INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique, Ecole Normale Supérieure de Lyon
CNRS identification code: UMR5672
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Internship location: ENS de Lyon (sometimes Radiall company in the Lyon area)

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

Improving coherence times and residual excitation of superconducting quantum circuits using thermodynamics at the mesoscopic scale

Over the last decade, quantum technologies have migrated from academic laboratories to industries as the level of control over quantum systems now reached maturity. Applications of quantum technologies in computing, sensing, and communication are in sight and superconducting circuits are leading the way on several fronts. Such circuits host microwave modes whose quantum purity relies on the condition that the thermal energy is much smaller than the energy of a single photon. In the microwave domain, this requires working in a cryogenic environment, typically below 20 mK. Beyond the residual thermal excitation of superconducting quantum bits, this temperature directly affects their coherence time.

While commercial dilution refrigerators offer a base plate at less than 10 mK, thermalizing the microwave modes themselves turns out to be more challenging than just anchoring the superconducting circuit to the plate. Effectively, superconducting qubits are coupled to a heat bath that is often in the 50-100 mK range, which drastically downgrades their coherence time. A key element to getting lower effective temperatures is the microwave attenuator that is the closest to the quantum circuit. Recent progress has been made by a couple of companies using conductive casing (gold coated copper) instead of stainless steel. However, the dissipative elements are thin films that are not able to evacuate Joule power (up to about 100 nW) well enough into the dilution refrigerator. This is particularly detrimental for quantum error correction or amplification, which both require strong microwave drives.

The project consists of removing this current bottleneck by designing, fabricating, and testing better attenuators for superconducting quantum circuits. We will first model the thermodynamics of an attenuator using the theoretical tools of mesoscopic physics in order to design a well-enough thermalized attenuator. Prototypes will then be fabricated using microfabrication techniques and the expertise in microwave components of the ENS de Lyon and the Radiall company. Benchmark superconducting circuits will also be designed and fabricated to test how much the built attenuators extend their coherence times or lower their residual excitation. Once these concepts have been demonstrated, we will work on the miniaturization and develop attenuators that are compatible with high-density microwave cables that are a requirement of large superconducting quantum processors. The packaging of these attenuators and filters is key to an adequate thermalization of the signals driving quantum processors. This part will be addressed by the student. As a side project, proper filtering and shielding of the circuits will be developed and investigated, as well as applications to other kinds of quantum systems such as spins, or quantum dots.

The candidate will work on mesoscopic modeling and simulations, microwave design, nanofabrication, low-noise cryogenic setups, pulsed microwave measurements, data processing and analysis and dissemination of scientific research. This is a joint project between Radiall company and ENS de Lyon.

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