Making the invisible visible: Dual laser excitation boosts light emission at nanoscale

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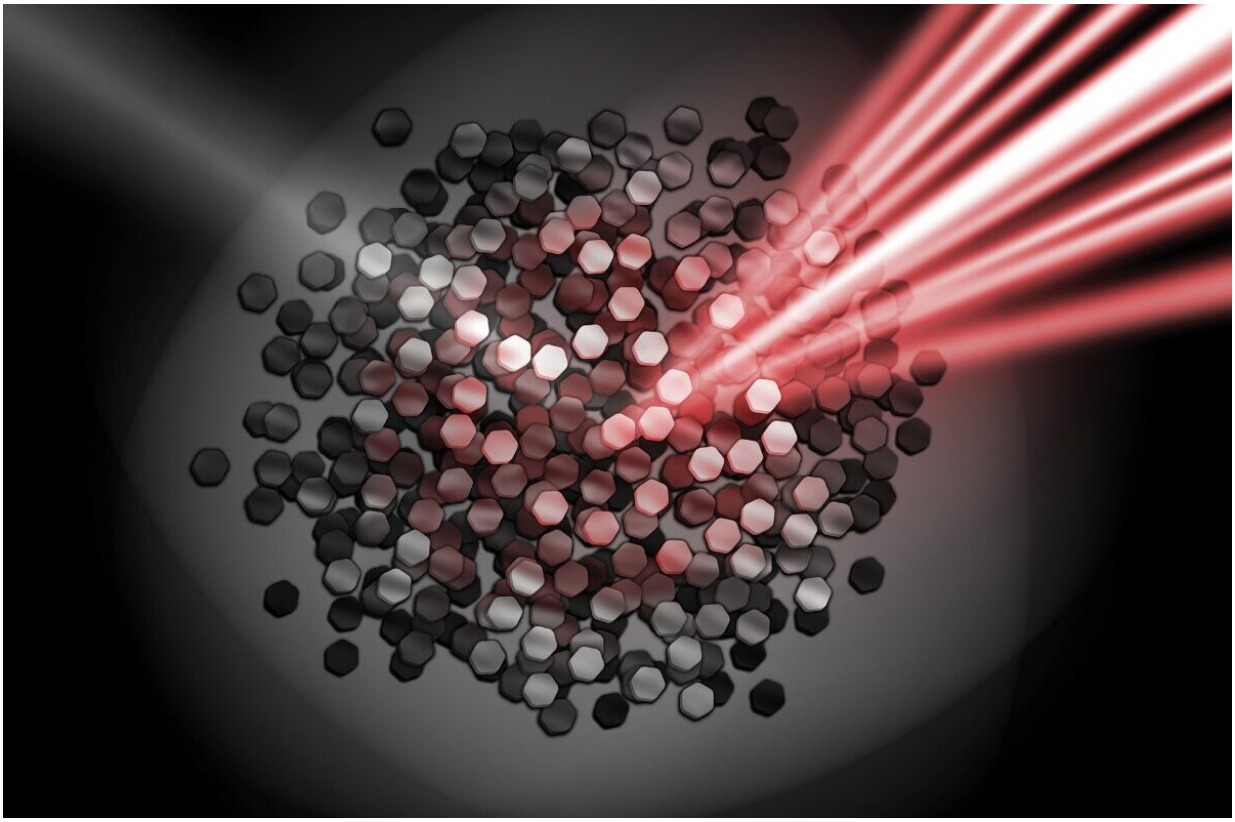

Simultaneous excitation of YbTm-doped upconverting nanoparticles at 975 and 1213 or 1732 nm results in significantly stronger anti-Stokes emission than excitation with either beam alone. Credit: *ACS Nano* (2025). DOI: 10.1021/acsnano.5c08510

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, the 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 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.

Influence of 975 nm and NIR beam intensity on the 800 nm emission intensity of YbTm nanoparticles under coexcitation. (a, b) Surplus emission from nanoparticles excited simultaneously by the 975 nm beam and (a) 1732 or (b) 1213 nm beam, plotted as a function of the NIR beam intensity for selected intensity levels of the 975 nm beam (dashed lines are an aid for the eye). (c, d) Surplus emission from nanoparticles excited simultaneously with a 975 nm beam and a (c) 1732 or (d) 1213 nm beam (black dots), plotted as a function of the intensity of both excitation beams. The fitted function is represented by the two-dimensional power-law surface. Credit: *ACS Nano* (2025). DOI: 10.1021/acsnano.5c08510

A completely new area of potential applications has been opened by

Paulina Rajchel-Mieldzioć, a Ph.D. 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 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 was carried out in collaboration with the research group led by prof. Artur Bednarkiewicz from the Institute of Low Temperature and Structure Research, the Polish Academy of Sciences.

More information: Paulina Rajchel-Mieldzioć et al, Strong Emission Enhancement via Dual-Wavelength Coexcitation in YbTm-Doped Upconverting Nanoparticles for Near-Infrared and Subdiffraction Imaging, *ACS Nano* (2025). DOI: 10.1021/acsnano.5c08510

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