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Abstract Booklet

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Ministry of Science and ICT

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KIAS 고등과학원
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QuIST | 양자정보과학기술연구회
Quantum Information Science and Technology

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[Program Schedule]

Aug. 26th (Wed)

Time	Title	Speaker
08:40	Opening (과기정통부장관/고등과학원장)	
09:00	**Keynote 1**: Quantum supremacy using a programmable superconducting processor	John Martinis (UCSB)
09:50	Break (20 min)	
10:10	Superconducting universal quantum computing system development report	Yonuk Chong (SKKU)
10:40	Development of Quantum Computer based on Ion Trap	Taehyun Kim (SNU)
11:00	Silicon-photonic qubit pair generation and CNOT gate operation	Jong-Moo Lee (ETRI)
11:20	Error mitigation in NISQ processors by quantum measurement reversal	Seung-Woo Lee (KIAS)
11:40	Controllable high-dimensional entangled Qudit	Han Seb Moon (Pusan U)
12:00	Lunch (90 min)	
13:30	Developing photonic quantum simulators and its application technologies	Yong-Su Kim (KIST)
14:00	Scalable entangled states of light	Young-Sik Ra (KAIST)
14:20	Resource-efficient and fault-tolerant quantum computing with light	Hyunseok Jeong (SNU)
14:40	Efficient quantum algorithms for lattice-based problems	Jeong San Kim (Kyung Hee U)
15:00	Quantum Algorithm Optimization using quantum Karnaugh Map	Doyeol Ahn (U of Seoul)
15:20	Break (20 min)	
15:40	Coherent control of field gradient induced quantum dot spin qubits	Dohun Kim (SNU)
16:10	The R&D of base technology on silicon P donor-Nanomagnet qubit	Jongbae Kim (ETRI)
16:30	Development of cryogenic multiplexer for scalable multi-qubit system	Sungwan Cho (ETRI)
16:50	Break (20 min)	
17:10	**Keynote 2:** Quantum Computation and Quantum Simulation with Strings of Trapped Ca+ Ions	Rainer Blatt (U Innsbruck)
18:00	Discussion	

Aug. 27th (Thur)

Time	Title	Speaker
09:00	**Keynote 3:** Quantum algorithms for simulating physics	Stephen Jordan (Microsoft)
09:50	Break (20 min)	
10:10	Introduction of Quantum Information Research Support Center	Yonuk Chong (SKKU)
10:40	Entanglement Witness 2.0	Joonwoo Bae (KAIST)
11:00	End-to-End Quantum Software Stack for Virtual Execution	Jaejin Lee (SNU)
11:20	General methods for studying quantum correlations using operational quasiprobabilities	Junghee Ryu (KISTI)
11:40	Bell-type correlation at quantum phase transitions in the spin-1 chain	Wonmin Son (Sogang U)
12:00	Lunch (90 min)	
13:30	Quantum simulation using ultracold atoms	Jongchul Mun (KRISS)
14:00	Site-Specific and Coherent Manipulation of Individual Qubits in a 1D Optical Lattice	Donghyun Cho (Korea U)
14:20	Quantum Channel Capacity Problem and Quantum Algorithms	Kabgyun Jeong (SNU)
14:40	Quantum state rotation	Yonghae Lee (Kyung Hee U)
15:00	Break (20 min)	
15:20	Bright NV Single Photon Source with Diamond Nano Structures	Sang-Wook Han (KIST)
15:50	Toward programmable two qubit operation based on diamond spin qubits	Donghun Lee (Korea U)
16:10	Coherent control of trapped Rydberg atoms in non-symmetric assemblies: the beginning	Bo Young Chang (SNU)
16:30~	Closing	

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Keynote Session

August 26, 2020 (Wed) / 09:00~09:50

Quantum supremacy using a programmable superconducting processor

Keynote Speaker1: *John Martinis* (UCSB)

The promise of quantum computers is that certain computational tasks might be executed exponentially faster on a quantum processor than on a classical processor. A fundamental challenge is to build a high-fidelity processor capable of running quantum algorithms in an exponentially large computational space. Here I report the use of a processor with programmable superconducting qubits to create quantum states on 53 qubits, corresponding to a computational state-space of dimension 2^53 (about 10^16). Measurements from repeated experiments sample the resulting probability distribution, which we verify using classical simulations. The Sycamore processor takes about 200 seconds to sample one instance of a quantum circuit a million times—our benchmarks currently indicate that the equivalent task for a state-of-the-art classical supercomputer would take approximately 10,000 years. This dramatic increase in speed compared to all known classical algorithms is an experimental realization of quantum supremacy for this specific computational task, heralding a much-anticipated computing paradigm.

August 26, 2020 (Wed) / 17:10~18:00

Quantum Computation and Quantum Simulation with Strings of Trapped Ca+ Ions

Keynote Speaker2: *Rainer Blatt* (Innsbruck U)

The state-of-the-art of the Innsbruck trapped-ion quantum computer is briefly reviewed. We present an overview on the available quantum toolbox and discuss the scalability of the approach. Fidelities of quantum gate operations are evaluated and optimized by means of cycle-benchmarking [1] and we show the generation of a 16-qubit GHZ state. Entangled states of a fully controlled 20-ion string are investigated [2] and used for quantum simulations.
In the second part, we present both the digital quantum simulation and a hybrid quantum-classical simulation of the Lattice Schwinger model, a gauge theory of 1D quantum electrodynamics. Employing universal quantum computations, we investigate the dynamics of the pair-creation [3] and using a hybrid-classical ansatz, we determine steady-state properties of the Hamiltonian. Hybrid classical-quantum algorithms aim at solving optimization problems variationally, using a feedback loop between a classical computer and a quantum co-processor, while benefitting from quantum resources [4]. With randomized measurements, we describe a protocol for cross-platform verification of quantum simulators and quantum computers [5].

[1] A. Erhard et al., arXiv:1902.08543 (2019)
[2] N. Friis et al., Phys Rev X. 8 021012 (2018)
[3] E. A. Martinez et al., Nature 534, 516 (2016)
[4] C. Kokail et al., Nature 569, 355–360 (2019)
[5] A. Elben et al., Phys. Rev. Lett. 124, 010504 (2020)

August 27, 2020 (Thu) / 09:00~09:50

Quantum algorithms for simulating physics

Keynote Speaker3: *Stephen Jordan* (Microsoft)

Simulating physical systems was one of the first applications proposed for quantum computers. In some sense it is a problem that quantum computers solve natively. Already by 1996 methods were found by which very general classes of Hamiltonian time evolution could be simulated using efficient quantum circuits. However, this by no means rendered the subject closed. In this talk I will survey recent developments extending quantum simulation algorithms to a broader range of applications, including simulating classical physics, as well as the new perspective brought about by quantitative investigations into resource requirements for running quantum simulations on foreseeable hardware.

Invited (Domestic) Session

August 26, 2020 (Wed) / 10:10~10:40 (Session 1-1)

Superconducting Universal Quantum Computing System Development Report

Yonuk Chong (SKKU, PI of superconducting quantum computing system project team*)

We report our recent research on the superconducting universal quantum computing system development. The goal of the project is to demonstrate a 5-qubit level universal quantum processor and system based on superconducting qubit technology. We designed, tested and optimized 8-qubit devices and its components, and we present the device yield, uniformity, and targeting of our fabrication. The device is based on circuit QED architecture: resonators coupled to a transmon is again coupled to a common transmission line. The multiplexing is performed in frequency domain. We show the individual addressing of 8-qubits for control and readout. For the uniformity, the qubit frequency spread is less than 2% on-chip. The qubits showed >99% single qubit gate fidelity by the randomized benchmarking. We will present more details of the multi-qubit operations and our future plans with the outline of our project.

*Superconducting Quantum Computing System Project Team:
Yong-Ho Lee, Gahyun Choi, Sun Kyung Lee, Woon Song, Sang Min Lee, Kwon-Kyu Yu, Jin-Mok Kim, Sang Gil Lee (KRISS), Euyheon Hwang, Jung Hoon Han, Young Jae Song, Joonsuk Huh, Yonuk Chong (SKKU), Mahn-Soo Choi (Korea Univ.), Kyung Soon Moon (Yonsei Univ.), Kee Hoon Kim (Seoul National Univ.), Dae-Hyun Kim (Kyungpook National Univ.), Kibog Park (UNIST)

August 26, 2020 (Wed) / 10:40~11:00 (Session 1-2)

Development of Quantum Computer based on ion trap

Taehyun Kim (SNU)

In this talk, I will begin with an overview of a quantum computing system based on ion trap. Trapped ion has many advantages in developing quantum computers, such as long coherence time, low state preparation and measurement (SPAM) error, quantum gates with high fidelity, and direct connectivity between any arbitrary pair of qubits. On the other hand, there are also several challenges in developing a scalable system. Therefore I will present what we have done so far to overcome such challenges and summarize our progress. Finally, I will summarize the recent progress in both research and commercialization worldwide.

August 26, 2020 (Wed) / 11:00~11:20 (Session 1-3)

Silicon-photonic qubit pair generation and CNOT gate operation

Jong-Moo Lee (ETRI)

We demonstrate an operation of the controlled-NOT (CNOT) gate which is an essential logic gate for a gate-based quantum computer. We design and fabricate a silicon nitride (SiN) photonic integrated circuit (PIC) including the CNOT gate and a silicon PIC to generate identical photonic qubit pairs based on the spontaneous four-wave mixing. CNOT gate operation is demonstrated based on the coincidence measurement of photonic qubits through the linear-optic elements integrated on the SiN PIC. The 2nd-order correlation of the heralded single-photon from the Si PIC is measured lower than 0.05. We also measure the visibility of Hong-Ou-Mandel (HOM) interference with the single-photon pairs better than 85%. The Fidelity of the CNOT gate operation is measured better than 80% when the single-photon pairs from the Si PIC are input to the SiN PIC.

August 26, 2020 (Wed) / 11:20~11:40 (Session 1-4)

Error mitigation in NISQ processors by quantum measurement reversal

Seung-Woo Lee (KIAS)

Worldwide efforts from both academia and industry have made significant progress in the early stage of quantum technologies, and we are now in the stage aiming to build a scalable quantum processor and network. The most challenging problems for this may be 'protection of qubits from noise' and 'coherent control of scalable systems.' These become harder as the size of the quantum system is larger. In this talk, I would like to first briefly introduce our project on 'error mitigation in noisy intermediate-scale quantum (NISQ) computers' including our approaches, previous accomplishments, and research plan. Then, I would like to move to further details of one of our approaches based on measurement reversal. In a general framework of quantum measurement and reversal, we have recently established the global information balance by deriving the full quantitative trade-off relations between the information gain, disturbance, and reversibility of quantum measurement [1,2,3]. The reversibility turns out to play an important role, filling the gap between the information gain and disturbance, in completing the information balance. Our results imply that the total information is preserved in ideal quantum measurement and reversal processes. These determine the fundamental upper bounds of the performance of measurement-based quantum information protocols, which would provide a potential solution for the noise problem in near-term quantum processors. I will introduce our methodology for error mitigation by quantum measurement reversal with preliminary results and discuss further ideas and plans.

[1] Y. W. Cheong and S.-W Lee, PRL 109, 150402 (2012)
[2] H.-T. Lim, Y.-S. Ra, K.-H. Hong, S.-W. Lee, Y.-H. Kim, PRL 113, 020504 (2014)
[3] S.-W. Lee and J. Kim, arXiv.1912.10592 (2019)

August 26, 2020 (Wed) / 11:40~12:00 (Session 1-5)

Controllable high-dimensional entangled Qudit

Han Seb Moon (Pusan National U)

본 연구에서는 원자 기반 양자정보 기술의 핵심이 되는 고효율의 양자 얽힘 광원을 개발하고, 양자컴퓨팅 구현에 필요한 제어 가능한 다차원 양자 얽힘 큐디트 개발을 통해서 국제적인 경쟁력을 가진 국내 양자정보 기술을 확보하고자 한다. 본 연구에서는 새로운 양자컴퓨팅 구현을 위한 원천 기술의 확보를 위해서 공간 모드 위상 제어를 이용하여 다중모드 광섬유의 다중 공간모드 경로 얽힘을 통한 프로그램밍 가능한 고차원 양자 얽힘 큐디트 생성 및 단방향 양자 프로세싱 구현이라는 연구개발 목표를 달성하고자 한다.

August 26, 2020 (Wed) / 13:30~14:00 (Session 2-1)

Developing photonic quantum simulators and its application technologies

Yong-Su Kim (KIST)

최근 양자통신, 양자컴퓨터의 응용가능성이 증가함에 따라 이에 대한 연구개발 투자가 전 세계적으로 매우 활발하게 진행되고 있다. 특히 어느 정도 오류가 있는 중규모 크기의 양자정보처리(Noisy Intermediate-Scale Quantum, NISQ) 가 곧 가능할 것으로 내다보고 있으며, 이를 실용적인 문제 풀이에 활용하고자 하는 연구가 많이 진행되고 있다. 본 발표에서는 KIST, 포항공대, 한양대, 성균관대, 아주대, 그리고 고등과학원에서 함께 진행하고 있는 광자기반 양자정보처리 응용 연구에 대해 소개한다.

August 26, 2020 (Wed) / 14:00~14:20 (Session 2-2)

Scalable entangled states of light

Young-Sik Ra (KAIST)

양자컴퓨팅을 대표로 하는 양자기술의 핵심요소는 양자중첩과 양자얽힘이다. 빛의 양자상태는 상온에서 구현되고 결맞음 유지가 용이하여 많은 관심을 받아왔지만 양자시스템 규모의 확장이 어렵다는 것이 단점으로 인식되어왔다. 본 발표에서는 이러한 한계를 극복할 수 있는 빛의 연속변수 기술을 소개하고 [1], 이를 기반으로 큰 규모의 양자얽힘상태를 구현하는 방법을 제안한다. 이때 핵심이 되는 빛의 양자압축상태 구현 방법을 소개하고 [2], 이를 확장하기 위해 빛의 다중모드를 제어하는 기술을 논의할 것이다 [3]. 특히 빛의 시간/주파수 모드를 활용하여 큰 규모의 양자얽힘상태를 구현하는 방법을 논의한다 [4,5].

참고문헌

[1] U. L. Andersen *et. al.*, Nat. Phys. 11, 713–719 (2015).
[2] U. L. Andersen *et. al.*, Physica Scripta 91, 053001 (2016).
[3] C. Fabre and N. Treps, arXiv:1912.09321 (2019).
[4] J. Roslund, *et. al.*, Nat. Photon. 8, 109–112 (2014).
[5] Y.-S. Ra *et. al.*, Nat. Phys. 16, 144–147 (2020).

August 26, 2020 (Wed) / 14:20~14:40 (Session 2-3)

Resource-efficient and fault-tolerant quantum computing with light

Hyunseok Jeong (SNU)

Schemes for all-optical quantum computation have been developed mainly using single-photon qubits, entangled photon pairs, passive linear optics elements and photodetectors. A formidable limitation to this method is that some crucial gate operations, necessary either for in-line computation or for off-line resource-state generation, cannot be performed in a deterministic way, or it can be done only with increasingly large resources. Several alternative approaches have been developed to overcome this obstacle using different types of qubits beyond single-photon qubits. I will discuss how these schemes can be used to overcome limitations of previous schemes and expedite fault-tolerant and resource-efficient quantum computing. In particular, our new approach with hybrid cluster states is shown to significantly improve both the resource efficiency and the fault-tolerant threshold at the same time.

References
[1] S. Omkar, Y. S. Teo and H. Jeong, "Resource-efficient topological fault-tolerant quantum computation with hybrid entanglement of light," Phys. Rev. Lett. 125, 060501 (2020).
[2] S.-W. Lee, K. Park, T. C. Ralph, and H. Jeong, "Nearly Deterministic Bell Measurement for Multiphoton Qubits and its Application to Quantum Information Processing," Phys. Rev. Lett. 114, 113603 (2015).
[3] H. Jeong, A. Zavatta, M. Kang, S.-W. Lee, L. S. Costanzo, S. Grandi, T. C. Ralph, and M. Bellini, "Generation of hybrid entanglement of light," Nature Photonics 8, 564 (2014).

August 26, 2020 (Wed) / 14:40~15:00 (Session 2-4)

Efficient quantum algorithms for lattice-based problems

Jeong San Kim (Kyung Hee U)

In this talk, we provide a brief review of quantum algorithms concerned with lattice-based problems, and introduce the main aims and methodology of our research project.

August 26, 2020 (Wed) / 15:00~15:20 (Session 2-5)

Quantum Algorithm Optimization using quantum Karnaugh Map

Doyeol (David) Ahn (U of Seoul)

Every quantum algorithm is represented by set of quantum circuits. Any optimization scheme for a quantum algorithm and quantum computation is very important especially in the arena of quantum computation with limited number of qubit resources in NISQ-based machines. Major obstacle to this goal is the large number of elemental quantum gates to build even small quantum circuits. Recently, we proposed and demonstrated a general technique called quantum Karnaugh map (QKM) that significantly reduces the number of elemental gates to build quantum circuits. This is impactful for the design of quantum circuits, and we showed this could reduce the number of gates by 60% and 46% for the four- and five-qubit Toffoli gates, two key quantum circuits, respectively, as compared with simplest known decomposition. Reduced circuit complexity often goes hand-in-hand with higher efficiency and bandwidth. The quantum circuit optimization protocol realized in NISQ machines would provide leapfrogging ground for the optimization of quantum computing algorithms.

August 26, 2020 (Wed) / 15:40~16:10 (Session 3-1)

Coherent control of field gradient induced quantum dot spin qubits

Dohun Kim (SNU)

The electron spin degree of freedom in solids form natural basis for constructing quantum two level systems, or qubits. The electron spin qubit offers a route for fast manipulation of spins using magnetic resonance or field gradient induced electric control, but generally suffers from dephasing due to strong coupling to the environment, especially nuclear spin bath, where decoherence dynamics is often non-Markovian. This talk will review experimental progress of fast GaAs based spin qubits and efforts to mitigate or even control the environment nuclear spin bath using hyperfine interaction. Starting from discussing general introduction to quantum transport measurements in quantum dots, circuit design, and need for high-throughput measurement methods for developing highly coherent and scalable qubit platform, the talk will focus on implementations of advanced quantum measurement and control protocols of singlet-triplet qubits including high fidelity singlet-shot measurements and Bayesian estimation-based adoptive control.

August 26, 2020 (Wed) / 16:10~16:30 (Session 3-2)

The R&D of base technology on silicon P donor-Nanomagnet qubit

Jongbae Kim (ETRI)

범용 양자컴퓨터를 구현하기 위해서는 100만~10억(10^6 ~ 10^9)개 정도의 큐빗이 요구될 것으로 알려져 있다. 이러한 다수의 큐빗을 결맞음 상태로 집적화하기 위해서는 실리콘 기반의 나노기술이 필연적이다. 실리콘 P donor 큐빗 기술은 긴 결맞음 시간, Micromagnet 실리콘 양자점 기술은 고속의 전기적 스핀 제어의 장점이 있다. 본 연구는 "실리콘 P donor-Nanomagnet 큐빗 기반기술 연구개발"을 목표로 소자 설계 및 나노 전극 공정, Nanomagnet 및 단일 전자 트랜지스터 공정, 전기적 스핀 제어 큐빗 기초기술 연구를 포함한다. 본 발표에서는 주제의 주요 내용과 그 동안의 진행된 연구개발 내용에 대하여 간략히 소개한다.

August 26, 2020 (Wed) / 16:30~16:50 (Session 3-3)

Development of CMOS-based Cryogenic Multiplexer for Scalable Multi-Qubit System

Sungwan Cho (ETRI)

본 연구에서는 qubit의 decoherence를 줄이기 위해 사용되는 냉각기 구동 환경에 맞춘 multiplexer를 개발하는 것을 목표로 한다. 수~ GHz 수준의 동작 주파수를 가지는 solid-state 기반 qubit은 집적이 가능한 장점을 보유하나 안정된 동작을 유지하기 위해서 1 K이하의 온도에서 동작하여야 하는 제한을 가지고 있다. 아울러, 집적화 된 qubit들의 제어 및 측정을 위해 여러 단계의 냉각과정과 상온에서부터 연결되는 여러 개의 입력 및 출력 line을 필요로 하며 이들을 통해 전달되는 thermal load는 qubit들의 안정된 동작을 해칠 가능성이 있다. 이러한 문제를 해결하고자 현재 저온 및 극저온에서 활용 가능한 집적소자 및 주문형 소자의 연구 및 개발을 진행 중이며,1,2,3 이를 통해 집적화 된 qubit의 안정적인 제어 및 측정을 위한 노력을 기울이는 중이다. 따라서 본 연구진도 Cryogenic multiplexer를 통해 다수의 집적화된 qubit 동작을 가능케 하고 thermal load를 줄여 복수의 qubit을 안정적으로 구동할 수 있는 기반을 마련하고자 한다.

본 목표의 진행을 위해 FD-SOI 기반의 저전력 CMOS 트랜지스터로 이루어진 Multiplexer를 개발하고 있으며 4-6 GHz 대역에서의 최대 4개 input-output을 한 개의 line으로 전송할 수 있는 4:1 multiplexer의 제작을 목표로 한다. 차후 이를 8:1, 16:1 의 multiplexer로 확장할 예정이며 이를 통해 수십 개 수준 이상의 qubit의 제어를 위한 신호를 최소화된 line을 통해 전송하고자 한다.

Reference

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[2] Y. Yang, et. Al. “A Cryo-CMOS Voltage Reference in 28-nm FDSOI”, IEEE Solid-State Circuits Lett. pp186-189, 3 (2020)

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August 27, 2020 (Thu) / 10:10~10:40 (Session 4-1)

Introduction to Quantum Information Research Support Center

Yonuk Chong (SKKU)

"Quantum Information Research Support Center 소개"

August 27, 2020 (Thu) / 10:40~11:00 (Session 4-2)

Entanglement Witness 2.0

Joonwoo Bae (KAIST)

An entanglement witness is an observable detecting entanglement for a subset of states. We present a framework that makes an entanglement witness twice as powerful due to the general existence of a second (lower) bound, in addition to the (upper) bound of the very definition. This second bound, if non-trivial, is violated by another subset of entangled states. Differently stated, we prove via the structural physical approximation that two witnesses can be compressed into a single one. Consequently, our framework shows that any entanglement witness can be upgraded to a witness 2.0. The generality and its power are demonstrated by applications to bipartite and multipartite qubit/qudit systems.

Reference: npj Quantum Information 6 15 (2020)

August 27, 2020 (Thu) / 11:00~11:20 (Session 4-3)

End-to-End Quantum Software Stack for Virtual Execution

Jaejin Lee (SNU)

This presentation introduces a study on an end-to-end quantum software stack for quantum computing. Specifically, (1) a high-performance classical quantum simulator supporting simulation functions including errors, (2) a quantum optimization compiler supporting classical quantum simulation and quantum circuit optimization, (3) quantum programming language including support for high-level abstract operations, (4) visualization programming tools that support visual programming and debugging functions, and (5) quantum benchmark programs for measuring the performance of classical quantum simulators. Currently, we try to increase the size of full-state classical quantum simulations using NVMe storage devices. We developed a gate scheduling technique that changes the amplitude layout, a computation-communication overlapping technique, and a gate reordering technique. We implement the techniques in Qiskit. As a result, we can simulate the 40-qubit 24-depth Quantum Supremacy circuit within 30 hours and the 40-qubit 24-depth Quantum Fourier Transform circuit within 15 hours on a system that could only simulate maximum 33-qubit quantum circuits with the main memory alone.

August 27, 2020 (Thu) / 11:20~11:40 (Session 4-4)

General methods for studying quantum correlations using operational quasiprobabilities

Junghee Ryu (KISTI)

Negative probability was introduced by Feynman to address a mystery of quantum mechanics [1]. Since then such approach has been applied to investigate various kinds of quantum resources such as quantum entanglement and superposition. However, the negative values of the probability distribution could lead to a conceptual problem on interpreting the quantity in terms of the frequency of the events occur. An operational interpretation of these negative values is missing. Recently, an alternative approach is introduced where the quasiprobability operationally reveals the negativity of measured quantities; we call it operational operational quasiprobabilities (OQs) [2,3,4]. Here, we will present how the OQs method can be used as a verification of quantum process or computation.

[1] R. Feynman, in Negative Probabilities in Quantum Mechanics, edited by B. Hiley and F. Peat (Routledge, London, 1987).
[2] J. Ryu, et al., Operational quasiprobabilities for qudit, Phys. Rev. A 88, 052123 (2013).
[3] J. Jae, et al., Operational quasiprobabilities for continuous variables, Phys. Rev. A 96, 042121 (2017).
[4] J. Ryu, et al., Optical experiment to test negative probability in context of quantum-measurement selection, Sci. Rep. 9, 19021 (2019).

August 27, 2020 (Thu) / 11:40~12:00 (Session 4-5)

Bell-type correlation at quantum phase transitions in the spin-1 chain

Wonmin Son (Sogang U)

For the identification of the non-trivial quantum phase, we exploit a Bell-type correlation that is applied to the one-dimensional spin-1 XXZ chain with on-site anisotropy. It is found that the bipartite Bell correlation can take a series form of transverse spin correlations together with the high order correlations. The formulation of density-matrix renormalisation group is utilized to obtain the ground state of a given Hamiltonian and subsequently Bell-type correlation is evaluated through the analysis of the matrix product state. Diverse classes of quantum phase transitions in the spin-1 model are identified precisely through the evaluation of the first and the second derivatives of the correlations. The role of high-order terms in the criticality has been identified and its meaning has been discussed.

August 27, 2020 (Thu) / 13:30~14:00 (Session 5-1)

Quantum simulation using ultracold atoms

Jongchul Mun (KRISS)

In this talk, we present brief introduction to our new research project “quantum simulations using ultracold atoms in optical lattices”. Our proposed quantum platform – ultracold atomic system and optical lattice technique will be reviewed. Ultracold atomic systems represent an ideal platform for simulations of complex quantum many-body problems in wide range physics from condensed matter physics, statistical physics, quantum chemistry, and high-energy physics. In addition, the high degree of controllability, system purity, and wide range of particle correlation parameters provides unique quantum engineering tool box.
We also discuss the target quantum problem that we propose to simulate: Hubbard type model. Hubbard type model is experimentally realized, and “encoded” in our quantum simulator by engineering optical lattices and physical parameters such as interaction strengths. Our proposed experimental implementation for Hubbard type model simulations will be described.

August 27, 2020 (Thu) / 14:00~14:20 (Session 5-2)

Site-specific and Coherent Manipulation of Individual Qubits in a 1D Optical Lattice

Donghyun Cho (Korea U)

We demonstrate gate operations on a single qubit at a specific site without perturbing coherence of an adjacent qubit in a 1D optical lattice when the site separation is only 532 nm. Three types of spin rotations are performed on the target qubit with fidelities between 0.88 ± 0.05 and 0.99 ± 0.01 while the superposition state of the adjacent one is preserved with fidelities between 0.93 ± 0.04 and 0.97 ± 0.04. The qubit is realized by a pair of Zeeman-sensitive ground hyperfine states of a ^{7}Li atom, and each site is identified by its resonance frequency in a magnetic field gradient of 1.6 G/cm. We achieve the site-specific resolving power in the frequency domain by using magic polarization for the lattice beam that allows a Fourier-limited transition linewidth as well as by highly stabilizing the lattice parameters and the ambient conditions. We also discuss a two-atom entanglement scheme using a blockade by cold collisional shifts in a 1D superlattice, for which a coherent manipulation of individual qubits is a prerequisite.

August 27, 2020 (Thu) / 14:20~14:40 (Session 5-3)

Quantum Channel Capacity Problem and Quantum Algorithms

Kabgyun Jeong (SNU)

In this talk, I will briefly introduce the quantum channel capacity problem in Quantum Information Theory, and address recent results on the capacity problem based on quantum entropy power inequalities. Especially, I will show you a main intuition on how can channel-capacity tools be used to improve quantum algorithmic problems, via net analysis and concentration of measure phenomena over pure quantum states.

August 27, 2020 (Thu) / 14:40~15:00 (Session 5-4)

Quantum state rotation

Yonghae Lee (Kyung Hee U)

Quantum state exchange is a quantum communication task for two users in which the users exchange their respective quantum information in the asymptotic scenario. We generalize the quantum state exchange task to a quantum communication task for M users in which the users rotate their respective quantum information. We assume that every two of the users may share entanglement resources, and they make use of local operations and classical communication in order to perfectly perform the task. In this talk, we call this generalized task the quantum state rotation. First of all, we formally define the quantum state rotation task and its optimal entanglement cost, which means the least amount of total entanglement resources required to carry out the task. We then present lower and upper bounds on the optimal entanglement cost, and provide conditions derived from zero optimal entanglement costs. Based on these results, we find out a difference between the quantum state rotation task and the quantum state exchange task.

August 27, 2020 (Thu) / 15:20~15:50 (Session 6-1)

Bright NV Single Photon Source with Diamond Nano Structures

Sang-Wook Han (KIST)

In this talk, the research scope of the project "Scalable quantum computing systems based on point defects in solids" will be introduced. And then, among various technologies being studied, recent results of the quantum interface using diamond nanostructures will be mainly presented. We have implemented inverted nano-cone structures having single NV centers, and report 20-fold enhancement in the photon collection efficiency while preserving a long electron spin coherence time. At last, next research plan with the bright single photon source will be provided.

August 27, 2020 (Thu) / 15:50~16:10 (Session 6-2)

Toward programmable two qubit operation based on diamond spin qubits

Donghun Lee (Korea U)

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.

In this talk, I will introduce overall research activities in our laboratory particularly focusing on recent efforts related to the quantum computing project. In this project, we aim to realize programmable two qubit quantum processor based on solid-state spin qubits in diamond. In principle, any universal quantum operations can be decomposed into single-qubit and two-qubit gates. Moreover, small enough error rate in two-qubit gates is essential for realizing fault-tolerant quantum computation. We are currently studying qubit pairs consisting of electron-electron and electron-nuclear spins associated with defect centers in diamond. To demonstrate programmable two-qubit unitary operations, we plan to test the well-known algorithm such as the Deutsch-Josza algorithm and the Grover search algorithm.

August 27, 2020 (Thu) / 16:10~16:30 (Session 6-3)

Coherent control of trapped Rydberg atoms in non-symmetric assemblies: the beginning

Bo Young Chang (SNU)

Atoms trapped in optical tweezers, interacting through Rydberg blockade, can be used to generate few multi-particle entanglement and simple quantum circuits. To go further in the quest of the quantum computer, we need to improve the system addressability and controllability. Our novel proposal is to study irregular two-dimensional and three-dimensional assemblies of atoms and to develop and apply the theoretical tools needed to understand and optimize such systems. Because irregular arrays of atoms are complex structures, the use of theoretical modelling and coherent control techniques is essential. We will calculate the precise energies and couplings of the systems merging quantum chemistry codes (XCHEM) with many-body techniques. We will find pulse sequences that allow the adiabatic manipulation of single qubits. We will design pulse sequences and spatial patterns of the atoms in the array that will allow the generation of efficient and robust Toffoli and GHZ gates, as well as the generation of many multi-particle entangled W states. The aim of this project is to be in position to predict at the end of the day which structures can be used to build complex quantum circuits based on many entangled states with current technology. In this talk I will lay out the initial planning of the project and show the first results obtained in simulating the implementation of a CPHASE (CZ) gate on two Rubidium atoms (qubits encoded in the $5^2S_{1/2}$ (F=2) and $5^2P_{1/2}$ (F=2) hyperfine states) using the dipole blockade mechanism as in (assuming atoms separated by 4μm) through non-resonant two-photon transitions to the n=67 Rydberg state using ∏ pulses or STIRAP pulse sequences [1].

Reference: [1] Michael H. Goerz, Eli J. Halperin, Jon M. Aytac, Christiane P. Koch, and K. Birgitta Whaley, Phys. Rev. A 90, 032329 (2014).