"Effect of DC electric field on longitudinal resistance of two dimensional electrons in a magnetic field"

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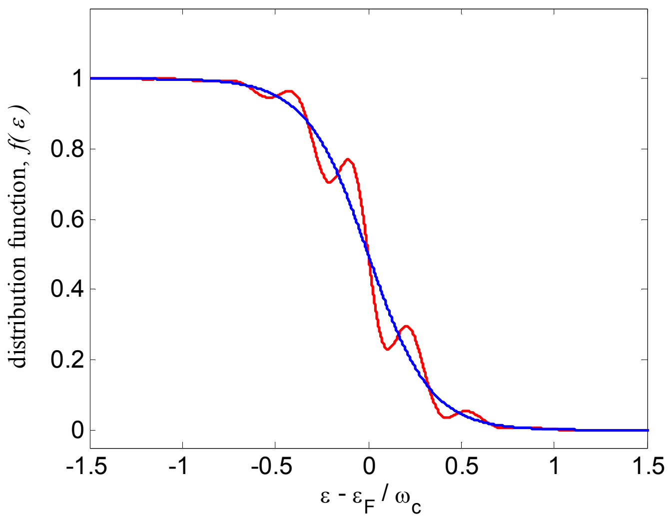
Recommended and a commentary by Rafi de Picciotto, Bell Laboratories.

When a clean two dimensional electron gas is placed in a magnetic field and is driven by a moderately strong electric field intriguing phenomena occur. With a DC driving field, the longitudinal resistance was shown to oscillate with field. The oscillations period satisfies the condition $2eR_cE_H = n\hbar\omega_c$, where n is an integer, R_c is the Larmor radius of electrons at the Fermi level, ω_c is cyclotron frequency and E_H is the Hall electric field - induced by the applied electric field. Strong oscillations of the longitudinal resistance can also be produced by microwave radiation. Here the period satisfy the condition $\omega = n\omega_c$, where ω is the microwave frequency. At high microwave power levels the oscillations minima can reach values close to zero. This striking so-called zero resistance state has stimulated extensive theoretical interest [1]. In this paper the authors demonstrate a new related phenomenon that occurs at weaker DC electric fields. The longitudinal resistance, peaked at zero field, drops to nearly a tenth of its zero field value before the field-induced oscillations commence.

These nonlinear phenomena in high mobility 2DEGs occur because of the effects of an electric field on the electron distribution function and its effects on the kinematics of electron scattering. The latter is less important at low temperatures, where the inelastic time far exceeds the single particle relaxation time. Yet, the effect of an electric field on the distribution function can have dramatic consequences. The field causes nontrivial oscillations of the non-equilibrium electron distribution function near the Fermi surface [2] with period of the order of $\hbar\omega_c$, as illustrated in the figure below. The amplitude of these oscillations is stabilized by inelastic scattering, dominated by electron-electron scattering at low temperatures. These undulations, in turn, cause a reduction of the longitudinal conductivity with driving field. In a clean 2DEG with a magnetic field present, the Hall angle is large and a zero bias peak in the longitudinal conductivity translates to a zero bias peak in the longitudinal resistance – detected in this experiment. The sign of the effect is fortunate because it is opposite to the expected behavior should the driving electric field simply have heated up the electronic system.



Oscillations (in red) are imposed on the equilibrium distribution function (blue) by an applied DC electric field [2].

The experimental findings agree favorably with theoretical predictions in the high temperature regime, $kT > \hbar\omega_c$, where the theory applies. Further, the phenomenon persists and in fact is most pronounced at lower temperatures, outside the scope of existing theoretical models.

[1] See the manuscript's reference list for publications describing recent experimental and theoretical developments. See also ref. [2] below and references therein.

[2] I. A. Dmitriev, M. G. Vavilov, I. L. Aleiner, A. D. Mirlin and D. G. Polyakov, PRB **71**, 115316 (2005).