Excited States in 1.3 μm Emitting Single InGaAs/GaAs Quantum Dots Probed by Photoluminescence Excitation Spectroscopy

Paweł Podemski [1], Aleksander Maryński [1], Anna Musiał [1], Artem Bercha [2], Witold A. Trzeciakowski [2], Tobias Heuser [3], Nicole Srocka [3], David Quandt [3], André Strittmatter [3], Sven Rodt [3], Stephan Reitzenstein [3] and Grzegorz Sęk [1]

[1] *Laboratory for Optical Spectroscopy of Nanostructures, Department of Experimental Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wrocław, Poland*
[2] *Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw, Poland*
[3] *Institute of Solid State Physics, Technische Universität Berlin, Berlin, Germany*

The development of quantum communication networks requires reliable single-photon sources with high temporal stability and with good spectral quality output. One of the solutions are self-assembled quantum dots with deep confining potential and emitting at 1.3 μm, realised in well-established GaAs-based material system. However, the typical emission wavelength of InAs/GaAs dots commonly does not go beyond 1 μm. The required redshift of the emission can be induced by an additional strain reducing layer covering the quantum dot layer.

Before specific quantum dots can be implemented in optoelectronic devices, there is a necessity to learn their energetic structure and optical properties. Single dot spectroscopy in a form of microphotoluminescence makes possible insight into quantum dot ground state, by and large responsible for the emission. Nevertheless, the broader picture requires knowledge on higher quantum dot energetic structure, particularly the excited state which can feed the ground state emission from quantum dot. The insight into the electronic structure of a single quantum dot can be achieved by employing photoluminescence excitation spectroscopy (PLE), which also allows for tracing energy transfer processes. However, when the emission from quantum dots is redshifted above 1 μm, single dot PLE becomes quite demanding because of the deficiency of convenient tunable excitation laser sources.

Here, we present optical study of single InGaAs/GaAs quantum dots designed for 1.3 μm emission and aiming at single-photon applications for fibre-based quantum communication systems. The shift of the emission wavelength to 1.3 μm was realised by deposition of InGaAs strain reducing layer on top of quantum dot layer during the MOCVD growth. The emission from single dots was investigated in microphotoluminescence setup equipped with continuous-flow cryostat (providing temperatures down to 5 K) and liquid-nitrogen-cooled InGaAs linear array detector. For the PLE experiment, the setup was additionally extended to provide the tunable excitation source in a form of external cavity laser in Littman configuration, offering continuous wavelength tuning range of around 100 nm with a single laser diode in a rather unexplored range of the second telecom window. The tunable laser source was additionally filtered spectrally, to achieve high quality excitation of single quantum dots. The presented study focuses on energy transfer processes in single InGaAs/GaAs quantum dots, particularly on detailed insight into single dot excited states, providing broader picture of energetic structure of this application-relevant system.

There is acknowledged the support from the National Science Centre (Poland) within the project No. 2014/15/D/ST3/00813, and FI-SEQUR project jointly financed by the National Centre for Research and Development in Poland, grant No. 2/POLBER-2/2016 (project value 2 089 498 PLN) and by the German Research Foundation via the collaborative research center CRC787.