Q 68: Quantum Gases: Fermions III

Time: Friday 14:30–16:30 Location: e001

Q 68.1 Fri 14:30 e001

Quantum many body physics using strontium atoms — •Rodrigo Gonzalez — Max Planck Institute of Quantum Optics Garching

In the last few years alkaline earth atoms have become the most precise tools for metrology and time measurement available. It is due to their rich internal atomic structure and high controllability what makes them ideal for this area of research.

On the other hand, quantum gas microscopes present themselves as one of the most powerful tools for understanding the dynamics of electrons in solids. However, the complexity of this systems makes a precise mathematical description impossible.

The extension of the Quantum Gas microscope technique to fermionic isotopes of alkaline atoms represents already an important milestone in the development and understanding of this systems

In this context, we report the very first stages of a new experiment witch aims to create a Quantum Gas microscope of Strontium atoms at the Max Planck Institute of Quantum Optics.

Q 68.2 Fri 14:45 e001

Site-resolved imaging of a fermionic Mott insulator — •Daniel Greif[1], Maxwell F. Parsons[1], Anton Mazurenko[1], Christie S. Chiu[1], Sebastian Blatt[1,2], Florian Huber[1], Geoffrey Ji[1], and Markus Greiner[1] — [1]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Probing quantum many-body systems on a microscopic level with single-site resolution offers unique insight with unprecedented control and level of detail. We report site-resolved imaging of two-component fermionic Mott insulators, metals, and band insulators with ultracold Li-6 atoms in a square lattice. We observe large, defect-free 2D Mott insulators for strong repulsive interactions, which are characterized by a constant single-site occupation and strongly reduced variance. For intermediate interactions we observe a coexistence of phases. From comparison to theory we find trap-averaged entropies per particle of $1.0\,k_\mathrm{B}$ and local entropies as low as $0.5\,k_\mathrm{B}$. This experiment is a vital step towards probing quantum-mechanical models in regimes inaccessible by modern theoretical methods.

Q 68.3 Fri 15:00 e001

Direct probing of the Mott crossover in the SU(N) Fermi-Hubbard model — Christian Hofrichter[1,2], Luis Riegger[1,2], Francesco Scazza[1,2], Moritz Höfer[1,2], •Diogo Rio Fernandes[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

The Fermi-Hubbard model (FHM) is a cornerstone of modern condensed matter theory. Developed for interacting electrons in solids, which typically exhibit SU(2) symmetry, it describes a wide range of phenomena, such as metal to insulator transitions and magnetic order. Its generalized SU(N)-symmetric form, originally applied to multi-orbital materials such as transition-metal oxides, has recently attracted much interest owing to the availability of ultracold atomic gases with unbroken SU(N)-symmetry. In this talk we report on a detailed experimental investigation of the SU(N)-symmetric FHM using local probing of an atomic gas of ytterbium in an optical lattice. We prepare a low-temperature SU(N)-symmetric Mott insulator and characterize the Mott crossover by directly determining the equation of state of the gas, giving model-free access to density and compressibility.

Q 68.4 Fri 15:15 e001

Local probing of the equation of states in two-dimensional Fermi Hubbard Model — •Chun Fai Chan[1], Eugenio Cocchi[1,2], Luke Miller[1,2], Jan Henning Drewes[1], Daniel Pertot[1], Ferdinand Brennecke[1], and Michael Köhl[1,2] — [1]Physikalisches Institut, Universität Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

Ultracold fermions in optical lattices are promising candidate for simulating the Hubbard model. The Hubbard model contains various interesting phases, such as the Mott insulating phase, spin-ordered states and possibly d-wave superconductivity. Using 40K atoms in optical lattices, we perform high-resolution imaging and radio-frequency spectroscopy to probe the two-dimensional Hubbard model. Here we report on the experimental determination of the equation of state, which enables us to fully characterize the thermodynamics of the Hubbard model in the charge sector.

Q 68.5 Fri 15:30 e001

Microscopic Observation of Pauli Blocking in Degenerate Fermionic Lattice Gases — •Timon Hilker, Ahmed Omran, Martin Boll, Katharina Kleinlein, Guillaume Salomon, Immanuel Bloch, and Christian Gross — Max-Planck-Institute für Quantenoptik

Ultracold atoms in optical lattices provide a powerful platform for the controlled study of quantum many-body physics. We present here the first studies of a Fermi gas with a new generation quantum gas microscope, which allows to observe the full atom number statistics on every site. The common problem of light induced losses is avoided by an additional small scale "pinning lattice" for Raman sideband cooling during the imaging.

We report the local observation of Pauli's exclusion principle in a spin-polarized degenerate gas of ^{6}Li fermions in an optical lattice. In the band insulating regime, we measure a strong local suppression of particle number fluctuations and we extract a local entropy as low as $0.3\ k_B$ per atom. Our work opens an avenue for studying local density and even magnetic correlations in fermionic quantum matter both in and out of equilibrium.

Q 68.6 Fri 15:45 e001

Fluctuations and correlations in the two-dimensional Hubbard Model — •Jan Henning Drewes[1], Luke Miller[1,2], Eugenio Cocchi[1,2], Chun Fai Chan[1], Daniel Pertot[1], Ferdinand Brennecke[1], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

Quantum gases of interacting fermionic atoms in optical lattices promise to shed new light on the low-temperature phases of the Hubbard model such as spin-ordered phases, or in particular, on possible d-wave superconductivity. In this context it remains challenging to access the correlation functions underlying strongly-correlated many-body states. We experimentally realise the two-dimensional Hubbard model by loading a quantum degenerate Fermi gas of 40K atoms into a three-dimensional optical lattice geometry. High resolution absorption imaging in combination with radio-frequency spectroscopy is applied to spatially resolve the atomic distribution in a single layer in the vertical direction. We focus on local measurements of fluctuations of the density of singly- and doubly occupied lattice sites as well as of the local spin-imbalance. Our measurements allow for thermometry using the fluctuation-dissipation theorem and provide information about spatial spin-correlations.

Q 68.7 Fri 16:00 e001

Studying the interplay of order and geometry in the Hubbard model with ultracold fermions — Rémi Desbuquois[1], •Gregor Jotzu[1], Michael Messer[1], Thomas Uehlinger[1], Frederik Görg[1], Sebastian Huber[2], Daniel Greif[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland

The geometry of a lattice plays a crucial role in determining the order which can form therein. This shows up in the types of spin-correlations supported by a particular lattice, but can even play a role in the charge/density degree of freedom. In particular, when a symmetry of the system is broken by the lattice, the resulting quantum state is expected to display this broken symmetry.

For example, in the ionic Hubbard model, an energy-offset between neighbouring sites breaks inversion symmetry leading to a charge-density wave. However, strong repulsive interactions can drive the system into a Mott-insulating regime, where the broken symmetry is suppressed in the density-distribution.

Ultracold atoms in optical lattices are well suited for styding the effects of varying the lattice geometry, as both local observables such as the double-occupancy, and long-range observables such as noise-correlations are accessible. In addition, the excitation spectrum of the system can be probed by dynamically modulating the lattice parameters.

Q 68.8 Fri 16:15 e001

Multiple particle-hole pair creation in the Fermi-Hubbard model by a pump laser — •Nicolai ten Brinke and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, D-47057 Duisburg, Germany

We study the Fermi-Hubbard model in the strongly correlated Mott regime under the influence of a harmonically oscillating electric field created by a pump laser. Using a Peierls transformation, the pump field can be represented as an effective, oscillating hopping rate in terms of the Fermi-Hubbard Hamiltonian. As the oscillation leads to a reduction in the effective time-averaged hopping rate, a sudden switch of the pump laser is analogous to a quantum quench in the lattice parameters. Apart from that, particle-hole pairs can be created via the oscillating components of the effective hopping rate, when the pump frequency is in resonance with the Mott gap. Further, it should be possible to create multiple particle-hole pairs if the pump frequency is an integer multiple of the Mott gap. These findings should be relevant for pump-probe experiments.