Spatially–resolved analysis of edge–channel equilibration in quantum Hall circuits

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The transport phenomena in two-dimensional electron systems (2DES) in the quantum Hall (QH) regime [1] are successfully explained with the concept of 1D channel at the sample edge. The ability of building complex QH circuits with these channels relies on the suppression of the back-scattering due to the spatial separation between counter-propagating edges. On the other hand, the control of the interaction between *co-propagating* (i.e. at the same side of the QH liquid) edge states seems to be the crucial point for the achievement of a new generation of QH interferometers for quantum information technology [2]. In the past, intra-channel transport was studied only in devices with fixed channel interaction length d [1]. Here we demonstrate an innovative quantum Hall circuit in which d can be tuned continuously exploiting the tip of a scanning gate microscope (SGM) as a local gate.

Figure 1 schematically depicts our experiment: inner (i) and outer (o) edge channels originate from two distinct voltage contacts at potential V_1 and V_2, respectively. They travel together for a distance d and are then separated and sent to two current contacts I_A and I_B. By measuring I_A and I_B as a function of d and V we can locally probe the equilibration behaviour.

Samples were fabricated from a high-mobility AlGaAs/GaAs heterostructure. The QH circuit was defined by Schottky-gates patterned on the sample by means of electron beam lithography. Experiments were performed at 300 mK and bulk 2DES filling factor $\nu = 4$ (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. [3]. The inner and outer edge channels meet at the entrance of a 6 μm-long constriction and travel in close proximity for a distance d before they are separated by the action of the SGM tip.

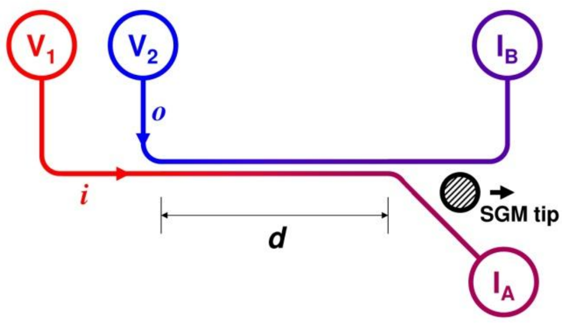

Fig. 1: Sketch of the experimental setup

We exploit this additional degree of freedom offered by the SGM to identify the microscopic mechanisms that allow two co–propagating edge channels to equilibrate their charge imbalance [4]. Experimental results are compared with tight–binding simulations based on a realistic model for the disorder potential. This work provides also an experimental realization of a beam mixer between co–propagating edge channels, a still elusive building block of a recently proposed new class of quantum interferometers.

[1] E. Deviatov: *Edge states in the regimes of integer and fractional quantum Hall effects*, Physics – Uspekhi **50**, 197 (2007).
[2] V. Giovannetti, F. Taddei, D. Frustaglia, and R. Fazio: *Multichannel architecture for electronic quantum Hall interferometry*, Phys. Rev. B **77**, 155320 (2008).
[3] N. Paradiso, S. Heun, S. Roddaro, L. N. Pfeiffer, K. W. West, L. Sorba, G. Biasiol, and F. Beltram: *Selective control of edge channel trajectories by scanning gate microscopy*, Physica E **42**, 1038 (2010).
[4] N. Paradiso, S. Heun, S. Roddaro, D. Venturelli, F. Taddei, V. Giovannetti, R. Fazio, G. Biasiol, L. Sorba, and F. Beltram: *Spatially–resolved analysis of edge–channel equilibration in quantum Hall circuits*, Phys. Rev. B, in press, arXiv:1102.4170v1 [cond-mat.mes-hall].