Seeing electrons in two dimensions: Optical spectroscopy of graphene

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Optical spectroscopy provides an excellent complement to transport measurements as a means of understanding the distinctive properties of electrons graphene. Within the simplest description, one has for the graphene monolayer a zero-gap semiconductor with direct transitions between the conical bands. This gives rise to a predicted absorption that is frequency independent and has a strength of $\pi\alpha$ = 2.3%, where α is the fine-structure constant. This prediction is indeed satisfied in an appropriate spectral range in the near infrared [1], but that at higher photon energies band-structure and electron-hole interactions significantly modify this result, leading to the formation of a saddle-point exciton [2].

Optical absorption spectroscopy also permits a detailed analysis of how the linear bands of graphene are modified through interlayer interactions. In particular, graphene bilayers, with their lowered symmetry support a band gap under the application a strong perpendicular electric field. Such a tunable band gap, with a magnitude up to 200 meV, has been observed by infrared measurements [3]. For the case of few-layer graphene samples, more complex 2D band structure develops, as can be traced through the optical absorption spectra and their critical points [4,5,6].

Another important aspect of laser spectroscopy is the ability to examine the dynamics of fundamental excitation in graphene by time-resolved techniques. We describe measurements on femtosecond electron dynamics based on measurement of the light emission from graphene induced by femtosecond laser pulses [7]. The studies reveal very rapid electron thermalization, as well as equilibration with strongly coupled optical phonons. This stage is followed, on the picosecond time scale, by cooling through anharmonic phonon decay [8].

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