Quantum simulation and ground state preparation for the honeycomb Kitaev model

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Strongly-correlated magnetism represents a formidable challenge, where an efficient classical description is inapplicable due to the sign problem and long-range entanglement. The striking example is a quantum spin liquid (QSL) phase [1]. From the theoretical perspective QSL materials are often described by spin lattice models with bond-dependent Heisenberg coupling. Here, the paradigmatic model that hosts QSL is the Kitaev model of spin-1/2 arranged in a honeycomb lattice [2]. While being classically solvable at zero magnetic field, when biased it requires an exact diagonalization and its treatment is limited to small system sizes [3].

In the talk, I will describe a quantum algorithm that allows preparing a ground state of the honeycomb Kitaev model using a variational circuit with the shallow depth. Our approach efficiently uses the underlying symmetries of the model. It is based on the stabilization procedure, the developed centralizer ansatz, and utilizes the vortex basis description being the most advantageous for qubit-based simulation [4]. We demonstrate the high fidelity preparation of quantum spin liquid ground states in the zero magnetic field Kitaev model and effective field. Specifically, we simulate the preparation of the QSL ground state with up to N=24 qubits (spins) with the depth of d=5, where the ansatz is composed of the nearest-neighbor two-qubit gates. Next, we show that the prepared ground state can be evolved in time, revealing the dynamical correlations between distant spins. Finally, we extended the variational search to prepare QSL at non-zero magnetic field. Our study points the route towards a quantum advantage for the complex material science problem.

References

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