Dynamic and polarisation properties of InAs/InAlGaAs/InP hybrid quantum well-quantum dot structures emitting at 1.55 µm

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Quantum-dot-based semiconductor lasers have highly demanded operating parameters, such as temperature stability and low threshold current. However, in order to fully benefit from their advantages in telecom devices, it is necessary to increase their modulation speed, limited by hot carrier population. It can be achieved in a tunnel injection scheme, where carriers are supplied to the quantum dot (QD) ground state from an adjacent quantum well (QW), acting as a carrier reservoir and separated by a thin tunnelling barrier from QDs. Similar systems can be also used in semiconductor optical amplifiers and memory devices. Hybrid QW-QD structures are also interesting objects of fundamental investigations due to a complex 2D-0D character of confinement [2].

We investigate molecular beam epitaxy structures grown on InP substrates and comprising of an InGaAs QW, separated by a thin InGaAlAs barrier from InAs QDs, with room temperature emission around 1.55 µm. The application of As_2 sources during growth assures increased symmetry and homogeneity of QDs, as compared to typically grown highly elongated InAs/InP quantum dashes [3]. To control the coupling between the QW and QD parts, we tailor the thickness of the tunnelling barrier and the QW width, which command the wave function overlaps and energy level separation. This affects the optical transitions' rates, inducing changes from an uncoupled system, where the optical response is just a sum of responses from two isolated elements, to a strongly coupled system, exhibiting mixed 2D-0D transition characteristics, leading to the ground state indirect in the real space. The changes of the band structure are deduced from photoreflectance and photoluminescence (PL) spectra, including polarisation and time resolved PL experiments. The results show both considerable changes in the PL decay times for the ground state (from 2 to 10 ns) and different values of its degree of linear polarisation, which reflect shifting localisation of confined states involved in the fundamental optical transition. Optical spectroscopy is supported by 8-band $k\cdot p$ modelling, including realistic geometry, strain and piezoeffect. Numerical simulations of confined state energies and their corresponding wave function localisations allow us to relate the experimental results to the band structure of the investigated samples and to propose guidelines for the design of tunnel injection structures enabling the construction of efficient telecom lasers.

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