Q 27: Quantengase: Optische Gitter 2

Time: Tuesday 14:00–16:00 Location: V53.01

Q 27.1 Tue 14:00 V53.01

Single fermions immersed in a Bose Einstein Condensate — •Raphael Scelle, Tobias Schuster, Arno Trautmann, Tobias Rentrop, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

We present studies on lithium exposed to a species-selective one dimensional lattice in a background gas of Bose Einstein condensed gas of sodium atoms. The population of the Bloch states (lowest and first excited) are inferred from time-of-flight measurements after adiabatically ramping down the lattice potential i.e. band mapping. For deep lattices, atoms are transferred coherently between first and second Bloch Band, i.e. coherent Rabi oscillations between Bloch states are observed. By immersing the fermions into a Bose Einstein condensate of sodium atoms dissipation can be introduced in a controlled way. The experimental setup allows for the investigation of the relaxation dynamics of the populations as well as the coherence of the motional degree of the fermionic lithium.

Q 27.2 Tue 14:15 V53.01

An Ultracold Gas doped with few and single Impurity Atoms — •Nicolas Spethmann[1], Farina Kindermann[2,1], Dieter Meschede[1], and Artur Widera[2,1] — [1]Institut für angewandte Physik, Wegelerstr. 8, 53115 Bonn — [2]TU Kaiserslautern, FB Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

Ultracold gases doped with impurity atoms are promising hybrid systems that pave the way for the realization of intriguing scenarios,such as studying polaron physics,forming local, coherent probes for a many-body system, coherent cooling of individual neutral atoms containing quantum information. Here, we immerse single and few Cs atoms into an ultracold Rb cloud. The sympathetic cooling of the impurity atoms is observed, where the temperature is limited only by the temperature of the Rb gas. The thermalization dynamics is analyzed to deduce the elastic interspecies scattering length. Inelastic three-body collisions are studied atom-by-atom and event-by-event, allowing to unambiguously assign losses to Rb-Rb-Cs three-body recombination. In all experiments, the ultracold Rb gas remains unaff*ected by the interaction with the Cs impurity atoms, demonstrating the feasability of using single atoms as probes for a many-body system.

Q 27.3 Tue 14:30 V53.01

Bosons with tunable interactions in optical lattices: Superfluid to Mott insulator transition and non-equilibrium dynamics — •Michael Schreiber[1,2], Simon Braun[1,2], Jens Philipp Ronzheimer[1,2], Daniel Garbe[1,2], Sean Hodgman[1,2], Tim Rom[1,2], Ulrich Schneider[1,2], and Immanuel Bloch[1,2] — [1]LMU München — [2]MPQ Garching

The Bose-Hubbard model is the most prominent model for the description of many-body states of bosons in optical lattices. Recently, the use of Feshbach resonances has made the full parameter space of this model accessible.

After preparing a Bose-Einstein condensate of ^{39}K atoms in a red-detuned dipole trap, we superimpose a blue-detuned optical lattice. The independent control over these two potentials gives us access to the external confinement as well as the tunneling of the atoms. Utilizing a broad Feshbach resonance, we can additionally adjust the scattering length and thus control all parameters of the Bose-Hubbard model individually. Making use of this flexibility, we map out the superfluid to Mott insulator transition as a function of the interaction strength and tunneling. In addition we present our latest results on the dynamics of non-equilibrium states in this system.

Q 27.4 Tue 14:45 V53.01

Universal probes for antiferromagnetic correlations and entropy in cold fermions on optical lattices — •E.V. Gorelik[1], D. Rost[1], T. Paiva[2], R. Scalettar[3], A. Klümper[4], and N. Blümer[1] — [1]Institute of Physics, Johannes Gutenberg University, Mainz, Germany — [2]Instituto de Fisica, Universidade Federal do Rio de Janeiro, Brazil — [3]Department of Physics, UC Davis, USA — [4]University of Wuppertal, Germany

A major hurdle on the way of using ultracold fermionic atoms on optical lattices as “quantum simulators” of correlated solids is the verification of antiferromagnetic (AF) signatures. Current experimental efforts focus on nearest-neighbor (NN) spin correlation functions and on cooling below a central entropy per site of $s < \log(2)/2$.

Our calculations in the strong-coupling regime of the half-filled Hubbard model using DMFT, determinantal QMC, and Bethe ansatz [1] reveal AF signatures in the double occupancy, spin correlations, and kinetic energy already at $s \lesssim \log(2)$ with surprising universality regarding dimensionality, when viewed as a function of entropy (which is appropriate in the cold-atom context). Both the onset of next-nearest neighbor spin correlations and a minimum in the double occupancy clearly separate the AF Heisenberg regime (at $s \lesssim \log(2)$) from dominant charge physics and should be used experimentally to probe both the AF correlations and the entropy of the system.

[1] E. V. Gorelik, D. Rost, T. Paiva, R. Scalettar, A. Klümper, N. Blümer, arXiv:1105.3356

Q 27.5 Tue 15:00 V53.01

Tunable frustration as a discriminator of antiferromagnetic signatures in cold atoms — •Nils Blümer and Elena Gorelik — Institut für Physik, Universität Mainz

Very recently, it has become possible to continuously tune optical lattices from square to triangular (or honeycomb) topology [1]. We propose, based on quantum Monte Carlo simulations within dynamical mean-field theory (DMFT), that the variable frustration introduced by diagonal hopping t' can help to establish unambiguous signatures of antiferromagnetism, even in the presence of large experimental errors. A concomitant change of energy scales can be avoided by adding suitable inter-plane hopping, effectively allowing for pure tuning of frustration at constant effective coordination number. We show that the recently suggested signature [2] of antiferromagnetic (AF) correlations, an enhanced double occupancy at strong coupling, is suppressed (proportional to t'^2) even before the AF order breaks down; in contrast, nonmagnetic phases are unaffected. We expect that this DMFT scenario survives the suppression of long-range order (with dimensionality $2 \leq d \leq 3$) by spatial fluctuations; in experiments, the dependence of D on t' then reveals *local* AF order for entropy $s \lesssim \log(2)$ per particle.

[1] L. Tarruell, D. Greif, T. Uehlinger, G. Jotzu, and T. Esslinger, arXiv:1111.5020.

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

[3] E. V. Gorelik, D. Rost, T. Paiva, R. Scalettar, A. Klümper, and N. Blümer, arXiv:1105.3356.

Q 27.6 Tue 15:15 V53.01

Critical exponents of flux-equilibrium phase transitions in fermionic lattice models — •Michael Höning, Matthias Moos, and Michael Fleischhauer — Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

We discuss reservoir induced phase transitions in a flux-equilibrium state of fermionic lattice models coupled to local reservoirs. The interaction with the environment can induce correlations in the system, which - under certain conditions - may become critical in the sense of a divergent correlation length and time. In analogy to phase transitions in unitary systems the spectrum of decay rates of the corresponding Liouvillian becomes gapless when the critical state is approached.

We derive the static and dynamical critical exponents for a class of couplings and show that their possible values, defining classes of flux-equilibrium phase transitions are determined by the range of the independent local reservoirs.

Q 27.7 Tue 15:30 V53.01

Stability of (Super) Bloch Oscillations in the Presence of Time-Dependent Nonlinearities — •Christopher Gaul[1], Elena Díaz[1], Cord A. Müller[2], Rodrigo Lima[3], and Francisco Domínguez-Adame[1] — [1]GISC, Departamento de Física de Materiales, Universidad Complutense, E-28040 Madrid, Spain — [2]Centre for Quantum Technologies, National University of Singapore, Singapore 117543, Singapore — [3]Instituto de Física, Universidade Federal de Alagoas, Maceió AL 57072-970, Brazil

Bose-Einstein condensates (BECs) in optical lattices are employed to model fundamental problems of condensed-matter physics. Feshbach resonances can be used to arbitrarily modulate the s-wave scattering length, and by optical means the lattice potential can be accelerated back and forth (shaking). In presence of a constant force, the BEC performs Bloch oscillations (BOs). Here, we consider BOs in the presence of a time-modulated s-wave scattering length and/or in the presence of shaking. The beating of the shaking with the BO leads to so-called super-BO (SBO), with large amplitudes in real space.

Generically, the nonlinearity leads to dephasing and decay of the wave packet. Based on time-reversal symmetries, we find an infinite family of (harmonic) modulations that lead to a periodic time evolution of the wave packet, both for BOs [1] and for SBOs. In order to quantitatively describe the dynamics of (S)BOs in the presence of time-modulated nonlinearities, we employ collective coordinates and the linear stability analysis of an extended wave packet.

[1] Gaul et al. PRL 102, 255303 (2009), PRA 84, 053627 (2011)

Q 27.8 Tue 15:45 V53.01

Quantum dynamics at an unstable classical fixed point — •Wolfgang Müssel, Tilman Zibold, Helmut Strobel, Eike Nicklas, Jiří Tomkovič, Moritz Höfer, Ion Stroescu, David Hume, and Markus Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

We experimentally investigate quantum dynamics in a two component BEC of 87-Rubidium. The system is initially prepared in a coherent spin state centered on an unstable fixed point in the classical phase space of the Bosonic Josephson Junction.

For short evolution times, the interplay of linear coupling and nonlinear interaction between the particles generates squeezing of the Gaussian quantum state. For longer evolution times, the measured distributions of the population imbalance indicate a non-Gaussian character of the many particle state. The ability to perform simultaneous measurements on up to 40 BECs in an optical lattice yields sufficient statistics for tomographic reconstruction of the final state's Wigner distribution.