Ultrafast photoinduced carrier dynamics in atomically-thin 2D materials and topological insulators

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Two-dimensional (2D) materials have gained a lot of attentions due to their unique physical properties and due to the possible applications such as ultrafast optoelectronics. Moreover, hybridization of these materials and artificial materials has opened up new avenues for novel optoelectronic applications. Here, we discuss the ultrafast photoinduced carrier dynamics in novel 2D materials (MoS_2, topological insulators).

For monolayer TMDs, reduced dielectric screening invokes strong Coulomb interactions, which lead to the large exciton binding energy. Recent theory predicts that the subset of excitons is much richer, such that internal transitions between excitons (1s, 2s, 2p,…) should prevail the photo-induced optical response [1]. Here, we performed ultrafast optical pump and mid-infrared (IR) probe spectroscopy to investigate such transient intraexcitonic dynamics in a monolayer MoS_2.

Topological insulators are new quantum maters where gapless Dirac surface and normal insulating bulk coexist [2]. First, with recently discovered topological phase transition in $(Bi_{1-x}In_x)_2Se_3$, we report new tunable Fano interference phenomena. By engineering the spatial overlap of surface Dirac electrons with bulk lattice vibration, we continuously modulate, abruptly switch, and dynamically tune the Fano resonance. Second, we present ultrafast optical modulation of plasmons in a topological insulator Bi_2Se_3 micrio-ribbon array. Unprecedented giant modulation depth up to 2,400 % is obtained with very low fluence of optical control pulse.

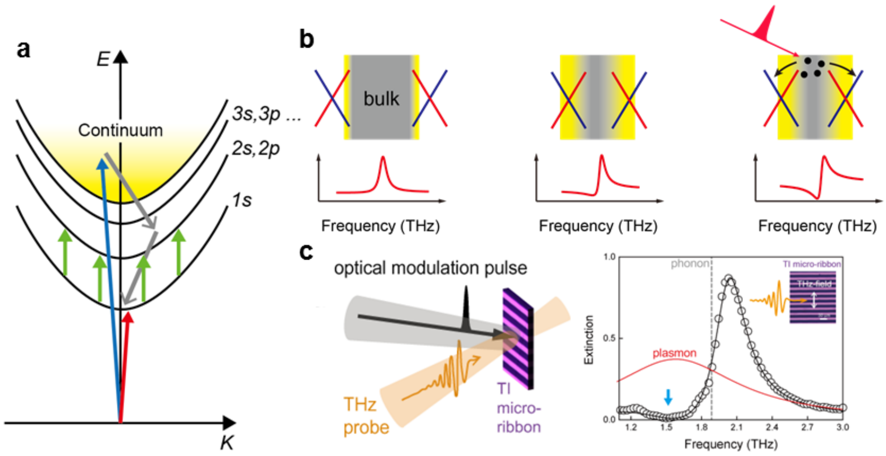

Fig. 1. Schematics of the ultrafast spectroscopy on 2D materials. a. E-K diagram of MoS2 excitons representing ultrafast intraexcitonic spectroscopy. b. Schematics of optically-tunable Fano resonance in topological insulator. c. Schematics representing optical modulation of THz probe using TI plasmonic structures.

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