Theoretical evaluation of the thermostimulated intrinsic radiation in a dipole phase transition

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Abstract. Our research is devoted to a more detailed study of the generation of radiation by two-level quantum medium. An electric dipole transition is considered. From the equations of Maxwell-Bloch, the amplitude of the radiation as a function of the phase transition frequency was obtained.

1. Introduction
Currently, many scientists are studying the problem of thermally stimulated self-radiation of matter at phase transitions (PT) and using this phenomenon in a variety of practical devices. Such devices include generators of electromagnetic waves on the basis of solids, paramagnetic amplifiers with low intrinsic noise of the lasers. For the first time, the effect of strong over-temperature radiation was observed for a layer of boiling water in the near and infrared (IR) region of the spectrum [1]. A similar effect takes place when boiling metals [2]. Flash radiation is recorded as well during the crystallization of the alkali halide solids and sapphire [3, 4]. In addition, an internal radiation in the temperature interval close to magnetostructural PT 1-St and 2-nd type were observed for alloys Ni-Mn-Ga-Fe and Ti-Ni [5].

Independently, the physics and technology of vacuum tunnel structures develop, in which the temperature difference in the vacuum interval causes the appearance of a tunnel current, which, in turn, can generate a high specific power of electric energy with a strong temperature gradient and serve as a source of energy with a high efficiency parameter due to the fact that the heat transfer in vacuum is strongly suppressed [6, 7].

Thus, there is an experimental material confirming the existence of such radiation. However, the phenomenon of phase-transition radiation does not follow from the existence of the PT concept and is not taken into account when considering their kinetics. Such effects can be considered on the model of a two-level quantum medium. Especially that the interaction of radiation with such a model explains many phenomena related to the properties of substances such as absorption and dispersion of light, saturation and enlightenment transition, generation of electromagnetic radiation in lasers. Moreover, this model allows us to consider both electric and magnetic dipole transitions [8].

For the implementation of PT radiation it is necessary that the optical transition time of particles from the ground state of one phase to the ground state of another phase is less than or the order of the temperature of non-radiative relaxation [9]. This can be achieved in a large group of particles. For the first time, the possibility of radiative PT for a group of particles was
considered in the frame of quantum electrodynamics even before the experimental detection of the phenomenon of collective spontaneous radiation or over emission [10–13].

2. Theoretical model
To model the self radiation in the PT, consider the two-level model of a quantum dipole transition. The system of Maxwell-Bloch equations in this case has the following form [?]:

\[
\dddot{\vec{P}} + \frac{2}{T_2} \dot{\vec{P}} + \Omega^2 \vec{P} = \frac{2\Omega}{\hbar} L |\mu_{12}|^2 \Delta N \vec{E},
\]

\[
\frac{\partial \Delta N}{\partial t} + \Delta N - \Delta N^e = -\frac{2}{\hbar \Omega} (\vec{P} \cdot \vec{E}),
\]

\[
\nabla \times \left( \nabla \times \vec{E} \right) + \eta \frac{\partial \vec{E}}{\partial t} + \frac{\eta^2}{c^2} \frac{\partial^2 \vec{E}}{\partial t^2} = -\mu_0 \frac{\partial^2 \vec{P}}{\partial t^2}.
\]

For plane wave distributing along \( z \) axis solution of these equations for the amplitude of self-radiated wave can be found as:

\[
E_x = \sqrt{\frac{3\hbar^2 \Omega (\Omega - \omega - \frac{1}{T_2})}{2\omega L |\mu_{12}|^2}} e^{-i(\omega t - kz)},
\]

where \( T_1 \) is a longitudinal relaxation time, \( T_2 \) - a transverse relaxation time, \( \Omega \) - transition frequency, \( L \) - Lorentz correction coefficient, \( \eta \) - refractive index of matter, \( A \) - power attenuation factor, \( \Delta N \) - population difference per unit volume, \( \Delta N^e \) - population difference per unit volume under equilibrium conditions, \( |\mu_{12}| \) - matrix element of the dipole moment operator connecting the states \(|1\rangle\) and \(|2\rangle\).

3. Conclusion
The obtained equation (4) can be used to estimate thermally stimulated self-radiation of matter at PT that is determined by quantum dipole transition at the boundary of different phases.

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