Modelling the electronic structure and optical properties of Interband Cascade lasers on InP Substrate

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There has recently been reported a significant progress in important class of coherent radiation sources in the mid-wave infrared have become the interband cascade lasers (ICLs) employing type II, indirect in the real space optical transitions [1,2]. ICLs combines a relatively long upper-level lifetime with the voltage-effcient cascading scheme, what borrowed from the quantum cascade lasers with and conventional diode laser. Current ICLs are grown by molecular beam epitaxy on GaSb or InAs substrates. So far, many applications have been developed based on this type of laser, it is still necessary to improve the active region and the characteristics of the device or to reduce the fabrication costs. These would potentially be obtainable when ICLs could be grown in mature and cheaper technologies based on GaAs or InP.

In this work, we discuss a possibility of implementing a novel type-II QWs design, which we propose designs of an interband cascade laser (ICL) active region able to emit in the application-relevant mid infrared (MIR) spectral range and to be grown on an InP substrate. We have modelled the influence of material configuration (compositions and layers' thicknesses) on the electronic structure and the material gain of a type-II W-design QWs as the active region of an interband cascade laser. The proposed original solution is based on a combination of InGaAs/GaAsSb materials, forming a broken gap layout, with an included additional InAs layer in the active part. The calculations have been carried out within the eight-band k·p theory including strain. We showed that the inclusion of a thin InAs layer into such a type II system brings a useful additional tuning knob to tailor the electronic confined states, optical transitions' energy and their intensity. We concentrated on the emission wavelengths of about 3–5 μm as it is the target range for many optical laser based gas sensing applications, while still keeping reasonably high gain when compared to the state-of-the-art ICLs. In order to verify the application prospect the results will be confronted with the common W-design QWs [3].

[1] R. Q. Yang, *Infrared laser based on intersubband transitions in quantum wells*. Superlattices Microstruct. 77, 17 (1995).
[2] J.R. Meyer, W. W. Bewley, C. L. Canedy, C. S. Kim, M. Kim, C. D. Merritt, I. Vurgaftman, *The Interband Cascade Laser*, Photonics 7, 75 (2020).
[3] K. Ryczko, J. Andrzejewski, G, Sęk, Towards Interband Cascade lasers on InP Substrate, Materials 15, 60 (2022).

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