Spin and charge dynamics in 2D semiconductors under high magnetic fields

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Hexagonal transition metal dichalcogenides (TMDs) are promising two-dimensional direct bandgap semiconductors that have shown multiple interesting properties related to their strong spin-orbit coupling. The two energy-degenerated valleys and spin species are connected via time-reversal symmetry. When an out-of-plane magnetic field is applied, time-reversal symmetry is broken and the energies of the spin-polarized bands shift, resulting in a different bandgap at the K_+ and K_- valleys [1]. So far, the effect of this splitting on the ultrafast spin dynamics has been studied from theory but a direct measurement, which can provide new information to the understanding of these materials, is still missing [2]. Here, we explore the charge and spin dynamics on a monolayer $MoSe_2$ when this valley-splitting, also called the valley-Zeeman effect, takes place. We use an optical pump-probe approach, by exciting the sample with circularly polarized light (right/left) to populate independently each specific spin state generating a spin imbalance. We measure the spin relaxation dynamics through the time-resolved Kerr rotation for a $MoSe_2$ monolayer under an out-of-plane magnetic field. We observe that the valley-Zeeman effect stabilizes one spin direction, leading to an enhanced spin lifetime, while reducing the spin lifetime for spins in the opposite direction. Our results provide an experimental insight on the ultrafast charge and spin dynamics in TMDs and a way to control it, which will be useful for the development of new spintronic and valleytronic applications.

References

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Figures

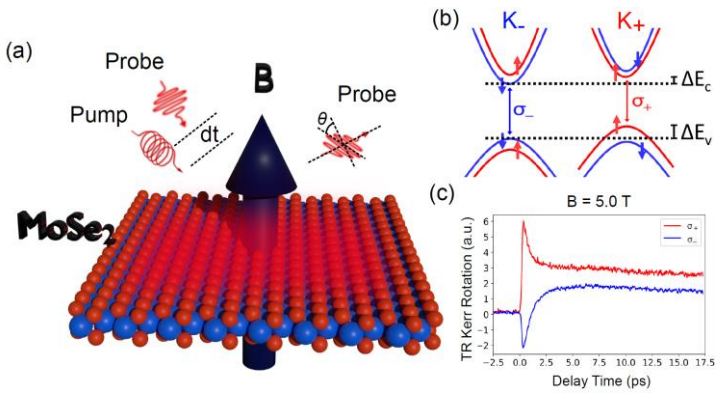

Figure 1: (a) Schematic of the time- resolved Kerr Rotation (TRKR) on a monolayer MoSe2 under a magnetic field. (b) Valley-Zeeman effect on the two different valleys. (c) TRKR at B=5.0 T shows the enhancement of the lifetime of one specific spin direction.