Extremely Efficient Light-Exciton Interaction in a Monolayer WS2 van der Waals Heterostructure Cavity

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Abstract: Excitons in monolayer transition-metal-dichalcogenides dominate their optical response, however, the achieved light-exciton interaction strength have been far below unity, and a complete picture of its underlying physics and fundamental limits has not been provided. Using a van der Waals heterostructure cavity (VHC), we demonstrate near-unity excitonic absorption, together with efficient emission at ultra-low excitation powers. We find that the interplay between the radiative, non-radiative and dephasing decay rates plays a crucial role in this interaction, and unveil a universal absorption law for excitons in 2D systems.

In this work [1], we demonstrate a WS2-based high quality VHC (Fig. 1(a)), which is tailored to enhance the optical response of excitons in a WS2 monolayer, and their interaction with the illuminating light. This approach yields a value of 92% excitonic absorption, which can be controlled electrically, optically, and with temperature (Fig. 1(b)). The VHC also enables the excitation of a large photo-excited excitonic population, while still maintaining low optical power. This high density of excitons allows the observation of efficient bi-excitonic emission, with ultra-low continuous-wave laser power excitation down to few nW (Fig. 1(c)).

Combined with an analytical framework to describe the light-exciton-cavity interaction, we find an intriguing relation between the exciton radiative, non-radiative and dephasing decay rates, and the existence of a universal absorption law for 2D excitonic systems under these conditions.

This enhanced light-exciton interaction paves the way for studying excitonic phase transitions and quantum nonlinearities in TMDs, and the realization of practical optoelectronic devices based on monolayer semiconductors.

Figures

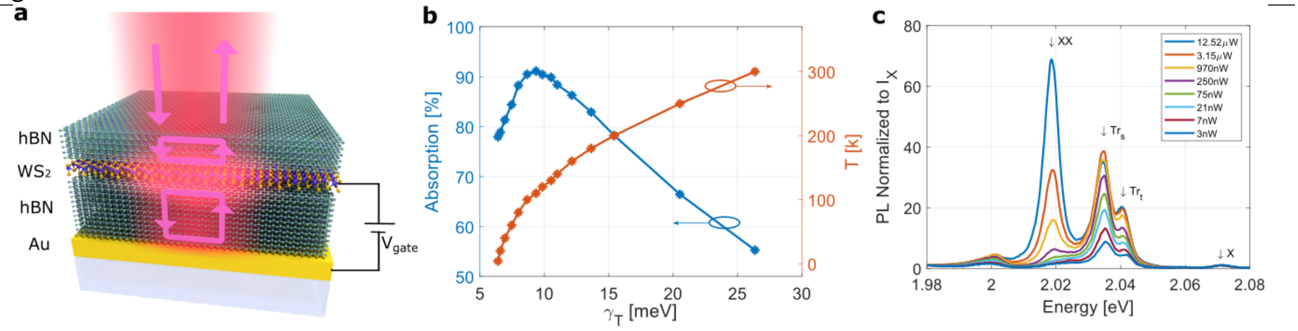

Figure 1: (a) Schematics of the VHC structure. (b) Excitonic absorption and temperature vs total linewidth (γ_T). (c) Photoluminescence spectra of the VHC showing the exciton (X), singlet/triplet trion (Trs/t) and bi-exciton (XX) emission peaks for several cw excitation powers down to few nW.

References

[1] I. Epstein et al, "Near-unity Light Absorption in a Monolayer WS2 Van der Waals Heterostructure Cavity", arXiv:1908.07598 .