Interaction of Three-level Atom with Non-Classical Light and Generation of Non-Gaussian States

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Abstract

We report our theoretical research of the three-level atom dynamics in non-classical electromagnetic fields. Features of the atomic dynamics in quantum light and possibility to form the dark state are analyzed. Strong entanglement between atomic and field subsystems is found. Significant change in photon statistic is demonstrated. Possibility of generation of non-Gaussian states is discussed.

At the present time a wide variety of non-classical states of light are reproduced successfully in experiments. This includes few-photon Fock and coherent states with small mean photon number, biphoton pairs, multiphoton squeezed states [1, 2, 3]. The interaction of these states with matter leads to new physical effects. It is important to mention that field characteristics are also changed during the interaction. Therefore the field states with new properties may appear. The dynamics of the two-level system is well studied, however, as the number of components increases, the problem becomes much more complicated.

We consider the interaction between the three-level model atom and two non-classical electromagnetic fields. This problem is described by the non-stationary Schroedinger equation. The exact analytical solution is obtained for the case of resonant fields. The dynamics of bi-partite "atom + quantum field" system is examined. Different initial field states are considered: coherent states with a small mean number of photons, squeezed states, two-mode squeezed vacuum and Schroedinger cat states. Dramatic difference in atomic dynamics is shown for these initial field conditions. In the case of initially coherent fields regimes of "collapse" and "revival" in atomic transitions are observed [4]. The sensitivity to the phase between atomic levels is investigated. If at least one of the fields is squeezed, the phase dependence is absent. This means that the dark state cannot be formed due to distractive interference effect [4, 5]. This fact is explained in quasi-energies approach.

The entanglement between atomic and field subsystems is found and is characterized quantitatively. Properties of the field subsystems are strongly changed due to interaction with the atom.

Additionally, the problem of the interaction between a model atom and single non-classical field is also solved analytically. In the quasi-energies formalism the optimal conditions were selected for the formation of a dark state in the case of using squeezed light. A significant change in the photon statistics is found, which is associated with noticeable population of Fock states with odd numbers. Such new generated light states are analyzed in terms of Wigner function. We discovered negative regions of Wigner function which correspond to strongly non-Gaussian states. Thus, field states with new properties can be generated.

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