Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique des Solides
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Thesis possibility after internship: YES
Funding: NO If YES, which type of funding:

Dynamics and correlations of magnetic impurities on a superconductor

Hybrid magnet-superconducting systems (i.e. arrays of magnetic impurities on a superconducting substrate) have attracted widespread interest for their high potential in topological quantum computation. Nano-fabrication techniques combined with local probe microscopies have recently revealed the emergence of zero-energy modes on ferromagnetic chains [1,2] and ferromagnetic nano-islands on s-wave superconductors [3,4]. The next main challenge is to control these (alleged Majorana) modes, and to understand their coherence and entanglement properties.

The starting point is the time-dependent properties of single magnetic impurities on a superconductor, whose partially screened spin generates Bogoliubov excitations with electron-hole parity named Yu-Shiba-Rusinov (YSR) states. Here, we will investigate then the coherence times of these states and the back-action of the adatom on the condensate. This analysis will be extended in a second time into YSR chains and islands and Majorana states.

In this project, we will first upgrade the current low-temperature STM [5,6] adding microwave circuitry and ultra-high vacuum (UHV) capabilities. This new instrument will serve to grow defect-free hybrid structures and perform electron spin resonance (ESR) measurements [7].

As a master student, you will first become familiar with the scanning tunnelling microscopy (STM) setup and characterise the finite frequency circuitry. Following this, you will fabricate the magnetic systems in-situ under UHV conditions following well-defined recipes. Lastly, you will study the quantum dynamics of the YSR states by finite-frequency STM measurements.

[1] S. Nadj-Perge et al., *Science* **346**, 6209 (2014)
[2] H. Kim et al., *Science Adv.* **4**, eaar5251 (2018)
[3] G. Menard et al., *Nat. Comm.* **8**, 2040 (2017)
[4] A. Palacio-Morales et al., *Science Adv.* **5**, aav6600 (2019)
[5] F. Massee, *Rev. Sci. Instrum.* **89**, 093708 (2018)
[6] F. Massee et al., *Nat. Comm.* **10**, 544 (2019)
[7] S. Baumann et al., Science **350**, 417-420 (2015)

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

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