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Investigating the Gain Characteristics of Erbium Doped Tellurite Glasses for fiber amplifiers

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Abstract— This paper presents the gain characteristics of Rare Earth by investigating the variation of concentration Erbium Oxide. Fabrication is done by using the melt quenching method. Er_2O_3 doped TeO_2-Bi_2O_3-ZnO glasses are prepared from high purity oxides mixtures, melting in an alumina crucible in air atmosphere. The physical property of glass density was measured using pycnometer. Absorption spectra of glass be learned using UV-VIS spectroscopy in the range 400 nm to 1100 nm. Refractive index values were measured using the method of Brewster angle at a wavelength of 632.8 nm. Investigating the Gain Characteristics analyzed using mathematical model. The result of characterization shows that the gain increase as the Er^{3+} ions concentration doped to tellurite glasses. This makes these glasses are good candidate for fiber amplifiers.

Keywords—gain; erbium; tellurite glasses; mathematical model, fiber amplifiers

I. INTRODUCTION

Recently, combination communication that combines between voice and picture develops quickly especially internet development. Information speed is an important thing to get lot information. The solution is by using optic telecommunication system. In the beginning development of optic communication, optical signal amplification done by changing optical signal to electricity signal, then electricity signal upheld and changed into optical signal, so the upheld done in electricity area. This condition made optical network system is not efficient. Thus, a good, cheap, and efficient optical amplifier is a need. One of sample of optical amplifier is Erbium Doped Fiber Amplifier (EDFA).

By using EDFA will decrease need of repeater. Repeater usually used in conventional system to raise low signal. The strengthen of EDFA are: having gain characteristic that not sensitive on polarization, easy in connecting to the optical fiber network with low shrinkage loss and low noise characteristic [1]. In addition, high gain power of EDFA allows to apply not only for previous optical but also for power amplifier.

The first parameter in designing EDFA is optical fibre material. Characteristic of wave guide fiber are : (1) concentration ion erbium profile, (2) the length of fiber used, (3) source pumping, and (4) using of integrated both active and passive component [2]. That parameter used to get EDFA which has big gain in application as optical amplifier. The big gain can be obtained by using longer erbium doped fiber (EDF) or big erbium concentration, or also by using big pumping power [2] . With the election of those factors increasing, so the result of noise figure will increase [3]. Thus, it needs giving attention to optimum value in each parameter to get suitable EDFA.

Based on the problems above, the researcher will do investigation in effectiveness of ion erbium concentration to EDFA. The concentration variation is in composition $55TeO_2$-$2Bi_2O_3$-(43-x)ZnO-xEr_2O_3 with (x=0,5; 1,5; 2,5; 3). From this research, hopefully get optimum value of ion erbium concentration, so it will get EDFA which has maximum gain that can used as optical amplifier.

II. METHODOLOGY

The research method was an experimental study. Basically, this research is aimed to know gain glass with composition 55TeO2-2Bi2O3-(43-x) ZnO-xEr2O3 and (x=0,5; 1,5; 2,5; 3). Fabrication is done by using the melt quenching method. Characterization of glass on the study includes refractive index, density, and absorbance. Measurement of the refractive index values by using a spectrometer with the method of Brewster used HeNe with wavelength 632.8 nm in the dark place. Density of the samples is measured using Archimedes method of Pycnometer appropriate. While measuring the absorbance values are performed using a UV-Vis. The measurement done by interval length 400nm till 1100nm. Measurement results used to analysed gain characteristics using mathematical model.

III. RESULT AND DISCUSSION

In this research, sample made by composition 55TeO2-2Bi2O3-(43-x)ZnO-xEr2O3 whether (x=0,5;1,5;2,5 and 3). Sample composition data can be seen at table 1.

Table 1. Percentage of mass in glasses sample

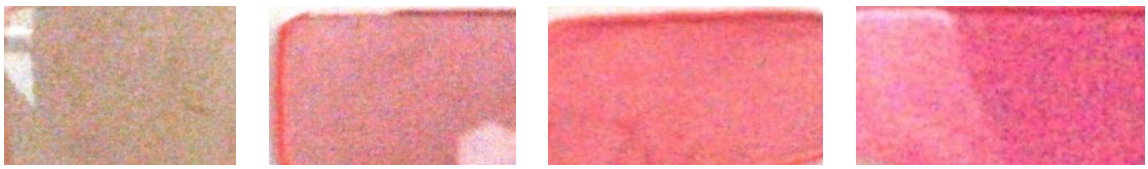
Material	Composition sample in gram			
	x =0,5	x =1,5	x =2,5	x =3
TeO_2	5,2557	5,1398	5,0290	4,9753
Bi_2O_3	0,5580	0,5457	0,5340	0,5283
ZnO	2,0718	1,9784	1,8891	1,8459
Er_2O_3	0,1145	0,3360	0,5479	0,6505

Sample made by total mass 8 gram, calculation sample mass used equation, mass = mol x Mr/Ar (molar mass, whether mol is comparison of x value and mr is total of ar value from each material (TeO2, Bi2O3, ZnO, Er2O3). From composition of table 1 can be seen that amount of ion value Er2O3 from each sample showed in table 2.

Table 2. Amount Ion Er_2O_3 in glasses sample

Sample	concentration Er_2O_3 (mol)	Amount of ion Er_2O_3 ($x10^{21}$)
1	0,5	0,36
2	1,5	1.05
3	2,5	1.72
4	3,0	2.05

Result of fabrication glasses showed in picture 1, whether a is glasses with 0,5 mol Er_2O_3, b is glasses with 1,5 mol Er_2O_3, c is glasses with 2,5 mol Er_2O_3 and d is glasses with 3 mol Er_2O_3. From those glasses seen that pink glasses, higher concentration erbium looks more red.



a *b* *C* *d*

Picture 1 glasses result of fabrication sample

Measurement results of density and refractive index can be seen in table 3. Relation of density (ρ) and refractive index (n) in this research had support theory of Plot Lorentz-Lorenz for glasses Alkali-Tellurite [4]. Relation between refractive index and density fulfilled linearity 1 [4] that popular with equation Lorentz-Lorenz.

$$\frac{n^2-1}{n^2+2}\left(\frac{M}{\rho}\right) = R_M \quad (1)$$

Those results also support [5] explain that equation

$$R_M = V_m \frac{n^2-1}{n^2+2} \quad (2)$$

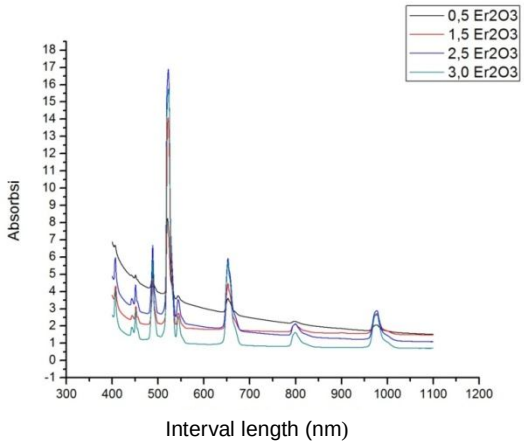
Whether V_m is volume molar which has same value $\frac{M}{\rho}$.

Table 3. Measurement results

Sample	Concentration Er_2O_3 (mol)	density (gr/cm^3)	refractive index
1	0,5	5,5813 ± 0,0988	1,9013 ± 0,0098
2	1,5	5,5341 ± 0,0844	1,9500 ± 0,0000
3	2,5	5,7905 ± 0,1150	1,9833 ± 0,0058
4	3,0	5,8742 ± 0,0456	1,9533 ± 0,0058

Absorption spectrum sample measured by using Spectrometer PerkinElmer Lambda 25. The measurement done by wave length 200nm till 1100 nm with range the increase in wavelength 0,1 nm. Absorption spectrum sample showed in picture 3 in 400 nm areas till 1100 nm. In that picture, found peaks that had different absorption intensity.

It shows that each energy level like picture 2. From glasses sample found eight peaks in wavelength area 408, 451, 489, 521, 544, 653, 799, 980 nm or same with energy level notation 4H9/2 , 4F5/2 , 4F7/2 , 4H11/2, 4S3/2, 4F9/2, 4I9/2dan 4I11/2 that based on Russell Saunders. This energy level will make easier in explaining process of transition energy level [6].

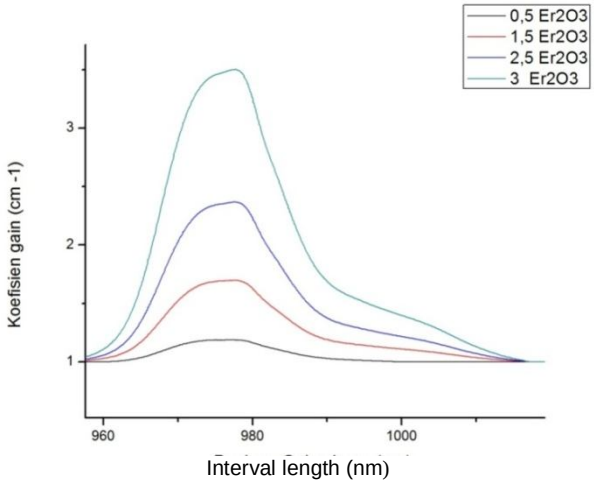


Picture 2. Sample absorption spectrum

Gain coefficient (g) is as erbium concentration erbium $E_r(n_{core})$ that stated in linearity 3 [7]. Whetеher relative infention $D = 1$, $\sigma_a(\lambda_k)$ and $\sigma_e(\lambda_k)$ as absorp and emition of from sample.

$$g = E_r(n_{core}) \frac{\{\sigma_e(\lambda_k)(1+D) - \sigma_a(\lambda_k)(1-D)\}}{2} \quad (3)$$

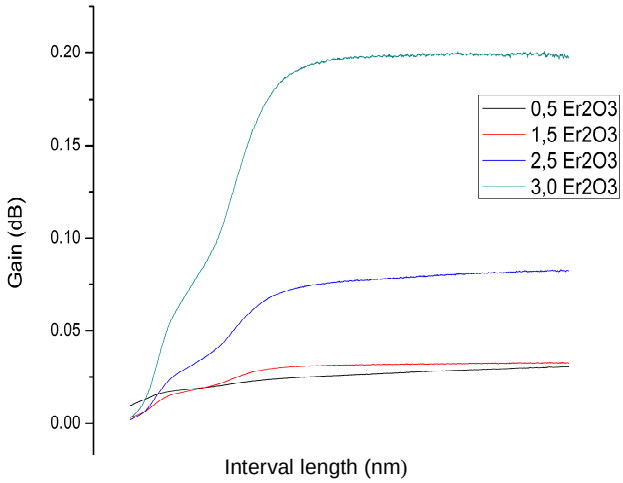
Based on the three linearity above, absorption spectrum sample in picture 3 can display with baseline on the peak 980nm like picture 4 as a gain coefficient. From the picture 5 the concentration 0,5 Er2O3 has lower gain coefficient and concentration 3 Er2O3 has the lowest gain coefficient. This result has similar result with [7][8] research result.



Picture 3. Gain coefficient

Mathematical modelling of gain spectrum prediction (G) can be know from gain coefficient (g) stated in linearity 4 [8]. Whether $\Gamma(\lambda)$ is relative inversion which value 1 that like in linear 4 and ρ_0 is density sample and the result of measurement showed in table 3.

$$G(\lambda) = \sigma_e(\lambda)\Gamma(\lambda)\rho_0 \quad (4)$$



Picture 4. Spectrum gain

The result of linearity 4 showed in picture 4 that addition of concentration Er_2O_3 will improve gain spectrum and so do the result of [7][8] for different material sample. From those result, it can be concluded that characteristic of gain spectrum (G) is linear with erbium concentration from each sample.

IV. CONCLUSION

Characterization sample result $55TeO_2$-$2Bi_2O_3$-(43-*x*) ZnO-*x*Er_2O_3 with (*x=0,5;1,5;2,5* and *3)* showed characteristic of gain spectrum (*G*) linier with erbrium concentration doped in each sample. From those discussion can be known that sample which concentration 3 mol Er_2O_3 has the biggest gain value (*G*). This makes these glasses are good candidate for fiber amplifiers.

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