Controlling the optical properties of van der Waals heterostructures through interlayer rotation

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The absence of strict lattice matching requirement in van der Waals heterostructures [1] allows for the introduction of interlayer rotation, creating a unique degree of freedom that isn't accessible in conventional heterostructures. The rotational misalignment leads to both a change of the real-space atomic registry and a rotation of the Brillouin zones in momentum space, which can significantly alter the mechanical and electronic coupling between the layers.

In this talk, I will show that interlayer rotation can be used to efficiently control the optical properties of two-dimensional transition metal dichalcogenide (TMD) heterostructures. I will start with a brief introduction of two-dimensional materials and van der Waals heterostructures, their fabrication and characterization methods [2]. The first part of this talk will focus on resonant hybridization between intra- and interlayer excitons in incommensurate $MoSe_2/WS_2$ heterobilayers. I will show that, due to the near-resonant alignment of the conduction band edges, the two exciton species can hybridize with each other through hopping of carriers across the heterojunction interface, causing the splitting of the exciton bands and periodic modulation of their energy as a function of the twist angle between the individual layers [3]. In the second part I will discuss our recent results of investigating the effects of rotational misalignment on emission properties of twisted $MoSe_2/MoS_2$ heterostructures. We demonstrate that, although significant band offset in these structures prevents efficient exciton-exciton hybridization, rotation alignment can strongly affects their optical properties, leading to more than 70 meV modulation of the interlayer exciton emission energy.

[1] Geim, A. K., & Grigorieva, I. V. "Van der Waals heterostructures". Nature, 499(7459), 419 (2013).
[2] Alexeev, E. M., et al. "Imaging of interlayer coupling in van der Waals heterostructures using a bright-field optical microscope." Nano letters, 17(9), 5342-5349 (2017)
[3] Ruiz-Tijerina, D. A., & Fal'ko, V. I. "Resonantly enhanced moiré superlattice coupling in heterostructures and transition-metal dichalcogenide bilayers with matching band edges". arXiv:1809.09257.