SUMMARY

This thesis is devoted to an experimental investigation of the critical behavior of integer quantum Hall transitions in two-dimensional electron systems at low temperatures. One of the main goals of this work is to experimentally verify the concept of universality of the quantum Hall transitions. We especially focus on how macroscopic sample inhomogeneities influence the magnetotransport data. Values of the critical exponents extracted from the experimental transport data are compared to those obtained by numerical calculations for samples with small carrier density gradients.

The critical behavior of the integer quantum Hall effect has been a subject of debate for more than 15 years now. Although the critical indices are predicted to be universal, experimental results reported in the literature often contradict the concept of universality. In the course of this work, we recognized that in our samples the only transition which gives proper access to the critical behavior is the plateau-insulator (PI) transition, which take place when the Fermi level crosses the lowest Landau level. Data taken at the transitions between adjacent plateaus most of the time are not suitable for studying critical behavior as they are strongly affected by inhomogeneities present in the samples.

Before presenting our principal results, we focus our attention on sample selection and on certain important features of the experimental setup (Chapter 2). Since most of our experiments are carried out in strong magnetic fields, the magnetic field dependence of the thermometers was investigated thoroughly, as to avoid systematic errors in the extracted values of the critical exponents. In Chapter 3 we present some selected theoretical aspects of quantum critical behavior in the quantum Hall regime.

The key experiment for understanding the role of inhomogeneities is the observation of reflection symmetry in the longitudinal resistance at the plateau-plateau (PP) transitions (Chapter 4). Such a symmetry is accounted for by a small gradient in the electron density, which can be considered as an inhomogeneity on a length scale larger than the sample size. In some samples, the density gradient can be controlled by simultaneous measurements of the Hall

resistance from two pairs of potential contacts, combined with pulse illumination at low temperatures. By decreasing the density gradient to a very small value, we are able to reveal another aspect of universality - the semicircle law. We show that for a homogeneous sample the components of the conductivity tensor obey the semicircle relation for all resolved PP transitions (thus not only for the PI transition as previously perceived).

Despite the significant progress made in understanding the effect of inhomogeneities in Chapter 4, our semiconductor structures were found to be not suitable for studying critical behavior of the PP transitions. Therefore, in Chapters 5 and 6, we focus on the PI transitions. For two different semiconductor structures we observe proper scaling behavior with very similar values of the critical exponents. The extracted critical exponent $\kappa \approx 0.58$ is significantly larger than the Fermi-liquid value $\kappa = 0.42$, which suggests that Coulomb interactions play an important role in the integer quantum Hall phase transitions. The sample studied in Chapter 5 is the same as in the pioneering work of Wei *et al.*, where the value $\kappa \approx 0.42$ was reported for the first time. With the PI data at hand, we can assert now that the "universal" value reported by Wei *et al.* is largely affected by inhomogeneities and does not represent the true critical exponent. In Chapter 6 we report experiments on a sample with a tunable electron density n_e. The critical exponent κ does practically not depend on the carrier concentration. The tiny increase of κ with increasing n_e is attributed to the overlap of Landau levels at lower electron densities. We also report in Chapter 6 a new way of presenting scaling behavior. This method has a number of advantages compared to the traditional method.

A substantial contribution to this thesis is the numerical simulation of the influence of sample inhomogeneities on the transport properties, described in Chapter 7. Assuming universality of κ for the local resistivity tensor and a constant carrier density gradient, we are able to calculate the 4-point resistances for different temperatures, filling factors and density gradients (directions and magnitude). The results of our simulations are in a good qualitative agreement with experiments. Inhomogeneities strongly affect the width of the PP transitions at low temperatures and result in an underestimated value of the critical exponent κ. Our simulations also reproduce and explain the hitherto not quite understood T-dependence of the maximum of the longitudinal resistance. At the same time, we confirm that the PI transition is robust and insensitive to small gradients in the carrier concentration.