Contribution ID: **256** Type: **Oral**

On the use of the 229mTh isomers from the alpha decay of 233U in a hydrochloric acid solution for a nuclear clock

Saturday 5 July 2025 16:30 (20 minutes)

In isomeric transition the 229mTh nuclei emit photons of 8.4 eV energy and a frequency of 2020.409 THz, which can serve as a reference frequency for the most accurate clocks. Isomeric transitions for 229mTh atoms without valence electrons (ionization degree n = 4+) occur only by photon emission, at n = 1+, 2+, 3+ transitions mainly occur through an electron bridge, in neutral 229mTh atoms, electron conversion mainly occurs. Initially, 229mTh isomers were obtained in 2% of the alpha decay of 233U nuclei. But in 2024, isomers were first obtained by resonant laser irradiation of 229Th nuclei in the ground state in crystals where the Th atoms were in the form of ions. For the 229mTh isomers obtained in this way, in [1] and in subsequent works, emission of isomeric transition photons was observed.
Laser excitation of isomers allows the development of nuclear clocks similar to atomic ones. The 229Th nuclei in the ground state are embedded in a crystal, irradiated with a laser with a tunable frequency, and the resonance frequency is found based on the maximum excitation of the isomers, which is the reference frequency for the clock (see, e.g, [2]). However, unlike short-lived excited atomic states, the 229mTh isomer lives in a crystal for more than 10 minutes, and when changing the laser frequency to search for resonance, it is necessary to wait for the decay of the previously excited 229mTh isomer or replace the target.
In view of this, it is interesting to consider the possibility of amplifying the emission of photons from a source with the 229mTh isomers and using this frequency-stable optical signal in a clock. For example, such a source could be 229mTh isomers excited by a laser in a crystal. It is also promising to try a weaker, but also much simpler source with the 229mTh isomers obtained by alpha decay of 233U in a hydrochloric acid solution, where atoms with isomeric 229mTh are in the form of 4+ ions and the only channel for the isomers decay is photons emission [3]. In this way it is possible to observe the emission of photons by 229mTh isomers, and not the luminescence of the solution under the action of radiation from other daughter products of U decay. Radiochemical separation of freshly formed Th from a solution with 100 mg of 233U gives a source emitting 229mTh photons with an intensity of ~ 1000 ph/s [3]. This intensity is sufficient for resonance amplification, see for example [4] about photon-level broadband spectroscopy with two frequency combs.

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Session Classification: 3. Modern methods and technologies of nuclear physics

Track Classification: Section 3. Modern methods and technologies of nuclear physics.