Institut de Physique et Chimie des Matériaux de Strasbourg

Université de Strasbourg

Excitons in van der Waals materials as quantum sensors

Host Institution: Université de Strasbourg and CNRS, Institut de Physique et Chimie des Matériaux de Strasbourg **(IPCMS, UMR 7504)** - 23 rue du Lœss, BP 43, 67034 Strasbourg - France
Supervisors: Stéphane BERCIAUD and François FRAS
Contact: stephane.berciaud@ipcms.unistra.fr | francois.fras@ipcms.unistra.fr

Context -Two-dimensional semiconductors such as transition metal dichalcogenides (2D TMDs) have garnered significant interest due to their unique electronic and optical properties. These physical properties combined with their flexibility, mechanical strength, processability and integrability hold promise for applications in next-generation (opto-)electronics, photonics, and quantum technologies. Specifically, the high sensitivity of TMD to their local environment and external fields is particularly relevant for applications in quantum sensing.

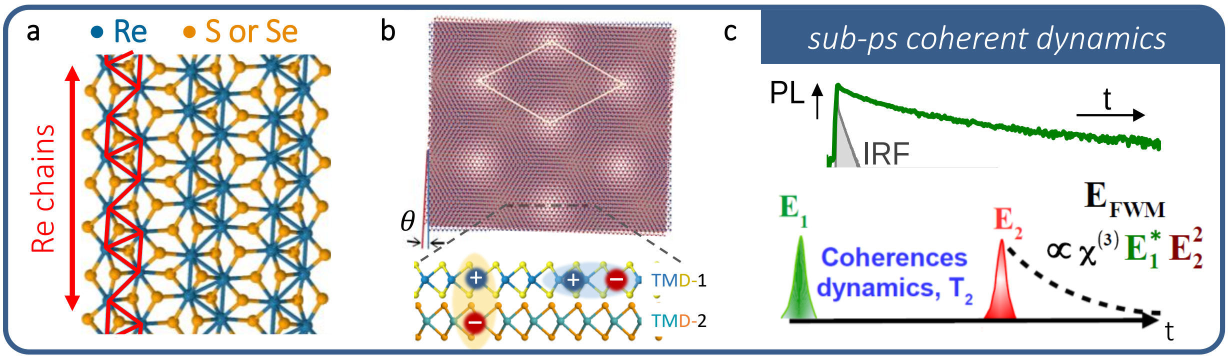

Figure 1 | **a** *- Anisotropic TMDs such as 1T'-ReX_2 (X=S, Se) showing covalent Re chains display anisotropic excitons will be studied to probe strain gradients [1].* ***b*** *- Twisted TMD heterobilayer (θ is the twist angle). Excitons (illustrated in real space) may localize in the moiré superpotential or be hybridized by the same [2].* ***c*** *- All-optical sensing methods using time-resolved photoluminescence (PL) spectroscopy [3,4] as well as four-wave mixing (FWM) microscopy [5].*

PhD project - In this stimulating context, **we envision new schemes for strain sensing by exploiting the rich exciton physics in TMDs and van der Waals heterostructures based on the latter**. We will focus on two types of systems: anisotropic excitons in atomically-thin ReS_2 and $ReSe_2$ [1] and moiré excitons in TMD heterobilayers [2]. Samples will be fabricated in house (STnano facility) and studied using cutting-edge setups that combine **low temperature optical microscopy and spectroscopy** [3,4] with **ultrafast non-linear coherent spectroscopy** [5]. The latter allows to optically probe and manipulate quantum superpositions of states with diffraction-limited spatial resolution and a ~ 100 fs temporal resolution (Fig. 1c). We will probe how the exciton characteristics, in particular their dynamics and quantum coherence are sensitive to externally applied strain, for instance in a nanodrum-like geometry [6]. **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, light-matter interactions, ultrafast optical spectroscopy and quantum sensing**.

The candidate will assemble and characterize van der Waals heterostructures, perform optical measurements, data analysis and modelling. He/She will join a dynamic collaboration between two teams at IPCMS that is part of a national ANR project involving INSA Toulouse (LPCNO) for theoretical modelling and the Grenoble High Magnetic field laboratory (LNCMI-G). **Funding for this PhD project is already secured and the candidate will also be part of our international graduate school QMat (https://qmat.unistra.fr/).**

Selected references from the team (except ref. 2):

[1] E. lorchat *et al.*, ASC Nano **10**, 2752 (2016) - doi:10.1021/acsnano.5b07844
[2] K. Seyler *et al.*, Nature **567**, 66 (2019) - doi:10.1038/s41586-019-0957-1 | N. Wilson *et al.*, Nature **599**, 383 (2021)
[3] M. S. Islam *et al.*, arXiv:2309.15023
[4] E. Lorchat, L. E Parra López *et al.*, Nature Nanotechnology **15**, 283 (2020) - doi :10.1038/s41565-020-0644-2
[5] F. Fras *et al.*, Nature Photonics **10**, 155 (2016) -. doi :10.1038/nphoton.2016.2
[6] X. Zhang, et al., Nature Communications **11**, 5526, (2020) - doi:10.1038/s41467-020-19261-3