Neodymium doped GGG laser compared with YAP, SLGO and YAG lasers.

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ABSTRACT

In this work the optical and lasing features of 1.2at.% neodymium doped GGG crystals in comparison to YAG (1at.%), SLGO (5 and 10at.%) and YAP (1at.%) ones are presented. Influence of UV and gamma radiations on a change of absorption and luminescence spectra of the crystal is also reported. The strong influence of UV radiation of pump lamp on lasing characteristics of GGG:Nd crystals is stated. After cut off UV from pump lamp spectrum the slope efficiency of GGG:Nd laser can be placed between SLGO:Nd (10at.%) and SLGO (5at.%) ones.

Keywords: gadolinium gallium garnet, strontium lantanium gallate, yttrium orthoaluminate
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1. INTRODUCTION

Many properties of gadolinium gallium garnet single crystals including those induced by different kinds of irradiation are sensitive to the presence of growth defects. Particularly an additional optical absorption (AA) is induced by an action of high-energy part of the pumping lamp radiation or γ-quanta [1]. The form of the additional absorption spectrum is a consequence of number, kind and nature of the colour centers (CCs) [2]. CCs influence lasing characteristics of SLGO:Nd laser, giving large decrease in its slope efficiency. The same situation but to different degree takes also place for other crystals doped with neodymium. Especially sensitive to UV and gamma radiation are SLGO and YAP crystals, for which it is necessary to use cut off filters on the level of 450 nm inside laser cavity [3, 4]. Therefore in the present work an attempt to generalize the results of the radiation effects and its influence on lasing performance investigations in neodymium doped GGG, SLGO, YAP and YAG crystals is done.

2. EXPERIMENTS AND RESULTS

All the crystals were grown by the Czochralski method: GGG:Nd and YAP:Nd in Institute of Materials, Lvov and YAG:Nd and SLGO:Nd in Institute of Electronic Materials Technology, Warsaw. Their optical, thermal and lasing parameters are listed in table 1. Growth conditions of these crystals were presented in earlier papers [1, 3-4].

2.1 Optical investigations

Samples about 2 mm in thickness, with both sides optically polished, were cut out from Nd^{3+}-doped crystals in the direction perpendicular to the optical c axis. Samples were also excited with UV and gamma radiation (UV: 10 pulses of 50 J energy with the use of pulse pump xenon lampe). Gamma ray irradiation of the samples was performed with ^{60}Co source at a rate of 170 rads/sec and dosage levels of the order of 10^3-10^6 Gy (1.25 MeV). Additional absorption was calculated from transmission measurements:

$$\Delta K=1/d\times \ln T_1/T_2, \quad (1)$$

where: d-sample thickness, T_1-transmission of a sample before gamma exposure, T_2- after gamma irradiation. These samples were similar in quality to the laser rods.

The absorption threshold is placed at 240 nm and lattice absorption is observed above 6500 nm. One can see different values of absorption coefficient in the range of diode pumping for above mentioned crystals. Fig. 1 presents additional absorption bands in GGG and GGG:Nd crystals after UV irradiation and after gamma irradiation with dose of 10^5 Gy in comparison to UV exposure. It can be seen that neodymium dopant leads to an increase in AA values for the case of UV irradiation. The same behaviour is observed for YAP:Nd crystal. For SLGO and YAG crystals doped with neodymium and irradiated by UV the opposite process takes place. Gamma-induced AA bands of GGG:Nd crystal (dose 10^5 Gy) have lower values than UV-induced ones. All other crystals has larger AA values after gamma irradiation.

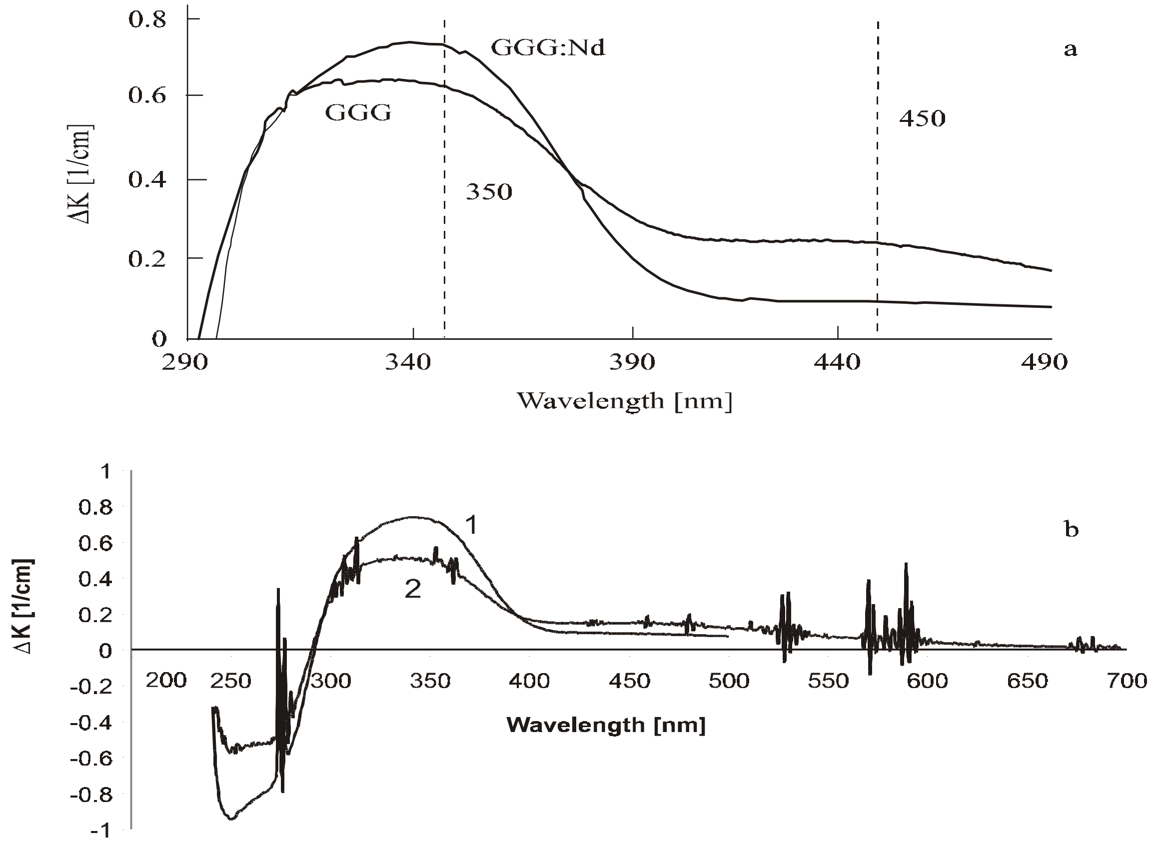

Fig. 1. Additional absorption bands: a-after UV irradiation (10 pulses of pump lamp with energy of 42 J and time interval 15 sec), b-after gamma exposure (2) with dose of 10^5 Gy and UV (1) as above.

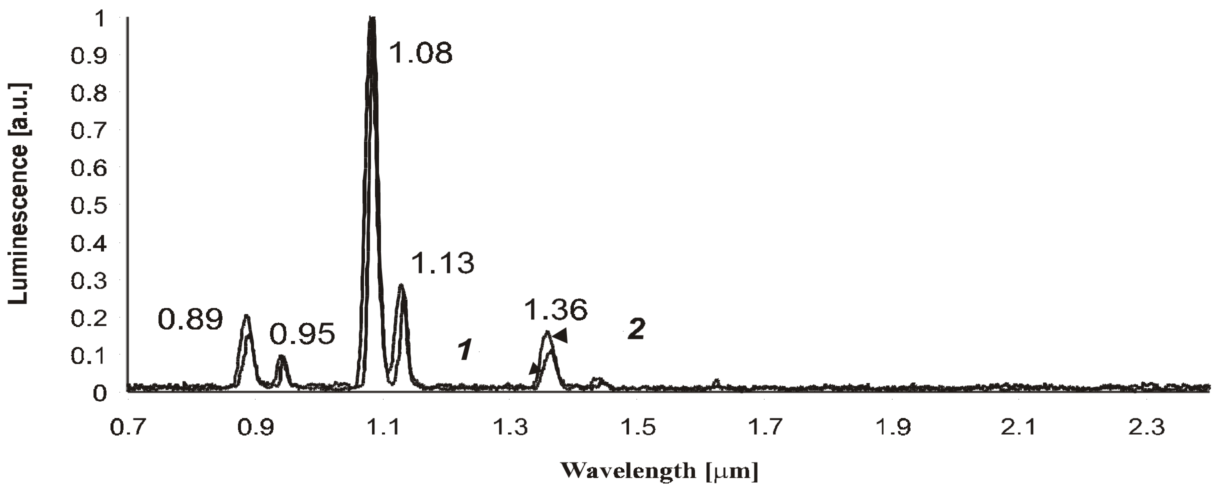

Fig. 2. Luminescence before (1) and after (2) gamma irradiation of GGG:Nd crystal.

Table 1. Optical, thermal and lasing parameters of neodymium doped GGG, SLGO, YAP and YAG crystals.

Name	GGG:Nd [5]	SLGO:Nd [6]	YAP:Nd [7]	YAG:Nd [7]
Chemical composition	$Gd_3Ga_5O_{12}$	$SrLaGa_3O_7$	$YAlO_3$	$Y_3Al_5O_{12}$
Melting point	1850 °C	1760 °C	1875 °C	1950 °C
symmetry	cubic	tetragonal	ortorhombic	cubic
Unit cell parameters	a - 1.2382 nm	a - 0.805 nm c - 0.533 nm	a - 0.518 nm b - 0.532 nm c - 0.738 nm	a - 1.201 nm
Density	7.08 g/cm^3	5.24 g/cm^3	5.35 g/cm^3	4.55 g/cm^3
Refraction index	1.94	1.84	a - 1.97 b - 1.96 c - 1.94	1.84
Emission wavelength	1064 nm	1064 nm	b - 1079 c - 1064	1064 nm
Thermal conductivity	12.9 W/mK	11 W/mK	11 W/mK	11 W/mK
Luminescence lifetime	240 μsec	290 μsec	180 μsec	235 μsec
Stimulated emission cross section	3.2×10^{-23} m^2	a:5.96×10^{-24} m^2 c:2.98×10^{-24} m^2	b:3.8×10^{-23} m^2 c:1.7×10^{-23} m^2	8×10^{-23} m^2
Nd^{3+} concentration	1.2 at.%	5 and 10 at.%	1 at.%	1 at.%

In fig. 2 changes in luminescence spectrum of GGG:Nd crystal after gamma exposure with dose of 10^5 Gy are presented. It can be seen that for 0.89 μm and 1.37 μm an increase of luminescence takes place after gamma irradiation.

2.2 Lasing investigations

Five rods were used for lasing investigations: GGG:Nd - Φ=4mm, l=48mm, SLGO:Nd - Φ=4mm, l=36.6mm, YAP:Nd - Φ=8mm, l=100mm, YAG:Nd - Φ=4mm, l=50mm and YAG:Nd - Φ=10mm and l=100mm. All rods had no AR coated end faces. GGG:Nd, SLGO:Nd and YAG:Nd rods 4mm in diameter were put into the plane-parallel laser cavity 24 cm long, made of messing covered with gold. A single xenon lamp with a diameter of 4 mm was excited with energies of 7-60 J. The pulse width was 120 μs, and the output mirror transmission was 36.6% for 1.06 μm.. The laser light was detected with high-sensitive HgCdTe photoconductor. The energy of laser pulses was measured by Gen-Tec radiometer with ED-500 gauge head. The investigations of single-pulse generation were carried out for output mirror transmission equal to 36.6%. The passive Q-switch was used (dye foil of PMM:[BDN] type, transmission T_o=46.6%). All the investigations were carried out with the use of the cut off filter (<350 nm - sodium glass).

YAP:Nd and YAG:Nd rods with diameters of 8 and 10 mm and length equal to 100mm were put into the plane-parallel cavity 28 cm long. A single xenon lamp with a diameter of 6 mm was excited with energies of 20-200J. The pulse width was 360 μs and the output mirror transmissions were: 8%, 11.8%, 19.7%, 24.9%, 30.2%, 38.1%, 50.5%, 61.7%, 70%, 75.3% and 86.7% for 1.06 μm. Calculated value of ”dynamical” absorption coefficient (ρ) for YAP:Nd rod was equal to 0.019 cm^{-1} (for SLGO:Nd - 0.062, for YAG:Nd - 0.005). Fig. 3 ilustrates the influence of UV inside of pump spectrum on free-runnig optical output of GGG:Nd crystal. One can see, that after the use of 350 nm cut off filter the slope efficiency of the laser increases many times. Fig. 4 compares optical outputs for all rods 4 mm in diameter. It can be seen, that GGG:Nd laser slope efficiency lays between SLGO:Nd (5at.%) and SLGO:Nd (10at.%) ones.

In Fig. 5 lasing features of YAP:Nd and YAG:Nd large crystals are compared. From this figure it is seen that for YAP:Nd laser optimum output mirror does not exist. All other lasers have optimum output mirrors values equal to about 30%. In Fig. 6 single-pulse investigations for GGG:Nd, SLGO:Nd and YAG:Nd lasers are shown. One can see that YAG:Nd laser gives lower values of lasing threshold, next GGG:Nd, SLGO:Nd (10at.%) and SLGO:Nd (5at.%). Energies of single-pulse generation increase as follow: GGG:Nd, YAG:Nd, SLGO:Nd (5at.%) and SLGO:Nd (10at.%). Efficiency of single-pulse generation for YAP:Nd laser is very low (6mJ for the same parameters of Q-switch).

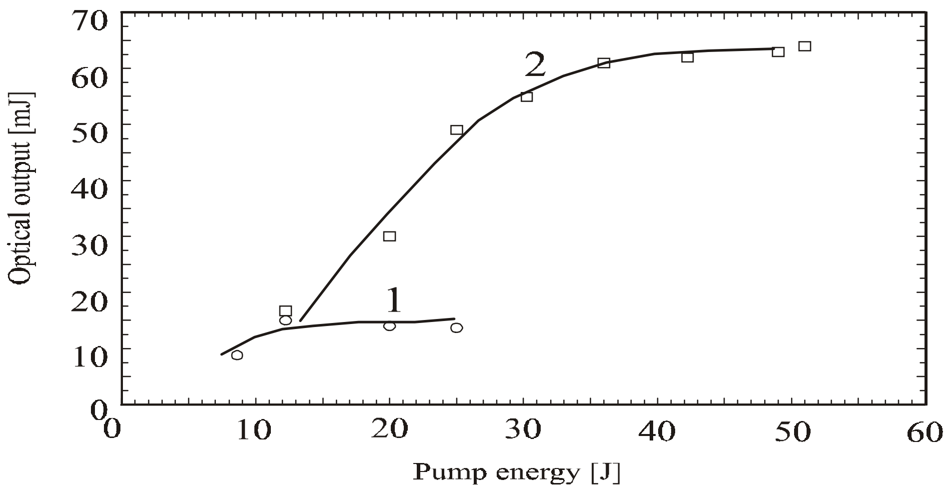

Fig. 3. Optical output of GGG:Nd laser without cut off filter (1) and with that filter (2) for 1.06 μm.

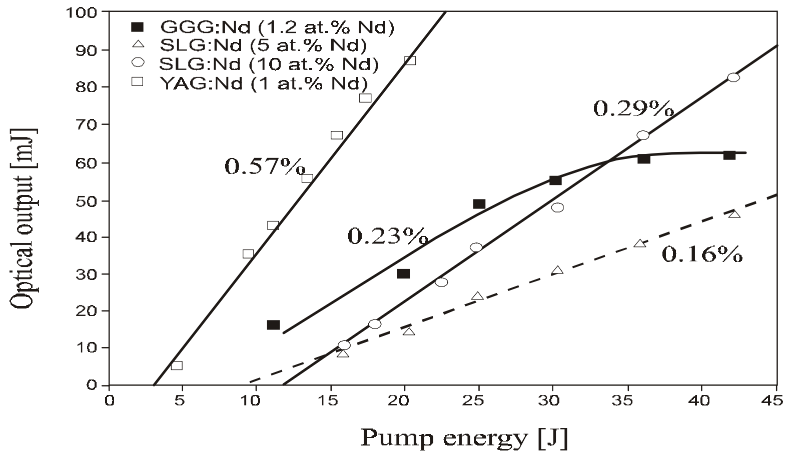

Fig. 4. Optical output of GGG:Nd laser in comparison to YAG:Nd, and SLGO:Nd ones. Near curves the values of slope efficiences are seen.

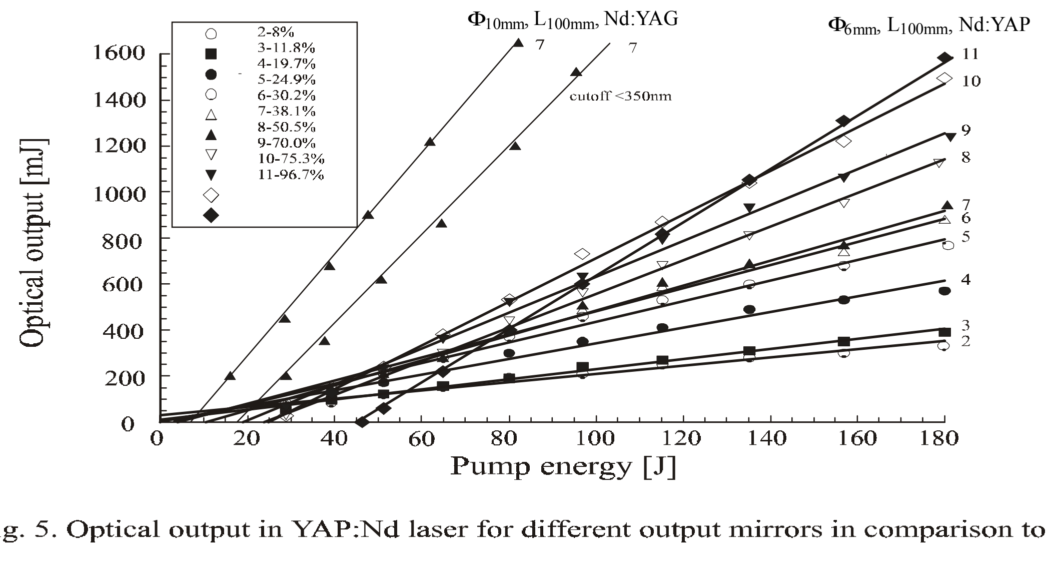

Fig. 5. Optical output in YAP:Nd laser for different output mirrors in comparison to YAG:Nd.

3. CONCLUSIONS

It was stated that external radiation field has very strong influence especially on GGG:Nd lasing characteristics. After use of cut off filter (<350 nm) the free-running energy increases many times. AA bands are higher for UV excitation than for gamma quanta (10^5 Gy). Gamma quanta excitation can lead to an increase of luminescence value for 0.89 and 1.36 μm peaks. All the investigated lasers differ in absorption coefficient spectrum, especially in the range of diode pumping. GGG:Nd slope efficiency for free-running generation is placed between SLGO:Nd ones (5 and 10 at.%). In single-pulse generation mode GGG:Nd crystal have low threshold of single pulse range (~12 J) and low values of pulse energy (~4mJ).

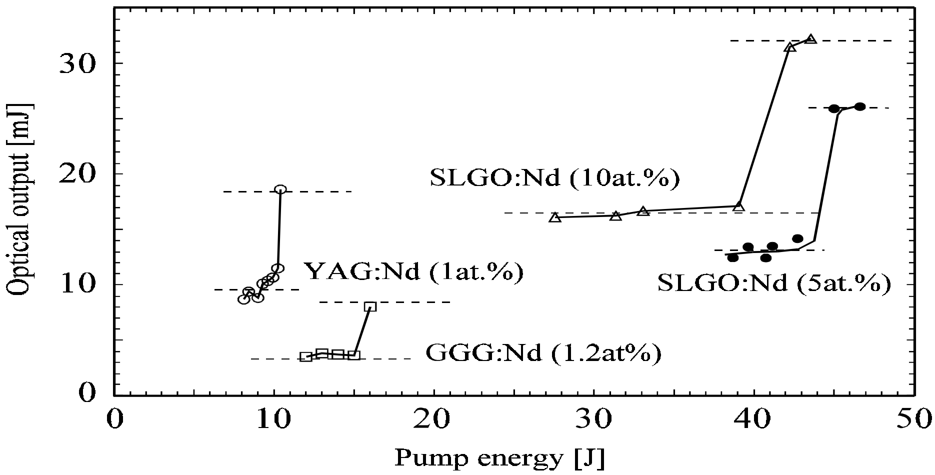

Fig. 6. Single-pulse mode generation for GGG:Nd, YAG:Nd and SLGO:Nd lasers.

4. ACKNOWLEDGEMENTS

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