Experiments with ultracold Fermions in optical lattices: A quantum simulator for the Hubbard model

Ultracold fermionic atoms in an optical lattice represent a versatile quantum simulator for correlated electrons in a solid, as they allow for a clean and defect-free implementation of the Fermi Hubbard model with tunable parameters.

During the last two years, significant advances in combining optical lattices with Feshbach resonances have allowed for the first experimental observation of strongly correlated phases of fermionic atoms in these lattices.

For repulsive interactions, we experimentally observed the crossover from a metallic into a Mott insulating regime and compared our results with a DMFT calculation [1].
In the attractive Hubbard model an anomalous expansion of the atomic cloud in the pseudogap regime of the BEC-BCS crossover [2] could be observed, which represents a new possible way to investigate the properties of low entropy phases using a high entropy sample.

Furthermore, ultracold atoms offer the possibility to control all relevant parameters in real time during the experiment. By suddenly changing the harmonic confinement at constant lattice depth we could create an out-of-equilibrium situation which allows us to study transport properties of the Hubbard model.

[1] U. Schneider, L. Hackermuller, S. Will, Th. Best, I. Bloch, T. A. Costi, R. W. Helmes, D. Rasch, and A. Rosch
Metallic and Insulating Phases of Repulsively Interacting Fermions in a 3D Optical Lattice.
Science, 322,1520, (2008)

[2] L. Hackermuller, U. Schneider, M. Moreno-Cardoner, T. Kitagawa, S. Will, T. Best, E. Demler, E. Altman, I. Bloch, B. Paredes
Anomalous Expansion of Attractively Interacting Fermionic Atoms in an Optical Lattice
arXiv:0910.3598