Since 80's of XX century scientific research on semiconductor heterostructures with two dimensional electron gas (2DEG) allows us to understand many physical phenomena observed at mesoscopic scale like: integer and fractional quantum Hall effect, conductance quantization in quantum point contacts (QPC) or Aharanov-Bohm oscillations in quantum rings. At low temperatures where the coherent flow is present, quantum transport is determined by the Fermi level wave function. Recently it became possible to apply a local (at some point of the sample) perturbation of the system and then measure the response of the system to that perturbation. One of such techniques which allows us to probe the local properties of the mesoscopic systems is the scanning gate microscopy (SGM), in which surface of the sample is scanned with biased tip of Atomic Force Microscope (AFM). The electrical charge on the AFM tip interacts with the 2DEG located beneath the surface sample and affects electron transport in the quantum device. By changing the position of the tip above the sample we can prepare so-called conductance maps -- conductance in function of the position of the tip. The response of the system can be very complicated thus theoretical study is needed to help with the interpretation of the experimental data and this is the aim of my scientific work. The SGM technique can be also used with systems where the spin nature of electron plays important role in the transport processes and help to understand or even discover a new physical phenomena. Many of those spin-related problems are still not explained e.g. currently scientist discuss the possibility that spin-orbit (SO) coupling has a big influence on the shape of the so-called 0.7 anomaly, but actually we still do not have clear explanation what the origin of this anomaly is (there are plenty of theoretical models which explain its origin in various ways). Additionally the contemporary fabrication methods become better and better and allow us to create new types of semiconductor structures e.g. recently discovered InSb heterostructure which exhibits very strong SO coupling, much stronger than in well known InGaAs. Such strong SO coupling makes InSb a good candidate for future spintronic application, because they allow to generate spin polarized currents without presence of the external magnetic field, which was a big problem. That is why spin transport recently became a very interesting field for scientific research.

One of the aims of this project is to study the influence of the SO interaction on the so-called effective Lande factor g*. According to the recent experimental papers the value of g* strongly depends on the direction of the external magnetic field B and the largest influence on the g* is when B is perpendicular to the surface of the sample. This effect is explained in terms of the Zeeman shift and exchange interaction, which is not connected to the SO interaction, but our preliminary studies show that SO coupling also plays an important role in this problem and has to be investigated in order to explain the origin of this effect.

Another problem we want to study is a simulation of a new type of electron magnetic focusing experiment in which one could map (with SGM technique) the splitting of the electron trajectories into two beams with opposite spin orientation. In the standard magnetic focusing experiment one deflects the electron beam by applying magnetic field B perpendicular to the sample surface, such that the beam is directed to the drain which leads to the conductance increase. By changing the strength of the applied magnetic field one may change the curvature of the beam (the system behave same as classical electrons in the magnetic field) and measure the conductance in function of magnetic field. When there is no spin polarization, only one main maximum is observed in the conductance signal. In case of presence of the spin polarization, the electron with spin oriented in the same direction that B field travels with a different velocity than an electron with opposite spin, thus different Lorentz forces act on both electrons which should lead to double maximum visible in the conductance plot. The relation between splitting of both beams and SO coupling has to be investigated.