Optical Properties of MOVPE Grown InAs/InP(001) Quantum Dots for C- and L- Telecom Bands Single Photon Sources

C. Ciostek [1], **P. Holewa** [1], **P. Wyborski** [1], **C. Schneider** [2], **S. Kadkhodazadeh** [3], **E. Semenova** [4] **and M. Syperek** [1]

[1] *Laboratory for Optical Spectroscopy of Nanostructures, Department of Experimental Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wyb. Wyspiańskiego 27, 50-470 Wrocław, Poland*
[2] *Technische Physik & Wilhelm Conrad Röntgen-Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074, Würzburg, Germany*
[3] *Center for Electron Nanoscopy (CEN), Technical University of Denmark, Fysikvej 307, 2800 Kongens Lyngby, Denmark*
[4] *DTU Fotonik, Technical University of Denmark, Kongens Lyngby, DK-2800, Denmark*

In the past two decades, considerable effort has been put into the realization of a solid-state semiconductor, and non-classical single-photon generator operating in the lowest attenuation regime of silica optical fibers near 1550 nm photon wavelength utilized for metro- and long-haul quantum-secured data transmission lines. State-of-the-art single photon generators are capable of emitting in the telecom C-band (1530–1565 nm). However, a continuously increasing density of information puts a demand on semiconductor technology to use broader bandwidth, shifting the working mode into the telecom L-band (1565–1625 nm).

Here we report on the spectroscopic investigations of Metalorganic Vapour-Phase Epitaxy (MOVPE) grown self-assembled InAs/InP quantum dots (QDs) emitting in the spectral range of 1.25–2.0 μm at 10 K. Initial photoluminescence (PL) investigations revealed a broad emission spectrum consisting of at least 7 distinct peaks attributed to the multimodal height distribution among the QDs grouped into families. The Atomic Force Microscopy image suggested that the dots have an aerial density of $\sim 10^9$ cm^{-2} and their sizes are large in-plane (50-70 nm) with the length-to-width aspect ratio of ~1.3. However, the height of buried QDs is ranging from a single to a few monolayers (1 ML=0.28 nm) above the ~1 nm thick wetting layer, as suggested by the Transmission Electron Microscopy micrograph. The ML fluctuation in the QD height between families of dots is directly reflected in the abovementioned multimodal PL emission. The confinement parameters for investigated QDs is tested through the temperature-dependent PL measurement that allowed for establishing the average activation energies for PL suppression (quench). As expected, the respective quench activation energy increases with the increase of a dot height and spans the energy range of ~50-250 meV. The activation process is attributed to the escape of a ground state electron from a QD to the WL that found its confirmation in single-particle numerical calculations of a QD band-structure within the 8-band $\mathbf{k}\cdot\mathbf{p}$ framework. Moreover, time-resolved PL experiment showed that an average PL lifetime ranges from 1 to 2 ns with a strong energy dispersion suggesting that an e-h pair in a QD remains in the intermediate confinement regime considering respective Coulomb correlations and quantization energies.

Finally, the QD structure is additionally processed by electron-beam lithography and dry etching techniques to create mesas ranging from 5×5 μm to 100×100 nm to isolate only one or few emitters per mesa. Further micro-PL studies revealed high intensity emission lines from the dots covering both C- and L- telecom bands, paving the way for future research concerning single-photon sources utilizing the investigated material.

The research was financed from Polish budgetary science funds for 2018-2020 within the "Diamond Grant" programme (DI2017 011747).