Quantum computing – status and application to many-body systems

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State-of-the-art quantum computers are now at 100+ qubits and may soon reach the kilo-qubit level [1]. While we have witnessed demonstrations of “supremacy” [2] and “advantage” [3], and whole-device large-scale entanglement [4], the immediate prospects of solving real-world problems on near-term Noisy Intermediate Scale Quantum (NISQ) hardware will be largely dictated by device noise/errors. For many-body problems, in the implementation of hybrid algorithms such as the variational quantum eigensolver (VQE) [5], the direct quantum computation of the energy/cost function of the problem can be strongly affected by hardware errors as the problem scales. While error mitigation strategies can improve the output of such calculations, we have developed an alternative approach based on quantum computed moments (QCM) [6] to improve energy/cost function results. The QCM approach combines the computation of moments of the problem Hamiltonian with respect to a trial-state on the quantum computer with a higher order energy/cost function estimate derived from Lanczos expansion theory [7,8]. Implementations on IBM Quantum devices for a range of problem contexts – including quantum magnetism [6] and chemistry [9] – demonstrate that the approach does indeed produce superior energy/cost function estimates, and displays consistently strong noise suppression in the results. The scaling of the QCM method to larger problems is being investigated, including additional classical costs in pre and post processing, to test the ability to obtain similarly noise-robust estimates for larger-scale many-body problems.

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