NANOSTRUCTURES A LA NANOSECONDE (NS2)

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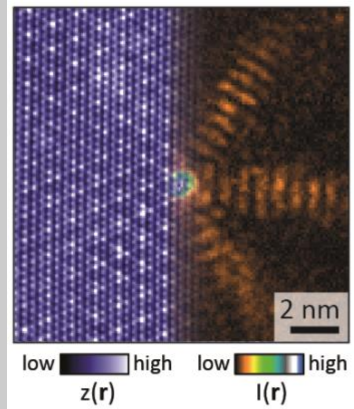
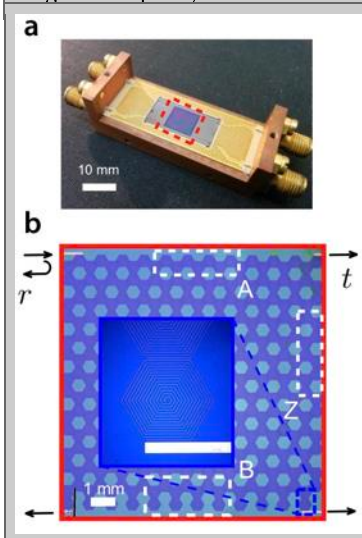
https://www.equipes.lps.u-psud.fr/ns2/ (being transferred and may be experiencing issues)

The NS2 group studies quantum matter, more specifically the dynamics of spins, electrons and photons in both solid state materials and quantum circuits. We use very-low-temperature technologies to perform electron transport experiments, optical and microwave spectroscopy, as well as atomic scale measurements using scanning tunneling microscopy.



(left) STM image of superconducting $NbSe_2$, and (right) simultaneously recorded current showing an extended in-gap state generated by a sub-surface magnetic impurity.



(a) Honeycomb network of microwave resonators in a sample holder. (b) Zoomed-in view of the network and, in the inset, of a single resonator.

Nanometric and Mescoscopic Superconductivity and Magnetism

To address not only the static properties of new phases of matter, but also their dynamics, we designed and built a unique new instrument: a scanning tunneling microscope with cryogenic circuitry operating in the MHz regime that allows us to measure the current fluctuations in addition to the time averaged current. Using this technique, we study, among other systems, topological and unconventional superconductivity at the atomic scale. In parallel, we also study the physics of (non-)equilibrium spins in mesoscopic-sized superconducting devices using quantum transport measurements. We use the Zeeman effect, spin-orbit coupling and spin resonance to directly access Cooper pairs' spin degree of freedom.

Microwave optics and simulation

Progress in nanotechnology and quantum electronics has made possible the fabrication of artificial quantum materials made up of large numbers of coupled circuits, which can be used to study n-body physics. We focus on new quantum device- and simulator architectures which use mesoscopic superconducting circuits to produce new on-chip photonic meta-materials. We study the strong coupling between microwave photons and electrical transport in these circuits, and the photon-photon interactions in open networks.

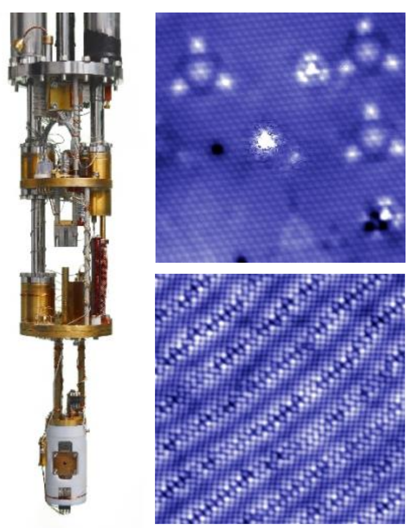
Plasmonics

When a voltage of a few volts is applied between two metals separated by a thin insulating barrier, a tunnel current flows. This well-known electrical phenomenon is accompanied by an optical phenomenon: the generation of light. By directly studying the relationship between the quantum statistics of current fluctuations through a tunnel junction and the resulting plasmon and photon emission, we investigate how electron statistics can be transferred to both plasmon and photon populations.

PhD position
Identifying Majorana modes using atomic scale shot-noise

The Nanosecond at the Nanoscale group at the Laboratoire de Physique des Solides offers a PhD position focussing on atomic scale current noise studies of correlated electron systems. In particular, current noise measurements with a scanning tunnelling microscope (STM) will be used to reveal the tunnelling process into individual atoms in superconductors. The main aim will be to distinguish trivial from non-trivial topological states, which is a major experimental challenge. Atomic scale current noise measurements are expected to provide a solution to this problem because the tunnelling characteristics and accompanying noise of a Majorana mode and that of a conventional in-gap state, which can be interpreted as a pair of Majorana modes that are equally coupled to the STM tip, are very different [1].

You will be tasked with running the state-of-the-art current noise STM facility at the LPS [2], as well as contributing to the broader activities of the research group. In addition to access to the wide range of experimental facilities at the LPS, the candidate will enjoy theoretical support from the in-house theory group. The position is funded by the ANR project MMNOISE.



Left: *Shot-noise compatible scanning tunnelling microscope of the NS2 group with a base temperature of 300mK and an external magnetic field up to 5T.* ***Right***: *two examples of atomically resolved surfaces studied to date within the group:* Bi_2Se_3 *containing Fe impurities (top) [3], and the high temperature superconductor* $Bi_2Sr_2CaCu_2O_{8+x}$ *(bottom) [4, 5]. In this project, you will combine regular imaging and spectroscopy with noise measurements to unveil the nature of states inside the superconducting gap [6].*

[1] V. Perrin et al., *PRB* **104**, L121406 (2021)
[2] F. Massee et al., *Rev. Sci. Instrum.* **89**, 093708 (2018)
[3] L. Desvignes et al., *ACS Nano* **15**, 1421-1452 (2021)
[4] F. Massee et al., *Nature Comm.* **10**, 544 (2019)
[5] F. Massee et al., *Science* **367**, 68-71 (2020)
[6] U. Thupakula, arXiv:2111.04749 (2021)

Required profile: The position is particularly suited to candidates with a background in condensed matter physics. You must have a M.Sc. in physics at the time of the start date and a good knowledge of solid state physics. Good communication skills (written and oral) in English are mandatory.

Starting date: The starting date is flexible, but should be before October 2022.

AGENCE NATIONALE DE LA RECHERCHE
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Duration: 3 years.

How to apply: please send your CV, a list of your M.Sc. grades and a brief cover letter to Freek Massee (freek.massee@universite-paris-saclay.fr).

PhD or postdoc position
Towards a direct probe of triplet superconductivity via spin resonance

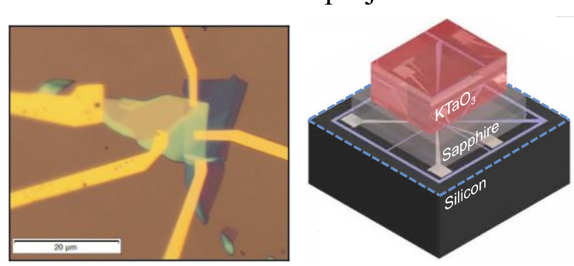
While the ground state of conventional (Bardeen Cooper Schrieffer) superconductors is a spin singlet state of paired electrons (Cooper pairs), triplet superconductivity is expected to arise in systems with superconducting correlations in which non-colinear magnetic fields exist, perhaps most notoriously in magnetic textures. Triplet pairs have recently been predicted to exist in superconductors with Ising (or valley Zeeman) spin-orbit coupling (ISOC), such as the transition metal dichalcogenide $NbSe_2$, due to the non-colinearity between the Ising field, which pins Cooper pair spins out-of-plane, and an applied in-plane magnetic field.

Despite significant efforts and some preliminary evidence, the existence of equal-spin triplet superconductivity remains an unsettled question. We propose a novel approach: coupling directly to the triplet pairs' spin degree of freedom in resonance measurements.

You will first perform numerical simulations, fabrication and characterisation of resonators (either superconducting or dielectric) for spin resonance measurements. After carrying out tests on better-known systems such as ferromagnetic metals or insulators, you will use the resonators for the detection of spin resonance of triplet pairs in superconducting $NbSe_2$. This will be either in the microwave regime, or through quantum transport (critical current, kinetic inductance, tunnel conductance…).

This position is funded by the French Agence Nationale de Recherche project TRIPRES (coordinated by Charis Quay), which also involves Julia Meyer (theory) and Hervé Aubin (triplet superconductivity in proximitized semiconducting systems) and others in their groups.

The Nanostructures at the Nanosecond timescale (NS2) group has extensive experience in mesoscopic superconductivity, spin-orbit physics and 2D systems, as well as low-temperature transport and microwave measurements.



Left: a typical $NbSe_2$ device with contacts. Right: a dielectric resonator (cf. Vahapoglu et al., Science Advances 2021).

References

M Kuzmanović, T Dvir, D LeBoeuf, S Ilić, D Möckli, M Haim, S Kramer, JSM Meyer, M Houzet, M Aprili, M Khodas, H Steinberg, CHL Quay, 'Tunneling spectroscopy of few-monolayer NbSe2 in high magnetic field : Ising protection and triplet superconductivity', arXiv:2104.00328.

CHL Quay, Y Chiffaudel, C Strunk and M Aprili, 'Quasiparticle spin resonance and coherence in superconducting aluminium,' Nature Communications 6, 8660 (2015).

Candidate profile (PhD): Background in condensed matter physics (superconductivity a plus), lab experience (low temperatures a plus). Masters in physics awarded before the start date.

Candidate profile (postdoc): PhD in condensed matter awarded before the start date. Experience with some or all of the following would be a plus: low temperatures, superconductivity, nano-fabrication, 2D materials, microwaves.

Starting date: Flexible, preferably by October 2022.

Duration: 3 years in principle (PhD), 2 years (postdoc) with possible extension

How to apply: please send your CV and a cover letter to Charis Quay (charis.quay@universite-paris-saclay.fr). For PhD candidates, please include masters transcript and internship reports.