Time-resolved dynamics of electron wave packets in chaotic and regular quantum billiards with leads

I. V. Zozoulenko
Department of Science and Technology (ITN), Linköping University, S–601 74 Norrköping, Sweden

T. Blomquist
Department of Physics (IFM), Linköping University, S–581 83 Linköping, Sweden and Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6

We perform numerical studies of wave packet propagation through open quantum billiards whose classical counterparts exhibit regular and chaotic dynamics [1]. We show that for $t \lesssim \tau_H$ (τ_H being the Heisenberg time), the features in the transmitted and reflected currents are directly related to specific classical trajectories connecting the billiard leads. When $t \gtrsim \tau_H$, the calculated quantum mechanical current starts to deviate from its classical counterpart, with the decay rate obeying a power law that depends on the number of decay channels, see Fig. 1. In a striking contrast to the classical escape from chaotic and regular systems (exponentially fast $e^{-\gamma t}$ for the former vs. power-law $t^{-\xi}$ for the latter), the asymptotic decay of the corresponding quantum systems does not show a qualitative difference, see Figs. 1,2.

[1] I. V. Zozoulenko and T. Blomquist, "*Time-resolved dynamics of electron wave packets in chaotic and regular quantum billiards with leads*", Phys. Rev. B **67**, 085320 (2003).

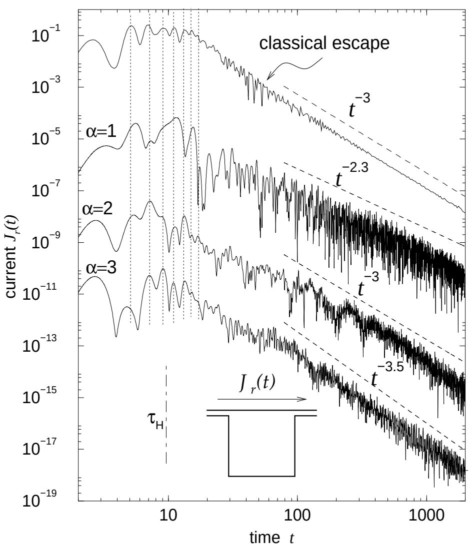

FIG. 1: Quantum mechanical transmitted current through a square billiard for different incoming modes of the wave packet $\alpha = 1, 2, 3$ with $\langle k\rangle\pi/w = 1.5, 2.5, 3.5$ respectively. The upper curve indicates corresponding *classical* current. Vertical dotted lines are guides for an eye indicating the same positions of the peaks in the current. Dashed lines give the asymptotic power-law decay obtained by the best fit in the interval $80 < t < 2000$. The Heisenberg time τ_H is indicated by a dot-dashed line. The curves are shifted for clarity.

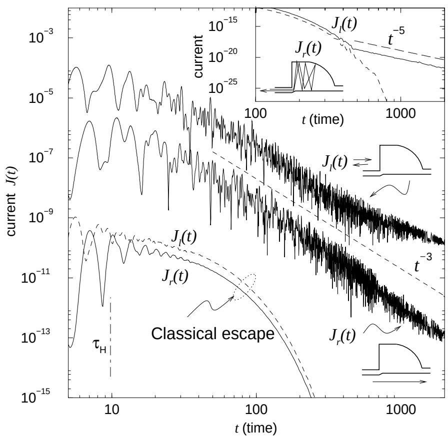

FIG. 2: Quantum mechanical reflected and transmitted current through a stadium-shaped billiard. Lower curves show corresponding *classical* currents. The wave packet enters the billiard in the second mode $\alpha = 2$; $\langle k\rangle = 2.5w/\pi$. The inset show a long-time assymptotics of classical escape along with the example of a bouncing-ball trajectory. Dashed lines give the asymptotic power-law decay obtained by the best fit in the interval $50 < t < 2000$. The Heisenberg time τ_H is indicated by a dot-dashed line. Time is measured in the units of the traversal time of the equivalent square of the same area. The curves are shifted for clarity.