Q 38: Precision Spectroscopy of Atoms and Ions III (joint session A/Q)

Time: Wednesday 14:30–16:30 Location: N 3

Invited Talk Q 38.1 Wed 14:30 N 3

Enhanced Sensitivity for Electron Affinity Measurements — •Franziska Maria Maier, Erich Leistenschneider, Lutz Schweikhard, and Stephan Malbrunot-Ettenauer — CERN

The electron affinity (EA) reflects the energy released when an electron is attached to a neutral atom and encodes key information about atomic structure, electron correlation effects and chemical reactivity. However, the EA of the heaviest elements of the periodic table remain experimentally unexplored despite their fundamental importance to benchmark atomic many-body calculations with implications across atomic and nuclear physics, quantum chemistry and radiopharmaceutical research. We have developed a novel technique to determine EAs through Laser Photodetachment Threshold Spectroscopy, performed in an electrostatic ion beam trap, a so called MR-ToF device [1]. Our method increases the sample's exposure to laser photons and, thus, enhances the experimental sensitivity by three orders of magnitude. By applying this technique, we measured the EA of ^{35}Cl to be 3.612720(44) eV, achieving state-of-the-art precision while employing five orders of magnitude fewer anions. This unprecedented sensitivity paves the way for systematic EA measurements across isotopic chains - including isotope shifts and hyperfine splittings - and ultimately for the first direct determination of electron affinities in superheavy elements. This presentation will introduce our novel method and present our experimental results. [1] F. M. Maier, E. Leistenschneider et al., Nat. Commun. 16, 9576 (2025).

Q 38.2 Wed 15:00 N 3

High resolution dielectronic recombination of beryllium-like heavy ions at the CRYRING@ESR storage ring — •Mirko Looshorn[1,2], Carsten Brandau[3], Mike Fogle[4], Jan Glorius[3], Elena Hanu[3,5,6], Volker Hannen[7], Pierre-Michel Hillenbrand[3], Claude Krantz[3], Michael Lestinsky[3], Esther Menz[3,8], Reinhold Schuch[9], Uwe Spillmann[3], Ken Ueberholz[7], Shuxing Wang[1,2], and Stefan Schippers[1,2] — [1]Justus-Liebig-Universität Gießen — [2]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [4]Auburn University — [5]Helmholtz-Institut Jena — [6]Goethe University Frankfurt — [7]Universität Münster — [8]Universität zu Köln — [9]Stockholm University

Electron-ion collision spectroscopy is a powerful tool for studying highly charged ions. The heavy-ion storage ring CRYRING@ESR offers excellent conditions for high-resolution dielectronic recombination (DR) measurements due to its ultra-cold electron cooler. Such high-precision DR spectroscopy enables sensitive tests of higher-order QED contributions in strong fields. We present recent DR studies of heavy berylliumlike systems, including fully evaluated results for Pb^{78+} [1] and measurements of Au^{75+}, which are currently under analysis. Comparisons with state-of-the-art theory highlight the potential of these systems to benchmark precision atomic-structure calculations in the high-Z regime.

[1] S. Schippers et al., Phys. Rev. Lett. **135**, 113001 (2025).

Q 38.3 Wed 15:15 N 3

Adaptive, symmetry-informed Bayesian metrology for precise measurements — •Matt Overton[1], Jesús Rubio[2], Nathan Cooper[1], Janet Anders[3], and Lucia Hackermüller[1] — [1]University of Nottingham, Nottingham, UK — [2]University of Surrey, Guildford, UK — [3]University of Exeter, Exeter, UK

High-precision measurements are crucial for addressing major scientific and technological challenges; however, obtaining these measurements can be time-consuming. Here, we present a systematic strategy for parameter estimation in the low-data limit that integrates experimental control parameters and natural symmetries. The method is guided by a Bayesian quantifier of precision gain, enabling adaptive optimisation tailored to any experiment.

This adaptive strategy is demonstrated in a quantum technology experiment, in which ultracold caesium atoms are confined in a micromachined hole in an optical fibre. We find a five-fold reduction in the fractional variance of the estimated parameter, compared to the standard measurement procedure. Equivalently, our strategy achieves a target precision with a third of the data points previously required. Such enhanced device performance and accelerated data collection will be essential for applications in quantum computing, communication, metrology, and the wider quantum technology sector.

Q 38.4 Wed 15:30 N 3

Resolving the recoil splitting in Doppler-free spectroscopy of calcium in a heat pipe — •Andreas Reuss and Simon Stellmer — Universität Bonn, Germany

Calcium, as an alkaline-earth metal, is of significant interest to both the atomic and nuclear physics communities. The narrow intercombination line at 657 nm is of particular interest and can be probed in a simple vapor cell using Doppler-free saturated absorption spectroscopy to generate a narrow and stable reference signal. However, recoil effects lead to a splitting of the absorption line, introducing a variable asymmetry in the lineshape that degrades the stability of this reference. In this work, we reduce all broadening mechanisms to a level that allows us to resolve the recoil splitting. We lock a laser to one of the recoil components and quantify the frequency stability.

Q 38.5 Wed 15:45 N 3

Development of a cw laser system at 185nm — •Jonas Gottschalk, Sascha Heider, Thorsten Groh, Simon Stellmer, and UVQuanT Consortium — Universität Bonn, Germany

Many of the strong transitions in diatomic molecules with double bonds, such as O_2, N_2 or NO, are located in the vacuum-UV part of the spectrum between 100 and 200 nm. The generation of tunable cw light in this wavelength range remains a major challenge, but recent advancements in laser technology motivate new attempts.

We present a DUV laser system based on two continuous-wave VECSEL lasers, one operating at 431.4 nm via intracavity frequency doubling and the other at 1299.8 nm.

The fundamental waves are combined in a sequence of sum-frequency-generation stages to produce light at 185 nm.

We will use the system to perform spectroscopy on the $^1S_0$ - $^1P_1$ transition of mercury and to explore molecular oxygen lines in the Schumann-Runge bands, with implications for fundamental physics and astrochemistry.

Q 38.6 Wed 16:00 N 3

A single frequency continuous wave OPO laser as powerful and flexible tool for high resolution spectroscopy — •Jakob Weiss[1], Katrin Weidner[1], Raphael Hasse[1], Thorben Niemeyer[1], Matou Stemmler[1], Klaus Wendt[1], and Sapida Akhundzada[2] — [1]Johannes Gutenberg-Universität Mainz — [2]Hübner GmbH & Co. KG, Division HÜBNER Photonics, Kassel

Optical parametric oscillators (OPOs) pumped at 780 nm provide widely tunable laser radiation, covering almost the entire spectral range from 510 nm up to 3400 nm (including SHG). The possibility of automated continuous wave operation with line widths in the order of 1 MHz makes them extremely versatile tools for precision spectroscopy. Remaining limitations in the width and speed of continuous frequency scanning as well as coarse linewidth adjustment over large spectral ranges are presently addressed for enabling specific spectroscopic applications in atomic and molecular spectroscopy.

Feasibility studies are carried out using the C-WAVE GTR (HÜBNER Photonics) for investigations on the hyperfine structure of Fe isotopes by resonance ionization spectroscopy and in photodetachment studies on molecules, for which in both cases a smooth and well controlled tuning behavior of the laser frequency is a fundamental requirement. For this purpose a continuous, high-resolution fine-range scan mode as well as a wide-range coarse-scan algorithm have been developed to provide quick and flexible wavelength access, enhancing the versatility of the C-WAVE GTR and its suitability for advanced spectroscopic applications.

Q 38.7 Wed 16:15 N 3

A robust technique for ground-state cooling of antimatter in cryogenic multi-Penning traps — •Nikita Poljakov[1], Philipp Hoffmann[1], Marek Prasse[1], Jan Schaper[1], Julia Coenders[1], Juan Manuel Cornejo[2], Klemens Hammerer[3], Stefan Ulmer[4,5], and Christian Ospelkaus[1,6] — [1]Leibniz Universität Hannover, Germany — [2]Universidad de Cádiz, Spain — [3]Universität

Innsbruck, Austria — [4]Ulmer Fundamental Symmetries Laboratory, RIKEN, Japan — [5]Heinrich-Heine-Universität Düsseldorf, Germany — [6]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Within the BASE collaboration, we deployed a cryogenic multi-Penning trap to contribute to high-precision (anti-)proton *g*-factor measurements[1,2] to test CPT symmetry via quantum logic spectroscopy (QLS)[3] with a $^{9}Be^{+}$ cooling and logic ion. After demonstrating key steps - optical sideband spectroscopy[4], ground-state cooling[5] of a $^{9}Be^{+}$ ion, and fast adiabatic transport[6] - we turn to ground-state cooling of the (anti-)proton. We simulate its Coulomb coupling to a $^{9}Be^{+}$ ion in a double-well potential in a microfabricated Penning trap. The 9:1 mass ratio causes anharmonicities that hinder cooling of 4 K (anti-)protons under static potentials. A frequency sweep of the $^{9}Be^{+}$ well maintains resonance and enables ground-state cooling. This technique is also applicable to other laser-inaccessible (anti-)particles. [1]G. Schneider et al., Science 358 (2017) [2]C. Smorra et al., Nature 550 (2017) [3]P. Schmidt et al., Science 309 (2005) [4]J. Cornejo et al., Phys. Rev. Res. 6 (2023) [5]J. Cornejo et al., Phys. Rev. Res. 6 (2024) [6]M. Boehn et al., Comms. Phys. 8 (2025).