MS 2: Precision Mass Spectrometry and Fundamental Applications II

Time: Monday 17:00–19:00 Location: RW 2

Invited Talk MS 2.1 Mon 17:00 RW 2

Single-ion Penning-trap mass spectrometry using a single ion as detector — •Daniel Rodriguez — Departamento de Física Atómica, Molecular y Nuclear, Universidad de Granada, 18071, Granada, Spain

The eigenfrequencies of a charged-particle stored in a Penning trap (PT) are obtained from the current the oscillating particle induces in the trap electrodes, amplified e.g., by means of a tuned circuit operated at liquid-helium temperature. This detection method has been successfully implemented at several laboratories, yielding outstanding results, but with the highest sensitivity limited to particles with low or medium mass-to-charge ratios. With the primary goal of extending the applicability of PT mass spectrometry to any (single) ion, and make practicable for example PT measurements on SuperHeavy Elements produced in fusion-evaporation reactions, we are developing a method consisting in replacing the tuned circuit by a laser-cooled $^{40}Ca^{+}$ (sensor) ion stored in an adjacent trap. After probing an eigenfrequency of the ion of interest, this will be coupled to the sensor ion hold in vacuum at mK temperatures, the emitted photons will be collected, and the analysis of the distribution will allow determining the eigenfrequency. In this contribution, I will show the layout of the TRAPSENSOR facility built in Granada, and the outcomes from a series of developments and experiments, like the construction of the first micro-PT mass spectrometer, and the detailed characterization of the sensor ion used as high-sensitive detector. I will finish the talk discussing on-going experiments in Granada and the medium-term prospects.

MS 2.2 Mon 17:30 RW 2

A Cryogenic Single Nanoparticle Mass and IR Spectrometer — •Tim K. Esser and Knut R. Asmis — Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie, Universität Leipzig, Linnestrasse 2, D-04103 Leipzig, Germany

Nanoparticles play an increasingly important role for the development of new materials e.g. for electrotechnology, catalysis and medicine. These particles exist in the atmosphere and participate in the formation of cloud condensation nuclei which directly impact the climate. Despite the environmental relevance, many of their properties are still not well understood. Here, we describe a cryogenic mass and infrared (IR) spectrometer to investigate the surface structure and chemistry of a single nanoparticle. The nanoparticle is confined in a quadrupole ion trap and oscillates with a frequency characteristic for its mass-to-charge (m/z) ratio. Optical detection of this frequency enables mass assignment with ppm resolution. The setup can monitor the mass variation of a single nanoparticle, as a function of temperature (10-350 K), background gas and interaction with light, over several days. IR spectra will be obtained and compared to data from solids and gas phase clusters.

MS 2.3 Mon 17:45 RW 2

Production of Highly Charged Ho-163 Ions in a Room Temperature Electron Beam Ion Trap — •Christoph Schweiger[1], Rima X. Schüssler[1], Alexander Rischka[1], Peter Micke[1,2], José R. Crespo López-Urrutia[1], Pavel Filianin[1], Sergey Eliseev[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]QUEST Institute for Experimental Quantum Metrology, 38116 Braunschweig

The ECHo experiment [1] aims to determine an upper limit of the electron neutrino mass in the sub-eV range by a calorimetric measurement of the de-excitation spectrum of Dy-163 following the electron capture process in Ho-163. As a consistency check the Q-value of this process will be measured as the mass difference of Ho-163 and Dy-163 with the high-precision Penning-trap mass spectrometer PENTATRAP [2] aiming for a relative mass uncertainty of 10^{-11}. At this level of precision highly charged ions have to be used and an efficient way for their production is the use of an electron beam ion trap (EBIT). Given an available Ho-163 sample size of less than 10^{13} atoms, the wire probe technique [3] will be applied for their precise injection into the trapping volume of a compact room temperature EBIT. In the talk the current status concerning setup, characterisation and measurements of the EBIT and the wire probe will be presented.

[1] Gastaldo, L. et al.. J. Low Temp. Phys. 176, 876 (2014)
[2] Repp, J. et al., Appl. Phys. B 107, 983 (2012)
[3] Elliott, S.R. et al., Nucl. Instr. and Meth. B 100, 523 (1995)

MS 2.4 Mon 18:00 RW 2

Recent upgrades of the SHIPTRAP setup — •Francesca Giacoppo[1,2], Klaus Blaum[3], Michael Block[1,2,4], Stanislav Chenmarev[3,5], Premaditya Chhetri[6], Christian Droese[7], Sergey Eliseev[3], Pavel Filianin[3,8], Stefan Götz[1,2,4], Yuri Gusev[5], Fritz-Peter Hessberger[1,2], Oliver Kaleja[4], Mustapha Laatiaoui[1,2], Felix Lautenschläger[6], Steffen Lohse[2,4], Enrique Minaya Ramirez[9], Andrew Mistry[1,2], Yuri Novikov[5,8], Sebastian Raeder[1,2], Daniel Rodriguez[10], Lutz Schweikhard[7], and Peter Thirolf[11] — [1]GSI Darmstadt — [2]Helmholtz Institut Mainz — [3]MPIK Heidelberg — [4]Universität Mainz — [5]PNPI KI Gatchina — [6]TU Darmstadt — [7]Universität Greifswald — [8]SPbSU St. Petersburg — [9]IPN Orsay — [10]Universidad de Granada — [11]LMU München

Recently, the SHIPTRAP double Penning-trap system was moved to a new location on axis with the recoil separator SHIP to integrate a cryogenic buffer-gas cell for a more efficient slowing down of the fusion-evaporation products of interest. This upgrade aims at extending the groundbreaking program of direct mass spectrometry towards the superheavy elements.

In addition, a second superconducting magnet was installed at a 90^{o} angle with the existing beam line. It will be connected to the surface and laser ablation ion sources to develop the single-ion mass spectrometry technique based on the image charge detection (FT-ICR). An overview of the technical developments and the latest off-line measurements with stable nuclides will be presented in this contribution.

MS 2.5 Mon 18:15 RW 2

Recent results from the FRS Ion Catcher — •Emma Haettner and the FRS Ion Catcher Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH

The accelerator complex at GSI and in the future, FAIR, gives access to the study of short-lived nuclei. The properties, such as the mass, are difficult to predict with sufficient accuracy to e.g. identify the limits of nuclear stability or fully understand the nucleosynthesis in stars. Thus mass measurements are mandatory to improve nuclear models.

Many nuclei far from stability can be produced in fragmentation or fission reactions. For precision experiments with the FRS Ion Catcher, the nuclei are produced and separated in-flight, momentum-compressed, and slowed-down in the fragment separator (FRS) and subsequently thermalized in a cryogenic stopping cell. The ions are extracted and guided through a multi-purpose RFQ beamline followed by a multiple-reflection time-of-flight mass spectrometer (MR-ToF-MS) for mass measurements or separation. A mass resolving power in excess of 600,000, its speed and single-ion sensitivity makes the method ideal for experiments with rare short-lived nuclei.

Recent measurements with the FRS Ion Catcher demonstrate the feasibility of the experimental scheme; the access to rare short-lived nuclei, operation as an isobar/isomer separator and high precision mass measurements. The latter method of operation used also as a complementary method for unambiguous particle identification of nuclei separated in the FRS. A highlight is the first direct mass measurements of 213-Rn, 218-Rn and 217-At, all with a half-life below 40 ms.

MS 2.6 Mon 18:30 RW 2

Peak shape analysis of high resolution Multiple-Reflection Time-of-Fight Mass Spectrometer (MR-TOF-MS) data — •Sivaji Purushothaman and The FRS ION Catcher Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

At the FRS Ion Cather setup, GSI, Darmstadt, the in-flight produced and separated radioactive isotopes are thermalized in a gas stopping cell and delivered to a Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS). Due to the universal production in combination with the fast and high precision, high accuracy mass measurement capability, the FRS ion catcher setup is an ideal tool for studies of long-lived isomers (life times greater than a few milliseconds). However, the detected peak shape in MR-TOF-MS often shows symmetric and asymmetric deviations from a Gaussian form as a result of several processes,

which cannot be disentangled. In the case of overlapping peaks, the peak position and the area will be influenced by the underlying tails from the neighboring peaks. This is critical for many high precision measurements, for example to deduce isomeric-to-ground state ratios and to determine the excitation energy of an isomer. A new probability distribution function called hyper-Exponentially Modified Gaussian (hyper-EMG), which can model a Gaussian distribution modified with multiple exponential tails at either one or both edges is presented. The application of the new peak shape model in MR-TOF-MS data analysis is demonstrated with the isomers observed from projectile (^{211}Po) and fissions (^{133}I) fragmentation of ^{238}U.

MS 2.7 Mon 18:45 RW 2

How does the isotopic enrichment in 28Si influences the measurement uncertainty of isotope ratio MC-ICP-mass spectrometry? — •Axel Pramann and Olaf Rienitz — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

In the attempt for the re-defintion of the SI unit kilogram, the determination of the Avogadro constant N_A is one of the promising approaches using the X-ray-crystal-density XRCD method by counting silicon atoms in single-crystalline Si spheres, enriched in various degrees in 28Si [1]. One of the key parameters for the determination of N_A is the molar mass M of silicon of the spheres with lowest possible uncertainties u(M) accessible via high resolution multicollector ICP-mass spectrometry [2]. The evolution of u_rel(M) as a function of the enrichment of silicon crystals used is described (from x(28Si) = 0.922 mol/mol up to the latest extremely high enriched material with x(28Si) = 0.999 99 mol/mol). The uncertainty contributions are compared and discussed in the context of both methodological and experimental mass spectrometric improvements. In summary, the uncertainty contribution of M in N_A decreased from 60 % in 2003 down to 6 % in 2016, enabling u_rel(N_A) < 1.5 * 10-8, one of the preconditions of the refediniton of the kilogram and the mole.

[1] K. Fujii et al. Metrologia, 53, A19 (2016). [2] A. Pramann, K.-S. Lee, J. Noordmann, O. Rienitz. Metrologia, 52, 800 (2015).