Ultrafast spin valley dynamics in single layer WS_2

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The single layer two dimensional transition metal dichalcogenides (TMDs), such as MoS_2 and WS_2, are widely considered as emerging valleytronic materials primarily due to the coupled spin-valley at K/K' points of the Brillouin zone [1]. Valley polarization carried by the circularly polarized light excited quasi-particles (excitons, trions or biexcitons) could be used as a discrete degree of freedom, therefore, valley depolarization dynamics of these photoexcitations in TMDs should be well understood.

Studies on electron spin/valley dynamics in single layer MoS_2 show a characteristic intervalley scattering time of ~200 fs for A exciton [2]. Different from MoS_2, single layer WS_2 has larger conduction band splitting with no band crossing [3], better spectrally resolved trion signature [4]. Such peculiar features have attracted intense studies, both experimentally and theoretically, on spin/valley relaxation mechanism in this material [5,6].

In this work, we study the spin/valley relaxation process in a mechanically exfoliated WS_2 sample at liquid nitrogen temperature using the Time Resolved Circular Dichroism (TRCD) and Time Resolved Faraday Rotation (TRFR) techniques with typical ~100 fs temporal resolution pump and probe laser pulses. By carefully tuning the laser photon energy resonant to WS_2 A, B exciton and trion peaks, we are able to access the various electron spin process in K and K' valley, specifically the inter- and intra-valley spin relaxation dynamics involving both neutral and charged excitons.

References

[1] D. Xiao, et al., Phys. Rev. Lett. 108 (2012) 196802.
[2] S. Dal Conte, et al., Phys. Rev. B 92 (2015) 235425.
[3] Hongyi Yu, et al., Natl Sci Rev 2 (2015) 57-70.
[4] Jones AM, et al., Nat Nanotechnol. 8 (2013) 634-8.
[5] G. Plechinger, et al., Nat. Comms. 7 (2016) 12715.
[6] Hanan Dery and Yang Song, Phys. Rev. B 92 (2015) 125431.

Figures

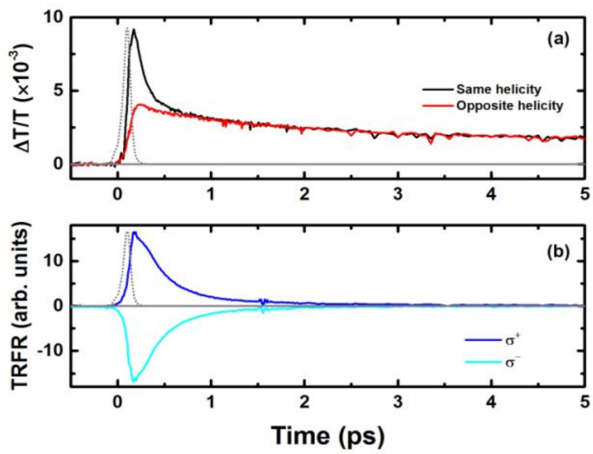

Figure 1: (a) Time resolved circular dichroism measurements on single-layer WS_2. Both pump and probe are resonant to A exciton peak. Black and red curve: pump and probe have the same and opposite helicity, respectively. (b) Time resolved Faraday rotation of monolayer WS_2. Blue and cyan curve: pump with left and right circularly polarized light. Gray dashed curve: laser pulse shape.