Local investigation of edge channels

In this chapter we discuss measurements aiming at the local investigation of edge channels in the quantum Hall regime. Several techniques will be discussed, which have been reported by a small number of groups worldwide. An experiment will be looked at in more detail in which the tunneling resistance between edge channels was measured. By using a local potential perturbation induced by the tip of a scanning force microscope, it was possible to enhance the tunneling coupling and map its strength along the edge of the two-dimensional electron gas.

16.1 Brief introduction to edge channels

The importance of the sample edge for the quantum Hall effect [48] was pointed out soon after its discovery on the basis of a model of non-interacting electrons [432]. Later interactions were considered by using self-consistent descriptions of the sample edge [50, 433, 434]. Figure 16.1 shows the general notion of the self-consistent potential and the electron density at the sample edge in equilibrium. In the bulk of the electron gas (left in the figure) the Landau levels have an energetic spacing of \( \hbar \omega_c \), where \( \omega_c = eB/m^* \) is the cyclotron frequency, \( B \) is the magnetic field normal to the plane of the electron gas, and \( m^* \) is the effective mass of the electrons. The electron density in the bulk is constant. Near the edge the Landau levels have to follow the increasing electrostatic confinement potential and the electron density has to go to zero. Owing to the density of states in a magnetic field with peaks in energy at the positions of the ideal Landau levels, the density of states at the Fermi energy oscillates strongly as a function of position leading to oscillating screening properties of the electron gas at the edge. Whenever an Landau level crosses the Fermi energy screening is good and the potential flattens out. At the same time the electron density shows a strong gradient. These regions are called compressible strips because they have a finite density of states at the Fermi energy. The regions between compressible strips are called incompressible, because the density of states at the Fermi energy vanishes there. In these strips the potential has a strong gradient while the density is flat. Screening in the incompressible strips is poor. Geller and Vignale have calculated the
equilibrium currents in the compressible and incompressible strips self-consistently [434]. They found that in the compressible regions the current proportional to the density gradient and the current direction leads to a diamagnetic magnetic moment. In the incompressible regions the equilibrium current is proportional to the potential gradient and produces a paramagnetic effect. The subtle interplay between these two spatially separated types of current lead naturally to the oscillatory magnetization of a two-dimensional electron gas as a function of magnetic field [435].

Since the theoretical prediction of the existence of self-consistent edge-channels and compressible and incompressible strips in the quantum Hall regime, there has been a series of experimental attempts to measure local properties at sample edges in high magnetic fields. Electron–phonon interaction was used in first experiments [436]. Optical techniques with a spatial resolution of about 1 μm in the best case also supported the notion of edge channels [437–439]. Later experiments tried to detect the edge currents inductively, but evidence for bulk currents was found [440, 441]. Recently, edge strips were imaged using a metallic single-electron transistor fabricated near the edge of a 2-dimensional electron gas (2DEG) [442].

### 16.2 Scanning probe experiments

It is obvious to employ scanning probe techniques with their unprecedented potential of spatial resolution for such investigations and several experiments have been

![Fig. 16.1. Self-consistent edge channel structure](image-url)