Radiation dynamics of PbSe quantum dots embedded in three-dimensional photonic crystals

Michael James Ventura, Craig Bullen and Min Gu

Centre for Micro-Photonics and Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), School Faculty of Engineering and Industrial Sciences, Mail 38, Swinburne University of Technology, PO Box 218, Hawthorn, VIC 3122
Australia

Phone: +61-3-9214 4303, email:mventura@swin.edu.au

Purcell showed that the rate of spontaneous emission can be greatly altered inside a high quality factor cavity [1]. Using photonic crystals allows for a unique opportunity to engineer environments into which quantum dots can be introduced and their emission altered. Exhibiting a photonic bandgap in which propagating electromagnetic modes cannot exist at all or only for certain directions, photonic crystals allow for the highly efficient manipulation of light at wavelengths on the scale of their dielectric periodicity. Controlling the spontaneous emission rates of quantum dots introduced into photonic crystal lattices is seen by many as a pivotal step towards the realisation of functional photonic crystal devices. We present experimental results in which the radiation dynamics of PbSe quantum dots are modified using the main photonic bandgap as well as higher-order gaps of three-dimensional void-channel based photonic crystals.

Femtosecond-laser direct writing of submicron-size voids into a pre-cured liquid resin, resulting in a solid polymer host [2,3] is a single step process which allow for the generation of arbitrary non-overlapping channel arrangements and requires no chemical post-processing. Controlled defects can be introduced at any location within the lattice geometry. Microcavities are fabricated at the centre of a twenty-four layered woodpile structure by the introduction of a displacement lid of all layers beyond the twelfth [4]. Such a system is analogous to a Fabry-Perot etalon consisting of two parallel quarter-wave stacks, in which each layer of void channels contributes two quarter-wave layers of different average dielectric constants, one containing the channels and another one consisting entirely of cured resin. Infrared transmission measurements revealed main photonic bandgaps centred at 4.5 μm with higher order gaps at 2.25 μm. A sharp spike with the main photonic bandgap was characteristic of the defect layer size (Δd) and could be tuned though the gap.

PbSe quantum dots with standard deviation of five to ten percent are produced by wet chemical methods. The quantum dots are then introduced into selected structures by dispersing them into the liquid polymer host before curing and fabrication. A series of systems are investigated by selection of the emission wavelengths of the quantum dots so as too coincided with the main photonic bandgap, localised defect states as well as higher order gaps. Time resolved florescence measurements are made and pronounced features are observed, attributed to the interaction with the photonic crystals periodic structure.

References
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Oral presentation

Biography: Michael Ventura
Oral presentation

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Michael is currently a final year PhD student at the Centre for Micro-Photonics, Swinburne University of Technology, Melbourne, Australia. His field of investigation is into the realisation of functional photonic crystals and devices. Michael has published several papers in international referred journal papers as well as conference proceedings.