TEMPERATURE AND MAGNETIC FIELD DEPENDENCE OF RADIATION-INDUCED MAGNETO-RESISTANCE OSCILLATIONS IN A TWO-DIMENSIONAL ELECTRON GAS

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In the last two decades, specially since the discovery of the Quantum Hall Effect, a lot of work and progress has been made in the study of two-dimensional electron gas (2DEG) and very important and unusual properties have been discovered when those systems are subjected to the influence of external AC and DC fields. Recently, two experimental groups[1, 2] have announced the existence of vanishing resistance in 2DEG, i.e. zero resistance states (ZRS), when these systems are under the influence of a moderate magnetic field (B), and microwave (MW) radiation simultaneously. In the same kind of experiments, large magnitude resistivity oscillations have been reported[1, 2, 3].
The discovery of this novel effect has led to a great deal of theoretical activity. Some like Girvin et al, argue that this striking effect has to do with a multi photon-assisted impurity scattering. Others relate the ZRS observed with a new structure of the DOS of the system in the presence of light. According to Andreev's approach, the key is the existence of an inhomogeneous current flowing through the sample due to the presence of a domain structure in it. To date there is no consensus about the real origin. All the theories above have in common that they predict negative resistivity, while it was not experimentally confirmed.

We present a theoretical model in which the existence of radiation-induced zero-resistance states is analyzed. Exact solution for the harmonic oscillator wave function in the presence of radiation and a perturbation treatment for elastic scattering due to randomly distributed charged impurities form the foundations of our model. We reproduce experimental features (see Fig. 1), in particular, the physical origin for ZRS. The existence of zero resistance states is explained in terms of the interplay of the electron MW-driven orbit dynamics and Pauli exclusion principle.

The MW field forces the orbits to move harmonically back and forth. For large MW field amplitudes, final states for electrons, which semiclassically describe orbits whose center positions oscillate due to the MW field, become occupied. It blocks the electron movement between orbits, i.e., longitudinal conductivity and resistivity ρ_{xx} will be zero. We explain the dependence of ρ_{xx} with temperature (see Fig. 2) by means of electron interaction with acoustic phonons acting as a damping factor in the forced quantum oscillators and we discuss the ZRS dependence with magnetic field. We observe them at ω/ω_c=j+1/4 for the experimental parameters of reference [1].

References

[1] R.G. Mani, J.H. Smet, K. von Klitzing, V. Narayanamurti, W.B. Johnson, V. Umansky, Nature **420** 646 (2002).

[2] M.A. Zudov, R.R. Lu, N. Pfeiffer, K.W. West, Phys. Rev. Lett. **90** 046807 (2003).

[3] S.A. Studenikin, P.T. Coleridge, N. Ahmed, P. Poole, A. Sachrajda, Phys. Rev. B **68**, 035317 (2003).

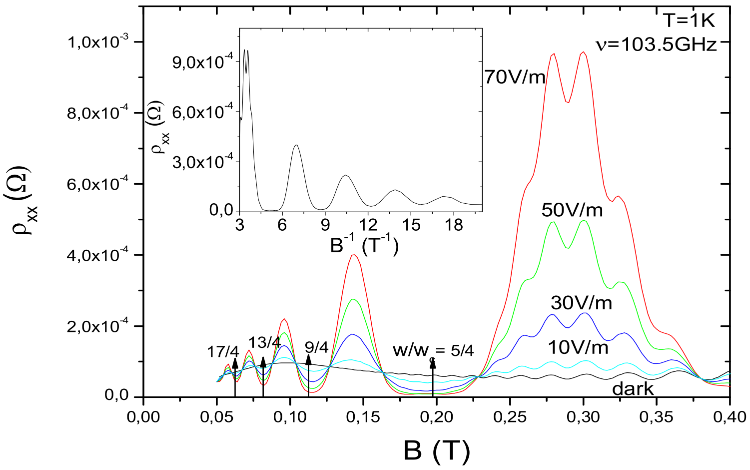

Figure 1: Calculated magnetoresistivity ρ_{xx} as a function of magnetic field, for different MW intensities but for the same frequency: $\nu = 103.5GHz$. The darkness case is also presented. In the inset we show ρ_{xx} vs B^{-1}, resulting to be periodic in B^{-1} (T=1K).

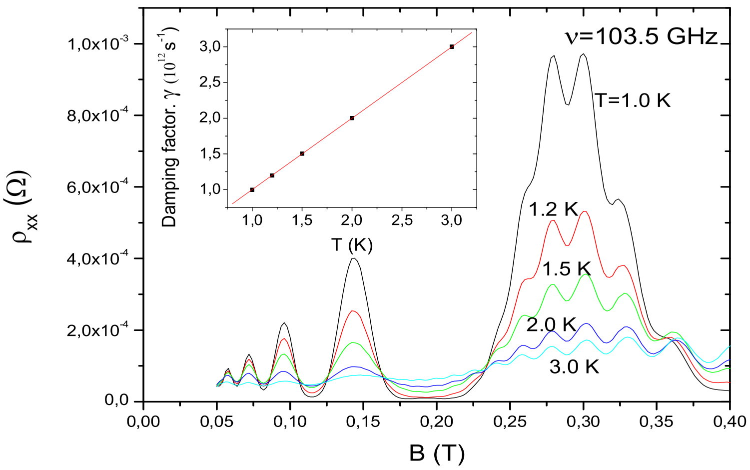

Figure 2: Dependence of the magnetoresistivity upon temperature with constant power excitation. Oscillations are getting smaller as temperature is increased. However the position of the minima are keeping constant. In the inset we represent a calculated linear response between γ and T.