FRI 6: Quantum Error Mitigation

Time: Friday 10:45–12:00 Location: ZHG007

FRI 6.1 Fri 10:45 ZHG007

Error Mitigation for Time-Evolution Approach for Greens Functions on Quantum Computers — •Jannis Ehrlich[1] and Daniel F. Urban[1,2] — [1]Fraunhofer-Institut für Werkstoffmechanik IWM, Freiburg, Germany — [2]Freiburger Materialforschungszentrum, Universität Freiburg, Germany

The computation of Greens functions plays a central role in many-particle physics, as they are directly connected to the energy of the system and the spectral function. Their calculation with classical computers is challenging due to the explicit treatment of electron interactions, especially in the case of strong correlation effects. We present a time-evolution approach for extracting the Greens function by simulating the quantum system on a quantum computer. We explicitly investigate the influence of errors on the results and proper error mitigation strategies as well as the effect of symmetry protection for simulations on current quantum devices.

FRI 6.2 Fri 11:00 ZHG007

Coherently mitigating boson samplers with stochastic errors — Deepesh Singh[1], Ryan J Marshman[1], •Nathan Walk[2], Jens Eisert[2,3], Timothy C Ralph[1], and Austin P Lund[1,2] — [1]University of Queensland — [2]Freie Universität Berlin — [3]Helmholtz-Zentrum Berlin

Sampling experiments provide a viable route to show quantum advantages of quantum devices over classical computers in well-defined computational tasks. However, devices such as boson samplers are susceptible to various errors, including stochastic errors due to fabrication imperfections causing the implemented unitary operations to deviate randomly from their intended targets. Whilst full-scale quantum error correction remains challenging, quantum error mitigation schemes have been devised to estimate expectation values, but it is unclear how these would work for sampling experiments. Here, we adopt the unitary averaging protocol which employs multiple stochastic boson samplers to generate a distribution that better approximate the ideal distribution as the number of samplers increases. We derive rigorous upper bounds on the trace distance between the output probability distributions induced by invertible vacuum-heralded networks based on the Schur-Weyl duality. More broadly, these results suggests a path towards understanding error mitigation for sampling experiments and developing analysis tools for photonic circuits incorporating measurements and feed-forward. Other applications include the implementation of linear combination of unitaries and fabrication benchmarking.

FRI 6.3 Fri 11:15 ZHG007

Quantum error mitigation combining subspace and probabilistic techniques — Prachi Sharma[1], João C. Getelina[2], Thomas Iadecola[2,3], Yong-Xin Yao[2,3], and •Peter P. Orth[1] — [1]Department of Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Ames National Laboratory, Ames, Iowa 50011, USA — [3]Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

As quantum computing advances toward real-world applications, mitigating errors remains a critical challenge, particularly when determining ground state energies of many-body models on noisy quantum hardware. To address this, synergistic approaches to quantum error mitigation are necessary, combining the strengths of multiple techniques to ensure more reliable quantum operations. In this work, we integrate quantum subspace expansion methods with probabilistic error reduction techniques to address these challenges. We apply this framework to ground state energy calculations of a 16-site mixed field Ising model on IBM quantum hardware and noisy simulators using the Variational Quantum Eigensolver (VQE) [1]. Our results demonstrate a two order-of-magnitude improvement in the accuracy of the ground state energy on IBM's noisy backend simulators, highlighting the effectiveness of this approach in systematically enhancing the reliability of quantum computations.

[1] J. Getelina et al., APL Quantum 1, 036127 (2024).

FRI 6.4 Fri 11:30 ZHG007

Mitigation of correlated readout errors without randomized measurements — •Adrian Aasen[1,2], Andras Di Giovanni[3], Hannes Rotzinger[3], Alexey Ustinov[3], and Martin Gärttner[2] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany — [2]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Jena, Germany — [3]Physikalisches Institut, Karlsruher Institut für Technologie, Karlsruhe, Germany

Quantum simulation, the study of strongly correlated quantum matter using synthetic quantum systems, has been the most successful application of quantum computers to date. It often requires determining observables with high precision, for example when studying critical phenomena near quantum phase transitions. Thus, readout errors must be carefully characterized and mitigated in data post-processing, using scalable and noise-model agnostic protocols. We present a readout error mitigation protocol that uses only single-qubit Pauli measurements and avoids experimentally challenging randomized measurements. The proposed approach captures a very broad class of correlated noise models and is scalable to large qubit systems. It is based on a complete and efficient characterization of few-qubit correlated positive operator-valued measures (POVMs), using overlapping detector tomography. To assess the effectiveness of the protocol, observables are extracted from simulations involving up to 100 qubits employing readout errors obtained from experiments with superconducting qubits.

FRI 6.5 Fri 11:45 ZHG007

Revealing correlated noise with single-qubit operations — •Balázs Gulácsi, Joris Kattemölle, and Guido Burkard — University of Konstanz

Spatially correlated noise poses a significant challenge to fault-tolerant quantum computation by breaking the assumption of independent errors. Existing methods such as cycle benchmarking and quantum process tomography can characterize noise correlations but require substantial resources. We propose straightforward and efficient techniques to detect and quantify these correlations by leveraging collective phenomena arising from environmental correlations in a qubit register. In these techniques, single-qubit state preparations, single-qubit gates, and single-qubit measurements, combined with classical post-processing, suffice to uncover correlated relaxation and dephasing. Specifically, we use that correlated relaxation is connected to the superradiance effect which we show to be accessible by single-qubit measurements. Analogously, the established parity oscillation protocol can be refined to reveal correlated dephasing through characteristic changes in the oscillation line shape, without requiring the preparation of complex and entangled states.