Modification of the effective g-factor by lateral confinement

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Recent advances in our understanding of spin interactions in solid-state devices break traditional neglect of the spin degree of freedom and resulted in emergence of a new field called *spintronics*, where spin, rather than charge, carries information[1]. Further progress toward realization of *quantum* spintronic devices (such as spin-based q-bits) requires the ability to precisely manipulate single spins and, in turn, better understanding of spin interactions with environment. In particular, we have to know whether and how the confining potential effects the spin interaction with an external magnetic field.

In this work we report the influence of lateral confinement on the effective Langè g-factor in quantum point contacts (QPCs) fabricated from p-type GaAs. We define the effective g^* as a linear in B (Zeeman) term in the Hamiltonian, $sg^*\mu_B B$. In-plane B is predominantly acting on the spin part of the Hamiltonian and the magnitude of the Zeeman splitting can be obtained from energy level spectroscopy. Specifically, we determined critical fields B_C at which half-integer steps in the conductance (in units $2e^2/h$) appear for different directions of the in-plane B. A difference in B_C for B in $[\bar{1}10]$ and $[\bar{2}33]$ directions is expected due to intrinsic anisotropy of the g-factor in p-GaAs on $[\bar{3}11]$A. However, the measured ratios of g^* for two field orientations differ from the ones reported for 2D hole gas [2], and can be larger or smaller depending on the crystallographic orientation of the point contact. We show that confinement *decreases* the value of the g-factor in the direction perpendicular to the 1D channel by as much as 50%.

The QPCs are formed from a two-dimensional hole gas (2DHG) using atomic force microscopy local anodic oxidation techniques (AFM LAO) [3, 4]. The heterostructure is grown by MBE on $[\bar{3}11]$A GaAs. The novel very shallow (350Å below the surface) quantum well structure has an exceptionally high mobility $0.4 \cdot 10^6$ V·s/cm^2 for a relatively low hole density $p = 1.38 \cdot 10^{11}$ cm^{-2}. During AFM LAO the surface is effectively shifted by $100 - 120$Å toward the QW depleting the 2DHG underneath, resulting in the formation of a ~ 200 meV barrier.

An AFM image of a quantum point contact (QPC) is shown in the inset in Fig. 1a. The white oxide lines effectively separate 2DHG in source (S), drain (D) and gate (G) regions (dark areas). In different devices the 1D channel is aligned with $[\bar{2}33]$ or $[\bar{1}10]$ crystallographic directions. The potential within the QPC is controlled by applying a voltage on the two side gates G (the use of side, rather than top, gates circumvents the problem related to the excessive gate leakage due to low Schottky barrier in p-type GaAs). Conductance as a function of the gate voltage is plotted in Fig. 1 for two samples: $I \parallel [\bar{1}10]$ (low-μ, g^*), and $I \parallel [\bar{2}33]$ (high-μ, g^*). In-plane magnetic field was applied either along $[\bar{2}33]$ direction (left panels) or along $[\bar{1}10]$ direction (right panels). The ratios $g_{[\bar{2}33]}/g_{[\bar{1}10]}$ are ~ 1.8 and > 4 for the two QPC orientations, significantly modified from ~ 2.5 reported for a 2D hole gas.

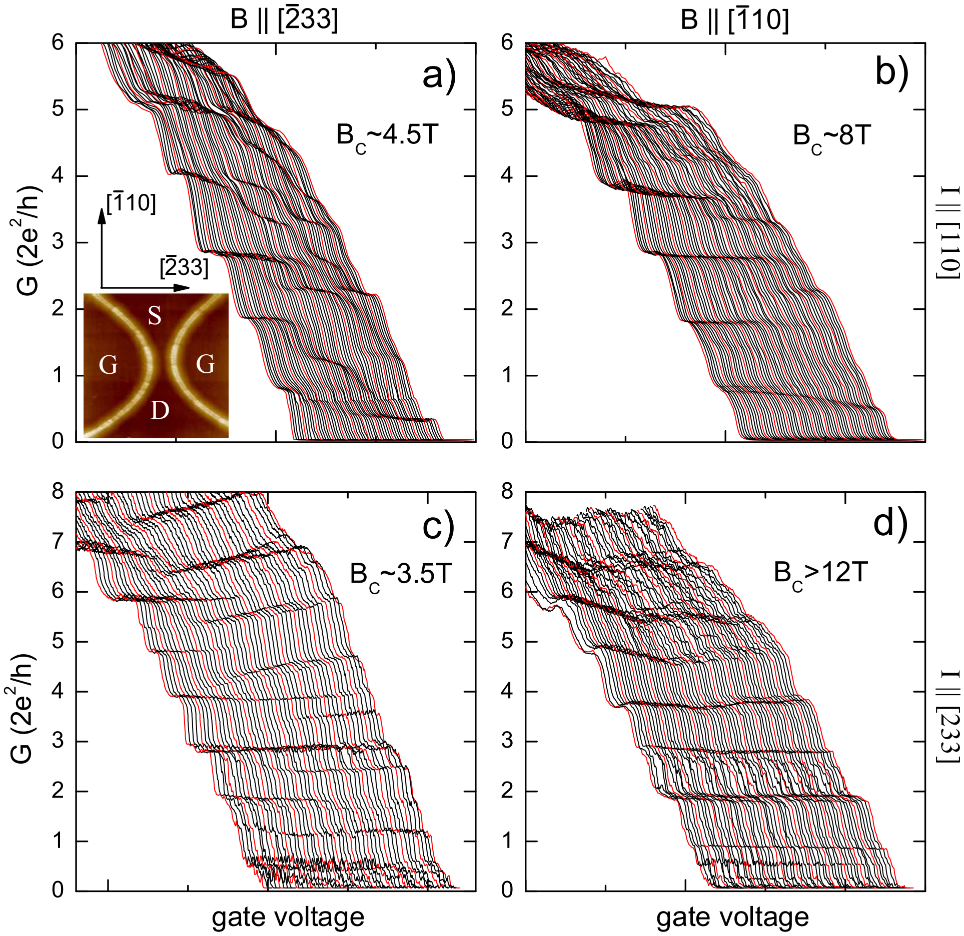

FIG. 1: Conductance vs. gate voltage characteristics for two point contacts with 1D confinement in high-g [$\bar{2}$33] (a,b) and low-g [$\bar{1}$10] (c,d) directions measured in different in-plane magnetic fields between 0 and 12 Tesla pointing in [$\bar{2}$33] (a,c) and [$\bar{1}$10] (b,d) directions. Curves' offset is proportional to the field, zero-field trace is the leftmost. The critical field B_C indicates the appearance of half-integer steps (in units of $2e^2/h$). An AFM image of a point contact is shown in the inset, the size of the image is 2μm $\times$ 2μm.

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