PhD position on Quantum Transport in Topological Insulators

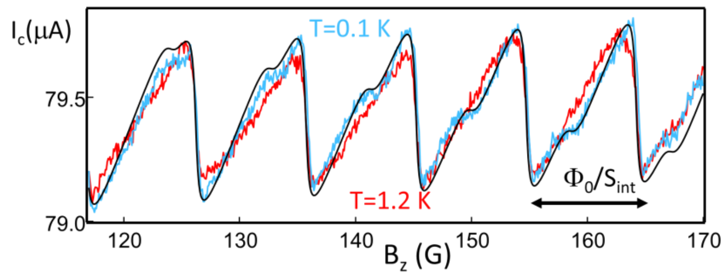
Revealing topological edge states with proximity induced superconductivity

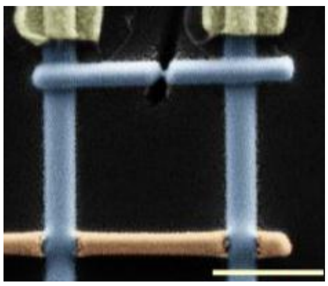
Intriguing phenomena have been predicted recently when mesoscopic conductors made from materials with strong spin-orbit interaction (SO) couple two superconductors. One of the most exciting possibility is to inject supercurrent through edge states in a topological insulator. Based on such ideas, the aim of this PhD work is to exploit proximity-induced superconductivity to reveal and select those ballistic edge states.

The work builds upon our results on crystalline bismuth nanowires. In such nanowires, conduction is due to surface states that possess a huge spin orbit coupling energy, larger than the Fermi energy, a property that is rarely encountered. When those (non superconducting) nanowires are connected to superconducting contacts, a supercurrent runs through them. Our experiments found unexpected features, that indicate that the supercurrent flows through very few one-dimensional channels rather than through the entire surface.

Very recently we provided a direct signature of *ballistic* one-dimensional transport along those channels. This was done by inserting the Bi nanowires in a SQUID interferometer, exploiting the extreme sensitivity of the relation between the supercurrent through a nanostructure and the superconducting phase difference at its ends. The sharp sawtooth-shaped current-phase relation we found demonstrates that transport occurs ballistically along two edges of the nanowire. This is predicted to occur if the surfaces are topological, in which case only one-dimensional, topologically protected ballistic states carry the current with perfect transmission.

In addition, we demonstrated the possibility to manipulate the phase of these supercurrent-carrying edge states and generate spin supercurrents.





Left: Sawtooth-shaped CPR of the S/Bi/S junction seen in critical current of asymmetric SQUID at 0.1 K (blue) and 1K (red). The black curve is a theoretical combination of two sawtooth-shaped currents. Φ_0=h/2e is the superconducting flux quantum and S_{int} the area delimited by the SQUID loop. Right: Micrograph of the asymmetric SQUID: a high-critical-current tungsten nanoconstriction (in blue) is in parallel with the smaller-critical-current S/Bi/S junction (in brown).The scale bar is 1micron. From Murani et al. https://arxiv.org/abs/1609.04848

The internship and PhD work aim to establish the topological character of these edge states. In particular, we will investigate different geometries, from the short to the long junction limit, by exploiting the sub-10-nm-resolution Focused-Ion-Beam microscope recently installed in our university. We will also couple these junctions to a superconducting resonator to explore the high frequency response, which should contain unambiguous signature of topological states.. We also plan to investigate 2D geometries with MBE-grown monocristalline Bi islands, and graphene/dichalcogenide heterostructures.

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The PhD project should start no later than October 2017 (an earlier start may be possible).
Applications should be received by 31 August 2017.