New Anisotropic Behavior of Quantum Hall Resistance in (110) GaAs Heterostructures at mK Temperatures and low Filling Factors

Frank Fischer[1], Matthew Grayson[1], Erwin Schuberth[2], Dieter Schuh[1], Max Bichler[1], and Gerhard Abstreiter[1]

[1] *Walter Schottky Institut, Technische Universität München, 85748, Garching, Germany*
[2] *Walther Meissner Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany*

Recently there has been increasing interest in transport anisotropies of the longitudinal resistance at half-odd-integer filling factors from $\nu = 9/2$ upwards [1]. The anistropy is observed in high-mobility (001) oriented GaAs/AlGaAs modulation-doped heterostructures with low resistance direction typically aligned along the [110] direction, however alignment along the $[1\bar{1}0]$ direction has also been observed depending on electron density or in-plane magnetic fields [2,3]. To explain this effect, new types of ground states have been proposed within high Landau levels of the quantum Hall effect (QHE) which are based on striped phases which align parallel to the low-resistivity direction. To learn more about the influence of crystal orientation, we use a different substrate orientation, namely (110) GaAs/AlGaAs δ-doped heterostructures with a spacer thickness of $800\mathring{A}$ resulting in peak-mobilities up to $\mu \approx 5 \cdot 10^6 cm^2/Vs$ at densities $n \approx 2.1 \cdot 10^{11}/cm^2$. In comparison with (001) grown structures, the two in-plane orthogonal crystal directions on (110), namely $[1\bar{1}0]$ and [001], have explicitly different crystallographic symmetry. We optimized the growth on (110) GaAs in a such a way, that the samples have excellent morphologies, and to our knowledge the best reported mobilities to date for this crystal orientation.

Due to the fragile nature of the anisotropic ground states it is necessary to measure at very low temperatures, especially in the case of (110) 2DEG's where the mobility is not as high as in (001)-based systems. The measurements are performed in a dilution refrigerator cryostat with a base temperature of $T = 5\,mK$ and a magnetic field up to $B = 6\,T$.

A trace of the longitudinal resistance for two perpendicular current directions at $T = 8\,mK$ is shown in Fig. 1. The fractions from $\nu = 9/2$ upwards show a highly anisotropic behavior, similar to the one already observed in (001) systems. Strong increase of the longitudinal resistance is observed along [001], concomitant with a decrease along the $[1\bar{1}0]$ direction with decreasing temperature, indicating the alignment of striped phases along the $[1\bar{1}0]$ direction (Fig. 2). No anisotropy is observed for the $\nu = 7/2$ resistance peak.

However there is a striking anisotropy developing for lower fractions, especially below filling factor 2 where fractional quantum Hall states are evident (Fig. 1). This is especially pronounced at filling factors $\nu = 7/4$, 13/8 and 11/8 which correspond to the effective filling factors $\nu^* = 3/2$, 5/2 and 3/2 in the composite fermion picture between $\nu = 1$ and 2. Both show a temperature dependence very similar to the one observed at $\nu = 9/2$ (Fig. 2). We emphasize that in Fig. 2, all the resistivity peaks become isotropic again around 100mK. To our knowledge this is the first observation of strong anisotropy of the longitudinal resistance in the fractional Quantum Hall regime, an effect which is puzzling in that, it can not be explained by current theories for higher Landau levels [4].

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[3] J. Zhu et al., Phys. Rev. Lett. 88, 116803 (2002)
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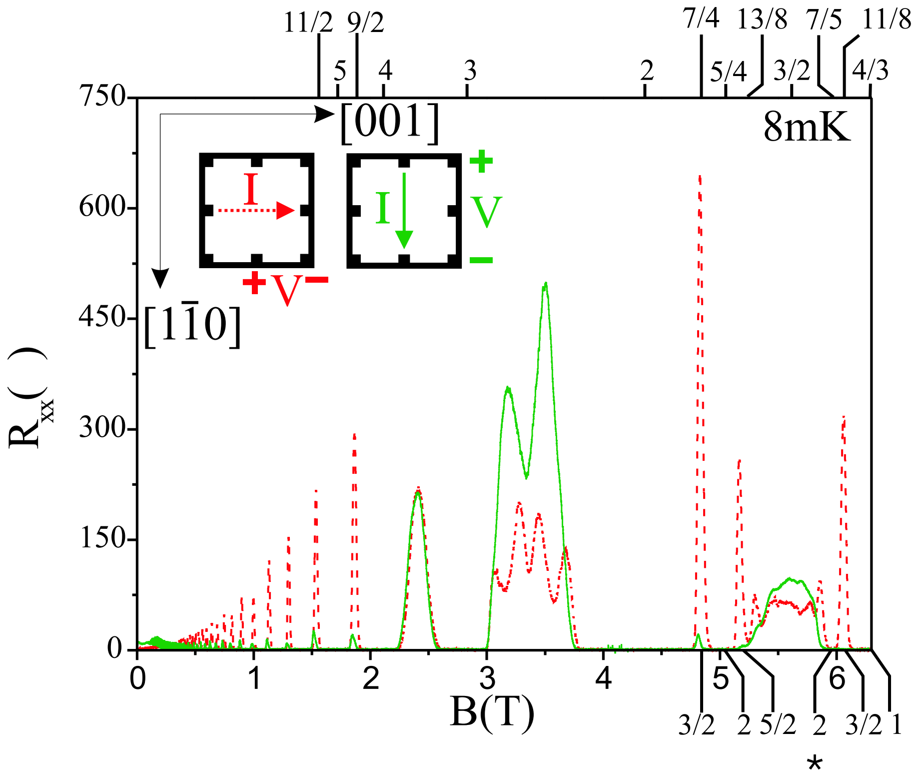

Figure 1: Trace of the longitudinal resistance R_{xx} for the two perpendicular current directions indicated in the inset at $T = 8\,mK$. The low temperature traces develop a strong anisotropy both at $\nu > 4$ ($B < 2\,T$) and strikingly at $\nu < 2$ ($B > 4.5\,T$).

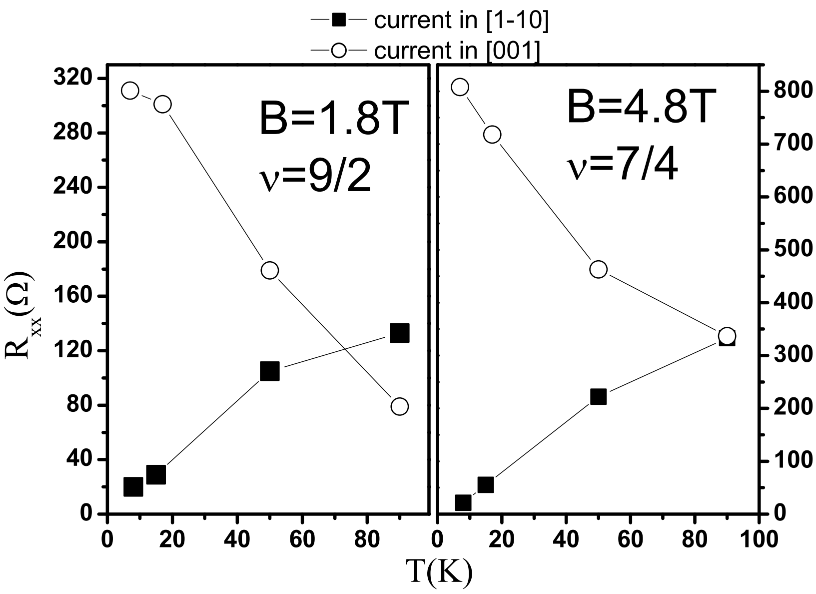

Figure 2: Left graph: T-dependence of the $\nu = 9/2$ maximum for the contact configuration of Fig. 1. Right graph: T-dependence of the maximum at $\nu = 7/4$ for the same contacts.