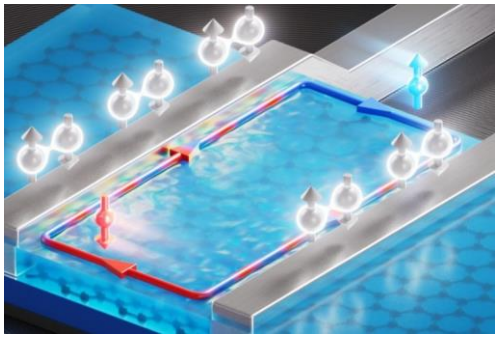
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Hybridizing superconductivity and quantum Hall physics

Hybridizing superconductivity with the quantum Hall (QH) effect has notable potential for designing circuits capable of inducing and manipulating non-Abelian states for topological quantum computation. A variety of QH states exhibits remarkable properties, as full spin polarization, helical phases with spin-momentum locking[1], fractionalization of charges into anyons quasiparticles, or a non-local nature and non-commutative braiding properties for non-Abelian anyons.



Figure| Graphene quantum Hall Josephson junction. The supercurrent that is a mixture of electrons (blue) and holes (red) is carried non-locally by the quantum Hall edge channel.

Last year, our group demonstrated the first Josephson junction made with graphene operating in the quantum Hall regime[2] up to a record magnetic field of 8T. We showed that the supercurrent in this regime is carried by the QH edge states, which are one dimensional channel propagating unidirectionally at the edges of the sample (see Figure), resulting in an unusual chiral supercurrent[2].
The project builds on this breakthrough to explore more exotic regimes of the QH effect, where coupling with superconductivity is expected to proximity-induce non-conventional superconducting states, such as p-wave superconductivity and topological Andreev bound states with non-Abelian properties.

The M2 internship will consist of realizing state-of-the-art high mobility graphene van der Waals heterostructures, in which suitably designed Josephson junctions will be fabricated and equipped with gate electrodes for tuning the quantum Hall states and controlling the trajectories of the edge channels. Quantum transport measurements will be performed in our highly-filtered dilution refrigerator, at a temperature of 10 mK and up to 14 T.

This internship aims to be integral to a PhD project that will extend to the coupling of such junctions with superconducting resonators, for performing circuit quantum electrodynamics and unveiling the Andreev bound states of the junctions.

Possible extension as a PhD: YES
Funding: YES (ERC grant)
Starting date: Flexible
Required skills: We are looking for highly motivated students with a strong background in condensed matter physics or quantum physics who can work collaboratively. Notice that lab visits are highly encouraged.

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[1] *Helical quantum Hall phase in graphene on $SrTiO_3$*, L. Veyrat et al. Science 367, 781 (2020) arxiv:1907:02299

[2] *Evidence for chiral supercurrent in quantum Hall Josephson junctions*, H. Vignaud et al. Nature 624, 545 (2023) arxiv:2305.01766