Q 27: Quantum Gases (Bosons) III

Time: Monday 16:15–17:45 Location: K 2.020

Q 27.1 Mon 16:15 K 2.020

Dimensional Crossover in a Bosonic Quantum Gas — •Polina Matveeva, Denis Morath, Dominik Strassel, Axel Pelster, Imke Schneider, and Sebastian Eggert — Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

From the Mermin-Wagner theorem it follows that there is no Bose-condensation in 1D at any finite temperature. Therefore one can ask the question about new critical exponents, that emerge when the 1D-3D crossover is studied in context of 3D anisotropic bosons on a lattice. Our model is represented by 1D tubes with hopping between them, which can be simulated in experiments with optical lattices [1]. Tuning the hopping between the tubes allows us to drive our system continuously from 1D to 3D. Here we determine the exponent, that appears for T_c, when it increases from zero as a function of inter-chain hopping [2]. To this end we use an effective potential approach to calculate the Landau potential and to derive critical parameters of the system as a function of inter-chain hopping, which we take into account perturbatively. We perform calculations both for non-interacting bosons in tubes and also for interacting bosons with infinite on-site repulsion and nearest neighbor density-density interaction. In the latter case these interactions are taken into account using the bosonization technique. We also compare our results with numerical results for the critical exponent, obtained from extensive Quantum Monte-Carlo simulations.

[1] A. Vogler et al., Phys. Rev. Lett. **113**, 215301 (2014)
[2] B. Irsigler and A. Pelster, Phys. Rev. A **95**, 043610 (2017)

Q 27.2 Mon 16:30 K 2.020

Finite size effects and scrambling at the quantum phase transition of a 1D Bose gas — •Benjamin Geiger, Quirin Hummel, Juan Diego Urbina, and Klaus Richter — Institut für theoretische Physik, Universität Regensburg, Germany

It is known from mean-field theory that a system of bosons with attractive contact interactions in one dimension exhibits a quantum phase transition at a certain critical coupling [1]. At this critical point the Bogoliubov spectrum collapses to a single point and thus mean-field theory fails to describe the characteristical finite level spacing. We investigate the situation for a large but finite number of particles in a momentum-truncated model and show that semiclassical many-body torus quantization allows to calculate the precursors of the quantum phase transition. We show that the phase transition is accompanied by a change in the topology of the available classical phase space, a fact that enables us to define a sharp critical coupling wherever the topology of a quantized torus changes, despite the fact that the spectrum is analytic in the interaction parameter. Our approach has a direct application to the description of scrambling times around criticality, a subject of large recent interest.

[1] R. Kanamoto, H. Saito, M. Ueda, Phys. Rev. A **67**, 013608 (2003)

Q 27.3 Mon 16:45 K 2.020

Multifractal properties of the ground state of the Bose-Hubbard model — •Jakob Lindinger, Andreas Buchleitner, and Alberto Rodriguez — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

We study the multifractal properties of the ground state of the one-dimensional Bose-Hubbard model in Fock space. We confirm that the limit of vanishing interaction exhibits non-trivial multifractality in the Fock basis [1]. In order to get access to the multifractal properties at arbitrary values of the interaction strength, we use exact diagonalisation and quantum Monte Carlo simulations (which enable us to reach $L = 30$ in certain cases, corresponding to a Hilbert space of size $\mathcal{N} \approx 6 \times 10^{16}$). Our results suggest the existence of non-trivial multifractality in the ground state for a large range of interaction values. We find that an analysis of the generalised fractal dimensions for different densities exposes qualitatively the superfluid to Mott insulator transition. We furthermore explore different methods to quantitatively characterise the transition.

[1] E. Bogomolny. Multifractality in simple systems. Presentation at the conference "Complex patterns in wave functions: drums, graphs, and disorder" at the Kavli Royal Society Centre, UK. 2012

Q 27.4 Mon 17:00 K 2.020

Bottom-up approach to many-body physics with ultracold atoms in adjustable lattices — •Martin Sturm, Malte Schlosser, Gerhard Birkl, and Reinhold Walser — Institute for applied physics, TU Darmstadt, Darmstadt, Germany

Ultracold atoms in optical lattices have proven to be a powerful toolbox for quantum simulation of many-body physics. With the demonstration of single-site resolved imaging, local properties have shifted into the focus of this field. This development is complemented by the construction of double-well systems from single atoms in optical tweezers.

We present an experimental avenue to scalable and adjustable arrays of optical dipole traps using microlens arrays and spatial light modulators [1]. This setup closes the gap between the aforementioned approaches and allows for a bottom-up construction of many-body systems adding one atom at a time. In order to evaluate the experimental feasibility of this approach, we compute the accessible parameter regime for ^{7}Li, ^{23}Na, ^{41}K, and ^{87}Rb based on measurements and simulations of the light field. In addition, we investigate loading procedures starting from Bose-Einstein condensates as well as from low-entropy states in the deep Mott-insulator regime [2]. As a possible application, we analyze two coupled ring lattices that exhibit many-body resonances in their tunneling dynamics.

[1] M. R. Sturm et al., Phys. Rev. A **95** 063625 (2017)
[2] M. R. Sturm et al., to be published.

Q 27.5 Mon 17:15 K 2.020

Statistically Induced Phase Transition in the Extended Anyon-Hubbard Model — •Kevin Jägering, Shijie Hu, Martin Bonkhoff, Imke Schneider, Axel Pelster, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

We investigate the impact of non-trivial exchange statistics on bosonic SPT (symmetry protected topological) phases in one-dimensional optical lattices. As the underlying model we study the anyonic version of the extended Bose-Hubbard Hamiltonian with a generalized Pauli exclusion principle, restricting the maximal occupation up to two particles per site. Combining numerical DMRG techniques and a Gutzwiller Mean-Field treatment, we present the phase diagram of the system for different values of the statistical parameter. Additionally we employ bosonization to derive a low-energy field theory in order to describe the universal behaviour of the system near the critical points, and analyze the mechanism behind statistically induced phase transitions present in the system.

Q 27.6 Mon 17:30 K 2.020

Current reversals and metastable states in the infinite Bose-Hubbard chain with local particle loss — •Maximilian Kiefer-Emmanouilidis[1,2] and Jesko Sirker[2] — [1]Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]University of Manitoba, Winnipeg, Canada

Many-body interactions lead to unexpected effects in the open Bose-Hubbard model. When the model is subjected to local loss, particle currents are induced. Away from the dissipative site the currents start to reverse their direction at intermediate and long times. This leads to a metastable state with a total particle current pointing away from the dissipative site. We studied the model numerically by combining a quantum trajectory approach with a density-matrix renormalization group scheme. An alternative equation of motion approach based on an effective fermion model shows that the reversal of currents can be understood qualitatively by the creation of holon-doublon pairs at the edge of the region of reduced particle density. The doublons are then able to escape while the holes move towards the dissipative site.