Excitation Schemes for the Nuclear Clock Candidate ^{229}Th

T Kirschbaum[1], M Pimon[2], T Schumm[2], and A Palffy[1]

[1] *Institute for Theoretical Physics and Astrophysics, University of Würzburg, Würzburg, Germany*
[2] *Atominstitut, TU Wien, Vienna, Austria*
Contact Email: tobias.kirschbaum@physik.uni-wuerzburg.de

The thorium ^{229}Th isotope has attracted increased interest over the past few decades. This is related to its extremely low-lying first excited state at $\sim$ 8 eV with long radiative lifetime of a few 10^3 s [1]. These properties render ^{229}Th an ideal candidate for a nuclear clock with outstanding properties promising a variety of applications [2]. Just recently, the direct laser excitation of the isomeric transition has been reported [3]. However, the experimental realization of the nuclear clock remains challenging due to its relatively large uncertainty on the transition energy and the lack of narrowband VUV lasers.

Here, we investigate theoretically in the first place an approach to indirectly populate ^{229}Th's isomeric state. We consider Electronic Bridge (EB) schemes in a VUV-transparent crystal environment doped with ^{229}Th. EB involves electronic defect states which appear in the band gap due to ^{229}Th doping [4]. We present different EB schemes and the corresponding excitation rates for ^{229}Th:LiCAF.

Once a more accurate determination of the transition energy is achieved and laser technology provides narrowband VUV sources, one may proceed with resonant driving and metrology applications of ^{229}Th. To this end, we also study theoretically the interaction of ^{229}Th with structured light, in particular optical vortex beams carrying orbital angular momentum [5]. We investigate temporal and spatial dynamics in a single ^{229}Th ion resulting from resonant driving.

References

[1] S Kraemer, J Moens, M Athanasakis-Kaklamanakis *et al.*, Nature **617**, 706 (2023)

[2] E Peik, T Schumm, M S Safronova, A Pálffy, J Weitenberg and P G Thirolf, Quantum Sci. Technol. **6**, 034002 (2021)

[3] J Tiedau, M V Okhapkin, K Zhang *et al.*, Phys. Rev. Lett. **132**, 182501 (2024)

[4] B S Nickerson, M Pimon, P V Bilous, J Gugler, K Beeks, T Sikorsky, P Mohn, T Schumm and A Pálffy, Phys. Rev. Lett. **125**, 032501 (2020)

[5] T Kirschbaum, T Schumm and A Pálffy, arXiv:2404.13023v1 (2024)