Two-phonon scattering in graphene in the quantum Hall regime

Arseny Alexeev[1] and Mikhail Portnoi[1,2]

[1] School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, United Kingdom
[2] International Institute of Physics, Av. Odilon Gomes de Lima, 1722, Capim Macio, CEP: 59078-400, Natal - RN, Brazil
A.Alexeev@exeter.ac.uk

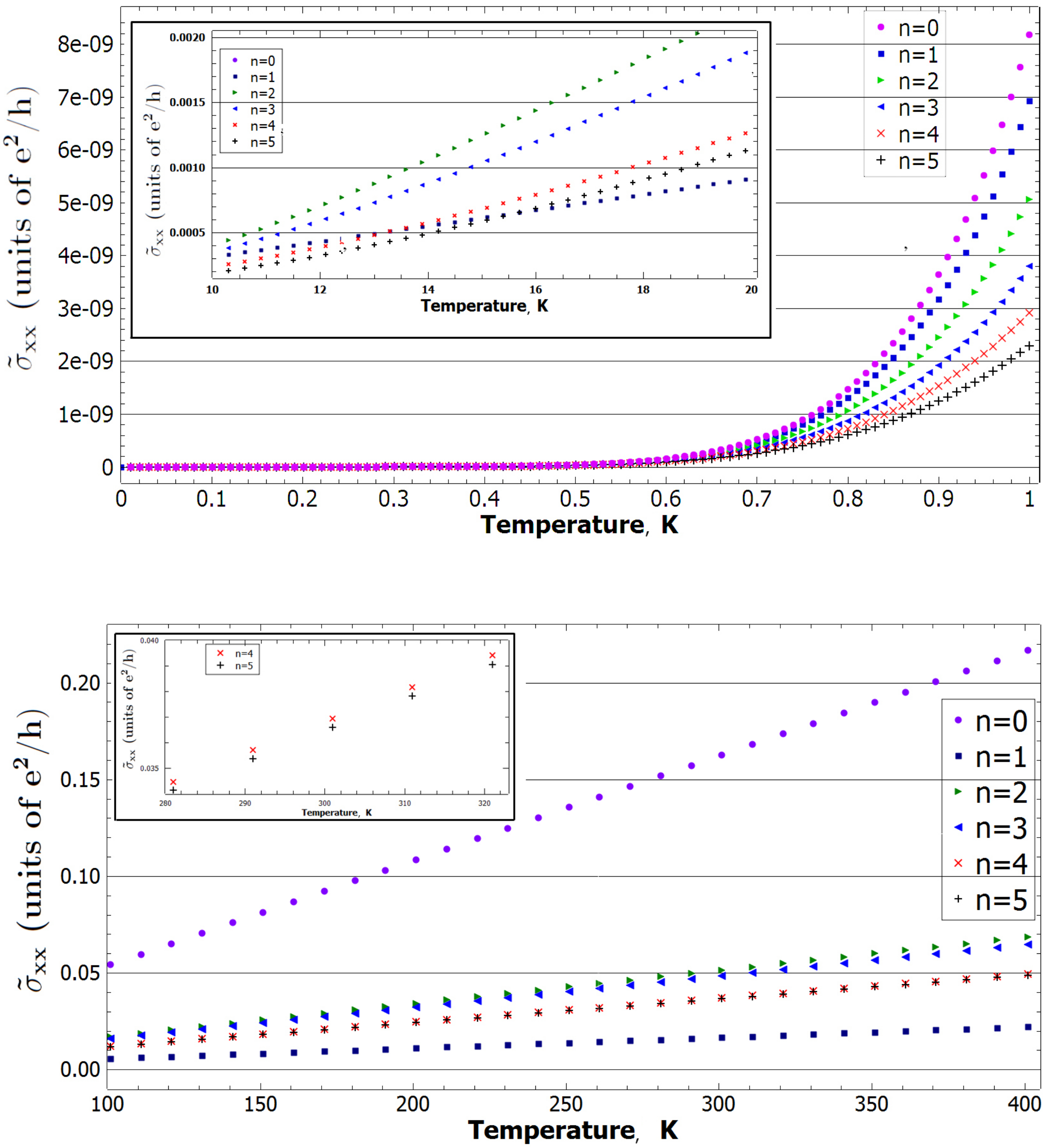
One of the most distinctive features of graphene is its huge inter-Landau-level splitting in experimentally attainable magnetic fields resulting in the room-temperature quantum Hall effect. We calculated the longitudinal conductivity due to two-phonon scattering in graphene in quantizing magnetic fields over a broad range of temperatures. The multi-phonon scattering mechanism [1] is known to be negligible for conventional two-dimensional systems under the quantum Hall conditions apart from exotic cases such as magneto-roton dissociation in phonon spectroscopy [2]. However, our calculations show that this mechanism dominates in the high-temperature quantum Hall regime in graphene, since at elevated temperatures the energy of an acoustic phonon with a wavevector comparable to the inverse magnetic length is much smaller than the temperature; therefore, a number of such phonons increases drastically. Single-phonon processes in pristine graphene in this regime remain suppressed due to momentum and energy conservation requirements. We show that the two-phonon scattering mechanism provides a significant error in Hall conductivity measurements and it is therefore the major obstacle in using graphene as a room-temperature quantum Hall standard of resistance.

The results of our calculations in two temperature regimes are shown in the figure below. In both panels we plot the temperature dependence of the pre-exponential factor in the phonon-induced dissipative conductivity σ_{xx}. The low temperature regime corresponds to $k_{\mathrm{B}}T << \hbar s/\lambda$, whereas the high-temperature regime is when $k_{\mathrm{B}}T >> \hbar s/\lambda$, where $\lambda = \sqrt{\hbar/eB}$ is the magnetic length and s is the speed of sound in graphene. In both cases we remain in the quantum Hall regime, which requires $k_{\mathrm{B}}T << \hbar v_{\mathrm{F}}/\lambda$, where v_{F} is the Fermi velocity in graphene. One can see that in the high-temperature regime the phonon-induced longitudinal conductivity is of the order of e^2/h, which is comparable to the disorder-induced contribution to σ_{xx}.

References

[1] V.N. Golovach and M.E. Portnoi, Phys. Rev. B 74, 085321 (2006).
[2] V.M. Apalkov and M.E. Portnoi, Phys. Rev. B 66, 121303 (2002).

Figures



The pre-exponential factor in phonon-assisted dissipative conductivity in the low-temperature (top panel) and high-temperature (bottom panel) regime calculated for different Landau levels from n=0 *to* n=5 *in a magnetic field* *B*=10T.