

Laser Spectroscopy of Heavy Elements at SHIPTRAP

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The aim of this project is the investigation of atomic and nuclear properties of heavy elements with charge numbers $Z \geq 100$ by laser spectroscopy. Any atomic spectroscopy, even with the most sensitive laser methods, is seriously hampered by the fact that no information on the atomic structure is available for these elements. To get acquainted with such a spectroscopy experiments were performed for the element fermium ($Z = 100$) [1]. A first experiment for the elements with $Z > 100$ is being prepared on the element nobelium with the charge number $Z = 102$. Since the production rate is only in the order of 5 ions/s and the beam projectile isotope ^{48}Ca is very expensive, the experimental method is being developed at the chemical homolog ^{155}Yb which is also α -active with a half-life $t_{1/2} = 1.75$ s. The reaction products, separated by SHIP, are stopped in a buffer gas cell in which Resonance Ionization Mass Spectroscopy (RIS) is performed with the detection of the ionization process by the α -decay [2].

A large gain factor in the efficiency can be obtained if the 85% fraction of the thermalized ions is transported to a filament from which the ions will be re-evaporated as atoms with the aid of high temperature pulses. This way, a localized atom cloud will be generated and the overlap with the laser beams can also be improved. This idea was pursued in the last year.

The improved experimental setup was tested off-line in two ways. First a mass of about 0.3 mg of the stable element Yb was electrolytically deposited on a tantalum filament. By the evaporation of Yb atoms and their subsequent laser ionization it is possible to simulate thermalized ions from SHIP in the buffer gas. Two dye laser beams, were used for resonance ionization. The first one had a wave length of $\lambda_1 = 398.912$ nm, the second of $\lambda_2 = 399.587$ nm excited a Rydberg state. By a relative comparison of the collected ion charges the efficiency of the resonance ionization process was determined to be in the order of 10^{-2} . The second testing method makes use of a radioactive ^{223}Ra source. In the decay series ^{211}Pb recoils are produced and the charged fraction is transported in the buffer gas by electrical fields on a catcher electrode. After a suitable activation time in the order of 1 hour the catcher is moved into the buffer gas cell in front of a filament. Thereafter, ^{207}Tl recoils from the α -decay of ^{211}Bi can be employed for the simulation of a particle beam. This setup was used to optimize the extraction potentials, to determine the energy shift of α -decays in the buffer gas and to measure the efficiency of the resonance ionization of ^{207}Tl . For the latter test, ^{207}Tl ions were captured on the catcher filament, re-evaporated at a temperature of about 800°C , laser ionized and extracted to a Passivated Implanted Planar Silicon (PIPS) detector which detects the β -decay of ^{207}Tl . Recoil ^{207}Tl ions, directly

transported to the detector, served as a reference to determine the resonance ionization efficiency. In good agreement with the experiments with the above described experiment using stable Yb, these measurements yielded also efficiencies in the order of 10^{-2} .

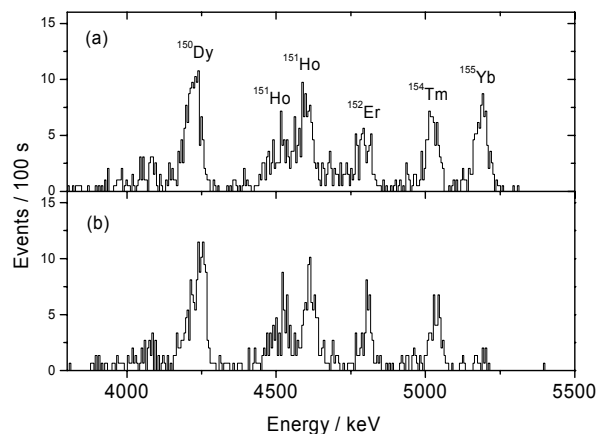


Figure 1: The α -particle spectrum with assignments of the isotopes collected on the filament. (a) at room temperature, (b) after heating up the filament for about one second to 1400°C .

An on-line test experiment with the improved setup was performed at the beginning of July, 2005 at the SHIP facility. ^{155}Yb recoil ions were produced by the reaction $^{107}\text{Ag}(^{52}\text{Cr}, p3n)^{155}\text{Yb}$ at a projectile energy of 4.57 MeV/u. The secondary ^{155}Yb recoil beam was focused into the buffer gas cell. The ions were guided in the electrical field of about 100 V/cm to the Ta-filament catcher. The isotopes on the catcher were identified by the energy of the α particles and their half-lives. For that purpose, an additional semiconductor detector was moved periodically in front of the catcher in the beam-off periods. The evaporation temperature of the collected Yb ions on the filament was determined by performing measurements with stepwise increased temperatures of the filament for which a decrease of the alpha decay rate of the ^{155}Yb isotope was observed. In figure 1 two measured α spectra are shown, (a) for a cold filament and (b) for a filament heated up to 1400°C . At the high temperature the α intensity of the ^{155}Yb isotope decreased significantly. Laser spectroscopic measurements at the Yb atoms could not be performed in the running beam time because of a short circuit of one of the electrodes in the cell.

References

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- [2] H. Backe, et. al., Phys. Rev. Lett. **80**, 920 (1998)