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The elusive 229-Thorium isomer: On the road towards a nuclear clock

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Today's most precise time and frequency measurements are performed with optical atomic clocks. However, it has been proposed that they could potentially be outperformed by a nuclear clock, which employs a nuclear transition instead of an atomic shell transition. There is only one known nuclear state that could serve as a nuclear frequency standard using currently available technology, namely, the isomeric first excited state of 229Th. Since more than 40 years nuclear physicists have targeted the identification and characterization of the elusive isomeric ground state transition of 229mTh. Evidence for its existence until recently could only be inferred from indirect measurements, suggesting an excitation energy of 7.8(5) eV. Thus the first excited state in 229Th represents the lowest nuclear excitation so far reported in the whole landscape of known isotopes. Recently, the first direct detection of this nuclear state could be realized via its internal conversion decay branch [1], which confirms the isomer's existence and lays the foundation for precise studies of its properties. Subsequently, the half-life of neutral 229mTh could be measured [2] and its hyperfine structure was resolved via collinear laser spectroscopy [3]. An optical excitation scheme based on existing laser technology [4] as well as a measurement scheme for the isomeric excitation energy [5] have been developed. This would pave the way towards an all-optical control and thus the development of an ultra-precise nuclear frequency standard. Moreover, a nuclear clock promises intriguing applications in applied as well as fundamental physics, ranging from geodesy and seismology to the investigation of possible time variations of fundamental constants.

[1] L. v.d. Wense et al., Nature 533, 47-51 (2016).
[2] B. Seiferle, L. v.d. Wense, P.G. Thirolf, Phys. Rev. Lett. 118, 042501 (2017).
[3] J. Thielking et al., Nature, in press (2018).
[4] L. v.d. Wense et al., Phys. Rev. Lett. 119, 132503 (2017)
[5] B. Seiferle, L. v.d. Wense, P.G. Thirolf, Eur. Phys. Jour. A 53, 108, (2017).

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