Threshold operation of quantum-cascade vertical-cavity surface-emitting lasers

M. Janczak[1], R. P. Sarzała[1], M. Dems[1], A. Kołek[2], M. Bugajski[3], W. Nakwaski[1] and T. Czyszanowski[1]

[1] *Lodz University of Technology, Institute of Physics, ul. Wólczańska 217/221, 93-005 Łódz, Poland*
[2] *Department of Electronics Fundamentals, Rzeszow University of Technology, al. Powstańców Warszawy 12, Rzeszów 35-959, Poland*
[2] *Łukasiewicz Institute of Microelectronics and Photonics, al. Lotników 32/46, Warszawa 02-668, Poland*

The structures of in-plane quantum-cascade lasers (QCLs) are mature enough to serve crucial role in gas detectors. However, their properties do not rank them at the first place of such applications. Vertical-cavity surface-emitting lasers (VCSELs) merge single mode operation, high-quality circular output beam, low threshold currents and wafer testability. The lack of the light polarization component perpendicular to the epitaxial layers of quantum-cascade active regions in conventional VCSELs design prevents stimulated emission. Utilizing subwavelength monolithic high-contrast grating (MHCG) in place of distributed Bragg reflector (DBR) overcomes this problem by inducing polarization component necessary for stimulated emission inside the grating and serving a role of the mirror [1].
The work is based on QC-VCSEL simulations under pulse operation regime. Physical phenomena influencing the architecture of the structure has been investigated. The active region behavior such as voltage-driven gain cumulation has been shown to be significant and main factor limiting the QC-VCSEL performance. The threshold analysis has been performed in exhaustive numerical simulations considering the influence of optical and electrical aperture dimensions. The transversal fundamental mode and higher order modes operation has been considered and estimated threshold currents are lower than typical thresholds currents for in-plain QCL.

[1] T. Czyszanowski, IEEE Photonics Technol. Lett. **30**(4), 351–354 (2018).

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