Q 39: Ultracold atoms and BEC - IV (with A)

Time: Wednesday 14:30–16:30 Location: N 1

Q 39.1 Wed 14:30 N 1

Bosonic many-body systems with topologically nontrivial phases subject to gain and loss — •Felix Dangel, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Topology has emerged as a powerful tool leading to deeper insights into the classification of phases of matter. Ultracold atoms in optical lattices provide a toolbox for engineering and investigating various models with interesting topological properties. We focus on Bosonic many-body systems such as the one-dimensional superlattice Bose-Hubbard model, which exhibits topologically nontrivial phases. Edge states at open boundaries are an indicator of such phases and numerical evidence for their occurrence in the topologically nontrivial Mott-insulating phase with half-integer filling as well as a possible experimental realization have been provided in a recent work [1]. Addressing the question how edge-states are influenced when the system is extended to an open quantum system, we combine the one-dimensional superlattice Bose-Hubbard model and non-Hermitian $\mathcal{PT}$-symmetric potentials which are capable of effectively describing quantum systems with balanced gain and loss.

[1] Grusdt et al., Phys. Rev. Lett. **110**, 260405 (2013)

Q 39.2 Wed 14:45 N 1

Characterization and investigation of topologically nontrivial states in $\mathcal{PT}$-symmetric many-body systems — •Marcel Wagner, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

$\mathcal{PT}$-symmetric quantum mechanics allows for an effective description of open quantum systems with variable particle numbers. $\mathcal{PT}$-symmetry of the quantum state ensures a purely real energy spectrum. Topologically nontrivial phases are known to occur in such many-body systems. However, their characterization is not yet well understood and raises open questions. We investigate ways to characterize topologically nontrivial phases in $\mathcal{PT}$-symmetric quantum systems. The purpose of our work is to classify these phases by searching for appropriate topological invariants.

Q 39.3 Wed 15:00 N 1

Exotic energy bands and topological phases in systems with oscillatory long-range potentials — Beatriz Olmos Sánchez[1,2], Robert J. Bettles[3], Igor Lesanovsky[1,2], and •Jiří Minář[1,2] — [1]School of Physics and Astronomy, University of Nottingham, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Non-equilibrium Quantum Systems, University of Nottingham, United Kingdom — [3]Joint Quantum Center (JQC) Durham-Newcastle, Department of Physics, Durham University, United Kingdom

The effective interaction between neutral atoms mediated by virtual photon exchange in general leads to a non-trivial long-range potential featuring both attractive and repulsive interaction [1,2] which goes beyond the typically considered simple power-law (dipolar, Van der Waals) potentials. Considering the full potential in two dimensions (which becomes relevant for atomic separations comparable to the atomic transition wavelength, situation achievable e.g. with strontium atoms), we show that it gives rise to energy spectrum with one-sided divergences in the Brillouin zone. This apparently unphysical situation is a consequence of the superextensivity of the potential and the thermodynamic limit. We perform a study for finite size systems and find new topological phases absent in the dipolar case. Moreover, the shape of the potential leads to a novel situation where energy peaks in the spectrum of arbitrary height and position can be created. Finally, we discuss the relation between the bulk and the edge states in case of square and hexagonal lattice. [1] R. H. Lehmberg, Phys. Rev. A **2** 883 (1970), [2] D. F. V. James, Phys. Rev. A **47** 1336 (1993)

Q 39.4 Wed 15:15 N 1

An Optical Quasicrystal for Ultracold Atoms — •Konrad Viebahn[1], Matteo Sbroscia[1], Edward Carter[1], Michael Höse[1], Max Melchner[1], and Ulrich Schneider[1,2] — [1]University of Cambridge, Cavendish Laboratory, JJ Thomson Ave, Cambridge CB3 0HE, UK — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstrasse 4, 80799 Munich, Germany

We will present our experimental progress towards realising an optical quasicrystal.

A quasicrystal is a long-range ordered structure with no translational symmetry. Correspondingly, quasicrystals lie at the interface between ordered and disordered systems. On the one hand, ultracold atoms in regular (periodic) optical lattices have been studied extensively in the past years. Major achievements in this field include the first observation of the superfluid-Mott insulator transition, the realisation of the Fermi-Hubbard model, and the realisation of topological models, such as the Haldane model. On the other hand, the recent observation of many-body localisation in quasi-random optical lattices triggered another area of interest: interacting disordered systems. Now, we hope to bridge the gap between ordered and disordered systems using ultracold atoms in an optical quasilattice.

Interestingly, quasicrystals often have high rotational symmetries, five-fold or eight-fold, for example, which are forbidden in periodic crystals by the crystallographic restriction theorem. Optical lattice experiments lend themselves to realising these special geometries by superimposing lattice beams in a rotationally symmetric fashion.

Q 39.5 Wed 15:30 N 1

Quantum and thermal phase transitions in a bosonic atom-molecule mixture in a two-dimensional optical lattice — •laurent de Forges de Parny[1,4], valy rousseau[2], and tommaso roscilde[3,4] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder Straße 3, D-79104, Freiburg, Germany — [2]Physics Department, Loyola University New Orleans, 6363 Saint Charles Ave., LA 70118, USA — [3]Institut Universitaire de France, 103 bd Saint-Michel, 75005 Paris, France — [4]Laboratoire de Physique, CNRS UMR 5672, École Normale Supérieure de Lyon, Université de Lyon, 46 Allée d'Italie, Lyon, F-69364, France

Recent progress in ultracold gases have allowed the study of multiple component bosonic systems, such as atomic and molecular mixtures. We will show that the coherent coupling of the atomic and molecular state, can lead to a novel insulating phase - the Feshbach insulator - for bosons in an optical lattice close to a narrow Feshbach resonance. This new phase appears around the resonance, preventing the system from collapsing when the effective atomic scattering length becomes negative. Surprisingly enough, the transition from condensate to Feshbach insulator has a characteristic first-order nature, due to the simultaneous loss of coherence in the atomic and molecular components. Our realistic numerical study shows that these features appear clearly in the ground-state phase diagram of e.g. rubidium 87 around the 414 G resonance, and they are therefore directly amenable to experimental observation. We also observe unconventional Berezinskii-Kosterlitz-Thouless transition when heating the superfluids.

Q 39.6 Wed 15:45 N 1

Approaching non-Abelian Lattice Gauge Theories with Quantum Information Methods — Mari Carmen Bañuls[1], Krzysztof Cichy[2,3], J. Ignacio Cirac[1], Karl Jansen[4], and •Stefan Kühn[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Goethe-Universität Frankfurt am Main, Institut für Theoretische Physik, Max-von-Laue-Straße 1, 60438 Frankfurt am Main, Germany — [3]Faculty of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznań, Poland — [4]NIC, DESY Zeuthen, Platanenallee 6, 15738 Zeuthen, Germany

Originally developed in the realm of quantum information theory, Tensor Network States and in particular Matrix Product States have proven themselves as promising candidates for the numerical exploration of lattice gauge models in recent years. In this talk, we explore a family of 1+1 dimensional SU(2) lattice gauge models, where the color electric flux is truncated at a finite value, with this method. We show how on finite lattices with open boundary conditions the gauge field can be integrated out, thus greatly reducing the degrees of freedom present in the system. This formulation might be suitable for a potential future quantum simulator and, moreover, allows to efficiently address the model numerically with Matrix Product States. Using this approach, we explore the low lying spectrum of these models and systematically study the effect of truncating the color electric flux at a finite value.

Q 39.7 Wed 16:00 N 1

Multipulse interaction quenched ultracold few-bosonic ensembles in finite optical lattices — •Simeon Mistakidis[1], Jannis Neuhaus-Steinmetz[1], and Peter Schmelcher[1,2] — [1]Zentrum fuer Optische Quantentechnologien, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The correlated non-equilibrium dynamics following a multipulse interaction quench protocol in few-bosonic ensembles confined in finite optical lattices is investigated. The multipulse interaction quench gives rise to the cradle and a global breathing mode, which are generated during the interaction pulse and persist also after the pulse. The tunneling dynamics consists of several channels accompanying the dynamics. The majority of the tunneling channels persist after the pulse, while only a few occur during the pulse. The induced excitation dynamics is also explored and a strong non-linear dependence on the delayed time of the multipulse protocol is observed. Moreover, the character of the excitation dynamics is also manifested by the periodic population of higher-lying lattice momenta. To solve the underlying many-body Schroedinger equation we employ the Multi Configuration Time-Dependent Hartree method for Bosons (MCTDHB) which is especially designed to treat the out-of-equilibrium quantum dynamics of interacting bosons beyond the mean field and linear response approximations. The above mentioned findings pave the way for future investigations on the direct control of the excitation dynamics.

Q 39.8 Wed 16:15 N 1

Superfluidity and relaxation dynamics of a laser-stirred 2D Bose gas — •Vijay Pal Singh[1,2], Christof Weitenberg[2], Jean Dalibard[3], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]Laboratoire Kastler Brossel, Collège de France, ENS-PSL Research University, CNRS, UPMC-Sorbonne Universités, 11 place Marcelin Berthelot, 75005 Paris, France

We study the superfluid behavior of a two-dimensional (2D) Bose gas of ^{87}Rb atoms. In the experiment by R. Desbuquois *et al.*, Nat. Phys. **8**, 645 (2012) a 2D quasicondensate in a trap is stirred by a blue-detuned laser beam along a circular path around the trap center. Here, we study this experiment from a theoretical perspective. The heating induced by stirring increases rapidly above a velocity v_c, which we define as the critical velocity. We identify the superfluid, the crossover, and the thermal regime by a finite, a sharply decreasing, and a vanishing critical velocity, respectively. A direct comparison of our results to the experiment shows good agreement, if a systematic shift of the critical phase space density is included. We relate this shift to the absence of thermal equilibrium between the condensate and the thermal wings in the experiment, which were used to extract the temperature. We expand on this observation by studying the full relaxation dynamics between the condensate and the thermal cloud. Analytical results on the vortex formation are also discussed.