ICFP M2 INTERNSHIP PROPOSAL 2026

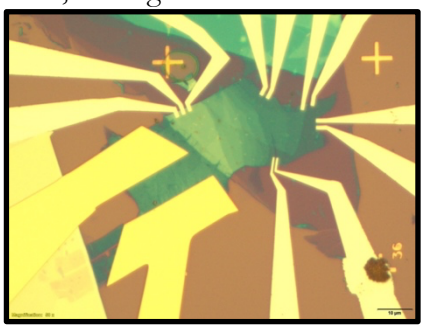
Laboratory: Laboratoire de Physique des Solides (CNRS UMR 8502)
Internship supervisors: Charis Quay, Freek Massee (LPS)
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https://equipes.lps.u-psud.fr/charis-quay/, https://fmassee.nl/
Internship location: Laboratoire de Physique des Solides
PhD possible after internship: YES Funding: MAYBE

TMD Superconductors: the Monolayer Challenge

In conventional Bardeen-Cooper-Schrieffer (BCS) superconductors, Cooper pairs of electrons of opposite spin (i.e. singlet structure) form the ground state. Unconventional equal spin triplet pairs (ESTPs) have been predicted, and we have recently seen preliminary evidence for these in tunnel devices based on the transition metal dichalcogenide (TMD) superconductor 2*H*-$NbSe_2$ at high magnetic fields, in the magnetic field dependence of the superconducting energy gap. ESTPs are of great interest for superconducting spintronics and topological superconductivity.

In addition to ESTPs, recent experiments on TMDs have been interpreted as evidence for other unconventional superconducting phases, e.g. the finite-momentum 'orbital FFLO' state, which requires > bilayer thickness. Other predicted unconventional phases include a striped FFLO phase and pair density waves. Recently, a transition from phonon- to Coulomb-interaction-mediated superconductivity has been predicted, likely occurring as the material goes from bilayer to monolayer thickness. Although most theoretical work has been done for monolayer $NbSe_2$ and related superconducting TMDs, so far there have been no reports on tunnelling into monolayer $NbSe_2$, and thus very little spectral evidence for above predictions.

Continuing previous work by Mai Lê, Banan El-Kerdi and Jericho Narvasa, the intern will fabricate and measure superconducting TMD tunnelling devices incorporating exfoliated and CVD-grown $NbSe_2$ monolayers. S/he shall also perform scanning tunnelling measurements on the CVD-grown samples. The intern will be trained on an exfoliation procedure recently developed by Charis Quay and Banan El-Kerdi, which gives thin flakes reliably. S/he will also gain hands-on experience in nanofabrication (e-beam lithography, metal deposition) and low-noise low-temperature (milikelvin) electronic measurements, and is welcome to contribute to the group's other TMD projects. This project is part of a collaboration with Jing Kong's group at MIT, among others.



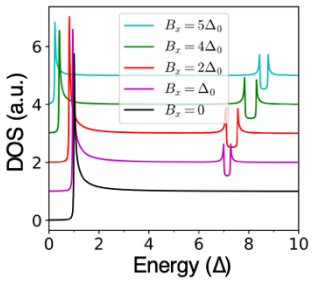


Figure (left) Optical image of a typical tunnel junction TMD device made by Banan El-Kerdi and Charis Quay. The crosses are about 8μm across. **(right)** Expected spectral signatures of triplet superconductivity. (From reference below.)

References

M Kuzmanović, T Dvir, D LeBoeuf, S Ilić, M Haim, D Möckli, S Kramer, M Khodas, M Houzet, JS Meyer, M Aprili, H Steinberg, CHL Quay, 'Tunneling spectroscopy of few-monolayer $NbSe_2$ in high magnetic field: Ising protection and triplet superconductivity', Physical Review B **106**, 184514 (2022), *Editor's Suggestion*
G Tang, C Bruder and W Belzig, 'Magnetic field-induced "Mirage" fap in an Ising superconductor', Physical Review Letters **126**, 237001 (2021)
P Wan e*t al.*, 'Orbital Fulde–Ferrell–Larkin–Ovchinnikov state in an Ising superconductor', Nature **619**, 46–51 (2023)
J Siegl e*t al.*, 'Friedel oscillations and chiral superconductivity in monolayer $NbSe_2$', Nat. Commun. **16**, 8228 (2025)

Suitable speciality(ies):

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