Dissociation of 2D excitons and efficient photocurrent generation in monolayer WSe_2 p-n junctions

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Two-dimensional (2D) semiconductors, such as single layer transition-metal dichalcogenides (TMDs), have recently emerged as promising candidates for optoelectronic applications due to their unique electronic and optical properties [1,2]. One of the most interesting features 2D semiconductors is the presence of strongly enhanced Coulomb interactions which results in exciton with large binding energies (>100 meV). Efficient conversion of photons to electrical current in 2D TMD relies, as a first step, on the dissociation of these strongly bound excitons into free electrons and holes. Many studies have investigated the photodetection performances of 2D TMDs [3,4], but quantitative discussion on the dissociation process has been rare, and in most case it has not been considered at all.

Here we address this issue by performing spectral and time-resolved photocurrent on hBN-encapsulated WSe_2 p-n junctions. We report the observation and electrical tuning of Stark shift and the concomitant Franz-Keldysh effect by in-plane electric field. The excellent agreement found between the measured and calculated electro-absorption spectrum indicates an exciton binding energy of 170 meV. We further assess the intrinsic response time of the device by photocurrent autocorrelation measurements and observe two response regimes: at low field, the response is limited by the dissociation of the excitons whereas at high-field, the rate-limiting step is the drift of carriers out of the p-n junction. Our study provides direct insight into the dynamic processes governing the quantum efficiency and detection speed of these 2D semiconductors and demonstrates their potential as a platform for future optoelectronic devices.

References

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Figure

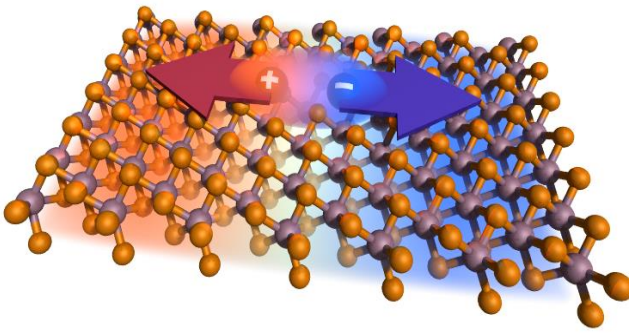

Figure 1: Artistic view of in-plane exciton dissociation in a monolayer TMD p-n junction