Dissipative Superradiant State in a Fabry-Perot Cavity with Weakly Reflecting Mirrors

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We study the dissipative (nonequilibrium) superradiant phase transition in a dense extended ensemble of active centers (atoms or excitons) located inside a low-Q Fabry-Perot cavity under the action of continuous (CW) nonresonant incoherent pumping. The phase transition occurs due to a self-consistent population inversion grating which is formed by the self-generated counterpropagating waves and plays a part of a localized Bragg mirror inside the cavity [1,2].

We analyze an interplay between this intrinsic Bragg mirror and the Fabry-Perot mirrors by numerical modeling of the Maxwell-Bloch equations for an ensemble of active centers with almost homogeneous broadening of a spectral line and a polarization lifetime greater or of the order of a photon lifetime in the cavity. We show that the Bragg mirror is well localized if its reflection factor is greater than the reflection factors of the facet mirrors, although the latter influence strongly the structure and properties of the Bragg mirror. Choosing various reflection factors of the facet mirrors, in particular, rather small as well as different values of the left and right ones, we find several superradiant states of the self-consistent field and ensemble of active centers with qualitatively different spatial-temporal structure.

Even in the case of a symmetric cavity, the Bragg mirror is formed, as a rule, not at the cavity center, but near one of the facets, spontaneously breaking the mirror symmetry of the field and the ensemble of active centers and leading to a multiple difference in the intensities of coherent radiation emitted from opposite facets. In a wide range of parameters, including the case of an asymmetric cavity, the self-consistent grating precludes the chaotic generation of superradiant pulses and makes the dynamics of the new phase state regular. In particular, it creates either a stationary state or a dissipative time crystal (periodic or quasiperiodic). We discuss the fundamental differences between the predicted dissipative superradiant phase transition associated with a localized Bragg mirror and the previously suggested Dicke superradiant phase transitions, including those in the presence of an external coherent field, as well as various dynamic phase transitions in the standard lasing under an incoherent CW pumping.

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References

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