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Light-matter interaction in monolayer semiconductors and their heterostructures

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Excitons are elementary excitations of solids that consist of a pair of an electron and a hole that are held together by Coulomb forces. Two-dimensional (2D) semiconductors such as monolayer MoS_2 and WSe_2 support strongly bound excitons with unique quantum mechanical properties and strong light coupling. We study exciton relaxation behaviors in 2D semiconductors and their heterostructures with a view to realizing efficient opto-electronic and electro-optic devices with "molecular" thicknesses. In this talk, I will discuss our experimental investigation of band nesting effects that give rise to unusual light-matter coupling in some 2D semiconductors despite being atomically thin. I will then share our recent findings on fast interlayer energy transfer in $MoSe_2$/WS_2 hetero-bilayers. We show that interlayer energy transfer in this system takes place in sub-picosecond time scales and involves excitons in the WS_2 layer resonantly exciting higher order excitons in the $MoSe_2$ layer. Our results indicate that energy transfer competes with interlayer charge transfer with efficiencies exceeding 80% despite the type-II band alignment [1]. Following this discussion, I will also discuss our recent findings on exciton-plasmon coupling in 2D semiconductors hybridized with Ag nanoparticles. We show that strong exciton-plasmon coupling in this system results in electromagnetically induced transparency. Finally, we will discuss realization of electro-optical effects that reveal the unique many-body effects of these material systems.

References

[1] D. Kozawa et al. 'Efficient interlayer energy transfer via 2D dipole coupling in $MoSe_2$/WS_2 heterostructures' Arxiv:1509.01875.
[2] W. Zhao et. al. "Exciton-plasmon coupling and electromagnetically induced transparency in monolayer semiconductors hybridized with Ag nanoparticles" Adv. Mater. (2016).