Introduction

Two-dimensional electron systems (2DESs) at low temperatures and high magnetic fields exhibit the integer quantum Hall effect (IQHE), characterized by vanishing diagonal resistivity ($\rho_{xx}$) and quantized Hall resistance ($R_{xy}$), whenever the ratio of the electron density to the Landau level (LL) degeneracy takes integer values. Vanishing $\rho_{xx}$ and quantized $R_{xy}$ persist even slightly away from these integer “filling factors” ($\nu$) as a result of disorder-broadening of the density of states. The peaks in $\rho_{xx}$ between IQHE minima are generally expected to be centered at half-integer $\nu$.

Experimental

We performed magnetotransport measurements of a 2DES in a 5.4 nm wide AlAs quantum well using the 18/20 T superconducting magnet of the NHMFL mK facility. The electrons in this sample occupy a single, isotropic conduction-band minimum. We used standard low-frequency lock-in techniques down to 20 mK, and tilted the sample in situ.

Results and Discussion

As the sample is tilted, the $\rho_{xx}$ peak corresponding to a LL separating IQHE states shifts to lower or higher field as its spin changes to majority ($\downarrow$) or minority ($\uparrow$) respectively. The former case is illustrated in Fig. 1(a), where the LL changes from a $\uparrow$ to a $\downarrow$ spin level, causing a 0.5 T shift of the center of the peak, and of the $R_{xy}$ plateau transition, to lower field. This shift, along with the spin-dependent amplitude of the peak, can produce spike-like features in $\rho_{xx}$ when there are sudden QH ferromagnetic spin-reversals [1]. Such hysteretic spikes have been observed before and have been attributed to scattering at domain-wall boundaries [2], however we see here that they can also arise from a different mechanism. That the hysteresis occurs mostly on the right side of the spike in Fig. 1(b) corroborates our interpretation that the phase transition only takes place on that side and not throughout the whole spike.

A possible cause for the shifts may be spin-dependent screening of donors. Experiments have shown that a preponderance of attractive impurities can shift IQHE features to lower field [3]. Here, that effect of the donors may be switched on and off depending on the spin of the electrons at the Fermi level.

Conclusions

In summary, we have observed a spin-dependent shift in the field positions of $\rho_{xx}$ peaks in the IQHE regime. The shifts contribute to the existence of resistivity spikes and may result from spin-dependent screening of donors.

Acknowledgements

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

References