Q 22: Quantengase: Fermionen im Gitter

Zeit: Dienstag 14:00–16:00 Raum: VMP 6 HS-A

Preisträgervortrag Q 22.1 Di 14:00 VMP 6 HS-A
Strong correlations in ultracold fermionic gases — •Corinna Kollath — CPHT, Ecole Polytechnique, CNRS, 91128 Palaiseau, France — Trägerin des Hertha-Sponer-Preises

Atomic gases cooled to Nanokelvin temperatures are a new exciting tool to study a broad range of quantum phenomena. In particular, the outstanding degree of control which has been achieved over these quantum systems facilitates access to strongly correlated quantum many body physics. For example, optical lattices have been created to mimic condensed matter systems. We perform a theoretical study of a fermionic gas with two repulsively interacting hyperfine states confined to an optical lattice. We determine a generic state diagram in the presence of a harmonic confining potential. We further discuss implications for current experiments.

Q 22.2 Di 14:30 VMP 6 HS-A
Theoretical study of the anomalous expansion of increasingly attractive fermionic atoms in an optical lattice — Lucia Hackermüller[1], Ulrich Schneider[1], Takuya Kitagawa[2], •Maria Moreno-Cardoner[1], Thorsten Best[1], Sebastian Will[1], Simon Braun[1], Eugene Demler[2], Immanuel Bloch[1], and Belén Paredes[1] — [1]Institut für Physik, Johannes Gutenberg-University, 55099 Mainz, Germany — [2]Physics Department, Harvard University, Cambridge, MA02138, USA

We study theoretically and compare with the experimental result the size behaviour of an ultracold spin mixture of fermions in an optical lattice when adiabatically entering the strongly correlated regime. The size of the cloud, directly measured in the experiment using insitu imaging, behaves as expected for weak interactions, decreasing (increasing) for an attractive (repulsive) gas. However, in the strongly interacting regime entropy is redistributed among the lattice sites in a dramatically different way leading to unexpected phenomena like an anomalous expansion of the gas on the attractive side.

Q 22.3 Di 14:45 VMP 6 HS-A
A Mott insulator of ultracold fermions in an optical lattice — •Robert Jördens, Niels Strohmaier, Daniel Greif, Leticia Tarruell, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Strong interactions between electrons in a solid material lead to surprising effects such as the Mott insulator, where a suppression of conductivity occurs due to interactions rather than due to a filled Bloch band. Proximity to the Mott insulating phase is the origin of many intriguing phenomena in condensed matter physics, most notably high-temperature superconductivity.

We implement the Fermi-Hubbard model, which encompasses the physics of the Mott insulator, by trapping a repulsively interacting two-component Fermi gas in an optical lattice. In agreement with theoretical models, the double occupancy provides a versatile and sensitive probe to the system's properties and signals the formation of a Mott insulator by three features: a drastic suppression of doubly occupied lattice sites, a strong reduction of the compressibility, and the appearance of an excitation mode corresponding to the creation of double occupancies. In the regime of strong interactions, this mode establishes a direct measurement of the Hubbard U and allows us to study the process of creation and decay of double occupancies.

Q 22.4 Di 15:00 VMP 6 HS-A
Attractively Interacting Fermionic Mixtures in Optical Lattices — •Lucia Hackermueller[1], Ulrich Schneider[1], Maria Moreno Cardoner[1], Takuya Kitagawa[2], Thorsten Best[1], Sebastian Will[1], Simon Braun[1], Eugene Demler[2], Belen Paredes[1], and Immanuel Bloch[1] — [1]Staudingerweg 7, Universität Mainz, 55099 Mainz — [2]Physics Department, Harvard University, Cambridge, MA 02138, USA

We present an experimental study of a balanced spin mixture of ultracold fermionic ^{40}K in $|F, m_F\rangle = |\frac{9}{2}, -\frac{9}{2}\rangle$ and $|F, m_F\rangle = |\frac{9}{2}, -\frac{7}{2}\rangle$. The mixture is loaded into the combination of a three dimensional blue detuned optical lattice with a red detuned optical dipole trap, which allows an independent control of lattice depth and trapping potential. A Feshbach resonance located at 202.1G can be used to change the interaction strength and to create molecules by ramping adiabatically over the resonance. When the interaction is tuned from repulsive to attractive we measure a continuous decrease in cloud size and observe a minimum for intermediate attractive interactions, while for strong attractive interactions the size increases again. The increase in size coincides with a large fraction of the atomic cloud residing on doubly occupied sites and can be compared with the predictions of high temperature expansion theory. In addition we present measurements on the mobility of bound pairs in the optical lattice.

Q 22.5 Di 15:15 VMP 6 HS-A
Static and dynamic properties of repulsivly interacting fermions in optical lattices — •Ulrich Schneider, Lucia Hackermüller, Thorsten Best, Sebastian Will, Simon Braun, and Immanuel Bloch — Johannes Gutenberg-Universität Mainz

Fermionic atoms in optical lattices can serve as a model system for condensed matter physics: They implement the Hubbard model with high experimental control of the relevant parameters. We study static and dynamic properties of ultracold Fermions in different regimes, ranging from metallic and band-insulating states in the non-interacting case to complex metals and the Fermionic-Mott-Insulator for strongly repulsive systems.

In the experiment, spin mixtures of fermionic ^{40}K are loaded into a combination of a blue detuned three dimensional optical lattice and a red detuned dipole trap. This combination of optical potentials allows an independent control of lattice depth and harmonic confinement, thus enabling us to explore different regimes. In addition to measurements of the in-situ cloud size and the doublon fraction we present measurements of the dynamic response of the system to changes in the external parameters.

Q 22.6 Di 15:30 VMP 6 HS-A
Spin waves in spin-3/2 1D optical lattices — •Arturo Argüelles and Luis Santos — Leibniz Universität Hannover, D-30167 Hannover, Germany

The dynamics of the Hubbard Hamiltonian in 1D optical lattices is very rich. For instance, by taking only spinless particles, it is possible to observe how a hole can propagate throughout the lattice with a certain velocity. If additionally, the spin is taken into account it shows the spin-charge separation phenomenon. For higher spins, the super-exchange collisions allow the system to have several different spin-wave velocities and therefore one can see more general separation of the modes. Our calculations are performed using the Matrix Product State ansatz.

Q 22.7 Di 15:45 VMP 6 HS-A
Doublon relaxation in the Fermi-Hubbard model — •Niels Strohmaier, Daniel Greif, Robert Jördens, Leticia Tarruell, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Switzerland

The investigation of interacting quantum many-particle systems in non-equilibrium has recently attracted a lot of attention. However, a theoretical understanding of experimental results remains challenging due to the complexity of the systems. Ultracold atoms in optical lattices, well described by the Hubbard model, offer a new approach. Their cleanliness and the unique tunability of parameters make them well suited for the emulation of condensed matter systems.

We report on our latest experiments with repulsively interacting Fermions in a 3D optical lattice. Starting either from a Mott insulator or from a metallic state, we perturb the sample by generating a significant amount of doubly occupied lattice sites. The following relaxation of the system back to its thermal equilibrium is monitored in time-resolved manner. We study this decay of doublons for a wide range of parameters of the Fermi-Hubbard Hamiltonian and observe a clear dependence on the ratio of interaction energy and kinetic energy.