Impact of Disorder on the 5/2 Fractional Quantum Hall State

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Motivation

• Find a high as possible energy gap for the fractional 5/2 state
  – Discrepancy of 2 K between calculations and achieved gaps → attributed to “disorder broadening”
  – Try new systems

• Important role of disorder
  – MIT in GaAs
  – Quantum Hall effect: plateau-to-plateau transition
  – Fractional Quantum Hall States
Scaling of Plateau to Plateau Transition

- PPT is a localization delocalization transition
- Following the idea of a quantum phase transition and a finite scaling theory

\[ R_{uv} = R_{uv} \frac{L}{\xi} \]

\[ \xi \propto |B - B_c|^{-\nu} \]

\[ L_{\phi} \propto T^{-\frac{p}{2}} \]

\[ \frac{dR_{xy}}{dB} \propto T^{-\kappa} \]

\[ \kappa = \frac{p}{2\nu} \]

Li et al. PRL 102, 216801 2009
Non universal behaviour

4-3 Transition
At base bath temperature $T_B=1\text{mK}$

Sample width: 100μm, 500μm
Sample length: width = 4.5:2.5

$\kappa = 0.42$

$T_s \sim W^{-1}$

$Al_{0.62}Ga_{0.38}As-Al_{0.8}Ga_{0.22}As$
with $x=0.85%$

4-3 Transition
Impact of Disorder

- Localization length depends on disorder
  → for short range disorder:
    \[ \kappa = 0.42 \]

  → for long range disorder: non universal behaviour,
    (possible transition to at low T)

Li et al. PRB 81, 033350 2010

Li et al. PRL 94, 206807 2005
HIGFET

- No Doping, no ionized impurities → no long range disorder
- Surface roughness → short range disorder

Energy gap measurement

- Gate voltage is swept
- $R_{xx}$ shows activated behavior
- Gap increases with density, but is not dependent on mobility
Density dependence of gap

Spin polarized ground state fit:

\[ \Delta = \frac{\alpha e^2}{\epsilon l_b} - \Gamma \]

Unpolarized ground state gives worse fit:

\[ \Delta = \frac{\alpha e^2}{\epsilon l_b} - \Gamma - g^* \mu_b B \]

Normalize gap with e⁻-e⁻ interaction:

\[ \frac{e^2}{\epsilon l_b} \]

Gamez et al. arXiv:1101.5856
Comparison to Quantum Wells

• Long range disorder in quantum wells

• Short range disorder in HIGFET

• $1/\mu$ is a rough measure of disorder

• HIGFET Gap is not dependent on disorder
Possible Mechanisms

• Attraction between ionized donors and 2D electrons affects composite fermion pairing

• Size of quasiparticles about 0.1 µm
  → Subnanometer surface roughness has no effect

• GS Deformation around impurities, i.e. e⁻ puddles
  → Rotons are being excited
  → Energy gap is affected by rotons
  → Puddle size determines gap size
Conclusion

• In HIGFET devices the gap is not mobility dependent

• Different disorders play different roles

• Density dependent result of the gap is more consistent with a spin polarized ground state