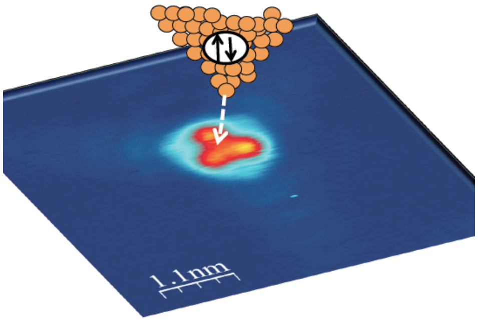
INSTITUT NEEL Grenoble

Topic for Master 2 internship – Academic year 2019-2020

Superconductivity in atomic-scale magnetic nanostructures

Nanometer scale scatterers (a single atom, a molecule, a quantum dot or an atomic nanowire) can interact with a superconducting condensate via potential scattering and/or magnetic exchange coupling. This leads to bound states, at energies below the superconducting gap, with peculiar spatial and spectral properties [1]. In particular, these states can be topologically trivial (the case of so-called Shiba states) or not (predicted Majorana zero modes).

The ability of electrons to tunnel between two conductors is extremely sensitive to both distance and density of states. This has made scanning tunneling microscopy/spectroscopy (STM/STS) an extremely sensitive and versatile tool to visualize atomic scale topographic features and variations in the local density of states.



Spatial map of a low-energy bound state around a Fe nanoisland on super-conducting Pb and sketch of STM experiment.

Using low temperature STM, we will investigate the signatures of magnetic interactions and possible topological superconductivity in a range of novel combinations of superconductors and magnetic nano-objects. By using superconducting tips, we will be able to combine at the same location tunneling experiments involving single electrons (standard tunneling spectroscopy) and Cooper pairs (Josephson current spectroscopy). This will be possible owing to the unique milliKelvin STM operation capability available in the Grenoble host group [2].

This project will be carried out using a low temperature STM operating at 100 mK, at Institut Néel [1]. Part of the experiments will be performed in the group of K. Franke (Berlin), in a low temperature STM with complementary capabilities [2]. The student's work will encompass:

- Participating in setting up a new ultra-high vacuum surface preparation chamber
- Preparing magnetic nanostructures by self-assembly or single-atom manipulation
- Performing low temperature scanning probe measurements
- Theoretical analysis and interpretation

[1] *Magnetic anisotropy in Shiba bound states across a quantum phase transition*, N. Hatter, B. W. Heinrich, M. Ruby, J. I. Pascual, K. J. Franke, Nature Comm. **6**, 8988 (2015).
[2] *Charge Puddles in Graphene Near the Dirac Point*, S. Samaddar, I. Yudhistira, S. Adam, H. Courtois, and C. B. Winkelmann, Phys. Rev. Lett. **116**, 126804 (2016).

Interactions and collaborations

This project will be carried out in tight collaboration with the group of K. Franke (Berlin) and complementary experiments will be carried out at both laboratories. Analysis and interpretation will benefit from strong local theoretical support in Grenoble and Berlin.

Possible extension as a PhD: Yes

Required skills: Master level (ongoing) or equivalent in Physics , with focus on condensed matter, quantum physics, or nanophysics.

Starting date: beginning of 2020

Contact : clemens.winkelmann@neel.cnrs.fr, herve.courtois@neel.cnrs.fr
Institut Néel - CNRS : 04 76 88 78 36, 04 76 88 11 51
Plus d'informations sur : http://neel.cnrs.fr/spip.php?rubrique49