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# Exploring Phase structure of the Schwinger model on superconducting Quantum Computers

We explore the phase structure of the lattice Schwinger model in the presence of a toplogical $\theta$-term, a regime in which conventional Monte Carlo simulations suffer from the sign problem, using the variational quantum eigensolver (VQE). Constructing a suitable variational ansatz circuit for the lattice model using symmetry-preserving 2-qubit gates, we perform classical simulations showing that the ansatz is able to capture the relevant physics. In particular, we observe the remnants of the well known first-order phase transition at $\theta = \pi$ occurring in the continuum model for large enough fermion masses. Furthermore, we implement our ansatz on IBM's superconducting quantum hardware. Using state-of-the art noise suppression techniques, namely readout error mitigation, dynamical decoupling, Pauli twirling, and zero-noise extrapolation, we are able to explore the phase structure of the model directly on quantum hardware with up to 12 qubits. We study two regimes on the hardware device, a fermion mass well below the transition point and a fermion mass well above. In both cases, our ansatz performs well and we obtain data, which are in good agreement with exact diagonalization.

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