Opto-Electronics Review, No 2'93, 54-57
ISSN 1230-3402

Spectral and generation characteristics of $SrLaGa_3O_7:Nd^{3+}$ crystal

S.M. KACZMAREK, Z. MIERCZYK, K. KOPCZYŃSKI
Military University of Technology, Institute of Quantum Electronics
01-489 Warszawa, Poland

1. Introduction

The $Srlaga_3O_7:Nd^{3+}$ crystal (SLG) belongs to the family of gallate and lantanate of rare earth elements, which are described by general formula ABC_3O_7. The A symbol in the formula means Ca, Sr or Ba, the B symbol means La or Gd and the C means Al or Ga. As an example of the member of this family of compounds the $BaLaGa_3O_7:Nd^{3+}$ crystal was described in Refs. [2, 3, 4]. However, the high energetic threshold for pumping that crystal was observed (about 90 J, [3]). It is due to the high density of defects in the crystal structure and eliminates it from the group of new active materials useful in laser technique.

Substituting barium by strontium in the compound and obtaining the $SrLaGa_3O_7:Nd^{3+}$ crystal should improve the laser characteristics because these elements have small difference of ion radii (it is equal to 6%). This is confirmed by the results of this work: the generation threshold of about 9 J was observed in laser resonator with output mirror of 37% transmission. For comparison, in the same resonator the threshold equal to 3 J was observed for $YAG:Nd^{3+}$ laser rod.

Parameters of the $SrLaGa_3O_7:Nd^{3+}$ crystals

Density	5.23 g/cm^3
Luminescence decay time	290 µs
Effective bandwidth for the transition $^4F_{3/2} - {}^4I_{11/2}$ 2 at 300 K	16.9 nm
Cross-section for stimulated emission by light polarized:	
perpendicularly to the optical axis	5.96 10-24 m^2
parallel to the optical axis	2.98 10-24 m^2
Wavelength of generated radiation	1060 nm
Refractive index	1.84
Nd^{3+} concentration (10% by weight)	5.53 10^{26} m^{-3}

The paper presents the investigation of spectral and generation characteristics of $SrLaGa_3O_7:Nd^{3+}$ crystals manufactured by Institute of Electronic Materials Technology, Warsaw. The crystals were produced using Czochralski's method. The main parameters of the manufactured crystals are given in the Table.

2. Experimental results

2.1 Spectroscopic measurements

Four laser rods of 4 mm in diameter and one plano-parallel plate with thickness 6.7 mm was manufactured using the $SrLaGa_3O_7:Nd^{3+}$ crystal with 10% by weight of Nd^{3+} doping. The

Opto-Electronics Review, No 2'93, 54-57
ISSN 1230-3402

rods used in this papers were designed SLG1, SLG2, SLG3 and SLG4 and they have length 48.5, 48.8, 35.0 and 36.8 mm, respectively. The spectrometers used to measure the characteristics were UVVIS LAMBDA 2 and FT-IR 1705 from Perkin-Elmer.

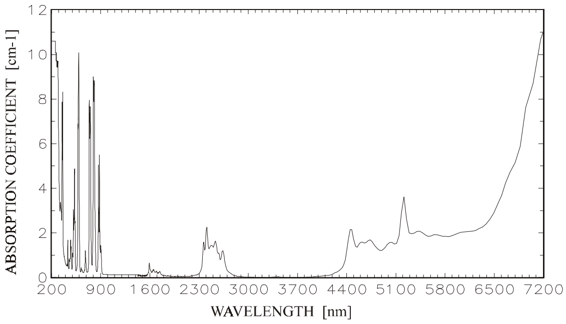


Fig. 1. Spectrum of absorption coefficient for $SrLaGa_3O_7:Nd^{3+}$ plate

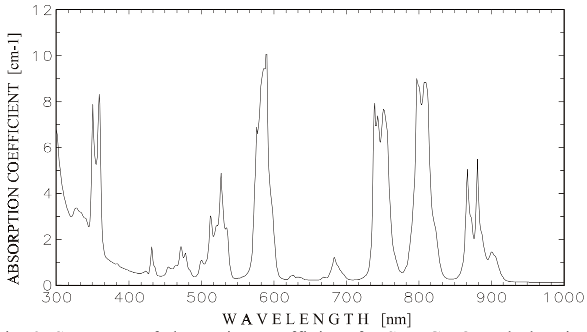


Fig. 2. Spectrum of absorption coefficient for $SrLaGa_3O_7:Nd$ plate in the wavelength range of 300-1100 nm

The absorption spectrum within the range 200-6200 nm is shown in Fig. 1. It is visible the absorption edge at 250 nm and also the lattice absorption for the wavelengths greater than 6200 nm. More detailed absorption spectrum (within the wavelength range 300-1100 nm) is given in Fig. 2.

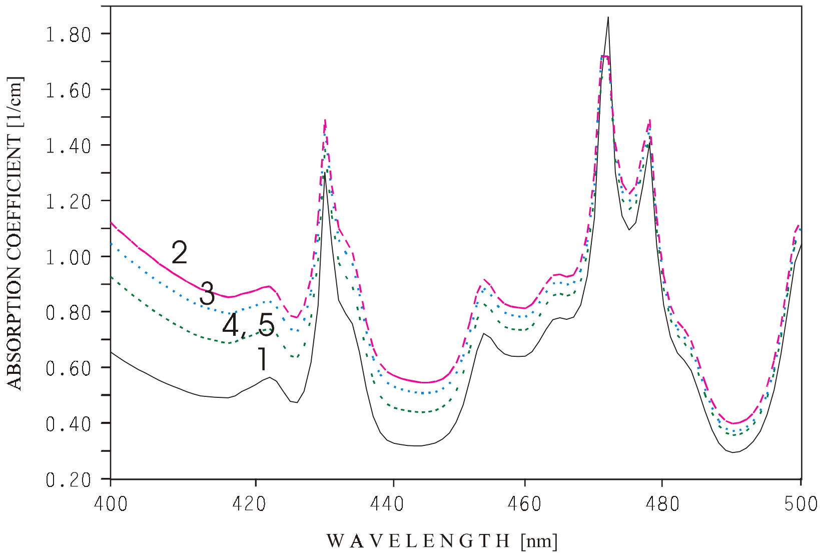


Fig. 3. Changes of absorption for excited SLG rod: 1 – before excitation, 2 – 1 hour after excitation without any UV removing filter, 3 – 1 hour after excitation with GG-5 filter, 4 – 24 hours after excitation, 5 – 72 hours after excitation

The spectral measurements were repeated after the investigation of laser generation to determine the influence of the flashlamps radiation on the absorption characteristics of the crystal. The essential changes in absorption spectrum were observed within ranges 346-368 nm, 429-441 nm and 450-490 nm. To determine if these changes are durable, the next series of the measurements were curried out. The results are shown in Figs. 3-5. The changes of the absorption of the investigated rods and plate are given there as a function of time measured from the moment of their excitation by 40 pulses from the pumping flashlamp, each of energy 24 J. Within 24 hours the characteristics does not return to the form observed before the excitation, hence the changes are stable.

To determine the reasons why the above described changes take place, the investigated rod and plate are then annealed in oxidizing atmosphere. The spectral characteristics of absorption confirms the disappearing of these newly-created absorption bands. However, these bands appear again when the annealed crystals have been excited by flashlamp radiation (see Fig. 6).

Opto-Electronics Review, No 2’93, 54-57
ISSN 1230-3402

The probable reason of such changes in absorption spectra is a presence of doping centers [5] in the crystal lattice. Hence, the further works on quality improvements of the manufactured crystals are necessary.

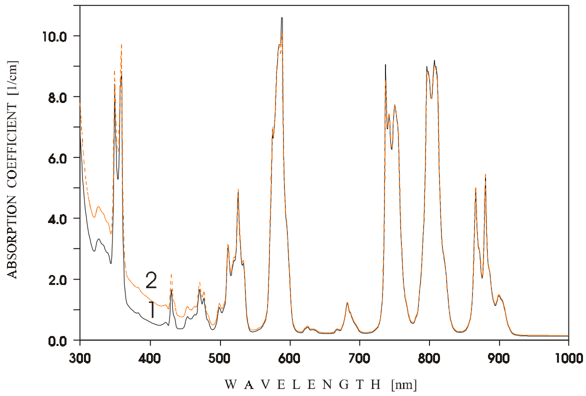


Fig. 4. Changes of absorption for the excited SLG plate: 1 – before excitation, 2 – after excitation by 40 flashes of energy 25 J

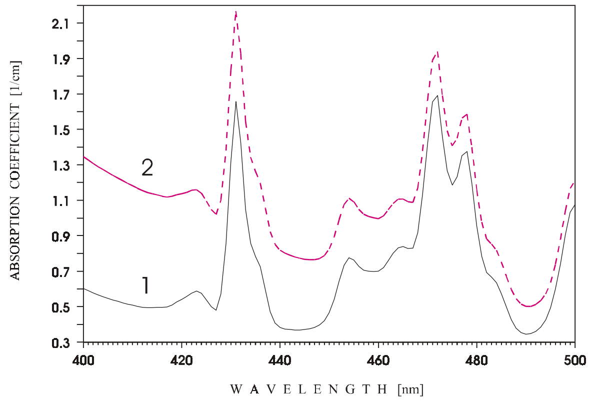


Fig. 5. Details of changes of absorption for the excited SLG plate: 1 – be – fore excitation, 2 – after excitation by 40 flashes of energy 25 J

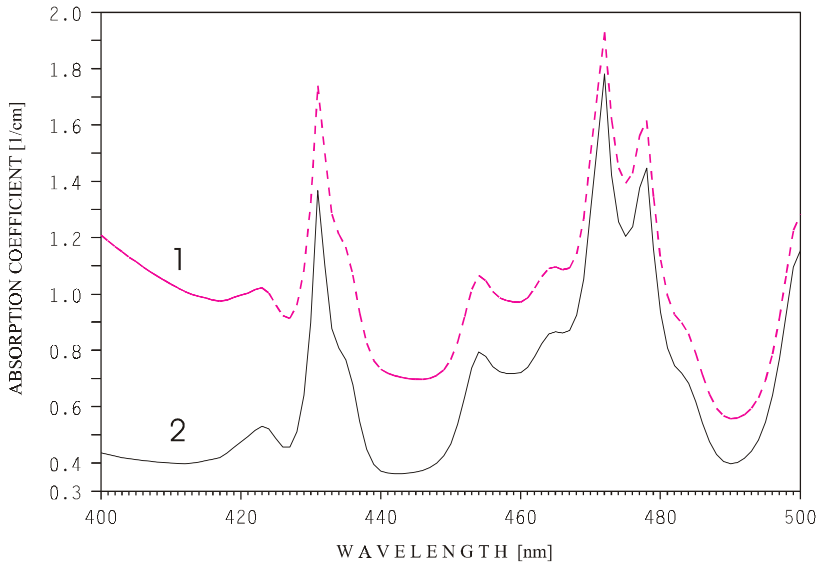


Fig. 6. Changes of absorption for the annealed and excited SLG rod: 1 – 1 hour after excitation, 2 – after excitation and annealing

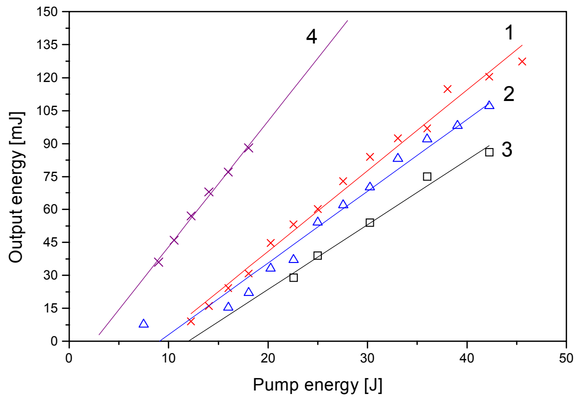
2.2. Free-running laser emission

The investigations were curried out using laser resonator of length 24 cm, with plane mirrors. The output mirror of different transmission was applied (i.e. 8, 20, 37, 42, 51, 62 and 75%). The laser head consisted of a single linear flashlamp of 4 mm in diameter and a reflector made of gold-covered brass. The duration of flashlamp pulse was equal to 120 ms and the power supply can supply energies within range from 7 to 100 J. To avoid the parasite heating of the laser rod the cut-off filters made of GG-5 glass (cut-off wavelength 350 nm) were used. The emitted laser radiation energy was measured by means of Gentec Model ED-200 probe. Simultaneously, the laser pulses were observed on the Tektronix oscilloscope using a high-sensitivity Si photodetector.

The results of the investigations of the four rods are shown in Figs. 7-10. The differential efficiency of the SLG1 laser rod, compared to the efficiency of YAG:Nd^{3+} rod is shown in Fig. 7. It is clearly visible the higher efficiency of the YAG:Nd^{3+} rod. The influence of the excitation of doping centers on the generation characteristics of the SLG crystal is shown in

Opto-Electronics Review, No 2'93, 54-57
ISSN 1230-3402

Fig. 7 as the curve 2. The stable change in the spectral characteristics caused decrease of the laser efficiency and increase of the threshold pump energy. It is observed also that placing the GG-5 glass plate within the resonator (to cut-off the UV radiation) caused decrease of emitted energy and increase of generation threshold.



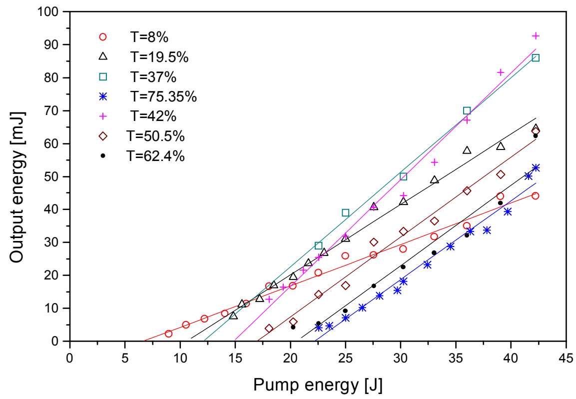
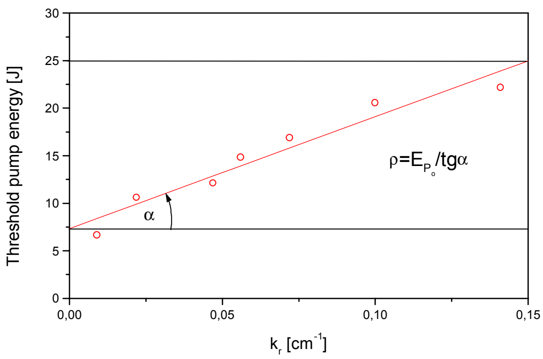


Fig. 7. Efficiency of the SLG (with SLG1 rod) and YAG lasers: 1 – SLG, first measurement (efficiency 0.37%, threshold 8.842 J), 2 – SLG, second measurement (efficiency 0.33%, threshold 9.075 J), 3 – SLG with GG-5 filter (efficiency 0.29%, threshold 11.995 J), 4 – YAG (efficiency 0.57%, threshold 2.848 J)

Fig. 8. Output energy of the free-running laser with SLG1 rod and different output mirrors

The dependence of the generation thresholds and laser efficiency on the transmission of the output mirrors is shown in Fig. 8 and 9. The characteristics given there also define the value of dynamic loss coefficient. It is visible in Fig. 9 that this value is small (ρ=0,0523 cm^{-1}) if we consider the presence of defects in the crystal, but it is large comparing to the value of dynamic loss coefficient for YAG:Nd^{3+} rods (ρ=0.005 cm^{-1}).



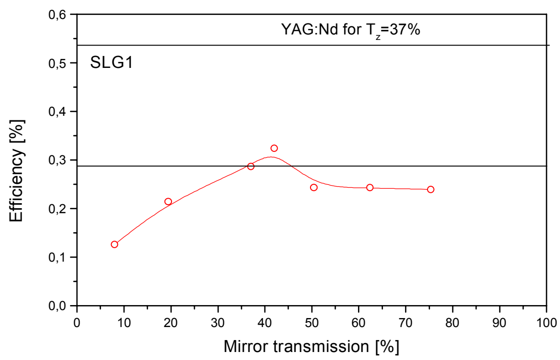


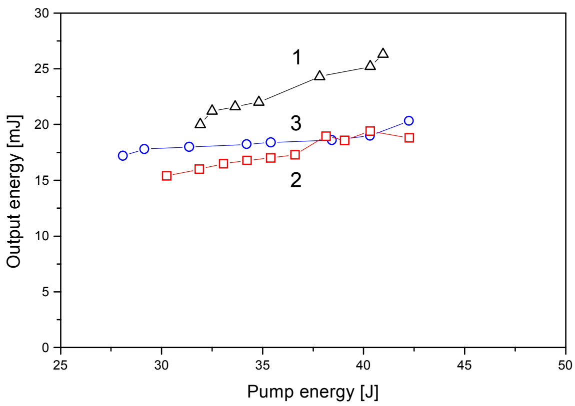
Fig. 9. Determination of dynamic loss coefficient (value of the dynamic loss coefficient is equal to 0.065 cm^{-1}. K_r – resonator loss coefficient)

Fig. 10. Efficiency of the SLG1 and YAG lasers vs. transmission value of the output mirror

The dependence of the SLG laser efficiency on the transmission of output mirror is shown in Fig. 10. It is compared with the efficiency of the YAG:Nd^{3+} laser shown in the same figure. The optimized value of the output mirror transmission is equal to 37.7% for the SLG1 rod.

2.3. Single pulse generation

The investigation of single pulse generation was curried out for optimized value of the output mirror transmission. The passive Q-switch was used (dye foil of type PMM:[BDN], transmission To=46.6%). The UV region was removed from the spectrum of pumping light by means of plates made of GG-5 glass (cut-off wavelength 450 nm) and sodium glass (cut-off wavelength 350 nm), which were placed into the laser resonator.



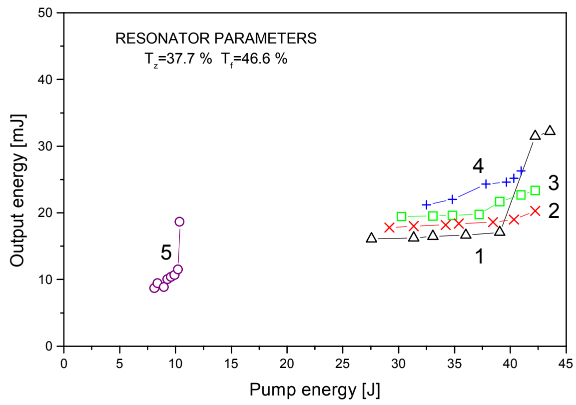


Fig. 11. Generation of the single pulse by the SLG1 rod (output mirror transmission equal to 37.7%): 1 – with GG-5 filter, 2 – with AR coatings, 3 – without filter

Fig. 12. Comparison of the single pulse generation for SLG and YAG rods: 1 – first measurement, 2, 3 – measurements with GG-5 filter, 5 – YAG rod

The generation of a single pulse obtained for SLG1 laser rod is shown in Fig. 11. The generation was investigated without and with UV-removing plates in the resonator. As it can be observed, the deeper UV cut-off (GG-5 glass plate) improves essentially the generation characteristics of the laser, i.e. the laser pulse energies are higher and generation threshold is lower. Using the plate made of sodium glass has practically no influence on the laser generation.

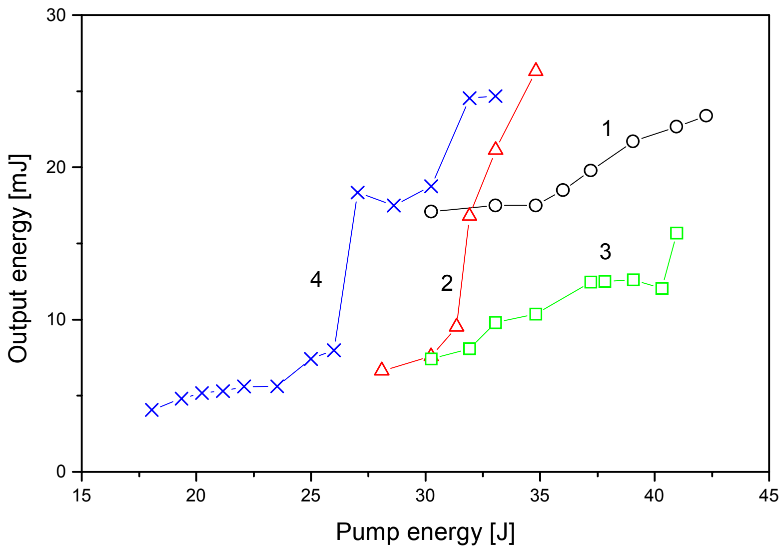


Fig. 13. Generation of the single pulse for all manufactured SLG rods (with GG-5) filter): 1 – SLG1 rod with AR coating, 2 – SLG2 rod without coating, 3 – SLG3 rod without coating, 4 – SLG4 rod without coating

The increase of the energy of output laser pulse observed if the GG-5 glass plate is present in the resonator is a contrary effect, comparing to the appropriate changes of energy during free-running generation (see Fig. 7).

Opto-Electronics Review, No 2'93, 54-57
ISSN 1230-3402

The comparison of a single laser pulse generation for SLG and YAG rods is shown in Fig. 12. All investigated rods cut out from the same $SrLaGa_3O_7:Nd^{3+}$ crystal have different threshold energies for pulse generation, as can be seen in Fig. 13.

3. Conclusions

It was stated, that the investigated SLG crystals are suitable for pulsed laser applications, despite of their structural imperfection which increases threshold energy values comparing to YAG crystals. The energy of obtained single pulses was two times higher than for the YAG rod in the same resonator.

It is necessary to remove the parasite UV radiation (of wavelengths shorter than 450 nm), because of rod heating and exciting of doping centers.

The threshold of laser generation and the efficiency can be improved if the crystal has less defects concentration. The doping with Nd^{3+} ions is essential here, because the Nd^{3+} ion is smaller than La^{3+}, substituted by the former in the lattice.

References

1. *W. Ryba-Romanowski* et al.: Mater. Sci. Eng. B., (1992) (in the print)
2. *W. Ryba-Romanowski* et al.:J. Lumin., 36 (1987) p.369
3. *W. Ryba-Romanowski* et al.: J. Phys. Chem. Solids, 49 (1988) p. 199
4. *M. Berkowski* et al.: Electronic Properties of High T_c Superconductors, June 1990
5. *A.F. Ludtschenko*: Quantum transitions in doping centers of solids, Naukova Dumka, Kiev 1978