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Measuring the Influence of Dielectric Environment on 2D Excitons in Monolayer Semiconductors: Insight from High Magnetic Fields[1]

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The relatively heavy electrons and holes in monolayer semiconductors such as MoS_2 form tightly-bound excitons with large binding energies, thus motivating magneto-optical studies in high magnetic fields. Because 2D excitons in these materials necessarily lie close to a surface, their properties are expected to be strongly influenced by the surrounding dielectric environment. However, systematic studies exploring this role are challenging, in part because the most readily accessible exciton parameter – the exciton's optical transition energy – is largely unaffected by the surrounding medium. Here we show that the role of the dielectric environment can be revealed through its systematic influence on the size of the exciton, which can be directly measured via the diamagnetic shift of the exciton transition in high magnetic fields [1,2]. Using exfoliated WSe_2 monolayers affixed to single-mode optical fibers, we tune the surrounding dielectric environment by encapsulating the monolayers with different materials, and perform polarization resolved low-temperature magneto-absorption studies to 65 tesla. The systematic increase of the exciton's size with dielectric screening, and concurrent two-fold reduction in binding energy (also inferred from these measurements), is quantitatively compared with leading theoretical models based on the Keldysh potential. These results demonstrate how exciton properties can be tuned in future 2D devices and van der Waals heterostructures. [1] A.V. Stier et al., Nature Comm. 7:10643 (2016). [2] A.V. Stier et al., Nano Lett. 16, 7054 (2016). [1]In collaboration with S.A. Crooker (NHMFL); J. Kono (Rice University); K.M. McCreary, B.T. Jonker (Naval Research Lab); N.P. Wilson, G. Clark, X. Xu (University of Washington).