OBSERVATION OF STRONGLY DEFORMED
GROUND–STATE CONFIGURATIONS
IN $^{184}\text{Au}$ AND $^{183}\text{Au}$ BY LASER SPECTROSCOPY

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Observation of Strongly Deformed Ground-State Configurations in $^{184}$Au and $^{183}$Au by Laser Spectroscopy

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Abstract: Resonance ionization mass spectroscopy (RIMS) and pulsed-laser induced desorption (PLID) have been combined in order to study the isotope shift (IS) and hyperfine structure (HFS) of $^{184}$Au ($T_{1/2} = 53$ s) and $^{183}$Au ($T_{1/2} = 42$ s) in the $6s^2S_{1/2} \rightarrow 6p^2P_{1/2}$ ($\lambda = 267$ nm) transition. The Au isotopes were obtained as daughters in the decay of $^{184,185}$Hg produced and mass separated at the new ISOLDE-3 facility at CERN. It was found that the strong deformation $\beta_2 \approx 0.25$ setting in at $^{185}$Au persists down to $^{183}$Au.

Introduction: The discovery of a huge change in the IS, i.e. in the mean-square charge radius $<r^2>$, between $^{187}$Hg and $^{190}$Hg [1], its interpretation as an onset of strong deformation [1], and the observation of a drastic odd-even staggering of the IS for $A \leq 186$ [2] stimulated considerable interest in these so called transitional nuclei, located near a closed proton, but in the middle of a neutron shell. In a preceding experiment [3,4] we applied RIMS to the neighbouring Au isotopes in the mass range $197 \geq A \geq 185$. Similar to the case of the neutron-deficient Hg isotopes, a drastic change in $<r^2>$ was observed. However, this shape transition is restricted to the isotope pair $^{187,186}$Au. Obviously, the intruding $h_{9/2}$ proton is stabilizing the strongly deformed prolate shape in $^{186}$Au and $^{185}$Au.

Experimental Set-up and Measurements: In order to study the nuclear shape of still lighter Au isotopes, the detection efficiency of our experimental set-up had to be increased significantly. This could be achieved by applying PLID in order to produce a pulsed atomic Au beam [5] instead of the continuous one used earlier [3,4]. Fig. 1 shows the apparatus for on-line RIMS-PLID at the new isotope separator ISOLDE-3 at CERN. The mass-separated Hg$^+$ beam was focused onto a wheel made of graphite. After a suitable time for the decay of Hg into Au the wheel was turned by 180°. Subsequently the implanted atoms were evaporated by the 10 ns, 200 mJ/cm$^2$ pulses of a Nd:Yag laser ($\lambda = 532$ nm). The atoms desorbed in a bunch were ionized via a three-colour, three-step resonant excitation ($\lambda_1 = 267$ nm, $\lambda_2 = 407$ nm, $\lambda_3 = 532$ nm) by
Figure 2: Changes of the mean-square charge radii in the ground state of Au nuclei relative to the stable isotope $^{197}$Au. The errors are less than the size of the symbols. Data from this work and Ref. 3 are marked by dots. The data indicated by squares are taken from Ref. 7. In case of $^{184}$Au the error bar represents the uncertainty due to the unknown nuclear spin.

the light pulses of three tunable dye lasers pumped by a second Nd:YAG laser. The latter was synchronized with the desorption laser. As in the previous experiment [3,4] the photo ions were detected mass-selectively by time-of-flight spectroscopy. The detection efficiency could be increased by three orders of magnitude compared to the continuous evaporation of Au atoms. Since the number of atoms accumulated on the wheel (given approximately by the product of production yield and half life) drops below $A = 185$ by a factor of about 20 per each neutron taken away, two lighter isotopes, $^{184}$Au and $^{183}$Au, could be investigated. A signal-to-background ratio as high as 20 was obtained even at a beam current of $10^8$ $^{192}$Hg$^+$ ions per second.

Results: The observed HFS and IS in the D$_1$ line ($\lambda = 267$ nm) were evaluated as in Refs. [3,4]. Since the spin of $^{184}$Au is not known, the nuclear magnetic moment can only be $\mu_I(184\text{Au}) = 1.813(19) \cdot I/(I+\frac{1}{2}) \mu_N$, $I \geq 3$. Lower spin values can be excluded by the measured intensity ratios of the HFS components in the optical transition. Assuming $I=3$ we obtain from the IS a value of $\delta < r^2 > ^{184,197} = -0.137(7)$ fm$^2$ which approaches $\delta < r^2 > ^{184,197} = -0.22$ fm$^2$ for very high spin values.

With I ($^{182}$Au) = 5/2 [6] the corresponding values for $^{194}$Au are: $\mu_I = +1.972(23) \mu_N$ and $\delta < r^2 > ^{184,197} = -0.130(9)$ fm$^2$. The $\delta < r^2 >$ values of the Au isotopes are shown in Fig. 2. Regardless of the uncertainty due to the unknown spin of $^{184}$Au, obviously both $^{184}$Au and $^{183}$Au maintain the strong prolate deformation of $\beta_2 \approx 0.25$ observed also for the two neighbouring heavier isotopes. The reason for this behaviour are the energetically almost degenerate oblate and prolate configurations in the Hg-Pt region [4] and the strong polarising power towards prolate deformation of the intruding Hg/2 valence proton in Au.

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References


