ICQC2019

International Conference on Quantum Computing 2019

Abstract Booklet

July 11-12, 2019

El Tower, Yangjae, Seoul, Korea

Ministry of Science and ICT
KIAS 고등과학원 KOREA INSTITUTE FOR ADVANCED STUDY
NRF National Research Foundation of Korea
QuIST 양자정보과학기술연구회

http://www.quist.or.kr

Venue

5th floor, Marygold Hall, El Tower, Yangjae, Seoul, Korea

Period

July 11 (THUR) ~ July 12 (FRI), 2019

Keynote Speakers:

Barry Sanders (Institute for Quantum Science and Technology, Univ. of Calgary)
Yasunobu Nakamura (Tokyo Univ.)

Invited speakers:

Jaewook Ahn (KAIST)
Joonwoo Bae (KAIST)
Jaeyoon Cho (APCTP)
Mahn-Soo Choi (Korea Univ.)
Joonsuk Huh (SKKU)
Dohun Kim (SNU)
Jehyung Kim (UNIST)
Donghun Lee (Korea Univ.)
Jaejin Lee (SNU)
Junghyun Lee (KIST)
Soojoon Lee (Kyung Hee Univ.)
Thomas Monz (AQT & Univ. of Innsbruck)
Hyunchul Nha (TAMU at Qatar)
Tanumoy Pramanik (KIST)
June-Koo Kevin Rhee (KAIST)
Selim Shahriar (Northwestern Univ.)
Jae-Yoon Sim (POSTECH)
Emre Togan (ETH Zurich)

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Yong-Su Kim (KIST)
Jinhyoung Lee (Hanyang Univ.)
Soojoon Lee (Kyung Hee Univ.)
Han Seb Moon (PNU)
Wonmin Son (Sogang Univ.)

Program

July 11

Time	TITLE	Speaker
8:30-9:10	registration	
9:10-9:30	opening	
9:30-11:10	Machine Learning for Quantum Control	Barry Sanders (Univ. of Calgary)
	Superconducting quantum circuits: quantum computing and other applications	Yasunobu Nakamura (Univ. of Tokyo)
11:10-11:20	Break (10 min)	
11:20-12:40	Quantum Simulation Methods for Molecular Vibronic Spectra	Joonsuk Huh (SKKU)
	Building Blocks of Quantum Computers in the Perspective of Computer Science	Jaejin Lee (SNU)
12:40-14:00	Lunch (80 min)	
14:00-16:00	Quantum information and sensing based on diamond NV centers	Donghun Lee (Korea Univ.)
	Utilizing electronic spins in diamond for quantum information applications	Junghyun Lee (KIST)
	Solid-State Quantum Emitters with Photonic Integrated Circuits for Quantum Photonics	Jehyung Kim (UNIST)
16:00-16:20	Break (20 min)	
16:20-18:20	Quantum Reinforcement Learning on Parity Pattern in Binary String	June-Koo Kevin Rhee (KAIST)
	Spin-charge hybrid qubits in semiconductor quantum dots	Dohun Kim (SNU)
	Quantum computing with trapped ions	Thomas Monz (AQT & Univ. of Innsbruck)
18:20-	Discussion	

July 12

Time	TITLE	Speaker
9:30-10:50	Heisenberg Limited Precision Metrology using Maximally Entangled Schroedinger Cat States with Increased Quantum Noise	Selim Shahriar (Northwestern Univ.)
	Quantum non-Gaussianity and secure communications	Hyunchul Nha (TAMU at Qatar)
10:50-11:00	Break (10 min)	
11:00-12:20	Ultimate Precision of Direct Tomography of Wave Functions	Mahn-Soo Choi (Korea Univ.)
	Structure of the ground states of gapped local Hamiltonians in one dimension	Jaeyoon Cho (APCTP)
12:20-14:00	Lunch (1 hour 40 min)	
14:00-16:00	Quantum state exchange and its entanglement cost	Soojoon Lee (Kyung Hee Univ.)
	Coding of a Quantum Measurement	Joonwoo Bae (KAIST)
	Engineering for Scalable Quantum Computer	Jae-Yoon Sim (POSTECH)
16:00-16:20	Break (20 min)	
16:20-18:20	Rydberg atom entanglement in the weak coupling regime	Jaewook Ahn (KAIST)
	Enhanced interactions between dipolar polaritons	Emre Togan (ETH Zurich)
	Activation of different nonlocal quantum correlations after occurring sudden deaths	Tanumoy Pramanik (KIST)
18:20-	Closing	

- July 11 -

Keynote 1.

Machine Learning for Quantum Control

Barry Sanders

Institute for Quantum Science and Technology, University of Calgary, Alberta T2N 1N4, Canada

We develop a framework that connects reinforcement learning with classical and quantum control, and this framework yields adaptive quantum-control policies that beat the standard quantum limit, inspires new methods for improving quantum-gate design for quantum computing, and suggest new ways to apply classical and quantum machine learning to control.

Keynote 2.

Superconducting quantum circuits: quantum computing and other applications

Yasunobu Nakamura

Research Center for Advanced Science and Technology (RCAST), The University of Tokyo, Tokyo 153-8904, Japan
Center for Emergent Matter Science (CEMS), RIKEN, Wako, Saitama 351-0198, Japan

Superconducting qubits have been around already for twenty years. Thanks to the orders-of-magnitude improvement of the coherence time, we can now play with them various quantum operations. Integration of qubits for scalable quantum computing is a challenging but growing research field we are also involved in. In addition, microwave quantum optics based on superconducting circuits has led to a number of sophisticated techniques such as microwave single photon detectors. As a well-controlled quantum system, superconducting qubits and resonators are also exploited in quantum information thermodynamics as well as in implementations of hybrid quantum systems with collective excitations in solid, e.g., magnons in ferromagnetic materials and phonons in surface acoustic wave resonators. All these topics manifest the uniqueness of superconducting quantum circuits as artificially-designed macroscopic quantum objects.

Invited Talk 1.

Quantum Simulation Methods for Molecular Vibronic Spectra

Joonsuk Huh

Department of Chemistry, Sungkyunkwan University, Suwon, 16419, Korea
SKKU Advanced Institute of Nanotechnology (SAINT), Sungkyunkwan University, Suwon 16419, Korea

Quantum computer is expected to attempt the quantum supremacy in near-term with potentially useful applications. Among the various quantum simulation problems, a quantum sampling problem with noninteracting bosonic particles, i.e. boson sampling, is very likely to demonstrate the quantum supremacy with relatively limited physical resources. In my talk, I will present a molecular problem (molecular vibronic spectra), which can be interpreted as a Gaussian boson sampling problem. Additionally, a quantum circuit based algorithm for the same molecular problem will be presented.

Invited Talk 2.

Building Blocks of Quantum Computers in the Perspective of Computer Science

Jaejin Lee

Dept. of Computer Science and Engineering, Seoul National University, Seoul 08826, Korea

Quantum computing is viewed as a possible future option to tackle intractable problems of classical computing with a fundamentally different computing paradigm. However, in the perspective of computer science, quantum computing is still in its early stage and quantum computers are not easily accessible to computer scientists. In this talk, we address the gap existing between computer scientists and the current quantum computing technology. As a means to reduce the gap, we address the importance of an end-to-end software stack for the virtual execution environment of quantum algorithms/programs.

Invited Talk 3.

Quantum information and sensing based on diamond NV centers

Donghun Lee

Department of Physics, Korea University, Seoul 02841, Korea

Various quantum systems have been studied in the field of quantum information, quantum network and quantum metrology. Among the systems, atom-like defect center in diamond crystal has got rapidly increasing attention due to its unique properties for quantum applications. Particularly nitrogen-vacancy (NV) defect centers in diamond are solid-state spin-qubits possessing remarkable quantum properties applicable to various fields including quantum information science and quantum sensing. For instance, its atomic-scale size, long spin coherence times, and high magnetic field sensitivity are suitable for nanometer and nanotesla magnetometry.

Invited Talk 4.

Utilizing electronic spins in diamond for quantum information applications

Junghyun Lee

Center for Quantum Information, Korea Institute of Science and Technology (KIST), Seoul 02792, Korea

In recent years, the nitrogen-vacancy (NV) color center in diamond, electronic spin defect embedded in a solid-state system, has emerged as a promising platform for quantum information science in ambient temperature. Its capability of robust but high-precision spin control allows the NV center to be an attractive system for diverse quantum measurements. In this talk, I will describe how we can utilize NV center electronic spins as a builiding block for quantum processors.

Invited Talk 5.

Solid-State Quantum Emitters with Photonic Integrated Circuits for Quantum Photonics

Jehyung Kim

Department of Physics, Ulsan National Institute of Science and Technology, Ulsan 44919, Korea

A large-scale quantum photonic system relies on the ability to generate and control quantum light on a chip. Solid-state quantum emitters provide an efficient source of single photons, and photonic integrated circuits can route, modulate, filtering the photons in a miniaturized chip. Combining these two platforms, therefore, enables us to utilize the advantages of both systems and makes integrated quantum photonic devices more feasible. We present the recent results on control of multiple quantum emitters and new approaches for hybrid integration of solid-state quantum emitters into a photonic circuit.

Invited Talk 6.

Quantum Reinforcement Learning on Parity Pattern in Binary String

Daniel K.D. Park, Jonghun Park, and June-Koo Kevin Rhee

School of Electrical Engineering, KAIST, Daejeon 34141, Korea
ITRC of Quantum Computing for AI, KAIST, Daejeon 34141, Korea

Quantum machine learning algorithms are volatile in a sense that the trained feature and model are lost as the output state collapses with measurements. This behavior can be improved if one can combine classical and quantum algorithms to make an effective hybrid quantum reinforcement learning. We develop a reinforcement learning algorithm consisting of a quantum environment and a classical agent to find a hidden parity string in a data coded with low density parity. The result shows clear signatures that the quantum reinforcement can learn hidden string more efficiently than an optimal classical algorithm as the algorithm cumulates leaning in the aspects of sample and computational complexities.

Superconducting qubits have been around already for twenty years. Thanks to the orders-of-magnitude improvement of the coherence time, we can now play with them various quantum operations. Integration of qubits for scalable quantum computing is a challenging but growing research field we are also involved in. In addition, microwave quantum optics based on superconducting circuits has led to a number of sophisticated techniques such as microwave single photon detectors. As a well-controlled quantum system, superconducting qubits and resonators are also exploited in quantum information thermodynamics as well as in implementations of hybrid quantum systems with collective excitations in solid, e.g., magnons in ferromagnetic materials and phonons in surface acoustic wave resonators. All these topics manifest the uniqueness of superconducting quantum circuits as artificially-designed macroscopic quantum objects.

Invited Talk 7.

Spin-charge hybrid qubits in semiconductor quantum dots

Dohun Kim

Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea

The charge and spin degrees of freedom of an electron constitute natural bases for constructing quantum two level systems, or qubits, in semiconductor quantum dots. The quantum dot charge qubit offers a simple architecture and high-speed operation, but generally suffers from fast dephasing due to strong coupling of the environment to the electron's charge. On the other hand, quantum dot spin qubits have demonstrated long coherence times, but their manipulation is often slower than desired for important future applications. This talk will review experimental progress of fast semiconductor based quantum qubits, focusing on recently developed 'hybrid' qubits formed by three electrons in Si/SiGe double quantum dots or GaAs, where strong inter dot coupling combined with singlet and triplet spin states form spin states that is controllable with electric field thereby realizing a good ratio of coherence to manipulation time. Starting from discussing general introduction to quantum transport measurements in quantum dots, circuit design, and material issues for developing highly coherent qubits in semiconductors, the talk will also discuss implementations of advanced quantum measurement and validation protocols and paths toward realizing scalable quantum computing architecture using semiconductor quantum dots as artificial atoms.

Invited Talk 8.

Quantum computing with trapped ions

Thomas Monz

Institut für Experimentalphysik, Universität Innsbruck, Technikerstrasse 25, A-6020 Innsbruck, Austria
Alpine Quantum Technologies GmbH, 6020 Innsbruck, Austria

Ion-trap devices are one of the most promising architectures for quantum technologies: trapped ions are used as frequency standards, demonstrated quantum simulations with the largest numbers of qubits, readily support optical interfaces for communication purposes, and are likely the most versatile quantum computing platform. This talk will provide a background on ion-trap based quantum computing, explain fault-tolerant quantum control, to then focus on algorithmic achievements. The presentation will conclude with an outlook towards engineering of next-generation ion-trap quantum devices.

- July 12 -

Invited Talk 9.

Heisenberg Limited Precision Metrology using Maximally Entangled Schroedinger Cat States with Increased Quantum Noise

Selim M. Shahriar

Department of EECS, Northwestern University, Evanston, IL 60208, USA
Department of Physics and Astronomy, Northwestern University, Evanston, IL 60208, USA

One axis twist squeezing (OATS) using non-linear interaction in a cavity can increase the sensitivity of metrological devices beyond the standard quantum limit (SQL). When the squeezing parameter is tuned to a critical value, OATS produces the maximally entangled Schroedinger Cat (SC) state, which is an equal superposition of all atoms being spin-up and all atoms being spin-down. However, the orientation of the SC state depends critically on the parity of the number of atoms, N. Changing N by unity causes the orientation to change by ninety degrees. For an experiment employing atoms released from a trap, for example, the parity of N fluctuates between odd and even, thus washing out the SC state. We describe a protocol which, for a given parity, produces a phase magnification by a factor of N, while increasing quantum noise by a factor of root-N, thus reaching the Heisenberg Limit (HL). However, the signal for one parity is filtered out, thus making it possible to achieve the HL within a factor of root-2. The increased quantum noise makes it very robust against classical noise [R. Sarkar, R. Fang, S.M. Shahriar, Phys. Rev. A 98, 013636, 2018; R. Fang, R. Sarkar, S.M. Shahriar, arXiv:1707.08260v7]. We also show that this increased quantum noise makes this process highly insensitive to dissipation via spontaneous emission and cavity decay during the squeezing process. We will also discuss our effort to use such an interferometer for testing two models for collapse of macroscopic quantum superpositions: the Continuous Spontaneous Localization model [A. Bassi et al., Rev. Mod. Physics 85: 471, 2013], and the Diosi-Penrose model [R. Penrose, Gen. Rel. Grav. 28: 581,1996; L. Diosi, Phys. Rev. A 40: 1165,1989] for gravitationally induced collapse.

Invited Talk 10.

Quantum non-Gaussianity and secure communications

Hyunchul Nha

Department of Physics, Texas A & M University at Qatar, P.O. Box 23874, Doha, Qatar

Quantum information processing using continuous-variables mainly relies on the Gaussian regime employing Gaussian states, operations and measurements. This is because it allows a compact analysis using well-established mathematical formulations and an experimental accessibility using quantum optics tools. While quantum non-Gaussian states are known to be essential for certain crucial tasks, little is explored about quantum non-Gaussianity and its critical role in quantum informatics. In the long run, it is necessary to develop a theoretical framework to comprehensively deal with quantum non-Gaussian regime to enhance our capacity for information processing.We here address secure quantum communication in view of no-cloning theorem for a broad class of quantum non-Gaussian states. We specifically discuss the relation between quantum non-Gaussianity and the requirement to achieve secure communication.

Invited Talk 11.

Ultimate Precision of Direct Tomography of Wave Functions

Mahn-Soo Choi

Department of Physics, Korea University, Seoul 02841, Korea

Unlike the standard quantum state tomography, the direct tomography allows the access to the complex values of the wave function (i.e., the expansion coefficient in a fixed basis). Originally put forward as a special case of weak measurement, it can be extended to arbitrary measurement setup. We generalize the idea of "quantum metrology," where a real-valued parameter is estimated, to complex valued-parameter estimation, and apply it for the direct tomography of the wave function. We propose a measurement scheme that can go beyond the stand quantum limit and eventually approach the Heisenberg limit.

Invited Talk 12.

Structure of the ground states of gapped local Hamiltonians in one dimension

Jaeyoon Cho

Asia Pacific Center for Theoretical Physics, Pohang 37673, Korea
Department of Physics, POSTECH, Pohang 37673, Korea

In non-relativistic lattice spin systems, local interaction manifests itself as an emergent locality in the dynamics, producing an effective causality cone given by the Lieb-Robinson bound. In this talk, I overview the universal properties of such systems in one dimension without referring to their microscopic details, relating the spectral gap, the correlation length, and the scaling of entanglement entropies.

Invited Talk 13.

Quantum state exchange and its entanglement cost

Soojoon Lee

Department of Mathematics and Research Institute for Basic Sciences, Kyung Hee University, Seoul 02447, Korea

We consider a quantum communication task between two users Alice and Bob, called the quantum state exchange, in which Alice and Bob exchange their respective quantum information by means of local operations and classical communication assisted by shared entanglement. Here, we assume that classical communication is free. In this work, we first derive lower and upper bounds for the least amount of entanglement which is necessary to perfectly perform the quantum state exchange task in the asymptotic or one-shot setting, and provide conditions on the initial state such that the protocol succeeds with zero entanglement cost in the one-shot setting. Based on these results, we reveal two counter-intuitive phenomena in this task, which make it different from the SWAP operation. One tells how the users deal with their symmetric information in order to reduce the entanglement cost. The other shows that it is possible for the users to gain extra shared entanglement after this task.

Invited Talk 14.

Coding of a Quantum Measurement

Joonwoo Bae

School of Electrical Engineering, KAIST, Daejeon 34141, Korea

We consider the preservation of a measurement for quantum systems interacting with an environment. Namely, a method of preserving an optimal measurement over a channel is devised, what we call channel coding of a quantum measurement in that operations are applied before and after a channel in order to protect a measurement. A protocol that preserves a quantum measurement over an arbitrary channel is shown only with local operations and classical communication without the use of a larger Hilbert space. Therefore, the protocol is readily feasible with present day's technologies. The protocol of preserving a quantum measurement is demonstrated with IBM quantum computers.

Invited Talk 15.

Engineering for Scalable Quantum Computer

Jae-Yoon Sim

Dept. Electrical Engineering, POSTECH, Pohang 37673, Korea

Recent progress in quantum computing has moved its phase from theoretical and physical studies to the field of engineering, which provides new challenges and opportunities of interdisciplinary engineering research toward the realization of fault-tolerant quantum computers. The Scalable Quantum Computer Technology Platform Center has been recently launched. It is the first-time Engineering Research Center (ERC) funded by Korea Ministry of Science and ICT in the field of quantum computing. This talk introduces strategies of the center for the implementation of full-stacked scalable quantum computers. I will talk about issues and considerations in the design of CMOS integrated circuits operating at deep-cryogenic temperatures, 3D integration of quantum processor, and computer architecture including system software such as compiler and logic synthesizer which generate optimum quantum instructions depending on qubit connectivity.

Invited Talk 16.

Rydberg atom entanglement in the weak coupling regime

Jaewook Ahn

Department of Physics, KAIST, Daejeon 34141, Korea

We propose and experimentally demonstrate Rydberg atom entanglement scheme in the weak coupling regime. Our method achieves entanglements between remote atoms even in the presence of closer atoms, which is different from the widely-used entanglement method based on Rydberg-atom blockade in the strong coupling regime. So, the this method overcomes the previous two limitations: (1) only atoms closer than a Rydberg blockade radius can be entangled, and (2) all atoms within the radius are to be entangled together. For remote and selective entanglements, we adopt a coherent control method using two Ramsey interactions that are time-delayed with respect to each other, and as a result controlled phase gates between any pair of atoms among N atoms can be implemented.

Invited Talk 17.

Enhanced interactions between dipolar polaritons

Emre Togan

Institute of Quantum Electronics Auguste-Piccard-Hof 1, 8093 Zürich, Switzerland

Realization of a strongly interacting photonic systems is one of the central ideas of quantum optics. In the solid-state, a promising experimental platform to realize strongly interacting photons is the exciton polariton system, consisting of a cavity photon and a quantum well exciton. We increase the short range, exchange based, interactions among excitons by embedding coupled quantum well structures into the microcavity. When the direct exciton in the quantum well strongly couples to both the high Q cavity mode as well as the indirect excitons, dipolar polaritons are formed as the elementary excitations. These dipolar polaritons show enhanced interactions due to long-range dipole-dipole interactions.

In this talk I will focus on two recent results, with potential applications in quantum simulation and quantum sensing. First, I will show how we can use these enhanced interactions to demonstrate stronger quantum correlations (anti-bunching) for dipolar polaritons that are formed in a small mode volume high Q fiber cavity. Second, I will demonstrate how dipolar polaritons can be used as electric field sensors, and how the interactions between polaritons can be used to boost the electric field sensitivity.

Invited Talk 18.

Activation of different nonlocal quantum correlations after occurring sudden deaths

Tanumoy Pramanik

Center for Quantum Information, Korea Institute of Science and Technology (KIST), Seoul 02792, Korea

Nonlocal quantum correlation is the resource of different quantum information processing tasks. The presence of nonlocal quantum correlation makes quantum information processing more effective than classical information processing. But, in practice, quantum systems continuously interact with the environment. As a result, quantum correlation decreases with time, and this phenomenon is known as decoherence. We have studied the effect of amplitude damping decoherence on different nonlocal quantum correlations. According to our result, different nonlocal quantum correlations show different dynamics in the presence of amplitude damping decoherence. We also have studied the technique of local filtering operations to protect different nonlocal quantum correlations from decoherence. Our results indicate that different nonlocal correlations are operationally different from each other.