TWO-MODE COHERENT AND SQUEEZED STATES OF ONE OF THE JAYNES—CUMMINGS' NONLINEAR MODELS

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S u m m a r y

The interaction of a two-level atom having the level energies $E_1 < E_2$ in states $|1\rangle$ and $|2\rangle$, respectively, with two modes of the electromagnetic field having frequencies ω_1 (pumping) and ω_2 (Stokes component) is considered. The transition of $|1\rangle \rightarrow |2\rangle$ is allowed in the quadrupole approximation. We assume the difference $\Delta = \omega_1 - \omega_2 - \omega_0 (\Delta/\omega_i << 1, \quad i = 0, 1, 2)$ to be small in studies of the energy spectrum and stationary states of the atom+field system. It is shown that the spectrum of energies $E_\nu(N_1', N_2')$ consists of three groups conditioned by the eigenvalues of the operators of excitation numbers $N_i' (i = 1, 2)$, being the integrals of motion. The interaction between the atom and the field modes appears only for those steady states where $N_i' \geq 1$. Being a superposition of the atom states $|1\rangle, |2\rangle$ and quantum states of the field modes, they are referred to as dressed states. The states do not mix up by interaction if one of the numbers N_i' equals zero. In this case, a value of the level energy does not depend on the interaction nature. Using the unitary transformation in the basis of "dressed" states, we define the Bose operators of creation $\hat{A}_i^+$ of excitations and the spin operators $\hat{\Sigma}_z, \hat{\Sigma}_\pm$, in terms of which all basic operators are presented, namely, the number of photons in the modes $\hat{n}_i$, the difference of atomic level populations $\hat{\sigma}_z$, and the Hamiltonian operator $\hat{H}$ of the model under consideration. We represent the operator $\hat{H}$ as a sum of Hamiltonians of two interacting anharmonic oscillators and study statistical properties of the two-mode coherent and squeezed states of a nonlinear Jaynes—Cummings' (JC) model of the Raman type constructed by using the operators $\hat{A}_i^+$, $\hat{A}_i$ and the squeeze operator $\hat{S}\left(\hat{A}_i^+, \hat{A}_i, r\right)$. It is shown that the interaction between the atom and the field mode results in a time dependence of average values of all investigated physical quantities except for the integrals of motion. By its nature, this dependence is collapse and revival of the Rabi oscillations and reaches its maximum at the resonance ($\Delta = 0$). The impact of spontaneous and stimulated Raman scattering on the time dependence of the average value of a difference of atom-level populations $\langle \tilde{\sigma}_z(t) \rangle$ is discussed.