NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Graphene based superconducting quantum circuits

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. The building blocks of quantum circuits are quantum bits and quantum limited amplifiers. 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 electrical control of the system.

Research topic and facilities available :
In this internship, 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 the building blocks for a quantum platform: quantum bits and Josephson parametric amplifiers. In the team we have already demonstrated the fabrication of such graphene based Josephson junctions and their use in quantum circuits[1]. The next step, which is the goal of this work is to demonstrate that it can have functionalities and performances to be competitive with other platforms.
A one atom-thick sheet of graphene will thus have to 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, noise of the amplifier...
[1] G. Butseraen et al *Nature Nanotechnology* 17, 1153 (2022); arXiv:2204.02175

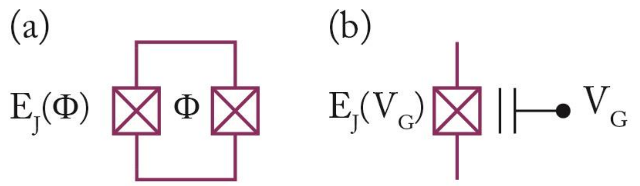

Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). This is the essence of the project.

Possible collaboration and networking : The student will be part of the Hybrid team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, US, Canada).
Possible extension as a PhD : Yes
Required skills: The internship (and 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.
Starting date : March 2024 (flexible)

Contact :
Name: Julien Renard Institut Néel - CNRS
Phone: 0456387176 e-mail: julien.renard@neel.cnrs.fr http://perso.neel.cnrs.fr/julien.renard/

More information : http://neel.cnrs.fr