Int. Workshop “Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects”
ed. Nikolay Minkov, Heron Press, Sofia 2026

# Laser-driven excitation schemes for the $^{229}$Th isomer

**Tobias Kirschbaum**, **Adriana Pálffy**

Julius-Maximilians-Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

## Abstract

The nucleus of $^{229}$Th has attracted great interest in recent years as a candidate for a nuclear clock with outstanding properties [1, 2]. This is related to its low excitation energy of 8.36 eV and its exceptionally long lifetime of a few $10^3$ s. In this talk, we investigate theoretically driving and quenching schemes that support the development of a nuclear clock.

Motivated by recent advances in VUV laser technology [3], the first part of this talk is devoted to the photoexcitation of the nuclear isomer using structured light [kir1]. We focus on spatial and temporal excitation patterns induced by Bessel and higher-order Gaussian modes for the magnetic dipole channel of the nuclear transition. Nuclear excitation in both solid-state targets and single ions is investigated, and the differences to plane wave driving are highlighted.

In the second part, we investigate laser-assisted internal conversion (IC) and electronic bridge (EB) schemes in the large band gap crystal $^{229}$Th:LiSrAlF$_6$. Doping-induced symmetry breaking within the pristine crystal leads to the emergence of electronic defect states around the $^{229}$Th nucleus that can facilitate processes like EB and IC [5, 6]. We find that targeted laser-assisted EB and IC schemes for nuclear deexcitation prove to be significantly more efficient than spontaneous nuclear decay. This offers promising prospects for the operation of a solid-state clock.

## References

[1] J. Tiedau et al., *Phys. Rev. Lett* **132** (2024), 182501.
[2] L. T. De Col et al., *arXiv preprint* (2026), arXiv:2606.04997.
[3] V. Lal et al., *Optica* **12** (2025), 1971-1974.
[4] T. Kirschbaum et al., *Phys. Rev. C* **110** (2024), 064326.
[5] T. Kirschbaum et al., *Phys. Rev. A* **113** (2026), 023118.
[6] H. W. T. Morgan et al., *Phys. Rev. Lett* **134** (2025), 253801.