A 24: Ultracold atoms, ions, and BEC V (joint session A/Q)

Time: Thursday 11:00–13:00 Location: f303

Invited Talk A 24.1 Thu 11:00 f303

Status update of the muonic hydrogen ground-state hyperfine splitting experiment — •A. Ouf and R. Pohl on behalf of the CREMA collaboration — Johannes Gutenberg-Universität Mainz, Institut für Physik, QUANTUM & Exzellenzcluster PRISMA +, Mainz, Germany

The ground state hyperfine splitting (1S-HFS) in ordinary hydrogen (the famous 21 cm line) has been measured with 12 digits accuracy almost 50 years ago [1], but its comparison with QED calculations is limited to 6 digits by the uncertainty of the Zemach radius determined from elastic electron-proton scattering. The Zemach radius encodes the magnetic properties of the proton and it is the main nuclear structure contribution to the hyperfine splitting (HFS) in hydrogen. The ongoing experiment of the CREMA Collaboration at PSI aims at the first measurement of the 1S-HFS in muonic hydrogen (μp) with the potential for a hundredfold improved determination of the proton structure effects (Zemach radius and polarizability), which will eventually improve the QED test using the 21 cm line by a factor of 100. The experiment introduces several novel developments toward the (μp) 1s-HFS spectroscopy. We will present the current efforts of the various developments from the pulsed 6.8 μm laser, to the novel multi pass cavity, and the scintillator detection system.

[1] L. Essen *et al*, Nature **229**, 110 (1971)
[2] R. Pohl *et al.*, Nature **466**, 213 (2010)
[3] A. Antognini *et al.*, Science **339**, 417 (2013)

A 24.2 Thu 11:30 f303

Precision Spectroscopy of an Interacting Ytterbium Fermi-Fermi Mixture — •Benjamin Abeln[1], Marcel Diem[1], Koen Sponselee[1], Nejira Pintul[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Laserphysics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

We perform high precision spectroscopy on the $^1S_0$ to $^3P_0$ clock transition of ^{171}Yb and ^{173}Yb to investigate interactions in an ultracold Fermi-Fermi mixture of ^{171}Yb and ^{173}Yb. We find and characterize an SU(*2*) × SU(*6*) symmetric interspecies interorbital interaction. The Yb Fermi-Fermi mixture in the ground state is characterized by strongly attractive inter-species interactions, while the intra-species interactions are vanishing for ^{171}Yb and repulsive for ^{173}Yb. We discuss prospects of spectroscopic methods to gain information on the underlying many-body phase diagram.

A 24.3 Thu 11:45 f303

Status of a buffer gas cooled Low-Emittance Laser Ablation Ion Source with two RF funnels — •Tim Ratajczyk[1], Philipp Bollinger[1], Tim Lellinger[1], Victor Varentsov[2,3], and Wilfried Nörtershäuser[1] — [1]Institute für Kernphysik, TU Darmstadt — [2]Facility for Antiproton and Ion Re- search in Europe (FAIRGmbH), Darmstadt — [3]Institute for Theoretical and ExperimentalPhysics, Moscow, Russia

Ion sources of low-emittance are of interest in many applications of experimental low-energy physics, for example as ion sources for collinear laser spectroscopy or ion trap experiments, or as ion sources for accelerators and for production of fine focusing beams for industrial microelectronics technologies. Often, surface ion sources are used due to their simple construction and easiness of operation. However, they can only deliver a very small range of elements, mostly alkaline and alkaline earth ions and a few other species. Laser ablation in vacuum opens the possibility to produce ion beams even from transition metals or compound materials. The drawback of this technique is the high emittance of the beam. The presented ion source will counteract this drawback by using He buffer gas to stop the ions and extracting them through optimized RF funnels into high vacuum conditions.

This work is supported by BMBF 05P19RDFN1 and HIC for FAIR

A 24.4 Thu 12:00 f303

A cryogenic Penning trap system for sympathetic laser cooling of atomic ions and protons — •Johannes Mielke[1], Teresa Meiners[1], Matthias Borchert[1,3], Frederik Jacobs[1], Julian Pick[1], Amado Bautista-Salvador[2], Juan Manuel Cornejo[1], Ralf Lehnert[1,4], Malte Niemann[1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]Ulmer Fundamental Symmetries Laboratiory, RIKEN, Wako, Saitama 351-0198, Japan — [4]Indiana University Center for Spacetime Symmetries, Bloomington, IN 47405, USA

High precision comparisons of the fundamental properties of protons and antiprotons carried out within the BASE collaboration serve as tests of CPT invariance in the baryon sector. However, preparation and measurement schemes based on resistive cooling and image current detection are time-consuming and highly sensitive to the particle's motional energy. Thus, experimental schemes based on sympathetic cooling of single (anti-)protons through co-trapped atomic ions can contribute to the ongoing strive for improved precision through fast preparation times and low particle temperatures.

Here we present a cryogenic multi-Penning trap system for free space coupling of two single particles in an engineered double-well potential and report on latest results obtained with Doppler cooled $^9Be^+$ ions. Prospects for proton loading and sympathetic cooling in a microcoupling trap will be discussed.

A 24.5 Thu 12:15 f303

Collinear laser spectroscopy of the $2s\ ^3S_1 \leftrightarrow 2p\ ^3P_2$ transition in He-like Boron — •Konstantin Mohr[1], Zoran Andelkovic[2], Axel Buss[3], Volker Michael Hannen[3], Phillip Imgram[1], Kristian König[4], Jörg Krämer[1], Bernhard Maass[1], Simon Rausch[1], Rodolfo Sánchez[2], Christian Weinheimer[3], and Wilfried Nörtershäuser[1] — [1]IKP, TU Darmstadt — [2]GSI, Darmstadt — [3]IKP, WWU Münster — [4]NSCL, Michigan State University

We aim for a determination of nuclear charge radii of light isotopes in an all-optical approach, i.e., without reference to elastic electron scattering. The calculations required for this approach can currently be only accomplished for hydrogen-like systems but will soon become established for He-like systems [1]. While the ground state of He-like systems is not easily accessible by laser spectroscopy, transitions starting from the metastable $^3S_1$-state can be adressed.

The $2s\ ^3S_1 \leftrightarrow 2p\ ^3P_j$ transitions of $^{11}B^{3+}$ have already been measured with a different technique [2]. At the HITRAP-facility at the GSI accelerator complex designed to prepare heavy highly charged ions for precision spectroscopy [3] we used an Electron Beam Ion Source (EBIS) and measured the $2s\ ^3S_1 \leftrightarrow 2p\ ^3P_2$ transition in ^{10,11}B. In this contribution we report about the current status of this experiment.

[1] V. A. Yerokhin et al., Phys. Rev. **A98**, 032503 (2018)
[2] T. P. Dinneen et al., Pys. Rev. Lett. **66**, 2859, (1991)
[3] Z. Andelkovic et al., Hyp. Int. **235**, 37 (2015)

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A 24.6 Thu 12:30 f303

Towards a high-accuracy Al$^+$ optical clock — •Johannes Kramer[1], Fabian Dawel[1], Lennart Pelzer[1], Ludwig Krinner[1], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt Braunschweig — [2]Gottfried Wilhelm Leibniz Universität Hannover

We aim to build an optical atomic clock taking advantage of the 8 mHz narrow clock transition of a single $^{27}Al^+$ ion stored inside a linear Paul trap together with a single $^{40}Ca^+$ ion acting as logic ion. The low sensitivity of the aluminium ion's $^1S_0$ to $^3P_0$ clock transition to external fields and its potential high Q-factor allow to reach accuracies on the level of 10^{-18}. Frequency standards with such high accuracy are candidates for a future redefinition of the SI second as well as for cm-scale resolution in measuring the gravity field of the Earth due to the gravitational redshift. In this talk we present our experimental setup as well as latest results on measuring the clock transition of the ground-state cooled Al^+-Ca^+ crystal by quantum logic protocols.

A 24.7 Thu 12:45 f303

World's first atom interferometer with a metastable He BEC — •Oleksiy Onishchenko, Rudolf F. H. J. van der Beek, Kjeld

S. E. Eikema, Hendrick L. Bethlem, and Wim Vassen — LaserLaB, Department of Physics and Astronomy, Vrije Universiteit, Amsterdam, the Netherlands

Atom interferometry has established itself as a valuable precision measurement tool for the gravitational potential, the Einstein equivalence principle, and the fine structure constant (α) among other things. While most interferometry experiements with ultracold atoms up to now have been performed with alkali or alkaline-earth atoms, metastable helium (He*) stands apart with unique advantages. Among those are the possibility to do high-accuracy atom number detection on a multichannel plate, a very small second-order Zeeman shift, and a very high critical acceleration and recoil velocity [1]. Those advantages are especially suitable for a high-precision measurement of α in a manner independent of quantum electrodynamics calculations. We experimentally demonstrate a crucial tool for such a measurement with He*, namely a large number of Bloch oscillations in an optical lattice, performed with high efficiency. This technique coherently transfers a well-known quantity of linear momentum to the atoms, which strongly reduces the uncertainty in atom recoil velocity measurements for determining α. We also demonstrate a proof-of-principle Mach-Zehnder interferometer with He*.

[1] W. Vassen *et al.* "Ultracold metastable helium: Ramsey fringes and atom interferometry". *Appl. Phys. B* **122**, 289 (2016).