Non-Equilibrium Edge Channel Spectroscopy in the Integer Quantum Hall Regime.
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Measuring the electron energy relaxation in a conductor requires an access to the electron energy distribution function. Such an access was achieved in an elegant experiment with a metallic nanowire over a decade ago [1]. The out-of-equilibrium electron distribution there was created by applying a finite bias V to the wire. In the absence of relaxation, the distribution function at some point x within the wire would be

$$f(x,E)=(x/L)f_L(E)+(1-x/L)f_R(E)\,.$$

Here L is the wire's length and x is measured from its left end, and $f_{L,R}(E)$ are Fermi functions with different chemical potentials ($\mu_L-\mu_R=eV$). The the distribution was inferred from a small tunnel current "siphoned off" the wire though a tunnel junction to a superconducting electrode. Moving the sharp BCS feature of the electrode's density of states along the energy axis by a voltage applied to the electrode, the authors of Ref. [1] were able to scan the energy distribution function $f(x,E)$ at the position of the junction. These scans first posed a puzzle of anomalously fast relaxation. Later on, the puzzle was resolved by relating the fast relaxation to the presence of minute amounts of magnetic impurities. The experimental verification of their role involved measurement of $f(x,E)$ in the presence of strong magnetic field (needed for Zeeman splitting of the impurities states) [2]. Magnetic field rendered superconducing lead useless, but the authors of [2] successfully used the zero-bias tunneling anomaly caused by electron-electron interaction in the resistive normal lead.

Being made of conventional metals, wires in experiments [1,2] measured hundreds or thousands of Fermi wavelengths in width and thickness. What happens with the electron energy relaxation if the number of channels is reduced to a few? The technique developed in [1,2] was applied to carbon nanotubes [3], but the data interpretation was complicated by unwanted (in that case) Luttinger liquid effects.

The reviewed here work [4] of Altimiras *et al* applied a variation of the same technique to measure the out-of-equilibrium electron distribution in an edge state formed in the conditions of integer quantum Hall effect. In the simplest picture, such states are described by a one-dimensional chiral Fermi liquid, for which the complications with the interpretation of the measurement are minimal. The applicability of a single-mode description though is questionable, as it does not account for the screening of electrostatic confinement potential and also ignores the possibility of edge reconstruction. Despite these potential problems, the obtained experimental data apparently are well-explained by propagation of a two-step fermion energy distribution function along an edge. The experiment demonstrated very little relaxation over a length of $\sim 0.8\mu$m at temperatures $T \sim 0.1K$

In conditions of the experiment, the filling factor was kept at $\nu = 2$. The two-step distribution function,

$$f_D(E) = \tau f_{D1}(E) + (1-\tau) f_{D2}(E)$$

was created in the outer edge channel by injecting additional carriers through a biased (with respect to $D2$) quantum point contact ($D1$) of transmission coefficient τ. The distribution was sensed by measuring tunnel current passing through a resonant level formed in a quantum dot (the level's energy was controlled by a separate electrostatic gate). The two-step structure of $f_D(E)$ was checked for a fixed bias of $V = 36\mu$V between the electrodes $D1$ and $D2$ and full range of transmissions, $0 < \tau < 1$. In addition, this structure was also verified at $\tau = 0.5$ as a function of V in the range between -18μV and 54μV.

The slight evolution of the distribution function over 0.8μm separating the point contact and quantum dot does not allow to infer the energy relaxation length for the edge channel (if at all such a characteristic makes sense). Altimiras *et al* checked though that the energy remains within the probed mode, and apparently excluded the energy exchange with the other edge channel which should exist at $\nu = 2$ but was not directly contacted in the conditions of the experiment. This work is the second recent measurement addressing the energy distribution equilibration in an integer quantum Hall effect edge state. The earlier work [5] addressed cooling of electrons propagating along an edge of $\nu = 1$ state. Experiments with various samples and contacts configurations indicated the electrons cool off after passing $\sim 20\mu$m along the edge. Therefore there is no at least obvious contradiction between the data of the two experiments [4,5]. The energy relaxation mechanisms for the edge states apparently [5] are not fully understood yet.

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