Weak Antilocalization in a Strained InGaAs/InP Quantum Well Structure

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When spin-orbit scattering is strong the weak localization feature in a 2-dimensional system develops, extra, antilocalization structure. This is seen in the low field magneto-resistance and provides a convenient means of monitoring the spin-orbit interaction. Knowledge of this is needed if spins are to be manipulated for spintronic and quantum computing applications in semiconductors. Results are presented for a strained InGaAs/InP quantum well, where the antilocalization feature is prominent, but where a number of results cannot be explained using currently available theories.

(1) Although tilting the magnetic field is expected to decouple the spins from the orbital motion it was found that both the weak localization and weak antilocalization features depend only on the perpendicular component of the field, ie on the orbital motion.

(2) Using a theory expected to work for arbitary magnetic fields (but assuming a single dominant spin-orbit mechanism) it was not possible to describe the experimental magnetoresistance in terms of a phase breaking time and a single spin-orbit scattering time.

(3) The spin-orbit scattering parameter extracted from fits to the data is found to depend non-monotonically on gate voltage, ie on density, with a maximum at a density of approximately $3x10^{15}/m^2$ and a decrease for both larger and smaller density. This is inconsistent with the behaviour expected for both the Rasba and Dresselhaus mechanisms.

These results emphasise the need for an improved theoretical understanding of the spin-orbit interaction in gated semiconductor structures if it is to be used to manipulate the spin-polarisation.

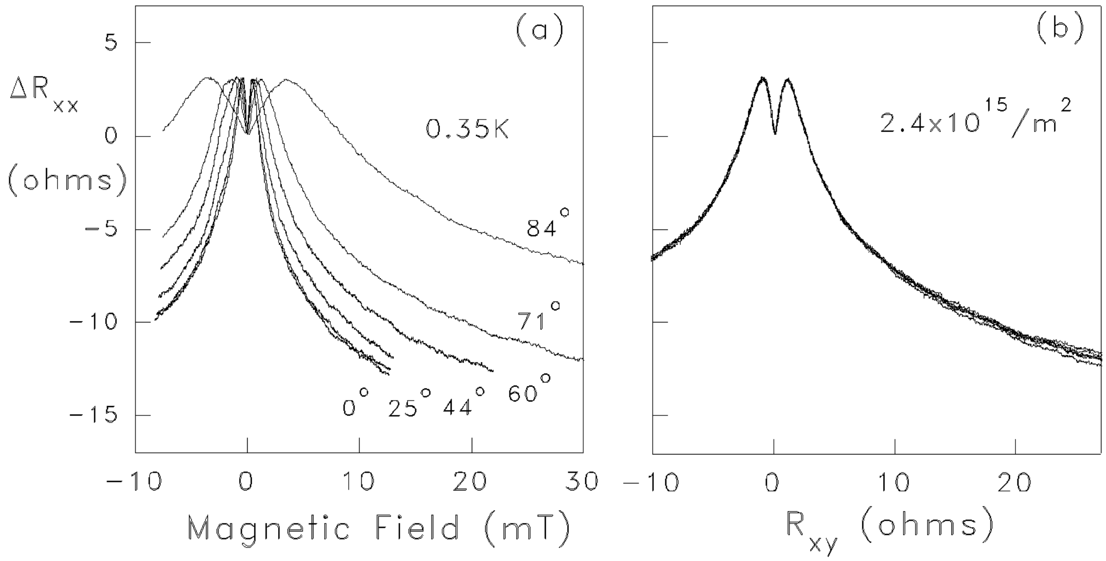

Figure 1. Weak antilocalization feature in a strained InGaAs/InP quantum well in tilted magnetic fields: **(a)** as a function of total magnetic field and **(b)** as a function of the Hall resistance R_{xy} which depends only on the perpendicular component of the field.

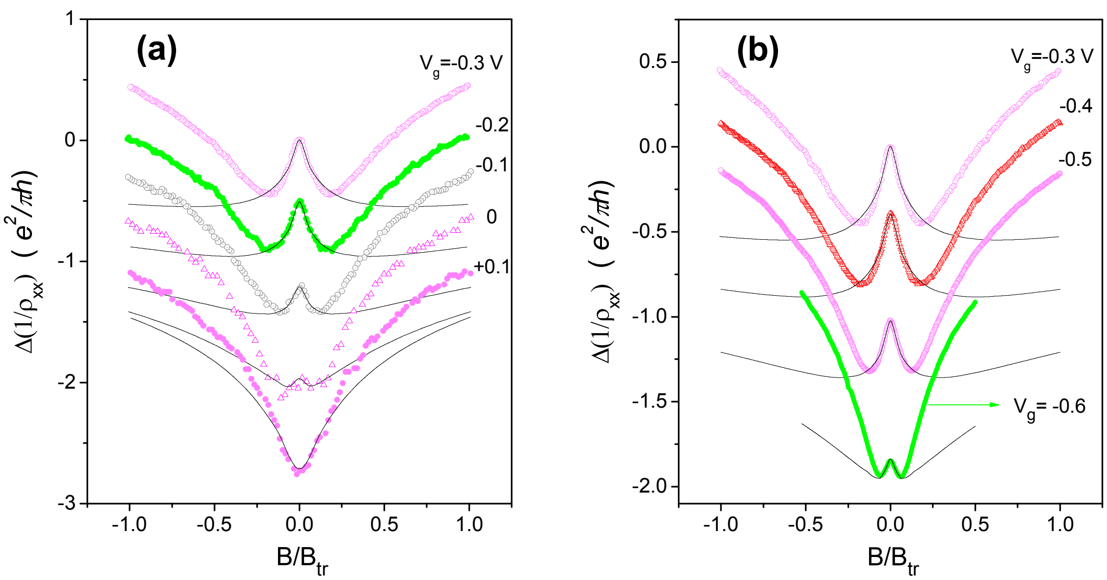

Figure 2. Gate voltage dependence, at a temperature of 0.36K, showing a maximum in the antilocalization, corresponding to a maximum in the spin-orbit scattering rate, at a gate voltage corresponding to a density of approximately $3x10^{15}/m^2$. Solid lines show fits to the low field region of the data used to extract τ_ϕ and τ_{so}. It was not possible to fit the data, over the whole field range, with just these two parameters.