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Laser spectroscopy of the heaviest elements

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While nuclear shell effects are responsible for the existence of the heaviest elements, their atomic structure is strongly influenced by relativistic effects that lead to different atomic and chemical properties than their lighter homologs. Here, laser spectroscopy is a powerful tool for revealing fundamental atomic and also nuclear properties, which are reflected as subtle changes in the atomic transitions studied. The general lack of atomic information on the heavy elements, the low production rates and the relatively short half-lives make experimental investigations a challenge and require very sensitive experimental techniques.

Laser spectroscopy of heavy nobelium isotopes (No, Z=102) produced in accelerators in atom-at-a-time quantities became accessible through the pioneering experiment with the RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique coupled to the SHIP velocity filter at GSI in Darmstadt. With additional developments of the setup, the range of the method was extended to ^{251,255}No and for the first time also to on-line produced fermium isotopes (Fm, Z=100). These online experiments are complemented by off-line laser spectroscopy measurements at the RISIKO mass separator of the University of Mainz on reactor-grown heavy actinides with suitable long lifetimes. Hot cavity laser spectroscopy on radiochemically purified samples enabled the investigation of isotopes of the heavy actinides curium, californium, einsteinium and fermium. These experimental efforts are accompanied by improvements in theoretical atomic calculations, which are essential for determining the properties of the nuclear ground state from the extracted atomic observables of isotopic shifts and hyperfine structure parameters. The combination of results from different fields of research provides an insight into the special nuclear nature of the heaviest elements. The results obtained are discussed with respect to the predictions of nuclear theory and the perspectives for laser spectroscopic investigations in even heavier systems.

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