Electronic Dynamics of Layered Two-Dimensional Materials in the Quantum Hall Regime at Very High Magnetic Fields

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Introduction

The main objective of this proposal is the investigation of the fundamental many-body interactions of two-dimensional electron and hole gases at high magnetic fields. The main experimental goal in the proposed work is to perform coherent four-wave mixing (FWM) and two-dimensional Fourier transform (2DFT) experiments systematically on the GaAs/AlGaAs and transition-metal dichalcogenides (TMD) materials.

Experimental

We have measured time-integrated FWM on monolayer $MoSe_2$ at the presence of magnetic fields up to 25 T. The monolayer $MoSe_2$ was grown by chemical vapor deposition and transferred on an optically transparent quartz substrate. The three laser beams used to generate the FWM signal are provided by the MONSTR instrument (Fig. 1 (c)).

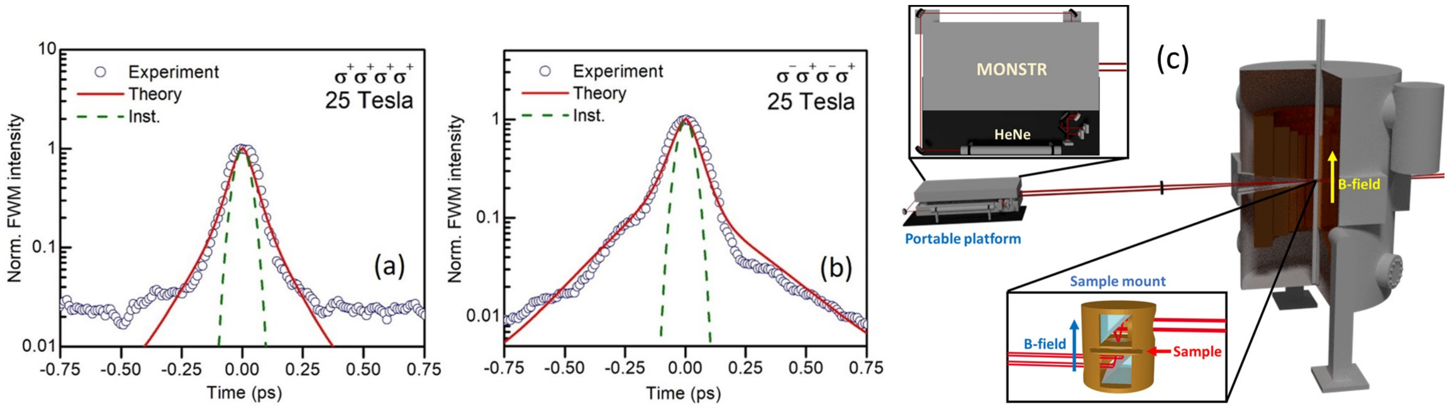

Fig1. Time-integrated FWM intensity as a function of the time delay τ at 25 Tesla for two different polarization sequences (σ+σ+σ+σ+) (a) and (σ-σ+σ-σ+) (b), where the individual polarizations correspond to the laser pulses A*,B,C and detection, respectively. The time delay T between pulses B and C is kept fixed at zero femtoseconds. Blue circles are the experimental data, whereas the red lines are the time-integrated FWM calculated using time-dependent DFT.

Results and Discussion

We measured time-integrated FWM on monolayer $MoSe_2$ at magnetic fields up to 25 Tesla. Significant changes are observed when excitons of opposite spins in different valleys are excited, leading to much longer dephasing times for inter-valley biexcitons despite the large differences in crystal momenta (Fig. 1 (a-b)). In external magnetic fields, we observe interesting ordering of the electrons and holes by means of strong Coulomb interactions into a four-particle correlated state. The optical dephasing takes place in a four-particle ordered state comprised of inter-valley biexcitons, creating favorable conditions for interesting new states of matter, including the creation of multiple exciton complexes, exciton superfluidity and biexciton condensates. The results were published in: "*Biexcitons in monolayer transition metal dichalcogenides tuned by magnetic fields*" Nature Communications **9**, 3720 (2018).

Conclusions

In external magnetic fields, we observe interesting ordering of the electrons and holes by means of strong Coulomb interactions into a four-particle correlated state. The optical dephasing takes place in a four-particle ordered state comprised of intervalley biexcitons, creating favorable conditions for interesting new states of matter, including the creation of multiple exciton complexes, exciton superfluidity, and biexciton condensates.

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