Exciton fine structure splitting and biexciton binding energy in InAs/InGaAlAs/InP quantum dashes

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The fine structure splitting (FSS) of exciton and binding energy (ΔE_{XX}) of biexciton in quasi-zero-dimensional systems are crucial parameters for developing a new kind of quantum-electrodynamics-based devices, as sources of single photons or entangled photon pairs with defined polarization. In view of applications it is beneficial to control both of them. Quantum-dot-like structures in the InAs/InP material system can potentially be considered due to their easily tunable emission wavelength covering well the telecommunication range, and far beyond. However up to now, any comprehensive study of both the FSS and ΔE_{XX} has not been reported.

Hereby, we present systematic investigation of molecular-beam-epitaxy-grown InAs/InGaAlAs/InP quantum dashes (QDashes) which are characterized by strongly elongated geometry and long-wavelength emission between 1.2 and 1.6 µm, depending on their cross-sectional size. We performed a high resolution microphotoluminescence experiment on small submicron mesas etched on the sample surface, in order to focus on the properties of strictly single emission lines. Preliminary identification of exciton and biexciton emission from a single QDash relies on excitation power dependent series compared with a rate equation model [1]. In this work we try to establish a reliable statistics of both the FSS and ΔE_{XX} values, their spectral/size dispersions and find out which system properties determine them primarily. There belong here such effects as Coulomb correlations, electron-electron and electron-hole exchange interactions, but also the regime of quantum confinement and the strain conditions. Some trends have been shown for small and symmetric InAs quantum dots in AlAs and GaAs matrices [2-4], but also for slightly anisotropic InAs/GaAs QDs, suggesting basically a decrease of both FSS and ΔE_{XX} for very small dots. Here, the physical situation is more complex due to the strong elongation of the investigated structures and the probable existence of the local carrier/exciton trapping on the dash size fluctuations [5]. For most of the dashes we obtained a very small values of FFS, significantly below 100 µeV, in agreement with the localization picture, however, we observed also sporadically values in a range of 100-300 µeV, which suggests an impact of anisotropic exchange interactions for the asymmetrically extended states of the dashes without a confining traps. Additionally, the increasing trend of biexciton binding energy with exciton's energy up to 3.7 meV is contrary to the previous reports for GaAs-based structures [2-4], which supposedly means a different origin of emission, namely lower energy lines come from fluctuations in larger QDashes, whereas higher energy emission is from the excitons localized within the entire QDash volume. Our study shows that the shape anisotropy and confinement regime are actually the factors driving the single dash properties in these nanostructures.

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