Probing energy relaxation in quantum Hall edge states utilizing quantum point contacts

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Quantum Hall edge states attract strong interests in basic science and application to quantum electronics because of their long coherence lengths in solids and well defined chiralities. For the application of quantum Hall edge states, it is important to investigate the local electronic properties in microscopic way. Recently, experiments probing the local electronic states and energy relaxation in quantum Hall edge states utilizing quantum dots as local probes have been reported [1]. In our experiment, we measured the local electronic states with a different kind of probe: quantum point contacts (QPCs). With this local probe, we investigated the spatial change of the electronic states and evaluated energy relaxation lengths. By comparing the results with previous experiments, we have checked the validity of our method. We applied this method to probe energy relaxation around a specific energy dissipation point called as a hotspot in quantum Hall regimes which is formed near a gate by applying large bias across the gate and creating hot electrons.

Figure (a) shows a schematic of the device structure. Five QPCs connected to a mesa were fabricated on a GaAs/AlGaAs heterostructure wafer. Non-equilibrium energy distribution in the edge channels, which induced the energy relaxation, was generated by using QPC_1 and the change of the local electronic states was monitored by QPC_n with different propagation lengths d. First, we measured the energy relaxation only with energy exchange between edge channels. We set the conductance through QPC_1 to e^2/h and created the distribution with two Fermi levels (μ_0 and μ_1) with $\mu_1 - \mu_0 = eV_1$ in the outer edge channel and measured the voltage V_n at QPC_n. The observed change of the signal (dV_n/dV_1) as a function of d is shown in Fig. (b). We observed decay of dV_n/dV_1. From the fitting, the relaxation length was evaluated as 3 ± 1 μm. We did same measurement in the case of the energy relaxation with electron tunneling between edge channels. The obtained relaxation length was > 30 μm. These results are consistent with previous reports [1, 2, 3] and show the validity of our method. We applied this method to probing energy relaxation around a hotspot created by hot electrons. We observed relaxation length of 2 ± 1 μm and this implies the possible relaxation mechanism is the energy exchange without electron tunneling.

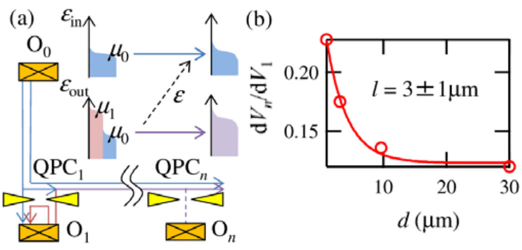

Figure: (a) Schematic of the device structure. We prepared five QPCs to initialize (QPC_1) and probe local electronic states ($QPCn$, n = 2, 3, ···, 5) in the quantum Hall edge states. (b) dV_n/dV_1 as a function of d. The solid line is the result of fitting.

[1] H. le Sueur *et al.*, Phys. Rev. Lett. 105, 056803 (2010).
[2] G. Müller *et al.*, Phys. Rev. B 45, 3932 (1992),
[3] S. Komiyama *et al.*, Phys. Rev. B 45, 11085 (1992).

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