Imaging of spin-resolved quantum Hall edge states by near-field scanning optical microscopy

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The Hall conductance is closely related to the topological invariant Chern number [1] and the low energy excitations in the edge state characterize topological quantum liquids through the bulk-edge correspondence [2]. Thus the edge states are closely related to the bulk property, and for this reason the edge states have received much attention recently, for example, to clarify the symmetry of pair potential of a topological superconductor [3]. The chiral edge states in the integer quantum Hall effect is the simplest but most useful system to investigate the topological nature of quantum liquids. An optical approach was demonstrated to be a strong tool for the measurement of spin polarizations of the electrons in the edge states [4]. There are several reports on mappings of the quantum Hall edge states, but direct spin-resolved mappings of the quantum Hall edge states have not been reported.

Here we report on Hall photovoltage mappings of the spin-resolved quantum Hall chiral edge states using a near-field scanning optical microscope (NSOM) [5]. Spatial profiles of the photovoltage are investigated depending on the sign of magnetic field (B) and the circular polarizations of the incident beam. The sample was a standard Hall-bar structure of a GaAs/AlGaAs modulation-doped single heterojunction with a mobility of 178 m^2/Vs. A tunable laser beam was irradiated on the sample surface through the NSOM probe aperture at the excitation power of less than 1 nW. The polarization of the incident beam was controlled by a Berek compensator and a polarizer located close to the dilution refrigerator.

Figure 1 shows B dependence of a mapping of the spatial derivative of the photovoltage (dV/dx) at the excitation energy of E_p=1.5194 eV irradiated with an unpolarized beam. The position with large dV/dx (red) corresponds to the position of the incompressible strips. In-between the incompressible strips with even local filling factor (ν_L), the photovoltage signals due to odd ν_L are clearly observed at around B=3.50, 2.62, and 2.06 T. Circular polarization dependence of the photovoltage signals has been investigated at odd and even ν_L at E_p=1.5120 eV near the onset of the absorption at B and $-B$. The obtained scanning photovoltage mappings clearly indicate that the degree of circular polarization is large at odd ν_L in the vicinity of the edge. Our results open up a novel method to investigate spin selective mappings of the edge states of topological quantum liquids. This work was partly supported by Kakenhi Nos. 20104005, and 20221007 and 21340076.

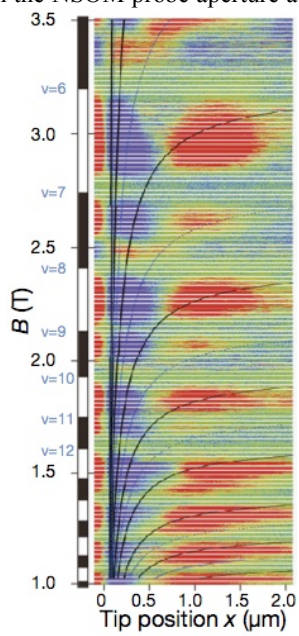

Fig. 1 Magnetic field dependence of a mapping of dV/dx at E_p=1.5194 eV at T = 250 mK.

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