IPS Meeting 2023
27 - 29 September

Institute of Physics Singapore

Preliminary Program

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Contents

1 Schedule

(This is still the preliminary schedule – change of times are possible but increasingly unlikely)

Wednesday, 27 September

9.00 AM	Plenary talk P1: Giovanni VIGNALE (Venue: LT27)			
9.45 AM	Plenary talk P2: Silvija GRADECAK (Venue: LT27)			
10.30 AM	Coffee/Tea Break + Exhibition (Library Atrium)			
11.00 AM	Technical Sessions			
	T1 (Room 1) Quantum Dynamics 1	T2 (Room 3) Quantum Devices and Quantum Communication	T3 (Room 4) Materials 1	T4 (Room 2) Astronomy
12.30 PM	Lunch + Exhibition ()			
2.00 PM	Technical Sessions			
	T5 (Room 1) Quantum Dynamics 2	T6 (Room 3) AMO Physics	T7 (Room 4) Materials 2	
3.30 PM	Coffee/Tea Break + Exhibition (Library Atrium)			
4.00 PM	Technical Sessions			
	T9 (Room 1) Quantum Information 1	T10 (Room 3) Bio and Molecular Physics	T11 (Room 4) Materials 3	
5.30 PM	End of Wednesday sessions			

Thursday, 28 September

9.00 AM	Technical Sessions			
	T13 (Room 1) Topological Systems	T14 (Room 3) Machine Learning 1	T15 (Room 4) Electronic Devices	T16 (Room 2) Light Souces and Lasers
10.30 AM	Coffee/Tea Break + Exhibition + Poster mounting (Library Atrium)			
11.00 AM	Plenary talk 3: David WILKOWSKI (Venue: LT28			
11.45 AM	Plenary talk 4: ZHU Di (LT28)			
12.30 PM	Rapid Fire poster Pitch session (Venue: LT28)			
1.00 PM	Lunch + Posters + Exhibition (Library Atrium)			
2.00 PM	Technical Sessions			
	T17 (Room 1) Photonics	T18 (Room 3) Classical and Quantum Machine Learning 2	T19 (Room 4) Quantum Information 2	T20 (Room 2) Superconductivity
3.30 PM	Coffee/Tea Break + Exhibition + Poster mounting (Library Atrium)			
4.00 PM	Poster session + Exhibition (Library Atrium)			
5.30 PM	Poster awards + Pizza + Drinks (Library Atrium)			
6.30 PM++	End of Thursday sessions			

Friday, 29 September

9:00 AM	Diversity talk D1: Burçin MUTLU-PAKDIL (Venue: Room 4)			
10.00 AM	Coffee/Tea Break + Exhibition (Library Atrium)			
10.30 AM	Plenary talk P5: Nelly NG (Venue: LT28)			
11.15 AM	Plenary talk P6: Xavier GARBET (Venue: LT28)			
12.00 Noon	IPS Award ceremony (Venue: Room 1)			
12.30 PM	Lunch + Exhibition (Library Atrium)			
2.00 PM	Technical Sessions			
	T21 (Room 2) Plasma Physics and Fusion	T22 (Room 1) Many Body Physics	T23 (Room 3) Quantum Computing	T24 (Room 4) Quantum Optics
3.30 PM	End of Conference			

2 Plenary sessions

We have several distinguished plenary speakers this year – with a nice overview of recent activities in physical sciences in Singapore.

P1: Undergap currents and the anomalous Hall effects

Prof. Giovanni VIGNALE
Department of Materials Science and Engineering and
The Institute for Functional Intelligent Materials (I-FIM),
National University of Singapore

Wednesday, 27 September 09:00am, Venue: LT27

Abstract

Anomalous Hall effects, such as the valley, the orbital, and the spin Hall effect, are usually detected by measuring the accumulation of the corresponding densities (valley, orbital, or spin density) on the edges of a bar-shaped device (Hall bar). However, the relation between this accumulation and the bulk current, which is supposed to "feed" the accumulation, is far from straightforward. For example a BN nanoribbon with Fermi level in the gap supports a bulk valley Hall current in spite of being an insulator. However, this "undergap" current does not produce a valley density accumulation as long as there are no edge states crossing the Fermi level. Therefore we see that there is no direct connection between the magnitude of the bulk valley current (quantified by a finite valley Hall conductivity) and the magnitude of the edge accumulation (zero in this case). The reason for this puzzling state of affairs is that the conservation of the valley density (as well as the orbital magnetic moment density and other densities that depend on crystal momentum) is broken in an unexpected way by the very same electric field that drives the valley Hall effect. It turns out that the relation between edge accumulations and bulk current for non-conserved densities is a delicate one, which necessarily involves dissipation from bulk and/or edge state at the Fermi level. We provide an exact formula, based on linear response theory, for calculating the effective bulk current that feeds the accumulation, and show that it can be expressed as a Fermi surface average, which depends critically on the presence or absence of localized edge states at the Fermi level as well as the reflection coefficients of extended bulk states at the edges of the system. We argue that this formula can be used to accurately model the density accumulations in experimental measurements of the valley Hall effect.

* This talk is based on the paper by Alexander Kazantsev, Amelia Mills, Eoin O'Neill, Hao Sun, Giovanni Vignale, Alessandro Principi, arXiv:2211.12428.

P2: *Quo vadis*, nanomaterials: from lab to real-world applications

Prof. Silvija GRADECAK Department of Materials Science and Engineering
National University of Singapore

Wednesday, 27 September, 09:45am, Venue: LT27

Abstract

Functionality of novel nanomaterials and their impact on society will be ultimately dictated by our ability to precisely control their structural properties, size uniformity, and dopant distribution at the atomic level. In this presentation, we will discuss our recent efforts on the implementation of nanomaterials – including two dimensional (2D) ultrathin films, one dimensional (1D) nanowires/nanotubes, and zero dimensional (0D) nanocrystals – into real-world applications. First, we will discuss recent initiatives within the Applied Materials-NUS Advanced Materials Corporate Lab with a special focus on the wafer-scale integration of 2D materials for the current and future semiconductor industry nodes. Furthermore, we will discuss a new type of freestanding down-conversion color filters based on colloidal 1D quantum dots for the next generation of high-resolution displays. An outlook on new ways to tailor properties of nanomaterials using highly focused ion- and electron-beams or a twist will be presented.

P3: Artificial Gauge fields: From geometric Qubits to Ramsey interferometry

Assoc. Prof. David WILKOWSKI,
School of Physical and Mathematical Sciences,
Nanyang Technological University

Thursday, 28 September, 11:00am, Venue: LT28

Abstract

Among other, ultracold atoms' platforms are currently used as simulators in quantum physics. One of the drawback of atoms is their lack of charge preventing simulations of magnetism to target important effects such as quantum Hall or high-Tc surperconductivity to name a few. However, one can partially lift this limitation with engineered light-atom couplings, leading to the appearance of artificial Gauge fields. Interestingly, the generation of gauge fields does not only act on an effective charge but also on higher dimensional quantum objects such as pseudo-spin or pseudo-color-charge. In this talk, I will discuss how we were able to experimentally generate and control those high dimensionality gauge fields. I will also present few illustrative examples where we take advantage of the richness of such systems to generate geometric Qubits, simulate Dirac equation, and perform new type of Ramsey interferometry.

P4: Scalable single-photon technologies for quantum information processing

Asst. Prof. ZHU Di
Institute of Materials Research and Engineering
A*STAR

Thursday, 30 September, 11:45am Venue: LT28

Abstract

Single-photon technologies allow the generation, manipulation, and detection of light at its fundamental limit. They form the cornerstone of photonic quantum information processing. Besides stringent performance metrics, practical quantum systems for computation and simulation further impose demanding requirements on scalability. In this talk, we will discuss several critical technologies for scalable single-photon generation, manipulation, and detection, with a particular emphasis on integrated photonics solutions. Specifically, we first introduce thin-film lithium niobate as an emerging material platform for integrated quantum photonics, demonstrating how it enables efficient single-photon generation, spectral control, and coherent transduction. We then present superconducting nanowires as outstanding single-photon detectors, highlighting recent advances in their scalable readout and on-chip integration. Combining both paves the way towards fully integrated quantum photonic processors.

D1: Galaxies and Diversity in Physics

Asst. Prof. Burçin MUTLU-PAKDIL
Darthmouth College
Friday, 29 September, 9:00am, Venue: Room 4 (via zoom)

This event will feature a talk on the implications of and efforts behind finding the faintest galaxies, as well as Prof. Burçin's outreach programs on bringing scientific efforts and discoveries to the community.

The talk is organized by the EDIphy team in physics to promote equity, diversity and inclusion in physics, and also an opportunity for the physics community to engage with the team in a casual setting.

P5: Catalysis in Quantum Information Theory

Asst. Prof. Nelly NG
School of Physical and Mathematical Sciences,
Nanyang Technological University

Friday, 29 September, 10:30am, Venue: LT28

Abstract

Catalysts open up new reaction pathways which can speed up chemical reactions while not consuming the catalyst. A similar phenomenon has been discovered in quantum information science, where physical transformations become possible by utilizing a (quantum) degree of freedom that remains unchanged throughout the process. In this talk, I give a comprehensive overview of the concept of catalysis in quantum information science and discuss its applications in various physical contexts.

P6: Fusion energy: why, how and when?

Prof. Xavier GARBET,
School of Physical and Mathematical Sciences,
Nanyang Technological University

Friday, 29 September, 11:15am, Venue: LT28

Abstract

Fusion is one of the great challenges in this century, as it potentially provides a clean, safe and virtually inexhaustible source of energy. Confining hot plasmas with intense magnetic fields is one promising path towards a commercially viable reactor. A major step in this direction will be reached with the ITER international project, under construction in France, and expected to start operation in 2030. The seminar will start with an introduction to plasma physics and technology for magnetic confinement fusion, with some focus on tokamaks – the most advanced magnetic configurations so far. The main results on theory, modelling and experiments will be summarised. Alternative schemes to tokamaks will also be presented, in view of recent developments and initiatives in the private sector.

This thriving field of experimental research begs for a robust programme in theory and modelling in order to interpret results, prepare future experiments, and design future reactors. An ambitious research programme has been devised in Singapore, in collaboration with foreignlaboratories, which aims at modelling fusion plasmas, based on ab initio simulations, theoretical plasma physics and AI algorithms. Also diagnostics to characterise fusion burning plasmas and means to control it will be developed. This challenging programme will be detailed and commented.

3 Posters

As previously, 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 posters@ipsmeeting.org, or leave it with the reception desk.

IPS Best Poster Award

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

General poster presentation

Format

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

Poster Abstracts

PO.15 High-quality silicon waveguide-based heralded single-photon source with 355kHz observed coincidence count.

Jinyi Du*, George Chen*, Hongwei Gao*, Dawn Tan*, James Grieve*, Alexander Ling* (Centre for Quantum Technologies, NUS; Department of Physics, NUS)

We designed and fabricated a high-quality heralded single photon source based on spontaneous four-wave mixing (SFWM) on silicon-on-insulator (SOI). A silicon waveguide is pumped by a 1550nm continuous wave laser. The spontaneously generated signal and idler photons are separated by two narrow-band filters at 1539nm and 1561nm respectively. With the help of specially designed ultra-low loss fibre-chip edge couplers, the measured heralding efficiency is as high as 13.1% with a 200ps coincidence window using 80% efficiency single photon detectors. Compared with the state of the art, this measured heralding efficiency marks a new milestone for silicon chip sources. Also, the source can operate stably at 355kHz observed photon pair rate (100ps coincidence window) with +-0.1dB vibration over 10 days without any active mechanism or adhesive. At such a pair rate, the source can guarantee measured coincidence to accidental ratio (CAR) 381 and heralded self-correlation function g2(0) of 0.01. This demonstrates the high-quality heralded single photon emission at a very high observed pair rate. When using lower pump power and a narrower coincidence window, the observed pair rate is 9.4kHz and the CAR reaches 5346 while g2(0) is 0.001, indicating the source has very low noise and almost no multi-photon emission. With the same chip, we can also achieve a CAR exceeding 10,000. Our source paves the road for a high-quality finger-size heralded single photon source with a simple control system.

PO.20 Preparing to Distribute Polarization-encoded Qubits from Single-Photon Emitter over $\approx$30 km Deployed Fiber

Xingjian Zhang*, Jinchang Liu, Alexander Ling (Centre for Quantum Technologies, NUS)

Our experiment demonstrates the practicality of distributing 1310 nm polarization qubits with $<5\%$ error rate and $\approx$16dB loss over a $\approx$30 km fiber distance in Singapore, which enables utilizing a 400 kcps GaN single-photon emitter as the source.

PO.27 Design and Applications of Atomic Sensors

Fong En Oon*, Kai Sheng Lee*, Nathan Shettell*, Elizaveta Maksimova, Christoph Hufnagel, Rainer Dumke (NUS)

Atomic interferometry has witnessed a surge of experimental progress and interest within the physics community in the past few decades. Atoms, exhibit wave-like properties in certain circumstances, such as interference; one can tailor the design of an interferometer to extract desired quantities from the interference pattern. In our case, we have designed an atomic interferometer which can measure gravity, better known as an atomic gravimeter, at an extremely precise resolution of 3.8×10^{-9}g. In addition, our gravimeter does not suffer from bias-drift, which is an inevitable hindrance to classical gravimeters.

Here, we present the design and construction of our gravimeter. It is module based, which allows for a compact design and facilitates performing maintenance. As an application, we recently (May 2023) conducted a geophysical gravity survey using the atomic gravimeter as an absolute reference, that way we could extend its long-term stability to classical gradiometers (*CG6-Autograv*). Moreover, we are able to filter out any temporal effects in gravity due to tidal motion and isolate gravitational shifts due to subterranean variation. Finally, we discuss the state of our design of an atomic accelerometer, which can measure acceleration about any arbitrary axis, and with sufficiently many of them, can also function as an atomic gyroscope.

PO.28 All-Transparent Optical Routers for a Quantum Network Embedded in a Classical Optical Fibre Network

Hou Shun Poh*, Christian Kurtsiefer (Centre for Quantum Technologies, National University of Singapore)

Deployed optical fibre networks are the main infrastructures carrying data around within metropolitan areas. Quantum networks could potentially be embedded in these optical fibre networks provided the routes between the nodes are transparent, preserving the quantum states of the transported photons. Optical fibre switches provide a means to establish such transparent routes between different nodes.

In this work, we characterised commercial-off-the-shelf optical fibre switches and found them to be suited for the above application. Based on a possible network topology, we designed and implemented an optical router that incorporated these optical fibre switches. When installed in a QKD link, the router was found to marginally increase the QBER to no more than 8% from a QBER of 3% to 5% without the router.

PO.32 Towards correlated photon triplets using six-wave mixing in a cold atomic ensemble

Yifan Li*, Xi Jie Yeo, Christian Kurtsiefer* (Centre for Quantum Technologies)

While correlated photon pairs have been extensively investigated in various schemes, like spontaneous down-conversion in nonlinear medium and four-wave mixing from an atomic ensemble, the direct generation of correlated photon triplets is still challenging due to its weak nonlinearities and stringent phase matching requirements. Here, we explore a new approach for directly generating correlated photon triplets from a phase-matched parametric nonlinear process in a Rb87 cold atom ensemble. We propose a scheme to integrate electromagnetically-induced-transparency-based (EIT-based) photon pair generation in double-Λ energy levels with a four-wave mixing process in ladder energy levels. This results in a higher-order nonlinear parametric process referred to as six-wave mixing. The correlated photon triplets generated through this method have the potential to form a Greenberger-Horne-Zeilinger state of light, providing a distinct quantum source for investigating quantum entanglement and potential uses in three-party quantum communication protocols. Additionally, the narrow bandwidth of the generated photons, derived from the atomic natural linewidth, makes them appropriate for direct interaction with atoms. Therefore they have potential applications in quantum networks utilizing atom-based quantum repeaters.

PO.34 Seismic Sensing with Optical Fibres

Thormund Tay*, Fabio Joel Auccapuclla*, Miguel Garcia Alonso*, Yicheng Shi*, Seth Poh*, Christian Kurtsiefer* (Centre for Quantum Technologies, NUS and Department of Physics, NUS)

Widespread deployed optical fibre networks form a large part of the modern-day telecommunication infrastructure. Strains in these fibres caused by sources of ambient vibrations, e.g.: seismic and human activities, induce phase shifts in the light travelling through them. Measurement of these phase shifts allows us to characterise the initial vibration events, thus making deployed fibres the ideal candidate for the application of seismic sensing. In this work, we implemented a fibre phasemeter based on the Michelson interferometer. Light from a fibre-Bragg-grating stabilised 1550 nm laser (linewidth 100 Hz) is split by a fibre splitter into two arms; measurement and reference arm. Faraday rotator mirrors installed at the end of both arms ensure the retro-reflected light arrives back at the fibre splitter with the same polarisation, maximising the interferometric visibility. The frequency of the light in the reference arm is shifted by 140 MHz by a double pass through an AOM. The interference signal at the output port is detected by a fast photodiode (bandwidth > 2.0 GHz) which is in turn sampled at a frequency of 20 kHz. I/Q demodulation is then performed on the recorded data to reconstruct the phase information which was continuously logged. The phasemeter was tested with measurement arm consisting of fibres spools of different lengths. In these tests we were able to detect vibration events from human activities, e.g.: human and vehicular traffic in the nearby surrounding. With deployed fibre running through the building, we were able to observe diurnal change in these vibration events. For each of these events, we were able to resolve the phase evolution. When combined with frequency analysis of the logged data, the specific type of activity that caused the vibration event could be identified. This has opened the possibility for us to detect seismic sensing with deployed fibres.

PO.40 Quantum metrology: A cost-conscious perspective

Yink Loong Len*, Tejas Acharya, Alexia Auffèves, Hui Khoon Ng (Yale-NUS College and CQT)

One of the most promising quantum-enhanced technologies are the quantum sensors that by utilizing quantum features of platforms, capable of operating at unprecedented sensitivities. In particular, the inter-entanglement of the sensor probes opens doors to beating classical limits imposed on the sensitivity–as has been demonstrated in the quantum-enhancement in gravitational-wave detection.

Conventionally, the advantage offered by quantum sensors is measured by the number of probes (n) directly performing the sensing task: Classical limits would correspond to sensitivity (quantified by Fisher Information) that scales ≈n, whereas quantum limits $\approx$n^2. This characterization, however, disregards the physical resource costs of the full metrological cycle, from state preparation, to interaction, to measurement, and finally reset. Here, we study quantum metrology from a cost-conscious perspective, taking the full costs of each stage into account.

PO.46 Progress of Triple Species Sympathetic Cooling in Optical Plugged Quadrupole Trap

Xiaoyu Nie*, Canming He*, Victor Avalos*, Anbang Yang*, Kai Dieckmann* (CQT)

We are trying to cool the Li and K into degeneracy via Rb sympathetic cooling in the Optical Plugged Quadrupole Trap (OPQT). OPQT can avoid the Majorana loss in the center of the quadrupole trap by repelling atoms away from the area where B 0. Compared to the previous quadrupole-Ioffe trap, it should have less evaporation duration because of the tighter trapping regime and larger overlapped area of three species.

Here we start from the modeling of OPQT with 532nm plug beam and indicate it as a near magic wavelength for the triple species. In the experiment, we show that the Majorana loss has been suppressed with the plug beam. Thereafter, we successfully evaporate Rb cloud into the Bose–Einstein condensate. We also implement gray molasses for Li to increase the density before transferring to OPQT. Lastly, we load all three species into the OPQT, and some preliminary results of the sympathetic cooling are presented.

PO.47 Efficient Creation of Ground State ^{6}Li^{40}K Molecules

Canming He*, Xiaoyu Nie*, Victor Avalos*, Anbang Yang*, Sofia Botsi*, Sunil Kumar*, Kai Dieckmann* (Centre for Quantum Technologies)

We report on the creation of ground state ^{6}Li^{40}K molecules with an efficiency of 98%. The singlet stimulated Raman adiabatic passage (STIRAP) pathway is selected to transfer the ultracold ^{6}Li^{40}K molecules from the Feshbach state to $X^1\Sigma$ ro-vibrational ground state and $|\nu' = 23\rangle$ vibrational state of the unperturbed $A^1\Sigma^+$ potential is chosen as the intermediate state. After applying a reverse STIRAP pulse, the ground state ^{6}Li^{40}K molecules are transferred back to the Feshbach state for detection by using absorptive imaging. The single-trip efficiency of 98% can be inferred by comparing the number of molecules before and after the round-trip STIRAP. The lifetime of the ground state molecules is measured to be around 6ms, which is limited by the two-body collision loss. We also perform the dark resonant spectroscopy on the $J = 2$ rotational state and minimize the error of rotational constant B0 toward ≈20 kHz. Then We conduct the rotational microwave spectroscopy on the ground state molecules to transfer them into $J = 1$ rotational hyperfine states. Rabi oscillation between $J = 0$ ground state and $J = 1$ excited state is also observed.

PO.48 Imaging of periodically poled domains in thin-film lithium niobate using scanning electron microscopy

Veerendra Dhyani*, Sakthi Sanjeev Mohanraj, Sihao Wang, Xiaodong Shi, Angela Anna Baiju, Victor Leong, Di Zhu* (Institute of Materials Research and Engineering, (A*STAR) 2 Fusionopolis Way, Singapore)

Periodically poled lithium niobate (PPLN) is widely used in nonlinear and quantum optics applications, such as spontaneous parametric down conversion (SPDC), squeezed light generation, and quantum frequency conversion. The most widely used methods to visualize the periodically poled domains in lithium niobate are piezoresponse force microscopy and second-harmonic imaging. The former suffers from slow imaging speed while the latter requires a dedicated system that is not commonly available in standard fabrication facilities. Alternatively, scanning electron microscopy (SEM) has shown evidence to be able to reveal domain structures in ferroelectric materials. If done reliably, it can be a more flexible and convenient technique to investigate the domains in PPLN due to its wide availability and fast scanning speed. In this work, we study ferroelectric domain imaging in thin-film lithium niobate through SEM, by exploiting the effect of polarization-dependent electron-beam surface charging. We first created periodically inverted ferroelectric domains in x-cut thin-film lithium niobate through electric poling with microfabricated surface electrodes. In SEM, we were able to obtain brightness-contrast images under the specific condition of a cathode voltage of Vo = 1 V and a probing beam current of Ib = (2 to 15 pA). The contrast formation between different ferroelectric domains can be explained using a model that takes into account the pyroelectric and piezoelectric effects, which originate from electron beam heating and different charge accumulation rates on the material's top surfaces. The results presented here could provide guidance for using SEM to perform non-destructive investigation of periodic poling in lithium niobate.

PO.49 Fabrication, characterization, and optimization of periodic poling in x cut thin film lithium niobate

Sakthi Sanjeev Mohanraj, Veerendra Dhyani, Sihao Wang, Xiaodong Shi, Angela Anna Baiju, Victor Leong, Di Zhu* (Institute of Materials Research and Engineering, Agency for Science Technology and Research (A*STAR))

Interest in using thin-film lithium niobate (TFLN) in integrated nonlinear and quantum optics applications has increased tremendously over recent years. Apart from strong second-order nonlinearity, a key differentiating property of lithium niobate is its ferroelectricity. It allows periodic inversion of the material's spontaneous polarization orientations, a process called periodic poling, for achieving quasi-phase matching, which is critical for second-order nonlinear processes such as spontaneous parametric down conversion and quantum frequency conversion. Importantly, the performance of these processes critically relies on the poling quality. Here, we present our work on the fabrication, characterization, and optimization of periodic poling of x-cut TFLN. The poling is achieved by applying high-voltage pulses across microfabricated electrodes on top of MgO-doped x-cut TFLN, and the inverted domains are imaged using a custom-built second-harmonic microscope. We assess a comprehensive parameter space, including electrode geometry, voltage pulse shape, temperature, and buffer layer, on the effect of the poling results, including domain shape, duty cycle, and poling depth. We achieved reliable processes to create uniform periodic poling with period down to $\approx 2\,\mu$m over a length of > 5 mm. This work can provide valuable information on achieving high-fidelity periodic poling and thus creating high-efficiency nonlinear optical devices.

PO.55 Observation of vacuum Rabi splitting in a compact stable near-concentric cavity

Wen Xin Chiew*, Florentin Adam*, Adrian Utama*, Christian Kurtsiefer* (NUSCQT)

In order to engineer and achieve coherent interaction between atoms and photons, optical resonators are fundamental candidates. Governed by cavity quantum electrodynamics, cavity systems require to contain photons in a small mode volume to perform strong atom-light interaction. Conventionally, this small mode volume is achieved through the use of small high-finesse optical resonators. However, a different cavity configuration can also implement small mode volumes, namely large optical resonators operated in the near-concentric regime. Due to their configuration, near-concentric cavities provide a large optical access between the mirrors and only require low-finesse to operate. Nevertheless, a stable cavity length is necessary to perform interaction with a single atom.

We present a compact near-concentric cavity design to address the cavity length stability required for single atom interaction. In our new structure, we make use of the equivalence of the transverse and rotational displacements in the near-concentric regime to manage the cavity alignment and compare the two movement configurations to demonstrate the superiority of a tip-tilt cavity structure in terms of cavity length stability for the near-concentric regime. We then operate our cavity system with Rubidium atoms via a dipole trap and observe the vacuum Rabi splitting induced by the atom-cavity system.

PO.61 Progress Towards Loading Fermionic Lithium in 2D Disordered Optical Lattice

Athira Krishnan Sreedevi*, Haotian Song*, Rishav Koirala*, Kai Dieckmann* (Centre for Quantum Technologies, National University of Singapore)

Experiments with Ultracold atoms opens the possibility to investigate quantum many-body physics in a controllable environment. Using ultracold atoms in optical lattices can be seen as an implementation of a quantum simulator with exceptional purity and the system can be engineered using tools that are developed in the field of atomic physics over the last few decades. With the high degree of tunability and the possibility of efficient detection techniques, these systems opened the pathway to a wide variety of applications in several fields especially in condensed matter physics. We aim to study ultracold fermi gas in optical lattices, mainly in disordered optical lattice potentials, and the atomic interactions that lead to localization effect. We have developed an efficient production scheme for a large quantum degenerate sample of fermionic lithium. These atoms are an ideal choice as they can be used to realize a strongly interacting quantum gas with long lifetimes. The approach is based on the narrow-line $2S_{1/2} \rightarrow 3P_{3/2}$ laser cooling and the transport and evaporation of the trapped atoms into the quantum degenerate regime using an Optical Dipole Trap. We are setting up a 2D optical lattice using two orthogonal standing waves and an ”accordion” type optical lattice to ensure two-dimensionality. The relative phase between lattice beams must be stabilized in time to have well-defined trap depths for holding atoms. We use a Michelson-type interferometer setup based on a Red Pitaya FPGA with PID control for phase stabilization. Similarly, an imaging phase stabilization scheme is implemented for the ”accordion” lattice phase stabilization. We extend this setup to a disordered lattice by adding disorder in the form of an optical speckle potential formed by a single blue-detuned laser beam focused through a diffuser and a high-numerical-aperture microscope objective. The accessible ranges of the Hubbard parameters in the Disordered Fermi Hubbard Hamiltonian were theoretically determined with our laser parameters to ensure the possibility of an efficiently tunable system for the future steps.

PO.62 FPGA based frequency stabilization of low-phase-noise diode lasers

Victor Avalos*, Canming He*, Xiaoyu Nie*, Anbang Yang*, Kai Dieckmann* (Centre for Quantum Technologies; Department of Physics, National University of Singapore)

We present the comparison of a field-programmable-gate-array (FPGA) based digital servo module with an analog counterpart, for the purpose of frequency stabilization of a low-phase-noise laser. The transfer functions of both the digital and analog modules for proportional-integral-derivative control are measured. For lasers stabilized to an optical high-finesse cavity, we measure the singe-sideband power-spectral-density of fast phase noise by means of an optical beat with filtered light transmitted through the cavity. The comparison between the digital and analog modules is performed for two low-phase-noise diode lasers at 1120nm and 665nm wavelengths. The performance of the digital servo module compares well to the analog one, for the lowest attained levels of 30mrad for the integrated phase noise and 10^{-3} for the relative noise power. The laser linewidth is determined to be in the sub-kHz regime, only limited by the high-finesse cavity. Our work exploits the versatility of the FPGA-based servo module (STEMlab), when used with open-source software and hardware modifications. We demonstrated that such modules are suitable candidates for remote-controlled low-phase-noise applications in the fields of laser spectroscopy, and atomic, molecular and optical physics.

PO.64 Cooling Optically Trapped Single Atoms with Electromagnetically Induced Transparency

Chang Hoong Chow*, Boon Long Ng, Vindhiya Prakash, Christian Kurtsiefer (Centre for Quantum Technologies)

Single neutral atoms in a tightly focused dipole trap is a promising platform for quantum information processing, but an elevated temperature can lead to qubit decoherence. A ground-state laser cooling technique based on electromagnetically induced transparency (EIT) is proposed as a robust solution that can cool several vibrational modes simultaneously through continuous excitation [1]. Previous experimental efforts focus on trapped ions [2,3] and neutral atoms in a standing wave trap [4].

In this work, we demonstrate EIT cooling of an optically trapped single neutral atom, where the trap frequencies are two orders of magnitude smaller than the ion trap. We resolve the signature Fano profiles in the fluorescence excitation spectrum and also the temperature measurement. A final temperature of around 6 μK has been achieved with EIT cooling, a factor of two lower than the previous value obtained using the polarization gradient cooling technique [5].

[1] G. Morigi et al., Phys. Rev. Lett., 85, 4458 (2000) [2] C. F. Roos et al., Phys. Rev. Lett. 85, 5547 (2000) [3] R. Lechner et al., Phys. Rev. A, 93, 053401 (2016) [4] T. Kampschulte et al., Phys. Rev. A 89, 033404 (2014) [5] Y.-S. Chin et al., Phys. Rev. A, 96, 033406 (2017)

PO.67 Clock Synchronization using Thermal Correlations without External Frequency Standards

Justin Yu Xiang Peh, Darren Ming Zhi Koh, Zifang Xu, Xi Jie Yeo, Peng Kian Tan, Christian Kurtsiefer* (Center for Quantum Technologies)

Clock synchronization is necessary for communication and distributed computing tasks. In quantum communication systems, photo-detection events need to be discriminated with sub-nanosecond accuracy in order to distill information from correlations at a sufficiently high rate. This typically entails significant resource overheads, such as the use of ultra-stable frequency references, that will also scale with the number of communicating endpoints. Here, we demonstrate an alternative clock synchronization scheme using thermal correlations without the need for external frequency standards. The scheme relies on tracking timing correlations in the photon bunching behaviour of thermal light generated using a sub-threshold laser. The 10MHz quartz oscillators onboard the time-taggers have a typical frequency accuracy of 10^{-4}; by performing cross-correlation measurements to identify the position and drift rate of the bunching peak, we can continuously correct for the frequency difference to within 10^{-9} of each other, comparable to that of a Rubidium frequency standard. A similar line of work relies on strong timing correlations in photon pairs from spontaneous parametric down-conversion sources for synchronization. We believe our scheme using thermal light sources significantly improves clock synchronization over longer distances due to its intrinsically higher brightness and low attenuation within the C-band optical window of G.652D standard-compliant telecommunication fiber, whilst requiring only an easily-acquirable laser diode and simple temperature control for operation.

PO.68 Quantum Sensor of Mechanical Vibrations

Jaren Gan*, Mu Young Kim*, Rongjie Zhang*, Nigel Lee*, Jiacheng You*, Eugene Koh*, Vincent Lau*, Dzmitry Matsukevich* (Centre for Quantum Technologies)

We demonstrate the use of a single trapped ion to detect mechanical vibrations of an ion trap at the picometer scale. The vibrations are induced via a transducer, which is attached to the vacuum chamber where the ion trap is housed. The ion motion is initially cooled to the ground state. Tuning the transducer on resonance to the motional mode frequencies of the ion results in excitation of the ion's motion, which can be detected at the level of a single motional quanta. Classical analysis of the system shows that we are able to measure the amplitude of trap displacements of 2.3pm in 5ms, which may be further improved on by using longer drive times and higher mode frequencies.

PO.70 Quasi local plasmons in strong electron correlated perovskite systems

Anindita Chaudhuri*, Andrivo Rusydi (National University of Singapore)

Plasmons in the infrared energy range are attractive in diverse fields of applications, such as transformation optics [1], photodetection, nonlinear frequency generation [2], biomolecule sensors [3], pharmacology, and many more [4]. However, conventional plasmonic materials have an inherited limitation in the infrared energy range because of their metallic components that usually introduce large negative permittivity and high absorption resulting in high loss in this region [5]. Therefore, the search for a new class of "designer plasmonic materials" in the mid- to near-infrared (IR) range has been the research focus in recent years. In principle, one could achieve plasmons in IR energy by diluting the free electrons of the metal to redshift the plasma frequency into lower energy range, or by doping a semiconductor to blueshift the plasmon energy towards the desired energy range. While the limiting factor for conventional metals is the high absorption yielding high plasmonic loss, the fundamental constraint for conventional doped semiconductors is the finite carrier density. Therefore, strongly correlated electron systems such as transparent perovskite oxides are promising, particularly for their ability to tune the optical band gap and charge carrier as well as to confine the electromagnetic radiation in the subwavelength range. Our study shows that the plasmons occurring from these doped perovskites, viz., $Eu_{0.3}Ba_{0.7}Ti_{1-x}Nb_xO_3$ $(0 \leq x \leq 0.1)$, $EuTi_{1-x}Nb_xO_3$ $(0 \leq x \leq 0.1)$, $Pr_{0.6}Sr_{0.4}Co_{1-x}Mn_xO_3$ $(x = 0 - 0.4)$ are capable of producing plasmons in infrared (≥ 1 eV) energy; and are exceptional in character[6,7,8]. They originate from the electrons which are not entirely free, in Drude sense, due to strong electron correlations exploring lattice-, charge-, spin- and orbital-degrees of freedom. We have named this special class of plasmons as 'quasi local plasmons' and study their characteristics in the strong electron correlated perovskite systems. Reference [1] G. V. Naik, J. Kim, and A. Boltasseva, Opt. Mater. Express 1,1090 (2011). [2] P. Q. Liu, I. J. Luxmoore, S. A. Mikhailov, N. A. Savostianova, F. Valmorra, J. Faist, and G. R. Nash, Nat. Commun 6, 8969 (2015). [3] Y. Zhong, S. D. Malagari, T. Hamilton, and D. M. Wasserman,J. Nanophotonics 9, 093791 (2015). [4] A. Sobhani, M. W. Knight, Y. Wang, B. Zheng, N. S. King, L. V. Brown, Z. Fang, P. Nordlander, and N. J. Halas, Nat. Commun4, 1643 (2013). [5] G. V. Naik, V. M. Shalaev, and A. Boltasseva, Adv. Mater. 25, 3264 (2013). [6] A. Chaudhuri, K. Rubi, T. C. Asmara, X. Chi, X. J. Yu, R. Mahendiran, A. Rusydi, Phys. Rev. B 98, 165303 (2018) [7] A. Chaudhuri, A. Midya, K. Ruby, X. Chi, T. C. Asmara, X. J. Yu, R. Mahendiran, A. Rusydi, Phys. Rev. B 100, 085145 (2019) [8] A. Chaudhuri, A. Chanda, X. Chi, X. Yu, C. Diao, M. B. H. Breese, R. Mahendiran, and A. Rusydi, Phys. Status Solidi - Rapid Res. Lett. 15, 2000257 (2021)

PO.80 Theoretical determination of the effect of a screening gate on the superconductivity in twisted bilayer graphene

Liangtao Peng*, Indra Yudhistira, Giovanni Vignale, Shaffique Adam (National University of Singapore)

The discovery of superconductivity in magic-angle twisted bilayer graphene (MATBG) has attracted tremendous interest in part due to the similarity of the observed phase diagram with the long-standing problem of high-temperature superconductivity in cuprates. At present, there is no consensus on the microscopic mechanism for superconductivity in a system as simple as two rotated sheets of carbon. Recent experimental studies [Stepanov et al. Nature 583 375 (2020); Saito et al. Nature Physics 926 (2020); Science 371 1261 (2021)] seem to rule out a purely electronic mechanism due to the insensitivity of the critical superconducting temperature with either a highly doped screening layer or the proximity to a metallic screening gate. In this theoretical work we explore the role of external screening layers on the superconducting properties of twisted bilayer graphene within a purely electronic mechanism. Remarkably, consistent with the experimental observations, we show that the critical temperature is unaffected by screening unless the screening layer is closer than 3 nanometers. We explore other properties of this plasmon-paired superconductor including the non-monotonic dome feature and single-particle density of states.

PO.81 Protecting the quantum interference of cat states by phase-space compression

Jonathan Schwinger*, Xiaozhou Pan* (CQT)

Cat states, with their unique phase-space interference properties, are ideal candidates for understanding fundamental principles of quantum mechanics and performing key quantum information processing tasks. However, they are highly susceptible to photon loss, which inevitably diminishes their quantum non-Gaussian features. Here, we protect these non-Gaussian features against photon loss by compressing the phase-space distribution of a cat state. We achieve this compression with a deterministic technique based on the echo conditional displacement operation in a circuit QED device. We present a versatile technique for creating robust non-Gaussian continuous-variable resource states in a highly linear bosonic mode and manipulating their phase-space distribution to achieve enhanced resilience against photon loss. Compressed cat states offer an attractive avenue for obtaining new insights into quantum foundations and quantum metrology, and for developing inherently more protected bosonic codewords for quantum error correction.

PO.85 Geometrically frustrated Rb atom arrays in Rydberg states for quantum many-body simulation

Weikun Tian, Fan Jia, Wen Jun Wee, An Qu, Jiacheng You, Prithvi Raj Datla, Huanqian Loh* (Centre for Quantum Technologies & Department of Physics, National University of Singapore)

Spin-frustrated lattices are an interesting class of condensed matter systems to study, where exotic quantum phenomena such as the quantum spin liquid phase and spin glasses have been predicted to exist. With the recent development of programmable optical tweezer arrays, neutral atom arrays with long-range Rydberg interactions have become a powerful platform to simulate quantum many-body physics in these systems. Here we introduce our quantum simulation platform using defect-free atom arrays with up to 225 Rb atoms rearranged into triangle-based frustrated geometries [1]. We also report our progress on high-fidelity ground state preparation via optical pumping and Rydberg state excitation through two-photon transitions. The combination of large-scale atom arrays and high-fidelity Rydberg state preparation and detection paves the way for probing quantum many-body physics in large physical systems with frustrated geometries.

[1] W Tian, et al, Phys Rev Applied 19, 034048 (2023).

PO.89 Introducing flux-tunability in high-Q superconducting cavity devices

Fernando Valadares Calheiros Siqueira*, Atharv Joshi, Kyle Chu*, Lingda Kong, Ni-Ni Huang, Pengtao Song, Weipin Chua, Aleksandr Dorogov, Yvonne Gao (Centre for Quantum Technologies)

Three-dimensional (3D) superconducting microwave cavities have been shown to exhibit long lifetimes of up to several milliseconds, making them promising candidates for storing continuous-variable quantum information. Effective control of these cavities requires non-linear auxiliary circuits. Incorporating flux-tunable elements such as SQUID or SNAIL devices is highly desirable as they can potentially enable fast operations without imparting unwanted dynamics on the cavity modes. However, this integration is non-trivial due to need to apply external magnetic bias in a 3D superconducting enclosure. Consequently, the implementations demonstrated so far are limited to only either DC or fixed-frequency AC bias. In this work, we realise a device that uses a μ-metal magnetic hose to provide fast adiabatic bias to a SQUID circuit coupled to a cavity. The architecture is compact and has the potential to provide effective biasing of the SQUID element without compromising the coherence times of the cavity. Furthermore, we demonstrate the possibility of using this device to enact fast resonant control of individual sideband transitions of the cavity. This highlights the value of our architecture in achieving robust operations on 3D superconducting for continuous-variable quantum information processing.

PO.90 Quantum-enhanced Phase Estimation in Three-dimensional Superconducting Circuits

Xiaozhou Pan*, Tanjung Krisnanda*, Ni-Ni Huang*, Yvonne Gao* (Centre for Quantum Technologies)

Certain quantum states offer great potential for improving measurement sensitivity and accuracy in metrology. Here, we report a deterministic phase estimation protocol implemented using a three-dimensional superconducting cavity. We find that the fundamental Heisenberg limit can be approached by utilising quantum states of a single Bosonic mode. Furthermore, we find the phase sensitivity measurement is robust against dephasing and energy decay. Our scheme provides a promising strategy for quantum metrology in superconducting circuits.

PO.92 Ground state search by local and sequential updates of neural network quantum states

Wenxuan Zhang*, Xiansong Xu*, Zheyu Wu*, Vinitha Balachandran*, Dario Poletti* (Singapore University of Technology and Design)

Neural network quantum states are a promising tool to analyze complex quantum systems given their representative power. It can however be difficult to optimize efficiently and effectively the parameters of this type of ansatz. Here we propose a local optimization procedure which, when integrated with stochastic reconfiguration, outperforms previously used global optimization approaches. Specifically, we analyze both the ground state energy and the correlations for the nonintegrable tilted Ising model with restricted Boltzmann machines. We find that sequential local updates can lead to faster convergence to states which have energy and correlations closer to those of the ground state, depending on the size of the portion of the neural network which is locally updated. To show the generality of the approach we apply it to both 1D and 2D nonintegrable spin systems.

PO.95 Bayesian Retrodiction of a Black Hole

Peter Sidajaya*, Winston Fu, Clive Cenxin Aw, Valerio Scarani* (Centre for Quantum Technologies, National University of Singapore)

Hayden and Preskill showed using a thought experiment of a toy model of a black hole evaporation process that old black holes act as an 'information mirror', returning information thrown into them in a short timescale through the Hawking radiation that comes out of them. In this paper, we put the whole thought experiment into the framework of Bayesian retrodiction, mainly embodied in the Petz map. We show that the Petz map gives many of the same result, while also extending the result to show Don Page's observations that the information is mostly hidden until half of the black hole has been evaporated. We also show that the Petz map has better performance, in terms of the fidelity of the recovered information, in comparison to the recovery protocol presented by Yoshida and Kitaev.

PO.97 Development of a controllable and robust cold atomic source using laser ablation

Xiang Ru Xie*, Chang Chi Kwong, David Wilkowski (Center for Quantum Technology, National University of Singapore)

Cold strontium atoms system, with its special energy levels, play an important role in quantum technological applications such as creating artificial gauge field [1] and quantum sensing [2]. We previously developed a simple and compact cold atomic source using laser ablation [3]. While we were successful in directly loading a strontium MOT with long lifetime from the ablated strontium vapour, the issue of strontium deposition on the glass cell limits its practical usage. In a new design, we aim to overcome this issue by reflecting the ablation beam inside the vacuum system, thus avoiding a direct line-of-sight between the ablation point and the viewport. Moreover, we will control the release of strontium vapour with a PID feedback on the 1064 nm ablation laser power. With this new design, we hope to achieve a robust and controllable compact atomic source for portable cold atomic experiments.

[1] F. Leroux et al, "Non-Abelian and adiabatic geometric transformation in a cold atomic gas", Nat. Commun, 9, 3580 (2018). [2] G. M. Tino et al., "SAGE: A proposal for a space atomic gravity explorer", Eur. Phys. J. D, 73, 228 (2019). [3] C. C. Hsu et al., "Laser induced thermal source for cold atoms", Sci. Rep. 12, 868 (2022).

PO.99 Fast cavity universal control with quantum gates: ECD and CNOD gates at comparison

Giorgio Canalella*, Xiaozhou Pan*, Yvonne Gao (CQT)

Circuit quantum electrodynamics (cQED) presents itself as one of the most promising frameworks to achieve scalable quantum computers. In this field, quantum gates are of particular interest since they allow universal control of the cavities quantum state space, as well as state tomography. My project focuses on simulating realistic cQED systems to provide a better understanding of how different quantum gates operate on the system, analysing their strengths and weaknesses in different parameter regimes and noise models. The echoed conditional displacement (ECD) is a well-known quantum gate compared to the novel Conditional Not Displacement (CNOD) gate designed by Diringer et al. The goal is to achieve a better understanding of the similarities and differences between the two quantum gates, and provide a framework of comparison at different parameter regimes. Understanding which input pulses are optimal for the use of each gate is an important step to achieve fast high-fidelity cavity control.

PO.102 Laser-Driven Higher Chern Number And Spin Chern Number States in the Quantum Spin Hall Phase of α–T3 Model

Jalen Andrew Mateo*, Yee Sin Ang*, Peihao Fu* (Singapore University of Technology and Design (SUTD))

The high-frequency driven phase diagram in a quantum spin Hall phase of α–T3 model is studied. After absorbing the effect of the driving field using Floquet theory, abundant phases are obtained, including (i) three photon-indued quantum Hall states with Chern number C = 2, 3, and 4 supporting two, three and four chiral edge states, respectively, (ii) photon-dressed quantum spin Hall states with spin Chern number C = 1 and 2 corresponding one and two helical edge states, respectively, and (iii) the coexisting of chiral and helical edge states with non-zero Chern and spin Chern numbers.

PO.104 Efficient and robust state tomography with quantum reservoir processing

Tanjung Krisnanda* (National University of Singapore)

The use of bosonic superconducting circuits for quantum information processing is promising due to their hardware efficiency and error-correction capabilities. In this setting, conventional methods for characterising bosonic states, such as Wigner tomography, require many measurements and are not feasible for scaling up to multimode systems. Here, we present a Quantum Reservoir Processing (QRP) approach that uses ergodic dynamics on the bosonic systems with operations such as programmable beamsplitter, displacement, and squeezing. By identifying the action of the dynamics as a linear map, we perform state estimation from a few measured simple observables. We show that our approach allows for robust reconstruction of an arbitrary input state of dimension D with high fidelity from at least $D^2 - 1$ measured photon number distribution, which is not only fewer than the measurements required for standard Wigner tomography but also simpler. Our protocol offers an efficient, robust, and versatile tool for state tomography in bosonic superconducting circuits.

PO.106 Enhanced Cherenkov radiation based on flatband metasurface

Juanfeng Zhu*, Lin Wu (Science, Mathematics and Technology (SMT), Singapore University of Technology and Design (SUTD))

Cherenkov radiation (CR) shows significant potential for applications in particle detection and illumination within challenging contexts. However, conventional CR exhibits relatively low efficiency, prompting multiple endeavors to enhance interaction effectiveness. In this manuscript, flatband dispersion enhanced CR is demonstrated, leveraging the capabilities of flat-band optics for electromagnetic wave manipulation. Through the incorporation of anisotropy into the grating design, a hyperbolic metasurface is achieved. This modification transforms the topological characteristics from closed to open, allowing the attainment of flatband dispersion precisely at the topological transition frequency. By adhering to the momentum matching principle, free electrons readily excite the surface wave, consequently generating CR. Remarkably, the application of flatband dispersion leads to a substantial increase in CR intensity. This advancement presents a compelling approach for the creation of a integrated radiation source, thus contributing to the advancement of the field.

PO.107 Inverse design of diffusion-absorption hybrid metasurfaces

Zicheng Song*, Jiaqi Zhu (Harbin Institute of Technology)

To breakthrough wave-front manipulation performance of random metasurfaces, we propose a diffusion-absorption hybrid metasurface based on the Babinet principle using an inverse design approach. Complementary bilayer metasurfaces are employed for impedance matching, with optimized intralayer resonances and interlayer couplings for achieving precise and wideband absorptive elements. By optimizing the spatial distribution of elements, we introduce diffusion and achieve a continuous scattering-field reduction. For proof-of-concept, we fabricate and experimentally verify representative structures, demonstrating a reduction range of 12.32-24.46 dB. This approach paves the way for designing multi-mechanism hybrid meta-devices with powerful wavefront manipulation capabilities.

PO.108 Simulating quantum transport via collisional models on a digital quantum computer

Rebecca Erbanni*, Xiansong Xu, Tommaso Demarie, Dario Poletti (SUTD)

Digital quantum computers have the potential to study the dynamics of many-body quantum systems. Nonequilibrium open quantum systems are, however, less straightforward to be implemented. Here we explore the feasibility of studying steady-state transport in strongly interacting many-body quantum systems on a digital quantum computer. To do so, we consider a collisional model representation of the nonequilibrium open dynamics for a boundary-driven XXZ spin chain. More specifically, we investigate how the depth of the quantum circuit is affected by how close we want the steady state to be to the one expected from the underlying master equation. We study the simulation of a boundary-driven spin chain in regimes of weak and strong interactions, which would lead in large systems to diffusive and ballistic dynamics, considering also possible errors in the implementation of the protocol. Last, we analyze the effectiveness of digital simulation via the collisional model of current rectification when the XXZ spin chains are subject to non-uniform magnetic fields and show that, although the circuit depths required to reach steady states are still prohibitive for today's hardware, few collisions are enough to suggest a strong rectifying power

PO.114 Method to detect a signal of an obstruction within shot noise

Zhengxin Liang*, Christian Kurtsiefer*, Peng Kian Tan* (Centre for Quantum Technologies, National University of Singapore)

We investigate a method to detect a signal of an obstruction of a single spatial mode source when it is within shot-noise and can't be increased. We radially inverted one of the paths of a Mach-Zehnder interferometer, separating the shot noise into the dark and the bright fringe. Any asymmetric optical modes due to the obstruction will thus not interfere with each other and be detectable in the dark fringe. The increased in Signal-to-Noise ratio by separation of the shot noise into separate channels is thus examined.

PO.116 Towards compact accelerometer with cold atomic interferometry

Jianing Li*, Swarup Das*, Chang Chi Kwong, Thomas Zanon Willette, Shau-Yu Lan, David Wilkowski* (NTU)

Atom interferometry exploits the wave-like properties of matter to create interference patterns with atoms and can be used for precision measurements of fundamental constants, gravitational waves, and quantum tests of general relativity. We present in the poster a new project aiming to build a compact cold strontium atomic accelerometer by reducing the interferometric volume by holding the separated wave packets in optical lattices and introducing simultaneous dual interferometer scheme to improve the sensitivity and accuracy of atom interferometers by canceling out common-mode noise sources such as vibrations, rotations, and laser frequency fluctuations.

PO.117 Machine learning-optimization of strontium quantum gas

Chirantan Mitra*, Chetan Sriram Madasu, Chang Chi Kwong, Lucas Antoine Gabardos, David Wilkowski* (Nanyang Technological University)

During an experimental sequence to produce ultracold quantum gases, it is often necessary to precisely control various parameters over time, such as the power and detuning of the lasers, magnetic field strengths, among other things. The final atom count and density in the trap can be very sensitive to non-trivial ramps of these parameters, which can be discovered using machine learning algorithms. In our study, we make use of the Gaussian process regression (GPR) algorithm to optimize the number of atoms in the strontium-87 narrow-line red magneto-optical trap (MOT). This work opens the door to efficient quantum gas production using AI optimization.

PO.118 Engineering the outcoupling pathways in plasmonic tunnel junctions via photonic mode dispersion

Zhe Wang*, Vijith Kalathingal*, Yongxin Guo*, Goki Eda*, Christian Nijhuis* (University of Twente)

Optical and plasmonic outcoupling from inelastic electron tunneling (IET) have attracted significant attention in nanophotonics due to low operating voltages and rapid excitation rate. However, achieving selectivity among various outcoupling channels remains a challenging task in the field due to the statistical nature of the energy loss associated with inelastic tunneling. Employing nanoscale antennas to enhance the local density of optical states (LDOS) associated with specific outcoupling energies partially addressed the problem, along with the integration of conducting 2D materials to tunnel junctions (TJs), improving the outcoupling to waveguide modes with specific momentum. However, these methods often involve complex fabrication steps and lack fine-tuning options. Here we propose an alternative approach by modifying the dielectric medium surrounding TJs. By employing a simple multilayer substrate with a specific permittivity combination for the TJs under study, better mode selectivity in outcoupling to a plasmonic or a photonic-like mode, characterized by distinct cutoff behaviors and propagation lengths, is demonstrated. Theoretical and experimental results from a SiO_2-SiN-glass multilayer substrate demonstrate high relative coupling efficiencies of $\approx$63% and $\approx$29%, and figure of merit values of $\approx$180 and $\approx$140 for plasmonic and photonic-like modes, respectively. Our approach allows LDOS engineering and customized TJ device performance, seamlessly integrable into standard thin film fabrication protocols while avoiding the complexity of nanoscale antenna fabrication.

PO.119 Dynamics of cold gas in synthetic non-Abelian gauge fields in free space

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

We report on experimental results of studies of dynamics of a cold gas subjected to synthetic non-Abelian gauge fields. In sharp contrast with the Abelian case, spatially uniform non-Abelian gauge fields can induce particle non-inertial motion. We explore this intriguing phenomenon with a degenerate Fermi gas subjected to a two-dimensional synthetic SU(2) and SU(3) non-Abelian gauge fields in free space. We demonstrate the spin-Hall characteristics of the dynamics as well as its anisotropy in amplitude and frequency due to the spin texture of our SU(2) system. We draw the similarities and differences of the observed wave packet dynamics and the well-known Zitterbewegung effect. As opposed to SU(2) systems with two ladder operators viz., raising and lowering operators, SU(3) systems have additional ladder operators due to eight generators of the symmetry. We demonstrate the existence of additional ladder operators in our SU(3) system by performing two kinds of Π-pulses between the basis states

PO.123 Development of Superconducting Quantum Processor

Rangga Perdana Budoyo*, Long Hoang Nguyen, Yuanzheng Paul Tan, Kun Hee Park, Patrick Bore, Senthil Kumar Karuppannan, Rasanayagam Kajen, Christoph Hufnagel, Yung Szen Yap, Rainer Dumke (Centre for Quantum Technologies)

Recently, we have developed our qubit fabrication techniques to consistently fabricate 2D (planar) transmon qubits to have a consistent coherence time of about 10 us. We are also exploring the use of different materials and surface treatments to improve coherence. In collaboration with Institute for Microelectronics (A*STAR), we are developing technologies to scale up our quantum processors, including flip-chips and through-silicon vias. Additionally, recent improvements in FPGA architecture, used in qubit control and readout, results in improvements in measurement repetition rates and qubit state determination.

PO.129 Optical Superoscillatory Techniques for Quantum Gases

Hamim M. Rivy, Syed A. Aljunid, Emmanuel Lassalle, Vincent Mancois, Kelvin Lim, Nikolay I. Zheludev, David Wilkowski* (Centre for Quantum Technologies, National University of Singapore, 117543 Singapore, Singapore.)

We demonstrated experimentally the trapping of single ^{133}Cs atom in a superoscillatory hotspot smaller than the Abbe's diffraction limit. The trap is characterized by measuring the trap frequency, lifetime, and temperature of the atom [1].

We are now exploring new applications of superoscillatory fields for quantum gases. First, we would like to use superoscillatory fields as a probing tool of atomic probability distribution in classical or quantum states. Second, superoscillatory trap should also provide a way to realize arrays of traps with subwavelength separation distance, which is a promising platform for quantum simulation or quantum information processing.

[1] Rivy, H.M., Aljunid, S.A., Lassalle, E. et al. Single atom in a superoscillatory optical trap. Commun Phys 6, 155 (2023).

PO.130 Two-dimensional weak topological insulators and superconductors

Yuanjun Jin*, Xingyu Yue, Guoqing Chang* (Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University)

The one-dimensional (1D) Su-Schrieffer-Heeger (SSH) model is central to band topology in condensed matter physics, which allows us to understand and design topological states. The Su-Schrieffer-Heeger (SSH) model serves as a basis for topological insulators and provides insights into various topological states. In this letter, we find another mechanism to analogize the SSH model by introducing intrinsic spin-orbital coupling (SOC) and in-plane Zeeman field instead of relying on alternating hopping integrals. In our model, the bound states are protected by a quantized hidden polarization and characterized by a weak Z2 index (0;01) due to the inversion symmetry I. When the I symmetry is broken, charge pumping is achieved by tuning the polarization. Moreover, by introducing the p + ip superconductor pairing potential, a new topological phase called weak topological superconductor (TSC) is identified. The new TSC is characterized by a weak Z2 index (0;01) and nonchiral bound states. More interestingly, these nonchiral bound states give rise to a chiral nonlocal conductance, which is different from the traditional chiral TSC. Our findings not only innovate the SSH model, but also predict the existence of weak TSC, providing an alternative avenue for further exploration of its transport properties.

PO.131 Asymmetric liquid deformation based on chiral plasmon-induced optofluidics

Cuiping Ma*, Wenhao Wang, Zhiming Wang* (University of Electronic Science and Technology of China)

Photothermal conversion of energy in plasmonic nanostructures brought a new fascinating field of plasmon-induced optofluidic to life. The plasmon heating and convective fluid flow lead to the emergence of the surface tension gradient on a free liquid surface interface with air, resulting in the Marangoni effect-driven fluid flow observed as water deformation. Here, we demonstrate nanoscale asymmetric fluid deformation based on the chiral photothermal effect, which further trigger plasmon-induced optofluidic effect. By engineering the plasmonic structure or tuning the incident light intensity, deformation at different depths can be achieved. The maximum photothermal circular dichroism of 5K and the largest deformation depth of $\approx$30nm are reported here. The demonstrated light-induced asymmetric deformation provides a new path for controlling fluid flow at the micro- or nano-scale, which has great potential in the applications of integrated fluidic devices, biochemistry, and clinical biology.

PO.134 Laser-Enriched recovered Carbon Black with Improved Performance as Anode for Lithium-Ion Battery

Liu Yuqing*, Lim Sharon Xiaodai*, Sow Chorng Haur* (National University of Singapore)

Hard carbon (HC) material is thought to be a potential candidate for lithium-ion batteries (LIBs). It has a higher capacity than graphite and it is more stable than alloy anodes. In this work, economical HC materials recycled from recovered carbon black is transformed into functional anode for Li ion battery. By way of a facile focused laser beam modification, the as-prepared anode is further engineered to achieve enhanced electrochemical performance. The laser-modified anode exhibits a capacity (about 516 mAh g^{-1}) at 0.1 A g^{-1}. Additionally, it can maintain over 100% capacity retention for 700 cycles at 1 A g^{-1} while maintaining over 100 mAh g^{-1} for 4000 cycles even at 2 A g^{-1}. The improved performance of the laser-modified anode is attributed to a few factors. Namely, laser annealing gives rise to sample with better connectivity to facilitate charge movement. Moreover, the structure is also relatively more roughened to present added active sites. Laser treatment generates surface defects that tend to increase Li ions adsorption by lowering Li ions diffusion barrier. Laser transformation creates carbon micro-crystallites with larger d-spacing than that of graphite. This will facilitate Li ions intercalation. As an added bonus of this discovery, the carbon materials with surface defects exhibit bright fluorescence emission when excited by UV light. In this way, we can rely on the fluorescence emission as an indicator of the suitability of the materials as anode.

PO.137 An ultracold indium apparatus

Seth Chew*, Xianquan Yu*, Jinchao Mo, Tiangao Lu, Ting You Tan, Travis Nicholson* (Centre for Quantum Technologies, National University of Singapore)

Despite the remarkable progress made by ultracold physics in the past few decades, most atomic species have not been cooled to quantum degeneracy. Our work is the first to explore an atom (indium) in main-group III of the Periodic Table at ultracold temperatures.

Due to its anisotropic ground state and level structure, indium contains several important properties that are not found together in existing quantum degenerate gases. Examples include ground state Feshbach resonances, large spin exchange interactions, clock transitions, stable spinor degrees of freedom, and encouraging spin-orbit coupling capabilities.

Here we describe our apparatus for preparing laser cooled indium. This includes blue and UV laser systems, an ultrahigh vacuum chamber, a permanent magnet Zeeman slower, an indium magneto-optical trap, and hardware for sub-Doppler cooling.

PO.142 Optimised spin-orbit torque efficiency by a low-energy mixed species ions exposure.

Abdillah Shaik, Subhakanta Das, Sabpreet Bhatti, Jianpeng Chan, S.N Piramanayagam* (Nanyang Technological University)

Spin-obit torque (SOT) magnetisation reversal has been extensively studied as of late due to its potential applications in low-power, non-volatile magnetic memory. Various methods have been explored in engineering SOT-enhanced heterostructures. Among them, light ion irradiation has shown promising results in tailoring magnetic properties and enhancing SOT efficiency through structural modifications. Besides, studies into ion implantation on the heavy metal layer have shown improved spin-charge interconversion. Here, we investigate the effects of combining these two compatible methods simultaneously on the SOT efficiency of Ta/Pt/Co/W structures. We show that concurrent Ar and He irradiation at 600 eV with varying partial pressure ratios represents a promising approach to tune to magnetic properties such as effective anisotropy field and coercivity while maintaining strong perpendicular magnetic anisotropy. The proposed approach provided a 4.5-fold increase in damping-like efficiency as determined via loop shift measurement for a sample irradiated at 1:3 Ar: He ratio for 24s. We further probed the current-induced SOT magnetisation switching, showing a three-fold reduction in critical current density. These enhancements were attributed to the cumulative effects of interatomic displacements along the HM/FM interface in conjunction with the introduction of impurity defects in the HM layer. These results demonstrate a novel approach for effectively engineering enhanced SOT heterostructures.

PO.148 Apparent strange metal in small angle twisted bilayer graphene

Indra Yudhistira*, Liangtao Peng, Shaffique Adam (National University of Singapore)

Strange metals are an intriguing class of conductors that exhibit unconventional electronic properties. These poorly understood materials are usually identified by a linear-in-temperature dependence of resistivity and a linear-in-field dependence of magnetotransport. We focus on the electronic transport properties of twisted bilayer graphene, a material that some claim exhibits strange metal behavior. We determine the window in parameter space for the apparent strange metal behavior defined by the co-existence of linear-in-temperature resistivity and linear-in-field magnetotransport. Our findings highlight the potential for ordinary metals to imitate strange metal behavior and emphasize the need for careful interpretation of experimental results.

PO.149 Unsupervised learning of quantum scars using intrinsic dimension

Harvey Cao*, Daniel Leykam, Dimitris Angelakis (National University of Singapore)

Quantum many-body scarring is a phenomenon describing the weak ergodicity breaking that arises from an intruiging interplay between integrability and chaos in quantum many-body systems. In this regime the predictions made by the Eigenstate Thermalization Hypothesis no longer remain valid across the full spectrum. Instead, an isolated sector of atypical, non-thermal eigenstates exhibits slow relaxation dynamics which retain memory of the system's initial configuration, known as quantum many-body scars. Within the past decade, dimensionality reduction techniques from machine learning have been extensively applied for extracting universal properties of complex quantum systems, such as learning phases in an unsupervised setting. In this work we focus directly on the intrinsic dimension, a topological quantity which describes the number of variables required for minimal representation of a data set. We apply a recent method for estimation of intrinsic dimension using discrete observables typically arising in quantum simulation experiments to analyze the PXP model, an effective spin system with constraints imposed by nearest-neighbour interactions. Our scheme provides an experimentally accessible way of learning scar states in an unsupervised manner, as well as a novel perspective on the use of dimensionality reduction without the projection of data onto lower dimensions.

PO.151 Observation of negative photoresistance caused by the superballistic electron flow in graphene

Mikhail Kravtsov*, Artur Shilov, Yaping Yang, Mikhail Kashchenko*, Andrei Kudriashov*, Denis Bandurin* (Department of Materials Science and Engineering, National University of Singapore, 117575 Singapore)

Due to the vanishing specific heat of Dirac electrons, the absorption of low-energy photons by graphene can lead to a significant increase in its electronic temperature (Te). This property holds the promise of efficient light sensors. Nevertheless, the real-life realization of graphene-based bolometers faces technical challenges due to the weak variation of its resistivity with respect to Te, demanding more sophisticated temperature-to-voltage conversion schemes. In this presentation, we will discuss the emergence of negative photoresistance induced by terahertz (THz) radiation in graphene devices, promoting hydrodynamic electron flow. We show that absorbed THz radiation can raise Te by more than 100 K above the lattice temperature, causing a notable resistance drop in graphene point contacts (PC) due to the superballistic collective flow of electrons. We investigate the dependencies of the photoresistance on carrier density, lattice temperature, and THz power, revealing THz excitation as an effective probe for electron hydrodynamics. Beyond its fundamental implications, our findings demonstrate the potential use of electron hydrodynamics in designing ultra-fast THz sensors.

PO.153 Practical Demonstration of Polarization-Entanglement Quantum Key Distribution over Standard Telecommunication Fiber

Justin Yu Xiang Peh*, Darren Ming Zhi Koh, Zifang Xu, Christian Kurtsiefer* (Center for Quantum Technologies)

The use of standard telecommunication fibers for quantum key distribution (QKD) in metropolitan areas is appealing due to its compatibility with existing telecommunication networks. Earlier demonstrations of polarization-entangled QKD use dispersion-shifted fibers to circumvent limitations on transmission losses and dispersion, which compromised their practicality. In a previous work [1], we constructed a bright source of polarization-entangled photon pairs using a wavelength non-degenerate downconversion scheme, to generate 1310 nm light in the dispersion-free window of SMF-28e.

In this work, we demonstrate BBM92-QKD over a 50 km SMF-28 fiber spool (-17 dB loss) using avalance photodetectors (APDs), achieving a long-term secret key rate of 350 bits per second. This secret key rate remains positive at 50 bits/s with a longer 70 km fiber spool (-23 dB loss). Polarization drifts due to mechanical and temperature fluctuations in the fiber are actively compensated for using a set of liquid crystal variable retarders (LCVRs). Our system additionally removes reliance on Rubidium frequency standards for synchronizing the remote time taggers, by performing clock frequency precompensation to facilitate coincidence peak finding and tracking.

Ongoing work is currently in progress to characterize long-running system performance over 46 km of deployed fiber running between CQT and SUTD.

PO.156 Injection-Limited and Space-Charge-Limited Conduction in Wide Bandgap Semiconductors with Velocity Saturation Effect

Kok Wai Lee, Yee Sin Ang* (Singapore University of Technology and Design (SUTD))

Carrier conduction in wide bandgap semiconductors (WBS) often exhibits velocity saturation at the high-electric field regime. How such effect influences the transition between contact-limited and space-charge-limited current in a two-terminal device remains largely unexplored thus far. Here, we develop a generalized carrier transport model that includes contact-limited field-induced carrier injection, space charge, carrier scattering and velocity saturation effect. The model reveals various transitional behaviors in the current-voltage characteristics, encompassing Fowler-Nordheim emission, trap-free Mott-Gurney (MG) SCLC and velocity-saturated SCLC. Using GaN, 6H-SiC and 4H-SiC WBS as examples, we show that the velocity-saturated SCLC completely dominates the high-voltage (102. . .104 V) transport for typical sub-μm GaN and SiC diodes, thus unravelling velocity-saturated SCLC as a central transport mechanism in WBG electronics.

PO.159 NbTiN nanowires on the SOI platform for integrated quantum photonics

Filippo Martinelli, Shuyu Dong, Anton Vetlugin*, Darren Koh Ming Zhi*, Christian Kurtsiefer*, Cesare Soci* (Nanyang Technological University)

Integration of superconducting nanowire single-photon detectors (SNSPDs) on the silicon-on-insulator (SOI) platform is considered a necessary step to realize scalable photonic circuits with high efficiency and low noise, suitable for universal quantum computation. However, due to the complexity of the heterointegration and nanofabrication processes, only a few examples of NbTiN detectors integrated on the SOI platform exist to date. To simplify the fabrication workflow and achieve a faster turnaround, we employ an etchless polymer waveguide technology based on the bound states in the continuum (BIC) that is compatible with cryogenic temperatures and suitable for the planar integration of complex superconducting detector arrays. We will discuss our progress in fabricating SNSPDs in a low-loss photonic circuit and discuss the opportunities and challenges of this platform for scalable quantum and classical technologies.

PO.171 Intertwining of magnetism and charge ordering in kagome FeGe

Sen Shao*, Guoqing Chang (NTU)

Recent experiments report a charge density wave (CDW) in the antiferromagnet FeGe, but the nature of the charge ordering and the associated structural distortion 1remains elusive. We discuss the structural and electronic properties of FeGe. Our proposed new ground state phase accurately captures atomic topographies acquired by scanning tunneling microscopy. We show that the $2\times2\times1$ CDW likely results from the Fermi surface nesting of hexagonal-prism-shaped kagome states. FeGe is found to exhibit distortions in the positions of the Ge atoms instead of the Fe atoms in the kagome layers. Using in-depth frst-principles calculations and analytical modeling, we demonstrate that this unconventional distortion is driven by the Intertwining of magnetic exchange coupling and CDW interactions in kagome materials. The movement of Ge atoms from their pristine positions also enhances the magnetic moment of the Fe kagome layers. Our study indicates that magnetic kagome lattices provide a promising materials platform for exploring the effects of strong electronic correlations on the ground state and their implications for novel transport, magnetic, and optical responses in materials.

PO.172 Charge transport in spin-orbit coupled semimetals

Gautham Varma K*, Azaz Ahmad, Gargee G. Sharma* (School of Physical Sciences,Indian Institute of Technology Mandi, Himachal Pradesh, India)

Recently, chiral anomaly (CA) has been proposed to occur in spin-orbit coupled (SOC) non-centrosymmetric systems, motivating CA to be a Fermi surface property rather than a Weyl node property. Although the nature of the anomaly is similar in both SOC and Weyl systems, here we point out significant fundamental differences between the two. The different nature of the orbital magnetic moment (OMM) in the two systems leads to nontrivial consequences, particularly the sign of the longitudinal magnetoconductance always remains positive in SOC metal unlike a Weyl metal that can display either sign. However, planar hall conductance profile qualitatively remains the same for the two systems.

PO.173 Longitudinal magnetoconductance and the planar Hall conductance in inhomogeneous Weyl semimetals

Azaz Ahmad*, Karthik V. Raman, Sumanta Tewari, G. Sharma* (School of Physical Sciences,Indian Institute of Technology Mandi, Himachal Pradesh, India)

Elastic deformations (strain) couple to the electronic degrees of freedom in Weyl semimetalsas an axial magnetic field (chiral gauge field), which in turn affects their impurity-dominateddiffusive transport. Here we study the longitudinal magnetoconductance (LMC) in the presence of strain, Weyl cone tilt, and finite intervalley scattering, taking into account the momentum dependence of the scattering processes (both internode and intranode), as well as charge conservation. We show that strain-induced chiral gauge field results in 'strong sign-reversal' of the LMC, which is characterized by the reversal of orientation of themagnetoconductance parabola with respect to the magnetic field. On the other hand, external magnetic field results in 'strong sign-reversal', only for sufficiently strong intervalley scattering. When both external and chiral gauge fields are present, we observe both strong and weak sign-reversal, where in the case of weak sign-reversal, the rise and fall of magnetoconductivity depends on the direction of the magnetic field and/or the chiral gauge field, and is not correlated with the orientation of the LMC parabola. The combination of the two fields is shown to generate striking features in the LMC phase diagram as a function of various parameters such as tilt, strain, and intervalley scattering. We also study the effect of strain-induced chiral gauge field on the planar Hall conductance and highlight its distinct features that can be probed experimentally.

PO.174 An Atomtronic Setup For Inducing Rotations in a Ring BEC

Koon Siang Gan* (Nanyang Technological University)

Atomtronics experiments require versatility of the optical trapping potential to readily spatially and temporally manipulate ultracold atoms. Digital Micromirror Devices (DMDs) are perfect candidates to address this requirement in the lateral plane. An additional gravitational confinement of the Bose-Einstein Condensate (BEC) enables pseudo-2D systems to be realised. An Atomtronic experiment setup is presented here which can trap Rb-87 BECs and the lateral optical traps manipulated in real-time. Therefore, smooth lateral optical potentials are essential to prevent unnecessary excitations. Dithering algorithms can be used to address this through the creation of a flat-top potential. An initial experiment is conducted which creates 2 independent BECs from a single cloud, and matter-wave fringes are observed after a Time-of-Flight (ToF) sequence. Another experiment illustrates the smoothness of these potentials by inducing circulation via an optical paddle rotation. This demonstration is a key requirement for many atom SQUID experiments.

4 Technical Sessions

Please observe the technical instructions for talks to comply wiht regulations. We will leave a copy for each chair in the rooms.

T1: Quantum Dynamics 1

Time: Wednesday 27 Sept, 11:00am; Venue: Room 1; Chair: Gong Jiangbin
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T1.94 (INVITED) Typicality and strong prethermalization of nonequilibrium quantum systems

Xiansong Xu*, Chu Guo, Dario Poletti (Singapore University of Technology and Design)
11:00am – 11:20am

We study the quasi-steady current generation between two finite nonintegrable environments each following the eigenstate thermalization hypothesis. With different types of typical initial states for each environment, we show that the emergent quasi-steady currents are also typical, i.e., the vast majority of the current has a value close to steady current obtained from baths with microcanonical initial conditions. This is evident by an exponential decay with respect to the environment size of the current sample variance. We then show that the formation of the steady currents is a manifestation of the prethermalization phenomenon, a quasi-equilibrium dynamical process with weak breaking of conserved quantities. We demonstrate that the emerging current is prethermalized in a strong sense, analogously to strong thermalization, meaning that the current values stay close to the steady one most of the time during the prethermalization dynamics. Last, we present a possible experimental realization based on superconducting qubits.

T1.26 Tabletop Time-Reversibility for the Quantum Regime

Clive Aw*, Lin Htoo Zaw*, Valerio Scarani (Centre for Quantum Technologies)
11:20am – 11:35am

From entropy production to state recovery, be it in classical or quantum theory, reversibility is central in understanding key concepts both in physics and information science. That said, by introducing an ancillary system, every irreversible process can always be seen as a marginal of a larger reversible global process. How then does reversal on marginal level compare to that in the global picture?

In this work, we show (1) how these two levels of reversal are logically consistent under a Bayesian framework if one consistently assigns correlations, (2) the notable cases for which one does not need to assign these correlations, which may be called ”tabletop time-reversible” (with theorems pertaining two-qubit channels) and (3) physical and thermodynamic insights that emerge in these cases.

For more, see arXiv:2308.13909

T1.22 (INVITED) Perspectives on single-particle-exact density functional theory

Martin-Isbjoern Trappe*, Jun Hao Hue, Jonah Huang, Mikolaj Paraniak, Djamila Hiller, Jerzy Cioslowski, Berge Englert (CQT)
11:35am – 11:55am

We recently established 'single-particle-exact density functional theory' (1pEx-DFT, arXiv:2305.03233), a novel density functional approach that represents all single-particle contributions to the energy with an exact functional in terms of 'participation numbers' of the single-particle part of a quantum many-body system. These participation numbers play the role of the variational variables akin to the particle densities in standard orbital-free density functional theory. Our proof-of-principle implementation features new schemes for constructing the density matrices that enter the energy functional for all those quantum systems that are also amenable to Hartree-Fock theory. We minimize the energy with evolutionary algorithms. For illustration, we will present our simulations of interacting Fermi gases as well as the electronic structure of atoms and ions, also with relativistic corrections. We will also discuss possible conceptual and technical improvements that could make 1pEx-DFT an accurate, scalable, and transferable technology for simulating mesoscopic quantum many-body systems.

T1.79 Synchronization of quantum Stuart-Landau oscillators and beyond

Yuan Shen*, Wai-Keong Mok, Changsuk Noh, Andy Chia, Leong-Chuan Kwek*, Hong Yi Soh (Centre for Quantum Technologies)
11:55am – 12:10pm

A paradigm for quantum synchronization is the quantum analog of the Stuart-Landau oscillator. We show that quantum phase synchronization can be enhanced by homodyne measurement, single-photon noise and two-photon squeezing. We also propose a new metrics for measuring quantum phase synchronization based on classical and quantum Fisher information. The quantum Stuart-Landau oscillator corresponds to a van der Pol oscillator in the limit of weak (i.e., vanishingly small) nonlinearity, thus fails to capture interesting nonlinearity-induced phenomena such as relaxation oscillations. To explore beyond weakly nonlinear regime, we propose an alternative model that remains numerically tractable with large nonlinearity. This allows us to uncover interesting phenomena in the deep-quantum strongly nonlinear regime with no classical analog.

T1.35 Kardar-Parisi-Zhang Physics in the Density Fluctuations of Localized Two-Dimensional Wave Packets

Sen Mu*, Jiangbin Gong, Gabriel Lemarié (Department of Physics, National University of Singapore)
12:10pm – 12:25pm

We identify the key features of Kardar-Parisi-Zhang universality class in the fluctuations of the wave density logarithm, in a two-dimensional Anderson localized wave packet. In our numerical analysis, the fluctuations are found to exhibit an algebraic scaling with distance characterized by an exponent of 1/3, and a Tracy-Widom probability distribution of the fluctuations. Additionally, within a directed polymer picture of KPZ physics, we identify the dominant contribution of a directed path to the wave packet density and find that its transverse fluctuations are characterized by a roughness exponent 2/3. Leveraging on this connection with KPZ physics, we verify that an Anderson localized wave packet in 2D exhibits a stretched-exponential correction to its well-known exponential localization.

T2: Quantum Devices and Quantum Communication

Time: Wednesday 27 Sept, 11:00am; Venue: Room 3; Chair: Alex Ling
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T2.87 (INVITED) A privacy-preserving publicly verifiable quantum random number generator

Tanvirul Islam*, Anindya Banerji, Chin Jia Boon, Wang Rui, Ayesha Reezwana, James Grieve, Rodrigo Piera, Alexander Ling (National University of Singapore)
11:00am – 11:20am

Verifying the quality of a random number generator involves performing computationally intensive statistical tests on large data sets commonly in the range of gigabytes. Limitations on computing power can restrict an end-user's ability to perform such verification. There are also applications where the user needs to publicly demonstrate that the random bits they are using pass the statistical tests without the bits being revealed. We report the implementation of an entanglement-based protocol that allows a third party to publicly perform statistical tests without compromising the privacy of the random bits.

T2.65 (INVITED) Levitated Ferromagnets for Sensing Applications

Joel K Jose*, Tao Wang*, Ping Koy Lam (A*STAR)
11:20am – 11:40am

A levitating micron-sized ferromagnet will exhibit quantum properties. It will precess about the magnetic field, similar to atomic spins at the Larmor frequency, provided that the spin angular momenta dominates over the rotational angular momenta. This requires the ferromagnet to be placed in a region with the external magnetic field below a threshold value to reduce its rotational angular momenta. The observation of this quantum phenomenon, the intrinsic spin angular momenta, at the micrometer scale is due to the levitated ferromagnetic particle being a correlated system of spins, allowing for the rapid averaging of quantum uncertainty. This levitated ferromagnet would have exceptional sensitivity, even beating the standard quantum limit by orders of magnitude for a magnetometer, gravimeter, and gyroscope. Moreover, such a levitated particle would also be an excellent candidate for tests of fundamental physics as the levitating potential is completely passive and has no externally driven fields, removing an intrinsic noise source. Since the experiment needs to be conducted at cryogenic temperatures to achieve superconductivity, the thermal noise sources are also well diminished.

Ref: [1] Derek F Jackson Kimball, Alexander O. Sushkov and Dmitry Budker: Precessing Ferromagnetic Needle Magnetometer, Phys. Rev. Lett. 116,190801 (2016) [2] Andrea Vinante, Chris Timberlake and Hendrik Ulbricht: Levitated Micromagnets in Superconducting Traps: A New Platform for Tabletop Fundamental Physics Experiments, Entropy 24, 1642 (2022)

T2.135 Building a certifiable source device independent quantum random number generator

Kaiwei Qiu*, Yu Cai*, Nelly Ng*, Jing Yan Haw* (Centre for Quantum Technologies, National University of Singapore)
11:40am – 11:55am

Randomness, in particular trusted private randomness is an important resource for applications in cryptography. Quantum physics provides some natural ways to generate genuine randomness. However, the generation of certifiable randomness with a good balance between practicality and the implementation assumptions still meets various theoretical and technical challenges. In this work, we experimentally implemented a certifiable source device independent quantum random number generator (SDI-QRNG) proposed by Drahi et al. and extended their work to include the usage of unbalanced homodyne photodetectors for randomness generation. This device is built with off-the-shelf optical and electronic components. The resulting device is compact and portable, with a randomness generation rate of 229kb/s and a real-time random number extraction rate of 1.20kb/s with a security parameter $\epsilon = 5 \times 10^{-10}$. Furthermore, its security makes no assumptions about the input light source, while its performance is constantly monitored by an integrated certification test. Lastly, we demonstrated its security against a potential eavesdropper attacks via light injection.

T2.146 Polarization sensitive superconducting single photon detector array for quantum state tomography

Pierre Brosseau*, Anton Vetlugin*, Shuyu Dong*, Cesare Soci* (Centre for Disruptive Photonics Technologies, SPMS, TPI, Nanyang Technological University, Singapore)
11:55am – 12:10pm

Polarization state tomography of quantum light usually requires complicated alignment of movable optical components, such as polarizers and waveplates. Here we present a new design concept of a multi-pixel superconducting nanowire single-photon detector (SNSPD) array that recovers quantum state of light without additional optics. Each pixel is designed to be highly sensitive to one polarization state of a photon - horizontal, vertical, diagonal, anti-diagonal, left- or right-handed circular, and insensitive to the orthogonal polarization state. For instance, a pixel can be triggered by a horizontally polarized photon, while not “seeing” a vertically polarized photon. We will present preliminary results on the realization of a polarization sensitive SNSPD array in NbTiN platform and discuss its potential for quantum state tomography of single photons and polarization-entangled photon pairs based on finite element method simulation of pixels with different geometries. Besides polarization state tomography, such SNSPD arrays may find useful applications in QKD networks and quantum imaging.

T2.77 Visible-Light Integrated PIN Avalanche Photodetectors

Victor Leong*, Prithvi Gundlapalli, Jun Rong Ong, Thomas Y.L. Ang, Salih Yanikgonul, Shawn Yohanes Siew, Ching Eng Png, Leonid Krivitsky (Institute of Materials Research and Engineering, A*STAR)

12:10pm – 12:25pm

Integrated photodetectors are key building blocks of scalable photonics platforms. Many recent improvements have been made for integrated avalanche photodetectors (APDs) operating at infrared telecommunications wavelengths, but their visible-spectrum counterparts remain relatively unexplored. Here, we demonstrate PIN-doped silicon APDs for visible light detection, monolithically integrated with a silicon nitride photonics circuit via end-fire coupling. An in-depth study of multiple PIN doping profiles reveals different optimal designs based on the desired operating regimes. We compare the current PIN devices with previous PN counterparts, and attempt to draw insights towards achieving single-photon detection in Geiger-mode operation

T3: Materials 1

Time: Wednesday 27 Sept, 11:00am; Venue: Room 4; Chair: TBD
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T3.18 (INVITED) Highly anisotropic spin transport in a two-dimensional semiconductor

Ahmet Avsar* (National University of Singapore)
11:00am – 11:20am

Exploitation of the intrinsic spin of an electron, spintronics, facilitates the development of multifunctional and novel devices which could play an important role in the Beyond-CMOS era. Two-dimensional (2D) crystals and their van der Waals heterostructures are particularly promising for spintronics device applications due to their unique properties, including strong responses to field effect gating and proximity interactions, which may enable new functionalities that are not possible with conventional bulk materials [1].

Black phosphorus is a particularly promising 2D semiconducting material for spintronics research due to its high charge mobilities, low atomic mass, and puckered crystalline structure, which are expected to lead to anisotropic spin transport with nanosecond spin-lifetimes. In this seminar, I will introduce ultra-thin BP as a unique platform for studying rich spin-dependent physics. Firstly, I will show that BP supports all electrical spin injection, transport, precession and detection up to room temperature [2]. Then, I will present our recent findings on the impact of the unique crystal structure of BP on its spin dynamics, revealing strong anisotropic spin transport along three orthogonal axes [3]. The exceptional spin transport and its strong gate-tunability together with the strong spin-lifetime anisotropy we observe in BP add to the growing body of evidence for the potential of 2D materials in functional spin-based device applications.

[1] A. Avsar et al., Rev. Mod. Phys. 92, 021003 (2020) [2] A. Avsar et al., Nat. Phys. 13, 888-894 (2017) [3] L. Cording et al., submitted (2023)

T3.136 (INVITED) Extended magic phase in twisted graphene multilayers

Darryl Foo*, Zhen Zhan, Mohd. Alezzi, Liangtao Peng, Shaffique Adam, Francisco Guinea (CA2DM)
11:20am – 11:40am

Theoretical and experimental studies have verified the existence of “magic angles” in twisted bilayer graphene, where the twist between layers gives rise to flat bands and consequently highly correlated phases. Narrow bands can also exist in multilayers with alternating twist angles, and recent theoretical work suggests that they can also be found in trilayers with twist angles between neighboring layers in the same direction. We show here that flat bands exist in a variety of multilayers where the ratio between twist angles is close to coprime integers. We generalize previous analyses, and, using the chiral limit for interlayer coupling, give examples of many combinations of twist angles in stacks made up of three and four layers which lead to flat bands. The technique we use can be extended to systems with many layers. Our results suggest that flat bands can exist in graphene multilayers with angle disorder, that is, narrow samples of turbostatic graphite.

T3.53 Unravelling Strong Electronic Interlayer and Intralayer Correlations in a Transition Metal Dichalcogenide

Thomas Whitcher*, Andrivo Rusydi* (National University of Singapore)
11:40am – 11:55am

Electronic correlations play important roles in driving exotic phenomena in condensed matter physics. They determine low-energy properties through high-energy bands well-beyond optics. Great effort has been made to understand low-energy excitations such as low-energy excitons in transition metal dichalcogenides (TMDCs), however their high-energy bands and interlayer correlation remain mysteries. Herewith, by measuring temperature- and polarization-dependent complex dielectric and loss functions of bulk molybdenum disulphide from near-infrared to soft X-ray, supported with theoretical calculations, we discover unconventional soft X-ray correlated-plasmons with low-loss, and electronic transitions that reduce dimensionality and increase correlations, accompanied with significantly modified low-energy excitons. At room temperature, interlayer electronic correlations, together with the intralayer correlations in the c-axis, are surprisingly strong, yielding a three-dimensional-like system. Upon cooling, wide-range spectral-weight transfer occurs across a few tens of eV and in-plane p–d hybridizations become enhanced, revealing strong Coulomb correlations and electronic anisotropy, yielding a two-dimensional-like system. Our result shows the importance of strong electronic, interlayer and intralayer correlations in determining electronic structure and opens up applications of utilizing TMDCs on plasmonic nanolithrography.

T3.12 Vanadium-vacancy defect complexes in monolayer tungsten diselenide

Jingda Zhang*, Leyi Loh, Michel Bosman, Goki Eda*, Su Ying Quek* (National University of Singapore)
11:55am – 12:10pm

We present a comprehensive study of the formation of defect complexes of vanadium substitutional dopants and selenium vacancies in monolayer tungsten diselenide. Different defect complexes were identified and analyzed by the statistical treatment of scanning transmission electron microscope (STEM) datasets. Using density functional theory (DFT) calculations, we studied the thermodynamic stability of these defect complexes under experimental growth conditions. Both theory and experiment reveal that vanadium substitutional defects lower the formation energy of surrounding selenium vacancies. Increasing the vanadium concentration results in a larger density and average size of the vanadium-vacancy complexes. Nevertheless, the formation of larger complexes requires higher energy costs, and the most commonly observed defect complex configuration consists of a single vacancy adjacent to a vanadium defect. Our results pave the way for exploration of engineering impurity-vacancy complexes by substitutional doping in 2D TMDs.

T3.141 Small angle atomic relaxation in twisted bilayer graphene

Gayani Pallewela*, Adam Shaffique*, Mohammed Mohammed Esmail Alezzi, Peng Liangtao, Harshitra Mahalingam (The Centre for Advanced 2D Materials (CA2DM), at the National University of Singapore (NUS))
12:10pm – 12:25pm

Twisted bilayer graphene exhibits intriguing electronic properties when stacked with small twist angles. In such systems, the interplay between lattice mismatch and the delicate balance of interlayer van der Waals forces leads to atomic position adjustments commonly referred to as relaxation. These adjustments have significant implications for the physical characteristics of the material. Consequently, achieving an accurate representation of relaxation is particularly crucial, especially at marginal twist angles. In this theoretical study, structural relaxation was carried out using molecular dynamics simulations. This approach proves to be an efficient tool for investigating structures with larger moiré wavelengths and a substantial number of atoms. We explore the impact of structural relaxation on the modifications in the electronic band structures of van der Waals heterostructures with small twist angles.

T4: Astronomy

Time: Wednesday 27 Sept, 11:00am; Venue: Room 2; Chair: TBD
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T4.29 (INVITED) New Physics or Poor Modeling? Studying Black Hole Environments for Gravitational Wave Detection

Shubham Kejriwal*, Alvin Chua (National University of Singapore)
11:00am – 11:20am

The upcoming space-based observatory, LISA, aims to detect GW signals from extreme-mass-ratio binary black hole sources called EMRIs, with a promise to have high enough precision to test General Relativity (GR). However, current state-of-the-art EMRI models claiming the above do not account for the effects of EMRI environments, such as an accretion disk, and the community remains divided on whether or not these effects will be negligible for EMRI measurements. In this talk, we highlight building evidence for the latter and propose new ways to systematically include EMRI environments in current models.

T4.39 Modelling gravitational waveforms of extreme mass-ratio inspirals:

Soichiro Isoyama* (NUS)
11:20am – 11:35am

LIGO's 2015 discovery of gravitational waves from a merging black-hole binary has birthed a new era in astronomy. The theoretical modelling of binaries is central in gravitational-wave astronomy, as it enables the extraction and interpretation of their waveform signals in noisy data. As gravitational-wave detectors become more sensitive (to lower frequencies), they will increasingly detect binaries with smaller mass ratios, larger spins, and higher eccentricities and inclinations. In this talk we present recent progress (in the NUS team) toward modelling these systems.

T4.83 Daytime radiative cooling under a cloudy sky in the tropical climate near the equator

Jaesuk Hwang* (the Centre for Quantum Technologies)
11:35am – 11:50am

The sky as a permanent cold surface is a vast natural energy resource we cannot afford not to exploit in the near future. Radiative cooling, taking advantage of the coldness of the sky, does not require any energy input and does not release any heat to the environment, therefore is viewed as a sustainable alternative to meet the cooling energy needs. Hot and humid regions would benefit most from such innovative cooling technology, but radiative cooling has so far been regarded as a challenge in an equatorial tropical climate because the weather is hot, humid, cloudy and constantly changing. Furthermore, an inherent hurdle for the radiative cooling near the equator is that a radiative cooling device must point towards the zenith for a maximum cooling effect, but the sun path traverses the zenith. To utilise radiative cooling in such adverse weather, a high-performance radiative cooling device is necessary. We point out the key role of the degree of thermal insulation of the radiative cooling system, which is often overlooked over the solar reflectivity and the emissivity. By enclosing a radiative cooling surface in a high-vacuum chamber, we demonstrate that a sub-ambient cooling up to 8 degrees is possible during daytime under a cloudy sky of Singapore. We also observe that due to the high ambient temperature, the clouds can serve as the heat sink needed for radiative cooling. Our study, proving the feasibility of radiative cooling in one of the most adverse weathers, is a manifestation of the universal applicability of the technique.

T4.74 Null Geodesics of a Static Black Bottle

Hexiang Chang*, Kenneth Hong (National University of Singapore)
11:50am – 12:05pm

This research studies the spacetime geometry of the black bottle, as well as the geodesic motion of particles in it. A black bottle is a black hole where one end of the event horizon is spherical and the other end is punctured, extending to infinity, and forming the shape of a bottle. The static form of the black bottle is investigated.

The investigation of geodesic motion of particles around the black bottle will allow us to understand the way it interacts with objects in its neighbourhood. For null trajectories, corresponding to photon motion, its clear relevance lies in astronomical detection of celestial objects via receiving the light around them. Similar studies of null geodesics around other black holes have recently allowed the construction of black hole images.

The geometry of the black hole horizon is investigated by varying its physical parameters. The horizons are then isometrically embedded in a fictitious, three-dimensional Euclidean space as a tool to visualise their curvature. Geodesics are solved numerically using Python and then compared to their analytical solutions obtained from differential equations. Various parameters are tuned to obtain all possible geodesics, and these are classified based on a set of appropriate conserved physical quantities. There are stable orbits of various periodicities, tracing out interesting shapes around the horizon. Other orbits simply fall into the horizon, while some escape to infinity, depending on the initial conditions. The geodesics are then visualised using isometric embedding alongside the black bottle horizons.

T4.37 Improving the scalability of Gaussian-process error marginalization in gravitational-wave inference

Miaoxin Liu*, Xiao-Dong Li, Alvin Chua* (Department of Physics/Department of Mathematics, National University of Singapore, Singapore, Singapore)
12:05pm – 12:20pm

The accuracy of Bayesian inference can be negatively affected by the use of inaccurate forward models. In the case of gravitational-wave inference, accurate but computationally expensive waveform models are sometimes substituted with faster but approximate ones. The model error introduced by this substitution can be mitigated in various ways, one of which is by interpolating and marginalizing over the error using Gaussian process regression. However, the use of Gaussian process regression is limited by the curse of dimensionality, which makes it less effective for analyzing higher-dimensional parameter spaces and longer signal durations. In this work, to address this limitation, we focus on gravitational-wave signals from extreme-mass-ratio inspirals as an example, and propose several significant improvements to the base method: an improved prescription for constructing the training set, GPU-accelerated training algorithms, and a new likelihood that better adapts the base method to the presence of detector noise. Our results suggest that the new method is more viable for the analysis of realistic gravitational-wave data.

T5: Quantum Dynamics 2

Time: Wednesday 27 Sept, 2:00pm; Venue: Room 1; Chair: TBD
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T5.122 (KEYNOTE) Microscopic theory of energy, momentum, and angular momentum transfer mediated by photons

Jian-Sheng Wang* (National University of Singapore)
2:00pm – 2:25pm

The energy, momentum, and angular momentum transfer in the fluctuational electrodynamics is usually formulated by the materials properties of a frequency dependent dielectric function. In recent years, we made attempt to describe the matter (metal or electrons) and photon interaction by a more fundamental form of the quantum electrodynamics within the framework of nonequilibrium Green's functions and tight-binding Hamiltonian for the electrons. In this talk, I will present the theory and most recent numerical results in this direction. Examples are the emissions of energy from graphene surface and van der Waals forces between bulky balls C60.

Ref.: arXiv: 2208.03511; and 2307.11361.

T5.82 Interactions and integrability in weakly monitored Hamiltonian systems

Bo Xing*, Xhek Turkeshi, Marco Schiró, Rosario Fazio, Dario Poletti (Science, Mathematics and Technology Cluster, Singapore University of Technology and Design, 487372 Singapore)
2:25pm – 2:40pm

Interspersing unitary dynamics with local measurements results in measurement-induced phases and transitions in many-body quantum systems. When the evolution is driven by a local Hamiltonian, two types of transitions have been observed, characterized by an abrupt change in the system size scaling of entanglement entropy. The critical point separates the strongly monitored area-law phase either from a volume law or from a sub-extensive, typically logarithmic-like, one at a low measurement rate. Identifying the key ingredients responsible for the entanglement scaling in the weakly monitored phase is the key purpose of this work. For this purpose, we consider prototypical one-dimensional spin chains with local monitoring featuring the presence/absence of U(1) symmetry, integrability, and interactions. Using exact numerical methods, the system sizes studied reveal that the presence of interaction is always correlated to a volume-law weakly monitored phase, while noninteracting systems present sub-extensive scaling of entanglement. Other characteristics, namely integrability or symmetry, do not affect the character of the entanglement phase.

T5.50 Percolation-induced PT symmetry breaking

Mengjie Yang, Ching Hua Lee* (Department of Physics, National University of Singapore)
2:40pm – 2:55pm

Critical percolation underscores a large variety of second-order phase transitions. In this work, we discover that the percolation threshold can even hold the key to PT-symmetry breaking in non-Hermitian systems. To elaborate, when the islands are extremely small, the bulk propaga-

tion dominates the system. As these islands merge to form larger ones, the topological edge states propagate without any overall gain or loss over time. However, crossing the percolation threshold and thus forming extensively large clusters results in PT symmetry breaking for the topological spectrum. This PT symmetry breaking enables the topological states to experience indefinite exponential amplification over time. Furthermore, we show that such a phenomenon exists whenever there is a competition of different non-Hermitian skin effect (NHSE) channels in the system, This competition gives rise to an emergent length scale, beyond which amplification takes place. In this paper, we illustrate this by developing a model with two coupled Chern layers with antagonistic NHSE, such that inter-layer state tunneling occurs with the emergence of the PT-symmetry breaking, whenever that length scale is exceeded. Our discovery provides further investigation of the intriguing interplay between NHSE, critical percolation, and Chern topological edge states in non-Hermitian dynamics.

T5.44 KPZ class fluctuations in two dimensional strong Anderson localised regime - A Monte Carlo study

Nyayabanta Swain*, Shaffique Adam, Gabriel Lemarie (Centre for Quantum Technologies, National University of Singapore)
2:55pm – 3:10pm

We present numerical studies of the conductance fluctuations and their distribution in two-dimensional Anderson model in the strongly localised regime. The lng distribution is non-Gaussian in this regime. The fluctuations of lng grow with system size as $L^{1/3}$, a hallmark of systems exhibiting the Kardar-Parisi-Zhang (KPZ) physics. These fluctuations follow universal Tracy-Widom distributions that depend on the type of leads attached to the system. We provide an in-depth analysis of this behaviour by showing the analogy of our model with the directed polymer in a random medium. Furthermore, using an importance-sampling scheme of fluctuations based on a Markov chain Monte Carlo method in the disorder, we are able to access very large conductance fluctuations which are otherwise impossible to access via standard sampling procedure. As a result, we can distinguish between the fluctuations belonging to the Tracy-Widom GUE and GOE classes. Besides this, we explore another class of KPZ fluctuations - the Baik-Rains class, with our Monte Carlo method, which has not been studied for the conductance in the Anderson model.

T5.45 Critical dynamics of long-range quantum disordered systems

Weitao Chen*, Gabriel Lemarie, Jiangbin Gong (Department of Physics, National University of Singapore; MajuLab; Centre for Quantum Technologies.)
3:10pm – 3:25pm

Long-range hoppings in quantum disordered systems are known to yield quantum multifractality, whose features can go beyond the characteristic properties associated with an Anderson transition. Indeed, critical dynamics of long-range quantum systems can exhibit anomalous dynamical behaviours distinct from those at the Anderson transition in finite dimensions. In this paper, we propose a phenomenological model of wave packet expansion in long-range hopping systems. We consider both their multifractal properties and the algebraic fat tails induced by the long-range hoppings. Using this model, we analytically derive the dynamics of moments and Inverse Participation Ratios of the time-evolving wave packets, in connection with the multifractal dimension of the system. To validate our predictions, we perform numerical simulations of a Floquet model that is analogous to the power law random banded matrix ensemble. Unlike the Anderson transition in finite dimensions, the dynamics of such systems cannot be adequately described by a single parameter scaling law that solely depends on time. Instead, it becomes crucial to establish scaling laws involving both the finite-size and the time. Explicit scaling laws for the observables under consideration are presented. Our findings are of considerable interest towards applications in the fields of many-body localization and Anderson localization on random graphs, where long-range effects arise due to the inherent topology of the Hilbert space.

T6: AMO Physics

Time: Wednesday 27 Sept, 2:00pm; Venue: Room 3; Chair: TBD
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T6.91 (INVITED) Transforming Rydberg Interactions with Floquet Frequency Modulation

Luheng Zhao*, Michael Dao Kang Lee*, Mohammad Mujahid Aliyu*, Huanqian Loh* (Centre for Quantum Technologies, National University of Singapore)
2:00pm – 2:20pm

Tweezer arrays of Rydberg atoms offer rich possibilities for exploring quantum many-body physics and quantum information processing. Much of the programmability of Rydberg atom arrays thus far come from the ability to precisely position atoms. Here we report the enhanced control of Rydberg interactions between two tweezer-trapped atoms via Floquet frequency modulation. We demonstrate Rydberg-blockade entanglement beyond the traditional blockade radius, which breaks the longstanding constraint for local gate operation. Further, the coherence of entangled states can be extended under Floquet frequency modulation. Finally, the anti-blockade of closely spaced Rydberg atoms is observed when the resonance condition is satisfied. Our work transforms between the paradigmatic regimes of Rydberg blockade versus anti-blockade and paves the way for realizing more connected, coherent, and versatile neutral atom quantum processors with a single approach [1].

[1] L Zhao, M D K Lee, M M Aliyu, H Loh, arXiv:2306.08596 (2023).

T6.121 (INVITED) Dual atomic interferometry for differential inertial sensing

Jianing Li*, Swarup Das, Chang Chi Kwong, Thomas Zanon, Shau-Yu Lan, David Wilkowski* (Nanyang Technological University)
2:20pm – 2:40pm

We present an experimental demonstration of testing the universality of free-fall, realized through a dual atomic interferometer with cold strontium atoms. The strontium-88 atoms are initially prepared in a mixture of ground ($^1S_0$) and excited ($^3P_0$) states of the clock transition prior to the atomic interferometer phase. We implement a Mach-Zehnder interferometer based on Bragg diffraction and conduct the differential measurement between the atomic samples in different states. By using same pulses on both internal states, the common-mode noise can be efficiently rejected. Furthermore, this scheme allows us to probe the spin-dependent forces. We apply a 671 nm laser in the path of interferometer, and the internal state-sensitive acceleration can be induced by differential light shift. Consequently, this state-dependent force can be quantified through the phase difference observed in the dual atomic interferometer.

T6.125 Systematic analysis of relative phase measurement in 1D atom interferometry

Taufiq Murtadho*, Marek Gluza, Nelly Ng*, Sebastian Erne, Jörg Schmiedmayer, Arifa Khatee Zatul (Nanyang Technological University)
2:40pm – 2:55pm

Matter-wave interference upon free expansion enables measurements of the relative phase between two adjacent one-dimensional Bose gases. In this work, we comprehensively investigate systematic error sources that can arise in the analysis of experimental data, which is typically conditioned on various modelling assumptions. We provide a formula capturing the detrimental effect of longitudinal expansion dynamics on the accuracy of phase extraction. The formula contains a correction that results from mixing with common phase degrees of freedom not measured in experiments. Furthermore, we numerically simulate the estimation of thermal properties of the gases and assess the read-out error propagation. Our analysis incorporates experimental systematic errors such as photon diffusion, recoil, and shot noise from the imaging devices. This work characterizes the reliability and robustness of interferometric measurements, directing us towards the improvement of existing phase extraction methods, which would enable the capturing of novel physics observations in cold-atomic quantum simulators.

T6.56 Highly Efficient Creation of Ultracold Ground-state ^{6}Li^{40}K Polar Molecules

Canming He*, Xiaoyu Nie*, Victor Pinillos*, Sofia Botsi*, Sunil Kumar*, Anbang Yang*, Kai Dieckmann* (Centre for Quantum Technologies, National University of Singapore)
2:55pm – 3:10pm

We report on the first and efficient creation of ground state ^{6}Li^{40}K molecules using the stimulated Raman adiabatic passage (STIRAP). Starting from the weakly-bound Feshbach molecules, the STIRAP transfer to the singlet ro-vibrational ground state is achieved via an intermediate state in the $A^1\Sigma^+$ potential. The coherent transfer is facilitated by two narrow-linewidth and low phase-noise lasers. We achieved a single-trip transfer efficiency up to 98%, which is the highest compared to other reported bi-alkali species. Our work demonstrates the high efficiency of the singlet STIRAP pathway for the coherent creation of ground state molecules. Combined with the high dipole moment of ground state ^{6}Li^{40}K, this work paves the way for studying quantum chemistry, quantum simulation of exotic phase of matter and quantum information processing with strong long-rage anisotropic dipole-dipole interactions.

T6.132 Realization of an ultracold indium gas

Tiangao Lu*, Xianquan Yu*, Jinchao Mo, Ting You Tan, Travis Nicholson* (Centre for Quantum Technologies, National University of Singapore)
3:10pm – 3:25pm

Three atom types have been responsible for nearly all the remarkable progress in quantum degenerate gas experiments, namely alkalis, alkaline earths, and dipolar lanthanides. Meanwhile main-group elements III-VIII remain unexplored in the quantum degenerate regime.

Our work focuses on ultracold indium, which is a main-group III element. Indium is a multipurpose atom that contains many useful properties found only in isolation in other ultracold atom types. For example, indium simultaneously contains magnetic Feshbach resonances, optical clock transitions, strong spin exchange interactions, spinor gas capabilities, and promising spin-orbit coupling capabilities.

In this talk we describe our realization of a laser-cooled indium gas, including a Zeeman slower and efficient magneto-optical trap. We also discuss our progress toward sub-Doppler cooling indium.

T7: Materials 2

Time: Wednesday 27 Sept, 2:00pm; Venue: Room 4; Chair: TBD
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T7.105 Semimetal contacts to monolayer semiconductor: weak metalization as an effective mechanism to Schottky barrier lowering

Tong Su, Yueyan Li, Qianqian Wang, Weiwei Zhao, Liemao Cao*, Yee Sin Ang* (Singapore University of Technology and Design, Singapore 487372, Singapore)
2:00pm – 2:15pm

Recent experiment has uncovered semimetal bismuth (Bi) as an excellent electrical contact to monolayer MoS_2 with ultralow contact resistance. The contact physics of the broader semimetal/monolayer-semiconductor family beyond Bi/MoS_2, however, remains largely unexplored thus far. Here we perform a comprehensive first-principle density functional theory investigation on the electrical contact properties between six archetypal two-dimensional (2D) transition metal dichalcogenide (TMDC) semiconductors, i.e. MoS_2, WS_2, $MoSe_2$, WSe_2, MoTe2 and WTe2, and two representative types of semimetals, Bi and antimony (Sb). As Bi and Sb work functions energetically aligns well with the TMDC conduction band edge, Ohmic or nearly-Ohmic n-type contacts are prevalent. The interlayer distance of semimetal/TMDC contacts are significantly larger than that of the metal/TMDC counterparts, which results in only weak metalization of TMDC upon contact formation. Intriguingly, such weak metalization generates semimetal-induced gap states (SMIGSs) that extends below the conduction band minimum, thus offering an effective mechanism to reduce or eliminate the n-type Schottky barrier height (SBH) while still preserving the electronic structures of 2D TMDC. A modified Schottky–Mott rule that takes into account SMIGS, interface dipole potential, and Fermi level shifting is proposed, which provides an improved agreement with the density functional theory-simulated SBH. We further show that the tunneling-specific resistivity of Sb/TMDC contacts are generally lower than the Bi counterparts, thus indicating a better charge injection efficiency can be achieved through Sb contacts. Our findings reveal the promising potential of Bi and Sb as excellent companion electrode materials for advancing 2D semiconductor device technology.

T7.103 Electronic and Contact Properties of MA_2N_4(MN) (M=Mo, W; A=Si, Ge)

Che Chen Tho, Yee Sin Ang* (Singapore University of Technology and Design)
2:15pm – 2:30pm

The discovery of two-dimensional (2D) MA_2N_4 family, such as $MoSi_2N_4$ and WSi_2N_4, opens a new avenue towards the development of novel 2D material device technology [1,2]. Due to their excellent air-stability, mechanical strength, and electrical properties, $MoSi_2N_4$ and WSi_2N_4 have been intensively studied recently [3,4]. Particularly, the built-in atomic protection of $MoSi_2N_4$ and WSi_2N_4 allows the construction of electronically clean interfaces at the metal(2D)/semiconductor(2D) contacts of their van der Waals heterostructures (VDWH) [4]. More recently, a new kind of monolayer material, $MoSi_2N_4$/(MoN)4n, has been synthesized which is confined between layers of $MoSi_2N_4$ [5]. In contrast to the formation of an oxide layer on semiconductors, the for-

mation of metallic layers during the growth of a semiconductor is the first time being reported. Different from the semiconducting $MoSi_2N_4$ monolayer, $MoSi_2N_4$/(MoN)4n monolayer is a phonon-mediated superconductor [5] at 9.02K that is natively grown during chemical vapor deposition of $MoSi_2N_4$. In this current work, we examined the electronic structures and stability of monolayers MA_2N_4(MN) (M=Mo, W; A=Si, Ge). Intriguingly, we found that the electronic states around the Fermi level is localized vertically around the inner core atomic sublayers and insulated by the outer Si(Ge)-N sublayers. Such behavior reveals a peculiar atomic layer protection mechanism that may be useful for electrode applications. Driven by the opportunities that this family of metallic homologous compounds offers towards the expansion of heterostructure building blocks, contact properties with commonly studied semiconductors (Si, SiC, GaN) are also investigated. Our work reveals promising electronic properties of MA_2N_4(MN), and the realization of electronically clean metal/semiconductor contacts that can be achieved even for heterostructures that are not weakly coupled by weak van der Waals interactions.

References: [1] Y.L. Hong, Z. Liu, L. Wang, T. Zhou, W. Ma, C. Xu, S. Feng, L. Chen, M.L. Chen, D.M. Sun, X.Q. Chen, H.M. Cheng, W. Ren, Chemical vapor deposition of layered two-dimensional MoSi(2)N(4) materials, Science, 369 (2020) 670-674. [2] Q. Wang, L. Cao, S.-J. Liang, W. Wu, G. Wang, C.H. Lee, W.L. Ong, H.Y. Yang, L.K. Ang, S.A. Yang, Y.S. Ang, Efficient Ohmic contacts and built-in atomic sublayer protection in $MoSi_2N_4$ and WSi_2N_4 monolayers, npj 2D Materials and Applications, 5 (2021) 71. [3] L. Cao, G. Zhou, Q. Wang, L.K. Ang, Y.S. Ang, Two-dimensional van der Waals electrical contact to monolayer $MoSi_2N_4$, Applied Physics Letters, 118 (2021) 013106. [4] B. Mortazavi, B. Javvaji, F. Shojaei, T. Rabczuk, A. Shapeev, X. Zhuang, Exceptional piezoelectricity, high thermal conductivity and stiffness and promising photocatalysis in two-dimensional $MoSi_2N_4$ family confirmed by first-principles, Nano Energy, 82 (2021) 105716. [5] Z. Liu, L. Wang, Hong, Hong, X. Q. Chen, H. M. Cheng, W. Ren, Two-dimensional superconducting $MoSi_2N_4$ (MoN) 4n homologous compounds, National Science Review, 10 (2023), nwac273.

T7.98 Symmetric and Excellent Scaling Behavior in Sub-5 nm Wide Bandgap Oxide Semiconductor Transistors

Linqiang Xu*, Yee Sin Ang* (Singapore University of Technology and Design (SUTD))
2:30pm – 2:45pm

Wide bandgap oxide semiconductors are regarded as promising channel candidates for complementary metal-oxide-semiconductor (CMOS) integration. Ultra-thin (UT) In_2O_3 is one of the most potential n-type oxide semiconductors because its field-effect transistors (FETs) exhibit extremely high drain current (104 μA/μm) and transconductance (4000 μS/μm). Based on this, we simulate the performance limits of sub-5 nm UT In_2O_3 FETs by using the ab initio quantum transport simulation. Our results show that the on-state current, delay time, and power dissipation of UT In_2O_3 FETs can satisfy the International Technology Roadmap for Semiconductors (ITRS) standards for high-performance (HP) and low-power (LP) devices when the gate length (Lg) is reduced to 2 and 3 nm, respectively. On the other hand, two-dimensional TeO_2 with thickness down to bilayer (BL) is shown to have a high hole mobility of $232\,cm^2V^{-1}s^{-1}$ at room temperature and $6000\,cm^2V^{-1}s^{-1}$ at -50 °C, which is useful for forming PMOS. Hence, we also study the performance limits of sub-5 nm BL TeO_2 by the same method. The anisotropy of BL TeO_2 results in different transport properties. In the x direction, n-type BL TeO_2 FETs show similar performance to UT In_2O_3 FETs for both HP and LP applications at Lg of 3 nm. Remarkably, for the first time, we demonstrate that the NMOS and PMOS symmetry can be realized in the same oxide semiconductors along the y direction. Therefore, our investigations reveal the tremendous prospects of wide bandgap oxide semiconductors for CMOS applications.

T7.128 Ultrafast Exciton Fluid flow in monolayer MoS_2

Indrajit Wadgaonkar*, Andres Granados Del Aguila*, Stefano Dal Forno*, Marco Battiato* (Nanyang Technological University, Singapore)
2:45pm – 3:00pm

Excitons (bound electron-hole pairs) in semiconductors can show unique collective states with striking properties. In atomically thin MoS_2 such a collective, short-lived, excitonic phase was experimentally observed to propagate like a classical liquid for ultra-long distances ($\approx 60\,\mu$m) and with a speed comparable to the speed of light ($\approx 1.8 \times 10^7$ m/s). Theoretical simulations showed that the observed density profile was explained well by a momentum-conserving fluid flow model using the compressible Navier-Stokes equations. First-principle calculations were carried out for the speed of sound in the excitonic fluid and a steeply rising potential with the inter-excitonic distance was predicted. Using the Navier-Stokes simulations and the first-principles calculations the classical liquid-like character of the excitonic phase was established.

T7.31 Emergence of Complex Domain Boundary Structures via a Hybrid Probabilistic Generative Model

Jiadong Dan*, Duane Loh* (National University of Singapore)
3:00pm – 3:15pm

A continuing challenge in atomic resolution microscopy is to identify significant structural motifs and their assembly rules in synthesized materials with limited observations. Here we propose and validate a simple and effective hybrid generative model capable of predicting unseen domain boundaries in a potassium sodium niobate thin film from only a small number of observations, without expensive first-principles calculation. Our results demonstrate that complicated domain boundary structures can arise from simple interpretable local rules, played out probabilistically. We also found new significant tileable boundary motifs and evidence that our system creates domain boundaries with the highest entropy. More broadly, our work shows that simple yet interpretable machine learning models can help us describe and understand the nature and origin of disorder in complex materials.

T7.169 Mechanism of phonon attenuation in three-dimensional amorphous solids

Shivam Mahajan* (NTU)
3:15pm – 3:30pm

The thermal and transport properties of a material are governed by its vibrational density of states (vDOS). The vibrational spectra of crystals exhibit three significant differences from amorphous solids featuring: (i) a boson peak, (ii) low-frequency quasi-localised modes (QLMs), and (iii) strong phonon attenuation termed as Rayleigh scattering. Various theories based on elastic disorder have been proposed to explain these anomalies.

In this talk, I discuss the mechanism of sound attenuation through the numerical simulation of various model glass formers. As in Rayleigh's original picture, three-dimensional stable glasses attenuate sound waves as homogeneous elastic media punctuated by defects. Via diverse approaches, I demonstrate that these defects are the QLMs, which act as scattering sources. I further show that Rayleigh's prediction coincides with a version of fluctuation elasticity theory accounting for correlations in the local elastic properties, corr-FET. On the contrary, in two dimensions, Rayleigh's picture fails. Sound attenuation is well described by the earlier version of fluctuation elasticity theory (FET), which assumes no correlation between the local elastic constants. The dimensionality dependence of sound attenuation appears to reflect those of the QLMs, which are localised in three spatial dimensions, not in two.

T9: Quantum Information 1

Time: Wednesday 27 Sept, 4:00pm; Venue: Room 1; Chair: Valerio Scarani
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T9.7 Quantum Bayesian Inference in Quasiprobability Representations

Clive Aw*, Valerio Scarani, Kelvin Onggadinata, Dagomir Kaszlikowski (Centre for Quantum Technologies)
4:00pm – 4:15pm

Bayes' rule plays a crucial role in logical inference in information and physical sciences alike. Its extension into the quantum regime has been the subject of several recent works. These quantum versions of Bayes' rule have been expressed in the language of Hilbert spaces. In this paper, we derive the expression for the Petz recovery map within any quasiprobability representation, with explicit formulas for the two canonical choices of "normal quasiprobability representations" (which include discrete-Wigner representations) and of representations based on symmetric informationally complete positive operator-valued measures (SIC-POVMs).

By using the same mathematical syntax of (quasi)stochastic matrices acting on (quasi)stochastic vectors, the core difference in logical inference between classical and quantum theory is found in the manipulation of the reference prior rather than in the representation of the channel. Meanwhile, other notable structural similarities and differences are identified and unpacked, for their insights regarding inference in classical and quantum regimes.

T9.41 Quantum metrology with imperfect measurements

Yink Loong Len*, Tuvia Gefen, Alex Retzker, Jan Kolodynski (Yale-NUS College)
4:15pm – 4:30pm

The impact of measurement imperfections on quantum metrology protocols has not been approached in a systematic manner so far. In this work, we tackle this issue by generalising firstly the notion of quantum Fisher information to account for noisy detection, and propose tractable methods allowing for its approximate evaluation. We then show that in canonical scenarios involving N probes with local measurements undergoing readout noise, the optimal sensitivity depends crucially on the control operations allowed to counterbalance the measurement imperfections—-with global control operations, the ideal sensitivity (e.g., the Heisenberg scaling) can always be recovered in the asymptotic N limit, while with local control operations the quantum enhancement of sensitivity is constrained to a constant factor. We illustrate our findings with an example of NV-centre magnetometry, as well as schemes involving spin-1/2 probes with bit-flip errors affecting their two-outcome measurements, for which we find the input states and control unitary operations sufficient to attain the ultimate asymptotic precision. [Nat. Commun. 13, 6971 (2022)]

T9.25 Dynamics-based Certification of Quantumness: Beyond Harmonic Systems

Lin Htoo Zaw*, Valerio Scarani (Centre for Quantum Technologies)
4:30pm – 4:45pm

Based on a preprint by Tsirelson [1], we introduced a protocol that detects nonclassicality of a single system, or entanglement between two harmonic oscillators, under the sole assumption that the measured variables are undergoing a uniform precession with a known angular frequency [2]. This protocol involves measuring one of the precessing variables at a randomly-chosen time every round, and calculating the score as the probability that it was found to be positive. Nonclassicality can be detected with suitable quantum states, which are able to attain scores larger than the maximum possible classical score. In a recent work, we show that the primary assumption can be relaxed to a certain extent—for example, if the angular frequency is only known to be within some range of frequencies, or if the system is anharmonic [3]. A general procedure for using the protocol in a system governed by an arbitrary time-independent Hamiltonian with a single degree of freedom will be covered, and several examples are explicitly studied: some that are approximately harmonic in the limits of low energy (Kerr nonlinearities, the pendulum, and the Morse potential) and one that is not (the particle in an infinite well). A quantum mechanical advantage is still present in many of the above cases, thereby demonstrating that the protocol is robust even when its primary assumption is relaxed.

[1] Zaw, L.H., Aw, C.C., Lasmar, Z., & Scarani, V. (2022). Detecting quantumness in uniform precessions. Phys. Rev. A 106, 032222; Jayachandran, P., Zaw, L.H., & Scarani, V. (2022). Dynamics-Based Entanglement Witnesses for Non-Gaussian States of Harmonic Oscillators. Phys. Rev. Lett. 130, 160201 [2] Tsirelson, B. (2006). How often is the coordinate of a harmonic oscillator positive?. arXiv:quant-ph/0611147 [3] Zaw, L.H. & Scarani, V. (2022). Dynamics-based quantumness certification of continuous variables using time-independent Hamiltonians with one degree of freedom. Phys. Rev. A 108, 022211

T9.158 Scalable multiparty steering based on a single pair of entangled qubits

Travis Baker*, Alex Pepper, Yuanlong Wang, Qiu-Cheng Song, Lynden K. Shalm, Varun B. Verma, Sae Woo Nam, Nora Tischler, Sergei Slussarenko, Howard M. Wiseman, Geoff J. Pryde (Nanyang Quantum Hub, Nanyang Technological University)
4:45pm – 5:00pm

The distribution and verification of quantum nonlocality across a network of users is essential for future quantum information science and technology applications. However, beyond simple point-to-point protocols, existing methods struggle with increasingly complex state preparation for a growing number of parties. Here, we show that, surprisingly, multiparty loophole-free quantum steering, where one party simultaneously steers arbitrarily many spatially separate parties, is achievable by constructing a quantum network from a set of qubits of which only one pair is entangled. Using these insights, we experimentally demonstrate this type of steering between three parties with the detection loophole closed. With its modest and fixed entanglement requirements, this work introduces a scalable approach to rigorously verify quantum nonlocality across multiple parties, thus providing a practical tool towards developing the future quantum internet.

T9.13 Towards fully quantum observational entropy

Ge Bai*, Dominik Safranek, Joseph Schindler, Francesco Buscemi, Valerio Scarani (National University of Singapore)

5:00pm – 5:15pm

We observe that the difference between the quantum observational entropy and von Neumann entropy can be interpreted as, and quantitatively equal to, the expected entropy production of the measurement process. Based on this observation, we provide a generalization of quantum observational entropy that includes a reference prior state that need not commute with the measured state. Such generalization is justified by its agreement with the quantum generalization of entropy production, which is related to the quantum generalization of the Bayesian retrodiction defined with the Petz recovery map.

T9.139 Quantum Uncertainty Principles for Measurements with Interventions

Yunlong Xiao*, Yuxiang Yang, Ximing Wang, Liu Qing, Mile Gu (Institute of High Performance Computing (IHPC))

5:15pm – 5:30pm

This work builds upon the findings presented in our recent publication [Phys. Rev. Lett. 130, 240201 (2023)]. Heisenberg's uncertainty principle implies fundamental constraints on what properties of a quantum system can we simultaneously learn. However, it typically assumes that we probe these properties via measurements at a single point in time. In contrast, inferring causal dependencies in complex processes often requires interactive experimentation - multiple rounds of interventions where we adaptively probe the process with different inputs to observe how they affect outputs. Here we demonstrate universal uncertainty principles for general interactive measurements involving arbitrary rounds of interventions. As a case study, we show that they imply an uncertainty trade-off between measurements compatible with different causal dependencies.

T10: Bio and Molecular Physics

Time: Wednesday 27 Sept, 4:00pm; Venue: Room 3; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T10.166 (INVITED) From cell sorting to wound healing and collective motion: Emergent tissue phenomena

Anshuman Pasupalak*, Massimo Pica Ciamarra* (SPMS NTU)
4:00pm – 4:20pm

We propose a novel state-of-the-art approach to modelling tissue mechanics from the bottom up, with individual, living, deformable cells as building blocks. This approach allows modelling cell tissues at a much finer resolution than existing approaches. We demonstrate the modelling capabilities by accurately reproducing in vivo experiments on cell sorting and showcase wound healing at constant number density for the first time in simulations. We also reproduce tissue rupture in response to tensile stretching, focusing on local stresses at intercellular adhesions.

T10.150 Atomic sculpting of a nanopore edge using electric field excitations

Kittipitch Yooprasertchuti*, Tihomir Marjanovic, Slaven Garaj (Department of Physics, National University of Singapore)
4:20pm – 4:35pm

Solid-state nanopore sensor is a crucial tool for the detection and analysis of individual biomolecules, but the established ex-situ nanofabrication methods require complicated instrumentation and significant efforts to control the pore size in a single-digit nanometer regime. Here we explore controlled dielectric breakdown (CBD) as a method for the nanopore fabrication within the nanofluidic cell, allowing for the in-situ sub-nanometer control of the pore size. We employ a series of short electrical pulses across SiN_x free-standing membrane separating two liquid compartments (electric field $\approx$0.2V/nm). This leads to seeding in a single sub-nm defect within the membrane, and a consequent controlled growth of the nanopore around it, where the pore size is monitored by its ionic conductivity. To gain insight into the physical mechanism of dielectric breakdown and the nanopore growth, we investigate the parameters impacting the CBD process, including characteristics of the voltage pulses, material properties of the membranes, and the chemical environment. The study analyzes the stochastic process of the nanopore drilling, considering the removal and flow of SiN_x material during voltage pulse application. Notably, the research sheds light on the influence of nanopore geometry on the enlarging etch rate, providing insights that could drive advancements in nanopore-based technologies.

T10.115 The synergistic modulation of FET biosensors

Zheng Zhi* (Department of Materials Science and Engineering, College of Design and Engineering, National University of Singapore)
4:35pm – 4:50pm

Field effect transistor (FET) biosensors have arouse great attention in fields of biological science research, medical diagnosis, environmental monitoring due to merits of high integration, good stability and real-time detection. The FET biosensors were are made up of two parts: 1) FET parts, 2) Bio parts including probes and targets. However, previous work only modulates FET part and Bio part of FET biosensors respectively, which will bring potential limit. Therefore, developing novel detection strategies to synergistically modulate FET parts and Bio parts is vital important for the construction of high-performance FET biosensors. In this work, we firstly shorted the distance between biological probe molecules and the channel surface of the indium oxide thin film by regulating the modification sites of the antibody probe molecules. The constructed FET biosensors shows low detection limit (100 nU/mL) and a wide linear response range (100 nU/mL to 1 U/mL) for detecting the ovarian cancer marker CA125. Further, we precisely modulate Debye length (λD) be close to MIN(LP, LP+T) (LP is the length of probe molecules before binding with the target, LP+T is the length of probe molecules after binding with the target) by controlling the thickness of passivation layer and the concentration of saline solution. Thus, the effective charge concentration of biological probe molecules and the conductive charge concentration of indium oxide thin film of FET channel are rationalized. The detection limit of serotonin can be as low as 5.0 fM, the linear range reaches 10 fM to 1.0 nM, which could further expand to the performance improvement of dopamine and glucose. Furthermore, we modulated the interaction between biological probe molecules and the channel of indium oxide thin film by regulating the gate voltage of FET biosensors. The sensitivity of FET biosensors for telomerase detection was effectively improved with an extremely low detection limits (13 cells) and wide linear ranges (100 to 5000 cells). Our work enhanced the performance of FET biosensors by synergistic regulation of the indium oxide film and the biological probe/target molecule, providing a new idea for the development of high-performance FET biosensors.

T10.164 Nanopore Squeezing Technology – Exploring the mechanical properties of nanoscale biological objects.

Kun Li, Arjav Shah, Patrick Doyle*, Slaven Garaj* (National University of Singapore)
4:50pm – 5:05pm

The understanding of the mechanical properties of small (generally below 100 nm) viruses and other deformable biological particles could help determine the structure of their shells and interiors, and give insight into their key functions. Currently, the commonly used techniques for characterizing the nanomechanical properties of single particles include nanoindentation, atomic force microscopy, and optical tweezers. The disadvantages of these technologies is the complex operations and low throughput, significantly limiting their applications. Here we demonstrate a new nanopore squeezing technique for rapid, high-throughput mechanical characterization of individual particles. The method relies on the electrophoretic pulling of a soft particle through a nanopore that is significant smaller that the particle itself, observed a range of the driving electrical voltages. The translocation dynamics is characterized by measuring the transient drop in the ionic current through the nanopore during the squeezing process. As a proof of principle, we explore the squeezing of two types of DNA origami particles with similar contour sizes (30 nm) but different rigidities, through a different nanopores with a range of diameter between Dp=5-40 nm. We found three regimes in the nanoparticle translocation: (1) creep regime—at a low driving voltage, the particles slowly pass through the nanopore with velocities that scale weakly with the voltage; (2) plop regime —at a high voltage, the particles deform rapidly and pass through the nanopore as in the free-translocation regime, with their velocity scaling linearly with the driving force; (3) transient regime— observed at a onset voltage Von where the signature of both translocation mechanism are observed within the individual current traces. A series of squeezing experiments shows the linear scaling of the Von with DP, and its strong dependence on the particles' mechanical properties. Using those results and employing deep learning protocols, we could distinguish between similarly sized but structurally disparate particles with 96% of accuracy. We are further exploring the application of this method in diagnostics, for fingerprinting biologically relevant nanoparticles and viruses.

T10.52 Precision Ellipsometry for Studies of Molecular Interactions

Nikolai Yakovlev* (National University of Singapore)
5:05pm – 5:20pm

Ellipsometry, as optical analytical technique, gains it sensitivity from measurement of phase shift between components of light polarisation rather than intensity. Precision ellipsometry (PREL) uses modulation of polarisation, which makes it even more sensitive: in the range of micro-radians. This translates to 0.01 nm of oxide or organic molecules on silicon substrate. Recent innovations of polarisation modulators allowed making PREL systems compact, low in power consumption, and even portable keeping same sub-nanometre sensitivity. They enable quantitative real-time measurements of molecular interactions, binding, adsorption and desorption on a reflecting substrate in liquid, gas or vacuum. A review of the results on binding of small molecules (amino-silane, tannin) and macromolecules (polyelectrolytes, proteins) will be presented. The most recent innovation is imaging PREL, where a video camera is synchronised with the polarisation modulator. When several receptors are placed on the substrate, it enables measurement of selectivity and affinity of each receptor to one target molecule supplied in solution in one run. All the results show that PREL combines quantitative measurement in real time with high sensitivity and at low cost. Thus it has high analytical potential.

T10.111 STERIC EFFECT ON ELECTROOSMOTIC FLOW IN NANOCHANNELS

Rajni* (O. P. Jindal Global University)
5:20pm – 5:35pm

Fluids in nanoconfinements, such as nanochannels exhibit strong interactions due to electric double layer (EDL) overlap. Electroosmotic flow (EOF) describes the motion of fluids due to the presence of an EDL. Ions in fluids have considerable finite size represented by steric factor, which is comparable to Debye length of EDLs in nanochannels, thus making them impossible to neglect. Steric effect has been shown to influence EDL overlapping [S. Das and S. Chakraborty, Physical Review E, vol. 84, p. 012501, 2011] and electrocapillarity in nanochannels [Rajni, J. M. Oh and I. S. Kang, Physical Review E, vol. 93(6), p. 063112, 2016]. In this study, the electroosmotic flow for systems not less than 10 nm are investigated using the continuum approach. At this scale, the van der Waals force cease to be significant over the electrostatic forces, thus it is appropriate to use continuum approach. For inclusion of steric effect in the formulation, asymmetric ion size model proposed by [Y. Han, S. Huang, and T. Yan, Journal of Physics:

Condensed Matter, vol. 26, p. 284103, 2014] has been used. The influence of steric factor on electroosmotic flow behavior in nanochannels is studied. The variation of electroosmotic velocity and mobility with respect to steric effect and nanochannel widths has been examined.

T11: Materials 3

Time: Wednesday 27 Sept, 4:00pm; Venue: Room 4; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T11.88 (INVITED) In-plane dominant anisotropy stochastic magnetic tunnel junction for probabilistic computing: A Fokker-Planck study

Chee Kwan Gan* (Institute of High Performance Computing)
4:00pm – 4:20pm

Recently there is considerable interest to realize efficient and low-cost true random number generators (RNGs) for practical applications. One important way is through the use of bistable magnetic tunnel junctions (MTJs). Here we study the magnetization dynamics of an MTJ, with a focus to realize efficient random bit generation under the assumption that the orientation dependence of the energy of the nanomagnet is described by two perpendicular in-plane anisotropies. We find that a high rate of random bit generation is achievable away from the pure easy-axis situation by tuning a single parameter H so that it is either (a) toward a barrierless-like single easy plane situation when H reduces to zero, or (b) toward a stronger easy plane situation when H becomes increasingly negative where transitions between low energy states are confined in the stronger easy plane that contains the saddle points. We find that the MTJs maintain their fast magnetization dynamical characteristics even in the presence of a magnetic field. Our findings provide a valuable guide to achieving efficient generation of probabilistic bits for applications in probabilistic computing.

T11.152 Focused Laser Enticed Effulgent Carbon/Copper Monosulfide Composite

Hengxing Yang, Xiaodai Sharon Lim*, Chorng Haur Sow* (National University of Singapore)
4:20pm – 4:35pm

This work introduces a method to obtain a quenched material by using laser cutting on Cu¬2S-coated carbon nanotube samples. The process results in site-selective formation of nanoparticles with distinct fluorescence characteristics. PL characterization of these fluorescent nanoparticles identified distinct visible red fluorescence at λ=660nm and infrared emission at λ=920nm. Through SEM observation, it is found that these fluorescent nanoparticles are formed on the top of the CNT layer. Through Raman characterization, TEM measurement and XPS analysis, it is determined that the nanoparticles comprise a mixture of $Cu_2O(SO_4)$, $CuSO_4$ and Cu_2O. Combining the energy band structures of these substances and comparing them with the PL result, the visible fluorescence is proposed to be contributed by the Cu_2O, while the infrared emission comes from the electron-hole pair separation at the oxygen atomic defect energy band in $CuSO_4$. After analysing the mechanism of the observed fluorescence, SERS effect in $Cu_2O(SO_4)$ successfully detects Rhodamine B molecules at a concentration less than 10^{-7}M.

T11.11 Atmospheric Pressure Plasma Jet Synthesis and Characterisation of Copper-Silver Bimetallic Materials.

Stefanos Agrotis*, Daren J. Caruana, Albertus Denny Handoko (University College London (UCL) / A*STAR)
4:35pm – 4:50pm

Plasmas at atmospheric pressure are of tremendous interest in recent years due to their accessibility, low-cost and sustainable applications in a plethora of fields (Biomedicine, Material science, Nanotechnology, etc). In this work, copper-silver (Cu-Ag) alloys were synthesised under various ratios using a newly developed Atmospheric Pressure Plasma Jet (APPJ) system in a single step in under 15 minutes. The samples exhibited strong adhesion onto various substrates such as glass and glassy carbon. This direct-deposition technique requires low power output ($<$50W) without the need for any pre- or post-treatment processes, and with little to no waste. This contrasts with wet chemistry, where deposition normally takes 12-24 hours followed by thermal processes that produce several waste products. Considering the high melting points of pure Cu and Ag (Cu = ca. 1,085 °C, Ag = 962 °C), and the fact that they are immiscible, the formation of copper-silver alloys usually requires a high amount of energy under intense conditions[1].

These Cu-Ag alloys were characterised via cyclic voltammetry, Raman spectroscopy, X-ray diffraction (XRD), Scanning electron microscopy (SEM) and Energy-dispersive X-ray spectroscopy (EDS). Here, we demonstrate that by only mixing low-concentration metal salt solutions and using a neutral gas (helium), we can readily synthesise metal alloys while controlling their thickness, shape, composition, and metal ratios. Copper is the only heterogeneous catalyst that converts CO_2 into valuable chemicals, including hydrocarbons, aldehydes, and alcohols[2]. Interestingly, we illustrate that the addition of silver improves and enhances the catalytic activity of copper towards CO_2 reduction reaction. This is a desirable property given the anticipated transition to green energy.

References 1. Banhart, J., et al., Electronic properties of single-phased metastable Ag-Cu alloys. Physical Review B, 1992. 46(16): p. 9968. 2. Kuhl, K.P., et al., New insights into the electrochemical reduction of carbon dioxide on metallic copper surfaces. Energy & Environmental Science, 2012. 5(5): p. 7050-7059.

T11.76 Investigating ferromagnetic coupling of quasiparticle charge carriers in cuprate heterostructures using novel resonant soft X-ray magnetic scattering

Bin Leong Ong, Kaushik Jayaraman*, Caozheng Diao, Thomas James Whitcher, Anjali Jain, Hillson Hung, Mark B. H. Breese, Eng Soon Tok, Andrivo Rusydi* (ARiCES, Department of Physics, NUS)
4:50pm – 5:05pm

Resonant soft x-ray scattering (RSXS), is a relatively new technique that combines spectroscopy and scattering methods to give us the means to study charge ordering in materials. Here, in a similar, new method, we utilize circularly polarized photon beams, which helps provide a means to probe the spin ordering in the sample. Combining this novel resonant soft x-ray magnetic scattering (RSXMS) and x-ray magnetic circular dichroism (XMCD), we demonstrate a new technique to study the ferromagnetism of the quasiparticle doped holes in cuprate heterostructures.[1] RSXMS and XMCD measurements at O K-edge and Cu L3,2 edges were carried out on

HOSG-QDs/d $La_{1.8}Ba_{0.2}CuO_4/LaAlO_3(001)$ heterostructures, where d = 4, 8 and 12 unit cells. It reveals strong anomalous ferromagnetism of the doped holes both in and out of the Cu-O plane at different temperatures. We also observe a new ferromagnetic (002) Bragg peak which is enhanced with an increase in the thickness of the $La_{1.8}Ba_{0.2}CuO_4$ layer, d. Our work way for exploring correlation between ferromagnetism and unconventional superconductivity and also opens up exciting prospects for further investigations showcasing the potential of RSXMS as a valuable tool for studying complex electronic phenomena.

[1]Nat. Commun. 13, 4639 (2022)

T11.155 Superfluorescent J-aggregates Coupled to Dielectric Metasurfaces

Marco Marangi*, Wang Yutao, Mengfei Wu, Febiana Tjiptoharsono, Arseniy Kuznetsov, Giorgio Adamo, Cesare Soci (Centre for Disruptive Photonic Technologies, TPI, Nanyang Technological University, Singapore 637371)

5:05pm – 5:20pm

J-aggregates, coupled molecular emitters in which dipole transition moments are naturally aligned, are expected to manifest cooperative behaviour leading to an intense burst of highly directional emission that scales as the square of the number of coupled emitters. However, this phenomenon - known as superfluorescence, is hardly achievable at room temperature. In this work, we couple molecular J-aggregates to resonant dielectric metasurfaces to enhance their superfluorescence yield by the Purcell effect. We show a greater than 5-fold enhancement of the photoluminescence of TDBC dyes deposited on TiO_2 metasurfaces designed to match the emission wavelength of the J-aggregates, with angular dispersion and polarization matching the resonant photonic modes of the metasurface. Furthermore, the pump-fluence dependence of the photoluminescence indicates the emergence of room temperature cooperativity of the coupled J-aggregates. Our preliminary results show that integration of superfluorescent J-aggregates with designer dielectric metasurfaces is a promising avenue to foster cooperative effects at room temperature, opening new opportunities for power-efficient, ultrabright and fast-switchable light-emitting devices.

T13: Topological Systems

Time: Thursday 28 Sept, 9:00am; Venue: Room 1; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T13.113 (INVITED) Discrete time crystal made of topological edge magnons

Dhiman Bhowmick*, Hao Sun, Bo Yang, Pinaki Sengupta (Nanyang Technological University)
9:00am – 9:20am

We report the emergence of time-crystalline behavior in the π-Berry phase protected edge states of a Heisenberg ferromagnet in the presence of an external driving field. The magnon amplification due to the external field spontaneously breaks the discrete time-translational symmetry, resulting in a discrete time crystal with a period that is twice that of the applied electromagnetic field. We discuss the nature and symmetry protection of the time crystalline edge states and their stability against various perturbations that are expected in real quantum magnets. We propose an experimental signature to unambiguously detect the time crystalline behavior and identify two recently discovered quasi-two-dimensional magnets as potential hosts. We present a realization of time crystals at topological edge states, which can be generalized and extrapolated to other bosonic quasiparticle systems that exhibit parametric pumping and topological edge states.

T13.51 (INVITED) Correlated plasmons in topological insulators

Pranab Kumar Das*, T. J. Whitcher, M. Yang, X. Chi, Y. P. Feng, W. Lin, J. S. Chen, I. Vobornik, J. Fuji, K. A. Kokh, O. E. Tereshchenko, Jisoo Moon, Seongshik Oh, H. Castro-Neto, M. B. H. Breese, A. T. S. Wee, A. Rusydi* (Department of Physics, National University of Singapore, 117576, Singapore)
9:20am – 9:40am

Electronic correlation is believed to play an important role in exotic phenomena such as insulator-metal transition, colossal magneto resistance and high temperature superconductivity in correlated electron systems. Recently, it has been shown that electronic correlation may also be responsible for the formation of unconventional plasmons. Herewith, using a combination of angle-dependent spectroscopic ellipsometry, angle resolved photoemission spectroscopy and Hall measurements all as a function of temperature supported by first-principles calculations, the existence of low-loss high-energy correlated plasmons accompanied by spectral weight transfer, a fingerprint of electronic correlation, in topological insulator $(Bi_{0.8}Sb_{0.2})_2Se_3$ is revealed. Upon cooling, the density of free charge carriers in the surface states decreases whereas those in the bulk states increase, and that the newly-discovered correlated plasmons are key to explaining this phenomenon. These results show the importance of electronic correlation in generating correlated plasmons and could have significant implications in plasmonic-based topologically-insulating devices especially when considering the low-loss nature of the correlated plasmons.

T13.133 Transverse circular photogalvanic effect associated with Lorentz Symmetry Breaking

Mohammad Yahyavi*, Guoqing Chang* (Assistant Professor of Nanyang Technological University)

9:40am – 9:55am

Nonlinear optical responses of quantum materials are drawing intense current interest. Despite the deep connections with high-energy physics, the optics-based approaches for investigating relativistic effects from quasiparticles in condensed matter remain elusive. By exploring the circular photogalvanic effect (CPGE) in Weyl semimetals, we show that photocurrents can originate through Lorentz violation in condensed matter systems. We find that the transverse photocurrents of Weyl fermions are associated with the degree of symmetry breaking, being forbidden in systems possessing Lorentz symmetry. By employing a generic two-band model-based analysis, we introduce a new formulation of the problem that allows efficient evaluation of the transverse CPGE in which effects of the tilting and warping terms associated with Lorentz-symmetry breaking are properly taken into account. The formalism is used to explore photocurrents in the currently realized Weyl materials intensively. Our study advances the realistic modeling of optical responses of Weyl semimetals and paves the way for the rational design of next-generation relativistic optoelectronics materials platforms.

T13.1 Light-induced half-quantized Hall effect and Axion insulator

Fang Qin*, Ching Hua Lee*, Rui Chen* (Department of Physics in Hubei University)

9:55am – 10:10am

Motivated by the recent experimental realization of the half-quantized Hall effect phase in a three-dimensional (3D) semi-magnetic topological insulator [M. Mogi et al., Nature Physics 18, 390 (2022)], we propose a new scheme for realizing the half-quantized Hall effect and Axion insulator in experimentally mature 3D topological insulator heterostructures. Our approach involves optically pumping and/or magnetically doping the topological insulator surface, such as to break time reversal and gap out the Dirac cones. By toggling between left and right circularly polarized optical pumping, the sign of the half-integer Hall conductance from each of the surface Dirac cones can be controlled, such as to yield half-quantized (0+1/2), Axion (-1/2+1/2=0) and Chern (1/2+1/2=1) insulator phases. We substantiate our results based on detailed band structure and Berry curvature numerics on the Floquet Hamiltonian in the high-frequency limit. Our work showcases how new topological phases can be obtained through mature experimental approaches such as magnetic layer doping and circularly-polarized laser pumping, and opens up potential device applications such as a polarization chirality-controlled topological transistor.

T13.3 Topology and Geometry of 3-Band Models

Tan Chien Hao*, Chinghua Lee* (Institute of High Performance Computing)

10:10am – 10:25am

Berry curvature is a property of N-band models which plays an analogous role of the magnetic field. The Majorana Stellar Representation (MSR) is a method of decomposing N- band states into multiple 2-band states, which paves way for a more intuitive geometric understanding of

N-band models. We utilise the MSR to obtain a new formula for the Berry curvature of 3-band models in terms of individual contributions from each star and cross terms involving both stars, which could be insightful for investigating berry curvature uniformity and topological behaviour of stars. We applied the MSR method to a model with uniform berry curvature and investigated the cancellation of the divergences among 3 out of 4 of the terms to yield an overall non-divergent berry curvature. In summary, the MSR approach aids the discovery of materials with uniform berry curvature and is a powerful tool in the study of Fractional Chern Insulators (FCI).

T14: Machine Learning 1

Time: Thursday 28 Sept, 9:00am; Venue: Room 3; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T14.84 Interpretable DFT-based Machine Learning Framework for Predicting Catalytic Activities of Dual-Atom Photocatalysts towards CO_2 Reduction

Chen-Chen Er, Lutfi K. Putri, Yee Sin Ang*, Nikhil V. Medhekar, Siang-Piao Chai* (Monash University Malaysia)
9:00am – 9:15am

The photocatalytic reduction of CO_2 (CO_2RR) to solar fuels by utilizing both CO_2 and solar energy is desirable to achieve an equitable energy transition toward net zero emissions by 2050. However, the catalytic activity of CO_2RR is limited by the linear scaling relation of adsorption energies between the reaction intermediates. Dual-atom photocatalysts (DAPs) have been proposed to circumvent the scaling relation to achieve a breakthrough in enhancing catalytic activity. High-throughput screening and machine learning are promising approaches to efficiently searching the large chemical space of DAPs. Herein, we present an interpretable density functional theory (DFT)-based machine learning (ML) strategy to predict and rationalize the CO_2RR catalytic activity of hundreds of transition metal (TM)-based graphitic carbon nitride (gC_6N_6) DAPs. A new database consisting of 299 different combinations of DAPs was developed. The AdaBoost regressor model trained on this dataset, using structure-sensitive features (Magpie data) and structure-property features (Coulomb Matrix Eigenvalues), predicted the potential determining step (PDS) of the considered reaction pathway, with an accuracy of R2 = 0.95 and root-mean-square error of 0.06 eV. The mean electronegativity of the TM atoms embedded in the carbon nitride central cavity is found to be the most significant descriptor during posterior mean feature selection. The results of the ML model predicted ScTi and RhMo/gC_6N_6 DAP as promising CO_2RR photocatalysts with a limiting potential of 0.58 eV and 0.73 eV, respectively. Further DFT calculations revealed that the optoelectronic properties of ScTi and RhMo/gC_6N_6 DAP are suitable for CO_2RR. Overall, the proposed methodology in this work enables the construction of predictive models which are accurate and physically interpretable for accelerated materials discovery and design.

T14.59 Neural Network Approach to the Simulation of Entangled States with One Bit of Communication

Peter Sidajaya*, Aloysius Dewen Lim, Baichu Yu, Valerio Scarani (Centre for Quantum Technologies)
9:15am – 9:30am

Bell's theorem states that Local Hidden Variables (LHVs) cannot fully explain the statistics of measurements on some entangled quantum states. It is natural to ask how much supplementary classical communication would be needed to simulate them. We study two long-standing open questions in this field with neural network simulations and other tools. First, we present evidence that all projective measurements on partially entangled pure two-qubit states require only one

bit of communication. We quantify the statistical distance between the exact quantum behaviour and the product of the trained network, or of a semianalytical model inspired by it. Second, while it is known on general grounds (and obvious) that one bit of communication cannot eventually reproduce all bipartite quantum correlation, explicit examples have proved evasive. Our search failed to find one for several bipartite Bell scenarios with up to 5 inputs and 4 outputs, highlighting the power of one bit of communication in reproducing quantum correlations.

T14.38 Topological Classification of Non-linear Chaotic Topolectrical Circuits Through Machine Learning

Haydar Sahin*, Hakan Akgun, Zhuo Bin Siu, Rafi-Ul-Islam S.M., Jian Feng Kong, Mansoor Bin Abdul Jalil, Ching Hua Lee* (Department of Physics, National University of Singapore, Singapore)
9:30am – 9:45am

Topolectrical circuits have received considerable attention as a promising medium for exploring condensed matter phenomena, including topological and non-Hermitian phases [1,2,3]. However, the existing framework is predominantly applicable to linear systems, owing to the linear nature of the circuit Laplacian. The presence of non-linearity necessitates a new approach for evaluating system dynamics [4]. The topological properties, when non-linear pumping is present, serve as an intriguing subject, as the system's non-trivial topology may categorize the chaotic non-linear dynamics of a topological non-linear system.

In this presentation, we aim to investigate this prospect by examining how topological phases influence the chaotic dynamics of a one-dimensional chaotic Su-Schrieffer-Heeger (cSSH) circuit, which comprises a Chua's circuit at each node. We observe that identically coupled Chua's circuits display unique chaotic phase portraits at the edge nodes due to the topologically non-trivial coupling arrangement. The non-trivial topology results in exponential voltage localization at both edges, leading to a transition in the chaotic phase portraits of the edge nodes.

The topological phase of the circuit is discernible in the impedance response, which manifests a strong resonance at the resonant frequency in the non-trivial phase, but no resonance in the trivial phase [5,6]. Our study reveals topological protection for the chaotic dynamics of the circuit, originating from the exponential edge localization. When an external signal is introduced, which can be viewed as a perturbation to the system, the non-trivial topological phase protects the chaotic dynamics of the circuit.

To identify the phase space of our cSSH, we calculate the total effective inductance of each node and employ machine learning (ML). Utilizing simple linear relations derived from the ML model, we can analogously construct the phase diagram from the total inductance approach. Our study presents effective methods for classifying chaotic phases in relation to their interplay with topologically non-trivial phases, leading to the emergence of topological chaos. Our approach may lay the groundwork for determining topological phase space in the presence of non-linear elements such as memristors, which could potentially store topological phases due to their information storage capacity.

T14.140 Fundamental Limitations on Communication over a Quantum Network

Junjing Xing, Tianfeng Feng, Zhaobing Fan, Haitao Ma, Kishor Bharti, Dax Koh, Yunlong Xiao* (Institute of High Performance Computing (IHPC))
9:45am – 10:00am

Quantum entanglement, a cornerstone of quantum mechanics, has immense value in secure communication and surpassing classical limits. However, previous research has overlooked the crucial role of dynamic entanglement creation, focusing primarily on static entangled states. In this work, we propose a framework for investigating temporal entanglement, spanning multiple time points. We demonstrate that the performance of quantum networks in transmitting information depends on temporal entanglement. Through case studies, we illustrate the framework's ability to enhance quantum teleportation, achieve exponential gains in quantum repeater protocols, and double communication distances in specific noise models. Our findings address the impact of temporal entanglement on non-Markovian processes, pushing the boundaries of quantum information science.

T14.30 Ghostbuster: a diffraction tomography algorithm based on phase retrieval

Joel Yeo*, Benedikt Daurer, Dari Kimanius, Deepan Balakrishnan, Yong Zi Tan, Duane Loh* (National University of Singapore)
10:00am – 10:15am

Continual advances in methods development for single particle imaging in cryogenic electron microscopy (cryo-EM) have paved the way towards ever-increasing resolution for three-dimensional (3D) particle reconstruction. Further breaking the existing resolution limit would require reconstruction methods to take into account the effects of multiple scattering within the particle. However, many state-of-the-art cryo-EM software currently assume the projection approximation. This sometimes results in the appearance of 'ghost' atoms in the reconstructions as intra-particle diffraction is unaccounted for. Beam propagation physics must be used in order to model and reverse this effect accurately. To do so, however, requires knowledge of the phases of the electron wave which are unfortunately lost upon measurement with a detector.

In this work, we propose a new diffraction tomography algorithm named Ghostbuster. This algorithm employs a two-step approach to solving the aforementioned problem. Firstly, we utilize a phase retrieval algorithm to recover the approximate phases of the electron exitwaves from the real-valued intensities measured by the detector. Secondly, a gradient descent algorithm is used to converge towards a solution for the 3D particle which produces exitwaves that best concurs with the phase-retrieved exitwaves. Using a simulated dataset, Ghostbuster yielded improved 3D reconstruction resolution as compared to existing state-of-the-art cryo-EM software such as RELION and CryoSPARC. Our proposed method does not require a different imaging setup and can be applied to experimental images in existing cryoEM databases. We believe that the untapped potential of retrieving the lost phases can further push the limits of recoverable resolution for cryoEM imaging.

T15: Electronic Devices

Time: Thursday 28 Sept, 9:00am; Venue: Room 4; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T15.9 (INVITED) Giant magnetoresistance in high-mobility graphene

James Lourembam*, Na Xin, Piranavan Kumaravadivel, A. E. Kazantsev, Zefei Wu, Ciaran Mullan, Julien Barrier, Alexandra A. Geim, I. V. Grigorieva, A. Mishchenko, A. Principi, V. I. Falko, L. A. Ponomarenko, A. K. Geim, Alexey I. Berdyugin (Institute of Materials Research and Engineering, Agency for Science Technology and Research (A*STAR), Singapore)
9:00am – 9:20am

Dirac semi-metals, exemplified by graphene, hold great potential for displaying substantial intrinsic magnetoresistance. In our investigation, we have made a notable discovery regarding the behavior of the Dirac plasma. We found that it exhibits an exceptional quadratic MR, surpassing 100% even at low magnetic fields of 0.1T and at room temperature (RT). This magnitude of MR surpasses any previously observed system by orders of magnitude at RT. The remarkable attributes of graphene, such as its massless dispersion spectrum and exceptionally high mobility, are responsible for this outstanding performance. It is worth noting that the Dirac Plasma is also characterized by frequent instances of "Planckian-limit" scattering. As the magnetic field strength increases, the phenomenon of Landau quantization comes into play, resulting in the emergence of a colossal linear MR. At room temperature, this linear MR reaches an astonishing level of approximately 13,000% in a 12T magnetic field. Remarkably, this linear MR remains practically unaffected by temperature variations and can be suppressed by employing a proximity gate, suggesting its origin in a many-body system. Our research draws attention to intriguing parallels between the magnetoresistance observed in graphene and that of strange metals, thereby emphasizing the importance of further investigating "Planckian-limit" scattering in other two-dimensional quantum-critical systems.

T15.2 (INVITED) Ultrathin Oxides from Liquid Metals for Atomically Smooth 2D Heterostructures

Chit Siong Aaron Lau*, Kuan Eng Johnson Goh* (Institute of Materials Research and Engineering, A*STAR)
9:20am – 9:40am

Despite over a decade of intense research efforts, the full potential of two-dimensional transition-metal dichalcogenides continues to be limited by major challenges. The lack of compatible and scalable dielectric materials and integration techniques restrict device performances and their commercial applications. Conventional dielectric integration techniques for bulk semiconductors are difficult to adapt for atomically thin two-dimensional materials.[1] We had shown that industrial techniques such as atomic layer deposition led to interface roughness scattering that severely limits 2D semiconductor device applications for nanoelectronics and quantum technologies.[2]

Here, we adopt a new approach towards atomically smooth dielectric/semiconductor heterostructures by leveraging on the conformal nature of liquid metals. We achieved large-area liquid-metal-printed ultrathin (3 nm) Ga_2O_3 dielectrics directly printed on CVD 2D WS_2.[3] The atomically smooth Ga_2O_3/WS_2 interfaces enabled by the conformal nature of liquid metal printing are directly visualized through cross-sectional STEM imaging. Atomic layer deposition compatibility with high-k Ga_2O_3/HfO_2 top-gate dielectric stacks on a chemical-vapor-deposition-grown monolayer WS_2 is demonstrated, achieving EOTs of $\approx$1 nm and subthreshold swings down to 84.9 mV/dec. Gate leakage currents are well within requirements for ultra-scaled low-power logic circuits. These results show that liquid-metal-printed oxides can bridge a crucial gap in dielectric integration of 2D materials for next-generation nanoelectronics.

[1] C.S. Lau et al., 'Dielectrics for Two-Dimensional Transition Metal Dichalcogenide Applications', ACS Nano (2023) https://doi.org/10.1021/acsnano.3c03455

[2] C.S. Lau et al., 'Gate-Defined Quantum Confinement in CVD 2D WS_2', Advanced Materials, 34, 2103907 (2022) https://doi.org/10.1002/adma.202103907

[3] Y. Zhang et al., 'Liquid-Metal-Printed Ultrathin Oxides for Atomically Smooth 2D Material Heterostructures', ACS Nano, 17, 8, 7929-7939 (2023) https://doi.org/10.1021/acsnano.3c02128

T15.101 (INVITED) Concepts of Half-Valley Ohmic Contact and Valleytronic Barristor

Yee Sin Ang*, Xukun Feng, Shengyuan A. Yang (Singapore University of Technology and Design)

9:40am – 10:00am

Two-dimensional (2D) ferrovalley semiconductor (FVSC) [1] with spontaneous valley polarization offers an exciting material platform for probing Berry phase physics. How FVSC can be incorporated in valleytronic device applications, however, remain an open question. Here we generalize the concept of metal/semiconductor (MS) contact into the realm of valleytronics. In this work [2], we propose a half-valley Ohmic contact based on FVSC/graphene heterostructure where the two valleys of FVSC separately forms Ohmic and Schottky contacts with those of graphene, thus allowing current to be valley-selectively injected through the 'Ohmic' valley while being blocked in the 'Schottky' valley. We develop a theory of contact-limited valley-contrasting current injection and demonstrate that such transport mechanism can produce gate-tunable valley-polarized injection current. Using RuCl2/graphene heterostructure as an example, we illustrate a device concept of valleytronic barristor where high valley polarization efficiency and sizable current on/off ratio, can be achieved under experimentally feasible electrostatic gating conditions. These findings uncover contact-limited valley-contrasting current injection as an efficient mechanism for valley polarization manipulation, and reveals the potential of valleytronic MS contact as a functional building block of valleytronic device technology.

[1] W.-Y. Tong, S.-J. Gong, X. Wan, C.-G. Duan, "Concepts of ferrovalley material and anomalous valley Hall effect", Nat. Commun. 7, 13612 (2016).

[2] X. Feng, C. S. Lau, S.-J. Liang, C. H. Lee, S. A. Yang, Y. S. Ang, "Half-Valley Ohmic Contact and Contact-Limited Valley-Contrasting Current Injection", arXiv:2308.03700 (2023).

T15.143 Electron hydrodynamics at density junctions

Ramal Afrose*, Aydin Keser, Giovanni Vignale, Shaffique Adam (National University of Singapore)

10:00am – 10:15am

We study the effect of hydrodynamic electron flow, resulting from strong electron-electron scattering, at nn and pn junctions in 2D electron gas in GaAs heterostructures, single-layer and bilayer graphene. In nn junctions at high doping, ballistic scattering is insignificant and hydrodynamics determine the conductance provided density gradient at the junction is sufficiently high. In p-n junctions in graphene, we use a scheme used by Fogler et. al [1] for impurity-dominated scattering to hydrodynamic flow. We find that e-e scattering mean-free-path in graphene is too large to significantly affect the junction resistance. However, the problem is significantly less in bilayer graphene, so that the hydrodynamic contribution to resistance becomes non-negligible compared to the ballistic contribution. However, applying different gate voltages almost always opens a gap, and the tunneling resistance through it dominates all other resistances.

[1] M.M. Fogler et. al, PRB 77, 075420 (2008)

T15.100 Computational Screening for Sustainable Ultrawide Bandgap Two-Dimensional Semiconductors

Yee Sin Ang*, Chuin Wei Tan, Linqiang Xu* (Peking University)

10:15am – 10:30am

The sustainable development of next-generation device technology is paramount in the face of climate change and the looming energy crisis. Tremendous effort has been made in the discovery and design of nanomaterials that achieve device-level sustainability, where high performance and low operational energy cost are prioritized. However, many of such materials are composed of elements that are under threat of depletion and pose elevated risks to the environment and human health. The role of materials-level sustainability in computational screening efforts has been overlooked thus far. In this work [1], we present a general van der Waals materials screening framework imbued with sustainability-motivated search criteria. Using ultrawide bandgap (UWBG) materials as a backdrop, 25 sustainable UWBG layered materials comprising only of low-risks elements resulted from this screening effort based on 2DMatPedia, with several meeting the requirements for dielectric, power electronics, and ultraviolet device applications. These findings constitute a critical first-step towards reinventing a more sustainable electronics landscape beyond silicon, with the framework established in this work serving as a harbinger of sustainable 2D materials discovery.

[1] C. W. Tan, L. Xu, H. Y. Yang, S. A. Yang, J. Lu, Y. S. Ang, ”Towards Sustainable Ultrawide Bandgap Van der Waals Materials: An ab initio Screening Effort”, arXiv:2306.14519 (2023).

[2] J. Zhou, L. Shen, M. D. Costa, et al, ”2DMatPedia, an open computational database of two-dimensional materials from top-down and bottom-up approaches”, Sci Data 6, 86 (2019).

T16: Light Sources and Lasers

Time: Thursday 28 Sept, 9:00am; Venue: Room 2; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T16.170 Chirality controlled broadband spintronic terahertz emitter

Piyush Agarwal, Sobhan Subhra Mishra, Rohit Medwal, John Rex Mohan, Hironori Asada, Yasuhiro Fukuma, Ranjan Singh* (NTU Singapore)
9:00am – 9:15am

Polarization control of terahertz (THz) wave is crucial for improving signal modulation and developing efficient on-chip THz devices. Thus, leveraging the degree of freedom to generate chiral THz waves is envisioned to increase the link capacity for next-generation 6G communication; however, controlling the chirality across the entire THz bandwidth has remained a challenge. This talk presents a method for achieving magnetic-field-controlled linear-to-circular polarized THz emission from synthetic anti-ferromagnetic heterostructures coupled through Ruderman–Kittel–Kasuya–Yosida interactions across the Ruthenium(Ru) interlayer.

T16.157 Electrically Tunable Nanolasers in a Hybrid Photonic-Plasmonic Bound States in the Continuum Metasurface

Omar Abdelrahman Mohamed Abdelraouf*, Ramón Jose Paniagua Dominguez*, Hong Liu* (IMRE, A*STAR)
9:15am – 9:30am

Room-temperature tunable nanolaser devices are desirable for achieving compact and tunable photonic devices. However, too many parameters must integrate and optimize to achieve this goal, such as high gain medium, high-quality resonant cavity, tunable material with low optical losses, compatible external tuning mechanism, and efficient device design. Here, we designed an electrically tunable nanolaser in a hybrid plasmonic-photonic metasurface operating in the visible regime. The proposed hybrid metasurface supports the Friedrich–Wintgen (FW) bound states in the continuum resonance (BICs) to theoretically boost the optical cavity quality factor to infinity and the light-matter interactions. We report a wide bandwidth tunable lasing emission up to 60 nm after tuning the refractive index of liquid crystals. Moreover, we observe light phase change up to 2π with a reflection efficiency of more than 90 %. Achieved results of electrically tunable nanolaser would enable complete control of the lasing emission wavelength and the lasing wavefront for future phase gradient applications.

T16.109 Light source characterisation using interferometric photon correlations

Xi Jie Yeo*, Eva Ernst, Darren Ming Zhi Koh, Justin Yu Xiang Peh, Alvin Leow, Jaesuk Hwang, Lijiong Shen, Peng Kian Tan*, Christian Kurtsiefer* (Department of Physics, National University of Singapore; Centre for Quantum Technologies)
9:30am – 9:45am

We present a technique of light source characterisation using interferometric photon correlations, which extracts both the visibility and second-order correlation of the light source in the same measurement. Interferometric photon correlation is performed by measuring the photon correlation between the output ports of an asymmetric Mach-Zehnder interferometer. This technique was originally used to differentiate between a laser emitting chaotic light and emitting coherent light undergoing amplitude fluctuations. We used this technique to estimate the fraction of coherent emission from the brightest mode in a laser as it transits across its threshold, and identified a region where a laser mode hop occurred. Using this technique, we also find a difference in the interferometric photon correlation between a laser operating below its threshold, and laser light scattered by a rotating ground glass, wherein both show a similar signature in its second-order correlation.

T16.165 Enhancing the compositionally-tunable emission of hybrid perovskite quantum dots by resonant metasurfaces

Qi Ying Tan*, Marco Marangi, Mengfei Wu, Febiana Tjiptoharsono, Arseniy Kuznetsov, Giorgio Adamo, Cesare Soci (Centre for Disruptive Photonic Technologies, TPI, Nanyang Technological University, Singapore 637371)
9:45am – 10:00am

Hybrid perovskite quantum dots – semiconductor nanoparticles with diameters of 2 to 10 nm – have attracted great attention for their high photoluminescence quantum yield, narrow linewidth, size- and compositionally-tunable emission. In this work, we propose a coupled perovskite quantum dot-metasurface platform consisting of mixed-cation perovskite quantum dots ($Cs_{1-x}FA_xPbBr_3$) and dielectric (TiO_2) nano-disk arrays. By tailoring both the stoichiometry of the quantum dots and the sub-wavelength nanostructures, we achieve high brightness, spectrally tunable quantum dots that show greatly enhanced emission and fast radiative rates. This system holds good potential for colour-tunable, room temperature single photon emitters with accelerated radiative rates, that are highly desirable in quantum applications.

T17: Photonics

Time: Thursday 28 Sept, 2:00pm; Venue: Room 1; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T17.138 (INVITED) Atmospheric turbulence measurements as a starting point for the development of a quantum optical ground station

Moritz Mihm*, Xi Wang, Clarence Liu, Alexander Ling (Centre for Quantum Technologies)
2:00pm – 2:20pm

Light traveling through the atmosphere is subject to turbulence, fluctuations in the refractive index due to variations in temperature and thus density. Signal distortion due to turbulence is an important factor in space-based quantum key distribution, whether selecting a suitable location for a ground station or choosing its design parameters. To estimate the actual impact on the signal, on-site turbulence measurements are the most accurate way.

Here we report on a site survey performed in Q2/Q3 2023 at a planned ground station site in Luxembourg. We first describe the atmospheric modelling to derive the requirements for the measurement equipment, experimental setup, and analysis procedure. We then discuss our results and compare them with measurements conducted in Singapore.

On average, we find an atmospheric seeing in x and y of (3.33 ± 0.19)arcsec and (3.40 ± 0.18)arcsec, respectively, which is considerably worse than in Singapore, where we found the seeing to be in the range of 1.5 – 2.0arcsec (for x and y).

T17.57 (INVITED) Conical diffraction of pseudospin-2 states in a chiral borophene photonic lattice

Daniel Leykam* (National University of Singapore)
2:20pm – 2:40pm

Conical intersections occur between energy bands in certain two-dimensional periodic lattices. The propagation of a wavepacket in the vicinity of a conical intersection mimics that of relativistic spinor particles, where the role of the particle spin is played by an internal spin-like ”pseudospin” degree of freedom within the lattice, such as the presence of multiple sublattices [1]. The simplest type of conical intersection, the pseudospin-1/2 ”Dirac cone” between two bands, occurs in the band structure of graphene and its photonic analogues and is responsible for many of their intriguing properties. Generalizations of Dirac cones to pseudospin-1 conical intersections between three bands have also attracted great interest and have been demonstrated in a variety of platforms including photonic waveguide arrays, structured microcavities, and engineered atomic lattices [2]. Here, I will present a design for a ”chiral borophene” waveguide lattice hosting a pseudospin-2 conical intersection between five bands and discuss its interesting properties, including the generation of high charge vortices via conical diffraction [3].

[1] D. Leykam and A. S. Desyatnikov, “Conical intersections for light and matter waves,” Advances in Physics: X 1, 101 (2016). [2] M. R. Slot et al., ”Experimental realization and characterization of an electronic Lieb lattice,” Nature Physics 13, 672 (2017). [3] P. Menz, H.

Hanafi, D. Leykam, J. Imbrock, and C. Denz, ”Pseudospin-2 in photonic chiral borophene,” Photonics Research 11, 869 (2023).

T17.86 An optical ground station in Singapore for satellite-to-ground quantum communication

Ayesha Reezwana*, Xi Wang, Moritz Mihm, Alexander Ling (Centre for Quantum Technologies, NUS)
2:40pm – 2:55pm

An optical ground station is a pre-requisite for satellite-to-ground quantum communication. Here, we present the design considerations and architecture of an optical ground station being developed on National University of Singapore campus. The primary objective of the station is to enable quantum key distribution and facilitate other free space communication protocols. The development of the optical ground station is underway and it is projected to be commissioned by 2023. In this work, we elaborate on the building blocks and design techniques of the optical ground station in Singapore that can receive i.e downlink weak quantum signals from a satellite and perform necessary analysis to generate secret keys in a quantum key distribution experiment. We emphasize on the different subsystems namely the telescope system, quantum receiver, polarization correction system, and the pointing, acquisition and tracking system. We envision our ground station to support a range of beacon wavelengths to ensure its compatibility with various similar satellite missions. The working lab-configuration of the station is able to receive and analyse state of photons around 800 nm. To achieve a global quantum network cross-compatibility among optical ground stations and quantum satellites is crucial. To facilitate this, we have initiated a collaboration with various academic groups involved in satellite based quantum key distribution research to standardize the configuration of an optical ground station. This collaboration aspires to create cross-compatibility among multiple optical ground stations and quantum satellites to enhance the efforts of a global quantum network.

T17.161 Fast Tuning of Perovskite Metasurface Lasing via Microheaters

Tim Meiler*, Yutao Wang, Saurabh Srivastava, Giorgio Adamo, Ramón Paniagua-Dominguez, Arseniy Kuznetsov*, Cesare Soci* (Centre for Disruptive Photonic Technologies, TPI, Nanyang Technological University, Singapore)
2:55pm – 3:10pm

Metasurfaces have opened an avenue to miniaturizing optical devices with subwavelength structures. Current research is exploring multiple ways to gain dynamic control over their extraordinary properties, which remain static otherwise. Perovskites are a promising material platform for such schemes due to low-cost manufacturing, tunable optoelectronic properties paired with optical gain. Our aim is to develop microscale light sources with active control over their wavelength, polarization or emission direction, surpassing current modulation speeds as well as miniaturization.

In order to reach this goal, we implement a versatile microheater platform, heating surrounding material to rapidly modulate laser emission. Photolithography structures a film of indium tin oxide to transparent microheater wires, covered with the Perovskite methylammonium lead iodide ($MAPbI_3$) via spin-coating. A focused ion beam directly mills a metasurface into the film, optimized to overlap high quality factor modes of bound states in the continuum with optical gain.

In this work, we achieved millisecond switching speeds between lasing modes in Perovskite metasurfaces. Angle-resolved photoluminescence measurements reveal a wavelength shift and narrowing of laser emission angle, when an electrical heater reversibly drives the material above its phase transition temperature. Furthermore, we observe a topological polarization pattern in the back focal plane.

With the final goal of reducing switching times to microseconds or below and controlling large arrays of microwires at the single pixel/nanoantenna level, we aim to extend the application range of this type of active and tunable metasurface devices for their use in dynamic holography, light detection and ranging (LiDAR) and/or optical communications.

T17.154 Exciton-Polariton Electroluminescence from Perovskite Metasurface

Yutao Wang, Jingyi Tian, Maciej Klein, Gorgio Adamo, Son Tung Ha, Cesare Soci* (Centre for Disruptive Photonic Technologies; School of Physical and Mathematical Sciences, NTU)
3:10pm – 3:25pm

Exciton-polaritons, unique bosonic quasiparticles formed by exciton-photon coupling in resonant cavities, are interesting systems to realize Bose-Einstein condensation, unconventional lasers, and quantum simulators. So far, practical demonstrations have mainly relied on optical excitation. Our innovation lies in achieving electrically driven exciton-polariton emission within a perovskite light-emitting transistor (LET), incorporating a novel metasurface hosting photonic bound states in the continuum (BIC). Intriguingly, spin-locked exciton-polariton electroluminescence due to the photonic Rashba effect is observed, enabling tunable polariton chirality and emission direction via electrical control. This work advances the understanding of electrically-driven exciton-polaritons and opens new avenues for polaritonic light-emitting devices.

T18: Classical and Quantum Machine Learning 2

Time: Thursday 28 Sept, 2:00pm; Venue: Room 3; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T18.58 Pop-out 3D metrology: a single-shot, coherent 3D imaging method for transmission electron microscopy

Deepan Balakrishnan*, Joel Yeo, Justin Ong Jun Kiat, See Wee Chee, Michel Bosman, Utkur Mirsaidov, Duane Loh (National University of Singapore)
2:00pm – 2:15pm

Nano-scale 3D imaging is critical for obtaining information about complex and intricate nanostructures. Though transmission electron microscopes (TEM) are the most prominent tool to investigate materials at the nano-scale resolution, they are predominantly used for 2D measurements. Electron tomography can provide a 3D volumetric reconstruction of the specimen from a tilt series, but it is slow and unsuitable for extended specimens due to the missing wedge problem. Here we present pop-out 3D metrology, a computational imaging method that enables non-tomographic 3D imaging from a single energy-filtered 2D micrograph by utilising the coherent interference that encodes the depth information of the specimen. The method can be employed for fast in-situ inline process control and defect detection in nanofabrication of 3D devices over extended surfaces without physically sectioning or fracturing the sample as in critical dimension metrology. Utilising just a single frame (2D image) and applicable to a wide range of specimens, this method has the potential to image millisecond dynamics with high-resolution 3D structural information.

T18.24 Noisy Quantum Convolutional Neural Network

Zeyu Fan*, Jonathan Wei Zhong Lau*, Leong Chuan Kwek* (Centre for Quantum Technologies)
2:15pm – 2:30pm

Neural networks is a machine learning technique based on the architecture of neurons in biological systems. Yet, it is a far cry from its original biological counterparts. Recently, convolutional quantum neural network has been extended to a quantum analogue. In this work, we seek to find whether there exist any such benefits in introducing noise to a quantum convolutional neural network.

T18.93 Probabilistic Cellular Automaton Prediction with Matrix Product Operators

Heitor Casagrande*, Xing Bo, Dario Poletti* (Singapore University of Technology and Design)

2:30pm – 2:45pm

Tensor Networks hold great computing power. Over the years, many techniques have been developed to leverage this power in order to process and study many different phenomena, being particularly well fit to ground-state search and time evolution of many body systems. One recent application is the usage of Matrix Product Operators to perform sequence-to-sequence learning. It has been previously demonstrated that such a framework is fitting for learning Deterministic Cellular Automata dynamics in 1D. In this work, we expand this previous work for Probabilistic Cellular Automata dynamics. We show that, despite the increased complexity, one can reproduce the statistics of Classical Probabilistic Cellular Automata that comprise combinations of deterministic local rules.

T18.126 Topological Classification of Topological Gapped Systems via Machine Learning

Yang Long*, Baile Zhang* (Nanyang Technological University)
2:45pm – 3:00pm

A remarkable breakthrough in the classification of topological phases is the development of the topological periodic table, which is primarily based on classifying space analysis or K theory, rather than specific Hamiltonians with finite bands or those that emerge in a lattice. Despite this advancement, identifying the topological phase of an arbitrary Hamiltonian remains challenging, and the current approach involves checking a growing list of topological invariants one by one, often through trial and error. In this study, we present unsupervised classifications of topological gapped systems with symmetries and demonstrate the data-driven construction of the topological periodic table without a prior knowledge of topological invariants. Our unsupervised data-driven strategy can incorporate spatial symmetries and classify phases that were previously classified as trivial. By introducing machine learning into topological phase classification, our work opens the door for intelligent exploration of new phases of topological matter.

T18.147

3:00pm – 3:15pm

T19: Quantum Information 2

Time: Thursday 28 Sept, 2:00pm; Venue: Room 4; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T19.162 Mixed-state additivity properties of magic monotones based on quantum relative entropies for single-qubit states and beyond

Roberto Rubboli*, Ryuji Takagi (Center for Quantum Technologies (CQT))
2:00pm – 2:15pm

We prove that the stabilizer fidelity is multiplicative for the tensor product of an arbitrary number of single-qubit states. We also show that the relative entropy of magic becomes additive if all the single-qubit states but one belong to a symmetry axis of the stabilizer octahedron. We extend the latter results to include all the $\alpha - z$ Rènyi relative entropy of magic. This allows us to identify a continuous set of magic monotones which are additive for single-qubit states and obtain tighter lower bounds for the overhead of probabilistic one-shot magic state distillation. Moreover, we recover some already-known results and provide a complete picture of the additivity properties for single-qubit states for a wide class of monotones based on quantum relative entropies. We also derive a closed-form expression for all single-qubit states for the stabilizer fidelity and the generalized robustness of magic. Finally, we show that all the monotones mentioned above are additive for several standard two and three-qubit states subject to depolarizing noise, for which we give closed-form expressions.

T19.163 Quantum theory in finite dimension cannot explain every general process with finite memory

Josep Lumbreras*, Marco Fanizza, Andreas Winter (Center for Quantum Technologies, National University of Singapore)
2:15pm – 2:30pm

Arguably, the largest class of stochastic processes generated by means of a finite memory consists of those that are sequences of observations produced by sequential measurements in a suitable generalized probabilistic theory (GPT). These are constructed from a finite-dimensional memory evolving under a set of possible linear maps, and with probabilities of outcomes determined by linear functions of the memory state. Examples of such models are given by classical hidden Markov processes, where the memory state is a probability distribution, and at each step it evolves according to a non-negative matrix, and hidden quantum Markov processes, where the memory state is a finite dimensional quantum state, and at each step it evolves according to a completely positive map. Here we show that the set of processes admitting a finite-dimensional explanation do not need to be explainable in terms of either classical probability or quantum mechanics. To wit, we exhibit families of processes that have a finite-dimensional explanation, defined manifestly by the dynamics of explicitly given GPT, but that do not admit a quantum, and therefore not even classical, explanation in finite dimension. Furthermore, we present a family of quantum processes on qubits and qutrits that do not admit a classical finite-dimensional realization, which includes examples introduced earlier by Fox, Rubin, Dharmadikari and Nadkarni as functions of infinite dimensional Markov chains, and lower bound the size of the memory of a classical model realizing a noisy version of the qubit processes.

T19.72 Characterization of Quantum Stochastic Process Modeling Complexity and Beyond

Andrew Tanggara*, Kelvin Onggadinata, Mile Gu, Dagomir Kaszlikowski (Centre for Quantum Technologies)
2:30pm – 2:45pm

Time-series data analysis has been an indispensable part of the sciences that allows one to interpret and predict both natural and social phenomenons. In these endeavours, one often mathematically describes the source a time-series data as a stochastic processes which in turn can be modeled using a Hidden Markov Model (HMM). Thus, the analysis of how much an HMM has to retain to perform this task is of great importance in practical terms as well as interesting in its own rights, both physically and information theoretically. It has been shown that quantum HMMs can be simpler than any classical model, whereas beyond-quantum HMMs can be even simpler than their quantum counterpart. But one left with the question: How are these classical - quantum and quantum - beyond quantum separations can be characterized? Is there any underlying physical or information-theoretic principle bounding the complexity of HMMs in these different physical theories? In this talk, I'm going to give an (perhaps, incomplete) overview of characterizations both model-specific and intrinsic to a given stochastic process that bounds the complexity of an HMM.For a simple stochastic process, we propose an HMM that is parameterized by the distinguishability between its internal states such that one may obtain classical, quantum, or beyond-quantum models by tuning its parameter. Using this model, one is able to observe the reduction of its complexity as this parameter is tuned towards more non-classical end of the spectrum. At the same time, as it gets more non-classical one may also observe the increase of negativity in the model's quasi-probabilistic representation, which may be thought as a quantifier of non-classicality.When restricted to the quantum regime of the parameter, it can be shown that simplest model in that regime is precisely the quantum model known to be optimal in a previous work. Whereas, when tuned to beyond-quantum regime, its features can be interpreted physically using known results on complete-positivity of quantum channels. Finally, I'm going to discuss possible generalization of this parameterized HMM to all stochastic process.

T19.66 Maximal intrinsic randomness of a quantum state

Shuyang Meng*, Fionnuala Curran, Gabriel Ignacio Senno, Victoria J. Wright, Máté Farkas, Valerio Scarani, Antonio Acin (National University of Singapore)
2:45pm – 3:00pm

One of the most counterintuitive aspects of quantum theory is its claim that there is 'intrinsic' randomness in the physical world. Quantum information science has greatly progressed in the study of intrinsic, or secret, quantum randomness in the past decade. With much emphasis on device-independent and semi-device-independent bounds, one of the most basic questions has escaped attention: how much intrinsic randomness can be extracted from a given state ρ, and what measurements achieve this bound? We answer this question for two different randomness quantifiers: the conditional min-entropy and the conditional von Neumann entropy. For the former, we solve the min-max problem of finding the measurement that minimizes the maximal guessing probability of an eavesdropper. The result is that one can guarantee an amount of conditional min-entropy $H^*_{min} = -\log_2 P^*_{guess}(\rho)$ with $P^*_{guess}(\rho) = (tr\sqrt{\rho})^2/d$ by performing suitable projective measurements. For the latter, we find that its maximal value is $H^* = \log_2 d - S(\rho)$, with$S(\rho)$ the von Neumann entropy of ρ. Optimal values for H^*_{min} and H^* are achieved by measuring in any basis that is unbiased with respect to the eigenbasis of ρ, as well as by other less intuitive measurements.

T19.124 Resource Theories and Noise Reduction

Graeme Berk*, Simon Milz, Felix Pollock, Kavan Modi (Nanyang Technological University)
3:00pm – 3:15pm

Despite the brisk pace of progress on physical substrates for quantum information, there remains little prospect of truly isolating the system of interest from its noisy environment. As such, it is imperative to ensure that quantum quantum information can safely coexist with environmental noise. Thankfully, there exist a wealth of methodologies aiming to tackle this problem. Dynamical decoupling is one such example, where a fixed sequence of unitaries is rapidly repeated to ‘average away’ the influence of the environment. Another more complex method is quantum error correction, which requires syndrome measurements on ancillary qubits and corresponding feedback control.

As much promise as these techniques show, we are still far from fault tolerance, and greatly more quantum volume is required to reap the potential of quantum computing. Are these techniques are optimally leveraging the existing quantum hardware, or are there are untapped resources that can be utilised to improve noise reduction? How far can noise reduction via active interventions ultimately be taken? Quantum resource theories have addressed analogous questions before, which would lead one to hope that their tools can be applied to noise reduction too.

Building upon recent developments on dynamical resource theories, we present resource theories of temporal resolution which treat multitime quantum processes as resource objects. The resource transformations consist of experimental control and — crucially for noise reduction — a notion of temporal coarse graining. Using this framework, we can understand dynamical decoupling as a resource distillation task, but from temporal subsystems of the many-body Choi state of a process tensor, into the two-body Choi state of a quantum channel. Non-Markovianity is identified as a monotone in this resource theory, and we devise a new SDP-based noise reduction method to produce optimised pulse sequences that account for multitime non-Markovianity. Our numerical simulations with a prototypical noise model show that a more efficient consumption of multitime non-Markovianity via this method results in significantly improved noise reduction, compared to traditional methods.

Conversely to the case of dynamical decoupling, quantum error correction can be seen as a distillation task for spatial subsystems, from physical qubits to logical qubits. However, the most general resource theoretic noise reduction task is spatiotemporal resource distillation which harnesses both effects simultaneously. We explore upper bounds on asymptotic performance at this task, which — with significant assumptions and limitations — roughly corresponds to bounds on the ratio of physical and logical qubits in a quantum computer at scale.

T19.60 Maxwell's Demon walks into Wall Street: Stochastic Thermodynamics meets Expected Utility Theory

Andres F. Ducuara, Paul Skrzypczyk, Francesco Buscemi, Peter Sidajaya, Valerio Scarani* (National University of Singapore)
3:15pm – 3:30pm

The interplay between thermodynamics and information theory has a long history, but its quantitative manifestations are still being explored. We import tools from expected utility theory from economics into stochastic thermodynamics. We prove that, in a process obeying Crooks' fluctuation relations, every α Rényi divergence between the forward process and its reverse has the operational meaning of the "certainty equivalent" of dissipated work (or, more generally, of entropy production) for a player with risk aversion $r = \alpha - 1$. The two known cases $\alpha = 1$ and $\alpha = \infty$ are recovered and receive the new interpretation of being associated to a risk-neutral and an extreme risk-averse player respectively. Among the new results, the condition for $\alpha = 0$ describes the behavior of a risk-seeking player willing to bet on the transient violations of the second law. Our approach further leads to a generalized Jarzynski equality, and generalizes to a broader class of statistical divergences.

T19.21 Negativity as a resource for memory reduction in stochastic process modelling

Kelvin Onggadinata*, Andrew Tanggara*, Dagomir Kaszlikowski* (National University of Singapore)
3:30pm – 3:45pm

Finding the most efficient model for stochastic processes is an important and ubiquitous task in the field of quantitative sciences. The most used framework is the hidden Markov model (HMM), which consists of internal states and transition probabilities that emulate the statistics of the given stochastic process that it models. The best classical HMM, known as epsilon-machine, has been shown to be the unique model with the least amount of memory, as quantified by statistical complexity — an entropic-based measure of HMM's stationary distribution. In the last decade, many works have shown that one can reduce the memory requirement further by encoding the states into a quantum system called the q-machine. Despite the additional memory advantage, such models are still unable to reach the absolute lower bound for the memory, known as the excess entropy. Models that generate accurate stochastic process' statistics with minimal memory are known as ideal models, and the question on how to construct one is an interesting problem to study from an information-theoretical and physical standpoints.

In this work, we provide a general protocol to construct such ideal model, referred here as n-machine, by relaxing the positivity of HMM, i.e., allowing negative probability (or quasiprobability) in its transitions. Recently, there has been substantial work in showing that quasiprobability is an unavoidable feature in quantum and generalized probability theory (GPT) and, more importantly, has been attributed as a resource for nonclassical advantage in the field of quantum

information, computation, and communication tasks. The results obtained here provide more evidence that quasiprobability is a necessary (but not sufficient) resource in the subject of memory complexity, and we also study its relationship with the negativity of the n-machine. The protocol also provides some insights on how q-machine obtained their advantage as we observed some of the n-machine's features manifest in the q-machine as studied in its quasiprobability representation. In light of the quasi-probabilistic HMM construction, we propose the use of Renyi entropy as an alternative measure to quantify statistical complexity. In particular, we show that it still captures most of the properties satisfied by the traditional measure, and that it is well-defined and reasonable even for quasiprobability distributions. We believe that our work is valuable in the study of general theories of HMM and the distinction between classical, quantum, and post-quantum model in the setting of stochastic process modelling.

T20: Superconductivity 1

Time: Thursday 28 Sept, 2:00pm; Venue: Room 2; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T20.110 (INVITED) Electron pairing across a band intersection may create a highly conductive state

Maxim Trushin*, Liangtao Peng, Girish Sharma, Giovanni Vignale, Shaffique Adam (National University of Singapore)
2:00pm – 2:20pm

Twisted stacks of 2D materials provide an exciting opportunity to explore interacting electrons in strongly correlated regimes not accessible so far. A few different correlated electronic phase states can emerge in the same sample depending on temperature, electron density, and other parameters tunable externally [1]. Here, we report on a new electron correlated state that may emerge due to the cross-band superconducting pairing in a 2D Dirac semimetal as soon as the Dirac velocity falls down below a certain threshold [2]. The state can be seen as a conventional Fermi sea, where the empty and filled states are separated by a layer of paired electrons, playing a role of the Fermi level. The thickness of the correlated electron layer is given by a self-consistent order parameter deduced from a mean-field equation. Even though no superconducting gap opens, the electrons turn out to be immune to elastic scattering by, e.g., intrinsic disorder. Hence, the electrical resistivity is expected to demonstrate a sudden drop once the electrons transition to the state predicted. This is what has been observed recently in twisted double-bilayer graphene at some specific filling factors corresponding to high density of states at the Fermi level [3].

[1] Shen, C., Chu, Y., Wu, Q. et al. Correlated states in twisted double bilayer graphene. Nat. Phys. 16, 520-525 (2020). [2] M. Trushin, L. Peng, G. Sharma, G. Vignale, S. Adam, arXiv:2207.05974. [3] He, M., Li, Y., Cai, J. et al. Symmetry breaking in twisted double bilayer graphene. Nat. Phys. 17, 26-30 (2021).

T20.4 (INVITED) The high-temperature Nickel age of Superconductivity

Lin Er Chow*, Zhaoyang Luo, Saurav Prakash, Ariando* (Department of Physics, National University of Singapore)
2:20pm – 2:40pm

The discovery of high-temperature (high-Tc) superconductivity in cuprates four decades ago motivates intense theoretical and experimental efforts to pursue and understand the phenomenon [1]. One of the ideal routes is through a ‘twin sister’ – a cuprate analogue which mimics the electronic and structural templates of the high-Tc cuprate. Standing beside copper in the periodic table, Ni1+ in infinite-layer phase hosts 3d9 electronic structure with lifted orbital degeneracy resembles Cu^{2+} state in cuprate superconductors. Despite more than two decades of theoretical predictions [2,3], superconducting infinite-layer nickelate was only successfully synthesized in 2019 in thin film form [4]. Nevertheless, the challenging material synthesis has obscured experimental effort in understanding the nature of its low-energy excitations, correlated ground states, and electronic structures. Bulk nickelates are not superconducting with resistivity in the order of $\approx 1 - 10$ Ω.cm [5,6]. Here, by employing systematic growth and topochemical reduction optimization, we demonstrate the synthesis of high crystallinity superconducting samples with a large residual-resistivity-ratio RRR up to ≈ 13, and residual resistivities at the order of few ≈ 10 $\mu\Omega$.cm. These high crystallinity samples allow us to probe the fundamental symmetries and various ground states of the system in relation to its superconductivity. We will also briefly discuss our recent observation of rare-earth dependent gap symmetry [7], Pauli-limit violation in all directions [8], and dimensionality manipulation [9] in this newfound family of nickelates superconductors.

References: [1] J. G. Bednorz, M. Takashige, K. A. Müller, Z. Phys. B 64 (1986) 189-193 [2] T. M. Rice, Phys. Rev. B - Condens. Matter Mater. Phys. 59 (1999) 7901-7906 [3] K. W. Lee, W. E. Pickett, Phys. Rev. B - Condens. Matter Mater. Phys. 70 (2004) 1-7 [4] D. Li et. al., Nature 572 (2019) 624-627 [5] Q. Li et. al., Commun. Mater. 1, 16 (2020) [6] P. Puphal et. al., Sci. Adv. 7, 49 (2021) [7] L. E. Chow et. al., arXiv:2201.10038 [8] L. E. Chow et. al., arXiv:2204.12606 [9] L. E. Chow et. al., arXiv:2301.07606

T20.144 (INVITED) Material Science Breakthroughs in Superconducting Nanowire Single-Photon Detectors

Mariia Sidorova*, Cesare Soci (Nanyang Technological University)
2:40pm – 3:00pm

Superconducting Nanowire Single-Photon Detectors (SNSPDs) have become pivotal in both quantum communication and classical/quantum light detection, setting high standards in timing resolution, low dark counts rate, and wide spectral sensitivity up to the mid-infrared range. As these detectors find applications in cutting-edge fields such as deep-space communication and dark matter detection, their performance requirements are approaching the fundamental limits.

The capabilities of SNSPD technology, however, are constrained by the properties of superconducting materials used. Materials with low transition temperatures (e.g., NbTiN, Tc $\approx$ 10 K) offer optimal performance but require power-intensive and costly cryogenics. In contrast, materials with higher Tc (e.g., MgB_2, Tc $\approx$ 35 K) relax cooling requirements, opening new opportunities for airborne and space applications, but they lack single-photon sensitivity even in the visible range.

This talk delves into the role of material science in overcoming these limitations. We will explore a range of strategies - from manipulating the disorder to tailoring phonon and electron properties - that provide new pathways for optimizing SNSPD performance. Through a showcase of recent experimental results [1, 2], the talk will highlight how material engineering can redefine what's possible with SNSPDs, setting new performance benchmarks and expanding the range of their applications.

References: [1] M. Sidorova, A. D. Semenov, H-W. Hübers, S. Gyger, S. Steinhauer, X. Zhang, and A. Schilling, "Magnetoconductance and photoresponse properties of disordered NbTiN films," Physical Review B 104, 184514 (2021). [2] M. Sidorova, A.D. Semenov, I. Charaev, M. Gonzalez, A. Schilling, S. Gyger, S. Steinhauer "Phonon heat capacity and disorder: new opportunities for performance enhancement of superconducting devices" arXiv:2308.12090 (2023)

T20.96 Field-Effect Josephson Diode via Asymmetric Spin-Momentum Locking States

Peihao Fu*, Ching Hua Lee, Yee Sin Ang* (Singapore University of Technology and Design)
3:00pm – 3:15pm

We propose a mechanism of field-effect Josephson diode based on the electrostatic gate control of finite momentum Cooper pair. We propose a topologically protected diode with a gate-tunable efficiency of over 90%. The proposed mechanism can also be employed in semiconductor-based devices, demonstrating excellent agreement with recent experiments. These findings unveil the important role of asymmetric spin-momentum locking in achieving nonreciprocal superconducting devices and yield important light on the design of high-performance gate-reconfigurable super electronics device technology

T20.160 Optimization of NbTiN deposition for superconducting single-photon detectors

Shuyu Dong*, Filippo Martinelli*, Pierre Brosseau*, Mariia Sidorova*, Anton Vetlugin*, Darren Ming Zhi Koh*, Christian Kurtsiefer*, Cesare Soci* (Nanyang Technological University)

3:15pm – 3:30pm

Superconducting nanowire single-photon detectors (SNSPDs) are rapidly becoming the leading technology in single-photon sensing in both telecom and middle-infrared wavelengths. At the telecom range, they outperform conventionally used semiconducting detectors in key metrics such as detection efficiency, counting rate, and timing resolution. Among the different superconducting materials used for SNSPD, niobium titanium nitride (NbTiN) is preferred thanks to its high absorption coefficient at telecom wavelengths, relatively high critical temperature (10 K), and proven compatibility with a variety of photonic platforms. These unique properties make NbTiN the best candidate for achieving both high detection efficiency and exceptional timing performance in a single device. However, realizing the full potential of NbTiN material requires stringent control over film quality, which includes aspects like stoichiometric composition, surface condition, and nanofabrication. In our work, we aim to optimize NbTiN films to enhance SNSPD performance. To address the challenge of film quality, we exploit the flexibility of the reactive co-sputtering deposition technique by fine-tuning deposition conditions. As a result, our homegrown NbTiN films show good surface morphology, favorable superconducting properties, and desirable composition. SNSPD devices patterned using our homegrown films have demonstrated saturated efficiency at 532 nm, which is comparable to that of commercial devices. This work paves the way for highly efficient SNSPDs, promising advancements in several photonics applications.

T21: Plasma Physics and Fusion

Time: Friday 30 Sept, 2:00pm; Venue: Room 2; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T21.42 (KEYNOTE) Turbulence and transport at the boundary of magnetically confined fusion plasmas

Odd Erik Garcia*, Sajidah Ahmed*, Synne Brynjulfsen*, Gregor Decristoforo*, Aurora Helgeland*, Juan Losada*, Olga Paikina*, Audun Theodorsen* (UiT The Arctic University of Norway)
2:00pm – 2:25pm

The boundary region of magnetically confined plasmas is a non-equilibrium system with order unity relative fluctuation level of plasma parameters, broad radial profiles and high particle density and pressure at the main chamber wall. This may have numerous detrimental effects on future fusion power reactors, including enhanced erosion of wall material, impacting auxiliary heating and plasma control by electromagnetic waves, control of divertor detachment and exhaust mitigation, and likely underlies the empirical density disruption limit.

Experimental measurements have demonstrated that the fluctuations in the boundary are due to radially outwards motion of blob-like plasma filaments. These structures are elongated along the magnetic field lines and localized in the plane perpendicular to the magnetic field. The average profiles and their fluctuations are determined by the blob size, velocity, amplitude and frequency of occurrence. In order to predict the role of turbulence and fluctuations in the boundary region, it is thus necessary to clarify the relation between these quantities, their statistical distributions and their dependence on plasma and device parameters.

Recently, the fluctuations have been shown to possess universal statistical properties across plasma parameters, confinement regimes and devices. This includes the shape of large-amplitude fluctuations, their probability distribution function, frequency power spectral density and rate of level crossings. The intermittent fluctuations are well described as a super-position of uncorrelated pulses with fixed shape, describing the presence of broad profiles and predicting threshold phenomena such as sputtering.

This presentation will give a review of recent progress on turbulence and fluctuation-induced transport in the scrape-off layer of fusion plasmas, comprising experimental measurements, modelling and numerical simulations.

T21.73 Beam model of Doppler backscattering

Valerian Hall-Chen*, Felix Parra, Jon Hillesheim (Institute of High Performance Computing, A*STAR, Singapore 138632, Singapore)
2:25pm – 2:40pm

We use beam tracing—implemented with a newly-written code, Scotty—and the reciprocity theorem to derive a model for the linear backscattered power of the Doppler backscattering (DBS) diagnostic. Our model works for both the O-mode and X-mode in tokamak geometry (and certain regimes of stellarators). We present the analytical derivation of our model and its implications for the DBS signal localisation and the wavenumber resolution. In determining these two quantities, we find that it is the curvature of the field lines and the magnetic shear that are important, rather than the curvature of the cut-off surface. We also provide an explicit formula for the hitherto poorly-understood quantitative effect of the mismatch angle. Consequently, one can use this model to correct for attenuation due to mismatch, avoiding the need for empirical optimisation. This is especially important in spherical tokamaks, since the magnetic pitch angle is large and varies both spatially and temporally

T21.75 Analytic instrumentation function of X-mode Doppler backscattering in slab geometry

James Winston Tumbokon*, Valerian Hall-Chen*, Juan Ruiz Ruiz* (Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3PU, UK)
2:40pm – 2:55pm

Microwave diagnostics are a robust way of measuring fusion plasmas. Interpreting data from such diagnostics requires determining their electric field as they propagate through the plasmas. Full wave solutions are complicated to solve, so we use a geometrically reduced model to find insights on how a wave beam interacts as it travels through a plasma. We find solutions to the beam tracing equations as formulated in [Hall-Chen, PPCF, 2022] for a slab geometry. Here, we solve for the X-mode case. We present results on the instrumentation function of the Doppler backscattering diagnostic, which is typically used to measure turbulence and flows.

T21.23 Flow generation in tokamak plasmas

Robin Varennes*, Laure Vermare*, Xavier Garbet* (Nanyang Technological University)
2:55pm – 3:10pm

One of the main obstacles to achieve commercial nuclear fusion reactors with tokamaks is energy confinement. Indeed, extreme thermodynamical gradients are responsible for heat turbulent transport that diffuses energy outside of the vessel, preventing access to the required fusion temperatures. An elegant way to regulate and control the turbulence is through plasma flows, i.e. by pumping turbulent energy or by shearing turbulent structures that lead to a reduction of the resulting transport. However, the physics behind the generation of these flows, even in the absence of external momentum input, remains opaque. In the core, while the generation of flows is known to arise from both collisional processes and turbulence itself, their interplay and primary control parameters remain an active research topic. To tackle this challenge, a kinetic approach is essential for an accurate description. This study focuses on the interplay between collisional processes and turbulence using gyrokinetic simulations, using the code GYSELA [1], that are able to describe turbulence driven by ion temperature gradient and collisional processes self-consistently. Our approach to investigate the flows resulting from this mixed-physics is to manipulate the collisional processes' strength. To achieve this, the idea is to play with the inhomogeneity of the magnetic configuration that modifies the velocity distribution of particles and thus the way collisions modify trajectories. In this work, two operational relevant parameters involved in the magnetic configuration are considered. The first one is the modulation of the magnetic field caused by the finite number of coils, called "ripple". By varying the ripple amplitude in turbulent simulations, it appears that a competition occurs between the friction induced by collisions and the viscosity resulting from turbulence [2] for the control of the flow. Furthermore, this work reveals that the ripple exerts a significant influence on the turbulent momentum source carried by the Reynolds stress. The second parameter of interest is the safety factor, which is a proxy for the winding rate of magnetic field lines. Experimentally, it is observed in the Tore Supra and WEST [3] tokamaks that reducing the safety factor results in an enhanced edge flow velocity. This is explained by the collisional friction that damps the turbulent source at high safety factor, explaining the enhanced velocity at low safety factor values [4]. This study highlights some intricate interplay mechanisms between collisional processes and turbulence, providing valuable insights for turbulence control in tokamaks.

[1] V. Grandgirard et al., Computer Physics Communications 207, 35 (2016). [2] R. Varennes et al., Physical Review Letters 128, 255002 (2022). [3] L. Vermare et al., Nuclear Fusion 62, 026002 (2021). [4] R. Varennes et al., in prep., .

T21.19 Analysis of low-n Toroidal Alfven Eigenmodes using gKPSP

Youngwoo Cho*, Jaemin Kwon, Kimin Kim (Nanyang Technological University)
3:10pm – 3:25pm

We report a benchmark study of toroidal Alfven eigenmode (TAE) simulation) using the hybrid-gyrokinetic code GyroKinetic Plasma Simulation Program (gKPSP). A simulation capability for energetic particles based on the gyrokinetic delta f method has been newly implemeted in gKPSP code. Benchmark simulations have been performed in both circular and realistic tokamak geometries. Good agreement has been found with previously reported results, demonstrating the new capability of the gKPSP code. We have investigated the effects of the distribution function on TAE stabililty by examining isotropic slowing-down distribution of energetic particles. The slowing-down distribution produces a higher linear growth rate than a Maxwellian distribution. This can be attributed to competition between Landau damping and the linear drive, which are correlated with the fraction of resonant passing particles and their distribution in phase space. We also investigate the TAE measured at KSTAR experiment using gKPSP. The linear characteristics of TAE estimated from gKPSP simulation show good agreement with those from the KSTAR experiment.

T22: Many Body Physics

Time: Friday 30 Sept, 2:00pm; Venue: Room 1; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T22.16 (INVITED) Superconductivity with Wannier-Stark Flat Bands

Si Min Chan*, Alexei Andreanov, Sergej Flach, George Batrouni (National University of Singapore)
2:00pm – 2:20pm

We investigate superconducting transport in the DC field induced Wannier-Stark flat bands in the presence of interactions. Flat bands offer the possibility of unconventional high temperature superconductivity, where the superfluid weight is enhanced by the density overlap of the localized states. However, construction of flat bands typically requires very precise tuning of Hamiltonian parameters. To overcome this difficulty, we propose a feasible alternative to realize flat bands by applying a DC field in a commensurate lattice direction. We systematically characterize the superconducting behavior on these flat bands by studying the effect of the DC field and attractive Hubbard interaction strengths on the wavefunction, correlation length, pairing order parameter and the superfluid weight. In particular, we find that the superfluid weight is dramatically enhanced at an optimal value of the interaction strength and weak DC fields.

T22.71 Novel Spin-Correlated Plasmon in Novel Highly Oriented Single-Crystalline Gold Quantum Dots

Bin Leong Ong, Muhammad Avicenna Naradipa*, Angga Dito Fauzi, Muhammad Aziz Majidi, Caozheng Diao, Satoshi Kurumi, Pranab Kumar Das, Chi Xiao, Ping Yang, Mark B. H. Breese, Sheau Wei Ong, Khay Ming Tan, Eng Soon Tok, Andrivo Rusydi* (Singapore Synchrotron Light Source, National University of Singapore)
2:20pm – 2:35pm

Spin plasmons are a collective mode of spin-density that was proposed since the 1930s. By confining the photon energy in the subwavelength scale, the combination of spintronics and plasmons are realized through nanoscale single magnetic-domains in the quest for device miniaturization. However, spin plasmon in strongly correlated electron systems is yet to be realized. Herein, we present a new spin correlated-plasmon at room temperature in novel Mott-like insulating highly oriented single-crystalline gold quantum-dots (HOSG-QDs). Interestingly, the spin correlated-plasmon is tunable from the infrared to visible, accompanied by spectral weight transfer yielding a large quantum absorption midgap state, disappearance of low-energy Drude response, and transparency. Supported with theoretical calculations, spin-correlated plasmons are realized throughinterplay of surprisingly strong electron-electron correlations, s-p hybridization and quantum confinement in the s band. Furthermore, we present the first demonstration of the highly sensitive spin correlated-plasmon application in surface-enhanced Raman spectroscopy.

T22.145 Kondo effect in superconductivity without inversion symmetry

Shangjian Jin*, Darryl Foo, Shaffique Adam* (Centre for Advanced 2D Materials, National University of Singapore)

2:35pm – 2:50pm

We investigate the behavior of Kondo effect in superconductors (SC) without inversion symmetry. To study the competition between Kondo effect and superconductivity, we build a periodic Anderson model (PAM) with an antisymmetric spin-orbital coupling. By solving the linearlized gap equations, we calculate the singlet and triplet superconducting critical temperatures. A Kondo region with finite resistance below the SC transition temperature Tc is predicted. As expected, Kondo hybridization enhances the Kondo transition TK but reduces the SC critical temperature Tc. While the magnetic field suppresses the singlet superconductivity, it stabilizes the triplet SC by screening out magnetic impurities, causing a reentrant superconductivity at high field. However, the precence of antisymmetric spin-orbital coupling will suppress the triplet superconductivity and lead to an upper critical field. Our results offer a comprehensive understanding of superconducting phase diagrams of heavy fermion superconductor UTe_2 and Co doped $NbSe_2$.

T22.10 Excitonic near resonance-enhancement of shift currents in monolayer $NbOCl_2$

Mingrui Lai*, Su Ying Quek, Fengyuan Xuan (Center for Advanced 2D Materials)

2:50pm – 3:05pm

The shift current is a static nonlinear photocurrent exhibited by crystals lacking center-of-inversion symmetry. Such photocurrents have been widely studied for their potential photovoltaic applications and can go beyond the Shockley-Queisser limit. As such, an accurate theoretical description of the phenomenon is essential for material design. Density functional theory is often utilized in first principles calculations of the shift current, treating the electrons independently. In 2D materials however, the reduced screening results in signficant many-body interactions and photo-excitations are more accurately described with excitons. We have developed a theoretical framework which captures these excitonic effects using many-body perturbation theory within the nonlinear optical response. We derive an expression for the exciton shift current from the static nonlinear response. The many-body excited states are obtained using the GW-BSE formalism by solving the Bethe- Salpeter Equation with quasi-particle energies. Using the many-body excited states, we then compute the excitonic shift current. We show that there is a large enhancement in the shift curent when considering many-body interactions, mainly due to the near-resonance condition between two near-degenerate excited states.

T22.112 Deconfined quantum criticality in one dimensional electrons

Jon Spalding*, Pinaki Sengupta (Nanyang Technological University)

3:05pm – 3:20pm

The Landau-Ginzburg-Wilson symmetry-breaking description of phase transitions is based on classical thermal phase transitions and underlies theoretical descriptions across physics. Although this paradigm has been successful in describing many quantum phase transitions, violations included phase transitions in interacting spin models and electron models at low temperatures wherein one order transforms continuously into another order by tuning an interaction parameter. In this talk we discuss new results for one of the original examples of a one-dimensional system of interacting electrons that exhibits a continuous transition between two different ordered phases.

T22.54 Unravelling a new many-body large-hole polaron in a transition metal oxide that promotes high photocatalytic activity

Xiao Chi*, Andrivo Rusydi*, Ping Kian Loh Kian Loh*, Lily Mandal, Liu Cuibo, Thomas J. Whitcher, Yu Xiaojiang* (National University of Singapore)
3:20pm – 3:35pm

A many-body large polaron, which is important for both fundamental physics and technological applications, has been predicted to occur in bismuth vanadate ($BiVO_4$). Herein, using a combination of high-resolution spectroscopic ellipsometry, X-ray absorption spectroscopy at the V L3,2- and O K-edges, and high-resolution X-ray diffraction supported by theoretical calculations, we reveal a new many-body large-hole polaron in W-doped $BiVO_4$ films and the interplay of the large-hole polaron and indirect bandgap when determining the photocatalytic activity. With various W doping concentrations and temperatures, anomalous spectral weight transfers in the complex dielectric function are observed, revealing electronic correlations, particularly the on-site Coulomb interactions of O p (Upp) and V d (Udd), and screening in $BiVO_4$. Due to the distortion of BiO8 dodecahedra and Udd, Bi 6s is lifted to the top of the valance band, which results in the formation of an indirect bandgap and a large-hole polaron. The large-hole polaron is found to form as a localized midgap state, consisting of O p hybridized with the V d and Bi sp orbitals, and this is important when determining the high photocatalytic activity of $BiVO_4$. Our results show the importance of the interplay among the charge, orbital, and lattice degrees of freedom in forming the many-body large-hole polaron, which improves the conductivity and results in a transition metal oxide with high photocatalytic activity.

T23: Quantum Computing

Time: Friday 30 Sept, 2:00pm; Venue: Room 3; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T23.127 Double-bracket flow quantum algorithm for diagonalization

Marek Gluza* (NTU Singapore)
2:00pm – 2:15pm

A quantum algorithm for preparing eigenstates of quantum systems is presented which makes use of only forward and backward evolutions under a prescribed Hamiltonian and phase flips. It is based on the Głazek-Wilson-Wegner flow method from condensed-matter physics or more generally double-bracket flows considered in dynamical systems. The phase flips are used to implement a dephasing of off-diagonal interaction terms and evolution reversal is employed for the quantum computer to approximate the group commutator needed for unitary propagation under the double-bracket generator of the diagonalizing flow. The presented algorithm is recursive and involves no qubit overheads. Its efficacy for near-term quantum devices is discussed using numerical examples. In particular, variational double-bracket flow generators, optimized flow step durations and heuristics for pinching via efficient unitary mixing approximations are considered. More broadly, this work opens a pathway for constructing purposeful quantum algorithms based on double-bracket flows also for tasks different from diagonalization and thus enlarges the quantum computing toolkit geared towards practical physics problems.

T23.36 Tailoring Non-Stabilizer Simulations for Analyzing Fault-Tolerant Error-Correction Codes

Mark Bryan Myers II*, Hui Khoon Ng, Mariesa Teo, Jing Hao Chai (Centre for Quantum Technologies)
2:15pm – 2:30pm

As quantum devices emerge with increasing qubit counts, implementations with fault-tolerant quantum error correction (FTQEC) are of particular significance; however, such systems are challenging to verify and validate due to difficulties associated with simulating large systems under the effects of realistic noise. We aim to expand the understanding of quasi-probabilistic methods, for simulating non-stabilizer noise in quantum circuits, by investigating the method in the context of FTQEC simulations. We were able to achieve improved simulation efficiency, by tailoring the method using domain knowledge, which we found to be consistent across the various non-unitary and unitary noise channels we investigated.

T23.33 Approaching optimal entangling collective measurements on quantum computing platforms

Lorcan Conlon* (Agency for Science Technology and Research)
2:30pm – 2:45pm

Entanglement is a fundamental feature of quantum mechanics and holds great promise for enhancing metrology and communications. Much of the focus of quantum metrology so far has been on generating highly entangled quantum states that offer better sensitivity, per resource, than what can be achieved classically. However, to reach the ultimate limits in multi-parameter quantum metrology and quantum information processing tasks, collective measurements, which generate entanglement between multiple copies of the quantum state, are necessary. Here, we experimentally demonstrate theoretically optimal single- and two-copy collective measurements for simultaneously estimating two non-commuting qubit rotations. This allows us to implement quantum-enhanced sensing, for which the metrological gain persists for high levels of decoherence, and to draw fundamental insights about the interpretation of the uncertainty principle. We implement our optimal measurements on superconducting, trapped-ion and photonic systems, providing an indication of how future quantum-enhanced sensing networks may look.

T23.17 Quantum Algorithm for the Preparation of Highly Excited Eigenstates with Spectral Transforms

Shao Hen Chiew*, Leong Chuan Kwek (CQT, National University of Singapore, Entropica Labs)
2:45pm – 3:00pm

We propose a natural application of Quantum Linear Systems Problem (QLSP) solvers such as the HHL algorithm to efficiently prepare highly excited interior eigenstates of physical Hamiltonians in a variational manner. This is enabled by both the efficient representation of physical eigenstates on quantum computers and the efficient computation of inverse expectation values due to the QLSP solvers' exponentially better scaling in problem size. The usage of the QLSP solver in this context does not conceal exponentially costly pre/post-processing steps that usually accompanies it in generic linear algebraic applications. We detail implementations of this scheme for both fault-tolerant and near-term quantum computers, analyze their efficiency and implementability, and detail conditions under which it is advantageous over existing quantum and classical approaches. Simulation results for applications in many-body physics and quantum chemistry further demonstrate its effectiveness and scalability over existing approaches.

T23.167 Multi-Objective Optimization and Network Routing with Near-Term Quantum Computers

Shao Hen Chiew*, Kilian Poirier*, Ulrike Bornheimer, Rajesh Mishra, Ewan Munro, Si Han Foon, Christopher Wanru Chen, Wei Sheng Lim, Chee Wei Nga (Entropica Labs)
3:00pm – 3:15pm

Multi-objective optimization is a ubiquitous problem that arises naturally in many scientific and industrial areas. Network routing optimization with multi-objective performance demands falls into this problem class, and finding good quality solutions at large scales is generally challenging. In this work, we develop a scheme with which near-term quantum computers can be applied to solve multi-objective combinatorial optimization problems. We study the application of this scheme to the network routing problem in detail, by first mapping it to the multi-objective shortest path problem. Focusing on an implementation based on the quantum approximate optimization algorithm (QAOA) – the go-to approach for tackling optimization problems on near-term quantum computers – we examine the Pareto plot that results from the scheme, and qualitatively analyze its ability to produce Pareto-optimal solutions. We further provide theoretical and numerical scaling analyses of the resource requirements and performance of QAOA, and identify key challenges associated with this approach. Finally, through Amazon Braket we execute small-scale implementations of our scheme on the IonQ Harmony 11-qubit quantum computer.

T23.6 Characterization of 4T-period time crystal on a NISQ-era quantum processor

Tianqi Chen*, Ruizhe Shen*, Bo Yang, Ching Hua Lee*, Raditya Bomantara* (King Fahd University of Petroleum and Minerals)
3:15pm – 3:30pm

Time crystals, a kind of novel phase of matter which scientists have been striving to chase after, has received tremendous attention in recent years [1-4]. It spontaneously breaks time-translation symmetry which is obeyed by other matter in our day life at thermal equilibrium, such as gas, water, and ice, and it maintains the order in a constantly excited state with doubling of the driving period T. Most recently, it is claimed that time crystal has been experimentally realized on a superconducting quantum circuit by Google [5], as well as in a nuclear spin diamond system [6].

However, so far it remains unclear whether the higher order of period doubling could be realized and captured on a NISQ-era quantum processor. In this work, we propose a method on the implementation of the time evolution quantum circuit which could exhibit clear 4T-period time crystal behavior. By combining the variational quantum algorithm for quantum circuit recompilation [7-11], the Floquet time evolution is transformed to a target circuit. Compared with the conventional Suzuki-Trotter decomposition approach, our method has a much shallower circuit depth with much less CNOT gates, which is suitable for the current NISQ-era device of which the qubit error is inevitable. The 4T-period time crystal signature is therefore captured on an IBM Q quantum device, and has also been benchmarked using both the state-of-art matrix product states (MPS) for larger system size. Finally, the robustness of the 4T-period time crystal is also discussed.

References: 1. Wilczek, Frank. ”Quantum time crystals.” Physical review letters 109.16 (2012): 160401. 2. Bruno, Patrick. ”Impossibility of spontaneously rotating time crystals: a no-go theorem.” Physical review letters 111.7 (2013): 070402. 3. Watanabe, Haruki, and Masaki Oshikawa. ”Absence of quantum time crystals.” Physical review letters 114.25 (2015): 251603. 4. Sacha, Krzysztof, and Jakub Zakrzewski. ”Time crystals: a review.” Reports on Progress in Physics 81.1 (2017): 016401. 5. Zhang, Jiehang, et al. ”Observation of a discrete time crystal.” Nature 543.7644 (2017): 217-220. 6. Randall, J., et al. ”Many-body–localized discrete time crystal with a programmable spin-based quantum simulator.” Science 374.6574 (2021): 1474-1478. 7. Koh, Jin Ming, et al. ”Stabilizing multiple topological fermions on a quantum computer.” npj Quantum Information 8.1 (2022): 16. 8. Koh, Jin Ming, Tommy Tai, and Ching Hua Lee. ”Simulation of interaction-induced chiral topological dynamics on a digital quantum computer.” Physical Review Letters 129.14 (2022): 140502. 9. Koh, Jin Ming, Tommy Tai, and Ching Hua Lee. ”Observation of higher-order topological states on a quantum computer.” arXiv preprint arXiv:2303.02179 (2023). 10. Chen, Tianqi, et al. ”High-fidelity realization of the AKLT state on a NISQ-era quantum processor.” arXiv preprint arXiv:2210.13840 (2022).

11. McArdle, Sam, et al. ”Variational ansatz-based quantum simulation of imaginary time evolution.” npj Quantum Information 5.1 (2019): 75.

T24: Quantum Optics

Time: Friday 30 Sept, 2:00pm; Venue: Room 4; Chair:
Time allocated for keynote/invited talks is 20/15 min speaking time, plus 5 min Q&A, and time allocated for contributed talks is 12 min speaking time plus 3 minutes Q&A.

T24.78 (INVITED) Fiberized nonlinear interferometry for greenhouse gas sensing

Thomas Produit, Tanmoy Chakraborty, Ang Deng, Wonkeun Chang, Anna Paterova* (Institute of Material Research and Engineering, A*STAR)
2:00pm – 2:20pm

Infrared (IR) spectroscopy is an important tool for material characterization, biomedical and gas sensing applications. Conventional IR spectroscopy techniques use IR point detectors, which however suffer from strong background noise. An alternative to the schemes with the direct detection of IR light is using a nonlinear interferometry technique, which allows inferring the IR properties of a specimen from the detection of visible/near-IR (NIR) light. IR spectroscopy with the detection of visible/NIR light was demonstrated in earlier studies. However, in those schemes the short optical path of the IR light through the medium under study limited the sensitivity of the method. Here, we introduce a modified configuration of the nonlinear interferometry scheme, in which the optical path of the probing IR light is extended via using the hollow core fiber (HCF).

T24.14 Repeated Gamma Irradiation and Thermal Annealing via Built-In Thermo-electric Coolers of Si Avalanche Photodiodes

Shuin Jian Wu*, Moe Thar Soe, Alexander Ling (Centre for Quantum Technologies)
2:20pm – 2:35pm

This work reports that thermal annealing silicon avalanche photodiodes mitigates damage from repeated gamma radiation by: (1) halving the increase in dark counts on average and (2) outperforming room temperature (25°C) annealing by about 33%.

T24.43 (INVITED) Parametric wavelength conversion in etchless thin-film lithium niobate waveguides

Xiaodong Shi*, Sakthi Mohanraj, Veerendra Dhyani, Sihao Wang, Angela Baiju, Victor Leong, Di Zhu* (Institute of Materials Research and Engineering, A*STAR)
2:35pm – 2:55pm

Parametric wavelength conversion is a nonlinear process that allows coherent generation and conversion of optical wavelengths. It plays important roles in applications such as quantum networks and mid-IR sensing. Here, we demonstrate a fabrication-friendly approach to achieve efficient parametric wavelength conversion on thin-film lithium niobate (TFLN), a burgeoning integrated photonic platform renowned for its high second-order nonlinearity. In contrast to conventional ridge waveguides that rely on abrupt index contrasts created by direct etching, we simply use electron-beam resists to form loaded waveguides on top of flat TFLN. Despite having a low refractive index, the loading material creates an effective photonic potential that is sufficient for waveguiding while keeping the optical mode mostly confined within TFLN. We tailored the waveguide dimensions and applied carefully designed periodic poling on the TFLN waveguides to achieve quasi-phase-matched three-wave mixing involving telecom C-band, O-band, and visible-wavelength light. We fabricated the etchless, periodically poled TFLN and measured sum frequency generation with a normalized on-chip efficiency of 920% $W^{-1}cm^{-2}$. Our work circumvents the challenging task of lithium niobate etching and can be used for on-chip quantum frequency conversion, parametric amplification, and photon-pair generation.

T24.63 12.6 dB squeezed light at 1550 nm from a bow-tie cavity for long-term high duty cycle operation

Biveen Shajilal*, Oliver Thearle, Aaron Tranter, Yuerui Lu, Elanor Huntington, Syed Assad, Ping Koy Lam, Jiri Janousek (IMRE, ASTAR)
2:55pm – 3:10pm

Squeezed states are an interesting class of quantum states that have numerous applications. This work presents the design, characterisation, and operation of a bow-tie optical parametric amplifier (OPA) for squeezed vacuum generation. We report the high duty cycle operation and long-term stability of the system that makes it suitable for post-selection based continuous-variable quantum information protocols, cluster-state quantum computing, quantum metrology, and potentially gravitational wave detectors. Over a 50 hour continuous operation, the measured squeezing levels were greater than 10 dB with a duty cycle of 96.6%. Alternatively, in a different mode of operation, the squeezer can also operate 10 dB below the quantum noise limit over a 12 hour period with no relocks, with an average squeezing of 11.9 dB. We also measured a maximum squeezing level of 12.6 dB at 1550 nm. This represents one of the best reported squeezing results at 1550 nm to date for a bow-tie cavity. We discuss the design aspects of the experiment that contribute to the overall stability, reliability, and longevity of the OPA, along with the automated locking schemes and different modes of operation.

T24.69 Efficient photon-pair generation in thin-film periodically poled lithium niobate waveguides

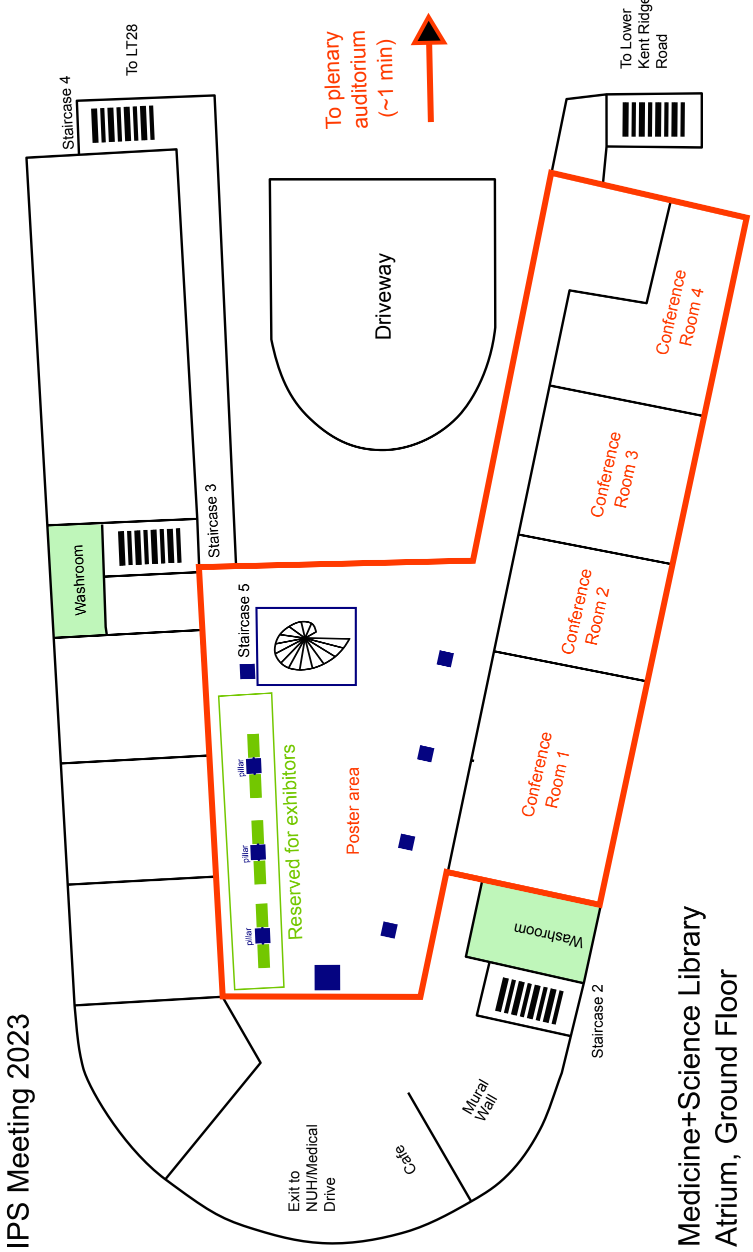
Sihao Wang, Xiaodong Shi, Veerendra Dhyani, Sakthi Sanjeev Mohanraj, Angela Anna Baiju, Anna Paterova, Victor Leong, Di Zhu* (Institute of Materials Research and Engineering, Agency for Science Technology and Research (A*STAR), Singapore)
3:10pm – 3:25pm

Thin-film lithium niobate has emerged as one of the leading platforms for integrated quantum photonics. In this work, we present the design, fabrication, and measurement of periodically poled thin-film lithium niobate as a photon-pair source based on spontaneous parametric down conversion through quasi-phase matching. By uniformly poling a 5-mm long half-etched waveguide, we achieved a high on-chip pair generation rate of 9.5 GHz/mW and measured a coincidence-to-accidental ratio of 1623$\pm$710 at a pump power of 100 pW. We demonstrated the single-photon nature with a heralded second-order correlation of $g_H^{(2)}(0) = 0.08 \pm 0.03$. This device can serve as a useful and scalable resource for quantum communication, networking, and computing.

(notes)

Author List

5 Location Map



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