The 10th International Workshop on

Solid-State Quantum Computing

November 29th-December 1st, 2021

Mr. & Mrs. Ho Chun Hung Lecture Theatre (LT-12)

City University of Hong Kong

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IWSSQC

Aiming to pursue excellence in the research of solid-state quantum computing and related areas, the series of IWSSQC has brought together researchers from the greater China region and overseas. The first IWSSQC was held in Nanjing (2007), and then Taipei (2008), Hong Kong (2009), Shanghai (2010), Hong Kong (2011), Beijing (2013), Nanjing (2015), Taipei (2017), and Hangzhou (2018).

The 10th IWSSQC was originally scheduled to be held in City University of Hong Kong in November 2019, but was unfortunately postponed. IWSSQC-10 will be held between November 29 and December 1, 2021 in a hybrid form. IWSSQC-10 will be a three-day workshop providing an opportunity for the international scientific community to discuss the recent experimental and theoretical developments in all aspects of solid-state implementations for quantum information processing as well as related areas. Topics covered will include, but not limited to, superconducting qubits, trapped ions, nuclear magnetic resonance, quantum dots, quantum optics, topological quantum computing, quantum algorithms and quantum sensing.

Registration:

Registration is free for all participants. Please click here for online registration, or use the link: https://bit.ly/3nh0PFe .

Attendance to face-to-face sessions is by invitation only.

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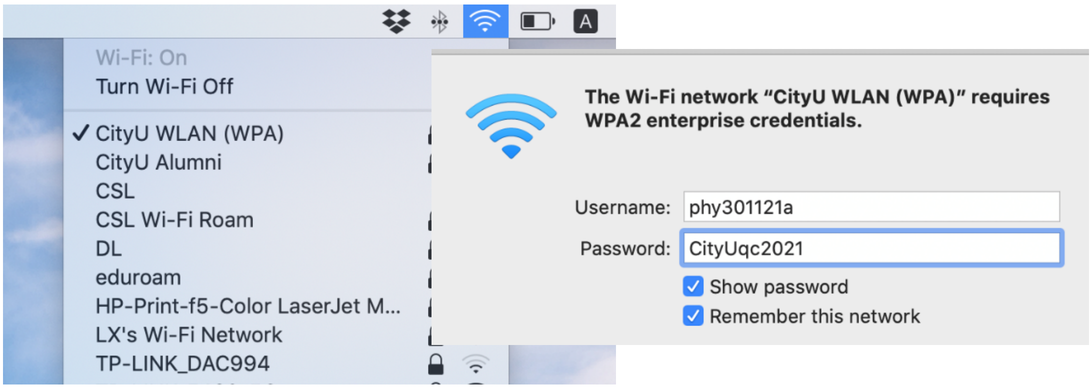

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- Simple lunch will be served to students and postdocs. However, please refrain from having lunch inside the lecture theatre.

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PROGRAM

Day 1 (Monday Nov. 29th, 2021) online only

(highlighted time indicates the speaker's local time)

14:00-14:15	Welcome & Opening Remarks **Prof. Way Kuo** **President of City University of Hong Kong**

Plenary Session

14:15-15:15 15:15 (UTC+9)	*Superconducting circuits for quantum technologies* **Yasunobu Nakamura** **RIKEN and University of Tokyo, Japan**
15:15-16:15 16:15 (UTC+9)	*Virtual photons in ultra-strongly coupled systems or quantum nonlinear optics without photons* **Franco Nori** **RIKEN, Japan and University of Michigan, USA**
16:15-17:15	*From multi-photon entanglement to quantum computational advantage* **Jianwei Pan** **University of Science and Technology of China**

Evening Session

19:00-19:30	*Deterministic loading of microwaves onto an artificial atom using a time-reversed waveform* **Io Chun Hoi** **City University of Hong Kong**
19:30-20:00	*High efficiency coherent microwave-to-optical conversion* **Hui Yan** **South China Normal University**
20:00-20:30 14:00 (UTC+2)	*Frequency estimation and resolution at the nano-scale* **Alex Retzker** **The Hebrew University of Jerusalem, Israel**
20:30-21:00 13:30 (UTC+1)	*Chiral quantum optics with giant atoms* **Anton Kockum** **Chalmers University of Technology, Sweden**
21:00-21:30 8:00 (UTC-5)	*Controlled-Z gate dynamically corrected against charge noise in Si spin qubits despite crosstalk* **Jason Kestner** **University of Maryland, Baltimore County, USA**
21:30-22:00 14:30 (UTC+1)	*Diamond technologies and complex systems* **Jorge Casanova** **University of the Basque Country, Spain**
22:00-22:30 15:00 (UTC+1)	*TBA* **Xi Chen** **University of the Basque Country, Spain**
22:30-23:00 09:30 (UTC-5)	*Noise-resistant quantum control from geometric space curves* **Edwin Barnes** **Virginia Tech, USA**
23:00-23:30 10:00 (UTC-5)	*Spin qubits in Si: the effects of valley-orbit coupling* **Xuedong Hu** **State University of New York at Buffalo, USA**

Day 2 (Tuesday Nov. 30th, 2021) hybrid sessions

Morning Session LT-12, City University of Hong Kong

9:00-9:30 17:00 NOV29 (UTC-8)	*Robust preparation of many-body ground states in Jaynes-Cummings lattices* **Lin Tian** **University of California Merced, USA**
9:30-10:00 17:30 NOV29 (UTC-8)	*Harnessing valley state in Si for fast semiconductor qubits* **Hongwen Jiang** **University of California, Los Angeles, USA**
10:00-10:30	*Quantum nonlinear spectroscopy enabled by quantum sensing* **Renbao Liu** **Chinese University of Hong Kong**
10:30-10:45	*Break and photo taking*
10:45-11:15	*Exploring quantum coherence and correlations in graphene* **Dong-Keun Ki** **University of Hong Kong**
11:15-11:45	*Study dynamics of spin bath via solid state qubits* **Sen Yang** **Hong Kong University of Science and Technology**
11:45-12:15	*Cavity-controlled quantum dynamics of complex materials* **Zhedong Zhang** **City University of Hong Kong**

Afternoon Session online

14:30-15:00 16:30 (UTC+10)	*Qubit as a quantum probe of control distortions and temperature* **Arkady Fedorov** **University of Queensland, Australia**
15:00-15:30 14:00 (UTC+7)	*Mitigating qubit dephasing from random telegraph noise using spectator qubits* **Areeya Chantasri** **Mahidol University, Thailand**
15:30-16:00 8:30 (UTC+1)	*Towards universal quantum computation with bosonic qubits encoded in superconducting cavities* **Yvonne Yuan Gao** **National University of Singapore**
16:00-16:30 17:00 (UTC+9)	*Coherent manipulation of strongly correlated electron states in GaAs quantum dots* **Dohun Kim** **Seoul National University, Korea**
16:30-17:00	*Architecture for high-fidelity two-qubit gate operation on superconducting quantum chips* **Yang Yu** **Nanjing University, China**
17:00-17:30	*High-fidelity and robust two-qubit controlled-Z gates for direct-coupling superconducting transmon qubits* **Hsi-Sheng Goan** **National Taiwan University**
17:30-18:00	*Development of multiqubit superconducting devices for simulating quantum many-body physics* **Haohua Wang** **Zhejiang University, China**

Day 3 (Wednesday Dec 1st, 2021) hybrid sessions

Morning Session LT-12, City University of Hong Kong

9:00-9:30	*A quantum tensor singular value decomposition algorithm with applications to 3D recommendation systems* **Guofeng Zhang** **Hong Kong Polytechnic University**
9:30-10:00	*Many-body localization in the presence of strong long-range interactions* **Xiao Li** **City University of Hong Kong**
10:00-10:30	*NISQ: error correction, mitigation, and noise simulation* **Bei Zeng** **Hong Kong University of Science and Technology**
10:30-10:45	*Break*
10:45-11:15	*Topological control of quantum states in non-Hermitian spin-orbit-coupled fermions* **Gyu Boong Jo** **Hong Kong University of Science and Technology**
11:15-11:45	*Recovering interference from an unbalanced SU(1,1) interferometer* **Jeff Zhe-Yu Ou** **City University of Hong Kong**
11:45-12:15	*Ultimate precision limit in quantum metrology* **Haidong Yuan** **Chinese University of Hong Kong**

Afternoon Session online

14:30-15:00	*Valley electron and exciton in twisted homobilayer semiconductors* **Wang Yao** **University of Hong Kong**
15:00-15:30	*Magnon Kerr effect in cavity magnonics* **Jianqiang You** **Zhejiang University, China**
15:30-16:00	*Quantum error correction and error-transparent gates based on a binomial bosonic code* **Luyan Sun** **Tsinghua University, China**
16:00-16:30	*Controlling qubit decoherence through solitary pulses* **Hou Ian** **University of Macau**
16:30-17:00	*Electric-dipole spin resonance in Si and Ge quantum dots* **Haiou Li** **University of Science and Technology of China**
17:00-17:30	*Quantum software engineering for NISQ* **Man-Hong Yung** **Southern University of Science and Technology**
17:30-18:00	*Manipulating Majorana qubit states without braiding* **Wei-Min Zhang** **National Cheng Kung University**
18:00-18:30	*TBA* **Zidan Wang** **University of Hong Kong**
18:30	*Closing Remarks* **Zidan Wang** **University of Hong Kong**

ABSTRACTS

14:15[15:15(UTC+9)]-15:15, Monday, Nov. 29, 2021

Superconducting circuits for quantum technologies

Yasunobu Nakamura

RIKEN Center for Quantum Computing and

Research Center for Advanced Science and Technology, The University of Tokyo, Japan

Superconducting circuits are widely investigated for various applications in quantum information technologies these days. Thanks to the drastic improvement of the coherence properties of superconducting qubits in the last two decades, as well as to their large dipole moment and strong nonlinearity that allow fast control and readout, they are considered as one of the most promising platforms for implementing quantum information processors flexibly designed on-chip. In addition, based on circuit quantum electrodynamics, qubits are coupled to resonators and waveguides to exploit the properties of those bosonic modes, either localized or propagating. The auxiliary modes can also be replaced with other collective modes, e.g., acoustic and magnetic ones, to form hybrid quantum systems, expanding the realm of quantum technologies. In this talk, we present our research activities on superconducting quantum circuits in those aspects, i.e., (i) integrated qubits for quantum computing, (ii) microwave quantum optics in superconducting circuits, and (iii) hybrid quantum systems.

15:15[16:15(UTC+9)]-16:15, Monday, Nov. 29, 2021

Virtual photons in ultra-strongly coupled systems or quantum nonlinear optics without photons

Franco Nori

RIKEN, Japan and University of Michigan, USA

How to excite two or more atoms simultaneously with a single photon: We consider two separate atoms interacting with a single-mode optical or microwave resonator. When the frequency of the resonator field is twice the atomic transition frequency, we show that there exists a resonant coupling between one photon and two atoms, via intermediate virtual states connected by counter-rotating processes. If the resonator is prepared in its one-photon state, the photon can be jointly absorbed by the two atoms in their ground state which will both reach their excited state with a probability close to one. Like ordinary quantum Rabi oscillations, this process is coherent and reversible, so that two atoms in their excited state will undergo a downward transition jointly emitting a single cavity photon. This joint absorption and emission process can also occur with three atoms. The parameters used to investigate this process correspond to experimentally demonstrated values in circuit quantum electrodynamics systems.

Quantum nonlinear optics without photons: Spontaneous parametric down-conversion is a well-known process in quantum nonlinear optics in which a photon incident on a nonlinear crystal spontaneously splits into two photons. Here we propose an analogous physical process where one excited atom directly transfers its excitation to a pair of spatially separated atoms with probability approaching 1. The interaction is mediated by the exchange of virtual rather than real photons. This nonlinear atomic process is coherent and reversible, so the pair of excited atoms can transfer the excitation back to the first one: the atomic analog of sum-frequency generation of light. The parameters used to investigate this process correspond to experimentally demonstrated values in ultrastrong circuit quantum electrodynamics. This approach can be extended to realize other nonlinear interatomic processes, such as four-atom mixing, and is an attractive architecture for the realization of quantum devices on a chip. We show that four-qubit mixing can efficiently implement quantum repetition codes and, thus, can be used for error-correction codes.

A few recent references (mostly 2016-2021) on this topic (ultra-strong coupling cavity QED) are listed below and freely available online at: http://dml.riken.jp/pub/Ultra-strong/

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063849 (2017); M. Cirio, et al., Amplified Optomechanical Transduction of Virtual Radiation Pressure, Phys. Rev. Lett. **119**, 053601 (2017); R. Stassi, et al., Quantum Nonlinear Optics without Photons, Phys. Rev. A **96**, 023818 (2017).

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[8] V. Macrì, F. Nori, A.F. Kockum, Simple preparation of Bell and Greenberger-Horne-Zeilinger states using ultrastrong-coupling circuit QED, Phys. Rev. A **98**, 062327 (2018).

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16:15-17:15, Monday, Nov. 29, 2021

From multi-photon entanglement to quantum computational advantage

Jianwei Pan

University of Science and Technology of China

Photons, the fast flying qubits which can be controlled with high precision using linear optics and have weak interaction with environment, are the natural candidate for quantum communications. By developing a quantum science satellite Micius and exploiting the negligible decoherence and photon loss in the out space, practically secure quantum cryptography, entanglement distribution, and quantum teleportation have been achieved over thousand-kilometer scale, laying the foundation for future global quantum internet. Surprisingly, despite the extremely weak optical nonlinearity at single-photon level, an effective interaction between independent indistinguishable photons can be effectively induced by a multi-photon interferometry, which allowed the first creation of multi-particle entanglement and test of Einstein's local realism in the most extreme way. By developing high-performance quantum light sources, the multi-photon interference has been scaled up to implement boson sampling with up to 76 photons out of a 100-mode interferometer, which yields a Hilbert state space dimension of 1030 and a rate that is 1014 faster than using the state-of-the-art simulation strategy on supercomputers. Such a demonstration of quantum computational advantage is a much-anticipated milestone for quantum computing. The special-purpose photonic platform will be further used to investigate practical applications linked to the Gaussian boson sampling, such as graph optimization and quantum machine learning.

19:00-19:30, Monday, Nov. 29, 2021

Deterministic loading of microwaves onto an artificial atom using a time-reversed waveform

Io Chun Hoi

City University of Hong Kong

We demonstrate that coherent-state microwave photons, with an optimal temporal waveform, can be efficiently loaded onto a single superconducting artificial atom in a semi-infinite one-dimensional (1D) transmission-line waveguide. Using a weak coherent state (average photon number $N \ll 1$) with an exponentially rising waveform, whose time constant matches the decoherence time of the artificial atom, we demonstrate a loading efficiency of 96.5% from 1D semi-free space to the artificial atom. The high loading efficiency is due to time-reversal symmetry: the overlap between the incoming wave and the time-reversed emitted wave is up to 98%. Our results open up promising applications in realizing quantum networks based on waveguide quantum electrodynamics.

19:30-20:00, Monday, Nov. 29, 2021

High efficiency coherent microwave-to-optical conversion

Hui Yan

Guangdong-Hong Kong Joint Laboratory of Quantum Matter,
Frontier Research Institute for Physics, South China Normal University,
Guangzhou 510006, China

Quantum transducers, capable of converting quantum signals from the microwave to optical domain, are a crucial optical interface for quantum information technology based on solid state qubits. Coherent microwave-to-optics conversions have been realized with various physical platforms, but they are all limited to low efficiencies of less than 50%, the threshold of the no-cloning quantum regime. Here we report a coherent microwave-to-optical transduction in Rydberg atoms with an efficiency of 81.5% and a bandwidth of 1 MHz, through the development of off-resonant scattering technique. The high conversion efficiency is maintained from thousands of microwave photons to about 50 microwave photons, suggesting our device is readily applicable to the single-photon level transduction.

20:00[14:00(UTC+2)]-20:30, Monday, Nov. 29, 2021

Frequency estimation and resolution at the nano-scale

Alex Retzker

The Hebrew University of Jerusalem, Israel

Quantum sensing is an important tool at estimating various parameters at the nano-scale. Of special importance is the estimation of frequencies, i.e., spectroscopy, at small scales. In this talk I will discuss a few surprising aspects of spectroscopy at minute scales, while concentrating at the NV center in diamond.

20:30[13:30(UTC+1)]-21:00, Monday, Nov. 29, 2021

Chiral quantum optics with giant atoms

Anton Frisk Kockum

Chalmers University of Technology, Sweden

In quantum optics, it is common to assume that atoms can be approximated as point-like compared to the wavelength of the light they interact with. However, recent advances in experiments with artificial atoms built from superconducting circuits have shown that this assumption can be violated [1, 2, 3]. Instead, these artificial atoms can couple to an electromagnetic field in a waveguide at multiple points, which are spaced wavelength distances apart. Such systems are called giant atoms. They have attracted increasing interest in the past few years [4], in particular because it turns out that the interference effects due to the multiple coupling points allow giant atoms to interact with each other through the waveguide without losing energy into the waveguide [5, 2]. In this talk, I will discuss the situation when the coupling between the giant atoms and the waveguide is chiral, i.e., when the coupling depends on the propagation direction of the light. I will show how this affects the decoherence-free interaction between giant atoms and the formation of dark states [6]. Finally, I will also show how a giant atom coupled to a waveguide with varying impedance can give rise to chiral bound states [7].

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21:00[08:00(UTC-5)]-21:30, Monday, Nov. 29, 2021

Controlled-Z gate dynamically corrected against charge noise in Si spin qubits despite crosstalk

Jason P. Kestner
University of Maryland, Baltimore County, USA

While silicon is a promising host material for quantum dot spin qubits, it is hindered by charge noise affecting the exchange couplings. This limits the gate fidelity. Moreover, dynamical correction of this noise becomes difficult when the rotating wave approximation is invalid due to a Zeeman energy difference between two spins comparable in magnitude to the exchange (leading to "flip-flop" interactions) and/or the Rabi frequency (leading to crosstalk during local rotations). In this talk I will present a new combination of an analytical composite sequence and neural-network-based shaped pulses designed to overcome these challenges and boost the fidelity of the controlled-Z gate.

21:30[14:30(UTC+1)]-22:00, Monday, Nov. 29, 2021

Diamond technologies and complex systems

Jorge Casanova
University of the Basque Country, Spain

Quantum Sensing with nitrogen-vacancy (NV) centers in diamond promises to revolutionize detection and imaging techniques. Via the adequate application of radiation patterns over the NV sensor, one can increase spectral resolution up to a level that enables the detection of individual nucleus/electrons in a target sample such as large biomolecules. In this talk I will explain distinct quantum control protocols based on dynamical decoupling techniques that can be applied to complex systems for technological applications such as imaging at the nanoscale.

22:00[15:00(UTC+1)]-22:30, Monday, Nov. 29, 2021

TBA

Xi Chen
University of the Basque Country, Spain

TBA

22:30[9:30(UTC-5)]-23:00, Monday, Nov. 29, 2021

Noise-resistant quantum control from geometric space curves

Edwin Barnes

Virginia Tech, USA

I will present a new theoretical framework for deriving control waveforms that dynamically combat decoherence by driving qubits in such a way that noise effects destructively interfere and cancel out. This theory exploits a rich geometrical structure hidden within the time-dependent Schrödinger equation in which quantum evolution is mapped to geometric curves. Control waveforms that suppress noise can be obtained by drawing closed curves and computing their curvatures. I will show how this can be done for single- and multi-qubit systems.

23:00[10:00(UTC-5)]-23:30, Monday, Nov. 29, 2021

Spin qubits in Si: the effects of valley-orbit coupling

Xuedong Hu

Department of Physics, State University of New York at Buffalo, USA

Over the past decade, various experiments have shown that electron spin qubits in Si have remarkable coherence properties. High-fidelity manipulation of spin qubits have also been demonstrated in recent years. However, degeneracy at the bottom of Si conduction band introduces low-energy excited orbital states, i.e. valley excited states, which could interfere with dynamics of a spin qubit. To truly establish spin qubits in Si as a scalable platform for a universal quantum computer, a thorough understanding of the valley-orbit coupling in Si quantum dots is thus needed.

In this talk I discuss our recent works that shed light on the effects of valley-orbit coupling in a Si double quantum dot (DQD). In one project, we find that valley physics has to be incorporated in order to measure tunnel coupling accurately using the charge sensing method widely adopted in the experimental community. In another project, we calculate spin exchange coupling in a symmetric Si DQD. We find that exchange splitting can be strongly suppressed at finite valley phase differences between the dots because of the valley-phase-dependent dressing of the ground states, and a small valley splitting can render the Heisenberg exchange Hamiltonian invalid in describing the low-energy spin dynamics, due to nearby excited states. Our results clearly illustrate the need for consistent control of valley-orbit coupling in a quantum dot array in order to achieve reliably controllable spin qubits.

We thank support by US ARO.

9:00[17:00(UTC-8)Nov29]-9:30, Tuesday, Nov. 30, 2021

Robust preparation of many-body ground states in Jaynes-Cummings lattices

Lin Tian

School of Natural Sciences, University of California, Merced, USA

Preparing quantum many-body states with high accuracy is a challenging question in quantum computing. In particular, many-body states in strongly-correlated systems can be highly entangled, unknown, and often impossible to be generated with programed quantum logic gates. Here we study the robust preparation of many-body ground states in a finite-sized Jaynes-Cummings (JC) lattice. This model describes strongly-correlated polaritons that exhibit quantum phase transitions between the Mott-insulating and the superfluid phases at integer fillings. We employ different methods, including the optimized nonlinear ramping and quantum optimal control, and demonstrate that many-body ground states of the JC lattice can be generated with high fidelity in almost the entire parameter space. The methods can be applied to many other systems.

9:30[17:30(UTC-8)Nov29]-10:00, Tuesday, Nov. 30, 2021

Harnessing valley state in Si for fast semiconductor qubits

Hongwen Jiang

University of California, Los Angeles, USA

Semiconductor quantum dots are a leading approach for the implementation of solid-state based quantum computing, as the coherence time of the qubits can be extremely long and various interactions, inherent to semiconductors, can be harvested to precisely control superposition and entanglement. Although spin and charge of single electrons are normally used for encoding qubits, valley states in silicon represent another quantum degree of freedom to store and process quantum information, with a string of desirable properties. Indeed, coherent manipulation and projective read-out of valley states in a Si/SiGe quantum dot device showed promise of fast electrical control as well as protection against charge noise [1]. In this talk, I present recent advances in full quantum control of valley qubits. In particular, two-axis quantum control of a valley qubit using gate pulse sequences with X and Z rotations, occurring within a fast operation time of 300 ps, has been accomplished [2]. A set of gate operations and quantum measurements completely map out the surface of the Bloch sphere in a single phase-space plot, which is subsequently used to evaluate various qubit operation fidelities by state and process tomography. We have also performed a pump-probe experiment to directly measure the inter-valley relaxation time at zero magnetic field. An unexpected long relaxation time of 12.0 ± 0.3 ms, a value that is unmodified when a magnetic field is applied, has been obtained. I will also present our very recent results to couple two valley qubits in a linear four-quantum-dot array using capacitive or tunnel interactions.

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10:00-10:30, Tuesday, Nov. 30, 2021

Quantum nonlinear spectroscopy enabled by quantum sensing

Renbao Liu

Chinese University of Hong Kong

TBA

10:45-11:15, Tuesday, Nov. 30, 2021

Exploring quantum coherence and correlations in graphene

Dong-Keun Ki

Department of Physics, The University of Hong Kong

Graphene is an only one-atom-thin honeycomb lattice of Carbon atoms whose valence and conduction bands touch at the six corners of the hexagonal Brillouin zone (namely, the charge neutrality point; CNP). Such an ultimate 2D nature of electron transport and the absence of an energy gap separating the conduction and valence bands make graphene layers a unique platform to investigate and engineer various quantum transport phenomena. Here, we will review some of our past and ongoing efforts in the relevant research area. First, we will discuss experimental efforts to build various types of ultraclean suspended graphene devices [1-3], where we found quantum correlated insulating phases in graphene layers up to 8 layers at CNP [4-6]. Secondly, we will show that by stacking graphene on semiconducting transition metal dichalcogenides, we can significantly enhance the spin-orbit coupling in graphene [7, 8], which has been of considerable interests in both fundamental and application aspects. Lastly, we will talk about our group's ongoing efforts to reveal new quantum coherence and correlations effects in graphene and 2D materials.

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11:15-11:45, Tuesday, Nov. 30, 2021

Study dynamics of spin bath via solid state qubits

Sen Yang

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Qubits based on point defect in solids have emerged as one of the most promising candidates for the physical realization of quantum computers. They have various advantages such as long coherence time, high fidelity of initialization, manipulation and readout. However, the bath spins around these qubits are the source of decoherence. Being able to study and control those spins, not only can help increasing the decoherence time, but also lead to more auxiliary qubits for scale-up quantum nodes. In this talk, I will introduce a few approaches in pursuit better understanding and control of those spin bath.

11:45-12:15, Tuesday, Nov. 30, 2021

Cavity-controlled quantum dynamics of complex materials

Zhedong Zhang

City University of Hong Kong

Quantum states of the light, e.g., single photons, entanglement and squeezing, opens up a new avenue for spectroscopy by utilizing the parameters of quantum optical fields as novel control knobs and through the variation of photon statistics. With the advance of cavity quantum electrodynamics and light source technology, imaging and controlling the electron and vibrational motions of molecules can be achieved, towards unprecedented resolution and precision, not accessible by the classical light pulses. Two key issues emerge in nanoscale: quantum states of photons and strong matter-light interaction. The underlying physics is still an open issue for molecules and spectroscopy. In this talk, I will present an overview of our recent work on multidimensional control and probes of ultrafast dynamics of molecular polaritons. Several schemes will be discussed: multidimensional coherent probe, photon-coincidence counting, and Raman spectra with quantum fields. Microscopic models for molecular polaritons using reduced density matrix and Heisenberg-Langevin approach will be incorporated for a unified understanding of the signals.

14:30[16:30(UTC+10)]-15:00, Tuesday, Nov. 30,2021

Qubit as a quantum probe of control distortions and temperature

Arkady Fedorov

University of Queensland, Australia

Control lines distortions lead to gate infidelities while non-zero effective temperature leads to improper initialization of qubits' states. Characterising these imperfections and distortions becomes imperative to progress towards real-world applications and breaking the error-correcting threshold for current noisy intermediate-scale quantum processors. In this talk, I am going to present a set of tools we have developed to employ a qubit itself as a probe of transfer functions of control lines, effective temperature, setup stability and how to use the results to improve the fidelity of entangling gates. I will also present the application of on-the-fly data processing with neural networks to state classification in a single-shot quantum measurement.

15:00[14:00(UTC+7)]-15:30, Tuesday, Nov. 30,2021

Mitigating qubit dephasing from random telegraph noise using spectator qubits

Areeya Chantasri[1], Hongting Song[2], Behnam Tonekaboni[3], and Howard M. Wiseman[3]

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Decoherence mitigation for logical qubits is one of the most important tasks towards implementing quantum technologies in practical settings. To mitigate decoherence, one needs to learn more about environmental noises affecting the qubits and thus make appropriate corrections. In this work, we consider decoherence in solid-state qubits from the charge noise, i.e., noise from electrons or holes trapped in impurities. The noise is commonly described by a random telegraph process (RTP), where its realization is a series of random switches between two fixed values. We introduce a theoretical protocol for RTP noise estimation-correction using a “spectator qubit” that is sensitive to the noise and can be measured with a fast time scale; therefore, it can be used to protect the coherence of any "data qubits" nearby. Using our developed Bayesian map approach, we derive an optimal protocol called “Map-based Optimized Adaptive Algorithm for Asymptotic Regime” (MOAAAR) and show that the data qubit decoherence rate can be reduced with a scaling of (K/gamma)^2, where K is the spectator sensitivity to the noise and gamma is the switching rate of the RTP.

15:30[8:30(UTC+1)]-16:00, Tuesday, Nov. 30,2021

Towards universal quantum computation with bosonic qubits

Yvonne Yuan Gao

National University of Singapore

The realisation of robust universal quantum computation with any platform ultimately requires both the coherent storage of quantum information and (at least) one entangling operation between individual elements. The use of multiphoton states encoded in superconducting microwave cavities as logical qubits is a promising route to preserve the coherence of quantum information against naturally-occurring errors. However, operations between such encoded qubits can be challenging due to the lack of intrinsic coupling between them.

In this talk, I will discuss the recent experimental work on engineering a coherent and tunable bilinear coupling between two otherwise isolated microwave quantum memories in a three-dimensional circuit quantum electrodynamics architecture. Building upon this coupling, we also demonstrate programmable interference between stationary quantum modes and realise robust entangling operations between two encoded qubits. Our results provide a crucial primitive for universal quantum computation using bosonic modes.

16:00[17:00(UTC+9)]-16:30, Tuesday, Nov. 30,2021

Coherent manipulation of strongly correlated electron states in GaAs quantum dots

Dohun Kim

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The electron spin and charge degree of freedom in solids form natural basis for constructing quantum two level systems, or qubits. Along with recent developments based on canonical spin-1/2 states, multielectron states in a quantum dot is beginning to attracting attention. Compared to single particle states, many-body states can exhibit so far unexplored phenomenon like significant excited level quenching and electron localization inside a quantum dot due strong electron-electron interaction. In this talk, I will present some of the recent experimental results observing signatures of strongly correlated Wigner molecule formation inside a GaAs quantum dot, coherent manipulation of such levels, and efforts to use these additional resources for quantum information technology.

16:30-17:00, Tuesday, Nov. 30,2021

Architecture for high-fidelity two-qubit gate operation on superconducting quantum chips

Yang Yu

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High-quality two-qubit gate operations are crucial for scalable quantum information processing. Often, the gate fidelity is compromised when the system becomes more integrated. Therefore, a low-error-rate, easy-to-scale two-qubit gate scheme is highly desirable. Recently, we proposed new architectures and parameter regime to increase the two-qubit gate fidelity. These designs are relatively easy to scalable, supplying promising schemes for NISQ.

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17:00-17:30, Tuesday, Nov. 30,2021

High-fidelity and robust two-qubit controlled-Z gates for direct-coupling superconducting transmon qubits

Chia-Hsien Huang[1, 2] and Hsi-Sheng Goan[1, 2, 3, *]

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Quantum supremacy has been demonstrated experimentally by using the frequency-tunable super-conducting qubits. To achieve the ultimate goal of fault-tolerant quantum computation or to increase the reliable circuit depth (the number of gates that can be successively and reliably performed in a quantum circuit) on noisy intermediate-scale quantum (NISQ) machines, keeping pursuing high-fidelity and robust quantum universal gates is an important and timely issue. Here we construct single-shot smooth flux pulses to achieve the high-fidelity and robust two-qubit controlled-Z (CZ) gates for the direct-coupling superconducting qubits by our robust control method. For superconducting qubits, shrinking the gate time can reduce the decoherence error, but will enhance the leakage error. The gate time of our optimized CZ gate constructed by controlling only the external fluxes can be reduced to 12 ns, and the leakage error can still be kept to be $\sim 2.5 \times 10^{-5}$, demonstrated by simulations using the experimental system parameters and also considering the finite bandwidths of the commercial arbitrary waveform generators. We characterize the slow and fast dephasing noises from the experimental data, and use the characterized noises to setup the noise models in our robust control method. The optimized 12 ns CZ gate can be reduced the total dephasing error to $\sim 4.1 \times 10^{-5}$, and the CZ gate infidelity is limited by the energy relaxation process with error $\sim 4.0 \times 10^{-4}$ for T1 = 30 μs. Finally, we take the dephasing and relaxation noises and system parameter uncertainties into the robust control method to provide the optimal control solutions for the high-fidelity and robust CZ gates.

17:30-18:00, Tuesday, Nov. 30,2021

Development of multiqubit superconducting devices for simulating quantum many-body physics

Haohua Wang

Zhejiang University, China

Multiqubit superconducting devices provide a promising platform for quantum simulation tasks, which can be useful for investigating various intriguing phenomena of quantum many-body systems. The simulation efficiency depends on various intertwining factors including the underlying device structures, the upper-level simulation protocols, and the number of highly coherent qubits that can be precisely controlled and measured. In this talk, I will introduce the two types of 30-qubit superconducting devices that are being developed in our lab. The first one features all-to-all connectivity with multiple qubits interconnected by a central bus resonator, and the second one is a flip-chip device with the qubits forming a square lattice, where couplers are inserted between neighboring qubits for implementation of high-fidelity controlled phase gates. I will briefly discuss the many-body physics that can be investigated on these devices using the analog/digital quantum simulation protocols.

9:00-9:30, Wednesday, Dec. 1, 2021

A quantum tensor singular value decomposition algorithm with applications to 3D recommendation systems

Guofeng Zhang

Hong Kong Polytechnic University

In this talk, we first present the tensor singular value decomposition (T-SVD) developed by Kilmer and Martin in 2011. Then we show how to implement T-SVD using quantum circuits. As an application, we propose a quantum algorithm for 3D recommendation systems by incorporating users' contextual information into personalized recommendation. Specifically, the preference information of users is encoded in a third-order tensor of dimension N; It is well-known that such a tensor can be approximated by the truncated T-SVD of a subsample tensor. We implement this procedure quantumly. Unlike the classical algorithms that reconstruct the whole approximated preference tensor using truncated T-SVD, our quantum algorithm obtains the recommended product under certain context by measuring the output quantum state corresponding to an approximation of a user's dynamic preferences. Finally, we show that our algorithm achieves the time complexity O(sqrt(k)N polylog(N)) in contrast to the classical counterpart with complexity O(kN^3), where k is the truncated tubal rank.

9:30-10:00, Wednesday, Dec. 1, 2021

Many-body localization in the presence of strong long-range interactions

Xiao Li

City University of Hong Kong

In this talk I will discuss one of our recent works on many-body localization (MBL). In particular, we studied MBL for interacting 1D lattice fermions in random (Anderson) and quasiperiodic (Aubry-Andre) models, focusing on the role of interaction range. We obtain the MBL quantum phase diagrams by calculating the experimentally relevant inverse participation ratio (IPR) at half-filling using exact diagonalization methods and extrapolating to the infinite system size. For short-range (SR) interactions, our results produce in the phase diagram a qualitative symmetry between weak and strong interaction limits. For long-range (LR) interactions, no such symmetry exists as the strongly interacting system is always many-body localized, independent of the effective disorder strength, and the system is analogous to a pinned Wigner crystal. We obtain various scaling exponents for the IPR, suggesting conditions for different MBL regimes arising from interaction effects. I will also discuss how Hilbert space fragmentation manifests itself in the presence of strong SR and LR interactions.

10:00-10:30, Wednesday, Dec. 1, 2021

NISQ: error correction, mitigation, and noise simulation

Bei Zeng

Hong Kong University of Science and Technology

Error-correcting codes were invented to correct errors on noisy communication channels. Quantum error correction (QEC), however, may have a wider range of uses, including information transmission, quantum simulation/computation, and fault-tolerance. These invite us to rethink QEC, in particular, about the role that quantum physics plays in terms of encoding and decoding. The fact that many quantum algorithms, especially near-term hybrid quantum-classical algorithms, only use limited types of local measurements on quantum states, leads to various new techniques called Quantum Error Mitigation (QEM). This work addresses the differences and connections between QEC and QEM, by examining different application scenarios. We demonstrate that QEM protocols, which aim to recover the output density matrix, from a quantum circuit do not always preserve important quantum resources, such as entanglement with another party. We then discuss the implications of noise invertibility on the task of error mitigation, and give an explicit construction called quasi-inverse for non-invertible noise, which is trace-preserving while the Moore-Penrose pseudoinverse may not be. We also study the consequences of erroneously characterizing the noise channels, and derive conditions when a QEM protocol can reduce the noise.

Reference: arXiv:2111.02345

10:45-11:15, Wednesday, Dec. 1, 2021

Topological control of quantum states in non-Hermitian spin-orbit-coupled fermions

Gyu Boong Jo

Department of Physics, Hong Kong University of Science and Technology

While spin-orbit coupling (SOC), an essential mechanism underlying quantum phenomena from the spin Hall effect to topological insulators, has been widely studied in well-isolated Hermitian systems, much less is known when the dissipation plays a major role in spin-orbit-coupled quantum systems. I will report the realization of the non-Hermitian spin-orbit-coupled quantum gases and observation of a parity-time (PT) symmetry-breaking transition as a result of the competition between SOC and dissipation. In our experiment, tunable dissipation, introduced by state-selective atom loss, enables the energy gap, opened by SOC, to be engineered and closed at the critical dissipation value, the so-called exceptional point (EP). The realized EP of the non-Hermitian band structure exhibits chiral response when the quantum state changes near the EP. This topological feature enables us to tune SOC and dissipation dynamically in the parameter space, and observe the state evolution is direction- dependent near the EP, revealing chiral spin transfer between different quantum states when the quantum state encircles the EP. This topological control of quantum state for non-Hermitian fermions provides new methods of quantum control, and also sets the stage for exploring non-Hermitian topological states with SOC.

11:15-11:45, Wednesday, Dec. 1, 2021

Recovering interference from an unbalanced SU(1,1) interferometer

Jeff Zhe-Yu Ou

City University of Hong Kong

SU(1,1) interferometers are a new type of quantum interferometers using parametric amplifiers for wave splitting and mixing. They have some unique properties for quantum sensing applications. Indistinguishability in path is required for quantum interference so these interferometers usually work with balanced paths. We report a method of homodyne detection that can recover otherwise lost interference effect in an unbalanced SU(1,1) interferometer. The indistinguishability due to amplitude measurement and slow detection is responsible for the recovery of interference.

11:45-12:15, Wednesday, Dec. 1, 2021

Ultimate precision limit in quantum metrology

Haidong Yuan

Chinese University of Hong Kong

A pivotal task in science and technology is to identify the highest achievable precision in measuring and estimating parameters of interest and design schemes to reach it. The ultimate limit is not only constrained by the resource but also by the fundamental law of nature, which, up to date, is most accurately captured by quantum mechanics. With many unintuitive non-classical features, quantum mechanics also offers many possibilities to go beyond the classical limit. With recent development of technology, it is now possible to design measurement protocols utilizing quantum mechanical effects, such as entanglement, to attain far better precision than the classical schemes. In this talk I will present a general framework for quantum metrology that can identify the ultimate precision limit. Optimally controlled schemes that can attain the ultimate limit will also be presented, which is shown to outperform the existing schemes.

14:30-15:00, Wednesday, Dec. 1, 2021

Valley electron and exciton in twisted homobilayer semiconductors

Wang Yao

Department of Physics, The University of Hong Kong

Long wavelength moiré pattern in van der Waals stacked 2D materials has provided a powerful tool towards designer quantum materials that can extend the exotic properties of the building blocks. For band edge carriers located at the Brillouin zone corners (valleys), the interlayer coupling features sensitive dependence on the atomic registry between the constituting layers. In twisted TMDs homobilayers, such coupling in the moiré pattern results in a spatial texture of layer pseudospin that gives rise to non-Abelian Berry connections. Berry phase in the adiabatic limit leads to fluxed superlattices tunable by twist angle, strain and interlayer bias, underlying the quantum spin Hall effect in low energy mini-bands [1,2]. I will also discuss carrier dynamics in moiré patterns distorted by non-uniform strain, and show how the interplay of moiré interlayer coupling and strain together leads to non-Abelian Berry phase effects [3]. For dipolar valley excitons in the twisted homobilayers, we find that the spatial texture of layer configuration results in a luminescence anomaly in the moiré traps, where a tiny displacement of the exciton by interactions dramatically increases its brightness and changes polarization from circular to linear, exploitable to distinguish ordered phases and domain boundaries of the exciton many-body states at fractional filling [4]. The work was supported by Research Grant Council of HKSAR (17302617, 17312916, AoE/P-701/20), Croucher Foundation, and the National Key R&D Program of China (2020YFA0309600).

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15:00-15:30, Wednesday, Dec. 1, 2021

Magnon Kerr effect in cavity magnonics

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As a hybrid quantum system, the cavity magnonic system consisting of magnons strongly interacting with cavity photons has emerged as a new direction of research in recent years. In this talk, I first show our results regarding the magnon-polariton bistability in this hybrid system. In our setup, we align, respectively, the [100] and [110] crystallographic axes of a small yttrium iron garnet (YIG) sphere parallel to the static magnetic field and find very different bistable behaviors (e.g., clockwise and counter-clockwise hysteresis loops) in these two cases. Then, I present our new results on multistability by demonstrating the transition from bistability to tristability. I also show the long-time memory effect in this cavity magnonic system, providing a way towards cavity magnonics-based information storage and processing.

15:30-16:00, Wednesday, Dec. 1, 2021

Quantum error correction and error-transparent gates based on a binomial bosonic code

Luyan Sun

Tsinghua University, China

Quantum error correction (QEC) is necessary for a practical quantum computer because of the inevitable coupling of quantum systems with the uncontrolled environment. Encoding quantum information on photonic states in a microwave cavity for QEC has attracted a lot of interests because of its hardware efficiency. This scheme benefits from the infinite dimensional Hilbert space of a harmonic oscillator for redundant information encoding and only one error syndrome that needs to be monitored. In this talk, I will describe our experimental realizations of repetitive QEC and full control of a binomial bosonic code in a circuit quantum electrodynamics architecture, as well as error transparent gates based on the binomial code.

16:00-16:30, Wednesday, Dec. 1, 2021

Controlling qubit decoherence through solitary pulses

Hou Ian

University of Macau

We investigate the forward scattering motion of a microwave pulse through a superconducting qubit, during which the qubit would experience zero decoherence. For a slow-varying pulse making its interaction with the qubit adiabatic, it is concluded that the pulse shape conforms to that of a soliton with area as integer multiples of 2π when the longitudinal and transverse relaxations are eliminated. The phenomenon extends the self-induced transparency effect observed in many atomic systems where the pulse area makes a difference. We find further that the solitary pulse would conversely be split into multiple humps during its propagation through the qubit. The splitting not only depends on the pulse area, but also the spectral distribution of the environmental reservoir assumed. The study broadens our knowledge of the qubit decoherence dynamics when driven.

References: NJP 22 (10), 103041; Quan. Inf. Proc. 19 (9), 1. (2020)

16:30-17:00, Wednesday, Dec. 1, 2021

Electric-dipole spin resonance in Si and Ge quantum dots

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Spins in semiconductor quantum dots (QDs) are considered one of the most promising qubit designs for scalable quantum information processing with long coherence times and fault-tolerance fidelity already demonstrated. By applying an alternating magnetic field, the electronic spin can be coherently controlled through electron spin resonance. Alternatively, such control can be implemented electrically via intrinsic or synthetic spin-orbit coupling (SOC), which is termed as electric-dipole spin resonance (EDSR).

Here, we show some of our latest experimental progress on SOC and EDSR. In Si QDs, we have demonstrated the giant anisotropy of spin relaxation and spin-valley mixing based on SOC [1] and the control of synthetic spin-orbit coupling with magnetic field [2]. Furthermore, we have realized the manipulation of high-fidelity single-spin qubit gate and the characterization of two-qubit gates. In Ge QDs, we have realized the measurement of anisotropic g-Factor and spin-orbit field [3] and obtained an electric-field-tuned spin-orbit length lSO = 1.5–35.4 nm. Recently, we report ultrafast single-spin manipulation in a hole-based Ge hut wire (GHW) double QDs. Mediated by the strong SOI, a Rabi frequency exceeding 540 MHz is observed, setting a record for ultrafast spin qubit control in semiconductor systems. We demonstrate that the strong SOI of heavy holes in our GHW, characterized by a very short spin-orbit length of 1.5 nm, enables the rapid gate operations we accomplish. Our results demonstrate the potential of ultrafast coherent control of hole spin qubits to meet the requirement of DiVincenzo's criteria for a scalable quantum information processor [4].

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17:00-17:30, Wednesday, Dec. 1, 2021

Quantum software engineering for NISQ

Man-Hong Yung

Southern University of Science and Technology of China

Quantum computing is now emerging as a rapidly-growing industry on a global scale. This is mainly because of the many technological breakthroughs achieved over the last few years. Remarkably, it was experimentally demonstrated that the status of computational advantage (also known as quantum supremacy) can be reached with only 53 noisy qubits. The next step is to demonstrate how near-term chips can solve practical problems better than any classical means. For this purpose, hardware improvement is not enough; what is perhaps more important might be the algorithm and/or software part. In this talk, I will share my experience over the last few years in trying to push forward this direction.

17:30-18:00, Wednesday, Dec. 1, 2021

Manipulating Majorana qubit states without braiding

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We propose a new scheme to manipulate the Majorana qubit states other than braiding. By utilizing electron transport through Majorana zero modes and tuning the magnetic flux in the setup, the aim of Majorana qubit state manipulation can be fulfilled. The principal part of the setup is an Aharonov-Bohm (AB) interferometer consisting of two topological superconducting chains (TSCs) connected to two leads. We obtain the exact master equation as well as its solution and study the general properties of the real-time dynamics of the Majorana qubit states. The parity of the Majorana qubit state can be almost perfectly polarized by tuning the bias and can also be flipped by switching the sign of the cross-couplings between the TSCs and the leads. Moreover, the qubit coherence shows a phase rigidity due to the intrinsic particle-hole symmetry of the Majorana AB interferometer, which is different from that in the double-quantum-dot AB interferometers without topological properties.

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18:00-18:30, Wednesday, Dec. 1, 2021

TBA

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