Exciton spin polarization relaxation in InAs/InP quantum dashes under optical-phonon-mediated resonant excitation

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Quantum dash (QDash) is epitaxially grown nanostructure strongly elongated in one of the in plane directions. Significant anisotropy of its physical dimensions and non-uniform strain distribution results in strongly asymmetric electron and hole confining potential that consequently leads to the inverted spin structure of an exciton [1] and a valence subband mixing pinning the polarization state of the emitted photons [2]. These unique properties open a route towards fundamental research concerning spin state of an electron and a hole in the anisotropic confinement including spin injection, control and relaxation. Moreover, the electron and hole spin properties merged with the InAs/InP(001) QDash technology can open a route towards spin-photonic devices operating at 1.3 μm and 1.55 μm spectral ranges, which can help to introduce new ideas within such well-established technology including lasers utilizing spin injection of cold carriers, spin-based quantum memories or polarization conversion amplifiers.

We have examined exciton-spin dynamics within an ensemble of InAs/InP QDashes emitting around 1.55 μm by means of polarization-resolved photoluminescence-excitation and time-resolved photoluminescence (TRPL) experiments at T=4.2 K. Under non-resonant excitation (NRE) conditions we observed linearly polarized radiation pinned to the dash elongation axis (EA) with degree of linear polarization equal to around ~25 %, which stems from a strong valence band mixing [2]. In case of photon-polarization-controlled resonant injection of an electron-hole pair via the LO-phonon mediated scattering process we are able to selectively excite one of the two fine structure split bright exciton states. Consequently, we observe increase in the value of degree of linear polarization (defined in respect to injected radiation polarization) of ~28 % and ~38 % along and perpendicular to the EA (in respect to the NRE case), respectively. Therefore, we demonstrate that the spin injection mechanism involving the LO-phonon scattering process is well realized in the investigated InAs/InP(001) QDashes. Polarization-resolved TRPL experiment performed under the LO-phonon mediated excitation condition shows that for both the fundamental bright exciton spin states the degree of polarization decays with ~4 ns time-constant, which is 3-4 times longer than the exciton lifetime (~1.2 ns in case of those particular dashes). This observation clearly shows that injected exciton spin confined in a QDash is weakly perturbed by the presence of spin relaxation mechanism.

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