Q 50: Ultra-cold atoms, ions, and BEC VI (joint session A/Q)

Time: Thursday 14:00–15:45 Location: f303

Invited Talk Q 50.1 Thu 14:00 f303

Dynamics of a mobile hole in a Hubbard antiferromagnet — •Martin Lebrat, Geoffrey Ji, Muqing Xu, Christie Chiu, and Markus Greiner — Harvard University, Cambridge, MA, USA

The interplay between spin and charge underlies much of the phenomena of the doped Hubbard model. Quantum simulation of the Hubbard model using quantum gas microscopy offers site-resolved readout and manipulation, enabling detailed exploration of the relationship between the two. We use this platform to explore spin and charge dynamics upon the delocalization of an initially-pinned hole dopant. We first prepare a two-component quantum gas of Lithium-6 loaded into a square optical lattice at half-filling and strong interactions, where the atoms exhibit antiferromagnetic spin ordering. During the loading process, we use a digital micromirror device to pin a localized hole dopant into the antiferromagnet. We then release the dopant and examine how it interacts with and scrambles the surrounding spin environment. The microscopic dynamics of dopants may provide further insight into the phases that appear in the doped Hubbard model.

Q 50.2 Thu 14:30 f303

Hubbard Parameters for Quasi-Two-Dimensional Optical Lattices — •Tobias Ilg and Hans Peter Büchler — Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, DE-70550 Stuttgart, Germany

We investigate a microscopic model of two particles interacting via a Feshbach resonance in a quasi-two-dimensional optical lattice. The transverse direction is confined by a harmonic trap, and in the quasi-two-dimensional regime we make the connection between the Hubbard parameter of a single band two-dimensional Hubbard model and the scattering length in three dimensions. Our procedure takes into account the proper renormalization of the low-energy scattering amplitude as well as contributions from all higher bands. We shows that in contrast to the three-dimensional case, higher bands always have an impact on the Hubbard parameter, even for deep optical lattices.

Q 50.3 Thu 14:45 f303

Three-dimensional time-reversal-invariant Hofstadter-Hubbard model — •Bernhard Irsigler[1], Jun-Hui Zheng[1,2], Fabian Grusdt[3,4], and Walter Hofstetter[1] — [1]Goethe-University Frankfurt, Germany — [2]NTNU, Trondheim, Norway — [3]MCQST, Munich, Germany — [4]LMU, Munich, Germany

We report on the three-dimensional time-reversal-invariant Hofstadter model with finite spin-orbit coupling. We introduce three numerical methods for characterizing the topological phases based on twisted boundary conditions, Wilson loops, as well as the local topological marker. Besides the weak and strong topological insulator phases we find a nodal line semimetal in the parameter regime between the two three-dimensional topological insulator phases. Using dynamical mean-field theory combined with the topological Hamiltonian approach we find stabilization of these three-dimensional topological states due to the Hubbard interaction. We study surface states which exhibit an asymmetry between left and right surface originating from the broken parity symmetry of the system. Our results set the stage for further research on inhomogeneous three-dimensional topological systems, proximity effects, topological Mott insulators and non-trivially linked nodal line semimetals.

Q 50.4 Thu 15:00 f303

Bilayer Fermi - Hubbard physics with a quantum gas microscope — •Sarah Hirthe[1], Joannis Koepsell[1], Dominik Bourgund[1], Jayadev Vijayan[1], Pimonpan Sompet[1], Guillaume Salomon[1], Immanuel Bloch[1,2], and Christian Gross[1,3] — [1]Max-Planck-Institute of Quantum Optics — [2]Ludwig-Maximilians Universität München — [3]Eberhard Karls Universität Tübingen

The bilayer Fermi-Hubbard model is of special interest for quantum simulation, as bilayered structures are prominent in materials such as the high-Tc superconducting cuprates. We have recently upgraded our Fermi gas microscope with a highly stable vertical superlattice, which now allows us full control over a strongly interacting fermionic bilayer system. We investigate the bilayer phase diagram by probing the Mott insulator to band insulator as well as the metal to band insulator transition. We confirm the expected transition point at an interlayer coupling of four times the intralayer coupling. Furthermore, making use of the full control over the lattice potential, we demonstrate a new technique based on topological charge pumping to reach single-site resolution of each layer. We benchmark the power of this technique by applying it to fully spin resolve a two-dimensional system. We find a strongly correlated system at temperatures consistent with the coldest temperatures reported in cold atoms.

Q 50.5 Thu 15:15 f303

Coherent control in a driven Fermi-Hubbard system — •Anne-Sophie Walter, Frederik Görg, Kilian Sandholzer, Joaquín Minguzzi, Konrad Viebahn, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, Switzerland

Coherent control is a widely applied technique in fields ranging from chemistry to ultracold atoms. It aims at steering quantum dynamics by controlling the relative phase between external light fields. In the context of Floquet engineering in optical lattices, where the system is periodically driven in time, the drive can resonantly couple to higher Bloch bands leading to atom loss. To overcome this problem we apply a coherent control scheme which would allow for a wider range of possible driving frequencies.

In our experiment, we periodically modulate the potential depth of our 3D optical lattice at a frequency that excites atoms to a higher band. We apply coherent control by tuning the phase of an additional drive at twice the fundamental frequency which destructively interferes with the first. Through this technique we preserve both the band population as well as the fraction of double occupancies for two orders of magnitude longer compared to the single-frequency case. We find this technique to be effective even at strong Hubbard interactions. Strikingly, the lifetime of spin correlations, which are highly susceptible to heating, is also improved by two orders of magnitude and comparable to the static value. This successful application of coherent control in a periodically driven many-body system opens new possibilities for Floquet engineering in the presence of strong interactions.

Q 50.6 Thu 15:30 f303

A single beam grating magneto optical trap on an atom chip — •Hendrik Heine[1], Alexander Kassner[2], Christoph Künzler[2], Marc C. Wurz[2], Waldemar Herr[1], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Mikroproduktionstechnik, Leibniz Universität Hannover

Matterwave interferometry with Bose Einstein Condensates (BEC) promises exciting prospects in inertial sensing and research on fundamental physics both on ground and in space. BECs can be created very efficiently by using an atom chip and compact realisations have already been shown. However for transportable or space applications, it is vital to reduce the complexity in order to lower size, weight and power demands of the device.

In this talk I will present a magneto optical trap and sub-Doppler cooling using only a single beam of light in combination with an optical grating on an atom chip. This reduces the complexity of the overall optical system and promises greater long-term stability. Finally, the atom chip allows for magnetic trapping and evaporative cooling by forced radio frequency evaporation towards a BEC.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under grant number DLR 50WM1947 (KACTUS-II) and by the German Science Foundation (DFG) under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".