Electric field-induced charging could improve colloidal quantum dot lasing

SINGAPORE — Researchers at Nanyang Technological University (NTU Singapore) have demonstrated tunable, controllable amplified spontaneous emission (ASE) in a colloidal semiconductor device via electric field-induced charging. Their work could open new avenues for achieving electrically pumped colloidal quantum dot (CQD) lasers.

In experiments, the NTU scientists embedded CQDs between two electrodes to create an electric field to control and change the properties inside the CQDs. The researchers quantitatively determined the contribution of neutral and singly and doubly charged CQDs to the ASE and demonstrated the dominant role of singly charged CQDs in achieving a low ASE threshold.

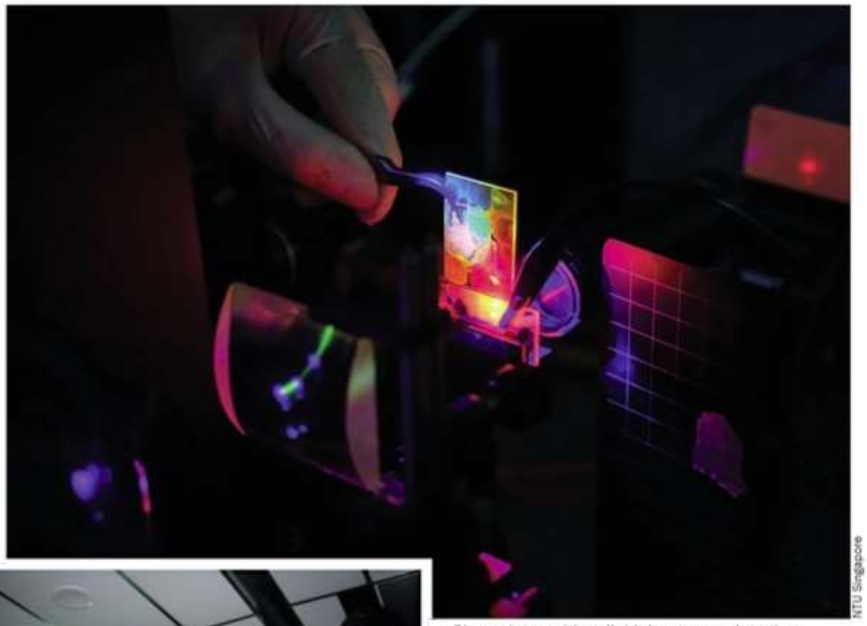
Specifically, singly charged CQDs lower the energy threshold needed for lasing due to the preexisting electron in the conduction band, while strongly enhanced Auger recombination in doubly charged CQDs obstructs the ASE. Both the experimental results and a kinetic equation model used to simulate ASE behavior showed that the ASE threshold could be lowered by about 10%.

According to the researchers, this is the first time the energy threshold for CQD lasing has been lowered using an electric field instead of electrochemical methods or chemical doping. "Our successful experiment brings us one step closer toward developing single-material, full-color lasers that can be electrically pumped," professor Steve Cuong Dang said. "That achievement would eventually make it possible to put lasers on chip-integrated systems used in consumer electronics and the Internet of Things."

CQDs are semiconductor nanoparticles that can generate vivid, saturated color efficiently for use in electronic device displays. The low cost, tunable emission color, and high emission efficiency of colloidal nanomaterials make them attractive to laser makers. Although CQDs should be promising as laser materials, they have not been practical because they need to be powered through fast, intense, coherent optical pumping, and this makes them too bulky for use in semiconductor electronics. The work by the NTU researchers could make electrically pumped CQD lasers viable by lowering the lasing threshold of CQDs, enabling them to emit laser light using only a fraction of the energy traditionally required to drive a laser.

The researchers are now exploring ways to make tiny CQD lasers on a chip and how the team might work with industry partners interested in developing the CQD lasing technology into proof-of-concept devices with practical applications.

The research was published in *Science Advances* (www.doi.org/10.1126/sciadv.aav3140).



NTU Singapore

Glass plates with colloidal quantum dots that emit light when electrically and optically pumped **(above)**.

NTU Singapore

NTU researchers: **(from left)** research fellow Sushant Shendre, assistant professor Steve Dang, professor Hilmi Volkan Demir, and researcher Junhong Yu hold up colloidal quantum dots that can produce laser light when powered.