Ultrafast optical dynamics in graphene like materials

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Materials composed of two dimensional, atomically thin layers have been known in their bulk forms for decades. However, single layers of these materials have only been isolated in 2005[1]. The discovery of graphene, followed by more recent findings on transition metal chalcogenides (TMCs) has propelled an unprecedented, multidisciplinary research effort at the interface between quantum electrodynamics, solid state physics and materials science and engineering. Atomically thin layers exhibit unique electronic and optical properties and can be integrated in nano- and micro-optoelectronic devices, thus offering a broad range of exciting fundamental and applied perspectives. Using mechanical exfoliation techniques, bulk crystals of TMCs are easily exfoliated down to the mono-layer limit. These semiconductors share some physical properties with graphene: in a single-layer of MoS_2, the top of the valence band and the bottom of the conduction band are located at the **K** and **K'** points of the hexagonal Brillouin zone (fig. 1-a). However, TMCs present some essential differences as compared to graphene. A single layer of MoS_2 has a 1.9 eV direct bandgap that allows rich optical studies[2] while the lack of inversion symmetry leads to optical selection rules depending on the valley index for interband transitions at the **K** points (figure 1-b). Moreover, the strong spin-orbit interaction implies a whole coupling between the valley index and the electronic spin that enables to photocreate a valley-polarized population of electrons[3-5].

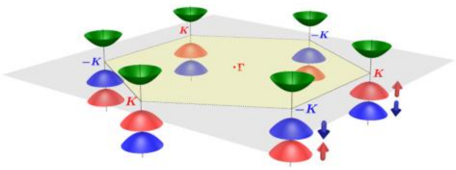

Figure 1-a: first Brillouin zone of MoS_2

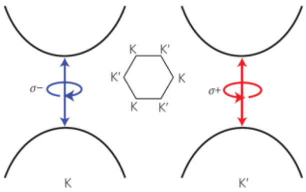

Figure 1-b: Optical selection rules

The subject of this thesis is to extend optical orientation experiments to the time domain and to study the valley dynamics by using ultrafast spectroscopy in order to identify and understand the relaxation processes of these elementary excitations. Time-resolved photoluminescence or pump-probe experiment can be considered to measure lifetimes and/or spin relaxation times of photo-carriers. We are strongly interested in the optical creation and manipulation of coherent superpositions of valley states for potential applications in quantum information and quantum computing. Some new and unexpected physical effects, specific to the low dimensionality of these systems are likely to be highlighted.

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