V. V. Zheleznyakov, V. V. Kocharovskiĭ, and Vl. V. Kocharovskiĭ. *Polarization waves and superradiance.* The basic ideas and results of the macroscopic approach to the description of nonsteadystate coherent collective optical processes in active media, and primarily Dicke superraidance, were summarized in the report. The physical nature of superradiance and its properties in macroscopic samples were studied by the method used for analyzing normal waves in active media and collective modes of excitation of bounded samples. The method is based on the equations of the so-called semiclassical description of the interaction of a medium with an electromagnetic field. This method, which is a standard method in the electrodynamics of continuous media, turned out to be very fruitful also in the new area of its application. It enabled taking into account directly the collective character of the behavior of molecules in a self-consistent field.

Until recently, the literature on this question has dealt primarily with the microscopic approach, based on the ideas of the quantum electrodynamics of a system of separate molecules and a field in a vacuum. As is well known, however, the transition from these starting microscopic ideas to the direct calculation of the observed macroscopic characteristics of collective processes involves significant, and in most cases insurmountable, difficulties.

The results of the macroscopic approach to this problem, based on the study of the characteristic excitations of the active medium and the field on the basis of the electrodynamics of continuous media, refer primarily to systems of inverted two-level molecules (see, in particular, Refs. 1–5).

The properties of the characteristic excitations of an active medium consisting of two-level molecules are studied in detail in Refs. 1 and 5, where its is shown that together with waves of the electromagnetic type, close to waves in a vacuum, other types of normal waves exist also. They include polarization waves, in which the relative amplitude of the oscillations of the polarization of the active medium is substantially larger than in an electromagnetic wave (see Fig. 1). In an inverted medium the polarization wave has negative energy. Therefore, as the solution of the initial problem shows, in the presence of dissipative losses the energy of the polarization wave decreases with time, becoming increasingly more negative, i.e., the amplitude of the polarization wave increases. As a result there arises the dissipative instability of the polarization wave, while the standard maser instability of the electromagnetic wave of positive energy in this case vanishes.

Studies of bounded samples in the form of a flat layer and a sphere established that the physical mechanism of superradiance, realized in an inverted medium under condi-

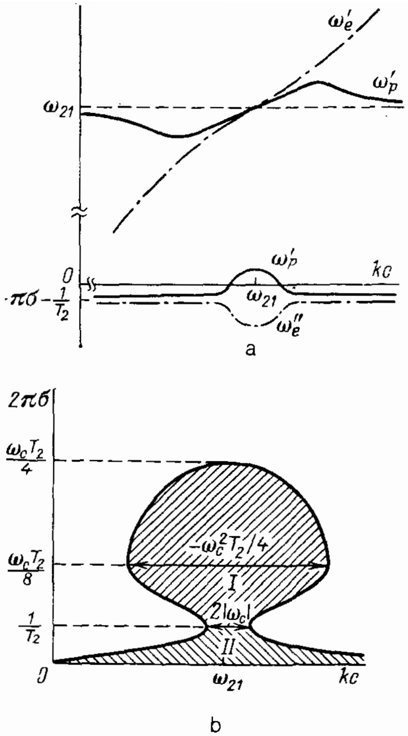

FIG. 1. a) Dispersion branches $\omega_{e,p}(k) = \omega_{e,p}' + i\omega_{e,p}''$ of normal waves $\propto \exp(ikz - i\omega t)$ in an inverted two-level medium with homogeneous broadening of the spectra line $1/T_2$ and "background" electrical conductivity σ. For $1/T_2 < 2\pi\sigma < -\omega_c^2 T_2/4$ the polarization wave has the increment $\omega_p'' > 0$, while the electromagnetic wave decays ($\omega_e'' < 0$). The quantity ω_c is called the cooperative frequency of the two-level medium and is determined by the difference population density $\Delta N = N_1 - N_2$, the frequency ω_{21}, and the two-level transition dipole moment d: $\omega_c^2 = 8\pi d^2 \Delta N \omega_{21}/3\hbar$. b) Regions of dissipative instability of the polarization wave (I) and of the maser instability of the electromagnetic wave (II).

tions of weak incoherent relaxation, is the dissipative instability of a polarization wave of negative energy, developing owing to energy losses to radiation through the boundary of the active sample.[1,2] Small reflections have a strong effect on the properties of superradiance. A reflection coefficient $R \sim 10^{-2}$–10^{-4} is usually sufficient for making a transition from the regime of superradiation of waves with a continuous spectrum to a regime of superradiation of polariton modes with a discrete spectrum. The latter is characterized by a shorter delay time and synchronous superradiation of identical modes from the opposite ends of a long sample. The form and intensity of the superradiance pulse is also affected by the presence of distributed losses. An increase in distributed losses transform superradiance from the oscillator type into the single-pulse type. Owing to the dissipative instability of the polarization wave, as a result of Ohmic losses, in an inverted medium superabsorption,[1,2,4] analogous to superradiation and giving rise to impulsive transition into heat stored in the internal energy of the molecules in the medium, can develop. There is an analogy between superradiance in quantum radiophysics and the dissipative instability in classical electronics and plasma physics.

A description of the quantum-statistical properties of nonstationary collective processes, based on the phenomenological quantization of the characteristic excitations of the active medium and of the field (normal waves or modes in an active sample), was developed.[2,3] The observed fluctuations in the parameters of the superradiation are linked with the fact that in the process of development of the dissipative instability transport of quantum fluctuations of the collective excitations of molecules and of the field on a macroscopic level occurs. The dependence of the statistics of superradiance on the form of the sample is determined by the number of dissipatively unstable polariton modes, and not by the specific geometry of the sample.[2,3]

The ideas indicated above enabled a new interpretation of Dicke superradiance linking it with the dissipative instability of the polarization wave. These ideas can be used to construct a more complete macroscopic description of the properties of nonstationary collective optical processes.

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