Spontaneous Symmetry Breaking of the Superradiant State: Effect of the Sideband Modes

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Unlike conventional lasers with high-Q Fabry-Perot cavities, superradiant lasers [1] require low-Q cavities in which the photon lifetime is shorter than the phase relaxation time of active centers. In the typical mode of operation of these lasers with symmetric cavities, under continuous-wave incoherent pumping and a significant excess of the lasing threshold, the same (on average) quasi-periodic sequences of coherent superradiant pulses are emitted from both ends of the cavity.

However, as shown in [1,2], at larger excess of the lasing threshold for a sufficiently wide range of parameters of the cavity and active medium, the pulsed generation mode changes to a strongly asymmetric self-modulated quasi-monochromatic mode. The latter regime is due to the formation of a highly asymmetric half-wavelength grating of population inversion of active centers under the action of counterpropagating waves. These waves, both polarization and electromagnetic ones, constitute mainly a nonlinear laser mode which is resonant to the working two-level transition of active medium. Also, these waves contain a couple or several couples of nonresonant polariton or electromagnetic modes which are responsible for self-modulation and excited due to Rabi oscillations of active centers in the field of the resonant polariton mode [2,3].

In the present talk, based on a set of numerical solutions to the Maxwell-Bloch equations, we reveal the mechanism of the spontaneous symmetry breaking of superradiant lasing in a low-Q symmetric Fabry-Perot cavity. It is shown that a symmetric steady-state solution is unstable due to spontaneous asymmetric emission of superradiant pulses. In the resulting transient asymmetric structure, the Rabi-excitation of the nonresonant sideband modes takes place. They lead to moderate phase oscillations of the counterpropagating electromagnetic waves as well as the counterpropagating polarization waves and population inversion grating in an active medium.

These phase oscillations increase an efficient reflection factor, i.e., the ratio of the amplitudes of counterpropagating electromagnetic waves, in the close vicinity of one mirror as compared to an actual reflection factor of the Fabry-Perot mirrors. Namely, for a steady self-modulated superradiant lasing, according to a number of numerical simulations, the efficient reflection factor at a point with minimum of an amplitude of the wave propagating to the laser center becomes from tens per cents to several times greater than that of mirrors. Such a difference is enough to support a steady strongly asymmetric self-modulated superradiant state.

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References

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