# New rapidly relaxing passive shutter for a neodymium-glass laser

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We report the development of a passive shutter whose bleached time has a record low value $\tau = 1.5$ psec. This shutter has been produced for the first time and ensures stable generation of light pulses of 2 psec duration. Results are reported of investigations of the generation characteristics of a laser with the new passive shutter.

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The need for developing rapidly relaxing passive shutters for neodymium-glass lasers has been indicated in many papers devoted to the application and generation of ultrashort light pulses (USP). To produce a passive shutter having a short relaxation time, we have investigated a large number of specially synthesized dyes of different classes. From among these we found two dyes, No. 3282u and No. 3323u,[1)] whose solutions have much shorter relaxation times than the presently known dyes. Thus, the relaxation time of the American dye EK=9740 in chlorbenzene is $\tau = 8$ psec, and of the solution of the dye EK=9860 in 1.2 dichlorethane is $\tau = 9$ psec,[1] while the presently employed solution of the domestic dye No. 3955 in nitrobenzene has $\tau = 40$ psec.[2]

The passive-shutter relaxation time was estimated by the method described in[2] from the plot of the transmission coefficient of the dye solution against the radiation power density at a pulse duration exceeding the relaxation time. In the present study, the pulse duration was 90 psec.

Figure 1 shows the result of such measurements for the solution of dye No.

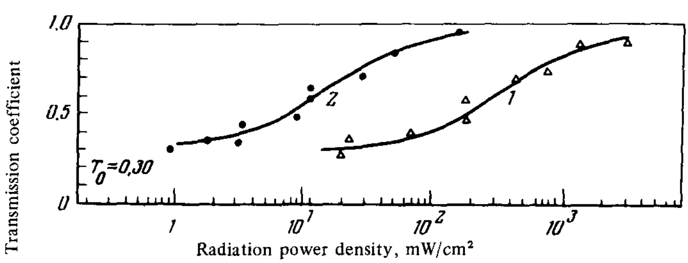


FIG. 1. Dependence of the transmission coefficient of the investigated passive shutters on the radiation power density: 1—solution of dye No. 3282u in nitrobenzene, 2—solution of dye No. 3955 in nitrobenzene. The points correspond to the experimental values. Solid lines—calculated curves for the following data: $1 - \sigma = 4.2 \times 10^{-16}$ cm$^2$; $T_0 = 0.30$; $\tau = 1.5$ psec $2 - \sigma = 3.2 \times 10^{-16}$ cm$^2$; $T_0 = 0.30$; $\tau = 40$ psec.

  

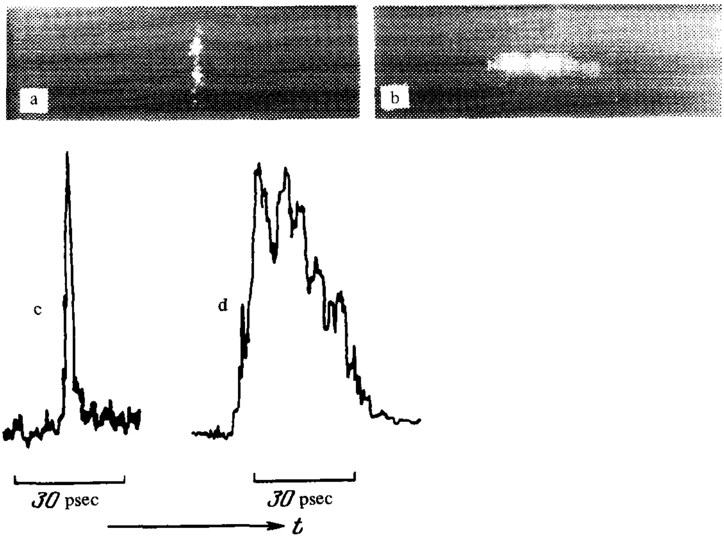


FIG. 2. Photographs of the streak camera screen and corresponding microphotograms of neodymium-glass laser pulses with two passive shutters: a, c—solution of dye No. 3282u in nitrobenzene; b, d—solution of dye No. 3955 in nitrobenzene. The time resolution of streak camera in the slit scanning regime was 1.8 psec.

3282u in nitrobenzene (they are analogous for the dye No. 3323u), as compared with the solution of the dye No. 3955. Taking into account that rather good agreement between the calculated curves and the experimental data and the appreciable shift of the section of the nonlinear blecahing of the compared dye solutions, it can be concluded that $\tau$ of the solution of dye No. 3282u in in nitrobenzene is much less than $\tau$ of the solution of dye No. 3955, and amounts to $\tau = 1.5 \pm 0.3$ psec. Analogous measurements for the solution of the dye EK-9740 in chlorobenzene yielded a value $\tau = 8 \pm 2$ psec, which is in good agreement with[1].

This was followed by investigations of the lasing characteristics of a neodymium-glass laser with solutions of the dyes 3282u and 3955 in nitrobenzene as the passive shutters. The active element was a rod of GLS-1 glass of 10 mm diameter and 130 mm length, with end faces cut at the Brewster angle to the resonator axis. Measures were taken to eliminate mode selection.

The time development of the laser radiation was investigated with the aid of a streak camera with UMI-93M tube,[3] having a time resolution 1.8 psec, and was monitored by high-speed oscillography with a resolution $\approx 0.3$ nsec. In addition, the two-photon luminescence (TPL) method was used to register simultaneously the autocorrelation function of the radiation intensity. These investigations have shown that the lasing characteristics of a laser with passive shutters of solutions of the dyes No. 3282u and No. 3955 differ substantially. Thus, when working with dye No. 3282u, the time evolution of the radiation on the axial curve comprised almost always single UPS whose average duration

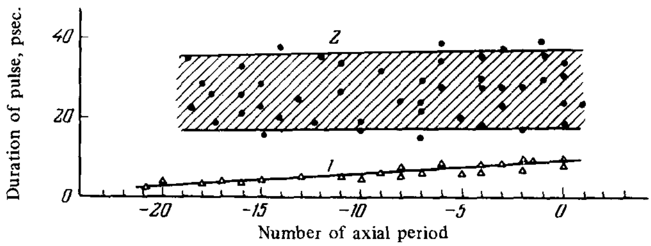


FIG. 3. Radiation-pulse duration at the start of the train of the "giant" laser pulse with the following investigated types of shutters: 1—solution of dye No. 3282u in nitrobenzene, 2—solution of dye No. 3955 in nitrobenzene. The zero on the abscissa axis corresponds to the maximum of the giant pulse.

at the start of the train of the "giant" pulse, measured with the aid of the streak camera, was 2 psec. On the other hand, when working with dye No. 3955, additional pulses were frequently observed on the axial period, and the average duration, even at the start of the lasing was ≈ 27 psec. This difference in the time pictures is particularly clearly revealed by the typical photographs shown in Fig. 2, of the scanned radiation, photographed from the streak-camera screen. The values of the pulse durations obtained with the aid of the streak camera were in good agreement with the data determined from the autocorrelation function of the radiation intensity by the TPL method.

It was of interest to compare the durations of the registered pulses as functions of their positions in the train of a "giant" pulse. The radiation pulses were separated with an electro-optical shutter. The results are shown in Fig. 3. In the case when a passive shutter with $\tau = 1.5$ psec was used (solution of dye No. 3282u in nitrobenzene) the duration of the radiation pulses, amounting to ≈ 2 psec at the start of the train, increased almost linearly as the maximum of the "giant" pulse was approached, and amounted to ≈ 10 psec near the maximum. The mechanism of the observed increase of the pulse duration in the train is presently under study by us.

If a passive shutter with $\tau = 40$ psec is used in the laser (solution of dye No. 3955 in nitrobenzene) a large scatter is observed in the pulse durations, regardless of their position in the train of the "giant" pulse,

The comparison of the laser emission energies have shown that in the case when the solution of the dye No. 3282u in nitrobenzene is used as the passive shutter, the total radiation energy of the entire "giant" pulse was 1.2 times larger than for a laser with a solution of dye No. 3955 in nitrobenzene.

Special notice should be taken of the photochemical endurance and stability of the solutions of the new dyes No. 3282u and 3323u in nitrobenzene. Thus, after six months of storage in darkness the initial transmission coefficients did not change by more than 1%. A laser with these passive shutters, without forced flow of the solution, had lasing parameters that remain stable for 10 000 flashes.

Thus, the use of a new rapidly relaxing passive shutter makes it possible to obtain with high stability short light pulses of duration 2 ± 1 psec at the start of the train of the "giant" pulse in a neodymium glass laser.

[1)]In this article we do not touch upon the physical and chemical properties of these dyes, which are the subject of a special article, and confine ourselves only to their designating numbers.

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