Quantum Hall Effect in a Two-Dimensional Electron System Bent by 90°

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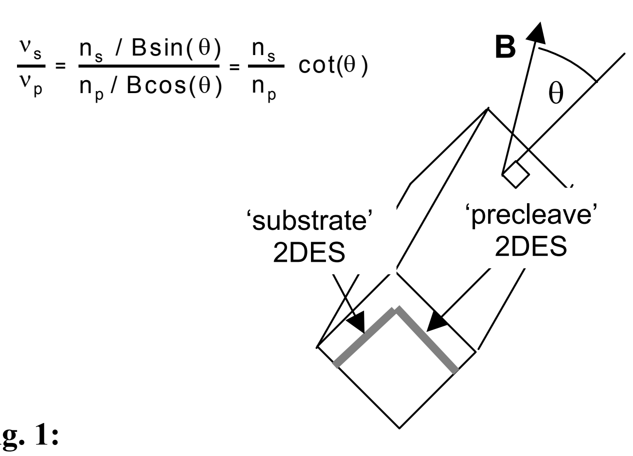
Using a new MBE growth technique, we fabricate a two-dimensional electron system (2DES) which is bent around an atomically sharp 90° corner. In tilted fields, we can measure equilibration between both *co-* and *counter*-propagating edge channels of arbitrary filling factor. With counter-propagating edge channels of the same filling factor, we observe anomalous Landauer-Büttiker reflection coefficients for both integer and fractional edge channels when they traverse the corner.

We call our device the corner-quantum well heterojunction (CQW), fabricated by overgrowing a standard GaAs/AlGaAs heterojunction structure on a precleaved corner. We identify one side of the device as the 'substrate', and the other side as the 'precleave' as in Fig. 1, and measure slightly different densities, $n_s = 1.07 \times 10^{11}$ cm^{-2} and $n_p = 1.30 \times 10^{11}$ cm^{-2} for the two facets, respectively. Indium contacts to each side are alloyed away from the corner junction. In the presence of a tilted magnetic field at an angle defined in Fig. 1, the relative filling factor between the two systems ν_s/ν_p can be tuned according to the equation shown in the inset. The high quality of the growth is demonstrated by fractional quantum Hall effect (FQHE) minima appearing on both facets below 1K. For angles $+90^o > \theta > 0^o$ the edge channels counter-propagate as in planar gated structures, but for $0^o > \theta > -90^o$, the normal component of the magnetic field *changes sign* across the junction, resulting in a junction of ***co***-propagating edge states -- a situation that is impossible to realize in gated planar structures. In Fig. 2, we measure the device in this mode, with various 4-point resistances demonstrating full equilibration of co-propagating edge channels at the 3 mm long corner junction, proving that the standard edge-state picture is valid here.

An unexpected effect is observed at $\theta = 39.4^o$ where the edge channels counter-propagate and the filling factors on both facets are exactly equal and of the same sign ($\nu_s/\nu_p = 1$), and we observe an anomalous behavior in the R_{xx} minima when measured across the corner junction. In Fig. 3, we send current across the corner and perform a 4-point longitudinal resistance measurement using various combinations of voltage contacts. When the two voltage contacts lie on the same facet, i.e. R_{xx}(AB) and R_{xx}(CD), the QHE minimae drop to zero as expected. However for R_{xx}(BC) when the voltage contacts straddle the corner, the minima at higher filling factor ($\nu \geq 3$) do *not* go to zero but instead remain finite.

This behavior can be explained within the Landauer-Büttiker model of edge state transport if one assumes that the reflection coefficient at the corner is non-zero. This result is remarkable in that the junction boundary is macroscopic (3mm). The inset of Fig. 3 shows a cartoon of this edge state model with finite reflection $\mathcal{R}$ and transmission $\mathcal{T}$ coefficients. And within a given filling factor minimum there is



$$\frac{\nu_s}{\nu_p} = \frac{n_s / B\sin(\theta)}{n_p / B\cos(\theta)} = \frac{n_s}{n_p}\cot(\theta)$$

Fig. 1:
Schematic of the overgrown corner showing the imbedded substrate and precleave 2DES's, as well as the orientation of the magnetic field, B, in tilted field experiments. The inset equation shows how the tilt angle can define an arbitrary filling factor ratio.

variation of R_{xx} with B, implying that the reflection coefficient has a magnetic field dependence within a given QHE minimum. And at $\nu = 1$ (not shown) and $\nu = 2$ the minimae in $R_{xx}(BC)$ *do* go to zero, implying furthermore that the reflection coefficient depends on the filling factor index, ν. All told, preliminary results also indicate dependences of the reflection coefficient on temperature, T, and junction length, L, resulting in a functional dependence $\mathcal{R}(\nu, B, T, L)$. Data at fractional filling 2/3 will also be presented, where once again a significant non-zero reflection coefficient is observed.

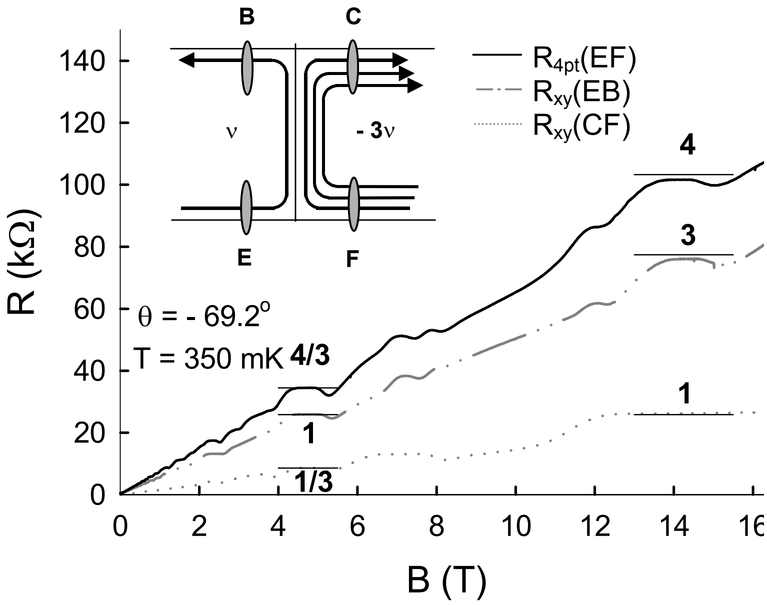


Fig. 2:
$\nu_s/\nu_p = -1/3$: Quantized resistance plateaus, $R_{xy} = h/ne^2$ with n listed in the figure. Inset shows overhead view of corner junction.

R_{xy} for the substrate (measured between E and B), and for the precleave (between C and F), with current flowing across the corner.

R_{4pt} (between E and F) showing new resistance quanta equal to the sum of the constituent R_{xy}'s. Full equilibration of co-propagating edge-channels takes place at the corner junction (see inset).

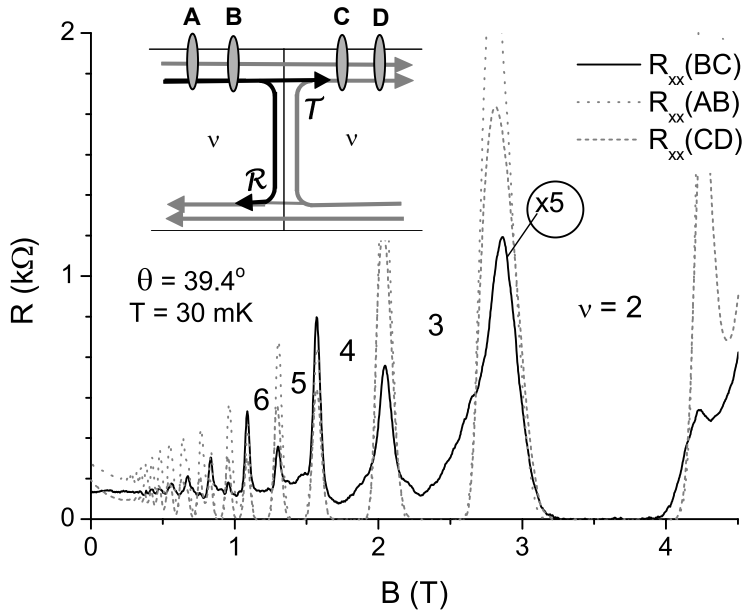


Fig. 3:
$\nu_s/\nu_p = 1$: Longitudinal resistance, R_{xx}. Inset shows overhead view of corner junction.

R_{xy} for the substrate (measured between A and B) and precleave (between C and D), with current flowing across the corner. Integer QHE minima all go to zero.

R_{xx} (between B and C) showing non-zero minima for filling factors $\nu \geq 3$. This behavior can be explained if one assumes non-zero Landauer-Büttiker reflection coefficients at the corner junction (see inset).