Spontaneous Symmetry Breaking in a CW Superradint Lasing in a Symmetric Low-Q Cavity

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We found a set of asymmetric solutions to the Maxwell-Bloch equations for a two-level one-dimensional model of a CW class C superradiant laser with a symmetric low-Q Fabry-Perot – distributed-feedback cavity. The solutions present the inhomogeneous counter-propagating waves with different amplitudes accompanied by self-consistent highly asymmetric inhomogeneous gratings of polarization and population inversion of an active medium [1,2].

The results are based on numerical modelling of the Maxwell-Bloch equations for an ensemble of active centers with weak inhomogeneous broadening and a polarization (optical dipole) lifetime much longer than a photon (cavity) lifetime. We describe both the steady and dynamic spontaneous symmetry breaking. The phenomenon exists in the Fabry-Perot cavities both with or without a prefabricated distributed feedback and manifests itself in the unequal output intensities of the counter-propagating waves at the opposite (left and right) ends of the cavity.

We show that, in a wide range of laser parameters, the asymmetric steady-state superradiant lasing is typical at the pumping level much higher than the so-called second, non-stationary lasing threshold. In a wider range of parameters, there exists a quasi-periodic asymmetric lasing. Moreover, the resulting asymmetric structure may be metastable and spontaneously switch to a mirror symmetric, with respect to the cavity center, one. Hence, the regions of a maximum population inversion and a minimum field intensity can spontaneously jump from the left part of the cavity to the right part and back. Such a spontaneous switching between the metastable laser states leads to temporal changes in the intensity and correlation properties of emitted radiation.

The discovered phenomenon of spontaneous symmetry breaking in a superradiant laser, leading to the formation of the asymmetric steady-state or self-modulated lasing structure in a homogeneous ensemble of two-level centers, manifests a nonequilibrium phase transition to a novel coherent light-matter state.

Acknowledgements: The support by Center of Excellence «Center of Photonics» funded by The Ministry of Science and Higher Education of the Russian Federation, contract № 075-15-2020-906 is acknowledged.

References

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