Acoustic modulation of excitonic complexes in hBN/WSe_2/hBN heterostructures

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The interaction of surface acoustic waves (SAWs) and excitonic states in two-dimensional (2D) materials offers a challenging opportunity to explore novel effects and potential functionalities. Since van der Waals heterostructures (vdWHs) can be tailored by the deterministic stacking of different 2D material layers, resulting in excitonic dynamics driven by a variety of different quantum interactions, many strategies can be envisioned to optimize the control of exciton dynamics with the SAW strain and piezoelectric field. In this contribution, we probe the interaction of neutral excitons, trions, (neutral and charged) biexcitons and localized states with SAWs in a hexagonal boron nitride (hBN) encapsulated WSe_2 vdWH (hBN/WSe_2/hBN). Differently from what is observed at room temperature, we show that neutral excitons respond very weakly to the SAW stimulus at 5 K due to their higher binding energy and lower mobility. The other excitonic complexes observed at low temperatures, however, because of their lower binding energy or charged character, interact much more efficiently with the SAW piezoelectric field. We discuss how temperature and laser-induced photodoping can affect the exciton dissociation dynamics induced by the acoustic fields. In particular, we observe that the degree of photoluminescence quenching (a measure of the exciton dissociation rate) induced by the SAW piezoelectric field is larger around 200 K due to the larger carrier mobility, reaching values of up to 80%. We also show that the SAW can partially revert laser-induced photodoping at room temperature, opening possibilities of using SAWs to address metastable charge effects in vdWHs [1]. Our findings provide a contribution to the understanding of the interaction of excitons and SAWs in vdWHs, especially the so far unexplored case of biexciton modulation, important for 2D materials-based optoelectronic and energy harvesting devices.

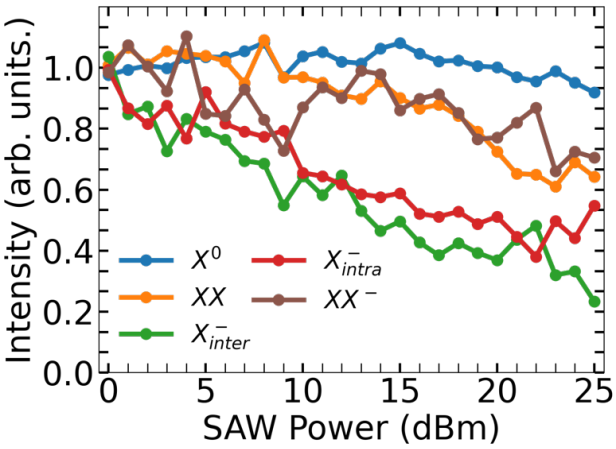

Figure 1: Normalized μ-PL intensity as a function of the SAW power for the different excitonic emissions detected in the hBN/WSe_2/hBN heterostructure at 5 K.

References

[1] M. L. F. Gomes, P. W. Matrone, A. R. Cadore, P. V. Santos and O. D. D. Couto Jr., *Nano Lett.* **24**, 15517 (2024).

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