Electron Transport in Quasi One-Dimensional Systems Induced by a Strong Magnetic Field

T. Kubo

Department of Physics, Tokyo University of Science, Tokyo, Japan

A three-dimensional conductor placed in a strong magnetic field such that only the lowest Landau level is occupied (quantum limit, QL) provides quasi one-dimensional system. We thus expect its transport properties to be similar to those of one-dimensional systems. Effects of the electron-electron interaction on the electron transport in the magnetic-field-induced quasi one-dimensional systems have recently been studied by several authors [1-3]. In such systems, measurement of the electron tranport is much easier than in one-dimensional systems. Moreover, one may be able to extract the interaction effects from the experimental data by making use of the magnetic field dependence of the transmission probability. Thus it is important to estimate the parameters which determine the temperature dependence of the transmission probability in approximations as good as possible, in order to verify the interaction effect from the experimental data. The important parameter are $\tilde{V}(0)$, and $\tilde{V}(2k_F)$, where $\tilde{V}(q)$ is the Fourier transform of the interaction, $\tilde{V}(0)$ is divergent, and in Refs. [1] and [2] the authors used the static screened coulomb interaction for $\tilde{V}(0)$, and $\tilde{V}(2k_F)$. We show that this replacement is not appropriate. We will see that we should use dynamical screened interaction for $\tilde{V}(0)$ and bare coulomb interaction for $\tilde{V}(2k_F)$.

We investigate effects of the electron-electron interaction on the transmission probability of electrons through a tunnel junction in QL. Starting with the Hartree-Fock approximation, we show that the coulomb interaction, which gives rise to the divergence of Fock correction, should be replaced by the dynamically screened interaction. We also show that one should use the bare coulomb interaction for Hartree term. However, the results obtained by the perturbation theory diverge logarithmically at low temperature. So we take into account higher order contributions using the poor man's scaling approach. The temperature dependence of the transmission probability is qualitatively similar to that of a one-dimensional Tomonaga-Luttinger (TL) liquid, except that the parameter of the electron-electron interaction is magnetic field dependent, and may be either positive or negative. We show the magnetic field dependences of the parameter in some cases. This result is different from that of TL liquid, and the electron-electron interaction may either suppress or enhance the transmission. On the other hand, it is well-known that the electron-electron interaction in QL leads to a charge density wave (CDW) [4,5]. We also investigate the crossover between TL liquid regime and the field-induced CDW regime.

Furthermore, we investigate the possibility of the Peierls instability in the electron-lattice system in QL, i.e. the instability caused by the electron-phonon interaction. We also study the dynamics of Peierls-Fröhlich state in QL. The magnetic field dependences of some physical quantities are estimated in QL.

References

[1] C. Biagini, D. L. Maslov, M. Yu. Reizer, and L. I. Glazman: Europhys. Lett. **55** (2001) 382.
[2] S.-W. Tsai, D. L. Maslov, and L. I. Glazman: Phys. Rev. B (Rapid Commun.), **65** (2002) 241102.
[3] T. Kubo and A. Kawabata: J. Phys. Soc. Jpn. (to be published).
[4] H. Fukuyama: Solid State Commun. **26** (1978) 783.
[5] D. Yoshioka and H. Fukuyama: J. Phys. Soc. Jpn. **50** (1981) 725