Deformation and Dynamics of Excitations of Quantum Hall Edges

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Quantum Hall (QH) edge state is one of the one-dimensional electron systems and can be described as a chiral Luttinger liquid, whose position can be defined by voltage applied to a metal gate on the sample surface. Recently, there has been a proposal to utilize such edge manipulation to perform analog universe experiments by expanding and contracting the edges [1, 2]. Using the technic of scanning optical stroboscopic confocal microscopy [3, 4], we succeeded in arbitrarily controlling the edge position under a translucent gate with our ultrafast spectroscopy system. We also found untrivial disappearance of edge excitation (EE) signals in certain conditions in fractional quantum Hall (FQH) regime. In this presentation, we present our works for visualization of deformation of QH edges and investigation of the untrivial disappearance phenomenon.

In this work, A 15 nm GaAs-AlGaAs quantum well was used as 2DEG and two metal gates, excitation gate for generating excitations of QH edges and translucent gate for applying local external potential to electrons of the 2DEG under the gate, which had capacitive couplings to the 2DEG were fabricated on the sample surface. We used a Ti-Sapphire pulse laser (period ~13 ns, width ~1 ps, central wavelength ~790 nm) as the light source and square-wave pulse voltage (100 mV → -100 mV falling pulse, width 2 ns) synchronized with the pulse light was applied to the excitation gate to excite the QH edges. Time-resolved measurements were made by varying delay time t_{delay} of the pulse light relative to the pulse voltage. The pulse light was focused to the quantum well by a lens so that the spot had its diameter of ~1 μm, and photoluminescence (PL) of the generated charged excitons was collected and detected with a monochromator and a CCD for spectroscopy.

We calculated intensity of collected light by integrating within an energy range of photons, e.g., normalized reflectance intensity I_{ref} (Fig. 1 (a)) and normalized PL intensity I_{PL}, and normalized PL intensity ratio γ_{PL} to the standard delay time in time-resolved measurements. Decreasing PL intensity ratio, which represents EEs, were observed near the sample edge (Fig. 1 (b)) and the boundary of the translucent gate (Fig. 1 (d)) at $\nu = 1/3$ FQH state by applying the different translucent gate voltages. We interpret we succeeded in imaging of switching paths of QH edges by applying external potentials. However, at certain conditions, the signal of the EEs became unclear and branched out into two paths as shown in Fig. 1 (c). This behavior of the EEs has never been reported and we will discuss more detailed experimental results in this presentation.

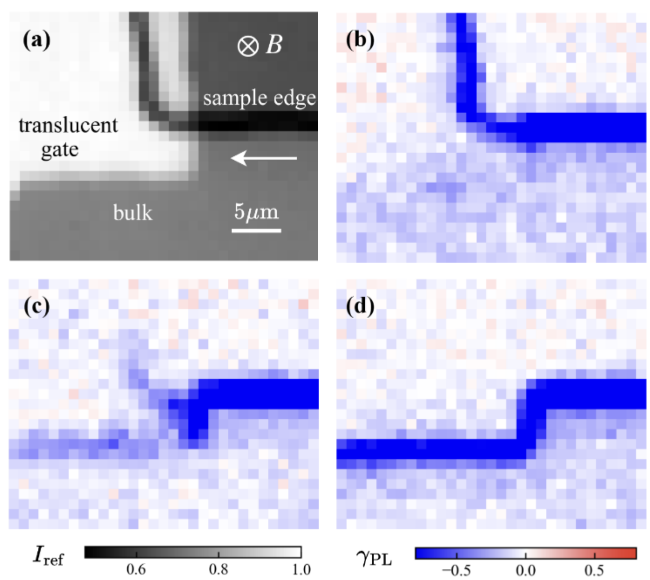

Fig. 1. (a) Image of I_{ref} integrated between 1551.3 and 1587.9 meV around the translucent gate. The arrow in white indicates the direction of EEs' flow. (b)-(d) Images of γ_{PL} in the corresponding region to (a) while applying DC voltages to the translucent gate, (b) +0.5 V, (c) 0.0 V, (d) -1.0 V, at temperature 51 ~ 58 mK and magnetic field B = 14 T. The intensities were integrated between 1532.0 and 1533.4 meV and the intensity ratios at $t_{\mathrm{delay}} = 5.0$ ns to 2.5 ns.

References

[1] M. Hotta *et al.*, Phys. Rev. A **89**, 012311 (2014)
[2] M. Hotta *et al.*, Phys. Rev. D **105**, 105009 (2022).
[3] A. Kamiyama *et al.*, Phys. Rev. Res. **4**, L0123040 (2022).
[4] A. Kamiyama *et al.*, Appl. Phys. Lett. **122**, 202103 (2023).