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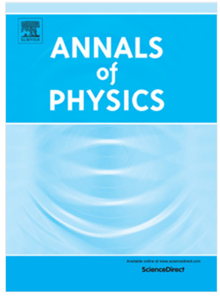

Output enhanced quantum correlations using a coherence-controlled atomic reservoir

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Output enhanced quantum correlations using a coherence-controlled atomic reservoir

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We show that the output steady-state quantum correlations are prominently enhanced via dissipative atomic reservoir by employing a two-level atomic system driven by a strong laser field inside a two-mode cavity. It is found that the output two-mode quantum entanglement is obviously enhanced in comparison to that of the intracavity fields without adiabatic elimination atomic variables. On the other hand, the output asymmetrical one-way Einstein-Podolsky-Rosen steering could be obtained with unbalanced coupling strength. Physically, the enhanced quantum correlations can be essentially attributed to the coherence-controlled effective two-mode squeezed thermal state.

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I. INTRODUCTION

Quantum correlations including quantum entanglement, Einstein-Podolsky-Rosen (EPR) steering and quantum nonlocality are nonclassical correlations. As is well known, quantum entanglement is one of the most potential resource for quantum teleportation [1–3], quantum dense [4] and universal quantum computation [5]. In last years, continuous variable (CV) entanglement has been extensively studied due to its relative simplicity and high efficiency in generation, manipulation, and detection [6]. Numerous theoretical and experimental schemes are therefore proposed to prepare bipartite and multipartite CV entanglement based on nonlinear parametric interaction [7], coherence-controlled two-photon process [8], correlated emission laser (CEL) [9], four-wave mixing [10] and etc.. The EPR steering, which is first introduced by Schrödinger in 1935 [11] in response to the famous EPR paradox [12], refers to an interesting phenomenon that one observer (Alice) can perform local measurements to remotely control the state of the other (Bob). In 1989, M. Reid proposed an efficient criterion to deduce whether the continuous variable EPR steering effects for Gaussian states are obtained or not according to Heisenberg's uncertainty relation [13]. This paves an avenue to study the EPR steering effect in different systems and a great deal of work has been done in theory and experiment[14–23]. Specially, Midgley et al. have demonstrated that asymmetric steering for the case of Gaussian measurements is possible in a bipartite system [16]. Cavalcanti and Skrzypczyk have given an an overview to discuss quantum steering through semidefinite programming, which may open an avenue to address these problems including the detection and quantification of quantum steering effects [24]. Generally, the properties of two-way EPR steering are similar to quantum entanglement, i.e., the quantum correlations between the two observers are symmetrical. However, the one-way EPR steering is one of the asymmetrical quantum correlations, which attracts much attention because its interesting properties are different from quantum entanglement. This gives a new insight into quantum physics and opens a new field of applications in quantum information, such as one-sided device-independent quantum key distribution [25–27], secure quantum teleportation [28], and entanglement assisted subchannel discrimination [29].

Up to now, the asymmetrical one-way EPR steering is generated based on optomechanical coupling system [30, 31], effective atomic reservoir effect [32, 33] and quantum interference effect [34] and etc.. Among these schemes, coherence-controlled quantum reservoir has been proved to be a useful way to generate quantum correlations [35–40]. It is shown that the atomic ensemble in dressed state presentation can be treated as an effective squeezed reservoir by adiabatically eliminating the atomic variables and then gives rise to quantum entanglement and steering effect. The main merits of this scheme lie in the following points: (i) The long-lived atomic coherence effect can be created via atomic reservoir, thus the generated quantum correlations are usually stable. In principle, it can even exist for a long enough time, which may find potential applications for distant quantum communications. (ii) The initial preparation of nonclassical states to obtain nonclassical correlations is not required, in which the quantum correlations arise from the internal nonlinear process. (iii) The dissipative atomic reservoir scheme is applicable to resonant and non-resonant cases, which provides convenience for experimental implementation. Notably, the adiabatic elimination is usually useful when the decay rate of the atom denoted by γ is much bigger than the cavity loss κ or vice versa, i.e., $\gamma \gg \kappa$ or $\gamma \ll \kappa$. On one hand, if the decay rate of the atom is assumed to be large enough, the atom ensemble would quickly evolve into steady state and the adiabatic elimination of atomic variables is effective. On the other hand, if the loss rate of the cavity is much larger than the that of the atoms, the cavity would quickly evolve into steady state and the adiabatic elimination of the cavity fields is also effective. Nevertheless, the adiabatic elimination is no longer valid when the atomic decay rate is comparable to the cavity loss ($\gamma \sim \kappa$). Accordingly, an effective approach is applied to obtain quantum entanglement in three-mode optomechanical system without adiabatical elimination of the intermediate mode [30, 31, 41, 42].

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