INTERFACIAL COUPLING AND ELECTRONIC PHASES IN VAN DER WAALS HETEROSTRUCTURES

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Van der Waals materials consist of stacked crystalline layers that are only one or a few atoms thick. Their remarkable physical properties hold promise for applications in flexible electronics, optoelectronics and photonics. Combined in the form of van der Waals (vdW) heterostructures, these materials display novel and sometimes unexpected phenomena, which are attracting considerable scientific interest. Motivated by our previous works (see Fig. 1 and [1,2,3]) as well as recent breakthroughs in our scientific community [4,5], we propose to investigate and control interfacial coupling and electronic phases in vdW heterostructures formed from two-dimensional semiconductors, namely transition metal dichalcogenides (TMD), such as MoS_2, $MoSe_2$, WS_2 and WSe_2, with a focus on $MoTe_2$ [3,5], a near-infrared bandgap semiconductor. We will start with charge-tunable TMD/graphene heterostructures as model systems to unravel the microscopic details of interfacial coupling. Next, we will investigate twisted TMD homo- and heterobilayers bilayers (Fig. 1c), in which a variety of electronic phases can be engineered and probed optically [4,5].

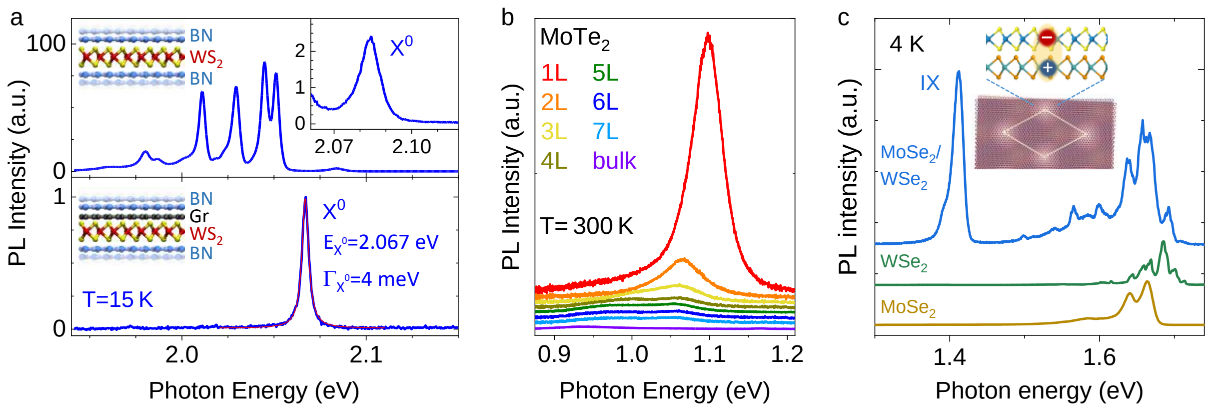

Figure 1 – a) Photoluminescence (PL) spectra of a WS_2 monolayer with (top) or without (bottom) a graphene monolayer (Gr). Graphene "filters" the PL spectrum of WS_2 leaving only one bright, single and spectrally narrow PL line assigned to the bright intrinsic exciton X^0 [1]. b) PL spectra of mono- and few-layer $MoTe_2$ evidencing near-IR emission [2]. c) Low T PL spectrum of a $WSe_2/MoSe_2$ heterostructure, showing PL from an interlayer exciton (IX) near 1.4 eV (data from our team). IX may be trapped by the moiré superpotential that develops in twisted heterobilayers (see inset, partly adapted from K. Seyler *et al.*, Nature **567**, 66 (2019)).

The PhD candidate will be involved in all stages of the project, including the fabrication of charge tunable van der Waals heterostructures in the STNano facility, experimental developments for advanced optical and opto-electronic measurements at low temperature, data acquisition, analysis and modelling.

[1] E. Lorchat, L. E Parra López *et al.*, Nature Nanotechnology **15**, 283 (2020)
[2] G. Froehlicher, E. Lorchat, S. Berciaud, Physical Review X **8**, 011007 (2018)
[3] G. Froehlicher E. Lorchat, S. Berciaud, Physical Review B **94**, 085429 (2016)
[4] N. Wilson *et al.*, Nature **599**, 383 (2021)
[5] C. Repellin, Nature **622**, 36 (2023)