Q 63: Quantum gases: Lattices III

Time: Friday 14:00–16:00 Location: UDL HS2002

Q 63.1 Fri 14:00 UDL HS2002

Short-range quantum magnetism of ultracold fermions in an optical lattice — •Daniel Greif[1], Thomas Uehlinger[1], Gregor Jotzu[1], Leticia Tarruell[1,2], and Tilman Esslinger[1] — [1]ETH Zürich, Switzerland — [2]ICFO-Institut de Ciencies Fotoniques, Spain

Quantum magnetism describes quantum many-body states with spins coupled by exchange interactions. At low temperatures this leads to short- and long-range magnetic ordering, which is for example the case in spin-liquids, valence-bond solids and antiferromagnets.

We report on the observation of magnetic spin correlations on neighboring sites of a Fermi gas in an optical lattice. The key to obtaining and detecting the short-range magnetic order is an entropy redistribution technique in a tunable-geometry optical lattice. We load a low-temperature two-component gas with repulsive interactions into either a dimerized or anisotropic simple cubic lattice. The correlations manifest as an excess number of singlets as compared to triplets consisting of two atoms with opposite spins. For the anisotropic lattice, we determine the transverse spin correlator from the singlet-triplet imbalance and observe antiferromagnetic correlations along one spatial axis. We find good agreement when comparing our results to numerical calculations.

Q 63.2 Fri 14:15 UDL HS2002

Microscopic observation of magnon bound states and their dynamics — •Sebastian Hild[1], Takeshi Fukuhara[1], Peter Schauss[1], Johannes Zeiher[1], Frauke Seesselberg[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München, Germany

Ultra-cold atoms in optical lattices provide an ideal system for the study of spin Hamiltonians. The system parameters can be well controlled and site resolved detection of the atoms in the lattice offers a novel local probe for such systems. Here we report on the observation of free and bound magnon states in the ferromagnetic Heisenberg model. We study the dynamics of these states after a local spin flip excitation. The free magnon state is discriminated from the bound state by in-situ correlation measurements and their different effective mass results in a distinct propagation speed.

Furthermore we report on ongoing experiments studying the dynamics of spin waves initially imprinted into the system.

Q 63.3 Fri 14:30 UDL HS2002

Competing Magnetic and Superfluid Phases in the Two-Channel Fermi-Hubbard Model — •Victor Bezerra[1], Flavio Nogueira[2], and Axel Pelster[3] — [1]Department of Physics, Freie Universität Berlin, Germany — [2]Department of Physics, Ruhr-Universität Bochum, Germany — [3]Department of Physics and Research Center OPTIMAS, Technische Universitatät Kaiserslautern, Germany

We consider a two-channel Bose-Hubbard model where the fermions interact repulsively and the Feshbach bosons emerge from a coupling of two fermions. Within a mean-field theory at zero temperature we analyze the possibility of a competing presence of both an antiferromagnetic (AF) and an s-wave superconducting (SC) order parameter. The resulting phase diagram reveals that both phases never coexist and that the transition between them is of first order in accordance with the Ginzburg-Landau-Wilson paradigm. If the fermionic density is equal to unity, the system can be either in a SC or an AF phase depending on the respective values of the other physical parameters. For a fermionic filling different from unity we have only observed the existence of a SC phase. Such a two-channel Hubbard model could be interesting in simulating the novel pnictide high-temperature superconductors, as they also show an interplay between an AF and a SC phase.

Q 63.4 Fri 14:45 UDL HS2002

Full control over two interacting fermions in a single double-well potential — •Andrea Bergschneider[1], Simon Murmann[1], Vincent Klinkhamer[1], Gerhard Zürn[1], Thomas Lompe[1,2], and Selim Jochim[1] — [1]Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Department of Physics, Massachusetts Institute of Technology, Massachusetts Avenue 77, Cambridge, MA, USA

We have realized the deterministic preparation of two fermions in a single double-well potential, having full control over the two-particle quantum state. Starting with two non-interacting atoms in the ground state of a single harmonic potential we can either access the ground state of the double-well by means of an adiabatic passage, or diabatically switch on the second well to observe tunneling dynamics.

When the two particles are interacting, their tunneling dynamics in the double-well is correlated. For strong interaction we find resonant two-particle and off-resonant single-particle tunneling. Combined with the scalability in the number of sites and atoms, this makes our system well suited for the realization of quantum gates.

With the two fermions prepared in the ground state of the double well, a change to repulsive (attractive) interactions allows us to change the particle statistics showing strong enhancement (suppression) of singly occupied sites. In terms of a finite Fermi-Hubbard model this can be understood as a two-particle analogy to a Mott-insulator (charge-density wave). Adding more wells to the system we aim for an experimental bottom-up approach to Fermi-Hubbard physics.

Q 63.5 Fri 15:00 UDL HS2002

Precision spectroscopy of ultracold fermions in a triangular optical lattice — •Nick Fläschner[1], Dominik Vogel[1], Frieder Fröbel[1], Jasper Simon Krauser[1], Jannes Heinze[1], Christof Weitenberg[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Institut für Laserphysik, Universität Hamburg, Germany — [2]Zentrum für Optischen Quantentechnologien, Universität Hamburg, Germany

Ultracold fermions in optical lattices provide an ideal testing ground for solid-state theories due to the high experimental control and wide range of tunable parameters. Probing the elementary excitation spectrum of these systems is of great interest and it is of substantial interest to measure both the band structure and the filling of the lowest bands. In this talk, we present measurements of the full two-dimensional band structure of ultracold fermions in a triangular lattice using a versatile, fully momentum-resolved spectroscopy method based on lattice amplitude modulation. Our newly implemented lattice setup allows us to tune the tunneling matrix elements in each lattice direction independently. In combination with the high precision of the spectroscopy technique, this is promising for engineering and investigating novel lattice systems with interacting fermionic spin-mixtures and non-equilibrium phenomena in exotic lattice geometries including strong artificial gauge fields.

Q 63.6 Fri 15:15 UDL HS2002

Quantum magnetism of ultracold fermions on optical lattices with novel geometries — •Elena Gorelik and Nils Blümer — Institute of Physics, Johannes Gutenberg University, Mainz, Germany

Recently, it has become possible to tune optical lattices continuously between square and triangular geometries. We compute thermodynamics and spin correlations in the corresponding Hubbard model using determinant quantum Monte Carlo and show that the frustration effects induced by the variable hopping terms can be clearly separated from concomitant bandwidth changes by a proper rescaling of the interaction. An enhancement of the double occupancy by geometric frustration signals the destruction of nontrivial antiferromagnetic (AF) correlations at weak coupling and entropy $s \lesssim \ln(2)$ (and restores Pomeranchuk cooling at strong frustration), paving the way to the long-sought experimental detection of AF in ultracold fermions on optical lattices.

Using the same method, we also explore AF signatures in other types of tunable optical lattices. We compute the double occupancy and spin correlation functions in the dimerized half-filled Hubbard model in the whole range of parameters (with lattices varying from honeycomb through simple square to isolated dimers), separate the effects of bandwidth change from the non-trivial spin-correlation physics, and determine the optimal parameters for experimental detection. Additionally, we study the impact of impurities on the AF correlations at half filling and find interesting magnetization patterns that deviate significantly from corresponding real-space DMFT predictions.

Q 63.7 Fri 15:30 UDL HS2002

Ultracold Fermions in Optical Superlattices — •Michael Schreiber[1,2], Pranjal Bordia[1,2], Frederik Görg[1,2], Henrik Lüschen[1,2], Pau Gomez[1,2], Simon Braun[1,2], Sean Hodgman[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans Kopfermann Str. 1, 85748 Garching b. München

Fermionic ^{40}K atoms in a conventional blue detuned optical lattice can serve as a highly tunable quantum simulator of the Fermi-Hubbard model. Within this model the charge dynamics have been studied in recent years, examples include the formation of fermionic Mott insulators and various transport experiments. By upgrading one axis to a bichromatic superlattice we are now able to conduct a whole new range of experiments by directly creating and probing various staggered orders.

The additional possibilities range from the observation of microscopic processes like singlet-triplet oscillations or superexchange interactions in individual double wells to the preparation of e.g. charge-density waves or magnetically ordered states.

We present our latest data on in- and out-of-equilibrium phenomena in these systems.

Q 63.8 Fri 15:45 UDL HS2002

Towards a Quantum Gas Microscope for Ultracold Fermions — •Thomas Lompe, Lawrence Cheuk, Melih Okan, Matthew Nichols, and Martin Zwierlein — Massachusetts Institute of Technology

In the past decade ultracold atoms in optical lattices have been established as an ideal model system to study quantum many body physics in a clean and well-controlled environment. Recently, experiments at Harvard and MPQ Munich using bosonic ^{87}Rb atoms have made these systems even more powerful by demonstrating the ability to observe and address atoms in optical lattices with single site resolution.

The goal of our experiment is to achieve such single-site resolution for a quantum gas of fermionic atoms. Such local probing would reveal microscopic density or spin correlations which are difficult to extract from bulk measurements. This technique could for example be used to directly observe antiferromagnetic ordering in a fermionic Mott insulator. The ability to locally address and probe the system could also be used to create and detect sharply localized quantum states such as edge states at the boundary of topological states of matter.

As the starting point for our experiments we cool fermionic potassium atoms with bosonic sodium as a sympathetic coolant. The atoms are then magnetically transported to an optical trap located ten microns below a solid immersion microscope for high-resolution imaging. In this talk we give a description of our experimental setup and report on our progress towards performing fluorescence imaging of ^{40}K atoms trapped in a deep optical lattice.