International Journal of Advance Research in Science and Engineering
Volume No. 11, Issue No. 06, June 2022
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Spectral and FTIR Analysis of Dy^{3+} Doped ZincLithium LeadCalcium Alumino Tellurite Glasses

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Abstract

Glass sample of Zinc Lithium Lead Calcium Alumino Tellurite (40-x)TeO_2:10ZnO:10Li_2O:10PbO:10CaO:20Al_2O_3:xDy_2O_3. (where x=1, 1.5,2 mol %) have been prepared by melt-quenching method. (where x=1,1.5 and 2 mol%) have been prepared by melt-quenching technique. The amorphous nature of the prepared glasssamples was confirmed by X-ray diffraction.Optical absorption,Excitation, fluorescence and FTIR spectra have been recorded at roomtemperature for all glass samples.Judd-Ofeltintensity parameters Ω_λ (λ=2, 4 and6) are evaluated from theintensities of various absorption bands of opticalabsorption spectra. Using these intensity parameters variousradiative properties like spontaneous emission probability, branching ratio, radiative life time and stimulatedemission cross–section of various emission lines have been evaluated.

Keywords: ZLLCAT Glasses,Optical Properties, Judd-Ofelt Theory, Transmittance Properties

I. Introduction

Glasses are receiving considerable attention due to theirpotentialapplication in optical devices such as frequency-conversion materials,laser actionand optical fiber amplifiers [1-5].Among different host matrices, tellurite glasses have wide range of applications in the field of glass ceramics, with the advantages such as low non-linear refractive index, good physical and chemical stability and high transparency [6-10].Tellurite glasses have relatively low phonon energy and good thermal stability. Additionally, such glasses are characterized by a high capacity for dissolving rare earth elements [11-14].Recently, glass-ceramics containing dysprosium oxides have been found in applications for several different purposes.Dy^{3+} doped glasses have attracted much interest due to their important optical properties used in lasers, optical amplifiers, network formers, photonic devices and as infrared sensors [15-18].

The present work reports on the preparation and characterization of rare earth doped heavy metal oxide (HMO) glass systems for lasing materials.I have studied on the absorption and emission properties of Dy^{3+}doped zinc lithium calciummagnesium borophosphate glasses. The intensities of the transitions for the rare earth ions have been estimated successfully using the Judd-Ofelt theory, The laser parameters such as radiative probabilities(A),branching ratio (β),radiative life time(τ_R) and stimulated emission cross section(σ_p) are evaluated using J.O.intensity parameters(Ω_λ, λ=2,4 and 6).

II.Experimental Techniques

Preparation of glasses

The following Dy^{3+}doped tellurite glass samples (40-x)TeO_2:10ZnO:10Li_2O: 10PbO:10CaO: 20Al_2O_3:xDy_2O_3. (where x=1, 1.5 and 2 mol %) have been prepared by melt-quenching method. Analytical reagent grade chemical used in the present study consist of TeO_2,ZnO,Li_2O, PbO,CaO,$Al_2O_3$and Dy_2O_3. They were thoroughly mixed by using an agate pestle mortar. then melted at 1052^{0}C by an electrical muffle furnace for 2h., After complete melting, the melts were quickly poured in to a preheated stainless steel mould and annealed at temperature of 250^{0}C for 2h to remove thermal strains and stresses. Every time fine powder of cerium oxide was used for polishing the samples. The glass samples so prepared were of good optical quality and were transparent. The chemical compositions of the glasses with the name of samples are summarized in **Table 1.**

Table 1.

Chemical composition of the glasses

Sample	Glass composition (mol %)
ZLLCAT (UD)	40TeO_2:10ZnO:10Li_2O:10PbO:10CaO:20Al_2O_3
ZLLCAT (DY1)	39TeO_2:10ZnO:10Li_2O:10PbO:10CaO:20Al_2O_3:1Dy_2O_3.
ZLLCAT (DY1.5)	38.5TeO_2:10ZnO:10Li_2O:10PbO:10CaO:20Al_2O_3:1.5Dy_2O_3.
ZLLCAT(DY2)	38TeO_2:10ZnO:10Li_2O:10PbO:10CaO:20Al_2O_3:2Dy_2O_3.

ZLLCAT (UD) -Represents undopedZinc Lithium Lead Calcium AluminoTellurite glass specimen.

ZLLCAT (DY)-Represents Dy^{3+}dopedZinc Lithium LeadCalciumAluminoTellurite glass specimens.

III.Theory

3.1Oscillator Strength

The intensity of spectral lines are expressed in terms of oscillator strengths using the relation [19].

$f_{expt.} = 4.318 \times 10^{-9} \int \varepsilon (\nu)\, d\nu$ (1)

where, $\varepsilon (\nu)$ is molar absorption coefficient at a given energy ν (cm^{-1}), to be evaluated from Beer–Lambert law.

Under Gaussian Approximation, using Beer–Lambert law, the observed oscillator strengths of the absorption bands have been experimentally calculated [20], using the modified relation:

$$P_m = 4.6 \times 10^{-9} \times \frac{1}{cl} \log \frac{I_0}{I} \times \Delta\upsilon_{1/2} \quad (2)$$

where c is the molar concentration of the absorbing ion per unit volume, I is the optical path length, $\log I_0/I$ is optical density and $\Delta\upsilon_{1/2}$ is half band width.

3.2. Judd-Ofelt Intensity Parameters

According to Judd[21] and Ofelt[22] theory, independently derived expression for the oscillator strength of the induced forced electric dipole transitions between an initial J manifold $|4f^N (S, L) J\rangle$ level and the terminal J' manifold $|4f^N(S', L') J'\rangle$ is given by:

$$\frac{8\Pi^2 mc\bar{\upsilon}}{3h(2J+1)} \frac{1}{n} \left[\frac{(n^2+2)^2}{9} \right] \times S(J, J') \quad (3)$$

Where, the line strength S (J, J') is given by the equation

$$S(J, J') = e^2 \sum_{\lambda=2,4,6} \Omega_\lambda \langle 4f^N(S, L) J \| U^{(\lambda)} \| 4f^N(S', L')J' \rangle^2 \quad (4)$$

In the above equation m is the mass of an electron, c is the velocity of light, ν is the wave number of the transition, h is Planck's constant, n is the refractive index, J and J' are the total angular momentum of the initial and final level respectively, Ω_λ (λ=2,4and 6) are known as Judd-Ofelt intensity parameters.

3.3 Radiative Properties

The Ω_λ parameters obtained using the absorption spectral results have been used to predict radiative properties such as spontaneous emission probability (A) and radiative life time (τ_R), and laser parameters like fluorescence branching ratio(β_R) and stimulated emission cross section (σ_p).

The spontaneous emission probability from initial manifold |4f^N (S', L') J'> to a final manifold |4f^N (S,L) J >| is given by:

$$A[(S', L') J'; (S,L)J] = \frac{64\pi^2 \nu^3}{3h(2J'+1)} \left[\frac{n(n^2+2)^2}{9}\right] \times S(J',\bar{J}) \qquad (5)$$

Where, $S(J', J) = e^2 [\Omega_2 \| U^{(2)} \|^2 + \Omega_4 \| U^{(4)} \|^2 + \Omega_6 \| U^{(6)} \|^2]$

The fluorescence branching ratio for the transitions originating from a specific initial manifold |4f^N (S', L') J'> to a final many fold |4f^N (S,L)J > is given by

$$\beta [(S', L') J'; (S , L) J] = \sum \frac{A[(S' \ L)]}{A[(S' \ L')J'(S \ L)]} \qquad (6)$$

S L J

where, the sum is over all terminal manifolds.

The radiative life time is given by

$$\tau_{rad} = \sum A[(S', L') J'; (S,L)] = A^{-1}_{Total} (7)$$

S L J

where, the sum is over all possible terminal manifolds.The stimulated emission cross -section for a transition from an initial manifold |4f^N (S', L') J'> to a final manifold |4f^N (S,L)J >| is expressed as

$$\sigma_p(\lambda_p) = \left[\frac{\lambda_p^4}{8\pi c n^2 \Delta\lambda_{eff}}\right] \times A[(S',L')J';(\bar{S},\bar{L})\bar{J}] \qquad (8)$$

where,λ_p the peak fluorescence wavelength of the emission band and $\Delta\lambda_{eff}$ is the effective fluorescence line width.

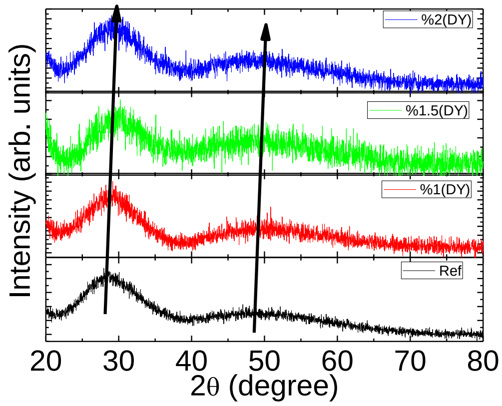
IV. Result and Discussion

4.1XRD Measurement

Figure 1 presents the XRD pattern of the sample contain –TeO_2 which is show no sharp Bragg's peak, but only a broad diffuse hump around low angle region. This is the clear

International Journal of Advance Research in Science and Engineering
Volume No. 11, Issue No. 06, June 2022
www.ijarse.com
IJARSE
ISSN 2319 - 8354

indication of amorphous nature within the resolution limit of XRD



instrument.

Fig.(1) X-ray diffraction pattern of TeO_2:ZnO:Li_2O:PbO:CaO:Al_2O_3:Dy_2O_3.

4.2 FTIR Transmission spectra

The FTIR spectrum of ZLLCAT (DY 01) glass is in the wave number range400-1600$cm^{-1}$is presented in Fig.2 and the possible mechanism bands are tabulated in Table 2.

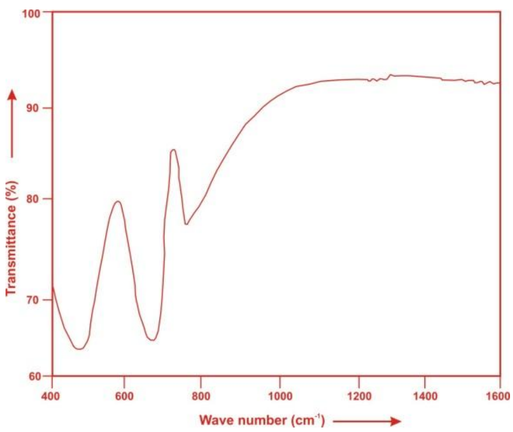


Fig. (2) FTIR spectrum of ZLLCAT DY (01) glass.

The band observed at 472 cm^{-1} is attributed to the symmetric vibration of the Zn-O bond [23]. The observed band around at 680 cm^{-1} is due to the stretching vibration of Te-O bonds in trigonalbipyramidal units TeO_4[24].while the occurrence of band around 771cm^{-1} is assigned to the vibration of the continuous network composed of TeO_4 and Te-O stretching vibration of TeO_{3+1} polyhedra [25].

International Journal of Advance Research in Science and Engineering
Volume No. 11, Issue No. 06, June 2022
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Table2. Assignment of infrared transmission bands ofZLLCAT(DY 01) glass.

Peak position(cm^{-1})	**Band Assignment**
~ 472	Symmetric stretching vibration of Zn-O bond
~680	Stretching vibration of Te-O bonds in TeO_4
~771	Stretching vibration of TeO_{3+1} polyhedra

4.3 Absorption Spectrum

The absorption spectra of Dy^{3+}doped ZLLCAT DY (01) glass specimen has been presented in Figure 3 in terms of Intensityversus wavelength.Thirteen absorption bands have been observed from the ground state $^6H_{15/2}$to excited states $^6H_{13/2}$, $^6H_{11/2}$, $^6H_{9/2}$+$^6F_{11/2}$,$^6H_{7/2}$+$^6F_{9/2}$,$^6F_{7/2}$+$^6H_{5/2}$,$^6F_{5/2}$,$^6F_{3/2}$,$^6F_{9/2}$,$^4I_{15/2}$,$^4G_{11/2}$, $^6F_{7/2}$+$^4I_{13/2}$,$^6M_{19/2}$+4(P,D)$_{3/2}$and$^4G_{9/2}$+$^6P_{3/2}$for ZLLCA DY(01)glass.

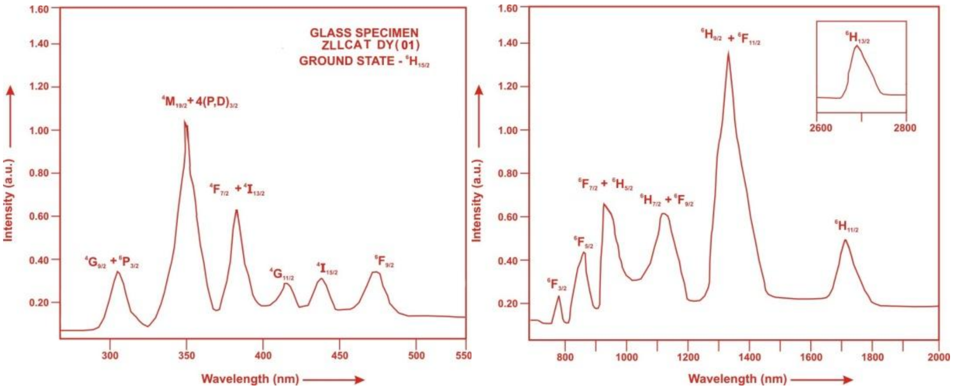


Fig. (3) Absorption spectrum of ZLLCAT DY (01) glass.

The experimental and calculated oscillator strength for Dy^{3+}ions in ZLLCAT glasses are given in **Table 3.**

Table 3: Measured and calculated oscillator strength (P_m×10^{+6}) of Dy^{3+}ions in ZLLCAT glasses.

Energy level from $^6H_{15/2}$	**Glass ZLLCAT(DY01)**		**Glass ZLLCAT(DY1.5)**		**Glass ZLLCAT(DY02)**	
	P_{exp}.	P_{cal}.	P_{exp}.	P_{cal}.	P_{exp}.	P_{cal}.
$^6H_{13/2}$	3.16	2.94	3.13	2.92	3.09	2.90
$^6H_{11/2}$	2.42	2.88	2.38	2.85	2.35	2.81
$^6H_{9/2}$+$^6F_{11/2}$	11.44	11.43	11.41	11.40	11.37	11.36
$^6H_{7/2}$+$^6F_{9/2}$	6.52	6.29	6.48	6.26	6.43	6.21
$^6F_{7/2}$+$^6H_{5/2}$	5.74	5.28	5.71	5.23	5.66	5.17
$^6F_{5/2}$	2.54	2.60	2.50	2.57	2.46	2.54

$^6F_{3/2}$	0.96	0.49	0.94	0.49	0.91	0.48
$^6F_{9/2}$	1.03	0.41	1.00	0.40	0.98	0.40
$^4I_{15/2}$	0.98	1.02	0.96	1.013	0.93	1.00
$^4G_{11/2}$	0.88	0.14	0.85	0.14	0.82	0.14
$^6F_{7/2}+^4I_{13/2}$	4.59	4.76	4.56	4.72	4.52	4.68
$^6M_{19/2}$+4(P,D)3/2	8.95	10.28	8.92	10.28	8.87	10.24
$^4G_{9/2}+^6P_{3/2}$	2.68	2.85	2.64	2.83	2.60	2.80
r.m.s. deviation	0.5201		0.5203		0.5165	

In theZinc Lithium LeadCalciumAluminoTelluriteglassesΩ_2, Ω_4 and $\Omega_6$parameters decrease with the increase of x from 1 to 2 mol%. The order ofmagnitude of Judd-Ofelt intensity parameters is $\Omega_2>\Omega_6>\Omega_4$for all the glass specimens. The spectroscopic quality factor (Ω_4/Ω_6) related with the rigidity of the glass system has been found to lie between 0.6315 and 0.6552in the present glasses.

The values of Judd-Ofelt intensity parameters are given in **Table 4.**

Table4:Judd-Ofelt intensity parameters for Dy^{3+}doped ZLLCATglass specimens.

Glass Specimen	**Ω_2(pm^2)**	**Ω_4(pm^2)**	**Ω_6(pm^2)**	**Ω_4 /Ω_6**	**Ref.**
ZLLCAT(DY01)	3.509	1.417	2.244	0.6315	P.W.
ZLLCAT(DY1.5)	3.491	1.428	2.215	0.6447	P.W.
ZLLCAT(DY02)	3.476	1.431	2.184	0.6552	P.W.
ZP(DY)	2.483	0.950	0.673	1.412	[26]
LLCTMBB(DY)	2.457	1.471	1.116	1.318	[27]

4.4Excitation Spectrum

The Excitation spectra of Dy^{3+}doped ZLLCAT glass specimen has been presented in Figure 4 in terms of Excitation Intensity versus wavelength.The excitation spectrum was recorded in the spectral region 315–465 nm fluorescence at 575nm having different excitation band centered at 322,353, 365, 385, 425, 454 and 473 nmare attributed to the $^6P_{3/2}$, $^6P_{7/2}$,$^4P_{3/2}$,$^4I_{13/2}$,$^4G_{11/2}$,$^4I_{15/2}$ and$^4F_{9/2}$ transitions, respectively. The highest absorption level is $^4I_{13/2}$ and is at 385nm.So this is to be chosen for excitation wavelength.

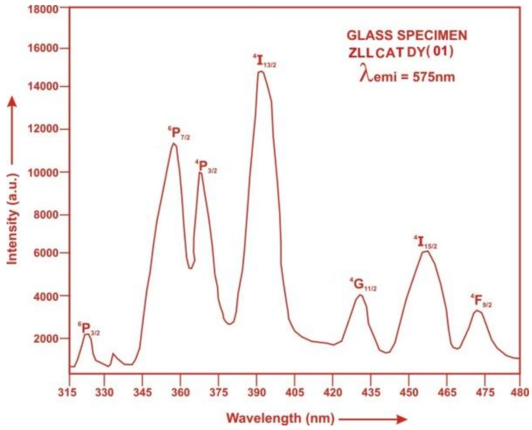


Fig. (4) Excitation spectrum of ZLLCATDY (01) glass.

4.5 FluorescenceSpectrum

TheFluorescence spectrum of Dy^{3+}doped in Zinc Lithium Lead Calcium Alumino Tellurite glass is shown in Figure 5. There are four broad bands observed in the Fluorescence spectrum ofDy^{3+}dopedZinc Lithium Lead Calcium Alumino Tellurite glass. The wavelengths of these bands along with their assignments are given in Table 4. The peak with maximum emission intensity appears at 485nm, 575nm, 665nm and 752 nm corresponds to the($^4F_{9/2}\rightarrow{}^6H_{15/2}$),($^4F_{9/2}\rightarrow{}^6H_{13/2}$),($^4F_{9/2}\rightarrow{}^6H_{11/2}$) and ($^4F_{9/2}\rightarrow{}^6H_{9/2}$)transition.

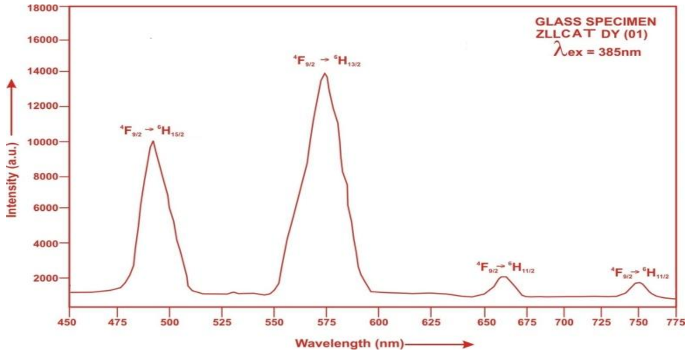


Fig. (5). Fluorescence spectrum of ZLLCAT DY (01)glass.

Table5:Emission peak wave lengths (λ_p),radiative transition probability (A_{rad}),branching ratio (β),stimulated emission cross-section(σ_p) and radiative life time(τ_R)for various transitions in Dy^{3+} doped ZLLCATglasses.

IJARSE
ISSN 2319 - 8354

Transition		ZLLCAT(DY01)				ZLLCAT(DY1.5)				ZLLCAT(DY02)			
	λ_{emi} (nm)	$A_{rad}(s^{-1})$	β	σ_p (10^{-20} cm^2)	$\tau_R(\mu s)$	$A_{rad}(s^{-1})$	β	σ_p (10^{-20} cm^2)	$\tau_R(\mu s)$	$A_{rad}(s^{-1})$	β	$\sigma_p(10^{-20}$ $cm^2)$	$\tau_R(10^{-20}$ $cm^2)$
$^4F_{9/2}\rightarrow{}^6H_{15/2}$	485	111.12	0.2192	0.247	1971.40	110.14	0.2185	0.241	1983.88	109.05	0.2176	0.233	1995.80
$^4F_{9/2}\rightarrow{}^6H_{13/2}$	575	336.13	6626	1.564		334.21	0.6630	1.516		332.53	0.6637	1.469	
$^4F_{9/2}\rightarrow{}^6H_{11/2}$	665	34.01	0.0670	0.181		33.88	0.0672	0.178		33.75	0.0673	0.173	
$^4F_{9/2}\rightarrow{}^6H_{9/2}$	752	25.90	0.0511	0.164		25.83	0.0512	0.162		25.73	0.0513	0.159	

V. Conclusion

In the present study, the glass samples of composition (40-x) TeO_2:10ZnO:$10Li_2O$:10PbO:10CaO:$20Al_2O_3$: xDy_2O_3 (where x =1, 1.5and 2mol %) have been prepared by melt-quenching method. The value of stimulated emission cross-section (σ_p) is found to be maximum for the transition ($^4F_{9/2}\rightarrow{}^6H_{13/2}$) for all glass specimens. Thisshows that ($^4F_{9/2}\rightarrow{}^6H_{13/2}$) transition is most probable transition.The FTIR of glasses revealed the presence of characteristic bonding vibrations of different functional groups.

References

[1]. Monisha, M., Nancy,A. , Souza, D., Nimitha ,V. L., Prabhu, S and Sayyed, M.I.(2020). Dy^{3+} doped SiO_2- B_2O_3-Al_2O_3-NaF-ZnF_2 glasses: An exploration of optical and gamma radiation shielding features, Current Applied Physics 20(11), 1207-1210.

[2].Rao,T.G.V.M., Kumar, A. R., Neeraja, K., Veeraiah, N.and Reddy, M.R.(2013).Optical and structural investigation of Eu^{3+} ions in Nd^{3+} co-doped magnesium lead borosilicate glasses, J. Alloy. Compd. 557,209–217.

[3]. Dousti, M.R. , Poirier, G.Y.and de Camargo, A.S.S.,(2020).Tungsten Sodium Phosphate glasses doped with trivalent rare earth ions (Eu^{3+}, Tb^{3+}, Nd^{3+}, Er^{3+}) for visible and near infrared applications, Journal of Non- Crystalline Solids 530, 119838.

[4]. Manasa, P, Srihari, T, Basavapoornima, C., Joshi, A .S. and Jayasankar, C. K.(2019). Spectroscopic investigations of Nd^{3+} ions in niobium phosphate glasses for laser applicationsJ. Lumin. 211, 233–42.

[5]. Meena,S.L.(2017). Polarizability and optical Basicity of Dy^{3+} ions doped yttrium Zinc lithium Bismuth Borate Glasses, Journal of pure Applied and Industrial physics.J.Pure and App.Ind.Phy., 7,310-318.

[6]. Mohan Babu, A., Jamalaiah, B. C., Suresh Kumar, J., Sasikala, T.and Rama Moorthy, L. (2011). Spectroscopic and photoluminescence properties of Dy^{3+} doped lead tungsten tellurite glasses for laser materials, Journal of Alloys and Compounds 509,457-462.

[7]. Stambouli,W., Elhonichet, H., Gelloz, B. and Ferid, M.(2013). Optical and spectroscopic properties of Eu^{3+} doped tellurite glasses and glass ceremics, Journal of luminescence 138,201-208.

[8].Ahmmad,S.K.,Samee,M.A.,Edukondalu,A. and Rahman,S.(2012).Physical and Optical properties of zinc arsenic tellurite glasses,2,175-181.

[9]. Hussain,N.S., Hungerford,G., El-Mallawany,R., Gomes,M.J.M., Lopes,M.A., Ali,N., Santos,J.D. and Buddhudu,S.(2008).Absorption and Emission Analysis of RE^{3+}(Sm^{3+} and Dy^{3+}): Lithium BoroTellurite Glasses,
Journal of Nanoscience and Nanotechnology,8, 1–6,

[10]). Anashkina, E.A.(2020.Laser Sources Based on Rare-Earth Ion Doped Tellurite Glass Fibers and Microspheres,
Fibers , 8,1-17.

[11].Jha, A., Richards, B., Jose, G., Teddy-Fernandez, T., Joshi, P.m, Jiang, X. and Lousteau(2012).J. Rare-earth ion doped TeO_2 and GeO_2 glasses as laser materials. Prog. Mater. Sci., 57, 1426–1491

[12].Yakovlev, A.I., Snetkov, I.L., Dorofeev, V.V. and Motorin, S.E.(2018). Magneto-optical properties of high-purity zinc-tellurite glasses. J. Non-Cryst. Solids, 480, 90–94.

[13].Denker, B.I., Dorofeev, V.V., Galagan, B.I., Koltashev, V.V., Motorin, S.E., Plotnichenko, V.G.,Sverchkov, S.E. (2019). 2.3 μm laser action in Tm^{3+}-doped tellurite glass fiber. Laser Phys. Lett., 16, 015101.

[14].Kishi, T., Kumagai, T., Shibuya, S., Prudenzano, F., Yano, T.,Shibata, S.(2015). Quasi-single mode laser output from a terrace structure added on aNd 3+-doped tellurite-glass microsphere prepared using localized laser heating. Opt. Express, 23, 20629–20635.

[15].Linganna, K.,Rao, C.S. andJayasankar,C.K. (2013).Optical properties and generation of white light in Dy^{3+} doped lead phosphate glasses, Journal of Quantitative Spectroscopy and Radiative Transfer,118,40-48.

[16].Pawar, P.P., Munishwar, S.R. and Gedam, R.S. (2017). Intense white light luminescent Dy^{3+} doped lithium borate glasses for WLED: a correlation between physical, thermal, structural and optical properties. Solid State Sci., 64, 41–50.

[17].Pisarski, W.A., Zur, L. andPisarska, J. (2011).Optical transitions of Eu^{3+} and Dy^{3+} ions in lead phosphate glasses. Opt. Lett., 36, 990–992.

[18].Zang, X.M.,Li,D.S.,Pun,E.Y.B. and Lin, H.(2017). Dy3+ doped borate glasses for laser illumination, Optical Material Express,7(6),2040-2054.

[19]. Gorller-Walrand, C. and Binnemans, K. (1988). Spectral Intensities of f-f Transition. In: Gshneidner Jr., K.A. and Eyring,L., Eds.,Handbook on the Physics and Chemistry of Rare Earths, Vol. 25, Chap. 167, North-Holland, Amsterdam, 101-264.

[20]. Sharma, Y.K., Surana, S.S.L. and Singh, R.K. (2009). Spectroscopic Investigations and Luminescence Spectra of Sm^{3+} Doped SodaLime Silicate Glasses. Journal of Rare Earths, 27, 773.

[21]. Judd, B.R. (1962). Optical Absorption Intensities of Rare Earth Ions. Physical Review, 127, 750.

[22]. Ofelt, G.S. (1962). Intensities of Crystal Spectra of Rare Earth Ions. The Journal of Chemical Physics, 37, 511.

[23].Elkhoshkhany, N.,Marzouk, S. Y.,Khattab, M. A. and Dessouki, S. A.(2018). Influence of Sm_2O_3 addition on JuddOfelt parameters, thermal and optical properties of the TeO_2-Li_2O-ZnO-Nb_2O_5 glass system, Mater. Charact. 144 ,274–286.

[24].El-Mallawany, R.A.H.(2002).Tellurite Glasses Handbook; CRC Press: Washington, DC, USA, [25].Elkhoshkhany, N., Mohamed, H.M.(2019). UV–Vis-NIR spectroscopy, structural and thermal properties of novel oxyhalidetellurite glasses with composition TeO_2 -B_2O_3 -$SrCl_2$ -LiF-Bi_2O_3 for optical application. Res. Phys., 13, 102222.

[26].Chandrasekhar,A.V.,Radhapathy,A.,Reddy,B.J.,Reddy,Y.P.,Ramamoorthy,L.and Kumar Ravi, R.V.S.S.N.(2003).
Optical absorption spectrum of dysprosium zinc phosphate glass,Opt.Mat.,22,215-220.

[27].Meena, S.L. (2020).Spectroscopic properties of Dy^{3+} doped lead lithium cadmium tantalum magnesium bismuth borate glasses,Int.J.of Chem. And Phy.Sci., 9(1),5-12.