Resonant Excitation of ^{45}Sc Nuclear Isomer Transition: Prospects for Nuclear Clock and Other Applications

O Kocharovskaya[1]

[1] *Department of Physics and Astronomy, Texas A&M University, College Station, TX, USA*
Contact Email: kochar@physics.tamu.edu

Nuclear resonances with high-quality factor, like those in atomic clocks, can be achieved at solid density and even at room temperature, as the nuclei are naturally trapped in a crystal lattice. The major advantage of nuclear vs atomic transitions is a smaller sensitivity to frequency shifts caused by electric and magnetic fields perturbations. Besides, the Mössbauer effect makes it possible to effectively eliminate thermal-motion broadening. Thus, nuclear transitions offer an appealing platform for new precision metrology. However, all the known nuclear isomer transitions (with the unique exception of ^{229m}Th [1]) lay in the hard X-ray range. Their resonant excitation, coherent control and interfacing with the resonant X-ray photons is challenging due to absence of the bright narrow-band coherent sources and high-quality cavities in the hard X-ray range.

Recently the nuclear isomer state at 12.4 keV with the lifetime of 0.46 s (natural linewidth of 1.4 feV) in 45 Sc was resonantly excited with the train of X-ray pulses from the EuXFEL [2]. The resonant excitation of the isomer state was detected via delayed nuclear decay products, namely, characteristic X-rays at about 4 keV photon energy. The transition frequency is determined with 200 times higher accuracy than previously known. It is the narrowest nuclear transition ever resonantly excited.

In this talk we will discuss the prospects for potential applications of this super-narrow nuclear resonance (such as realization of nuclear clocks [1], super-dense quantum nuclear memory [3,4] and super-resolution nuclear coherent forward scattering spectroscopy [5]) opened by this experimental breakthrough as well as the further experimental and theoretical studies which are required for implementation of these prospects.

Acknowledgements: This work is supported by NSF (Grant No. PHY-2012194).

References

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

[2] Yu Shvyd'ko, R Röhlsberger, O Kocharovskaya, J Evers, G A Geloni *et al.*, to be published

[3] X Zhang, W-T Liao, A A Kalachev, R N Shakhmuratov, M O Scully and O Kocharovskaya, Phys. Rev. Lett. **123**, 250504 (2019)

[4] S Velten, L Bocklage, X Zhang, K Schlage, A Panchwanee, I Sergeev, O Leupold, A I Chumakov, O Kocharovskaya and R Röhlsberger, to be published

[5] Yu Shvyd'ko, R Röhlsberger, O Kocharovskaya, J Evers *et al.*, to be published