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REGULAR ARTICLE

Quantum Zeno and anti-Zeno effects in classical noise

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Abstract: Most of the existing studies are devoted to the quantum Zeno and anti-Zeno effects in open quantum systems under quantization environment; little attention has been paid to the quantum zeno dynamics behavior under classical noise. In this paper, we analyze the quantum Zeno and anti-Zeno dynamics under the random telegraph noise and the family of low-frequency noise with $1/f^{\alpha}$ spectrum. Based on qualitative analysis of effective decay rate, we find that the two kinds of classical noise under different conditions have significant influence on the Zeno and anti-Zeno dynamics. For random telegraph noise, the switching rate $\gamma > 2$ can influence the coupling strength between the system and the environment so that it can make the effective decay rate present different properties. In the case of colored noise, different coefficient and number of fluctuators N_f will make the effective decay rate change. Moreover, we also give physical explanations for these phenomena.
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I. INTRODUCTION

One of the appealing consequences of the quantum mechanics is that the observation unavoidably disturbs the observed system [1]. This is particularly revealed by the so-called quantum Zeno effect [2–4] which shows that rapidly repeated measurements can slow down the evolution of a quantum system. In the limiting case of continuous measurement, the evolution is expected to come to a standstill. The quantum Zeno effect is thought to be a general feature of quantum mechanics, applicable to radioactive [5] or radiative decay

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processes [6, 7]. In some cases, however, when the measurements are not frequent enough, they may actually accelerate the evolution, an effect called the anti-Zeno effect [8, 9]. It was shown in Ref. [9] that the inhibitory quantum Zeno effect may be feasible in a limited class of systems, the opposite effect–anti-Zeno effect–appears to be much more ubiquitous. The first observation of the quantum Zeno and anti-Zeno effects in an unstable system is report in Ref. [10].

The transition between quantum Zeno effect and anti-Zeno effect was studied recently. Facchi proposed that the crossover from Zeno effect to anti-Zeno effect can be specified by comparing the effective decay rate with the natural decay rate which does not involve measurement [11]. The quantum Zeno effect occurs when the effective decay rate is smaller than the natural decay rate whereas the anti-Zeno effect occurs. The transition between the quantum Zeno effect and anti-Zeno effect in a model of a damped quantum harmonic oscillator has been studied [12]. They showed that the short time behaviors of the environmentally induced decoherence plays an important role. Besides, the transition also can be observed in spin-bath models [13], and it is controlled by the system-bath dimensionless coupling strength, as well as the temperature and the energy bias between the spin states. Quantum Zeno and anti-Zeno effects on pure dephasing have been studied [14]. They showed that if the system environment coupling strength is not weak, the nontrivial evolution of the environment between measurement scan considerably alter the quantum Zeno effect and anti-Zeno effect. We note that these works focus on the Gaussian noise cases. As far as we know, little attention has been paid to the quantum Zeno and anti-Zeno effects in non-Guassian noise case.

When the physical systems are at very low temperature, experiments show that the decoherence is typically dominated by coupling with localized modes, e.g. the hopping background charges or general quantum bistable fluctuators in superconducting qubits [15–19], and nuclear spins [20]. Therefore, these localized modes could be described as finite-dimensional Hilbert spaces with finite energy cutoffs and could be mapped onto an environment of quantum system we concern. In this case different microscopic configurations of the environment leading to the same spectra may correspond to different physical phenomena. Under certain condition the knowledge of the noise spectrum is not sufficient to describe decoherence phenomena, then the noise is referred to as non-Gaussian. The role of non-Gaussian noise becomes important when the systems become smaller [21–23]. Non-Gaussian random telegraph noise commonly appears in semiconductor, metal, and superconducting devices [23]. Recently, the characteristic parameters of non-Gaussian noise are estimated by using a single quantum probe [24].The non-markovianity of random telegraph noise and decoherence induced by random telegraph noise have been investigated in Refs. [22, 23].

In this paper, we pay attention to the transition between quantum zeno effect and