Laser Spectroscopy with Trans-Einsteinium Elements

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Fermium (Z=100) is the first heavy element for which no atomic data at all are presently known. An ultrasensitive laser spectroscopic method is being developed for the investigation of the atomic structure of such elements. The method is based on Resonance Ionization Spectroscopy (RIS) in a buffer gas cell with detection of the ionization products by the Ion-Guide-Quadrupole-Mass-Separation (IGQMS) technique. The basic principles of the method are described in ref.[1]. The experimental set-up, as installed at the MP-tandem accelerator facility in Heidelberg, can be found in a previous annual report [2]. Fermium will be produced by the ^{249}Cf(α,2n)^{251}Fm nuclear reaction. Since production and handling of the radioactive ^{249}Cf target is rather difficult, the experimental procedure has been tested by the reaction ^{161}Dy(α,2n)^{163}Er, leading to erbium, the chemical homologue of fermium. The report includes also results from an off-line experiment with a ^{255}Fm sample of 10 pg.

Test Experiments with Erbium

Resonance Ionization has been performed with the neutralized fraction of erbium produced in the ^{161}Dy(α,2n)^{163}Er reaction. The α-particle energy was 28 MeV. An 80% enriched ^{161}Dy target with $\rho d = 200\ \mu g/cm^2$ was located inside the buffer gas cell in such a manner that the erbium ions, recoiling out the target, were stopped in a domain illuminated by two laser beams from an excimer-dye-laser combination. The total efficiency ε of the system, as defined by the ratio of the mean count rate of the channeltron detector $\dot{N}$ to the production rate $\dot{P}$, was determined to be $\varepsilon = \dot{N}/\dot{P} = 1 \cdot 10^{-4}$. The quantity $\dot{P} = 5 \cdot 10^5$/s was estimated with the saturation thickness of the target of $\rho d_{eff} = 137\ \mu g/cm^2$ and the mean beam current of $\bar{I}_\alpha =$ 160 pnA. Without further improvements of the efficiency the search for atomic levels by this method is rather difficult. Therefore, an alternative experimental method has been pursued in which the ^{251}Fm ($t_{1/2}$ = 5.3 h) recoil ions will first be implanted into a catcher foil and subsequently re-evaporated from the foil into the buffer gas cell. The latter procedure was tested with a small sample of ^{255}Fm ($t_{1/2}$ = 20.1 h) which was made available to us by DOE via ORNL. This experiment is described in the following.

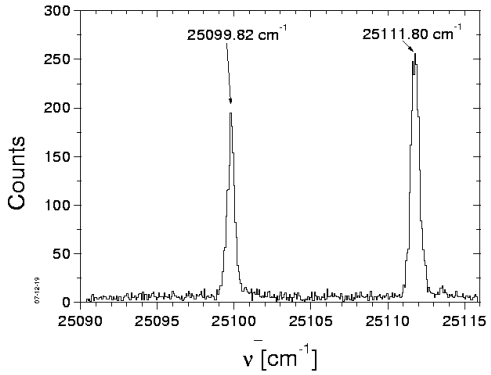


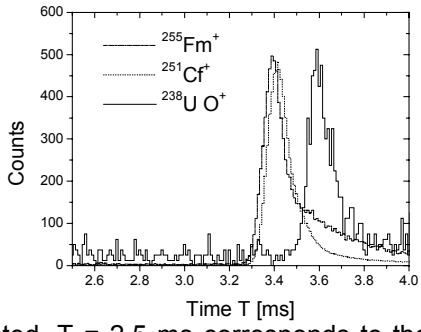
Fig.1: Wave number scan of the dye laser at mass number A=255 with a ^{255}Fm sample.

First Observation of Optical Transitions in Fermium

About 1 ng ^{255}Fm with a half-life of 20.1 h was prepared at ORNL, Oak Ridge, USA, by milking from ^{255}Es produced in the High Flux Isotope Reactor (HFIR) and shipped to Mainz. Here a fraction of $2.7 \cdot 10^{10}$ atoms was electrodeposited on a Ta filament and covered with 1 μm Ti. From this filament, the Fm atoms were evaporated at a temperature of about 1000 °C in the buffer gas of the optical cell [1] and resonantly ionized with two beams of an excimer- dye-laser combination running with XeF at wavelengths of 351/353 nm. The resulting ions were identified by mass selective detection employing the Ion-Guide-Quadrupole-Mass Separation (IGQMS) technique [1]. Two resonant transitions were found at energies of 25100 cm^{-1} and 25112 cm^{-1}, see Fig. 1.

The time distribution of the ions, as detected with a channeltron detector behind the QMS, is shown in Fig. 2. The shift of the peaks reflects changes of the mobility of the ions in the argon buffer gas. It contains information about the ion radii.

Fig.2. Time distribution of mass selected ions as indicated. T = 2.5 ms corresponds to the laser trigger. Note that the ions are transported in the buffer gas by electric fields towards the nozzle [1].



[1] H. Backe et al., Nucl. Instr. Meth. Phys. Res. **B 126**, 406 (1997)

[2] H. Backe et al., Jahresbericht 1999 IKMz **2000-1**, 4 (2000)