Laser diodes are based on two types of semiconductors. Infrared diodes (used e.g. in fiber telecommunications and in CD players) and red diodes (used in DVD players) are grown on InP or on GaAs. These crystals have the cubic symmetry (the atoms form a cubic lattice) and under uniaxial strain (perpendicular to the facet of the cube) their symmetry is lowered (the cube becomes a cuboid). This leads to splittings and shifts of energy bands in the crystal described by the so called deformation potentials. The second type of semiconductor crystal used for the growth of blue and green lasers (used e.g in BlueRay players and in laser projectors) is the gallium nitride GaN (and its alloys with indium nitride InN and alluminium nitride AlN). Nitride semiconductors crystallize usually in wurtzite structure which is similar to the cubic crystal stretched in the direction of the diagonal of the cube. This stretching leads to the separation of the planes of positive and negative ions which generates nonzero electric field (and polarization) in the crystal. These crystals are called polar crystals, as opposed to nonpolar cubic crystals where the electric field vanishes. In polar crystals the uniaxial pressure (in the direction of polarization) will not only shift the energy bands but it will change the separation of charge and, therefore, the electric polarization. Deformation in the directions not changing the charge separation will not affect the electric field. In laser structures the electric field will be also affected by the voltage applied to the diode and by the presence of free carriers (electrons and holes) in the crystal - these carriers create the field opposing the external field, this is called the "screening effect".

In the current project we plan to study the properties of semiconductor lasers under uniaxial pressure perpendicular to the plane of the laser for polar (GaAs type) and nonpolar (GaN type) laser structures. This will allow to understand the effects of shifts of energy bands and the effects of electric fields in the structure. We have to control the free-carrier concentration in the laser (screening the electric fields). Uniaxial pressure may change the emission wavelength of the laser (the color of light) and the current required to start the laser action (so called threshold current). We shall also perform the photocurrent measurements, consisting in illuminating the laser with monochromatic (single color) light and measuring the current excited by this light. This is approximately equivalent to absorption measurements in the active layer of the laser and allows to determine the energies of optical transitions between different energy states of the laser. Different states shift with different rates under uniaxial pressure, which helps identify these states. The crossover of such states may change the polarization of laser light.

In nitride structures (blue and green lasers) many parameters are still uncertain; we expect that uniaxial measurements will allow to determine the deformation potentials for the energy bands and the so called "piezoelectric constants" determining the changes of electric polarization under strain.

We developed a special setup for uniaxial measurements: the laser chip (typically 1 x 0.5 x 0.1 mm) is clamped between two steel "columns" in the direction perpendicular to the active layer of the laser. The current is supplied through these columns and the force acting on the chip is measured by a tensometer. This force is varied from 0 to 400 N which implies the pressure from 0 to 8 kbar (0.8 GPa) because the area of the sample is around 0.5 mm^2. The whole setup is placed on the XY table under the microscope objective. Laser emission is measured by the so called Optical Spectrum Analyzer or a spectrometer and the monochromatic light for photocurrent measurements is obtained from the lamp with monochromator (or from the fiber white light source and monochromator). We have already obtained preliminary results using this setup, showing significant changes of the emission spectra and of the threshold currents of different laser samples.

We shall also perform calculations of the uniaxial stress effects on the properties of laser structures and we shall compare the results with the experimental data.