ONE-PHOTON STATE GENERATION IN A KICKED CAVITY WITH NONLINEAR KERR MEDIUM

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ANALYTICAL RESULTS

We discuss a cavity with the nonlinear oscillator (corresponding to a Kerr medium) periodically kicked by a series of ultra-short laser pulses. This system is governed by the following Hamiltonian[1] (in the interaction picture):

$$H_{int} = \frac{\hbar\chi}{2} (\hat{a}^\dagger)^2 \hat{a}^2 + \hbar(\epsilon\hat{a}^\dagger + \epsilon^*\hat{a}) \sum_{n=0}^{\infty} \delta(t - nT) , \tag{1}$$

where χ denotes nonlinearity of the Kerr medium and ϵ is a strength of the field-medium coupling. In addition, we assume that the field is initially in the vacuum state $|0\rangle$. Assuming that the field coupling is weak, i.e. $\epsilon \ll \chi$, we apply the standard perturbation method of rediagonalization of the Hamiltonian[2]. In consequence, we obtain the analytical formulas for the probabilities corresponding to the vacuum $|0\rangle$, one-photon $|1\rangle$ and two-photon $|2\rangle$ Fock states. Thus, for the time t just after k-th laser pulse, we have

$$\begin{aligned} |a_0(k)|^2 &= (\cos(k\epsilon))^2 + \mathcal{O}(\epsilon^2) , \\ |a_1(k)|^2 &= (\sin(k\epsilon))^2 + \mathcal{O}(\epsilon^2) , \\ |a_2(k)|^2 &= 2\epsilon^2 |B|^2 (\sin(k\epsilon))^2 + \mathcal{O}(\epsilon^4) , \end{aligned} \tag{2}$$

where

$$B = \frac{\exp(-i\chi T/2)}{\sin(\chi T/2)} . \tag{3}$$

It is seen from (2), that the contribution of the two-photon number state to the system dynamics is negligible. In consequence, the system evolution is restricted to the

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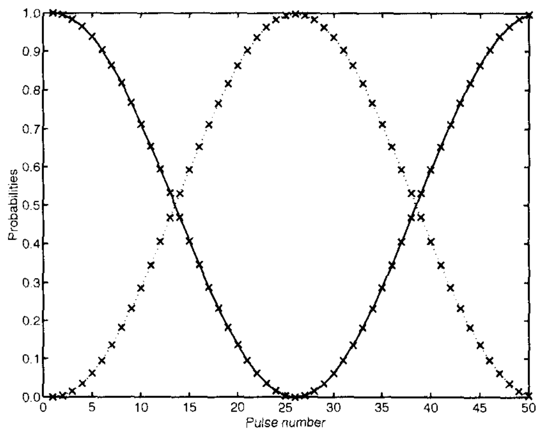

Figure 1. Time evolution of the probabilities for the vacuum (solid line) and one-photon (dashed line) states. Marks correspond to the numerical experiment results. The time $T = \pi/\chi$ and $\epsilon = \pi/50$.

two states states - the vacuum and the one-photon state. Owing to this fact, after $k = \pi/(2\epsilon)$ laser pulses, the system reaches the pure one-photon state $|1\rangle$. Of course, the time T between two subsequent laser kicks should be appropriately chosen as to exclude all resonances except that for the $|0\rangle$ - $|1\rangle$ transitions.

NUMERICAL EXPERIMENT

To verify these results we shall now perform a numerical experiment and compare its results with those based on our formulas. This will be done similarly as in the paper[1].

The history of our system is governed by the unitary evolution operator $\hat{U}(t)$ defined as follows ($\chi = \hbar = 1$):

$$\hat{U}(t) = \exp\left(-i(\epsilon\hat{a}^\dagger + \epsilon^*\hat{a})\right) \exp\left(-i(\hat{a}^\dagger)^2\,\hat{a}^2 T/2\right) \quad . \tag{4}$$

Hence, the wave-function just after k-*th* laser pulse can be expressed as: $|\Psi_k\rangle = \hat{U}^k\,|0\rangle$. Thus, Fig.1 shows the time dependence of the probabilities for the vacuum and the one-photon states obtained from eqs.(2,3) and from the numerical experiment. It is visible that the dynamics of our system is restricted to the two states: $|0\rangle$ and $|1\rangle$, and that the results of our experiment show very good agreement with the analytical results. This nice picture can also be significantly changed by the damping in the system. Nonetheless, our results show that, at least in principle, the one-photon number state can be generated when a passive nonlinear medium is contained in a cavity pumped with a classical field.

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