Quantum dot lasers move a step closer with electric-pumping development

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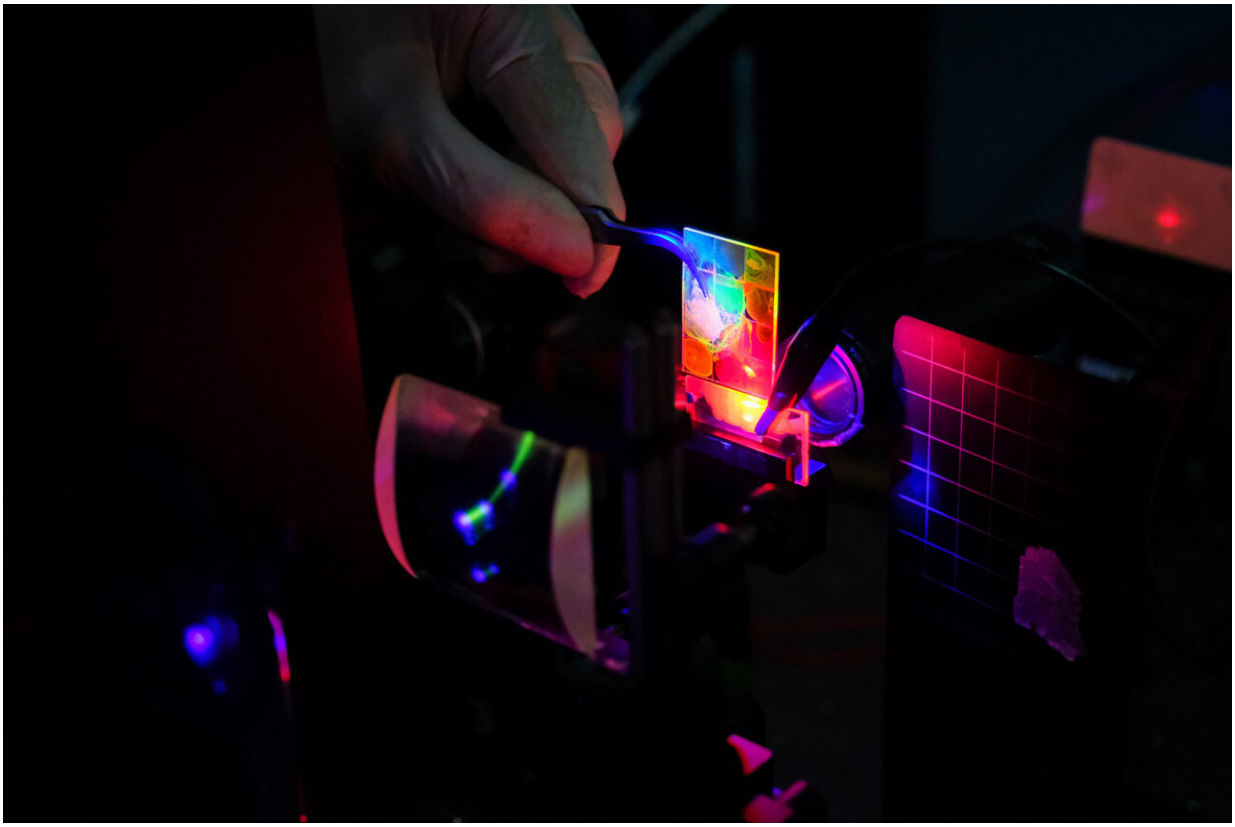

Glass plates with applied colloidal quantum dots which can emit different spectrums light when electrically and optically pumped, which makes it suitable as a laser material. Credit: Nanyang Technological University

Scientists from Nanyang Technological University, Singapore (NTU

Singapore) have developed a way to make Colloidal Quantum Dots produce laser light with the help of an electric field.

Colloidal Quantum Dots (CQDs) are semiconductor nanoparticles that can generate vivid and saturated colors of light efficiently, which are used to make display screens of many electronic devices.

Though CQDs should be promising as laser materials, they are not yet practical since they need to be powered by another source of light energy—a method known as optical pumping. However, this renders them too bulky for use in semiconductor electronics.

Over the last few years, researchers have tried various approaches to make it easy to use CQDs in lasers, including electrochemical methods or chemical doping. These approaches require the use of harsh chemical solvents or oxygen-free environments in their production, and so have been limited to lab-scale experiments.

In a paper published in *Science Advances*, NTU Assistant Professor Steve Cuong Dang together with Ph.D. student Yu Junhong, have demonstrated how an electric field can help CQDs emit laser light while using only a fraction of the energy traditionally required to drive a laser.

In their experiments, the NTU scientists embedded CQDs between two electrodes, which provides an electric field to control and change the properties inside the CQDs. By manipulating these properties, the scientists lowered the energy threshold needed for lasing by around 10 percent, bringing the prospect of CQD lasers closer to reality.

This threshold reduction is the first time researchers have lowered it using an electric field, instead of difficult-to-employ electrochemical methods.

Being able to build low-cost, small size lasers that are "electrically driven" in a wide range of colors is the holy grail for many optical and optoelectronic researchers. Lasers are the backbone technology for various industries including medical, security and consumer electronics, and are essential to the development of laser televisions.

"Our successful experiment brings us one step closer towards developing single-material full-color lasers that can be electrically pumped. That achievement would eventually make it possible to put lasers on chip integrated systems used in consumer electronics and the Internet of Things (IOTs)" said Asst Prof Dang, from the School of Electrical and Electronic Engineering (EEE).

Benefits of Colloidal Quantum Dots

Colloidal Quantum Dots are easily and economically produced in simple liquid-phase chemical syntheses, and their optical and electronic properties can be altered and controlled by varying the particle size.

Colloidal nanomaterials are attractive to laser makers due to their low-cost, tune-able emission colour and high emission efficiency. However getting them to lase currently requires fast, intense and coherent optical pumping, whereas electric pumping is slow, weak and incoherent.

Together with his collaborators Prof Hilmi Volkan Demir and Assoc Wang Hong from EEE, and Prof Sum Tze Chien from the School of Physical and Mathematical Sciences, Asst Prof Dang showed that applying an electric field lowers the lasing threshold of CQDs, and could lead to viable electrically-pumped CQD lasers.

Prof Demir said, "The next big challenge in laser research is to develop nanoscale lasers and integrate them into on-chip photonic devices and ultrasensitive sensors. This would bring significant impacts to modern

society especially in data and information processing, that is driving the 4th industrial revolution. Achieving it would be a major advance within Singapore's Industry 4.0 transformation."

The team is now looking to research further into making tiny CQD lasers on a chip and to work with industry partners keen to develop the technology into proof-of-concept devices with practical applications.

This interdisciplinary project was funded by Ministry of Education, National Research Foundation Singapore (NRF) and Agency for Science, Technology and Research (A*STAR), and involved Ph.D. student Yu Junhong and Dr. Sushant Shendre, a research fellow at NTU's LUMINOUS! Centre of Excellence for Semiconductor Lighting and Displays.

Paper titled "Electrically control amplified spontaneous emission in colloidal quantum dots," published in *Science Advances*, 25 Oct 2019.

More information: Junhong Yu et al. Electrically control amplified spontaneous emission in colloidal quantum dots, *Science Advances* (2019). DOI: 10.1126/sciadv.aav3140

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