Nonlinear Response in Two-Dimensional Electron Systems in Tilted Magnetic Fields

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Introduction

Over the past decade it was realized that magneto-resistance oscillations, other than Shubnikov-de Haas oscillations, can be induced in two-dimensional electron system (2DES) by microwave [1,2] or dc [3] electric fields. These oscillations originate from inter-Landau level transitions owing to microwave absorption and/or scattering off of disorder, respectively, and are termed microwave-induced resistance oscillations (MIRO) and Hall field-induced resistance oscillations (HIRO). MIRO have been extensively studied but unresolved issues remain. In particular, very recently it was shown that MIRO are suppressed by modest in-plane magnetic fields [4]. The origin of this suppression remains unclear and there are no corresponding tilt-field experiments on HIRO available to date.

Experimental

Our sample was lithographically defined Hall bar (width of 100 μm) fabricated from a GaAs/Al₀.₂₄Ga₀.₇₆As 30-nm-wide quantum well grown by molecular beam epitaxy. High quality Ohmic contacts were made by e-beam evaporation of Au/Ge/Ni and rapid thermal annealing in forming gas. Mobility $\mu$ and density $n$ were $12.5 \times 10^6$ cm$^2$/Vs and $4.35 \times 10^{11}$ cm$^{-2}$, respectively. Experiments were performed in the SCM2 18/20 T Magnet/3He system equipped with the rotating probe at constant coolant temperature of 0.3 K. Differential resistance, $r = dV/dI$, was measured using a standard low frequency (few hertz) lock-in technique.

Results and Discussion

We have studied the effect of the in-plane magnetic field on the nonlinear response of a high mobility two-dimensional electron system using sample tilting technique. In Fig. 1 we present differential resistivity, $r$, versus perpendicular magnetic field, $B$, for various tilt angles measured at a fixed applied current $I = 90 \mu$A. At zero tilt (dotted line) we observe three well developed HIRO maxima. With increasing tilt angle HIRO amplitude diminishes. More careful examination reveals that the strongest, fundamental HIRO peak is the most sensitive to the tilt, disappearing completely at the highest angle [cf., Fig.1 (c)].

Conclusions

In conclusion, we have observed that HIRO gradually decay with increasing tilt, much like MIRO [4]. However, we have also found that the fundamental HIRO peak disappears faster than the higher order peaks.

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References


Fig. 1. Differential resistivity vs. perpendicular magnetic field for tilt angles (in degrees) of 0 (dotted line, offset for clarity), 70.3 (a), 77.6 (b), 81.2 (c), and 83.1 (d) at dc current $I = 90 \mu$A. Vertical lines mark HIRO maxima.