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PULSATIONS OF RADIATION POWER IN DISTRIBUTED FEEDBACK DYE LASER

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Theoretical investigation of radiation power pulsations in distributed feedback dye laser has been carried out. It is shown that the frequency change of pulse duration within the gain spectrum of active medium is attributed to the appropriate change of stimulated emission probability of dye molecule.

In classical laser the feedback necessary for the laser action is provided by a resonator consisting of two mirrors. Feedback can also be generated by periodic modulation of the gain factor or of the refractive index of the active medium. In such a distributed feedback laser (DFB) the feedback is caused by Bragg reflections on the periodic structure. These lasers have the possibility to generate very short single pulses in an inexpensive way. In [1-3] were considered the duration of single pulses in DFB laser. Experimentally the spectral dependence of duration of pulse generated by DFB dye laser was studied in [2].

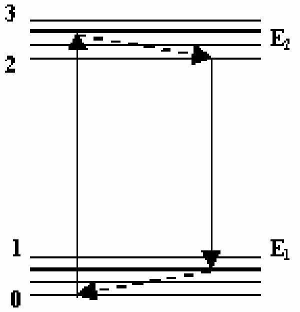

Fig. The four level system used for the rate equations.

In this work we theoretically investigated the pulse duration spectral dependence in DBF dye laser.

Energy level scheme of an active dye molecule is considered as a four level system (Fig.).

The levels 0 and 1 are vibration states of the electronic ground state. The first exited electronic state is E_2. The numbers 2 and 3 indicate vibration levels of the exited electronic state. The exited vibration levels 1 and 3 decay very quickly to the vibration ground states 2 and 0 respectively. Therefore, the density n of all active laser molecules is given by the sum of density n_1 of the molecules in the ground state 0 and the density n_2 of the molecules in the upper laser level 2

$$n = n_1 + n_2 \qquad (1)$$

The time dependence of $n_2(t)$ can be calculated by solving the balance equations which is derived from the equation of motion for the density matrix of the dye molecules

$$\frac{dn_2}{dt} = n_1 B_{03} U_p - A_{21} n_2 - n_2 B_{21} U \qquad (2)$$

The symbols in (2) have the following meaning: U-describes the laser field density in the active medium, B_{03} U_P-pump rate, A_{21}-spontaneous emission probability, B_{03}, B_{21} – Einstein's factors.

To provide feedback for the gain-coupeled DBF laser the pumping rate is spatially modulated with a period Λ

$$B_{03} U_p(z,t) = B_{03} U_p(t)(1 + \gamma \cos \frac{2\pi}{\Lambda} z) \qquad (3)$$

where γ denotes the visibility of the interference pattern. The value of Λ depends on the pump light wavelength λ_p and the angle of incidence :

$$\Lambda = \frac{\lambda_p}{2\sin\theta} \qquad (4)$$

The photon rate equation model will be used here for theoretical description of the population inversion in the active laser material as well as for photon number of the laser mode. The rate equation for laser radiation field U is [3]:

$$\frac{dU}{dt} = U(by - \frac{1}{\tau_c}) \qquad (5)$$

where $\tau_c = \frac{\eta^3 L^3 \gamma^2 b^2 n_2^2}{8c^3 \pi^2 n^2}, b = B_{21} h\nu n$

τ_c is the effective cavity decay time, L-length of the exited region, η -refractive index of the material, y-population inversion.

The equations (2) and (5) correctly predicts the transient behavior of the gain-coupled distributed feedback laser in the limit where pump pulse length is much longer then the pumped region transit time ($\tau_p >> \eta L / c$). One can see that for DFB laser the effective cavity decay time $\tau_c \sim n_2^2$. In this reason the effective cavity decay time modulation arises as a result of laser field changes. This phenomenon is called as self modulation of gain factor.

Following system of equations may be used to find peak power of the short pulse

$$\frac{dy(t)}{dt} = -B_{21}(\nu)U(t)y(t) \tag{6}$$

$$\frac{dU(t)}{dt} = U(t)[by(t) - \frac{a}{y(t)^2}] \tag{7}$$

where $y(t) = n_2(t) / n$, $a = \frac{8c^3\pi^2}{\eta^3 L^3 \gamma^2 b^2}$

From these equations we have for maximum of radiation energy

$$B_{21}(\nu)U^M = b(y_i - y_f) + \frac{a}{2}(\frac{1}{y_f^2} - \frac{1}{y_i^2}) \tag{8}$$

where y_i and y_f the values of populations for initial and final moment of pulse. Time dependence of population *y(t)* within maximum value of pulse will be given

$$y(t) = y_0 - y_0 B_{21} U^M (t - t^M) \tag{9}$$

In (9) $y_0 = \sqrt[3]{a/b}$.

Taking account (9) in (7) and after integration we obtain expression for the duration of short pulse

$$\tau = 2\sqrt{\frac{2\ln 2}{3B_{21}(\nu)U^M b y_0}} \tag{10}$$

We can see from (10) that spectral dependence of the pulse duration is determined by the stimulated emission rate $B_{21}(\nu)U^M$.

It is well known that spectral dependence of Einstein factor $B_{21}(\nu)$ for dye molecules may be described

$$B_{21}(\nu) = B_0 e^{-(\frac{\nu-\nu_0}{\Delta\nu})^2} \tag{11}$$

Where ν_0 -line center frequency and $\Delta\nu$ -half width of Gaussian line, B_0 – Einstein factor for center of emission line.

Including (11) in (10) it is easy to have formula for pulse duration frequency dependence

$$\tau = 2\sqrt{\frac{2\ln 2}{3by_0B_0U^M} e^{(\frac{\nu-\nu_0}{\Delta\nu})^2}} \tag{12}$$

For central frequency of spectral line we obtain.

$$\tau_0 = 2\sqrt{\frac{2\ln 2}{3by_0B_0U^M}} \tag{13}$$

Comparison (12) and (13) gives next expression

$$\tau = \tau_0 \sqrt{e^{(\frac{\nu-\nu_0}{\Delta\nu})^2}} \tag{14}$$

It is seen that the pulse duration τ is minimum for spectral line centre.The more frequency deviation of laser emission the longer pulse duration. Estimation for Rodamin 6G dye laser gives $\tau_0 = 50ps$. Results obtained in this paper can explain experimental pulse duration spectral dependence which was shown in [2].

As a rezult of fast gain change in active medium of DFB dye laser arises single short pulse. In the present work theoretically was investigated the spectral dependence of duration of pulse generated by DFB dye laser. Expressions for pulse duration and spectral dependence as well were obtained. It is shown that the frequency change of pulse duration within the gain spectrum of active medium may be explained by the appropriate change of stimulated emission probability of dye molecule.

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