Development of Temperature-Sensitive High Kinetic Inductance Thin-Films Superconducting Resonators

Master/Semester project

(Section: Microengineering – Physics – Electric Engineering – Materials Science)

The operation of large cryogenic apparatus often relies on distributed temperature measurements. The well-established electric thermometers (4-wire approach) presents a series of inconveniences: feedthrough space requirement, risk of leaks, risk of electric breakdown, heat input (conduction in wires), need for thermalization, etc… Allocating large number of thermometers or compensating for the absence of distributed thermometry imposes important constraints in the design of the apparatus.

At the LMIS1, we are currently investigating new possibilities of providing a temperature measurement system in cryogenic environment (T < 10 K) by means of RF lumped elements resonators, electromagnetically coupled to standard coplanar waveguides PCBs (Figure a-b). Such a goal would be achieved by exploiting the superconductor's kinetic inductance and London penetration depth temperature dependencies inducing a frequency response of the resonator to temperature (Figure c).

This student project will contribute to enhance the temperature sensitivity of such resonators, either by exploiting new materials (e.g. Nb(Ti)N for low and YBCO for high temperature ranges), by investigating thin film nano-structuration and localized film oxidation, or by suggesting innovative RF designs, which will be then fully tested and characterized in cryogenic (T < 10 K) environments using liquid He and cryostat apparatuses. The topic is highly multidisciplinary, involving aspects of condensed matter physics, RF electronics design and test, cleanroom microfabrication and materials science: the focus can be adjusted depending on the student's preferential interests, best knowledge, previous experience and motivation.

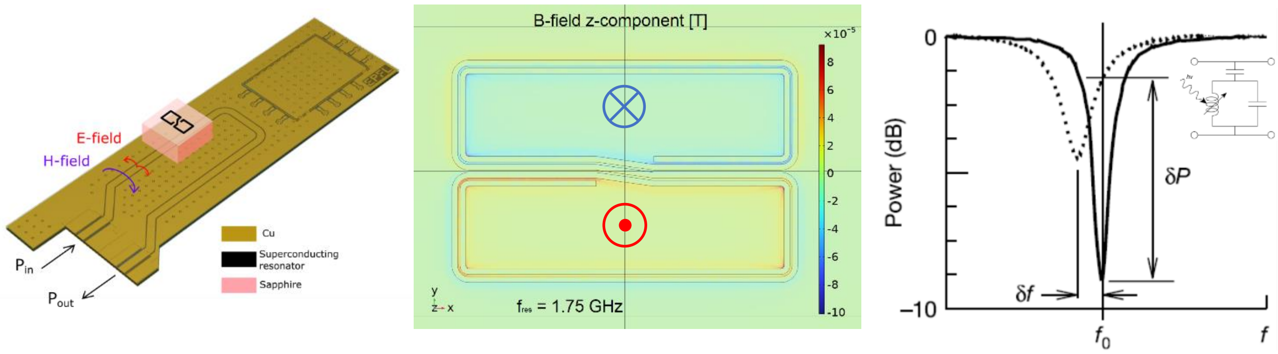

Figure 1 : *(a) schematic showing the superconducting resonator chip coupled to a standard Cu PCB; (b) COMSOL simulation of an S-shaped split ring resonator, showing the correct orientation of the B-field for CPW coupling; (c) principle of temperature sensing by kinetic inductance-induced resonance frequency shift [1-2]*

Possible tasks:

- Simulate and analyze superconducting RF components and resonators.
- Design, optimize and/or execute process flows at EPFL's state-of-the-art CMi cleanroom:
    - Process flow conception,
    - Drawing individual devices and aggregated chip/wafer lithography layouts,
    - Characterization of the resulting components using SEM, AFM, and other metrology tools.
- Cryo-RF characterization of finalized devices in a cutting-edge experimental setup.

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[1] P.K. Day et al. (2003) Nature 425 817.
[2] H. Yu et al (2022) SN Applied Sciences 4:67.

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