Optical Spectroscopy of Trans-Fermium Elements at SHIPTRAP

H. Backe[1], A. Dretzke[1], R. Horn[1], T. Kolb[1], P. Kunz[1], W. Lauth[1], P. Thörle[2], and N. Trautmann[2]
[1]Institut für Kernphysik, Universität Mainz, Germany; [2]Institut für Kernchemie, Universität Mainz, Germany

An ultra sensitive laser spectroscopic method is being developed for the investigation of the completely unknown atomic structure of the elements No and Lr. Such experiments aim in the investigation of relativistic effects. These, roughly speaking, originate from a shrinkage of the wave functions of inner shell electrons which, in turn, influence the binding energy of the valence electrons and thus the chemical properties. A direct approach to investigate relativistic effects may be to study first ionization potentials (IP) or even better, the atomic level schemes [1].

First experiments will be performed within the SHIPTRAP collaboration at No which will be produced via the fusion reaction ^{208}Pb(^{48}Ca,2n)^{254}No. The reaction products, separated by SHIP, will be stopped in a buffer gas cell in which Resonance Ionization Spectroscopy (RIS) is performed with detection of the ionization process by the α-decay of ^{254}No. The technique is similar to that developed for RIS at fission isomers [2]. The experimental setup is shown in Fig. 1. The reaction products with an energy of 40 MeV are injected into the argon buffer gas trap and stopped in the gas at an pressure of 100-300 mbar. The neutral part of about 15% will be ionized resonantly and guided by electric fields onto a detector which registers the α-decay radiation. After each detuning of the laser frequency of the first excitation step one has to wait for the decay of the accumulated ions. The symmetric construction offers the opportunity to collect on one detector ions, that are resonantly ionized while counting with the other one the activity collected at a different wavelength.

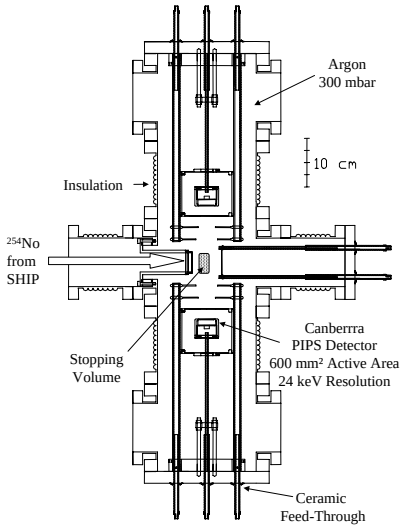

Figure 1: *Experimental set-up. The separated fusion product from SHIP is injected into a buffer gas trap. About 10% of these ions neutralize in the slowing down process and are thus available for laser spectroscopic investigations.*

A first on-line test experiment at GSI was carried through with the radioactive isotopes ^{152,153}Er (half-lives of 10.3 s and 37.1 s, α-decay) which were produced by the nuclear reaction ^{40}Ar(^{116}Sn,xn)^{152,153}Er with the relatively large reaction cross sections of about 100 mb. The atomic level scheme of erbium is well known, and this reaction thus provides an ideal test case. The longitudinal and transversal distribution of the recoils has been measured with the aid of a semiconductor strip detector. For the resonance ionization spectroscopy experiments a mixture of approx. 150 mbar Ar and approx. 40 mbar N_2 was chosen. The pressure was optimized in such a way that the stopping distribution was located in the middle of the cell, where the overlap with the laser beams (λ_1 = 472 nm, 100 μJ and λ_2 = 351 nm, 2 mJ) is maximal. A slight but significant increase of the α-events in the detector was observed. A dependency on the laser frequency λ_1 could not be observed, meaning that the ionization is a non-resonant process. A possible reason for the non-resonant low ion signal could be that erbium compounds, such as ErN, are formed.

The second on-line experiment was performed on ytterbium, the chemical homolog of nobelium. It was produced by the fusion reaction ^{40}Ca(^{118}Sn,xn)^{154,155}Yb. The gas cell was filled with 150 - 250 mbar argon. Wave lengths λ_1 = 398.9 nm and λ_2 = 399.6 nm were chosen for the first and second level, respectively. The second level is a Rydberg state, which should provide a higher efficiency as excitation into the continuum. Results of these measurements are shown in Fig. 2. Although the apparatus could be proven in this experiment to be operational, the efficiency for resonance ionization turned out to be only $2\text{-}4\cdot10^{-5}$. An increase of the efficiency by a large gain factor may be obtained if the 85% fraction of the thermalized ions are collected by and reevaporated from a filament as atoms by a high temperature pulse. The atom cloud, localized in this way, would also improve the overlap with the laser beams.

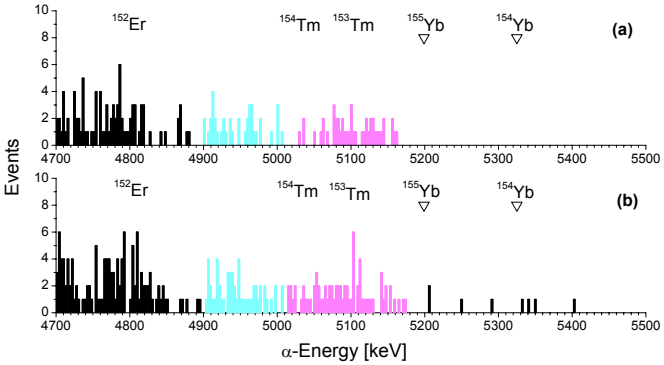

Figure 2: *Resonance ionization signals of ^{154}Yb and ^{155}Yb. (a) α-energy spectrum off-resonant and (b) at resonance ($\overline{\nu}_1$ = 25068.24 cm^{-1}, $\overline{\nu}_2$ = 25025.84 cm^{-1}). The α-lines of the ^{154,155}Yb decay are marked with $\bigtriangledown$.*

Work supported by the Bundesministerium für Bildung und Forschung under contract 06 MZ 959I.

References

[1] M. Sewtz et al., Phys. Rev. Lett. 90, 163002-1 (2003)
[2] H. Backe et al., Phys. Rev. Lett. 80, 920 (1998)