and even quantum computing.

For example, by layering a superconducting material onto the surface of a topological insulator, it may be possible to create a theoretical but yet unseen particle that is its own antiparticle, one that could persist in the material undisturbed for long periods. Discovery of these so-called Majorana fermions would be an achievement in itself, and could also provide a way of overcoming the main obstacle to realizing a working quantum computer, a method of indefinitely storing data as "qubits."

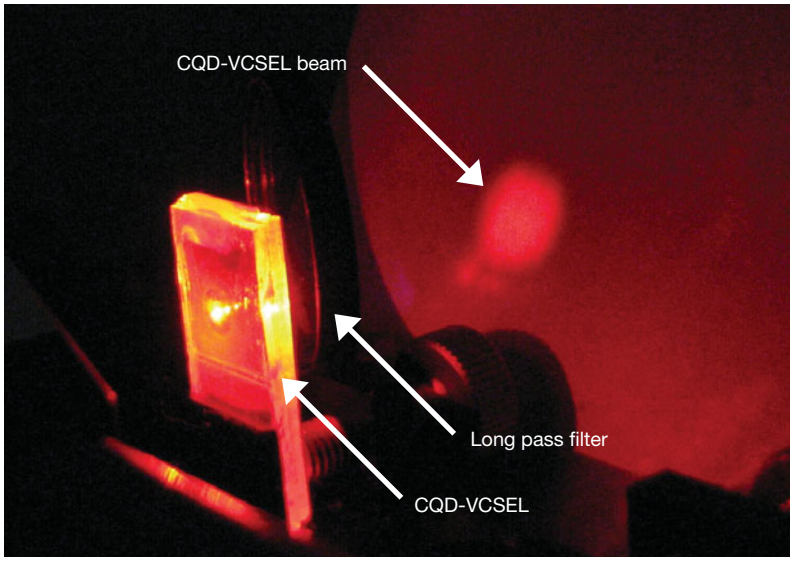
Nano Focus

Colloidal quantum dot films show RGB lasing

Colloidal semiconductor quantum dots exhibit efficient luminescence and bandgap controllability due to quantum confinement effects. However, to obtain laser emission from these materials, it is necessary to achieve a high colloidal-quantum-dot (CQD) packing density, and to reduce losses arising from nonradiative, multi-excitonic (Auger) recombination. In a joint collaboration, C. Dang of Brown University, C. Breen of QD Vision, Inc., Massachusetts, and their colleagues have demonstrated how these requirements can be met to achieve red-green-blue (RGB) lasing.

As published in the May issue of *Nature Nanotechnology* (DOI: 10.1038/nnano.2012.61; p. 335), the researchers report lasing emission from CdSe/ZnCdS core/shell CQD with aromatic ligands. These form densely packed films that exhibit optical gain across the visible spectrum with an average of less than one exciton per CQD. This single-exciton gain allows the films to reach the threshold of amplified spontaneous emission at very low optical pump energy densities of 90 μJ cm^{-2}. This is more than one order of magnitude better than previously reported values. The gain of these nanocomposite films was used to produce the first colloidal quantum dot, vertical-cavity surface-emitting laser (CQD-VCSEL).

In this work, the researchers prepared type I CdSe/$Zn_{0.5}Cd_{0.5}S$ core/shell CQDs by high-temperature organometallic synthesis with nominal CdSe core diameters of 4.2 nm, 3.2 nm, and 2.5 nm. The thin (1 nm) ternary shell reduces strain and creates a moderate core/shell bandgap difference. Transmission electron microscopy images showed well-defined crystallinity and "pyramid-like" morphologies. Together, these properties modify the electronic states from those of ideal spherical CQDs, where the anisotropic shape of the CQDs is a key feature that enables lasing with one single exciton.



Photographic image of a red colloidal quantum dot, vertical-cavity surface-emitting laser (CQD-VCSEL) showing a spatially well-defined output beam, which is collinear with the pump beam. Reproduced with permission from *Nat. Nanotechnol.* **7** (2012) DOI: 10.1038/nnano.2012.61; p. 335. © 2012 Macmillan Publishers Ltd.

In ideal spherical CQDs, the Auger process is typically two orders of magnitude faster than photoluminescence decay, which severely hinders the dynamic buildup of population inversion. In this work, the dynamics of optical gain in CQD films were studied in pulsed stripe, photoexcitation experiments. Emission from the film edge with increasing pump power exhibits a clear transition from photoluminescence to stimulated emission (here observed as amplified spontaneous emission, ASE) through an abrupt increase in output intensity and spectral narrowing.

In contrast, in the densely packed CQD films, the ASE process is so fast that it can readily overcome this Auger loss. Indeed, very low thresholds of ASE across the RGB spectrum were obtained and the first CQD-VCSELs by single-exciton gain in type I CQD films were reported. Single-exciton gain was confirmed in this work by four independent

Correction

The affiliations for the authors of the article, "Survey reveals interdisciplinarity of MSE faculty," published in *MRS Bulletin* **37** (June 2012) p. 541, are Parag Banerjee, Department of Mechanical Engineering and Materials Science, Washington University, St. Louis, MO (parag.banerjee@wustl.edu) and Robert M. Briber, Department of Materials Science and Engineering, University of Maryland, College Park, MD (rbriber@umd.edu).

https://doi.org/10.1557/mrs.2012.153 Published online by Cambridge University Press

experimental results: direct absorption measurement, multi-exciton contribution through time-resolved photoluminescence, linear dependence of photoluminescence intensity on excitation energy at threshold levels, and a very low CQD-VCSEL threshold.

The researchers said that their results represent a significant step toward full-color, single-material lasers.

Rosalía Serna

News

Materials Researchers

Mildred S. Dresselhaus receives Kavli Nanoscience Prize

Mildred S. Dresselhaus of the Massachusetts Institute of Technology has received the 2012 Kavli Prize in Nanoscience "for her pioneering contributions to the study of phonons, electron–phonon interactions, and thermal transport in nanostructures." For more than five decades, Dresselhaus has made multiple advances in helping to explain why the properties of materials structured at the nanoscale can vary significantly from those of the same materials at larger dimensions.

As early as the 1960s, Dresselhaus led one of the first groups that explored carbon materials that form the basis for two-dimensional (2D) graphene and one-dimensional carbon nanotubes. These early experiments helped to map out the electronic band structure of these materials, critical to further understanding the unique properties they might possess. Dresselhaus studied intercalated 2D graphene sheets and provided important insights into the properties of not only 2D graphene, but also of the interactions between graphene and the surrounding materials. Her early work on carbon fibers, beginning in the 1980s, provided Dresselhaus with the understanding and perspective to postulate the existence and unusual attributes of 1D "single-walled carbon nanotubes (SWNTs)" years in advance of their actual discovery. A key prediction included the possibility that SWNTs could behave as either a metal or a semiconductor, depending on the chirality. Dresselhaus and co-workers said that nanotubes can be viewed as arising from the folding of a single sheet of carbon. They showed that this rearrangement of their structure controlled their properties. Through her studies of the fundamental physics of carbon-based solids, Dresselhaus laid the foundation for knowledge that has been integral to today's nanoscience of carbon.

Dresselhaus studied the transport and optical properties of nanostructured matter through experimental techniques providing unprecedented microscopic understanding. Regarding carbon nanostructures, she pioneered Raman spectroscopy as a sensitive tool for the characterization of materials one atomic layer in wall thickness, namely carbon nanotubes and graphene. Diameter selective resonance enhancement led to the observation of Raman spectra from one single nanotube. The high sensitivity of Raman spectroscopy to diameter and chirality made the technique the prime method for the characterization of carbon nanotubes.

Materials are held together by electrons shared between atoms. When the energy of an electron in a solid is altered, the local bonding of the solid is perturbed, resulting in a change in the position of the atoms that make up the solid. In nanoscale materials, the spatial extent of electrons and phonons can be modulated, leading to dramatically different behaviors compared with extended solids. Dresselhaus has investigated this fundamental electron–phonon interaction in nanostructures using Raman and resonance Raman spectroscopy.

This science also laid a foundation for practical work today aimed at controlling how energy flows. Thermoelectric materials have the ability to convert heat energy to an electrical signal or, alternatively, to utilize electrical energy to actively cool a material. Nature provides materials in which the electrical and thermal conductivity are strongly linked, resulting in a seeming limit to the achievable efficiency of a thermoelectric material. Dresselhaus demonstrated that in a 1D structure, it is possible to separately adjust electrical and thermal conductivity, and that this should allow the creation of new generations of thermoelectric refrigerators and new ways of scavenging waste heat for useful purposes.

The Kavli Prizes recognize scientists for their seminal advances in three research areas: astrophysics, nanoscience, and neuroscience. Consisting of a scroll, medal, and cash award of one million dollars, a prize in each of these areas has been awarded biennially since 2008. The Kavli Prize is a partnership between the Norwegian Academy of Science and Letters, the Kavli Foundation (USA), and the Norwegian Ministry of Education and Research. □

https://doi.org/10.1557/mrs.2012.153 Published online by Cambridge University Press