Tuning Fermi Contour Anisotropy of GaAs of Quasi-2D Electron and Hole Systems in Parallel Magnetic Fields

D. Kamburov, M.a. Mueed, M. Shayegan, L.N. Pfeiffer, K.W. West, K.W. Baldwin, and R. Winkler†

Department of Electrical Engineering, Princeton University, USA
†Department of Physics, Northern Illinois University, DeKalb, Illinois 60115, USA

In a quasi-2D carrier system with finite (non-zero) layer thickness, the coupling between the carriers' out-of-plane motion and an applied magnetic field ($B_{||}$) parallel to the sample plane could lead to a severe distortion of the energy bands and the Fermi contours (FCs). Such a distortion can affect devices and/or experiments which rely on ballistic transport of the carriers in the presence of a strong $B_{||}$ used, e.g., to spin-polarize the carriers.

Here we present both numerical calculations (Fig. 1) and experimental data that shed light on this field-induced anisotropy [1,2]. We show results for the FCs of both quasi-2D electrons and holes confined to GaAs quantum wells. As seen in Fig. 1, at $B_{||} = 0$ the FC is circular for electrons. With increasing $B_{||}$, the majority-and minority-spin FCs are deformed, and eventually the minority-spin FC disintegrates. In contrast to the electron case, the hole FCs are slightly anisotropic and split even at $B_{||} = 0$; the splitting is a result of the strong spin-orbit interaction. The hole FCs show much stronger splitting at finite $B_{||}$ and the anisotropy is much more pronounced for the majority spin FC (see, e.g., the contours for $B_{||} = 10$ T).

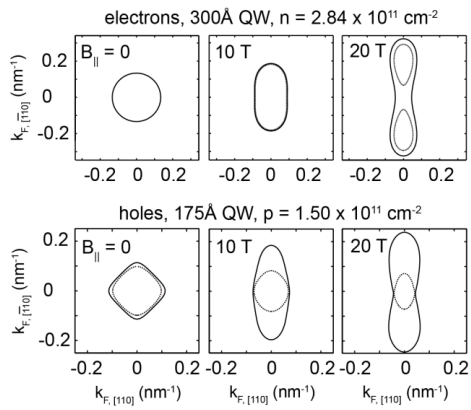

Fig. 1. Results of 8 x 8 Kane Hamiltonian calculations of the FCs. The majority- and minority-spin FCs are shown by solid and dotted lines. Top row: FCs for electrons confined to a 300-Å-wide GaAs quantum well. Bottom row: FCs for holes in a 175-Å-wide quantum well.

Experimentally, we use the commensurability between the quasi-classical orbits of the carriers with a periodic potential modulation [1-3] to measure the size of the Fermi wave vector k_F along both [110] and [$\bar{1}$10] as a function of $B_{||}$. We use a novel technique that allows us to apply a large $B_{||}$ as well as a small perpendicular field to induce the commensurability oscillations.

Our results agree semi-quantitatively with the numerical calculations given in Fig. 1 [1-3]. They demonstrate the *tuning* and *probing* of the GaAs 2D carrier dispersions and FC anisotropy through the application of $B_{||}$.

References:

[1] D. Kamburov *et. al*., preprint.
[2] D. Kamburov *et al.*, Phys. Rev. B **86**, 241302 (2012).
[3] D. Kamburov *et al.*, Phys. Rev. B **85**, 121305(R) (2012).