Pr^{3+}: doped YAG and SLGO laser rods

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ABSTRACT

Examined praseodymium doped crystals with 1at. % of Pr^{3+} ions for YAG and $SrLaGa_3O_7$ (SLGO) hosts were produced using Czochralski method. The luminescence for the range of 200 - 800 nm and absorption spectra for a wide range of 200-6000 nm , for Pr^{3+}:YAG and Pr^{3+}:SLGO crystals have been measured. It was stated that for praseodymium doped YAG and SLGO crystals, the strongest peaks of luminescence occur at 0.489 and 0.502 µm and the strongest peaks of absorption occur at 0.44 - 0.5 and 0.58 - 0.62 µm bands.

A free - running laser emission of λ=0.62 µm radiation for both types of crystals Pr:YAG and Pr:SLGO for two different transmissions of output mirrors have been obtained.

Keywords: doping, laser crystals, optical properties, lasing properties, UV radiation sensitivity, absorption, luminescence.

1. INRODUCTION

Trivalent praseodymium in crystals is a well known ion which have a very rich emission spectrum extending from ultraviolet (UV) to infrared (IR)[1, 2]. Because of the energy level structure [3] and suitable lifetimes of the excited states, Pr^{3+} systems are specially attractive as an active materials for lasers emitting in short wavelength range. The CW stimulated emission at several orange and red wavelengths in Pr^{3+} doped perovskite (YAP) has been reported in [4, 5]. Simultaneous blue and orange wavelengths lasing in Pr^{3+} doped YAP and YAG crystals have been observed in [6]. In this lecture several topics relating to the short wavelength solid state lasers: YAG and SLGO doped with Pr^{3+} (0.62µm) are discussed.

2. EXPERIMENTAL RESULTS

Samples from Pr:YAG and Pr:SLGO crystals with diameters of 10 mm and thickness of 1 - 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 has 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:
(i) - LAMBDA - 2 of PERKIN-ELMER in the spectral range of 200 - 1100 nm,
(ii) - ACTA VII of BECKMAN in the range of 1100 - 1400 nm and
(iii) - Fourier spectrophotometer FTIR 1725 of PERKIN-ELMER in the range of 1400nm to 25 µm. Dispersion of the absorption coefficient was calculated from transmission measurements with the consideration of multiple reflections inside a sample.

Luminescence investigations were carried out using PERKIN-ELMER LS - 5B spectrofluorimeter .

For the typical laser head, 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 21% and 35% transmition at 0.619 µm. The laser head consisted of a single linear xenon flashlamp of 4 mm in diameter and a reflector made of gold-covered brass. The duration of flashlamp pulse was equal to 150 µs and the pump energy was changed from 4 to 40 J.

2.1 Optical investigations

The results of spectroscopic investigations are shown in Figs 1-4. It can be seen that intensity of absorption lines for Pr:YAG 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 both crystals, appear at 300 nm and lattice absorption is observed above 5500 nm.

The results of luminescence measurements are shown in Figs 5a and b. It was stated that for Pr^{3+}:YAG crystals, the strongest peaks of luminescence occur at 0.489, 0.502, 0.565 and 0.620 μm . For Pr^{3+}:SLGO crystals the strongest peaks of luminescence are: 0.489, 0.503, 0.616 and 0.645 μm.

Fig.6 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 15s 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 1%/1000s.

2.2 Lasing investigations

A free-running laser emission of λ=0.62 μm radiation for both types of crystals and for two different, above mentioned transmissions of output mirrors have 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 of laser cavity. The results of lasing measurements can be seen in Fig. 7. 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 centers generated by illuminating the rod with xenon flashlamp. 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. CONCLUSIONS

Intensity of absorption lines for Pr:YAG crystals is larger than for Pr:SLGO ones (the same doping level of 1at.%). These lines are placed in the same region of absorption spectrum. Optical density is greater for Pr:SLGO crystals. Short-wave edge of absorption is the same for both crystals and equal to 300 nm. Lattice absorption for both crystals is equal to about 5300 - 5800 nm.

A free-running laser emission of λ=0.62 μm radiation for both types of crystals Pr:YAG and 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 centers generated by illuminating the rod with xenon flashlamp.

4. REFERENCES

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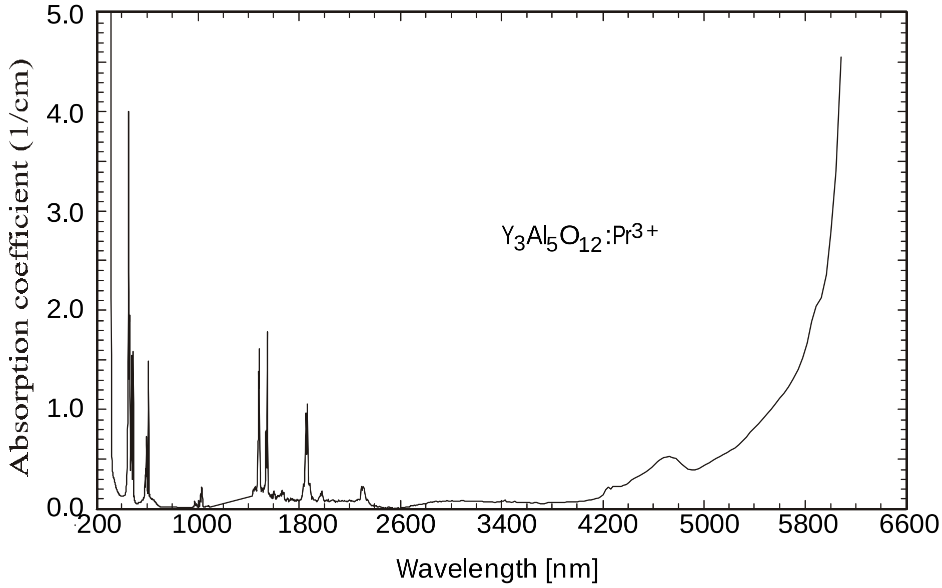


Fig.1 Absorption coefficient of $Y_3Al_5O_{12}$:Pr^{3+} (1at%) for wavelength range of 200-6200 nm and room temperature.

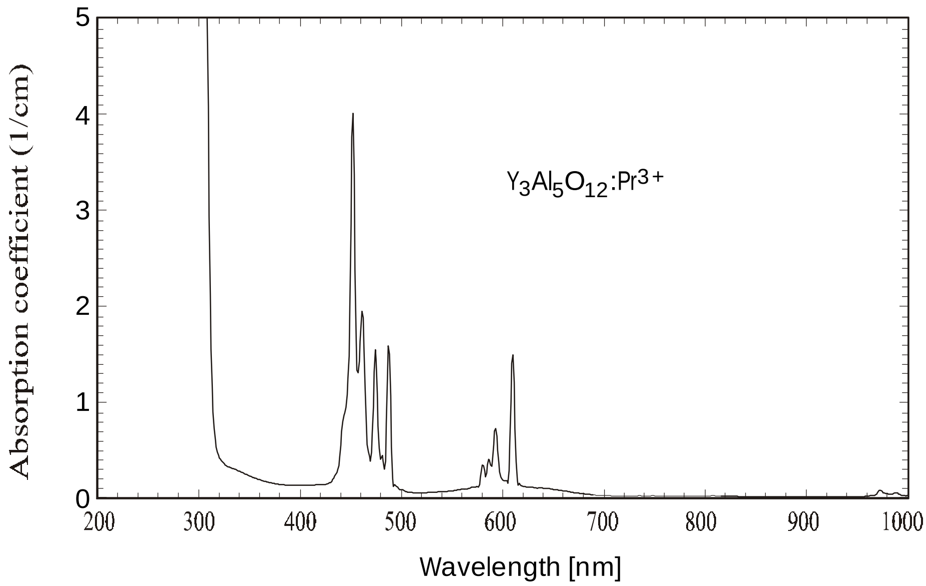


Fig.2 Absorption coefficient of $Y_3Al_5O_{12}$:Pr^{3+} (1at%) for wavelength range of 200-1100 nm and room temperature.

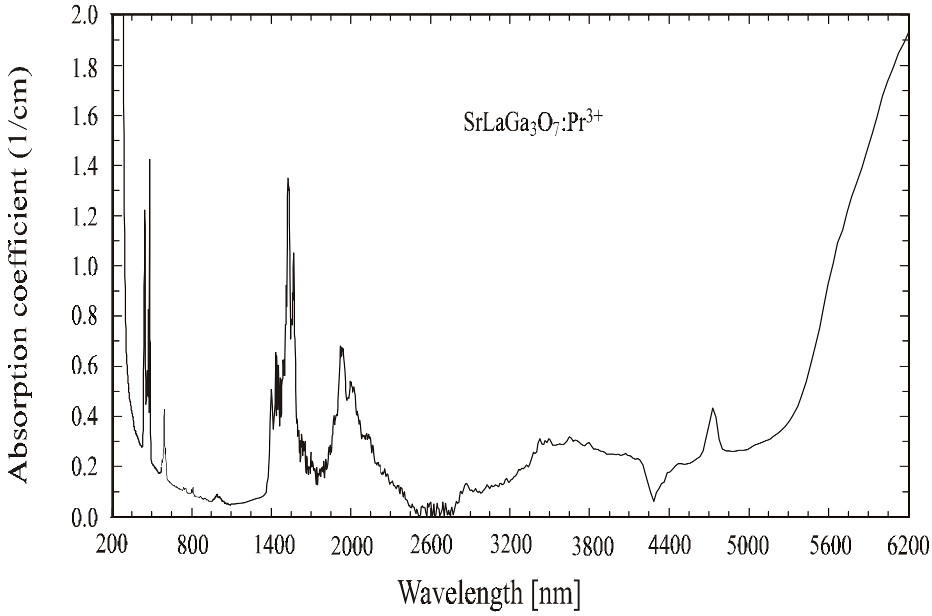


Fig.3 Absorption coefficient of $SrLaGa_3O_7:Pr^{3+}$ (1at%) for wavelength range of 200-6200 nm and room temperature.

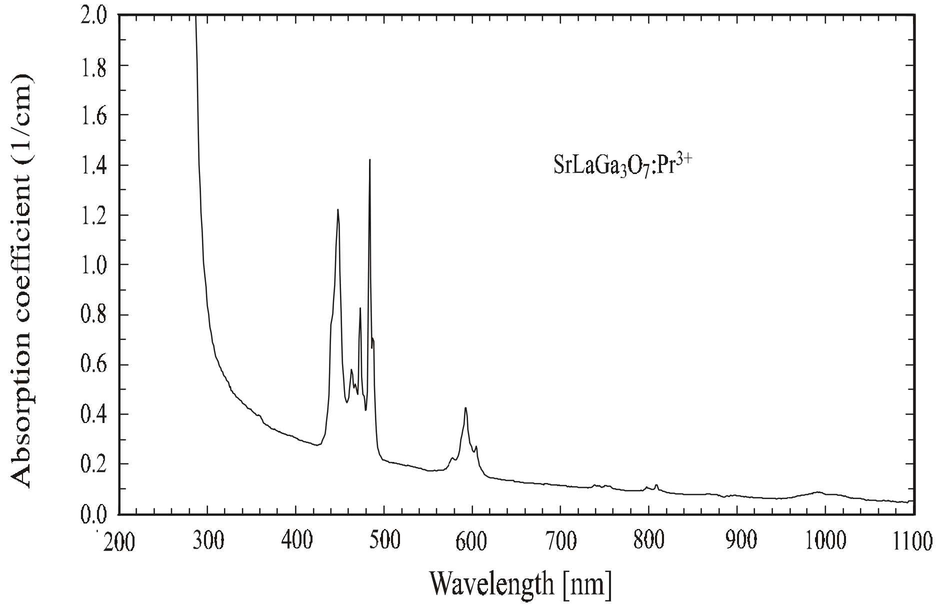
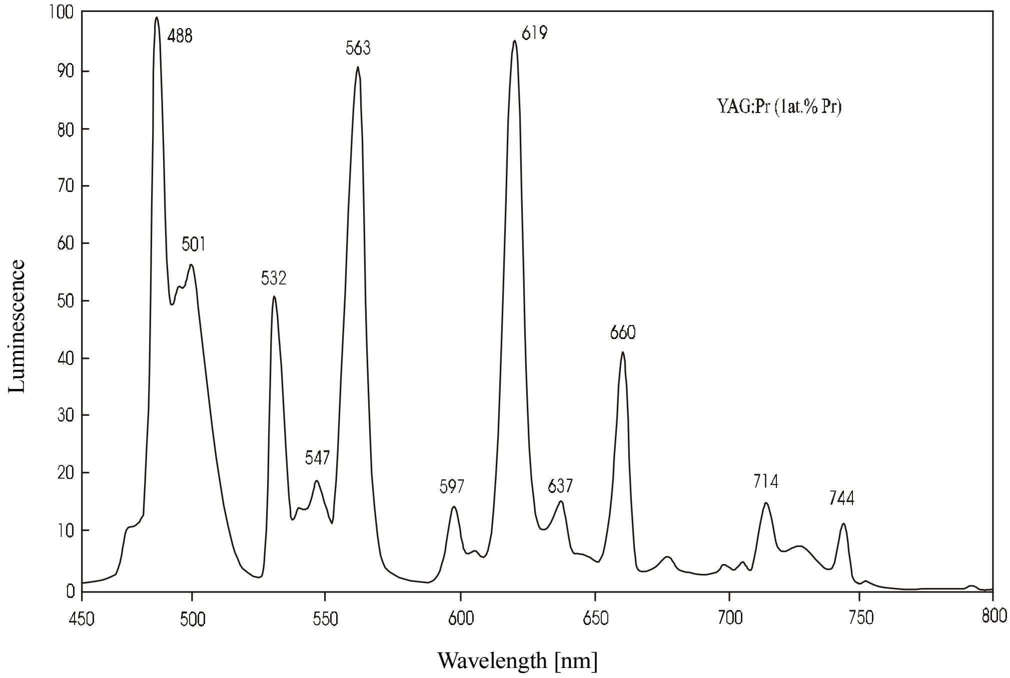


Fig.4 Absorption coefficient of $SrLaGa_3O_7:Pr^{3+}$ (1at%) for wavelength range of 200-1100 nm and room temperature.

a



b

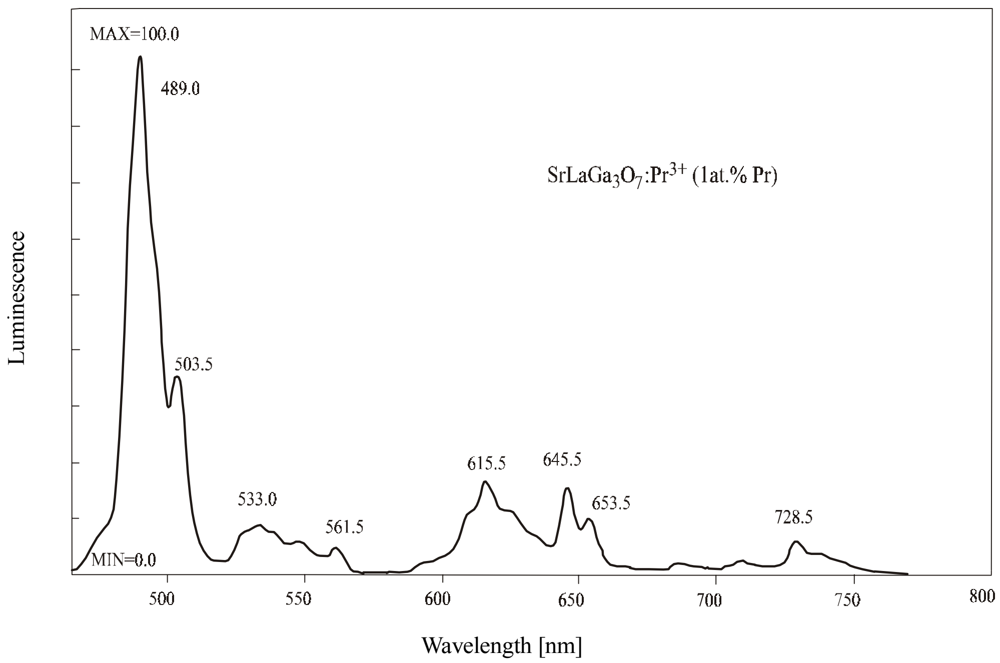


Fig.5 Luminescence spectra of YAG:Pr (a) and SLGO:Pr (b) at room temperature.

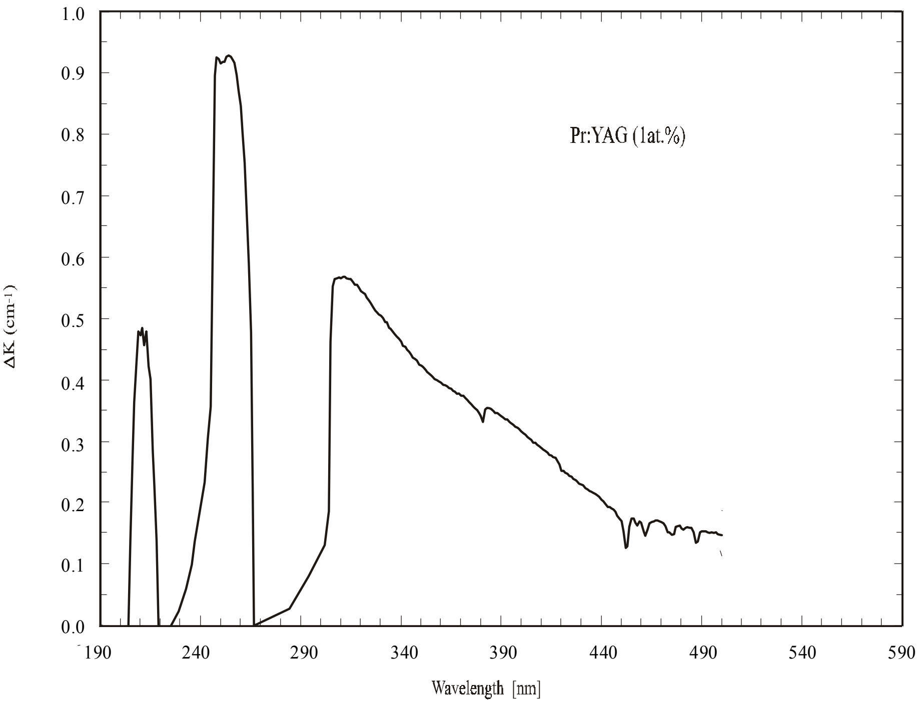


Fig.6 Additional absorption bands of Pr:YAG after excitation with UV

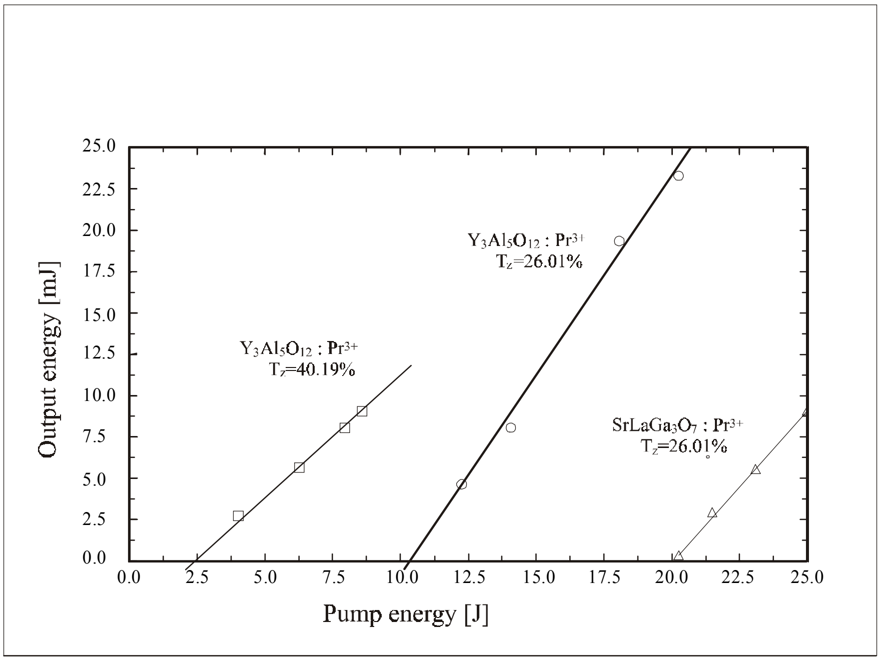


Fig.7 Free-running emision for SLGO:Pr and YAG:Pr with two different transmission values of output mirrors: 26.01% i 40.19% for λ=0.62 μm.