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Gate Voltage Dependence of the Magnetotransport in Double Quantum Wells

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We have investigated the magnetoresistance of strongly asymmetric double-well structures. The structures were prepared by inserting a thin $Al_{0.3}Ga_{0.7}As$ barrier into the GaAs buffer layer of standard modulation-doped GaAs/$Al_{0.3}Ga_{0.7}As$ heterojunctions. The resulting double-well system consists of a nearly rectangular well and of a triangular well coupled by tunneling through the thin barrier. With a proper choice of growth parameters one can control the occupancy of the two wells and of the two lowest energies (bonding and antibonding) subbands. The electron properties may also be changed by applying front- or back-gate voltage between the electrodes attached to corresponding gate layer and the 2DEG. Two samples with different barrier distance from the main interface (70 and 110 nm) were studied.

The experiments were carried out in magnetic field range up to 30 Tesla at temperature 0.4K, using low-frequency (13 Hz) *ac* technique. For every corresponding gate voltage the sample was measured at different tilt angles close to the parallel magnetic field orientation and also in the exactly perpendicular magnetic field. Several local extremes have been observed on the magnetoresistance curves that can be associated with field-induced changes of the well and/or band occupancy. In Fig.1 the magnetoresistance $\Delta\rho_{xx}/\rho_{xx}(0)$ taken in parallel configuration is drawn together with the calculated changes $\Delta g/g(0)$ of the DOS for the 110 nm sample. Due to the approximately large width of rectangular well, the back-gate has strong effect on the electrons of low-populated triangular well. While the critical fields B_{C1} and B_{C2} which correspond to the depopulation of the high, antibonding, subband and to the splitting of the Fermi sea into two separate electron sheets, respectively, do not depend substantially on the applied gate voltage, the third critical field B_{C3} (at which due to depletion of the triangular well the system returns to the single layer state) is very sensitive to the change of the total concentration N induced by the back-gate voltage. An increase of N due to positive back-gate voltages leads to a shift of B_{C3} to higher magnetic fields (See Fig.2, left). At higher back-gate voltages there are too many electrons in the triangular well and the minimum in magnetoresistance corresponding to B_{C3} can be observed at very high magnetic fields only.

In a sample with narrower rectangular well (70 nm) the front-gate voltages have rather stronger effect on system behaviour. In fact 2DEG in each well plays role of screen for electrons in the neighboring one. No third critical field were observed on this sample (Fig.2, right). But, it has been observed, that the zero-field longitudinal resistance depends strongly on front-gate voltage as well. In a Fig.3 the plot of this phenomenon is presented. We attribute such oscillation of the resistance to the emptying of the antibonding subband.

So, the magnetic field oriented parallel to the 2D electron system induces a deformation of the Fermi contours corresponding to bonding and antibonding subbands, depopulation of the higher occupied subband at the critical field B_{C1}, and the transition into the decoupled bilayer at the critical field B_{C2}. The in-plane field evolution of the electron concentration in the individual subbands was reconstructed from the experimental data and at the same time described by a numerical self-consistent calculation within the local spin density approximation.

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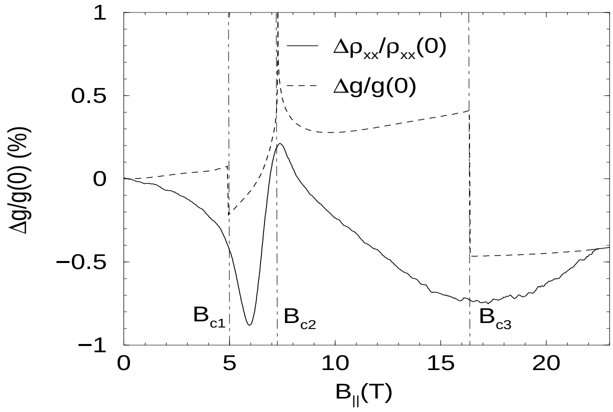

Figure 1. Magnetoresistance oscillation together with the calculated changes $\Delta g/g(0)$ of the DOS.

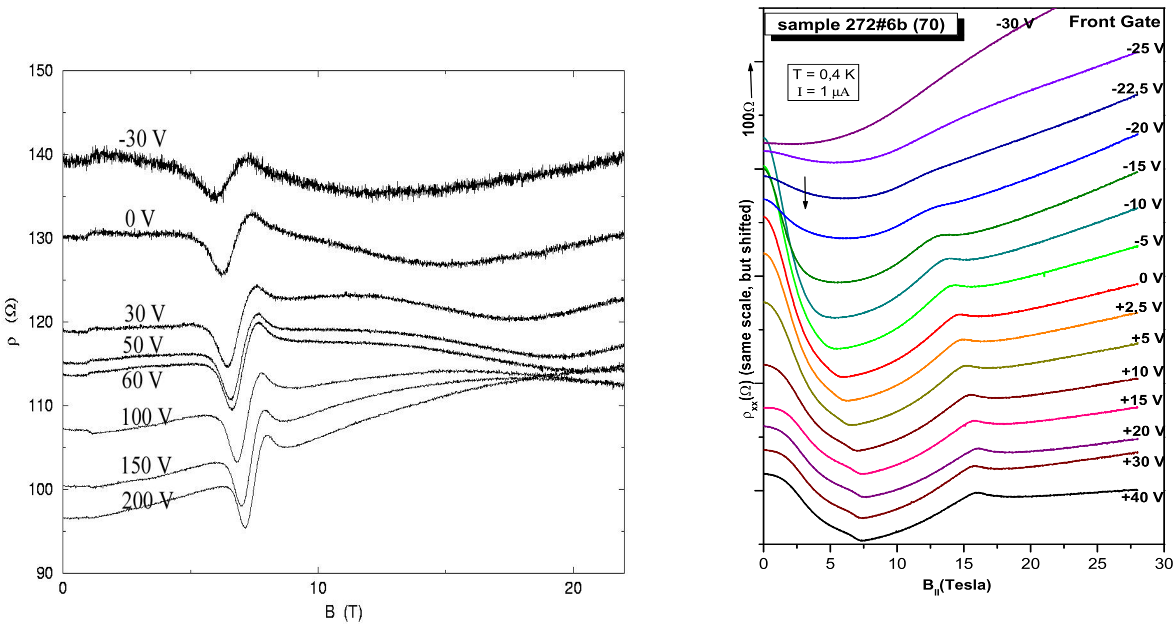

Figure 2. Magnetoresistance dependence on back-gate (left) and front-gate (right) voltages in parallel magnetic field (two different samples are presented).

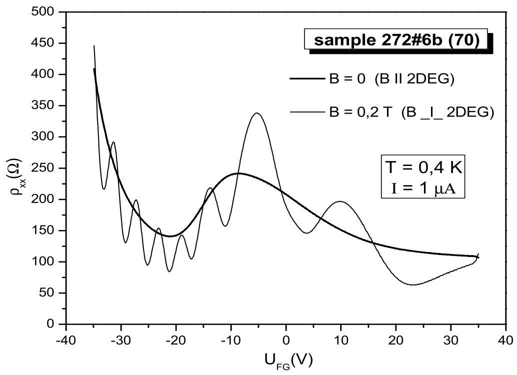

Figure 3. Zero-field longitudinal resistance dependence on gate voltage shown together with small-field oscillations in perpendicular magnetic field.