Negative parabolic magnetoresistance induced by electron-electron interaction in two-dimensional electron gas with diffusive transport

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Since the discovery of the weak localization effect in two-dimensional electron system twenty years ago, the study of negative magnetoresistance (NMR) has attracted a lot of attention. Recently the interest for NMR studies has been renewed in the context of the study of electron-electron interaction.

The simplest example of NMR is the parabolic NMR in diffusive 2D transport ($T\tau/\hbar << 1$; T is temperature and τ is the transport relaxation time). This NMR should appear in 2DEG at magnetic fields corresponding to the suppression of the single-electron weak localization term. The main reason for this NMR to appear is that the interaction correction to Hall conductivity at $T\tau/\hbar << 1$ is absent. Theory [1] gives the following quite simple expression for the negative MR in this case:

$$\Delta\rho_{xx}(B)/\rho_0 = (e^2/\pi h)\cdot\rho_0\cdot[(\omega_c\tau)^2 - 1]\cdot \ln T\tau \qquad (\omega_c \text{ is cyclotron frequency}) \quad (1)$$

As surprising as it is, there is still no experimental checking of expression (1). In fact, previous experiments were made in ballistic regime for $T\tau/\hbar > 1$, which proved to be much more complicated for theoretical description.

The main purpose of this work is to carry out the experimental study of the NMR that occurs when the weak localization NMR is suppressed and to verify how accurately expression (1) describes the experiment in diffusive regime $T\tau/\hbar << 1$. For this purpose we grew a AlGaA/GaAs/AlGaAs 50 A quantum well in which a very low mobility 2DEG was created by means of Si δ-doping of of this well. The main parameters of this 2DEG were: the mobility $\mu = (0.5 - 1)\cdot 10^3$ cm^2/Vc and electron density $N_s = (1.7 - 4.5)\cdot 10^{12}$. So that the criteria $T\tau/\hbar << 1$ is very well verified for T < 20K. The magnetoresistance ρ_{xx} and Hall resistance ρ_{xy} of the samples were measured in magnetic fields up to 15 T and for temperatures between 0.05 K and 1 K.

Figure 1 presents the typical experimental magnetoresistance curve. For B<1T weak localization is gradually destroyed leading to this strong NMR which saturates around 1 T.
After a saturation for 1 T> B >3 T the NMR value further increases and for B>12 T SdH oscillations appear. The insert shows $\Delta\rho_{xx}(B)$ as function of B^2. One can clearly see that in the range of magnetic fields exceeding 3T $\Delta\rho_{xx}(B^2)$ is a strait line. This is an evidence of the parabolic NMR. Expression (1) predicts very important particularity of this parabolic NMR: at magnetic field corresponding to $\omega_c\tau = 1$ interaction correction should have zero value. So $\rho_{xx}(B)$ curves measured at different temperatures should cross at this magnitude of $\omega_c\tau$ and the value of ρ_{xx} should corresponds to Drude formula because weak localization correction is completely suppressed. The measurements of temperature dependence of NMR (fig.2) show the cross at magnetic field B = 14 T. It corresponds $\omega_c\tau = (1 \pm 0.05)$. Thus the behavior of the parabolic NMR observed in our samples is in good agreement with theory [1].

[1] Houghton, J.R.Senna, and S.C.Ying, Phys.Rev B **25**, 2196 (1982)

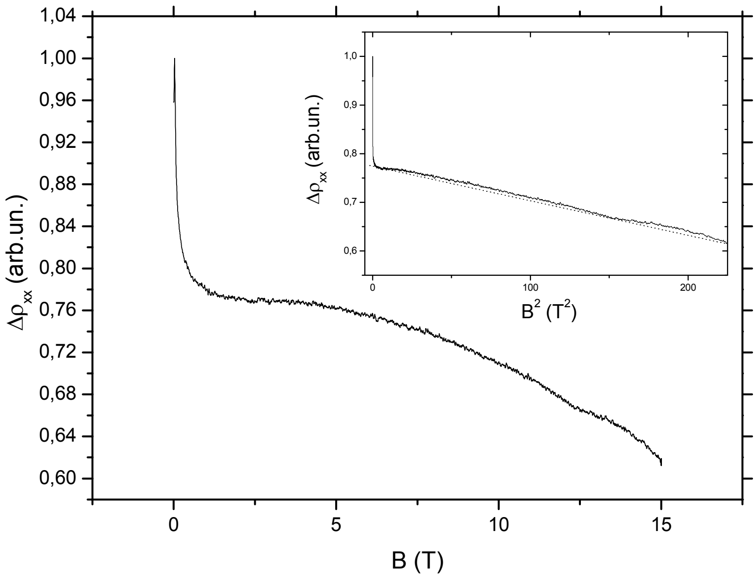

Figure 1: *$\Delta\rho_{xx}(B)$ at lowest temperature T = 50 mK. Insert: $\Delta\rho_{xx}(B^2)$*

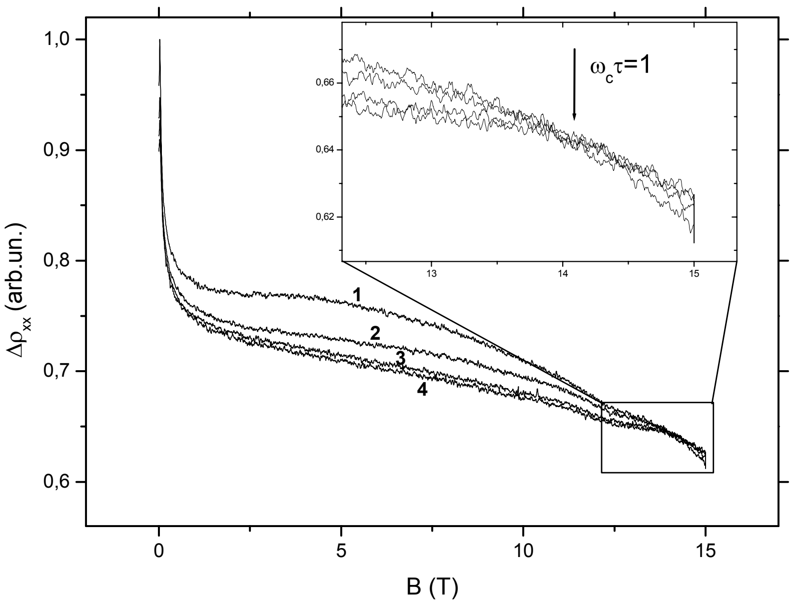

Figure 2 *: $\Delta\rho_{xx}(B)$ at different temperatures: 1 - 0.05 K, 2 - 0.6 K, 3 – 1.1 K, 4 – 1.7 K*