Microwave Spectroscopic Observation of a Wigner Crystal of 1/2-Charged Quasiholes

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Introduction

In the lowest Landau level a single-layer two dimensional system of carriers exhibits fractional quantum Hall effects (FQHEs), centered at odd-denominator filling factors (ν). In GaAs based wide quantum wells (WQWs), and double quantum wells (DQWs), the charge distribution can separate into two layers and form a ν = 1/2 FQHE state [1,2], Within the ν ranges of the integer quantum Hall effect [3] and of the 1/3 FQHE [4], quasiparticles and –holes of the system are dilute and may form Wigner solids. The solids exhibit an rf or microwave pinning mode resonance, in which pieces of solid oscillate within the residual disorder potential. Here we identify a pinning mode of solidified quasiholes near ν = 1/2 in a GaAs based WQW.

Experimental

A meandering coplanar waveguide was lithographically patterned on a WQW of width w = 80 nm. We obtain microwave conductivity spectra from the propagation characteristics of the waveguide, cooling the sample in SCM1.

Results and Discussion

In Fig. 1 (a) we present microwave spectra, real diagonal conductivity, Re (σ_{xx}), vs frequency, f, obtained from a w = 80 nm sample with symmetric charge distribution of carriers at density n = 1.57 x 10^{11} cm^{-2}. For ν = 0.480, we observe a well-developed resonance with peak frequency f_{pk} ~ 0.5 GHz, which we have attributed to the formation of a bilayer electron solid [4] *not* associated with the ½ FQHE. In addition, we observe a *second* resonance with a peak frequency of f_{pk} ~ 1.3 GHz. We fit the spectra to a two peak function (the extraction of the two resonances is highlighted for the ν = 0.480 trace) that showed the high f_{pk} resonance is a pinning mode for solidification of ν = 1/2 quasiparticles. This result is demonstrated in Fig. 1 (b) where we plot the extracted f_{pk} (right axis, open symbols) and the measured S/f_{pk} (left axis, closed symbols) for this resonance. S is the integrated Re (σ_{xx})(f), and according to a sum rule [5], $S/f_{pk}=e^2\pi\nu^*/2h$, where $\nu^*=1/2-\nu$ is the filling factor for 1/2-quasiholes and full participation of 1/2-quasiholes in the resonance is assumed. The measured S/f_{pk} agrees well with the sum rule. The 0.5 GHz resonance, taken to be due to a coexisting bilayer solid, does not account for enough carriers to affect this agreement.

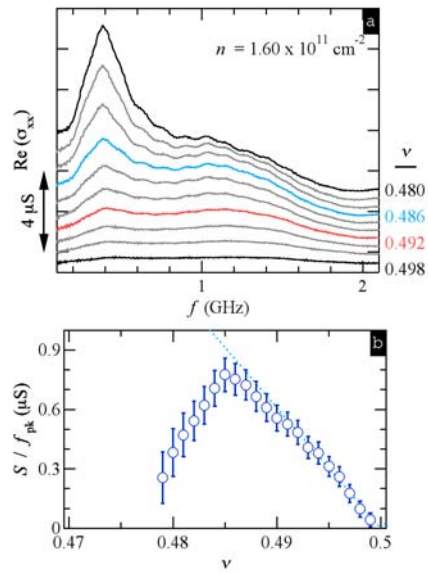

Figure 1: (a) Microwave spectra, Re (σ_{xx}) vs f, at wveral ν. (b) S/f_{pk} vs ν. Dashed line is theoretical value from sum rule for S/f_{pk} for quasiholes of ½ FQHE.

Conclusions

The measurements provide evidence for solidification of quasiholes of the ½ FQHE in a WQW.

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