Status Report on Optical Spectroscopy at Nobelium (Z=102) ◇

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First laser spectroscopic investigations of the atomic level scheme of Nobelium (Z=102) are prepared at the MLL tandem accelerator facility.

Deviations from the periodicity in the atomic shell structure may be caused by relativistic effects which gain in particular importance for the heaviest elements in the region beyond $Z = 100$. A critical test of theoretically predicted relativistic effects would be to compare first ionization potentials and the atomic level schemes [1] of the heaviest elements [2] with modern Multi-Configuration-Dirac-Fock (MCDF) or Coupled- Cluster calculations and other methods [3,4,5]. However, the required experimental methods have to be sensitive enough to explore atomic (and perhaps also nuclear) properties of trans-einsteinium elements even at very low production rates, short lifetimes and the complete lack of information on atomic excitation schemes.

A novel method [6] has been developed to probe the totally unknown atomic level scheme of nobelium which is produced at the UNILAC accelerator of GSI. Using the reaction ^{208}Pb(^{48}Ca,2n), the isotope ^{254}No is produced with a rate of 17/s. The fusion reaction products are separated from the primary beam using the velocity filter SHIP and are stopped inside a buffer gas cell at an argon pressure of 60 mbar. The ions are transported continuously by electrical fields on a small catcher filament opposite to the entrance window, see Fig. 1. Here, they are adsorbed and after an appropriate collection time re-evaporated as atoms by a short heating pulse into the buffer gas, where they can be resonantly ionized by laser beams. Subsequently the ions are guided by electrical fields onto the particle detector with which the resonance ionization is identified by the α decay. In a first experiment the $5f^{14}7s7p\ ^1P_1$ level of nobelium was sought for with three laser systems: The wavenumber range from 25800 cm^{-1} to 28300 cm^{-1} was scanned with two excimer laser-pumped dye lasers and the wavenumber range from 28000 cm^{-1} to 30800 cm^{-1} was scanned with a frequency doubled Nd:YAG laser pumped OPO system. The efficiency of 0.8% should have been sufficient to detect the transition predicted by MCDF and RCC calculations. Still, no transition was observed during the 54 h scanning period. A possible reason may have been a drop in the detection efficiency due to buffer gas impurities which was not monitored during the whole experiment.

With the aim to monitor and to increase the detection efficiency the setup has been installed at the MLL-tandem accelerator and first test experiments have been performed at ^{155}Yb. The isotope ^{155}Yb which is an α emitter ($t_{1/2} = 1.65$ s, $E_\alpha = 5.2$ Mev) was produced via the reaction ^{144}Sm (^{16}O,5n)^{155}Yb. The reaction cross section amounts to 33 mbarn at the beam energy $E_{Lab} = 117$ MeV. Using a $^{16}O^{8+}$ beam which is available at an current of 15 pnA, the production rate amounts to $2 \cdot \dot{p} = 10^5$/s. Since no kinetic recoil separator is available at the MLL a concept was followed which was developed by G. Sprouse et al. [7]: The primary beam was blocked in front of the buffer gas cell with a beam stop of 10 mm diameter. Still, a fraction of 0.7 of the fusion reaction products passed around the beam stop due to larger scattering angles. The ^{155}Yb ions were stopped between window and filament during an beam-on-period of 2 s and extracted to the filament with an electrical field of ≈ 100 V/cm field strength.

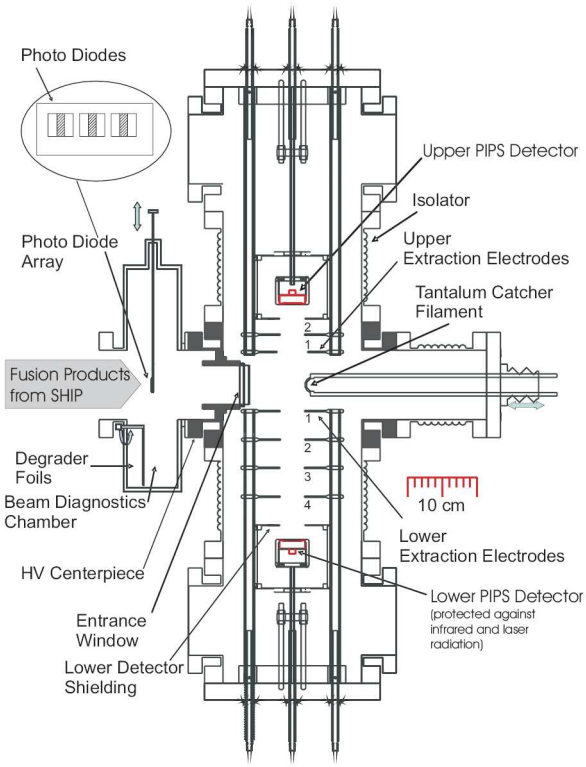

Fig. 1: Optical buffer gas cell for RIS on a fusion product beam from SHIP. The high vacuum of the SHIP beamline and the buffer gas volume are separated by a thin Mylar entrance window.

Spectra were recorded before and after re-evaporation from the filament at 1300-1400°C. The isotope ^{155}Yb was identified by it's half-lifetime of 1.65 s and it's decay energy of 5.2 MeV. In a next step resonance ionization of the re-evaporated ytterbium atoms is envisaged via a two step excitation. The $4f^{14}6s6p\ ^1P_1$ level of Yb will be excited with a tunable dye laser at the wavelength of 398.912 nm. Subsequently, using a second dye laser at 399.587 nm, a Rydberg state will be populated from which ionization occurs in buffer gas collisions.

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