

2nd Threshold of Superradiant Lasing: Typical Cases of Variable Cavity

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In laser physics, it is common to introduce two thresholds of lasing, which are reached by varying the parameters of the cavity and the active medium. Overcoming the 1st threshold leads to single-mode steady-state generation, while overcoming the 2nd leads to a transition to a non-stationary regime. For conventional lasers with high-Q cavities, where the photon lifetime T_E exceeds the phase (incoherent) relaxation time T_2 of the optical polarization of the active medium, the parameter range corresponding to stable single-mode or non-stationary single- and multimode lasing, as well as the various mechanisms leading to this instability upon crossing the 2nd threshold, have been thoroughly studied [1].

In superradiant lasers with continuous-wave (CW) incoherent pumping [2, 3], which have low-Q cavities with an inverse ratio of the field and polarization relaxation times, $T_E < T_2$, the mechanisms for the loss of stability of single-mode lasing are only beginning to be studied. What's important here are not electromagnetic modes, but polariton modes, which can be highly inhomogeneous due to (i) weak reflection factors at the ends of the combined Fabry-Perot cavity (FP), (ii) given modulation of the waveguide layers (distributed feedback – DFB), and (iii) the self-generated half-wavelength population inversion grating of the active centers. The latter is created by the beats of counter-propagating field waves and polarization waves of the active medium and largely determines the 2nd threshold and the mode of operation.

We reveal the influence of cavity parameters on the 2nd threshold and the lasing modes near it, taking into account this grating. Such a problem of superradiant lasing is relevant for media with a high density of active centers and small inhomogeneous broadening of their spectral lines, for example, excitons and impurity centers in solid-state matrices, electrons in quantum cascade lasers, and electrons and holes in magnetized quantum wells [2, 3]. Based on the Maxwell-Bloch equations for the electromagnetic field and a simple model of two-level active medium in a combined FP-DFB cavity, we show that the self-consistent population inversion grating strongly influences the value of the 2nd threshold and the superradiant dynamics above it. Specifically, it is established that non-stationary lasing can take place as either a quasi-periodic sequence of very short Dicke superradiance pulses or weak self-modulation of the fundamental polariton mode.

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References

- [1] Ya I Khanin, Principles of Laser Dynamics (North Holland, 2012)
- [2] VL V Kocharovsky, V V Zheleznyakov, E R Kocharovskaya and V V Kocharovsky, Phys. Usp. **60**, 345 (2017)
- [3] VL V Kocharovsky, V A Kukushkin, S V Tarasov, E R Kocharovskaya and V V Kocharovsky, Semiconductors **53**, 1287-1294 (2019)