Non-equilibrium magneto transport in graphene

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Abstract
We explore the non-equilibrium regime in graphene using a large dc current in combination with a perpendicular magnetic field. The strong in-plane Hall field generated in the bulk of the graphene channel results in Landau levels that are tilted spatially. The energy of the cyclotron orbits varies as a function of the spatial position of the guiding centre, enabling us to observe a series of compelling features. While Shubnikov-de Haas oscillations are predictably suppressed in the presence of the Hall field, a set of fresh magnetoresistance oscillations emerge near the charge neutrality point as a function of dc current. Two branches of oscillations with linear dispersions are evident as we vary carrier density and dc current, the velocity of which match with the TA and LA phonon modes suggesting phonon-assisted intra-Landau level transitions between adjacent cyclotron orbits. Our results offer unique possibilities to explore on-equilibrium phenomena in two-dimensional materials and other van der Waals heterostructures.

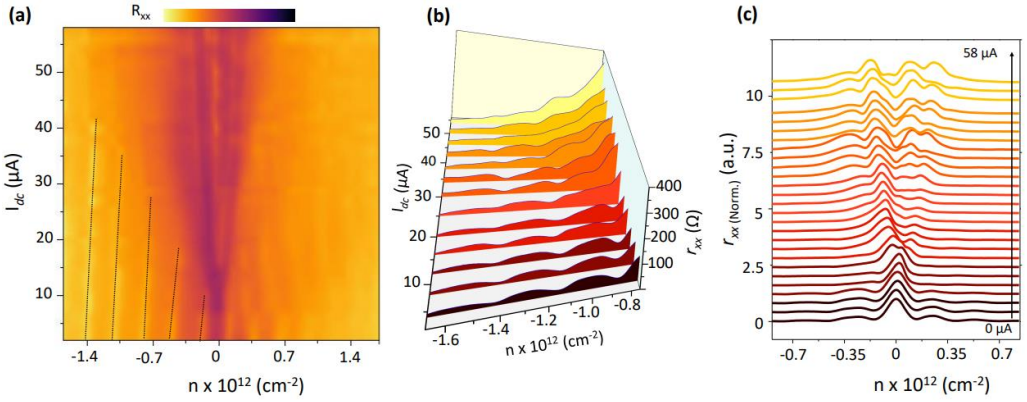

Figure 1: (a) Differential Longitudinal Magnetoresistance as function of dc current and carrier density at 3 T (b)section of the magnetoresistance on hole doped regime as function of dc current (c) section profile near charge neutrality point

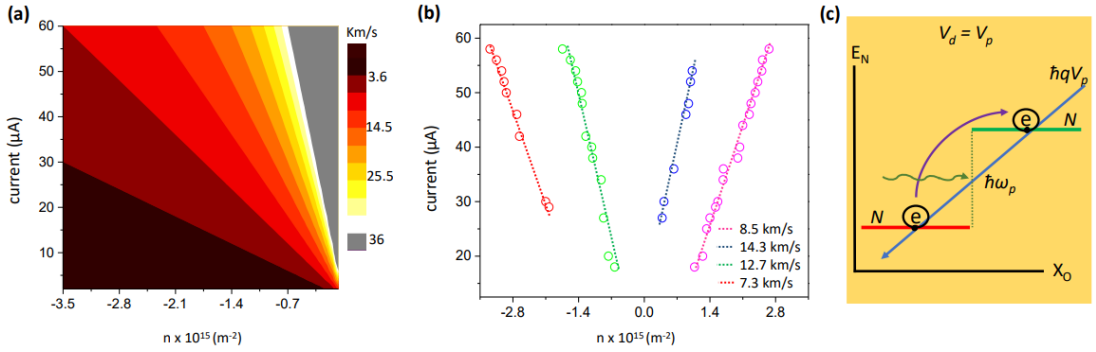

Figure 2: (a) drift velocity map near charge neutrality point (b) resistance peak as function of carrier density and dc current indicating the velocity associated with the two branches of oscillation (c) intral-Landau level transition mediated by phonon in energy momentum phase space