Long-wavelength (10+ μm) quantum cascade lasers based on InAlAs/InGaAs/InP heterostructures

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Quantum cascade lasers (QCLs) based on InAlAs/InGaAs/InP are compact and powerful coherent light sources in range from ~3.5 μm to ~12 μm. In case of QCLs, the light emission is the result of interband transition of electrons between two energy states of coupled quantum wells surrounded by injector/extractor region. The emitted wavelength depends on the separation of these energy levels. This allows for relatively easy selection of emitted wavelength through the appropriate design of the QCLs active region. It makes QCLs widely applied in the gas sensing applications e.g. for CO/CO_x (lasers emitting ~4.5 μm) for NO_x (~5.2 μm), and for organic hydrocarbon (~11 μm).

In case of the InAlAs/InGaAs/InP material system, the best performance of the QCLs is achieved near ~9 μm where lattice constants are well fitted. Short-wavelength (below ~8 μm) QCLs require design of stresses-compensated active region because of the lattice constants mismatch of $In_xGa_{1-x}As$, $In_xAl_{1-x}As$ and InP materials. Despite the fact that in long-wavelength QCLs the strain-compensated active region is not necessary, the higher free-carrier absorption (which increases as root square of wavelength) and lower confinement factor than in shorter-wavelength QCLs. Therefore, the careful and special design of heterostructure active region and waveguide layers is required.

In this work the various types of long-wavelength QCLs designed and obtained in Infrared Photonics Research Group of Łukasiewicz – Institute of Microelectronics and Photonics. Lasers based on InAlAs/InGaAs/InP heterostructures grown by molecular beam epitaxy (MBE) are presented. Devices were based on 4 QW active region design. The electro-optical, spectral and beam characterization of Fabry-Pérot and single-frequency lasers (coupled-cavity design) are described, as well as, the numerical results of heterostructure, and lasers design simulations.

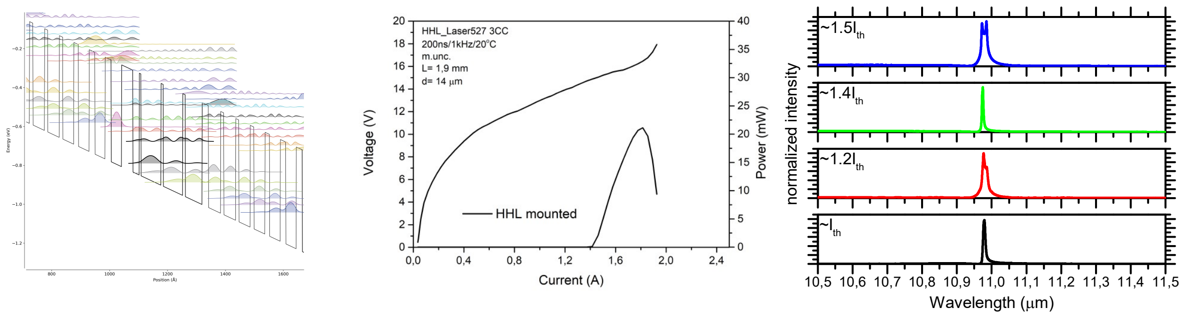

Fig. 1 Numerical results of active region simulation (a), L-I-V (b) and spectral (c) characteristics of typical single frequency long-wavelength (~11 μm) coupled-cavity quantum cascade laser.