Search for atomic transitions in nobelium

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Relativistic effects influence the valence electron configuration of the heaviest elements having a big impact on their physical and chemical properties. These effects can be described using the modern multi configuration Dirac-Fock (MCDF) and Relativistic Coupled-Cluster [1, 2, 3] calculations. To have a benchmark for theoretical calculations, a comparison between the measured and predicted atomic properties is needed. At present, no spectroscopic data is available for the atomic properties of transfermium elements (Z>100). Thus the study of the atomic structure of these elements is of great interest.

In our experiments we aim to search for the atomic levels of the element nobelium based on the Radiation Detected Resonance Ionization Spectroscopy (RADRIS) [3] technique. ^{254}No can be produced at the UNILAC at GSI with rates of approximately 17/s via the reaction ^{208}Pb(^{48}Ca,2n)^{254}No. The separated fusion-product beam from SHIP is stopped in a buffer gas cell in 90 mbar argon gas of 99.9999% purity and collected on a tantalum filament. After an appropriate collection time, the accumulated ions are then re-evaporated as neutral atoms by a short heating pulse into the buffer gas, during the beam-off period. We then employ a two-step photoionization process to ionize the atoms. In case of resonant ionization, the photoions are transported by suitable electric fields to a particle detector (PIPS detector) where they are identified by their characteristic α-decay.

Laser light for the first excitation-step, from four tunable dye lasers (Lambda Physik, FL series) and an optical parametric oscillator (OPO) (GWU, SFM housing) system, is transported to the experimental setup using UV-fibers. The dye lasers-operated in the UV-range, were pumped by two excimer lasers (Lambda Physik, LPX 210i and EMG104MSC) at 248 nm. The OPO pumped by a frequency-tripled Nd:YAG (Continuum, Precision II) laser, was operated in a frequency mixing mode, delivering light in the range below 400 nm. The 351 nm-light for the second non-resonant step was provided by a high power excimer laser (Lambda Physik, LPX220) and was transported to the experimental setup by high reflectivity UV-mirrors. The wavelengths of the dye lasers and the OPO-system were monitored by wavemeter capable of measuring wavenumbers with a precision of 0.01 cm^{-1}. LabView based software was designed, for experiment control and data acquisition.

Preceding the measurements in nobelium, the cell efficiency was determined using ytterbium, which is the chemical homologue of nobelium. The radionuclide of interest ^{155}Yb was produced by the fusion reaction ^{112}Sn(^{48}Ca,5n)^{155}Yb with a beam intensity of I_p =360 nA$_p$ and a production rate of about 9000/s. A dye laser was set to a wavelength corresponding to the $^1S_0 \rightarrow {}^1P_1$ transition in ytterbium at 25068.5 cm^{-1}. The second non-resonant step was provided by the excimer laser as mentioned before. The resulting alpha spectrum can be seen in Fig.1. A cell efficiency of ϵ^{tot}=1.2% with a selectivity of about 100 has been determined from the data shown in Fig.1. In the second part of the experiment, the search for the $^1P_1$ level in ^{254}No was performed. Theories predict this level to be at about 30300 cm^{-1} [2, 3]. Three dye lasers scanned a range from 28900 cm^{-1} - 30500 cm^{-1} and the OPO-system scanned from 30500 cm^{-1} - 33000 cm^{-1} . A measurement time of 50 s was chosen per step with a step size of 1 cm^{-1}. The data analysis is in progress.

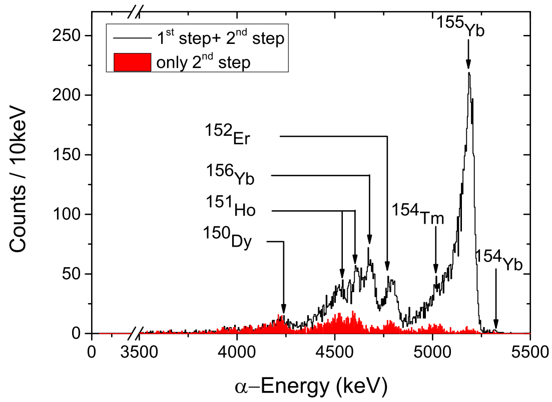

Figure 1: Two step photo-ionization of ^{155}Yb. Alpha spectrum with lasers on (black line) and laser off (red filled area). The measurement was performed at a buffer-gas pressure of 90 mbar, filament temperature of 1175°C, laser excitation energy $\bar{\nu_1}$ = 25068.5 cm^{-1}, $\bar{\nu_2}$ = 28490.03 cm^{-1} with laser pulse energy $E_{\bar{\nu_1}}$=163 μJ and $E_{\bar{\nu_2}}$= 60mJ and laser repetition rate of 100Hz.

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References

[1] S. Fritzsche, Eur. Phys. J. D **33**, 15 (2005)

[2] V. Dzuba et al., Phys. Rev. A **90**, 012504 (20114)

[3] A. Borschevsky et al., Phys. Rev. A **75**, 042514 (2007)

[4] H. Backe et al., Eur. Phys. J. D **45**, 99 (2007)

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