# §33. The Quantum Transport Phenomena in the Non-equilibrium System in the Strong Magnetic Field

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We study the Nernst effect in the two dimensional electron gas (2DEG) system in the regime where the ballistic conduction is almost realized, aiming at the investigation of the transport phenomena of charged particles and the thermal transport phenomena in the non-equilibrium quantum system.

The Nernst effect in a bar of conductor is the generation of a voltage difference in the *y* direction under a magnetic field in the *z* direction and a temperature bias in the *x* direction. Each of the left and right ends of the conductor is attached to a heat bath with a different temperature, $T+$ on the left and $T-$ on the right. An electric insulator is inserted in between the conductor and each heat bath, so that only the heat transfer takes place at both ends. A constant magnetic field $B$ is applied in the $z$ direction. Then the Nernst voltage $V_N$ is generated in the $y$ direction.

Our basic idea is illustrated in Fig.1.[1] An edge current circulates around the Hall bar when the chemical potential is in between neighboring Landau levels. The edge current along the left end of the bar is in contact with the heat bath with the temperature $T+$ and equilibrated to the Fermi distribution $f(T+, \mu+)$ while running from the corner $C_4$ to the corner $C_1$. The edge current along the upper edge runs ballistically, maintaining the Fermi distribution $f(T+, \mu+)$ all the way from the corner $C_1$ to the corner $C_2$. It then encounters the other heat bath with the temperature $T-$ and equilibrated to the Fermi distribution $f(T-, \mu-)$ while running from the corner $C_2$ to the corner $C_3$. The edge current along the lower edge runs ballistically likewise, maintaining the Fermi distribution $f(T-, \mu-)$ all the way from the corner $C_3$ to the corner $C_4$. The Nernst voltage $V_N$ is thus generated.

Using a simple argument based on edge currents, we predict that, when the chemical potential is located between a pair of Landau levels, (i) the Nernst coefficient is strongly suppressed and (ii) the thermal conductance is quantized with the unit $\pi k_B^2 T / 3\hbar$.

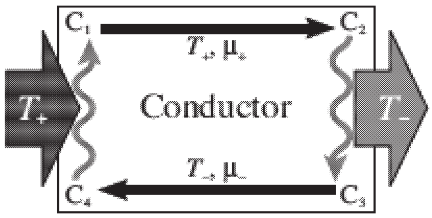


Figure 1: A schematic view of the dynamics of electrons in a Hall bar under the setup for the Nernst effect.

We must take account of effect of impurities on the thermoelectric coefficients when the chemical potential coincides with a energy level of the bulk states. We apply the self-consistent Born approximation to the 2DEG system. We consider the equations of the heat conduction and the thermal electric current based on the current-current correlation functions. Quantization of the thermal conductivity and the quantum Nernst effect are demonstrated numerically (Fig. 2). The fluctuation of the thermo-electric power is induced by the impurity scattering in the bulk states.

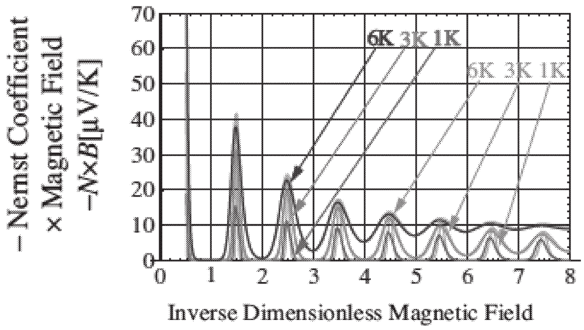


Figure 2: Scaling plots of the Nernst coefficient against $1/B$.: The curves indicate the results at $T$=1,3,6 K, respectively. The gray curve corresponds to the ballistic transport.

[1] H. Nakamura, N. Hatano and R. Shirasaki, Solid State Comm. **135**, 510 (2005).

[2] R. Shirasaki, H. Nakamura, and N. Hatano, *e-J. Surf. Sci. Nanotech.* **3,** 518 (2005).