SUMMARY

This thesis is an experimental study on the quantum critical behavior of integer quantum Hall effect transitions that occur in two-dimensional electronic systems at extremely low temperatures. The main contributions of this work are twofold. First, we have accounted for the presence of macroscopic inhomogeneities in realistic samples, and second, our experimental findings of the plateau-insulator (PI) transition at high magnetic fields have led to the establishment of universal scaling functions, enabling a deeper understanding of the problem in the context of the renormalization group (RG).

Before describing the magneto-transport experiments, we examine in Chapter 4 the disorder prerequisites for probing quantum-Hall quantum critical behavior. We find that the quantum critical regime is not only determined by the *amount* of disorder, but also by its *range* as well as by the particular Landau level in which the transition occurs. Short-ranged scattering, at length scales in the order of the magnetic length ℓ_B ($\lesssim$ 20 nm) is essential for proper experimental studies of quantum Hall criticality. The disorder characteristics of two InGaAs/InP heterojunctions with similar sample structure are examined and compared. We find that alloy scattering alone is not sufficient for scaling behavior, and suggest the importance of interface roughness and background impurities in the suitability of the sample for scaling. Hence, for quantum critical experiments MOCVD-grown samples are preferred over those grown under ultra-high vacuum conditions such as MBE and CBE. In the weak localization regime, the phase-breaking exponent p for sample HWP#2 used in subsequent quantum Hall experiments was found to be approximately 1, in accordance with theory.

In Chapter 5 a framework for the analysis of the PI transition in the presence of (weak) macroscopic inhomogeneities is proposed. Starting from the general symmetries in $\rho_{xx}(B)$ and $\rho_{xy}(B)$, and making use of the particle-hole symmetry of the conductances, we arrive at a general form for the PI transition resistivity tensor. The range of validity of this general form is estimated for the case of weak macroscopic inhomogeneities.

Armed with this new framework, we present the experimental results of the PI transition in Chapter 6. We find a scaling relationship with a non-Fermi liquid critical exponent of $\kappa = 0.57$, reflecting the influence of Coulomb interaction between the electrons. Furthermore, the unique behavior of the Hall resistance ρ_{xy} of the PI transition is investigated. We find that ρ_{xy} remains quantized beyond the critical point in the thermodynamic limit ($T \to 0$), but shows a weak power-law divergence for finite temperatures. In this way we are able to identify and measure for the first time the irrelevant scaling exponent y_σ. The PP transitions are also investigated in a similar manner, but due to inhomogeneities the analysis is less robust than that of the PI transition. Furthermore, several critical parameters such as κ are found to be inconsistent with the PI result, undermining the concept of universality. Influence of thermal broadening effects and of the irrelevant scaling field are examined. Away from the critical point we find that the transport mechanism crosses over from an extended bulk state into variable-range hopping. The higher-order terms of the longitudinal resistivity in this cross-over regime are identified for both the PI and PP transitions and are shown to exhibit consistent behavior. Chapter 7 takes the results of Chapters 5 and 6 one step further. Using the universal scaling functions and the experimentally determined values of κ and y_σ we are able to construct the experimental RG β-functions and flow diagram close to the critical point. Employing recent theoretical results and by applying Chern-Simons transformations to our scaling functions we are able to interpolate the complete β-function at $\sigma_{xy} = \frac{1}{2}$, and produce flow diagrams extending into the fractional regime.

In Chapter 8 we present an analytical approach for tackling macroscopic carrier density gradients in the PP and PI transitions, by expanding the resistivity tensor and current density to higher orders in x and y. Our results to cubic order tentatively explain the lower value of κ for the PP transition, as well as the T-dependence of the maximum critical conductivity σ^*.

Finally, in Chapter 9 we investigate the variable-range hopping electron transport in the Landau level tails in the same manner as was recently done by Hohls *et al.* on low-mobility GaAs/AlGaAs samples. By measuring the I-V characteristics on Corbino geometries at various magnetic fields, we are able to extract the localization length directly as function of T for several InGaAs/InP and GaAs/AlGaAs samples. On the whole, the results of both samples are inconsistent with universal scaling behavior. However, this is not surprising in the light that these samples most likely lie outside the critical regime for this temperature range.