Probing the spectrum of excited states in single, strongly elongated InP-based nanostructures emitting in the telecom spectral range

P. Wyborski[1], M. Gawełczyk[1,2], H. Salamon[1], P. Podemski[1], J. Misiewicz[1], J. P. Reithmaier[3], S. Höfling[4,5] and G. Sęk[1]

[1] *OSN Lab, Department of Experimental Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wrocław, Poland*
[2] *Department of Theoretical Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wrocław, Poland*
[3] *Institute of Nanostructure Technologies and Analytics, CINSaT, University of Kassel, Germany*
[4] *Technishe Physik, University of Würzburg, Germany*
[5] *SUPA, School of Physics and Astronomy, University of St. Andrews, United Kingdom*

Photoluminescence excitation (PLE) spectroscopy is a powerful method for studying the fundamental electronic and optical properties of nanostructures. In particular, in a high-spatial-resolution setup, it is possible to investigate single quantum dots, which allows one to determine the details of their electronic/excitonic structure. This is especially useful when dealing with novel kinds of nanostructures and even more crucial if their application in optoelectronic or photonic devices, such as semiconductor lasers or single photon sources, is considered. However, due to several technical limitations (e.g. the lack of convenient tunable continuous-wave laser sources), probing the PLE down to the level of single quantum dots is seldom used in the application-relevant telecommunication C band (~ 1550 nm).

Here, we concentrate on strongly in-plane (along $[1\bar{1}0]$) elongated nanostructures (quantum dashes) made by self-assembly of InAs on InP substrates, offering a growth-stage tunability of the near-infrared emission in the C band and suitable for laser applications and non-classical light emitters [1,2]. However, the spectrum of excited states in such structures and its relation to their morphology remains unknown. To fill this gap, we have constructed an experimental PLE setup with a tunable laser (external-cavity design; tuning range of 1440-1540 nm), equipped with a microscope objective (20x magnification, 0.4 numerical aperture), which provides high spatial resolution. In addition, we have obtained a high-quality excitation beam by filtering it with a monochromator (300 mm focal length). With this, our study of individual quantum dashes emitting in the near-infrared spectral range became feasible.

We present the results of PLE measurements performed on single InAs/InP quantum dashes. Detailed analysis of collected spectra allows us to demonstrate the possible channels of optical stimulation in single nanostructures of various sizes, as well as to determine the excited-states energy ladder. For more insight, we confront the obtained spectra with the structure of confined states obtained theoretically within the 8-band $\boldsymbol{k}\cdot\boldsymbol{p}$ framework combined with the configuration-interaction approach for construction of exciton states [3].

There is acknowledged a support from the Polish National Agency for Academic Exchange and from the National Science Centre (Poland) within the projects 2014/15/D/ST3/00813 and 2014/14/M/ST3/00821.

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