Towards broad and spectrally tuned polarization-independent gain of interband cascade lasers in the mid-infrared

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Interband cascade lasers (ICLs) are an important class of efficient mid-infrared (MIR) semiconductor light sources. In past few years, there has been achieved a significant progress in the performance of ICLs on GaSb substrates, which had been stimulated by increasing importance of such lasers in many applications, including medical diagnostics, trace-gas analysis, pollution monitoring and molecular spectroscopy. The application potential originates mostly from unique operational characteristics of ICLs as they can cover the spectral region of below 3 to above 7 μm with room temperature continuous wave operation, and in most of this range also with single mode emission [1,2], but also offer much smaller electrical power consumption [3] when compared to the main competitor which are quantum cascade lasers. One of the demanded and still not existing devices is a polarization-independent emitter in the mid-infrared. The possible polarization-independent electroluminescence from ICL structures was suggested already more than 15 years ago [4] but never demonstrated.

We have studied a novel design of an ICL active region in a form of type-II W-shaped AlSb/InAs/GaAsSb/InAs/AlSb QWs grown on a GaSb substrate, i.e. with the commonly used compressively-strained GaInSb layer, as a confinement layer for holes, replaced with tensely-strained layer of GaAsSb [5]. We present results of theoretical modelling in the framework of eight-band k·p theory of the ICLs‘ band structure under external electric field imitating the conditions occurring in an operational device. Utilizing the Fermi's golden rule allowed us to find the optical material gain of a quantum well assuming the Lorentzian line-shape, and including realistic carrier concentrations and the respective occupation of the subbands out of k = 0. We have demonstrated that the strain and confinement engineering make possible to switch the character of the fundamental optical transition into a light-hole-like in this kind of QWs, which in turn allows for a control of the contributions of the transverse electric (TE) and transverse magnetic (TM) polarizations in the in-plane emission by just tailoring the thicknesses or the composition of the GaAsSb layer. This can lead to broad ranges of polarization insensitive optical gain with the central wavelengths freely tuned over at least the rage of 3-5 μm.

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