Quantum simulation of mesoscopic Fermi systems

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Ultracold quantum gases in optical potentials have achieved spectacular progress in the experimental simulation of complex quantum systems. Complementary to many-body experiments, mesoscopic systems comprised of a small number of atoms offer the possibility to study entangled quantum states with an exceptional degree of versatility and control.

We have implemented a highly tunable platform to study such correlated few-fermion systems. Using reconfigurable optical microtraps, we prepare quantum states of ^{6}Li atoms with a deterministic atom number and spin configuration and tune interactions via a magnetic Feshbach resonance. A novel readout scheme with single-particle sensitivity allows us to measure spin-resolved correlations in time of flight.

Such momentum correlations characterize few-body systems via the coherence and symmetry of the wavefunction. Focusing on the Fermi-Hubbard double-well, we observe high-contrast interference of indistinguishable fermions, the build-up of correlations due to interactions and the emergence of entanglement between particles. Our techniques can be applied to larger systems to characterize many-body phases via their high-order correlation functions.