Q 31: Quantum gases: Optical lattices I

Time: Tuesday 14:00–16:15 Location: E 001

Group Report Q 31.1 Tue 14:00 E 001

Observation of critical behavior at the non-equilibrium Dicke phase transition — •Ferdinand Brennecke[1], Rafael Mottl[1], Renate Landig[1], Kristian Baumann[2], Tobias Donner[1], and Tilman Esslinger[1] — [1]Quantum Optics Group, ETH Zurich, Switzerland — [2]Department of Applied Physics, Stanford University

We experimentally study critical behavior of the Dicke phase transition, realized by Raman coupling motional degrees of freedom of a Bose-Einstein condensate to the field in a high-finesse optical cavity. We use the natural dissipation channel of the cavity to observe the incoherent fluctuation spectrum of the coupled system in real time. The corresponding measurement backaction introduces additional density fluctuations in the atomic gas and changes the critical behavior of the system. A correlation analysis of the light exiting the cavity reveals the diverging time scale of the fluctuation dynamics, in agreement with the experimentally observed mode softening in the excitation spectrum. We quantitatively compare our measurements with a theoretical model taking into account both cavity and atomic dissipation channels. Future directions of the experiment include Bose-Hubbard physics with cavity-mediated long-range interactions and self-organization in lower dimensions.

Q 31.2 Tue 14:30 E 001

Semiclassical Study of Intrinsic Photoconductivity of Ultracold Fermions in Optical Lattices — •Alexander Itin[1,2,3], Jannes Heinze[1], Jasper Simon Krauser[1], Nick Fläschner[1], Bastian Hundt[1], Sören Götze[1], Klaus Sengstock[1,2], Christoph Becker[1,2], and Ludwig Mathey[1,2] — [1]Institut für Laser-Physik, Universität Hamburg, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [3]Space Research Institute, Moscow, Russia

We present theoretical analysis of recent experiments reported in [J. Heinze et al., arxiv::1208.4020v2]. Ultracold fermionic atoms in optical lattices were used to simulate the phenomenon of photoconductivity. Using amplitude modulations of the optical lattice, the analog of a persistent alternating photocurrent was induced in the atomic gas. A small fraction of the atoms was excited to the third band as a wavepacket with a well-defined quasimomentum, leaving a hole in the momentum distribution of atoms in the lowest band. The subsequent dynamics is due to an external harmonic trap. It was observed that the particle excitations in the third band exhibit long-lived oscillations with a frequency determined by the initial quasimomentum, while holes in the lowest band behave strikingly differently: an initial fast collapse was followed by periodic partial revivals. We explain both observations by a semiclassical approach to lattice dynamics. By using the Truncated Wigner Approximation and mapping the system onto a classical Hamiltonian resembling a nonlinear pendulum, both the long-lived particle oscillations and decaying hole revivals are understood quantitavely.

Q 31.3 Tue 14:45 E 001

Motional coherence of fermions immersed in a bosonic bath — •Raphael Scelle, Arno Trautmann, Tobias Rentrop, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

We study the impact of a Bose Einstein condensate of sodium atoms on the motional coherence of lithium atoms. For this purpose the lithium atoms are exposed to a species-selective lattice potential which allows to prepare the lithium atoms in a motionally coherent state by control of the lattice position. We developed a spin echo technique in order to investigate the bath impact on the coherent evolution of the lithium atoms. The interaction between the two components induces a decay of the motional coherence and we extract the corresponding time scale by comparing the spin echo signal for freely evolving lithium atoms to the signal for atoms evolving within the bosonic bath. The observed coherence decay time is consistent with the time scale expected from relaxation measurements of motionally excited states.

Q 31.4 Tue 15:00 E 001

Collective modes of interacting bosons in artificial gauge fields — •Ivana Vidanovic, Ulf Bissbort, and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt/Main, Germany

Rapid experimental progress in the realization of artificial magnetic fields for cold neutral atoms heads toward the creation and direct observation of exotic quantum states under highly controllable experimental conditions. By combining mean-field and beyond mean-field approaches, we explore the phase diagram of strongly interacting lattice bosons in an artificial magnetic field. We calculate the ground state properties and excitation spectra of various phases. To demonstrate how the physical quantities of our system can be detected in experiments, we perform numerical calculations of the systems non-equilibrium behaviour under realistic perturbations.

Q 31.5 Tue 15:15 E 001

Gapped chiral phases and spontaneous symmetry breaking for ultracold bosons in zig-zag optical lattices — •Sebastian Greschner, Luis Santos, and Temo Vekua — Institut für theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Ultracold bosons in (quasi-)one-dimensional zig-zag optical lattices - apart from being a theoretically well controllable test-bed to study the properties of possible quantum simulators of quantum antiferromagnetism - exhibit a wealth of interesting physical phenomena some of which are particular for one-dimensional systems [1]. In this talk we present the full phase diagram of ultracold bosons in zig-zag optical lattices for non-integer fillings. We comment on how interactions lead to a competition between spontaneous symmetry breaking chiral SF and two-component SF phases and analyse the emergence of insulating phases as well as gapped chiral phases exhibiting both local currents as well as a finite excitation gap. Some issues of phase preparation and detection are discussed.

[1] S. Greschner et al., arXiv:1202.5386 (2012)

Q 31.6 Tue 15:30 E 001

Quantum simulation of curved spaces in optical lattices containing topological defects — •Nikodem Szpak — Fakultät für Physik, Universität Duisburg-Essen

We discuss the possibility of quantum simulation of relativistic fields living in curved spaces realized in optical lattices loaded with ultra-cold atoms. In the low energy regime their dynamics can be described by the Hubbard model which, under some circumstances, can be mapped onto a discrete version of a relativistic quantum field theory. Manipulation of the hopping constants and the lattice topology can lead to the coupling to an artificial Riemann-Cartan geometry containing curvature and torsion. We give examples of several lattice geometries and discuss the properties of the emergent curved spaces with the field theoretic effects, like scattering on curvature centers or vortices and birefringence on torsion lines.

Q 31.7 Tue 15:45 E 001

Impact of inhomogeneities on antiferromagnetism in cold atom systems — •Elena Gorelik and Nils Blümer — Institute of Physics, Johannes Gutenberg University, Mainz, Germany

The study of inhomogeneities in antiferromagnets (AF) is of considerable interest both in condensed matter physics and in the cold-atom context. In atomic clouds, the intrinsic inhomogeneity is due to the presence of a confinement potential, whereas in material context interfaces provide an example of the large-scale inhomogeneities. Localized inhomogeneities, in particular impurities, in both homogeneous and spacially variable background, play important role in the interplay of competing phases.

We employ the real-space extension of dynamical mean-field theory (RDMFT) combined with Hirsch-Fye quantum Monte Carlo (QMC) impurity solver [1,2] to explore the effect of single/multiple impurities on the formation of AF correlations. Both the dimensional aspects and the proximity effects are analyzed. In $d = 2$, RDMFT results are compared with those of direct calculations using the determinantal quantum Monte Carlo method.

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

[2] N. Blümer and E. V. Gorelik, Comp. Phys. Comm. **182**, 115 (2011).

Q 31.8 Tue 16:00 E 001

Direct Measurement of the Zak phase in Topological Bloch Bands — •Marcos Atala[1,2], Monika Aidelsburger[1,2], Julio T. Barreiro[1,2], Dmitry Abanin[3], Takuya Kitagawa[3], Eugene Demler[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstr. 4, 80799 Munich, Germany — [2]Max Planck Institute of Quantum Optics, Hans-Kopfermann Str. 1, 85748 Garching, Germany — [3]Department of Physics, Harvard University, 17 Oxford Str., Cambridge, MA 02138, USA

In this talk I will present our latest results on the direct measurement of the Zak phase for a dimerized optical lattice, which models polyacetylene. The experimental protocol consists of a combination of Bloch oscillations and Ramsey interferometry from where we extract the Zak phase - the Berry phase acquired during an adiabatic motion of a particle across the Brillouin zone - which can be viewed as an invariant characterizing the topological properties of the band. This work establishes a new general approach for probing the topological structure of Bloch bands in optical lattices.