Abstract of the PhD thesis

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Thesis title: **GaAs-based quantum dots grown by MBE on metamorphic buffers as a platform for single-photon emitters in the telecommunication spectral range**

Semiconductor quantum dots (QDs) can serve as efficient, near-perfect sources of single photons, as has been repeatedly demonstrated experimentally. Modern epitaxial growth technologies allow controlling the morphological and optical properties of the dots, including tuning of the emission wavelength. In order to achieve emitters in the telecommunications range, i.e., in the spectral region of the minimal transmission losses in fiber-optic networks, it is necessary to select semiconductor materials appropriately. One of the most technologically mature is the InAs/GaAs system. However, due to the significant difference in crystal lattice constants, quantum dots in this material system emit typically around 1 μm or below. Shifting the optical transitions to the telecommunication range requires special technological approaches aiming at band structure and strain engineering. One of the options is the use of an additional metamorphic buffer layer preceding the quantum dot layer, which reduces the strain and hence shifts the emission to infrared. This work aims at characterizing InAs QDs grown by molecular beam epitaxy (MBE) on a metamorphic InGaAs buffer, for its different composition gradients, to connect the dots' structural, electronic and optical properties. In particular, the work focused on obtaining single-photon emission from such quantum dots, including especially the range of the third telecommunication window as the most application-demanded, while at the same time the most difficult to obtain within the GaAs-based technology.

In the thesis, there was demonstrated that by modifying the metamorphic buffer layer composition it is possible to control the QD emission wavelength over a wide spectral range, reaching also the 1.55 μm window, and beyond. The results of spectroscopic measurements confronted with electronic structure calculations utilizing the collected morphological parameters of such dots allowed identifying the main factors responsible for shifting the optical transitions. In addition, a non-zero value of the degree of linear polarization of the emission was obtained, resulting from the mixing of valence states due to anisotropy of the carrier confinement potential in the plane of the dot and enhanced by the low strain and shallow confinement conditions. The temperature dependence of photoluminescence indicated fingerprints of carrier redistribution between QDs and allowed identifying the escape of carriers into the buffer layer as the main thermal loss mechanism and quenching of emission intensity. Observation of the increase in photoluminescence intensity in the range of low temperatures for single quantum dots confirmed the presence of shallow carrier trapping states in their surroundings. Measurements of photoluminescence in a function of excitation power density and polarization initially identified the fundamental charge (excitonic) complexes confined in single QDs, origin of which was confirmed in the second order correlation function via cross-correlating events of emission from different complexes. Results on the exciton and biexciton lifetimes derived from time-resolved measurements suggested the intermediate confinement regime in such dots, which was also supported in calculation of the excitonic states. Whereas low exciton fine structure splitting indicated slight anisotropy of the confinement potential in the plane perpendicular to the growth direction.

Photon autocorrelation measurements proved of unequivocally single-photon character of emission, including both the second and third telecom windows, thus demonstrating that this type of quantum dots grown by the MBE can compete with other single-photon emitters in this spectral range. The lineshape of the measured second-order autocorrelation functions in the pulsed regime confirmed the occurrence of trapping and carrier release processes from charge states in the vicinity of the dots, in agreement with the results of previous experiments, which also indicates the direction for further optimization of these nanostructures.