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Optical Excitation and Energy Relaxation in Graphene: Layer by Layer

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Intralayer and stacking-dependent interlayer optical excitations, and the cooling of hot electrons are the critical processes underlying the operation of exciting new graphene-based optoelectronic and plasmonic devices. In this talk, I will discuss the optical excitations and subsequent energy relaxation in single layer graphene and coupled graphene layers. We will first discuss the hot electron cooling rate near the Fermi level by measuring the electron temperature as it cools dynamically. We found that a disorder-enhanced supercollision cooling mechanism provides a complete and unified picture of energy loss near the Fermi level over the wide range of electronic (15 to $\sim$ 3000 K) and lattice (10 to 295 K) temperatures, supported by measurements done both electrically (using photocurrent thermometry) and optically. In bilayer graphene, the misorientation (or twist) angle between the two layers creates new pathways for interlayer optical excitations resulting in an interlayer optical resonance with a strongly angle-dependent energy. Our Raman, broadband absorption/reflection, and transient absorption studies on bilayer graphene samples with known twist angles confirm that the dispersion of the interlayer resonance peaks follows closely the band structure of single layer graphene; however, its energy relaxation is significantly slower. These studies may lead to new methods for customizing fundamental optical characteristics of multilayer 2D materials, including the optical conductivity, (circular) polarization dependence, and the cooling dynamics of hot carriers.