LASER SPECTROSCOPY IN THE $Z < 82$ REGION

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Abstract

The nuclei with $Z < 82$ and $N \approx 104$ have attracted considerable attention during the last years following the observation of a sudden change of the nuclear deformation in the light Hg isotopes by optical spectroscopy^{1,2}. In the meantime systematic measurements have been performed in the mass range $181 \leq A \leq 206$. An update of the existing information has been published recently³.

Similar data on properties of nuclear ground and isomeric states of neighbouring elements are of interest in order to study the influence of pairing and shell effects. Hence we started a program to investigate neutron-deficient Au isotopes at the on-line isotope separator ISOLDE/CERN.

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Fig.1: Changes of mean-square charge radii of Hg (left scale, squares) and Au isotopes (right scale, dots).

Several techniques were tested and their detection efficiencies determined. These are polarization spectroscopy⁴, fluorescence spectroscopy⁵, two-photon spectroscopy⁶, resonance ionization mass spectroscopy (RIMS)⁷ and a combination of RIMS with pulsed-laser induced desorption⁸. Data on the hyperfine structure and isotope shift could be obtained^{4,5,7} for the Au isotopes in the mass range $185 \leq A \leq 197$. The resulting changes in the nuclear charge radii are shown in Fig. 1 together with the data of Hg³. An onset of strong deformation is observed at ¹⁸⁶Au which continues for ¹⁸⁸Au in contrast to the situation in Hg. The stabilization of strongly deformed (prolate) nuclear shape is attributed to the down-sloping $\pi 1h_{9/2}$ intruder state.

An extension of the investigations to still more neutron-deficient Au isotopes requires a drastic increase in detection efficiency at low background. In the case of the RIMS experiments⁷, the ISOLDE Hg beam was implanted into an oven. A continuous thermal atomic beam was formed by heating the oven after a suitable delay in order to let the Hg nuclei decay to the Au daughter isotope. The Au atoms were ionized by stepwise, resonant excitation with pulsed dye laser beams via intermediate atomic levels into the continuum. The ions resulting were detected mass-selectively by time-of-flight (TOF) spectroscopy. In resonance one Au ion was detected per 10^8 atoms implanted into the oven at a background event rate of 1 per 1000 laser shots.

The main reason for the low detection efficiency of $\epsilon = 10^{-8}$ is the mismatch between the continuous evaporation of the Au atoms and low repetition rate of a high-power, pulsed laser system: A duty cycle of only 10^{-4} is calculated for the interaction of a continuous

Fig.2: Experimental setup for pulsed-laser induced desorption and resonance ionization mass spectroscopy. The potentials are $U_0 = 0$ V, $U_1 = 2.6$ kV, $U_2 = 2.4$ kV and $U_3 = -2$ kV.

Fig.3: Part of the time-of-flight signal in case of resonance ionization mass spectroscopy of $5 \cdot 10^9$ atoms of ^{195}Au ($T_{1/2} = 183$ d) implanted at 60 keV into graphite.

thermal atomic beam with the laser beams (diameter $d = 1$ cm) of a pulsed dye laser system, pumped by a Nd:Yag laser (repetition rate $\nu_{\text{rep}} = 10$ Hz).

We could increase the detection efficiency to $\epsilon = 10^{-5}$ by producing a pulsed thermal atomic beam^{8,9}. A second Nd:Yag laser was used in order to desorb ^{196}Au ($T_{1/2} = 183$ d) implanted at ISOLDE as ^{196}Hg into graphite (Fig. 2). When the desorbed atoms reached the region of interaction with the laser beams used for resonance ionization, the bunch of atoms was probed by these lasers, and the resulting ions were detected in the same way as before⁷. Fig. 3 shows part of a TOF spectrum in case of a sample with $5 \cdot 10^9$ implanted atoms of ^{195}Au . The large peak at mass $A = 197$ is due to stable ^{197}Au , and the small one at $41.3 \mu\text{s}$ is most probably due to ^{181}Ta . Both elements are present as impurities in the target material. About 60% of the implanted activity could be released by pulsed-laser induced desorption. As in the RIMS experiment the background was as low as 1 event per 1000 laser shots. Hence, optical investigation of isotopes with $A < 185$ and other refractive elements seems to be in reach.

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