Equilibration of integer quantum Hall edge channels studied by scanning gate microscopy

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The concept of one-dimensional (1D) edge channels can be successfully applied to the description of transport phenomena in two-dimensional electron systems (2DES) in the quantum Hall (QH) regime [1]. QH resistance is not sensitive to inter-channel scattering, but there is renewed interest in interactions between copropagating edge channels [2] mostly in view of possible applications in quantum information technology [3]. Inter-channel transport was studied in the past by several authors (for a review, see [1]), but only in devices with fixed channel interaction length d. Here we demonstrate for the first time the use of scanning gate microscopy (SGM) to realize devices in which d can be tuned continuously. We shall argue that this level of control is crucial to pinpoint the exact mechanism of edge-edge interaction.

Figure 1 schematically illustrates our experiment: inner (i) and outer (o) edge channels originate from two distinct voltage contacts at potential V_1 and V_2, respectively. They propagate together for a distance d and are then separated and guided to two current contacts I_A and I_B, respectively. In what follows we set $V_1 = V$ and $V_2 = 0$. If we assume that there is no equilibration between the two (spin-degenerate) edge channels, then $I_A = 2\, e^2/h\, V$ and $I_B = 0$. On the other hand, if we assume that the two edge channels equilibrate their voltage imbalance completely, then $I_A = I_B = e^2/h\, V$. In a model of spatially-uniform interaction one expects differential conductance to scale as $G_B = \partial_V I_B = G_0(1\text{-}e^{-2d/l})$ with $G_0 = e^2/h$ and l the equilibration length [4]. Therefore, a measurement of I_A and I_B as a function of d and V makes it possible to analyze the equilibration behavior and verify if it is indeed consistent with an exponential decay. Moreover it yields the value of l as a function of V.

Devices were realized starting from a high-mobility AlGaAs/GaAs heterostructure. A 6 μm-long 1D channel of two Schottky-gates with a constriction gap of 1 μm was patterned on the sample. Experiments were performed at 300 mK and bulk 2DES filling factor ν = 4 (two spin-degenerate edge channels). The selective backscattering of individual edge channels was achieved by the biased tip of a SGM, as described in detail in Ref. [5]. The inner and outer edge channels meet at the entrance of the 1D channel and travel in close proximity for a distance d before they are separated by the action of the SGM tip. Figure 2 shows the resulting differential conductance G_B as a function of d for a voltage $V = 5$ mV. The curve starts for $d = 0$ at $G_B = 0$, i.e. no equilibration occurs, and nearly reaches $G_B = e^2/h$ for $d \sim 5$ μm, i.e. complete equilibration is achieved.

We shall discuss our experimental results based on a theoretical model which takes into account the effect of impurities present in the 1D channel.

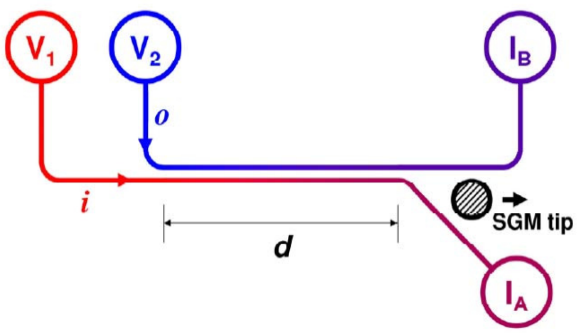

Fig. 1: Sketch of the experimental setup

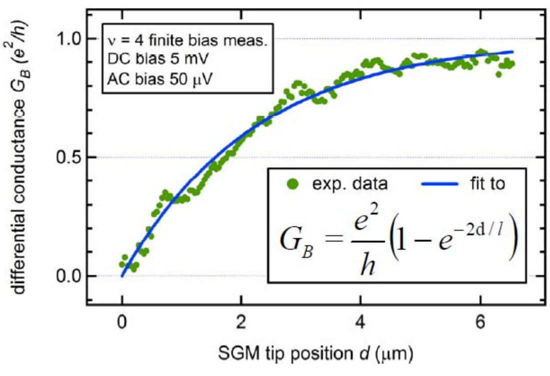

Fig. 2: Conductance G_B vs. d; from fit: l = 4.5 μm

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