Seeing Electrons in 2D – Light/Matter Interactions in Atomically Thin Semiconductors

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Transition metal dichalcogenides in the MX_2 family with M = Mo, W and X = S, Se, Te are layered van-der-Waals systems that can be prepared by exfoliation and chemical synthesis as stable sheets with thicknesses down to a single monolayer. These materials (in their 2H structure) are semiconductors and form fascinating counterparts to the semi-metallic graphene and insulating hexagonal BN monolayers.

In this paper we will describe progress made in understanding the distinctive electronic properties of these materials in the monolayer limit, primarily from the perspective of their light-matter interactions. An important emergent property in the monolayer limit is the fact that these systems, although indirect semiconductors in the bulk limit, become direct-gap materials as monolayers. As such, they are efficient light emitters and have been widely investigated by diverse spectroscopic techniques.

Among the noteworthy optical properties are the extremely strong and anomalous excitonic interactions in these semiconductor monolayers. The enhancement of these many-body interactions arises from the reduced dimensionality and from the reduced dielectric screening in the atomically thin limit. We will discuss the implications of these properties, including the possibility of tuning the quasiparticle band-gap by the external dielectric environment.

Another distinctive aspect of these materials is the possibility of selective access to one of the two degenerate valleys in the Brillouin zone using the handedness of circularly polarized light. Since the initial demonstration of this possibility, progress has been made not only in creating valley excitation, but also in tuning the corresponding valley pseudospin using optical and magnetic fields. We will describe recent steps taken in this direction.