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日時：
2022年7月20日(水) 16:20-17:50

場所：
物理系講義棟301

講師：
東京大学大学院理学系研究科
特任准教授 大久保毅 氏

Title:
Tensor network representation of Kitaev spin liquid and its application to quantum circuit-based variational calculations

Abstract:
To represent a quantum many-body state, such as quantum spin systems, we need to treat huge vectors in exponentially increasing dimensions as we increase the number of spins. Such an exponentially large vector space is a fundamental difficulty in treating quantum many-body problems in classical computers. One way to resolve this difficulty is a tensor network representation of quantum many-body states, where we represent a state as a network consisting of small tensors. This approach has been successful recently, particularly for quantum spin systems. On the other hand, if we use a quantum computer instead of classical computers, we may solve quantum many-body problems with a cost polynomial of the number of particles. In recent years, to use a noisy quantum computer for quantum many-body problems, the variational quantum eigensolver (VQE) [1] has attracted much interest. In the VQE approach, a quantum many-body state is represented as a quantum circuit, and we optimize circuit parameters to minimize the energy expectation value. However, it is still unclear whether the VQE approach can exceed classical computation, such as a tensor network approach, in practical quantum many-body problems.

In this seminar, We will discuss the possibility of using tensor network representations of quantum many-body states to design an efficient quantum circuit suitable for near future noisy quantum computers. As a concrete example, we will consider the spin liquid state in the honeycomb lattice Kitaev model [2]. We show that a simple tensor network state can capture qualitative properties of the spin liquid, and by adding short-range excitations, we can systematically improve its energy expectation value [3]. A similar procedure can be applied to the VQE approach by representing tensor network states as quantum circuits. We will discuss that through this approach, we can efficiently optimize the infinite system by solving an optimization problem in small clusters.

[1] A. Peruzzo, J. McClean, P. Shadbolt, et al., Nat. Commun. 5, 4213 (2014).
[2] A. Kitaev, Ann. Phys. 321, 2 (2006).
[3] H.-Y. Lee, R. Kaneko, T. Okubo, and N. Kawashima, Phys. Rev. Lett. 123, 087203 (2019).

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