**Magneto-Spectroscopy of Excitons in Monolayer MoSe2 and WSe2**

Ludwig, J.; Lu. Z.; Thirunavukkuarasu, K.; Moon, S.; Smirnov, D. (NHMFL); Zhang, F.; Cui, X.; Hone, J. (Columbia U., Physics); Li, Y.; Zhang, X.X. and Heinz, T.F. (Stanford U., Physics)

**Introduction**

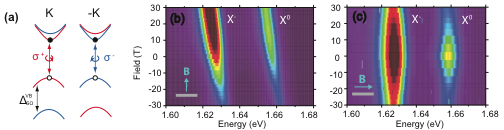
A monolayer of a transition metal dichalcogenide such as MoSe2 or WSe2 is a 2D semiconductor with a direct band gap. These 2D materials have a hexagonal lattice structure with broken inversion symmetry and two degenerate valleys at K+ and K- points of the Brillouin zone. The optical transitions are valley-selective with respect to the helicity of circularly polarized (CP) light. This enables selective control of K+ (K-) excitons with right (left) CP light, while a perpendicular magnetic field offers a possibility of lifting the valley degeneracy [1].

**Experimental**

MoSe2 and WSe2 monolayers were fabricated by mechanical exfoliation on to a SiO2/Si substrate. PL measurements were performed in magnetic fields up to 31 T in both Faraday and Voigt geometries. Unpolarized 2.33 eV laser light was used for excitation and the collected light was analyzed by an *in-situ* circular polarizer.

**Results and Discussion**

The low-temperature PL spectra of monolayer MoSe2 are dominated by two peaks corresponding to the emission from neutral (X0) and charged (X±) excitons. At low carrier density, the PL energies of both peaks experience a linear shift of ≈2μB/T in a perpendicular magnetic field. The direction of the shift is reversed for photons with opposite circular polarization, clearly demonstrating the lifting of the valley degeneracy due to the contribution of atomic orbital moments of the Mo atoms. This is further confirmed by measurements in parallel field, where no such splitting occurs. We observe similar shifts of the X0 and X- PL energies in ML WSe2, indicating that the valley Zeeman splitting is fundamental to all semiconducting ML TMDs. However, we observe an opposite change of the X- PL intensity with the magnetic field, which may indicate another configuration for the ground state trion in WSe2.

**Acknowledgements**

**Fig. 1** (a) Band diagram of monolayer MoSe2 at zero magnetic field. Red (blue) colors refer to spin up (down) bands. (b, c) Magneto-PL of MoSe2 as a function of an (b) out-of-plane (c) in-plane magnetic field at 5 K.

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**References**

[1] Li, Y., *et al*., Phys Rev. Lett., **113**, 266804 (2014).