Spatially and spectrally resolved Photoluminescence from single self-assembled Quantum Dots

C. Bonato, J. Gudat, D. Bouwmeetser (May 2010)

Application Note

Introduction

Quantum dots are semiconductor nanostructures where electrons are confined in all three spatial dimensions. They are very promising for quantum information applications, either as single photon sources or for the implementation of qubits for quantum computation.

In particular, we are interested in the manipulation of the spin of a single electron trapped in a quantum dot and in its interaction with light at the single photon level, in order to create a spin-photon quantum interface. To enhance the interaction between the electron spin and the electromagnetic field, we place the quantum dot (in our case a self-assembled InAs/GaAs quantum dot) in an optical microcavity. It is extremely important for our application to characterize the quantum dot optical transitions and the modes of the microcavities.

The main tool for characterization is photoluminescence using an spectroscopy CCD detector (iDus DU401A-BR-DD from Andor Technology) in combination with a high-resolution spectrometer. We pump our sample above the band-gap, creating electron-hole pairs which relax into the quantum dot and recombine, showing atom-like sharp optical transitions. The polarization of these optical transitions is correlated to the spin of the single electron trapped in the quantum dot.

Results

For our experiments with single quantum dot emitters, it is crucial to have good sensitivity in the near-infrared at very low optical power. Therefore we use the iDus spectroscopy CCD detector in combination with a high-resolution spectrometer to perform photoluminescence studies of self-assembled quantum dots for quantum optics applications (see Fig. 1).Moreover, the noise level should be extremely low, in order to have a good signal-to-noise ratio.

The DU401A-BR-DD model with a Back Illuminated Deep Depleted CCD chip gives us the high sensitivity and low-noise we need to investigate the emission from single quantum dots in the wavelength range between 900 nm and 950 nm. Low-noise performance is guaranteed by thermoelectric cooling, which allows much easier and quicker operation than nitrogen-cooled cameras. Moreover, this camera has an extremely compact design which can fit nicely into our spectrometer. Compared to other camera suppliers we have experienced, we appreciate the user-friendliness of the software.

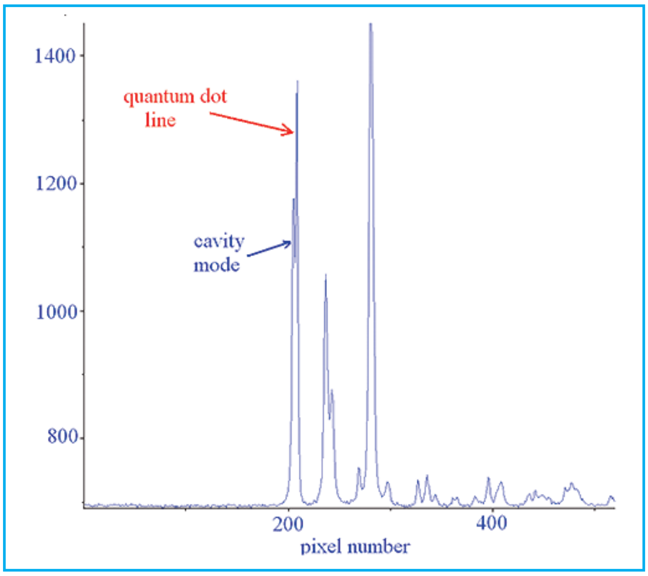

Fig. 1: high-resolution spectrometer data acquired with the iDus CCD detector. We can resolve photoluminescence from microcavity modes and single quantum dot lines.

Easy integration of the software development kit with our customized measurement programs enabled us to automate extensive spatial-spectral scanning of our structures (Fig. 2). Combined spatial-spectral scanning of our emitters is a very important characterization tool for our samples, which allows us to select the best candidate to perform quantum optics experiments.

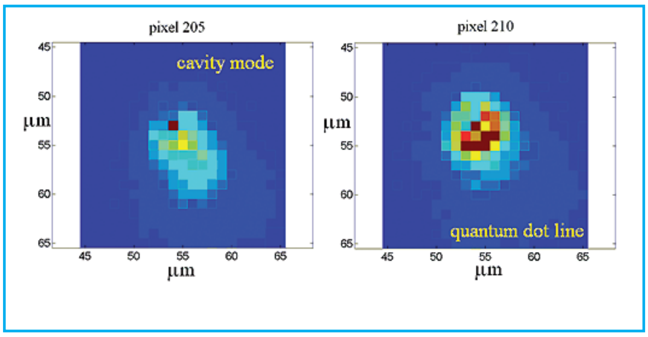

Fig. 2: Spatial scans for two different wavelengths, corresponding to pixels 205 and 210 of our iDus CCD detector (around 30 GHz separation). The image on the left shows the fundamental cavity mode, the one on the right a quantum dot optical transition. Using this combined spatial/spectral scanning we can determine the position of a single quantum dot with respect to our microcavity.

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References

[1] Stefan Strauf, Nick G. Stoltz, Matthew T. Rakher, Larry A. Coldren, Pierre M. Petroff and Dirk Bouwmeester, High-frequency single-photon source with polarization control, Nature Photonics 1, 704-708 (2007)

[2] M. T. Rakher, N. G. Stoltz, L. A. Coldren, P. M. Petroff, and D. Bouwmeester, Externally Mode-Matched Cavity Quantum Electrodynamics with Charge-Tunable Quantum Dots, Phys. Rev. Lett. 102, 097403 (2009)

[3] Cristian Bonato, Dapeng Ding, Jan Gudat, Susanna Thon, Hyochul Kim, Pierre M. Petroff, Martin P. van Exter and Dirk Bouwmeester, Tuning micropillar cavity birefringence by laser induced surface defects, Appl. Phys. Lett. 95, 251104 (2009)

Contact

Dr. Cristian Bonato, Dr. Jan Gudat
and Prof. Dirk Bouwmeester
Huygens Laboratory
Institute of Physics
Niels Bohrweg 2
2333 CA Leiden
The Netherlands

E-Mail: bouwmeester@molphys.leidenuniv.nl
Web: www.molphys.leidenuniv.nl/qo/index.htm