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Low-depth simulations of fermionic systems on realistic quantum hardware

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We present a general strategy for mapping fermionic systems to quantum hardware with square qubit connectivity which yields low-depth quantum circuits, counted in the number of native two-qubit fSIM gates. We achieve this by leveraging novel operator decomposition and circuit compression techniques paired with specifically chosen fermion-to-qubit mappings that allow for a high degree of gate cancellations and parallelism. Our mappings retain the flexibility to simultaneously optimize for qubit counts or qubit operator weights and can be used to investigate arbitrary fermionic lattice geometries. We showcase our approach by investigating the tight-binding model, the Fermi-Hubbard model as well as the multi-orbital Hubbard-Kanamori model. We report unprecedentedly low circuit depths per single Trotter layer with up to a factor 3.2 improvement upon previous state-of-the-art. Additionally, we show that our decomposition and compression formalism produces favourable circuits even when no native parameterized two-qubit gates are available.

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