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FLUORESCENCE IN QUANTUM SYSTEMS WITH VIOLATED SYMMETRY

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The present study is devoted to investigation of radiative properties of N-level quantum systems driven by external semi-classical monochromatic high-frequency electromagnetic field and interacting with a heat bath simultaneously. In essence, one-electron multi-level atom model with violated symmetry was studied under the assumption that its transition dipole operator possesses permanent diagonal matrix elements and not all of them are equal to each other, which assumption amounts to the violation of the spatial inversion symmetry. A general formula for the intensity of the electromagnetic field radiated from such a system in the far-distant zone was derived which does not contain contributions stemming from these non-zero permanent diagonal matrix elements of the transition dipole moments explicitly [1]. Hence, it can be concluded that the dynamics of these diagonal matrix elements may affect the system fluorescence only indirectly through the alteration of the time dependence of the non-diagonal matrix elements due to quantum processes of higher orders. As an example, radiative properties of a monochromatically driven two-level quantum system with permanent non-equal dipole moment diagonal matrix elements were thoroughly analyzed. The time evolution of the atomic subsystem of the whole quantum system (i.e. the atom + heat bath) was described by the approximate master equation for the atomic reduced density operator. On its basis, a closed set of evolution equations for the time-dependent averages of some selected relevant subsystem variables and their correlation functions was deduced. The so obtained set of equations was analyzed and solved by means of the well-established technique [e.g. 4, 5]. Equations derived were solved numerically in the steady-state limit. Finally, the steady-state fluorescence spectrum was calculated and it was found that the radiative properties (spectrum) of this two-level atom with violated spatial inversion symmetry can be significantly modified compared to those of atoms without such violation. In particular, it was found that the system in question can radiate at essentially lower frequencies than the frequency of the driving field [2]. It is important to note that the system dynamics itself was studied not only numerically but also analytically, and the existence of a small parameter governing this phenomenon of the low-frequency radiation was revealed explicitly as a result. The central part of this work results are the (plausible) conditions under which a simple two-level quantum system driven by external semi-classical monochromatic high-frequency electromagnetic (laser) field can radiate continuously at much lower frequency. It was shown that this can be possible under certain conditions and was also discussed how such a system could be realized in practice. The absorption-amplification response to the weak probe field in a simple two-level quantum system with non-equal permanent diagonal transitional dipole moment matrix elements driven by semi-classical monochromatic field at resonant frequency was studied too [3]. It was found that this system is able to amplify low-frequency EM radiation for a broad enough range of frequencies. It is reasonable to assume that all the results mentioned above may be of use in various fields of nano-electronics and can be employed in development of practically useful devices dedicated for generation and amplification of relatively low-frequency (terahertz) EM radiation.

Recent Publications

1. Bogolubov N.N. (Jr.), Soldatov A.V. (2018) Fluorescence in a quantum system with violated symmetry. Moscow University Physics Bulletin, 2018, No.2 (to appear).
2. Soldatov A.V. (2016) Laser frequency down-conversion by means of a monochromatically driven two-level system. Mod. Phys. Lett. B, 30:27, 1650331, 1-11.
3. Soldatov A.V. (2017) Broadband EM radiation amplification by means of a monochromatically driven two-level system. Mod.Phys.Lett.B, 31:4, 1750027,1-11.
4. Z. Ficek Z., Seke J., Soldatov A.V., Adam G. (2001) Fluorescence spectrum of a two-level atom driven by a multiple modulated field. Phys.Rev. A, 64, 013813, 1-10.
5. Ficek Z., Seke J., Soldatov A.V, Adam G., Bogolubov N.N. (Jr.) (2002) Absorption and dispersion by a multiple driven two-level atom. Eur. Phys. J. D, 19, 411–419.

Biography

Nikolai N. Bogolubov (Jr.) is a Chief Scientific Researcher at the V.A. Steklov Mathematical Institute of the RAS. His scientific interests are in general mathematical problems of equilibrium and non-equilibrium statistical mechanics and applications of modern mathematical methods of classical and quantum statistical mechanics to the problems of the polaron theory, superradiance theory, and the theory of superconductivity. His main works belong to the field of Theoretical and Mathematical Physics, Classical and Quantum Statistical Mechanics, Kinetic theory. He has published more than 150 works in the field of Statistical Mechanics, Theoretical and Mathematical Physics.

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