Q 38: Quantengase: Optische Gitter 3

Time: Thursday 10:30–12:45 Location: V53.01

Group Report Q 38.1 Thu 10:30 V53.01

Orbital optical lattices — •Matthias Ölschläger, Georg Wirth, Thorge Kock, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany

The orbital degree of freedom gives rise to a rich structural diversity in many particle systems and thus appears as an useful tool in the realm of optical lattices. Unfortunately bosonic atoms in higher Bloch bands generally suffer from short lifetimes, compromising the feasibility of this approach for such systems.

By using a bipartite optical square lattice with an adjustable time-phase difference, we can not only selectively excite atoms to higher bands but furthermore strongly suppress the interband relaxation. Collision aided condensation to the band minima reestablishes long range coherence and the resulting metastable orbital states can form exotic orders or be used to probe the underlying band structure.

Here, we report on our experimental observations and recent progress.

Q 38.2 Thu 11:00 V53.01

Experimental Realization of Strong Effective Magnetic Fields in an Optical Lattice — •Monika Aidelsburger[1,2], Marcos Atala[1,2], Yu-Ao Chen[1,2], Sylvain Nascimbène[1,2,3], Stefan Trotzky[1,2], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [3]Laboratoire Kastler Brossel, CNRS, UPMC, Ecole Normale Supérieure, 24 rue Lhomond, 75005 Paris, France

Ultracold atoms in an optical lattice are promising candidates to study quantum many-body phenomena, such as the integer or fractional quantum Hall effect. Here we report about the experimental realization of strong effective magnetic fields with ultracold atoms using Raman assisted tunneling in an optical superlattice. We studied the nature of the frustrated ground state in the presence of an effective staggered magentic field from its momentum distribution and directly revealed the quantum cyclotron orbit of a single atom exposed to the magnetic field.

Q 38.3 Thu 11:15 V53.01

Observation of a roton-type mode softening in a quantum gas with cavity-mediated long-range interactions — •Renate Landig, Kristian Baumann, Rafael Mottl, Ferdinand Brennecke, Tobias Donner, and Tilman Esslinger — Quantum Optics Group, ETH Zurich, Switzerland

We report on the observation of a characteristic change in the excitation spectrum of a Bose-Einstein condensate due to cavity-mediated long-range interactions. Increasing the strength of the interaction leads to a softening of an excitation mode at a finite momentum, preceding a superfluid to supersolid phase transition. The Bose-Einstein condensate is located inside an ultra-high finesse optical cavity and coupled to the vacuum mode of the cavity, using a non-resonant transverse pump beam. This gives rise to a long-range interaction which couples all particles. The mode softening is spectroscopically studied across the phase transition using a method which excites the system at a specific momentum. At the phase transition a diverging response is measured. The observed behavior is reminiscent of a roton minimum, as predicted for quantum gases with long-range interactions.

Q 38.4 Thu 11:30 V53.01

Formation of optical flux lattices using Raman transitions — •Gediminas Juzeliunas[1] and Ian Spielman[2] — [1]Institute of Theoretical Physics and Astronomy, Vilnius University, A. Goštauto 12, LT-01108 Vilnius, Lithuania — [2]Joint Quantum Institute, National Institute of Standards and Technology, and University of Maryland, Gaithersburg, Maryland, 20899, USA

It is now possible to create artificial magnetic field for ultra cold atoms using geometric gauge potentials [1]. Recently it was shown that the magnetic flux induced by the geometric potentials can be made proportional to the surface area of the atomic cloud and thus be considerably increased [2,3] as compared to the previous proposals where the flux was proportional to the linear extend of the cloud. For this extension it was suggested to use periodic atom-light coupling and detuning. Here we consider a realistic scheme of creating a square optical flux lattice using Raman transitions induced by a set of properly chosen polarization-dependent optical standing waves with a time-phase difference. Such a method produces both a non-stagard magnetic flux and also a lattice potential. [1] J. Dalibard, F. Gerbier, G.Juzeliunas, and P.Ohberg. Artificial gauge potentials for neutral atoms. Rev. Mod. Phys. 83 1523 (2011). [2] N.R. Cooper. Optical flux lattices for ultracold atomic gases. Phys. Phys. Lett. 106, 175301 (2011). 3. N. R. Cooper and J. Dalibard. Optical flux lattices for two-photon dressed states. Europhys. Lett. 95, 66004 (2011).

Q 38.5 Thu 11:45 V53.01

Real-time exploration of fluctuations in a quantum gas with cavity-mediated long-range interactions — •Rafael Mottl, Kristian Baumann, Renate Landig, Ferdinand Brennecke, Tobias Donner, and Tilman Esslinger — Quantum Optics Group, ETH Zurich, Switzerland

We report on the study of increased fluctuations approaching a superfluid-supersolid phase transition driven by cavity-mediated long-range interactions. The openness of the cavity allows for time-resolved information about the density fluctuations. We measure increased fluctuations near the phase transition which is accompanied by a mode softening. Quantum fluctuations dominate a wide region below the phase transition. We reveal the subtle role of atomic and photonic dissipation on the steady state of this open quantum system.

Q 38.6 Thu 12:00 V53.01

Reservoir induced criticality in bosonic lattice systems — •Matthias Moos, Michael Höning, and Michael Fleischhauer — Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We discuss reservoir driven phase transitions to critical states in one-dimensional bosonic lattices subject to local dissipation. By coupling to local reservoirs fermionic and bosonic lattice systems can be driven to a steady state which shows criticality in the sense of a diverging correlation length. For free bosonic systems this criticality is generically associated with a dynamical instability. To avoid this instability we introduce a nonlinearity by saturating the dissipative gain. We consider local reservoir couplings of different range and derive correlations as well as critical exponents of the induced quasi-phase transition in a mean-field approximation.

Q 38.7 Thu 12:15 V53.01

Gauge Field Induced Momentum Transport in an Optical Lattice — •Julian Struck[1], Christoph Ölschläger[1], Malte Weinberg[1], Juliette Simonet[1], André Eckardt[2], Patrick Windpassinger[1], and Klaus Sengstock[1] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Noethnitzer Str. 38, 01187 Dresden, Germany

We present the experimental realization of a widely tuneable artificial gauge field for ultracold atoms in a one-dimensional optical lattice. We can simulate any Peierls phase ranging from zero to two π in the tunneling matrix elements between nearest neighbours by applying an external periodic force to the atoms which is time-irreversible. This way it is possible to prepare ground state superfluids as well as out-of-equilibrium states at arbitrary, finite quasi momentum.

We investigate the different time scales for adiabatic transport and relaxations mechanisms in the momentum space of the lattice. Extending these ideas to two-dimensional non-rectangular optical lattices it is possible to realize staggered magnetic field configurations with very large fluxes per plaquette.

These results represent a new step towards the emulation of strong field physics in optical lattices which may result in the realization of exotic phases like quantum hall states and other topological ordered phases with ultracold atoms.

Q 38.8 Thu 12:30 V53.01

Adiabatic preparation of a Heisenberg antiferromagnet using an optical superlattice — •Michael Lubasch[1], Valentin Murg[2], Ulrich Schneider[3], Juan Ignacio Cirac[1], and Mari-Carmen Bañuls[1] — [1]Max Planck Institute of Quantum Optics,

Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [2]University of Vienna, Faculty of Physics, Boltzmanngasse 3, 1090 Vienna, Austria — [3]Ludwig-Maximilians-University Munich, Faculty of Physics, Schellingstrasse 4, 80799 Munich, Germany

We present an adiabatic protocol for the realization of a Heisenberg antiferromagnet (AFM) with ultracold fermions in an optical lattice [1]. The preparation of magnetic order in such a system is a highly desirable goal, as an intermediate step towards a true quantum simulator of the fermionic Hubbard model. However, realizing the AFM currently represents a big challenge for optical lattice experiments, since a very low entropy per particle is required.

We propose to create this state adiabatically, starting from a low entropic band insulator and slowly changing the lattice depth. By numerically simulating the dynamics with Matrix Product States (MPS) in 1D and Projected Entangled Pair States (PEPS) in 2D we demonstrate the feasibility of our protocol even in the presence of experimental imperfections. We observe a highly destructive effect of holes and devise a strategy to control them via the harmonic trap. Additionally, we show that it is possible to realize magnetic order on a part of the sample in a shorter time than required for the whole system.

[1] M. Lubasch *et al.*, Phys. Rev. Lett. **107**, 165301 (2011).