# MS 4: Heavy and Superheavy Elements

Time: Thursday 11:00–13:00 Location: F128

**Invited Talk** MS 4.1 Thu 11:00 F128

**Observation of the radiative decay of the thorium-229 nuclear clock isomer** — •Sandro Kraemer for the ISOLDE-IS658-Collaboration — Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium — Fakultät f. Physik, LMU München, Germany

A unique feature of thorium-229 is its isomeric first excited state with an exceptionally low excitation energy, proposed as a candidate for future nuclear optical clocks. The development of such an optical clock requires, however, knowledge of the excitation energy by at least an order of magnitude more precise. Additionally, spectroscopic experiments searching for a direct signature of the radiative decay have so far been unsuccessful.

In this work, an alternative approach using the beta decay of actinium-229 is studied as a novel method to populate the isomer with high efficiency and in low background conditions. Produced online at the ISOLDE facility at CERN, actinium is laser-ionized and implanted into a large-bandgap crystal.

A vacuum-ultraviolet spectroscopic study of implanted mass 229 beams at the ISOLDE facility will be presented. From the results obtained during a first measuring campaign it can be concluded that the radiative decay of the thorium-229 isomer has been observed for the first time, the excitation energy of the isomer has been determined with a factor of 5 improved uncertainty and the ionic lifetime in a crystalline environment was constrained.

**Invited Talk** MS 4.2 Thu 11:30 F128

**Mass measurements of heavy and superheavy nuclides and isomers with SHIPTRAP** — •Manuel J. Gutiérrez for the SHIPTRAP-Collaboration — GSI Darmstadt, Germany — HIM Mainz, Germany

The existence of superheavy elements is due to quantum shell effects, which stabilize them against spontaneous fission. Several theoretical models exist to describe these very complex nuclear systems. By providing nuclear binding energies, direct mass measurements can benchmark these models.

The Penning-trap mass spectrometer SHIPTRAP is devoted to performing mass measurements of heavy and superheavy nuclei produced via fusion-evaporation reactions with minute yields. Mass resolving powers in the $10^7$ range, which are achieved with the Phase-Imaging Ion-Cyclotron-Resonance technique, enable the study of low-lying, long-lived isomeric states. Within the FAIR Phase-0 campaign, the latest measurements focused on several nuclides with such isomeric states, ranging from $^{241}$Cf to $^{258}$Db. Additionally, measurements were carried out on the $^{206}$Fr–$^{202}$At–$^{198}$Bi chain, aiming to pin down the absolute excitation energies of two known isomers for the first time.

In this contribution, selected results from the analysis of the 2021 beamtime data will be presented, with emphasis on the studies of isomeric states.

MS 4.3 Thu 12:00 F128

**Progress of the Laser Resonance Chromatography** — •Eunkang Kim[1,2], Michael Block[1,2,3], Biswajit Jana[1,2], Sebastian Raeder[2,3], Harry Ramanantoanina[1], Elisabeth Rickert[1,2,3], Elisa Romero Romero[1,2,3], and Mustapha Laatiaoui[1,2] — [1]Department Chemie, Johannes Gutenberg-Universität, Fritz-Strassmann Weg 2, 55128 Mainz, Germany — [2]2Helmholtz-Institut Mainz, Staudingerweg 18, 55128 Mainz, Germany — [3]3GSI, Planckstraße 1, 64291 Darmstadt, Germany

Optical spectroscopy of superheavy elements is experimentally challenging as their production yields are low, half-lives are very short, and their atomic structure is barely known. Conventional spectroscopy techniques such as fluorescence spectroscopy are no longer suitable since they lack the sensitivity required in the superheavy element research. A new technique called Laser Resonance Chromatography (LRC) could provide sufficient sensitivity to study superheavy ions and overcome difficulties associated with other methods. In this contribution, I will introduce the LRC technique and report the progress and the results from the first LRC test experiments. This work is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

MS 4.4 Thu 12:15 F128

**Status of the gas-jet apparatus for laser spectroscopy of the heaviest elements** — •Matou Stemmler for the JetRIS-Collaboration — Institute of Physics, Johannes Gutenberg University Mainz, Germany

Laser spectroscopy measurements can provide information about fundamental properties of both atomic and nuclear structure. Such measurements are of particular importance for the heaviest actinides and superheavy elements, where data is sparse. In recent resonance-ionization-spectroscopy experiments on nobelium isotopes at GSI, Darmstadt, Germany, have been carried out with the in-gas-cell technique RADRIS [1,2]. However its limited spectral resolution hampers the precision, and occasionally renders the precise determination of nuclear moments and spins impossible. Furthermore, the inherent collection and measurement cycle precludes studies of isotopes with half-lives below $\approx$ 1 s. To overcome these limitations, a new JetRIS apparatus has been built to perform laser spectroscopy on atoms in a hypersonic jet [3].
This presentation will give an update on the JetRIS apparatus and discuss results from the 2022 beam time.

1 M. Laatiaoui, et al., Nature 538, 495-498 (2016)
2 S. Raeder, et al., Phys. Rev. Lett. 120, 232503 (2018)
3 S. Raeder, et al., Nucl. Instrum. Meth. Res. B, 463, 272-276 (2020)

MS 4.5 Thu 12:30 F128

**Status of Development of MR-ToF MS for JetRIS for laser spectroscopy of the heavy actinides at GSI/HIM** — •Danny Münzberg[1,2,3], Michael Block[1,2,3], Arno Claessens[4], Piet van Duppen[4], Rafael Ferrer[4], Jeremy Lantis[3], Mustapha Laatiaoui[3], Steven Nothhelfer[1,2,3], Sebastian Raeder[1,2], Moritz Schlaich[5], Lutz Schweikhard[6], Matou Stemmler[3], Thomas Walther[5], and Klaus Wendt[3] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE — [2]Helmholtz-Institut, Mainz, DE — [3]Department Chemie, Johannes Gutenberg-Universität, Mainz, DE — [4]Institut voor Kern- en Stralingsfysica, KU Leuven, Leuven, Belgium — [5]Technische Universität Darmstadt, DE — [6]Universität Greifswald, DE

At GSI-Darmstadt we use the in gas-Jet Resonant Ionization Spectroscopy (JetRIS) apparatus to perform laser spectroscopy of elements in the heavy actinide region to determine their nuclear and atomic properties. JetRIS utilizes $\alpha$-decay detection to maximize sensitivity while minimizing the background from unwanted ions. However, for long-lived nuclides ($t_{\frac{1}{2}} > 10$ h) a decay-based detection will not be practical. Thus, a multi-reflection time-of-flight mass seperator (MR-ToF MS) is being developed for the JetRIS apparatus, allowing a separation of ions according to their mass to charge ratios with a high mass-resolving power, opening the possibility of direct ion detection. This will allow measuring $\beta$-decaying species and long-lived isotopes. An overview of the MR-ToF MS design and its integrations into the system will be given. Prospects for measurements will be discussed.

MS 4.6 Thu 12:45 F128

**Relativistic calculation of binding energies of highly charged ions for precision mass spectroscopy** — •Zoltán Harman, Chunhai Lyu, Vincent Debierre, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg

Penning-trap mass spectrometry has recently enabled a novel determination of electron binding energies through the comparison of ionic masses. The collaboration of experiment and our multiconfiguration Dirac-Hartree-Fock theory has enabled the discovery of ultra-narrow ionic transitions, suitable for constructing future atomic clocks: in the Re 29+ ion, a long-lived electronic state with an excitation energy of 202 eV was observed via the mass difference of excited and ground-state ions [1]. A further application of such investigations is the determination of the Q value of the beta decay of various atomic isotopes, relevant for the determination of the neutrino mass [2]: experimentally, the masses of Re and Os ions could be determined to high precision, and our calculations have delivered the accurate binding energies of the electrons missing from the neutral atoms. Finally, mass spectrometry has largely contributed to a comparison of the magnetic moments of two isotopically different neon ions, allowing to set upper bounds on the coupling strength of new scalar bosons that might mediate a hypothetical interaction between electrons and nucleons [3]. – [1] R. X. Schüssler, et al., Nature 581, 42 (2020); [2] P. E. Filianin, et al., Phys. Rev. Lett. 127, 072502 (2021); [3] T. Sailer et al., Nature 606, 479 (2022).