M2 internship at IM2NP
(AMU, CNRS, Marseille)

Advancing Electron Spin Resonance Spectroscopy in the Realm of Quantum Technologies.

Keywords: Electron Spin Resonance (ESR) – quantum technologies – high-T_C superconducting resonator – microwave and ESR instrumentation

Context: Electron Paramagnetic Resonance (EPR) is a powerful spectroscopic technique that studies the magnetic properties of materials with unpaired electrons. It provides valuable information about the local environment of spins, such as their state and interactions with neighboring atoms. Used in chemistry, biology, physics, and particularly in nanosciences and quantum mechanics, EPR detects the absorption or emission of photons by spins in resonance with a microwave cavity. However, current commercial spectrometers, having limited sensitivity, require bulky samples (>1 µL), hindering small-scale research.
The second quantum revolution has enabled, through ESR detection using superconducting quantum bits at 10 mK, to achieve unparalleled precision, with detection volumes of 1 fL and single-spin sensitivity. However, for most practical applications, these advances need to extend to higher temperatures. Our project aims to develop an EPR spectrometer based on high-temperature superconductor (HTS) resonators, to improve spin sensitivity over a wide temperature range.
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Research topic: The objective of the proposed M2 internship is to participate in the design, integration, and characterization of these HTS resonators in an EPR spectrometer. The intern will first participate in the design, fabrication, and characterization of "classical" metallic resonators using the laboratory's infrastructure before implementing the same circuits in HTS. The internship will focus on the first steps of this project, measuring the microwave response of the resonators at cryogenic temperatures (down to ~6K), under magnetic fields (up to ~4T), and for different microwave powers (up to ~10W). The performance of the HTS resonators will thus be benchmarked to metallic resonators. Finally, the expected improvement in spin sensitivity will be evaluated with well-known spin species, such as DPPH. The study of innovative small-scale spin samples will thus be unlocked.

Perspectives: The internship will provide valuable experience in the field of superconducting technologies and microwaves, with potential applications in electron spin resonance and quantum devices. The results obtained could lead to a publication and a continuation into a PhD in this cutting-edge field. This subject proposal presents the key steps over a four-month period, with a balance between theoretical design, fabrication, and practical experimentation. It allows for the acquisition of varied skills in the field of superconductivity applied to microwaves and quantum technologies.

Possible extension as a PhD: yes, an ANR grant is already available.

Candidate profile: The candidate must have a background in physics, condensed matter physics and/or nanosciences, and be strongly motivated by instrumental development. Python programming skills would also be appreciated. We are looking for a candidate keenly interested in pursuing this research project as part of a PhD.

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