MS 5: Heavy and Superheavy Nuclei

Time: Wednesday 11:00–13:00 Location: HS 3042

Invited Talk MS 5.1 Wed 11:00 HS 3042

Laser spectroscopy studies of heavy actinides — •Dominik Studer for the Fermium-Collaboration — Helmholtz-Institut Mainz — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

Precise measurements of nuclear ground-state properties, e.g., spins, electromagnetic moments, and charge radii provide data on the shell structure and serve as benchmarks for theory, which contribute to obtaining a comprehensive picture of nuclear phenomena in heavy nuclei. However, experiments with exotic artificial transuranics are challenging due to limited sample sizes or production yields, and scarcity of atomic structure information. Here we report on an extended laser spectroscopy campaign, targeting isotopes of Cf, Es and Fm. These nuclides were predominantly produced at ORNL's High Flux Isotope Reactor. Part of the sample from ORNL was subsequently also re-irradiated at the high-flux reactor at ILL Grenoble, France, to produce ^{255}Es, serving as a ^{255}Fm generator, as well as ^{253,254}Cf. Laser spectroscopic studies were carried out at the RISIKO mass separator at the University of Mainz using resonance ionization spectroscopy. Broadband laser scans served to explore atomic spectra, and high-resolution spectroscopy - feasible with sample sizes on the femtogram level - allowed the extraction of isotope shifts and nuclear moments from hyperfine spectra. On-line laser spectroscopy of shortlived Fm isotopes, produced by nuclear fusion reactions at the GSI accelerator facility in Darmstadt, complement these studies and allowed the exploration of the N=152 neutron shell gap.

MS 5.2 Wed 11:30 HS 3042

Status of the JetRIS experiment for on-line laser spectroscopy of superheavy elements — •Sebastian Raeder for the JetRIS-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — Helmholtz-Institut Mainz

Laser spectroscopy of the heaviest elements is of high relevance for our understanding of fundamental atomic and nuclear structure. Atomic energy levels in heavy systems become strongly influenced by electron correlations as well as relativistic effects and are largely unknown for transfermium elements, while posing a major challenge to theory. From a nuclear physics point of view, superheavy elements lie on the frontier to the region of enhanced shell stabilization, with their unique structure manifesting in the evolution of various observables. Laser spectroscopy enables the determination of spins, electromagnetic moments and changes in mean square charge radii. Experiments on transfermium elements have to be performed on-line with quantities of few atoms per second or below. At GSI, fusion-evaporation products are separated from the primary beam by the SHIP velocity filter and stopped in a gas cell. In-gas cell spectroscopy has been used successfully to probe the spectra of No and Fm. However, the spectral resolution of this method is limited by Doppler- and pressure broadening, which often renders a detailed evaluation of hyperfine structures impossible. The JetRIS setup improves spectral resolution by performing spectroscopy in a low-pressure, low-temperature supersonic gas jet and enables experimental linewidths in the order of few hundred MHz. The current status of the JetRIS experiment will be presented.

MS 5.3 Wed 11:45 HS 3042

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], Alexandre Brizard[4], Arno Claessens[5], Rafael Ferrer[5], Paul Fischer[6], Christian Helmel[3], Mustapha Laatiaoui[3], Nathalie Lecesne[4], Sebastian Raeder[1,2], Hervé Savajols[4], Moritz Schlaich[7], Lutz Schweikhard[6], Matou Stemmler[3], Kenneth van Beek[1,7], Piet Van Duppen[5], Thomas Walther[7], Klaus Wendt[3], and Frank Wienholtz[7] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE — [2]Helmholtz-Institut, Mainz, DE — [3]Johannes Gutenberg-Universität, Mainz, DE — [4]GANIL, Caen, France — [5]KU, Leuven, Belgium — [6]Universität Greifswald, DE — [7]Technische Universität, Darmstadt, DE

The in gas-Jet Resonant Ionization Spectroscopy (JetRIS) apparatus is applied for laser spectroscopy of isotopes in the heavy actinide region to determine their atomic and nuclear properties, at GSI, Darmstadt, Germany. So far, JetRIS utilizes α-decay detection to maximize sensitivity while minimizing the background from unwanted ions. However, for long-lived nuclides ($t_{\frac{1}{2}} > 10$ h) decay-based detection will not be practical. Therefore a multi-reflection time-of-flight mass separator (MR-ToF MS) will be added to the JetRIS apparatus, allowing for a separation of ions by their mass-to-charge ratios with a high mass-resolving power and efficiency. This will open up the possibility of mass-selective ion detection with low background and will also enable the measurement of non α-decaying species, as well as long-lived and stable isotopes. The MR-ToF MS design is developed within the Darmstadt's MR-ToF (Da's MR-ToF) Collaboration and an overview on the setup and its integration into JetRIS will be given. The status of the comissioning, as well as experimental results and prospects for future measurements will be discussed.

MS 5.4 Wed 12:00 HS 3042

Characterization of the MR-ToF for JetRIS at GSI/HIM — •Christian Helmel[1,3], Michael Block[1,2,3], Alexandre Brizard[4], Arno Claessens[5], Rafael Ferrer[5], Paul Fischer[6], Mustapha Laatiaoui[3], Nathalie Lecesne[4], Danny Münzberg[1,2,3], Sebastian Raeder[2,3], Hervé Savajols[4], Moritz Schlaich[7], Lutz Schweikhard[6], Matou Stemmler[1], Kenneth van Beek[2,7], Piet Van Duppen[5], Thomas Walther[7], Klaus Wendt[1], and Frank Wienholtz[7] — [1]Johannes Gutenberg-Universität, Mainz, DE — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE — [3]Helmholtz-Institut, Mainz, DE — [4]GANIL, Caen, France — [5]KU, Leuven, Belgium — [6]Universität Greifswald, DE — [7]Technische Universität, Darmstadt, DE

At the GSI in Darmstadt and the Helmholtz Institute in Mainz laser spectroscopy is utilized to determine nuclear and atomic properties of heavy actinides with high precision. To extend the range of accessible nuclides practically independent of their half-lives and their decay mode the detection capability of the existing systems will be expanded by a Multi-Reflection Time-of-Flight Mass Separator (MR-ToF MS). This MR-ToF, built within the Da's MR-ToF Collaboration, enables mass-selective ion detection. Currently, the MR-ToF MS is in the characterization phase establishing the resolving power and the efficiency, for example, with off-line ion sources. An example of this would be the determination of the time focus on which the resolution and the circulation rate are to be optimized. Furthermore the influence of the beam path on the detector signal has to be tested. In addition, a cooler buncher is to be integrated to determine the influence of the energy distribution on the signal and make laser spectroscopy measurements with high repetition lasers possible. In the future, the MR-ToF MS will be added in the JetRIS setup for off-line and on-line MRToF assisted laser spectroscopy.

MS 5.5 Wed 12:15 HS 3042

Optimization and development of RFQ Cooler Bunchers for S3-LEB at GANIL and JetRIS at GSI — •Alexandre Brizard for the S3-LEB and JetRIS-Collaboration — GANIL, CEA/DRF-CNRS/IN2P3, Caen, France — GSI Helmholtzzentrum fur Schwerionenforschung GmbH, Darmstadt, Germany

At the focal plane of the S3 separator in GANIL, the S3-Low Energy Branch (S3-LEB) will perform in-gas-jet resonant laser ionization to access fundamental properties of exotic nuclei. This highly selective and efficient technique will produce pure beams for further measurements, among those mass measurements by a Multi-Reflection Time-Of-Flight Mass Spectrometer (MR-ToF-MS). JetRIS is working in complement to the Radiation Detected Resonance Ionization Spectroscopy (RADRIS) setup at GSI. The technique is similar to the one of the S3-LEB gas cell, with RIS performed in a hypersonic gas jet to reduce the pressure and Doppler broadening. Presently, an alpha detector is used for efficient detection with low background. An MR-ToF-MS will be installed to study long-lived nuclides where alpha detection is impractical as well as beta-decaying nuclides. The MR-ToF-MS requires a beam bunching. A RFQ Cooler Buncher (RFQcb) has been designed and is commissioned with the S3-LEB setup. Ion-trajectory simulations will help optimizing the transmission and properties of bunches. The design of the JetRIS bunching unit is finalised and its commissioning will happen in 2024. Here, we present the ongoing work on the RFQcb simulations to improve the performances of S3-LEB in GANIL, and the design of the new RFQcb for JetRIS at GSI.

MS 5.6 Wed 12:30 HS 3042

Hyperfine structure of a Lawrencium homologue via Laser Resonance Chromatography — •Aayush Arya[1], Eunkang Kim[1], Michael Block[1,2,3], Biswajit Jana[1], Sebastian Raeder[2,3], Harry Ramanantoanina[1], Elisabeth Rickert[1], Elisa Romero Romero[1], and Mustapha Laatiaoui[1,2,3] — [1]Johannes Gutenberg-Universität Mainz, D-55128 Mainz — [2]Helmholtz-Institut-Mainz, D-55128 Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt

Atoms of different chemical elements possess absorption lines which serve as their unique fingerprints and provide direct insight into their internal structure. At present, elements up to atomic number 118 have been discovered, but due to their very short lifetimes and extremely low production rates even at the most intense beam facilities, the transfermium elements have thus far evaded direct spectroscopy. Recently, resonance ionization spectroscopy of nobelium was successfully achieved "one atom at a time". However, pushing beyond nobelium with existing methods is challenging, and may require development of new methods for accessing even a single element. To this end, a technique named Laser Resonance Chromatography was conceived and has been successfully commissioned. Here, we present measurements of hyperfine structure and isotope shifts of lutetium ions using this method.As lutetium is an electronic homologue of lawrencium, our method relying on the ion-mobility based separation of different excited states directly demonstrates its potential for the laser spectroscopy of Lr and opens a new window for studying the superheavy elements.

MS 5.7 Wed 12:45 HS 3042

Designing a compact buffer-gas cell for recoil-ion sources for the SHIPTRAP experiment — •Jaykumar Patel[1,2], Michael Block[1,3,4], Francesca Giacoppo[1,4], Manuel J. Gutiérrez[1,4,5], and Alexandre Obertelli[6,7] — [1]GSI, Darmstadt, Germany — [2]TUD, Darmstadt, Germany — [3]JGU, Mainz, Germany — [4]HIM, Mainz, Germany — [5]University of Greifswald, Germany — [6]IKP, TU Darmstadt, Germany — [7]RIKEN Nishina centre, Japan

Masses of transuranium nuclides, for example around the N=152 deformed shell gap are pivotal for understanding shell evolution and nuclear structure in that region. By combining α decay energies and direct mass measurements e.g. from SHIPTRAP and RIKEN-KEK, various masses in this region have already been determined. However, expecting extended regions of enhanced stability, the shell gap evolution in different isotopic chains is of interest. Mass measurements on long lived isotopes can be performed with high precision with Penning traps by using different ion sources. Currently used laser-ablation ion sources need large sample sizes, which is unsuitable for transuranium isotopes. This can be overcome by recoil ion sources where the recoil ions from α decays can be used for mass measurements. This work aims at building a compact buffer gas cell in which recoil ions are stopped at low energies for efficient transport to the Penning trap. The cell with a funnel-type electrode system will operate at room temperature with He gas at pressures around 50 mbar. This setup, enabling offline measurements of certain isotopes, can serve as a reference for mass measurements of superheavy element at SHIPTRAP, GSI Darmstadt.