i.e., to locating the pickoff points a quarter-circle apart) is equal to:

$$\Delta\phi_{max} = \sqrt{\frac{2\pi GI}{c^3}}\,\omega_e t^2 . \qquad (9)$$

Substituting in (9) $\omega_e = 6 \times 10^{10}$ sec^{-1} and t = 1 sec (this is the "ringing" time in superconducting microwave resonators [5]) we find that to measure a gravitational-radiation flux $I = 1 \times 10^{-2}$ erg/sec-cm^2 it is necessary to register $\Delta\phi = 1 \times 10^{-9}$ rad. It is clear that an increase in the Q of the superconducting resonators (or, equivalently, an increase of t) and also a decrease of the distinguishable phase shifts will lead to an increase of the sensitivity of such a detector. If ω_g is not equal to 2c/r, then the factor $\omega_e t^2$ in (9) should be replaced by ω_e/Ω^2, where $\Omega = \omega_g - (2c/r)$ is the beat frequency. We emphasize once more that such a relatively high sensitivity is the consequence of the resonance between the frequency of the gravitational wave and the frequency of rotation of the field in the resonator (GER).

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INVESTIGATION OF THE CHARACTER OF THE EMISSION OF A NEODYMIUM GLASS LASER WITH A PASSIVE SHUTTER HAVING A FINITE RELAXATION TIME

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The relation between the relaxation time τ_{rel} of the population of the levels of dyes used as passive shutters in lasers, and the duration Δt of the ultrashort pulses (USP) is of great importance for obtaining complete mode locking, i.e., separation on the axial radiation period of a single USP with duration $\Delta t \sim (c\Delta\nu)^{-1}$, determined by the width $\Delta\nu$ of the radiation spectrum.

The existing theoretical papers on mode locking in lasers with passive shutters presuppose an infinitesimally short relaxation time of the dye, i.e., $\tau_{rel} \ll \Delta t$. There has been little theoretical study of the operation of a passive-shutter laser with a finite relaxation time. It is therefore of interest to investigate the emission characteristics of the lasers in order to establish a relation between τ_{rel} and Δt for the presently used passive shutters in neodymium-glass lasers.

The purpose of the present study was to estimate the relaxation time of the widely-used polymethine dyes[1)] and to investigate experimentally the emission characteristics of lasers with such shutters.

[1)] Soviet-made dyes known as Nos. 3955 and 1000.

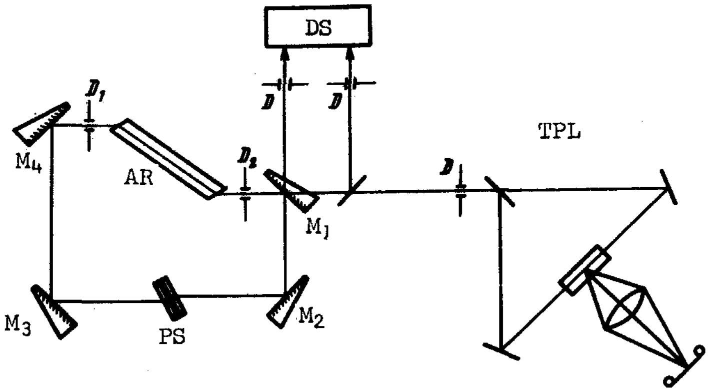

Fig. 1. Diagram of experimental setup. AR - active rod (neodymium glass, 15 mm diam x 295 mm; PS - cell 1 mm thick with passive shutter. Mirror reflection coefficients: $R_1 = 0.82$, $R_2 = R_3 = R_4 = 1.0$. Diameter of diaphragms D_1 and D_2 is 2 mm. Resonator length ~200 cm. DS - diffraction spectrograph, TPL - setup for registration of two-photon luminescence tracks. The diaphragms D were used to separate the radiation corresponding to the divergence of the laser axial modes.

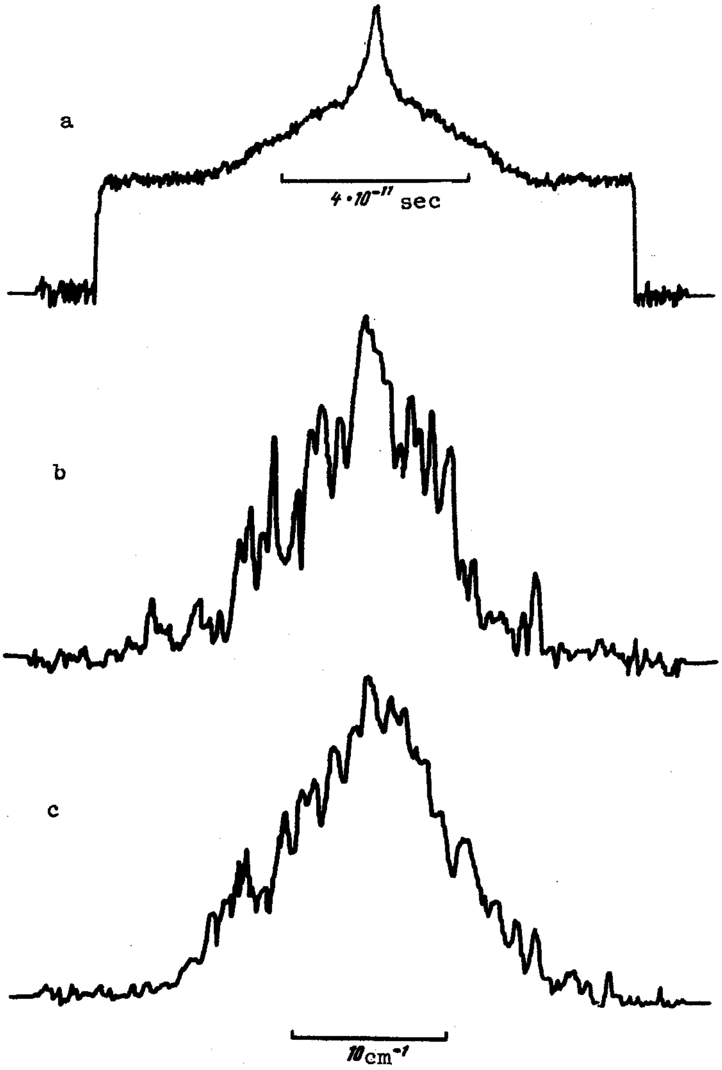

Fig. 2. a) Microphotograph of track of two-photon luminescence. Width of central peak $\sim 2.5 \times 10^{-12}$ sec. b, c) Microphotographs of spectra of radiation propagating in laser resonator in opposite directions.

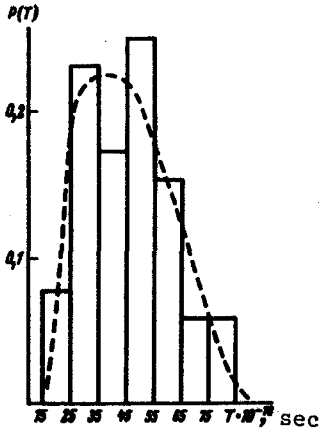

Fig. 3. Experimental probability density distribution P(T) for the durations of USP groups for the dye No. 3955 in nitrobenzene (the data for dye No. 1000 differ slightly from those given here).

The experimental setup is shown in Fig. 1. A ring resonator was used, which prevents the occurrence in the radiation spectrum of the structure connected with the cell position, and furthermore makes it possible to investigate the characteristics of radiation propagating in opposite directions. Measures were taken to eliminate "parasitic" mode selection. The transmission of the cell with the passive shutter was approximately 50% at the generation wavelength of the neodymium laser. Diaphragms D_1 and D_2 were used to separate only the axial modes of the laser. The spectra were registered with a diffraction spectrograph (DS) having an approximate resolution 15 cm^{-1}.

If the dyes employed by us have a finite relaxation time and the case $\tau_{rel} > \Delta t$ is realized, then it can be assumed that the change in the populations of the working levels in such dyes will be the result of radiation-energy absorption during a time on the order of the relaxation time. The passive shutter will then be bleached when the absorbed energy exceeds a level characteristic of the given dye. And since the intensity of the laser radiation has a noise-like character, the shutter will separate from this picture not single USP (as in the case when $\tau_{rel} << \Delta t$), but its most intense sections, i.e., groups of USP, the durations of which can differ.

To investigate the durations of the separated USP groups, we used a two-photon luminescence (TPL) procedure, since the presence of a group of closely-lying USP on the axial period should be manifest on the TPL track by a "plateau," on which there is a peak with duration $\Delta t \sim (c\Delta\nu)^{-1}$. The dimension of this "plateau" is a measure of the duration of the group. Since the durations of the groups are different if $\tau_{rel} > (c\Delta\nu)^{-1}$, this should be reflected in different lengths of the "plateaus."

A typical microphotograph of the track is shown in Fig. 2a. Statistical reduction of a large number ($\approx$100) of tracks has shown (under fixed laser operating conditions) that the dimension of the "plateau" indeed changes from flash to flash, in accord with the proposed mechanism for the separation of the groups. The results of the reduction of the TPL tracks are shown in Fig. 3, which shows the obtained experimentally-normalized probability density of the USP group durations.

As follows from Fig. 3, the passive shutter separated groups with durations from 18 to 85 psec, and no groups with duration shorter than 18 psec was observed by us. This indicates that no single USP were separated, as would be in the case $\tau_{rel} << (c\Delta\nu)^{-1}$, i.e., the dyes used by us have a considerable relaxation time $\tau_{rel} > \Delta t$. The relaxation time estimated by us from the shortest duration of the separated USP group is approximately 2×10^{-11} sec. On the other hand, the average group duration is about 40 psec. If it is assumed that the distance between the individual USP in the radiation is of the same order as their duration $\Delta t \sim (c\Delta\nu)^{-1}$ (in our case $\Delta\nu$ was 10 cm^{-1}), then the average group consists of approximately 20 pulses. According to [3], if a USP group exists on the axial period, the radiation spectrum should always have an irregular structure determined by the intervals between the pulses in the group and by their amplitudes, as was indeed observed in the experiment (Fig. 2b).

The results confirm the assumption that a passive shutter with $\tau_{rel} > (c\Delta\nu)^{-1}$ separates segments of the noise generation picture, with a total duration of the order of the relaxation time. Since the pulse groups propagating in the ring resonator in opposite directions are separated by the passive shutter from different noise pictures, the temporal structures of these groups will be different and statistically independent. Consequently the structures of the spectra of the radiations propagating in opposite directions should also be different and irregular. To confirm this, simultaneous investigations were made of the spectra of the radiations propagating in opposite directions. To this end, the radiation from both channels was projected on different sections of the spectrograph slit, and independent spectra of the radiation in the two directions were obtained during each flash. Each spectrum revealed an irregular structure that did not repeat from flash to flash; more importantly, the structures corresponding to opposite directions were always different. By way of examples, Figs. 2b and 2c show typical microphotographs of such "double" spectra, which show clearly the difference in the structure.

The case $\tau_{rel} > (c\Delta\nu)^{-1}$ is thus realized for the dyes used in our experiment, and it is therefore practically impossible to obtain complete self-synchronization of the modes with broad emission spectra. The relation $\tau_{rel} \ll (c\Delta\nu)^{-1}$, under which complete mode locking has a noticeable probability for our dyes, can be satisfied, for example, by decreasing $\Delta\nu$. As shown by us in [3], a decrease of the spectrum width $\Delta\nu$ from 20 to 2 cm^{-1} increases the probability of complete mode locking appreciably, at the expense of increasing the USP duration. The most promising, however, from the point of view of obtaining single pulses of high power at considerable spectrum widths, is the search and the use of dyes whose relaxation time τ_{rel} is shorter than the UPS duration $\Delta t \sim (c\Delta\nu)^{-1}$.

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OPTICAL FREQUENCY STANDARD WITH A BEAM TYPE ABSORBING CELL

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Lasers with nonlinearly absorbing gas cells saturated by the field of an electromagnetic wave, besides having spectroscopic applications, play an especially important role in the development of optical frequency standards [1]. The best results from the point of view of reproducibility of laser radiation have been obtained to date with an He-Ne laser ($\lambda = 3.39\ \mu$) with an internal methane absorbing cell, stabilized against the top of the power peak that arises when the rotational-vibrational transition $\nu_3[P(7)]$ of the methane molecule is saturated [2]. One of the main sources of errors in the reproducibility of the frequency of a laser of this type is the shift of the absorption line as a result of the collisions between molecules. The desire to reduce this shift makes it necessary to work at very low gas pressures in the absorbing cell. This, however, greatly decreases the amplitude of the peak, reduces the signal/noise ratio, leading in turn to a limitation on the attained stability and reproducibility of the gas-laser frequency.