Kinetics of electromagnetic field in nonequilibrium medium of emitters

S.F. Lyagushyn, Yu.M. Salyuk and A.I. Sokolovsky
Dnipropetrovs'k National University, Faculty of physics, electronics and computer systems, 72 Gagarin Ave., 49010 Dnipropetrovs'k, Ukraine,
E–mail: lyagush@dsu.dp.ua

This work is a generalization of previous investigations of two-level emitters kinetics with the purpose to consider electromagnetic field as a nonequilibrium subsystem. Emitters of the system are considered as located in space identical particles with dipole moments and can be in excited state with energy $\hbar\omega$. Hamilton operator of the system we take in the Dicke quasi-spin formalism

$$\hat{H} = \hbar\omega \sum_a \hat{r}_{az} + \sum_k \hbar\omega_k c^+_{k\alpha} c_{k\alpha} + \frac{\omega}{c} \int d^3x \hat{P}_l(x) \hat{A}_l(x)$$

(see, for example, [1]). Here $\hat{P}_l(x) = 2\sum_a d_{al}\, \hat{r}_{ax}\delta(x - x_a)$ is density of dipole moment of emitters, $\hat{r}_{al}$ is quasi-spin operator, $\hat{A}_l(x)$ is operator of vector potential of electromagnetic field in the Coulomb gauge. So, we neglect by direct emitter-emitter interaction. Our consideration is based on the Bogolyubov reduced description method. As reduced description parameters (RDP) we took average electric and magnetic fields, their binary correlations : $E_l(x,t), B_l(x,t)$, $(E^x_l E^{x'}_n)_t$, $(E^x_l B^{x'}_n)_t$, $(B^x_l B^{x'}_n)_t$ (variables γ_α) and energy density of emitters $\varepsilon(x,t)$ (its operator $\hat{\varepsilon}(x) = \hbar\omega \sum_a \hat{r}_{az}\delta(x - x_a)$). Quasi-equilibrium statistical operator (QESO) of the system was taken in the form $\rho_q = \rho_f(\gamma)\rho_m(\varepsilon)w_d w(\omega)$, where $\rho_f(\gamma)$ is QESO of the field, $\rho_m(\varepsilon)w_d$ is QESO of the emitters (w_d is distribution emitters in space and dipole directions). Also we included in ρ_q distribution function of emitters in frequencies $w(\omega) = [(\omega - \omega_0)^2 + \delta^2]^{-1}\delta/\pi$ to take into account nonresonance interaction of emitters with the field. Therefore, statistical operators of the system must be normalized by formulae a type $\int d\tau d\omega \mathrm{Sp}\rho_q = 1$, where $d\tau$ denotes integration over variables of distribution w_d. As a result evolution equations for RDP have been obtained and analyzed.

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1. Bogolyubov N.N. (jr.), Shumovsky A.S. *Superradiance.*– Dubna: JINR, 1987, 88 p. (in Russian).