Strain control of valley degree of freedom in monolayer WSe_2

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Abstract

Mechanical strain is an efficient knob to control the tightly bound excitons in the transition metal dichalcogenides (TMDs). Here, we apply remarkably large biaxial strain in a suspended monolayer WSe_2 (exceeding 2%) at cryogenic temperatures and unveil novel strain responses of excitons. First, we find that the conduction bands hybridize with the in-gap localized defects under ~1% strain. The hybridization breaks the spin-valley locking and brightens the lowest-lying dark excitons. Second, while the hybridization with defects leads to the loss of valley coherence (from 40% to 0%), the novel hybrid states preserve valley polarization up to 30% at 5K. Finally, we evidence ultrafast optical manipulation of spins under strain via time-resolved Kerr microscopy and suspect unconventional coupling between the defects and the valley pseudospins. In summary, we present a unique approach to controllably strain TMDs down to the cryogenic temperatures, and achieve strong strain manipulation of the spin/valley properties in monolayer WSe_2. Our observations may play critical role in the applications of TMDs in strain-valleytronics, for example, by activating the hybrid defects and dark states as information carriers.

Figures

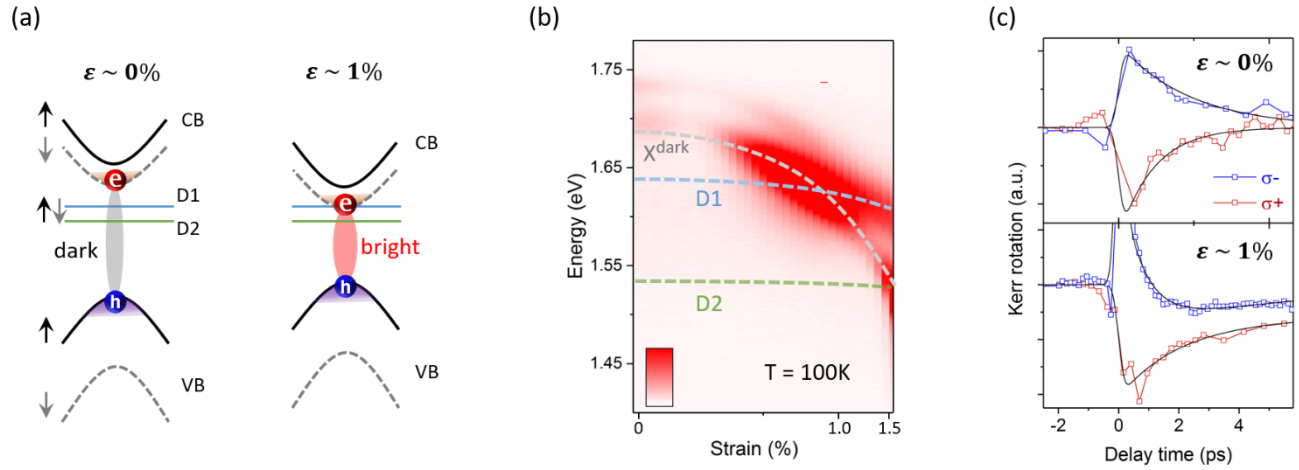

Figure 1: (a) Schematic band structure of monolayer WSe_2. Two localized in-gap states D1 and D2 associate with Se-vacancy defects (left panel). Uniform strain brings the conduction bands in resonance with D1/D2 leading to the brightening of dark states (right panel). **(b)** Photoluminescence evolution of a suspended WSe_2 membrane under biaxial strain at 100K. Dark excitons brighten as they come in resonance with either D1 or D2. **(c)** Time-resolved Kerr signal in WSe_2 vs. pump chirality. Spin/valley locking in the unstrained device is observed via the sign flip and identical dynamics of the Kerr signal (upper panel). In contrast, the signal undergoes rapid sign flip for σ- pump after 1ps of photoexcitation and suggests breaking of spin/valley symmetry.