FM 75: Quantum Computation: Simulation II

Time: Thursday 14:00–15:45 Location: 1010

FM 75.1 Thu 14:00 1010

Finding symmetry-broken ground states with variational quantum algorithms — •Nicolas Vogt[1], Sebastian Zanker[1], Jan-Michael Reiner[1], Thomas Eckl[2], Anika Marusczyk[2], and Michael Marthaler[1] — [1]HQS Quantum Simulations GmbH, Karlsruhe, Germany — [2]Robert Bosch GmbH, Renningen, Germany

One of the most promising applications for near-term noisy intermediate scale quantum computers (NISQ) is the preparation of the fully interacting ground state of strongly correlated electron systems. Besides the true ground state energy the properties of interest are, e.g., phases with broken symmetry and the corresponding order parameters.

We study the preparation of ground states with broken symmetry on a gate based quantum computer with different variational algorithms, specifically the variational Hamiltonian ansatz (VHA) including initial state preparation and extensions to deal with broken symmetry. The Hubbard model, which is known for its variety of phases, is used as a toy model to compare the different variational algorithms to each other and to exact diagonalisation. To this end, we simulate the full algorithm including initialisation and read-out running on a gate-based quantum computer. We use a hardware model based on the gates available in current generation superconducting quantum computers.

FM 75.2 Thu 14:15 1010

Finding the ground state of the Hubbard model by variational methods on a quantum computer with gate errors — •Jan-Michael Reiner[1,2], Frank Wilhelm-Mauch[3], Gerd Schön[1,4], and Michael Marthaler[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]HQS Quantum Simulations, c/o CyberLab, Haid-und-Neu-Straße 20, 76131 Karlsruhe — [3]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [4]Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany

A key goal of digital quantum computing is the simulation of fermionic systems such as molecules or the Hubbard model. Unfortunately, for present and near-future quantum computers the use of quantum error correction schemes is still out of reach. Hence, the finite error rate limits the use of quantum computers to algorithms with a low number of gates. The variational Hamiltonian ansatz (VHA) has been shown to produce the ground state in good approximation in a manageable number of steps. Here we study explicitly the effect of gate errors on its performance. The VHA is inspired by the adiabatic quantum evolution under the influence of a time-dependent Hamiltonian, where the – ideally short – fixed Trotter time steps are replaced by variational parameters. The method profits substantially from quantum variational error suppression, e.g., unitary quasi-static errors are mitigated within the algorithm. We test the performance of the VHA when applied to the Hubbard model in the presence of unitary control errors on quantum computers with realistic gate fidelities.

FM 75.3 Thu 14:30 1010

Robust Hamiltonian learning of Bose-Hubbard models — •Ingo Roth, Dominik Hangleiter, Lara Booth, Christian Krumnow, Juani Bermejo-Vega, and Jens Eisert — Freie Universität, Berlin, Deutschland

Complex quantum many-body systems can increasingly be controlled with unprecedented precision opening up tremendous potential for quantum analogue simulators as a near-term quantum technology. One of the key problems in the study of quantum simulators is to find ways to certify the correctness of the implementation of the Hamiltonian dynamics from data. In this work, we develop a flexible signal processing framework for the recovery of Hamiltonian models combining super-resolution techniques and non-convex recovery algorithms. We specificably explore the algorthmic approach in the context of learning quadratic Bose-Hubbard Hamiltonians in an experiment with superconducting qubits in collaboration with the Quantum group at Google AI. We arrive at an efficient and very robust learning scheme for such Hamiltonian models. This work provides a essential tool for the high-precision calibration of control models in the experimental implementation.

FM 75.4 Thu 14:45 1010

Spectral properties of optically driven one-dimensional extended Hubbard model: An exact diagonalization study — •Junichi Okamoto[1] and Shunsuke A. Sato[2,3] — [1]Institute of Physics, University of Freiburg, Freiburg, Germany — [2]Center for Computational Sciences, University of Tsukuba, Tsukuba, Japan — [3]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany

Quantum simulation is one of the key innovations in science, and has been elaborated in various platforms, e.g., cold atoms, quantum dots, and superconducting circuits. Recently, periodically driven quantum systems add another tuning knob to realize novel Hamiltonians via Floquet engineering. Notable examples are: control of band topology [PRL 118, 240403 (2017)], creation of artificial gauge fields [Nat. Phys. 9, 738 (2013)], and suppression of tunneling [PRL 100, 040404 (2008)]. Here we study dynamics induced by periodic driving in one-dimensional extended Hubbard model with an exact time-dependent Schrödinger equation solver. We characterize the driven system by transient conductivity and time-resolved spectral functions. We address various consequences due to different forms of driving, e.g., off-resonance, near resonance, continuous driving, or pulsed driving. For instance, when the system undergoes a transition from a Luttinger liquid to a gapped charge-density wave, an in-gap peak appears in the spectral function, while there is no Drude peak in conductivity, indicating localized carrier doping. On the other hand, when a charge-density wave is photodoped, we find no increase of in-gap density of states.

FM 75.5 Thu 15:00 1010

Functional renormalization group analysis of the response functions of the 2D Hubbard model — •Sarah Heinzelmann[1], Cornelia Hille[1], Agnese Tagliavini[1,2], Stefan Käser[3], Philipp Hansmann[4], Carsten Honerkamp[5], Alessandro Toschi[2], and Sabine Andergassen[1] — [1]Institut für Theoretische Physik and Centre for Quantum Science, Uni Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Institute for Solid State Physics, Vienna University of Thechnology, 1040 Vienna, Austria — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1 — [4]Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Straße 40 — [5]Institut for Theoretical Solid State Physics, RWTH Aachen University, 52056 Aachen

We present results for the magnetic, density and superconducting pairing susceptibilities in the weak-coupling regime, as obtained from a fully frequency and momentum dependent functional renormalization group (fRG) calculation, which takes into account all channels in an unbiased way. In contrast to RPA, we observe pronounced renormalisation effects due to the interplay of the channels. We analyse the impact of vertex corrections on both s- and d-wave components of the susceptibilities in different regions of the phase diagram. Including the multiloop extension of the fRG, the present computation schemes paves a promising route towards quantitative studies of more challenging systems and/or parameter regimes.

FM 75.6 Thu 15:15 1010

Closing the gaps of a quantum advantage with short-time Hamiltonian dynamics — •Jonas Haferkamp[1], Dominik Hangleiter[1], Adam Bouland[2], Bill Fefferman[3], Jens Eisert[1], and Juani Bermejo-Vega[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Electrical Engineering and Computer Sciences, University of California, Berkeley — [3]Joint Center for Quantum Information and Computer Science, University of Maryland

Demonstrating a quantum computational speed-up is a crucial milestone for near-term quantum technology. Recently, comparably feasible quantum simulation architectures have been proposed that have the potential to show such a quantum advantage, based on commonly made assumptions. The key challenge in the theoretical analysis of this scheme - as of other comparable schemes - is to lessen the assumptions and close the theoretical loopholes, replacing them by rigorous arguments. In this work, we prove two open conjectures for these architectures of quantum simulators: Anti-concentration of the generated probability distributions and average-case hardness of exactly evaluating those probabilities. The latter is proven building upon recently developed techniques for random circuit sampling. For the former, we develop new techniques that exploit the insight that approximate

2-designs for the unitary group admit anti-concentration. We prove that the translation-invariant, constant depth architectures of quantum simulation form approximate 2-designs in a specific sense, thus obtaining a significantly stronger result.

FM 75.7 Thu 15:30 1010

Simulating non-equilibrium two-electron transfer on a noisy quantum computer — •Sabine Tornow — Munich University of Applied Sciences, Department of Computer Science and Mathematics, Lothstrasse 64, 80335 Munich, Germany

We simulate the dynamics of two correlated electrons modeled by a two-site Hubbard model on a noisy quantum computer. To enable practical implementation we study the influence of both, algorithmic (e.g., the number of Trotter steps) and physical errors (e.g., gate errors and decoherence). Further, different error mitigation techniques such as extrapolation to the zero noise limit are applied. We find good agreement to our earlier results (S. Tornow, R. Bulla, F. Anders, A. Nitzan, Phys. Rev. B 78, 035434 (2008)).