

**TIME-RESOLVED LUMINESCENCE SPECTROSCOPY OF YAG  
AND YAG:Ce<sup>3+</sup> PHOSPHORS UNDER UV-EXCITATION<sub>2</sub>O<sub>4</sub>:Ce**

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*Many works have been devoted to the study of the intrinsic luminescence of YAG luminophores. Various models of UV-emitting centers are discussed. A self-trapped exciton is responsible for emission in the region of 340 nm. The emission of single crystals of garnet with the composition  $Y_3Al_5O_{12}$  in the region of 300 nm is associated with "lattice" defects, and the emission of the main band with a maximum at about 550 nm is associated with the radiative  $5d-4f$  transition in the  $Ce^{+3}$  ion. There is a point of view that anti-site defects are responsible for the luminescence of "pure" garnets activated by  $Ce^{+3}$  ions in the UV region. It is known that  $Y^{+3}$  ions occupying the  $Al^{+3}$  position play the role of isoelectronic impurities in the garnet structure and form two types of luminescence centers:*

- *- excitons localized near the anti-site defect (band with  $\lambda_{max} = 296$  nm);*
- *- radiative recombination of free electrons with holes localized at antisite defects (band with  $\lambda_{max} = 330$  nm).*

*The emission of the emission band at 400 nm is caused by the luminescence of  $F^+$  centers localized near centers of the  $Y_{Al}$  type (yttrium in the position of aluminum).*

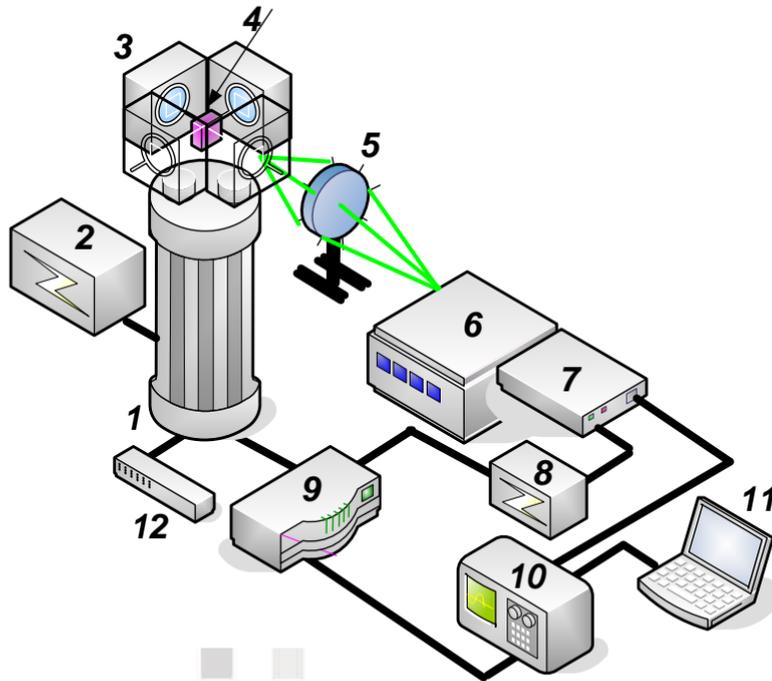
*The emission of cerium ions is closely related to the defects formed in the YAG lattice. The highest light output is exhibited by cerium-doped YAG single crystals grown by the Czochralski method in an atmosphere of argon and oxygen. The luminescence bands of intrinsic defects overlap significantly with the  $4f-5d$  absorption of the cerium ion, and therefore these defects are involved in the excitation of cerium luminescence.*

***The aim of this work is to study the luminescence properties of YAG and YAG : x mol% Ce nanopowder samples under exposure to UV radiation with different quantum energies using sources with nano- and picosecond pulse duration for excitation.***

The samples were synthesized by a high-temperature solid-state reaction in a nitrogen atmosphere. The initial components  $\text{Al}_2\text{O}_3$  (99.99%),  $\text{Y}_2\text{O}_3$  (99.99%),  $\text{CeO}_2$  (99.99%) were mixed according to the calculated ratio  $\text{Y}_{3-x}:\text{Al}_5:x\text{Ce}$ , ( $x = 0.02, 0.04, 0.08$  and  $0.1$ ), with the addition of 5%  $\text{BaF}_2$  of the calculated mass. The mixture with the addition of alcohol was stirred for 6 hours in a rotary device. Then, the powder samples were subjected to two-stage drying at  $120^\circ\text{C}$  and  $800^\circ\text{C}$  for two hours. Further, high-temperature treatment was carried out in an oven at a temperature of  $1600^\circ\text{C}$  for 12 hours, and then at a temperature of  $550^\circ\text{C}$  for 4 hours. After heat treatment, all samples were ground to make the powder homogeneous.

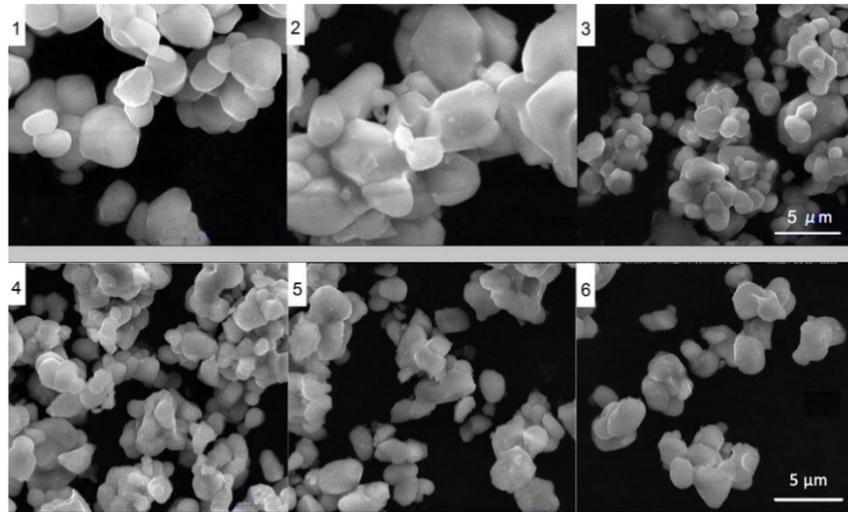
The surface morphology of the phosphors was studied using a scanning electron microscope (SEM, Quanta 250, FEI, USA) with an accelerating voltage of 10 kV. An X-ray diffractometer (TD-3500, Dandong, China) using  $\text{Cu K}\alpha_1$  radiation at 30 KV and 20 mA was used to register the crystalline phase for all samples. The photoluminescence (PL) and excitation (PLE) spectra were recorded with a fluorescence spectrophotometer (F-7000, Hitachi, Japan) with a 150 W xenon lamp at room temperature. The absorption spectra were recorded using a UV-Vis-NIR Cary spectrophotometer.

To measure luminescence, two types of excitation sources were used: a pulsed nitrogen laser ( $\lambda_{\text{ex}} = 337.1$  nm, 7 ns FWHM) and a UV-pulsed KrCl excilamp ( $\lambda_{\text{ex}} = 222$  nm, 150 ps FWHM). The luminescence kinetics was recorded with an FEU-84-6 photomultiplier tube using an MDR-3 monochromator and a TDS5052 digital oscilloscope (Tektronix). An AvaSpec-2048 spectrometer with an integration time of 2 ms was used to register the integrated luminescence spectra.



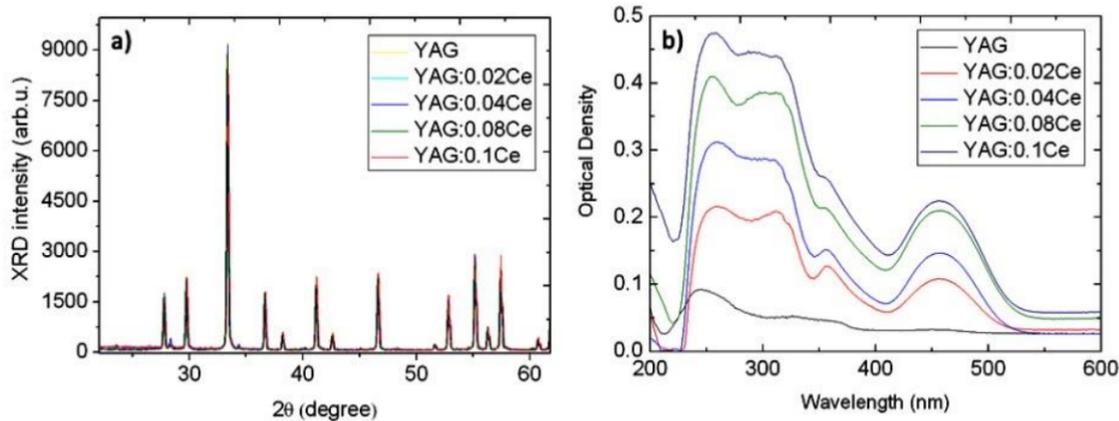
- 1- excitation source (nitrogen laser, excilamp);
- 2 – accelerator power supply unit; 3- measuring camera;
- 4 - the researched sample;
- 5 – lens system;
- 6 – monochromator;
- 7 -photoelectronic multiplier;
- 8 - power supply unit of FEM;
- 9 - pulse generator
- 10 oscillograph;
- 11 – computer;
- 12 - control panel

The luminophores are a powder consisting of microcrystalline particles with an average size of 1–2  $\mu\text{m}$ . The structure of the phosphor and the size practically does not change from the presence of cerium and is a set of rounded particles of irregular shape. The observed diffraction patterns show the absence of phase transformations in the samples obtained in this experiment. The intensity and width of the peaks for the obtained samples do not change with a change in the concentration of cerium ions.



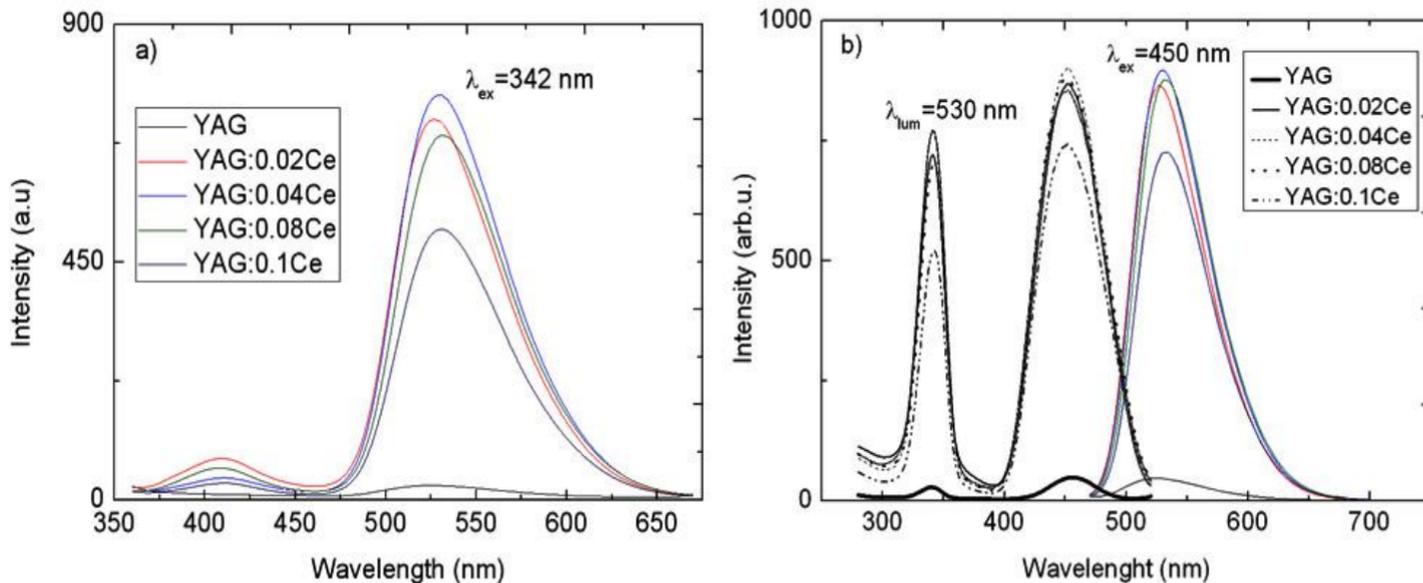
The morphology of the phosphor powders of  $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Ce}$  (X wt.%), X = 0; 0.02; 0.04; 0.08; 0.1

The structure of the absorption spectra shown in figure 2b. For all the samples is characterized by the absorption in the region from 200 to 520 nm. There are two intense absorption bands with maxima at 259 and 457 nm. In addition, peaks are observed at 315 and 357 nm. In the absorption spectra of "pure" YAG samples that do not contain cerium, the short-wavelength peak is shifted and its maximum falls on 244 nm, while the peaks at 315 and 357 nm are not recorded



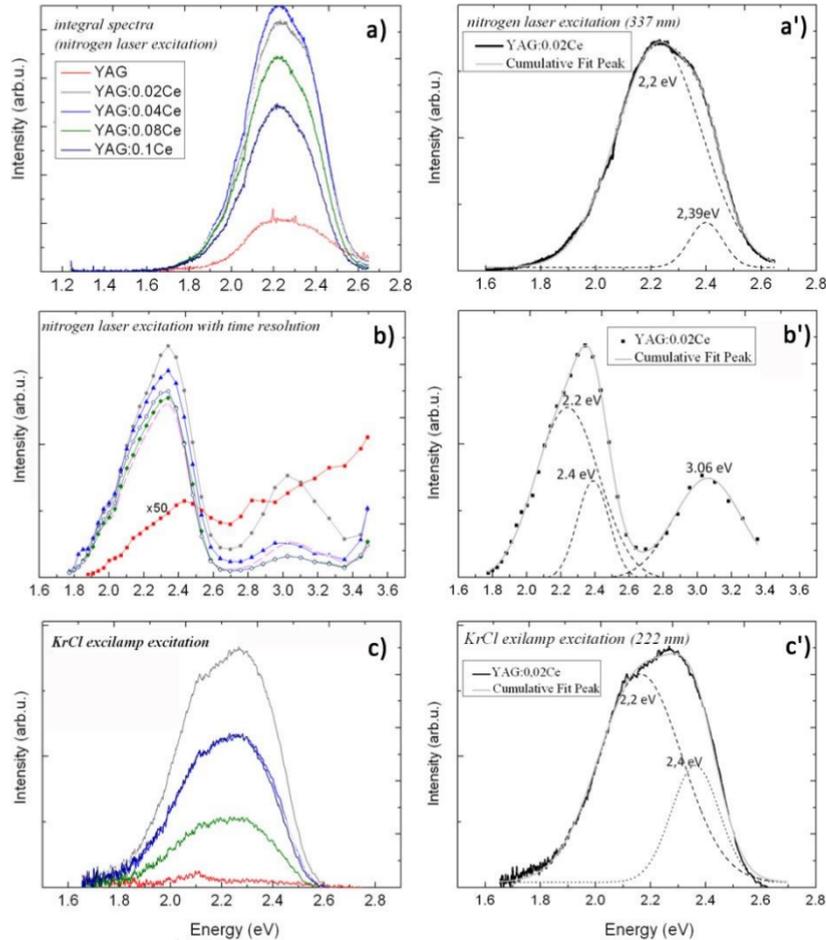
X-Ray diffraction (XRD) (a) and absorption spectrum (b) of the  $Y_3Al_5O_{12} : (X \text{ wt.}\%)Ce$ , where  $X = 0; 0.02; 0.04; 0.08; 0.1$  phosphor powders prepared by high-temperature solid-state reaction

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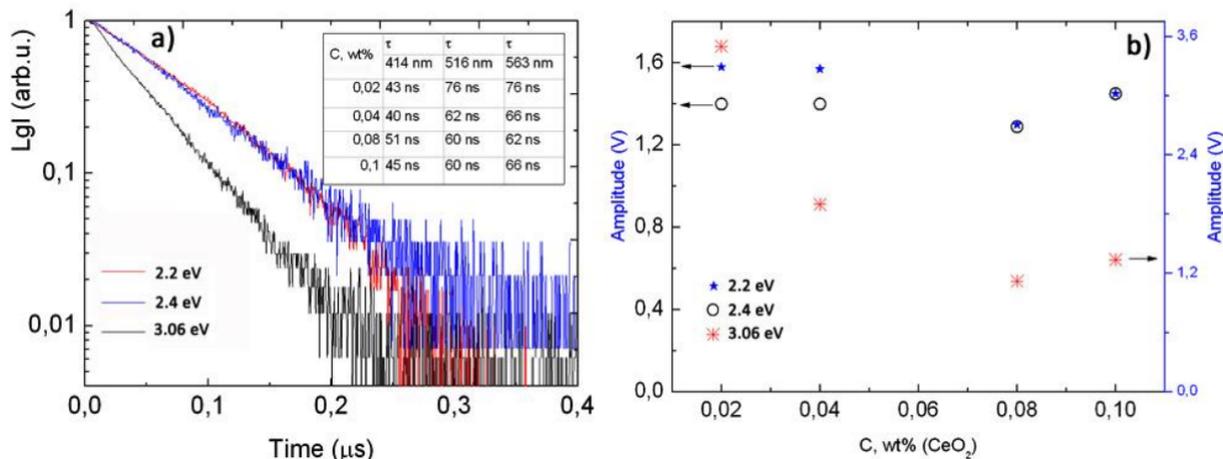


The excitation spectrum ( $\lambda_{lum} = 530 \text{ nm}$ ) (a) photoluminescence spectra ( $\lambda_{ex} = 342$  and  $450 \text{ nm}$ ) (b) excited by Xenon lamp (450W) of  $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Ce}$  (X wt.%), where X = 0; 0.02; 0.04; 0.08; 0.1.

# Luminescent properties



Integral (a, c) and time-resolved luminescence spectra (b) under different type of excitation for YAG and YAG:Ce powders.  
Decomposition of the spectrum of a YAG: 0.02Ce sample into Gaussians (a', b', c')



Pulsed photoluminescence decay kinetics excited nitrogen laser (337.1 nm) for YAG:Ce (0.02 wt%) (a); Amplitude volume of Intensity (b) at 2.2, 2.4 and 3.06 eV bands. Insert – time decay for YAG:Ce samples

- The optical, structural, and morphological properties of YAG powder samples synthesized by the solid-phase method were studied.
- The influence of cerium on the luminescence characteristics was investigated for various methods of photoexcitation. The shift in the position of the maximum of the luminescence band occurs when the excitation conditions (photon energy, excitation pulse duration) change.
- The introduction of a cerium ion into the YAG composition leads to an increase in the emission intensity in the “yellow” band in the region of 530-570 nm. With an increase in the cerium concentration, a decrease in the luminescence intensity in the “blue” band at 414 nm is observed. It is shown that the emission band in the 450-650 nm region has a complex structure and consists of two elementary bands with maxima at  $2.19 \pm 0.04$  and  $2.38 \pm 0.02$  eV. The luminescence efficiency of each of these bands depends on the excitation conditions.
- It was found that the spectral characteristics of pure and activated YAG powder samples are identical. It was shown that centers emitting in the 450-650 nm region are present in pure YAG samples and the introduction of cerium promotes their formation.
- It is assumed that the nature of the emission of this emission is due to intrinsic defects stabilized by cerium ions. With an increase in the amount of cerium, a decrease in the luminescence intensity of the F + centers is observed; therefore, it is possible that the formation of such defects is associated with the transformation of F + centers into complex complex defects.



Thank you for your attention!