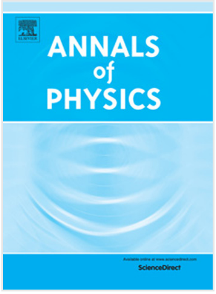

Classical-driving-assisted entanglement dynamics control

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Classical-driving-assisted entanglement dynamics control

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We propose a scheme of controlling entanglement dynamics of a quantum system by applying the external classical driving field for two atoms separately located in a single-mode photon cavity. It is shown that, with a judicious choice of the classical-driving strength and the atom-photon detuning, the effective atom-photon interaction Hamiltonian can be switched from Jaynes-Cummings model to anti-Jaynes-Cummings model. By tuning the controllable atom-photon interaction induced by the classical field, we illustrate that the evolution trajectory of the Bell-like entanglement states can be manipulated from entanglement-sudden-death to no-entanglement-sudden-death, from no-entanglement-invariant to entanglement-invariant. Furthermore, the robustness of the initial Bell-like entanglement can be improved by the classical driving field in the leaky cavities. This classical-driving-assisted architecture can be easily extensible to multi-atom quantum system for scalability.

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I. INTRODUCTION

Entanglement is considered as a crucial resource for quantum information processing [1–3]. However, it is generally fragile due to inevitable decoherence induced by environment. Entanglement can even disappear abruptly, a phenomenon known as early-stage disentanglement or entanglement sudden death [4–14]. Controlling entanglement dynamics, in particular, inhibiting entanglement decay and improving the robustness of entanglement are thus the great challenges towards the reliable quantum information processing [15–21].

Up to now, a number of schemes have been investigated to manipulate entanglement dynamics and achieve the robustness. The schemes such as quantum error correction [22–25] and decoherence-free subspace [26–29] need more physical qubits realization to encode fewer logic qubits. Other schemes by using quantum Zeno effect [30, 31] or dynamical decoupling [32–35] may need frequent and precise quantum operations. However, the scalability of qubits manufacture and a large number of quantum gates implementation are still the main hurdle in technology. Some other schemes may also need technologies which are presently still challenging for us. So how to devise an effective and feasible mechanism to control entanglement dynamics becomes extremely significant.

Here, we address this task by investigating a two-qubit system, where each qubit realized by a two-level atom is located in a single-mode photon cavity, in particular, an external classical driving field is applied as a control method, as depicted in Fig. 1. Our platform is based on cavity quantum electro-dynamics (QED) framework, which is shown to be a useful tool in manipulating quantum entanglement [36–39], quantum networking and quantum information processing [40–44], and is within current experimental technologies. As is know, the non-conserving energy terms (the anti-Jaynes-Cummings (AJC) model [38]), corresponding to exciting/deexciting the internal atomic state while creating/annihilating an optical cavity photon, have been discarded in the context of the cavity QED. However, in the ultra-strong atom-cavity coupling regime, the non-conserving energy terms become more important. As a consequence of the non-conserving energy terms in the Hamiltonian of cavity QED, even the ground state of the system would contain a finite number of virtual photons. And these virtual photons can be released by a non-adiabatic manipulation, where the Rabi frequency is modulated in time at frequencies higher than the atom transition frequency [45]. In our work, the effective atom-photon interaction Hamiltonian can enable the transition from Jaynes-Cummings (JC) model [46] to AJC model by adjusting the driving strength of the classical field and the atom-photon detuning of the frequencies. The transformation between the JC model and the AJC model has also been experimentally realized by the Nitrogen-Vacancy centers in diamond coupled to carbon nanotubes [47]. By using adjustable atom-photon interaction, three effective dynamics models (the double JC model, the double AJC model and one JC plus one AJC model) can be switched each other. Then entanglement dynamics of the two-atom system can be manipulated. Remarkably, occurrence or non-occurrence of entanglement sudden death can be completely controlled by the classical driving field, besides the robustness of the entanglement and the en-

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