Current Fluctuations in Mesoscopic Systems

Kensuke Kobayashi [1]

[1] *Graduate School of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan*

By virtue of nanofabrication technique we are able to investigate fascinating behaviors of "mesoscopic systems", namely, electronic devices that work in quantum regime. Since 1980’s they have been serving as ideal test-beds to demonstrate various quantum effects in a controllable and thus transparent way, as the electron transport through a single quantum site can be precisely probed and tuned. Especially, the Landauer-Büttiker formalism embodies this advantage of mesoscopic physics as has been successfully applied to many mesoscopic conductors (e.g. Aharonov-Bohm ring, quantum dot etc.), through which mesoscopic physics has been established [1].

So far, researchers in this field have mostly focused on the electric current, which is the average number of electrons that pass through the system for a finite time. These days, however, fluctuation (or "noise") in electric current, namely the fluctuation of the number of electrons passing through the system, is invoking great interest [2].

In this Lecture, I would like to discuss what we can learn from noise in mesoscopic systems. After introducing mesoscopic transport and noise, I will discuss non-equilibrium behavior of the many body state formed at a quantum dot where the Kondo effect occurs [3]. This topic clearly tells the significance to study noise.

The Kondo effect is a typical many body effect associated with spin, and therefore, its realization in a quantum dot (QD) in 1998 [4] has made it possible to test various theoretical predictions for Kondo physics. As shown in Figure 1, a single Kondo state can be formed in a quantum dot coupled to the leads. By tuning several parameters such as the number of spins in the dot, the temperature, the magnetic field, and the source-drain voltage, we can precisely address the behavior of the Kondo state from equilibrium to far-from-equilibrium. Especially, the non-equilibrium aspects of Kondo physics are recently attracting great interest. To understand how many-body states behave in the non-equilibrium still remains a big challenge in modern physics.

Recently, we have experimentally tuned a single-carbon-nanotube quantum dot in an ideal Kondo state and have successfully established non-equilibrium universal properties of the Kondo state. We detected an enhancement of the current fluctuations, which is perfectly explained by an effective charge for quasi-particles induced by residual interaction. Our achievement will pave a new road toward fully controlling quantum many body states [3].

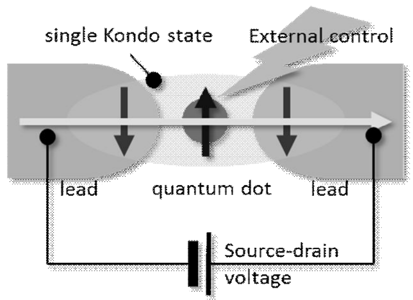

Figure 1: Kondo state formed in a quantum dot.

[1] S. Datta, *Electronic Transport in Mesoscopic Systems* (Cambridge University Press, Cambridge, England, 1997).
[2] Ya. M. Blanter and M. Büttiker, *Phys. Rep.* **336,** 1 (2000).
[3] M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, A. Oguri, K. Kobayashi, *Nature Physics* **12,** 230 (2016).
[4] D. Goldhaber-Gordon *et al., Nature* **391,** 156 (1998); S. M. Cronenwett, T. H. Oosterkamp, and L. P. Kouwenhoven, *Science* **281,** 540 (1998); J. Schmid, J. Weis, K. Eberl, and K.v. Klitzing, *Physica B* **256-258,** 182 (1998).