Phase Transitions in the Bilayer Solid in Wide Quantum Wells

Hatke, A.T.; Engel, L.W. (NHMFL); Liu, Y.; Shayegan, M.; Pfeiffer, L.N.; West, K.W.; Baldwin, K.W. (Princeton University)

Introduction

For a single layer two-dimensional electron system, fractional quantum Hall (FQH) series terminates at low Landau filling factor (ν) in an insulating phase (IP) for $\nu \leq 1/5$. In wide quantum wells (WQWs) when the density (n) of the well is large enough, the charge distribution begins to separate into two layers resulting in an onset of the IP for $\nu \leq 1/2$ as the system becomes bilayer like [1]. Microwave spectroscopy is ideal for investigation of low ν insulating phases, which exhibit a pronounced resonance, with a peak frequency f_{pk}. This resonance is understood as the pinning mode of a solid, which oscillates about a pinning potential. Here we use this technique to investigate the IP of the bilayer solid.

Experimental

A meandering coplanar waveguide was lithographically patterned on a WQW of width w = 80 nm. The loss and phase shift of the waveguide were used to obtain microwave conductivity spectra using the SCM1 and PDF systems.

Results and Discussion

In Fig. 1 (a) we present measurements of the microwave conductivity, Re (σ_{xx}), in the (f, ν)-plane obtained from a w = 80 nm sample with symmetric charge distribution of carriers at n = 1.26 x 10^{11} cm^{-2}. For ν < 0.5, we observe the onset of a resonance at ν ~ 0.44, which occurs well above the single layer state onset. We attribute this resonance to the bilayer solid. With decreasing ν within the bilayer solid range the resonance peak frequency f_{pk} begins to increase before making an abrupt jump. Further decrease in ν results in f_{pk} again increasing before performing another abrupt jump. Concurrent with these jumps in f_{pk} are sharp resonance intensity reductions, which we attribute to phase transitions. We extract the ν of these transitions over a wide density range and plot them as symbols in a phase diagram in Fig. 1 (b) in the (γ, ν)-plane, where γ is the ratio of the Coulomb energy to the subband separation. Here the measurement range lies between the dashed and dotted lines and a resonance is observed below the solid line. We observe *five* well defined phase transitions within the bilayer-insulating phase.

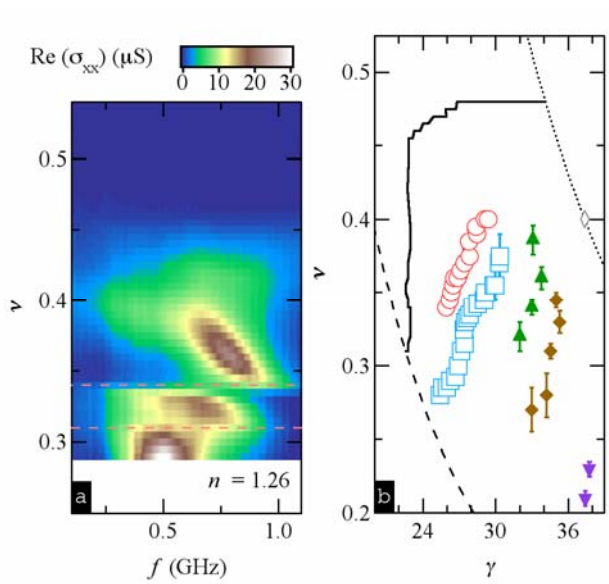

Figure 1: (a) False color plot of microwave spectra in the (f,ν)-plane. (b) Phase diagram in (γ,ν)-plane. Symbols mark phase transition positions, open symbols are from SCM1 and closed

Conclusions

Our microwave measurements establish the low ν insulator to be a bilayer solid as evidenced by the pinning mode resonance, which can be degraded by layer density imbalance. The unexpected, and large number, of phase transitions observed in the bilayer solid remain uncertain but are most likely due to structural transitions within the insulator.

Acknowledgements

This work was supported by DOE BES award DE-FG02-05ER46212. A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy.

References

[1] H. C. Manoharan *et al.*, Phys Rev. Lett., **77**, 1813-1816 (1996).