Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

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Internship location: IPCMS - Strasbourg
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

Atomic-scale quantum photonics of moiré superlattices

The quest for low-dimensional heterostructures with novel quantum properties is a most active research direction in physics. In this context, 2D materials and the "twist" degree of freedom between coupled 2D layers offer endless possibilities to design van der Waals heterostructures (vdWH) [1]. VdWH exhibit moiré superlattices (Fig. 1a), wherein the Coulomb potential is spatially modulated at twist-tunable moiré wavelengths (up to ~ 10 nm) that largely exceed the Bohr radius (~1 nm) of Coulomb-bound electron-hole pairs (i.e., excitons). The resulting moiré superpotential may be harnessed to tailor the electronic and optical properties and, in particular, to trap excitons [2]. The exciton Bohr radius and the moiré wavelength set the scales at which the physics of vdWH should be probed and correlated to the nanoscale environment. These scales are, however, two to three orders of magnitude below the resolution of diffraction-limited optical techniques, which is a major experimental obstacle.

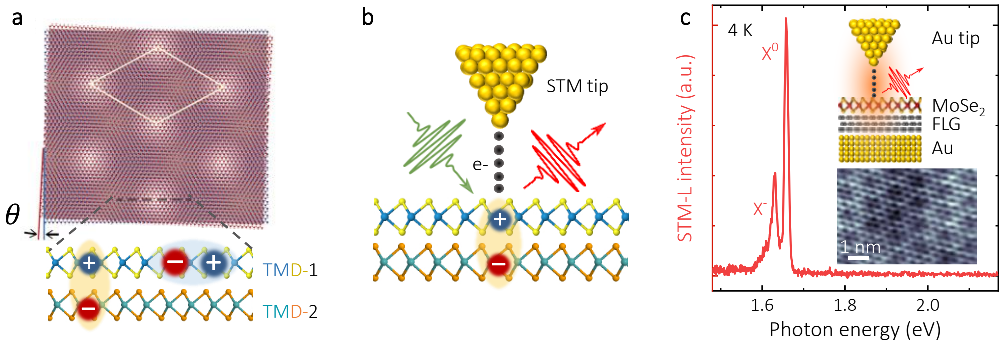

Figure 1 | *a - Illustration of a moiré superlattice in a 2D semiconductor heterobilayer twisted by an adjustable angle [2]. Inter and intra-layer excitons are illustrated in real space. b - Our approach: STM-induced luminescence (STML) and tip-enhanced optical spectroscopy of moiré excitons. c - First 4K STML measurement on a 2D semiconductor (here, MoSe2)/few-layer graphene (FLG) heterostructure. Two narrow emission lines are assigned to the neutral (X^0) and negatively charged exciton (X^-) in $MoSe_2$. A moiré superlattice is visible on the STM topography image (lower inset). Data from IPCMS, see Ref. [3] for more details.*

This research project takes up the challenge highlighted above and aims at understanding and controlling quantum light-matter interactions in vdW heterostructures with ultimate spatial resolution. For this purpose, twist-engineered vdWH (Fig. 1a,b) will be fabricated in house and studied using a state-of-the-art setup that combines low temperature scanning tunneling microscopy (STM) and optical spectroscopy ([3] and Fig. 1c). We are looking for a candidate with a solid background in fundamental physics and a strong taste for experimental research at the interface between condensed matter physics, optical spectroscopy and quantum photonics. The candidate will join dynamic collaboration between two teams at IPCMS.

Selected references:

[1] N. Wilson *et al.*, Nature **599**, 383 (2021) - doi: 10.1038/s41586-021-03979-1
[2] K. Seyler *et al.*, Nature **567**, 66 (2019) - doi:0.1038/s41586-019-0957-1
[3] L.E. Parra Lopez *et al.*, Nature Materials **22**, 482 (2023) - doi:10.1038/s41563-023-01494-4 | Unistra and CNRS press release | news and views (doi:10.1038/s41563-023-01514-3) | preprint: arXiv:2204.14022

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