The Thorium Isomer ^{229m}Th: From the Atomic to the Nuclear Clock

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In recent years the possibility to realize a so-called Nuclear Clock has attracted increasing attention, as today's most precise timekeeping devices, based on optical atomic clocks, could be challenged in performance by a nuclear clock, based on a nuclear transition instead of an atomic shell transition.

Such a nuclear clock promises intriguing applications in applied as well as fundamental physics, ranging from geodesy and seismology to the investigation of possible time varia-tions of fundamental constants and the search for Dark Matter [1, 2]. Only one nuclear state is known so far that could drive a nuclear clock: the 'Thorium Isomer ^{229m}Th', i.e. the isomeric first excited state of ^{229}Th, representing the lowest nuclear excitation so far reported in the whole landscape of nuclear isotopes. Since its first direct detection in 2016 [3], considerable progress could be achieved in characterizing the properties and decay parameters of this elusive nuclear excitation: the half-life of the neutral isomer was determined [4], the hyperfine structure was measured via collinear laser spectroscopy, providing information on nuclear moments and the nuclear charge radius [5] and also the excitation energy of the isomer could be directly determined 8.28(17) eV [6]. In a recent experiment at CERN's ISOLDE facility, the long-sought radiative decay of the Thorium isomer could be observed for the first time via implantation of (β-decaying) ^{229}Ac into a VUV transparent crystal and subsequent fluorescence detection in a VUV spectrometer. Thus, the excitation energy of ^{229m}Th could be determined with unprecedented precision to 8.338(24) eV, corresponding to a wavelength of 148.71(42) nm [7]. Moreover, the observation of the radiative decay lays the foundation for a future solid-state based nuclear clock as a promising alternative to an ion-trap based configuration.

This recent breakthrough opens the door towards a laser-driven control of the isomeric transition and thus to the development of an ultra-precise nuclear frequency standard. The talk will review the present status together with recently completed, ongoing and planned activities towards the realization of a first nuclear clock.

References

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