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# Scheme for generating W states via distant cavities

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**Abstract.** A scheme for generation of W state via distant cavities is presented. Employing resonant interactions between atoms and cavities, choosing different initial states, we can obtain non-maximally and maximally entangled states. In addition, our scheme could be easily generalized to generate N-atom W state. In contrast to the original scheme, our scheme is insensitive to the atomic spontaneous emission and cavity decay, it made the schemes more easily realize on experiments.

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**Key words**: W state, distant cavity, beam-splitter

## 1 Introduction

Quantum entanglement, one of the most fascinating features of quantum mechanics, not only provides an important tool for distinguishing the quantum mechanics from the classical physics, but also gives the possibility to test quantum mechanics against a local hidden variable theory [1-3]. In addition, quantum entanglement plays a key role in quantum information processing. For example, control a small amount qubits has been achieved in cavity QED, ion traps, etc. In order to achieve large-scale quantum information processing, we must find good methods for expand simple physical system. At the same time, for communication purposes to bring about the communication. Quantum information has to be shared among separated quantum nodes. To bring about the communication, stationary qubits are entangled by using photons is our best bet [4-7]. There are many protocols for remote entangling operations and probabilistic two-qubits gates were realized [8-16] The Barrett-Kok and zheng shi-biao scheme is particularly promising, since it is fully scalable and robust against experimental imperfections [12,13]. C. W. Chou and D. L. Moehring has proposed an experimental scheme of the remote entangling operations (or probabilistic two-qubit gates) between separated qubits have also

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been done in both atomic ensembles [17] and trapped single atoms [18-20]. They are important ingredients for fault-tolerant distributed quantum computation [12, 21-23]. There are a lot of classes of multipartite entanglement, for example, GHZ (Greenberger-Horne-Zeilinger) states [24], cluster states [25], and W states [26]. The W state has a strong property that even any particle of the state has been discarded the other particles also be in entangled state [27-29]. The W state can be used in quantum key distribution, teleportation, leader election, and information splitting [30-32]. The decoherence existed in W states can be counteracted in purification scheme [33]. The preparation of the W states by using optics has been discussed so far extensively both theoretically and experimentally [34-41]. In addition, the W state has been prepared in other systems, such as cavity QED or ion traps [42-46].

In this paper, we present an alternative scheme for generating a special W state in cavity QED. In contrast to the original scheme, our scheme is insensitive to the atomic spontaneous emission and cavity decay. In addition, the special W state could be used for perfect teleportation and dense coding with a probability of 100% in Ref. [47]. Furthermore, our scheme could generate maximally three-atom W state, and it can be scalable to N-atom W state.

The paper is organized as follows. In Section 2, we propose a method for generating a special W state via three distant cavities. Meanwhile, the N-atom W state can also be realized. In Section 3, we propose a scheme for generating maximally entangled state. Finally, we give a summary in Section 4.

## 2 Generation of W state through distant cavities

The atoms have one excited state $|e\rangle$ and two ground states $|g\rangle$ and $|f\rangle$, as shown in Fig. 1. The transition $|e\rangle \to |g\rangle$ is resonantly coupled to the cavity mode. The transition $|e\rangle \to |f\rangle$ is dipole forbidden. The setup is shown in Fig. 2. Three distant atoms are trapped in three separate single-mode optical cavities, respectively. Photons leaking out of the cavities are mixed on two beam splitters, which destroy which-path information. Then the photons are detected by two photon detectors. We assume here that the cavities are one sided so that the only photon leakage occurs through the sides of the cavities facing the beam splitter like in Ref. [13].

In our scheme each atom is first entangled with the corresponding cavity mode via resonant interaction. The detection of one photon leaking out of the cavities and passing through two beam splitters corresponds to the measurement of the joint state of the three cavities; it collapses the three distant atoms to an entangled state.

Assume that the atom is initially in the state

$$|\phi_j\rangle = \frac{1}{\sqrt{2}}(|g_j\rangle + |f_j\rangle) \tag{1}$$

The three cavities are initially in the vacuum state $|0\rangle$. The first step is the transfer of one photon to the cavity through a half-cycle of the vacuum Rabi oscillation of the