The civilization development was always connected with materials used by human. This is the reason of names of Stone Age or Iron Age. Today, we could say that present time is photonics age, and its base device is a laser. It allows development of electronics, telecommunication, informatics, medicine or metal manufacturing. Increased interest in molecular spectroscopy is caused by covering mid-infrared part of the spectrum. This allows for trace gas sensing based on absorption with the sensitivity of part per billion (ppb). This opens new possibilities in medicine, environment safety and military applications. In case of such fundamental role played by today's photonics, it is necessary to have a close look at this fascinating group of devices.

Laser is an electromagnetic wave emitter in ultraviolet, visible or infrared region. Its principle of operation utilizes basic physical effect called stimulated emission. Spontaneous emission is generation of random photons when electron is going from excited state to ground state. Stimulated emission is the photon emission which the same frequency, phase and direction as the initial photon. Thanks to that, the amplifying of specified electromagnetic wavelength occurs. Furthermore, the process can be controlled by parameters of the gain medium, where the mentioned photon generation takes places, and also by the resonator configuration. It ensures that the photons which have the chosen direction can create the standing wave in the resonator. The amplified stimulated emission after exceeding losses leads to laser action. The value of gain at which this happens is called a threshold gain.

The active region can be pumped electrically or optically by radiation of higher energy than emitted one. The consequence of this process is transition of electrons from ground state to excited state. The energy distance between these two states determines emitted wavelength. The laser active medium, can be gas, solid state, and semiconductors. The last one are the most promising group of devices; they are characterized by small dimensions, high reliability and ease of modulation. The typical semiconductor laser is based on p-n junction. The current flow in forward polarized junction leads to injection and subsequent recombination of electron-hole pairs. As a result photons are generated. The emitted wavelength is related to the bandgap of the material in which generation occurs. When different wavelength is needed by particular application one has to use another material system, which is a clear disadvantage. The solution to this inconvenience is the use of quantum well based active region. The quantum well is the structure made of two different semiconductors, where one of them has higher bandgap (barrier) and the other has lower bandgap (well). If the thickness of the well is small, comparable to the electron wavelength, carrier energy becomes quantized; the localization energies being dependent on thickness and the depth of the quantum well. This allows to control the active region energy levels structure and changing it, however still in limited range. The essential breakthrough occurred in 1994 when quantum cascade laser was invented. The quantum cascade laser operates by different principle; instead of band to band transitions it utilizes intersubband transitions within the conduction band which makes the transition energy not that much dependent on the material as on the geometry of quantum well. The quantum cascade laser is an ideal source of infrared radiation with numerous applications in industry, environment protection, medicine and security. The active region of quantum cascade laser is created by periodic structure of quantum wells and barriers with suitable tailored widths and heights, which creates specific energy levels. This gives wavelength flexibility within one material system family. The structure of quantum cascade laser consist of quantum well active regions followed by superlattice injectors, repeated many times to achieve, after applying an appropriate bias, cascading effect. Electron traveling through the consecutive parts of this cascade generates photons, which number can be equal the number of cascades in the favorable case. This significantly improves gain of the system.

Quantum cascade lasers are grown by gas phase epitaxy or molecular beam epitaxy. The most common material systems are InAlAs/InGaAs/InP and GaAs/AlGaAs. The first one, despite of higher conductive band discontinuity which allows to achieve better laser parameters, is more complicated in growth process. Furthermore, both ternary alloys are no lattice matched to InP substrate in general. The strictly determined compositions of the ternary layers have to be achieved to balance mismatch strain. The required precision of controlling of growth process parameters has to be maintained for many hours. Lasers based on AlGaAs/GaAs material system are easier to grow. In this case we have only one ternary component, which in for all possible compositions is lattice matched to GaAs substrate. The processing technology in the case of this material system is well known and don't differ much from that for interband lasers based on the same material. The main disadvantage of this lasers is small discontinuity of conduction band between barriers and wells in active region. It limits the emitted wavelength to mid-infrared region, enables only pulse mode operation and limits maximum operating temperature to approximately 300 K. The most important obstacle in commercialization of this type of quantum cascade lasers is low maximum operating temperature. In many applications the continuous operating mode is not demanded. In mid-infrared range we can also find many absorptions lines, which can be useful in trace gas sensing at very high sensing level.

Increasing discontinuity in conductive band can be realized by increasing aluminum content in barrier layers or by make the wells deeper. The maximum aluminum content in the barriers, which doesn't change the bandstructure of the material from direct to indirect equals 45%. The deeper wells can be achieved by introducing small amount of indium into GaAs quantum well. Such structure was already grown, and its maximum operating temperature increased to 50 ºC, which is much higher than before proposed modification. One my expect that further increasing of indium content in the wells will have positive influence on the structure energy band diagram. Unfortunately this introduces strain into heterostructure due to difference in lattice constants of used materials. This can have negative influence on booth, laser operating parameters and lifetime. The main goal of this project is to determine the maximum amount of indium which can be incorporated into the structure without deteriorating its crystalline quality. Study of growth process technology is the condition for further improvements in case of GaAs-based quantum cascades lasers.

Photonic and in particular lasers development in future depends on basic research on material parameters and physical principles of the systems. The research in progress are opening new possibilities and result in more complicated devices, which allow for exploration of new applications fields, thanks to covering new spectral ranges. It seems to the best time for photonics in the near future.