Comparing the spin/valley dynamics of resident carriers in gated WSe_2 and $MoSe_2$ monolayers

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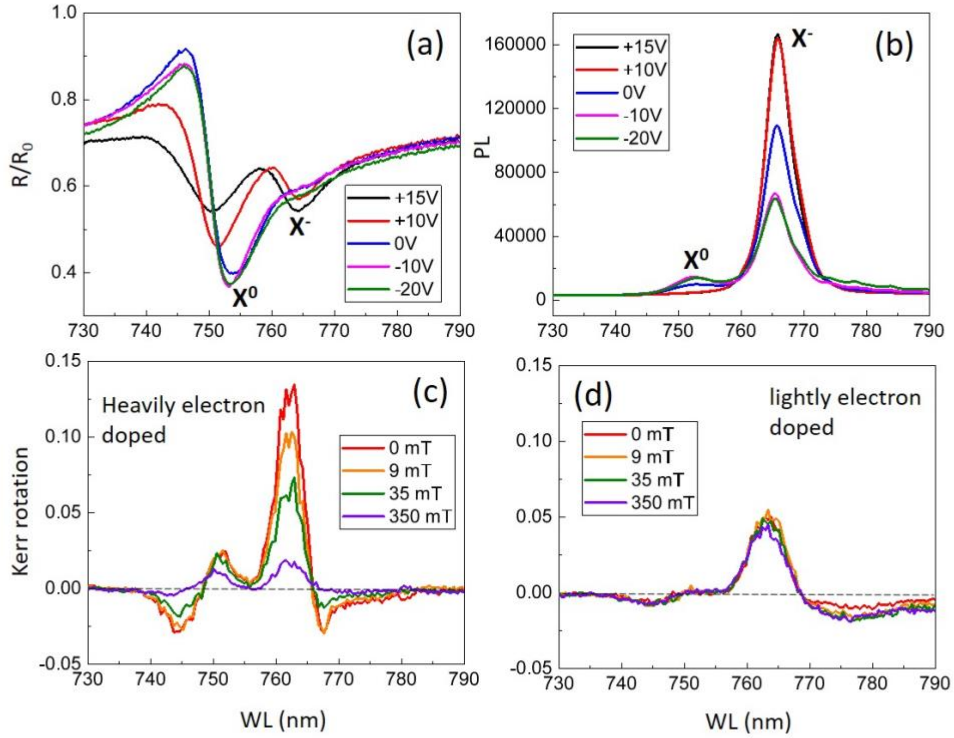
Introduction: The ability to populate and probe specific valleys in monolayer transition-metal dichalcogenides (TMDs) using polarized light has revived long-standing interests in valleytronics. An essential question therefore concerns the spin/valley relaxation timescales of the resident electrons and resident holes (not excitons) that exist in *n*-type or *p*-type TMDs. Using time-resolved Kerr rotation, we recently demonstrated extraordinarily long (microsecond) valley polarization lifetimes for resident holes in electrostatically-gated WSe_2 monolayers in the *p*-type regime [1]. However, an important question concerns the spin-valley dynamics behavior of $MoSe_2$, the molybdenum-based counterpart of WSe_2. Since WSe_2 and $MoSe_2$ monolayers exhibit conduction band spin-orbit splitting (Δ_c) of opposite sign, this could influence the measured dynamics, particularly in the weakly *n*-type regime.

Experiment: We have studied a single exfoliated flake of monolayer $MoSe_2$, electrostatically gated to tune the carrier density. We employ both continuous-wave Kerr rotation (CWKR) spectroscopy and time-resolved Kerr rotation (TRKR) spectroscopy to directly measure the dynamics of spin and valley polarization of resident carriers for different doping densities in the sample. Both CW and TR- Kerr rotation data as a function of transverse magnetic field (B_y) and temperature for different doping concentration were also obtained.



Results: Figures (a) and (b) show the low temperature (5K) reflectivity and photoluminescence respectively, as a function of gate voltage (and thus the carrier density). A clear sign of negatively charged trion (X^-) is observed when the sample is doped with electrons (for positive gate voltages) whereas no sign of positively charged trions was observed even for highly negative voltage. This indicates the sample is intrinsically heavily electron doped. Additionally, the oscillator strength of the neutral (X^0) and negatively charged exciton changes with applied gate voltage as expected. The charge neutrality point is somewhere between -10V and -20V as observed in the reflectivity data. Figures (c) and (d) demonstrate the CWKR spectroscopy data for heavily electron doped and lightly electron doped regime, respectively. In the heavily electron doped regime, CWKR signal amplitude decrease with applied in-plane field, B_y as observed in case of monolayer WSe2 [1]. However, no B_y dependence is observed for lightly electron doped regime. The CW Hanle data (not shown), is consistent with the observed CWKR data.

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Reference: [1] P. Dey *et al*., Phys. Rev. Lett. **119**, 137401 (2017)