Strong light-matter coupling in a quantum dot: local field effects

G. Ya. Slepyan, A. Magyarov, S.A. Maksimenko
Institute for Nuclear Problems, Belarus State University, Bobruiskaya 11, 220050 Minsk, Belarus
Tel. (+375 17) 2095262, (+375 297) 53 27 81, E-mail: magyar@inp.minsk.by

A. Hoffmann and D. Bimberg
Institut fuer Festkourperphusik, Technische Universitaet Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Electron-hole dipole-dipole interactions (local fields) has been incorporated into the Jaynes-Cummings(JC) model Hamiltonian of the single non-anisotropic quantum dot(QD). An analysis for both QD interaction with monochromatic field and ultra-short Gaussian pulse has been performed.

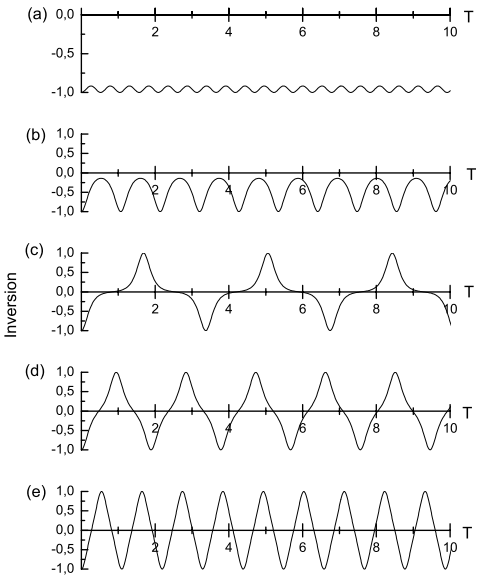

Fig.1 Rabi –oscillation dynamics for different field amplitudes defined by the ratio $\xi=\Omega/\Delta\omega$. (a) ξ =0.2; (b) ξ =0.495; (c) ξ = 0.5; (d) ξ =0.51; (e) ξ =0.6

QD is modeled as a strongly confined in space two-level quantum oscillator.

From the basis of the optical Bloch equations derived from JC Hamiltonian, the excitonic Rabi oscillation dynamics for different external field amplitudes has been calculated. As a result, the bifurcation in the Rabi oscillations of the QD exposed to the monochromatic field that separates two oscillatory regimes with drastically different characteristics have been predicted, (see Fig.1b and d). Field amplitude is defined by the ratio $\xi=\Omega/\Delta\omega$. Where Ω is the Rabi frequency, $\Delta\omega$ is the resonant frequency shift induced by local fields. In the vicinity of the bifurcation Rabi oscillations are strongly anharmonic. The analysis of the frequency detuning influence on the bifurcation has been performed.

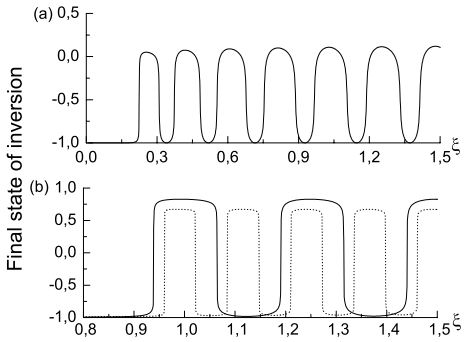

Fig.2 The final state of invesion as a function of field amplitude ξ. Detuned (a) and damped system (b).

Numerical calculations performed for the case of QD interacting with the Gaussian pulse whose time duration much less than relaxation times in the system, have been shown that after pulse has passed, inversion of the system (i.e., the difference between the excitonic population in the excited and the ground states) switches either to the ground or to the excited state. It has been obtained that the final state of inversion as a function of peak pulse strength demonstrates a quasi-step dependence. Incorporation of the detuning and damping significantly changes the effect manifestation: it has been obtained that such a step-like transition can be realized in a smaller field by an optimal choose of the frequency detuning (Fig 2a). A physical interpretation of effects predicted has been proposed. Possible

ways of application of effects in the quantum information processing and for the experimental measurement of QD parameters (such as the value of the resonant frequency shift induced by local fields, or electron-hole dipole-dipole moment) are discussed.