GLASSES OF HEAVY METAL OXIDE DOPED WITH YTTERBIUM

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Abstract

A new ytterbium doped heavy metal oxide glass (Yb:BPG) is presented in this work. The literature published the use of Pr^{3+}, Dy^{3+}, Tm^{3+} and Er^{3+}, in this host. We reported last year the use of Nd^{3+} and now the use of Yb^{3+}; the glass has high refractive index (of 2.52), transmission cutoff in the far infrared (at 9μm), knoop hardness of 321kg/mm^2 and density of 4.63g/cm^3. The concentration of Yb^{3+} was determined using the X ray fluorescent spectrometry. For 0.5wt% of Yb_2O_3 the absorption cross-section is of 2.2x10^{-20}cm^2 at the laser pump wavelength (968nm), the radiative lifetime is of 300μs, the fluorescence effective linewidth is of 86nm and the emission cross-section is of 0.75x10^{-20}cm^2 at 1012nm.

Introduction

In this paper we report the optical and physical properties of ytterbium doped BPG (Bi_2O_3-PbO-Ga_2O_3) glasses produced at the Laboratory of Glasses and Datation at FATEC-SP. This host of heavy metal oxide discovered by W. H. Dumbaugh, in 1985 [1], has applications in optoelectronic circuits because of the characteristics as transmission in the far infrared (up to 9μm), high refractive index and nonlinear optical behavior. It is known that the low vibrational frequencies of the heavy metal oxides cation-anion bonds, such Pb-O and Bi-O allow good infrared transmission and low nonradiative decay rate. Besides its high refractive index increases the radiative decay. These properties can give rise to new laser transitions and can increase the efficiency of those already used in other glass hosts.

Since 1995, the literature has presented the use of rare-earth (Pr^{3+}, Dy^{3+}, Tm^{3+} and Er^{3+}) [2,3,4] for laser applications in BPG glasses, last year we reported the use of Nd^{3+} [5] and this work deals with Yb^{3+}.

Experimental Procedure

The glass presented in this work, with 0.5wt% of Yb_2O_3 is prepared with 99.99% purity oxides (Bi_2O_3, PbO, Ga_2O_3), melted at 1000°C for approximately one hour and a half, in air, using platinum crucible, then poured onto preheated brass molds for a quick solidification and annealed at 300°C for 3 hours. Red colored transparent glass is produced with refractive index, of 2.52, determined by means of the "apparent depth method" [6]. This method relates the physical thickness of a transparent specimen to its optical thickness. The absorption spectrum was measured using a Cary Spectrometer in the range 920-1120nm at room temperature. The emission spectrum was obtained exciting the samples with a GaAlAs laser diode (Spectra Diode Labs - model SDL-2382-P1) as pump source (excited at 968nm). The emission from the sample was analyzed with a 0.5m (Spex) monochrometer and detected by a Ge detector. The signal was intensified with a EG&G7220 lock-in amplifier and processed by a computer. The lifetime was measured using a pulsed laser excitation (4 ns) from a OPO pumped by a frequency doubled Nd:YAG laser. The density, of 4.4g/cm^3 was measured with the Archimedes method, the concentration of Yb^{3+} (6.44x10^{19}ions/cm^3) was determined by the X ray Fluorescent Spectrometry with wavelength dispersion and used to determine the absorption cross-section.

Results

Figure 1 shows Yb^{3+} absorption and emission cross-sections spectra (σ_{abs} and σ_{eme}) with peaks of 2.2x10^{-20}cm^2 (λ_p = 968nm) and 0.75x10^{-20} cm^2 (λ_0=1012nm). The spontaneous emission probability (A_R), of 3000s^{-1}, and the emission cross-section were calculated using the following equations [7]:

$$A_R = \frac{8\pi c n^2 (2J'+1)}{\lambda_p^4 (2J+1)} \int k(\lambda) d\lambda \quad (1)$$

$$\sigma_{em}(\lambda) = \frac{\lambda^4 g(\lambda) A_R}{8\pi n^2 c} \quad (2)$$

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where c represents the velocity of light, n the refractive index, λ_p the absorption peak wavelength, the concentration of Yb^{3+} ions, $k(\lambda)$ the absorption coefficient, J' and J the total momenta for the upper and lower levels and $g(\lambda)$ the normalized line shape function of the fluorescence transition of Yb^{3+}; the fluorescence effective linewidth, of 86nm, was calculated using the emission spectrum and the following equation:

$$\Delta\lambda_{eff} = \int I(\lambda)d\lambda / I_{max}$$

Special interest for wide-band laser glasses has recently come from the search for better high-field lasers, where the bandwidth sets the ultimate limit to how short the laser pulse can get [8]. Tables 1 presents the spectroscopic properties of this new material, where $_{f}$ is the fluorescence lifetime.

Table 1: Spectroscopic properties for Yb:BPG glass (0.5wt% of Yb_2O_3)

Host	Concentration (10^{20} ion/cm^3)	$\sigma_{em}(\lambda_0)$ (10^{-20} cm^2)	$\sigma_{abs}(\lambda_p)$ (10^{-20} cm^2)	$\sigma_{abs}(\lambda_0)$ (10^{-20} cm^2)	λ_0 (nm)	A_R (s^{-1})	$\Delta\lambda_{eff}$ (nm)	$_{f}$ (ms)	σ_{em} $_{f}$ ($10^{-20}cm^2ms$)
Heavy metal oxides	0.644	0.23	2.20	0.22	1012	3000.0	86.00	0.40	0.10

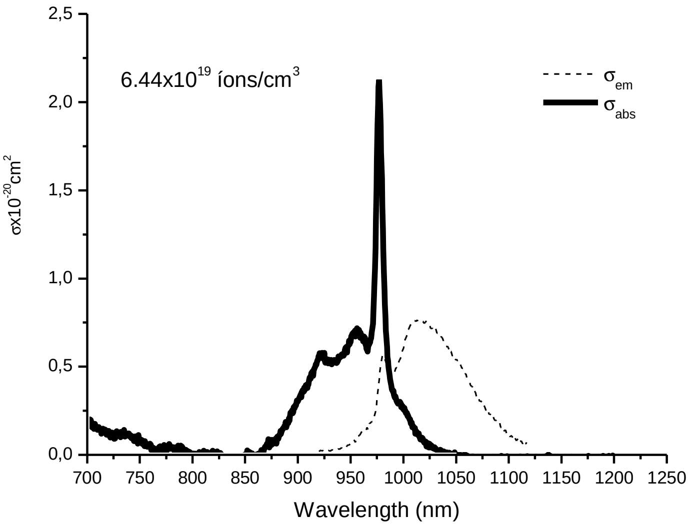

Figura 1. Absorption and Emission cross-sections spectra for Yb:BPG glass (0.5wt% of Yb_2O_3).

Conclusion

This is the first time that Yb^{3+} is used in Bi_2O_3-PbO-Ga_2O_3 glasses. A good mechanical resistance under high-brightness diode laser pumping was observed. We remark the high absorption cross-section, of $2.2x10^{-20}cm^2$ at 968nm, a moderate cross-section of $0.75x10^{-20}cm^2$ at the extraction wavelength and the effective fluorescence linewidth, of 86nm, an important feature for laser action in short pulse generation. Transfer of energy from ytterbium to erbium is being investigated in this heavy metal oxide host and the results will be published soon.

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