OBSERVATION OF SPIN-DEPENDENT LONGITUDINAL RESISTIVITY IN THE INTEGER QUANTUM HALL REGIME

K. Vakili, N.C. Bishop, Y.P. Shkolnikov, E. Tutuc, E.P. De Poortere, M. Shayegan (Princeton University, Electrical Engineering)

Introduction

The integer quantum Hall (QH) effect arises from quantization of the energies of two-dimensional electrons into discrete, macroscopically degenerate Landau levels (LLs) by the application of a perpendicular magnetic field (B). Disorder broadens these levels, dividing the available states into localized and extended components. This causes the longitudinal resistivity (ρ_{xx}) to oscillate with B as successive bands of localized and extended states pass through the Fermi energy (E_F). The field also energetically resolves the two spin components, leading to a doubling of the number of maxima in ρ_{xx} for sufficiently high B. Once the spin components are fully resolved, they are no longer expected to affect the magnitude of the ρ_{xx} maxima. Remarkably, we observe a significant dependence of ρ_{xx} at these maxima on the spin of the electronic energy levels.

Experimental

We performed magnetotransport measurements of two-dimensional electrons confined to a 4.5 nm AlAs quantum well (QW) using the 18/20 T DC magnet of the NHMFL millikelvin facility. In these narrow AlAs QWs, electrons occupy a single out-of-plane conduction band valley with an isotropic in-plane Fermi contour. We performed measurements down to T = 20 mK using standard, low-frequency lock-in techniques. Samples were mounted on a single-axis rotating stage to allow for the angle (θ) between the magnetic field and the sample normal to be varied in situ.

Results and Discussion

Our main result is displayed in Fig. 1. At $\theta = 0^o$, the ρ_{xx} maximum between the $\nu = 1$ and 2 quantum Hall states corresponds to E_F lying within the spin-up branch of the lowest LL. When the sample is tilted with respect to B, however, a parallel field component is introduced that increases E_Z at a given ν while leaving the cyclotron energy, E_C, fixed. Thus, the energy of the $0\uparrow$ level increases while that of the $1\downarrow$ level decreases, ultimately causing the levels to cross for sufficiently high angles (shown schematically in the figure for the indicated ρ_{xx} maxima). We find that this flip is accompanied by a large change in ρ_{xx}. The correspondence between resistivity enhancement and spin (large ρ_{xx} for majority spin levels, small ρ_{xx} for minority spin) exists at higher ν and subsequent level crossings as well.

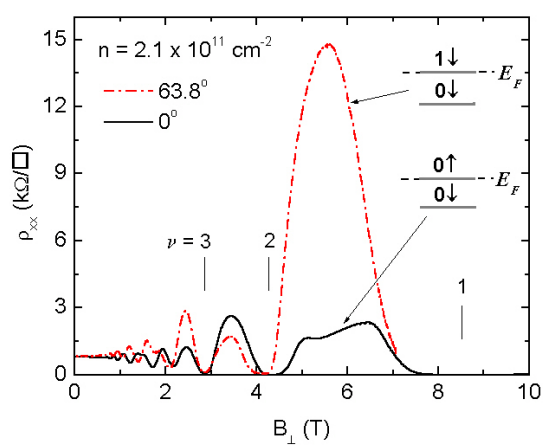

Figure 1

Though the precise cause of this spin dependence is not known, it may be related to the spin dependence of inter-LL screening. The large effective electron mass in this system makes E_C small compared to the electron-electron interaction energy, leading to mixing of different spin levels. The resistivity at a ρ_{xx} maximum, then, should depend on whether it's spin is aligned or anti-aligned with the majority spin of the system, as screening is more effective between charges with different spin.

Conclusions

In summary, we observe a strong spin dependence of ρ_{xx} maxima in the spin-resolved QH regime. This dependence may arise from spin-dependent screening effects combined with interaction-induced mixing of energy levels of different spin.

Acknowledgements

This work was supported by the NSF. We would like to thank Eric Palm, Tim Murphy, and Glover Jones for technical help.