Proposed gamma-ray laser could emit 'nuclear light'

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(PhysOrg.com) -- Building a nuclear gamma-ray laser has been a challenge for scientists for a long time, but a new proposal for such a device has overcome some of the most difficult problems. In the new study, Eugene Tkalya from the Institute of Nuclear Physics at Moscow State University has theoretically proven how the stimulated gamma emission of thorium nuclei can emit coherent visible light. Although the nuclear gamma-ray laser emits light based on stimulated emission, it operates a bit differently than a normal laser.

“Photons in a normal laser are emitted by atoms, by ions, and so on,” Tkalya told *PhysOrg.com*. “In the nuclear gamma-ray laser, the photons are emitted by atomic nuclei.”

In the study, which is published in a recent issue of Physical Review Letters, Tkalya explains that a nuclear gamma-ray laser has to overcome at least two basic problems: accumulating a large amount of isomeric nuclei (nuclei in a long-lived excited state) and narrowing down the gamma-ray emission line. The new proposal fulfills these requirements by taking advantage of thorium’s unique nuclear structure, which enables some of the photons from an external laser to interact directly with thorium’s nuclei rather than its electrons.

Tkalya’s proposal uses a lithium-calcium-aluminum-fluoride ($LiCaAlF_6$) compound, in which some of the calcium is replaced with thorium. After a sufficient amount of isomeric thorium nuclei have been excited by an external laser, the nuclei can interact with a surrounding electric or magnetic field to create a population inversion, so that the system contains more excited nuclei than unexcited nuclei. (In a regular laser, a population inversion usually involves getting more electrons in a higher energy level than a lower energy level.) Then, Tkalya showed that the nuclei can emit or absorb photons without recoil, allowing them to produce light without losing energy.

"The nuclear gamma-ray laser considered in my article can emit 'visible' (vacuum ultraviolet [VUV]) light (or gamma-rays of the optical range) only," Tkalya said.

As Tkalya explained, a nuclear gamma-ray laser could open up several interesting applications, although he has not thoroughly investigated them yet. One possibility is that the gamma-ray emission of the excited thorium nuclei is in the optical range called "nuclear light."

"In my opinion, it is interesting to see a 'nuclear light,'" he said. "An application of nuclear light is the nuclear metrological standard of frequency, or the 'nuclear clock.'"

In addition, the device could be used to test many fundamental properties of nature, such as the exponentiality of the decay law and the effect of the variation of the fine structure constant.

More information: E.V. Tkalya. "Proposal for a Nuclear Gamma-Ray Laser of Optical Range." *Physical Review Letters* 106, 162501.
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Abstract
A possibility of the amplification of the 7.6 eV γ radiation by the stimulated γ emission of the ensemble of the 229mTh isomeric nuclei in a host dielectric crystal is proved theoretically. This amplification is a result of (1) the excitation of a large number of 229mTh isomers by laser

radiation, (2) the creation of the inverse population of nuclear levels in a cooled sample owing to the interaction of thorium nuclei with the crystal electric field or with an external magnetic field, (3) the emission or absorption of the optical photons by thorium nuclei in the crystal without recoil, and (4) the nuclear spin relaxation through the conduction electrons of the metallic covering.