Properties and preparation of multiatom entangled state

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Abstract: In this paper, we show that multipartite entangled states prepared by our QED scheme have some interesting, peculiar entanglement properties. For example, the remaining reduce density matrices ρ_{ij} retain entanglement or disentanglement independently when any N-2 atoms of the N atoms is traced out , which can be chosen freely according to our need, and the relative entanglement strength of any pair of atoms(measured by the concurrence) can be adjusted arbitrarily. In addition, it may be completely symmetric under the permutation of any two atoms. Thus, it can perform certain quantum information tasks.

Keywords: multipartite entangled state

Quantum entanglement play a key role in recent years as a potential resource for quantum communication and quantum information processing . The properties , preparation and applications of multiparticle entangled states are now a hot topic and far from being solved in the field of quantum information[1-10]. Furthermore , multiparticle states have been shown to have many advantages over the two particle Bell states in quantum coining[11-13], quantum teleportation [14],and superdense coding[15].Then the preparation of entangled states, especially multiparticle states, becomes a critical technique in quantum information processing .

In this paper, we propose a cavity QED scheme for the multiparticle entanglement preparation. We consider the interaction of a ladder-type three level atom with a cavity. Then the effective Hamiltonian in the interaction picture is [16-18]

$$H_{eff}=\frac{g^2}{\Delta}a^{+}a(|f><f|-|e><e|) \tag{1}$$

where a+ and a are the creation and annihilation operators for the cavity mode, and g is the atom-cavity coupling strength. △is the detuning between the atomic transition frequency ω 0 and cavity frequency ω .

We assume that the cavity field is initially prepare in a coherent state $|\alpha>$ by a microwave source, the ith atom enters the cavity, it is initially prepared by laser excitation and microware manipulation[19], in the superposition of the states $|g_i>$ and $|e_i>$,i.e., $c_{ei}|e_i>+c_{gi}|g_i>$, where, $|c_{ei}|^2+|c_{gi}|^2=1$. We now examine the case for N successive atoms passing through the cavity one by one . After an interaction time τ_1, the atom-cavity system evolves into the state

$$\left|\psi_1\right\rangle=c_{g1}|g_1>|\alpha>+c_{e1}|e_1>|\alpha e^{-ig^2\tau_1/\Delta}> \quad . \tag{2}$$

We let ${g^2\tau_1}/{\Delta}=\pi$, then

$$\left|\psi_1\right\rangle=c_{g_1}|g_1>|\alpha>+c_{e}|e_1>|-\alpha> \quad . \tag{3}$$

After passage of the first atom, the second similarly prepared atom is injected into the cavity with ${g^2\tau_2}/{\Delta}=\pi$ too, then the atom-field state becomes:

$$\left|\psi_2\right\rangle=\left(c_{g1}c_{g2}|g_1g_2>+c_{e1}c_{e2}|e_1e_2>\right)|\alpha> \\ +\left(c_{g1}c_{e2}|g_1e_2>+c_{e1}c_{g2}|e_1g_2>\right)|-\alpha> \tag{4}$$

. Now atom-field entangled states have been created and selective measurements on the cavity the entangled atomic states. it is again assumed that

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measurements are made in a time short enough so that cavity dissipation effects can be ignored . If the cavity field is measured and found to be in state $|\alpha>$, the atoms in the case of only two atom, i.e., from Eq.(4), are in the entangled state

$$|\psi_2>_\alpha = c_{g1}c_{g2}\,|g_1g_2> + c_{e1}c_{e2}\,|e_1e_2> \qquad (5)$$

or if in $|-\alpha>$,

$$|\psi_2>_{-\alpha} = c_{g1}c_{e2}\,|g_1e_2> + c_{e1}c_{g2}\,|e_1g_2> \qquad (6)$$

Similarly, the N-atoms entangled state can be obtained as follows:

$$\left|\psi_N\right\rangle_\alpha = \left|\psi_{N-1}\right\rangle_\alpha c_{g_N}\left|g_N\right\rangle + \left|\psi_{N-1}\right\rangle_{-\alpha} c_{e_N}\left|e_N\right\rangle \qquad (7)$$

$$\left|\psi_N\right\rangle_{-\alpha} = \left|\psi_{N-1}\right\rangle_\alpha c_{e_N}\left|e_N\right\rangle + \left|\psi_{N-1}\right\rangle_{-\alpha} c_{g_N}\left|g_N\right\rangle \qquad (8)$$

we can calculate the concurrence[2,4]of pairs of parties, as a measure of entanglement strength of the bipartite reduced density operators ρ_{ij}. Note that C=0 corresponds to an unentangled state, C=1 corresponds to a completely entangled state.

In [11] Murao et.al point out: the telecloning state should be symmetric under permutations of the output qubits ; in particular, they should all be equally entangled with the port . furthermore , in order to optimize the transfer of information the entanglement of the receiving and transmitting sides should be as large as possible. However, the state $\left|\psi_N\right\rangle_\alpha$ or $\left|\psi_N\right\rangle_{-\alpha}$ prepared by our scheme just possess the desired properties. Hence, it is useful for telecloning[11,22].

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