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The development of Bogolyubov reduced description method in the application to spin and quasispin systems

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The development of Bogolyubov reduced description method in the application to spin and quasispin systems

Sokolovsky A. I., Lyagushyn S. F.
Oles Honchar Dnipro National University

The reduced description method (RDM) is based on the Bogolyubov's idea that at large time the non-equilibrium state evolution of a macroscopic system can be described with the limited number of parameters. The way to the right choice of such parameters and constructing the equations of time evolution for them was opened by the works of Kharkiv school in statistical physics [1]. Since early 2000-ies the authors deal with applying the proposed technique to Dicke superradiance – the unique phenomenon of emitter system self-organization in the process of reaching the equilibrium state from excited one. We are interested in a more detailed picture of correlation development both in emitter and field subsystems. The problem of correlator decoupling which arises in the Bogolyubov method of boson variable elimination [2], seems worthy of attention. In RDM, including the binary correlation functions into the set of reduced description parameters (RDPs) results in the necessity of calculating the averages with quasi-equilibrium Hamiltonians where such new parameters are present. Usually, two-level electromagnetic emitters are described using the quasispin operators constructed with Pauli matrices. While considering the acoustic superradiance, spin and phonon operators are necessary for the Hamiltonian construction. The operator forms prove to be the same for boson fields of different nature. Thus, we face the problem of averaging in the case when the exponential statistical operator includes a quadratic form of spin operators in the exponent that cannot be done exactly.

In our recent papers [3, 4], a new approach consisting of introducing additional small parameter in the theory of relaxation processes in spin systems has been proposed. While the spin-boson interaction constant is a customary small parameter in the specified theory, we put forward the idea of accounting for small deviations of correlation functions taken as RDPs from their values calculated in the picture with the only RDP describing the state of a spin (quasispin) system – the excitation degree of the emitter subsystem η_1 ($s^z = \sum\limits_{1\leq i\leq N} s_i^z$ in usual designations). Restricting ourselves with the concentrated Dicke model, we can use the known equation for s^z possessing the integral of motion including the binary correlation function $\left\langle \hat{s}^+\hat{s}^- \right\rangle$. In the theory of superradiance using $\left\langle \hat{s}^+\hat{s}^- \right\rangle$ as an independent RDP η_2 ($\hat{\eta}_2 = \hat{s}^+\hat{s}^-$), we construct the quasi-equilibrium statistical operator of RDM $\rho_q = e^{\Omega - Z_1\hat{\eta}_1 - Z_2\hat{\eta}_2}$ implying the condition of smallness of the deviation $\delta\eta_2 = Sp(\rho_q - \rho_q^0)\hat{\eta}_2$, i.e. difference between correlation function obtained with such operator and those of RDM model with η_1 only $\rho_q^0 = e^{\Omega^0 - Z_1^0\hat{\eta}_1}$. We use $\delta\eta_2$ as a new small parameter of the order μ and the statistical operator ρ_q can be expressed via ρ_q^0 in the form of μ power expansion. Thus, we obtain expressions for spin average deviations with an error up to μ^3 and evolution equations for η_1, η_2, and boson RDPs n_k. The solved problem relates to cumbersome calculations but only averages with linear forms of spin operators and quadratic forms of boson operators are needed. The technique of averaging for spin operators was improved in the framework of our activities. The results are applicable for different versions of Dicke model and Wagner model of acoustic superradiance.

1. Akhiezer, A. I. Methods of Statistical Physics / A. I. Akhiezer, S. V. Peletminskii. – Oxford: Pergamon Press, 1981. – 450 p.
2. Bogolyubov, N. N. (Jr.) Sverkhizlucheniye / N. N. Bogolyubov (Jr.), A. S. Shumovsky. – Dubna: JINR, 1987, JINR publication P17-87-176. – 88 p.
3. Lyagushyn, S. F. Taking into account the influence of correlations on the system dynamics in the reduced description method / S. F. Lyagushyn, A. I. Sokolovsky // Journal of Physics and Electronics. –2023 – Vol. 31(1). – P. 7 – 17. https://doi.org/10.15421/332302
4. Sokolovsky, A. I. Dynamics of a system of two-level emitters in the Dicke model taking into account small correlations between them / A. I. Sokolovsky, S. F. Lyagushyn // Journal of Physics and Electronics. –2023 – Vol. 31(2). – P. 88 – 110. https://doi.org/10.15421/332326

Primary authors: Prof. SOKOLOVSKY, Alexander (Oles Hohchar Dnipro National University); LYAGUSHYN, Serhiy (Oles Honchar Dnipro National University)

Presenter: LYAGUSHYN, Serhiy (Oles Honchar Dnipro National University)

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