

One of the peculiar properties of graphene is the possibility to induce a p-n junction using external gates, without the need for chemical doping. An intriguing feature of these junctions is the Klein tunneling. The p-n junction is then transparent for electrons incident normally and opaque for electrons incident tangentially. The angular dependence of the phenomenon has allowed for observation of Fabry-Perot interference in n-p-n junctions. On the other hand, in strong magnetic fields the p-n junctions form waveguides for the currents. The carriers move along the junction on snake orbits pushed to the p-n interface by the Lorentz force that acts in an opposite direction for states of the conduction and valence bands. We propose to study p-n junctions in graphene induced by external gates, including a charged tip of an atomic force microscope (so called scanning gate). Our ultimate goal is to design an electron interferometer using p-n junctions in the quantum Hall regime, that could detect the phase shifts phenomena due to the scattering between the Landau levels and the spin-interactions within the system. The design will be based on a numerical modeling using an atomistic tight binding approach.

In traditional semiconductor systems based on a two-dimensional electron gas one can monitor the electron flow in space using a charged tip of an atomic force microscope. The electron gas is buried shallow beneath the surface of the system and the charged tip of the microscope introduces the Coulomb perturbation to the potential landscape within the gas. In coherent conducting systems the flow of the current and the conductance is determined by wave phenomena of a non-local character. Nevertheless, the conductance measurement as a function of the tip position yields information on the wave function response to the local perturbation which allows for readout of the current map within the system, including the spatial quantization of the electron flow in quantum point contacts, the magnetic focusing etc. For graphene one can approach the electron gas at a very small distance, which should allow for imaging the transport phenomena with a very high resolution. However, due to so-called chirality of the carriers given by the relation of the electron momentum with the components of the wave function on the two triangular sublattices of graphene, the backscattering by a long-range tip potential does not occur. As a result the graphene does not respond to the tip by variation of the electrical resistance.

In this project we will attempt to propose a way allowing for using the external perturbation for imaging the transport phenomena in graphene using the scanning probe. We will use for this purpose the n-p junction confined below the tip, the resonant states localized in this region and the persistent currents flowing around the junction at high magnetic field. The currents will provide the effects resolvable in the electrical properties in conditions where a short circuit will be formed with the currents flowing along the edges of the sample or along the junctions defined by the other gates, which can be accomplished by adjustment of the microscope position. The project will establish the procedures for using the so-called scanning gate microscopy for mapping the currents in graphene based devices.