Fermi Contour Anisotropy of GaAs Electron-Flux Composite Fermions in Parallel Magnetic Fields

Kamburov, D.; Mueed, M.A.; Shayegan, M.; Pfeiffer, L.N.; West, K.W.; Baldwin, K.W. (Princeton U., Electrical Engineering)

Introduction

The composite fermion (CF) formalism elegantly describes the properties of interacting particles at high magnetic fields. In this picture, each electron pairs up with an even number of flux quanta to form CFs, which at even-denominator Landau level filling factors occupy a Fermi sea with a well-defined Fermi contour. The existence of a CF Fermi contour raises the question whether fermionization preserves any low-field Fermi contour anisotropy. To answer this fundamental question we determined, via measurements of commensurability oscillations, the $\nu = ½$ CF Fermi contour anisotropy induced by the application of in-plane magnetic field $B_{||}$.

Experimental

We studied 2D electrons confined to GaAs quantum wells (QWs) flanked on each side by undoped $Al_{0.24}Ga_{0.76}As$ barrier layers and Si δ-doped layers. Each sample has two perpendicular Hall bars covered with periodic gratings of negative electron-beam resist which, through the piezoelectric effect in GaAs, induce a periodic density modulation. We used SCM2 and the 31 T resistive magnets for measurements.

Results and Discussion

The magnetoresistance of patterned samples, shown in Fig. 1(a) exhibits a minimum whenever the $\nu = ½$ CF cyclotron orbit diameter becomes commensurate with the period of the density modulation. We deduce the effect of $B_{||}$ on the CF Fermi wave vector k^*_F by measuring the shift in the positions of the commensurability resistance minima along the two perpendicular arms of the L-shaped Hall as $B_{||}$ is applied. When transport is parallel to $B_{||}$ (along the [110] direction), the positions of the minima move away from $\nu = ½$ (Fig. 1(b)) while perpendicular to $B_{||}$ their shift is toward ½ (Fig. 1(c)).

The values of k^*_F along the two Hall bar directions, deduced from the positions of the magnetoresistance minima for each QW, reveal a severe CF Fermi contour distortion as a result of $B_{||}$ and indicate that the anisotropy depends on the QW width. Furthermore, they indicate that the Fermi contour areas remain nearly elliptical up to $B_{||} = 26$ T.

The strong quantitative dependence of the distortion on $B_{||}$ and on the QW width implies that the origin of this anisotropy is the coupling between $B_{||}$ and the out-of-plane motion of the CFs. It further suggests that besides its thickness, other parameters of the quasi-2D carrier system, such as the details of the band structure and effective mass, as well as the character of the Landau level where the CFs are formed, play important roles in determining the anisotropy of the CF Fermi contour in a strong $B_{||}$.

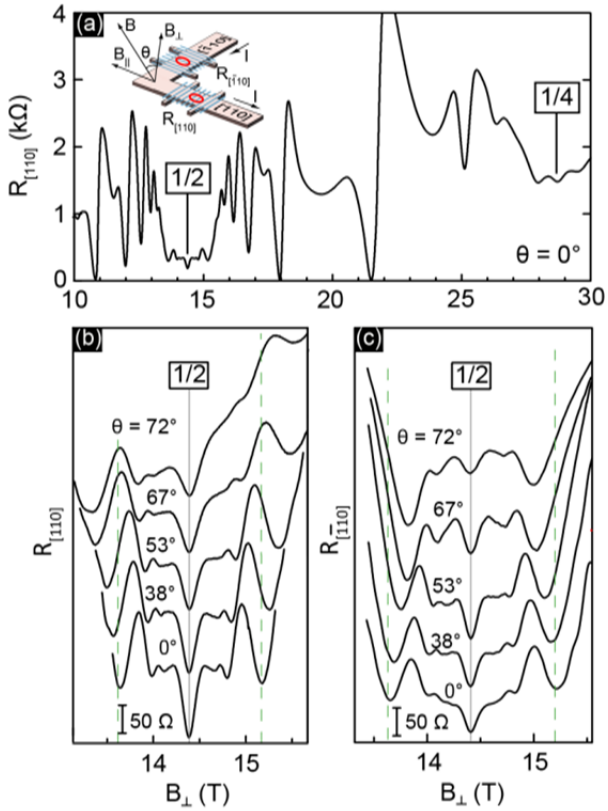

FIG. 1: (a) Magnetoresistance without tilt showing strong commensurability features around $\nu = ½$ and ¼. (b), (c) With increasing $B_{||}$ (higher tilt angles θ) the commensurability minima move outward from $\nu = ½$ in the [110] direction and inward in the perpendicular direction.

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