Q 58: Quantum Gases: Lattices II

Time: Friday 10:30–12:30 Location: E 001

Q 58.1 Fr 10:30 E 001

Dynamics of Atoms in a Hamiltonian Quantum Ratchet — •Tobias Salger, Carsten Geckeler, Sebastian Kling, Tim Hecking, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Ratchets are devices, that are able to generate a directed motion of particles in a fluctuating environment without gradients or net forces. In order to observe the ratchet effect, one has to break the spatiotemporal symmetry of the system [1]. Here we report on the first realization of a pure "Hamiltonian Quantum Ratchet" in the absence of dissipation [2]. A ^{87}Rb Bose-Einstein condensate is loaded into a sawtooth-like lattice potential, which is realized by superimposing an optical standing wave with $\lambda/2$ spatial periodicity with a four-photon lattice with $\lambda/4$ spatial periodicity [3]. Besides the spatial, also the temporal symmetry is broken by asymmetrically modulating the amplitude of the ratchet potential. We observe a directed motion of atoms arising from Hamiltonian ratchet transport at the quantum limit.
In more recent experiments we have investigated the dynamics of atoms in a Hamiltonian Quantum Ratchet under the influence of weak gradients. Absolute negative mobility, which describes the possibility to transport a particle against an external field, could be observed in the experiment.

[1] S. Denisov et al., Phys. Rev. A **75**, 063424 (2007)
[2] T. Salger et al., Science **326**, 1241 (2009)
[3] T. Salger et al., Phys. Rev. Lett. **99**, 190405 (2007)

Q 58.2 Fr 10:45 E 001

Dynamic localization in optical lattices — •Matthias Langemeyer, Stephan Arlinghaus, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg

The concept of dynamic localization is often disussed theoretically within the framework of a single-band tight-binding model. For possible applications with time-periodically shifted optical lattices, the theoretical ideal is endangered by interband transtions. In this talk we demonstrate with the help of numerical model calculations that nonetheless almost perfect dynamic localization of ultracold atoms in optical lattices can be reached for suitably chosen parameters. This allows one, in particular, to exert active control over the Aubry-Andre-like incommensurability transition which occurrs in bichromatic optical lattices.

Q 58.3 Fr 11:00 E 001

Localization of cold atoms in state-dependent optical lattices via a Rabi pulse — •Birger Horstmann[1], Stephan Dürr[1], Ignacio Cirac[1], and Tommaso Roscilde[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Laboratoire de Physique - ENS Lyon, 46 Alle d'Italie, 69007 Lyon, France

We propose a novel realization of Anderson localization in excited states of ultracold atoms trapped in state-dependent optical lattices. The disorder potential leading to localization is generated with a Rabi pulse which transfers a fraction of the atoms into a different internal state for which tunneling between lattice sites is suppressed. These frozen atoms create a quantum superposition of different random potentials, localizing the atoms. We investigate the dynamics of the mobile atoms after the Rabi pulse for non-interacting and weakly interacting bosons, as well as for infinitely repulsive bosons in one dimension.

Q 58.4 Fr 11:15 E 001

Free expansion of ultracold fermions in an optical lattice — •Jens Philipp Ronzheimer[1], Ulrich Schneider[1], Lucia Hackermüller[1], Sebastian Will[1], Simon Braun[1], Thorsten Best[2], Tim Rom[1], Michael Schreiber[1], Kin Chung Fong[1], and Immanuel Bloch[1] — [1]LMU München — [2]ALU Freiburg

We investigate the free expansion of fermionic ^{40}K atoms in an optical lattice. A balanced mixture of atoms in the $|\frac{9}{2},-\frac{9}{2}\rangle$ and $|\frac{9}{2},-\frac{7}{2}\rangle$ hyperfine states is initially prepared in a non-interacting band insulator state in the combination of a blue detuned optical lattice and a red detuned optical dipole trap. Using a Feshbach resonance, the interaction between the species is set to values varying from strongly attractive to strongly repulsive. The atoms are released by quickly ramping down the dipole trap to a strength that only compensates the anticonfinement due to the optical lattice while increasing the depth of the lattice in one direction, thereby creating sheets of homogeneous 2D lattices.

In the case of negligible interactions, the atomic cloud expands ballistically with a speed given by the tunneling rate. For interacting fermions, the expansion becomes diffusive with a density dependent diffusion constant. Independent of the sign of interactions, the outer regions of the cloud still expand ballistically while the expansion of the high density core slows down with increasing interaction strength. Eventually, the core stops expanding and instead starts to dissolve from the outside, shrinking over time.

These measurements demonstrate previously unobserved transport dynamics and give insight into timescales for density redistribution.

Q 58.5 Fr 11:30 E 001

Monomere und Dimere im Bose-Hubbard-Modell — •Mathias Schneider und Michael Fleischhauer — Technische Universität Kaiserslautern

Ein wesentlicher Aspekt von Vielteilchen-Systemen in periodischen Potentialen ist die Existenz repulsiv gebundener Teilchenpaare (Dimere). Diese treten auf, wenn der energetische Unterschied zwischen einem Dimer und zwei einzelnen Teilchen (Monomere), welche räumlich getrennt sind, in einer Bandlücke liegt, so dass der Zerfall dieser Objekte energetisch verboten ist. Kalte Gase in optischen Gittern eignen sich hervorragend für die Beobachtung repulsiv gebundener Paare, da hier - anders als im Festkörper - keine Zerfallskanäle existieren, welche die Lebensdauer dieser Objekte extrem verkürzen würden. Wir untersuchen die effektive Dynamik eines Systems von Dimeren, in Wechselwirkung mit einem thermischen Reservoir von Monomeren. Diese Kopplung führt, je nach Monomerdichte, zu Dimererzeugung und -Vernichtung, die durch Ratengleichungen beschrieben werden. Die möglichen Zerfallsprozesse und Raten von Dimeren unterscheidet sich für isolierte Dimere und zusammenhängende Cluster. Der Zerfall von Clustern führt dabei temporär zu verschränkten Zuständen

Q 58.6 Fr 11:45 E 001

Real-Time Ginzburg-Landau Theory for Ultracold Bosons in Optical Lattices — •Tobias Grass[1], Francisco Ednilson Alves dos Santos[1], and Axel Pelster[2,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24 14476 Potsdam, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Applying the Schwinger-Keldysh formalism to the Bose-Hubbard Model we derive a real-time Ginzburg-Landau theory at zero temperature [1]. Surprisingly, it reduces to the seminal Gross-Pitaevskii theory deep in the superfluid phase although it has been originally determined within a hopping expansion and should, therefore, be only applicable in the immediate vicinity of the quantum phase boundary. Furthermore, in an equilibrium application, we show that the particle-hole excitation spectra in the Mott phase merge continuously into corresponding excitation spectra of the amplitude and the phase of the order parameter in the superfluid phase, once the quantum phase boundary is crossed. Finally, we discuss as a non-equilibrium application that the damping observed within the collapse and revival experiments of Ref. [2] turns out to be due to the overall harmonic potential which confines the atoms inside a finite volume.

[1] B. Bradlyn, F.E.A. dos Santos, and A. Pelster, Phys. Rev. A **79**, 013615 (2009)
[2] M. Greiner, O. Mandel, T. W. Hänsch, and I. Bloch, Nature, **419**, 51 (2002)

Q 58.7 Fr 12:00 E 001

Probing superfluids in optical lattices by momentum-resolved Bragg spectroscopy — •Sören Götze, Philipp T. Ernst, Jasper S. Krauser, Jannes Heinze, Malte Weinberg, Christoph Becker, and Klaus Sengstock — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg, Germany

By the creation of ultracold quantum gases in optical lattices, superfluids can be realized over a wide range of tunable parameters, with a continuous connection to the regime of strong correlation. However, for full experimental access and a comprehensive comparison with condensed-matter systems, there is a need for new detection techniques to probe their fundamental behaviour, characterized i.e. by the dynamic structure factor. Here we report on a comprehensive study of superfluids in optical lattices by Bragg spectroscopy and present fully momentum-resolved measurements of the band structure and associated interaction effects at several lattice depths. In addition, we directly study the momentum composition of excitations in this system and observe strong indications for Bogoliubov backscattering[1]. Our measurements demonstrate the applicability and limits of the Bogoliubov theory to describe excitation properties of superfluids in periodic potentials and pave the way for further detailed studies of strongly correlated phases, quantum gas mixtures and novel quantum phases.

[1] P. T. Ernst et al., Probing superfluids in optical lattices by momentum-resolved Bragg spectroscopy, Nature Physics advance online publication, 29.11.2009 (DOI: 10.1038/nphys1476)

Q 58.8 Fr 12:15 E 001

Dynamics and stability of Bose-Einstein solitons in tilted optical lattices — •Christopher Gaul[1], Cord A. Müller[1], Elena Díaz[2], Rodrigo Lima[3], and Francisco Domínguez-Adame[2] — [1]Physikalisches Institut, Universität Bayreuth, Deutschland — [2]GISC, Departamento de Física de Materiales, Universidad Complutense, E-28040 Madrid, Spain — [3]Instituto de Física, Universidade Federal de Alagoas, Maceió AL 57072-970, Brazil

We consider a BEC whose mean-field interaction parameter $g(t)$ is modulated harmonically in time via Feshbach-resonance techniques. When the 1d lattice is tilted, the BEC wave packet starts to perform Bloch oscillations. We show that for suitable choices of $g(t)$, these Bloch oscillations are stable [1]. Moreover, solitonic wave packets can be effectively stabilized against certain experimentally relevant perturbations [2].

[1] Gaul et al. PRL 102, 255303 (2009)
[2] Díaz et al. arXiv:0911.5633 (2009)