Q 65: Quantum Gases : Lattices III

Time: Friday 14:00–16:00 Location: E 001

Group Report Q 65.1 Fr 14:00 E 001

Quantum Gases in Hexagonal Optical Lattices — •Parvis Soltan-Panahi, Julian Struck, Georg Meineke, Wiebke Plenkers, Andreas Bick, Christoph Becker, Patrick Windpassinger, and Klaus Sengstock — Luruper Chaussee 149, 22761 Hamburg, Deutschland

The physics of ultracold quantum gases in optical lattices has developed to a fascinating field with many connections to different areas like condensed matter physics, quantum computing or ultracold chemistry. So far, most experiments have been performed in cubic lattice structures with spin-independent potentials. We have realized a "magnetic", optical lattice with hexagonal symmetry, where atoms of different spin quantum number feel different potentials, e.g., having different periodicity. This leads to a specific "magnetic ordering" and state-dependent Mott-insulator transition points or more generally to new options to study "magnetism" in optical lattices.
In particular, we show that in case of a bosonic spin-mixture, interaction induced blocking of tunneling occurs. This manifests in terms of a significant shift of the quantum point of phase transition. To analyze the occupation of different lattice wells by the individual components of the spinor condensate we have developed a microwave spectroscopy technique that allows for unambiguous identification of different components and specific types of lattice sites. This enables us to observe a strong dependency of the atom-distribution due to the existence of several spin-components within the superfluid- and the Mott-insulating regime.

Q 65.2 Fr 14:30 E 001

Linear response thermometry with ultracold fermions in an optical lattice — •Daniel Greif, Leticia Tarruell, Thomas Uehlinger, Robert Jördens, Niels Strohmaier, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

The low-temperature Fermi-Hubbard model is expected to capture many fascinating phenomena such as d-wave superfluidity. In our experiment we use a repulsive two-component Fermi gas loaded into a 3D optical lattice to realize this simple model Hamiltonian. Currently several experiments are reaching out to achieve even lower temperatures with novel cooling schemes in order to access and characterize the magnetically ordered state. This requires a temperature sensitive probe in the lattice.

We show how linear response to weak lattice modulation can be used as a thermometer in the lattice. This can also be employed as a detector for local spin ordering.

Q 65.3 Fr 14:45 E 001

Quantitative temperature determination of ultracold fermions in an optical lattice — •Thomas Uehlinger[1], Robert Jördens[1], Daniel Greif[1], Niels Strohmaier[1], Leticia Tarruell[1], Henning Moritz[1], Tilman Esslinger[1], Lorenzo De Leo[2], Corinna Kollath[2], Antoine Georges[2,3], Vito Scarola[4], Lode Pollet[5], Evgeni Burovski[6], Evgeny Kozik[7], and Matthias Troyer[7] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Centre de Physique Théorique, CNRS, Ecole Polytechnique, 91128 Palaiseau, France — [3]Collège de France, 11 place Marcelin Berthelot, 75231 Paris, France — [4]Department of Physics, Virginia Tech, Blacksburg, Virginia 24061, USA — [5]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [6]Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris-Sud, 91405 Orsay, France — [7]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland

While experiments with ultracold fermions in optical lattices are approaching magnetically ordered states of the Fermi Hubbard model, a reliable determination of temperature in the regime of intermediate interaction has yet not been possible. We compare precise measurements of the double occupancy in our system with both DMFT calculations and the high-temperature series expansion. Both methods agree with the experimental data over a wide range of parameters. The entropy per atom in the center of the trap is about twice as large as the entropy required to enter the Néel phase. The corresponding temperature reaches values on the order of the tunneling energy t.

Q 65.4 Fr 15:00 E 001

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

Recent experiments with ultracold atoms in time-periodically forced optical lattices performed by the Pisa group have clearly revealed phenomena related to forcing-induced interband transitions. In this talk we will show that theoretical concepts known from laser-induced electronic transitions in atoms or molecules can be transferred to the description of such interband transitions occurring in optical lattices. In particular, we discuss the emergence of multiphoton-like resonances, and outline how these can be detected experimentally. Our results indicate that ultracold atoms in lattices subjected to forcings with slowly varying strength may serve as powerful probes for coherently controlled quantum dynamics.

Q 65.5 Fr 15:15 E 001

The Dicke Quantum Phase Transition in a Superfluid Gas Coupled to an Optical Cavity — •Kristian Baumann, Christine Guerlin, Ferdinand Brennecke, Silvan Leinss, Rafael Mottl, and Tilman Esslinger — IQE, ETH Zürich, Switzerland

A fundamental concept to describe the collective matter-light interaction is the Dicke model which has been predicted to how an intriguing quantum phase transition. We have realize d the Dicke quantum phase transition in an open system formed by a Bose-Einstein condensate coupled to an optical cavity, and observed the emergence of a self-organized supersolid phase. The phase transition is driven by infinitely long-ranged interactions between the condensed atoms. We show that the phase transition is described by the Dicke Hamiltonian, including counter-rotating coupling terms, and that the supersolid phase is associated with a spontaneously broken spatial symmetry. The boundary of the phase transition is mapped out in quantitative agreement with the Dicke model.

Q 65.6 Fr 15:30 E 001

Ginzburg-Landau Theory for the Jaynes-Cummings-Hubbard Model — •Christian Nietner[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

We develop a Ginzburg-Landau theory for the Jaynes-Cummings-Hubbard model which describes the thermodynamics of photons evolving in a lattice of cavities filled with a single two-level atom. To this end we follow Ref. [1] and calculate the effective action to first-order in the hopping expansion. Within this Ginzburg-Landau description we reproduce the finite-temperature mean-field quantum phase boundary of Refs. [2,3] between a Mott-insulating and a superfluid phase of polaritons. Furthermore, we report on our quest to determine the sound velocity of light in the superfluid phase.

[1] B. Bradlyn, F.E.A. dos Santos, and A. Pelster, Phys. Rev. A **79**, 013615 (2009)
[2] J. Koch and K.L. Hur, Phys. Rev. A **80**, 023811 (2009)
[3] S. Schmidt and G. Blatter, Phys. Rev. Lett. **103**, 086403 (2009)

Q 65.7 Fr 15:45 E 001

Pfaffian state(s) simulation in 2D Spin-1 Optical Lattices — Leonardo Mazza[1], •Matteo Rizzi[1], Maciej Lewenstein[2], and J. Ignacio Cirac[1] — [1]Max Planck Institut für Quantenoptik, Garching, Deutscheland — [2]ICREA and ICFO, Barcelona, Spain

We investigate the possibility of simulating bosons subject to an infinite three-body contact repulsion, and to an external magnetic field, with experimentally feasible cold atoms setups. A spin-1 (F=1) atomic Mott insulator with one atom per site provides the required three local degrees of freedom; suitable laser assisted couplings via an auxiliary F=2 ancilla tailor the dynamics of the experimental system to the desired one.

Such a scheme can be used to investigate Pfaffian (Moore-Read) states, arising in the context of Quantum Hall Effect (QHE) if particles are constrained to be not more than two in a single place; their bosonic version displays a QHE filling factor $\nu = 1$, i.e. one particle for each quantum of magnetic flux. One of their most intriguing features is the support of non-abelian topological excitations. Up to now, the long quest for Pfaffian physics has not produced experimental fingerprints: our proposal could open a new way towards this goal.

Finally, we characterize the ground state of the discrete system, demonstrating that for a dilute enough one the well-known topological properties of the continuum QHE are preserved. With the help of Chern numbers and ground state degeneracy, we show that even increasing the magnetic field these properties should not be abruptly washed out.