Steady-State Strongly Asymmetric Superradiant Lasing in a Slightly Asymmetric Fabry-Pérot Cavity: Analytical Solution

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We find an exact solution to the steady-state Maxwell-Bloch equations in a dense extended ensemble of active centers (atoms) located inside a low-Q slightly asymmetric Fabry-Pérot cavity under the action of continuous-wave (CW) nonresonant incoherent pumping. The solution takes into account a strongly asymmetric self-consistent half-wavelength population inversion grating which is formed by the self-generated inhomogeneous counterpropagating waves under the pumping exceeding the lasing threshold value in many times [1,2]. The resulting monochromatic lasing has a superradiant nature because the strongly asymmetric solution exists only if a polarization lifetime (a phase relaxation time of active centers) is grater then a photon lifetime in a cavity. In this case the counterpropagating polarization waves influence a lot the electromagnetic waves and they all together form very nontrivial inhomogeneous structure described analytically.

It is established that this dissipative superradiant state turns out to be much more asymmetric than the hot (polariton) laser modes and the corresponding cold (electromagnetic) cavity modes, which maintain the lasing and are generally asymmetric due to the unequal reflection factors of the Fabry-Pérot mirrors. The reason is the population inversion grating which play part of an internal highly-reflecting mirror located close to a mirror with a reflection factor slightly higher than that of an opposite mirror. The dependence of the structure of the predicted highly inhomogeneous state on the reflection factors of the mirrors, the laser length, and the level of CW pumping is analyzed. The nonlinear single-mode superradiant state found makes it possible to obtain practically unidirectional monochromatic radiation without the use of well-reflecting mirrors.

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References

[1] Vl V Kocharovsky, V V Zheleznyakov, E R Kocharovskaya and V V Kocharovsky, Phys. Usp. **60**, 345 (2017)

[2] Vl V Kocharovsky, V A Kukushkin, S V Tarasov, E R Kocharovskaya and V V Kocharovsky, Semiconductors **53**, 1287 (2019)