

Raman features of graphene beyond the standard nonadiabatic theory

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Although graphene has already been thoroughly studied with Raman spectroscopy, there still exists a disagreement about the broadening mechanisms of the E_{2g} mode and its actual temperature dependence [Nano Lett. 10, 466 (2010)]. Along with the importance of the nonadiabatic effects in graphene, higher order electron-phonon scattering processes also significantly impact the phonon spectrum. Specifically, the electron-phonon-induced lifetime and energy renormalization of the electron-hole pair excitations bring additional temperature dependence in the electron-coupled phonon modes and their corresponding linewidths. The nonadiabatic theory relying on first principles calculations, developed in [Phys. Rev. B 98, 041112(R) (2018)] is here successfully applied to graphene in various doping regimes.