Supercollision cooling in undoped graphene

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Abstract Carrier mobility in solids is generally limited by electron-impurity or electron–phonon scattering, depending on the most frequently occurring event. Three-body collisions between carriers and both phonons and impurities are rare; they are denoted supercollisions (figure). Elusive in electronic transport they should emerge in relaxation processes as they allow for larger energy transfers [1]. This is the case in undoped graphene, where the small Fermi surface drastically restricts the allowed phonon energy in ordinary collisions. Using electrical heating and sensitive noise thermometry we report on supercollision cooling in diffusive monolayer graphene [1]. At low carrier density and high phonon temperature the Joule power P obeys a $P \alpha T_e^3$ law as a function of electronic temperature T_e. It overrules the linear law expected for ordinary collisions which has recently been observed in resistivity measurements. The cubic law is characteristic of supercollisions and departs from the T_e^4 dependence recently reported for doped graphene below the Bloch–Grüneisen temperature [2]. These supercollisions are also observed in photocurrent relaxation [4] important for applications of graphene in bolometry [5] and THz photo-detection [6].

References

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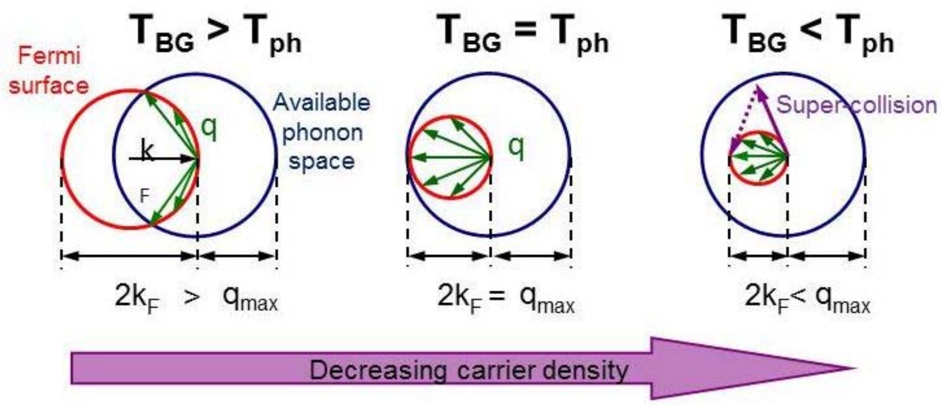
Figure



***Tunability of the Bloch–Grüneisen temperature and noise thermometry set-up**. **a**, Electron–phonon interactions scatter carriers from one point on the Fermi surface (red circle) to another, within the boundary of the available phonon space (blue circle). In low-temperature regime (Tph <T_{BG}), q_{max} is smaller than $2k_F$, which represents a full backscattering of electrons. **b**, The Fermi surface shrinks as the carrier density decreases, resulting in a smaller value of T_{BG}. Here, when T_{ph}=T_{BG}, q_{max} just equals $2k_F$. **c**, In the vicinity of the charge neutrality point, one enters the high-temperature regime, where T_{ph} >T_{BG}. Here, only phonons with $q \leq 2k_F$ can scatter off the electrons in the ordinary collisions (green arrows), whereas the entire thermal distribution of phonons is allowed for disorder-assisted supercollisions (purple arrow).*