Characterization of NbTi Superconducting Thin Film Non-Linear Devices for Quantum Superconducting Circuits

Master/Semester project

(Section: Microengineering – Physics – Electronic Engineering)

Nowadays, quantum technologies based on superconducting materials are becoming of primary importance for the development of new computational paradigms, as well as for designing a new generation of ultra-sensitive cryogenic sensors. The possibility to exploit nonlinear effects, such as the Josephson one, is crucial for the implementation of detection mechanisms relying on the quantization of physical parameters, like, for instance, the magnetic flux in Superconducting Quantum Interference Devices (SQUIDs) [1] and the frequency-to-voltage conversion based on the Shapiro steps phenomenon [2].

At LMIS1, we are currently investigating new possibilities of realizing alternatives to standard SIS or SNS Josephson junctions at cryogenic environments (T < 90 K). We are developing new ways of inducing the Josephson junction behavior on a localized region of the superconducting circuits by simple fabrication methods. The strategy consists of exploiting some of the quantum properties of the superconductors at the micro-nano-scale.

This student project will contribute to investigate the electronic transport of specific structure realized in superconducting NbTi thin films, eventually demonstrating the possibility to exploit them for realizing more complex structures based on nonlinear Josephson junctions (i.e. SQUIDs and Shapiro steps). The topic is highly multidisciplinary, involving aspects of condensed matter and low temperature physics, as well as DC/RF electronics design and test: the focus can be adjusted depending on the student's preferential interests, best knowledge, previous experience and motivation.

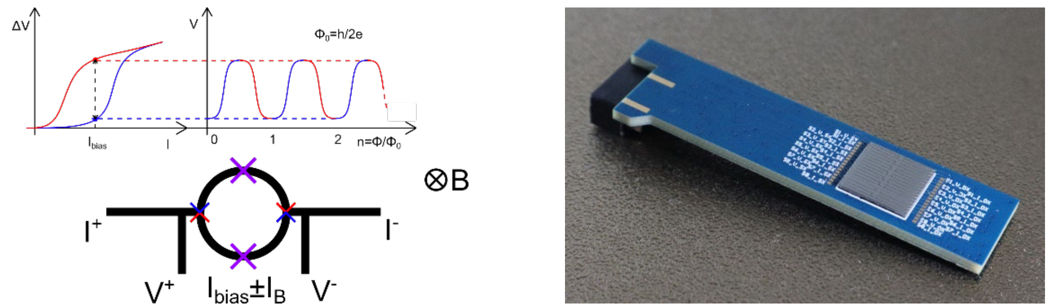

Figure 1 : *(a) schematic showing the working principle of a SQUID magnetometer; (b) Photograph of a chip containing superconducting structures in NbTi to be characterized in cryogenic environments (< 10 K).*

Possible tasks:

- Implementation of measurement apparatuses for cryogenic DC/RF testing
- Cryogenic characterization of NbTi thin film structures, either in liquid He or in a dry cryomagnet:
  - Temperature or magnetically induced effects in DC structures or RF resonators;
  - Sub-uT magnetic field detection based on our alternative SQUIDs;
  - Frequency-to-voltage conversion based on Shapiro steps phenomenon.

Contact: André Chatel *(andre.chatel @epfl.ch)*
Hernán Furci (*hernan.furci@epfl.ch)*
Giovanni Boero (*giovanni.boero@epfl.ch*)

[1] F. Qu et al. (2012) Scientific Reports 2:339, https://doi.org/10.1038/srep00339
[2] X. Bi et al., (2024) Quantum Frontiers 3:6, https://doi.org/10.1007/s44214-024-00053-5

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École polytechnique fédérale de Lausanne

Microsystems Laboratory 1
(Prof. J. Brugger)

EPFL STI IMT LMIS1
(Batiment BM)
Station 17
CH - 1015 Lausanne

Phone : +41 21 693 90 42
E-mail : hernan.furci@epfl.ch
Office : BM 3.112