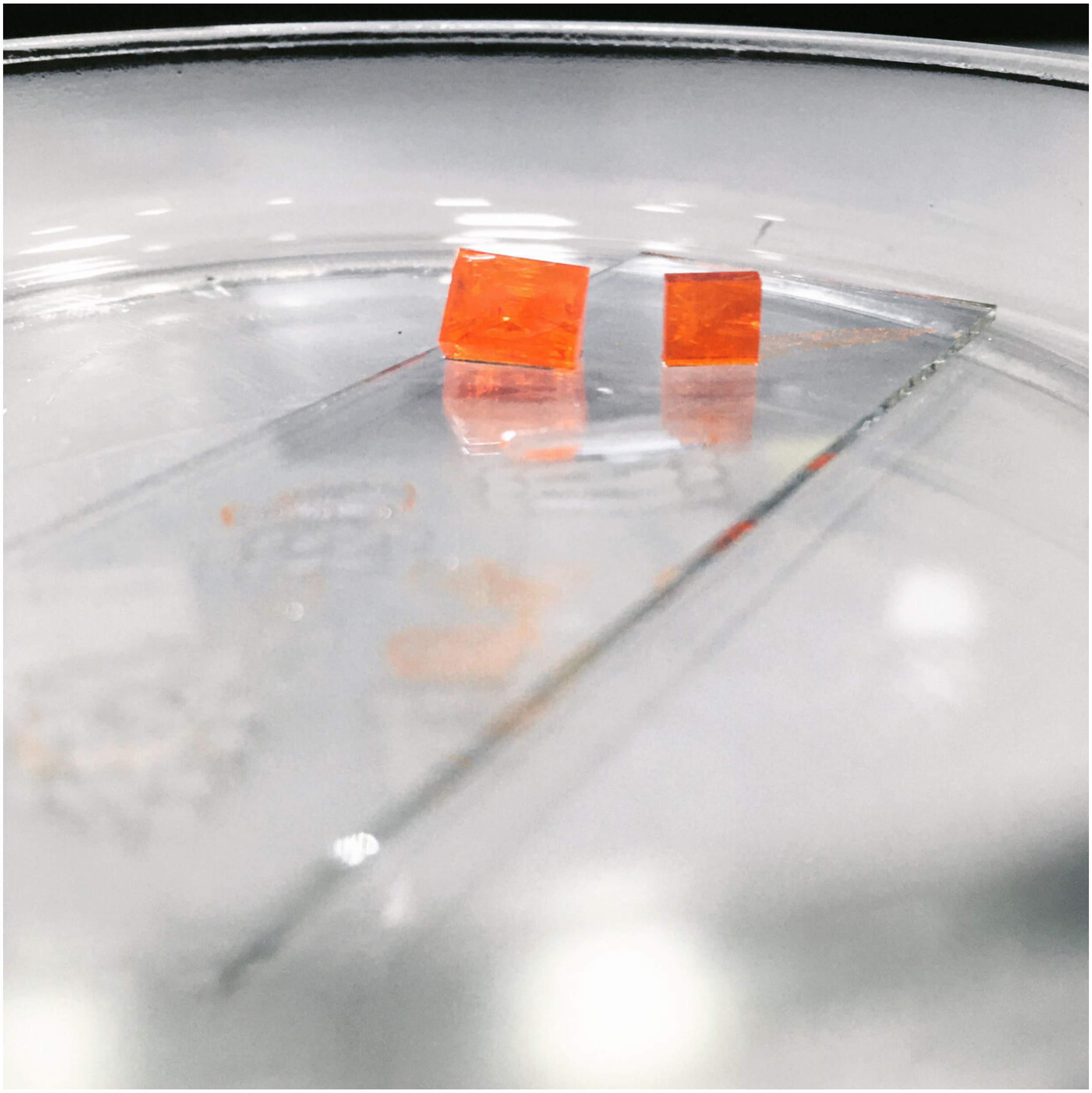
Scientists create smallest semiconductor laser that works in visible range at room temperature

June 3 2020, by Itmo University



Perovscite cubes. Credit: Article's authors

An international team of researchers has announced the development of the world's most compact semiconductor laser that works in the visible range at room temperature. According to the authors of the research, the laser is a nanoparticle of only 310 nanometers in size (which is 3,000 times less than a millimeter) that can produce green coherent light at room temperature. The research article was published in *ACS Nano*.

Sixty years ago, in mid-May, American physicist Theodor Maiman demonstrated the operation of the first optical quantum generator—a laser. Now, an international team of scientists, most of whom are from ITMO University, reports that they have demonstrated experimentally the world's most compact semiconductor laser that operates in the visible range at room temperature. This means that the coherent green light that it produces can be easily registered and even seen by a naked eye using a standard optical microscope.

The scientists succeeded in exploiting the green part of the visible band, which was considered problematic for nanolasers. "In the modern field of light-emitting semiconductors, there is the 'green gap' problem," says Sergey Makarov, principal investigator of the article and professor at the Faculty of Physics and Engineering of ITMO University. "The green gap means that the quantum efficiency of conventional semiconductor materials used for light-emitting diodes falls dramatically in the green part of the spectrum. This problem complicates the development of room temperature nanolasers made of conventional semiconductor materials."

The team chose halide perovskite as the material for their nanolasers. A traditional laser consists of two key elements—an active medium that allows for generation of coherent stimulated emission and an optical resonator that helps to confine electromagnetic energy inside for a long time. The perovskite can provide both of these properties: A nanoparticle of a certain shape can act as both the active medium and the efficient resonator.

As a result, the scientists succeeded in fabricating a cubic-shaped particle of 310 nanometers in size, which can generate laser radiation at room temperature when photoexcited by a femtosecond laser pulse.

"We used femtosecond laser pulses to pump the nanolasers," says Ekaterina Tiguntseva, a junior research fellow at ITMO University and one of the article's co-authors. "We irradiated isolated nanoparticles until we reached the threshold of laser generation at a specific pump intensity. After that, the nanoparticle starts working as a typical laser. We demonstrated that such a nanolaser can operate during at least a million cycles of excitation."

The uniqueness of the developed nanolaser is not limited to its small size . The novel design of nanoparticles allows for efficient confinement of the stimulated emission energy to provide a high enough amplification of electromagnetic fields for laser generation.

"The idea is that laser generation is a threshold process," explains Kirill Koshelev, a junior research fellow at ITMO University and one of the article's co-authors. "You excite the nanoparticle with a laser pulse, and at a specific 'threshold' intensity of the external source, the particle starts to generate laser emission. If you are unable to confine the light inside well enough, there will be no laser emission. In the previous experiments with other materials and systems, but similar ideas, it was shown that you can use Mie resonances of the fourth order or fifth order, meaning resonances where the wavelength of light inside the material fits the resonator volume four or five times times at the frequency of laser generation. We've shown that our particle supports a Mie resonance of the third order, which has never been done before. In other words, we can produce a coherent stimulated emission at the conditions when the resonator size is equal to three wavelengths of light inside the material."

Notably, there is no need to apply external pressure or very low temperature for the nanoparticle to work as a laser. All the effects described in the research were produced at a regular atmospheric pressure and room temperature. This makes the technology attractive for specialists who focus on the creation of optical chips, sensors and other devices that use light to transfer and process information, including chips for optical computers.

The benefit of lasers that work in the visible range is that with all other properties being equal, they are smaller than red and infrared sources with the same properties. Thing is, the volume of the small lasers generally has a cubic dependence on the emission's wavelength, and as the wavelength of green light is three times less than that of infrared light, the limit of miniaturization is a lot greater for green lasers. This is essential for the production of ultracompact components for future optical computer systems.

More information: Ekaterina Tiguntseva et al. Room-Temperature Lasing from Mie-Resonant Non-Plasmonic Nanoparticles, *ACS Nano* (2020). DOI: 10.1021/acsnano.0c01468

Provided by ITMO University

Citation: Scientists create smallest semiconductor laser that works in visible range at room temperature (2020, June 3) retrieved 26 June 2024 from https://phys.org/news/2020-06-scientists-smallest-semiconductor-laser-visible.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.