Observation of Fractional Quantum Hall Effect in an InAs Quantum Well

Ma, M.K., Hossain, M. S., Villegas Rosales, K.A., Deng, H. (Princeton U., Electrical Engineering); Tschirky, T., Wegscheider, W. (ETH Zürich); and Shayegan, M. (Princeton U., Electrical Engineering)

Introduction

The InAs two-dimensional electron system (2DES) is currently a prime candidate for hosting exotic quasiparticles such as Majorana fermions and Parafermions that exhibit non-Abelian statistics and can therefore support topological quantum computation. To achieve its full promise, however, the InAs 2DES must have good enough quality to show evidence of electron-electron interaction such as fractional quantum Hall effect (FQHE). In our experiments we study a very high quality, 24-nm-wide InAs quantum well with density 7.8×10^{11} cm^{-2} and mobility 1.8×10^{6} cm^2/Vs. At T ≈ 35 mK and magnetic field B ≈ 24 T, we observe a deep longitudinal resistance minimum accompanied by a nearly quantized Hall plateau at filling factor 4/3, signaling the presence of FQHE.

Experimental

Our sample consists of a 24-nm-wide InAs quantum well grown on top of a GaSb substrate. The quantum well is flanked by a 200-nm-thick $Al_{0.33}Ga_{0.67}Sb$ lower barrier and a 20-nm-thick AlSb upper barrier, following by a 5-nm-thick GaSb cap layer. The details of the sample structure are shown in Fig. 1 lower right inset. The measurements were done on a sample with 4 mm × 4 mm van der Pauw geometry. Indium contacts were alloyed into the 2DES by annealing the sample at 200 °C for 5 min. We performed transport measurement using low-frequency lock-in technique with an excitation current of ~ 100 nA. The measurements were carried out mainly using the 45 T hybrid magnet at the MagLab in the portable dilution refrigerator with base temperature of ≈ 35 mK.

Results and Discussion

Figure 1 shows the main result of this experiment: The observation of FQHE in an InAs quantum well. It shows the longitudinal resistance R_{xx} and Hall resistance R_{xy} vs. perpendicular magnetic field B from 0 to 45 T at base temperature of ≈ 35 mK. The vertical lines mark the magnetic field positions of several filling factors. The horizontal lines mark the expected quantized value of the Hall resistance at filling factor ν = 4/3. At magnetic field B ≈ 24 T there is a deep R_{xx} minimum accompanied by a Hall resistance R_{xy} to within 1% of the expected value of quantization. We observe the FQHE at ν = 4/3 thanks to the recent improvements in sample quality. As seen in the upper left inset of Fig. 1, the Shubnikov-de Haas oscillations start at B < 0.5 T (ν = 68) and become spin-resolved for B > 0.9 T (ν ≤ 37). The details of our work were published in Ref. [1].

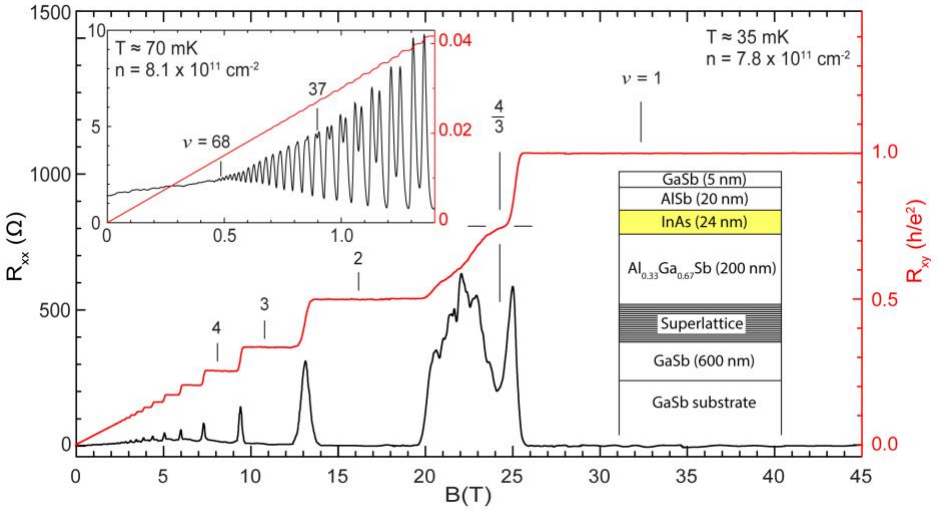

Fig.1 The longitudinal resistance R_{xx} and Hall resistance R_{xy} vs. perpendicular magnetic field B from 0 to 45 T for a 24-nm-wide InAs/$Al_{0.33}Ga_{0.67}Sb$ quantum well at ≈ 35 mK. The upper left inset shows the low field R_{xx} and R_{xy} traces taken at ≈ 70 mK. The quantum well structure is shown in the lower right inset.

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References

[1] Ma, Meng K., *et al.*, Phys. Rev. B **96,** 241301(R) (2017).