

Self-Pulsing Instabilities in Fast-Flow Gas Lasers

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Perturbation exchange processes in two-component active medium such as CO₂-N₂ gas mixture were shown to be a significant factor determined the threshold of self-pulsing oscillations in FFL. Analytical expressions allowed to define increments and frequencies of the oscillations on the base of stationary lasing parameters were obtained.

Information about mechanisms of self-pulsing instabilities occurred in moving active medium of powerful FFL may be applied to practical elaborations of new methods of lasing regime control. In the paper the results of analytical study and numerical simulations are presented concerning the conditions of instability appearance in gas mixture FFL with an unstable cavity.

The studies were performed in the framework of simplified kinetic model of two-component active medium each component having one excited level. Two various types of power instabilities were considered, first one was based on the excitation of relaxation oscillations (RO) and the second on the excitation of flow oscillations (FO). Main difference of their instability mechanisms lies in the nature of feedback [1]. In the case of RO the feedback is non-resonant and oscillation frequency depends on conditions at optical axes only. FO can excite at resonant frequencies associated to the active medium flow time. Appropriate feature of the FV is spatial modulation of the gain perturbations which arises at the edge of cavity mirror.

The role of the perturbation exchange processes in the instability growth were shown to be significant. In the active medium characterized with slow rate of component energy exchange $\gamma \ll \Omega$ (γ – probability of collision energy exchange, Ω – self-oscillation frequency) the perturbation transfer “active” mixture component to “storage” one causes the attenuation of instability. Along with the increasing of the exchange rate ($\gamma \sim \Omega$), the return transfer gives rise to perturbation increment Γ , so that at $\gamma > \Omega$ the increment becomes positive and the instability appears. In the limit case $\gamma \rightarrow \infty$ the behavior of two-component medium seems to be as of one-component having effective values of parameters. In the case the value of relaxation frequency Ω_R depends on the medium mixture composition: $\Omega_R = \sqrt{\xi} \Omega_0$, where ξ – relative concentration of active component, Ω_0 -relaxation frequency.

The approach used for FO study was based on the resolving of perturbations into fundamental modes of the mixture. It was shown that instability of flow type is connected with the excitation of in-phase perturbation modes. Under common conditions of lasing of CO₂-N₂ FFL the working pressure threshold of RO is about 10² Torr. Numerical simulations indicate that FO may exist under lower pressure (~10 Torr [2]). Interaction of perturbations cause to the growth of increments of high order FO modes as its frequencies tends to be near the frequency of RO mode.

Flow instabilities can be also found in some others optical resonator systems of FFL. So it was shown that quasi-periodical spatial structure of laser field in multi-pass amplifier can stimulate the resonant increase of FO increments.

[1] Odintsov A.I., Sarkarov N.E., Fedoseev A.I. Quantum Electronics **36** (9), 853-859 (2006)

[2] Anufrieva A.A., Kouzminsky L.S., Fedoseev A.I., Moscow Univ. Phys. Bull. **62** (2), 128-130 (2007)

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