# §29. The Quantum Nernst Effect in 3D Charged Particle System under the Strong Magnetic Field

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We have been studied the quantum Nernst effect (QNE) in the electron gas system (EGS) 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 is a thermoelectric phenomena which yields the transverse voltage when there is a magnetic field perpendicular to the temperature gradient. We study the QNE in 3D EGS to explain the QNE measured in Bi crystal by Behnia et al. [1], extending the theory on the QNE in 2D EGS [2].

We consider 3D EGS in the magnetic field setting the Hamiltonian divided in two parts:

$$H = H_{xy} + \frac{\hbar^2}{2m_z} k_z^{\,2}, \tag{1}$$

where $m_z$ is the zz component of the electron effective mass. The first term in the right hand side of eq.(1) is the dynamical part in the plane perpendicular to the magnetic field and the second term is the dynamical part in the direction parallel to the magnetic field.

We can see that, as with the case of the formation of the Landau levels in 2D EGS, the electron band is divided in sub-bands which have the dispersion relations of the form

$$\hbar^2 k_z^{\,2}/(2m_z) + \hbar\omega_B (n + 1/2), \tag{2}$$

where $\omega_B$ is the cyclotron frequency and $n$ is the integer enumerating the Landau levels.

Introducing the transport coefficient $L^{(ij)}{}_t(T,\mu)$ of 2D EGS described by the Hamiltonian Hxy, the transport coefficient $L^{(ij)}(T,\mu)$ of 3D EGS in the strong magnetic field is expressed by

$$L^{(ij)}(T,\mu) = \int_0^\infty \int_{-\infty}^\infty \left( -\frac{\partial f(T,\varepsilon-\mu)}{\partial \varepsilon} \right) (\varepsilon-\mu)^{i+j-2} \frac{\sqrt{2m_z}}{2\hbar\sqrt{E}} L^{(11)}{}_t(0,\varepsilon - E)\, d\varepsilon dE. \tag{3}$$

where $f(T,\varepsilon-\mu)$ is the Fermi distribution function.

We estimated the Nernst coefficient of Bi crystal considering the contribution from holes in Bi. Fig.1 shows the relation between the product of the Nernst coefficient multiplied by the magnetic field and the inverse magnetic field. The dimension of the vertical axis is $\mu V/K$. The peaks of the Nernst coefficients survive in three dimensions. However the actual value of the Nernst coefficient in the realistic Bi crystal is tens of times as large as the theoretical value. To explain the difference between the experimental value and the theoretical value of the Nernst coefficient, we should consider the phonon-drag effect in the Bi crystal. This is very interesting problem exploring in the future.

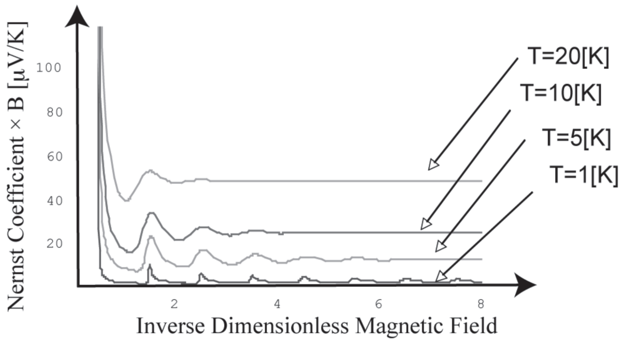


Fig. 1. The relation between the product of the Nernst coefficient multiplied by the magnetic field and the inverse magnetic field. The temperature is selected to be 1[K], 5[K], 10[K], and 20[K].

[1] K.Behnia, M.A. Measson, Y.Kopelevich, Phys. Rev. Lett. **98**, 166602 (2007)

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