A transition from 0D to Extended Ground State in InP-Substrate-Based Coupled Quantum Well - Quantum Dash System at 1.55 μm

M. Syperek,[1] J. Andrzejewski[1], A. Maryński[1], W. Rudno-Rudziński[1], J. Misiewicz[1], S. Hein[2], S. Höfling[2], and G. Sęk[1]

[1]*Laboratory OSN, Division of Experimental Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Poland*
[2]*Technische Physik, Univ. of Würzburg and Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, Am Hubland, Würzburg, Germany*
[3]*School of Physics and Astronomy, University of St. Andrews, St. Andrews, UK*

The concept of a coupled quantum-well quantum dot/dash system (QW-QD/QDash) remains a challenging issue in the context of its band structure engineering desired for specific applications. In the case of QW-QD/QDash-based lasers one of the problem is to preserve a quasi-0D-like character of the gain medium that results from a full 3D confinement of carriers. However, in the case of some QD/QDash memory applications there is required a weaker confinement in the dot allowing out tunnelling of carriers into the neighbouring QW. In this work we investigate a system based on InP substrate in which both scenarios can be realized by tailoring the well width (d_{well}).

The system under study consists of $In_{0.53}Ga_{0.47}As$ QW separated from a layer of InAs QDashes by 1.7-nm-wide InAlAs barrier. Four structures were investigated with d_{well} equal 4.5, 5.5 and 6.5 nm, and a reference structure with QDashes only. In all cases, the ground state (GS) emission of the entire system occurs at 1.55 μm. The electronic coupling is examined at T = 5 K by combination of various optical spectroscopy techniques, with the major role of time-resolved photoluminescence, supported by eight-band **k·p** calculations of the coupled system's band structure.

The experimental results show that with increasing d_{well} the electronic coupling between the QW and QDash parts at the GS increases considerably, as it is viewed by elongation of the PL lifetime (τ_{PL}). For d_{well}=4.5 nm the $\tau_{PL}\approx$1.8 ns is comparable with the one registered for the reference structure that resembles the Coulomb-correlated electron-hole recombination lifetime in quasi-0D confinement of a QDash. However, when the d_{well} increases to 5.5 nm, and 6.5 nm, the τ_{PL} increases up to ~4.9 ns, and ~9.7 ns, respectively. This indicates an extension of the GS of either electrons or holes from QDashes to the well. A similar effect has been observed in (In,Ga)As/GaAs coupled QW-QDs system [1] where mainly electrons have tendency to be smeared over QW and QD potential. For the system under study a reversed trend is expected as confirmed by the theoretical calculations: the electrons are strongly confined in dahs whereas the holes are leaking out into the well.

This experimental founding opens the rout towards exploration of an electron spin memory in a coupled system at 1.55 μm where initially addressed electron spin state through creation of a positively charged exciton can be left in the dash while holes can be removed away due to their tunnelling into a QW.

[1] M. Syperek, J. Andrzejewski, W. Rudno-Rudziński, G. Sęk, J. Misiewicz, E. M. Pavelescu, C. Gilfert, and J. P. Reithmaier *Phys. Rev. B **85**, 125311 (2012).*

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