Effective Mass from Microwave Photoresistance in GaAs/AlGaAs Quantum Wells

M.A. Zudov, A.T. Hatke (U. of Minnesota, Physics); J.D. Watson, M.J. Manfra (Purdue U., Physics); L. N. Pfeiffer, K. W. West (Princeton U., Electrical Engineering)

Introduction

A decrease of the carrier mass in 2D electron systems due to electron-electron interactions was predicted at intermediate carrier densities long ago [1]. However, confirmation of this prediction has remained limited [2,3] and controversial, likely due to limited reliability of the effective mass extraction method based on the temperature damping of Shubnikov-de Haas oscillations. In this work, we investigate the effective mass using the dispersions of the magneto-plasmon resonance (MPR) [4] and of the microwave-induced resistance oscillations (MIRO) [5].

Experimental

We have investigated two samples with densities of 2.7 and 3.2×10^{11} cm^{-2} and mobility of about 1×10^{7} cm^2/Vs.

Magnetotransport measurements were performed in SCM-2 using a standard low frequency (a few hertz) lock-in technique under continuous irradiation by microwaves (100 – 175 GHz) generated by a backward wave oscillator.

Results and Discussion

It is well established that high-order MIRO are well described by $-\sin(2\pi\omega/\omega_c)$, where $\omega=2\pi f$ and $\omega_c = eB/m^*$ are microwave and cyclotron frequencies, respectively. As a result, the effective mass m^* is readily available from the MIRO period or, equivalently, from the dispersion $f_i(B) = (i - 1/2)eB/2\pi m^*$, where $i = 3,4,\ldots$ is the MIRO order. Similarly, m^* can be found from the MPR dispersion [4], $f^2(B) = \text{const} + (eB/2\pi m^*)^2$. In **Figure 1(a)**, we present the magneto-resistance in one of our samples, measured at f = 170 GHz showing both MIRO and MPR. After repeating the measurements for different f we construct **Figure 1(b)**, showing m^* obtained by both methods as a function of f.

Conclusions

The effective mass extracted from MIRO is found to be $m^* = 0.059\ m_0$, which is about 12% lower that the band mass in GaAs, $m_b = 0.067\ m_0$. In contrast, the measured MPR dispersion is well described by the band mass. These findings suggest that, in contrast to MPR, the MIRO are sensitive to electron-electron interactions.

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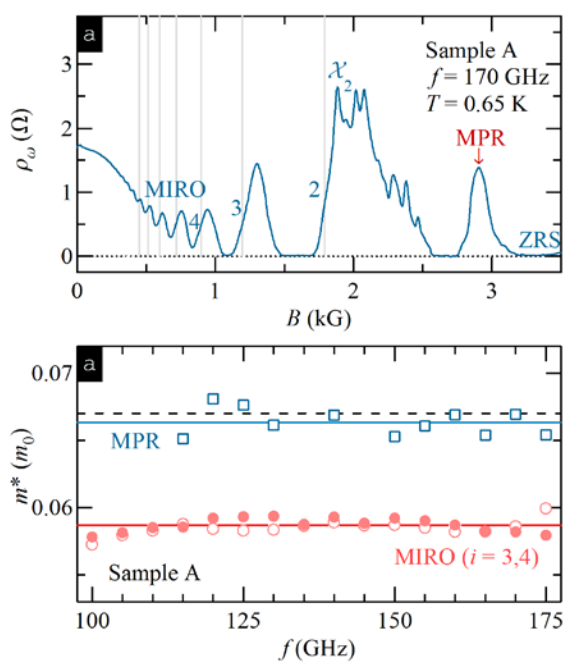

Figure 1 (a) Magnetoresistivity measured with microwaves of f = 170 GHz at T = 0.65 K. (b) Extracted effective mass values from MIRO and MPR versus frequency.