Interaction of an Atom with Two Resonant Few-Photon Coherent Electromagnetic Fields

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Today the experimental generation of non-classical states of light becomes possible. Few-photon Fock states, coherent states with small mean photon number, biphoton pairs and multiphoton squeezed states of light [1–3] are available and appears to be very useful for many perspective practical applications including quantum metrology, quantum information and quantum computing purposes. The interaction of quantum electromagnetic field with matter is a very interesting problem. The account for additional field degree of freedom and possible entanglement between atomic and field subsystems leads to many new physical phenomena. One of the most important problems in this field is a provision of a coherent control of atomic system. This can be performed using a superposition of photon states with some relative phases between them, for example, few-photon coherent states can be used. The coherent state is characterized by the Poisson distribution over the photon numbers. If the mean number of photons is much greater than unity, this case corresponds to the classical field. If the mean photon number is of the order of unity, then this is a quantum case, in which variations of the quadratures and the phase play an important role. The influence of the field phase and the role of the phase uncertainty on the dynamics of the interacting anomic system is a great and scantily explored problem as well.

We consider an interaction of a model three-level atom with two resonant electromagnetic quantum fields with in lambda-type transitions being taken into account. Both fields are supposed to be coherent states with rather small mean number of photons which can be much less than 1. Under these conditions the phases of used coherent states are not exactly determined values and are characterized by same uncertainty. Starting from the non-stationary Schrodinger equation we obtain a system of equations for probability amplitudes for different atomic and field eigenstates. For this system we find an exact analytical solution and analyze it for various atomic and field initial conditions and parameters.

The dynamics of atomic and field subsystems is investigated analytically in dependence on the relative phase between the two applied fields. The effects of "death" and "birth" of the oscillations of the populations of different atomic levels is found. Similar behavior is observed for the mean number and variance of photons of both fields. The possibility to control the atomic level populations using relative phase between fields is demonstrated. Strong entanglement between atomic and field subsystems is found and is analyzed in details. In addition, the evolution of the photon statistics of fields during the interaction with the atom is analyzed and the possibility to generate the non-Gaussian state is examined. The way to determine the relative phase from the atomic state formed during the interaction is discussed.

References

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