Quantum Simulation and Quantum Computing with Fermions

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Quantum simulation has emerged as a new and interdisciplinary research field that enables a microscopic view of quantum matter both in and out of equilibrium across different physical platforms. Recent applications of quantum simulations involving strongly correlated electronic systems using ultracold atoms in optical lattices and tweezers will be outlined. By comparing with state-of-the-art numerical methods, we show that quantum simulations with fermionic atoms can provide highly valuable and novel insights into the understanding of strongly correlated matter. As an example, we present an analysis of the emergence of the pseudogap phase in the fermionic Hubbard model. We identify a novel universal behaviour of magnetic correlations upon entering the pseudogap phase, observed in both spin-spin and higher-order spin-charge correlations.

In addition to analog methods, gate-based fermionic quantum computing offers distinct advantages in quantum computations. We demonstrate the elementary operations required to manipulate the orbital degrees of freedom, which form the basis of a fermionic quantum computer.