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Nuclear shape evolution in the lead region around the neutron midshell (N = 104)

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Modern laser spectroscopy techniques have sufficient sensitivity to measure extremely small shifts in the energy of the atomic electron levels, arising from changes in the charge distribution of the nucleus. For a given isotopic chain, this effect, known as the isotope shift (IS), arises due to changes in the nuclear mass and size. The change in mean-square charge radius ($\delta\langle r^2\rangle$) can be extracted from the IS in a nuclear-model independent way. Moreover, spin, magnetic dipole and electric quadrupole moments can be deduced from the hyperfine splitting of optical lines. The superior efficiency of the laser spectroscopy paves the way to investigation of the most exotic nuclei far from stability. The laser spectroscopy is therefore a powerful tool of probing the nuclear ground states and isomers that enable to obtain important information about shape evolution and shape coexistence in different regions of the nuclide chart.

The neutron-deficient isotopes in the lead region (Z = 82) exhibit striking variety of nuclear shape evolution phenomena. During the last decade, our collaboration at the ISOLDE facility in CERN performed extensive and successful laser and nuclear-spectroscopic studies of the long chains of the Hg (Z = 80) [1], Tl (Z = 81), Pb, Bi (Z = 83) [2] and Au (Z = 79) [3] isotopes. Developed in PNPI the method of the in-source resonance ionization spectroscopy proves to be the most efficient among the laser spectroscopy techniques. It gives the possibility to study the isotopes with production rate in the target less than 1 ion in 100 s.

Our recent in-source spectroscopy studies have shown that the gold, mercury, and bismuth chains display dramatic changes in ground-state deformation near the neutron mid-shell at N = 104. The observed jumps in $\delta\langle r^2\rangle$ indicate sudden transitions from near-spherical to strongly deformed configurations. At the same time, the patterns of nuclear shape evolution for these elements prove to be very different.

The experimental results for gold and bismuth nuclei are compared to mean-field calculations. The calculations reproduce the unusual behavior of $\delta\langle r^2\rangle$ quite well only when the nuclear ground states are chosen in accordance with experimental spin and magnetic moments rather than the energy of the corresponding levels. The general applicability of our approach was also investigated by performing calculations for neutron-deficient nuclei from mercury to astatine (Z = 85).

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