materials. However, the drawback of using this material is its unsatisfactory cycle life. After intensive research, some preparation methods have been developed to overcome this problem. Unfortunately, they are either unsafe, expensive, require a long process or instead lead to LiV_3O_8 with low discharge capacity. In this project, we aim to synthesis LiV_3O_8 powders with good electrochemical performance using a low-cost facile method involving a hotplate. Different chelating agents were introduced as well to study their effects on the physical, structural and electrochemical properties of the synthesised LiV_3O_8. After obtaining powders from the hotplate, a portion of the prepared samples was further calcined at 500°C for 2hin air for comparison. For analysis, LiV_3O_8 powders were characterized by X-ray diffraction, scanning electron microscopy (SEM) and Brunauer-Emmett-Teller (BET) surface area and density techniques. Electrochemical studies were conducted through galvanostatic cycling, cyclic voltammetry and electrochemical impedance spectroscopy (EIS) studies. Galvanostatic cycling results revealed that the calcined, citric acid-prepared sample exhibits a discharge capacity of 248 mAh/g at the end of the 2nd cycle. After 40 cycles, it retained a capacity of 230 mAh/g, demonstrating that the hotplate method has tremendous potential as a synthesis method for LiV_3O_8.

T2.26 Porous Metal Nitrides Synthesized via RF Plasma and Their Application in Elctrochemical Water Splitting

Yongqi Zhang, Hongjin Fan* (Nanyang Technological University)
12:20pm – 12:35pm

Catalytic electrochemical water splitting to generate oxygen and hydrogen gas could provide a promising method to store intermittent renewable energies such as wind and solar energy, and thus to eliminate the energy and environmental problems caused by burning fossil fuels. However, sluggish reactions extremely hinder the efficiency of water splitting. Developing highly active and cost-effective electrocatalysts for water splitting is critical to promote these sluggish reactions. Metal nitrides show unusual electron transport, optical and magnetic properties as compared to their metal counterparts and have the potential applications to promote the water splitting process. In most previous reports, metal nitrides are prepared by annealing precursors under caustic and hazardous ammonia (NH_3) flow. Even worse, it requires long processing duration (several hours) and high reaction temperature (600$\sim$800 °C). Here we employed a novel and environmental friendly method to synthesize metal nitrides via treating corresponding metal with N_2 plasma and studied their superior electrochemical performances for HER. i) We take the N_2 as Nitrogen source, which is abundant and environmental friendly. ii) Metal and metal oxides are able to transfer into metal nitrides at a short duration (few min) and low temperature (25$\sim$450 °C). iii) The overall water splitting cell assembled by obtained metal nitrides shows a low potential of 1.6 V to reach 10 mA cm^{-2} and excellent cycling stability. iv) Our research offers a new method to synthesize metal nitrides for various applications, such as catalysts, supercapacitors and batteries.

T2.8 A 2.0 V Capacitive Device Derived from Shape-Preserved Metal Nitride Nanorods

Changrong Zhu, Hong Jin Fan* (NTU-SPMS)
12:35pm – 12:50pm

A high working voltage and fast charging/discharging capability are important to a supercapacitor device in order to achieve decent energy densities with high power. In this work, we report 2.0 V quasi-solid-state symmetric capacitive device based on Fe_2N-Ti_2N (FTN) core-shell nanorod array electrodes. Through a surface protection by a thin and ultra-stable Ti_2N shell, Fe_2N converted from its oxyhydroxide precursor inhibits the original nanorod structure. Due to advantageous features of these core-shell metal nitride electrodes (e.g., high conductivity, structure stability, direct current path), the symmetric device permits ultrahigh scan rates (up to 50 V s^{-1}) and delivers fairly stable capacitance in long-term cycles ($\sim$82 F g^{-1} with $\sim$ 99% capacitance retention in 20000 cycles). As a result, the supercapacitor exhibits an impressive energy density of $\sim$48.5 Wh kg^{-1} at the power of 2700 W kg^{-1}. These results demonstrate the potentialities of metal nitride nanorods array for high energy density capacitive device.

T3: Open Quantum Systems

Time: Wednesday 22 Feb, 11:15am; Venue: E3; Chair: Dario POLETTI
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.

T3.81 (INVITED) Quantum absorption refrigerator with trapped ions

Jaren Gan*, Gleb Maslennikov*, Roland Hablutzel*, Shiqian Ding*, Stefan Nimmrichter*, Jibo Dai*, Alexandre Roulet*, Valerio Scarani*, Dzmitry Matsukevich* (Centre for Quantum Technologies)
11:15am – 11:40am

The study of thermodynamics and heat machines have recently been met with remarkable progress, with experiments probing down to micro and nano-scale systems such as the single Brownian particle, as well as the single atom. However, despite several theoretical proposals, implementation of heat machines in the fully quantum regime remains a challenge. We report on an experimental realization of a quantum absorption refrigerator in a system of three trapped ions, with three of its normal modes of motion coupled by a tri-linear Hamiltonian, such that heat transfer between two modes of motion is able to refrigerate the third in a way analogous to the classical absorption refrigerator. We investigate the dynamical and steady state properties of such a quantum absorption refrigerator, and compare the differences in cooling capabilities when squeezing is employed as a quantum resource. We also study the performance of the refrigerator in the single shot regime, and demonstrate cooling below both the steady-state energy and that predicted by the ideal adiabatic operation.

T3.91 (INVITED) Autonomous Rotor Heat Engine

Alexandre Roulet, Stefan Nimmrichter, Juan Miguel Arrazola, Stella Seah*, Valerio Scarani (National University of Singapore)
11:40am – 12:05pm

The triumph of heat engines is their ability to convert the disordered energy of thermal sources into useful mechanical motion. In recent years, much effort has been devoted to generalizing thermodynamic notions to the quantum regime, partly motivated by the promise of surpassing classical heat engines. Here, we instead adopt a bottom-up approach: we propose a realistic autonomous heat engine that can serve as a testbed for quantum effects in the context of thermodynamics. Our model draws inspiration from actual piston engines and is built from closed-system Hamiltonians and weak bath coupling terms. We analytically derive the performance of the engine in the classical regime via a set of nonlinear Langevin equations. In the quantum case, we perform numerical simulations of the master equation and find that free dispersion and measurement backaction noise generally lower the engine's performance.

T3.19 Hitting statistics from quantum jumps

Andy Chia*, Tomasz Paterek, Leong Chuan Kwek (CQT, National University of Singapore)

12:05pm – 12:20pm

We define the hitting time for a model of continuous-time open quantum walks in terms of quantum jumps. Our starting point is a master equation in Lindblad form, which can be taken as the quantum analogue of the rate equation for a classical continuous-time Markov chain [arXiv:1604.05652]. The quantum jump method is well known in the quantum optics community and has also been applied to simulate open quantum walks in discrete time. This method however, is well-suited to continuous-time problems. It is shown here that a continuous-time hitting problem is amenable to analysis via quantum jumps: The hitting time can be defined as the time of the first jump. Using this fact, we derive the distribution of hitting times and explicit expressions for its statistical moments. Simple examples are considered to illustrate the final results. We then show that the hitting statistics obtained via quantum jumps is consistent with a previous definition for a measured walk in discrete time [Phys. Rev. A 73, 032341 (2006)] (when generalised to allow for non-unitary evolution and in the limit of small time steps). A caveat of the quantum-jump approach is that it relies on the final state (the state which we want to hit) to share only incoherent edges with other vertices in the graph. We propose a simple remedy to restore the applicability of quantum jumps when this is not the case and show that the hitting-time statistics will again converge to that obtained from the measured discrete walk in appropriate limits.

T3.56 Quantum Digital Simulator Interacting with a Bath

Yicong Zheng*, Hui Khoon Ng (Centre of Quantum Techonlogy)

12:20pm – 12:35pm

For a quantum digital simulator (QDS) simulating a many-body quantum system, we ask the following question: if the target and its QDS interact with the same bath in the same manner, are their behavior similar to each other? In this paper, we study and compare the open system dynamics for both target system and its QDS. Analytically, we show that their stroboscopic dynamics can be close to each other for both Markovian and non-Markovian dynamics of the target if the gates implementation time is much shorter than both simulation cycle and correlation time of the bath. Numerical simulation using TCL-2 for a simplified Kitaev toric code model and its QDS interacting with a thermal Boson bath verifies the analytical results. It also shows that the QDS can provide certain ability to protect the quantum state encoded in the code space if it faithfully simulates the open system dynamics of the target. This result may shed light on developing new methods of quantum error correction.

T3.58 Atom interferometer in a hollow-core fiber

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

12:35pm – 12:50pm

Light pulse atom interferometry under free fall is a common tool for gravity measurement at high precision level. However, its sensitivity scales with the size of experimental apparatus and optical power due to the diffraction of the Raman beam used in free space Mach-Zehnder interferometer. One of the solution is to use a waveguide such as single mode hollow-core fiber (HCF) to guide atoms and light simultaneously and perform interferometry in it. In this presentation, I will show the details of Rb^{85} atoms loaded into a hollow-core photonic crystal fiber. Rb^{85} atomic cloud of temperature $\sim 100\mu$K is prepared above the HCF. It is loaded into HCF by gravity pulling with the aid of a 1mK deep intra-HCF dipole trap. Rabi flopping, Ramsey fringes, and spin echo signal using 3.035 732 439 GHz microwave antenna for the transition $5^2\mathrm{S}_{1/2}$ $F = 2$ to $F = 3$ and Raman beams with 1.276(2) GHz red detuned from $F = 3 \rightarrow F' = 2$ and $F = 2 \rightarrow F' = 2$ transition, are also demonstrated. Moreover, I will also show Mach-Zehnder interferometry signal, using $\frac{\pi}{2} - T - \pi - T - \frac{\pi}{2}$ sequence.

T4: Optical Computing

Time: Wednesday 22 Feb, 11:15am; Venue: E1; Chair: Marek MILLER
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.

T4.88 (INVITED) Cellular Automata in arrays of Photonic Cavities

Rimi Banerjee*, Timothy C H Liew* (nanyang technological university)
11:15am – 11:40am

Cellular automata (CAs) are mathematical model for complex natural systems, evolve with some simple local rules. They consist of a regular grid of cells, each in one of a finite number of states. When the time comes for the cells to change state, each cell looks around and gathers information on its neighbours' states. Then based on its neighbours' states, its own state and the rules of the CA, the cell decides what its new state should be. All the cells change state at the same time. This model studied in several scientific fields like computability theory, mathematics, physics, complexity science, theoretical biology and microstructure modelling. Conway's Game of Life is a popular version of two dimensional CAs model. It is known to be Turing complete, implies that, in principle, any calculation or computer program can be simulated using this automaton.

In recent years, optical information processing has attracted a tremendous interest due to its low-loss propagation and low heating, which increase the operation speed and reduce the noise. Optical computing and data processing depends on strong material nonlinearities. In conventional materials, nonlinear coefficients are generally small but this nonlinearity can be enhanced by confining light in resonating structures like micro-cavities or micro-ring resonators. In the micro-cavities, strong coupling of photons with excitons in quantum wells give rise to highly nonlinear exciton-polariton modes, which help for implementations of individual logic gates and transistors and it also allows low optical energy (pico-joule) switching between bistable states on ultrafast (picosecond) timescales. implies that, in principle, any calculation or computer program can be simulated using this automaton.

Here we are trying to propose theoretically a photonic Turing machine based on two- dimensional cellular automata in arrays of nonlinear cavities. we are trying to point out that the rule of Game of Life based on two-dimensional cellular automaton can be realized with a coupled set of cavities, corresponding to an array of nonlinear photonic crystal cavities or an array of coupled polariton boxes in a single micro-cavity structure. Our analysis includes couplings between different cavities. To visualise the binary logic states, we are using the phenomenon of optical (polariton) bistability in micro-cavities, driven by a near-resonant laser, in which losses are fully compensated by an external continuous drive. The sequential update of the automaton layers is achieved automatically. Due to the Turing completeness associated with the automaton, this would be one of few universal schemes of (classical) computation based on exciton-polaritons in micro-cavities.

T4.51 (INVITED) Quantum-enhanced multi-parameter estimation for unitary photonic systems

Nana Liu*, Hugo Cable (Singapore University of Technology and Design)
11:40am – 12:05pm

Precise device characterization is a fundamental requirement for a large range of applications using photonic hardware, and constitutes a multi-parameter estimation problem. Estimates based on measurements using single photons or classical light have precision which is limited by shot-noise, while quantum resources can be used to achieve sub-shot-noise precision. However, there are many open questions with regard to the best quantum protocols for multi-parameter estimation, including the ultimate limits to achievable precision, as well as optimal choices for probe states and measurements. In this paper, we develop a formalism based on Fisher information to tackle these questions for set-ups based on linear-optical components and photon-counting measurements. A key ingredient of our analysis is a mapping for equivalent protocols defined for photonic and spin systems, which allows us to draw upon results in the literature for general finite-dimensional systems. Motivated by the protocol in X.-Q. Zhou, et al., Optica 2, 510 (2015), we present new results for quantum-enhanced tomography of unitary processes, including a comparison of Holland-Burnett and NOON probe state

T4.110 Laser-written Waveguide Network as Optical Oracle

María Ramos Vázquez*, Vibhav Bharadwaj, Belén Sotillo, Shu-Zee Alencious Lo, Roberta Ramponi, Nikolay Zheludev, Shane Eaton, Cesare Soci (Nanyang Technological University)
12:05pm – 12:20pm

We implemented a laser-written "optical oracle" [1] chip to solve the famous travelling salesman classical graph theory problem of verifying the existence of a Hamiltonian path in a network. The glass waveguide chip consists of a unidirectional network with four cascaded directional couplers where each coupler plays the role of a node (town), also acting as a beam splitter to direct the light to other nodes. The various nodes are connected to each other by waveguides (roads). We interrogate the photonic network by injecting femtosecond optical pulses and resolving the pulse distribution in time from the optical oracle via optical cross-correlation. If the Hamiltonian solution exists, its delay will be equal to the sum of the travel times needed to visit all nodes of the network, which is made unique by design. This first demonstration of an integrated optical oracle in laser-written waveguides proves the prospect of implementing complex optical waveguide networks that are able to perform cognitive tasks, moving towards larger and scalable networks which may allow solving hard mathematical problems, optically.

[1] An optical fibre network oracle for NP-complete problems, K. Wu, J. García de Abajo, C. Soci, P.P. Shum, N.I. Zheludev, Light: Science & Applications 3, e147 (2014).

T4.61 Device-independent characterizations of the quantum state in a Bell experiment

Zhaohui Wei*, Jamie Sikora* (CQT)

12:20pm – 12:35pm

In a Bell experiment two parties share a quantum state and perform local measurements on their subsystems separately, and the statistics of the measurement outcomes are recorded as a Bell correlation. For any Bell correlation, it turns out that a quantum state with minimal size that is able to produce this correlation can always be pure. In this work, we first exhibit two device-independent characterizations for the pure state that Alice and Bob share using only the correlation data. Specifically, we give two conditions that the Schmidt coefficients must satisfy, which can be tight, and have various applications in quantum tasks. First, one of the characterizations allows us to bound the entanglement between Alice and Bob using Renyi entropies and also to bound the underlying Hilbert space dimension. Second, when the Hilbert space dimension bound is tight, the shared pure quantum state has to be maximally entangled. Third, the second characterization gives a sufficient condition that a Bell correlation cannot be generated by particular quantum states. We also show that our results can be generalized to the case of shared mixed states.

T4.12 Device-Independent Tests of Time-Like Correlations

Michele Dall'Arno*, Sarah Brandsen, Francesco Buscemi, Vlatko Vedral (Centre for Quantum Technologies, National University of Singapore)

12:35pm – 12:50pm

We address the problem of device-independent testing time-like correlations, that is to falsify a hypothesis about a quantum channel or measurement on the basis of an observed input-output correlation only. Formally, the problem consists of characterizing the set of input-output correlations compatible with any arbitrary given quantum channel or measurement. We first provide a closed-form, full characterization of such a set for any qubit measurement, and discuss its geometrical interpretation. For binary correlations, we further provide a closed-form, full characterization of the set of compatible correlations for any dihedrally-covariant qubit channel (such as any Pauli and amplitude-damping channels), and any arbitrary-dimensional universally-covariant commutativity-preserving channel (such as any erasure, depolarizing, universal cloning, and universal transposition channels).

T5: Topological Phenomena

Time: Wednesday 22 Feb, 1:30pm; Venue: EC3; Chair: CHONG Yidong
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.

T5.13 (INVITED) Topological winding numbers and edge modes in non-Hermitian systems

Daniel Leykam*, Konstantin Y. Bliokh, Chunli Huang, Yidong Chong, Franco Nori (Nanyang Technological University)
1:30pm – 01:55pm

Extending Hermitian topological invariants and edge modes to non-Hermitian systems, ubiquitous in photonics as media with gain or loss, is a pressing open problem. Previous studies applied existing Hermitian winding numbers such as the Berry phase to these systems. Analyzing a non-Hermitian 2D Dirac equation, we find three families of edge modes whose existence is intimately related to non-Hermitian degeneracies of the bulk spectrum. Such degeneracies form branch points of the spectrum, described by half-integer winding numbers. We find that in addition to the usual Berry phase, a second winding number associated with the chirality of the energy eigenvalues is required to completely characterize all three families. These non-Hermitian edge modes may be observable in arrays of coupled photonic ring resonators with suitably patterned gain or loss. Our results provide an important step towards the complete topological description and classification of non-Hermitian quantum systems.

T5.109 (INVITED) Tunable Room Temperature Skyrmions in Ir/Fe/Co/Pt Multilayers

Anjan Soumyanarayanan*, M Raju, Christos Panagopoulos* (Nanyang Technological University)
01:55pm – 02:20pm

Magnetic skyrmions are nanoscale topological spin structures offering great promise for next-generation information storage technologies. The recent discovery of sub-100 nm room temperature (RT) skyrmions in several multilayer films has triggered vigorous efforts to modulate their physical properties for their use in devices. Here we present a tunable RT skyrmion platform based on multilayer stacks of Ir/Fe/Co/Pt, which we study using X-ray microscopy, magnetic force microscopy and Hall transport techniques. By varying the ferromagnetic layer composition, we can tailor the magnetic interactions governing skyrmion properties, thereby tuning their thermodynamic stability parameter by an order of magnitude. The skyrmions exhibit a smooth crossover between isolated (metastable) and disordered lattice congurations across samples, while their size and density can be tuned by factors of 2 and 10 respectively. We further investigate their electrical signature using a combination of transport and imaging experiments, and explore their nucleation and stability in patterned nanostructures down to 100 nm. We thus establish a platform for investigating functional RT skyrmions, pointing towards the development of skyrmion-based memory devices.

T5.17 Relation Between Topological Edge Invariants and Exceptional Points

Wenchao Hu, Hailong Wang*, Yidong Chong* (Division of Physics and Applied Physics, SPMS, NTU)

02:20pm – 02:35pm

We study the topological edge invariant in a non-Hermitian network model of finite size, and find a direct relationship between a Hermitian topological invariant and non-Hermitian winding number of a pair of exceptional points (EPs). Such Hermitian topological invariant is formulated based on Laughlin's topological pump, and been strict in the limit of infinite-system. The non-Hermitian winding number arises when the underlying system is of finite size and went through a pair of EPs introduced by the non-Hermitian perturbation.

T5.27 Pressure Induced Topological Phase Transition and Large Insulating Gap in Layered Bi_2S_3

Yongzheng Luo*, Ming Yang, Lei Shen, Yuan Ping Feng* (Department of Physics, National University of Singapore)

02:35pm – 02:50pm

Modulating nontrivially topological states in trivial materials is of both scientific and technological interest. Inspired by the robustness to scattering of conducting edge states in quantum Hall systems, the searching of strong three-dimensional (3D) topological insulators (TIs) has successfully given rise to the Bi_2Se_3 family of compounds, which share a rhombohedral structure containing blocks of quintuple layers. In this study, via hybrid density functional theory based first-principles calculations, we first predict that Bi_2S_3, the lightest bismuth-based chalcogenide binary component, can also be realized in a similar rhombohedral structure, and it becomes a TI by a moderate compressive pressure of about 5.3 GPa with spin-orbit interaction (SOI). Interestingly, the inverted band gap is able to be tuned larger than 0.4 eV with an experimentally accessible pressure. Simultaneously, the surface states, Z2 invariants, and Berry curvature are calculated with maximally localized Wannier functions. The theoretical analyses presented here demonstrate that the topological quantum phase transition between a non-trivial phase and a trivial insulating/metallic phase can be realized by pressure, which also shed light on searching new TIs with large band gap by the control of SOI.

T5.29 Chiral Phase Transitions in a Metallic Frustrated Magnet

Munir Shahzad*, Pinaki Sengupta (NTU/SPMS)

02:50pm – 03:05pm

We explore the magnetic phases in a Kondo lattice model on the geometrically frustrated Shastry-Sutherland lattice at metallic electron densities, searching for topologically non-trivial chiral spin textures. Motivated by experimental observations in many rare earth based frustrated metallic magnets, we treat the local moments as classical spins and set the coupling between the itinerant electrons and local moments as the largest energy scale in the problem. Our results show that a canted flux state with non-zero static chirality is stabilized over an extended range of Hamiltonian parameters. The chiral spin state can be quenched efficiently by external fields like temperature and magnetic field as well as by varying the degree of frustration in the electronic itinerancy. Interestingly, unlike insulating electron densities, a Dzyaloshinskii-Moriya interaction between the local moments is not essential for the emergence of their non-coplanar ordering.

T6: Biophysics

Time: Wednesday 22 Feb, 1:30pm; Venue: E4; Chair: Slaven GARAJ
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.

T6.130 (INVITED) Flow of ions in single-nanometer sized graphene channels

Massimo Spina*, Seunghyun Hong, Slaven Garaj (NUS)
1:30pm – 01:55pm

Understanding the behaviour of water and ions in nanochannels with height of only one or two nanometers has immediate repercussion in biology, filtration and energy science. The mass flow in such channel, where only few water molecules span the lateral dimension, is highly sensitive on the physical and chemical properties of the walls.1 It has been shown that water flows unimpeded through graphene nanochannels2,3 and carbon nanotubes4,5, likely due the ordering of the water molecules.6 In this work, we investigate electrophoretic flow of ions within atomically smooth graphene nanochannels with the range of height of h$\sim$1-5 nm, and several microns long. We show that the mobility of different ions is defined by the size, distortion and dynamics of the ions' hydration shells. We were able to control the surface charge of such channels, controlling the charge selectivity of the channels. This gathered insight gives us a handle in ration design of graphene-based membranes for nanofiltration and desalination.

1.Hong, S. et al. Scalable Graphene-Based Membranes for Ionic Sieving with Ultrahigh Charge Selectivity. Nano Lett. (2016). 2.Joshi, R. K. et al. Precise and Ultrafast Molecular Sieving Through Graphene Oxide Membranes. Science 343, 752–754 (2014). 3. Radha, M. et al. Molecular transport through capillaries made with atomic-scale precision. Nature 538, 222–225(2016) 4. Holt, J. K. et al. Fast Mass Transport Through Sub-2-Nanometer Carbon Nanotubes. Science 312, 1034–1037 (2006). 5. Majumder, M., et al. Nanoscale hydrodynamics: Enhanced flow in carbon nanotubes. Nature 438, 44–44 (2005). 6. Algara-Siller, G. et al. Square ice in graphene nanocapillaries. Nature 519, 443–445 (2015).

T6.118 (INVITED) In-vivo biomagnetic characterization of the American cockroach

Ling-Jun Kong, Herbert Crepaz, Agnieszka Gorecka, Aleksandra Urbanek, Rainer Dumke, Tomasz Paterek* (Nanyang Technological University)
01:55pm – 02:20pm

We present a quantitative method, utilising a highly sensitive quantum sensor, to determine dynamics of magnetic materials in biological samples at room temperature. The method is applied to American cockroaches and reveals magnetic deposits with strikingly different behaviour in alive and dead insects. The observed dynamics allows for determination of physical properties of the sub-micron size deposits and matter around them despite their small volumes. We discuss these properties in light of other experiments and their possible relation to magneto-reception.

T6.108 Peeling of individual DNA molecules from graphene surfaces

Milan Blaskovic* (Centr for Advanced 2D Materials)
02:20pm – 02:35pm

Deeper understanding of interaction of DNA molecules with 2D materials in aqueous environments is important for the design of single-molecule sensors, such as nanopore DNA sequencers. We investigated such interactions at the level of individual molecules using force spectroscopy method with atomic force microscope (AFM).Individual DNA molecules were attached to surface of gold coated AFM probe via covalent Au-S bonding. Measurements of the molecular interactions are performed in aqueous buffer solution through repeated approaching of modified probe to the graphene surfaces. Very specific, DNA peeling force-distance curves were observed. Varying pH and molarity of the buffer solution are used to determine the nature of interaction. Knowledge obtained is used to design electrostatic control of the DNA-surface interaction with aim of sub-nanometer control of movement of a DNA molecule in a nanopore DNA sequencers.

T6.97 Nanopore detection of DNA molecules in crowded neutral polymer solutions

Rajesh Kumar Sharma, Patrick S. Doyle, Slaven Garaj* (National University of Singapore)
02:35pm – 02:50pm

Nanopore sensing is a precise technique for analysis of the structure and dynamics of individual biomolecules in different environments, and has even become a prominent technique for next-gen DNA sequencing. In the nanopore sensor, an individual DNA molecule is electrophoretically translocated through a single, nanometer-scaled pore in a solid-state membrane separating two chambers filled with electrolyte. The conformation of the molecule is deduced from modulations in the ionic current through the pore during the translocation event. Using nanopores, we investigated the dynamics of the DNA molecules in a crowded solution of neutral polymers of different sizes and concentrations. The translocation dynamics depends significantly on the size and concentration of the polymers, as different contributions to the electrophoretic and entropic forces on the DNA molecules come into play. This setup offers an excellent, tuneable model-system for probing biologically relevant questions regarding the behaviour of DNA molecules in highly confined and crowded environments.

T6.142 Characterization of organic semiconducting nanoparticles and their in vitro application

Elena Zucchetti*, Caterina Bossio, Ilaria Bargigia, Mattia Zangoli, Francesca Di Maria, Cosimo D'Andrea, Maria Rosa Antognazza, Giovanna Barbarella, Guglielmo Lanzani (Politecnico di Milano)
02:50pm – 03:05pm

In the last decades, searching for new multifunctional nanoscale materials with healthcare potential applications is remarkably impacting on biotechnological field. Among others, conjugated polymers gained attention for their applications in biosensing, bioimaging and drug delivery. Not only do they have intrinsic high biocompatibility, but they can also be exploited as light sensitive actuators by virtue of their photophysical properties[1,2]. In this work we investigate the possibility of taking advantage of poly(3-hexylthiophene) nanoparticles (P3HT-NPs) in biophotonics[3]. We report on the synthesis of P3HT-NPs by reprecipitation method with excellent colloidal stability in aqueous solution under sterile conditions. We extensively characterize their photophysical properties in different media, including buffer and extracellular solutions, by time-resolved photoluminescence analysis. P3HT-NPs are then incubated with Human Embryonic Kidney (HEK) cells and their effective internalization is assessed by confocal imaging. Finally, we report a detailed study of the interaction between internalized nanoparticles and living cells, based on UV-VIS absorption, cytotoxicity experiments, immunofluorescence assays, calcium imaging and electrophysiology. [1] Tuncel D.,Demir H.V. Nanoscale 2010, 2, 484-494. [2] Martino N., Feyen P., Porro M., Bossio C., Zucchetti E., Ghezzi D., Benfenati F., Lanzani G., Antognazza M.R. Sci. Rep. 2015, 5, 8911. [3] Zucchetti E., Zangoli M., Bargigia I., Bossio C., Di Maria F., Barbarella G., D‘Andrea C., Lanzani G., Antognazza M.R. J. Mater Chem B 2017, 5, 565-574.

T7: Quantum Information

Time: Wednesday 22 Feb, 1:30pm; Venue: E3; Chair: Weibo GAO
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.

T7.24 (INVITED) Covert Quantum Communication

Juan Miguel Arrazola*, Valerio Scarani* (National University of Singapore)
1:30pm – 01:55pm

Encryption is not sufficient when the sole fact that two parties are communicating can be incriminating to them. In such cases, we require methods of covert communication, where an eavesdropper cannot even detect that the communication is taking place. In this work, we extend covert communication to the quantum regime by showing that covert quantum communication is possible over optical channels with noise arising either from the environment or from the sender's lab. In particular, we show that sequences of qubits can be transmitted covertly by using both a single photon and a coherent state encoding. We study the possibility of performing covert quantum key distribution (QKD) and show that positive key rates and covertness can be achieved simultaneously.

Covert communication requires a secret key between the sender and receiver, which raises the problem of how this key can be regenerated covertly. We show that covert QKD consumes more secret bits than it can generate and propose instead a hybrid protocol for covert key regeneration that uses pseudorandom number generators (PRNGs) together with covert QKD to regenerate secret keys. The security of the new key is guaranteed by QKD while the security of the covert communication is at least as strong as the security of the PRNG.

T7.86 Experimental many-pair nonlocality

Hou Shun Poh, Alessandro Cerè, Jean-Daniel Bancal, Yu Cai*, Nicolas Sangouard, Valerio Scarani*, Christian Kurtsiefer (Center for Quantum Technologies and NUS)
01:55pm – 02:10pm

Bell violation is one of the defining features that separates quantum physics from classical physics. Experimental violation of the Bell inequality usually involves high fidelity entangled source and measurement on single quanta. We showed that the latter is not necessary. In this work, we studied the many-pair scenario, where we collectively measure n particles in each run of the experiment. By clever post processings of the data, one can still violate a Bell inequality up to some critical n, which is sensitive to the imperfection of the entangled source. A proof-of-concept experiment is conducted and bounds on the critical n were derived. The bounds can in turn be used to benchmark the quality of the source against the Werner state.

T7.54 All Pure Bipartite Entangled States can be Self-Tested

Andrea Coladangelo, Koon Tong Goh*, Valerio Scarani (Centre for Quantum Technologies, National University of Singapore)
02:10pm – 02:25pm

The canonical approach to test the integrity of a quantum device involves dismantling the device and checking the working condition of its components. However, performing such task requires a certain level of proficiency and knowledge in the inner workings of the device. This implies that the users of these devices often find themselves unqualified to implement these checks. On the other hand, the users are able to sidestep this problem by adopting a different approach. According to quantum theory, there exist non-local correlations that can only be produced by a unique quantum state (up to a local isometry). Hence, the observation of these correlations would characterise the quantum state in the device. This method is known as device-independent self-testing and it allows users to test the serviceability of their quantum devices without requiring any assumption to be made on its underlying mechanism. To date only a handful of entangled states were known to be self-testable. Here, by providing explicit correlations, we proved that all pure bipartite entangled states of any arbitrary dimension can be self-tested.

T7.23 Revealing non-classicality of unmeasured objects

Tanjung Krisnanda*, Margherita Zuppardo, Mauro Paternostro, Tomasz Paterek* (Nanyang Technological University)
02:25pm – 02:40pm

Some physical objects are not accessible to direct experimentation. An environment of an open quantum system being a paradigmatic example. It is then desirable to infer the properties of these objects based solely on their interactions with systems over which we have control. In this spirit, here we propose a method for assessing non-classicality of the environment from the gain of quantum entanglement between two systems individually interacting with the environment but not with each other. The framework is general and in principle allows detection of non-classical features of any inaccessible object able to mediate entanglement. We apply our method to opto-mechanical system consisting of a mechanical membrane mediating interaction between two driven cavity fields.

T7.11 Anomalous Hypersignaling in Operational Theories

Michele Dall'Arno*, Sarah Brandsen, Alessandro Tosini, Francesco Buscemi, Vlatko Vedral (Centre for Quantum Technologies, National University of Singapore)
02:40pm – 02:55pm

A paramount topic in quantum foundations, rooted in the study of the EPR paradox and Bell inequalities, is that of characterizing quantum theory in terms of the space-like correlations it allows. Here we show that to focus only on space-like correlations is not enough: we explicitly construct a toy model theory that, though being perfectly compatible with classical and quantum theories at the level of space-like correlations, displays an anomalous behavior in its time-like correlations. We call this anomaly, quantified in terms of a specific communication game, the "hypersignaling" phenomena. We hence conclude that the "principle of quantumness," if it exists, cannot be found in space-like correlations alone: nontrivial constraints need to be imposed also on time-like correlations, in order to exclude hypersignaling theories.

T9: General Theory 1

Time: Wednesday 22 Feb, 3:30pm; Venue: EC3; Chair: Hui 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.

T9.46 (INVITED) Error estimates of numerical methods for the nonlinear Dirac equation in the nonrelativistic limit regime

Weizhu Bao*, Yongyong Cai, Xiaowei Jia, Jia Yin (Department of Mathematics, National University of Singapore)
3:30pm – 03:55pm

We present several numerical methods and establish their error estimates for the discretization of the nonlinear Dirac equation (NLDE) in the nonrelativistic limit regime, involving a small dimensionless parameter $0 < \varepsilon \ll 1$, which is inversely proportional to the speed of light. In this limit regime, the solution is highly oscillatory in time, i.e. there are propagating waves with wavelength $\mathcal{O}(\varepsilon^2)$ and $\mathcal{O}(1)$ in time and space, respectively. We begin with the conservative Crank-Nicolson finite difference (CNFD) method and establish rigorously its error estimate which depends explicitly on the mesh size h and time step τ as well as the small parameter $0 < \varepsilon \ll 1$. Based on the error bound, in order to obtain 'correct' numerical solutions in the nonrelativistic limit regime, i.e. $0 < \varepsilon \ll 1$, the CNFD method requests the ε-scalability: $\tau = \mathcal{O}(\varepsilon^3)$ and $h = \mathcal{O}(\sqrt(\varepsilon))$. Then we propose and analyze two numerical methods for the discretization of NLDE by using the Fourier spectral discretization for spatial derivatives combined with the exponential wave integrator and time-splitting technique for temporal derivatives, respectively, Rigorous error bounds for the two numerical methods show that their ε-scalability is improved to $\tau = \mathcal{O}(\varepsilon^2)$ and $h = \mathcal{O}(1)$ when $0 < \varepsilon \ll 1$. Extensive numerical results are reported to confirm our error estimates.

T9.84 (INVITED) Semiclassical Particle Densities for Many-Fermion Systems

Thanh Tri Chau*, Jun Hao Hue, Martin-Isbjoern Trappe, Berthold-Georg Englert (Centre for Quantum Technologies)
03:55pm – 04:20pm

We present a mixed density-potential-functional reformulation of standard orbital-free density functional theory (DFT). This approach offers an alternative to other self-consistent schemes such as Kohn-Sham or Hartree-Fock to describe interacting many-fermion systems for arbitrarily large particle numbers. The Thomas-Fermi (TF) model, which erroneously predicts vanishing densities in the classicallly forbidden region, can be improved, for example, by gradient corrections or enhanced WKB methods like those discussed in [1]. Ribeiro et al.'s remarkably accurate one-dimensional particle density cannot be generalized to higher dimensions as the wave function has to be manually patched. We tackle this problem and aim for similarly accurate particle densities, expressed in terms of the propagator, by using Suzuki-Trotter decompositions. Thereby, we construct semiclassical densities, which are exact for the constant-force potential and are consistent with the leading-order gradient corrections. The densities resulting from the propagator, valid for any dimensions, require no patching and are ready to enter

the self-consistent scheme to include interactions. To benchmark our density approximations, we present preliminary results for the analytically accessible Hooke atom of two harmonically confined spin-1/2 fermions, interacting via Coulomb's potential.

[1]: R. F. Ribeiro et al., Phys Rev. Lett. 114, 050401 (2015)

T9.70 Finite sample corrections for parameters estimation and significance testing

Boon Kin Teh*, Siew Ann Cheong, Jia Jie Tay (Nanyang Technological University)

04:20pm – 04:35pm

Living in information age coupled with rapid technological advancements, every day we are continuously bombarded with massive amount of data and information. This information can be really useful if we understand its underlying mechanisms and dynamics with valid reasoning. In order to achieve this goal, one of the key steps is to distinguish noises and signals, which statistical significance testing of distribution plays an important role. Although there are a number of statistical significance testing methods have been developed, however, most of them do not adjust for finite sample effects (finite number elements effect and finite largest element effect). If do, they only account for finite number elements effect, but not finite largest element effect. In this presentation, we will discuss the severe impact of finite sample effects, which include: bias parameter estimation, bias goodness-of-fit measure, and unfair comparison between samples with different sample sizes. We will talk about ways to correct finite sample effects as well, follow by presenting the improved version of statistical significance testing model.

T9.82 Gradient Corrections to Particle Density and Kinetic Energy in 1D and 2D

Martin-Isbjoern Trappe*, Yink Loong Len, Hui Khoon Ng, Cord Axel Mueller, Berthold-Georg Englert (Centre for Quantum Technologies, Centre for Advanced 2D Materials and Graphene Research Centre)

04:35pm – 04:50pm

Density functional theory (DFT) is notorious for the absence of gradient corrections to the two-dimensional (2D) Thomas-Fermi kinetic-energy functional; it is widely accepted that the 2D analog of the 3D von Weizsäcker correction vanishes, together with all higher-order corrections. Contrary to this long-held belief, we show that the leading correction to the kinetic energy does not vanish, is unambiguous, and contributes perturbatively to the total energy. This insight emerges naturally in a simple extension of standard DFT, which has the effective potential energy (that accounts for interactions of the many-body system) as a functional variable on equal footing with the single-particle density. For the semiclassical gradient corrections to the particle density we reveal the invalidity of the zero-temperature limit. Higher-order gradient corrections, included via Airy functions, yield a smooth transition of the particle density into the classically forbidden region, illustrated for a harmonic potential energy, in excellent agreement with the exact densities even for very low but finite temperatures. We derive a kinetic-energy functional whose well-behaved zero-temperature limit improves on the Thomas-Fermi approximation. Analogous results are obtained for 1D, where the so far reported leading correction to the kinetic energy is not even bounded from below.

T9.74 Permutation-invariant qudit codes from polynomials

Yingkai Ouyang* (Singapore University of Technology and Design)
04:50pm – 05:05pm

A qudit code is a subspace of the state space of a fixed number of qudits. Such a code is permutation-invariant if it is unchanged under the swapping of any pair of the underlying qudits. Prior permutation-invariant qubit codes encode a single qubit while correcting t arbitrary errors, and their logical codewords have two important properties. First, the Dicke states over which the logical codewords are superposed over have weights spaced a constant number apart. Second, the probability of observing each logical codeword as a given Dicke state is proportional to a binomial coefficient. We design permutation-invariant qudit codes encoding a single qubit with logical codewords that need not have the above two properties, while still allowing the correction of t arbitrary errors. Polynomials govern the structure of the Dicke states and the probabilities in our construction.

T10: Metamaterials

Time: Wednesday 22 Feb, 3:30pm; Venue: E4; Chair: Cesare SOCI
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T10.111 (INVITED) Optical plasmonic response of niobium around the superconducting transition temperature

Chun Yen Liao, Harish N. S. Krishnamoorthy*, Vassili Savinov, Jun-Yu Ou, Kaveh Delfanazari, Chunli Huang, Giorgio Adamo, Eric Plum, Kevin F MacDonald, Yidong D Chong, Cesare Soci, Feodor V Kusmartsev, Din Ping Tsai, Nikolay I Zheludev (Center for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University)
3:30pm – 03:55pm

We present the first experimental evidence of a direct link between the optical properties of a material and onset of superconductivity. By measuring the dielectric constants of an unpatterned niobium film as well as the reflectivity of a nanostructured niobium metamaterial, we demonstrate a critical dependence of niobium optical response on temperature near its superconducting transition at 9K. Our studies point to a hitherto unknown connection between superconductivity and optical range plasmonics. We explain the experimentally observed critical dependence of the metamaterial resonance position on the transition temperature of niobium by means of a thermodynamics-based model that takes into account the change in the free energy of the metamaterial resonator between the normal and superconducting states. We argue that this is a signature of the transition to the superconducting state, which is detected by infrared photons.

T10.33 (INVITED) Small molecules detection at very low concentrations using optical metamaterials

Sreekanth Kandammathe Valiyaveedu* (Nanyang Technological University)
03:55pm – 04:20pm

Currently, researchers mostly rely on labeling techniques to study the binding kinetics of small molecules and their detection (molecular weights $< 500\,\text{Da}$) at very low concentrations (1fM to 1nM). However, the fluorescent tags used in this method for conjugation may modify or prevent the functionality of the targeted molecules. In this context, label-free techniques, including plasmonic biosensors have been proposed as an alternative choice. Even though, it can provide more accurate quantitative and kinetic measurements by monitoring the binding of analytes in their usual forms, the detection of very small molecule binding at lower concentrations is still not possible using conventional plasmonic biosensors. Recently, hyperbolic metamaterials (HMM)-based plasmonic biosensors have been demonstrated for the detection of D-biotin (244 Da) at low concentrations (10 μM and 10 pM), which showed maximum sensitivity at near infrared (NIR) frequencies and by employing wavelength shift interrogation scheme. The importance of the detection of biotin is that it is a model system for small molecule compounds such as other vitamins, cancer-specific proteins, hormones, therapeutics, or contaminants. Here, we further improve the detection limit by one-order of magnitude, even at visible frequencies. In order to achieve this, we first time develop a low-loss, metal-free and tunable multilayered HMM, which

is based on phase change material and TiN. By exciting the modes of HMM via prism coupling technique and by using Goos-Hanchen shift interrogation scheme, we demonstrate the detection of 1pM biotin and their real-time binding, through well-known streptavidin-biotin affinity model.

T10.77 Lattice Induced Transparency (LIT) in Metamaterials

Manukumara Manjappa*, Yogesh Kumar Srivastava, Ranjan Singh* (NTU)
04:20pm – 04:35pm

Metamaterials being the periodically arranged subwavelength resonator structures offer remarkable features in precise controlling and manipulating of light matter interactions across the wide range of electromagnetic spectrum. Over the years, metamaterials have shown immense potential as tuneable photonic devices demonstrating the resonance properties very much analogous to some of the quantum phenomenon such as electromagnetically induced transparency (EIT) effects observed in the atomic ensembles. In metamaterials, a sharp transmission can be achieved through the Fano type of interference between the 'bright resonator' mode and the resonant 'dark mode' that exist in the system. In such systems, the line width of the transmission peak is dictated by the sharpness of the dark mode, which could be a constraint in realizing ultra-sharp transmission resonances in classical systems. In this talk, I will present a new mechanism termed lattice induced transparency (LIT), which proved to be an elegant tool in achieving ultra-sharp transmission window by coupling the asymmetric metamaterial mode with the resonance lattice mode of the structure. The proposed LIT scheme involves the Fano type of interference effects occurring between a bright metamaterial mode with the two dark modes that strongly enhances the sharpness of the transmission resonance. We report record high group delay values of 20 ps and 4 orders of magnitude enhancement in the group index value (4.5×10^4) in the system at terahertz frequencies. Since the lattice modes are intrinsic to the periodic structures, the proposed LIT could be extended to wide range of system including the photonic crystals and the metamaterials operating from microwave to optical frequencies.

T10.3 Phase change metamaterial pollution sensor

Weiling Dong*, Yimei Qiu, Agnieszka Banas, Krzysztof Banas, Tun Cao, Robert Simpson (Singapore University of Technology and Design)
04:35pm – 04:50pm

We demonstrate a tuneable metamaterial device for gas sensing. The transmission peak of this metamaterial is tuned to over a wide frequency band in the mid-infrared. Upon inducing a structural phase transition in the chalcogenide, the transmission peak is red-shifted by 500 nm. We engineered the transmission peak by controlling the geometry of the metamaterial's features. The relatively large dimensions of the matamaterial features will enable fabrication of device over a large area using inexpensive methods such as nano imprinting. Compared with most other metamaterial designs that are passive and show transmission peaks at a fixed frequency, tuneable chalcogenide metamaterial-based filters will have extensive applications in sensing, displays, and spectroscopy.

T10.73 Plasmonic metasurfaces for optical super-oscillations and Fourier transforms

Guanghui Yuan*, Nikolay I. Zheludev (Centre for Disruptive Photonic Technologies, Nanyang Technological University)

04:50pm – 05:05pm

Super-oscillation is a physical phenomenon where a band-limited function can oscillate much faster than its highest Fourier component over arbitrarily large intervals. With super-oscillation, an optical field in the far-field can be focused into a hotspot with sub-diffraction resolution. In this work, I will introduce our recent progress on the generation of optical super-oscillations using plasmonic metasurfaces which give great flexibility on tuning the phase and amplitude of incoming wavefront. Optical Fourier transforms will also be discussed using similar metasurfaces to generate several special mathematical functions such as Airy and Weber functions.

T11: Quantum Simulation and Comptation

Time: Wednesday 22 Feb, 3:30pm; Venue: E3; Chair: Christoph HUFNAGEL
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.

T11.71 (INVITED) Nonequilibrium long range phase transition in cold atoms: Theory and experiment

Vincent Mancois*, David Wilkowski*, Pascal Viot*, Julien Barré*, Michael Joyce*, Bruno Marcos*, Mehedi Hasan*, Chang Chi Kwong*, Frederic Leroux*, Riadh Rebhi* (Nanyang Technological University)
3:30pm – 03:55pm

The inverse-square law of the gravitational force between two point masses is one of the best known and oldest laws in Physics. When many particles are involved, it is responsible for dramatic collective effects such as the collapse or the clustering of masses at the origin of galaxies in the present universe. At fixed temperature, we know that the stability of an extended phase, dominated by the long range interaction, or a collapsed phase, dominated by the short range repulsive interaction, depends on the dimensionality of the system. In 1D, only the extended phase is stable, whereas in 2D, we expect a phase transition for a critical temperature. Finally in 3D, only the collapsed phase is stable and the extended one is metastable.

During the talk, I will discuss our experimental effort to generate a gravitational-like interaction using a cold gas of neutral strontium atoms. We demonstrated this effect on a 1D test system. Using realistic experimental setup to generalized this approach for 2D system, we have shown that it leads to an unusual nonequilibrium phase transition due to forces which do not derive from a potential. We are currently implementing the 2D, where we expect to visualize a collapse similar to gravity featuring non equilibrium currents of matter. This would open a new door between statistical physics and cold atoms.

T11.135 (INVITED) Two-dimensional lattice of atomtronics flux qubits

Shabnam Safaei*, Benoit Gremaud, Rainer Dumke, Leong Chuan Kwek, Luigi Amico, Christian Miniatura (Centre for Quantum Technologies)
03:55pm – 04:20pm

We propose a system consisting of a simple combination of three laser beams to engineer a two-dimensional optical lattice of Mexican hat potentials able to host atoms in its ring-shaped wells. For high laser intensities, the tunneling between adjacent rings is highly suppressed and each ring, located in one unit cell of the lattice, can be treated as an isolated system. We show that, by an appropriate choice of parameters, an effectively two-level system with an energy spectrum similar to those of superconducting flux qubits can be engineered. As a result, one can associate a qubit to the state of atoms trapped inside the ring of each Mexican hat potential. Each of these two-level systems can be manipulated by a suitable configuration of Raman laser beams imprinting a synthetic flux onto each unit cell of the lattice. We suggest that this system can be considered as a scalable architecture for atomtronics flux qubits.

T11.106 Mesoscopic currents in coupled atomtronic ring ladders

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

04:20pm – 04:35pm

Recent experimental progress have revealed Meissner and Vortex phases in low-dimensional ultracold atoms systems. Atomtronic setups can realize coupled ring ladders, while explicitly taking the finite size of the system into account. This enables the engineering of quantized chiral currents and phase slips in-between them [1]. In particular, full control of the lattice configuration reveals a reentrant behavior of Vortex and Meissner phases. Our approach allows a feasible diagnostic of the currents' configuration through time of flight measurements.

[1] arXiv:1612.09109

T11.128 A measurement driven analog of adiabatic quantum computation

Liming Zhao*, Carlos A Perez Delgado*, Simon Benjamin, Joseph Fitzsimons* (SUTD)

04:35pm – 04:50pm

In this work, we show that one can drive the ground state from a Hamiltonian to which of another Hamiltonian under certain conditions. We also present an adiabatic-like measurement approach to achieve it for frustration free Hamiltonians. The strategy is randomly choosing and checking terms one by one to get the ground state of every changed intermediate-Hamiltonian and the bound of number of checking terms is also given. There must be many potential applications of our approach since its adiabatic-like property. We believe that our approach is more useful and efficient than adiabatic algorithm for some problems because of its advantages over the latter.

T11.79 Comparing surface code and linear code for quantum error correction

Jing Hao Chai*, Hui Khoon Ng (Centre of Quantum Technologies)

04:50pm – 05:05pm

Quantum error correction is crucial for mitigating the adverse effects of noise on quantum systems for scalable quantum computation. While recent analyses of surface codes for quantum error correction suggest that such architectures have better noise thresholds, and thus more favorable to implement than the traditional concatenated linear codes used in standard fault-tolerant proofs, such a conclusion is not so easily reached without also considering the practical aspects of implementing quantum error correction. It is also not straightforward to compare the noise threshold derived for different setups, implementation designs, and underlying assumptions. In this work we seek to answer which scheme is better under what circumstances, using a single platform. Specifically, we consider a fixed amount of experimental resources such as time, available qubits, or additional ancilla and compare the performance of each scheme in mitigating the effects of noise that come from gate operations and environment. Currently, we consider only the task of storing the quantum information with fidelity, but already, such a phase diagram is able to guide us in choosing the right architecture for different noise regimes encountered in experiments. We find that the naive conclusion, "surface codes always do better" needs to be modified. Because of the complicated decoding required for surface codes, there are significant regions of the noise landscape in which the linear code is the method of choice.

T13: Disordered 2D Materials

Time: Thursday 23 Feb, 11:00am; Venue: EC3; Chair: Vitor PEREIRA
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.

T13.94 (INVITED) Correlated fluorescence blinking in 2D semiconductor heterostructures

Weigao Xu*, Weiwei Liu, Weijie Zhao, Xin Lu, Qihua Xiong* (Nanyang Technological University)
11:00am – 11:25am

Fluorescence blinking, i.e., random switching between 'ON' (bright) and 'OFF' (dark) states of an emitter, is widely studied in zero-dimensional (0D) quantum dots and molecules, and scarcely in one-dimensional (1D) systems. Random switching between distinct charge state (or accompanied by fluctuations in charge-carrier traps) is a general mechanism for the interesting and puzzling phenomenon. Here, by construction of vertically stacked two-dimensional (2D) semiconductor heterostructures with a type-II band alignment (with proper interlayer spacing), we uncover a correlated fluorescence blinking effect [1]. The two monolayer components of transition metal dichalcogenides (TMDs) are weakly coupled, and shows intermittent and random interlayer carrier exchange events. For instance, at a certain time, if net electrons are injected from the conduction band of the electron donor to the electron acceptor, this 'electron-dominated' carrier-transfer process will cause a bright (dark) state of the electron acceptor (donor); meanwhile, a 'hole-dominated' carrier-transfer process will lead to a dark (bright) state of the electron acceptor (donor). Fluorescence cross-correlation spectroscopy analyses show that a bright state occurring in one monolayer will simultaneously lead to a dark state in the other monolayer, as predicted by the intermittent interlayer carrier-transfer (IICT) process. Our results provide unique platforms for the study of charge-transfer dynamics and non-equilibrium-state physics, further understanding of interlayer charge transfer underpins the rational tailoring of multi-component heterostructures, as well as delicate optoelectronic devices with valley functionalities. [1] W. G. Xu et al., "Correlated fluorescence blinking in two-dimensional semiconductor heterostructures", Nature, 541, 62-67 (2017).

T13.85 (INVITED) Thickness dependence of space-charge-limited currents in spatially disordered organic semiconductors

Muhammad Zubair*, Yee Sin Ang, Lay Kee Ang (Singapore University of Technology and Design)
11:25am – 11:50am

The electronic properties of disordered organic semiconductors are currently the focus of intensive experimental and theoretical research in many applications such as organic light emitting diodes (OLEDs), organic field effect transistors (OFETs) and organic solar cells (OSCs). The mobility of charge carriers is a key parameter for the performance of these devices, which is typically measured indirectly by fitting the measured current-voltage (J-V) characteristics with the suitable space charge limited current (SCLC) transport model. The transport in OSCs is complicated due to two kinds of microscopic disorders, namely the energetic disorder characterized by a broad distribution of localized states and the spatial disorder related to the morphological features of the material. Thus there are two improvements being added into the traditional SCLC model for organic semiconductors: field-dependent or carrier-density dependent mobility based on hoping conduction mechanism. However, for some organic materials, there are debates whether field-dependent or density-dependent mobility are valid. For example, a recent experimental paper [Adv. Funct. Mater. 26, 21 (2016)] indicated that the mobility of amorphous organic semiconductors (with both low- and high- carrier concentrations) is independent of the carrier-density, which is in contrast with the earlier observation [Appl. Phys. Lett. 86, 092105 (2005)]. Similar concerns had also been raised in a recent topical review paper [J. Phys.: Condens. Matter 27, 093201 (2015)]. In all prior models, the dependence of the thickness (L) of the organic semiconductors sandwiched between the diode have been assumed to be unchanged – similar to the traditional models derived for a bulk solid. In this work, we propose that the spatial disorder of an organic semiconductor cannot be treated as a bulk one-dimensional (1D) solid. By treating the solid as a fractal object, we formulate new SCLC models operating in different regimes: trap-free, trap-limited and field-dependent mobility. A detailed analysis of various experimental results reveals that the classical SCLC models might lead to incorrect extraction of mobility due to the inaccurate thickness-scaling proposed in these classical models. By applying our model, we are also able to reproduce the experimental results of PPV derivative based devices without using the questionable carrier-density dependent mobility.

T13.1 Universality of quadratic to linear magnetoresistance crossover in disordered conductors

Navneeth Ramakrishnan, Ying Tong Lai, Silvia Lara*, Shaffique Adam* (Yale-NUS College)
11:50am – 12:05pm

Many experiments measuring Magnetoresistance (MR) showed unsaturating linear behavior at high magnetic fields and quadratic behavior at low fields. In the literature, two very different theoretical models have been used to explain this classical MR as a consequence of sample disorder. The phenomenological Random Resistor Network (RRN) model constructs a grid of four-terminal resistors each with a varying random resistance. The Effective Medium Theory (EMT) model imagines a smoothly varying disorder potential that causes a continuous variation of the local conductivity. In this theoretical work, we demonstrate numerically that both the RRN and EMT models belong to the same universality class, and that a single parameter (the ratio of the fluctuations in the carrier density to the average carrier density) completely determines both the magnitude of the MR and the B-field scale for the crossover from quadratic to linear MR. By considering several experimental data sets in the literature, ranging from thin films of InSb to graphene to Weyl semimetals like Na3Bi, we show that this disorder-induced mechanism for MR is in good agreement with the experiments, and that this comparison of MR with theory reveals information about the spatial carrier density inhomogeneity.

T13.69 Theory of Coulomb Drag in Spatially Inhomogeneous Materials

Derek Ho*, Indra Yudhistira, Ben Yu-Kuang Hu, Shaffique Adam* (Graphene Research Centre and Department of Physics, National University of Singapore)

12:05pm – 12:20pm

Coulomb drag is a direct measurement of electron-electron interactions between two electronic layers. In actual experimental systems, imperfections such as surrounding impurities lead to spatially fluctuating charge density distributions within the layers. Furthermore, these layer imperfections may be correlated to one another, leading in turn to interlayer-correlated charge density fluctuations. We derive an effective medium theory formalism of Coulomb drag that takes into account these charge density fluctuations and possible interlayer correlations. As an example of application, we study the graphene system in the recent experiment of Gorbachev et al (Nat Phys 8, 896 (2012)) and show that several of the unexpected features reported therein are reproduced within our formalism. Lastly, we study drag in the presence of interlayer exciton condensation and find that the expected divergence in drag resistivity gets quenched by fluctuations in charge density.

T13.144 Electronic transport in disordered MoS_2 nanoribbons

Emilia Ridolfi*, Leandro Lima, Eduardo Mucciolo, Caio Lewenkopf (Physics Dep. and CA2DM affiliates)

12:20pm – 12:35pm

We propose an accurate eleven-band tight-binding parametrization for the band structure of MoS_2 monolayers near the main energy gap. The proposed set of model parameters reproduce both the correct orbital compositions and location of valence and conductance bands in comparison with ab initio calculations. Using this model, we study the electronic structure and transport properties of zigzag and armchair monolayer molybdenum disulfide nanoribbons. We study the electronic properties of pristine zigzag and armchair nanoribbons, paying particular attention to the edges states that appear within the MoS_2 bulk gap. By analyzing both their orbital composition and their local density of states, we find that in zigzag-terminated nanoribbons these states can be localized at a single edge for certain energies independent of the nanoribbon width. We also study the effects of disorder in these systems using the recursive Green's function technique. We show that for the zigzag nanoribbons, the conductance due to the edge states is strongly suppressed by short-range disorder such as vacancies. In contrast, the local density of states still shows edge localization. We also show that long-range disorder has a small effect on the transport properties of nanoribbons within the bulk gap energy window.

T14: Devices

Time: Thursday 23 Feb, 11:00am; Venue: E4; Chair: Carole Diederichs
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.

T14.121 (INVITED) Small polarons in white-emitting 2D perovskites

Daniele Cortecchia*, Jun Yin, Shu-Zee Alencious Lo, Gagik G. Gurzadyan, Annalisa Bruno, Jean-Luc Brédas, Cesare Soci* (Nanyang Technological University)
11:00am – 11:25am

2D perovskites are self-assembled, multiple quantum well-like layered materials consisting of alternating organic and inorganic sheets. Their unique structure induces confinement of charge carriers within the inorganic layers, causing a large increase of the exciton binding energy up to 400 meV. In certain cases, their strong excitonic characteristics lead to unusually broad, highly Stoke shifted luminescence. Here we study the emissive properties of the 2D broadband emitting perovskites (EDBE)PbX_4 (where X=Cl, Br, I) by combining density functional theory simulations (DFT) with steady-state and time-resolved spectroscopy, which reveal the formation of multiple photoinduced colour centres with wide energy distribution. DFT simulations of perturbed crystal structures and large perovskite molecular clusters have allowed identifying the emissive centres as self-trapped electrons (STEL) Pb_2^{3+} and holes (STH) X^{2-}, Pb^{3+}, I^{3-} (VF centres) formed within few nanoseconds after photoexcitation at specific inorganic lattice sites.1,2,3 By comparing perovskites with different photoluminescence properties, we further demonstrate that such self-trapping phenomena are induced by structural deformations of the Pb-X framework and favoured in case of high distortions of PbX_6 octahedra. These studies reveal the importance of excitonic and polaronic transport in hybrid perovskites toward the design of solution processable, broadband emitting materials for solid state lighting and displays.

References: [1] D. Cortecchia, J. Yin, A. Bruno, S.-Z, A. Lo, G. G. Gurzadyan, S. Mhaisalkar, J.-L. Brédas, C. Soci, Polaron Self-localization in White-light Emitting Hybrid Perovskites, arXiv:1603.01284 [2] J. Yin, H. Li, D. Cortecchia, C. Soci, J.-L. Brédas, Excitonic and Polaronic Properties of 2D Hybrid Organic-Inorganic Perovskites, ACS Energy Letters, accepted [3] D. Cortecchia, S. Neutzner, A. R. S. Kandada, E. Mosconi, D. Meggiolaro, F. De Angelis, C. Soci, A. Petrozza, Broadband Emission in Two-Dimensional Hybrid Perovskites: The Role of Structural Deformation, J. Am. Chem. Soc. 2016, DOI: 10.1021/jacs.6b10390

T14.96 (INVITED) Charge-selective Ion Transport in Graphene-based Membranes

Seunghyun Hong*, Charlotte Constans, Marcos Vinicius Surmani Martins, Yong Chin Seow, Juan Alfredo Guevara Carrió, Slaven Garaj (National University of Singapore)
11:25am – 11:50am

Ionic selectivity is a major attribute to consider when designing novel membranes for separation technologies. As one of promising candidates for next generation nanofiltration, graphene oxides (GO) membranes with tunable physiochemical properties offers an excellent framework to make highly efficient ion-selective channels without compromising ultrahigh water permeance. In this study, we demonstrate the ultrahigh charge selective transport in GO-based membranes with microscopic drift-diffusion method [1]. We identified primary mechanisms governing ionic rejection in GO membranes from precise investigation for a range of ionic species: surface charge groups inside the GO nanochannels are responsible for electrostatically repulsing co-ions. The charge selectivity opens up new venue for ion exchange and electrodialysis to GO membranes.

[1] S. Hong, C. Constans, M.V.S. Martins, Y.C. Seow, J. Carrió and S. Garaj, "Scalable graphene-based membranes for ionic sieving with ultrahigh charge selectivity," Nano Lett. 2016, DOI: 10.1021/acs.nanolett.6b03837

T14.103 High-Performance TMD Field Effect Transistors at Room Temperature

Tao Liu, Song Liu, Kun-Hua Tu, Goki Eda, Caroline Ross, Slaven Garaj* (Department of Physics, National University of Singapore)

11:50am – 12:05pm

Layered two-dimensional (2D) materials, such as Molybdenum disulfide (MoS_2), are excellent candidates for electronic, sensing and optoelectronic applications due to their finite bandgap and surface-defined electronic structure. MoS_2 channel-based electronic devices, especially field-effect transistors (FETs), have been widely investigated in the last few years. However, improving their limited electron mobility at room temperature is sorely needed for practical applications. Here we report significant improvement in room temperature performance of MoS_2 transistors via interface engineering. By employing variety of dielectric gate materials with different surface morphology, we found the performance of the devices could vary significantly with the nanoscale geometry of the substrates. With proper choice of substrates, we were able to increase the average mobility by order of magnitude at room temperature, and significantly increase the saturation current. Applying the same approach to the other TMD materials ($MoSe_2$, WSe_2), we could achieve similar performance improvement, regardless of intrinsic doping of the material. Hence, the interface engineering is universally valid route to increase the performance of TMD electronic devices.

T14.104 Space-charge-limited transport of relativistic quasiparticles in 2D Dirac semiconductor

Yee Sin Ang*, Muhammad Zubair, L. K. Ang (Singapore University of Technology and Design)

12:05pm – 12:20pm

Recent experiments on two-dimensional Dirac semiconductor such as MoS_2 [1] and hBN [2] monolayers revealed anomalous space-charge-limited current (SCLC) that follows unconventional voltage-dependence of $J \propto V^\alpha$ with $\alpha < 2$. Such dependence cannot be satisfactorily explained by existing theories [3], based on the classical Mott-Gurney SCLC model, which predicts $\alpha \le 2$. In this work, we propose a new model of relativistic SCLC that takes into account the relativistic dynamics of the transport electron and show that the $\alpha < 2$ scaling observed in experiments is a unique signature of the massive Dirac fermions in 2D Dirac semiconductors. Depending material properties, a continuous transition between the non-relativistic limit of $J \propto (V/L)^2$ and the ultra-relativistic limit of $J \propto (V/L)^{3/2}$ can be obtained for a 2D Dirac semiconductor of length L. Our results represent a new class of relativistic SCLC phenomena in solids and provide physical understanding on the space-charge-limited transport in 2D Dirac semiconductor.

[1] S. Ghatak and A. Ghosh, Appl. Phys. Lett. 103, 122103 (2013). [2] F. Mahvash, E. Parais, D. Drouin, T. Szkopek and M. Siaj, Nano Lett. 15, 2263 (2015). [3] M. A. Lampert and P. Mark, Charge Injection in Solids (Academic Press, New York and London, 1970).

T14.113 Hybrid Perovskite Light-Emitting Field-Effect Transistors

Francesco Maddalena*, Xin Yu Chin, Daniele Cortecchia, Annalisa Bruno, Cesare Soci (Nanyang Technological University)

12:20pm – 12:35pm

We present an improved $CH_3NH_3PbI_3$ perovskite light-emitting field-effect transistor (Pe-LEFET) with bottom gate, top contact configuration, which yields a tenfold improvement of the field-effect electron mobility (up to 0.1 $cm^2V^{-1}s^{-1}$) compared to previously reported bottom gate, bottom contact devices [1]. Furthermore, we show that an AC-driven gate bias modulation minimizes the ionic drift within the perovskite, significantly increasing the electroluminescence brightness compared to DC-driven gate bias at comparable voltages. Moreover, by tuning the amplitude of drain and gate bias modulation, we could achieve uniform light emission from the entire FET channel area, rather than the thin recombination layer typical of DC-operated LEFETs. Even more significantly, AC operation enables electroluminescence emission at significantly higher temperatures, approaching room temperature. These results constitute a significant step toward the development of large-area hybrid perovskite light-emitting field-effect transistor devices for lighting and displays.

[1] X. Y. Chin, et al., “Lead iodide perovskite light-emitting field-effect transistor”, Nature Communications 6, 7383 (2015).

T15: Techniques in Photonics

Time: Thursday 23 Feb, 11:00am; Venue: E3; Chair: Alexander 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.

T15.67 (INVITED) Spectral selection free infrared spectroscopy

Anna Paterova*, Shaun Lung*, Dmitry Kalashnikov*, Leonid Krivitsky* (A*STAR Data Storage Institute)
11:00am – 11:25am

Infrared (IR) spectroscopy is an indispensable tool for many practical applications including material analysis and sensing. Existing IR spectroscopy techniques face challenges related to the inferior performance and the high cost of IR-grade components. Here, we develop a new method, which allows studying properties of materials in the IR range using only visible light optics and detectors. It is based on the nonlinear interference of entangled photons, generated via Spontaneous Parametric Down Conversion (SPDC). In our interferometer, the phase of the signal photon in the visible range depends on the phase of an entangled IR photon. When the IR photon is traveling through the media, its properties can be found from observations of the visible photon. We directly acquire the SPDC signal with a visible range CCD camera and use a numerical algorithm to infer the absorption coefficient and the refraction index of the sample in the IR range. Our method does not require the use of a spectrometer and a slit, thus it allows achieving higher signal-to-noise ratio than the earlier developed method.

T15.42 Photon number and timing resolution of a near-infrared continuous-wave source with a transition edge sensor

Jianwei Lee*, Lijiong Shen, Brenda Chng, Alessandro Cerè, Christian Kurtsiefer (Centre for Quantum Technologies)
11:25am – 11:40am

The Transition Edge Sensor (TES) is a calorimetric spectrometer that have near unit efficiency and is photon-number resolving [1]. It proved fundamental in the experimental loophole-free violation of Bell's inequality [2]. Slow recovery time, on the order of microseconds, limits the number resolving and timing accuracy for high photon-flux detection. This is usually resolved by pulsing the light source or discarding overlapping signals, thereby limiting its applicability. In this work, we analyze the output signal when detecting a continuous wave source, and show a numerical recipe to determine amplitude and timing of overlapping pulses. While similar work has been done on detecting overlapping X-ray signals [3], lower signal-to-noise ratios of TES pulses detecting near-infrared photons complicates the direct estimation of their time-of-arrival. As a direct application, we measure the second-order correlation function of a coherent source in a single spatial mode using a single detector.

[1] A. E. Lita et al., "Superconducting transition-edge sensors optimized for high-efficiency photon-number resolving detectors," Proc. SPIE 7681, Advanced Photon Counting Techniques IV, 76810D, April 2010. [2] M. Giustina et al., "Significant-Loophole-Free Test of Bell's Theorem with Entangled Photons," Phys. Rev. Lett. 115, 250401, December 2015. [3] J. W. Fowler

et al., "Microcalorimeter spectroscopy at high pulse rates: a multi-pulse fitting technique," ApJS 219, 35, August 2015.

T15.117 Cathodoluminescence Spectroscopy of Multidimensional Organic-Inorganic Perovskites

Kar Cheng Lew, Daniele Cortecchia, Jinkyu So, Annalisa Bruno, Cesare Soci* (Centre for Disruptive Photonics Technoogy, Nanyang Technological University)
11:40am – 11:55am

Multidimensional organic-inorganic perovskites are multiple domain systems in which charge transfer and energy funnelling effects allow compositional control of the emission energy and recombination dynamics [1]. Here we employ, for the first time, steady-state and fast (ps) time-resolved cathodoluminescence spectroscopy to correlate spatially resolved yield and dynamics of the luminescence with the complex phase distribution of multidimensional perovskite polycrystalline films [2]. A bulky cation phenylethylammonium (PEA=$C_8H_9NH_3$) was used to induced the formation of layered perovskites of the Ruddlesden-Popper series, and the dimensionality (n) of the resulting $(PEA)_2(MA)_{n-1}$ $[PbnI_{3n+1}]$ was tuned by adjusting the ratio of methylammonium iodide to PEA iodide. We find that phase separation occurs into two preferential domains, corresponding to low- and high-dimensional perovskite rich areas. We discuss the relationship between structure and photophysical properties underlying surface recombination, charge transfer and carrier diffusion effects in this class of materials.

References [1] M. Yuan, L. Na Quan, R. Comin, G. Walters, R. Sabatini, O. Voznyy, S. Hoogland, Y. Zhao, E. M. Beauregard, P. Kanjanaboos, Z. Lu, D. Ha Kim, and E. H. Sargent, "Perovskite energy funnels for efficient light-emitting diodes," Nat. Nanotechnol., vol. 11, no. 10, pp. 872–877, 2016. [2] F. Chen, A. N. Cartwright, H. Lu, and W. J. Schaff, "Time-resolved spectroscopy of recombination and relaxation dynamics in InN," Appl. Phys. Lett., vol. 83, no. 24, p. 4984, 2003.

T15.141 Characterization of a photon pair source based on a cascade decay in a cold atomic ensemble

Mathias Seidler*, Alessandro Cere*, Christian Kurtsiefer* (Centre for Quantum Technologies, NUS and Department of Physics, NUS)
11:55am – 12:10pm

We obtain photon pairs from a four-wave mixing process in a cold atomic ensemble of ^{87}Rb[1]. The generated photon pairs have spectral line widths comparable with atomic transitions, as demonstrated in two recent experiments [2, 3]. We study the relation between photon pair rate and photon bandwidth for a range of parameters, as laser pump intensity, frequency and atomic ensemble properties. This characterization is useful for future experiments allowing the optimization of the source parameters for given experimental requirements.

References [1] Bharath Srivathsan et al., Phys. Rev. Lett. 111, 123602 (2013) [2] Victor Leong et al., Nature Communications 7, 13716 (2016) [3] Victor Leong et al., Phys. Rev. A 91, 063829 (2015)

T15.68 Engineering precise selection of emission opening angles to result in high brightness, high quality polarization entangled photon pairs.

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

12:10pm – 12:25pm

The implementation of bright entangled-photon pair sources to overcome long distances is of profound importance in numerous quantum technologies, such as Quantum Teleportation (QT) or Quantum Key Distribution (QKD). A significant effort has been devoted towards developing brighter entangled-photon pair sources over the past decade. Nevertheless, brightness and entanglement quality both need to preserve their uppermost levels in order for those entangled particles to remain useful in long distances.

Here we focus on entangled-photon pair sources based on spontaneous parametric down-conversion (SPDC) and the characteristic emission-opening angle of the SPDC photons. We have found the entanglement quality can be severely affected when the photons with higher emission opening angles are coupled into single-mode fiber. A study on the numerical model used as well as experimental data are presented in this work.

T15.143 The role of thermal motion in free-space light-atom interaction

Yue Sum Chin*, Matthias Steiner, Christian Kurtsiefer (Centre for Quantum Technologies)
12:25pm – 12:40pm

The prospects of distributed quantum networks have triggered much interest in developing light-matter interfaces. While this is usually realized by optical resonators, tightly focused free-space interfaces offer a complementary alternative. Our version of free-space light-matter interface is formed by a pair of high numerical aperture (NA=0.75) lenses and a single atom held in an optical tweezer. Operating near the diffraction limit, we demonstrate 17.7% extinction of a weak coherent field by a single atom. The thermal motion of the atom is commonly suspected to be one of the limiting factors of the interaction. Here we verify quantitatively this effect by measuring in-situ the interaction strength as the atom heats up.

[1] Y.S. Chin, M. Steiner, C. Kurtsiefer, arxiv.org, arXiv:1611.08048 (2016).

T16: General Theory 2

Time: Thursday 23 Feb, 11:00am; Venue: E1; Chair: Si-Hui TAN
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T16.28 (INVITED) Band structure renormalization in orbital-free DFT

Martin-Isbjoern Trappe*, Shaffique Adam (Centre for Advanced 2D Materials and Graphene Research Centre)
11:00am – 11:25am

We propose a versatile method for calculating band structures via a momentum-space variant of orbital-free density functional theory. Large particle numbers and long-range interactions of interacting many-body systems like quantum gases and solid states in various dimensions pose formidable challenges even to state-of-the-art theoretical methods. With the aid of Wigner's phase space formulation we establish semiclassical approximations of energies and particle densities for the interacting system. The interacting dispersion relations are then self-consistently obtained from the corresponding noninteracting system after specifying the interaction energy functional. We can address a variety of open problems like, for instance, interacting band structures and band gap renormalization in general, Fermi velocity renormalization in graphene, or interaction-induced modifications of the Fermi-Dirac distribution. Employing an analytically tractable version of our method, we present results for a Coulomb-interacting electron gas with Dirac-cone type dispersion relations.

T16.10 Doping dependence of a CDW driven by exciton condensation in 1T-TiSe$_2$

Chuan Chen*, Vitor Pereira* (Centre for Advanced 2D Materials)
11:25am – 11:40am

This layered transition-metal dichalcogenide hosts one of the more robust commensurate charge density wave (CDW) phases among low-dimensional electronic materials, and its origin has been a perennial source of new ideas, concepts, and controversy. Foremost among the quest for clarifying the underlying microscopic mechanisms at play has been the question of whether the CDW instability is primarily driven by electron-electron or electron-phonon interactions. Whereas it is clear that both ultimately play an important role in its overall electronic, lattice, and transport properties, the very low carrier density and particular CDW wavevector of this system has led to the suggestion that electron-electron interactions can be the dominant factor driving the CDW instability through a transition to an excitonic insulator state. By gathering the latest quantitative information about the bandstructure parameters from ARPES and performing a self-consistent Hartree-Fock calculation as a function of doping and temperature, we demonstrate that electron-electron interactions alone can explain very well the variation of Tc with electron doping seen in recent experiments up to densities where the superconducting dome emerges. In addition, the renormalized bandstructure predicted by our model provides a consistent interpretation for the development of partial gaps and the changes in the nature of charge carriers that are known, experimentally, to take place near Tc.

T16.25 Symmetry-protected degeneracies and four-dimension quantum Hall effect in Photonic crystals

Ching Hua Lee* (Institute of High Performance Computing)
11:40am – 11:55am

Of late, there has been intense interest in the realization of topological phases beyond conventional electronic materials, including phases defined in more than three dimensions. Photonic crystals are particularly suitable for this purpose since they can be relatively easily fabricated with features possessing any desired symmetry or periodicity. In this talk, I shall first introduce how non-symmorphic symmetries can arise in photonic crystals with suitably designed cavities, and how that leads to protected Dirac points and line nodes. In particular, there exist an interesting evolution of line nodes and transition between a type I and type II dirac cone as the cavities are rotated to obey pmg, pgg and p4g non-symmorphic group symmetries. Secondly, I shall describe how an effective 2nd Chern number - or 4-dimensional quantum Hall phase - can be realized through a lattice of defect resonators embedded within a regular resonator lattice. Through quasiperiodic spatial modulations in the defect radii, this defect lattice formally maps to two independent copies of Hofstadter models which together possess topologically nontrivial Chern bands living in four-dimensional synthetic space. Compared to previous proposals, these photonic crystal implementations provide arguably the simplest route towards experimental realization.

T16.60 Terahertz radiation from a nanoparticle

Kristin Bjorg Arnardottir*, Timothy C.H. Liew (Nanyang Technological University)
11:55am – 12:10pm

Terahertz (THz) radiation has many important applications, such as in medical imaging, submillimeter astronomy and security screening. Innovation over the past decade has brought out reliable THz sources but the current sources are lacking when it comes to efficiency. We propose a new source of THz radiation consisting on quantum dots in a THz cavity. The Quantum dots are multilayered, spherical quantum dots with a hydrogenic impurity in the center. The layers are then tuned in a way that gives rise to equidistant energy levels in the THz range. Having multiple transitions means that we can get quantum efficiency above unity. To demonstrate our proposal we have studied Al doped GaAs quantum dots, where the concentration of aluminium varies along the radius. We have found parameter sets that correspond to different values of radiation in the THz range and achieve quantum efficiency of over 3.

T16.129 Viscous Jetting from Single Droplet

Qingyun Zeng, Sophie Ten Voorde, Silvestre Roberto Gonzalez Avila, Claus-Dieter Ohl* (Nanyang Technological University)
12:10pm – 12:25pm

The fragmentation and atomization of liquids is important for many industrial and medical applications. Here we study the instabilities of liquid droplets undergoing a volume oscillation. This is accomplished by creating a vapour bubble within the droplet by locally boiling the liquid. Then jets may emerge from the surface which pinch off finer secondary droplets. We study the effect of the fluid viscosity experimentally and numerically. Experiments were carried out by levitating the droplet acoustically and generating a laser-induced cavitation bubble at droplet center. A Computational Fluid Dynamics simulation model based on OpenFOAM was then established to study the jetting dynamics and compare with experiment results. The volume of fluid method accounts for viscosity, compressibility and surface tension in the liquid and gas phase. Experiments and simulations are in excellent agreement. Additionally, an analytical model for the droplet surface stability was tested, which allows to cover a larger parameter space. It accounts for linear perturbations on a spherical droplet. Also this model predicts correctly the onset of jetting within the parameter space span by the Reynolds number and the normalized energy.

T17: Theory of 2D systems

Time: Friday 24 Feb, 11:00am; Venue: EC3; Chair: QUEK Su Ying
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T17.57 (INVITED) Excitonic states and defect physics of two-dimensional group-IV monochalcogenides

Lídia Gomes*, Alexandra Carvalho, Paolo Trevisanutto, Aleksandr Rodin, Antonio Castro Neto (CA2DM, NUS)
11:00am – 11:25am

Layered group-IV monochalcogenides have become an important group of materials within the ever-growing family of two-dimensional crystals. Among the binary IV-VI compounds, SnS, SnSe, GeS, and GeSe form a subgroup with orthorhombic structure which has shown exciting particularities and has been considered of high potential for numerous application. We give a brief overview of some important properties of the 2D form of this group and focus on recent results addressing the excitonic properties and the impact of the introduction of point defects on their structures. Vacancies and oxygen defects are modeled using first principles calculations. Energetic and structural analysis of five dif- ferent models for chemisorbed oxygen atoms, reveals a better resistance of these materials to oxidation if compared to their isostructural partner, phosphorene. We also discuss a parallel work where quasi-particle band structure and excitonic properties of GeS and GeSe monolayers are investigated through ab initio GW and Bethe-Salpeter equation calculations. Within the main results, we show that the optical spectra of both materials are dominated by excitonic effects, however, GeS presents a remarkably larger binding energy of 1 eV.

T17.49 (INVITED) The quantum Monte Carlo study of bilayer graphene

Ho-Kin Tang*, Igor Herbut, F. F. Assaad, Shaffique Adam* (Centre for Advanced 2D Materials, National University of Singapore; Yale-NUS College)
11:25am – 11:50am

At low energy, bilayer graphene has a touching parabolic conduction and valence band. Conventional wisdom holds that a energy gap opens up for infinitesimally small electron-electron interactions. However, recently, Pujari et al. PRL 117 086404 (2016) challenged this conclusion arguing using quantum Monte Carlo with an on-site Hubbard model that a bandgap appears only if the interaction exceeds a certain critical value. In this study, we use projective quantum Monte Carlo method with on-site Hubbard U and a realistic long-range Coulomb interaction 1/r tail.

Our preliminary results confirm the findings of Purjari et al. where an emergent linear term in renormalized energy spectrum stabilizes the metallic phase in interacting bilayer graphene. Moreover, by increasing the strength of long range interaction, we observe a novel transition from quadratic-k behaviour to linear-k behaviour, with strong implications for experiments.

T17.48 Mott Insulator Phase Transition in Graphene

Jia Ning Leaw*, Ho-Kin Tang, João N. B. Rodrigues, Shaffique Adam (National University of Singapore)

11:50am – 12:05pm

Controllably tuning the semimetal to Mott insulator phase transition in graphene could allow for the development of graphene-based low-power electronic devices. It is known in the literature (e.g. Juricic et al., PRB 80, 081405(R); Kaveh et al., PRB 71, 184519 and Gamayun et al., PRB 81, 075429) that increasing the long-range Coulomb interaction decreases the critical contact coupling for the phase transition of spinless Dirac fermions from a semi-metal phase to a charge-density-wave phase (CDW). In this work we consider the more realistic Gross-Neveu model relevant for spinfull Dirac fermions and study the transition between the semimetal and the Mott insulator spin-density-wave (SDW) phase. In contrast to the CDW phase transition, and contrary to conventional wisdom, our Renormalization Group calculation shows that the SDW phase transition occurs at stronger onsite potential if the nearest neighbour potential is increased. Our result implies that high-k dielectrics should favour the Mott transition in graphene.

T17.6 Realistic model for electron-electron interactions in graphene

Joao Rodrigues*, Ho-Kin Tang, Jia Ning Leaw, Pinaki Sengupta, Fakher F. Assaad, Shaffique Adam (Graphene Research Centre and Department of Physics, National University of Singapore)

12:05pm – 12:20pm

We study the effects of realistic electronic interactions in undoped graphene. Using projective quantum Monte Carlo simulations of tight-binding electrons on a honeycomb lattice interacting through a realistic effective Coulomb potential, we compute the phase diagram and renormalized Fermi velocity as a function of the strength of the short- and long-range components of the Coulomb potential. The short-range part of the interaction drives the semi-metal to antiferromagnetic Mott insulator transition. This transition is consistent with the Gross-Neveu-Yukawa critical theory. Far from the critical point, the Fermi velocity renormalization is dominated by the long-range part of the interaction, being compatible with the predictions from perturbative theory. In contrast, close to the antiferromagnetic Mott insulator transition, the Fermi velocity renormalization is modified by a competition between spin density wave and charge density wave fluctuations. Real graphene samples are typically halfway between these two limits. Since finite system sizes restrict the QMC results to large momentum scales, we perform a phenomenologial reconstruction of the renomalization group flow of the Fermi velocity to make predictions that can be tested against current experimental observations.

T17.18 Defects and doping in phosphorene

Alexandra Carvalho*, António Castro Neto* (National University of Singapore)

12:20pm – 12:35pm

Most two-dimensional materials are unintentionally doped, due to the growth process or as a result of the interaction with the atmosphere or with other device components. Phosphorene is known to be normally p-type, nevertheless it can be used as a channel material for ambipolar field effect transistors able to operate both in the n- and p-type regimes. In this talk, we analyze how single vacancies and tin can contribute to the p-type conductivity in phosphorene. We will also consider the different stages of interaction with oxygen and water, and how oxygen defects can be stabilized and deactivated.

T18: Acoustics and Nanomechanics

Time: Friday 24 Feb, 11:00am; Venue: E4; Chair: KUAN Pei-Chen
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T18.72 (INVITED) Nanomechanical sensing using spins in diamond

Phani Peddibhotla*, Marcus Doherty*, Michael Barson, Preeti Ovartchaiyapong, Kumar Ganesan, Richard Taylor, Matthew Gebert, Zoe Mielens, Berndt Koslowski, David Simpson, Liam McGuinness, Jeffrey McCallum, Steven Prawer, Shinobu Onoda, Takeshi Ohshima, Ania Jayich, Fedor Jelezko, Neil Manson (Australian National University)
11:00am – 11:25am

We employed the embedded nitrogen-vacancy (NV) defect states in single-crystal diamond cantilever for measuring external forces. In order to experimentally demonstrate the force sensing capabilities, we employed a tungsten tip to apply a force on the non-clamped end of the diamond cantilever, which in turn induces lattice strain to a NV center close to the clamping point of a cantilever. The strain-mediated coupling between NV spin and diamond mechanics is observable via clear signatures in the optically detected electron spin resonance (ESR) spectrum of the NV center [1, 2, 3].

[1] J. Teissier et al., PRL 113, 020503 (2014). [2] P. Ovartchaiyapong, et al., Nat. Commun. 5:4429 (2014). [3] M. Barson et al., arXiv:1612.05325 (2017).

T18.126 (INVITED) Time-resolved acoustic pressure generated from laser-induced cavitation bubbles near a solid boundary

Silvestre Roberto Gonzalez Avila*, Claus-Dieter Ohl (NTU)
11:25am – 11:50am

The bubble dynamics near a solid boundary has been studied extensively. High-speed video recordings have been usually employed to analyse the different features of the cavitation event; however, the profile of the acoustic wave and the amplitude of the pressure generated upon the bubble collapse have not been thoroughly studied, this has been due to the short rise time of the acoustic transient and the large time constant of conventional hydrophones (typically larger than tens of nanoseconds).

In this presentation the pressure generated and the profile of the acoustic transient from a single laser-induced cavitation bubble are resolved by means of an optic-fiber hydrophone (150 MHz bandwidth). Also, we present different acoustic profiles resulting from cavitation events created at different distances from the solid boundary. The results presented here are relevant for erosion on solid surfaces as a result of cavitation bubbles.

T18.124 Oscillate Boiling with Microheaters

Dang Minh Nguyen*, Fenfang Li, Silvestre Roberto Gonzalez Avila, Claus-Dieter Ohl* (Nanyang Technological University)

11:50am – 12:05pm

Boiling, a liquid-vapor phase transition due to excessive heat supply, is a common physical phenomenon which has been widely exploited in various power generation and refrigeration devices. To facilitate the boiling process, one can simply introduce more thermal energy to the system. However, there is an upper limit called critical heat flux where a thin film vapor is formed, separating the boiling liquid from the heating the surface, thus, blocking the flow of heat. This causes heat transfer coefficient to drop dramatically, boosting the device's temperature and in many cases causing thermal breakdown of the systems. While improving critical heat flux to avoid this boiling crisis has significant impact in energy efficiency, safety and cost, for many decades, it remains an unsolved challenge. Our work introduces a new boiling regime called oscillate boiling. In this regime, the heat source is confined to a microscopic area. Then the boiling bubble, instead of slow growth, oscillates at hundreds of kilohertz. These oscillations prevent the formation of a thin film vapor commonly attributed to the boiling crisis. Systems under this boiling regime can sustain a large amount of heat input, several orders higher than the critical value. The critical observations, characterizations as well as the physical mechanism of the phenomenon will be the focus of our work.

T18.53 Light-dragging effect in a moving medium with electromagnetically induced transparency

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

12:05pm – 12:20pm

As one of influential experiments on the development of modern physics, the phenomenon of light dragging in a moving medium has been discussed and observed extensively in different types of systems. In order to get a larger dragging effect, a long duration of light travelling in the medium is preferred. We therefore demonstrate a light-dragging experiment in an electromagnetically induced transparent cold atomic ensemble to enhance the dragging effect by at least three orders of magnitude compared with the previous experiments. With a large enhancement of the dragging effect, we realize an atom-based velocimeter that has a sensitivity two orders of magnitude higher than the velocity width of the atomic medium used. The result suggests the possibility of making a motional sensor using the collective state of atoms in a room temperature vapour cell or solid state material in the future.

T18.131 Laser induced bubble dynamics in soft solids

Julien Rapet*, Claus-Dieter Ohl (Nanyang Technological University)

12:20pm – 12:35pm

Bubbles and their specific features, such as jetting and shock wave emission are commonly used in biomedical applications, e.g. in liposuction, lithotripsy, histotripsy, and even cataract surgery. Bubble dynamics is strongly affected by the liquid properties such as viscosity and non-Newtonian features. Tissue and tissue mimicking phantoms are soft solids resisting deformations through a restoring force. In this research project the bubble dynamics resulting from a soft solid behavior is studied. First we will be reporting of our experimental setup to generate stable and oscillating bubbles in gelatin with the help of a focused and pulsed laser. Preliminary results showing single bubbles in gelatin of different concentrations reveal the importance of the bubble and the gas saturation of the gelatin. The bubble dynamics is compared to commonly used models for Newtonian fluids. Bubble-bubble, bubble-wall, and bubble-free interface interactions are also shown and reveal the importance of the displacement field in the soft solid. Yet, the 3-dimensional field needs to be analyzed. We present a technique to resolve the deformation using a beam-splitter and providing 4 views on a single sensor of the high-speed camera.

T18.145 Arbitrary photoacoustic waves from 3D printed transducers

Weiwei Chan, Thomas Hies, Claus-Dieter Ohl* (Nanyang Technological University)
12:35pm – 12:50pm

Photoacoustic waves are generated by applying laser pulses on a light absorbing surface. Hence, acoustic wave emission is induced by the transient thermal expansion of the surface. These waves can be focused using concave spherical surfaces. Previous designs employed glass substrates coated with carbon nanotubes using chemical vapor deposition. Here we show that arbitrary waves can be generated using 3D printed surfaces. We have developed a compatible coating process, which allows obtaining positive pressure amplitude of over 500 bar. We will present pressure measurements, and Schlieren images of the wave propagation and for simple and complex surfaces, which are supported with simulations of the wave propagation.

T19: Photonics

Time: Friday 24 Feb, 11:00am; Venue: E3; Chair: Gleb MASLENNIKOV
Time allocated for invited talks is 20 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T19.41 (INVITED) Photonics: as a co-curricular program

Erkan Polatdemir*, Peng Kian Tan (Hwa Chong Institution)
11:00am – 11:25am

The widespread applications of optics and photonics have ascertained a number of industries that the future workforce should be equipped with good skills, knowledge and understanding of this field. Leaving this strategic task to undergraduate studies might not be that effective especially for younger students who may already have passion and interest in the field. On the other hand, introducing such concepts to high school students is a challenging endeavor for various reasons. An effective program which combats the difficulties is therefore needed in order to introduce concepts in photonics to high school students seamlessly. In this paper, we will present such a co-curricular program which has been implemented in a high school in Singapore for more than three years. We will describe the main framework of this program such as the process of identifying right students, the activities to engage students deeply and stimulate their enthusiasm further in photonics. We will also provide details about students' learning outcomes both successes and failures. We will finally discuss about advantages and disadvantages of running such a co-curricular program in a school context.

T19.112 (INVITED) Control of Luminescence in Perovskite Metamaterials

Giorgio Adamo*, Behrad Gholipour, Kar Cheng Lew, Daniele Cortecchia, Harish N. S. Krishnamoorthy, Annalisa Bruno, Jin-Kyu So, Muhammad D. Birowosuto, Nikolay I. Zheludev, Cesare Soci (Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University)
11:25am – 11:50am

We show that luminescence spectra of solution-processable metal-halide perovskite films can be controlled by nanopatterning, leading to up to five-fold increase of luminescence yield. We engineered the optical response of the perovskite films using metamaterial design concepts and, as proof of principle, we fabricated all-perovskite dielectric metasurfaces and hybrid metal-perovskite metamaterials which show significantly enhanced luminescence emission and controlled spectral response throughout the visible region. The all-dielectric metamaterials were engraved by direct focused ion beam milling (FIB) onto thin films of methylammonium lead iodide perovskite ($CH_3NH_3PbI_3$) spin-coated on quartz substrate. The perovskite metasurfaces show vivid structural color tuning and strong field enhancement, dependent on the geometrical parameters of the nanometer sized metamolecules. We observed up to a five-fold Purcell enhancement of both photo- and cathodo-luminescence emission compared to the unstructured films. We also discuss hybridization of perovskite films with plasmonic metamaterials and metal-semiconductor-metal slab waveguide geometries to provide higher control on the light extraction properties. Our results prove that nanostructuring and hybridization of perovskites with metamaterials are viable routes to engineer tunable structural colour and radiative emission properties on-demand, thus defining a new paradigm to increase the efficiency, control the electroluminescence spectrum, and improve light extraction and directivity of light-emitting devices

T19.125 Bubble formation with a high repetition rate pulsed Tm laser

Milad Mohammadzadeh*, Weiwei Chan, Silvestre Roberto Gonzalez-Avila, Kun Liu, Zhiyu Yan, Qijie Wang, Claus-Dieter Ohl (Nanyang Technological University)
11:50am – 12:05pm

Thulium lasers are commonly used in medical applications for tissue ablation due to the strong absorption of water in the mid-infrared spectrum. Using high-speed photography, we present an experimental study of bubble formation at the tip of a fiber optic that delivers short pulses of Tm laser at high repetition rates. While a hemispherical bubble forms at the fiber tip at all laser settings, if the power is sufficiently high, a secondary bubble forms during the collapse of the first bubble. The secondary bubble expands at the tip of the initial bubble, moves away from it, and collapses with a jet pointing away from the fiber. A mathematical model is provided to estimate when secondary bubble formation can occur by calculating the maximum bubble radius as a function of the laser power. Finally, the relative translational motion of the bubbles is explained by considering the interaction between two bubbles that oscillate out-of-phase.

T19.89 Optical probing of the Coulomb interactions of an electrically pumped polariton condensate

Subhaskar Mandal*, Ge Rongchun*, Martin Klaas*, Amthor Matthias, Sebastian Klembt, Worschech Lukas, Christian Schneider, Sven Hoefling, Timothy C.H Liew* (Nanyang Technological University)
12:05pm – 12:20pm

Exciton-polaritons can be created in quantum well microcavity structures as a result of the strong coupling of excitons and photons. Their bosonic nature allows the creation of a condensate, which is inherently nonequilibrium due to the dissipative character of the system. Advantageous for the formation of this quantum degenerate state is the small effective mass of the quasiparticles which allows condensation up to room temperature in wide bandgap semiconductors like ZnO, GaN and organic materials. This macroscopically occupied state can show a variety of exciting many-body effects. One of the most interesting, from an application viewpoint, is laser-like emission without the necessity for inversion. An advantage of such polariton light sources is the possibility for very low thresholds. Furthermore, adding the fact that they can exhibit up to shot-noise limited temporal coherence and considerable spatial coherence, the polariton laser is a promising future device for coherent ultra-lowpower consumption applications. Only recently polariton lasing under electrical pumping has been achieved. The coulomb interactions emerging inside such a condensate are poorly understood compared to optically driven condensates in planer samples and micropillars.

Our main objective is to understand the fundamental interactive nature of the electrically formed condensates inside a ring shaped potential. Our analysis includes a Gross-Pitaevskii equation approach based on modeling the electrical and optical potentials. By positioning a weak non-resonant Gaussian continuous wave-beam inside the electrical condensate, we study the repulsion effect which is the characteristic of the part-excitonic nature of the microcavity system in strong coupling. we extend our investigation further by simulating the population dynamics of the polaritons by taking the phonon induced transition into account and the condensation of the ground state.

T19.99 Dielectric-Loaded Phonon Polaritons

Alexander M. Dubrovkin*, Bo Qiang, Harish N. S. Krishnamoorthy, Nikolay I. Zheludev, Qi Jie Wang (Nanyang Technological University)
12:20pm – 12:35pm

We report the first observation of highly confined polaritons with wavelength two orders of magnitude shorter than the free space wavelength that propagates on the surface of silicon carbide crystals covered by a few atomic layers of molybdenum disulfide. Confined surface polaritons attract increasing attention as a promising platform for nanoscale opto-electronic integrated circuits enabling strong light-mater interactions. Recently, a new approach for confining surface phonon-polaritons (SPhPs) in bulk polar crystals by ultrathin capping layer has been experimentally demonstrated in quartz/GST system. However, the ultimate performance of the device was limited by the film quality on few-nm thickness scale, and would also require a stronger polar crystal. In this work, we meet these requirements by placing nanometric layers of two-dimensional dielectric materials on a bulk silicon carbide substrate. To experimentally excite SPhPs we use mid-IR radiation of CO_2-gas laser at frequencies between 930 and 897 cm^{-1}. Scattering-type scanning near-field optical microscopy revealed deeply subwavelength confinement of SPhPs in the MoS_2-SiC interface down to bi-layer of the layered dielectric. The confinement factor is highly sensitive to both the MoS_2 thickness and the spectral line of excitation. We experimentally perform a systematic study of thickness and spectral dependency of the confinement, and fit the data with theoretically calculated dispersion. Approach discussed in our work enables realization of ultimate light-matter interaction on the interface of nanometric layered dielectrics supported by bulk polar crystals down to the fundamental atomic limit, opening a new avenue on the surface polaritons confinement at nanoscale.

6 Physics Olympiad Events

The 29th Singapore Physics Olympiad 2016 was held in October and November 2016, with more than 200 Junior College students from various schools in Singapore participating. As is tradition, the Awards Ceremony for the Olympiad as well as the announcing of some special prizes will be part of annual meeting of the Institute of Physics, Singapore. All teachers in charge are warmly invited to attend, even if your students have not won anything this time. All student winners (medallists and honourable mentions) are invited to receive their awards.

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

Friday afternoon, 24 February schedule

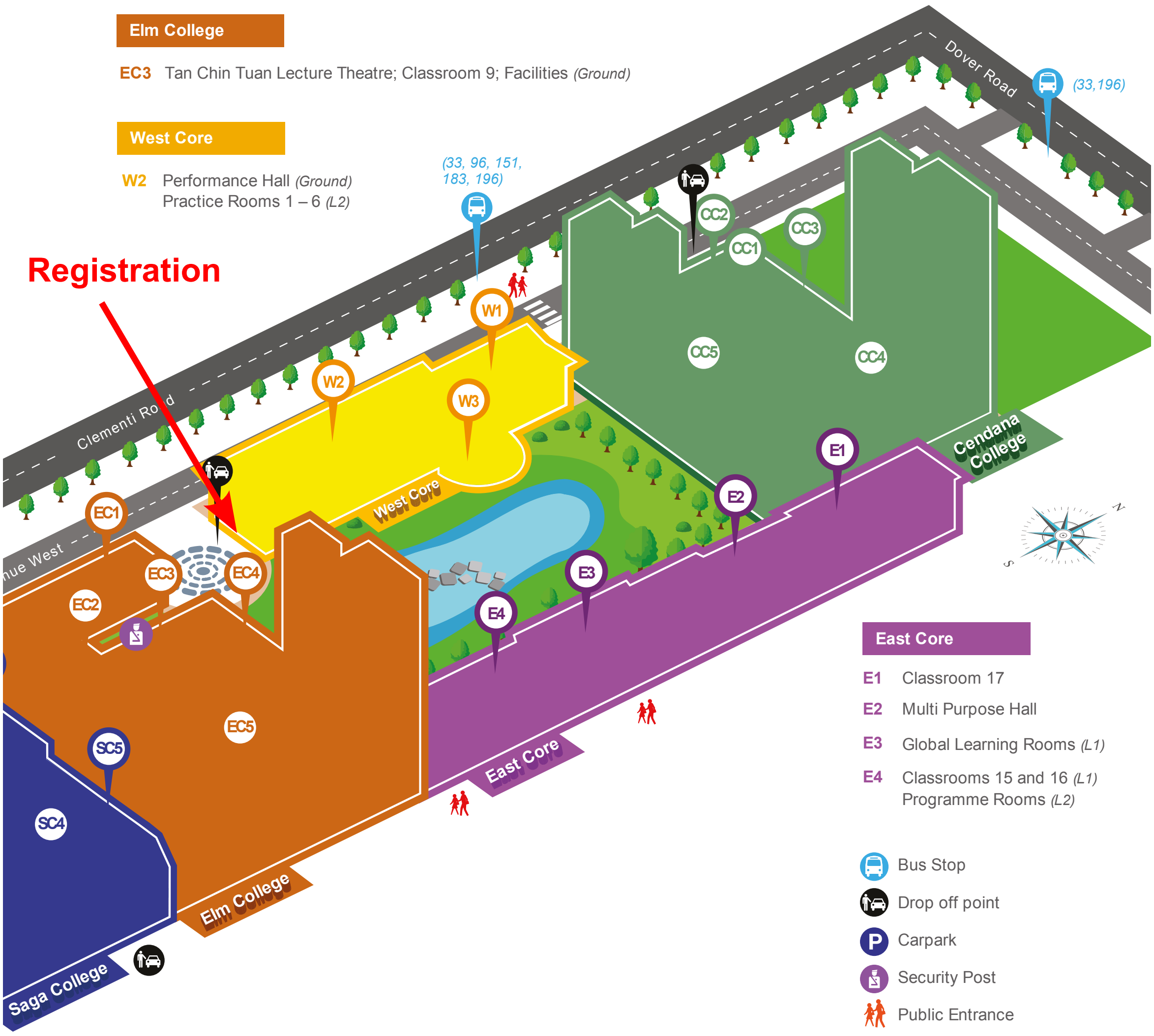
1.30 PM	Registration for award winners (Foyer outside Performance Hall) W2
2.00 PM	O1: Physics Olympiad award ceremony (Performance Hall) W2
3.00 PM	O2: Panel discussion ”Personal Perspectives on Physics” (Performance Hall) W2
4.30 PM	Refreshments and networking (Oculus, outside the Performance Hall)

Author List

(Notes)

7 Location Map

Most events take place at ground level of the Yale-NUS campus:



The big lecture theater "Performance Hall" in W2 is for plenary sessions, posterpitch presentations and the SPhO event near the registration and exhibitors on level 1. You can find a more detailed map at https://www.yale-nus.edu.sg/about/campus-map/.