A 7: Ultra-cold Atoms, Ions and BEC II (joint session A/Q)

Time: Tuesday 11:00–13:00 Location: KlHS Mathe

Invited Talk A 7.1 Tue 11:00 KlHS Mathe

Ultracold and ultrafast: Tandem ion imaging and electron spectroscopy for quantum gases — Jette Heyer, Julian Fiedler, Mario Grossmann, Lasse Paulsen, Marlon Hoffmann, Markus Drescher, Klaus Sengstock, Juliette Simonet, and •Philipp Wessels-Staarmann — Center for Optical Quantum Technologies, Universität Hamburg, Hamburg, Germany

Ultrashort laser pulses provide new pathways for probing and manipulating ultracold quantum gases. The strong light field of such a laser pulse can locally ionize few or many atoms in a Bose-Einstein condensate. This allows creating hybrid quantum systems consisting of ultracold atoms and ions. Moreover, an ultrafast excitation of interacting Rydberg atoms below the blockade radius becomes possible within femtoseconds due to the large bandwidth of the laser pulse.

Here we present a new instrument for charged particle analysis of ultracold atoms consisting of a tandem ion microscope and velocity-map-imaging electron spectrometer tailored to resolve the dynamics of these systems. The ion microscope can track the position of ions with a high spatial resolution, while the velocity-map-imaging spectrometer can measure the momentum of the electrons. Moreover, we can detect both properties in coincidence due to a high detection efficiency. A time-resolved extraction and detection on single digit nanosecond timescales allows following the emergence of correlations and many-body phenomena in interacting quantum systems of charged particles.

This work is funded by the Cluster of Excellence "CUI: Advanced Imaging of Matter" of the DFG - EXC 2056 - project ID 390715994.

A 7.2 Tue 11:30 KlHS Mathe

Quantum bubbles in the Einstein-Elevator facility at Leibniz University Hannover — •Charles Garcion[1], Thimothé Estrampes[1], Gabriel Müller[1], Sukhjovan S. Gill[1], Magdalena Misslisch[1], Éric Charron[2], Christoph Lotz[3], Jean-Baptiste Gérent[4], Nathan Lundblad[4], Ernst M. Rasel[1], and Naceur Gaaloul[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, Hannover, 30167, Germany — [2]Institut des Sciences Moléculaires d'Orsay, CNRS, Université Paris-sacay, F-91405, Orsay, France — [3]Institut für Transport- und Automatisierungstechnik c/o Hannover Institute of Technology, Leibniz Universität Hannover, Callinstraße 36, Hannover, 30167, Germany — [4]Department of Physics and Astronomy, Bates College, Lewiston, ME, USA

Quantum bubbles are systems in which atoms are confined to a two-dimensional closed surface. They enable the study of phenomena like vortices, collective modes, and self-interference during expansion. These bubbles are typically created using radiofrequency (RF) dressed potentials and form more naturally in microgravity. However, inhomogeneities in static and RF magnetic fields can alter this advantage.

The Quantumania project adapts the MAIUS-1 payload in the Einstein-Elevator at the Leibniz University Hannover to create quantum bubbles. It will also contribute to efforts in testing and refining techniques for the Cold Atom Laboratory aboard the ISS. A primary goal is optimizing antenna designs and selecting radiofrequency sources to enhance magnetic field homogeneity, ensuring effective trapping in bubble configurations.

A 7.3 Tue 11:45 KlHS Mathe

Josephson dynamics of a finite temperature BEC in a double well potential — •Kateryna Korshynska[1,2] and Sebastian Ulbricht[1,2] — [1]TU Braunschweig, Institut für Mathematische Physik Mendelssohnstr. 3 38106 Braunschweig — [2]Physikalisch-Technische Bundesanstalt Bundesallee 100 38116 Braunschweig

A many-particle bosonic system placed in a double-well potential is known to exhibit oscillatory dynamics of the particle populations between the wells. Such collective oscillations are well-known as the Josephson effect and have been intensively investigated both theoretically and experimentally. A well-established approach to describe this dynamics at low temperatures is to assume a two-state model, in which the Josephson equations govern population imbalance and phase difference between the wells. This model is formulated under the assumption that the Bose gas forms a fully coherent system, which holds at zero temperature. However, in typical experiment the finite-temperature BEC is not fully coherent, for instance when the thermal equilibrium is established. To describe this we use the density matrix approach and analyze the influence of higher energy levels on the double-well dynamics. We find that this effect is two-fold: while the higher energy levels below the barrier height contribute to the double-well dynamics, the even more excited particles may lead to thermalization and decoherence.

A 7.4 Tue 12:00 KlHS Mathe

Anyonic phase transitions in the 1D extended Hubbard model with fractional statistics — •Sebastian Eggert[1], Martin Bonkhoff[2], Kevin Jägering[1], Shi-Jie Hu[3], Axel Pelster[1], and Imke Schneider[1] — [1]University of Kaiserslautern-Landau — [2]Theoretische Physik, Univ. Hamburg — [3]Beijing Computational Science Research Center

Recent advances in quantum technology allow the realization of "lattice anyons", which have enjoyed large interest as particles which interpolate between bosonic and fermionic behavior. We now study the interplay of such fractional statistics with strong correlations in the one-dimensional extended Anyon Hubbard model at unit filling by developing a tailored bosonization theory and employing large-scale numerical simulations. The resulting quantum phase diagram shows several distinct phases, which show an interesting transition through a multicritical point. As the anyonic exchange phase is tuned from bosons to fermions, an intermediate coupling phase changes from Haldane insulator to a dimerized phase. Detailed results on the universality classes of the phase transitions are presented.

A 7.5 Tue 12:15 KlHS Mathe

Quantum-gas microscopy of fermionic ^{87}Sr — Carlos Gas[1], Sandra Buob[1], Jonatan Höshele[1], •Antonio Rubio-Abadal[1], and Leticia Tarruell[1,2] — [1]ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [2]ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

Ultracold atoms in optical lattices are a popular platform in quantum science for studies in the fields of quantum simulation and quantum metrology. Alkaline-earth atoms like strontium offer many opportunities, such as a large-spin fermions with SU(N) symmetry as well as narrow or ultranarrow transitions.

In particular, ^{87}Sr presents a nuclear spin of I=9/2 (and no electronic spin) allowing the study of the SU(N)-Fermi-Hubbard model and quantum magnetism with N up to 10.

In recent experiments, we have demonstrated single-atom imaging of ^{87}Sr with spin resolution using the narrow linewidth 689 nm transition. Through a combination of Zeeman shifts and spin-resolved optical pumping we aim at a reliable detection of all 10 spin states.

A 7.6 Tue 12:30 KlHS Mathe

Quantum phases of bosonic mixture with dipolar interaction — •Rukmani Bai and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

Ultracold dipoles in optical lattices, characterized by strong inter-site interactions, open new possibilities for ground-state phases as well as an intriguing dynamics. Recent experiments on dipolar mixtures of magnetic Lanthanide atoms are especially interesting, not only due to the dipolar interaction, but also because these atoms are particularly suitable for realizing component-dependent lattices. Using a combination of DMRG and cluster Gutzwiller methods, we study the ground-state physics that may result when the two components experience mutually intertwined optical lattices, which resemble interacting bilayer geometries.

A 7.7 Tue 12:45 KlHS Mathe

Chirality-protected state manipulation by tuning one-dimensional statistics — Friethjof Teel[1], •Martin Bonkhoff[2], Peter Schmelcher[1,3], Thore Posske[2,3], and Nathan Harshman[4] — [1]Center for Optical Quantum Technologies, Department of Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg Germany — [2]I. Institute for Theoretical Physics, Universität Hamburg, Notkestraße 9, 22607 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]Physics Department, American University, Washington, DC 20016, USA

Chiral symmetry is broken by typical interactions in lattice models, but the statistical interactions embodied in the anyon-Hubbard model are an exception. It is an example of a correlated hopping model in which chiral symmetry protects a degenerate zero-energy subspace. Complementary to the traditional approach of anyon braiding in real space, we adiabatically evolve the statistical parameter in the anyon-Hubbard model and we find non-trivial Berry phases and holonomies in this chiral subspace. States in this subspace possess stationary checkerboard patterns in their N-particle densities which are preserved under adiabatic manipulation. We give an explicit protocol for how these chirally-protected zero energy states can be prepared, observed, validated, and controlled.