A 12: Ultracold atoms, ions, and BEC III (joint session A/Q)

Time: Tuesday 14:00–16:00 Location: f303

Invited Talk A 12.1 Tue 14:00 f303

BECCAL - Quantum Gases on the ISS — •Lisa Wörner[1,2], Christian Schubert[1,3], Jens Grosse[1,2], Claus Braxmaier[1,2], Ernst Rasel[1,2], Wolfgang Schleich[1,4], and the BECCAL collaboration[1,2,3,4,5,6,7] — [1]German Aerospace Center, DLR — [2]University of Bremen — [3]Leibniz University Hanover — [4]University Ulm — [5]Humboldt University Berlin — [6]Johannes Gutenberg University — [7]Ferdinand Braun Institute

BECCAL (Bose-Einstein Condensate and Cold Atom Laboratory) is a bilateral NASA-DLR mission dedicated to execute experiments with ultra-cold and condensed atoms in the microgravity environment of the international space station. It builds on the heritage of NASA's CAL and the DLR founded QUANTUS and MAIUS missions. BECCAL aims to enable a broad range of experiments, covering atom interferometry, coherent atom optics, scalar Bose-Einstein gases, spinor Bose-Einstein gases and gas mixtures, strongly interaction gases and molecules, and quantum information. This contribution gives an overview over the current status of BECCAL and its anticipated capabilities for scientific investigations.

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A 12.2 Tue 14:30 f303

Cavity-Enhanced Microscope for Cold Atoms — •Tigrane Cantat-Moltrecht, Nick Sauerwein, and Jean-Philippe Brantut — LQG EPFL, Lausanne, Switzerland

We are setting up a novel type of microscope consisting of an ultra-cold Fermi gas of Lithium 6 atoms in a high-finesse cavity, combined with high-numerical-aperture optics (0.38).

Atoms in the cavity can be detected through their dispersive interaction with light. A second laser beam, focused tightly onto the lithium cloud, locally enhances the coupling of the atoms to the cavity, allowing for non-destructive measurements with sub-micron resolution. Controlling this coupling will also allow to tune the cavity-mediated interactions temporally and spatially, paving the way for novel schemes of quantum simulation of random all-to-all interactions between fermions.

Currently, the core of the optical system has been fully characterized and the vacuum and laser system are operational. I will summarize the important ideas and technical developments behind the design, present the current status of our setup and the next steps towards a working "cavity-microscope".

A 12.3 Tue 14:45 f303

Delta-kick collimation in dynamic time averaged optical potentials — •Henning Albers[1], Alexander Herbst[1], Ashwin Rajagopalan[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], Dennis Schlippert[1], and The PRIMUS-Team[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]ZARM, Universität Bremen

The precision of atom interferometers highly depends on the center-of-mass motion and the expansion rate of the atomic ensemble. By reducing the latter, systematic effects, e.g. through wavefront aberration, can be reduced. In our setup we perform evaporative cooling in a dynamic time averaged optical dipole trap, generated by spatial modulation of the trapping beams in the horizontal plane, yielding 2×10^5 condensed atoms after 3 s of evaporation. Subsequently we carry out delta-kick collimation (DKC). Beyond pulsed DKC, we use a trapped scheme keeping the atoms captured the entire time. DKC can be performed at any stage of evaporative cooling, thus short-cutting the generation of ultra-cold effective temperatures. In this talk we will show the results of fast BEC production and discuss the DKC results as well as limitations and the perspective of generating up to 10^6 delta-kicked condensed atoms within 1 s.

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A 12.4 Tue 15:00 f303

In-medium bound states of two bosonic impurities in a one-dimensional Fermi gas — David Huber[1], Hans-Werner Hammer[1,2], and •Artem Volosniev[3] — [1]TU Darmstadt, Darmstadt, Germany — [2]ExtreMe Matter Institute EMMI, Darmstadt, Germany — [3]IST Austria, Klosterneuburg, Austria

We investigate the ground-state energy of a one-dimensional Fermi gas with two bosonic impurities. We study the case where impurity and fermions have equal masses, and the impurity-impurity two-body interaction is identical to the fermion-impurity interaction, such that the system is solvable with the Bethe ansatz. For attractive interactions, we find that the energy of the impurity-impurity subsystem is below the energy of the bound state that exists without the Fermi gas. We interpret this as a manifestation of attractive boson-boson interactions induced by the fermionic medium, and refer to the impurity- impurity subsystem as an in-medium bound state. For repulsive interactions, we find no in-medium bound states.

A 12.5 Tue 15:15 f303

QUANTUS-2 - Towards double Bragg interferometry in microgravity with a collimated BEC — •Merle Cornelius[1], Peter Stromberger[2], Julia Pahl[3], Christian Deppner[4], Sven Herrmann[1], Claus Lämmerzahl[1], and The QUANTUS-Team[1,2,3,4,5,6] — [1]ZARM, Universität Bremen — [2]JGU Mainz — [3]HU Berlin — [4]LU Hannover — [5]Universität Ulm — [6]TU Darmstadt

Quantum sensors based on matter wave interferometry have a wide range of applications for geodesy or tests of fundamental physics. The sensitivity of such precision measurements increase with the interrogation time, thus operating on a microgravity platform is highly beneficial. As a pathfinder for future space missions, the QUANTUS-2 experiment was designed to perform atom interferometry during the free fall time at the ZARM drop tower in Bremen. Our atom chip setup enables rapid BEC production of Rb-87 atoms and utilization of delta-kick collimation to reduce the residual expansion below $100\,\mu$m/s. The collimated ensemble, observable after 2 s with a high signal to noise ratio, provides an excellent input source for atom interferometry on long time scales. Here we present first results on ground based interferometric measurements with single Bragg diffraction and a prospect to double Bragg interferometry with a collimated BEC in microgravity with long interferometer times in the range of seconds.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50WM1952.

A 12.6 Tue 15:30 f303

Observation of First and Second Sound in a Homogeneous Bose Gas — •Timon Hilker[1], Lena Dogra[1], Jake Glidden[1], Christoph Eigen[1], Robert Smith[1,2] und Zoran Hadzibabic[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]Clarendon Laboratory, University of Oxford, UK

The existence of two distinct sound velocities is one of the hallmarks of superfluids. In a compressible quantum gas both modes couple to density, which allows us to observe, for the first time, both sound velocities in a moderately interacting ultracold Bose gas. Using a magnetic field gradient, we excite centre-of-mass oscillations of a homogeneous K-39 Bose gas in a three-dimensional box trap, revealing two distinct resonant oscillations. In a microscopic analysis of the mode structure, we find quantitative agreement for the first (and second) sound with the hydrodynamic description of Landau's two-fluid model in terms of in-phase (out-of-phase) oscillations dominated by the thermal (BEC) atoms. We study the speed and the damping of both modes for various interaction strengths and temperatures and investigate in particular the crossover from collisionless to hydrodynamic behaviour above T_C.

A 12.7 Tue 15:45 f303

Continuous phase transitions in spinor Bose-Einstein condensates with spin-orbital angular momentum coupling — •Yuxiong Duan[1,2], Yuriy Bidasyuk[1], and Andrey Surzhykov[1,2] — [1]Physikalisch–Technische Bundesanstalt, D–38116 Braunschweig, Germany — [2]Technische Universität Braunschweig, D–38106 Braunschweig, Germany

Spin-orbital angular momentum (S-OAM) coupling in Bose-Einstein condensates has been recently realized using Raman coupling with Laguerre-Gaussian beams. A rich phase diagram even at zero temperature is predicted as a result of interplay between spin-orbit coupling, collisional interactions and quantization of angular momentum. In present work we focus on some key features introduced to the phase portrait by quantized angular momentum as this is the main difference of our system from more thoroughly studied linear momentum spin-orbit coupling. We demonstrate how appearance of quantized vortices in the S-OAM coupled system significantly alters the mechanism of phase transitions. In particular we find that the transition between the stripe phase and polarized (or unpolarized) phase is a continuous phase transition. During this process, a vortex molecule appears and contracts towards its center. This unique behavior is absent in the case of linear momentum spin-orbit coupling.