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Warsaw, 29th of August 2025

Making the invisible visible: a new way to boost light emission at the nanoscale

Light still holds surprises – as demonstrated by researchers from the Ultrafast Phenomena Lab at the Faculty of Physics, University of Warsaw, in collaboration with the Institute of Low Temperature and Structure Research, Polish Academy of Sciences, who have discovered a new enhancement effect in the emission of upconverting nanoparticles. They demonstrated that simultaneous excitation of these nanostructures with two near-infrared beams of laser light leads to a significant increase in emission intensity. Under carefully chosen conditions, visible emission emerges only when both beams are applied together, even though neither beam alone produces any emission at all. This discovery paves the way for visualizing infrared radiation beyond the sensitivity range of standard detectors. The findings, potentially applicable in microscopy and photonic technologies, have been published in the prestigious journal "ACS Nano".

Among photoactive materials used in photonic technologies, those that absorb lower-energy photons and emit higher-energy ones stand out. This process is made possible by sequential absorption of multiple photons, followed by the emission of a single photon with higher energy. While photon upconversion remains one of the most widely used features of these materials, other applications arise from their nonlinear response, that is, the intensity of the emitted light is not a linear function of the excitation intensity. This nonlinearity makes lanthanide-doped upconverting nanoparticles particularly useful in enhancing the resolution of microscopic imaging.

A completely new area of potential applications has been opened by Paulina Rajchel-Mieldzioć, a PhD candidate at the Ultrafast Phenomena Lab at the Institute of Experimental Physics. Her work leveraged the fact that rare-earth metal ions, the photoactive core of upconverting nanoparticles, exhibit a complex structure of energy levels, allowing them to interact with light across a wide range of wavelengths. She discovered that when these nanoparticles are illuminated not only with light of a wavelength typically used for excitation but also with additional beams in the near-infrared range, the emitted light intensity can increase dramatically, sometimes by several-fold. "Furthermore, under specific conditions, visible light emission can be triggered only through the joint action of two NIR beams—neither of which produces the effect on its own" says Paulina Rajchel-Mieldzioć.
This newly observed phenomenon may find applications in infrared detection and its conversion to the visible light, as well as in the development of novel microscopy techniques and purely optical computing— opening new possibilities for the future of photonic technologies.

The study, carried out in collaboration with the research group led by prof. Artur Bednarkiewicz from the Institute of Low Temperature and Structure Research Polish

Academy of Sciences, was published in ACS Nano and featured on the cover of issue 19, dated July 29, 2025.

Faculty of Physics at the University of Warsaw.
Physics and astronomy at the University of Warsaw appeared in 1816 as part of the then Faculty of Philosophy. In 1825, the Astronomical Observatory was established. Currently, the Faculty of Physics at the University of Warsaw consists of the following institutes: Experimental Physics, Theoretical Physics, Geophysics, the Department of Mathematical Methods in Physics, and the Astronomical Observatory. The research covers almost all areas of modern physics on scales from quantum to cosmological. The Faculty's research and teaching staff consists of over 250 academic teachers. About 1,100 students and over 170 doctoral students study at the Faculty of Physics UW. The University of Warsaw is among the 300 best universities in the world, educating in the field of physics according to Shanghai's Global Ranking of Academic Subjects.

SCIENTIFIC PUBLICATION:

P. Rajchel-Mieldzioć, A. Bednarkiewicz, K. Prorok, P. Fita, Strong Emission Enhancement via Dual-Wavelength Coexcitation in YbTm-Doped Upconverting Nanoparticles for Near-Infrared and Subdiffraction Imaging , ACS Nano 2025, 19, 29, 26932–26941
https://pubs.acs.org/doi/10.1021/acsnano.5c08510

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The results of research conducted by scientists from the Ultrafast Processes Laboratory at the Faculty of Physics, University of Warsaw, and the Institute of Low Temperature and Structure Research, PAS, have been published in the prestigious journal ACS Nano and are featured on the cover of issue 19 from July 29, 2025. (Source: ACS Nano, July 29, 2025, Volume 19, Issue 29, 26932–26941, Copyright © 2025 The Authors, Published by American Chemical Society).