Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

(One page maximum)

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ED

Topological Superconductivity for fault tolerant quantum computing

Quantum computing relies on the manipulation of coherent quantum systems such as superconducting Josephson junctions. As external noises lead to decoherence, it is important to either heavily shield the quantum bits (or qubits) or, to design qubits that are inherently resilient. Topological insulators are materials whose bulk energy spectrum is gapped similarly to 'trivial' insulators, but their surface (or edge in 2D) presents conducting gapless states. The gapless surface states are intrinsically linked to the transition between the topologically trivial exterior, to the 'non-trivial' interior of the material, and as such are robust against defects and external stimuli, since they do not depend locally on the surface itself. Similar topologically protected edge states can be found in topological superconductors, where gapless edge states exist within the superconducting gap. The superconductor should however be topologically non-trivial. The constraints on the superconductor are: lack of inversion symmetry and lack of time-reversal symmetry. Zero-bias excitations at the edge of such superconductors should be Majorana fermions which are protected by the whole superconductor. Hence topological superconductivity could play the leading role into building fault tolerant quantum computers from Majorana bound states.

In this project, we will investigate topological superconductivity in two different ways. The first one lies in an atomically thin layer of high temperature superconductors that naturally lacks inversion symmetry. Externally suppressing time reversal symmetry with a weak magnetic field should enable the presence of topological edge states. The second way is to inject cooper pairs from a 2D superconductor into the edge states of a 2D topological insulator by proximity effect. The success of both ways relies on our experience in fabricating and manipulating 2D layers of materials and their hetero-structures and the internship will concentrate on this aspect.

The actual presence of topological superconductivity in these two systems can be probed by by building Josephson junctions to manipulate Majorana bound states. These experiments will require the fabrication of complex devices by clean room nanofabrication techniques and could be the focus of a thesis following the internship.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO