Q 55: Precision Spectroscopy of Atoms and Ions III (joint session A/Q)

Time: Thursday 14:30–16:30 Location: F303

Invited Talk Q 55.1 Thu 14:30 F303

Laser spectroscopy of the heaviest elements with the RADRIS technique — •Tom Kieck for the RADRIS-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — Helmholtz-Institut Mainz, Germany

Exploring atomic and nuclear properties in the region of the heaviest elements through laser spectroscopy became possible with the RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique at GSI. Fusion evaporation reaction products are separated from the primary beam in the velocity filter SHIP and then stopped in high-purity argon gas and collected onto a thin hafnium filament. Following re-evaporation, the released neutral atoms are probed by two-step resonance laser ionization. The resulting photo-ions are guided to a silicon detector for identification by their characteristic alpha radiation.

After a first observation and characterisation of an atomic ground-state transition in nobelium (Z = 102), the technique was applied to several nobelium and fermium isotopes. We present advancements of the RADRIS technique together with recent results from the FAIR phase-0 beamtime 2022 at GSI. The setup performance was optimised to achieve higher total efficiency, which is now up to 15%. Improved stability of the system allowed the search for atomic levels in lawrencium (Z = 103) for more than 400 hours. In addition, the short-lived isotope ^{251}No ($T_{1/2}$ = 0.8 s) was studied along with several fermium and californium isotopes. These results and further prospects will be discussed.

Q 55.2 Thu 15:00 F303

Collinear laser spectroscopy in ^{12,13}C^{4+} — •Patrick Müller[1], Phillip Imgram[1], Kristian König[1], Bernhard Maass[2], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt, Germany — [2]Argonne National Laboratory, Chicago, IL, USA

Laser spectroscopy has since long been used to determine differential nuclear charge radii $\delta\langle r^2\rangle$ for stable and short-lived isotopes. Recently, much effort was put in improved atomic structure calculations of helium-like systems to be able to extract absolute nuclear charge radii from $1s2s\,^3S_1 \rightarrow 1s2s\,^3P_J$ transition frequencies [1]. This can be used in light He-like ions, i. e., Be to N, in which the metastable state has sufficient lifetime to perform collinear laser spectroscopy and the transition wavelengths are in the laser accessible region.
We report on high-precision collinear laser spectroscopy measurements of the $1s2s\,^3S_1 \rightarrow 1s2s\,^3P_{0,1,2}$ transitions in ^{12,13}C^{4+} using the **Co**llinear **A**pparatus for **L**aser Spectroscopy and **A**pplied Physics (COALA) at the Institute of Nuclear Physics, TU Darmstadt. Although theory has not reached the accuracy to directly extract $\langle r^2\rangle$ in He-like systems with competitive uncertainty yet, mass-shift calculations between ^{12,13}C^{4+} will provide $\delta\langle r^2\rangle^{12,13}$ with very high precision in the conventional approach. The measured hyperfine structure of ^{13}C^{4+} which is modulated by significant hyperfine mixing will serve as another benchmark for testing atomic-structure theory. This project is supported by DFG (Project-ID 279384907 - SFB 1245).

[1] Yerokhin *et al.*, Phys. Rev. A **106**, 022815 (2022)

Q 55.3 Thu 15:15 F303

Laser photodetachment threshold spectroscopy at FLSR: first results — •Oliver Forstner[1,2], Vadim Gadelshin[3], Lothar Schmidt[4], Kurt Stiebing[4], Dominik Studer[3], and Klaus Wendt[3] — [1]Friedrich Schiller-Universtität Jena — [2]Helmholtz-Institut Jena — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz — [4]Institut für Kernphysik, Goethe-Universität Frankfurt

The Frankfurt Low-energy Storage Ring (FLSR) is a room-temperature electrostatic storage ring, which can reduce the internal energy of stored ions almost to the ambient temperature, being suitable for laser photodetachment threshold (LPT) spectroscopy to determine the electron affinity of negatively charged ions. The latter play a key role in accelerator mass spectrometry (AMS): lasers can selectively neutralize undesired isobars, providing a purified beam of an isotope of interest. To extend the range of available AMS nuclides, it is necessary to identify neutralization schemes for unwanted atomic and molecular negative ions.

To achieve this goal, a source for negative ions was installed at FLSR and a compact laser lab was constructed guiding laser beams into FLSR. The laser setup is based on a tunable Ti:Sapphire laser pumped by a high repetition Nd:YAG laser. The neutralized ions are further downstream detected by a position sensitive MCP detector.

An overview of the setup and first results of precision spectroscopy of O^- will be presented. An outlook of further LPT studies will be given.

Q 55.4 Thu 15:30 F303

Laser spectroscopy of fermium across the deformed N=152 shell closure — •Elisabeth Rickert for the Fermium-Collaboration — GSI Darmstadt, Germany — JGU Mainz, Germany — HIM Mainz, Germany

The existence and stability of heavy nuclei is a forefront topic in nuclear physics. Modern laser spectroscopy techniques provide a unique tool to study nuclear shell effects by measuring isotope shifts to infer mean-square charge radii and hence deduce nuclear size and shape. Laser spectroscopy measurements of the isotope shift of an atomic transition of the actinide element fermium (Z=100) have been recently carried out covering isotopes across the N=152 shell closure. On-line and off-line laser spectroscopy experiments with direct and indirect production schemes and offline production methods were combined and methodologically pushed forward to measure isotope shifts in fermium isotopes. Previously inaccessible isotopes, short and long-lived, were covered, enabling experiments at atom-at-a-time quantities through newly developed detection concepts. Changes in the mean-square charge radii were extracted for the longest chain of isotopes investigated in the region of the heavy actinides revealing a discontinuity around the N=152 shell closure.

Q 55.5 Thu 15:45 F303

High-resolution spectroscopy of exotic silver with a cw OPO injection-seeded PDA — •Mitzi Urquiza-González[1], Volker Sonnenschein[1], Omorjit S. Khwairakpam[2], Bram van den Borne[3], Michael Heines[3], Ágota Koszorús[3], Katerina Chrysalidis[4], Ruben P. de Groote[3,5], Bruce Marsh[4], Korbinian Hens[1], and Klaus Wendt[6] for the CRIS-Collaboration — [1]Division HÜBNER Photonics, Hübner GmbH Co KG, Germany — [2]Istituto Nazionale di Fisica Nucleare LNL, Italy — [3]KU Leuven, Belgium — [4]CERN, Switzerland — [5]University of Jyväskylä, Finland — [6]Johannes Gutenberg Universität, Germany

Short-lived radioisotopes are of special interest for nuclear structure studies, as their characteristic provide valuable reference points for theoretical predictions far from stability. By using lasers, hyperfine transitions can be accessed, allowing direct measurement of nuclear observables. For such high-resolution spectroscopy, narrow-band pulsed lasers can be created by the pulsed amplification of a cw seed laser, keeping the amplifier's high power and short time profile whilst acquiring the seeder's spectral properties.

Spectroscopy on exotic Ag was performed at the CRIS experiment at CERN. A tunable cw single-mode OPO was employed as injection-seed for a two-stage pulsed dye amplifier. The hyperfine splitting of the ground-state $^2S_{1/2}$ to the level $^2P^O_{3/2}$ was measured and the hyperfine coupling constants were determined. For this work, ^{111,117}Ag are presented, showcasing this laser system's applicability for future high-resolution spectroscopy studies.

Q 55.6 Thu 16:00 F303

Hyperfine structures of neptunium — •Magdalena Kaja[1], Mitzi Urquiza-González[2], Felix Berg[1], Korbinian Hens[2], Tobias Reich[1], Matou Stemmler[1], Dominik Studer[1], Felix Weber[1], and Klaus Wendt[1] — [1]Johannes Gutenberg University, 55099 Mainz — [2]Hübner GmbH & Co. KG, Kassel, Germany

Neptunium is of major concern for the long-term safety of a high-level nuclear waste repository due to the long half-life of $2.1{\cdot}10^6$ years and the high radiotoxicity of its isotope ^{237}Np. In this context, trace analysis of environmental samples is of high relevance. Resonance ionization mass spectrometry (RIMS) is an excellent tool for selective and sensitive ultra-trace analysis of radionuclides but requires efficient excitation schemes and a suitable tracer for quantification. For isotope ratio determination, it is important to take into account the isotope-related effects in ionization schemes stemming from hyperfine structure (HFS) and isotope shift. Thus, new two-step excitation schemes for analysis

of ^{237}Np and ^{239}Np as a tracer were identified and investigated.

Narrow bandwidth spectroscopy on ^{237}Np and ^{239}Np has been carried out at RISIKO mass separator using the specific PI-LIST laser ion source geometry together with an injection-locked seeded Ti:sa laser system. The latter has a spectral bandwidth of 20 MHz, while also providing a high repetition rate pulsed operation with the high-power density required for RIS. The HFS of the atomic ground-state transitions to the levels at 25 075.15 cm^{-1} and 25 277.63 cm^{-1} has been measured and hyperfine coupling constants for both isotopes as well as the isotope shift between ^{237}Np and ^{239}Np have been determined.

Q 55.7 Thu 16:15 F303

High-resolution laser spectroscopy on the isotopes $^{244-248}$Cm — •Nina Kneip[1], Felix Weber[2], Christoph E. Düllmann[2,3,4], Christian M. Marquardt[5], Christoph Mokry[2,3], Petra J. Panak[5], Sebastian Raeder[3,4], Jörg Runke[2,4], Dominik Studer[3], Clemens Walther[1], and Klaus Wendt[2] — [1]Leibniz University Hannover, 30060 Hannover — [2]Johannes Gutenberg University Mainz, 55099 Mainz — [3]Helmholtz Institute Mainz, 55099 Mainz — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt — [5]Karlsruhe Institute of Technology, 76131 Karlsruhe

The transuranium element curium ($Z = 96$) is one of the minor actinides present in spent nuclear fuel. It is produced during power reactor operation in a series of nuclear reactions from ^{238}U. The resonance ionization mass spectroscopy (RIMS) method was used at the RISIKO mass separator at Mainz University for off-line studies in the complex, highly dense atomic structure of Cm. Due to its high ionization efficiency and outstanding elemental selectivity, RIMS is an excellent tool for high-precision laser spectroscopy on these minuscule samples. The isotope shift was measured for the isotope chain $^{244-248}$Cm for two different energy levels with the electron configurations $5f^7 6d7s7p\,^9D_3$ and $5f^8 6d7s\,^9D_3$. The odd-A iostopes were present with only $10^{11} - 10^{12}$ atoms. A narrow band Ti:sapphire laser system was used for high-precision measurements specifically to resolve the hyperfine structures of ^{245,247}Cm with 15 hyperfine transitions each. Finally, the modified King plot was used to determine the missing mean square charge radius of ^{247}Cm.