Interplay of valley polarized dark trion and dark exciton-polaron in monolayer WSe_2

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The interactions between charges and excitons involve complex many-body interactions at high densities. The exciton-polaron model has been adopted to understand the Fermi sea screening of charged excitons in monolayer transition metal dichalcogenides (TMD). The results provide good agreement with absorption measurements, which are dominated by dilute bright exciton responses. The Fermi-polaron model treats the quasiparticle responses of a single mobile impurity in a surrounding Fermi sea. In comparison, the exciton density in monolayer TMD can be tuned by laser fluence and be comparable to or exceed the charge density, where the analogy to a single mobile impurity no longer applies. The modification to Fermi sea screening at high exciton densities, however, is still not well understood. Apart from the bright excitons previously studied in reflection contrast measurements, different spin and momentum dark exciton species have been established, which are also expected to have many-body interactions with charges. The coupling between these different species of exciton-polarons has not yet been experimentally investigated.

Here we investigate the Fermi sea dressing of spin-forbidden dark excitons in monolayer WSe_2 [1]. With a Zeeman field, the valley-polarized dark excitons show distinct p-doping dependence in photoluminescence when the carriers reach a critical density (see Fig. 1). This density can be interpreted as the onset of strongly modified Fermi sea interactions and shifts with increasing exciton density. Through valley-selective excitation and dynamics measurements, we also infer an intervalley coupling between the dark trions and exciton-polarons mediated by the many-body interactions. Our results reveal the evolution of Fermi sea screening with increasing exciton density and the impacts of polaron-polaron interactions, which lay the foundation for understanding electronic correlations and many-body interactions in 2D systems.

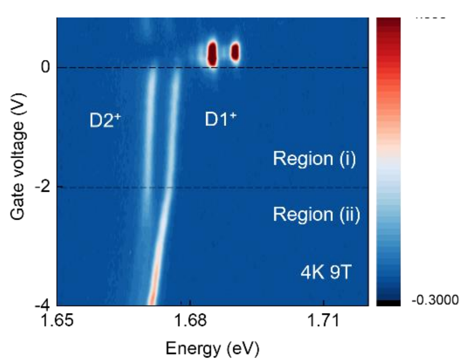

Figure 1. Dark exciton emission from a monolayer WSe_2 device at 4K, 9T out-of-plane magnetic field. D1+ and D2+ and the Zeeman-split dark trions. The dashed line at ~ -2V marks the crossover between region (i) and region (ii), which is also assigned to be the dark trion to dark exciton-polaron crossover for D1+. At the crossover, D2+ broadens and quenches in amplitude.

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