OPTICAL ABSORPTION PROPERTIES OF Nd^{3+}: B_2O_3 – Na_2O – LiF/AlF_3 GLASSES

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ABSTRACT

Optical properties are reported for Nd^{3+}: B_2O_3 – Na_2O – LiF/AlF_3 glasses from their absorption spectra. These glasses are have been characterized with respect to Physical, non-linearity and absorption properties. The intensities of f – f transitions are parameterized in terms of Judd – Ofelt intensity parameters Ω_λ (λ = 2, 4 and 6). From these parameters, the radiative properties such as transition probability (A), total transition probability (A_T) and branching ratios (β%) are estimated. Further, by adding AlF_3 into the borate glass matrices improved the optical absorption spectral properties.

Keywords: Absorption Spectra, Judd-Ofelt Parameters, Radiative Properties

I INTRODUCTION

The increasing importance of glasses doped with rare-earth ions as possible lasing materials has created considerable interest in the study of their optical properties. Optical properties of rare-earth ions doped glasses in general are being extensively studied on account of their potential applications in the field of lasers and fiber optics [1-3]. Borate glasses are most compatible for high concentrations of rare-earth ion doping [4] because of their transparency, resistance towards moisture and extended IR transmission range with a cut off wavelength of 3-4.5µm. Knowledge of the spectroscopic properties of rare-earth ions is of fundamental importance for laser action. According to Di Bartolo [5] and Fernadez[6], application of Judd - Ofelt theory to absorption and fluorescence spectra becomes an essential method in complete optical characterization of rare-earth doped glasses and crystalline materials. It has been noticed that the glasses prepared from B_2O_3 – Na_2O – LiF/AlF_3 are important optical materials. The present paper becomes continuation to the earlier work, in order to gain an insight into the absorption properties of another important lasing rare-earth ion namely Nd^{3+}.

II EXPERIMENTAL

The following are the compositions of the three Nd^{3+} doped glasses prepared by employing quenching technique as reported earlier [7]. The prepared glass samples labeled as LBG, ABG & LABG are used in the rest of the paper.

Lithium Borate Glass (LBG) : $81B_2O_3 + 10Na_2O + 8LiF + 1NdF_3$

Aluminium Borate Glass (ABG) : $81B_2O_3 + 10Na_2O + 8AlF_3 + 1NdF_3$

Lithium Aluminum Borate Glass (LABG) : $81B_2O_3 + 10Na_2O + 4LiF + 4AlF_3 + 1NdF_3$

The glasses are violet in colour (due to uniform distribution of Nd^{3+} ion in the glass matrices) and found to be free from air bubbles with good transparency. The glass densities and refractive indices have been measured for the host glasses and using the relevant expressions available in the literature [8], other related physical and non-linearity parameters have been computed. The absorption spectra of Nd^{3+} doped glasses were recorded on a UV-160A Shimadzu Corp. Spectrophotometer in the wavelength range 360-920nm.

III RESULTS AND DISCUSSION

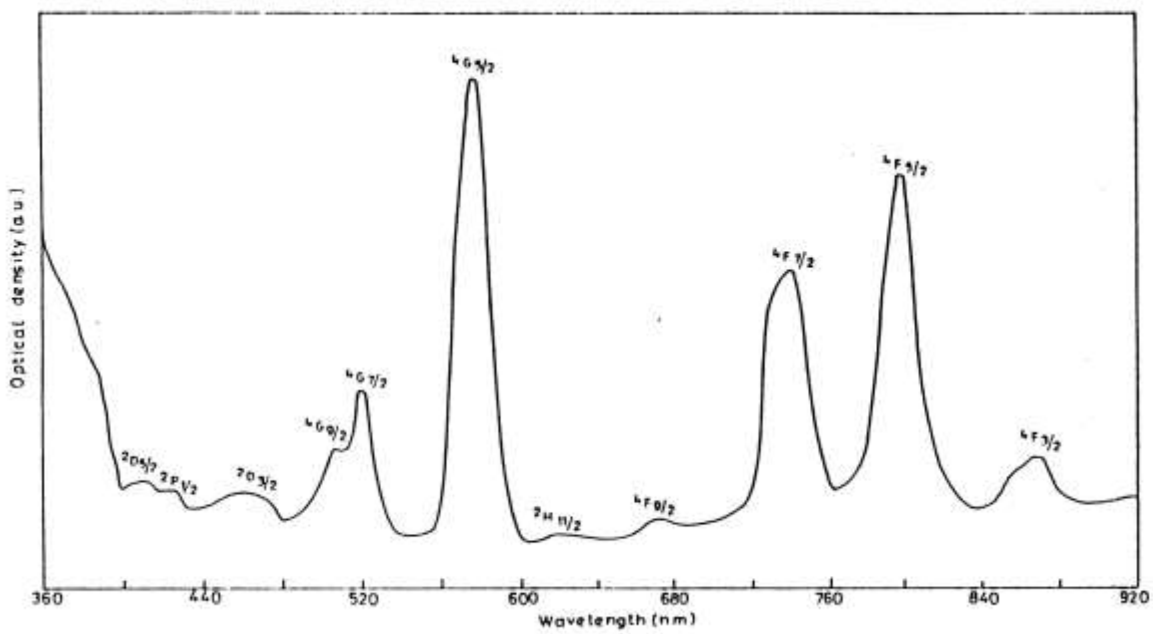
Based on the values of Physical and non-linearity parameters reported in Table 1, majority of the parameters in LABG show better properties due to the presence of AlF_3 content as a net work modifier in the fluoroborate glass system.

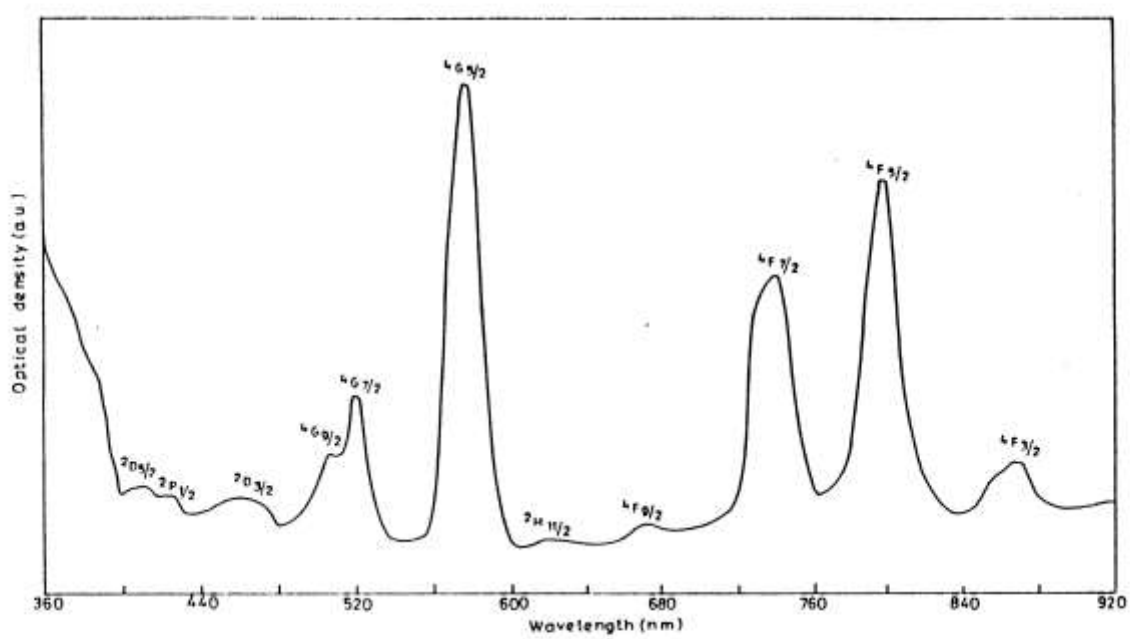
Table 1: Physical and Non-linearity properties of Nd^{3+}: B_2O_3 – Na_2O – LiF/AlF_3 Glasses

Physical Parameters	LBG	ABG	LABG
Average Molecular weight m (g)	64.769	69.412	67.091
Density d (g/cm^3)	1.6427	1.6627	1.6527
Dielectric constant $\in$	2.159	2.161	2.151
Nd^{3+} ion concentration N (10^{22} ions/cm^3)	1.5280	1.4432	1.4841
Atomic Volume V (g/cm^3/atom)	0.0609	0.0630	0.0620
Molar Refractivity R_M (cm^{-3})	10.872	11.647	11.258
Electronic Polarizability α_e ($10^{-24} cm^3$)	4.308	5.534	4.461
Polaron radius r_p (A^o)	1.624	1.655	1.64
Inter – ionic distance r_i (A^o)	4.030	4.107	4.069
Field strength F (10^{16} cm^{-2})	1.138	1.095	1.116
Non-Linearity parameters			
Refractive indices:			
At 486.1nm (n_f)	1.4695	1.476	1.4726
At 589.3 nm (n_d)	1.4636	1.470	1.4667
At 656.3 nm (n_c)	1.4612	1.4676	1.4643
Abbe Number (V_d)	55.83	55.96	55.99
Dispersive Power (V_d^{-1})	0.01791	0.01787	0.01786
Non-linear refractive index n_2 (10^{13} esu)	1.1883	1.2108	1.1960
Non-linear refractive index coefficient γ (10^{15} m^2w^{-1})	3.4009	3.4502	3.4157
Non-linear susceptibility $\chi^{e(3)}{}_{1111}$(10^{15}esu)	4.6134	4.7213	4.6531

The absorption spectra of Nd^{3+} - doped glasses are shown in Figs (a-c). From the recorded absorption spectra, the Optical Densities (OD), Oscillator strengths (f_{ed}) & Judd - Ofelt intensity parameters (Ω_λ) have been computed and reported in Table 2.

It has been observed that the hypersensitive transition ($^4I_{9/2} \rightarrow {}^4G_{5/2}$) of the Nd^{3+} glasses has all maximum optical density values and thereby higher oscillator strengths. Table 3, lists out the computed radiative parameters of the emission transitions of the Nd^{3+} doped glasses.





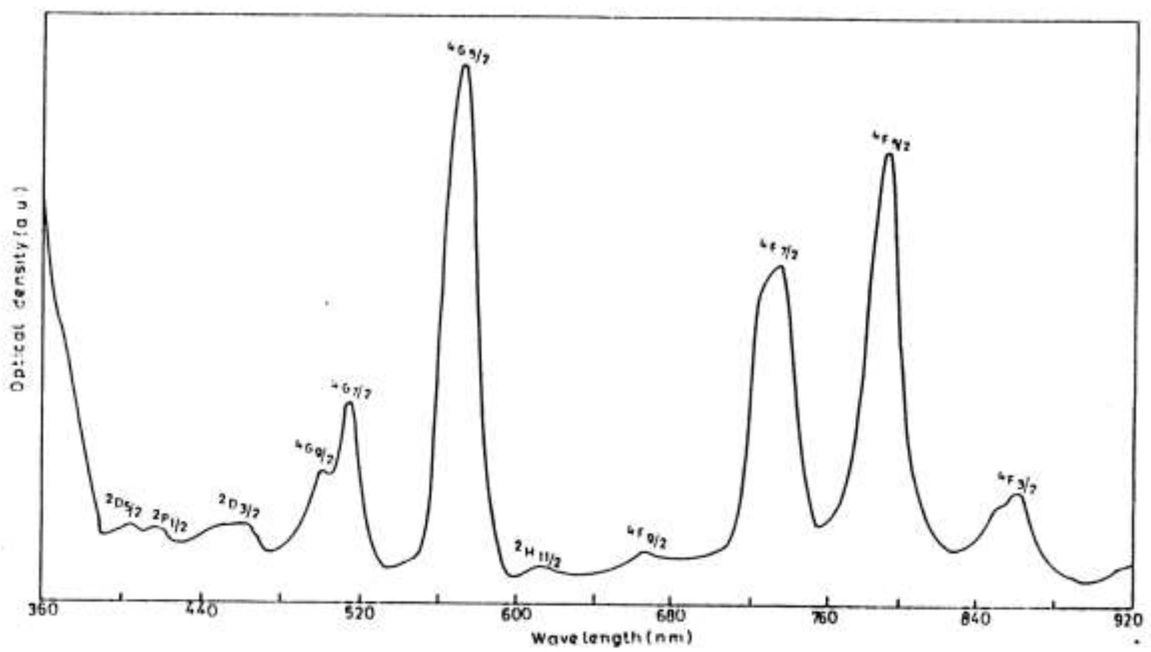


Fig.:(a – c) Absorption spectra of Nd^{3+} doped B_2O_3 – Na_2O – LiF/AlF_3 Glasses

Table 2: Optical Density (OD in arbitrary units), Oscillator strength (f_{ed} x 10^6) and Judd – Ofelt intensity (Ω_λ x 10^{20} cm^2) parameters of Nd^{3+}: B_2O_3 – Na_2O – LiF/AlF_3 Glasses.

Absorption bands	LBG		ABG		LABG	
	OD	f_{ed}	OD	f_{ed}	OD	f_{ed}
$^4I_{9/2}$ → $^4F_{3/2}$	0.45	3.38	0.42	3.15	0.54	4.07
→ $^4F_{5/2}$	1.39	16.03	1.20	13.75	1.67	18.83
→ $^4F_{7/2}$	1.08	9.12	1.08	7.62	1.29	10.63
→ $^4F_{9/2}$	0.24	1.86	0.27	1.57	0.33	2.18
→ $^2H_{11/2}$	0.18	0.51	0.23	0.43	0.27	0.59
→ $^4G_{5/2}$	**1.71**	**28.43**	**1.23**	**18.52**	**1.95**	**32.64**
→ $^4G_{7/2}$	0.66	20.09	0.63	12.99	0.81	22.99
→ $^4G_{9/2}$	0.48	3.11	0.48	2.71	0.57	3.67
→ $^2D_{3/2}$	0.32	0.25	0.36	0.26	0.41	0.31
→ $^2P_{1/2}$	0.33	0.51	0.33	0.53	0.39	0.63

→ $^2D_{5/2}$	0.36	0.15	0.36	0.12	0.40	0.17
Ω_2	10.219		5.724		**11.526**	
Ω_4	4.177		4.346		**5.219**	
Ω_6	20.217		16.771		**23.543**	

Table 3: Emission level energies (υ in cm^{-1}), Transition probability (A in sec^{-1}), Total transition probability (A_T sec) and Branching ratio (β_R %) of Nd^{3+}: B_2O_3 – Na_2O – LiF/AlF_3 Glasses.

Emission Transition	Energies	LBG		ABG		LABG	
		A	β_R %	A	β_R %	A	β_R %
$^4F_{3/2}$ → $^4I_{15/2}$	5450	46	1	39	1	54	1
→ $^4I_{13/2}$	7520	920	14	773	14	1078	14
→ $^4I_{11/2}$	9520	3841	59	3285	58	4524	59
→ $^4I_{9/2}$	11530	1682	26	1520	27	1961	26
	A_T	6489		5617		**7617**	

From this table, it is observed that for the emission transition ($^4F_{3/2}$ → $^4I_{11/2}$), the radiative probabilities are found to be higher for all the glasses. Both absorption & emission results make us to understand that the spectral characteristics are better in LABG.

IV CONCLUSIONS

It can be concluded that the results obtained from the physical, non-linearity & optical (absorption & emission) studies, confirm the validity of the application of J-O theory in evaluating the optical quality of the glass materials. Further the addition of AlF_3 into the Lithium Borate Glass (LBG) system enhances the optical properties.

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