INVESTIGATION OF THE FREQUENCY CHARACTERISTICS OF AN Xe-He LASER WITH A DIFFUSE MIRROR

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1. A laser with nonresonant feedback with the aid of a diffuse mirror was proposed and investigated in [1-3]. The laser operated in a pulsed mode, since the active medium was a ruby crystal operating at 300 or 77°K. In the present letter we report, for the first time, attainment of a continuous generation mode and an investigation of the frequency characteristic of an Xe-He gas laser operating at λ = 3.50 μ with feedback produced by a diffuse mirror. The generation line width was approximately 15 MHz and was limited to a relatively small number of interacting modes. The experiments have demonstrated that the average frequency of the generated radiation does not depend on the distance between the mirror and the scatterer. The results confirm the possibility of developing an optical frequency standard based on the principle of nonresonant feedback. We note that the absence of spatial radiation coherence in such a laser [3] does not prevent production of narrow emission lines with absolute frequency stability.

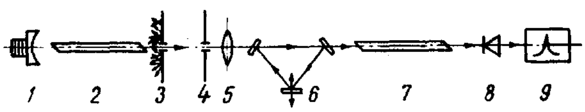

Fig. 1. Experimental setup: 1 - spherical mirror mounted on a piezoceramic, 2 - amplifying Xe-He discharge tube, 3 - diffuse mirror with aperture, 4 - diaphragm, 5 - matching lens, 6 - three-mirror scanning interferometer, 7 - optical quantum amplifier, 8 - InAs detector, 9 - automatic recorder.

2. The experimental setup is shown in Fig. 1. The laser had a tube excited by a high-frequency discharge, of length L = 120 cm and an inside diameter 2a = 0.7 cm, having a large gain at λ = 3.50 μ [4,5]. The tube was placed between a spherical mirror mounted on a piezoceramic and a scattering magnesium-oxide layer, having a small central outlet aperture for the radiation. The threshold was attained at a discharge length 90 cm. The angle of the generated emission was $\varphi_0 \simeq 0.2°$. Consequently, the number of the interacting modes was approximately

$$N \simeq (\phi_0/\frac{\lambda}{a})^2 \simeq 10,$$

and the expected width of the generation spectrum was

$$\Delta\nu \simeq \frac{c}{2L}\frac{1}{N} \simeq 10 \div 20 \text{ MHz}$$

The laser emission passed through two diaphragms, forming a narrow solid angle, to the input of a three-mirror scanning interferometer with base L' = 66 cm an and approximate resolution 10 MHz. The radiation passing through the interferometer was amplified 60 times by the Xe-He laser amplifier and was incident on a detector. The detector signal was recorded with an automatic recorder.

The line width of the generation with the diffuse mirror was approximately 15 MHz in most experiments (after subtracting the interferometer line width). In some cases it ranged from 10 to 20 MHz. The generation frequency stability was measured in the following manner. The laser spherical mirror was caused to oscillate at 100 Hz with a displacement amplitude $\delta L \simeq 1\ \mu$. The mirror motion did not lead to a broadening of the laser emission spectrum (Fig. 2). In the case of an ordinary laser, in which the scatterer was replaced by a second mirror, such a mirror motion broadened the emission spectrum by 40 MHz (Fig. 3).

4. The attained line width is not the limit, since it was substantially limited by the geometry of the discharge tube. The optimal geometry for obtaining a narrow generation line of high stability is one in which the generation is produced in a total solid angle 4π sr [6]. In this case the number of the interaction modes $N \simeq (a/\lambda)^2$ (a is the dimension of the laser) can reach $10^7 - 10^9$. At the same time, it is possible to avoid in such a system the influence of the inhomogeneous character of the Doppler line, since the probability of emission of an atom in an isotropic field does not depend on the velocity of the atom, and no holes can "burn out" in the line. Experiments with lasers of these types are

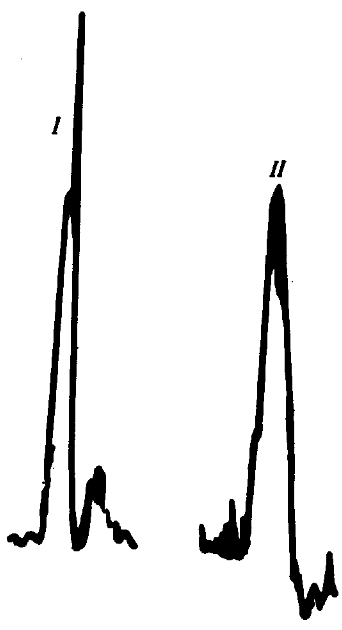

Fig. 2. Emission spectrum of a laser with diffuse mirror: I - generation with mirror 1 at rest, II - generation with mirror 1 oscillating.

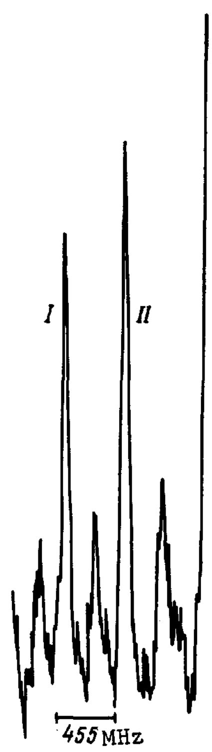

Fig. 3. Emission spectrum of a laser with a Fabry-Perot resonator: I - generation with mirror 1 at rest, II - generation with mirror 1 oscillating. Distance between maxima - 455 MHz.

now under way.

In conclusion, the authors are deeply grateful to P. G. Kryukov for numerous discussions and to E. P. Markin for great help.

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Figures 2 and 3 of this article should be interchanges, but the captions should be left in place.