We have also investigated the dependence of the gain on the spectral composition of the sounding radiation. Gain was obtained for both the P and the R branch of the 00^01 - 10^00 transition. We can therefore conclude that the inversion in our case was complete and not partial.

According to preliminary estimates, for conditions not optimized with respect to the most important parameters, the inversion under the conditions of the described experiments can reach 10^{17} cm^{-3} and the per-unit lasing energy $\sim$5 J/l.

The authors thank A. M. Prokhorov, I. S. Zaslonko, and B. F. Gordiets for useful discussions and advice.

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SPONTANEOUS SINGLE-FREQUENCY GENERATION OF A SOLID-STATE RING LASER

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Submitted 13 July 1973
ZhETF Pis. Red. 18, No. 4, 253 - 255 (20 August 1973)

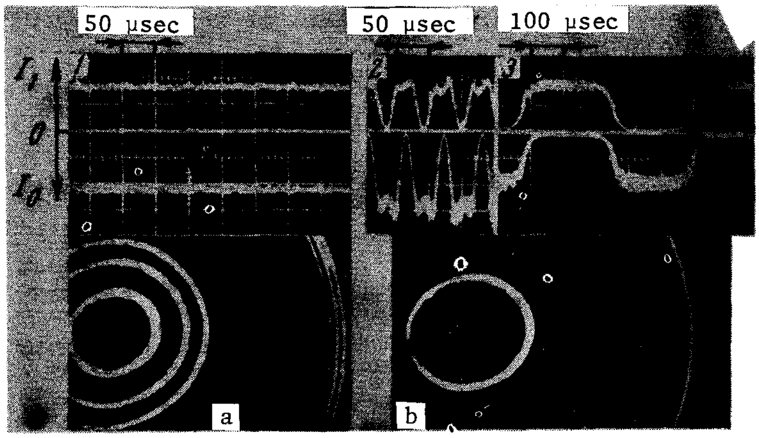
1. The known methods of obtaining single-frequency$^{1)}$ emission from solid-state lasers consist either of Q-discrimination of the axial modes, or of elimination of the spatial inhomogeneity of the field in the active medium, and special optical elements or mechanical motions are required in all cases. We consider here the possibility of obtaining single-frequency emission from a solid-state laser with homogeneously-broadened luminescence line. This possibility is based on the instability of the standing-wave regime in a ring resonator. We show that under certain conditions single-frequency lasing occurs in such a resonator spontaneously, i.e., without the use of the aforementioned special means.

2. At a sufficiently low scatter-induced coupling between the opposing waves, the generation of one axial mode is unstable, and a nonstationary self-oscillatory regime can set in [1 - 3], wherein the radiation becomes periodically unidirectional, and the phase difference between the opposing waves oscillates; this can be treated as the motion of the field maxima and minima along the resonator axis. It is natural to expect these singularities in the field pattern, which contribute to smoothing of the spatial inhomogeneity, to lead to single-frequency generation. On the other hand, stable stationary generation of standing waves of several axial modes remains feasible [1]. Which of these possibilities is realized depends on the relations between a number of factors, the character of the competition between them can be explained by means of the following qualitative considerations: Assume that at the initial instant there exists in the resonator a standing wave of one axial index at the frequency of the luminescence-line center, spatially modulating the inverted population. In accordance with the first possibility, a traveling wave of the same frequency and with a growth increment F_0 should appear in the resonator, and in accordance with the second possibility there should appear one more standing wave with an axial index that differs by ξ, shifted in space relative to the first at the center of the active medium by $\lambda/4$, with a growth increment F_ξ. One can expect the realized regime to be the one in which the growth increment of the corresponding wave is larger, this being more favored energywise. By comparing the increments, we obtain for their difference, after integrating over the length of the active medium:

$$F_\xi - F_0 \sim a(\sin 2\pi\xi\zeta / 2\pi\xi\zeta) - [b(1/g_\xi - 1) + (\gamma_\xi - \gamma_0)/g_\xi]. \qquad (1)$$

Here a and b are positive pump functions, g_ξ is the form factor of the luminescence line of the active medium, ζ is the coefficient of the filling of the resonator with the active medium along the optical length, and γ_0 and γ_ξ are the losses in the resonators at the corresponding frequencies. On the basis of [1] we can conclude that when the filling coefficient increases upward from zero, the single-frequency automodulation regime becomes more favored, and if $\zeta = 1/2$ and 1, this regime becomes preferred at all values of the pump regardless of the value of ξ. The single-frequency regime becomes more favored energywise also when selective losses $\gamma_\xi - \gamma_0 > 0$ are introduced into the resonator.

3. The experiments were performed with a three-mirror resonator having an optical length 50 cm, with generation of a fundamental transverse mode, using YAG:Nd^{3+} crystals at 1.06 μ



Generation kinetics (I_0 and I_1 are the intensities of the opposing waves) and spectrum of axial modes at different coefficients of filling of the resonator with active medium: a) $\zeta = 0.2$, b) $\zeta = 0.4$. 1 and 2 - pump near threshold, 3) 1.25 excess above threshold. Fabry Perot interferometer base 16 mm.

The figure illustrates the variation of the kinetics and spectrum of the emission with increasing ζ. In case (a), one of the two active elements placed in the resonator is pumped, and in case (b) both are pumped, i.e., ζ is doubled. As expected, when ζ was increased, spontaneous generation of one axial mode set in, and single-frequency generation was maintained up to an excess of 1.25 above threshold, the self-oscillation frequency decreasing with increasing pump. Frequency selectivity of the losses in the resonator was eliminated in this case by using specially shaped substrates for the mirrors and by inclining the active elements at an angle that excluded interference between the beams reflected from the end faces. It was also found that, in accord with the foregoing, a weak frequency selectivity introduced into the resonator when the laser generates many frequencies (when $\zeta = 0.2$) brings about a changeover to a single-frequency automodulation regime. The selector was a plane-parallel glass plate 8 mm thick, inclined approximately 10' to the resonator axis. When the plate was perpendicular to the resonator axis, a stationary regime with a broad spectrum set in, showing that this selector was too weak to suppress the multifrequency operation, and its role reduced indeed to ensuring an automodulation regime.

We note in conclusion that the output power obtained by this method from a single-frequency YAG:Nd^{3+} laser can be relatively high: it reached 0.12 W (in either direction) in the case of spontaneous single-frequency operation, and could be increased to 0.56 W with a plate.

The authors thank D. S. Prilezhaev and V. A. Fromzel' for useful discussions.

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[1] Throughout the article, "single frequency" refers to generation of one axial mode when the laser operates at a single transverse mode.

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