J. At. Mol. Sci.
doi: 10.4208/jams.050411.052411a

Vol. **3**, No. 2, pp. 177-186
May 2012

Dissipative dynamics of quantum and classical correlations for two-qubit under two-side and one-side decoherence

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Received 4 May 2011; Accepted (in revised version) 24 May 2011
Published Online 8 November 2011

Abstract. The dissipative dynamics of classical correlation(CC), quantum discord(QD) and entanglement (QE) of two qubits in two-side and one-side decoherence models are investigated under Markovian environments. We find the sudden change QD as well as CC and sudden death of entanglement (ESD). The results show that QD and QE decay faster with the increasing of squeezing parameter r; the dipole-dipole interaction Ω under two-side decoherence leads to the oscillation of quantum discord and concurrence for initial non-eigenstates; while in all cases when entanglement suddenly disappears, quantum discord keeps nonzero under same conditions.

PACS: 03.65.Yz, 03.65.Ta, 03.65.Ud

Key words: quantum discord, entanglement, classical correlation, dipole-dipole interaction, squeezing parameter

1 Introduction

Quantum entanglement is a vital resource and has the computational advantage of quantum over classical algorithms. Hence it has been playing a central role in quantum computation and information processing [1]. However, there are other non-classical correlations apart from the entanglement [2–5] that can be very important to these fields. In order to characterize all non-classical correlations, Ollivier and Zurek introduced a concept of quantum discord [2], it is a different type of quantum correlation than the entanglement, and it can be considered as a more universal resource because separable mixed states (without entanglement) can have nonzero quantum discord. This measure of quantum correlations holds a

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fundamental feature of classical bipartite states. When the discord is zero, the information is locally accessible and can be obtained by distant independent observers without perturbing the bipartite state. In addition, it was shown theoretically [6,7] and later experimentally [8] that, some separable states may also speed up certain tasks over their classical counterparts. Therefore, much attention has been paid to many relative topics of quantum discord [9–13].

It is well known that all quantum systems interact inevitably with their surrounding environments, this leads to decoherence which degrades the entanglement of the quantum system [14]. Thus it is important to know the influence of the environment on quantum correlation. Recently, the quantum correlation dynamics in open quantum systems have been studied [15–18]. It was shown that the quantum correlation measured by quantum discord is more resistant against the environment than quantum entanglement. For a certain class of states under Markovian dynamics, the quantum entanglement can disappear within a finite time, namely, entanglement sudden death (ESD) [19], but quantum discord only vanishes asymptotically at infinite time. In addition, for some special initial states, quantum correlation in a bipartite quantum system will not be affected by the decoherence environment during an initial time interval.

On the other hand, many typical environments have been investigated, such as, vacuum, squeezed vacuum, multi-mode vacuum cavity, single mode cavity and so on. The effects on the entanglement, such as dipole-dipole interaction between the particles and the couplings of particles with the same cavity field have been studied extensively. Zhang *et al.* [20] studied the entanglement character between two identical two-level atoms in a two-mode cavity field, where the authors discussed the influence of dipole-dipole interaction on entanglement between atoms. Chen *et al.* [21] study the influence of the dipole-dipole interaction on the evolution of entanglement between two atoms, they obtained different results. However, the dissipative dynamics of quantum discord in coupled qubit system under Markovian environments are rarely discussed. In this paper we investigate the dissipative dynamics of quantum discord and entanglement for two coupled qubit system subjected to Markovian environments, each of which interacts with a multi-mode squeezed vacuum field reservoir. We also compare the dynamics of quantum discord with that of the entanglement by using the standard numerical method, and examine the influence of dipole-dipole interaction and squeezing parameter on quantum discord and entanglement.

2 The model and its solution

The system consists of two identical qubits. By one-side decoherence, we mean that only one qubit A (or B) is subject to the multi-mode squeezed vacuum field reservoir. For the two-side decoherence, the two atoms characterized by an excited state $|1\rangle$ and a ground state $|0\rangle$, are independently subject to their respective reservoirs (assumed to be the same for both) described by annihilation b_k and creation operators b_k^+. In the interaction picture and the rotating-wave approximation, the interaction between the qubits and their reservoirs is