NÉEL INSTITUTE Grenoble

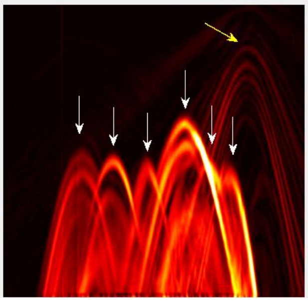
Topic for Master 2 internship – Academic year 2019-2020

Scanning gate microscopy of quantum Hall edge channels in graphene

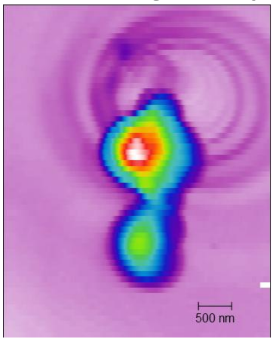
General scope:

Graphene is a monolayer of carbon atoms where electrons behave as massless Dirac fermions due to the linear dispersion relation around the K points of the Brillouin zone. In perpendicular magnetic field, the formation of discrete Landau levels gives rise to the well-known quantum Hall effect where electron transport takes place along the sample edges via chiral edge channels. The specificity of graphene is to present a relativistic quantum Hall effect with an electron-hole symmetric and four-fold degenerate Landau level spectrum. Interestingly, in high quality devices, the four-fold degeneracy is lifted, giving rise to four separate states with different spin and valley quantum numbers. The exact nature of each state is not precisely known but should result from the competition between the Zeeman energy, the long-range Coulomb repulsion, and the lattice-scale interactions. Using a substrate with a very high dielectric constant, we discovered a quantum spin Hall phase at charge neutrality which is characterized by helical edge transport properties. Achieving a better understanding of these quantum Hall states is important both from a fundamental point of view and for the perspectives of using graphene in future quantum technologies. This is the objective of the project.

Research project:



We will employ scanning gate microscopy (SGM) to investigate the spatial distribution and the properties of the quantum Hall edge channels resulting from the lifting of the Landau level degeneracy. A voltage-biased tip is used to change locally the carrier density and thus manipulate the position of the edge channels with sub-nanometer resolution while measuring the impact on the transmitted current. With this technique, one can obtain a real-space mapping of the edge channel distribution in the sample and probe their sensitivity to backscattering. This last property will serve to investigate the origin of the helical transport observed on the high-k dielectric substrates. The spatial separation between the edge channels with lifted degeneracy will give invaluable new insights to understand the effect of interactions on the quantum Hall effect in graphene.



In our group, we developed a state-of-the-art fabrication method to produce high-quality graphene devices with graphite bottom gates which are very suitable for scanning probe experiments. An heterostructure is built from exfoliated graphene and boron nitride flakes using a van-der-Waals picking and stacking technique. Clean-room processes (lithography, etching, deposition) are then applied to obtain the device.

During the internship, the student will learn the sample fabrication and then use the scanning gate microscope at low temperature and under high magnetic field to investigate the physics of graphene in the quantum Hall regime as described above. The student should be interested both by sample fabrication, delicate instrumentation, and fundamental physics.

Team : This work is supervised jointly by Hermann Sellier and Benjamin Sacépé (QNES team).
Required knowledge : Master in condensed matter physics, quantum physics, or nanophysics.
Starting date : February/March 2020.
Continuation on a PhD : Yes.
Contact : Hermann Sellier (or Benjamin Sacépé)
Néel Institute, CNRS / UGA, office: D418, tel: 04 76 88 10 86, hermann.sellier@neel.cnrs.fr
http://www.neel.cnrs.fr/spip.php?article4205