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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.[1,2] These emissions corresponds to the $^1G_4 \geq {}^3H_6$, $^3F_4 \geq {}^3H_4$ and, $^3H_4 \geq {}^3H_6$ 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.

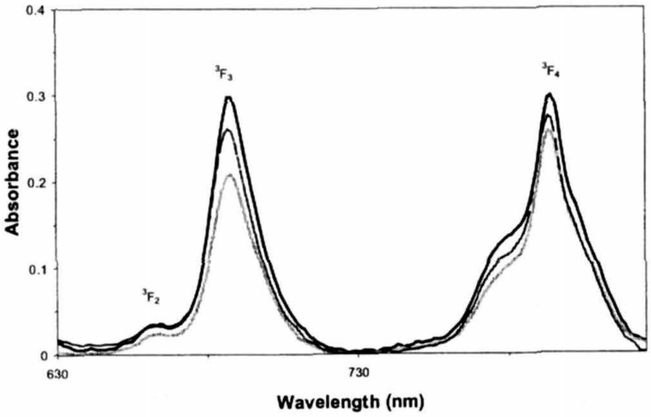
Absorption spectra of the 0.01 mol. Tm^{3+} doped tellurite glasses having 0.3 mol $CdCl_2$, LiCl or WO_3 as the network modifier in the 660 nm–800 nm pumping region are presented in Figure 1. The ratio of the absorbance at the peak wavelength of $^3F_3$ and $^3F_4$ban ds are about the *same for the 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[3,4] theory gives the calculated oscillator strength for an electric dipole transition from the ground state to an excited state in terms of the Ω_t (t = 2, 4, 6) intensity parameters.

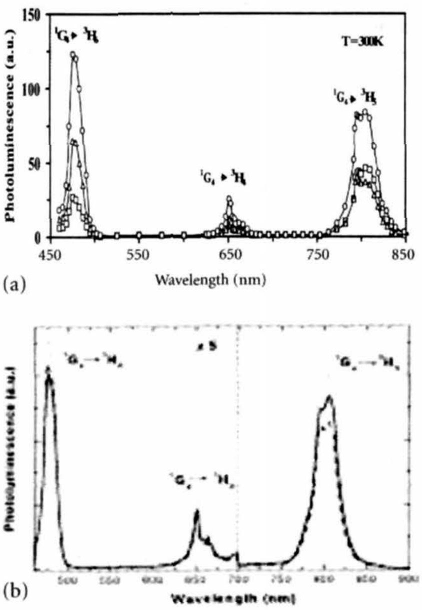
Spontaneous emission probability for an electric dipole emission can then be calculated using these intensity parameters. Our results show that the strongest dependence on the WO_3 content was observed for the parameter Ω_2. The Ω_2 and Ω_4 parameters are dominant for the $^3F_4 \rightarrow {}^3H_4$, $^3H_4 \rightarrow {}^3H_6$ and $^1G_4 \rightarrow {}^3H_6$ transitions of Tm^{3+} ion. Line strength of the $^3H_6 \rightarrow {}^3F_{2,3}$ transition used as the pumping level, is determined by Ω_6 which is found to be 2.16×10^{-20}, 2.09×10^{-20}, and

CTuK55 Table 1. Stimulated emission cross-sections, σ_{se}, for the emissions of Tm^{3+} in $(1-x)TeO_2-(x)WO_3$ glass observed upon 457.9 nm laser light excitation

Glass Composition (mol %)			σ_{se} (x 10^{-21} cm^2)					
			$^1G_4 \rightarrow {}^3H_6$		$^1G_4 \rightarrow {}^3H_4$		$^1G_4 \rightarrow {}^3H_5$	
TeO_2	WO_3	Tm_2O_3	T = 300 K	T = 10 K	T = 300 K	T = 10 K	T = 300 K	T = 10 K
85	15	1	3.9	4.2	5.8	7.5	7.5	23.1
75	25	1	4.3	7.3	2.4	3.8	1.3	22.8
70	30	1	4.5	7.9	2.1	8.2	1.2	22.7



CTuK55 Fig. 1. Variation of the Tm^{3+} absorbance with the modifier in the range of pumping wavelength 630 nm–800 nm (—: 0.3 mol. $CdCl_2$, ---: 0.3 mol. LiCl and ····: 0.3 mol. WO_3).



CTuK55 Fig. 2. a) Effect of composition on the luminescence bands (excitation was made with a laser tuned at 457.9 nm) □: 0.15 mol., △: 0.25 mol. and, ○: 0.30 mol. WO_3 content. b) Effect of composition on the spectral profiles of the luminescence bands (excitation was into the $^1G_4$ level of Tm^{3+} ion with a laser tuned at 457.9 nm) □: 0.15 mol., △: 0.25 mol. and, ○: 0.30 mol. $CdCl_2$ content in TeO_2-$CdCl_2$ glass.

1.95×10^{-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 $^1G_4 \rightarrow {}^3H_6$ transition first shows a decrease and then an increase while the integrated intensity of the emissions due to the $^1G_4 \rightarrow {}^3H_4$ and $^1G_4 \rightarrow {}^3H_5$ transitions decrease with increasing amount of modifier.

Stimulated emission cross-section at the peak wavelength of the emission bands, $\sigma(\lambda_p)$, 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 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

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