Evidence for a Nematic Fractional Quantum Hall State at ν = 5/2 in Parallel Magnetic Field

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The origin and properties of the fractional quantum Hall (FQH) state at Landau level filling factor ν = 5/2 have become of tremendous current interest, thanks to the possibility that this state might be non-Abelian and be useful topological quantum computing. We study the ν = 5/2 FQH state as a function of parallel magnetic field ($B_{||}$), applied in the sample plane, in a very high-quality 2D electron system. We find that the application of $B_{||}$ leads to a strong transport anisotropy as the resistance along $B_{||}$ becomes more than 30 times larger than in the perpendicular direction. Despite the enormous transport anisotropy, the energy gap for this FQH state has the same magnitude along both directions. We interpret our data in terms of a FQH nematic phase.

Figure 1 highlights our main findings. The data were taken in a 30-nm-wide GaAs quantum well, and $B_{||}$ is introduced via tilting the sample in magnetic field by an angle θ. The longitudinal resistances are measured parallel (R_{xx}) and perpendicular (R_{yy}) to $B_{||}$. At low temperatures (T < 0.1 K), both R_{xx} and R_{yy} decrease monotonically with decreasing T. At a given θ, the resistance anisotropy ratio remains constant over a relatively large T range so that the energy gaps we extract from the T-dependence of the resistances are the same for both directions. However, the resistance anisotropy increases tremendously as θ is increased (Fig. 1). Above about 0.12 K, R_{xx} starts to decrease as T is increased, signaling that transport is becoming less anisotropic.

Our transport measurements reveal that the application of $B_{||}$ leads to a ν = 5/2 FQH state whose in-plane longitudinal resistance is highly anisotropic and yet the energy gap deduced from the low-temperature data is the same for both transport directions. These observations are generally consistent with a FQH nematic phase [2], although other explanations might be possible [1]. Regardless of the interpretations, our results attest to the very rich and yet not fully understood nature of the enigmatic ν = 5/2 FQHS.

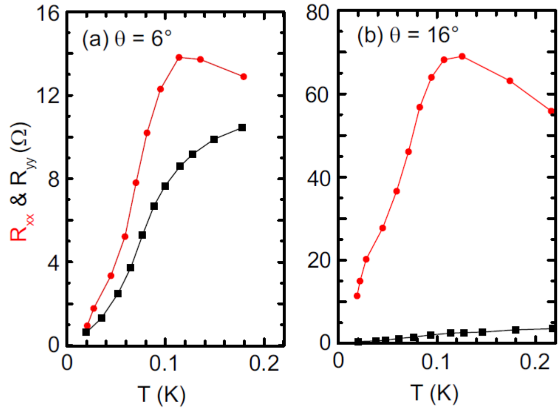

Fig. 1. Longitudinal magneto-resistances vs. temperature (T), measured parallel (R_{xx}) and perpendicular (R_{yy}) to the direction of the in-plane magnetic field $B_{||}$. θ denotes the angle between the total field and the normal to sample plane. The data were taken on a 2D electron system confined to a 30-nm-wide GaAs quantum well, at density 3.05 x 10^{15} m^{-2} and mobility 2,500 m^2/Vs. In both plots, the resistance decreases monotonically at lower temperatures. However, the low-temperature R_{xx}/R_{yy} anisotropy ratio increases from about unity at 6° to about 15 at 16°.

[1] Yang Liu, S. Hasdemir, M. Shayegan, L.N. Pfeiffer, K.W. West and K.W. Baldwin, cond-mat: 1302.6386 (2013).
[2] M. Mulligan, C. Nayak, and S. Kachru, Phys. Rev. B **84**, 195124 (2011).