Room Temperature Carrier Dynamics in the W-type GaInSb/InAs/AlSb Quantum Well Structure Emitting in Mid-Infrared Spectral Range

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The type II W-design quantum wells (QW) based on InAs/GaInSb broken gap materials' combination have been developed as a key element of the gain medium of interband cascade lasers (ICLs) emitting in mid-infrared spectral range [1]. The ICLs have been proven to have has a huge application potential in optical gas sensing of medically and environmentally relevant gasses, and overwhelming in some performances the systems based on quantum cascade lasers. In spite of that, some of the properties of the active region in this experimentally demanding spectral range are still not well known, and this concerns also carrier dynamics, on which only a very initial work has been reported [2]. In this work, we use experimentally challenging pump-probe technique utilizing pJ pulses in order to study at carrier dynamics at room temperature in the W-type QWs to get a set of characteristic laser-performance-related time constants.

The transient reflectivity (TR) experiment based on a pump-probe scheme has been used in order to test carrier relaxation dynamics in such a W-design QW structure. The QW is excited by a train of 140 fs-long pulses with the photon wavelength of 830 nm, and ~13.2 ns pulse-to-pulse distance that produces certain carrier population at the higher energy states in the well. Subsequent carrier relaxation is tested by a train of 200 fs-long probe pulses that are tuned to the ground state (GS) emission of the QW occurring at 2.5 μm. The TR signal reveals two characteristic processes: (i) population of the GS hindered in the rise of the TR signal, and (ii) its subsequent depopulation represented by the decay of the transient reflectivity amplitude. The measured TR rise time is 2.3±0.2 ps and it is supposed to be related to the longitudinal phonon-assisted relaxation channel since the initial population of photo-injected carriers is insufficient for the Auger-type relaxation. The GS depopulation occurs via two processes of a significantly different time scale. The long-lasting one in the nanosecond range is attributed to the radiative recombination of spatially separated electrons and holes - expected for the W-type QW structure. However, the origin of a short decay component of 240±0.2 ps time constant is not clear and has not been observed for such type of QWs. It can be attributed to the carrier escape process from the QW GS to some localized states at the InAs/GaInSb interfaces caused by the intermixing effect, which has been predicted previously [3].

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Work supported by the iCspec project of the European Union's Horizon 2020 research and innovation programme under grant agreement No 636930 and by the National Science Centre of Poland within Grant No. 2014/15/B/ST7/04663.