DISORDER AND QUANTUM HALL PLATEAU-TO-PLATEAU TRANSITION AT ULTRA-LOW TEMPERATURES

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Introduction

The integer quantum Hall effect is featured by successive plateaus in the Hall resistance (R_{xy}) of a two-dimensional electron system (2DES). The Hall plateaus over a finite range of magnetic field (B) represent separate energy regions of localized states, and between two adjacent plateaus there is a critical field B_c associated with one energy level of extended states. The plateau-to-plateau transition is understood as a transition between two localized phases of the 2DES through an energy level of extended states, with the localization length ξ following a power law $\xi \propto |B-B_c|^{-\nu}$. By using the finite size scaling theory, this critical behavior is related to a temperature scaling $(dR_{xy}/dB)|_{Bc} \propto T^{-\kappa}$, where $\kappa = p/2\nu$, and p is the temperature exponent of inelastic scattering.

The critical exponent κ has been under intensive study in both theories and experiments. Although κ is obtained to be 0.42 in some experimental systems, which is later confirmed by quantum phase transition theories, in different experimental systems κ was found to vary from 0.16 to 0.81, and the universality was called into question. Recent works on alloy systems of $Al_xGa_{1-x}As$-$Al_{0.32}Ga_{0.68}As$ heterostructures [1, 2] has brought new insight into the problem. The alloy scattering potential is characterized to be short-ranged (atomic size), strong (about 1eV) and temperature-independent [1]. Temperature scaling studies from 0.3K to 1.2K shows the exponent depends on the Al concentration x. When the value of x falls in a regime where the system is dominated by short-ranged disorder ($0.65\% < x < 1.6\%$), a perfect power law scaling was established from 1K to 30mK with $\kappa = 0.42 \pm 0.01$ [19].

Experimental

Since the plateau-to-plateau transition is a quantum phase transition, it's of great interest to investigate this problem at the low temperature limit. We have performed temperature scaling experiments to the low temperature end with **the high B/T facility of the NHMFL** located in the University of Florida. Our ultra-low temperature experiment was carried out in a demagnetization /dilution refrigerator with a base bath temperature (T_b) of 1mK. Hall resistance of samples with different x has been measured with Standard lock-in technique with a current excitation of 1nA and frequency of 5.7Hz. The sweep rate of the magnetic field is about 0.05T/Hour. The critical exponent is extracted from the dependence $(dR_{xy}/dB)|_{Bc} \propto T^{-\kappa}$.

Results and Discussion

From the data analysis, we found

1. For the sample with x=0.85%, a perfect power law scaling has been established from 1.2K down to 12mK [3].
2. At lower temperatures $(dR_{xy}/dB)|_{Bc}$ is found to saturate abruptly below 10mK, and an unintentional electron density gradient of 6% across the sample is proposed to explain the saturation [3].
3. Samples with low Al concentration x shows a crossover between temperature regions of κ=0.42 and of κ=0.58. The crossover temperature depends on x[4].

Conclusions

1. Effect of electron density gradient is observed at the low temperature limit.
2. The dependence of the quantum Hall plateau-to-plateau transition scaling on the nature of disorder has been found.

Acknowledgements

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References

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