Project "New designs of long-wavelength quantum cascade lasers on InP substrates" is focused on developing novel devices emitting in mid-infrared spectral range in the wavelength range of 10 µm ÷ 16 µm for trace gas sensing applications. Principle of operation of these devices is intersubband emission between electronic subbands in the conduction band formed due to quantum effects. The unique feature of QCLs is the possibility of achieving different emitting wavelengths for the lasers based on the same material system, by using different geometry of wells and barriers in the superlattice active region. Quantum cascade lasers operating in the longer spectral range are typically based on the AlGaAs/GaAs material system, while lasers in the 3.5 µm ÷ 10.0 µm range are fabricated in the InAlAs/InGaAs/InP material system. Although the latter allows for better performance of the devices, the heterostructure epitaxy process is more complex.

The research will be focused on developing of the new QCL active region design based on the InAlAs/InGaAs/InP material system, which allows for obtaining laser operation at the wavelengths above 10 µm. Due to free carriers absorption losses, which increase with the square of the emitted wavelength, the lasers emitting at the wavelength of λ=16 µm have almost ten times greater optical losses in the optical resonator than the laser emitting at wavelength of λ=5 µm. For this reason, it is necessary to make changes in the device's active region. The active region scheme utilizing the laser lower level depopulation by two optical phonons to the continuum of states, called "two-phonon-continuum", will be investigated. The numerical simulations as well as investigation of fabricated devices will allow for the determination of optimal heterostructure parameters such as: doping of the injector, thickness and geometry of wells and barriers and the number of the active region stages.

The quantum cascade laser is one of the most significant element in system for trace gas sensing applications in the mid-infrared region. They allows for detection and analysis of the different species composition of various gases with the accuracy on the level of one part per billion (ppb). The measurements are non-invasive and non-contact. This gives opportunity to use these systems in medical, industrial processes monitoring, environmental control and military applications. In the range of 10 µm ÷ 16 µm the strong absorption bands for aromatic hydrocarbons and organic solvents like benzene, toluene, ethylbenzene or xylene are presents. However the lack of emitters with good enough operating parameters which are necessary for achieving ultra-high detectivity demanded in trace gas sensing systems slows down development of this discipline. .

The final result of this project will be development $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As/InP$ quantum cascade lasers grown by molecular beam epitaxy (MBE), emitting in the range of 10 µm ÷ 16 µm, dedicated for specialized trace gas sensing systems.