Optical Spectroscopy of New Atomically-Thin Semiconductors to 65 Tesla

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A new family of atomically-thin semiconductors known as the “monolayer transition-metal dichalcogenides” (*e.g.,* MoS_2 or WSe_2), discovered in 2010, has the potential to advance many applications in opto-electronics, including light harvesting (solar cells) and light generation (LED lighting and lasers). As such, studies of their fundamental optical and electronic properties represent very active areas of present-day research.

Historically, magneto-optical measurements have played an essential role in determining the key parameters of electronic excitations in both bulk semiconductors and quantum-confined semiconductors (quantum wells and quantum dots). These excitations include excitons, an excited electron orbiting around the positively charged hole that was left behind by the exciting of the electron. Key parameters to characterize excitons include the exciton binding energy, size, spin, and dimensionality.

MagLab users have recently performed magneto-reflection spectroscopy on atomically-thin films of MoS_2 and WS_2 in pulsed magnetic fields to 65T. These measurements reveal the magnetic moment of the excitons in these 2D semiconductors, and also - for the first time - their physical size. Importantly, these parameters can then be used to constrain estimates of the exciton binding energy itself -- a parameter of significant interest in this new material class that is promising for future technological applications in solar energy and lighting.

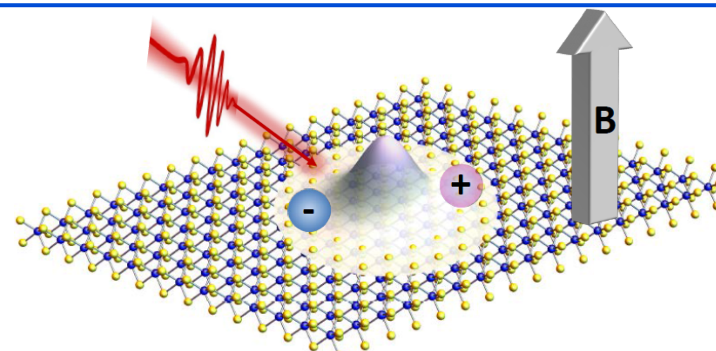

Figure 1: A depiction of the fundamental electron-hole excitation (exciton) in monolayer WS_2. Its size and magnetic moment are measured via magneto-reflection in high magnetic fields to 65T.

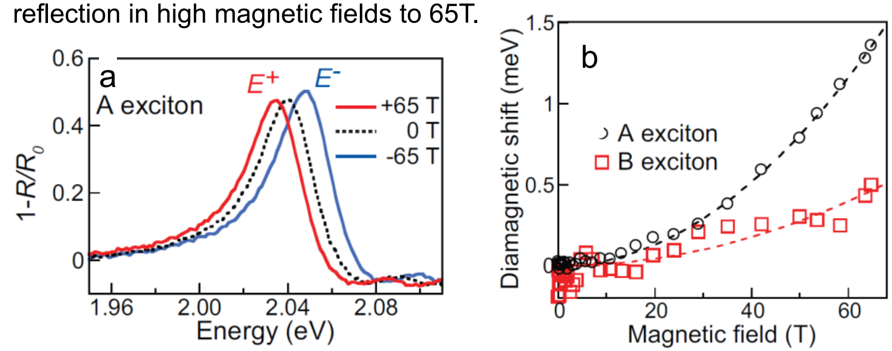

Figure 2: (a) The measured energy shift of the fundamental exciton peak at ±65T in monolayer WS2 (from reflection spectroscopy). In addition to the splitting (which reveals magnetic moment), the *average* peak position reveals (b), the quadratic diamagnetic exciton shift, from which the exciton radius is directly inferred (1.53 nm for the “A” exciton). The two types of excitons, A and B, indicate from which spin-split valence band the electron is excited: the A exciton is the lower energy exciton involving the spin-aligned valence band.

Facilities: NHMFL Pulsed Field Facility, Los Alamos National Laboratory; 65 tesla capacitor-driven magnet.

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