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Towards Exploring the Topological Vacuum Structure of the Schwinger Model with digital Quantum Computers

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This work investigates the capability of digital quantum computers to probe the phase diagram of the Schwinger model, which includes a single fermion flavor and a topological theta-term. The study aims to extend the analysis to higher dimensions where prevailing classical techniques exhibit inefficiency. Employing the variational quantum eigensolver (VQE), a range of ansatz architectures and gate types are evaluated to prepare quantum states. Through the application of error mitigation techniques, including zero noise extrapolation, ground states are successfully generated on digital quantum hardware. Various observables, such as electric field density and particle number, are measured to demonstrate the first-order phase transition of the model. Additionally, a continuum extrapolation at a constant volume for specific phase space parameters is presented, accomplished via matrix product states and density matrix renormalization group (DMRG). This extrapolation serves as a benchmark, providing insights into the quantum hardware requirements for executing such computations. The findings contribute to the ongoing advancement of quantum computing methodologies in studying complex quantum field theories and offer a stepping stone for future explorations into high-dimensional systems.

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