Towards laser excitation of the nuclear clock isomer ^{229m}Th

Johannes Thielking, Maksim V. Okhapkin, Ke Zhang, Johannes Tiedau, Gregor Zitzer, Ekkehard Peik
Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

The transition of the ^{229}Th nucleus between its ground state and its uniquely low-lying isomer at about 8 eV ($\approx$ 150 nm wavelength) has been proposed as a frequency reference for a highly precise type of optical clock [1]. Such a nuclear optical clock would be highly immune to field-induced frequency shifts and is expected to be a sensitive probe of temporal variations of fundamental constants. Although several advances have been made in determining the transition energy and nuclear properties [2], its direct optical excitation is still pending.

To this end, we are currently developing a vacuum ultraviolet (VUV) laser system based on resonance enhanced four-wave mixing in xenon. The mixing process is driven by two pulsed dye laser amplifiers with a pulse duration of 10 ns. The amplifiers are seeded with cw ring lasers to achieve a Fourier transform limited linewidth. The laser system provides VUV pulses with photon numbers of about 10^{13} per pulse and a broad tunability that covers the current uncertainty range of the nuclear excitation energy. In these experiments, we will use hyperfine spectroscopy as a sensitive double resonance detection method for the isomeric state [1, 3].

We will report on the current status of the laser development, as well as future experiments to excite the isomeric state in trapped ions and a Th-doped crystal.

[1] E. Peik, Chr. Tamm, *Europhys. Lett.* **61**, 181 (2003).
[2] K. Beeks et al., *Nature Reviews Physics* **3**, 238-248 (2021).
[3] J. Thielking et al., *Nature* **556**, 321-325 (2018).