The 3rd International Symposium on

Dynamics in Artificial Quantum Systems

DAQS2022 February 21-23, 2022, Tokyo

ONLINE

DAQS2022 Timetable

JST (UTC+9)	Feb 21 (Mon)	Feb 22 (Tue)	Feb 23 (Wed)
9:30	Opening: Nakamura	Lachance-Quirion	
10:00	Zhu	Ashida	Asavanant
10:30	Break	Usami	Gao
11:00	H. Wang	Break	Goto
11:30	Tabuchi	Noguchi	Lunch
12:00	Deng	Duan	
12:30	Lunch	Lunch	
13:00			Grimsmo
13:30			Darmawan
14:00	Biercuk	Kawakami	Fujii
14:30	R. Wang	Kim	Break
15:00	Lambert	Break	Kono
15:30	Break	Aikawa	Singh
16:00	Pla	Huang	Bowen
16:30	Takeda	Kawasaki	Closing

DAQS2022 Program

21 Feb (Mon)	Session / Presentation	Speaker	Affiliation
09:30-10:00	Opening	Yasunobu Nakamura	RIKEN / The University of Tokyo
	Superconducting quantum computing I	Chairperson: Yasunobu Nakamura	RIKEN / The University of Tokyo
10:00-10:30	Strong quantum computational advantage using a superconducting quantum processor	Xiaobo Zhu	University of Science and Technology of China
10:30-11:00	Break		
	Superconducting quantum computing II	Chairperson: Yasunobu Nakamura	RIKEN / The University of Tokyo
11:00-11:30	Flip-chip superconducting devices with tunable couplings for simulating quantum many-body physics	Haohua Wang	Zhejiang University
11:30-12:00	Towards error-resilient quantum computers on superconducting devices	Yutaka Tabuchi	RIKEN
12:00-12:30	Fluxonium: an alternative qubit platform for high-fidelity operations	Chunqing Deng	Alibaba
12:30-14:00	Lunch		
	Quantum control	Chairperson: Yutaka Tabuchi	RIKEN
14:00-14:30	Achieving 1000X algorithmic enhancement in superconducting quantum processors via autonomous error-robust control	Michael Biercuk	Q-CTRL / The University of Sidney
14:30-15:00	Quantum circuit architecture search on a superconducting processor	Ruixia Wang	Beijing Academy of Quantum Information Sciences
15:00-15:30	Pseudomodes: an exact method for modelling open quantum systems	Neill Lambert	RIKEN
15:30-16:00	Break		
	Spin detection/control	Chairperson: Eisuke Abe	RIKEN
16:00-16:30	Spin detection with a kinetic inductance parametric amplifier	Jarryd Pla	The University of New South Wales
16:30-17:00	High-fidelity quantum gates and error-correction with silicon spin qubits	Kenta Takeda	RIKEN

22 Feb (Tue)	Session / Presentation	Speaker	Affiliation
	Hybrid with condensed matter physics	Chairperson: Alto Osada	The University of Tokyo
09:30-10:00	Perspectives for quantum magnonics with superconducting circuits	Dany Lachance-Quirion	Nord Quantique
10:00-10:30	Shedding quantum light on quantum materials	Yuto Ashida	The University of Tokyo
10:30-11:00	Magnon-exciton proximity coupling at van der Waals heterointerface	Koji Usami	The University of Tokyo
11:00-11:30	Break		
	Electrons and ions I	Chairperson: Koji Usami	The University of Tokyo
11:30-12:00	Hybrid quantum systems with trapped electrons	Atsushi Noguchi	The University of Tokyo / RIKEN
12:00-12:30	Quantum computation/simulation with large-ion crystals and dual-type qubits	Luming Duan	Tsinghua University
12:30-14:00	Lunch		
	Electrons and ions II	Chairperson: Hiroki Takahashi	OIST

14:00-14:30	Dispersive read-out of the Rydberg states of electrons on helium	Erika Kawakami	RIKEN
14:30-15:00	Adiabatic quantum simulation of transverse Ising model with a 2D crystal of ions	Kihwan Kim	Tsinghua University
15:00-15:30	Break		
	Levitated nanoparticles	Chairperson: Erika Kawakami	RIKEN
15:30-16:00	Towards exploring macroscopic quantum mechanics with ultracold levitated nanoparticles	Kiyotaka Aikawa	Tokyo Institute of Technology
16:00-16:30	Testing new physics using diamagnetic levitated force sensor	Pu Huang	Nanjing University
16:30-17:00	Control and characterization of optically-levitated microspheres for applications to fundamental physics	Akio Kawasaki	AIST

23 Feb (Wed)	Session / Presentation	Speaker	Affiliation
	Continuous-variable quantum computing	Chairperson: Yasunari Suzuki	NTT
10:00-10:30	Optical quantum entanglement in time domain: a route toward scalable quantum computation	Warit Asavanant	The University of Tokyo
10:30:11:00	Programmable interactions between bosonic modes for quantum information processing	Yvonne Gao	CQT / National University of Singapore
11:00-11:30	Quantum computing, quantum optics, and quantum chaos using Kerr parametric oscillators	Hayato Goto	Toshiba
11:30-13:00	Lunch		
	Fault-tolerant quantum computing theory	Chairperson: Hayato Goto	Toshiba
13:00-13:30	Gottesman-Kitaev-Preskill states in a periodically driven quantum system	Arne Grimsmo	The University of Sydney
13:30-14:00	Practical quantum error correction with the XZZX code and Kerr-cat qubits	Andrew Darmawan	Kyoto University
14:00-14:30	Toward realization of quantum error correction and fault-tolerant quantum computing	Keisuke Fujii	Osaka University / RIKEN
14:30-15:00	Break		
	Opto/electromechanics	Chairperson: Atsushi Noguchi	The University of Tokyo / RIKEN
15:00-15:30	Multi-mode superconducting circuit optomechanics	Shingo Kono	EPFL
15:30-16:00	Superconducting hybrid device with a transmon qubit	Vibhor Singh	IISc Bangalore
16:00-16:30	Towards quantum control of room temperature mechanical resonators	Warwick Bowen	The University of Queensland
16:30	Closing		

DAQS2022 Abstracts

21 Feb, 10:00

Xiaobo Zhu

University of Science and Technology of China

In this talk, I will show our recent progress with our collaborators on superconducting multi-qubits systems. We designed and fabricated several versions of quantum processor, on which integrated up to 66 qubits. The fidelity of single-bit gate and two-bit gate are calibrated by randomized benchmarking or parallel cross-entropy benchmarking. For the single-qubit gate, the average error is ~0.14% and that of the two-qubit gate is ~0.59%. I will also show some of the multi-qubits experiment results, e.g., genuine multiparticle entanglement for 12 superconducting qubits [1], quantum walks on a programmable two-dimensional 62-qubit superconducting processor [2], and strong quantum advantage [3].

[1] Phys. Rev. Lett. 122, 110501 (2019).
[2] Science, 372, 948 (2021).
[3] Phys. Rev. Lett. 127, 180501 (2021); doi:10.1016/j.scib.2021.10.017.

21 Feb, 11:00

Haohua Wang

Zhejiang University

Superconducting devices provide a promising platform for simulating intriguing phenomena in 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 focus on the tunable-coupling devices that are being developed in our lab. These superconducting devices are fabricated using the flip-chip recipe, with up to 36 transmon qubits and 60 couplers located on the sapphire substrate and the control/readout wirings on the silicon substrate. The couplers are of transmon type, which are used to adjust the effective coupling strength between two neighboring qubits. By selecting a 10-qubit chain to characterize the gate performance, we obtain an averaged Pauli error around 0.09% for single-qubit pi/2 gates and that around 0.97% for two-qubit controlled pi-phase gates via simultaneous cross entropy benchmarkings. Based on these flip-chip devices, we further implement a digital quantum simulation protocol to realize a distinct type of non-equilibrium state of matter, a Floquet symmetry-protected topological phase, which breaks the time translational symmetry only at the boundaries and has trivial dynamics in the bulk.

21 Feb, 11:30

Yutaka Tabuchi

RIKEN

Scaling up quantum computers is one of the challenges for fault-tolerant quantum computation. Reliable computation with noisy qubits is performed based on an error-correction mechanism; a quantum state is encoded in redundant qubits, and logic gates are executed in the encoded space. Whereas it provides high-precision logical gates demanded in quantum algorithms for realistic problems, the cost overhead of the required number of qubits is enormous. A practical bottleneck in solid-state qubits is wiring complexity; the control and readout wires become more packed in the two-dimensional integration of the quantum circuits.

Here, we show our integrated qubits suitable for surface code implementation. Out-of-plane wiring enables dense signaling to the qubit chip, and tile-able qubit design with translational symmetry ensures scalability. We have established superconducting through-silicon vias on titanium nitride film for guiding microwave signals from the backside of the substrate. The entire qubit design with fixed-frequency transmons is optimized to the surface code implementation using cross-resonance gates under the finite qubit-frequency variation. We demonstrate small-sized surface code implementation, with vertically accessible qubits.

21 Feb, 12:00

Chunqing Deng

Alibaba

Superconducting qubits provide a promising path toward building large-scale quantum computers. The simple and robust transmon qubit has been the leading platform, achieving multiple milestones. However, fault-tolerant quantum computing calls for qubit operations at error rates significantly lower than those exhibited in the state of the art. Consequently, alternative superconducting qubits with better error protection have attracted increasing interest. Among them, fluxonium is a particularly promising candidate, featuring large anharmonicity and long coherence times. Here, we engineer a fluxonium-based quantum processor that integrates high qubit-coherence, fast frequency-tunability, and individual-qubit addressability for reset, readout, and gates. With simple and fast gate schemes, we achieve an average single-qubit gate fidelity of 99.97% and a two-qubit gate fidelity of up to 99.72%. This performance is comparable to the highest values reported in the literature of superconducting circuits. Thus our work, for the first time within the realm of superconducting qubits, reveals an approach toward fault-tolerant quantum computing that is alternative and competitive to the transmon system.

21 Feb, 14:00

Michael Biercuk

Q-CTRL / The University of Sidney

Quantum control provides a powerful framework for the optimization of quantum device performance without requiring changes in the underlying hardware, augmenting processes from gate design and calibration through to measurement. The use of machine learning and measurement-based feedback control in particular provides a path to efficiently control large systems, by allowing autonomous agents to determine the best control solutions across without the need for a detailed Hamiltonian model. We experimentally demonstrate how this strategy can enhance the success probability of a maximally compiled Bernstein Vazirani algorithm by up to 1000 times using a 16-qubit superconducting quantum computer. We first compare strategies to autonomously optimize individual multiqubit cross-resonance gates using deep reinforcement learning in runtime, black-box optimization, and automated parameterized gate-calibration. These experiments yield gates which outperform the best "traditionally" designed and calibrated alternatives, show robustness to system drift up to a month, and can be scalably optimized in parallel across entire devices. Next, we present an automated backend compilation routine to inject optimized two-qubit and identity gates into precompiled circuits. We also introduce a highly scalable neural-network-based measurement-error-mitigation strategy which exponentially reduces calibration overhead. Taken together we conclude by presenting a range of algorithmic benchmarking results for different system sizes, revealing an exponential benefit in control-enhancement with system size.

21 Feb, 14:30

Ruixia Wang

Beijing Academy of Quantum Information Sciences

Variational quantum algorithms (VQAs) have shown strong evidences to gain provable computational advantages for diverse fields such as finance, machine learning, and chemistry. However, the heuristic ansatz exploited in modern VQAs is incapable of balancing the tradeoff between expressivity and trainability, which may lead to the degraded performance when executed on the noisy intermediate-scale quantum (NISQ) machines. To address this issue, here we demonstrate the first proof-of-principle experiment of applying an efficient automatic ansatz design technique, i.e., quantum architecture search (QAS), to enhance VQAs on an 8-qubit superconducting quantum processor. In particular, we apply QAS to tailor the hardware-efficient ansatz towards classification tasks. Compared with the heuristic ansatze, the ansatz designed by QAS improves test accuracy from 31% to 98%. We further explain this superior performance by visualizing the loss landscape and analyzing effective parameters of all ansatze. Our work provides concrete guidance for developing variable ansatze to tackle various large-scale quantum learning problems with advantages.

21 Feb, 15:00

Neill Lambert

RIKEN

Modelling the influence of an environment on a quantum system non-perturbatively is an important task for understanding a range of physical systems, from photosynthesis to quantum technologies. I will describe our new approach to this problem based on capturing the influence of a continuum environment with a finite set of discrete pseudomodes, which differ from other discrete approaches to this problem via their unphysical nature. I will describe how to treat both bosonic and fermionic environments with this method, and describe applications including modelling ground-state virtual excitations, non-equilibrium transport, and Kondo resonance. I will also briefly discuss potential future applications to problems like quantum control and light-harvesting.

[1] N. Lambert, S. Ahmed, M. Cirio, F. Nori, Nature Communications 10, 3721 (2019).
[2] M. Cirio, P.C. Kuo, Y.N. Chen, F. Nori, N. Lambert, Physical Review B 105, 035121 (2022).

21 Feb, 16:00

Jarryd Pla

The University of New South Wales

Kinetic inductance is a property of superconductors that can be conveniently used to detect photons over wide range of wavelengths, from the far-infrared to X-rays [1]. The inherent nonlinearity provided by the kinetic inductance of a superconducting film has also been utilized to build travelling wave parametric amplifiers for microwave signals [2], with noise performances approaching the quantum limit [3]. Here I present the first degenerate parametric amplifier that exploits three wave mixing in a kinetic inductance wire [4], made from a planar resonator in a thin NbTiN film. I show that it operates close to the quantum noise limit and exhibits extremely weak high order nonlinearities, which yields an exceptionally high dynamic range and permits large phase-sensitive gains.

The high critical field of the NbTiN film allows the new kinetic inductance parametric amplifier to be operated in magnetic fields and interfaced with spin ensembles. I will present the results of experiments where we inductively couple the amplifier to an ensemble of bismuth donor spins in silicon. By parametrically driving the nonlinear resonator we demonstrate the direct amplification of echo signals emitted by the spins in magnetic fields up to 250 mT, with a large enhancement in the signal to noise ratio. Finally, I show that for large pump strengths the amplifier exhibits parametric self-oscillations, with a pump power threshold strongly dependent on the intracavity signal amplitude, which allows us to implement a high-gain latched-readout [5] of the spin echo signals.

[1] P. Day, et al., 'A broadband superconducting detector suitable for use in large arrays', Nature 425, 817 (2003).
[2] B. H. Eom, et al., 'A wideband, low-noise superconducting amplifier with high dynamic range', Nature Physics 8, 623 (2012).
[3] M. Malnou, et al., 'Three-Wave Mixing Kinetic Inductance Traveling-Wave Amplifier with Near-Quantum-Limited Noise Performance', PRX Quantum 2, 010302 (2021).
[4] D. J. Parker, et al., 'A near-ideal degenerate parametric amplifier', arXiv pre-print, 2108.10471v2 (2021).
[5] P. Krantz, et al. 'Single-shot read-out of a superconducting qubit using a Josephson parametric oscillator', Nature Communications 7, 11417 (2016).

21 Feb, 16:30

Kenta Takeda

RIKEN

Spins in silicon-based quantum dots are one of the most promising platforms for quantum computing due to their nanofabrication capability for scaling-up. In the first part of the talk, we report our recent progress on the implementation of high-fidelity two-qubit CNOT gate [1]. The CNOT gate is realized by a resonant controlled-rotation under a strong, but stable exchange coupling between the neighboring spins. We examine the gate fidelity via a randomized benchmarking and obtain a fidelity of 99.5 %, which crosses the threshold for surface code error-correction. In the second part of the talk, we report the realization of a basic concept of quantum error-correction in silicon. The two-qubit gate enables encoding/decoding of the three-qubit GHZ states [2]. In addition, we implement a correcting spin rotation by a single-step three-qubit iToffoli gate implemented similarly to the above CNOT gate. We then synthesize the three-qubit repetition code and demonstrate that the phase-flip errors can be mitigated [3].

[1] A. Noiri et al., Nature 601, 338–342 (2022).
[2] K. Takeda et al., Nat. Nanotechnol. 16, 965–969 (2021).
[3] K. Takeda et al., arXiv:2201.08581 (2022).

22 Feb, 9:30

Dany Lachance-Quirion

Nord Quantique

Quantum magnonics aims to study the interaction of magnons, quanta of collective excitations in magnetically ordered systems, with other quantum systems. Notably, recent proof-of-principle experiments in quantum magnonics with superconducting circuits have made quantum magnonics an emerging subfield of magnonics and quantum technologies. In this presentation, I will first briefly review previous experimental results in superconducting qubit-based quantum magnonics. With these results in mind, I will then present possible perspectives for the field both for fundamental research and the development of quantum technologies. A key research topic at the forefront of these perspectives is the very short lifetime of magnons that is currently greatly hindering any practical integration to the different quantum technological platforms. I will argue that understanding the mechanisms limiting the magnon lifetime, critical for the future of the field, should be a focus for future research. I will present some preliminary results providing new insights into magnon decay in the quantum regime and how the lifetime of magnons in yttrium iron garnet can be enhanced in situ and in the quantum regime.

22 Feb, 10:00

Yuto Ashida

The University of Tokyo

Strong coupling between matter and quantized electromagnetic modes in cavity or waveguide may offer yet another approach of controlling equilibrium phases or dynamics of many-body systems. Recent developments have shown promises for realizing such strong light-matter interaction in genuinely quantum and nonperturbative regimes, where conventional approximate theoretical methods cannot be applied in general. I will talk about how one can analyze strongly coupled quantum light-matter systems at arbitrary interaction strengths on the basis of an asymptotically disentangling unitary transformation [1,2]. I discuss its application to construction of tight-binding Hamiltonians, dynamics of bound states in the continuum, and revisiting dissipative quantum phase transition in resistively shunted Josephson junctions [3].

[1] Y. Ashida, A. Imamoglu and E. Demler, PRL 126, 153603 (2021).

[2] Y. Ashida, A. Imamoglu and E. Demler, arXiv:2105.08833.

[3] K. Masuki, H. Sudo, M. Oshikawa and Y. Ashida, arXiv:2111.13710.

22 Feb, 10:30

Koji Usami

The University of Tokyo

We report on an optically-probed ferromagnetic resonance experiment which elucidates the magnon–exciton coupling at a van der Waals heterointerface between a magnetic thin film and an atomically-thin semiconductor [1]. Our approach allies the long-lived magnons hosted in a film of yttrium iron garnet (YIG) to strongly-bound excitons in a flake of a transition metal dichalcogenide, MoSe2. We reveal dynamic magnetic proximity effects induced by the magnons in the YIG film on the excitons in the MoSe2 flake through a valley-specific gigahertz modulation of the exciton resonance. A quantitative evaluation of the strength of the magnon-exciton coupling is also presented. We discuss a refined opportunity that this new class of hybrid system provides for information transduction between microwave and optical regimes.

[1] A. Gloppe, M. Onga, R. Hisatomi, A. Imamoglu, Y. Nakamura, Y. Iwasa, and K. Usami, arXiv:2006.14257 [to appear in Phys. Rev. B].

22 Feb, 11:30

Atsushi Noguchi

The University of Tokyo / RIKEN

"Single Elementary Particle at Rest in Space" would be an ideal quantum system isolated from the environment. In recent years, the technology of electron trapping, which creates such a situation in the laboratory, has begun to attract attention.

The quantum control technology developed in ion traps has been mainly based on laser control, as exemplified by laser cooling. However, trapped electrons, which cannot be controlled by light, have not been studied much as a platform for quantum information processing.

Hybrid quantum systems, which combine quantum systems with different properties, recently have been studied.

Superconducting quantum circuits, in particular, have played a central role in these research because they can be designed with various parameters and can be coupled to other systems via electric and magnetic fields. Trapped electrons can be coupled to superconducting circuits because they involve a large electric dipole moment of the microwave frequency. Therefore, the electron trap quantum system controlled by superconducting quantum circuits was conceived as an alternative control method to lasers in ion traps. In this talk, I will describe the development of technology for cryogenic electron traps and the work on ultra-low error quantum computers using trapped electrons.

22 Feb, 12:00

Luming Duan

Tsinghua University

In this talk, I will show how to realize large ion crystals for quantum simulation and computation, how to quantum simulate the Rabi-Hubbard model beyond the classical simulation capability, and how to realize dual-type qubits with the same species of trapped ions for fault-tolerant quantum error correction so that one-type of qubits can be repeatedly measured with no detrimental influence on the other-type of qubits that carry the computational information.

22 Feb, 14:00

Erika Kawakami

RIKEN

Electrons on the surface of liquid helium present an extremely clean two-dimensional electron system. Thanks to its cleanliness, the quantum states of the electrons on helium are expected to have a long relaxation time, which provides a perfect platform to realize qubits with [1]. In particular, spin states are expected to have an extremely long coherence time [2]. The first part of my presentation will focus on our proposal on the realization of spin qubits by making use of the interaction between the Rydberg state and the spin state.

The main difficulty of electrons on helium being used as qubits lies in the fact that we cannot have direct Ohmic contacts to electrons on helium since they float in a vacuum. Thus, the detection of the electrons' states is not straightforward. In the second part, I will present our recent experimental efforts towards the Rydberg state detection of a single electron. We experimentally demonstrated a capacitive readout of the Rydberg states of many electrons on helium [3]. We are currently working on implementing an LC-tank circuit in proximity to the device in order to perform the dispersive read-out of the Rydberg states of electrons on helium.

[1] P.M. Platzman, and M. I. Dykman, Science 284, 1967 (1999).

[2] S. A. Lyon, Phys. Rev. A 74,052338 (2006).

[3] E. Kawakami, A. Elarabi, and D. Konstantinov, Phys. Rev. Lett. 123, 086801 (2019); E. Kawakami, A. Elarabi, and D. Konstantinov, Phys. Rev. Lett. 126, 106802 (2021).

22 Feb, 14:30

Kihwan Kim

Tsinghua University

In this talk, we present the strong experimental evidence of the quantum simulation by preparing ground state of the frustrated 2D Ising models through adiabatic evolution. We have developed a monolithic Paul trap that can hold the 2D crystal of ions. In the trap, we have mitigated the most serious problem, which is called micromotion problem, in the 2D crystal of ions for the coherent manipulation. In our trap, the micromotion direction of ions is perpendicular to the propagation direction of Raman laser beams for quantum operation [1]. In the experiment, first, we realize the vibrational ground states of 2D crystal of ions by applying EIT cooling method [2], then we perform the adiabatic quantum simulations [3] and prepare the ground-state of various quantum Ising Hamiltonian in 2D lattice. We control the characters of the spin-spin interactions by changing the detuning of Raman laser beams to various vibrational modes, which result in different ground states of the corresponding spin models including spin-frustration [4].

[1] Ye Wang, Mu Qiao, et al., Adv. Quant. Techn. 3, 2000068 (2020).
[2] Mu Qiao, et al., Phys. Rev. Lett. 126, 023604 (2021).
[3] Chris Monroe, et al., Rev. Mod. Phys. (2021).
[4] Mu Qiao, et al., in preparation.

22 Feb, 15:30

Kiyotaka Aikawa
Tokyo Institute of Technology

Ultracold single nanoparticles levitated in vacuum are expected to be a promising system for exploring macroscopic quantum mechanics as well as for realizing ultra-sensitive accelerometers. We develop an experimental apparatus based on an optical lattice, where nanoparticles oscillate in a higher frequency than in a conventional single-beam optical tweezer. We find that the laser phase noise significantly heats up the motion of nanoparticles. When the laser phase noise is carefully reduced by orders of magnitude, we observe that heating of nanoparticles is dominated by random photon recoils. Furthermore, in a carefully optimized optical setup, we achieve efficient feedback cooling of charged nanoparticles' motion to near the ground state in an optical lattice by applying oscillating electric fields. In this setup, we find that nanoparticles are subject to stray electric fields, which prohibit precision measurements of their motion. To minimize the impact of stray fields, we develop an approach for neutralizing the trapped nanoparticles and cooling their motion by a purely optical means.

22 Feb, 16:00

Pu Huang
Nanjing University

Diamagnetic levitated mechanical system is recently demonstrated as a sensitive force sensor, I will first give some very recent progresses of our research group on diamagnetic levitated sensors, including the preliminary results of the first realization of diamagnetic levitation at low temperature, where ultra-high sensitivity of force and acceleration is expected. Next, I will show result of acceleration measurement using diamagnetic levitated sensor of sub-millimeter size at room temperature, we reached imprecision as low as 10-12g (g is the gravity of earth) which represents the best value in currently reported methods. Finally, I will show two of our recent experiments on application of diamagnetic levitated sensor in study new physics, the first is the test of continuous spontaneous localization model, the second is the test of Chameleon theory, one of important candidate of dark energy.

22 Feb, 16:30

Akio Kawasaki

AIST

Optically-levitated nanospheres and microspheres have been receiving increasing attentions for its various applications ranging from quantum science of macroscopic objects to fundamental physics. We are developing systems to trap microspheres of radii between 5 and 10 um for the purpose of searches for new particles and interactions [1]. In the course of improving the apparatus, we established ways to control the sphere's translational [2] and rotational [3] motion, and characterize its charge [4], electric dipole moment [5], and mass [6]. The system is utilized for a search for non-Newtonian gravity [7] and millicharge [4,5]. The first reports demonstrate the proof-of-principle, and ongoing upgrades is expected to increase the search region beyond currently available best limits.

[1] A. Kawasaki, et al.: Rev. Sci. Instrum. 91, 083201 (2020)

[2] A. D. Rider, et al.: Phys. Rev. A 97, 013842 (2017)

[3] A. D. Rider, et al.: Phys. Rev. A 99, 041802(R) (2019)

[4] D. C. Moore, et al.: Phys. Rev. Lett. 113, 251801 (2014)

[5] N. Priel, et al.: arXiv:2112.10383 (2021)

[6] C. P. Blakemore, et al.: Phys. Rev. Applied 12, 024037 (2019)

[7] C. P. Blakemore, et al.: Phys. Rev. D 104, L061101 (2021)

23 Feb, 10:00

Warit Asavanant

The University of Tokyo

Practial quantum computer requires scalability, universality, and fault tolerance. In the recent years, continuous-variable optical systems have made large progresses regarding scalability. Scalable measurement-based architectures using temporal wave packet have been experimentally demonstrated and various related research, both experiment and theory, are being accelerated much more than ever. In this talk, I will introduce our recent works toward realization of optical quantum computer with the focus on the time-domain cluster states and their applications. Cluster state is a type of multipartite entanglement that can implement quantum operations when combined with measurements and feedforward operations. Although there have been various generations of small-scale cluster state, there are no generation of large-scale cluster state with entanglement structure that allows universal quantum computation. I will explain how we have used the time-domain-multiplexing methodology to generate cluster state for universal quantum computation and show the results regarding the implementation of quantum computation in time domain. In addition, our recent approaches to include fault tolerance to this architecture will be discussed as well.

23 Feb, 10:30

Yvonne Gao

CQT / 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 QED 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.

23 Feb, 11:00

Hayato Goto

Toshiba

Since our proposals in 2016 [1,2], Kerr parametric oscillators (KPOs) have inspired many interesting studies in the fields of quantum computing [3-7], quantum optics [8], and quantum chaos [9]. KPOs have recently been realized by using superconducting circuits [10,11]. Quantum annealing with KPOs has also inspired a novel classical algorithm called simulated bifurcation, leading to high-performance Ising machines [12-14]. Here we review these topics.

[1] H. Goto, Sci. Rep. 6, 21686 (2016).

[2] H. Goto, Phys. Rev. A 93, 050301(R) (2016).

[3] H. Goto, J. Phys. Soc. Jpn. 88, 061015 (2019).

[4] H. Goto et al., Sci. Rep. 8, 7154 (2018).

[5] H. Goto and T. Kanao, Commun. Phys. 3, 235 (2020).

[6] T. Kanao and H. Goto, npj Quant. Inf. 7, 18 (2021).

[7] T. Kanao et al., arXiv:2108.03091.

[8] H. Goto et al., Phys. Rev. A 99, 023838 (2019).

[9] H. Goto and T. Kanao, Phys. Rev. Res. 3, 043196 (2021).

[10] Z. Wang et al., Phys. Rev. X 9, 021049 (2019).

[11] A. Grimm et al., Nature 584, 205 (2020).

[12] H. Goto et al., Sci. Adv. 5, eaav2372 (2019).

[13] H. Goto et al., Sci. Adv. 7, eabe7953 (2021).

[14] K. Tatsumura et al., Nat. Electron. 4, 208 (2021).

23 Feb, 13:00

Arne Grimsmo

The University of Sydney

The Gottesman-Kitaev-Preskill code can be described as the ground space of a Hamiltonian that is periodic in both position and momentum. Although periodic degrees of freedom arise naturally in many physical quantum systems—for example, the superconducting phase across a Josephson junction—it is rather challenging to ensure periodicity in two conjugate variables simultaneously. In this talk I will discuss the possibility of using periodicity in one variable, together with periodicity in time, to effectively realize the GKP codewords as Floquet states in a time-dependent system. Physically, it may be possible to realize this scheme in a Josephson junction circuit where the Josephson energy is modulated in time.

23 Feb, 13:30

Andrew Darmawan

Kyoto University

The development of robust architectures capable of large-scale fault-tolerant quantum computation should consider both their quantum error-correcting codes, and the underlying physical qubits upon which they are built, in tandem. Following this design principle we demonstrate remarkable error correction performance by concatenating the XZZX surface code with Kerr-cat qubits. We contrast several variants of fault-tolerant systems undergoing different circuit noise models that reflect the physics of Kerr-cat qubits. Our simulations show that our system is scalable below a threshold gate infidelity of pCX~6.5% within a physically reasonable parameter regime, where pCX is the infidelity of the noisiest gate of our system; the controlled-not gate. This threshold can be reached in a superconducting circuit architecture with a Kerr-nonlinearity of 10MHz, a ∼6.25 photon cat qubit, single-photon lifetime of ≳64 us, and thermal photon population ≲8%. Such parameters are routinely achieved in superconducting circuits.

23 Feb, 14:00

Keisuke Fujii

Osaka University / RIKEN

Now that 50-100 qubit scale quantum computers have been realized, then an experimental demonstration of quantum error correction is becoming a reality. In this talk, I will present a result of simulation of quantum error correction on the scale of 50 qubits under a realistic noise model. Specifically, we will discuss what physical conditions are required to extend the lifetime of logical qubits against the coherence time of physical qubits. In the post-NISQ era, it is required to evaluate the performance of quantum error correction on the scale of 1000 qubits. For such a situation, we will show that it is possible to simulate quantum error correction over 1000 qubits by using a qusi-probability method, taking advantage of the fact that most of the quantum circuits employed in quantum error correction are Clifford. Furthermore, by applying quantum error mitigation, which was developed as a method to overcome the noise problem in NISQ devices, to quantum error correction, the number of required physical qubits can be greatly. We expect that these researches will make an important contribution to the evolution from the NISQ era to the FTQC era closing their gap.

23 Feb, 15:00

Shingo Kono

EPFL

Over the past decades, optomechanics has allowed major progress in the quantum control of mechanical systems, such as ground-state cooling, squeezing, and quantum entangling. While novel dynamics and applications are expected when utilizing optomechanical arrays and lattices, nearly all prior schemes have employed single- or few-mode optomechanical systems. Superconducting circuits are a promising platform to realize optomechanics with a flexible design and precise control. To date, however, realizing optomechanical lattices has been compounded by the limited scaling in contemporary circuit optomechanics. Here, we overcome this challenge and realize superconducting circuit optomechanical lattices. We demonstrate non-trivial topological microwave collective modes in a 10-site optomechanical chain as well as a 24 site honeycomb lattice, realizing the Su-Schrieffer-Heeger model. Furthermore, we present a technique exploiting embedded optomechanical interaction to directly measure the mode shape of the microwave modes, without using any local probe. Our new platform and measurement technique offers an avenue to explore many-body physics in optomechanical lattices.

23 Feb, 15:30

Vibhor Singh

IISc Bangalore

Control over the quantum states of a massive oscillator is important for several technological applications and to test the fundamental limits of quantum mechanics. Hybrid electromechanical systems using superconducting qubits, based on electric charge mediated coupling, have been quite successful in this regard. In this talk, I shall introduce a hybrid device, consisting of a superconducting transmon qubit and a mechanical resonator coupled using the magnetic flux. Such coupling stems from the quantum-interference of the superconducting phase across the tunnel junctions. Consequently, we detect thermomechanical motion using drive corresponding to average occupancy of less than one photon. In addition, the large coupling between qubit and mechanical resonator is manifested in the observation of the Landau–Zener–Stückelberg effect. I will further mention the prospects of such a device in the dispersive limit.

23 Feb, 16:00

Warwick Bowen

The University of Queensland

In this presentation I will introduce a new approach to controlling the quantum state of macroscopic mechanical resonators via measurement and conditioning. This approach is based on continuous position measurement and works outside of the usual rotating wave approximation. Outside this regime, it allows the preparation of quantum squeezed states of motion. Remarkably, our theory predicts that this is possible outside of both the backaction dominated and quantum coherent oscillation regimes, relaxing experimental requirements even compared to mechanical ground-state cooling. This provides a new way to generate nonclassical states of macroscopic mechanical oscillators and opens the door to quantum sensing and tests of quantum macroscopicity at room temperature.

I will present experimental progress towards demonstrating non-classical states of a mechanical resonator at room temperature, taking advantage of both structural damping -- which we show that, compared to the usual viscous damping, can improve quantum state preparation -- and arrays of mechanical modes. Specifically, I will present experiments demonstrating that continuous position measurement can prepare thermomechanical squeezed states of motion, and to this for ensembles of structurally damped mechanical resonances.