SCIENCE

US eyes developing 1000x less radioactive nuclear clocks with thorium thin films

Research on nuclear clocks using thorium thin films has achieved a major breakthrough.

Updated: Dec 19, 2024 04:36 AM EST


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a day ago

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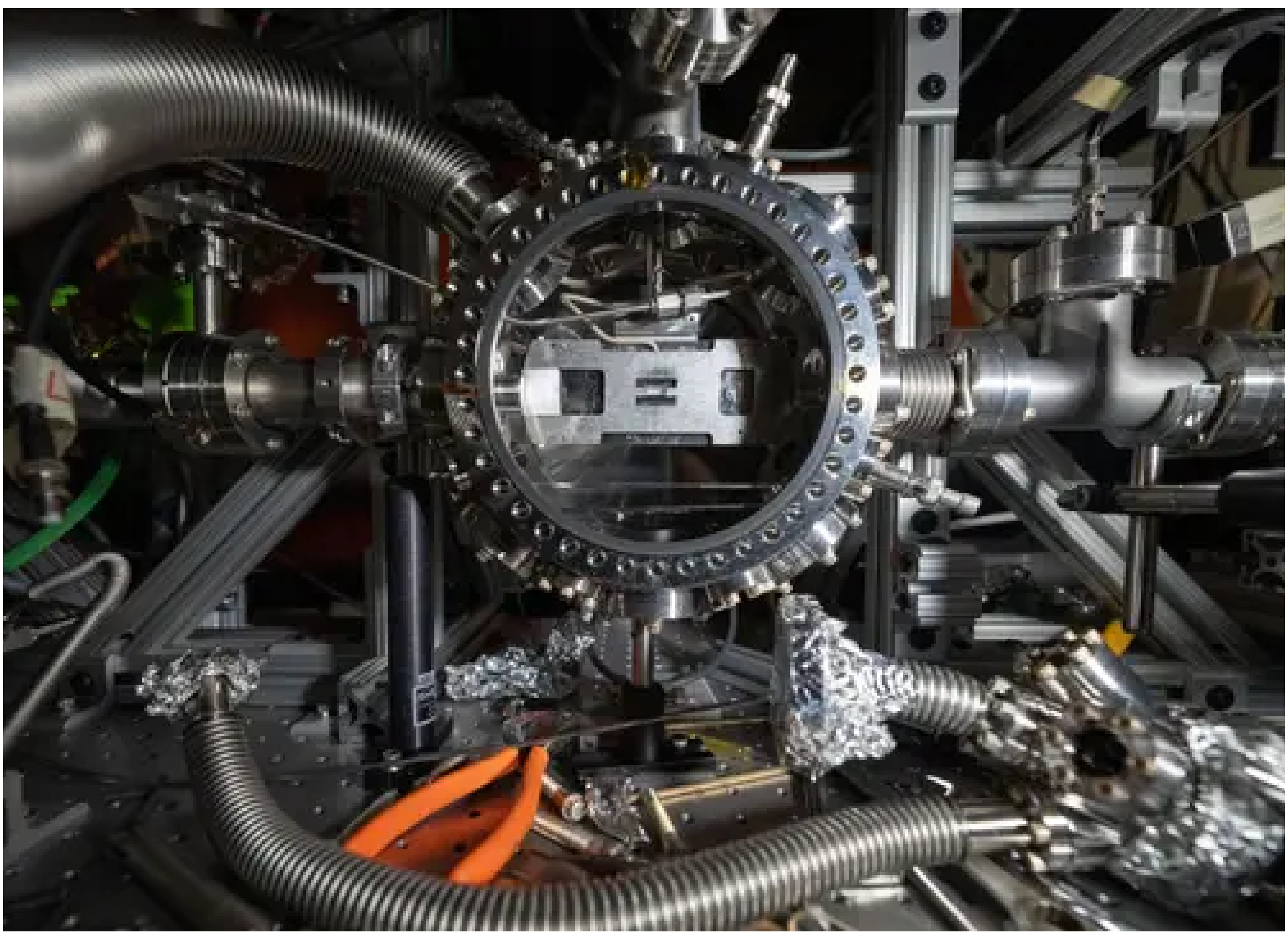

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California, Los Angeles (UCLA) have collaboratively found a new approach to building nuclear clocks using thorium thin films. The technological leap is equivalent to the use of semiconductors and integrated circuits in electronics and will allow the building of nuclear clocks that are 1000x less radioactive and less expensive, a press release said.

As scientists look for more accurate means of measuring time, nuclear clocks are proving to be much more accurate than the atomic clocks we have been using thus far. Since nuclear clocks use the energy transitions inside the atom's nucleus for their timekeeping, they are more accurate and less prone to perturbations from outside forces.

Nuclear clocks are also easily portable, making their widespread adoption possible. However, the accuracy of the nuclear clock comes at a heavy cost. At the core of the nuclear clock is thorium-229, which is rare, expensive, and highly radioactive.

To enhance their practicality, a team led by Jun Ye, a professor of physics at CU Boulder, and Eric Hudson, a professor at UCLA, used thin films of thorium tetrafluoride (ThF_4) to build nuclear clocks that are 1,000 times less radioactive and cheaper to build.

Thorium thin films

While thorium-based nuclear clocks have been in the works for over a decade, Jun Ye's team at CU Boulder has been working on using thorium thin films since 2017. The team experimented with thorium dioxide (ThO_2) since it has a lower bandgap and facilitates electron emission.

More recently, researchers have also observed photon emissions. "With only a slight change of procedure, we could produce some ThF_4 thin films using the apparatus originally built for ThO_2 thin film production," explained Chuakun Zhang, a researcher in the Ye lab, in an email to *Interesting Engineering*.

The team used the physical vapor deposition (PVD) process, where ThF_4 was heated in a chamber till it vaporized. The atoms are then condensed onto a substrate such as sapphire or magnesium fluoride since they are transparent to ultraviolet light, which is used for nuclear transition.

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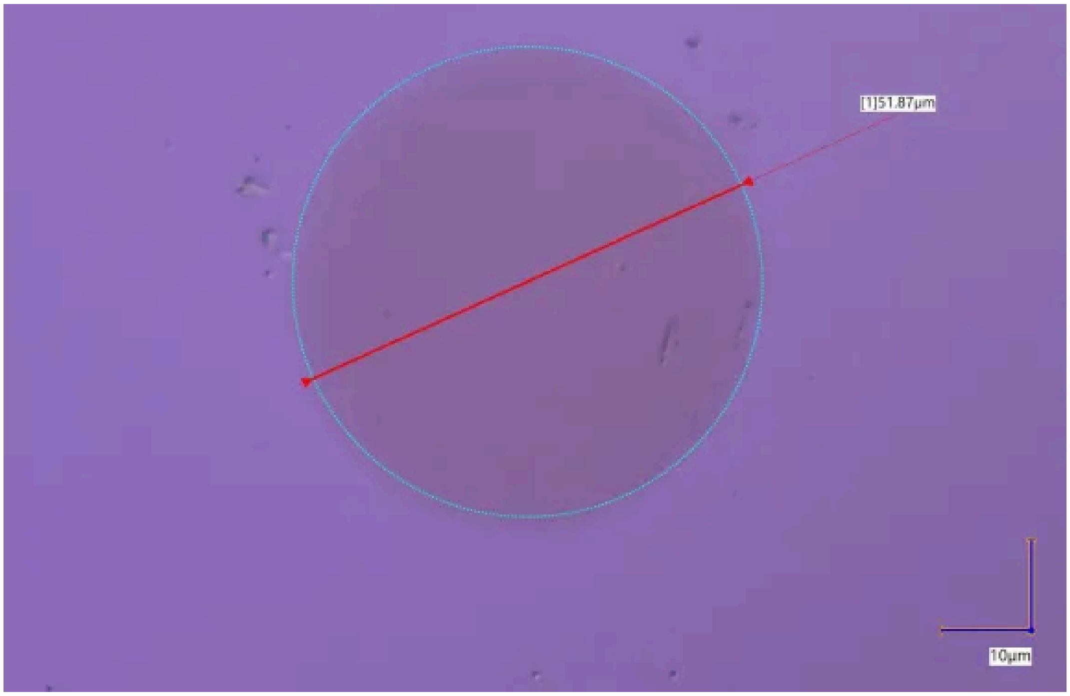

Image of thorium thin film created using physical vapor deposition process. Image credit: Ye Labs, JILA, NIST and Univ Colorado.

Using only micrograms of thorium-229, the researchers could create films that were 100 nanometers thick but 1,000 times less radioactive when compared to active thorium nuclei.

Finding energy transitions

Using a thin film also came with its own set of challenges since it produces variations in thorium environments, making energy transitions less consistent. So, the researchers reached out to the UCLA team to use the broadband laser light source to probe energy transitions. The broad-spectrum laser has its optical power concentrated in one spectrum, making it easier to excite thin thorium films.

When the energy from the laser was precise to bring about the transition, the thorium in the thin films emitted photons to return to their original state. These photons confirmed that thin films could be used in nuclear clocks.

“We made the thin film, we characterized it, and it looked pretty good,” added Tian Ooi, a graduate student at CU Boulder, in the press release. “It was cool to see that the nuclear decay signal was actually there.”

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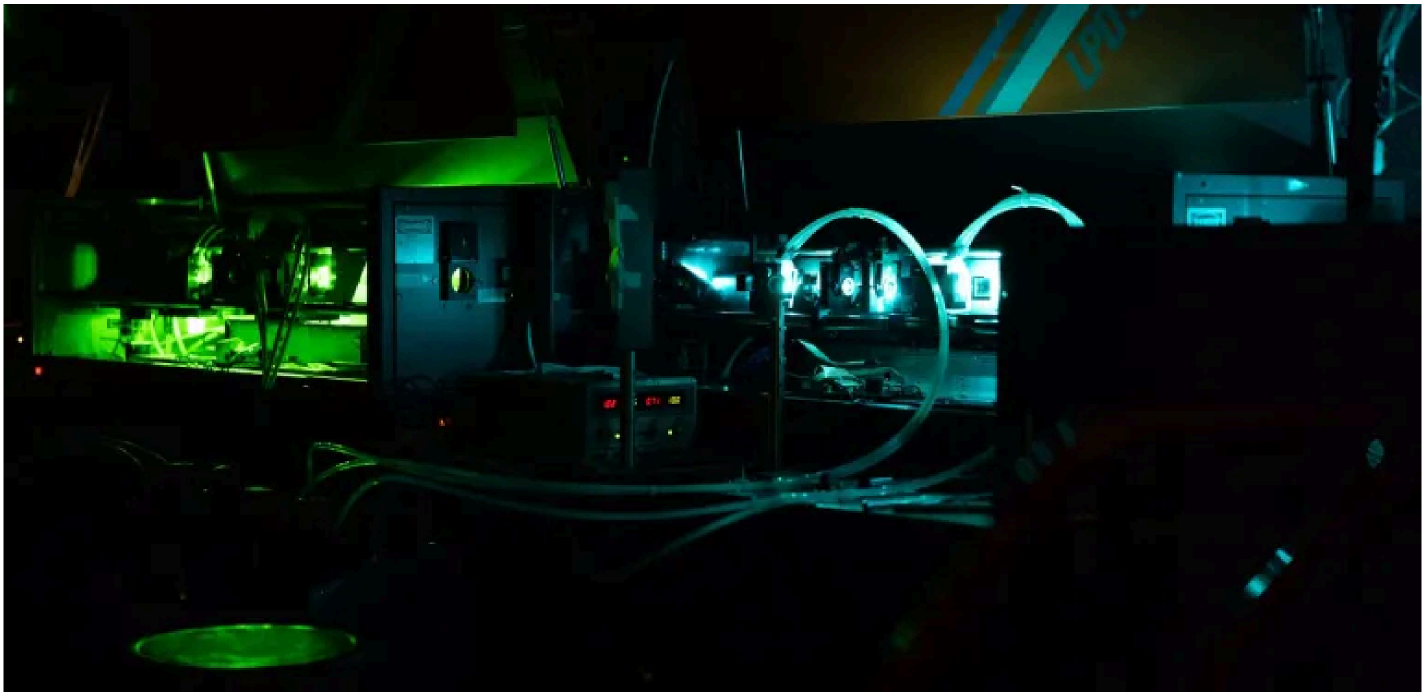

Pulsed laser firing in progress at UCLA for detecting photon emission from thorium films. Image credit: Richard Elwell/ UCLA

Nuclear clocks on wrists and beyond

Nuclear clocks have piqued interest since they have the potential to be shrunken and made portable. With thorium-thin films, wearing a nuclear clock on a wrist is no longer far-fetched. Not just accurate timekeeping but also small nuclear clocks could revolutionize future navigation and telecommunications. What researchers are also excited about is the new physics it could unveil.

“Nuclear clocks offer a precision measurement tool that’s based on fundamentally different interactions (nuclear forces) compared to precise atomic clocks (Coulomb forces),” stated Zhang in the email to *IE*.

“By comparing the nuclear clock with an atomic clock, one may be able to find some new physics if the ratio of the nuclear force and Coulomb force varies slightly over time. Such effects could be an indication of beyond Standard Model physics and dark matter.”

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“ThF4 platform may provide a platform to host many coherent quantum emitters in an extremely high density,” added Zhang in the email. “This may allow us to explore novel quantum optics phenomena and even benefit quantum information processing.”

The research findings were published in the journal *Nature*.

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Ameya Paleja Ameya is a science writer based in Hyderabad, India. A Molecular Biologist at heart, he traded the micropipette to write about science during the pandemic and does not want to go back. He likes to write about genetics, microbes, technology, and public policy.

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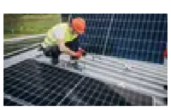

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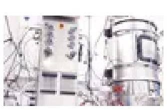

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