Funnel Effect of Excitons in Strained 2D Materials

Rafael Roldán

Instituto de Ciencia de Materiales de Madrid ICMM-CSIC, Cantoblanco, Madrid, Spain

rroldan@icmm.csic.es

Controlling the bandgap through local-strain engineering [1] is an exciting avenue for tailoring optoelectronic materials. Two-dimensional crystals are particularly suited for this purpose because they can withstand unprecedented non-homogeneous deformations before rupture: one can literally bend them and fold them up almost like a piece of paper. I will discuss our recent results on multi-layer MoS_2 and black phosphorus (BP) sheets subjected to periodic stress, that allows to modulate their optoelectronic properties [2,3]. The experimental measurements show a remarkable shift of the optical absorption band-edge, which in the case of black phosphorus can be of up to ~0.7 eV between the regions under tensile and compressive stress. Our theoretical results show that the so-called funnel effect, i.e., the possibility of controlling exciton motion by means of inhomogeneous strains [4], is much stronger in few-layer BP than in MoS_2 monolayers and, crucially, is of opposite sign. Instead of excitons accumulating isotropically around regions of high tensile strain like in MoS_2, excitons in BP are pushed away from said regions [5]. This inverse funnel effect is moreover highly anisotropic, with much larger funnel distances along the armchair crystallographic direction, leading to a directional focusing of exciton flow. A strong inverse funnel effect could enable simpler designs of funnel solar cells and offer new possibilities for the manipulation and harvesting of light.

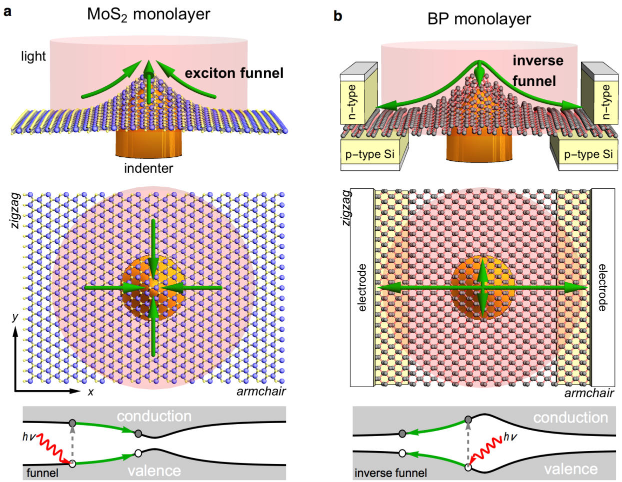

Figure 1: An exciton funnel for MoS_2 is represented in (a), where an indenter creates an inhomogeneous strain profile that modulates the gap (bottom) and pushes photogenerated excitons (in green) isotropically towards the center of indentation. In BP (b), the same strain profile creates a stronger, highly anisotropic inverse funnel effect that pushes excitons away from the indentation along the armchair direction.

References

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