SOME PECULIARITIES IN FORMATION OF THE POLARIZATION OF A FLASH-LAMP PUMPED DYE LASER RADIATION

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The processes influencing the formation of the emission polarization of isotropically pumped due lasers are investigated both theoretically and experimentally. In mathematical description of lasing, the system of rate equations for the set of polarization modes is used. The dependences of the gain and lasing intensity on the degree of cavity anisotropy and the pumping power were calculated. Polarization characteristics of the rhodamine 6G laser were studied experimentally as functions of the above parameters. The dependence of the gain factor anisotropy on the degree of cavity anisotropy and the pumping intensity has been revealed. As was established, the dependence of the gain anisotropy on the pumping intensity leads to the dependence of the degree of laser radiation polarization on the pumping power and results in a nonstationary polarization diagram.

The generation of polarized radiation with dye lasers (DLs) can be considered both as a separate problem resulting from concrete practical needs and as that accompanying the solution of other problems.

As known, the preferred polarization of the output radiation can be provided in three ways. The first one is to pump DL by a linearly polarized radiation of other laser; the second one is to use cavities anisotropic with respect to polarization; and, the third one is to inject a weak linearly polarized radiation into the DL active zone.

For generating polarized radiation in a flash-lamp pumped DL, the polarization-anisotropic cavities are used most often that is why the second way is of a practical importance. Nevertheless, the physical processes in these lasers are less studied than in lasers with a polarized radiation pump. This is likely to be because the basic principles of operation of lasers with polarization-anisotropic cavities are in use since 60s in application to solid state lasers[1] and they can be extended to DLs. Peculiarities inherent in liquid lasers were partially studied in Refs. 2 and 3. However up to now there is no complete analysis of polarized radiation generation in a flash-lamp pumped DL. Just that is the aim of our investigation.

For mathematical description of dye laser operation, the system of rate equations was used, in which the gain polarization anisotropy and the polarization of output radiation were taken into account.[4] In so doing, a molecule was modeled as a linear oscillator, common for absorption and emission with the two broadened electronic singlet states, the ground and first excited states. The cavity transmittance for beams of radiation with different polarization was described by the function $\Gamma = \cos^2\psi + \gamma\sin^2\psi$, where ψ is the angle between the vector of electromagnetic field strength and the laboratory coordinate system.

The system of rate equations has been solved numerically. Calculations were made for the rhodamine 6G laser with the pump pulse duration of 6 μs at the level of 0.1. We were interested in the dependence of the degree of laser radiation polarization P and gain factor $K_g(\psi)$ on the degree of the cavity anisotropy (i.e. γ) and pump intensity. The calculations have shown that for a fixed γ the increase in the pump rate results in a decrease in the polarization degree. This is because in the active medium of DL generating the polarized radiation the anisotropy of $K_g(\psi)$ appears, which is the greater, the greater are the cavity polarization anisotropy and the pumping intensity. This gives rise to conditions for generation of a large set of nonfundamental modes, what results in depolarization of radiation.

We have analyzed also the time-dependence of the instantaneous degree of polarization during the pulse. The dependence of $K_g(\psi)$ on the pump intensity was shown to lead to nonstationarity of the laser emission degree of polarization.

The dependence of anisotropy of $K_g(\psi)$ on the pump intensity can be connected with the value of excess over the generation threshold,[1] that was checked numerically in the stationary approximation. In this case, the corresponding formula for $K_g(\psi)$ calculation has the form

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$$K_g(\psi) = K_{th}(0)\left\{\cos^2\psi + \frac{1}{2}\left[\frac{3\beta}{\sqrt{a}}\arctan\sqrt{a} - 1\right]\sin^2\psi\right\},$$

where $a \approx 2.25\beta - 2.5$ (β is the value of pumping in excess over the threshold value).

The experiment has confirmed our theoretical results. In the experiment we have measured the degrees of rhodamine 6G laser polarization as functions of the cavity anisotropy at different values of pumping intensity, with the use of different solvents, and under varying the reflection coefficients of the cavity mirrors. As could be expected, increase in the generation threshold or decrease in the pump intensity resulted in increase in the polarization degree of the output radiation. The nonstationarity of the instantaneous degree of polarization with the value and the behavior dependent on the same factors was also observed.

As a result of our theoretical and experimental investigations, it was shown that in the active medium of isotropically pumped dye laser with a polarization-anisotropic cavity the gain factor anisotropy appears that influences the formation of polarization diagram of the laser output radiation. In this case, the degree of radiation polarization during the generation pulse may be essentially nonstationary in character, and the value of the polarization degree is determined by the degree of the gain anisotropy and depends on the value of pump excess over the threshold value. This allows us to conclude that in practice the degree of radiation polarization attained in pulsed laser depends not only on the efficiency of the intracavity polarizer but also on the parameters which determine the attainable value of excess over the generation threshold.

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