Evidence for a Fractional Quantum Hall State at $\nu=1/4$ in a Wide Quantum Well

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Introduction

Interest in the even-denominator fractional quantum Hall (FQH) state at $\nu=5/2$ continues to remain high, partially due to its potential relevance in fault-tolerant, topological quantum computing schemes. Yet observations of even-denominator FQH states have been rare beyond the $\nu=5/2$ state in single-layer systems. In particular, there is no evidence of a FQH state at $\nu=1/2$. In bilayer systems the situation is different. The presence of two nearby, interacting electron layers introduces an additional degree of freedom which can give rise to the formation of a FQH state at $\nu=1/2$, which, indeed, has been observed in double quantum wells [1] and in wide single quantum wells (WSQWs) [2]. In general a similar state should also occur at $\nu=1/4$, however, to the best of our knowledge it has not been observed experimentally. An observation of a FQHE state at $\nu=1/4$ would not only be important in itself but also may shed more light on the origin of still enigmatic $\nu=1/2$ FQH state in WSQWs.

Experimental

To search for a FQH state at $\nu=1/4$ we have used a high-quality GaAs quantum well with a well width of 50 nm, an electron density of $n = 2.55 \times 10^{11}$ cm$^{-2}$, and a mobility of $10^7$ cm$^2$/Vs. We have measured the electronic transport properties of this sample at $T \sim 35$ mK in magnetic fields up to 45 T using the Hybrid facility at NHMFL.

Results and Discussions

As shown in Figure 1, when the sample is perpendicular to the magnetic field, the diagonal resistance displays a kink and the Hall resistance shows a subtle deviation from the classical slope at $\nu=1/4$. When the sample is tilted to an angle $\theta=20.3^\circ$, the kink develops into a strong $R_{xx}$ minimum and a plateau emerges in clearly demonstrating a FQH state at $\nu=1/4$. As to the origin of the $\nu=1/4$ state, one possibility is a two-component Halperin state such as $\{553\}$ or $\{771\}$. On the other hand, the possibility that $\nu=1/4$ state is described by $\{771\}$ is unlikely considering the bilayer interpretation of the $\{nnm\}$ wavefunctions. For the $\{771\}$ wavefunction the electron filling factor in each layer would be $\nu=1/7$ and typical single-layer two-dimensional electron systems (2DESs) enter into an insulating phase beyond $\nu=1/5$ at low temperatures. An alternate possible description for the observed $\nu=1/4$ state may be the pairing of composite fermions, similar to the proposal for a $\nu=1/2$ FQH state in a thick 2DES [3].

Conclusions

Our data provide evidence for the existence of a FQH state at $\nu=1/4$ in our sample. The origin of this state has yet to be determined.

References