# Controlled nuclear transition for vastly more accurate clocks

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A Russian scientist from Skobelitsyn Research Institute of Nuclear Physics, MSU theoretically substantiated that the speed of transition of thorium-229 from ground to excited state may be managed depending on external conditions. The frequency of the transitions may be increased or decreased by dozens of times. This effect will contribute to extremely precise clocks exceeding even the best atomic clocks. The article was published in *Physical Review Letters*.

The most precise modern clocks are atomic clocks in which time is registered on the basis of the electron transition between energy levels. Recently, scientists suggested switching from electron to nuclear transitions that may considerably increase the precision of clocks due to higher frequency. However, in the majority of cases, this frequency and corresponding energy are too high for the method to be applied. The main candidate to be used in such clocks is the nucleus of thorium-229. Its low-energy transitions are unique and lead to the emanation of an UV-spectrum photon. The work with nuclei is complicated due to internal conversion that causes the energy released in the course of nuclear transition to be transferred to one of the electrons and not released as a photon. The probability of an electron gaining energy instead of its transition to a photon in a thorium-229 atom is 1 billion times higher. However, if the atom is placed in a crystal with a wide band gap, the situation changes.

"My idea is that in a crystal electronic sheath may be completely rearranged, allowing us to observe nuclear radiation without conversion," said author Evgeny Tkalya from RINP, MSU.

In his new work, he theoretically reviewed the transitions of a thorium-229 nucleus in a crystal; the whole system was covered with an isolator, a thin dielectric film, or metal. The author concluded that spontaneous emission can be controlled if the nucleus is placed within such materials. This phenomenon is well-known for optic electron transitions and is called the Purcell effect. Analysis has shown that the cover, depending on its size and properties, may change the transition speed up to 50 times. This process is specifically interesting in clocks, as the emission line becomes narrower as well, allowing the mechanisms to keep time more accurately.

"This may increase the precision by an order of magnitude compared to thorium-based clocks that do not take this effect into account," said the scientist. "Using these additional physical phenomena, we may reach relative precision over $10^{-20}$."

The main issue that hinders the development of a nuclear clock prototype is the lack of knowledge about transition energy. Currently, the inaccuracy of measurements for this value is tenths of electron-volts (eV), and to efficiently excite the nuclei with external radiation, the inaccuracy should be reduced to the level of the exciting laser line width (about $10^{-5}$ eV).

The scientist also shared the results of experiments carried out by a group of researchers at MEPhI showing that the radiation can be controlled and proving theoretical provisions of his work.

**More information:** E. V. Tkalya, Decay Rate of the Nuclear Isomer Th229(3/2+,7.8 eV) in a Dielectric Sphere, Thin Film, and Metal Cavity, *Physical Review Letters* (2018). DOI: 10.1103/PhysRevLett.120.122501

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