Invited talk

Nuclear laser spectroscopy of the 8.4 eV transition in Th-229

Peik E.
Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany
†ekkehard.peik@ptb.de

Recently, three experiments have obtained resonant laser excitation of a low-energy nuclear transition, from the ground state of Th-229 to its isomeric state at 8.4 eV, connected by a magnetic dipole transition with a natural linewidth in the range of 0.1 mHz. Table-top laser sources at a wavelength of 148 nm in the vacuum-ultraviolet have been used for the excitation[1]. The thorium nuclei have been prepared as dopant ions in VUV-transparent crystals like calcium fluoride. This opens a new field for experiments that connect nuclear physics with atomic physics, where a nuclear transition occurs in the energy range that is typical for transitions of atomic valence electrons. Among several possible applications, the development of an optical nuclear clock seems particularly attractive[2]. This clock would offer high accuracy, especially with laser cooled trapped Th-229 ions, high stability, because of the high number of nuclei that can be interrogated in Th-229-doped solids, and high sensitivity in clock-based tests of fundamental principles of physics, involving the strong interaction in addition to electromagnetism.

A range of activities on nuclear laser spectroscopy and towards such a clock is ongoing. I will present results of experiments at PTB using a laser system based on four-wave mixing in xenon and Th-229-doped calcium fluoride crystals grown at Technische Universität Wien, where we have recently observed a thermally activated laser-induced quenching, i.e. a shortening of the isomer lifetime under nonresonant laser radiation[3]. In an experiment with laser cooled $^{229}\mathrm{Th}^{3+}$ recoil ions from the α-decay of U-233 we have studied the hyperfine structure to obtain information on nuclear properties like the magnetic moment and the charge distribution[4].

[1] J. Tiedau *et al.*, *Phys. Rev. Lett.* **132**, 182501 (2024).
[2] K. Beeks, T. Sikorsky, T. Schumm, J. Thielking, M. V. Okhapkin, E. Peik, *Nature Reviews Phys.* **3**, 238 (2021).
[3] F. Schaden *et al.*, *arXiv:2412.12339* (2024).
[4] G. Zitzer, J. Tiedau, Ch. E. Düllmann, M. V. Okhapkin, E. Peik, *arXiv:2504.00974* (2025).