**Wigner Solid of Quasiholes of the  = 1/2 Fractional Quantum Hall Effect State**

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**Introduction**

In GaAs wide quantum wells (WQWs), at sufficiently high carrier density, *n*, the growth-direction carrier distribution can separate into two layers. If the disorder is low and the intralayer and interlayer interaction are comparable, a fractional quantum Hall effect (FQHE) can form, centered at Landau filling  = ½ [1].

Microwave spectroscopy is ideal for investigation of solid phases, since these phases exhibit a pronounced rf or microwave resonance. This resonance is understood as a pinning mode, a collective mode of a Wigner solid in which pieces of the solid, which oscillates within the pinning potential. Studies of pinning modes have revealed solidification of quasicarriers of the 1/3 FQHE liquid [2]. Here we find a pinning mode that signifies the solidification of quasiholes 1/2 FQHE state in a GaAs based WQW.

**Experimental**

We obtain diagonal conductivity of the carriers in the WQW from the measured loss and phase shift of a transmission line on the sample surface.

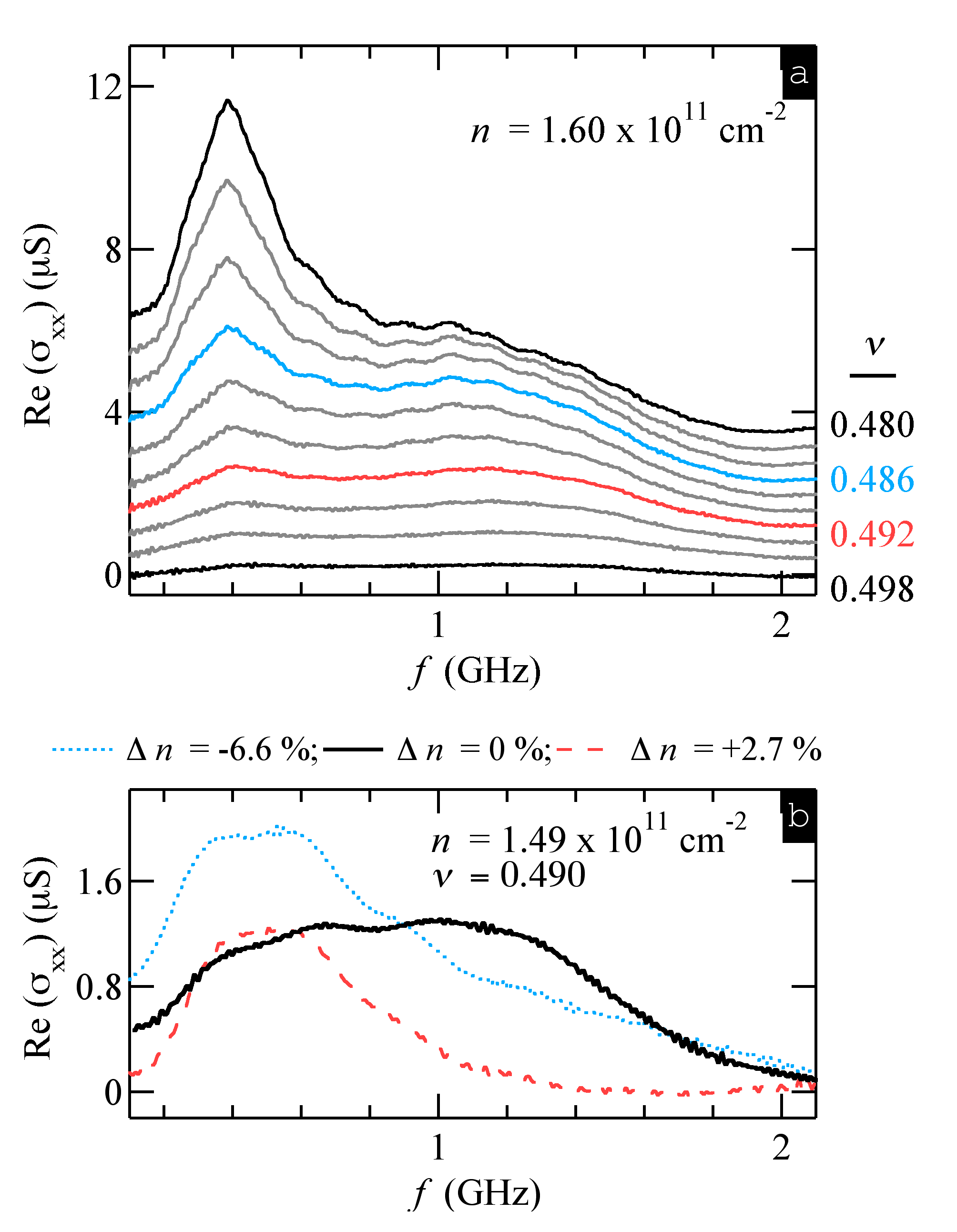


Figure 1: (a) Microwave spectra, Re (xx) vs *f*, at fixed *n* and various ** for symmetric charge distribution. (b) Spectra under different charge distributions about the well center.

**Results and Discussion**

In Fig. 1 (a) we present microwave spectra, Re (**xx) vs *f*, obtained with a symmetric growth-direction charge distribution for density *n* = 1.60 x 1011 cm-2. For **= 0.480, we observe a well-developed resonance at *f*pk ~ 0.4 GHz. This is the same frequency as the pinning mode seen at much lower **(much less than ½) and was ascribed to a bilayer solid [3] that is not associated with the ½ FQHE, but is a generic low-** state of low disorder quantum Hall systems. With increasing ** in the data set, we observe the development of a *second* resonance with a peak frequency of *f*pk ~ 1.1 GHz. By extracting two resonances with a two-peak fit function and analyzing the signal strength, we have shown that the higher *f*pk resonance arise from a solid of quasiholes of the 1/2 FQHE [4].

This solid is highly sensitive to the charge distribution within the well, consistent with its association with the ½ FQHE, which is likewise sensitive. We highlight this observation in Fig. 1 (b) where the spectra obtained at fixed ** and *n* are shown for three charge configurations. For *n* = 0 % the charge distribution is symmetric about the well center and we observe the high *f*pk resonance. Forced charged imbalance in either direction through asymmetric gating of the top and bottom of the sample destroys the high *f*pk resonance with concurrent strengthening of the low *f*pk resonance.

**Conclusions**

Our microwave measurements demonstrate the existence of a Wigner solid formed from the quasihole excitations of the  = 1/2 fractional quantum Hall. These quasiholes are expected to be of charge ¼, and to be of a *dipole nature*, with positive charge in one layer and negative charge in the other.

**Acknowledgements**

This work was supported by DOE BES award DE-FG02-05ER46212

**References**

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