# ***INTERNSHIP PROPOSAL***

*(One page maximum)*

Laboratory name: Matériaux et Phénomènes Quantiques
CNRS identification code: UMR 7162
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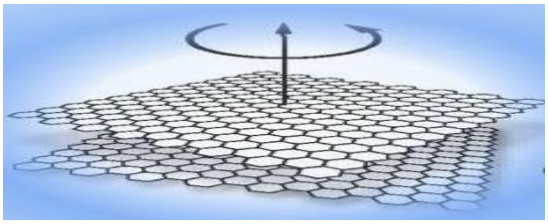
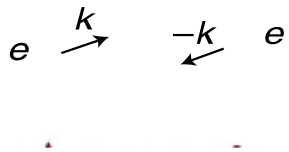
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

## Shining light on superconducting 2D transition metal dichalcogenides

**Transition metal dichalcogenides (TMDs)** have recently attracted significant interest because they allow the exploration of novel quantum phenomena down to the 2D limit. Of particular interest for the present project are metallic TMD like $NbSe_2$ which displays various quantum phases **like Superconductivity (SC) and charge density wave (CDW)** states [Xi16]. The possibility of fabricating these 2D crystals into vertical "van der Waals" (VdW) heterostructures make them ideal candidate for the integration into cavities to enhance light-matter interaction and achieve cavity control of quantum phases**.** In addition, the formation of **Moiré patterns** due to the lattice mismatch and crystalline misalignment between vertically stacked layers is another unique aspect of the VdW layered structures, offering opportunities for quantum engineering of material properties [Cao18]. Quantum interference effects between sheets of the 2D TMD with a twist angle allows an unprecedented control of the effective electron kinetic energy scale, driving the system to an interaction dominated regime and drastically enhancing anisotropies [Kennes21].



*Twisted layers yielding a Moire pattern that can tune drastically the 2D material's properties.*




*Superconducting electron Cooper pairs on a single layer of the 2D TMD $NbSe_2$*

During the internship, the student will participate in the first steps of this ambitious project. He/she will study TMD-based VdW heterostructures displaying SC properties using exfoliation techniques. He/she will work in close collabration with our partners experts in TMD fabrication (LPS, U. Paris Saclay) and THz cavities (LSI, Polytechnique). Going beyond traditional transport measurements, an originality of the project will be the use of low temperataure spectroscopic techniques with micron-size spatial resolution like Raman scattering to probe the SC state [Grasset2018,Grasset2019]. In the longer term these optical techniques will be implemented in out-of-equilibrium pump-probe schemes and in equilibrium on cavity-integrated samples.

*[Cao18] Y. Cao et al. « Unconventionnal superconductivity in magic angle twisted bilyaer graphene », Nature 556, 43-50 (2018).*

*[Grasset18]. Grasset, R., T. Cea, **Y. Gallais**, M. Cazayous**,** A. Sacuto, L. Cario, L. Benfatto, and M.-A. Méasson. Higgs- Mode Radiance and Charge-Density-Wave Order in 2H−NbSe2. Phys. Rev. B 97, 094502 (2018).*

*[Grasset19] Grasset, R., **Y. Gallais**, A. Sacuto, M. Cazayous, E. Coronado, et M.-A. Méasson. « Pressure-Induced Collapse of the Charge Density Wave and Higgs Mode Visibility in 2HTaS2 « . Physical Review Letters 122, no 12 (2019): 127001.*

*[Kennes21] D. M. Kennes et al. « Moiré heterostructures as a condensed matter quantum simulator » Nature Physics 17, 155-163 (2021)*

*[Xi16] Xi, X., Z. Wang, H. Berger, L. Forró, J. Shan, et K. F. Mak. Ising Pairing in Superconducting $NbSe_2$ Atomic Layers », Nat. Phys. **12**, 2, 13943 (2016)*

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 |