Microwave Activation Studies of Fractional Quantum Hall Effects Identify Marginal Metallic States in the GaAs/AlGaAs 2D Electron System

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Microwave photo-excited transport studies of 2-Dimensional Electron Systems (2DES) have revealed the microwave induced zero-resistance states, where the dark dissipative resistance of a 2DES at a low magnetic field can be switched off by photo-excitation at GHz frequencies.[1, 2] The observation of such zero-resistance states for electrons have suggested the search for microwave induced zero-resistance states of composite fermions at high magnetic fields in the vicinity of effective magnetic field $B^* = 0$. Thus, we have examined microwave photo-excited transport in the fractional quantum Hall regime in the 2DES. Although we have not yet observed the microwave induced zero-resistance states for composite fermions, our studies have revealed other interesting phenomena, which we report here. In particular, we found that microwave photo-excitation can serve to simplify and speed up activation studies of excitation gaps associated with FQHE by providing microwave-power-dependent localized-heating at the 2DES. Thus, we have developed microwave activation studies and utilized them to identify an unusual metallic state with a vanishing activation gap, at a filling factor $\nu = 8/5$ in the untilted specimen with $n = 2 \times 10^{11} cm^{-2}$, and at $\nu = 4/3$ at $n = 1.2 \times 10^{11} cm^{-2}$ under a $\theta = 66^0$ tilted magnetic field. The results suggest that, at the possible degeneracy point of states with different spin polarizations, where the $8/5$ or $4/3$ FQHE vanish, there occurs such a marginal metallic state that differs from the usual quantum Hall insulating state or the quantum Hall metallic state. Such a marginal metallic state exhibits a profound lack of temperature or microwave power sensitivity in the diagonal resistance at these filling factors.[3]

For these experiments, the microwaves were generated with a computer controlled frequency (f)- and power (P)-tunable- microwave synthesizer, and they were applied via a coaxial line while the dilution refrigerator was maintained base temperature ($\approx 40mK$). Instead of changing the temperature of the specimen to measure $R_{xx} vs. T$ at the FQHE minima to develop Arrhenius plots, we measured $R_{xx} vs. P$, where P is the microwave power at GHz frequencies, with the specimen at base temperature. A calibration technique then served to convert the applied power to the temperature. This calibration relied upon matching up resistance traces obtained at different P at base temperature, with different dark traces at elevated temperatures, see Fig. 1.

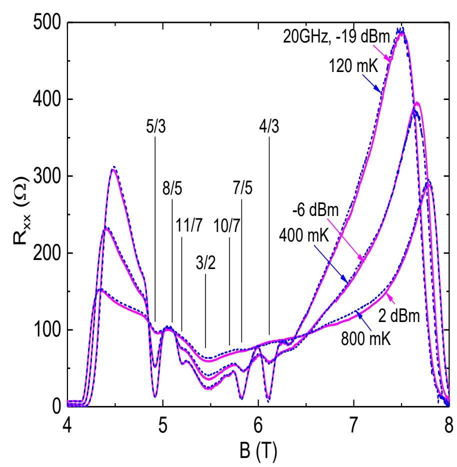

Fig. 1. R_{xx} vs. B traces obtained at various P, at base temperature, have been overlaid upon dark R_{xx} vs. B traces obtained at higher temperatures, T. Note the excellent registry over the entire B span.

References

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