GARNET LASERS WITH A Q-SWITCH OF LiF:F_2^- CRYSTALS

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Received July 26, 1995

This paper presents the comparative data on the use of the profiled and nonprofiled Q-switches in a Nd:YAG laser. The possibility of using LiF *crystals in different-type lasers control is demonstrated.*

When developing lasers with a Q-switch, great attention is paid to the energy and spatial characteristics of radiation. The passive Q-switches have a set of valuable qualities, however formation of the spatial characteristics of radiation occurs randomly, from noise, and a beam diffraction by limited apertures has the most substantial significance to a generation seed. In this case it is difficult to maintain single mode generation of a high-power pulse without selective elements.

As shown in Refs. 1–3, in order to obtain single mode generation with the use of active switches, it is necessary to apply the slow or step-by-step Q-switching. In order to obtain a single mode generation without use of diaphragms, the standing waves of switch deformation were put forward in Ref. 3 for use, which provided a Gaussian behavior of the transmission change in it over Q-switch cross section due to the piezooptic effect. It is natural that a complexity of this variant did not stimulate its wide use.

We have proposed in Ref. 4 a passive modification of a Q-switch with a gradual opening of the cavity in the transverse direction with respect to its axis. Such an objective has been achieved by "profiling" of the switch, i.e. by fabrication of Q-switch with a smooth increase of the transmission from its edge to axis. Profiled (shaped) switches are similar to "apodizing", "soft" diaphragms[5,6] and, in principle, they can be used as them as well.

However, the absence, in that time, of convenient technology for production of profiled switches with the given characteristics has not resulted in their wide use.

When optical elements with F-centers have appeared, it became possible to make switches with the specified parameters very simply. Already in Ref. 7 it was reported that profiled switches on F_2^-:LiF - centers were made and that substantial decrease in garnet laser radiation divergence happens with the same energy characteristics. One of technologies for these switches production is presented in Ref. 9. Similar investigations have gained further development in many works; we note, in particular, Ref. 8.

However, up to now no information is available from literature about the use of profiled Q-switches in order to obtain powerful single mode generation. In this paper comparative data on the use of profiled and nonprofiled Q-switches in Nd:YAG laser are presented and the possibilities of using LiF crystal are demonstrated for the control of operation of different lasers. The passive switches produced at LaserPrim company (Tomsk) were used.

1. LASERS WITH PROFILED Q-SWITCHES

The experimental investigations have been carried out with the use of a laser, the geometry of whose cavity is shown in Fig. 1. Active element on YAG:Nd was 80 mm in length, a pulse repetition frequency was 12.5 Hz.

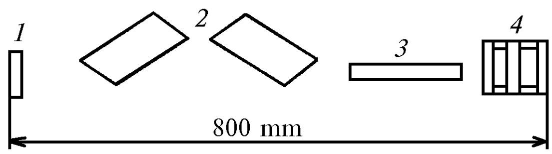

FIG. 1. The geometry of a Nd:YAG laser cavity with a profiled switch: a 100-percent mirror 1, modulation crystals 2, an active element 3, and a pile 4.

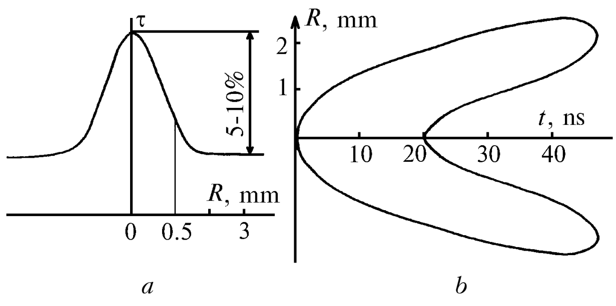

FIG. 2. Profile of the switch transmission (a) and near zone radiation field (b).

As an output mirror we used an optical pile for the maintenance of the single mode generation. Modulation crystals had a 6×6 mm cross section and 30 mm length, a transmission profile in a weak field is shown in Fig. 2*a*, a transmission modulation depth for different

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crystals varied from 5 to 10%. The threshold voltage of a pumping for a free generation mode was 470 V and 590 V when using transparent crystals (the capacitance of the discharge circuit was 75 μF.)

In the first series of experiments, one of two LiF crystals in the laser cavity was replaced with a profiled crystal. Crystals characteristic and generation parameters are presented in Table I. As a rule, single frequency generation can be reached easily, however, very fine adjustment of the cavity is required for some crystals.

TABLE I.

Crystal number	Initial transmission, %	Contrast	Pumping, V	Energy, mJ
16	36	11.9	740	13
19	36	14.6	740	15
20	40	16.7	750	13
28	40	13.6	760	12
32	38	12	730	12
34	34	13.6	770	21
39	38	13.5	750	21
40	30	10.2	760	18
47	34	12.4	760	16
49	36	10	720	16
51	40	12.7	740	23
52	32	15.8	830	15
56	44	11.4	750	12
59	34	12.4	740	26
63	40	12.9	700	15
70	32	16.3	730	20
71	40	13.5	750	15
75	30	11.3	810	17
77	40	11.6	750	15

In the second series of experiments, one and two modulation crystals were installed successively, the results are shown in Table II. The installation of two elements results in a decrease in the initial transmission of a *Q*-switch on the whole and in the increase of the output energy. The change also occurs in duration and profile of lasing pulse (the pulse top flattens). This effect is caused by the spread of lasing across the crystal,[4] that was recorded in the experiments (Fig. 2*b*).

Figure 3 shows general comparison of the obtained results and their comparison with data for usual (nonprofiled) gates. One can see that with the use of profiled *Q*-switches the output energy of single-frequency generation is three–five times greater.

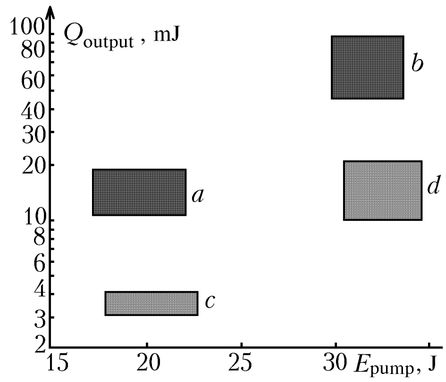

FIG. 3. Single pulse energy in a single-frequency lasing mode: a, b - profiled switch; c, d - usual passive switch; a switch length is 30 *(a,c) and* 60 mm *(b,d).*

It can be supposed that analogous effect will take place in other lasers with the passive switches as well; namely, in a ruby laser with LiF-OH (F_2^{+*}) switch[10] and in an alexandrite laser with the LiF switch with the thermoconverted F_3^+ color centers.[9]

2. Nd:KGdW LASER

Active element was 76 mm long, pulse repetition frequency was 5 Hz. The threshold energy of the pumping for a free generation was 3.4 J, at the installation of *Q*-switches it was from 3.9 to 6 J (we have tested more than 40 *Q*-switches).

The oscillation energy in single transverse mode is from 10 to 50 mJ depending on the initial transmission and the *Q*-switch contrast. When several modes reach lasing, then the energy increases up to 100 mJ in a single pulse.

TABLE II.

Crystal number	Initial transmission, %	Contrast	Pumping, V	Energy, mJ	Duration, ns
57	28	12.4	710	24	25
15	36	8.8	660	15.2	28
50	36	8.6	665	14.4	25
82	36	12.6	665	19.6	28
27	34	13.3	680	18	20
82+27	–	–	980	46.4	20
15+50	–	–	910	72	50
82+57	–	–	950	81	60

3. LTI-701 LASER

The home industry produces a laser of LTI-701 type with high pulse repetition frequency. *Q*-factor of the cavity is controlled by an optoacoustic switch. Nonlinear frequency converter is installed inside the cavity (see Fig. 4). The figure demonstrates also basic lasing parameters and shows schematic diagram of the lasing pulse.

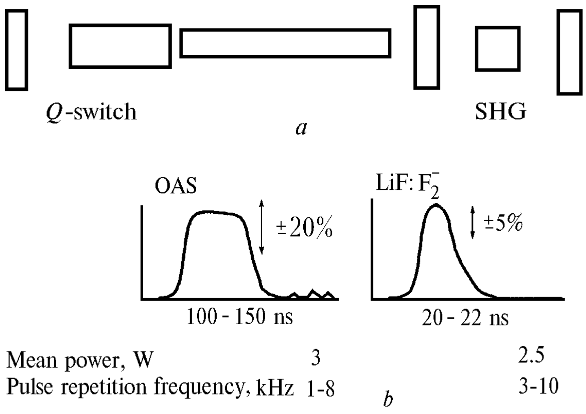

FIG. 4. The geometry of the cavity (a) and lasing characteristics (b) of LTI-701 laser.

In our experiments the optoacoustic switch was replaced with LiF:F_2^- crystal with the length of 50 mm, the rest elements of the cavity have not been replaced.

It is seen that energy stability in the lasing pulse increased substantially and radiation pulse shortened. The frequency of pulse repetition is controlled by a pumping level. We note that the characteristic times of the processes in LiF with F_2^-, which take place at *Q*-switching, allow one to reach the pulse repetition frequency of the order of 100 kHz.

Results presented in this paper allow us to consider the profiled switches to be very promising for obtaining high-power single-frequency generation, and their easy production can favor their wide use.

Further investigations in the given direction should deal both with the use of F-centers of different type for lasers, operating in other ranges, and with development of lasers, which emit monopulse narrow-band radiation of variable duration.

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