Magneto-spectroscopy of excitons in monolayer WSe_2

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A monolayer of a transition metal dichalcogenide such as WSe_2 is a 2D semiconductor with a direct band gap. These 2D materials have a hexagonal lattice structure with broken inversion symmetry and two degenerate valleys at K^+ and K^- points of the Brillouin zone. The optical transitions are valley-selective with respect to the helicity of circularly polarized light. This enables selective control of K^+ (K^-) excitons with right (left) circularly polarized light [1], while a perpendicular magnetic field offers a possibility of lifting the valley degeneracy [2].

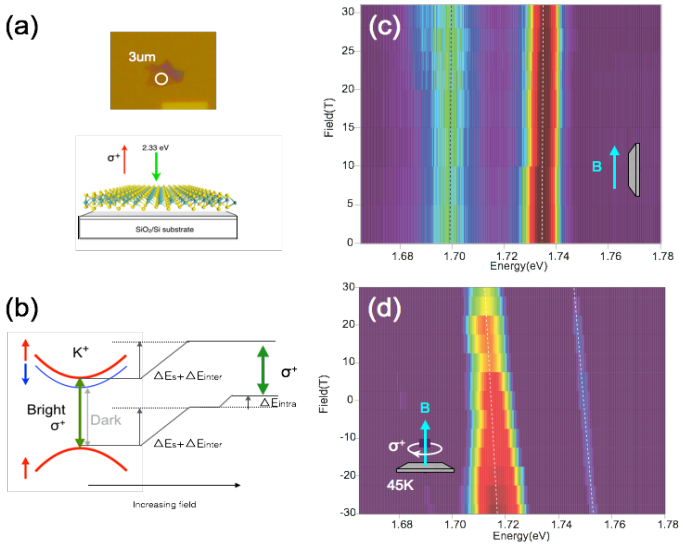

Figure 1 (a) Schematic of the monolayer WSe_2 sample. A 2.33eV laser with ~3μm spot is used to perform the PL measurement. (b) Band structure evolution with out-of –plane magnetic field. (c, d) Magneto-PL signal of WSe2 as a function of (c) in-plane (d) out-of-plane magnetic field.

Here, we report on high-field magneto-photoluminescence (PL) study of excitons in monolayer WSe_2. The samples were prepared by mechanical exfoliation and transferred on to a patterned SiO_2/Si substrate (Fig.1a). PL measurements were performed in the temperature range 2.2 K-45 K and in magnetic fields up to 31 T. A 2.33 eV laser was used for excitation and the collected light was analyzed by a right-hand circular polarizer (Fig. 1a).

The PL spectrum of a monolayer WSe_2 features two peaks corresponding to the emission from neutral exciton (X^0) and charged exciton (X^-). A perpendicular magnetic field (Faraday geometry) induces linear (Zeeman) shift in PL energy of both X^0 and X^-, while Voigt geometry does not affect the exciton energy (Fig.1c, d). The magnitude of Zeeman shift measured at 45 K is about 0.119 meV/T≈2μ_B. These results indicate lifting of the valley degeneracy caused by the shifting of valence band edge due to d-orbital contribution (ΔE_{intra}). It is worth mentioning that the conduction and valence band shift due to spin-Zeeman effect (ΔE_s) and intercellular (ΔE_{inter}) orbital magnetic moment did not contribute to the PL energy shifting. Our results are consistent with previous "low" field (B<9T) studies [3] but in conflict with recent high field studies [4], which will be discussed in more detail in our presentation.

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