

Title: Probing excitons on the nanoscale in two-dimensional semiconductors and their heterostructures

Keywords: nanophotonics; two-dimensional semiconductors; excitons; nano-optics; scanning tunnelling microscopy; optical microscopy; photoluminescence; electroluminescence

Scientific description: Two-dimensional semiconducting materials, such as transition metal dichalcogenide (TMD) monolayers, are key in the development of future device technologies. This is because such materials are only a few atoms thick and have unique optical and electronic properties. TMD monolayers are also considered an ideal platform for the study of excitons, i.e., bound electron-hole pairs, in 2D materials. Controlling the generation of excitons, their radiative decay, and their interactions with free charge carriers in 2D semiconductors is crucial for applications, e.g., in photovoltaic and light emitting devices. In this Masters thesis, the student will use nano-optical tools to probe the excitonic properties of TMD monolayers on the nanometer scale. The tunneling current between the sample and the tip of a scanning tunneling microscope (STM) will serve to locally excite the electroluminescence of the 2D semiconductor. The resulting light will be analyzed using optical microscopy and spectroscopy. Moreover, the student will carry out cutting-edge nano-optics experiments using the STM on “twist-engineered” heterostructures of these TMD monolayers. As has been recently discovered, new material properties may appear in such layered heterostructures depending on the misalignment angle (or “twist”) between adjacent layers.

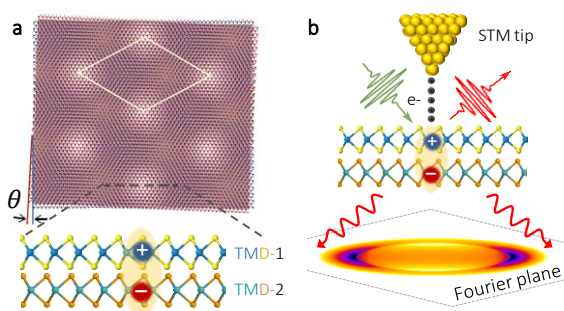


Figure: (a) Illustration of a moiré superlattice in a TMD heterostructure twisted by an adjustable angle θ . (b) STM-induced luminescence (STML) and Fourier plane imaging of excitons in a TMD heterostructure.

Techniques/methods in use: STM, optical microscopy and spectroscopy

Applicant skills: Basics in semiconductor physics and in physical optics

Industrial partnership: N

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Possibility for a Doctoral thesis: Y (Not financed yet. The student may apply for a thesis scholarship of the Ecole Doctorale Ondes et Matière)