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Efficient Ion Thermalization and Mass Spectrometry of (Super-)Heavy Elements at SHIPTRAP

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The quest for the *island of stability*, a region of nuclides with enhanced stability around proton and neutron numbers $Z \approx 114-126$ and $N \approx 184$, respectively, is at the forefront of nuclear physics. The survival of superheavy elements is intimately linked to nuclear shell effects, which can be experimentally probed by mass measurements. Experiments around this region are hampered by extremely low production rates of down to few ions per month. Nonetheless, the Penning-trap mass spectrometer SHIPTRAP, located at the GSI in Darmstadt, Germany, has shown that direct high-precision measurements of atomic masses of $_{102}$No and $_{103}$Lr isotopes around the deformed shell closure $N = 152$ are feasible and provide indispensable knowledge on binding energies, shell effects and yield important anchor-points on α-decay chains, affecting absolute mass values up to the heaviest elements.

To continue this groundbreaking program and to proceed towards heavier and more exotic nuclides, the drop in production rate has to be accomodated by several improvements. The Penning-trap system was recently relocated, allowing to integrate a second-generation gas-stopping cell, operating at cryogenic temperatures. Its stopping efficiency was optimized using the SRIM simulation software, and its purity was recently investigated using recoil-ion sources. In addition, the Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique was developed, increasing the sensitivity of mass measurements. To fully exploit its enhanced mass resolving power required improving the temporal stability of the electric and magnetic fields. Furthermore, its applicabilty in low-rate measurements, accumulating only few ions in total, yet had to be proven.

In the SHIPTRAP experimental campaign in summer 2018, we extended direct high-precision Penning-trap mass spectrometry into the region of the heaviest elements using the PI-ICR technique. For the first time, direct mass measurements of ^{251}No, ^{254}Lr and the superheavy nuclide ^{257}Rf were performed with rates down to one detected ion per day. Despite lowest rates the PI-ICR technique allowed resolving the isomeric states ^{251m,254m}No and ^{254m,255m}Lr from their respective ground states with mass resolving powers of up to 10.000.000 and to accurately determine their excitation energies, which had previously been derived only indirectly via decay spectroscopy.

In this contribution an overview of the technical developments and the recent results will be given.

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