



RESEARCH ARTICLE

ROLE OF SAMARIUM CONCENTRATION ON LUMINESCENCE PROPERTIES OF  
LITHIUM BORATE GLASSES FOR REDDISH-ORANGE APPLICATIONS

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ABSTRACT

Sm<sup>3+</sup> doped lithium borate (LB) glasses with compositions (in mol %) (60-x) B<sub>2</sub>O<sub>3</sub> + 20LiF + 10MgF<sub>2</sub> + 10ZnO + xSm<sub>2</sub>O<sub>3</sub> (where x = 0.1, 0.5, 1.0, 1.5 and 2 mol%) have been prepared by melt quenching technique and have been investigated using thermal measurements, optical absorption, luminescence, and decay kinetic techniques as well as Judd-Ofelt (J-O) analysis. The thermal stability of host glass system can be accessed from differential thermal analysis (DTA) measurements. For these glasses X-ray diffraction (XRD), optical absorption, emission and decay measurements were carried out. The glassy nature of the present glass matrices were confirmed by XRD profiles. From the optical absorption spectra, the spectral intensities (f) and Judd-Ofelt intensity parameters,  $\Omega_\lambda$  ( $\lambda = 2, 4, 6$ ) have been evaluated. From the photoluminescence spectra and using Judd-Ofelt intensity parameters, radiative transition probabilities ( $A_R$ ), experimental branching ratios ( $\beta_{exp}$ ) and stimulated emission cross-sections ( $\sigma_p$ ) are calculated. To investigate luminescence efficiency of <sup>4</sup>G<sub>5/2</sub> level of Sm<sup>3+</sup> doped different lithium borate glasses, lifetimes ( $\tau_{exp}$ ) are predicted from decay curve analysis for all prepared glass matrices. Finally, these observed results are discussed and compared with the literature data and suggested for the optical applications.

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INTRODUCTION

Rare earth spectroscopy offer variety of applications in various fields (Krause *et al.*, 2014). Borate glasses are good as a matrix material for rare-earth ions such as samarium since, they offer high optical transparency and robustness. The chemical base of borate glass is boron oxide as a network former and metal oxides as network modifiers. Type and concentration of the network former and modifier can be varied in a wide range; also mixed types of glass forming oxides are suitable for borate glass fabrication (Sharaf *et al.*, 1998). Three fold coordinated boron becomes four-fold coordinated during the melt by reducing the network modifiers. In last decade, the study of borate and their derivatives presents great interest due to their interesting physical, thermal, structural and optical properties (Kindrat *et al.*, 2015). This type of interest can be caused in order to that the glassy borate compounds are more promising materials than other systems with respect to simple and inexpensive producing technology, high thermal stability, and high coefficient of incorporation of the rare-earth ions. Attractive optical properties and high luminescence efficiency of the rare-earth doped borate materials opened new

possibilities for their different practical application e.g. in solid state lasers, display devices, telecommunication, and sensors, etc. (Steudel *et al.*, 2016). More useful functions of the rare-earth doped glasses inspiring the search of new host materials and investigations of their luminescence properties. Recently, Sm-doped glasses have shown a great potential in high-dose measurements. Spectroscopic and luminescence properties of the Sm<sup>3+</sup> ions already have been investigated in a various glass hosts such as borate (Boehm *et al.*, 1979), lithium strontium bismuth borate (Rajesh *et al.*, 2012), lithium aluminoborate (Kaur *et al.*, 2013), lithium borate (Lin *et al.*, 2005), lithium calcium borate (Srivastava *et al.*, 2004), lithium lead borate (Srivastava *et al.*, 2004), lithium calcium barium borate (Tripathi *et al.*, 2006), lithium zinc borate (Thomas *et al.*, 2013) and bismuth borate (Saisudha, 2002) glasses. In order to get good and suitable characteristics for practical purposes, to know the influence of glass host as well as doping concentration is essential. The present article reports the spectroscopic properties of a series samarium doped LB glasses with fixed glass composition and variation of doping concentration, obtained by optical absorption, photoluminescence (PL), and decay kinetics techniques. In order to predict radiative and emission properties such as radiative transition probabilities ( $A_R$ ), branching ratios ( $\beta$ ), and emission cross-sections ( $\sigma_e$ ) for certain emission transitions,

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Judd–Ofelt (OJ-O) analysis has been carried out. The present work mainly focused on the search of suitable  $\text{Sm}^{3+}$ -doped glassy like luminescent materials, which exhibit superior optical and radiative properties.

## Experimental

Lithium borate (LB) glass compositions with 0.1, 0.5, 1.0, 1.5 and 2.0 mol% of  $\text{Sm}^{3+}$  ions were prepared by melt quenching technique, and the precursor powders boric acid ( $\text{B}_2\text{O}_3$ ), lithium fluoride (LiF), magnesium fluoride ( $\text{MgF}_2$ ), zinc oxide (ZnO), samarium oxide ( $\text{Sm}_2\text{O}_3$ ) (purity 99.9%) obtained from Himedia were used. The details of prepared glass composition as follows

LBSm01:  $59.9\text{B}_2\text{O}_3 + 20\text{LiF} + 10\text{MgF}_2 + 10\text{ZnO} + 0.1\text{Sm}_2\text{O}_3$

LBSm05:  $59.5\text{B}_2\text{O}_3 + 20\text{LiF} + 10\text{MgF}_2 + 10\text{ZnO} + 0.5\text{Sm}_2\text{O}_3$

LBSm10:  $59.0\text{B}_2\text{O}_3 + 20\text{LiF} + 10\text{MgF}_2 + 10\text{ZnO} + 1.0\text{Sm}_2\text{O}_3$

LBSm15:  $58.5\text{B}_2\text{O}_3 + 20\text{LiF} + 10\text{MgF}_2 + 10\text{ZnO} + 1.5\text{Sm}_2\text{O}_3$

LBSm20:  $58.0\text{B}_2\text{O}_3 + 20\text{LiF} + 10\text{MgF}_2 + 10\text{ZnO} + 2.0\text{Sm}_2\text{O}_3$

The powders were weighed in stoichiometric amount and grinded in agate mortar. The grinded powders were taken in porcelain crucible and placed in electric furnace at  $1100\text{ }^\circ\text{C}$  for heating about 1 hour. After that, obtained liquid is poured on a preheated brass plate. The synthesized glass samples were subsequently annealed at  $250\text{ }^\circ\text{C}$  to remove thermal strains to do spectral measurements. Refractive index ( $n$ ) measurements were performed using an Abbe refractometer at sodium wavelength ( $583.3\text{ nm}$ ) with one-bromonaphthalene as contact liquid. The density ( $d$ ) was measured by Archimedes's principle using water as an immersion liquid. The prepared glasses were characterized for structural properties by using an X-ray diffractometer (XRD, SEIFERT). Differential Thermal Analysis (DTA) was performed using a Netzsch DTA 404 PC Eos differential thermal analyzer with a heat rate of  $10\text{ }^\circ\text{C min}^{-1}$ . Optical properties of the lithium borate glasses were analyzed by measuring absorption, excitation, and emission spectra. Absorption spectra were measured by using a UV-VIS-NIR spectrophotometer (ELICO SL 218). Excitation and emission spectra were measured by using JOBIN YVON Fluorolog-3 Spectrofluorimeter excited with xenon lamp. All the spectral measurements were carried out at room temperature.

## RESULTS AND DISCUSSION

### Thermal analysis- Differential thermal analysis (DTA)

In order to understand and interpret the thermal, crystallization and melting behaviour of glass system, differential thermal analysis (DTA) is important one. Through DTA analysis, phase changes are also observed during thermal heat treatment. The separated various phases like glass transition temperature ( $T_g$ ), crystallization temperature ( $T_c$ ) and melting point ( $T_m$ ) which are depend on the different constituting oxides such as glass former and modifiers in the glass systems. DTA profile is recorded for host LB glass matrix and is presented in Fig.1. From Fig.1, an endothermic peak located nearly at  $100\text{ }^\circ\text{C}$  is observed which is due glass transition temperature ( $T_g$ ). Two exothermic peaks follow after the glass transition temperature

indicating the stage of crystallization ( $T_c$ ) process.  $T_{C1}$  and  $T_{C2}$  are two crystallization events are formed during melting process. These two events are occurred nearly at  $150$  and  $305\text{ }^\circ\text{C}$  temperatures, respectively. From Fig. 1, where the higher  $T_{C2}$  and lower  $T_g$  are used to measure the thermal stability of the amorphous lithium borate glass system. The thermal stability or glass forming ability can be measured by difference of glass transition and crystallization temperatures ( $\Delta T = T_{C2} - T_g$ ). In the present work, it is observed that the thermal stability is found to be  $205\text{ }^\circ\text{C}$  for the lithium borate glass system. It is essential that the thermal stability should be as large as possible for fiber drawing purpose. Herein, the present lithium borate glass system has a high thermal stability, in comparison with other tellurite ( $147\text{ }^\circ\text{C}$ ) (El Sayed, 2005) and phosphate ( $202\text{ }^\circ\text{C}$ ) (Wu *et al.* 2016) glasses. So, the present glasses are good candidates for optical devices. The exothermic peak is followed by endothermic which show that the melting processes takes place nearly at  $790\text{ }^\circ\text{C}$ .

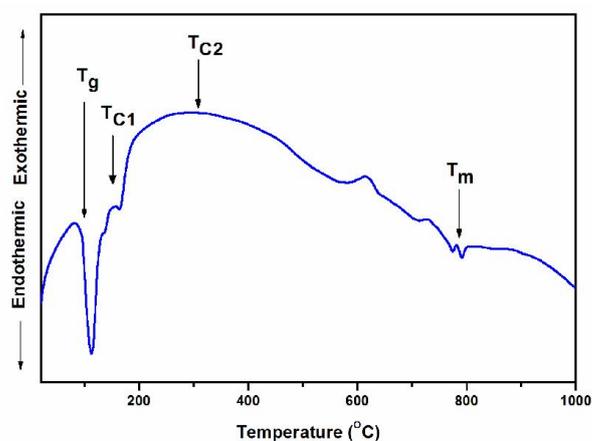


Fig.1. DTA profile of the lithium borate host glass matrix

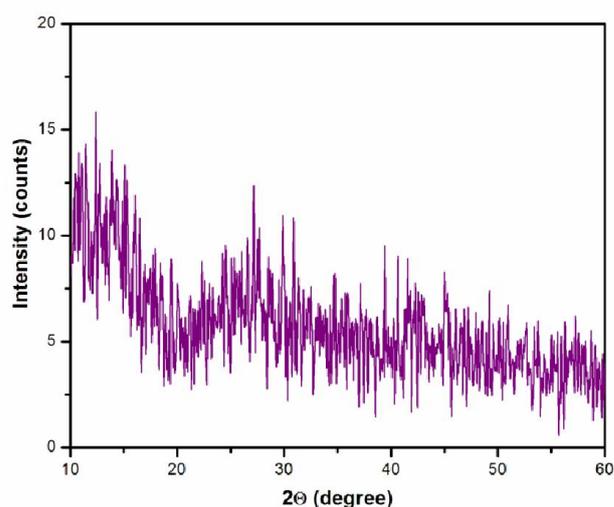


Fig.2. XRD profile of the lithium borate host glass matrix

### X-ray diffractogram (XRD) and Scanning Electron Microscopy (SEM)

The XRD diffractogram of the lithium borate host glass system is shown in Fig. 2. Obviously, the amorphous character of this

host glass matrix is evident from XRD pattern. Only a broad peak is observed for a glass sample free from samarium and indicating that these lithium borate glass samples are composed of glassy phase. The lithium borate host glass matrix, had broad hump in the region around  $20^\circ < 2\theta < 30^\circ$ , which is characteristic of glass system, is clearly observed.

### Optical absorption analysis

Fig.3a and 3b shows the optical absorption spectrum for LBSm05 lithium borate glass matrix. Fig. 3a and 3b represents the absorption transitions in the ultraviolet to visible and near infrared region, respectively. All the absorption transitions related to samarium ion, from lower states to higher states which are higher than the  ${}^6P_{3/2}$  level are masked by the host absorption edge, which extended below 350 nm wavelength. The absorption spectrum relatively dominated by two transitions, according to the hypersensitive character. The absorption bands centred at 404 and 1224 nm correspond to the  ${}^6P_{3/2}$  and  ${}^6F_{7/2}$  transitions, respectively. Among all the absorption bands, these transitions have high spectral intensity and are hypersensitive transitions for samarium ion. The oscillator strengths of various absorption transitions for LBSm05 system is shown in Table 1. In order to estimate change in environment around doped  $Sm^{3+}$  ion, it is important to calculate variations in spectral intensity parameters based on the Judd–Ofelt (J–O) theory. This theory can be used for quantitative characterization of optical transitions. The J–O model gives three parameters  $\Omega_\lambda$  such as ( $\lambda=2, 4, 6$ ). The admixing of the  $4f^n$  states in Ln ion depends on symmetry, local crystal field and bonding nature etc, J–O parameters in turn yield information on the local interactions of  $Sm^{3+}$  with the surrounding environment.

This theory allows the calculation of oscillator strengths, J–O intensity parameters and radiative parameters from the measured absorption spectra. Experimental and theoretical oscillator strengths are measured using relations mentioned in Ref. (Babu *et al.*, 2014). A least square fitting approach is used to determine  $\Omega_\lambda$  parameters, which gives the best fit to the experimental values. According to Jørgensen and Judd (Jørgensen, 1964) and Jørgensen and Reisfeld (Reisfeld and Jørgensen, 1977),  $\Omega_2$  is connected to the asymmetry of the local structure and the covalence of chemical bonds formed by rare earth ions, while  $\Omega_4$  and  $\Omega_6$  gives information related to the changes in viscosity or rigidity of a host medium which is related to the mean force constant of the RE–O bond (Krause *et al.*, 2014). For LBSm05 glass system obtained  $\Omega_2, \Omega_4$  and  $\Omega_6$  parameter magnitudes are  $0.38 \times 10^{-20}$ ,  $3.01 \times 10^{-20}$  and  $2.01 \times 10^{-20} \text{ cm}^2$ , respectively. In the present work,  $Sm^{3+}$ -doped LB glasses, the  $\Omega_\lambda$  trend has been observed as  $\Omega_4 > \Omega_6 > \Omega_2$  which is similar to tellurite (Kumar *et al.*, 2003) and heavy metal oxide borate (Herrera *et al.*, 2016) glasses. As stated earlier especially the  $\Omega_2$ , depend on the asymmetry and covalence of Ln ion sites in host i.e. value of  $\Omega_2$  increases with increasing site distortion of Ln ions and with increasing covalent character of Ln–O bonds. Slight change in  $\Omega_2$  is expected due to a lower symmetrical microenvironment around  $Sm^{3+}$  ions which may happen when ion experience asymmetrical non-crystalline fields. In our case, value of  $\Omega_6$  parameter increases which shows higher force constant, consequently stronger band strength (Sm–O).

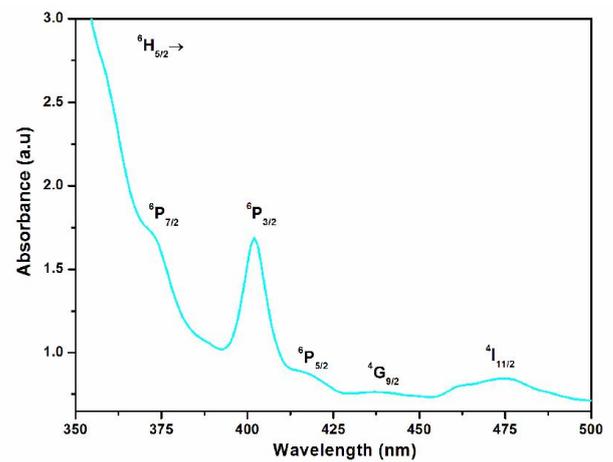


Fig. 3a. Optical absorption spectra (UV-VIS) of 0.5 mol% of  $Sm^{3+}$  doped lithium borate glass

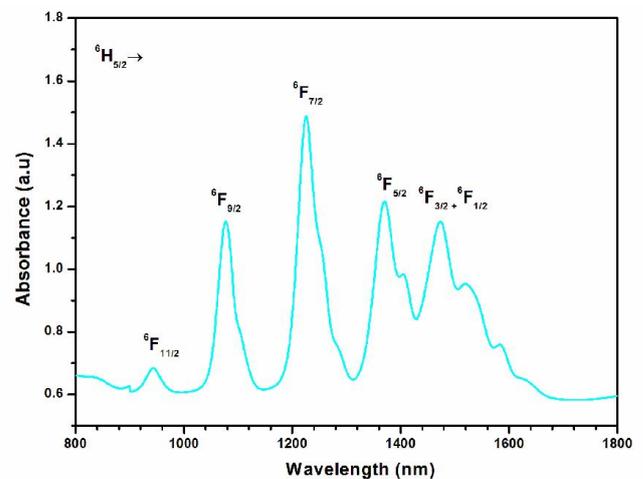


Fig. 3b. Optical absorption spectra (NIR) of 0.5 mol% of  $Sm^{3+}$  doped lithium borate glass

### Excitation and emission analysis

The excitation spectrum is recorded for the LBSm05 lithium borate glass matrix in the span of 300–550 nm wavelength by monitoring with the intense reddish-orange emission located at 601 nm and is shown in Fig.4. The excitation spectrum consists of one intense band at 404 nm in addition to other weak bands located at 344, 362, 374, 415, 440 and 469 nm, which are the characteristic f–f transition of  $Sm^{3+}$  given to the transition from  ${}^6H_{5/2}$  level to the  ${}^4H_{9/2}$ ,  ${}^4D_{5/2}$ ,  ${}^6P_{7/2}$ ,  ${}^4M_{19/2}$ ,  ${}^4G_{9/2}$  and  ${}^4I_{13/2} + {}^4I_{11/2} + {}^4M_{15/2}$  levels of f–f transition of  $Sm^{3+}$  ions, respectively. The strongest excitation or oscillator strength is observed at 404 nm related to  ${}^6H_{5/2} \rightarrow {}^4F_{7/2}$  transition and this can be convenient band for recording luminescence spectra. The nature of this excitation band hints for the possible enhancement of the principal emission line of  $Sm^{3+}$  ion. Fig.5 shows the characteristic of luminescence transitions of LBSm01, LBSm05, LBSm10, LBSm15 and LBSm20 lithium borate glasses under excited 404 nm. The luminescence spectra consist of four emission transitions of different intensities i.e.  ${}^4G_{5/2} \rightarrow {}^6H_{5/2}$ ,  ${}^6H_{7/2}$ ,  ${}^6H_{9/2}$  and  ${}^6H_{11/2}$ . Four bands appearing in these spectra can be unambiguously assigned to electron make a transitions from the  ${}^4G_{5/2}$  excited state to the  ${}^6H_J$  ( $J = 5/2, 7/2, 9/2$  and  $11/2$ ) terminal states.

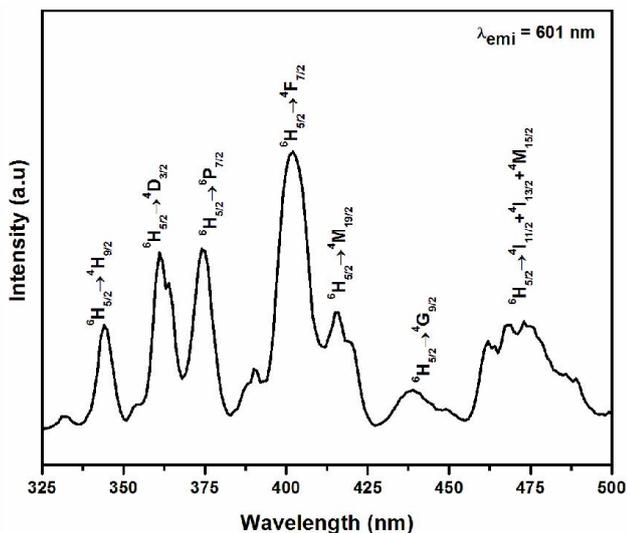


Fig. 4. Excitation spectrum of 0.5 mol% of  $\text{Sm}^{3+}$  doped lithium borate glass

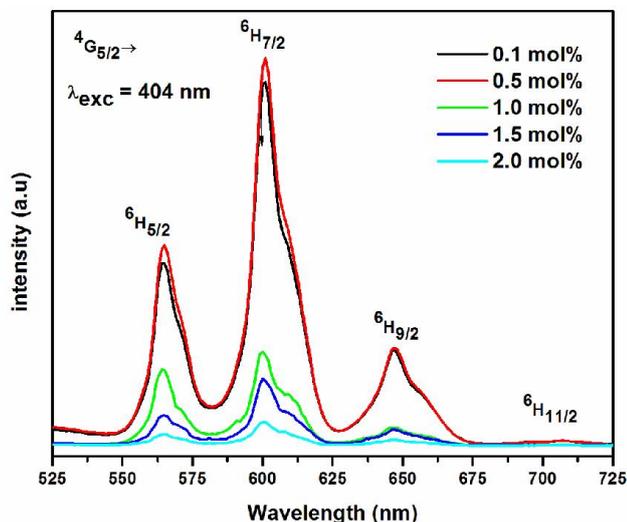


Fig. 5. Emission spectra of  $\text{Nd}^{3+}$  doped lithium borate glass with different concentrations

The fluorescence band intensity decreases in the order is:  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  (reddish-orange)  $>$   ${}^6\text{H}_{5/2}$  (yellow-green)  $>$   ${}^6\text{H}_{9/2}$  (red)  $>$   ${}^4\text{G}_{11/2}$ . This order remains constant with increase in  $\text{Sm}^{3+}$  content (Herrera *et al.*, 2016). Five samples are studied by varying concentration of samarium up to 2.0 mol%. When the  ${}^4\text{F}_{7/2}$  level (404 nm) of  $\text{Sm}^{3+}$  is excited and the ions quickly relax non-radiatively to the lower level  ${}^4\text{G}_{5/2}$  which has comparatively greater lifetimes than the  ${}^4\text{G}_{7/2}$  and  ${}^4\text{F}_{3/2}$  levels. This is owing to the large energy gap of about  $7209 \text{ cm}^{-1}$  between the  ${}^4\text{G}_{5/2}$  level and the next lower  ${}^6\text{F}_{11/2}$  level and which makes the multiphonon relaxation (MPR) negligible. There are several levels with smaller energy differences between  ${}^4\text{F}_{7/2}$  and  ${}^4\text{G}_{5/2}$  levels, which lead efficient non-radiative relaxation to the population of the  ${}^4\text{G}_{5/2}$  state. Thus, a radiative transition takes place from  ${}^4\text{G}_{5/2}$  state from which simulates bright reddish-orange perception. From Fig.5, it can be seen that the luminescence intensities are quenched for transitions of  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{5/2}$ ,  ${}^6\text{H}_{7/2}$ , and  ${}^6\text{H}_{9/2}$ . This is owing to the energy transfer from the excited samarium ions to the unexcited samarium ions in LB host glass matrix.

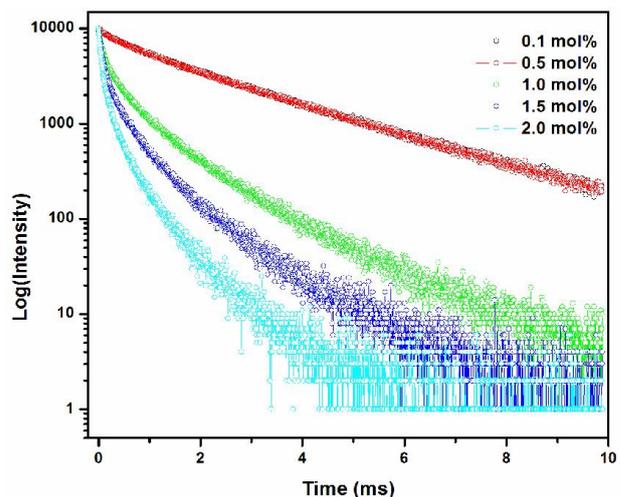


Fig. 6. Decay profiles of  $\text{Nd}^{3+}$  doped lithium borate glass with different concentrations

Initially enhancement (up to 0.5 mol%  $\text{Sm}^{3+}$ ) and then quenching in fluorescence emission intensities are due to the concentration effect of samarium ions and this fact can be seen from Fig.5. This suggests that the involvement of an energy transfer (ET) process through cross relaxations (CR) at relatively higher concentration of active ion. This is known as concentration quenching and occurs by the CR processes. Since, the ET process requires two  $\text{Sm}^{3+}$  ions in the intermediate excited states hence; its efficiency depends on the  $\text{Sm}^{3+}$ - $\text{Sm}^{3+}$  distance. The excited  $\text{Sm}^{3+}$  ions of the  ${}^6\text{F}_{11/2}$  level transfers energy to another neighboring excited  $\text{Sm}^{3+}$  ion of the same level. The CR processes appears to be responsible for decrease in intensity of the bands due to closer proximity of the  $\text{Sm}^{3+}$ - $\text{Sm}^{3+}$  ion pair i.e. the mean distance of  $\text{Sm}^{3+}$ - $\text{Sm}^{3+}$  decreases. In the present case, depopulation of the  ${}^4\text{G}_{5/2}$  storage level is enhanced by the CR processes which begin with one  $\text{Sm}^{3+}$  ion in these excited levels and one or more  $\text{Sm}^{3+}$  ion in the ground state ( ${}^6\text{H}_{5/2}$ ). The calculated phenomenological parameters  $\Omega_\lambda$ , which in turn form the basis for the calculation of other spectroscopic quantities such as radiative transition probability ( $A_R$ ), branching ratio ( $\beta$ ), and stimulated emission cross-sections ( $\sigma_e$ ) etc. using the relations taken from literature (Babu *et al.*, 2014) and are presented in Table 2. From Table 2, the obtained parameters depend on host glass composition. The larger is probability of transition, lower of its radiative lifetimes and vice-versa. In the present work, among different emission levels, a transition, the  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  transition has high magnitude of transition probability ( $A$ ) compared with rest of emissive transitions. A high value of transition probability provides better action of lasing in that host material. The larger emission cross section ( $\sigma_e$ ) value is observed for  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  transition than remaining transitions in LB05 lithium borate glass. The experimental branching ratios ( $\beta_{\text{exp}}$ ) are assessed by numerical integration of emission transitions. The higher  $\beta_{\text{exp}}$  value (54 %) is observed for  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  transition in LB05 lithium borate glass. The obtained  $\beta_{\text{exp}}$  is higher than corresponding values for  $\text{Sm}^{3+}$ -doped present prepared LB glasses. Reasonably high values of various radiative parameters evaluated for  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  (602 nm) transition suggest that the 0.5 mol%  $\text{Sm}^{3+}$ -doped LB05Sm glass is more suitable for the reddish-orange region and for the development of optical devices.

**Table 1. Experimental ( $f_{\text{exp}}$ ) and calculated ( $f_{\text{cal}}$ ) spectral intensities ( $\times 10^{-6}$ ) and Judd-Ofelt parameters ( $\Omega_{\lambda} \times 10^{-20} \text{ cm}^2$ ) of 0.5 mol% of  $\text{Sm}^{3+}$  doped lithium borate glass matrix**

Transitions	$f_{\text{exp}}$	$f_{\text{cal}}$
${}^6\text{P}_{7/2}$	1.02	1.02
${}^6\text{P}_{3/2}$	3.58	3.48
${}^6\text{P}_{5/2}$	0.56	0.69
${}^4\text{G}_{9/2}$	0.23	0.16
${}^4\text{I}_{11/2}$	1.01	1.45
${}^6\text{F}_{11/2}$	0.40	0.50
${}^6\text{F}_{9/2}$	2.08	2.19
${}^6\text{F}_{7/2}$	3.67	3.12
${}^6\text{F}_{5/2}$	2.10	2.20
${}^6\text{F}_{3/2}+{}^6\text{F}_{1/2}$	1.17	1.14
RMS Deviation	$\pm 0.47$	
$\Omega_2$		0.38
$\Omega_4$		3.01
$\Omega_6$		2.01

**Table 2. Emission band positions ( $\lambda_p$ , nm), effective bandwidths ( $\Delta\lambda_{\text{eff}}$ , nm), radiative transition probabilities ( $A_R$ ,  $\text{s}^{-1}$ ), peak stimulated emission cross-sections ( $\sigma_p$ ,  $\times 10^{-22} \text{ cm}^2$ ) and experimental branching ratios ( $\beta_{\text{exp}}$ ) of  ${}^4\text{G}_{5/2}$  state for the 0.5 mol%  $\text{Sm}^{3+}$  doped lithium borate glass matrix**

Parameters	${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{5/2}$	${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$	${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{9/2}$	${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{11/2}$
$\lambda_p$	565	601	646	705
$\Delta\lambda_{\text{eff}}$	12	10	17	29
$A_R$	100	165	75	46
$\sigma_p$	1.65	2.95	1.09	0.85
$\beta_{\text{exp}}$	0.21	0.54	0.14	0.11

### Decay analysis

The photoluminescence decay curves of the  $\text{Sm}^{3+}$ -doped LBSm01, LBSm05, LBSm10, LBSm15 and LBSm20 lithium borate glasses are measured and are shown in Fig.6. The decay curves are observed to be single exponential rule for the LBSm01 and LBSm05 glasses. This observation indicates that at low  $\text{Sm}^{3+}$  content the  ${}^4\text{G}_{5/2}$  level decays mainly by radiative transitions. Later on concentrations, decay profiles fitted to a second order exponential equation. All decay curves ( $\text{Sm} > 0.5$  mol%) of  ${}^4\text{G}_{5/2}$  level are experienced double exponential nature by an increase samarium concentrations. Doped atoms of lifetimes depends in which the dopant ion situated environment and, of its nearest neighbourhood environment. Its nearest neighbourhood plays the significant role in radiative and non-radiative processes of electron transition from the excited state to the ground state. This suggesting that due to the non-radiative or non exponential process occurred among the  $\text{Sm}^{3+}$  ions. The non-exponential nature can be predicted by Inokuti–Hirayama (I-H) model. The decay profiles are fitted with  $s=6$  parameter. It is worth noting that, the main contribution of energy transfer between optically active ions is from the dipole–dipole interaction. The decay lifetimes are found to be 1.62, 1.50, 1.01, 0.89 and 0.65 ms related to LBSm01, LBSm05, LBSm10, LBSm15 and LBSm20 glasses, respectively. Among all the LB glasses, LBSm01 has longer lifetimes and LBSm20 has shorter lifetimes. Due to increase in the samarium concentration, there is a possibility of decrement in distance between two active samarium centers  $\text{Sm}^{3+}$ - $\text{Sm}^{3+}$ . Relaxation of the  ${}^4\text{G}_{5/2}$  level for  $\text{Sm} > 0.5$  mol% may be faster due to the contribution of nonradiative cross relaxation process. This leads to energy transfer between two samarium atoms.

### Conclusions

$\text{Sm}^{3+}$  ions doped lithium borate glasses with compositions (in mol %)  $(60-x) \text{ B}_2\text{O}_3 + 20\text{LiF} + 10 \text{ MgF}_2 + 10\text{ZnO} + x \text{ Sm}_2\text{O}_3$  (where  $x = 0.1, 0.5, 1.0, 1.5$  and  $2$  mol%) were prepared by melt quenching technique and are investigated using thermal analysis, optical absorption, luminescence, and decay kinetic techniques as well as Judd–Ofelt (J–O) analysis. From DTA measurements, thermal stability is found to be  $205^\circ\text{C}$  for the lithium borate glass system. For these glasses X-ray diffraction (XRD), optical absorption, emission and decay measurements have been carried out. The glassy nature of the present glass matrices are confirmed by XRD profiles. From the optical absorption spectra, the spectral intensities and Judd-Ofelt intensity parameters,  $\Omega_{\lambda}$  ( $\lambda = 2, 4, 6$ ) have been evaluated. For LBSm05 glass system obtained  $\Omega_2$ ,  $\Omega_4$  and  $\Omega_6$  parameters magnitudes found to be  $0.38 \times 10^{-20}$ ,  $3.01 \times 10^{-20}$  and  $2.01 \times 10^{-20} \text{ cm}^2$ , respectively. For 0.5 mol%  $\text{Sm}^{3+}$ -doped LB glasses, the  $\Omega_{\lambda}$  trend has been observed as  $\Omega_4 > \Omega_6 > \Omega_2$ . Using Judd-Ofelt intensity parameters, radiative characteristics are calculated. From the photoluminescence spectra, experimental branching ratios ( $\beta_{\text{exp}}$ ) and stimulated emission cross-sections ( $\sigma_p$ ) are calculated. Five samples are studied by varying concentration of samarium up to 2.0 mol%. Initially enhancement (up to 0.5 mol%  $\text{Sm}^{3+}$ ) and then quenching in fluorescence emission intensities are due to the concentration effect of samarium ions and the involvement of an energy transfer (ET) process through cross relaxations (CR) at relatively higher concentration of active ion is observed. This is known as concentration quenching. The largest transition probabilities ( $A_R$ ) emission cross sections ( $\sigma_e$ ) and branching ratios value are observed for  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  transition in LB05 lithium borate glass. Reasonably high values of various radiative parameters evaluated for  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  (602 nm) transition suggest that the 0.5 mol%  $\text{Sm}^{3+}$ -doped LB05Sm glass is optimized LB glass system. The photoluminescence decay curves of the  $\text{Sm}^{3+}$ -doped LB glasses are measured. Among all the LB glasses, LBSm01 has longer lifetimes and LBSm20 has shorter lifetimes. Due to increase in the samarium concentration, there is a possibility of decrement in distance between two active samarium centers and this leads to energy transfer between atoms. Finally, it is concluded that the prepared 0.5 mol%  $\text{Sm}^{3+}$  doped lithium borate glass system is might be useful for photonic applications.

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