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Abstract of Dissertation entitled „Optical properties of single InAs epitaxial nanostructures for applications in nanophotonics”

This dissertation is focused on the optical properties of single InAs epitaxial nanostructures called quantum dashes which have been characterized by means of high-resolution microphotoluminescence experiment. Analysis of the experimental results allows to identify basic excitonic complexes (EC) as exciton, biexciton and one charged exciton. Therefore, the binding energies of the EC have been obtained. By measuring polarization resolved spectra we examined the excitonic fine structure splitting and the degree of linear polarization. Next, we determined the exciton g-factor, electron and hole g-factors and diamagnetic coefficients of different EC by applying external magnetic field. From diamagnetic coefficient we estimated the wave-function extension of exciton.

Experimentally verified optical properties which are relevant for the nanophotonic applications have been further summarized as dependencies versus energy of emission, which is related mainly to the size of the nanostructures. Showing all collected data for single quantum dashes, it has been established energy dependence of binding energies, fine structure splitting, g-factors, diamagnetic coefficients and degree of linear polarization. In this fragment, these results have been compared with theoretical results performed by many-body atomistic tight-binding model, 8-band kp caluclations and simulations of electromagnetic field distribution in a submicrometer structures that contains single quantum dashes. From such analysis we established that quantum dash is highly correlated system and thus biexciton remains in a binding state in all available spectral range. Charged exciton have been identified as a negatively charged trion. Positive trion has not been observed in the experiment probably due to high concentration of the excess charges from InP substrate. The fine structure splitting magnitude has been associated with the elongated geometry but also with the random atomistic distribution which strongly influence its value. The degree of linear polarization (DOLP) is related strongly to the size of the etched submicrometer mesa structure. The DOLP dependence for single quantum dashes using symmetric (quadratic) shape of the mesa reproduces well the value obtained for the emission from ensemble. However, by changing its shape the DOLP control has been obtained experimentally and verified by performing simulations of electromagnetic field distribution that couples to quantum dash EC. There have been examined both the influence of size using fixed asymmetry and the influence of the asymmetric mesa orientation with respect to the quantum dash elongation direction. The wave-function extension evaluated from diamagnetic coefficient has been compared to the 8-band kp analysis. The results show the probability density distribution of electrons and holes that matches the experimental values.

Excitonic fine structure splitting tuning by in-plane magnetic field has been examined for several quantum dashes and the ability to reduce its values below the lifetime-limited spectral width has been achieved. These feature appears for all examined examples in a broad spectral range which is promising in the context of using single quantum dash as a potential source of entangled photon pairs using biexciton-exciton cascade, and in a practical spectral range for telecommunication channels.