Analysis of Laser Action in Holmium doped ZFBP Glasses by Laser Parameters

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Abstract
Lanthanide holmium when doped with Zinc Fluoride Borophosphate Glasses are known as holmium doped ZFBP – glasses. The final composition of holmium doped ZFBP glasses in mol% is 16.67-Al_2O_3, 15.44-B_2O_3, 17.38-Na_2O, 39.77-P_2O_5, 10.74-ZnF_2 and dopant 0.2-Ho_2O_3. Holmium doped ZFBP glasses have been prepared by melt quenching technique. Their optical spectra have been measured in the region of 500-800 nm at room temperature.

The measured optical spectra can be discussed in the terms of laser parameters. Various laser parameters like spontaneous emission probability (SEP), fluorescence branching ratio (FBR), radiative life time (RLT) and stimulated emission cross-section (SEC) have been recorded for predicting the laser action in holmium doped ZFBP-glasses.

Keywords: ZFBP, SEP, FBR, RLT and SEC.

Introduction

The term LASER means "Light Amplification by Stimulated Emission of Radiation". Laser action in holmium doped ZFBP-glasses can be predicted with the help of Laser parameters. These laser parameters are as follows:

1. Spontaneous emission probability (A)
2. Fluorescence branching ratio (β)
3. Radiative lifetime (ʈ)
4. Stimulated emission cross-section (σ_p)

The values of all laser parameters can be determined by the specific formulae. All the transitions giving rise to fluorescence are not laser transitions. Laser parameters are calculated to find out which of the fluorescence transition can be used as laser transitions. These laser parameters are useful in predicting laser actions in various lanthanide doped glass specimens. These parameters have been widely used by Weber[4,7,29-34], Reisfeld[1-3,5,6,14-18], Laxman[8-13] and Tandon[19-28] groups.

Material and Methods

The starting materials sodiumhexametaphosphate, boric acid crystals, aluminium oxide and zinc fluoride were weighed with an analytical electronic balance. The batch material was ground in an automatic agate pestle mortor for two hours. The ground batch material was heated in an alumina crucible to 300°C in a silicon carbide Muffle furnace. The temperature was then slowly raised to remove the moisture and evolved gas.

Finally, the temperature was raised to 950°C which is the working temperature. The melt was stirred several time to ensure homogeneity and finally poured into the graphite mould fitted on a heavy copper block. A heavy copper hammer was then immediately pressed on it. The sudden transfer and cooling of melt in mould is known as quenching. After 12 hours the glass specimen was taken out. The glass specimen was then removed from the mould and kept for annealing in a the relek canthal wire furnace at 300°C for three and a half hours. The anneling was done to remove stress and strain.

It further gives thermal stability and strength to glass specimen. The glass specimen so prepared was laped with fine embery powder of grade 302 on the mechanically rotating flat. They were then polished on all sides by mechanically deriven device containing a flat covered with polishing cloth. For initial and final polishing, ZrO_2 and CeO_2 were used as polishing medium respectively. The polished specimen was then cleaned thoroughly with acetone and was kept for drying.

These specimen were again annealed in the therelek furnace at 300°C for two hours to remove mechanical stresses which might have developed during lapping and polishing. The glass specimen so prepared was of good optical quality and transparent

Results and Discussion

The fluorescence spectra of holmium as Ho_2O_3(0.2 mol%) doped ZFBP-glass specimen were recorded at room temperature. We can see two bands at wavelengths 555nm and 670nm. These two bands have been observed and they have been assigned by comparing their positions with the laser level scheme. All transition in the fluorescence spectra of holmium doped ZFBP-glass specimen start from the ground state to the various excited states.

The peak position and assignment have been given in table 1 and table 2. The laser actions of the observed transitions of holmium doped ZFBP-glass specimen have been measured in the terms of spontaneous emission probability (A), Fluorescence branching ratio (β), Radiative lifetime (ʈ) and stimulated emission cross-section (σ_p).

The values of spontaneous emission probability (A) for holmium doped ZFBP – glass specimen are comparatively

higher for the transition $^5F_4, {}^5S_2, \rightarrow {}^5I_8$ is suggested to be the good laser transition and the transition $^5F_5 \rightarrow {}^5I_8$ is suggested to be probable laser transition (table 1). Both the values are higher than the standard value, so both are the laser transitions.

The values of fluorescence branching ratio (β) for holmium doped ZFBP- glass specimen have been calculated for different transitions (Table 1). The values of 'β' are maximum for $^5F_4$, $^5S_2 \rightarrow {}^5I_8$ and $^5F_5 \rightarrow {}^5I_8$ transitions as compared to the standard value applicable for 0.2 mol% holmium doped glass samples. It shows that they are the good laser transitions.

The values of radiative life (ʈ) are given in table 1 for holmium doped ZFBP-glass specimen. The minimum 'ʈ' values have been obtained for $^5F_4$, $^5S_2 \rightarrow {}^5I_8$ and $^5F_5 \rightarrow {}^5I_8$ transitions. These values predict the laser actions.

The values of stimulated emission cross-section (σ_p) for $^5F_4, {}^5S_2 \rightarrow {}^5I_8$ and $^5F_5 \rightarrow {}^5I_8$ transitions are 1.045 ,0.408 pm^2 for holmium doped ZFBP- glass specimen which suggest that they are good laser transitions (Table 2).

Table 1
The spontaneous emission probability (A), fluorescence branching ratio (β) and radiative lifetime (ʈ) for holmium doped ZFBP-glass specimen

Transitions	λ(nm)	A(Sec^{-1})	B	ʈ(μsec)
$^5F_4$, $^5S_2 \rightarrow {}^5I_8$	555.0	2814.9	0.685	355.3
$^5F_5 \rightarrow {}^5I_8$	670.0	1291.9	0.315	774.1

Table 2
Stimulated emission cross-section (σ_p) for holmium doped ZFBP –glass specimen.

Glass Specimen	Transition	λ_p (nm)	λ_{eff}(nm)	σ_p (10^{-20}) (cm^2)
Holmium doped ZFBP-glass	$^5F_4, {}^5S_2 \rightarrow {}^5I_8$	555.0	15.0	1.045
	$^5F_5 \rightarrow {}^5I_8$	670.0	37.5	0.408

Conclusion

Fluorescence spectra of holmium (as Ho_2O_3=0.2mol%) doped ZFBP–glass specimen have been measured in the region 500-800nm at room temperature. Laser Parameter have been determined from the observed bands at 555nm and 670 nm. The values of laser parameters at transitions $^5F_4$, $^5S_2 \rightarrow {}^5I_8$ and $^5F_5 \rightarrow {}^5I_8$ predict the laser actions for holmium doped ZFBP-glass specimen and consider these transition as laser transitions.

The results of laser parameters indicate that the materials used to prepare the present glass specimen can be suitable for laser actions in the specific region.

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