Single photon emission from quantum dashes at the telecommunication wavelengths

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A true single photon source (SPS) operating in the C-band of silica fiber-based optical networks is a key element on the way to combine the idea of quantum cryptography and long-haul data transmission technology. However, the main challenge is to find a proper and compatible on every level technology which can result in obtaining an efficient, controllable, and reliable SPS. One of the solutions is utilizing the all-semiconductor technology. Here we show that a quasi-zero dimensional semiconductor nanostructure in the form of InAs/InP quantum dash (QDash) can be considered as a non-classical photon emitter, the crucial part of the SPS at 1.55 μm. Especially interesting in terms of obtaining high single-photon repetition rates is utilizing an SPS based on the emission of a trion, which, due to the lack of the fine structure allows for increased photon extraction in respect to the neutral exciton [1].

We present experimental and theoretical studies on the exciton (X), biexciton (BX) and charged exciton (CX) kinetics and photon emission statistics in single self-assembled $InAs/In_{0.53}Ga_{0.23}Al_{0.24}As/InP(001)$ QDashes emitting at the third telecommunication window [2,3]. The average QDash size is 3.5 nm in height, 20 nm in width and 50 to hundreds of nm in length. All experiments are based on high spatial resolution photoluminescence setup and its further crucial modification including the Hanbury-Brown and Twiss interferometer and the time-resolved photon-counting system employing the superconducting detectors. Low-temperature polarization-resolved and excitation power-dependent photoluminescence from single dashes allowed for an identification of the X, BX and CX emission features. The measurements of the second-order cross-correlation functions for the BX-X and CX-X pairs of lines confirmed undoubtedly their nature and origin of their emission from the same dash. This allowed determining internal parameters of the fundamental excitations including the X fine structure splitting, or the CX and BX binding energies. The measurements performed in the time-domain along with theoretical modeling provided the parameters of the relaxation kinetics in a single dash and revealed peculiar X emission dynamics related to the refilling of the X state form the BX one at elevated excitation power densities.

In order to check the non-classicality of the emission from exciton and charged exciton the photon auto-correlation measurements have been performed at T = 5 K. Sub-Poissonian photon emission statistics have been obtained and a clear photon antibunching in case of both X and CX emission have been detected with $g^{(2)}(0) = 0.18$ and $g^{(2)}(0) = 0.31$, respectively, without any dark counts subtraction or deconvolution. The latter corrections bring the $g^{(2)}(0)$ values to zero. Our observations confirm unambiguously that InAs-InP QDash can be considered as true single photon source employing neutral or charged exciton.

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[2] Ł. Dusanowski et al., Appl. Phys. Lett. 103, 253113 (2013).
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