Lasers in Manufacturing Conference 2015

# Creation of the laser system for testing the damage threshold of optical materials and coatings

Y.A.Kalinin[a] ; A.N. Ignatov[b]; B.N. Krayev[a] ; E. Y. Krekhova [b] *; V.S. Kurakin[b]; A.E. Pozdnyakov[b]; V.A. Serebryakov[c]; A.A.Skrynnik[a]; M.A.Filipov[a]

[a]*JSC Shvabe-Issledovaniya, Volokolamskoe shosse, H. 112, b1,c.3, Moscow, 125424, Russia*
[b]*JSC LZOS, H.1, Parkovay str., Lytkarino, 140080, Russia*
[c]*JSC SOI named after S. I. Vavilov, Babushkina str., H.36, c.1, Saint-Petersburg, 192171, Russia*

**Abstract**

This article describes the system for testing the damage threshold of laser phosphate glass active elements that should be resistant to impulse radiation with duration of 3÷5 ns at wavelength 1054 nm and stand single exposure not less than 30 J/cm$^2$. Measurements are conducted by direct focused laser radiation effect on bulk or surface of sample with recording the laser radiation parameters (energy, area of the exposure spot, distribution of radiation density in the exposure spot).

*Keywords:* damage threshold, pulse radiation, spot of exposure, active element

## 1. Actuality of the issue

In the recent decades the issue of development of the systems for testing the controlled laser thermonuclear fusion as an alternative energy source has been of significant interest. One of the technical issues to settle in the process of development of such systems is the production of large-dimensioned active disc elements from laser phosphate glass and testing their damage threshold (references by Basov et al., 1984; Shanin, 2012; Avakyants et al., 2013 and 2014). Active disc elements damage threshold testing is carried out using witness samples from phosphate glass of each melting and is an important part of the manufacturing process. Damage threshold means threshold density of energy or power of the laser

* Corresponding author. +7-495 -552-32-95; fax: +7-495-552-17-90.
*E-mail address:* e.krehova@mail.ru.

radiation, which leads to damage of optical medium integrity and to occurrence of visible damages on sample surface or in its bulk (references by Radi, 1974 and Aleshin et al., 1974). This particular parameter defines the quality of phosphate glass as laser active medium and also the possibility of its application as active disc elements in high-power amplifier stages of systems for research the controlled laser thermonuclear fusion.

In compliance with the requirements, active disc element from phosphate glass have to stand single exposure to radiation with density not less than 30J/cm2, which defines the possibility of its operating in conditions of multiple pulse laser radiation exposure with duration 3÷5 ns at wavelength 1054 nm. Testing of witness samples should be carried out in conditions close to the conditions of active disc elements operation within a high-power laser.

## 2. Design features of laser system with pulse radiation with 3÷5 ns duration.

The major equipment of laser system includes:

- high-power laser emitter;
- optical system of laser beam exposure generation to the sample;
- system for laser alignment and pointing the laser radiation to the sample;
- system for laser radiation parameters measurement;
- apparatus for registering the laser radiation exposure results.

Laser system operation principle implies that impulse radiation coming from the low power generator, with required time parameters, goes consequentially through amplifier stages gaining the power till the required value (10÷20 J). Then by means of optical system the energy is concentrated on the test sample providing the density around 40 J/cm$^2$ on the target. The measurement system records the exposing laser radiation parameters, then by means of a microscope the presence or absence of micro damages in the sample is defined.

Laser system facilities are located in clean production workshops (ISO grade 9) in three dedicated areas. This solution provides the required conditions for conducting the measurements and safety of the work. The first area houses equipment for system power supply (capacitive storages, charging devices, units ignition of pulse pumping lamps). The second area houses optomechanical part of the system including: driving generator, amplifier laser heads, vacuum spatial filter, measuring apparatus, material samples being tested, as well as cooling systems and vacuum pump. The third area houses control panel.

Solid-state laser on $LiYF_4$ crystal (yttrium-lithium tetra fluoride) with diode pumping is used for driving generator. It provides generation of pulses with duration 3÷5 ns and energy about $10^{-3}$ J per impulse. Amplifier stages used the phosphate glass doped $Nd^{3+}$ions as active laser medium. Luminescence spectrum of this glass practically coincides with $LiYF_4$-crystal radiation spectral characteristics. Figure 1a shows general view of the laser system.

Technical tasks which appear while development the laser amplifier with high gain coefficients, namely elimination of return flare effect on driving generator optics, suppression of amplifiers self-excitation are solved by including the nonreciprocal elements into the laser systems schematic: Faraday cells on the basis of TGG crystal (terbium gallium garnet) and passive laser shutter. By means of quarter-wave plate the circular radiation polarization in amplifier stages is implemented, vacuum spatial filter eliminates small-scale non-homogeneities and is adjusted for receipt of diverging radiation. The complex of these schematic technical decisions has allowed raise the thresholds of radiation self-focusing in active elements of tract laser system.

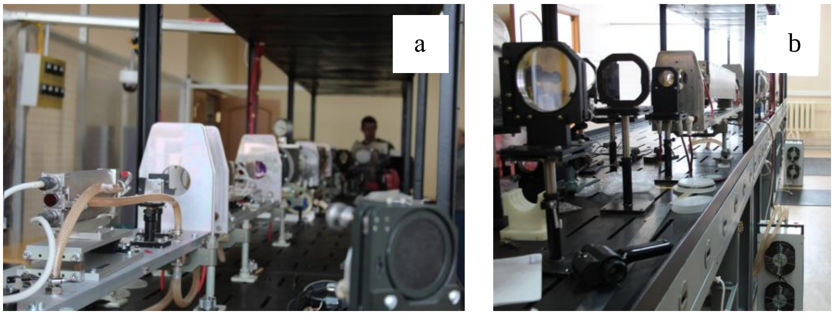


Fig. 1. General view of laser system: a) amplifier stages; b) radiation focusing system.

Laser radiation focusing by means of prismatic raster and convergence lens allows forming the area of exposure on the test sample with homogeneous distribution of radiation density within the spot of dimensions about 5x5 mm (ref. Fig. 1b, 2a).

Radiation energy parameters measuring system includes infrared heads of Ophir production and registering device Nova II, which provide measuring the energy of pulses radiation with error of ±3%.

Silicon photo diode FPS-1 with oscillograph is used for measuring the radiation time parameters, which allows registering an impulse with duration 3÷5 ns. (ref. Fig. 2b).

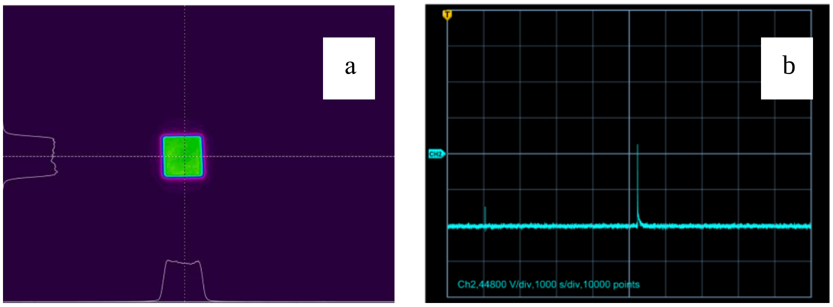


Fig. 2. (a) profile of focused beam radiation; (b) radiation pulse oscillogram

The generated construction of laser system provides stable characteristics of laser radiation, reflected in Table 1.

Table1. Parameters of laser system

| Parameter | The value |
|---|---|
| Radiation wavelength | 1054 nm |
| Duration of radiation pulse | 3÷5 ns |
| Output radiation energy in the pulse | 3÷15 J |
| Distribution of radiation density (degree of non-uniformity of distribution within the spot) | ±10% |
| Radiation density on the target | 1÷60 J/cm2 |
| Operation mode | One impulse per each 10 minutes |
| Size of exposure spot on the test sample, mm | Not less than 5x5 mm |

## 3. Results of testing the phosphate glass witness samples on the laser system

The following radiation parameter values were obtained during measurements:

- Impulse duration 3÷5 ns
- Output energy from 3 to 20 J, which was achieved by changing the level of voltage on capacitive storages (set within the range from 0 to 5000 V with accuracy 10 V).
- The radiation energy density in the area of test sample is from 3 to 50 J/cm$^2$ (depending on the spot size), which is achieved by radiation attenuation by means of a set of neutral light filters. Threshold energy density (damage threshold) of the test glass samples totaled more than 35 J/cm$^2$.

Thus the experience of operating the real laser system showed that it could be used for testing the damage threshold of a wide range of optical materials and coatings.

## References


Basov N.G., Mikhailov Y.A., Sklizkov G.V., Fedotov.S.I. 1984, Laser thermonuclear systems.: Science and Technology Achievements. Radiotechnics , VINIT, Moscow.

Shanin O.I. 2012, Adaptive optical systems in power impulse laser systems, «Technosfera», Moscow.

Avakyants L.I., Arbuzov V.I., A.I., Volynkin V.M., Ignatov A.N., Krekhova E.Y., Pozdnyakov A.E., Surkova V.F., Shashkin A.V., Fedorov Y.K., Frolova A.V. 2014, Neodymium and Cu+ phosphate glasses for the production of large-dimensioned rod and dics active elements for lasers and power high-energy radiation amplifiers: Optical journal, Saint-Petersburg, №12,v.81, p. 22-26.

Avakyants L. I., Arbuzov V. L, Fyodorov Yu. K., Ignatov A. N., Krekhova E. Yu., Pozdnyakov A. E., Shashkin A. V., Surkova V.F., 2013, Phosphate Glasses for Making Rod and Disc Active Elements of Lasers and High-Pick-Power/High-Energy Radiation Amplifiers:23rd International Congress on Glass Book of abstracts, Prague;.p75.

Radi J. 1974, Impact of powerful laser radiation, «Mir», Moscow.

Aleshin I.V., Imas Y.A., Komolov V.L. 1974, Low-absorption materials optical density, LDNTP, Saint-Petersburg.