Quantum fidelity decay of classically integrable dynamics with vanishing time averaged perturbation

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Abstract

We discuss quantum fidelity decay of classically regular dynamics, in particular for an important special case of vanishing time averaged perturbation operator. We show that quantum fidelity of *individual initial states* exhibits three different regimes in time: (i) for short times $t < t_1$ it follows the corresponding classical fidelity, (ii) then it *freezes* at a constant value - the plateau, (iii) only after much longer time t_2 it again starts to decay. This freezing of fidelity is purely quantum phenomenon and could find applications in improving stability of quantum devices.

We develop a semiclassical theory of quantum fidelity decay for systems with an integrable classical counterparts, perturbed by observables of vanishing time average. Such perturbations may not be generic, but provide an important special class of perturbations which are often enforced by symmetries. We have found that quantum fidelity will, after initial decay on a short perturbation independent timescale $t_1 \sim \hbar^{-1/2}$, exhibit a saturation around a constant value — the plateau, and stay there up to time $t_2 \sim \min\{\hbar^{1/2}\delta^{-2}, \hbar^{-1/2}\delta^{-1}\}$, such that the time span of the plateau $t_2/t_1 \sim 1/\delta$ can be made arbitrary long for small perturbation δ. For random initial states these two time scales go as $t_1 \sim 1$ and $t_2 \sim \delta^{-1}$. After the plateau, $t > t_2$, the fidelity will decay as a Gaussian for a coherent initial state, or as a power law t^{-d} for random initial states, just to name the two most important specific cases, where the timescale of decay is generally proportional to δ^{-2}. All these time scales can be nicely seen in figure 1 (see ref. 2), where we show numerical simulation for the quantized top. This freezeing of fidelity must be contrasted with the decay in the regular case of a non-zero time-average perturbation where the decay time scales with the perturbation strength as $\sim 1/\delta$ or equivalently the decay time scale of classical fidelity $\sim 1/\delta$. While the decay time scale of classical fidelity is the same regardless of the type of perturbation (just the shape changes from Gaussian to power law), quantum fidelity instead, for a vanishing time averaged perturbation, "freezes" and decays only after a much longer time. This increased stability of regular quantum systems to perturbations with a zero time average could be potentially useful in constructing quantum devices. This is even more so because the plateau also exists for random initial states which are expected to be more relevant for efficient quantum information processing.

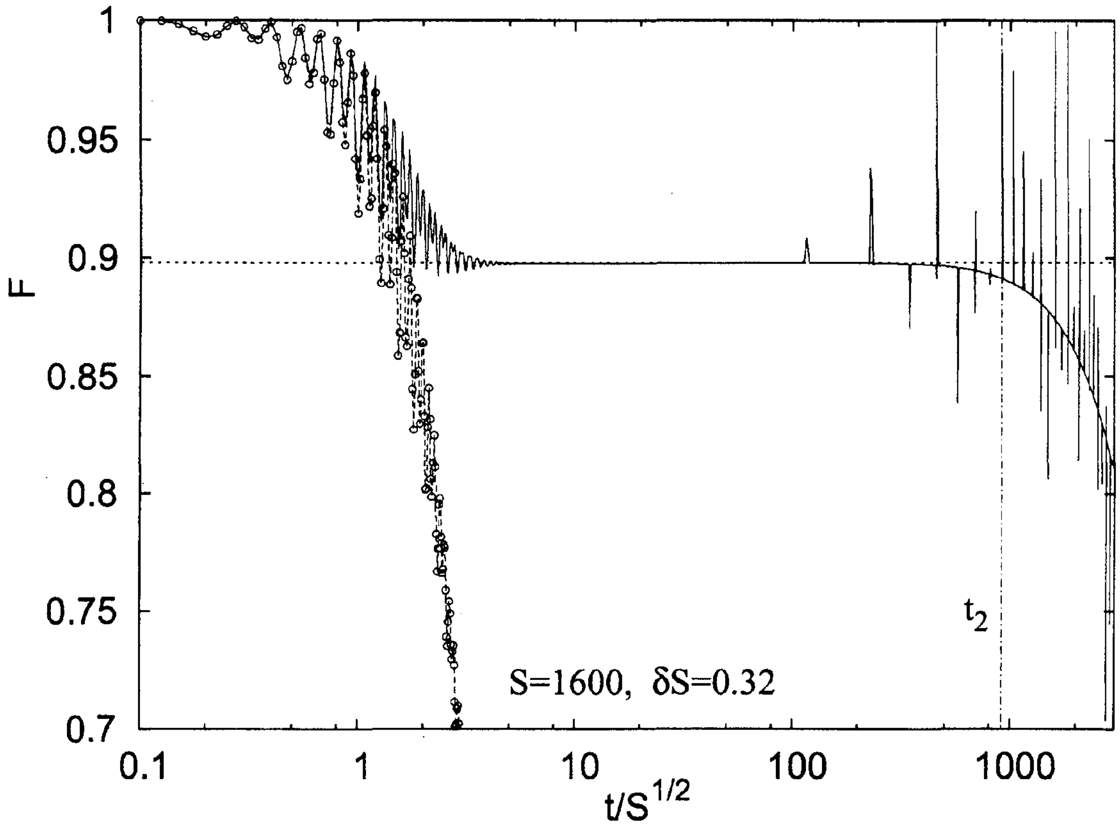

Figure 1: Fidelity decay (full line) for quantized top (coh.i.c.). Symbols denote the classical fidelity and the horizontal chain line is theoretical value of the plateau.

References

[1] T. Prosen and M. Žnidarič, 2002 J. Phys. A **35** 1455

[2] T. Prosen and M. Žnidarič, 2003 New Journal of Physics **5** 109