Role of acoustic phonons in the emission from strongly in-plane anisotropic nanostructures

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Nanostructures of increased size are predicted to be more robust against phonon-induced decoherence due to increased wave function extension resulting in the decrease of the exciton-phonon coupling strength and limited number of phonon modes that can effectively couple [1,2]. In this contribution those predictions were experimentally verified via measuring the temperature dependent linewidth (FWHM) of the single nanostructure emission in microphotoluminescence (μPL) spectra of InAs/InGaAlAs/InP quantum dashes (QDashes). The investigated structures are strongly anisotropic objects of increased volume (typically: 100 x 16 x 3 nm^3) - applicable as the active region of efficient light sources at 1.55 μm. The interpretation of the μPL data is supported by theoretical simulations based on the independent boson model and taking into account two exciton-acoustic phonon coupling mechanisms, i.e. via deformation potential and piezoelectric field.

The excitonic emission was identified based on the excitation power-dependent and polarization-resolved μPL. The observed low-temperature FWHM values are in the range of (50 - 250) μeV, strongly influenced by the spectral diffusion effects and as a result exhibit rather a Gaussian line shape. At 5 K no phonon-related spectral features were observed in agreement with the expected significantly lower visibility of emission sidebands related to acoustic phonons [1]. With increasing temperature the FWHM increases slightly due to increasing contribution of the phonon-assisted emission and then starts increasing abruptly at about 60 - 80 K. The latter is related to the acoustic phonon sidebands intensity exceeding the half maximum of the overall emission. Comparison of the experimental data with the results of calculations allowed us to verify the actual wave function extension (probability density distribution) in the elongation direction assuming nominal QDash cross-section after structural data. Two characteristic values of about 45 nm and 20 nm (both smaller than the typical QDash length) have been determined. The first one can result from the lens-shape geometry, composition inhomogeneity due to intermixing effects and strain distribution for strongly elongated objects, all influencing the detailed shape of the confining potential and possibly leading to the discrepancy between the physical length of the object and the wave function extension. However, it is very unlikely for such elongated nanostructures to localize the wave function in the 20 nm scale. This can be explained either by a large inhomogeneity of the QDash ensemble (and, as a result, broad length distribution including also much shorter QDashes) or by additional carrier trapping on potential fluctuations within the individual QDash structures [3].

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