Interactions in High-Mobility 2D Electron and Hole Systems

A. K. Savchenko[1], Y. Y. Proskuryakov[1], S. S. Safonov[1], L. Li[1], M. Pepper[2], M. Y. Simmons[2], D. A. Ritchie[2], E. H. Linfield[2], Z. D. Kvon[3]

[1]*School of Physics, University of Exeter, Stocker Road, Exeter EX4 4QL, U.K.*
[2]*Cavendish laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, U.K.*
[3]*Institute of Semiconductor Physics, Novosibirsk, 630090, Russia*

The origin of the 'metallic' behaviour of high-mobility 2D electron and hole gases (2DEG, 2DHG) has been attracting much attention in the last years [1], mainly due to the fact that the increase of the resistance with increasing temperature is in contradiction with the scaling theory of localisation [2]. As this theory does not take into account electron-electron interactions, their role in these systems has to be examined. The established theory [3] of the interaction correction to the Drude conductivity $\delta\sigma_{ee}(T)$ was developed for the 'diffusive' regime, $k_BT\tau/\hbar < 1$ where τ is the momentum relaxation time, and is not applicable to the high-mobility systems in the 'ballistic' regime, $k_BT\tau/\hbar > 1$. Fortunately, a new theory [4] makes the required bridge between the two regimes.

We study the interaction correction in the intermediate and ballistic regimes in different 2D systems where the parameter $k_BT\tau/\hbar$ changes from 0.1 to 10. The temperature dependence of the resistance and magnetoresistance in parallel and perpendicular magnetic fields are analysed in terms of recent theories of electron-electron interaction in systems with different degree of disorder and different character of the fluctuation potential.

For the theory [4] it is essential that the interacting electrons are scattered by a short-range potential – this condition is realised in our 2DHG in GaAs [5] and 2DEG in Si [6]. The obtained results are in agreement with theory and show a significant contribution of the interaction correction to the 'metallic' $\rho(T)$ near the 'metal'-to-'insulator' transition and also to the positive parallel-field magnetoresistance.

The condition of short-range scatterers is not realised in the studied 2DEG in GaAs [7] where a long-range scattering potential is dominant. In this case the interaction correction [4] is strongly suppressed, but becomes detectable if a strong $\omega_c\tau > 1$ perpendicular field is applied. For this structure we analyse, in terms of the recent theory [8], the temperature dependent negative magnetoresistance and find the value of the interaction correction $\delta\sigma_{ee}(T)$. We compare the value of the Fermi-liquid interaction constant F_0^σ, which determines the sign of $\rho(T)$, in all studied structures.

[1] E. Abrahams, S.V. Kravchenko, M.P. Sarachik, Rev. Mod. Phys. **73**, 251 (2001).
[2] E. Abrahams *et al.*, Phys. Rev. Lett. **42**, 673 (1979).
[3] B. L. Altshuler and A. G. Aronov, in *Electron-Electron Interaction in Disordered Systems*, edited by A. L. Efros and M. Pollak (NorthHolland, Amsterdam, 1985).
[4] G. Zala, B. N. Narozhny, and I. L. Aleiner, Phys. Rev. B **64**, 214204 (2001).
[5] Y. Y. Proskuryakov *et al.*, Phys. Rev. Lett. **89**, 076406 (2002).
[6] S. S. Safonov *et al.*, Phys. Rev. Lett. **86**, 272 (2001).
[7] L.Li *et al.*, Phys. Rev. Lett. **90**, 076802 (2003).
[8] I. V. Gornyi and A. D. Mirlin, Phys. Rev. Lett. **90**, 076801 (2003).