Q 41: Ultra-cold Atoms, Ions and BEC III (joint session A/Q)

Time: Wednesday 14:30–16:00 Location: F428

Q 41.1 Wed 14:30 F428

Dynamics of a single trapped ion in a high-density medium: A stochastic approach — Mateo Londoño[1], •Javier Madroñero[1], and Jesús Pérez-Ríos[2] — [1]Centre for Bioinformatics and Photonics (CIBioFi), Universidad del Valle, Cali, Colombia — [2]Department of Physics and Astronomy, Stony Brook University, Stony Brook, New York 11794, USA

Based on the Langevin equation, a stochastic formulation is implemented to describe the dynamics of a trapped ion in a bath of ultracold atoms, including an excess of micromotion. The ion dynamics is described following a hybrid analytical-numerical approach in which the ion is treated as a classical impurity in a thermal bath. As a result, the ion energy*s time evolution and distribution are derived from studying the sympathetic cooling process. Furthermore, the ion dynamics under different stochastic noise terms is also considered to gain information on the bath properties* role in the system*s energy transfer processes. Finally, the results obtained from this formulation are contrasted with those obtained with a more traditional Monte Carlo approach [1].

[1] Londoño M., Madroñero J., and Pérez-Ríos J., Phys. Rev A 106, 022803 (2022)

Q 41.2 Wed 14:45 F428

Competing non-superradiant Fermi-surface instabilities induced by cavity-mediated interactions — Bernhard Frank[1], •Michele Pini[2], and Francesco Piazza[2] — [1]Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187, Dresden, Germany

The experimental realization of ultracold Fermi gases in optical resonators provides an interesting new platform to study unconventional quantum phases of matter induced by long-range cavity-mediated interactions. So far, mostly superradiant instabilities accompanied by charge density waves of the fermions have been studied in these systems. Here, we report instead on pair condensation instabilities, solving the competition problem within a controlled perturbative approach by exploiting the long-range nature of the cavity-mediated interaction. We show that a spin-polarized Fermi gas undergoes a phase transition to either a Cooper or a pair density wave superfluid at a common T_c. Below T_c, however, these phases turn out to be mutually exclusive, with one of them always dominating above the other. Moreover, these pairing instabilities occur both for attractive or repulsive interactions. This allows to observe them in the latter regime, where the superradiant instability is absent. In addition, the value of T_c is also found to be well within reach of the parameters of current experimental realizations, which is very promising for an experimental observation of these non-superradiant instabilities in the near future.

Q 41.3 Wed 15:00 F428

Proposal for a long-lived quantum memory using matter-wave optics with Bose-Einstein condensates in microgravity — •Elisa Da Ros[1], Simon Kanthak[1], Erhan Sağlamyürek[2,3], Mustafa Gündoğan[1], and Markus Krutzik[1,4] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]University of Calgary, Calgary, Canada — [3]University of Alberta, Edmonton, Canada — [4]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Bose-Einstein condensates (BECs) are a promising platform for implementing optical quantum memories [1]. Most of the decoherence mechanisms that affect the lifetime of BEC-based memories can be compensated through conventional methods, but, ultimately, the density-dependent interatomic collisions set the upper limit on the lifetime to around 100~ms timescales. Here [2] we propose a new protocol that utilizes matter-wave optics techniques to minimize such density-dependent effects. Optical atom lenses first collimate and then refocus an initially expanding BEC. This allows performing the memory write-in and read-out operations at high density while decreasing the collision rate during the storage period. We show an expected memory lifetime in a microgravity environment of up to 100 s, which is ultimately limited by the background vacuum quality.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWK) under grant number No. 50WM2055.

[1] E. Sağlamyürek, et al., Nat. Photon. 12, 774-782 (2018).
[2] E. Da Ros, et al., arXiv:2210.13859 (2022).

Q 41.4 Wed 15:15 F428

Einstein-Elevator — •Alexander Heidt — HITec, Hannover, Niedersachsen

More and more people are striving to explore space and to colonize it as well as to use its advantages for basic research in physics. To be able to accomplish this, technologies are necessary that operate in special gravity conditions. With the motivation to develop and investigate such technologies, the Einstein-Elevator was built, which, in addition to simulating weightlessness, is able to simulate other gravity conditions. The advantages of the Einstein-Elevator are the high repetition rate of up to one hundred flights per day in combination with a weight of the payload of up to 1,000 kg for the experiment setup, which can have a diameter of up to 1.70 m and a height of 2 m. The duration of the gravity condition is four seconds and these can be adjusted between Lunar and Martian gravity down to microgravity. Currently, several projects are underway in various research fields, including the core research areas mechanical engineering and fundamental physics: In the area of fundamental physics research based on atom interferometry is carried out. Projects currently in progress include INTENTAS to measure the entanglement of atoms in microgravity with a compact sensor, with special requirements for stabilizing a magnetic field, and DESIRE to measure dark energy, where the motion, especially the rotation, of the Einstein elevator must be stabilized. In addition, the team is continuously developing the facility, opening up gravitational conditions that could not previously be simulated on Earth.

Q 41.5 Wed 15:30 F428

Statistically Suppressed Coherence in the Anyon-Hubbard Dimer — •Martin Bonkhoff, Imke Schneider, Axel Pelster, and Sebastian Eggert — Physics Departement and Research Center Optimas, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

The impact of statistical transmutation on superfluid tendencies is investigated for the Anyon-Hubbard dimer, a two-site restriction of the lattice generalization of Kundu anyons [1], experimentally accessible via the creation of density-dependent gauge phases and additional strong confinement [2]. We find a duality relation between the anyonic and the Bose-Hubbard dimer, which allows us to construct the corresponding, exact, algebraic Bethe-Ansatz solution. For large particle numbers and weak on-site interactions, the coherence properties are found to be strongly suppressed by statistical transmutation, with underlying mechanisms and applications analogous to one-axis spin-squeezing and entangled coherent states in quantum optics [3,4].

References:

[1] Bonkhoff, M. and Jägering, K. and Eggert, S. and Pelster, A. and Thorwart, M. and Posske, T., Phys. Rev. Lett. 126, 163201 (2021)
[2] Frölian, A., Chisholm, C.S., Neri, E. et al., Nature 608, 293-297 (2022)
[3] Kitagawa, M. and Ueda, M., Phys. Rev. A 47, 5138-5143 (1993)
[4] Rice, D. A., Jaeger, G. and Sanders, B. C., Phys. Rev. A 62, 012101 (2000)

Q 41.6 Wed 15:45 F428

Light-induced correlations in cold dysprosium atoms — •Marvin Proske[1], Ishan Varma[1], Nivedith Anil[1], Dimitra Cristea[1], Nico Bassler[2], Claudiu Genes[2,3], Kai Philipp Schmidt[2], and Patrick Windpassinger[1] — [1]Institut für Physik, JGU Mainz — [2]Department of Physics, FAU Erlangen-Nuremberg — [3]MPI for the Science of Light, Erlangen

When the average atomic distance in a cloud of ultracold atoms, is below the wavelength of the scattering light, a direct matter-matter coupling is introduced by electric and magnetic interactions. This alters the spectral and temporal response of the sample, where the atoms cannot be treated as individual emitters anymore. We intend to experimentally study light-matter interactions in dense dipolar media with large magnetic moments to explore the impact of magnetic dipole-dipole interactions onto the cooperative response of the sample. With the largest ground-state magnetic moment in the periodic table (10 Bohr-magneton), dysprosium is the perfect choice for these experiments.

This talk reports on the progess made in generating extremely dense cold dysprosium clouds. We discuss the measures taken to optically transport the atoms into a home-built science cell, which serves as a highly accessible platform to manipulate the atomic cloud. The small dimensions of the cell allow for extremely tight dipole trapping, enabled by a self-designed high NA objective. Further, we give a perspective on future measurements exploring collective effects in the generated atom cloud.