Transverse Electric Field Effects in the Quantum Hall Regime in InAs-based Quantum Wells

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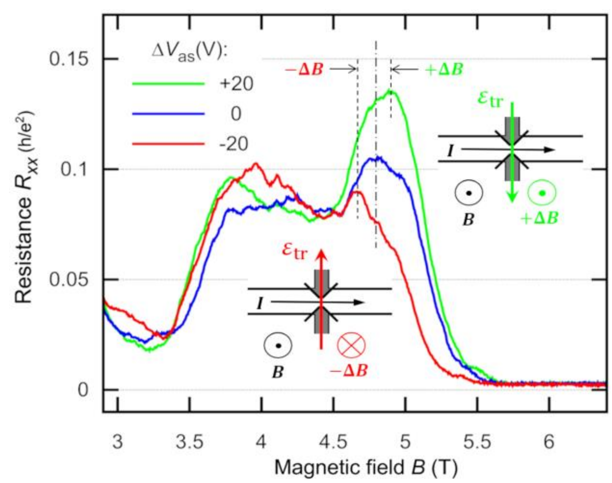
Two-dimensional electron gases (2DEGs) in perpendicular magnetic fields at low temperatures exhibit topological behavior leading to the quantum Hall (QH) effect, where the Landau levels (LLs) result in quantum Hall edge channels (QHECs) as chiral one-dimensional (1D) states. The transmission or reflection of QHECs can be controlled at potential barriers created by top- and split-gates [1]. Recent experiments on counterflow-edge transport in InAs quantum wells indicate that in the integer QH regime the microscopic structure of the edge states can differ from that inferred from macroscopic transport experiments [2]. For InAs-based heterostructures spin-orbit coupling may play a significant role [3] and in-plane electric fields may become a useful tool to act on spin-dependent transport properties. However, *transversal in-plane* electric fields have been rarely employed to control QHECs or the currents in the transitions between LLs.

Here we study the cross-over from quasi-2D to quasi-1D transport subject to *transverse in-plane electric fields* in the diffusive to quasi-ballistic and zero-field to QH regime [4]. Hall-bars with in-plane gates were fabricated [5] from an InGaAs/InAlAs/InAs quantum well [6], hosting a 2DEG with electron density of about $6.8 \times 10^{11}\ \mathrm{cm}^{-2}$, mobility of $1.8 \times 10^{5}\ \mathrm{cm}^{2}/\mathrm{Vs}$ and an effective mass of $0.042 m_\mathrm{e}$ after illumination. Magnetotransport measurements at temperatures down to 50 mK and perpendicular magnetic fields up to 12 T yield an effective Landé-factor of $|g^*| = 16$, enabling the resolution of spin-split subbands at fields of 2.5 T. In the QH regime, electrostatic control of an effective constriction width drives the reflection and transmission of QHECs, allowing a separation of fully spin-polarized QHECs at filling factors $\nu = 1$ und $\nu = 2$. Changing the orientation of a transverse in-plane electric field shifts the transition between Zeeman-split QH plateaus and is consistent with an effective magnetic field of up to $B_\mathrm{eff} \approx 0.1\ \mathrm{T}$ by spin-dependent backscattering, indicating a change in the spin-split density of states affected by spin-orbit coupling.



The resistance R_{xx} as a function of magnetic field B in a Hall-bar with in-plane gates at $T_\mathrm{bath} = 250\ \mathrm{mK}$. The transversal in-plane electric field $\mathcal{E}_\mathrm{tr}$ is proportional to ΔV_as. The dash-dotted line indicates a peak in the blue curve, from which the shifts $+\Delta B$ (green) and $-\Delta B$ (red) of peaks marked with dashed lines are measured.

References

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