Subsonic to Supersonic transition in Phonon-assisted Non-linear DC Transport in Ultra-high Mobility Two Dimensional Electron Gas

Z. Wang[1], M. Hilke[1], N. Fong[2], D. G. Austing[1,2], S. Studenikin[2], K. W. West[3] and L. N. Pfeiffer[3]

[1]*Department of Physics, McGill University, Montréal, Quebec H3A 2T8, Canada*

[2]*Emerging Technology Division, National Research Council of Canada, Ottawa, Ontario K1A 0R6, Canada*

[3]*Department of Electrical Engineering, Princeton University, Princeton, New Jersey 08544, USA*

hilke@physics.mcgill

Hall field- and phonon-induced resistance oscillations, HIROs and PIROs respectively, are examples of non-equilibrium phenomena close to zero magnetic (B-) field [1, 2]. The former (latter) is generally stronger at low (elevated) temperature. They can also be brought into coincidence by changing the DC current passed through a Hall bar and the B-field. Additionally, at high current, the drift velocity (v_D) can exceed the acoustic phonon velocity ("speed of sound" s) marking a transition from a "subsonic" regime to a "supersonic" regime [1-3]. Nonetheless, two notable studies, one featuring a GaAs/AlGaAs quantum well two-dimensional electron gas [1], and another featuring a monolayer graphene two-dimensional hole gas, stop at or just short of the transition to the supersonic regime. Furthermore, a comparison of experimental observations in both subsonic and supersonic regimes with the theory of phonon-assisted nonlinear dc transport reported in Ref. [3] has not been undertaken.

We investigate non-linear transport in a 15 µm wide Hall bar made from an ultra-high mobility (nominally ~30x10^6 cm^2/Vs) GaAs/AlGaAs quantum well structure. Measurements of the differential resistivity (ρ_{xx}) are performed by combining a DC current (I) and a small AC excitation current [4]. HIRO and PIRO features are studied in the temperature range of 40 mK to 3.7 K. Following Ref. [3], the measured map of ρ_{xx} in I-B space is transformed to ϵ_{DC}-1/B space where $\epsilon_{DC}= 2v_D k_F/\omega_c$, k_F is the Fermi wavevector, and ω_c is the cyclotron frequency [1]. For 40 mK (Fig.1. left-side), inside the red triangle (subsonic regime) whose sloped boundaries delineate the speed of sound (s~2.9 km/s from plot), HIROs are dominant (horizontal dashed lines up to third order shown) albeit with amplitude modulated by inter-Landau-level transitions involving phonons [1]. At the subsonic-supersonic boundary and beyond, $s \geq v_D$, **spontaneous** phonon emission occurs (black diagonal lines) [3]. For 3.7 K (Fig.1. right-side), in the subsonic regime HIROs are absent and features originating from phonon absorption and emission (following the black diagonal and anti-diagonal lines and intersections thereof) are now apparent [3]. Again, at the subsonic-supersonic boundary and beyond, **spontaneous** phonon emission is evident. The relative temperature insensitivity of the phonon features in the 40 mK and 3.7 K data in the supersonic regime is a key observation consistent with the theory in Ref. [3].

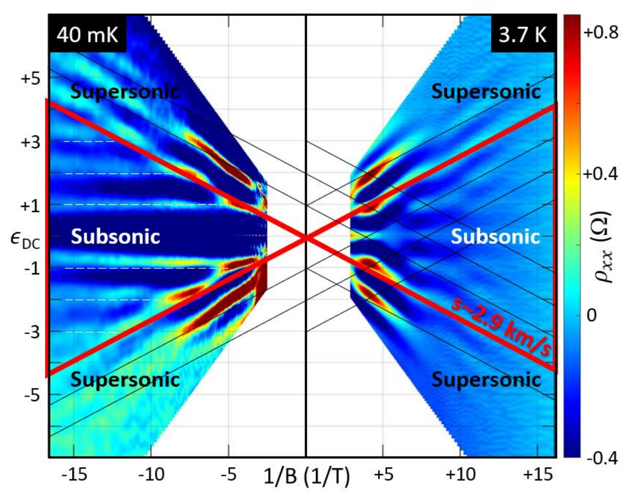

Fig.1. Differential resistivity ρ_{xx} (with background subtracted) as a function of 1/B and ϵ_{DC} at 40 mK (left-side) and 3.7 K (right-side).

References

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