Imaging Fractional Incompressible Stripes in Integer Quantum Hall Systems

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The non-interacting picture of the QH effect

Landau levels in a confined system

Edge state picture:
*current is carried by chiral 1D channels*

Backscattering is suppressed due to the large spatial separation between counter-propagating channels
The non-interacting picture of the QH effect

2DES in high field

Landau levels in a confined system

Edge state picture:

*current is carried by chiral 1D channels*

With a QPC we can intentionally induce backscattering, which provides us information about the edge properties

Roddaro et al.: PRL 90 (2003) 046805
Roddaro et al.: PRL 95 (2005) 156804
Roddaro, Paradiso et al.: PRL 103 (2009) 016802
Edge channel-based interferometers

The very large coherence length has been exploited to implement complex interferometers as the electronic Mach-Zehnder.

Edge channel-based interferometers

The very large coherence length has been exploited to implement complex interferometers as the electronic Mach-Zehnder.

**Puzzle:** internal structure of edge seems to play no role here

Roddaro *et al.*: experiments on QPCs revealed signatures of fractional components in “simple” integer channels


Need for spatially resolved measurements
Non-interacting VS interacting picture

- The self consistent potential due to e-e interactions modifies the edge structure.

- For any realistic potential the density goes smoothly to zero.

- Alternating compressible and incompressible stripes arise at the sample edge.

**Incompressible stripes:**
- The electron density is constant
- The potential has a jump

**Compressible stripes:**
- The electron density has a jump
- The potential is constant

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SGM technique: we select individual channels from the edge of a quantized 2DEG, we send them to the constriction and make them backscatter with the biased SGM tip.

- Bulk filling factor $\nu=4$
- $B = 3.04 \ T$
- 2 spin-degenerate edge channels
- gate-region filling factors $g_1 = g_2 = 0$
**SGM technique:** we select individual channels from the edge of a quantized 2DEG, we send them to the constriction and make them backscatter with the biased SGM tip.

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How we probe incompressible stripes

Self-consistent potential

Landau levels inside the constriction

\( \hbar \omega_c \)

Tip induced potential

Tip position
How we probe incompressible stripes

-100 0 100 200 300 400 500 600 700 800
0 1 2 3 4
conductance (e^2/h)
tip position (nm)

backscattering

↑ tip position
How we probe incompressible stripes

conductance ($e^2/h$)
tip position (nm)

$\uparrow$ tip position
How we probe incompressible stripes

Energy gap: $\hbar \omega = 5.7 \text{ meV}$
Plateau width: 60 nm
Incompr. stripe width: $\approx 30 \text{ nm}$
Histogram analysis

$v=6$

300nm

$G_T (e^2/h)$

Counts

$G_T (e^2/h)$

Position (nm)
Imaging fractional structures in integer channels (ν=1)

Imaging fractional structures in integer channels ($\nu=1$)

$\delta_{IS} \sim 12$ nm

Imaging fractional structures in integer channels ($\nu=1$)

Temperature dependence of $1/3$ peak in histogram

Fractional edge reconstruction

The finite range in GT defines a stripe in the SGM map.

\[ \delta_{IS} \text{ determined from SGM measurements} \]

\[ \frac{\delta_{IS}}{dr} \]

\[ \delta_{IS} \text{ determined from Chklovskii's formula} \]

\[ \delta_{IS}^2 = \frac{4 \Delta \mu_f \varepsilon}{\pi^2 e^2 \frac{dn}{dr}|_{r=r_f}} \]
Fractional edge reconstruction

The IS width values (colored dots) obtained from SGM images compare well with the reconstruction picture predictions (black lines).

Inner edge structure demonstrated and imaged

Quantitative test of the IS width dependence on the density slope
Summary

- Fractional incompressible stripes observed in integer edge channels
- Estimate width of these stripes
- Comparison with edge reconstruction theory