Towards Radiation Detected Resonance Ionization Spectroscopy of Nobelium*

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Relativistic effects are responsible for the change in the atomic structure and thus the order of the periodic table of the heaviest elements. In addition correlations between the many electrons in the shells are crucial. Nowadays, these relativistic effects can be described by using modern Multi-Configuration-Dirac-Fock (MCDF)[2] and Relativistic Coupled-Cluster (RCC)[3] calculations. A comparison of the predicted and the measured atomic properties is needed for benchmarking these theoretical predictions. At present, no data are available on the atomic level schemes of transfermium elements as they can be experimentally investigated solely online at low production rates. Thus, the study of the atomic structure of transfermium elements, e.g. nobelium (No) and lawrencium (Lr) via Radiation Detected Resonance Ionization Spectroscopy (RADRIS)[1] belongs to one of the most fascinating and challenging problems of modern atomic physics.

Based on RADRIS, it is possible to investigate the atomic properties of these elements. After separation from the primary beam by the velocity filter SHIP [4], the fusion products enter a buffer gas cell, where they are stopped in 50 mbar argon and collected on a tantalum filament. The next step is to re-evaporate the atoms and to ionize them with tunable lasers in a two-step photoionization process. In case of resonance ionization, the such created ions are transferred to a Si-detector with which they are identified by their characteristic α-decay. An optical buffer-gas cell for this method has been commissioned during a beamtime in 2006 with the radionuclide ^{155}Yb, a chemical homologue of nobelium. During this experiment, an overall efficiency of about 0.8% was obtained [1].

Meanwhile, this buffer-gas cell has been installed permanently at GSI, including a dedicated laser cabin. Extensive off-line measurements concerning the impact of critical parameters like buffer gas pressure, filament temperature, filament geometry, laser power, and laser repetition rates on the laser resonance ionization efficiency have been performed with nat. ytterbium. Among others, the position of the atomic cloud above the filament was mapped by the RIS ion signal for different filament temperatures and buffer-gas pressures. Due to convection phenomena above the filament, the atoms of interest diffuse out of the laser beam interaction volume resulting in a decrease of the resonance ionization efficiency.

Such problems require an on-line monitoring of the RIS efficiency during envisaged RADRIS experiments on the element nobelium, which can be produced at SHIP via the reaction ^{208}Pb(^{48}Ca,2n)^{254}No at a rate of 17/s. For that purpose and for the commissioning of a new data acqusition and several digital laser control systems we have performed an online experiment on ^{155}Yb in 2012. The radio nuclide ^{155}Yb has been produced in the reaction ^{112}Sn(^{48}Ca,5n)^{155}Yb at a typical particle beam intensity of I_p= 50 nA$_P$ (3 Hz parasitic) and an estimated incoming rate of about $R \approx 180\frac{1}{s}$ in front of the entrance window. In this experiments the efficiency of the gas cell has been measured. An evaporation and RIS efficiency of $\epsilon_{Evap} \cdot \epsilon_{RIS} \approx 15\%$ was determined, similar to that obtained in Ref. [1]. From this value, the overall efficiency of the gas cell could be determined as $\epsilon^{tot} \approx 0.8\%$. Based on this performance, we are ready to search for atomic states in nobelium in future on-line experiments.

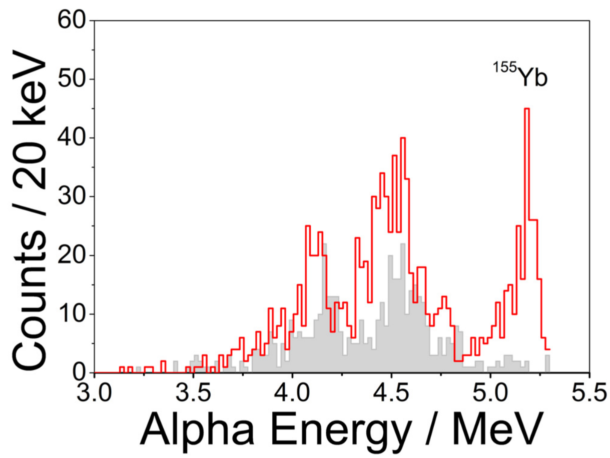

Figure 1: Two-step resonant laser ionization of ^{155}Yb. Alpha spectrum with laser on (red line) and off (black line). The measurement was performed for a buffer-gas pressure p= 60.4 mbar, filament current I$_{fil}$ = 2.6 A, laser excitation energy equivalents $\nu_1 = 25068.3$ cm^{-1}, $\nu_2 = 25026.2$ cm^{-1}, laser pulse energy P(λ_1)= 133 μJ, P(λ_2)= 242 μJ, laser repetition rate L$_{rep} = 100$ Hz, and laser beam diameter d$_{laser} = 40$ mm.

References

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