

A simple scheme for realizing six-photon entangled state based on cavity quantum electrodynamics

Deng-Yu Zhang*, Shi-Qing Tang, Xin-Wen Wang, and Li-Jun Xie

Department of Physics and Electronic Information Science, Hengyang Normal University, Hengyang, Hunan 421008, China

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Abstract. A simple scheme is presented for generating six-photon entangled state with resonant interaction between a cascade type four-level atom and two three-mode cavities. In the proposed protocol, the quantum information is encoded on Fock states of the cavity fields. We solve Schrödinger equation and obtain quantum states of interaction system. The detection of the atom can collapse the cavity to the desired six-photon entangled state.

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Key words: quantum information, cascade four-level atom, three-mode cavity, entangled state

1 Introduction

Cavity quantum electrodynamics (QED) is an ideal candidate for implementing quantum information processing [1]. The reason is based on the following two points. (i) Photons are ideal carriers for fast and reliable communication over long distances, and the atoms are good memorizers for storing and processing quantum information. Thus the combination of atoms and photons can be useful in quantum computation. (ii) The atoms trapped in a high-Q cavity have long decoherence time [2]. Entanglement of two or more particles is the most intriguing characteristic of quantum mechanics. In recent years, several physical system have been suggested to generate quantum entanglement [3–5], among which cavity quantum electrodynamics (QED) system is viewed as a promising tool in that recent development in cavity QED techniques have made us to produce quantum entanglement between cavity fields [6] and between atoms [7]. Entangled states not only are recognized as an essential ingredient for testing the foundation of quantum mechanics, but also have many significant applications in quantum-information processing (QIP) [8]. Generally, the more particles that can be entangled, the more clearly nonclassical effects are exhibited, and the more useful the states

*Corresponding author. *Email address:* dyzhang672@sohu.com (D. Y. Zhang)

are for quantum applications [9]. Thus generation and manipulation of multipartite entangled states are very important tasks in QIP and have been attracting much attention. Dür *et al.* have shown that there are two inequivalent classes of tripartite entanglement states, i.e., the GHZ class and the W class, under stochastic local operations and classical communications [10]. GHZ type of entangled state has many interesting properties. For example, the three-particle GHZ state is maximally stable against noise, maximally violates Bell inequalities, and can be used to implement perfect teleportation [11]. Meng *et al.* have proposed a scheme for preparing an N atoms GHZ entangled state through the interaction between N atoms and a cavity [12]. Although many schemes for tripartite entangled states have been studied [13, 14], the report about preparing multi-photon ($N > 3$) entangled state is very few.

2 Realization of six-photon entangled state

We consider the resonant interaction of a cascade type four-level atom with a three-mode cavity field is shown in Fig. 1. The interaction Hamiltonian for such a system can be described as ($\hbar=1$) [15]

$$H_1 = g_1(a^+|g\rangle\langle i| + a|i\rangle\langle g|) + g_2(b^+|i\rangle\langle j| + b|j\rangle\langle i|) + g_3(c^+|j\rangle\langle e| + c|e\rangle\langle j|), \quad (1)$$

where $a^+(b^+, c^+)$ and $a(b, c)$ are the creation and annihilation operators for the cavity fields, respectively, $g = g_1 = g_2 = g_3$ is the coupling constant of the interaction of atom with the cavity mode.

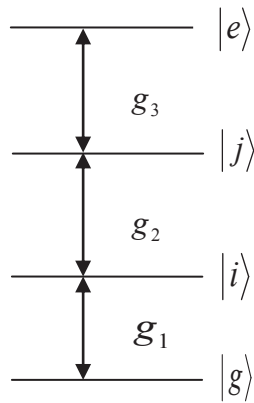


Figure 1: Atomic level structure of cascade type four-level atom coupling to a three-mode cavity.

For simplicity, assume that the cavities are initially prepared in $|0,0,0\rangle_1, |0,0,0\rangle_2$, the atom is initially in $|e\rangle$, we obtain the system initially prepared in the state

$$|\phi(t=0)\rangle = |e\rangle|0,0,0\rangle_1|0,0,0\rangle_2. \quad (2)$$