Laser Excitation of the Thorium-229 Nucleus – Towards a Nuclear Clock

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The low-energy nuclear isomer state in Th-229 is resonantly excited in Th-doped calciumfluoride crystals using a tabletop tunable laser system at 148 nm wavelength. The experiment is performed by a cooperation of PTB and TU Wien [1].

A resonance fluorescence signal is observed in two crystals with different Th-229 dopant concentrations, while it is absent in a control experiment using Th-232. The nuclear resonance frequency for the Th^{4+} ions in Th:CaF_2 is measured with an uncertainty of 3 GHz. The fluorescence lifetime in the crystal is 630(15) s, corresponding to an isomer half-life of 1740(50) s for a nucleus isolated in vacuum.

These results pave the way towards high-resolution nuclear laser spectroscopy of Th-229, quantum nucleonics in the low-energy regime where atomic and nuclear degrees of freedom interact, and an optical nuclear clock with high sensitivity in tests of fundamental physics.

References

[1] J. Tiedau, M. V. Okhapkin, K. Zhang, J. Thielking, G. Zitzer, E. Peik, F. Schaden, T. Pronebner, I. Morawetz, L. Toscani De Col, F. Schneider, A. Leitner, M. Pressler, G. A. Kazakov, K. Beeks, T. Sikorsky, and T. Schumm, Phys. Rev. Lett. 132, 182501 (2024)