Q 31: Quantum Gases: Opt. Lattice 2

Time: Wednesday 14:30–16:00 Location: HSZ 02

Q 31.1 Wed 14:30 HSZ 02

Probing nearest-neighbor correlations of ultracold fermions in an optical lattice — •Thomas Uehlinger, Daniel Greif, Leticia Tarruell, Robert Jördens, Gregor Jotzu, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We demonstrate a probe for nearest-neighbor correlations of fermionic quantum gases in optical lattices. It gives access to spin and density configurations of adjacent sites and relies on creating additional doubly occupied sites by perturbative lattice modulation. The measured correlations for different lattice temperatures are in good agreement with an *ab initio* calculation without any fitting parameters. This probe opens new prospects for studying the approach to magnetically ordered phases.

Q 31.2 Wed 14:45 HSZ 02

Momentum-resolved spectroscopy of ultracold fermions in optical lattices — •Jannes Heinze, Sören Götze, Jasper Simon Krauser, Bastian Hundt, Nick Fläschner, Dirk-Sören Lühmann, Christoph Becker, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg

The periodic dispersion of electrons in crystals gives rise to many important phenomena in solid-state physics. To characterize such systems a measurement of the energies and fillings is required for the lowest bands. Ultracold fermionic atoms in optical lattices show essentially the same physics, however, with much better control over the system parameters. This includes especially the arbitrary tuning between different lattice depths: From weak to strong lattices, conductive and insulating phases can be realized. We present a spectroscopy method which is sensitive to both, form and filling of the different bands fully momentum-resolved. Thus, we can measure the full band structure and therefore extract very accurately all derived properties as e.g. the tunneling energy. The additional filling information allows in principle for the determination of the systems' phase. Our sensitivity is promising for the extension of these studies to observe interaction shifts due to additional bosonic atoms as well as changes in the densitiy of states for interacting fermionic gases.

Q 31.3 Wed 15:00 HSZ 02

Néel transition of lattice fermions in a harmonic trap: a real-space dynamical mean-field study — •Elena V. Gorelik[1], Irakli Titvinidze[2], Walter Hofstetter[2], Michiel Snoek[3], and Nils Blümer[1] — [1]Institute of Physics, Johannes Gutenberg University, Mainz, Germany — [2]Institute for Theoretical Physics, Johann Wolfgang Goethe University, Frankfurt, Germany — [3]Institute for Theoretical Physics, University of Amsterdam, The Netherlands

Ultracold atoms on optical lattices attract enormous interest as potential "quantum simulators" of condensed-matter systems. A missing link in this context is the realization of antiferromagnetic (AF) Néel phases: in spite of enormous experimental efforts, concentrating in particular on achieving lower temperatures, no AF signatures have been detected so far.

We extend the range of applicability of the recently developed real-space dynamical mean-field theory (DMFT) to the temperatures of experimental interest by combining it with a highly efficient quantum Monte Carlo algorithm [1]. We demonstrate that the onset of AF correlations at low temperatures is signaled, for interactions $U > 10t$, by a strongly enhanced double occupancy [2]. This signature is directly accessible experimentally and should be observable well above the critical temperature for long-range order. Dimensional aspects appear less relevant (and DMFT more accurate) than naively expected.

[1] N. Blümer and E. V. Gorelik, Comp. Phys. Comm. **182**, 115 (2011). [2] E. V. Gorelik, I. Titvinidze, W. Hofstetter, M. Snoek, and N. Blümer, Phys. Rev. Lett. **105**, 065301 (2010).

Q 31.4 Wed 15:15 HSZ 02

Occupation-dependent multi-band Hubbard models — •Ole Jürgensen, Dirk-Sören Lühmann, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany

Typically, tunneling and interactions are competing processes in optical lattices, where the quantum phase transition to the Mott insulator is one of the most prominent examples. So far, often single band Bose-Hubbard models are used to study these systems theoretically. Recently it was pointed out that already for moderate parameters the interaction promotes particles to higher bands of the lattice which alters the energy gain connected with the tunneling significantly[1,2]. In bosonic systems, new quantum phases have been predicted for occupation-dependent tunneling.

Using a fully correlated treatment, we calculate the effective tunneling and on-site interactions in optical lattices for bosonic atoms and Bose-Fermi mixtures. The renormalized tunneling sums over all combinations of higher-band processes and shows substantial deviations from the uncorrelated tunneling. We introduce an occupation-dependent Hubbard model which effectively covers the role of higher-orbital physics.

The results obtained from our fully correlated calculation cast new light on the underlying processes and support the significance of occupation-dependent Hubbard models.

[1] D.-S. Lühmann et al., Phys. Rev. Lett. 101, 050402 (2008)
[2] T. Best et al., Phys. Rev. Lett. 102, 030408 (2009)

Q 31.5 Wed 15:30 HSZ 02

Probing Quantum Density Fluctuations of Ultracold Atoms with Matter Wave Optics — •Scott Sanderes, Florian Mintert, and Andreas Buchleitner — Albert-Ludwigs-Universität, Freiburg, Germany

In this talk, we discuss the utility of matter wave scattering as a means to probe quantum density fluctuations of ultracold bosons in an optical lattice. Such fluctuations are characteristic of the superfluid phase and vanish due to increased interactions in the Mott insulating phase. We employ an analytical treatment of the scattering and demonstrate that the fluctuations lead to incoherent processes, which we propose to observe via decoherence of the fringes in a Mach-Zender interferometer. In this way we extract the purely coherent part of the scattering. Further, we show that the quantum density fluctuations can also be extracted directly from the differential angular scattering cross section for an atomic beam scattered from the atoms in a lattice. Here we find an explicit dependence of the scale of the inelastic scattering on the quantum density fluctuations.

Q 31.6 Wed 15:45 HSZ 02

Resonance fluorescence as a precision test for single site addressability — •Peter Degenfeld-Schonburg, Martin Kiffner, and Michael Hartmann — Technische Universität München, Physik Department, James Franck Strasse, 85748 Garching, Germany

Pioneering methods in recent optical lattice experiments allow for addressing single atoms in individual sites of an optical lattice by focused laser beams. Inspired by this, we examine the resonance fluorescence spectrum of two-level atoms positioned in adjacent lattice sites, where a focused laser beam drives a single atom only. As compared to the case where the laser hits several atoms, the spectrum for single site addressing is no longer symmetric around the laser frequency. The shape of the spectrum of fluorescent light can therefore serve as a test for the precision of single site addressing. The effects we find can be attributed to a dipole-dipole interaction between the atoms due to mutual exchange of photons.