NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Topological superconductivity in quantum Hall 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 objectives 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 developed 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.

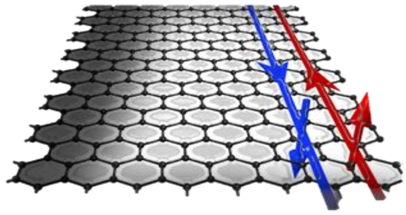

Figure | Graphene in the quantum Hall topological insulator state. A pair of counter-propagating, spin-filtered edge channels, the helical edge channels, propagates along the graphene edges.

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 (MoGe [2]). We have recently demonstrated the existence of a chiral supercurrent in quantum Hall Josephson junctions and this project will build on this unique expertise to unveil a helical supercurrent. These pioneer investigations of Josephson junctions in the quantum Hall topological insulator state are a first step towards coherent manipulation of Majorana bound states (PhD research program).

[1] *Helical quantum Hall phase in graphene on $StrTiO_3$*, L. Veyrat et al. Science 367, 781 (2020) arxiv:1907:02299

[2] *Imaging tunable quantum Hall broken-symmetry orders in graphene*, A. Coissard et al. Nature 605, 51 (2022). arxiv.org:2110.02811

[3] *Evidence for chiral supercurrent in quantum Hall Josephson junctions*, H. Vignaud et al. Nature *in press* (2023) arxiv.org:2305.01766

Possible extension as a PhD: YES
Funding: YES (ERC grant)
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.

Contact: Benjamin SACEPE (benjamin.sacepe@neel.cnrs.fr)
Website: http://sacepe-quest.neel.cnrs.fr/