SINGLE MODE RUBY RING LASER

L. S. KORNIENKO, N. V. KRAVTSOV, N. I. NAUMKIN, and A. M. PROKHOROV

Nuclear Physics Institute of the Moscow State University

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Results of an investigation of a ruby traveling-wave ring laser are presented. It is shown that such a laser operates under regular oscillation conditions. The width of the radiation spectrum is measured. It is demonstrated that during the generation time the temperature drift of the radiation frequency is small (< 7 MHz).

THE spectral properties of a single-mode traveling-wave ruby laser with a ring resonator were investigated in[1]. It was shown that in the traveling-wave ring resonator the single-mode regime sets in after a certain time from the start of lasing. At the start of lasing, on the other hand, during the first two or three spikes, the emission takes place simultaneously at several frequencies as a rule. It was also indicated in the cited paper that an appreciable change of frequency takes place during the course of generation, owing to thermal effects. The estimates of this change yielded a value on the order of 60 MHz, which is noticeably lower than the apparatus function of the Fabry-Perot etalon used in that investigation for the analysis of the spectral characteristics of the laser.

The purpose of the present investigation was to obtain a single-mode regime from the very outset of generation, to measure the width of the emission spectrum and the emission-frequency shift during the process of generation.

To obtain the single-mode regime, we used a traveling-wave ring laser to which we added a selector (Fabry-Perot etalon) 9.3 mm thick with a transparency of 16% at the emission wavelength. A diagram of the employed ring laser is shown in Fig. 1. The choice of the three-mirror scheme is dictated by the fact that in such a scheme there is no parallel running of the trajectories of the optical rays, as is the case when a selector is introduced into a resonator made up of four reflecting surfaces. The active element was a ruby crystal of medium quality (four rings could be observed with a Michaelson interferometer) 68 mm long and 6 mm thick.

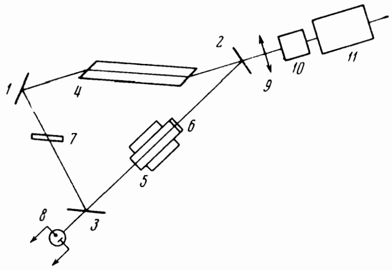

FIG. 1. Diagram of experimental setup: 1,2,3 – dielectric mirrors with reflection coefficient 95%, 4 – ruby crystal, 5 – Faraday isolator, 6 – quartz plate rotating the plane of polarizations by 32°, 7 – glass plate, 8 – photomultiplier, 9 – lens, 10 – Fabry-Perot interferometer, 11 – photographic camera.

To eliminate the back reflection, the end faces of the crystal were cut at the Brewster angle. The Faraday isolator was a solenoid, inside of which was inserted a TF-8 cylinder 90 mm long. The Faraday isolator, together with the quartz plate, ensured rotation of the plane of polarization by 64°. As shown by investigations, this rotation is perfectly sufficient for an effective separation of the opposing wave.

To investigate the spectrum characteristic of the ring-laser radiation, we used a Fabry-Perot interferometer 820 mm long with mirrors of 60 mm diameter and reflection coefficient 97%. The mirror finish was not worse than $\lambda/50$, thus ensuring a resolution on the order of 6–7 MHz. We note that the apparatus function of the interferometer, used in[1] was worse by one order of magnitude. The experiments have shown that generation at a slight excess over threshold (5%) occurs in a single mode during the entire generation time. When the threshold is exceeded by 10–15%, generation occurs on two–three modes. The width of the emission lines did not exceed 6–7 MHz (the measurement accuracy was determined by the apparatus function of the interferometer). An estimate of the width of the spectrum, obtained on the basis of the spike duration, yields a value on the order of 1 MHz. A spectrogram of the radiation is shown in Fig. 2.

The radiation of a ring laser in the single-mode regime was a regular sequence of a small number of spikes (usually 3–5) with a repetition period on the order of 30 μsec. The value of the repetition period is in good agreement with theoretical estimates obtained with the aid of the formula[1]

$$T = \sqrt{2\pi\tau Q / \nu(\alpha - 1)},$$

where Q is the quality factor of the resonator, τ the luminescence time constant, ν the emission frequency, and α the pump parameter.

An investigation of the spectrogram has shown that the total temperature shift of the radiation spectrum is relatively small (less than 7 MHz). It follows therefore that the temperature shift of the spectrum during the time of duration of one spike can be neglected. As noted above, in[1] the magnitude of the temperature shift was estimated at 60 MHz. Such a discrepancy can be attributed to the fact that during the generation time the change of temperature of the crystal is negligible, although the change of temperature during the entire operating time of the flash lamp, used for estimates in

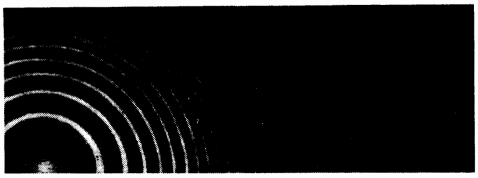

FIG. 2. Spectrogram of emission of single-frequency laser.

this investigation, can be appreciable.

The investigations have shown that only the central part of the crystal, with 1—1.5 mm diameter, generates near the threshold. The angular divergence of the radiation, measured on a base of 9.5 mm, is close to the theoretical one and amounts to less than 10^{-3} rad. The radiation energy in the single-frequency generation regime is approximately 0.02 J, corresponding to an average peak power in the spike of about 5 kW.

[1]C. L. Tang, H. Statz, G. A. De Mars, and D. T. Wilson, Phys. Rev. 136A, 1 (1964).

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