Direct Observation of the Composite Fermions and Their Fully Spin Polarized Fermi Sea Near Filling Factor 5/2

Hossain, M.S., Meng, K., Mueed, M.A., Pfeiffer, L.N., West, K.W., Baldwin, K.W., and Shayegan, M. (Princeton U., Electrical Engineering)

Introduction

Even-denominator fractional quantum Hall states (FQHSs) observed in high-quality two-dimensional electron systems (2DESs) in the first-excited (N = 1) Landau level, such as the enigmatic ν = 5/2 FQHS, are among the unsolved mysteries in condensed matter physics. They are predicted to be p-wave paired composite fermion (CF) states obeying non-Abelian statistics [1] and therefore can be of potential use in topological quantum computing [1]. In this project, we investigated the origin of ν = 5/2 FQHS and unraveled the existence of a fully spin-polarized CF Fermi sea near ν = 5/2 via geometric resonance measurements (**Fig. 1**) [2].

Experimental

We performed experiments in the SCM1 facility at the NHMFL, Tallahassee, Florida. Our samples have an array of electron beam resist stripes with periods of the order of 200 nm on their surface, patterned using electron-beam lithography. The stripes create a gentle periodic potential modulation in the 2DES, and we observe a geometric resonance when the cyclotron orbit of the CFs becomes commensurate with the period of the stripes. We emphasize that this technique provides a very straightforward probe of the CF Fermi sea since it provides a direct measure of the CF Fermi wave-vector. In addition, the technique is widely used to probe the Fermi sea near ν = 1/2 and 3/2 in the N = 0 Landau level [3-4].

Results and Discussion

We show in **Fig. 1** magneto-transport data for a very high-quality 2DES confined to a GaAs quantum well. The top surface of the sample is patterned with a periodic array of stripes which induces a minute (< 0.5%) density modulation. The sample shows a strong even-denominator FQHS at ν = 5/2, including a well-developed Hall (ρ_{xy}) plateau. Of particular interest are the clear minima marked by the vertical red arrows in **Fig. 1**. These minima in the longitudinal resistance (ρ_{xx}), which are not seen in samples without the periodic stripe array, signal the geometric resonance of the CF cyclotron orbits with the periodic potential induced by the array of stripes. Moreover, the positions of the minima are consistent with the CF Fermi sea being fully spin polarized.

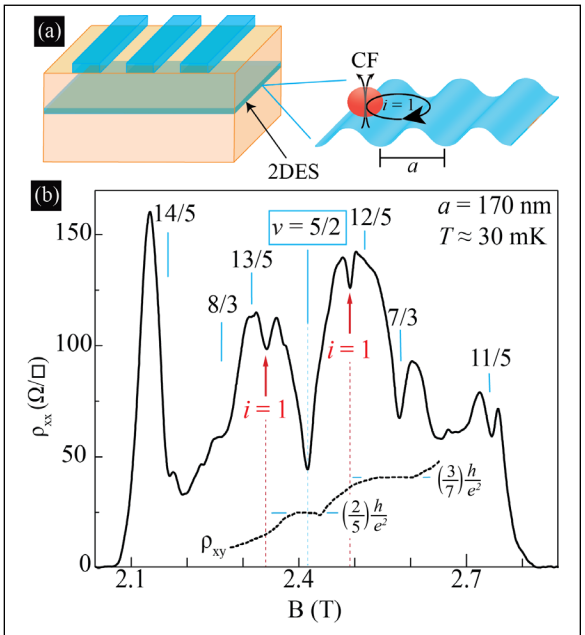

Fig.1 Geometric resonance of composite fermions (CFs) near the fractional quantum Hall state at filling factor ν = 5/2 in a GaAs 2D electron system (2DES) with a small periodic density modulation. The resistance minima marked by arrows prove the presence of CFs with a fully spin-polarized Fermi sea. (After Ref. [2])

Conclusions

Our findings, namely the direct observation of CF near ν = 5/2 and their full spin polarization, are crucial as they lend credence to the theoretical model of the 5/2 FQHS which involves a topological p-wave pairing of fully-spin-polarized CFs through their condensation into a non-Abelian state.

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