Collapse-revivals and population trapping in the m-photon mazer

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We will present a study of the collapse-revivals and population trapping phenomena that appear in the changes of atomic populations induced by the interaction of ultracold two-level atoms with electromagnetic high-Q cavities in resonance with an m-photon transition of the atoms (m-photon mazer – microwave amplification via z-motion-induced emission of radiation).

The one-photon mazer system was first described by Scully *et al.* [1] where it has been shown that a new kind of induced emission occurs when a micromaser is pumped by ultracold atoms, requiring a quantum-mechanical treatment of the center-of-mass motion. Zhang *et al.* [2] extended the concept of the one-photon mazer to the two-photon process by proposing the idea of the two-photon mazer. They showed that, when considering a high-Q cavity with a mesa mode function, the atomic excitation may exhibit collapse-revivals, which have different features in the ultracold regime compared to the thermal one.

We will show that results of Zhang *et al.* may not be generalized to the general m-photon mazer with arbitrary cavity field modes. For this purpose, we have written the quantum theory of the m-photon mazer by use of the dressed-state coordinate formalism recently introduced by Jonathan *et al.* [3] General expressions have been derived for the atomic populations and the cavity photon distribution after the interaction of the atom with the cavity. The theory is valid for any initial pure state of the atom-field system (entangled or not) at zero temperature with no dissipation in the high-Q cavity. More realistic sech^2 and gaussian cavity mode profiles have been considered and new features in the collapse-revival patterns, compared to the mesa function case, have been found.

We also studied the population trapping phenomenon in the framework of the mazer system. This phenomenon relates, as noted by Yoo and Eberly [4], to the persistent probability of finding the atom in a given level in spite of both the radiation field and allowed transitions to other levels. Population trapping is observed when the atom-field system is prepared in well-defined states, denominated *trapping states* [5]. We have demonstrated that the quantization of the atomic z-motion, as it is the case in the m-photon mazer, introduces new properties of the trapping states. In the usual scattering process of the mazer system, atoms are sensitive to both potential wells and potential hills inside the cavity. The trapping states have the peculiar property to make the atoms only sensitive to one of these potential components. These new features and experimental issues with possible applications will be discussed.

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