PHYSIKALISCHES KOLLOQUIUM

Wintersemester 2026/27

Das Kolloquium findet (soweit nicht anders angegeben) **jeweils montags um 14:15 Uhr im Röntgen-Hörsaal** des Physikalischen Instituts, Hubland Campus Süd, Universität Würzburg **und online via Zoom statt**.
Zugangsdaten siehe https://www.physik.uni-wuerzburg.de/aktuelles/veranstaltungen-aus-der-physik/physikalisches-kolloquium/

23.11.2026

Prof. Dr. Peter Thirolf
Ludwig-Maximilians-Universität München, Fakultät für Physik

The Heartbeat of the Nucleus: The Dawn of Nuclear Timekeeping

Abstract

The quest for an optical nuclear frequency standard, the 'nuclear clock' based on the elusive and uniquely low-energetic 'thorium isomer' ^{229m}Th, has increasingly triggered experimental and theoretical research activities in numerous groups worldwide in the last decade. Today's most precise timekeeping is based on optical atomic clocks. However, those could potentially be outperformed by a nuclear clock, based on a nuclear transition instead of an atomic shell transition. 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. 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 variations of fundamental constants and the search for Dark Matter [1].
After years of nuclear-spectroscopy driven identification and characterization activities of ^{229m}Th, recently seminal breakthroughs with first laser-driven excitations of the isomeric nuclear resonance in ^{229}Th could be achieved, both using intense broad-band [2,3] and VUV frequency-comb based narrow-band lasers [4], respectively. Hardly any physical observable experienced an improvement by 11 orders of magnitude within only 5 years, as it was reached for the excitation energy of the thorium isomer.
The obvious expectation of a nuclear clock prototype to appear soon was indeed realized recently, when almost simultaneously 2 groups reported on a breakthrough of realizing first working nuclear clocks based on optical excitation of ^{229m}Th and fluorescence detection in a solid-state approach using doped large-bandgap crystals [5,6], followed very recently by a third device [7].

Alternative approaches based on thin films [8] and laser-driven conversion-electron Mössbauer spectroscopy of the thorium isomer [9] also succeeded in isomer excitation, while the complementary approach using individual laser-cooled trapped ions in vacuum is still under study. The talk will review the status and perspectives of ongoing activities on realizing a high-precision nuclear frequency standard based on the thorium isomer both in the solid-state and trapped $^{229m}Th^{3+}$ ion approach.

[1] E. Peik et al., Quantum Sci. Technol. **6,** 034002 (2021)
[2] J.Tiedau et al., Phys. Rev. Lett. **132**, 182501 (2024)
[3] R. Elwell et al., Phys. Rev. Lett. **133**, 013201 (2024)
[4] Ch. Zhang et al., Nature **633**, 63-70 (2024)
[5] L. Toscani De Col et al., Nature **658**, 897 (2026)
[6] B. Huang et al., Nature **658**, 903 (2026
[7] Wang et al., arXiv 2610.10056 (2026)
[8] Ch. Zhang et al., Nature **636**, 603 (2024)
[9] R. Elwell et al., Nature **648**, 300–305 (2025

Für die Dozentinnen bzw. Dozenten der Fakultät

Prof. Dr. Trauzettel, Dr. Ünzelmann, Hr. Müller