MAS20-2020-000121

Abstract for an Invited Paper
for the MAS20 Meeting of
the American Physical Society

Electrons, Holes, and Excitons in Monolayer Semiconductors: Insights from Optical Spectroscopy in (Really) High Magnetic Fields

SCOTT CROOKER, Los Alamos National Lab

This talk will discuss recent magneto-optical studies that probe the physics of electrons, holes, and excitons in monolayer transition metal dichalcogenide (TMD) semiconductors such as MoS2 and WSe2, as well as the crucial role played by the surrounding dielectric environment. Our first studies focused on revealing fundamental properties relevant for optoelectronics, such as exciton mass, size, binding energy, and dielectric screening. Historically, magneto-optical spectroscopy has played an essential role in determining these properties in semiconductors; however, for TMD monolayers the relevant field scale is substantial (of order 100 tesla!) due to heavy carrier masses and huge exciton binding energies. Fortunately, modern pulsed magnets can achieve this scale. Using exfoliated monolayers affixed to single-mode optical fibers, we performed low-temperature magneto-absorption spectroscopy up to 90T of all members of the monolayer TMD family. By following the diamagnetic shifts of the excitons 1s ground state and its excited Rydberg states, we determined exciton masses, radii, binding energies, dielectric properties, and free-particle bandgaps [1,2]. These data provide essential ingredients for the rational design of optoelectronic van der Waals structures. Separately, WSe2 monolayers were then electrostatically gated and populated with a high density of electrons or holes. Well-resolved sequences of optical transitions were observed in both circular polarizations, which unambiguously and separately indicate the number of filled Landau levels (LLs) in both K and K' valleys. We find that the 2D hole gas becomes unstable against small changes in LL filling and can spontaneously valley polarize [3]. These results cannot be understood within a single-particle picture, highlighting the importance of exchange interactions in determining the ground state of 2D carriers in monolayer semiconductors. [1] M. Goryca et al., Nature Comm. 10, 4172 (2019). [2] A. V. Stier et al., PRL 120, 057405 (2018). [3] J. Li et al., PRL 125, 147602 (2020).