Nonequilibrium Steady States and Current Fluctuation of an AB Ring with a Quantum Dot

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For mesoscopic systems consisting of Aharonov-Bohm ring (AB ring) with a quantum dot (QD), the asymmetric conductance peak is known to be induced by a coupling between discrete states in the QD and continuous conduction arm (the so-called Fano resonance) [1]. The shape of the resonance peak is drastically affected by a magnetic flux enclosed with the two paths and the conductance oscillates periodically with respect to it due to the interference effect (AB oscillation). It is interesting to see how these features appear in the nonequilibrium regime and few approaches have been done to see such features. We rigorously investigate nonequilibrium-steady-states (NESS) and transport for a non-interacting model of an AB ring with a QD. The NESS is explicitly constructed with the aid of the method of C^*-algebra (see [2]). We then examine the bias-voltage-dependence of the Fano shapes and AB oscillation as well as the current fluctuation [3]. Here, after reviewing the previous results, we report on the magnetic-field-dependence of the current fluctuation at far-from-equilibrium regime.

The NESS for the above mentioned model are constructed as follows. The asymptotic in-coming field operators of conduction electrons are obtained and are used to represent the original operators. Initially the two electrodes are prepared to be in equilibrium with different temperatures and chemical potentials. Then the system evolves according to the total Hamiltonian and NESS can be obtained as $t \to +\infty$-limit. So-obtained NESS are quasi-free invariant states with non-vanishing currents. Then the steady-state current and its fluctuation are investigated as functions of the dot level and the bias voltage.

The wave-like behavior of electrons causes the Fano resonance. On the other hand, their particle-like behavior may be seen in the shot noise. In order to see their interplay in the nonequilibrium regime, the relative current fluctuation (fluctuation over current) is investigated in detail. Figures 1 and 2 show the magnetic-flux-dependence of the relative current fluctuation. In the low bias regime, when the current takes its minimum due to the destructive interference, the noise is almost Poissonian and when the current takes its maximum due to constructive interference, the fluctuation is suppressed. On the other hand, when the bias is high, the relative fluctuation does not show the peak-and-dip structure and does not strongly depend on the magnetic flux. This indicates that the contribution of the tunneling through the QD becomes relatively small as the bias voltage increases.

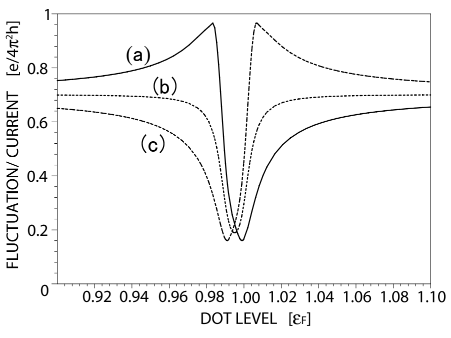

Fig.1. Relative fluctuation at low bias voltage eV ($eV/\epsilon_F = 0.01$. ϵ_F: Fermi energy at $eV = 0$) (a) magnetic flux $\varphi = \pi$, (b) $\varphi = \pi/2$, (c) $\varphi = 0$

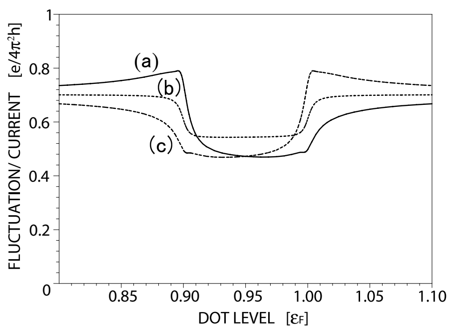

Fig.2. Relative fluctuation at high bias voltage eV ($eV/\epsilon_F = 0.1$) (a) $\varphi = \pi$, (b) $\varphi = \pi/2$, (c) $\varphi = 0$

References

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