Sci. Bull. (2015) 60(2):277
DOI 10.1007/s11434-014-0711-x

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Research Highlight

Digital quantum simulation goes to two fermions

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Published online: 8 January 2015

In a recent work, a group of researchers led by Gui-Lu Long of Tsinghua University proposed a digital quantum simulation algorithm for the dynamics of interacting quantum systems in real space. They experimentally implemented the algorithm to simulate the dynamics of two interacting fermions using a nuclear magnetic resonance (NMR) setup [1].

Quantum simulation [2], inspired by the development of quantum computer, is one of the blossoming sub-fields in quantum information science. Efficient simulations of many-body quantum systems are generally difficult on classical computers due to the exponential growth of the required resource with the system size, while quantum computer has been proved to provide intrinsic advantages for such simulation tasks.

Quantum simulation can be divided into two categories: analog simulation and digital simulation. An analog quantum simulator must have a sufficiently similar Hamiltonian to that of the target system to be simulated, and thus, on such quantum simulators, universal simulations of quantum systems cannot be realized [3]. In contrast, digital quantum simulation [4, 5] spares the requirement of similarity in Hamiltonians. A digital quantum simulator in principle can perform universal quantum simulations, and a quantum computer can play the role of a digital quantum simulator. A digital quantum simulation algorithm of a single-particle tunneling was proposed in 2012 [6]. Its first experimental realization was completed in 2013 [7].

Digital quantum simulations attract much attention recently. The simulation of real-space evolution of particles is one of the most attracting aspects among various quantum simulation tasks because of the fundamental role of real-space evolution problems in quantum physics. Investigation on the digital simulation of the quantum many-body spatial dynamics is difficult due to the large number of operations and qubits required.

In the work of the Tsinghua team [1], they studied digital simulation of interacting quantum many-body dynamics, for both non-identical and identical particle systems. In identical particle systems, second quantization formalism was used. As a representative illustration, they proposed and experimentally realized a small-scale simulation for the temporal–spatial dynamics of a two-fermion system with Coulomb interactions using a three-qubit NMR quantum information processor. The experiment demonstrated the attracting or repelling nature between the particles due to attractive or repulsive interactions. This should be an indication that the simulation of many-body dynamics of small quantum systems is within reach of today's small-scale quantum simulators with the help of digital quantum simulation algorithm, and quantum computers have promising superior powers in the simulation of complex quantum systems.

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