Optical Transitions of Tm$^{3+}$ Ions for Amplifiers: How the Local Structure Works
in (1 - x)TeO$_2$ + (x)M (where M = LiCl, CdCl$_2$, WO$_3$) Glass

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Tm$^{3+}$ doped glass is one of the most studied systems towards the achievement of compact blue upconversion lasers as well as fiber amplifiers in the telecommunication networks both at 1.5 µm and 1.8 µm due to its radiative emissions at 470 nm, 1.45 µm and 1.8 µm. These emissions correspond to the $^1G_4$ $\rightarrow$ $^3H_6$, $^3F_4$ $\leftrightarrow$ $^3H_4$ and $^3H_4$ $\rightarrow$ $^3H_6$ transitions upon excitation into either $^3F_3$ or $^3F_4$ levels, respectively.

This report reviews some studies on the spectroscopic properties of Tm$^{3+}$ doped several tellurite glasses. Effect of temperature on the stimulated emission cross-sections are also discussed.

Absorption spectra of the 0.01 mol. Tm$^{3+}$ doped tellurite glasses having 0.3 mol CdCl$_2$, LiCl or WO$_3$ as the network modifier in the 660 nm-800 nm pumping region are presented in Figure 1. The ratio of the absorbance at the peak wavelength of $^3F_2$ and $^3F_4$ bands are about the same for the samples having CdCl$_2$ and LiCl while the ratio of the same bands is measured to be 0.8 for the sample having WO$_3$ as the modifier.

Judd-Ofelt theory gives the calculated oscillator strength for an electric dipole transition from the ground state to an excited state in terms of the $\Omega_t$ ($t = 2, 4, 6$) intensity parameters.

Spontaneous emission probability for an electric dipole emission can then be calculated using these intensity parameters. Our results show that the strongest dependence on the WO$_3$ content was observed for the parameter $\Omega_4$. The $\Omega_2$ and $\Omega_4$ parameters are dominant for the $^3F_3$ $\rightarrow$ $^3H_6$, $^3H_4$ $\rightarrow$ $^3H_6$ and $^1G_4$ $\rightarrow$ $^3H_6$ transitions of Tm$^{3+}$ ion. Line strength of the $^2F_{5/2}$ $\rightarrow$ $^2F_{7/2}$ transition used as the pumping level, is determined by $\Omega_4$ which is found to be $2.16 \times 10^{-20}, 2.09 \times 10^{-20}$, and
CTuK55 Table 1. Stimulated emission cross-sections, $\sigma_{se}$ for the emissions of $\text{Tm}^{3+}$ in $(1-x)\text{TeO}_2-(x)\text{WO}_3$ glass observed upon 457.9 nm laser light excitation.

<table>
<thead>
<tr>
<th>Glass Composition (mol %)</th>
<th>$\sigma_{se}$ (x $10^{-21}$ cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TeO$_2$</td>
<td>WO$_3$</td>
</tr>
<tr>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>70</td>
<td>30</td>
</tr>
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CTuK55 Fig. 1. Variation of the $\text{Tm}^{3+}$ absorbance with the modifier in the range of pumping wavelength 630 nm–800 nm ($\cdots$: 0.3 mol CdCl$_2$, --: 0.3 mol LiCl and ····: 0.3 mol WO$_3$).

1.95 $\times$ 10$^{-20}$ cm$^2$ for the CdCl$_2$, LiCl and WO$_3$ modifiers, respectively.

Effect of the WO$_3$ (presented in Fig. 2a) and CdCl$_2$ (presented in Fig. 2b) content on the luminescence band structure and the intensities at room temperature are also very similar.

For both modifiers, integrated intensity of the emissions due to the $^{1}G_4 \rightarrow ^{3}H_4$ transition first shows a decrease and then an increase while the integrated intensity of the emissions due to the $^{1}G_4 \rightarrow ^{3}H_5$ and $^{1}G_4 \rightarrow ^{3}H_6$ transitions decrease with increasing amount of modifier.

Stimulated emission cross-section at the peak wavelength of the emission bands, $\sigma$($\lambda_m$), was determined using the formula given in ref. [5] and, the results obtained for the TeO$_2$-WO$_3$ glass are presented in Table 1.

From our data, it can be concluded that $\text{Tm}^{3+}$ doped binary tellurite glasses are promising materials for the infra-red amplifiers as well as the blue up-conversion lasers when the wavelength of the pumping light is chosen as 650 nm.

References