Magneto-optics of Massive Dirac Fermions in Strong Magnetic Fields.

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Massive Dirac Fermions (mDF) describe the low energy electronic properties of a class of two-dimensional crystals, from graphene in a staggered potential to transition metal dichalcogenides (TMDCs), such as MoS2 and WS2 [1-6]. In the energy structure of staggered graphene and TMDCs there exist two non-equivalent valleys, K and –K, with valence and conduction band separated by an energy gap E_g and split by a strong spin-orbit (SO) coupling. Recent experiments on TMDCs have shown that the optical transitions in these valleys couple to the oppositely circularly polarised light [2-4], which allows to address them independently.

The massive Dirac Fermions in strong perpendicular external magnetic field and their interaction with light have been studied in Refs. [6,7]. The magnetic field leads to the formation of degenerate levels, each being a mixture of different Landau levels (LLs) from the valence and conduction band. The mixing is controlled by the ratio of energy gap to Fermi velocity and by the strength of the SO coupling. The characteristic feature of Massive Dirac Fermions is the splitting of the two zero LLs of graphene into one attached to the top of the valence band in K valley and one attached to the bottom of the conduction band in the –K valley. In addition, topological magnetic moment, atomic magnetic moments and Zeeman splitting appear.

In this work we investigate the effect of electron-electron interactions on the optical properties of massive Dirac Fermions [8]. We start with the single-electron picture, using the massive Dirac equation with spin-valley-dependent low-energy gap [7]. We populate the N valence mDF levels and construct the Hartree-Fock (HF) ground state. We create quasi-electron and quasi-hole excitations out of the HF ground state, calculate self-energy, direct and exchange vertex corrections and solve numerically the Bethe-Salpeter equation to obtain the magneto-exciton spectrum in the two non-equivalent valleys. Using the selection rules for each spin, valley and polarisation of radiation, the absorption and emission spectra are calculated as a function of the mass-term, from massive to massless Dirac fermions. The magneto-exciton spectra will be compared with positively and negatively charged trions.

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