Electrical transport and electron-phonon coupling in suspended mono- and bilayer graphene

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Electron-phonon coupling is the basic means to control energy transport in a variety of devices which provide extreme sensitivity in calorimetry, bolometry, and radiation detection (infra red/THz). Owing to thermal noise, such devices are typically operated at cryogenic temperatures, at which the coupling between electrons and phonons becomes weak in clean samples [1]. Under these conditions, graphene is expected to have an advantage owing to its small heat capacity that allows fast operation even though its electron-phonon coupling becomes exceedingly small near the Dirac point.

This talk summarizes our results on electron-phonon coupling obtained using electrical transport experiments on both mono- and bilayer suspended graphene [2,3]. In monolayer samples, our experiments indicate strong "supercollision cooling" due to the presence of ripples in suspended graphene. In the high temperature limit, our results yield the first demonstration of the T^5 dependence for the electron-phonon heat transfer. In the low-T limit, our results indicate quadratic dependence on the chemical potential, which is a characteristic signature of non-conventional cooling processes. This μ^2 behavior is in line with the cross-over, found at $T \sim \mu/k_B$, from the quintic high-T behavior to cubic in the low-T regime. On the contrary, we find that electron-optical phonon scattering dominates in bilayer graphene under similar measurement conditions (see Fig. 1). The strength of the scattering follows theoretical expectations with a specific thermal activation behavior, and indicates the presence of electron scattering by zone edge and zone center optical phonons. The connection of our results to results obtained on graphene on substrate [4,5] will also be discussed.

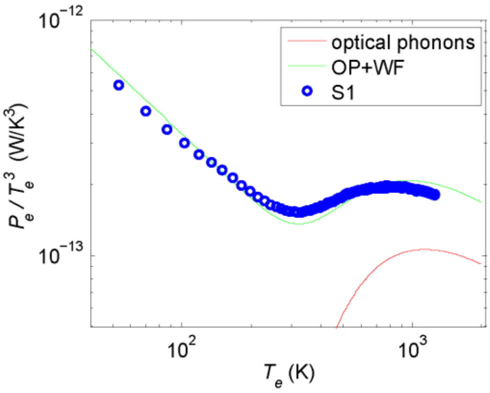

Fig. 1. Measured heat flow from electrons to phonons in a suspended bilayer graphene sample normalized by T_e^3 and displayed as a function of T_e. The green trace illustrates the theoretical curve: the red trace denotes the heat flow due to the optical phonon scattering alone, while the green curve contains additionally the electronic heat conduction. The existing theories are seen to match the data when long wave length longitudinal and transverse optical modes around zone center (Γ-point) are taken into account with additional contributions from zone edge modes (K-point).

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