Ultrafast Lightwave engineering in 2D Materials

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The discovery of two-dimensional (2D) graphene ignited a global surge in creating atomically thin materials with remarkable transport and optoelectronic properties -- key ingredients for next-generation technologies. In this talk, I will demonstrate how intense, *tailored* laser pulses can unlock functionalities in 2D materials that are otherwise forbidden by symmetry, enabling phenomena such as valley polarization and bulk photogalvanic currents even in inversion-symmetric systems.

I will first show how valley-selective excitation in gapless graphene can be achieved by all-optical means. By engineering laser waveforms to match the sublattice symmetry of graphene, it becomes possible to induce and probe valley polarization in a material long believed to be incompatible with light-driven valleytronics [1,2]. Building on this, I will present a fully coherent protocol that enables valley-selective excitation, de-excitation, and ultrafast switching between valleys within mere tens of femtoseconds -- well below typical valley decoherence times [3]. In the second part of the talk, I will introduce a new mechanism to achieve controllable valley polarization using a nonresonant, linearly polarized pulse, without relying on carrier-envelope-phase stabilization or multicolor fields. Finally, I will discuss an all-optical method to generate and control bulk photogalvanic currents in graphene and other 2D materials, opening pathways toward ultrafast valleytronics and on-chip light-driven electronics [4,5].

References

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