# Periodic Orbits Versus Transport In Open Chaotic Quantum Dots

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Almost a decade ago, Richter[1] and Hackenbroich-von Oppen[2] calculated the conductivity of clean antidot lattices using semiclassical approximation to the Kubo formula for conductivity, finding that it can be expressed as a summation over periodic orbits that are trapped in the corresponding classical system. Since quantum mechanically, Kubo formalism and Landauer-Büttiker formalism are equivalence to each other, one can ask whether we could have a periodic-orbit formula for the latter.

Here, we consider a quantum cavity connected to large baths of source and drain via entrance and exit quantum point contacts (QPCs) with effective length $L$ (see Figure 1). In real experiments, QPCs are soft-walled. We therefore assume that the transversal profile of the lower part of the QPCs can be approximated by harmonic potential. We realize that experiments are done in the large potential curvature $\omega$ so that the transverse component of the ground state is a very narrow Gaussian wave packet, whose width is typically much smaller compared to the width of the QPCs.

Considering this experimental facts and using Landauer-Büttiker formalism, we found that the quantum correction of the lowest mode conductance at Fermi energy $E_F$ can be approximated semiclassically ($\hbar \to 0$) as a summation over periodic orbits of the corresponding classical system that are well coupled to both of the QPCs as follows:

$$\delta g(E_F, B, V_g) = 4v_0^2 \sum_{p(ppo)} \Phi_p^l \Phi_p^r \sum_{n=1}^{\infty} A_{pn} \cos\Big( n\ (\ S_p(E_F, B, V_g)/\hbar - \frac{\pi}{2}\sigma_p\ )\Big),$$

$$\Phi_p^{l,r} = \frac{1}{L}\int_{l,r} dt\, e^{-y_p^2(t)/\lambda^2}, \qquad A_{pn} = \frac{R_n(T_p/\tau_\beta)}{\|(M_p^n - 1)\|^{1/2}}.$$

Here $B$ and $V_g$ respectively denote the magnetic field and gates voltage defining the dots, interesting parameters which are often used in experiments. The first summation is over the prime periodic orbits (ppo) and $n$ denotes their repetition. $v_0 = \hbar k_0/m$, and $k_0 = \sqrt{2m(E_F - \hbar\omega/2)}/\hbar$ is the longitudinal wave number of the ground state in the QPCs. $S_p$ is the classical action of the ppo, $T_p$ denotes the period and $\sigma_p$ and $M_p$ are its Maslov index and stability matrix respectively. All periodic orbits are assumed to be isolated which is verified in fully chaotic systems, otherwise the amplitude will diverge. The integration over time ($t$) in the second row runs along part of the periodic orbits that is trapped in the region of quantum point contacts (see Figure. 1), and $y_p$ is the $y$-component of the corresponding periodic orbits. $l$ and $r$ denote left and right QPCs respectively. $R_n(T_p/\tau_\beta) = \frac{nT_p/\tau_\beta}{\sinh(nT_p/\tau_\beta)}$ with $\tau_\beta = \hbar/(\pi k_B T)$ gives the damping factor which select only the few shortest periodic orbits. The damping factor also ensure that the quantum correction will vanish as the systems are dragged into the classical regime by increasing the temperature $T$.

[1]K. Richter, *Europhys. Lett.* **29(1)**, 7 (1995).
[2]G. Hackenbroich and F. von Oppen, *Europhys. Lett.* **29(2)**, 151 (1995).

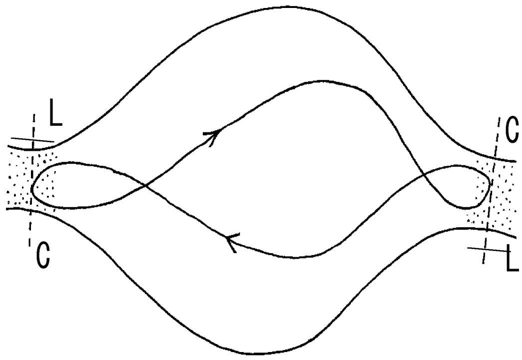


Figure 1: A single open quantum dot with a periodic orbit that is well coupled to both the entrance and exit openings. The shadowing area near both of the openings are the region of QPCs.

Using this formula we will show that conductance fluctuations of a single open chaotic dot are quasiperiodic whose periods corresponding to the properties of the periodic orbits that are well coupled to both of the openings. This last results confirm recent novel findings in experiments and self-consistent numerical calculations on transport through single quantum dots[3].

[3] R. Akis, D. K. Ferry, and J. P. Bird, *Phys. Rev. Lett.* **81**, 1745 (1998).