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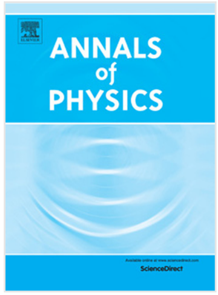

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Trapping of coherence and entanglement in photonic band-gaps

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We investigate the coherence trapping of a two-level atom transversally interacting with a reservoir with a photonic band-gap structure function. We then focus on the multipartite entanglement dynamics via genuinely multipartite concurrence among N independent atoms each locally coupled with its own reservoir. By considering the Lorentzian width and the system size, we find that for the resonant and near-resonant conditions, the increase of Lorentzian width and the decrease of system size can lead to the occurrence of coherence trapping and entanglement trapping. By choosing the multipartite GHZ state as atomic initial state, we show that the multipartite entanglement may exhibit entanglement sudden death depending on the initial condition and the system size. In addition, we also analyze how the crossover behaviors of two dynamical regimes is influenced by the Lorentzian width and the weight ratio, in terms of the non-Markovianity.

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I. INTRODUCTION

The quantum systems of interest always interact with surrounding dissipative environments in practice, and thus unavoidably lead to the appearance of decoherence and disentanglement [1, 2]. For this reason, the theory of open quantum systems has attracted a great deal of attention in quantum information processing and quantum computation [3]. In open systems, people found that in contrast with the Markovian processes, there is information backflow from the environment to the system in the non-Markovian processes due to the memory effect [4–7]. To thoroughly understand the non-Markovian effect, different kinds of analytical and numerical methods have been developed, such as pseudomodes [8–11] and Laplace transform [12, 13].

In recent years, some investigations mainly focus on several measures to detect the non-Markovian evolution of open systems [14–19]. In particular, Breuer *et al.* [14] proposed a general measure for non-Markovianity in terms of information flow between the system and its own environment. Then, this measure is also widely applied to investigate non-Markovian features for a single qubit exposed to a reservoir with Lorentzian spectral distribution [15, 16]. So far, some factors can effectively influence the non-Markovian dynamics, for instance, the strength of system-environment couplings [20], spectral density functions [11], initial correlations between system and environment [21, 22], and so on. However, the quantum system in certain cases may be simultaneously coupled to multiple environments [17–19]. In [17], the authors discussed the relationship between the non-Markovianity and the hierarchical environment consisting of a single-mode cavity and a reservoir with Lorentzian spectral density. In [18], the authors analyzed the non-Markovian dynamics of an open system interacting with two cavities which are in turn coupled to structured reservoirs. On the other hand, it is found that due to the non-Markovian effect, quantum coherence can be partly retained within an infinite time in the dynamical evolution, which is called coherence trapping [23, 24]. This may be an important theory of the long-time protection of quantum coherence in the application of quantum information using structured environments with suitable spectral densities. Moreover, this mechanism of coherence trapping is fundamentally different from the phenomenon of frozen quantum coherence naturally occurring under nondissipative noise for given initial conditions of the system, as theoretically predicted [25] and experimentally observed [26].

For N independent qubits each locally coupled to its corresponding reservoir with a photonic band-gap structure function, the study of coherence trapping and entanglement trapping in non-Markovian regime is scarce. Motivated by this, we consider a two-level atom interacting with a reservoir with a photonic band-gap structure function, and investigate the coherence trapping and the transition from non-Markovian to Markovian dynamics by adjusting the Lorentzian width. Moreover, we discuss the influences of resonant and off-resonant conditions on the coherence trapping in two dynamical regimes. Using the genuinely multipartite concurrence, we quantify and study the joint entanglement of N noninteracting atoms coupled to N reservoirs, and show entanglement trapping and entanglement sudden death induced by the initial condition and the system size. In addition, contrary to the equality of all the widths, we investigate the situation with N different widths. For the same model, we also explore how these environmental parameters affect the crossover properties in the non-Markovian to Markovian

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