A 25: Ultracold Atoms and Molecules I (joint session Q/A)

Time: Thursday 10:30–12:30 Location: Q-H10

A 25.1 Thu 10:30 Q-H10

Optical bench system for the BECCAL ISS quantum gas experiment — •Jean Pierre Marburger[1], Faruk Alexander Sellami[1], Esther del Pino Rosendo[1], André Wenzlawski[1], Ortwin Hellmig[2], Klaus Sengstock[2], Patrick Windpassinger[1], and THE BECCAL TEAM[1,3,4,5,6,7,8,9,10,11] — [1]Institut für Physik, JGU, Mainz — [2]ILP, UHH, Hamburg — [3]HUB — [4]FBH — [5]LUH — [6]ZARM — [7]Universität Ulm — [8]DLR-SC — [9]DLR-SI — [10]DLR-QT — [11]OHB

The DLR-NASA BECCAL multi-user experimental facility is intended for the study of quantum gases in the microgravity environment of the ISS. In this talk, we present a stable optical bench system that enables frequency stabilization, as well as efficient light distribution and manipulation for this facility. In contrast to a lab-based setup, this system needs to withstand the mechanical loads during launch, and be mechanically stable under varying temperature conditions on the ISS over a timeframe of many years. To this end, we use and expand upon an optical toolkit based on the glass-ceramic Zerodur, which has a negligible coefficient of thermal expansion. This toolkit has already been successfully deployed in the scope of the sounding rocket missions KALEXUS, FOKUS, MAIUS-1, and will be used for the upcoming MAIUS-2/3 missions.

Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50 WP 1433, 50 WP 1703 and 50 WP 2103.

A 25.2 Thu 10:45 Q-H10

Rapid generation of all-optical ^{39}K Bose-Einstein condensates — •Alexander Herbst, Henning Albers, Vera Vollenkemper, Knut Stolzenberg, Sebastian Bode, and Dennis Schlippert — Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany

Ultracold potassium is a promising candidate for fundamental research and quantum sensing applications as it offers multiple broad Feshbach resonances at small magnetic fields. These can be used to control the atomic scattering length and therefore allow, e.g., for the suppression of phase diffusion or the generation of solitons. To apply this technique the magnetic field must be kept as an external degree of freedom thus necessitating optical trapping. However, compared to their magnetic counterparts, optical traps suffer from slower evaporative cooling. This poses a major challenge if the experiment requires a high repetition rate. We investigate the production of all-optical ^{39}K BECs under different scattering lengths in a time-averaged crossed optical dipole trap. By tuning the scattering length in a range between 75 a_0 and 350 a_0 we demonstrate a trade off between evaporation speed and final atom number and decrease our evaporation time by a factor of five while approximately doubling the atomic flux. To this end, we are able to produce fully condensed ensembles with 5×10^4 atoms within 850 ms evaporation time at a scattering length of 234 a_0 and 1.5×10^5 atoms within 4 s at 160 a_0, respectively. We analyze the flux scaling with respect to collision rates and describe routes towards high-flux sources of ultra-cold potassium for inertial sensing.

A 25.3 Thu 11:00 Q-H10

Optical dipole trap in microgravity - the PRIMUS-project — •Marian Woltmann[1], Christian Vogt[1], Sven Hermann[1], and The PRIMUS-Team[1,2] — [1]University of Bremen, Center of Applied Space Technology and Microgravity (ZARM) — [2]Institut für Quantenoptik, LU Hannover

The application of matter wave interferometry in a microgravity (μg) environment offers the potential of largely increased interferometer times and thereby highly increased sensitivities in precision measurements, e.g. of the universality of free fall. While most μg-based cold atom experiments use magnetic trapping on an atom chip, we develop an optical dipole trap as an alternative source for matter wave interferometry in weightlessness. Solely using optical potentials offers unique advantages like improved trap symmetry, trapping of all magnetic sublevels and the accessibility of Feshbach resonances. Equipping a 50W trapping laser at a wavelength of 1064nm we implement a cold atom experiment for use in the drop tower at ZARM in Bremen, offering 4.7s of microgravity time. We demonstrated Bose-Einstein condensation of Rubidium in a compact setup on ground while now focusing on a fast, efficient preparation in microgravity using painted optical potentials. Within this talk we will report on the current status and latest results of the experiment. The PRIMUS-Project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 2042.

A 25.4 Thu 11:15 Q-H10

Compact and Robust Laser System for Cold Atom Experiments in BECCAL on the ISS — •Tim Kroh[1], Victoria A. Henderson[1], Jean Pierre Marburger[2], Faruk Alexander Sellami[2], Esther del Pino Rosendo[2], André Wenzlawski[2], Matthias Dammasch[3], Ahmad Bawamia[3], Andreas Wicht[3], Patrick Windpassinger[2], Achim Peters[1,3], and THE BECCAL TEAM[1,2,3,4,5,6,7,8,9,10,11] — [1]HUB, Berlin — [2]JGU, Mainz — [3]FBH, Berlin — [4]DLR-SC — [5]DLR-SI — [6]DLR-QT — [7]IQ & IMS, LUH — [8]ILP, UHH — [9]ZARM, Bremen — [10]IQO, UULM — [11]OHB

BECCAL (Bose-Einstein Condensate–Cold Atom Laboratory) is a cold atom experiment designed for operation on the ISS. This DLR and NASA collaboration builds upon the heritage of sounding rocket and drop tower experiments as well as NASA's CAL. Fundamental physics with Rb and K BECs and ultra-cold atoms will be explored in this multi-user facility in microgravity, providing prolonged timescales and ultra-low energy scales compared to those achievable on earth. Matching the complexity of the required light fields to the stringent size, weight, and power limitations presents a unique challenge for the laser system design, which is met by a reliable and robust combination of micro-integrated diode lasers (from FBH) and miniaturized free-space optics on Zerodur boards (from JGU), interconnected with fiber optics. The design of the BECCAL laser system will be presented, alongside the requirements, concepts, and heritage which formed it. This work is supported by DLR with funds provided by the BMWi under grant numbers 50 WP 1433, 1702, 1703, 1704, 2102, 2103, and 2104.

A 25.5 Thu 11:30 Q-H10

Few-Body Physics in Spherical Shell Traps — C. Moritz Carmesin[1] and •Maxim A. Efremov[2,1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, 89069 Ulm, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), 89081 Ulm, Germany

With the recent progress in cold atom physics in microgravity [1–5] it is feasible to trap atoms in spherical shell-shaped traps. We start our analysis from exploring both bound and scattering states of two identical particles in spherical shell traps. Due to the non-separability of the center-of-mass and relative motions, we have solved the 6-dimensional Schrödinger equation numerically. Moreover, we have derived analytical models for the effective interaction between the particles for small and large shell radii, where the latter features quasi-two-dimensional dynamics in curved space.

[1] D. C. Aveline et al., Nature 582,193 (2020).
[2] K. Frye et al., EPJ Quantum Technol. 8, 1 (2021).
[3] N. Lundblad et al., npj Microgravity 5, 30 (2019).
[4] R. A. Carollo et al., arXiv:2108.05880
[5] A. Wolf et al., arXiv:2110.15247

A 25.6 Thu 11:45 Q-H10

A lattice model for traid anyons — •Sebastian Nagies[1], Botao Wang[1], Nathan Harshman[2], and André Eckardt[1] — [1]Institute of Theoretical Physics, Technical University Berlin, Berlin — [2]Department of Physics, American University, Washington DC, USA

Hard-core two-body interactions in two dimensions leave the configuration space of particles not simply connected. This gives rise to anyons exhibiting fractional exchange statistics governed by the braid group. Recently it was pointed out that hardcore three-body interactions in one dimension leave similar defects in configuration space. This allows for novel exchange statistics described by the traid group, for which the Yang-Baxter relation no longer holds. Here we propose a lattice model realizing a specific abelian representation of this traid group. Our model uses bosons with number-dependent hopping phases to generate alternating bosonic and fermionic exchange phases. By combining numeric simulations with analytic derivation in the continuum limit, we find interesting ground state density distributions and energies that differ greatly from bosons, fermions and braid anyons. We define new traid anyon operators satisfying non-local commutation relations, and predict distinctive traid anyon quasi-momentum distributions. We discuss their possible relation with Haldane's exclusion statistics.

A 25.7 Thu 12:00 Q-H10

Reservoir-engineered shortcuts to adiabaticity via quantum non-demolition measurements — •Raphael Menu[1], Josias Langbehn[2], Christiane Koch[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany

The preparation of a quantum state via a slow tuning of the parameters of the system lies at the heart of the concept of adiabatic quantum computing. Yet, the realization of such types of computation requires a wide time-window over which dissipation effects may occur, ultimately leading to errors. Here, we propose a protocol that achieves fast adiabatic Landau-Zener dynamics by coupling a spin to an external system. The coupling realizes a quantum non-demolition (QND)Hamiltonian, where the external system acts as a meter. When the meter's decay rate is the largest frequency scale of the dynamics, the QND coupling induces an effective dephasing of the spin in the adiabatic basis and the spin dynamics is described by a quantum adiabatic master equation. We show, however, that adiabaticity can be maximized in the non-adiabatic limit when the coupling with the meter tends to suppress diabatic transitions via effective cooling processes. We investigate the protocol efficiency in terms of non-Markovianity measures for the spin-meter dynamics and qualitatively discuss the spectral gap of the incoherent dynamics. We finally show that the protocol is robust against imperfection in the implementation of the QND Hamiltonian.

A 25.8 Thu 12:15 Q-H10

Engineering of Feshbach Resonances by a Floquet Drive — •Christoph Dauer, Axel Pelster, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Feshbach resonances are a common tool in order to control the scattering length in ultracold quantum gases [1]. In this talk we discuss how time-periodic driving enables to induce novel resonances that are fully controllable by the parameters of the drive [2,3]. A theory allowing a deeper understanding of these driving induced resonances within the Floquet picture is given. Our method is capable of describing resonance positions and widths for general inter-particle potentials. We demonstrate our results on an experimentally relevant example.

[1] C. Chin et al., Rev. Mod. Phys. 82, 1225 (2010)
[2] D.H. Smith, Phys. Rev. Lett. 115, 193002 (2015)
[3] A.G. Sykes et al., Phys. Rev. A 95, 062705 (2017)