NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2019-2020

Topological superconductivity in graphene helical edge channels

General Scope: Graphene is a 2D material that has attracted a considerable interest since its discovery in 2005. Its gapless linear band structure that mimics massless Dirac fermions has led to the discovery of a wealth of new exciting transport properties. Moreover, the possibility to engineer very high mobility graphene devices in which electrons can travel in a ballistic fashion makes graphene the perfect playground to investigate quantum coherent phenomena in the quantum Hall regime, or when coupled with a superconducting condensate.

Research topic and facilities available: Our research focuses on a new topological state of matter, the quantum Hall topological insulator that our group recently discovered in graphene [1]. This special quantum Hall state harbors a pair of counter-propagating, one dimensional edge channels, so-called helical edge channels, which can serve as platform to induce an unconventional superconducting state once hybridized with superconducting electrodes. One of our main objective is to study the quantum transport properties to reveal the topological nature of this proximity-induced superconductivity, that is, the presence of Majorana zero modes, in suitably designed hybrid devices. Our group has develop state-of-the-art fabrication processes of high mobility graphene devices by encapsulation of graphene monolayers between insulating boron-nitride flakes, as well as of hybrid superconducting devices.

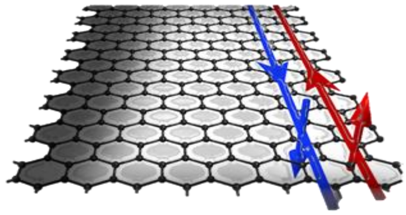

Figure | Graphene in the quantum Hall topological insulator state. A pair of counter-propagating, spin-filtered edge channels, the helical edge channels, propagates along the graphene edges.

The objective of the Master internship is to fabricate and perform quantum transport measurements (down to T=0.01K and up to B=18T) of high-mobility graphene Josephson junctions made with a high critical-field superconductor (amorphous indium oxide [2]). The capability of the superconducting electrodes to withstand a high magnetic field will enable to make pioneer investigations of Josephson junctions in the quantum Hall topological insulator state, and of more advanced devices [3] towards coherent manipulation of Majorana bound states (PhD research program).

[1] Helical quantum Hall phase in graphene on $StrTiO_3$, L. Veyrat et al. axriv:1907:02299

[2] Low temperature anomaly in disordered superconductors near Bc2 as a vortex glass properties. B. Sacépé et al. Nature Physics 48, 15 (2019)

[3]Tunable transmission of quantum Hall edge channels in split-gated graphene devices. K. Zimmermann, et al. Nature Communications 8:14983 (2017)

Possible extension as a PhD: YES (PhD grant funded by an EU project)

Starting date: Flexible
Required skills: We look for highly motivated students with a good background in condensed matter physics / quantum physics, and which are willing to address fundamental questions at the frontier of quantum solid-states physics. Notice that lab visits are highly encouraged.
Collaboration: This project will be carried out in close collaboration with theoreticians (Julia Meyer and Manuel Houzet from the CEA Grenoble) involved in the project.

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