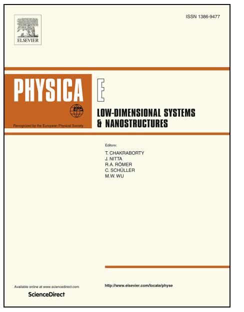

Nonclassical features of two SC-qubit system interacting with a coherent SC-cavity

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Nonclassical features of two SC-qubit system interacting with a coherent SC-cavity

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In this paper, the dynamics of two charged qubits interacting with a coherent SC-cavity in the presence of the intrinsic decoherence is investigated analytically. Some nonclassical features are discussed as: The behavior of the negativity part of the Wigner function, the Husimi function and its marginal distributions. It is shown that, the intrinsic decoherence has a clearly effect on the negative part of the Wigner function, where it does not vanish completely but reach its stationary value as the intrinsic-decoherence rate increases. A definition of the Husimi distribution for the two SC-qubit and its marginal distributions is described. Further, in the presence of the intrinsic decoherence, the dynamics of the Husimi function of the two-qubit is more robust than its marginal distributions. The phase space quantum coherence of the reduced density matrices is investigated via the Wehrl entropies, which are shown loss of the quantum coherence due to the interaction of coherent SC-cavity with the its system. It is found that, the stationary Wehrl entropies appear quicker due to increasing the intrinsic decoherence rate .
Keywords: Intrinsic decoherence, SC-qubits, Quasi-probability distributions

I. INTRODUCTION

The last two decades have seen a greatly increased interest in using superconducting quantum circuits (SQCs)[2], based on Josephson junctions. It has also been demonstrated that, SQCs possess discrete energy levels and behave like atoms. For this reason, SQCs are often referred as superconducting artificial atoms. The study of properties of SQCs and the interaction between SQCs and a classical microwave field is related to atomic physics [3–6]. The SQCs are a good candidate for the implementation of quantum logic gates and quantum algorithms [7, 8].

The quasi-probability distributions (QPDs), including Wigner function [9], Glauber-Sudarshan P-function [10], and Husimi function [11], are a powerful tool for exploring the nonclassical effects. These functions are obeyed the normal, anti-normal, and symmetric quantum operator orderings, respectively. The Wigner function was introduced as the first distribution function in quasi-probability distributions [12, 13]. The negative-part of Wigner function is a witness of the non-classicality and monitors the decoherence process of a quantum state [14, 15], where it was used as a measure for the non-classicality [16, 17]. These distribution functions also are used for computing the quantum corrections to the classical dynamics of a nano-mechanical resonator [18]. However, the Husimi function is always positive and measurable by quantum tomographic techniques [19]. It is one of the simplest distributions of quasi-probability in phase space.
The link between the Husimi quasi-probability and the classical information entropy (which can be measure the non-classical correlations for composite systems) was explored [19] via the definition of Wehrl entropy. The Wehrl entropy [19] is one of the most prodigious distribution functions because of its real and non-singular properties. In the phase space, the erasing information, the coherence loss and the relaxation processes were measured by using the Husimi function and its applications [20, 21]. Meanwhile, the Wigner function and Husimi function as well as some of their applications are realized for adjustable phase space information that is crucial to fundamental aspects of quantum mechanics. The Husimi function is investigated only for the coherent representation of the field mode and the spin-$\frac{1}{2}$ (qubit) [19–21] and the spin-1 (qutrit) [22, 23], but not for two qubits. Therefore, a definition of the Husimi distribution for two qubits and its marginal distributions for use as a quantum resource in information processing.

A superposition of coherent states was found to possess prominent quantum properties. There are several suggestions have been proposed to generate the superposition of coherent states to be used in the context of quantum information processing and computation [24].

In open systems, the decoherence destroys their nonclassical features and decreases the quantum correlations between their subsystems. The nonclassical features and quantum correlation has been broadly explored [25–29]. There are several types of decoherence in quantum systems which transit them to classical systems. Schrödinger equation is modified to Milburn equation to describe one of them that is called intrinsic decoherence [30, 31]. In this modification, the quantum coherence is automatically destroyed as the system evolves. The previous analytical descriptions of two 2-level systems under the intrinsic decoherence are introduced **only** when they interact with vacuum/number cavity field [32–35].

In this contribution we introduce: (i) An analytical description of two-qubits interacting with a coherent SC-

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