Tomography and manipulation of Quantum Hall edge channels by Scanning Gate Microscopy

Stefan Heun

NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Pisa, Italy

The interest in the development of solid state quantum devices goes well beyond fundamental research. In the last decade, entanglement of identical particles has become synonymous with quantum computing. In this context, Quantum Hall (QH) systems can be very useful. First of all, being implemented in solid state devices, they can be easily miniaturized and integrated on chip. Moreover, in QH systems, electrons move along counter-propagating chiral channels at sample edges. When the Landau Levels (LL) in the bulk are fully occupied, backscattering between counter-propagating edge states is drastically suppressed. When several LLs are populated, edge channels consist of a series of dissipationless edge states, that can be independently contacted much like a computer bus. Edge channels in the fractional QH regime are even more interesting, since their excitations are expected to display anyonic statistics.

A two-particle entangler can in principle be obtained by subsequently mixing counter-propagating and co-propagating edge channels. While coherent mixing between counter-propagating edge states was achieved by means of quantum point contacts, a coherent mixer operating between co-propagating states has not been demonstrated yet. Giovannetti et al. recently theoretically showed that if a coherent mixer between co-propagating edges is indeed realized, scalable simply-connected interferometers can be build [1].

The application of this scheme to the quantum computation of anyonic qubits crucially depends on the ability to determine (i) how parallel edge channels can be mixed, and whether this mixing is coherent or not; and (ii) the inner structure of edges, and in particular to determine possible fractional components that could be used as a bus of anyonic quasi-particles. We experimentally address these challenging questions by directly manipulating edge channels.

First, we exploited the scanning gate microscopy (SGM) technique to extract spatially-resolved information about the edge-channel inner structure [2]. Our SGM maps provide the first images of the fractional stripes that form the inner-edge structure. The high resolution of the SGM technique allowed us to directly measure stripe widths and compare them with the predictions of theory.

Next, we designed a QH circuit whose geometry can be controlled by moving the tip [3]. Such an innovative device was employed to locally investigate the microscopic processes that are responsible for charge equilibration of bias imbalanced co-propagating channels. I will discuss how such device can be exploited as a beam mixer in simply-connected Mach-Zehnder interferometers.

[1] V. Giovannetti, F. Taddei, D. Frustaglia, and R. Fazio, Phys. Rev. B **77**, 155320 (1990).

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