Coupling between edge states studied by time-resolved transport experiments.

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The concept of edge states has proven to be very successful in describing many transport phenomena in two-dimensional electronic systems (2DES). However, the dynamics of current carrying states is not understood in much detail up to now. Our work addresses the problem of the coupling between different edge channels on a very short time scale. We present time-resolved transport measurements on a sample, which allows for selective population and detection of the edge states.

Our T-shaped sample (Fig. 1) is made from an AlGaAs/GaAs heterostructure with a carrier concentration $n_s = 1.8\times10^{15}$ m^{-2} and a mobility $\mu = 70$ m^2/Vs, which contains the 2DES 105 nm under the surface. The experiments were carried out in a dilution refrigerator at a base temperature of 70 mK. A short (1μs) voltage pulse is applied to the contact 4. After propagating through the sample the pulse is detected by two contacts 1 and 2 simultaneously using two identical broad band amplifiers and a multi-channel digital oscilloscope. Two Schottky gates in the middle area are used to locally reduce the electron density and therefore induce a filling factor value different from the one in the bulk. The first gate (G1) acts as an injector of the edge states in the interaction region between the gates. The second gate (G2) redistributes the edge states between contacts 1 and 2 providing selective detection. Thus, for example, at filling factor $b = 4$ in the bulk and filling factor $g_2 = 2$ under this gate, two outer edge channels originating from the lowest Landau level are detected by the contact 1, two inner states by the contact 2.

An example of such redistribution in the DC limit is shown in Fig. 1 for the bulk filling factor $b = 4$. There, all 4 populated channels propagate undisturbed to the G2. The DC values of the conductivity indicate the expected full equilibration between all 4 populated edge channels on a long time scale (Fig. 1). Dynamical study on the time scale of 0-100 ns (Fig. 2) reveals, however, the striking difference between current traces corresponding to the transmission of the various edge channels. One observes that not all edge states are equally involved in the transport at short times. The appearance of similar transmission times for traces 4 and 3 (Fig. 2, upper panel) suggests the existence of the very fast propagating mode of edge magnetoplasmons (EMP) [1], which is strongly confined to the edge states arising from the lowest Landau level. After complete decoupling of the upper Landau level (trace 2), this mode is suppressed due to increased scattering across the incompressible stripe separating these two pairs of channels. Another mode of EMP localized within two compressible stripes formed by the higher Landau level can be observed comparing traces 1 and 2 in Fig. 2, lower panel. This mode propagates slower in accordance with the argument that the velocity of the propagation is inverse proportional to the width of the transmission region.

In addition, other intriguing effects were found in the regime of the non-equilibrated DC transport. E. g., at the bulk filling factor $b = 3$ we are able to inject only the innermost spin polarized edge state in the interaction region using the contact 3 as a source and tuning the filling factor g_1 under the gate G1 to the value of 2. Although, no coupling across the incompressible stripe separating two outer edge states from the injected inner one is found in the DC limit, we clearly observe additional features at times $t < 100$ ns, which we attribute to the excitation of EMP modes in the outer edge states through the capacitive influence of the populated channel.

[1] N. B. Zhitenev *et al.*, Phys. Rev. Lett. **71**, 2292 (1993).

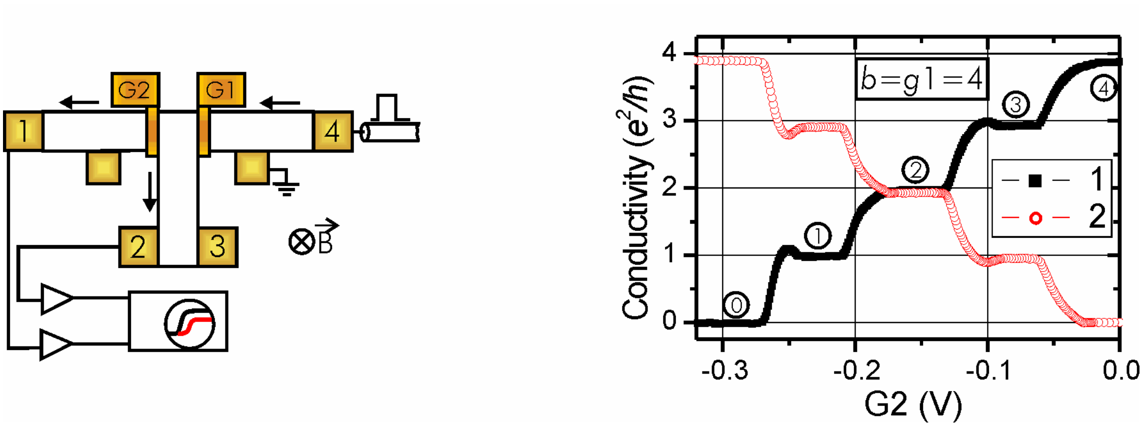

Figure 1: *Left:* Sketch of the experimental setup. The whole sample is covered with a metallic top gate (not shown). The separation of the gates G1 and G2 is 200 µm and the distance from each numbered contact to the interaction region between gates is 500 µm. Arrows denote the direction of the current transmission. Optionally the contact 3 can be used as a source. Time resolution is better then 1 ns. *Right:* Two-point conductivity $\sigma_{4\text{-}1}$ (full) and $\sigma_{4\text{-}2}$ (open) obtained at $t = 1$ µs, where complete saturation of the signal takes place, vs. voltage applied to G2. G1 is grounded, so that all edge states propagate to G2 where they are redistributed. The circled numbers denote the number of edge channels transmitted to the contact 1.

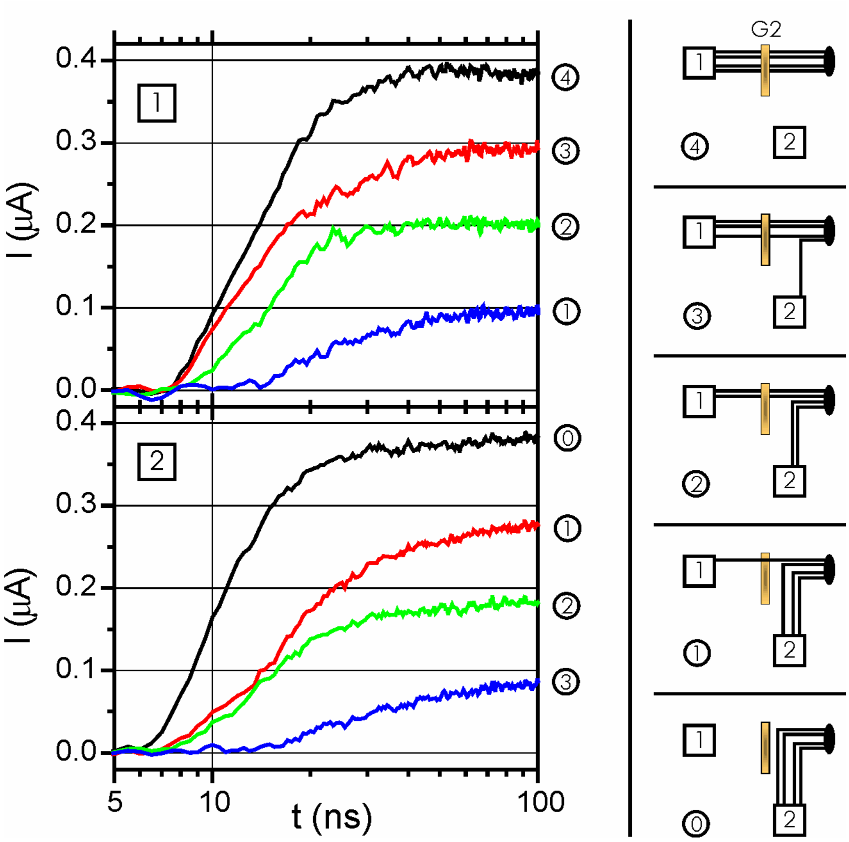

Figure 2: *Left*: Time-resolved current detected on the contact 1 (upper panel) and contact 2 (lower panel) for $b = g_1 = 4$. The circled numbers to the right denote the filling factor g_2 under G2 and hence the number of channels transmitted to the contact 1. After 100 ns the saturated value of the current is almost achieved for all traces on both contacts.
Right: Sketches of five possible configurations of redistribution of the edge states between contacts 1 and 2 for $b = g_1 = 4$ and contact 4 being a source. Squares denote the detecting contacts 1 and 2. Only populated edge states at the high potential boundary of the sample are shown.