Q 33: Quantum Gases: Bosons IV

Time: Wednesday 14:30–16:30 Location: A320

Q 33.1 Wed 14:30 A320

Tomography of a number-resolving detector by reconstruction of an atomic many-body quantum state — •Mareike Hetzel[1], Luca Pezzè[2], Cebrail Pür[1], Martin Quensen[2], Andreas Hüper[1,5], Jiao Geng[3,4], Jens Kruse[1,5], Luis Santos[6], Wolfgang Ertmer[1,5], Augusto Smerzi[2], and Carsten Klempt[1,5] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]QSTAR and INO-CNR and LENS, Firenze, Italy — [3]Key Laboratory of 3D Micro/Nano Fabrication and Characterization of Zhejiang Province, Westlake University, Hangzhou, China — [4]Institute of Advanced Technology, Westlake Institute for Advanced Study, Hangzhou, China — [5]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), DLR-SI, Hannover, Germany — [6]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

The high-fidelity analysis of many-body quantum states of indistinguishable atoms requires the accurate counting of atoms. Here we report the tomographic reconstruction of an atom-number-resolving detector. The tomography is performed with an ultracold rubidium ensemble that is prepared in a coherent spin state by driving a Rabi coupling between the two hyperfine clock levels. The coupling is followed by counting the occupation number in one level. We characterize the fidelity of our detector and show that a negative-valued Wigner function is associated with it. Our results offer an exciting perspective for the high-fidelity reconstruction of entangled states and can be applied for a future demonstration of Heisenberg-limited atom interferometry.

Q 33.2 Wed 14:45 A320

Bose-Einstein condensation for hard-core bosons: Universal upper bound and Bogoliubov theory — •Martina Jung, Sophie Brass, Julia Liebert, Sebastian Paeckel, and Christian Schilling — Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München

Hard-core bosons (HCBs), subjected to an artificial Pauli principle with respect to the lattice site basis, are not only of broad physical relevance due to their close relation to Spin-1/2 operators, but their theoretical description has recently revealed some intriguing conceptual features: the mixed commutation relations of HCB creation and annihilation operators give rise to a universal upper bound on the number of HCBs that can condense in the maximally delocalized state.

In this talk, we explain when and how this universal bound on the maximally possible degree of condensation - given by $f = 1-\nu$, where ν is the filling factor - is saturated and dictates the physical behaviour of HCBs. In particular, we show by exact numerical means that this novel exclusion principle lies at the heart of the quantum phase transition in the one-dimensional lattice gas model. Based on this observation we then propose and work out a Bogoliubov theory specifically for HCBs in the regime of almost maximal condensation $f \approx 1 - \nu$.

Q 33.3 Wed 15:00 A320

Optimal preparation of spin squeezed states with one-dimensional Bose-Einstein Condensates — •Tiantian Zhang, Mira Maiwöger, Filippo Borselli, Yevhenii Kuriatnikov, Jörg Schmiedmayer, and Maximilian Prüfer — Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien.

Rubidium Bose-Einstein Condensates (BECs) in double wells is spin squeezed in their ground state. However, direct preparation of two condensates is limited by thermal noise in the relative degree of freedom. We circumvent this on our experiment by spatially split a single one-dimensional condensate into two using radio-frequency dressing along the transverse direction of the trap with an Atom Chip. Our single-atom-sensitive fluorescence imaging system makes the sub-shot-noise detection of the number imbalance possible. We present a simple yet effective short-cut to adiabatic splitting. It exploits tunnelling dynamics in the Bosonic Josephson Junction. We have not only observed experimentally an overall enhanced number squeezing compared to direct splitting to a decoupled trap, but also directly measured the oscillation of the number squeezing. The oscillation frequencies scale with the plasma frequencies and have been measured across two orders of magnitude. We can further improve the efficiency by implementing a splitting quench. This enforces squeezing with the trap frequency which is a few times above the experimentally accessible plasma frequencies.

Q 33.4 Wed 15:15 A320

Engineering Correlated Spin-Momentum Pairs in a Quantum Gas Coupled to an Optical Cavity — Fabian Finger, Rodrigo Rosa-Medina, •Nicola Reiter, Panagiotis Christodoulou, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

Quantum correlations among the constituents of many-body systems determine their fundamental properties. Quantum gases with their pristine control over external and internal degrees of freedom offer a versatile platform to manipulate and detect such correlations at a microscopic level. Here, we report on the observation of correlated atomic pairs in specific spin and momentum modes. Our implementation relies on Raman scattering between different spin levels of a spinor Bose-Einstein condensate, which is induced by the interplay of a running-wave transverse laser and the vacuum field of an optical cavity. Far-detuned from Raman resonance, a four-photon process gives rise to collectively-enhanced spin-mixing dynamics. We investigate the statistics of the produced pairs and explore their non-classical character through noise correlations in momentum space. Our results demonstrate a new platform for fast generation of correlated pairs in a quantum gas and provide prospects for matter-wave interferometry using entangled motional states.

Q 33.5 Wed 15:30 A320

Interference of two composite bosons — Mama Kabir Njoya Mforifoum, Andreas Buchleitner, and •Gabriel Dufour — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

We study the Hong-Ou-Mandel interference of two identical composite bosons, each formed of two bosonic or fermionic constituents, as they scatter against a potential barrier in a one-dimensional lattice. For tightly bound composites, we show that the combination of their constituents' mutual interactions and exchange symmetry gives rise to an effective interaction between the composites, which induces a reduction of the interference contrast.

Q 33.6 Wed 15:45 A320

A dipolar quantum gas microscope — •Ralf Klemt[1], Kevin Ng[1], Jens Hertkorn[1], Paul Uerlings[1], Akshay Shankar[2], Lucas Lavoine[1], Tim Langen[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Indian Institute of Science Education and Research, Mohali

In this talk, we present experimental and theoretical efforts towards studying dipolar Bose- and Fermi-Hubbard models using ultracold dipolar quantum gases in optical lattices. In addition to Hubbard models which only incorporate short-range interaction, the anisotropic dipolar interactions found in dysprosium, allow us to introduce (next-) nearest neighbor interactions. This opens up the possibility to explore a wide range of problems ranging from quantum magnetism and lattice spin models to topological matter. We will discuss examples of quantum phases both with local and non-local order and lay out a path towards realizing and observing them experimentally.

We will present our new setup, which is designed to combine the single-site resolution of a quantum gas microscope with the long-range and anisotropic interactions found in lanthanides. We will use fermionic and bosonic isotopes of dysprosium trapped in an UV optical lattice with a lattice spacing of 180 nm. The short lattice spacing will significantly enhance the dipolar nearest neighbor coupling to be about 200 Hz (10 nK). We will combine this setup with a single-particle, spin- and energy resolved super-resolution imaging technique, in order to be able to extract almost arbitrary density correlation functions.

Q 33.7 Wed 16:00 A320

Towards coupling atomic tweezers to an optical cavity — •Stephan Roschinski, Johannes Schabbauer, Davide Natale, Giacomo Hvaring, Iris Haubold, Nicole Heider, Alexander Heiss, Marvin Holten, and Julian Léonard — Atominstitut, TU Wien, Austria

A central goal of current research is to efficiently create entangled states among an increasing number of qubits. While atomic platforms provide great scalability, they mostly rely on local interactions, for instance, collisional or Rydberg interactions. We describe the progress to build a novel platform to entangle atoms with non-local operations using photon-mediated interactions. The atoms will be trapped within individual optical tweezers which are coupled to the field of an optical cavity. Large optical access through a high-resolution microscope objective will enable us to individually address each atom and control its coupling with all-to-all connectivity. Further advantages of this platform include partial non-destructive readout and efficient multi-qubit entanglement operations. In the long term, the proposed platform provides a scalable path to studying many-body systems with programmable connectivity, as well as an efficient atom-photon interface for quantum communication applications.

Q 33.8 Wed 16:15 A320

Floquet analysis of quantum dynamics in periodically driven optical lattices — •Usman Ali[1], Martin Holthaus[2], and Torsten Meier[1] — [1]Paderborn University, Department of Physics, Warburger Strasse 100, D-33098 Paderborn, Germany — [2]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

Ultracold atoms in optical lattices exhibit very rich dynamics in response to time-periodic driving. With amplitude and frequency of the driving field being the main control parameters, it is shown that the initial phase of the drive induces significantly and qualitatively different dynamics. We discuss how the role of the phase can be understood within Floquet formalism. An approach that is based on the quantum pendulum approximation, allows to analytically obtain the quasi-energy spectrum and the Floquet states. This approximation is well justified for resonant driving conditions, yet our interpretations provide a general understanding of the dynamics. We evaluate our approach for an experimentally relevant example.