NÉEL INSTITUTE Grenoble

PhD project

Protected superconducting qubit with a graphene Josephson junction

General Scope :

The recent progresses in reproducible fabrication and understanding of quantum systems have brought us to the following situation: it is now possible to build devices that not only present quantum properties but in which quantum states can be initialized, manipulated and readout. Superconducting circuits is the most advanced platform in this context and it has reached several key milestones in the realization of a quantum computer. Despite such celebrated successes, other platforms are studied in order to gain flexibility and compatibility with current semiconductor technologies. In particular, hybrid platforms that couple superconducting and semiconducting properties are expected to bring a decisive advantage by allowing new functionalities.

Research topic and facilities available :

In this project, we will bring electrical tuning at the core of superconducting circuits by introducing a gapless semiconductor graphene, in the key element: the Josephson junction (see Figure). With such electrically tunable Josephson element, we can build a qubit with a new property: a gate tunable energy. In the team we have already demonstrated the fabrication of such graphene based Josephson junctions and their use in quantum circuits[1,2]. The next step, is to use the specificities of such junction to build a qubit protected from decoherence, which is the characteristic that makes a qubit usable for future quantum computing.

A one atom-thick sheet of graphene will be integrated into superconducting circuits using nanofabrication techniques available at the Institute. Such sample will then be measured at very low temperature (20mK) in a dilution refrigerator using radiofrequency (1-10 GHz) techniques. Measurements will be carried out to extract the figure of merit of the devices: lifetime of the Qubit, coherence, gate fidelity...

[1] G. Butseraen et al *Nature Nanotechnology* 17, 1153 (2022); arXiv:2204.02175

[2] S. Messelot et al *Phys. Rev. Lett*, in press (2024); arXiv:2405.13642

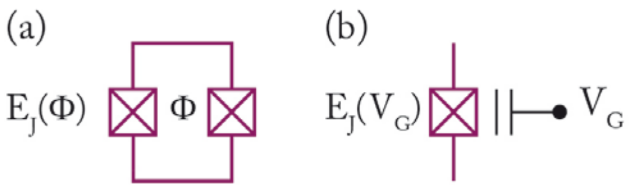

Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). In addition such junction presents original properties that can be used to build a protected qubit

Possible collaboration and networking :

The student will be part of the Quan2m team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, US, Canada).

Required skills : The PhD thesis will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, radiofrequency electronics, cryogenics...) and engage in a hands-on experimental work.

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