EXPERIMENTAL STUDY OF OUTPUT ENERGY PARAMETERS OF A SOLID LASER WITH SBS–MIRROR

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The YSGG:Cr^{3+}, Nd^{3+} *laser with the polarization–closed cavity and SBS–mirror switched by its own seeding radiation has been studied experimentally. The output energy and the SBS–mirror reflectivity were measured in dependence on the initial SBS–gain parameter. The increase of the SBS–mirror efficiency was found to be nonlinear function of the SBS excitation excess over the threshold.*

Feasibility of obtaining an essential increase in output energy and compensating for the intracavity phase distortions in a solid laser with the wave–front reversion mirror based on the effect of stimulated Brillouin scattering (SBS) makes the investigations of such lasers to be highly urgent.[1,2] Of special importance are such optical layouts for lasers operating by new active media based on scandium garnets activated with Cr^{3+} and Nd^{3+} ions. Though these crystals provide high output energy, they exhibit appreciable thermooptical distortions that lead to the increase in divergence and spatial inhomogeneity of the output beam.[3] Some preliminary results concerning the excitation of SBS–mirror by YSGG:Gr^{3+}, ND^{3+}–laser radiation and the influence of SBS–mirror on the lasing dynamics can be found in Ref. 4. Our paper presents some results of a further study of the output energy of a YSGG:Cr^{3+}, Nd^{3+} laser with a SBS–mirror.

The block diagram of the experimental setup is shown in Fig 1 . The active medium *3* (YSGG:Cr^{3+}, Nd^{3+} crystal 5.3×75 mm in size) was placed in a polarization–closed cavity providing for two–beam output.[3] Use of such a cavity enables the output beam depolarization caused by substantial thermal birefringence occurring in the YSGG:Cr^{3+}, Nd^{3+} crystal to be eliminated without a decrease in the lasing efficiency. It makes it possible to obtain a linearly polarized output radiation as well.

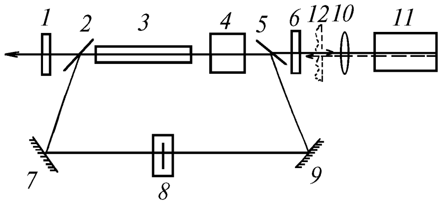

FIG. 1. Block diagram of the experimental setup.

Both single–mode Gaussian and multimode output beams were observed. The first case we have when uncoated surfaces of wedge–shaped glass plates *1* and *6* were used as output mirrors with the reflectivity of 4%. The multimode operation occurs when the plane–parallel plates are used as output mirrors with the reflectivity of 15%. Polarizers *2* and *5* and dead mirrors *7* and *9* formed circular part of the cavity. A rotator of the polarization plane *4* is a necessary component of the polarization–closed cavity that ensures mixing of radiation of different polarization in the active medium. *Q*–switching was performed with a passive switch *8* with the initial transmittance of 0.3.

SBS–mirror was located near one of the outputs of the cavity. It was composed of a cell *11* filled with tin tetrachloride and a lens *10* focusing the radiation into the nonlinear medium. The direction of scattered light propagation is indicated by a dashed horizontal line.

In the absence of SBS–mirror, the parameters of output radiation leaving the cavity through the mirrors *1* and *6* are the same. Linear polarization of the laser radiation in the horizontal plane was observed. The setup operated at a pulse repetition frequency of 5 Hz.

Multimode operation starts at the energy seed of 20 mJ per pulse of 40–ns duration. The beam divergence was found to be 2.5 mrad. This value is higher than the diffraction limit approximately by an order of magnitude for the output beam 5 mm in diameter. The stimulated Brillouin backscattering excited in the cell by those pulses had noticeable effect on the parameters of the output radiation leaving the cavity through mirror *1*. The average and peak power increased by a factor of 2.5, whereas the values of beam divergence and beam cross section remained the same. In this case, the output energy reached 50 mJ per slightly shorter pulse, and a shallow modulation corresponding to the temporal profile of the laser output. The period of this modulation corresponds to the time of the cavity round–trip. The reflectivity of the SBS mirror is measured as the ratio of experimental and calculated energy output[2] and is about 25%.

Excitation of the SBS mirror by a single–mode seeding radiation had more dramatic effect on the laser output power. In this case, the near difraction–limited beam was formed with the divergence of 0.8 mrad (the beam diameter of 1.2 mm was obtained at the lens). The output energy reaches 5 mJ over pulse 35 ns in duration. The reflection from the SBS–mirror resulted in 10–12 fold increase in the laser peak power, the pulse energy reached 60 mJ. The reflectivity of SBS–mirror of 60% has been observed. The divergence and the cross section of the laser beam remain almost unchanged. The intensity distribution over the cross section of the beam is close to a single–mode one. The temporal profile changed in the same manner as it did in the case of multimode operation.

The appreciable difference observed in the reflectivity of SBS–mirror in the case of multimode and single–mode operation is caused by variation of the initial gain increment of SBS G_0 produced in a nonlinear medium by seeding radiation. The value of G_0 was determined by the specific SBS gain b, seeding radiation intensity I_0, and the length of the nonlinear medium l in the ordinary way as

$$G_0 = b\, I_0\, l\ .$$

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The G_0 values equal to 20 and 35 for multimode and single–mode operations, respectively. In order to study the increase in the laser output energy and in the SBS–mirror reflectivity with respect to G_0 value, a number of phase plates *12* were placed between the plates *6* and the lens *10*. These plates indicated by dashed lines in Fig. 1 contribute to the single–mode beam divergence. In this case by varying I_0 value and the waist length one can vary G_0 value. At the same time, the degree of reaction coupling between the laser and SBS–mirror did not change, since the backscattered radiation exhibits the reversal wave front, and phase distortions introduced by a phase plate are compensated for.

According to our measurements, at $G_0 = 14$ and 23 the output energy approached 12 and 33 mJ, respectively. The cross structure of the beam was found to be single–mode one, as followed from photographs at a long distance.

Figure 2 presents reflectivity of the excited SBS–mirror R as a function of the initial gain increment G_0 generated in a medium by seeding radiation. As seen from Fig. 2, the increase in R with G_0 is nonlinear. It should be attributed to the fact that G_0 exceeds a threshold value G_t. As known, G_t value varies from 20 to 25 according to detectable level of scattering radiation in the experiments. In fact, G_0 values being of 20 and 23 are practically the threshold values, and efficiency of the SBS–mirror is low: its reflectivity does not exceed 30%. Excitation of SBS at $G_0 = 14$, that is, at lower than the threshold value, G_t, is caused by the proximity of the active medium lasing properties to that which appreciably amplifies the Stokes wave. In this case, the weak scattered radiation that can not be detected is amplified in the active medium, and SBS–mirror is excited after a few round–trips. The efficiency of the mirror is rather low: $R \sim 15\%$. When G_0 is significantly higher ($G_0 = 35$) than the threshold value, the reflectivity of SBS–mirror approaches 60%. Since there is no information on $E(G_0)$ and $R(G_0)$ functions[1] available from literature, our experimental data are assumed to promote the development of computer methods describing the effect of SBS–mirror on laser beam formation and laser output energy.

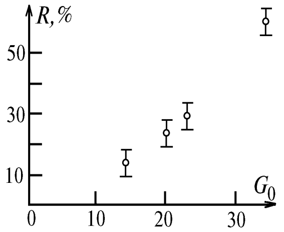

FIG. 2. Measured reflectivity of SBS–mirror as a function of the initial SBS gain value.

In conclusion it should be noted that a possibility of compensation for the phase distortions introduced not only by active medium, but also by other objects on the optical path between the laser cavity and SBS–mirror seems to be a very important result of our experiments.

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