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Direct Determination of Band Gap Renormalization in Photo-Excited Monolayer MoS_2

Abstract
A key feature of monolayer semiconductors, such as transition-metal dichalcogenides, is the poorly screened Coulomb potential, which leads to large exciton binding energies (E_b) and strong band renormalization (DE_g). The latter has been difficult to determine due to the cancellation between DE_b and DE_g at different carrier densities, resulting in little change in optical transition energy. Here we quantify bandgap renormalization in macroscopic (>3 mm) single crystal MoS_2 monolayers on SiO_2 using time and angle resolved photoelectron spectroscopy (TR-ARPES). At excitation density above the Mott threshold, $-DE_g$ is found to be as large as 360 meV for the n-doped MoS2 monolayer. We compare the excitation density dependent DE_g with theoretical calculations and show the necessity of knowing the doping/excitation densities in quantifying the bandgap.