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Kyoto University
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 quan­
tum phenomenon and could find applications in improving stability
of quantum devices.

We develop a semiclassical theory of quantum fidelity decay for sys­
tems with an integrable classical counterparts, perturbed by observables of
vanishing time average. Such perturbations may not be generic, but pro­
vide an important special class of perturbations which are often enforced
by symmetries. We have found that quantum fidelity will, after initial de­
cay 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 $t_2 \sim \min\{h^{1/2}\delta^{-2}, h^{-1/2}\delta^{-1}\}$, such that the time span of the plateau
$t_2/t_1 \sim 1/\delta$ can be made arbitrary long for small perturbation $\delta$. For ran­
dom 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 ini­
tial 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 $\delta^{-2}$. All these time scales can be nicely seen in figure 1 (see
ref. 2), where we show numerical simulation for the quantized top. This
freezing 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