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Effects of Atomic Motion on the Entropies and Entanglement for a JC Model with a Mixed State Input

A.-S. F. Obada,[1] H. A. Hessian,[2] and A.-B. A. Mohamed[2]

[1]*Faculty of Science Al-Azhar University, Nasr City, Cairo, Egypt*
[2]*Faculty of Science, Assiut University, Assiut, Egypt*

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In this article, we study the effects of the atomic motion and the field-mode structure on the entropies and entanglement of a generalized JC model. We have investigated different forms of the intensity dependent function on the evolution of the entropies and entanglement in the case of a coherent superposition state and a statistical mixture of coherent states as the initial field states. We investigate the partial entropies of the atom and field subsystems numerically. The setting of the initial state of the field-mode and the atomic motion plays an important role in the evolution of the sub-entropies and entanglement.

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I. INTRODUCTION

The Jaynes-Cummings (JC) model [1] has been generalized or extended further to incorporate the effects of the atomic motion and field mode structure [2, 3]. The influence of the atomic motion and field-mode structure on the atomic dynamics has been investigated [2]. It has been shown that the atomic motion and field mode structure give rise to nonlinear transient effects in the atomic population, which are similar to self-induced transparency and adiabatic effects. Quantum entanglement is widely used in quantum information processing [4]. In such physical processes one usually needs to find the entanglement properties and a way to control them. Therefore studying the dynamic properties of entanglement is useful for processing quantum information. Naturally it has become a subject of intensive study in fundamental physics. Many authors [5–15] have studied the evolution of the entropies as measures of entanglement for a non-decaying electromagnetic field mode interacting with a two-level atom in the JC model with the atom considered at rest for a superposition (SS) [16, 20] of coherent states. Whereas [21–24] are studies of the evolution of the entropies as a measure of entanglement while considering the initial field state to be a statistical mixture (SM) [19, 20] and the atom is considered to be at rest. The evolution of the entropies and entanglement have been studied by [25, 26] with a pure state of the system considering the effects of the atomic motion and field mode structure.

In this paper, we investigate the influences of the atomic motion, the field-mode structure, and the nonlinear intensity-dependent atom-field coupling $f(\hat{n})$ on the entropies and entanglement for a JC model with a supposed mixture states input. The material in this article is arranged as follows. In section II we introduce the model, present the reduced density operator of the field, which includes the effects of the atomic motion and the field-

