NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Optical probing of electronic excitations in van der Waals heterostructures

General Scope:
Van der Waals heterostructures are artificial quantum materials made by stacking two-dimensional materials, such as graphene, together. The vast library of materials that can be stacked and the way this stacking is done, for instance with a twist angle between the layers, give access to an extraordinarily rich diversity of electronic phases. This includes unconventional states of matter such as strange metals, superconductors, and charge or spin orders. A very powerful approach to discover novel phases, or understand better those reported recently, is to probe very clean samples with alternative experimental techniques. This is precisely what we propose to do with optical spectroscopy to explore the physics of electronic excitations that emerge in a bilayer of graphene in presence of a perpendicular electric field.

Research topic and facilities available:
Our team fabricates state-of-the-art (i.e. ultra-clean) van der Waals heterostructures and integrates them into electrical micro-devices. The goal of this project will be to fabricate such a device with a bilayer of graphene subjected to a controllable electric field (see Figure). The electric field will be generated by two electrostatic gates placed on top and at the bottom of the bilayer. To avoid direct electrical contact with the gate electrodes, graphene will be sandwiched between two thin layers of another van der Waals material, hexagonal boron nitride. In the bilayer, it is known that a small band gap opens, and that it comes together with electronic excitations whose nature is still an open question. We expect to obtain new answers using optical spectroscopy, by analyzing how these excitations produce inelastic light scattering, via an electronic Raman effect, at cryogenic temperatures. The way the electronic Raman signature will react to variable electric fields, temperature and light polarization will inform us about the quantum nature of the excitations. All the experimental tools required for the project are in place and available.

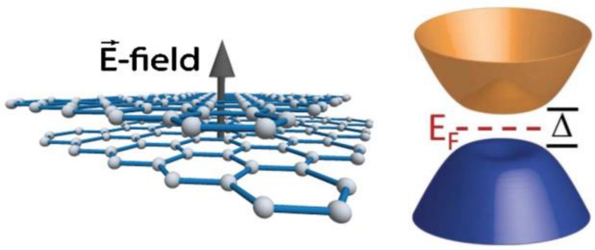

Figure: Illustration of a gapped bilayer graphene. *When subjected to an electric field E (left), a gap (□) opens at the Fermi level (E_F) of a bilayer graphene (right). Images from [1].*

[1] T. Taychatanapat et al, Phys. Rev. Lett. 105, 166601 (2010), L. Ju et al, Science 358, 907 (2017)

Possible collaboration and networking : The student will be part of the Hybrid team, which has a multidisciplinary expertise (nanofabrication, electronic transport, optical spectroscopy...). Collaborations are envisaged, on the medium-term, for measurement campaigns using high magnetic fields.

Possible extension as a PhD : Yes
Required skills: The internship will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, optical spectroscopy, cryogenics...) and engage in a hands-on experimental work.

Starting date : March 2024 (flexible)

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More information : http://neel.cnrs.fr