EPJ Web of Conferences **103**, 03007 (2015)
DOI: 10.1051/epjconf/201510303007

Influence of Stark Shift on Entanglement of Two Qubits in the Two-Photon Tavis-Cummings Model

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Abstract. Considering two-atom degenerate two-photon Tavis-Cummings model, we investigate the entanglement between two atoms prepared initially in the coherent disentangled states and cavity field prepared in few-photon Fock state, and study the effect of the Stark shift on entanglement. The results show that the atom–atom negativity evolve periodically with time and the periods are affected by the Stark shift and initial coherent atomic state and that the atom–atom entanglement can be greatly enhanced due to the presence of Stark shift. We also have shown that entanglement sudden death effect vanishes for some parameters of the considered system due to the presence of Stark shift. In addition, the entanglement sudden death effect vanishes due to the presence of Stark shift. We have derived that the dynamic Stark shift can be used to control entanglement between two initially disentangled atoms.

Key words: Stark shift, two-photon transitions, entanglement, Fock cavity field, atomic coherence

At present a lot of schemes are proposed for controlling and protecting the entanglement of qubits interacting with electromagnetic fields and different environments. Recently, the problem of controlling entanglement by dynamic Stark effect has attracted much attention. Ghosh et al. [1] have shown that the Stark shift can be used to enhance the magnitude of atomic entanglement over that obtained in the resonant condition for certain parameter values. Abdel-Aty and Moya-Cessa [2] have found that the Stark shift can produce sudden death of entanglement and long-lived entanglement between the qubits which are prepared initially in separable states or mixed state. These and subsequent investigations have shown that the Stark shift can be used to control entanglement between atoms interacting with quantum electromagnetic fields via two-photon transitions.

In this work we have considered the system consisting of two effective two-level atoms and a single-mode cavity. Each atom interacts alone with the cavity field through a two-photon process when the two atomic levels are coupled with comparable strength to the intermediate relay level and the Stark shift becomes significant. We have investigated the entanglement dynamics between atoms which are initially prepared in coherent disentangled states for weak few-photon Fock cavity fields. For simplicity, we have assumed that two-photon resonance takes place. The Hamiltonian describing such a model in the rotating wave approximation and in the interaction picture can be written as

$$H_I = \hbar g \sum_{i=1}^{2} (a^{+2} a_2^{+} R_i^{-} + R_i^{+} a^2) + \sum_{i=1}^{2} \hbar a^{+} a (\beta_2 R_i^{+} R_i^{-} + \beta_2 R_i^{-} R_i^{+}),$$

where a^+ and a denote the creation and annihilation operators of the quantization fields, $R_i^+ = |+\rangle_{ii}\langle -|, R_i^+ = |-\rangle_{ii}\langle +|$ are the atomic operators with $|+\rangle_i$ and $|-\rangle_i$ being the excited and ground states of the i th atom ($i=1,2$). The β_2 and β_1 are the parameters describing the intensity-dependent Stark shifts of the two levels of each atom due to the virtual transitions to the intermediate relay level, and g is the effective two-photon coupling constant between atoms and cavity. We have assumed that both atoms are initially prepared in a coherent superposition of the two levels, that is,

$$|\Psi_{A1}(0)\rangle = \cos\theta_1 |+\rangle + e^{i\varphi_1} \sin\theta_1 |-\rangle,\ \Psi_{A2}(0)\rangle = \cos\theta_2 |+\rangle + e^{i\varphi_2} \sin\theta_2 |-\rangle,$$

where θ_1 and θ_2 are the amplitudes of the polarized atoms, φ_1 and φ_2 are relative phases, and the cavity to be prepared initially in an Fock state.

We have obtained the time-depent atom-field wave function an the density matrix of the whole system. Using density matrix of the "two atoms+field" system we have derived the reduced atomic density matrix by tracing out the state of the cavity. Using the partial transposition of the atomic density matrix we have derived the atomic entanglement parameter − negativity. We have numerically calculated the time dependece of the negativity for considered initial state. The results of calculations shown that the entanglement between two disentangled atoms can be greatly enhanced and the entanglement sudden death effect vanishes due to the presence of Stark shift. These results take place for all degree of initial atomic coherence.

References

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