Time and Current Dependencies of Transport at the ν=2/3 Phase Transition in narrow Quantum Wells

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We have studied the ν=2/3 spin unpolarised to spin polarised transition in narrow GaAs quantum wells (15 nm). The transition is mapped in the density (*n*), filling factor (ν) and tilt angle planes and well described assuming a sqrt(*n*) dependence of the Composite Fermion (CF) mass. At high currents the Huge Longitudinal Resistance anomaly (HLR) appears along the phase boundary[1]. We present detailed time, DC current and AC current measurements that show that i) contrary to the case of AC currents, for DC currents HLR is fully induced only if the *B*-field is swept (slowly), ii) transport in the HLR is linear for low I_{AC} or I_{DC} and iii) once HLR is induced, there is still a small quasi logarithmic change in the resistance on long timescales. To explain the results a model is presented that treats the current induced nuclear spin polarisation as an additional source of disorder as it locally alters the electron Zeeman energy. This 'additional disorder' causes the initial domain structure already present at the phase boundary to change into smaller domains, thus producing more domain walls which leads to more backscattering along domain walls and thus to the huge resistance.

The spin unpolarised to polarised ν=2/3 transition occurs when the cyclotron energy of composite fermions equals their Zeeman energy. In the (density,fillingfactor)-plane the transition in our narrow QWs occurs around 8T and is well described assuming a realistic[2] $\sqrt{n}$ dependence of the CF mass; i.e. $m_{CF}/m_e=1.5*\sqrt{n}(10^{15}\ m^{-2})$ (fig1a). Surprisingly and unexplained however, both the addition of an in-plane magnetic field or an effective thermal nuclear spin field causes the transition to shift considerably less (by up to a factor of 5) than expected.

At high AC or DC currents HLR appears along the phase boundary(fig1b)[1] provided that the *B*-field is swept slowly (≤10 mT/min) (fig2a). At a constant magnetic field however, HLR can be induced fully only by a large AC current. When a large DC current is applied, the resistance initially rises, but after typically 10 minutes, it drops(fig2b). Also a combination of DC current with a density or magnetic field modulation at frequencies between 0.1-100Hz does not induce HLR fully. Only when the frequency of the modulation is extremely low (<<0.01 Hz) a response becomes noticable. It thus seems that variations that are quick on the timescale of the nuclear spin relaxation time (T_1) cannot induce HLR. It is then tempting to attribute HLR induced by I_{AC} to a partial rectification of this current, which would cause a DC-component (that is slow compared to T_1). This is however at odds with small DC current measurements (fig2c) that do not show HLR. Moreover, $I_{DC}(V_{DC})$ and $dI/dV(V_{DC})$ characteristics measured at several stages during the development and saturation of HLR (fig2d), show that the low-current transport is linear. The non-linearity at higher currents occurs instantaneously after switching on the current and is attributed to heating.

[1] S. Kraus et al., Phys. Rev. Lett **89**, 266801 (2002)
[2] I. Kukushkin et al., Nature **415**, 281 (2002)

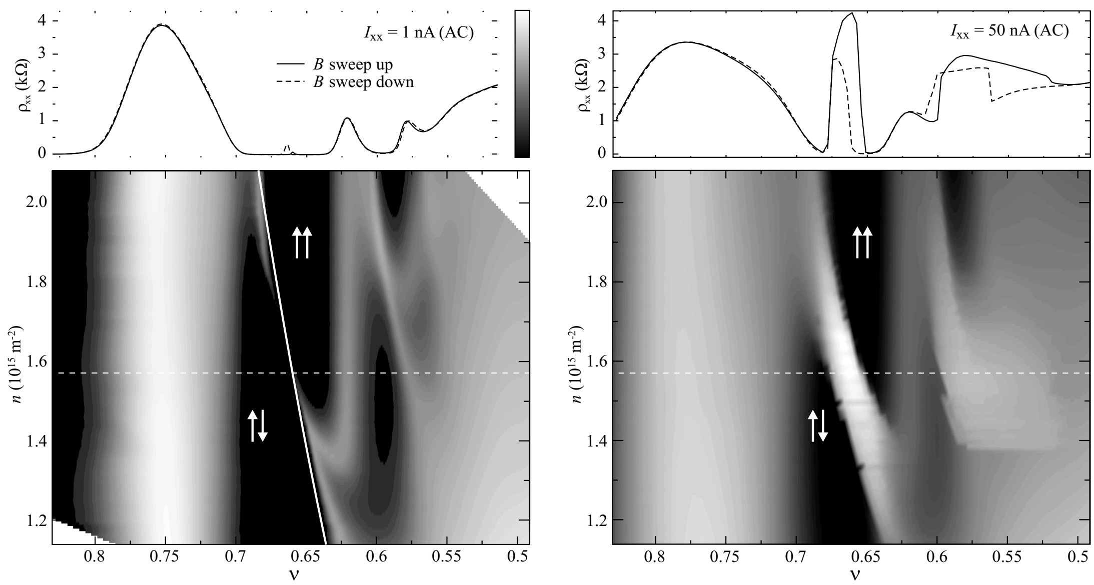

Fig1. Grayscale plot of the longitudinal resistance in the (fillingfactor,density)-plane around ν=2/3 for low currents (left) and high currents (right) at 20 mK. The spin unpolarised to spin polarised phase transition is clearly visible as it shifts through the ν=2/3 minimum. The solid white line marks the position where $E_{Z,CF}=E_{cycl,CF}$ under a √n-dependence of the CF effective mass and describes the phase transition fairly well. At high currents (right) HLR occurs along the phase boundary. Top panels plot ρ_{xx} at a density of 1.58 10^{15} m^{-2} indicated with the dashed line in the lower panel.

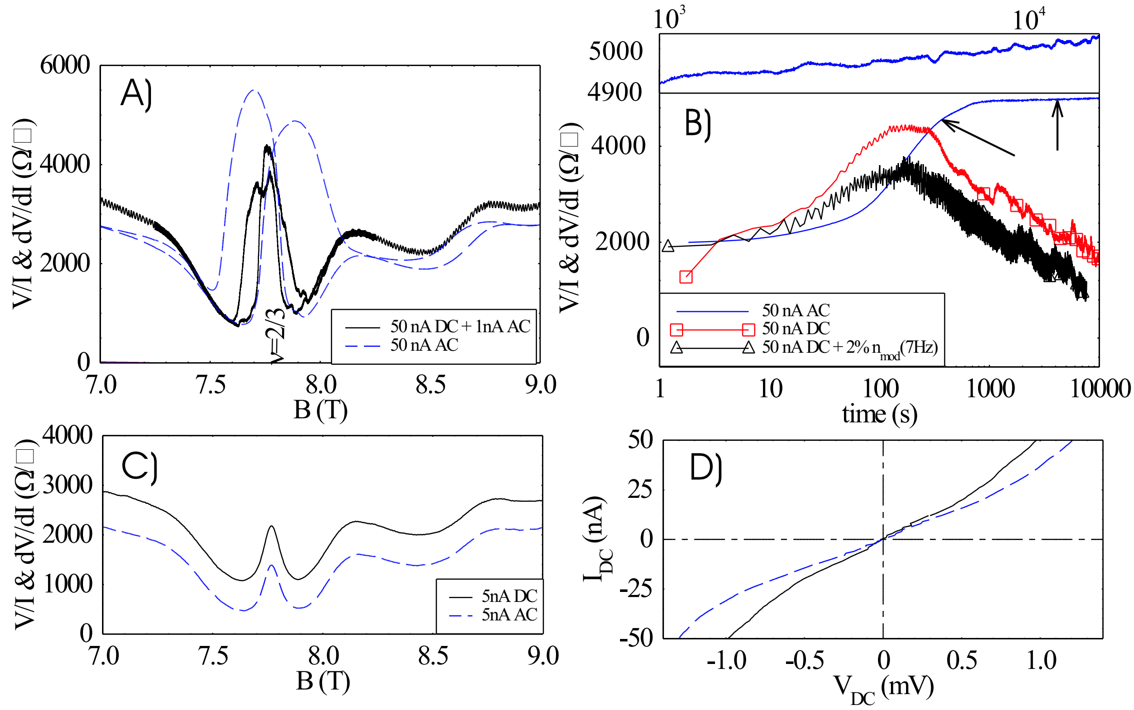

Fig2. A) DC and AC resistance versus magnetic field measured with 50 nA current. B) time dependence of the resistance at *B*=7.77 T after switching the AC or DC current on, showing a full development of the HLR for AC currents and an initial rise followed by an approximate logarithmic decrease for DC currents. Top panel plots a blow-up of the time dependence for AC currents. C) AC and DC resistance versus magnetic field for a low current (curves are offset for clarity). D) $I_{DC}(V_{DC})$ for AC-induced HLR at times indicated with the arrows in fig2B. For low currents (<15nA), transport is linear. For all measurements T=0.25 K