

Quantum Simulation and Quantum Computing with Fermions

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Ultracold fermionic atoms provide a powerful platform for quantum simulation and, increasingly, for quantum computation aimed at electronically correlated matter. In this talk, I will discuss how analog and digital approaches can be used to study the Fermi–Hubbard model, with an emphasis on its low-energy phases, including pseudogap behavior and ground-state properties. Over the past two decades, experiments with ultracold atoms in optical lattices have helped establish a broadly interdisciplinary field by enabling controlled studies of strongly interacting many-body systems both in and out of equilibrium. With single-particle-resolved preparation, manipulation, and detection, these systems now allow direct access to observables such as hidden order parameters, entanglement measures, full counting statistics, topological signatures, and the quantum dynamics of stripes. At the same time, quantum simulation with fermions can provide high-precision benchmark results for both numerical methods and quantum-computing approaches, thereby defining reference problems for the field as a whole. I will also discuss how high-fidelity collisional two-qubit gates can extend the capabilities of analog fermionic simulators, enabling hybrid analog-digital protocols for state preparation, control, and readout. Together, these developments position the field to address longstanding open problems in strongly correlated fermionic systems.