Magneto-Optical Studies of Excitons in Transition Metal Dichalcogenides

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Introduction

Transition metal dichalcogenides (TMDs) such as WSe_2 and $MoSe_2$ have recently drawn significant interest both for device applications and fundamental physics studies [1]. Although multi-layered TMDs are indirect bandgap semiconductors, at the monolayer level TMDs become direct bandgap semiconductors that interact strongly with light [2]. As is the case for various two-dimensional materials, TMDs can be easily stacked with other thin flakes to form so-called van der Waals (vdW) heterostructures. In particular, when $MoSe_2$ or WSe_2 flakes are encapsulated between layers of the insulator hexagonal boron nitride, their optical properties improve as can be seen from reduced linewidths of electron-hole (exciton) and charged exciton emission [3,4]. These improvements allow careful studies of the optical properties of atomically thin semiconductors particularly under a magnetic field, which lifts the valley degeneracy and splits exciton states. Here, we perform magneto-optical studies on monolayer $MoSe_2$ and bilayer WSe_2 vdW heterostructures, to investigate the fundamental properties of excitons, localized excitons and interlayer excitons.

Experimental

We perform photoluminescence (PL) and absorption measurements, using a 660 nm laser and a broadband halogen lamp, respectively. All measurements were performed in cell 3, in a free-space confocal setup we built, with galvo mirrors to image the sample (Fig. 1 A) and move the excitation/collection spot.

Results and Discussion

The PL spectra of monolayer $MoSe_2$, with no magnetic field or gate voltage applied, displays two features, the neutral exciton emission, and the charged exciton emission (Fig 1 B). Upon applying a 17.5T magnetic field (Fig 1 B) in the direction perpendicular to the TMD plane, we observe a splitting of both states with similar g factor, 3.96 and 4.05. This is expected based on band gap calculations and orbital quantum numbers. For bilayer WSe_2, there are low energy peaks in PL due to momentum-indirect, interlayer excitons at 0 T (Fig 1 C). The origin of these multiple peaks is an open research problem. When a 15 T perpendicular magnetic field is applied to the sample, the multiple peaks split with different g-factors ranging from 10.58 for the highest energy peak to 9.26 for the second highest energy peak (Fig 1 C). These different g-factors may give some indications regarding the physical origin of these states.

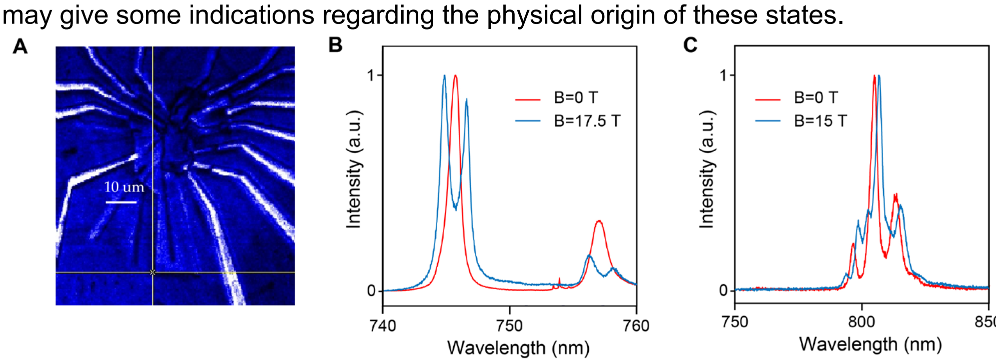

Fig.1 (A) Reflection image of a device using the Cell3 confocal setup, (B) PL Spectra of a monolayer $MoSe_2$ at T=4K and B=0T (red) and B=17.5T (blue), (C) PL spectrum of a bilayer WSe_2 at T=4K and B=0T (red) and B=15T (blue

Acknowledgements

These measurements were performed at the National High Magnetic Field Laboratory, which is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida. H.P. acknowledges the DoD Vannevar Bush Faculty Fellowship (N00014-16-1-2825), NSF CUA (PHY-1125846), NSF (PHY-1506284), AFOSR MURI (FA9550-17-1-0002), ARL (W911NF1520067) and Samsung Electronics. Device fabrication was carried out at the Harvard Center for Nanoscale Systems.

References

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