# *Chapter-7*

## *Conclusion*

## 7.1. Introduction

Luminescent characterization of certain rare earth ions ($Pr^{3+}$,$Nd^{3+}$,$Ho^{3+}$ and $Tm^{3+}$) doped lead tungsten tellurite glasses were studied and discussed in chapters 3-6. The present summarize the results obtained in chapters 3-6 and compares with the similar ion doped glasses to get the similarities/differences/challenges, specifically to design Rare earth ions based optical glass devices and also to derive the future scope of work in the field of rare earth doped glassy systems.

## 7.2. Comparison and summary of results obtained for $Pr^{3+}$ doped Lead Tungsten Tellurite glasses

The results obtained for different concentrations of $Pr^{3+}$ doped Lead Tungsten Tellurite (LTTPr001, LTTPr01, LTTPr05, LTTPr10, LTTPr15) glasses of present investigation are compared with earlier reported $Pr^{3+}$ doped glasses [103,226-245]. Judd-Ofelt (J-O) parameters and stimulated emission cross-section ($\sigma_{se}$) of the present investigated LTT glasses are compared with lead borate [226], $Pr^{3+}$:Cds [227], $ZnF_2$-PbO-$TeO_2$ [228], K-Borate[229], AP5 [230], PTBPr10 [231], $Pr^{3+}$:ZBLYAN [232], LZSB5 [233], Phosphate [234], LiTFP [235], ZBLAN [236], Al-Si glass [237], MgTP [103], Na-Ca [238], $Pr^{3+}$ glass [239], Phosphate glass [240], Lead glass [241], $GeO_2$.PbO.$PbF_2$ [242], ZBP5 [243], LSCB [244] and $Pr^{3+}$ :$GeO_2$BaoTi$O_2$[245] glasses in Table 7.1. From Table 7.1 it can be observed that, among all the LTT glasses, the LTTPr10 glass possesses maximum values of all parameters such as J-O parameters, branching ratios and Stimulated emission cross-section values. The J-O parameters for the LTTPr10 glass are higher than other reported values [103, 226-245], this can also be seen from Fig 7.3. The radiative and experimental branching ratios of LTTPr10 glass are in comparable with other reported values and stimulated emission cross-section values are higher than the other reported values [103, 226-245] this can be observed from Fig 7.1. From all these results obtained it was concluded that the glass LTTPr10 possesses higher covalency and able to emit Reddish-Orange color laser at 644 nm.

**Table 7.1.**

Comparison of JO Intensity parameters ($\Omega_2$, $\Omega_4$ and $\Omega_6$), and stimulated emission cross-section ($\sigma_{se}$ x $10^{-20}$ $cm^2$) of $Pr^{3+}$ ions doped Lead Tungsten Tellurite (LTT) glasses with other reported values.

| System | $\Omega_2$ | $\Omega_4$ | $\Omega_6$ | $\sigma_{se}$ | Reference |
|---|---|---|---|---|---|
| LTTPr001 | 4.78 | 6.14 | 2.21 | 33.5 | Present work |
| LTTPr01 | 11.06 | 7.15 | 2.85 | 101.0 | Present work |
| LTTPr05 | 12.88 | 5.64 | 4.41 | 134.0 | Present work |
| LTTPr10 | 13.89 | 6.70 | 4.60 | 161.0 | Present work |
| LTTPr15 | 8.31 | 5.50 | 3.48 | 89.8 | Present work |
| Lead borate | 2.41 | 2.50 | 4.35 | 0.18 | [226] |
| $Pr^{3+}$:CdS | 10.58 | 7.4 | 0.95 | 0.73 | [227] |
| $ZnF_2$-PbO-$TeO_2$ | 8.2 | 20.1 | 96.2 | 1.12 | [228] |
| K- Borate | 2.33 | 4.65 | 3.84 | - | [229] |
| AP5 | 0.87 | 0.91 | 2.10 | - | [230] |
| PTBPr10 | 1.19 | 3.59 | 6.09 | 0.84 | [231] |
| $Pr^{3+}$: ZBLYAN | - | - | - | 11.4 | [232] |
| LZSB5 | 0.7 | 5.3 | 5.0 | - | [233] |
| $Pr^{3+}$: Phosphate | - | - | - | 0.002 | [234] |
| LiTFP | 0.26 | 8.06 | 5.88 | 0.45 | [235] |
| ZBLAN | 0.94 | 6.54 | 3.84 | - | [236] |
| Al-Si Glass | 2.07 | 8.05 | 6.07 | 14.2 | [237] |
| MgTP | 2.69 | 11.8 | 8.39 | 3.0 | [103] |
| NA-Ca | 5.31 | 9.47 | 6.41 | 0.43 | [238] |
| $Pr^{3+}$ glass | 3.72 | 3.13 | 5.38 | 0.92 | [239] |
| Phosphate glass | 4.19 | 4.29 | 6.40 | - | [240] |
| Lead glass | 2.08 | 1.59 | 3.78 | 0.83 | [241] |
| $GeO_2$.PbO.$PbF_2$ | -0.66 | 12.4 | 3.17 | - | [242] |
| ZBP5 | 3.94 | 1.34 | 1.23 | 2.20 | [243] |
| LSCB | 14.0 | 3.41 | 19.9 | 0.91 | [244] |
| $Pr^{3+}$ Glass ($GeO_2BaOTeO_2$) | - | - | - | 275 | [245] |
| $Pr^{3+}$ Ceramics ($GeO_2BaOTeO_2$) | - | - | - | 203 | [245] |

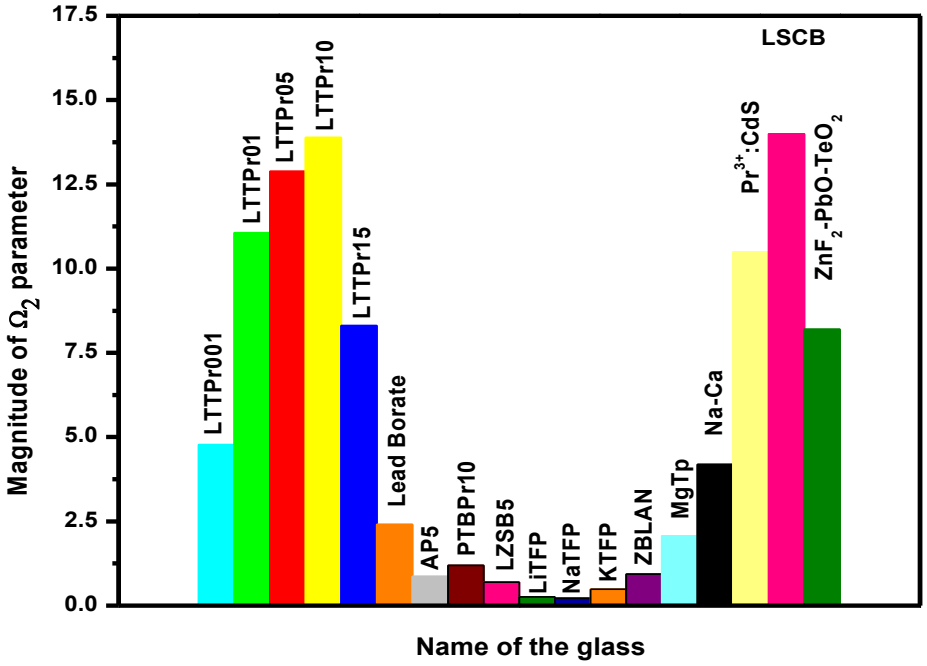


**Fig 7.1.** Comparison of J-O Parameter ($\Omega_2$) of $Pr^{3+}$ doped LTT glasses with other reported values

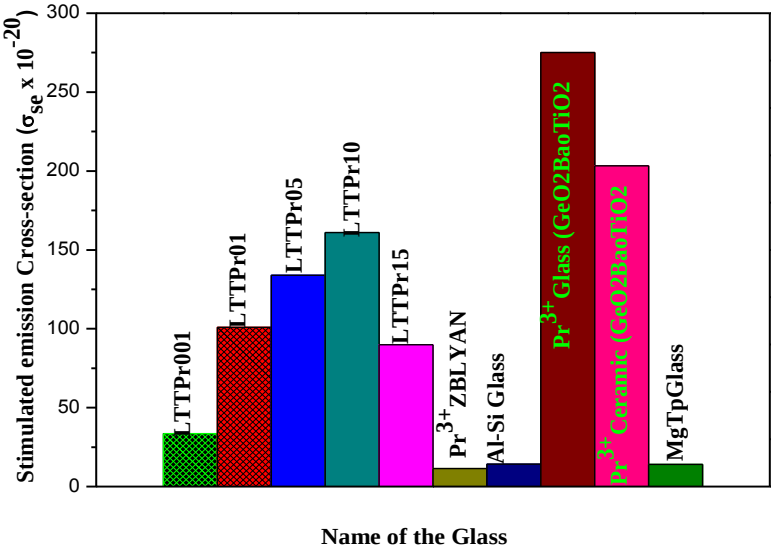


**Fig 7.2**. Comparison of stimulated emission cross-section values of LTTPr10 glasses with other reported values

### 7.3. Summary and comparison of results obtained for $Nd^{3+}$ ions doped LTT glasses

The results obtained for different concentrations of $Nd^{3+}$ ions doped LTT glasses of present investigation are compared with BNaNf [134], Q-88 [155], CLiBT [158], SFB [159], ZnAlBiBNd10[246], LBNNd10 [247], BINLAB1 [248], NdLiTB [249], CFBNd10 [250], LHG-8, LHG-80, LG- 750, LG-770, YAG:$Nd^{3+}$ [251], FP [252], PKSAN10 [253], and TW2 [254] glass systems in Table 7.3. From Table 7.3 it is observed that, the calculated J-O parameters of the present glass systems are comparable with the values reported for the mentioned systems. J-O parameters of the present glasses are follow in the trend $\Omega_4 > \Omega_6 > \Omega_2$ whch is different for the commercial reported systems and some other reported values. It is observed from the literature that the spectroscopic quality factor ( $\chi = \frac{\Omega_4}{\Omega_6}$), remains in the range of 0.6-0.9 for the fluoride glasses and 0.9-1.1 for various phosphate, silicate, borate and 1.0 to 2.54 for present tellurite glass systems. In the present glass systems, spectroscopic quality factor values are in comparable with the other reported values in the literature [134,155,158,159,246-254]. The variation of spectroscopic quality factor with the commercially available systems and other systems are shown in Fig 7.3. From this figure, it can be concluded that the spectroscopic quality factor for the present glasses is comparatively high when compared with commercially reported and some other glassy systems [134,155,158,159,253,254].

**Table 7.2.**

Comparison of J-O Intensity parameters ($\Omega_2$, $\Omega_4$ and $\Omega_6$), their trend, spectroscopic quality factor ($\chi$) and stimulated emission cross-section ($\sigma_{se}$) (x $10^{-20}$ $cm^2$) of $Nd^{3+}$ ions doped LTT glasses with the commercially available systems and other reported values.

| Glass System | $\Omega_2$ | $\Omega_4$ | $\Omega_6$ | Trend | $\chi$ | $\sigma_{se}$ | References |
|---|---|---|---|---|---|---|---|
| LTTNd01 | 1.81 | 5.27 | 2.17 | $\Omega_4 > \Omega_6 > \Omega_2$ | 2.42 | 14.7 | Present work |
| LTTNd05 | 4.46 | 5.31 | 5.14 | $\Omega_4 > \Omega_6 > \Omega_2$ | 1.03 | 32.4 | Present work |
| LTTNd10 | 4.54 | 5.79 | 5.69 | $\Omega_4 > \Omega_6 > \Omega_2$ | 1.01 | 47.5 | Present work |
| LTTNd15 | 2.60 | 3.91 | 3.59 | $\Omega_4 > \Omega_6 > \Omega_2$ | 1.08 | 23.0 | Present work |
| BNaNf | 5.33 | 2.84 | 4.90 | $\Omega_2 > \Omega_6 > \Omega_4$ | 0.57 | 4.18 | [134] |
| LHG-8 | 4.40 | 5.10 | 5.60 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.91 | 3.60 | [155] |
| LHG-80 | 3.60 | 5.00 | 5.70 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.91 | 4.20 | [155] |
| LG-750 | 4.60 | 4.80 | 5.60 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.86 | 3.70 | [155] |
| LG-770 | 4.30 | 5.00 | 5.60 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.89 | 3.90 | [155] |
| Q-88 | 3.30 | 5.10 | 5.60 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.91 | 4.00 | [155] |
| CLiBT | 2.43 | 3.41 | 3.96 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.86 | 3.91 | [158] |
| SFB | 8.06 | 4.83 | 11.3 | $\Omega_6 > \Omega_2 > \Omega_4$ | 0.42 | 3.46 | [159] |
| ZnAlBiBNd10 | 4.37 | 3.51 | 4.59 | $\Omega_2 > \Omega_6 > \Omega_4$ | 0.76 | 2.68 | [246] |
| LBNNd10 | 4.81 | 5.55 | 3.73 | $\Omega_4 > \Omega_2 > \Omega_6$ | 1.49 | 2.74 | [247] |
| BINLAB1 | 6.70 | 4.84 | 7.41 | $\Omega_6 > \Omega_2 > \Omega_4$ | 0.64 | 9.47 | [248] |
| NdLiTB | 5.27 | 3.92 | 6.09 | $\Omega_6 > \Omega_2 > \Omega_4$ | 0.64 | 2.77 | [249] |
| CFBNd10 | 4.37 | 4.50 | 6.48 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.70 | 3.09 | [250] |
| YAG:$Nd^{3+}$ | 0.20 | 2.70 | 5.00 | $\Omega_6 > \Omega_4 > \Omega_2$ | 0.54 | - | [251] |
| FP | 4.63 | 2.55 | 6.79 | $\Omega_6 > \Omega_2 > \Omega_4$ | 0.37 | 4.51 | [252] |
| PKSAN10 | 6.94 | 3.86 | 6.35 | $\Omega_2 > \Omega_6 > \Omega_4$ | 0.61 | 4.05 | [253] |
| TW2 | 5.52 | 3.27 | 5.48 | $\Omega_2 > \Omega_6 > \Omega_4$ | 0.60 | 4.20 | [254] |

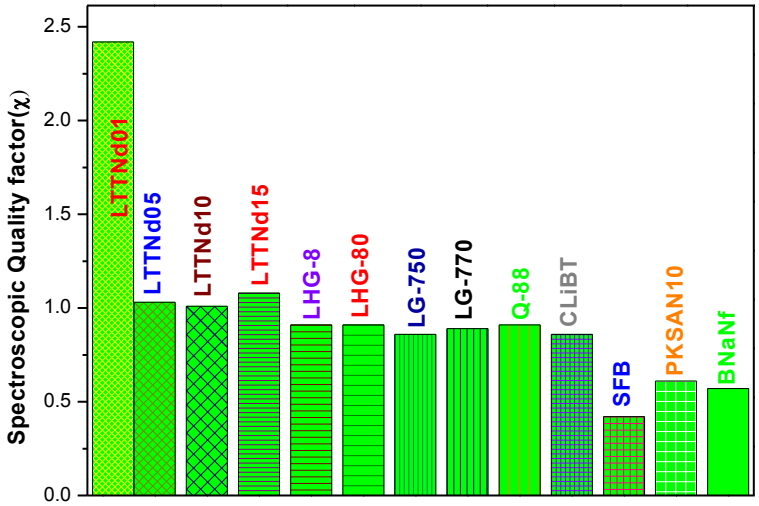


**Fig 7.3.** Comparison of spectroscopic quality factor values of LTTNd glasses with the commercially available systems

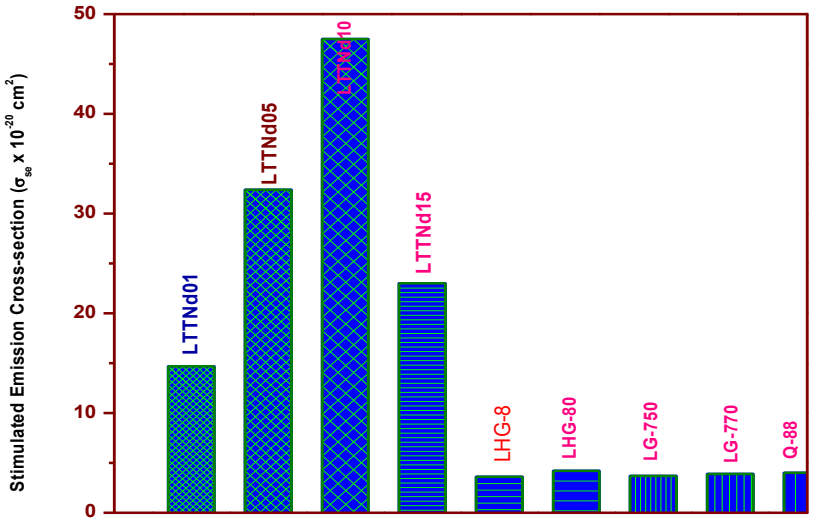


**Fig 7.4.** Comparison of stimulated emission cross-section values of LTTNd glasses with the commercially available systems

The Stimulated emission cross-section ($\sigma_{se}$) for the $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition are well comparable with the commercially available systems and other reported systems [155,158,159,246-250,252-254]. The comparison of stimulated emission cross-section values with the commercially available systems also shown in Fig 7.3. Among all the glasses, the LTTNd10 glass possesses highest J-O parameters and stimulated emission cross-section. Hence LTTNd10 glass can be proposed as best luminescent material suitable to emit laser emission in NIR region (1060 nm).

## 7.4. Summary and comparison of results obtained for $Ho^{3+}$ doped Lead Tungsten Tellurite glasses

The results obtained for different concentrations of $Ho^{3+}$ doped Lead Tungsten Tellurite glasses of the present investigations are compared with previous reported $Ho^{3+}$ doped glasses [94, 176, 186, 193, 194, 255-258]. J-O parameters and stimulated emission cross-section ($\sigma_{se}$) of the present investigated $Ho^{3+}$ ions doped LTT glasses are compared with ZnAlBiBHo10 [94], AH1 [176], Tellurite [186], ZBLAN [193],$YAlO_3$ [194], GLS glass [255], $TeO_2$-$B_2O_3$-$Li_2O$ [256], LBMBPH3 [257], Lead-Zinc-Borate [258] glasses in Table 7.3. From Table 7.3 it can be seen that, among all the LTT glasses the LTTHo10 glass possesses maximum values of J-O parameters and Stimulated emission cross-section values. The J-O parameters for the LTTHo10 glass are higher than other reported values [ 94, 176, 186, 193, 194, 255-258]. Fig 7.5 also shows the comparison of J-O parameter ($\Omega_2$) of LTTHo glasses with some reported values. The stimulated emission cross-section values for these transitions $^5F_4 \rightarrow {}^5I_8$ are higher than the other reported values [ 94, 176, 186, 193, 194, 255-258] which can also be observed from the Fig 7.6. From all these results obtained, it was concluded that the glass LTTHo10 possesses higher covalency and can be suggested as a good optical material to emit green lasers.

**Table 7.3.**

Comparison of J-O Intensity parameters ($\Omega_2$, $\Omega_4$ and $\Omega_6$) and stimulated emission cross-sections ($\sigma_{se}$ x $10^{-20}$ $cm^2$) of $Ho^{3+}$ doped LTT glasses other reported values for the $^5F_4 \rightarrow {}^5I_8$.

| System | $\Omega_2$ | $\Omega_4$ | $\Omega_6$ | $\sigma_{se}$ | Reference |
|---|---|---|---|---|---|
| LTTHo01 | 2.00 | 5.21 | 1.54 | 27.5 | Present work |
| LTTHo05 | 4.33 | 5.28 | 2.27 | 49.7 | Present work |
| LTTHo10 | 6.66 | 7.71 | 3.68 | 104 | Present work |
| LTTHo15 | 6.01 | 6.52 | 2.96 | 73.6 | Present work |
| LTTHo20 | 5.47 | 6.08 | 2.95 | 66.3 | Present work |
| LTTHo25 | 5.41 | 5.62 | 1.97 | 62.7 | Present work |
| ZnAlBiBHo10 | 16.47 | 4.06 | 0.81 | 24.1 | [94] |
| AH1 | 5.77 | 0.32 | 0.58 | 0.34 | [176] |
| Tellurite | 4.98 | 0.99 | 2.96 | 0.14 | [186] |
| ZBLAN | 1.90 | 2.09 | 1.56 | - | [193] |
| $YAl2O_3$ | 1.82 | 2.38 | 1.53 | - | [194] |
| GLS glass | 6.90 | 5.50 | 1.07 | - | [255] |
| $TeO_2$-$B_2O_3$-$Li_2O$ | 7.59 | 7.69 | 4.29 | 3.04 | [256] |
| $LBMBPH_3$ | 5.03 | 2.26 | 1.87 | 1.08 | [257] |
| lead–zinc–borate | 5.26 | 4.13 | 2.48 | 1.18 | [258] |

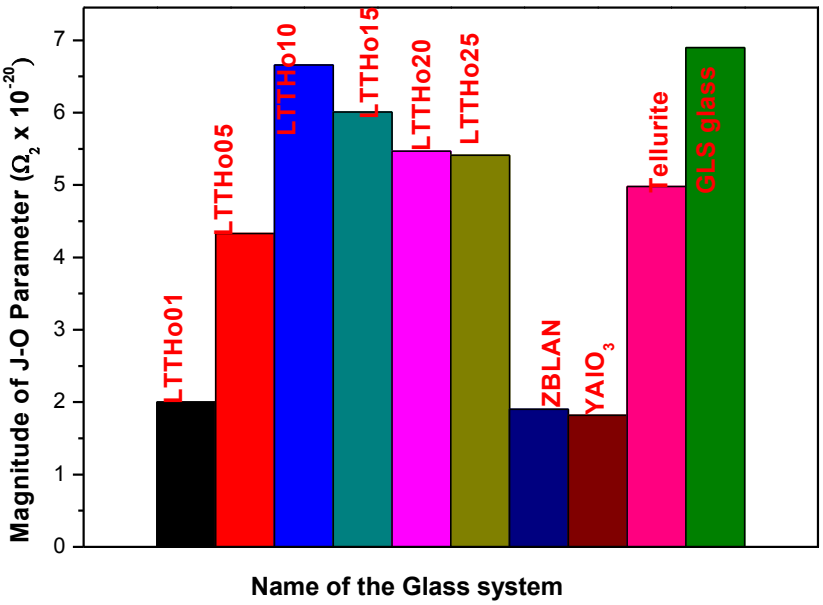


**Fig 7.5.** Comparison of J-O Parameter ( $\Omega_2$) of LTTHo10 glass with some of the other reported values.

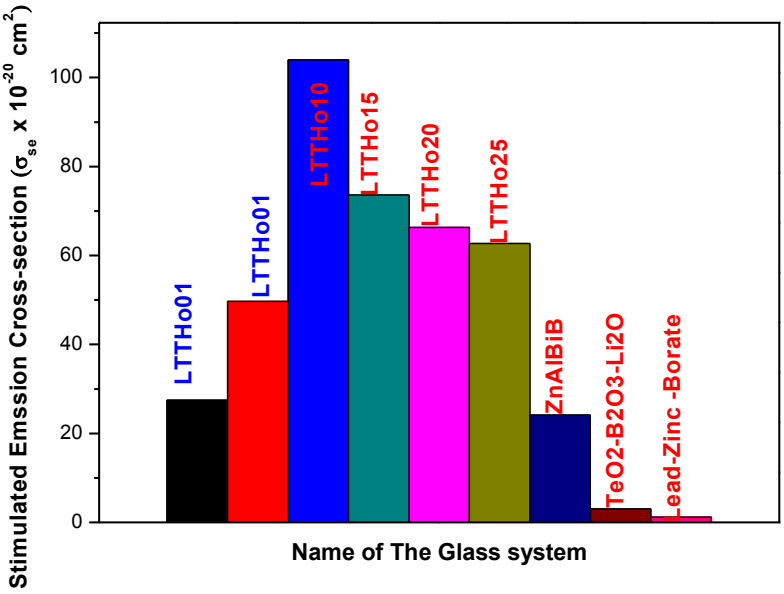


**Fig 7.6.** Comparison of stimulated emission cross-section values of LTTHo10 glasses with other reported values for the $^5F_4 \rightarrow {}^5I_8$ transition.

## 7.5. Comparison and summary of results obtained for $Tm^{3+}$ doped Lead Tungsten Tellurite glasses

The spectroscopic parameters of $Tm^{3+}$ ion doped LTT glasses in the present investigation is compared with the reported similar ion doped systems in Table 7.4. The reported systems include $Tm^{3+}$ ions doped PKMAT [217], Oxyfluoroborate [218], Tellurite [219], GGLS [220], NBWT10 ($47NaPO_3+12BaF_2+40WO_3+1TmF_3$) [259], Fluoroindate ($38InF_3+20ZnF_2+20SrF_2+16BaF_2+2GdF_3+2NaF+1GaF_3+1TmF_3$)[260], ZBLAN $ZrF_4+BaF_2+LaF_3+AlF_3+NaF$) [261] and Lead fluoro tellurite ($TeO_2+PbF_2$) [262] glasses. As can be seen from Table 7.4, the higher $\Omega_2$ value for almost all the glasses indicate a covalent bonding between $Tm^{3+}$ ions and the surrounding ligands. The trend of $\Omega_\lambda$ is found to be ($\Omega_2 < \Omega_6 < \Omega_4$) same for all the LTT glasses. Similar trend has been observed for some of the systems and some other follows in different.

**Table 7.4**.

Judd-Ofelt Parameters ($\Omega_\lambda$ x $10^{-20}cm^2$) of the $Tm^{3+}$ ions in LTT glasses

| Glass System | $\Omega_2$ | $\Omega_4$ | $\Omega_6$ | Trend | References |
|---|---|---|---|---|---|
| LTTTm01 | 5.210 | 1.360 | 1.409 | $\Omega_2>\Omega_6>\Omega_4$ | present work |
| LTTTm05 | 10.936 | 2.734 | 4.062 | $\Omega_2>\Omega_6>\Omega_4$ | present work |
| LTTTm10 | 10.894 | 2.612 | 2.923 | $\Omega_2>\Omega_6>\Omega_4$ | present work |
| LTTTm15 | 8.255 | 1.305 | 2.827 | $\Omega_2>\Omega_6>\Omega_4$ | present work |
| LTTTm20 | 6.983 | 0.408 | 1.958 | $\Omega_2>\Omega_6>\Omega_4$ | present work |
| LTTTm25 | 5.267 | 0.347 | 1.407 | $\Omega_2>\Omega_6>\Omega_4$ | present work |
| PKMAT | 9.32 | 1.82 | 3.21 | $\Omega_2>\Omega_6>\Omega_4$ | [217] |
| Oxyfluoroborate | 8.37 | 3.20 | 4.34 | $\Omega_2>\Omega_6>\Omega_4$ | [218] |
| Tellurite | 5.04 | 1.36 | 1.22 | $\Omega_2>\Omega_4>\Omega_6$ | [219] |
| GGLS | 7.11 | 1.46 | 1.96 | $\Omega_2>\Omega_6>\Omega_4$ | [220] |
| NBWT10 | 5.28 | 2.32 | 1.16 | $\Omega_2>\Omega_4>\Omega_6$ | [259] |
| Fluoroindate | 2.36 | 1.59 | 1.21 | $\Omega_2>\Omega_4>\Omega_6$ | [260] |
| ZBLAN | 2.31 | 1.28 | 1.17 | $\Omega_2>\Omega_4>\Omega_6$ | [261] |
| Leadfluoro Tellurite | 2.18 | 0.95 | 1.14 | $\Omega_2>\Omega_6>\Omega_4$ | [262] |

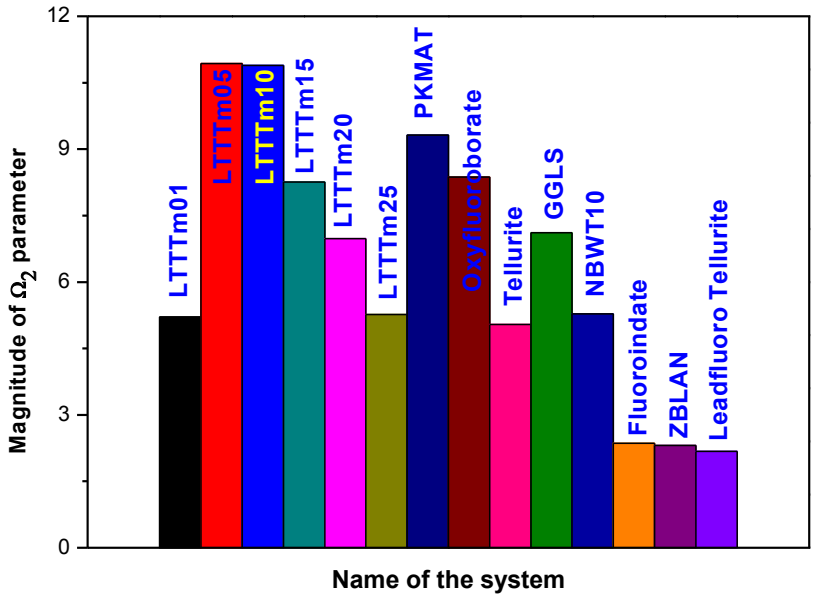


**Fig 7.7.** Comparison of J-O Parameter ($\Omega_2$) of LTTTm10 glass with some of the other reported values