Q 56: Precision Spectroscopy of Atoms and Ions V (joint session A/Q)

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

Invited Talk Q 56.1 Thu 11:00 KlHS Mathe

Breaking the barrier of resolution in broadband spectroscopy
— •Jérémie Pilat[1,2], Bingxin Xu[1,2], Theodor W. Hänsch[1,3], and Nathalie Picqué[1,2] — [1]Max-Planck Institute of Quantum Optics, Garching, Germany — [2]Max Born Institute, Berlin, Germany — [3]Ludwig-Maximilian University of Munich, Faculty of Physics, München, Germany

We provide the first experimental demonstration of a new type of spectroscopy with theoretically unlimited resolution and spans, which opens up new opportunities in broadband spectroscopy. We use a dual-comb spectrometer, where two frequency combs of narrow, equidistant lines with slightly different line spacing beat on a photodetector. Optical frequencies are mapped to measurable radiofrequencies. While dual-comb spectroscopy has existed for over a decade, we experimentally exploit here that its fundamentally different operation principle for the first time: as a pure time-domain spectrometer, it encounters no geometric limitations. As an illustration, combs of a narrow line spacing of 2.5 MHz are harnessed for sampling the 5S-SP transitions of Rubidium over a span of 130 GHz. More than 50000 comb lines are resolved in a single measurement of just one second. To achieve this resolution with a Fourier transform spectrometer, one would need a delay line of 60 m, and for a dispersive spectrometer, a grating of 60 m length.

Q 56.2 Thu 11:30 KlHS Mathe

R&D towards an atomic tritium source for future neutrino mass experiments
— •Caroline Rodenbeck for the KAMATE-Collaboration — Karlsruher Institut für Technologie, IAP-TLK

A purely kinematic way of measuring the neutrino mass is precision spectroscopy of the tritium beta-decay spectrum at its endpoint. Experiments following this approach have so far used tritium in its molecular form. The associated molecular final state distribution effectively broadens the spectrum and thus reduces the sensitivity on the neutrino mass.

For future experiments aiming for sensitivities as low as the lower boundaries obtained by neutrino oscillation experiments (e.g., $0.05\,\mathrm{eV/c^2}$ in case of inverted ordering), atomic tritium sources are needed. Before it is practical to carry out a neutrino mass experiment with an atomic tritium source, key challenges such as multi-stage cooling of an atomic tritium beam to a few mK and magnetic trapping of atoms have to be solved.

The Karlsruhe Mainz Atomic Tritium Experiment (KAMATE) aims to benchmark different types of atomic dissociators and to demonstrate primary cooling stages. KAMATE is a collaboration of JGU and of KIT's Tritium Laboratory Karlsruhe (TLK) which currently hosts the KATRIN experiment. Additionally, there are plans to extend the collaboration to build an atomic tritium demonstrator.

The talk gives an overview of the current plans and results within KAMATE and of the vision for a future atomic tritium demonstrator.

Q 56.3 Thu 11:45 KlHS Mathe

64-Pixel Magnetic Micro-Calorimeter Array to Study X-ray Transitions in Muonic Atoms
— •Daniel Kreuzberger, Andreas Abeln, Christian Enss, Andreas Fleischmann, Loredana Gastaldo, Daniel Hengstler, Andreas Reifenberger, Adrian Striebel, Daniel Unger, Julian Wendel, and Peter Wiedemann for the QUARTET-Collaboration — Kirchhoff Institute for Physics, Heidelberg University

The QUARTET collaboration aims to improve the knowledge on the absolute nuclear charge radii of light nuclei from Li to Ne. We use a low temperature Metallic Magnetic Calorimeter (MMC) array for high-precision X-ray spectroscopy of low-lying states in muonic atoms. MMCs are characterized by a high resolving power of several thousand and a high quantum efficiency in the energy range up to 100 keV. Conventional solid-state detectors do not provide sufficient accuracy in this energy range. A high statistics measurement with lithium, beryllium and boron has recently been performed at the Paul Scherrer Institute. We present the experimental setup and the performance of the detector used. We discuss the first preliminary spectra and systematic effects in this measurement. The high statistics data in combination with the achieved energy resolution and calibration accuracy should allow a more precise characterization of the muonic X-ray lines. With the knowledge gained, a significant improvement in the determination of nuclear charge radii is expected.

Q 56.4 Thu 12:00 KlHS Mathe

Towards entanglement-enhanced quantum metrology with cold ^{88}Sr atoms
— •Sofus Laguna Kristensen[1,2], Akhil Kumar[1,2], Klavdia Kontou[1,2], Ka Hui Goh[1,2], Saumya Shah[1,2], Trofim Ruzaikin[1,2], Immanuel Bloch[1,2,3], and Sebastian Blatt[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology, 80799 Munich, Germany — [3]Ludwig-Maximilians-Universität, 80799 Munich, Germany

Optical lattice clocks operating with ultra cold strontium or ytterbium offer unprecedented precision and accuracy in timekeeping. With fractional frequency uncertainties down to the 10^{-18} level, they enable scientific and technical advances from fundamental physics to global positioning systems. In our group we are developing a next-generation optical atomic clock, where spin squeezing of optically trapped ^{88}Sr atoms will allow us to surpass the standard quantum limit of the atomic interrogation. To improve the short-term stability of the atomic clock, our experiment aims to demonstrate low-latency optical qubit readout made possible by rapid and direct imaging of the ground and metastable clock states.

In this talk I will discuss the progress of the experiment, presenting our latest results of lattice trapping and spectroscopy of the clock transition in ^{88}Sr, and discuss the next steps towards rapid-readout entanglement-enhanced quantum metrology.

Q 56.5 Thu 12:15 KlHS Mathe

Ab initio calculations of the hyperfine structure of fermium
— •Joseph Andrews[1,2], Jacek Bieroń[3], Per Jönsson[4], Sebastian Reader[1,2], and Michael Block[1,2] — [1]Helmholtz-Institut Mainz, Mainz, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]Jagiellonian University, Kraków, Poland — [4]Malmö University, Malmö, Sweden

Fermium ($Z = 100$) is one of the two heaviest atoms for which experimental spectroscopic data exists, residing at the forefront of atomic and nuclear physics research. Over the past twenty years, it has been the subject of extensive theoretical and experimental investigation. Nuclear multipole moments are required to verify existing nuclear models, and one of the most accurate methods to determine nuclear dipole and quadrupole moments is to combine measured nuclear coupling constants with calculated deduced electric field gradients. Calculations were initially performed on its lighter homologue erbium where experimental results exist to determine the predictive accuracy of our model. Hyperfine interaction constants A and B of Er I and Fm I are investigated using the multiconfigurational Dirac-Hartree-Fock (MCDHF) method, involving over five million configuration state functions. Results of the ground state $5f^{12}7s^2$ ($4f^{12}6s^2$) of both neutral atoms are presented and compared to previous calculations and experiments.

Q 56.6 Thu 12:30 KlHS Mathe

Transportable optical clock for remote comparisons
— •Saaswath J. K.[1], Martin Steinel[1], Melina Filzinger[1], Jian Jiang[1], Thomas Fordell[2], Kalle Hanhijärvi[2], Anders Wallin[2], Thomas Lindvall[2], Burghard Lipphardt[1], Ekkehard Peik[1], Nils Huntemann[1], and the Opticlock consortium[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]VTT Technical Research Centre of Finland Ltd, National Metrology Institute VTT MIKES, P.O. Box 1000, 02044 VTT, Finland

We report on a transportable and user-friendly optical clock that uses the $^2S_{1/2} - {}^2D_{3/2}$ transition of a single trapped $^{171}\mathrm{Yb}^+$ ion at 436 nm as the reference. The system, called Opticlock, has been developed in an industry-lead collaboration. As a first step towards remote comparisons, the frequency instability of Opticlock has been improved by reducing the dead time, and its systematic uncertainty has been reduced by direct measurements of the AC magnetic field. Furthermore, a frequency comb was integrated into the system to provide clock output at 1.5 μm. In August 2024, Opticlock traveled to Finland to be compared with the $^{88}\mathrm{Sr}^+$ clock at VTT MIKES. A first inspection of the measurement data, with an overall uptime of 90 %, indicates proper operation of both clocks and will allow the frequency ratio to be determined with a statistical uncertainty below 1×10^{-17}. The results pave the way for future key comparisons of high-performance optical clocks using transportable standards as an alternative to satellite-based techniques and fiber links, yielding significant contributions to the milestones towards the redefinition of the SI second.

Q 56.7 Thu 12:45 KlHS Mathe

Trapping electrons and Ca+ ions with dual-frequency Paul trap — Vladimir Mikhailovskii[1], •Natalija Sheth[1], Yuzhe Zhang[1], Hendrik Bekker[1], Günther Werth[2], Guofeng Qu[3], Zhiheng Xue[4], K. T Satyajith[5], Qian Yu[6], Neha Yadav[6], Hartmut Häffner[6], Ferdinand Schmidt-Kaler[7], and Dmitry Budker[1,2,6] — [1]Helmholtz-Institut Mainz, GSI Helmholtzzentrum fur Schwerionenforschung, Mainz, Germany — [2]Johannes Gutenberg-Universitat, Mainz, Germany — [3]. Institute of Nuclear Science and Technology, Sichuan University, Chengdu, China — [4]University of Science and Technology of China, Hefei, China — [5]Nitte, Mangalore, India — [6]Department of Physics, University of California, Berkeley, USA — [7]QUANTUM, Institute für Physik, Johannes Gutenberg-Universitat, Mainz, Germany

Radiofrequency traps are well recognized for their ability to co-trap charged particles with different mass-to-charge ratios, such as different ion species, even atomic and molecular ones, or ions with charged nanoparticles [1]. At the AntiMatter-On-a-Chip project we currently work on cotrapping electrons and ions. In this report we present results on trapping electrons and Ca^{+} ions with a trap similar to the one described in [2]. Trapping of electrons is achieved by applying 1.6 GHz to the resonator while trapping Ca^{+} ions is achieved by applying 2 MHz to DC electrodes. The influence of dual-frequency operation on trapping stability and the lifetime of trapped particles were studied.

1. D. Bykov, et al. arXiv:2403.02034
2. C. Matthiesen et al, Phys. Rev. X; 11, 011019 (2021)