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SPECTROSCOPIC AND LASER PROPERTIES OF DIFFERENT MATERIALS DOPED WITH Pr^{3+} IONS

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Examined praseodymium doped crystals with 1 at.% of Pr^{3+} ions for $Y_3Al_5O_{12}$ (YAG), $SrLaGa_3O_7$ (SLGO) hosts and 3 at.% of Pr^{3+} ions for YAlO3 (YAP) hosts were produced using Czochralski method. The luminescence for the range of $200 \div 800$ nm and absorption spectra for a wide range of $200 \div 6000$ nm, for Pr^{3+}:YAG, Pr^{3+}:SLGO and Pr^{3+}:YAP crystals have been measured. A free-running laser emission of $\lambda = 0.744$ μm for Pr:YAG and $\lambda = 0.729$ μm for Pr:SLGO for two different transmissions of output mirrors has been obtained.

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1. Introduction

Trivalent praseodymium in crystals is a well known ion which has a very rich emission spectrum extending from ultraviolet (UV) to infrared (IR) [1,2]. Because of the energy level structure and suitable lifetimes of the excited states, Pr^{3+} systems are specially attractive as active materials for lasers emitting in a short wavelength range. The CW stimulated emission at several orange and red wavelengths in Pr^{3+} doped perovskite (YAP) has been reported in [3]. Simultaneous blue and orange wavelengths lasing in Pr^{3+} doped YAP and YAG crystals have been observed in [4].

2. Experimental results

Samples from Pr:YAG, Pr:SLGO and Pr:YAP crystals with diameters of 10 mm and thickness of $1 \div 2$ mm, both sides optically polished, were cut out from the most homogeneous parts of the crystals (examined with Mach–Zehnder interferometer system) made in the Institute of Electronic Materials Technology. These samples have undergone spectroscopic and luminescence investigations.

In order to determine the absorption coefficient in dependence on wavelength, the samples transmission was measured using the following spectrophotometers:

a) LAMBDA-2 of Perkin–Elmer in the spectral range of 200 ÷ 1100 nm,

b) ACTA VII of Beckman in the spectral range of 1100 ÷ 1400 nm and

c) Fourier spectrophotometer FTIR 1725 of Perkin–Elmer in the range of 1.4 to 25 μm.

Dispersion of the absorption coefficient was calculated from transmission measurements considering multiple reflection inside the samples.

Luminescence investigations were carried out using a Perkin–Elmer LS-5B spectrofluorimeter.

Rods of 3 mm in diameter and about 40 mm in length were investigated with reference to their laser features. The above investigations were carried out using plane-parallel laser resonator of length 23 cm, and output mirrors of 26% and 40% transmition at 0.73 μm. The laser head consisted of a single linear xenon flash-lamp of 4 mm in diameter and a reflector made of gold-covered brass. The duration of flash-lamp pulse was equal to 150 μs and pump energy was changed from 4 to 40 J.

2.1. Optical investigations

The results of spectroscopic investigations are shown in Fig. 1. It can be seen that intensity of absorption lines for Pr : YAG and Pr : YAP crystals is larger than for Pr : SLGO ones. These lines are placed in the same region of absorption spectrum. An average optical density is greater for Pr : SLGO crystals. The absorption threshold, for crystals, appears at 300 nm and lattice absorption is observed above 5500 nm.

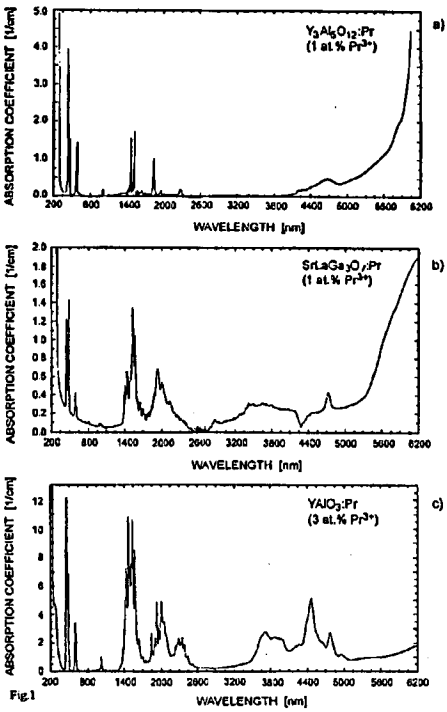
The results of luminescence measurements are shown in Fig. 2. It was stated that for Pr^{3+} : YAG crystals, the strongest peaks of luminescence occur at 488 nm, 501 nm, 532 nm, 563 nm, 619 nm, 660 nm, 714 nm and 744 nm. For Pr^{3+} : SLGO crystals the strongest peaks of luminescence appear at 489 nm, 503 nm, 534 nm, 562 nm, 615 nm, 646 nm, 654 nm, 729 nm. For Pr^{3+} : YAP crystals the strongest peaks of luminescence appear at 504 nm, 535 nm, 551 nm, 615 nm, 623 nm, 647 nm, 662 nm, 719 nm, 747 nm.

Figure 3 presents results of absorption measurements of Pr : YAG crystal (thin sample) after UV excitation with xenon pump lamp — 10 pulses of 42.2 J energy with time interval equal to 15 s between them. From this figure it results that Pr : YAG crystal is UV radiation sensitive and that there are unstable colour centres after UV radiation. Time quenching interval for transmission of these centres is equal to 1%/1000 s.

2.2. Lasing investigations

A free-running laser emission of $\lambda = 0.744\ \mu$m for Pr : YAG and $\lambda = 0.729\ \mu$m for Pr : SLGO for two different transmissions of output mirrors has been obtained.

The emitted laser radiation energy was measured by means of Universal Radiometer Rm6600 of Laser Precision Co. with RJP-735 probe. Simultaneously, the lamp pulses were observed on the Tektronix oscilloscope using a high-sensitivity Si photodetector. UV radiation was eliminated by using sodium glass filters inside laser cavity. The results of lasing measurements can be seen in Fig. 4. Thresholds



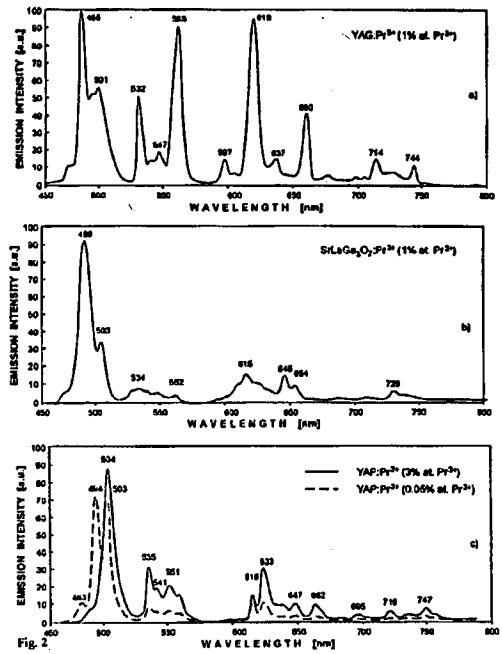
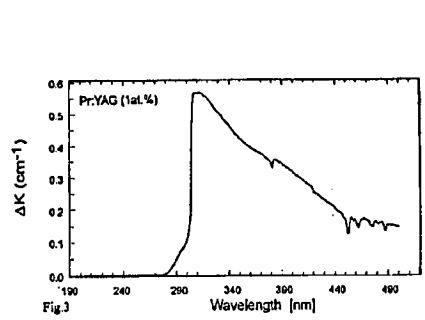


Fig. 1. Absorption coefficient of $Y_3Al_5O_{12}:Pr^{3+}$ (a), $SrLaGa_3O_7:Pr^{3+}$ (b) and $YAlO_3:Pr^{3+}$ (c) for a wavelength range of 200–6200 nm at room temperature.
Fig. 2. Emission spectra of YAG:Pr (a), SLGO:Pr (b) and YAP:Pr (c) at room temperature.



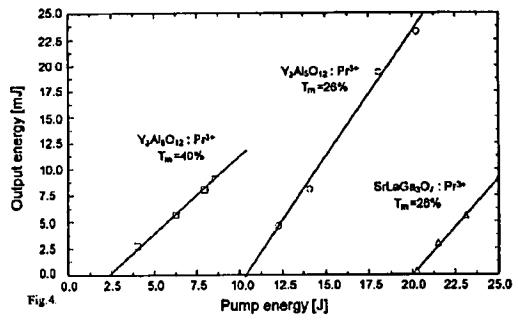


Fig. 3. Additional absorption bands of Pr:YAG after excitation with UV.
Fig. 4. Free-running emission for SLGO:Pr and YAG:Pr with two different transmission values of output mirrors: 26% and 40%.

of laser emission for Pr^{3+}:YAG crystals were smaller than for Pr^{3+}:SLGO ones (10 J and 20 J, respectively). Efficiencies of these lasers were 0.24% and 0.2%, respectively.

For both types of crystals and for some greater pump energies, the saturation of laser emission was noticed. In the case of Pr^{3+}: SLGO crystal there were observed coloured centres generated by illuminating the rod with xenon flash-lamp. To avoid the parasite heating of the laser rod and variations of its laser characteristics, the cut-off filters made of sodium glass (cut-off wavelength equal to 350 nm) were used.

3. Resume

Examined praseodymium doped crystals with 1 at.% of Pr^{3+}ions for $Y_3Al_5O_{12}$, $SrLaGa_3O_7$ hosts and 3 at.% of Pr^{3+} ions for $YAlO_3$ hosts were produced using Czochralski method. The luminescence for the range of $200 \div 800$ nm and absorption spectra for a wide range of $200 \div 6000$ nm, for Pr^{3+}: YAG, Pr^{3+}: SLGO and Pr^{3+}: YAP crystals have been measured. It was stated that for praseodymium doped YAG, YAP and SLGO crystals, the strongest peaks of luminescence occur at about 0.488, 0.620 and 0.730 μm and the strongest peaks of absorption occur at $0.44 \div 0.5$ μm and $0.58 \div 0.62$ μm bands.

A free-running laser emission of $\lambda = 0.744$ μm for Pr : YAG and $\lambda = 0.729$ μm for Pr : SLGO for two different transmissions of output mirrors has been obtained. Thresholds of laser emission for Pr^{3+}: YAG crystals were smaller than for Pr^{3+}: SLGO ones (10 J and 20 J, respectively). Efficiencies of these lasers were 0.24% and 0.2%, respectively. For both types of crystals and for some greater pump energies, the saturation of laser emission was noticed. In the case of Pr^{3+}: SLGO crystal there were observed coloured centres generated by illuminating the rod with xenon flash-lamp.

References

[1] A.A. Kaminskii, *Laser Crystals, their Physics and Properties*, Springer-Verlag, Berlin 1981.

[2] E.G. Gumanskaya, M.V. Korzhik, S.A. Smirova, V.B. Pavlenko, A.A. Fedorov, *Opt. Spectrosc.* **72**, 86 (1982).

[3] A. Bleckmann, F. Heine, J.P. Meyn, K. Peterman, G. Huber, in: *OSA Proceedings on Advanced Solid-State Lasers*, Eds. A.A. Pinto, T. Yee Fan, Vol. 15, Optical Society of America, Washington (DC) 1993, p. 199.

[4] M. Malinowski, M.F. Joubert, R. Mahiou, B. Jacquier, *J. Phys. IV Colloq. C4* **4**, 541 (1994).