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Modelling and Analysis of TDFA for Enhancing the Performance of DWDM Systems

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ABSTRACT

The TDFA model based on the simulation considering power of signal and power of the pump and other important parameters has been proposed in this paper. The analysis of TDFA for optimal length and (TDF) has been evaluated by considering the effect of the ASE; while ignoring outcomes on TDFA. An emphasis is being made to obtain maximum gain considering least possible length of fibers; in order to have low cost amplifier. Simulations were performed for the gain (without ASE), with ASE and gain (with and without ASE) and signals the wavelengths ranging from 1479nm to 1555nm in length of fibers ranging from 8m to 16m. The results show that 10 m is an optimal length with less value of ASE and more gain as compared with 16m.

Keywords: TDFA, ASE, Gain, Noise figure

I. INTRODUCTION

Doping of Thulium ions is a deciding factor in analyzing the performance of doped fiber amplifier thulium (TDFA) [1-5]. This work analyzed the equations of rate of TDFA in depth, renovated and improvised by taking account of the effect of the co-amplifier propagating the spontaneous emission (ESA). The length of the fibers is an important factor in the determination of the performance of the Amplifier. The analyzed shoed that lesser the value of ASE keep less noise pertaining to higher gain of the amplifier. Considering this impact, the duration of fiber is optimized, calculated and simulated the equations without noise ASE. The equations have been designed in order to improvise rate and used software MATLAB for simulation considering length of fiber Thulium (FDT) in a range varies from 0 and up to 64 m. The length of fiber is an important parameter used for calculating ASE and noise value, which need to be considered for making amplifier economic. The main hindrance occur in designing an amplifier with less value of gain which is not desirable, so simulated with optimal length of fiber.

II. MATHEMATICAL MODELING AND ANALYSIS OF TDFA WITH ASE

This section incorporates mathematical modeling of TDFA to examine the impact of the ASE. Modeling is being done to improvize the equations of rate of existing TDFA. To analyze the results of the mathematical equations developed have been simulated in MATLAB. Prior to performing the simulation in MATLAB, Simulink of the environment has been created by mathematical equations [6].

Interdependency of system parameters is being maintained; considering TDFA performance as shown in model. As shown in the energy transition diagram of TDFA in Figure 1, excited ions instantly relax from the excited state to the basic state by emitting a foreign particle that is uncorrelated with the signal. Cette instantly emitted particle amplification as it travels down the fiber and leads to noise. The ASE noise power is given as:

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$$P_{ASE} = 2\,hv\,\eta_{sp}\,\Delta v(G-1) + 2hv\frac{\beta}{\rho A}\Delta v N_1 \tag{1}$$

The ASE noise power in terms of time and length is written as:

$$\frac{P^{+}_{ASE}(L,t)}{P^{+}_{ASE}(0,t)} = 2hv\eta_{sp}\,\Delta v(G-1) + 2hv - \frac{b}{\rho A}\Delta v N_1 \tag{2}$$

Equation 5.34 is rewritten as:

$$\frac{P^{+}_{ASE}(L,t)}{P^{+}_{ASE}(0,t)} = 2hv\Delta v\left[\eta_{SP}(G-1) + \frac{b}{\rho A}N_1\right] \tag{3}$$

For implementing the present model, 1050nm pumping scheme is used [6]. So, equation (5.35) is written as:

$$\frac{P^{+}_{ASE}(L,t)}{P^{+}_{ASE}(0,t)} = 2hv\Delta v\left[(G-1) + \frac{b}{\rho A}N_1\right] \tag{4}$$

While considering co-propagating ASE effect, the equation of metastable population [6] becomes:

$$\begin{aligned}\frac{\partial N_1}{\partial t} &= P_S(0,t) - P_S(L,t) + P_P(0,t) - P_P(L,t) - \\ &\frac{N_1}{\tau} + P^{+}_{ASE}(0,t) - P^{+}_{ASE}(L,t)\end{aligned} \tag{5}$$

Using equation (4), the equation (5) becomes:

$$\begin{aligned}\frac{\partial N_1}{\partial t} &= P_S(0,t)[1-\exp(K_S N_1 - I_S)] + \\ &P_P(0,t)[1-\exp(K_P N_1 - I_P)] - \frac{N_1}{\tau} - \\ &P^{+}_{ASE}(0,t)[1 - 2hv\Delta v(G-1) + 2hv\frac{b}{\rho A}\Delta v N_1]\end{aligned} \tag{6}$$

The equation (6) represents effect of variable gain on TDFA including ASE. Í represent frequency of operating spectrum, Δν represents the change in frequency range around ν, h is the Planck's constant. The K and I are the terms related in terms of the Containment factors Γp and Γs, the absorption and emission cross sections (σ01, σ10 and σ03), the density of the thulium atoms ρ, the length the and the effective cross- sectional area A of the thulium doped fiber and N1 represents the population of thulium ions at metastable state. All other terms have already been defined [6]. In this paper, the work is emphasized on ESA while improving ordinary differential equation (6) non linearity characteristics. The equation (6) is taken as implented model of TDFA, involving ESA. The block diagram used for creating Simulink environment is shown in Figure 2, which depicts that the ASE only effects population in metastable state which affect the performance of TDFA in terms of noise level and value of gain; which suggests the kind of amplification at optimal length of fiber.

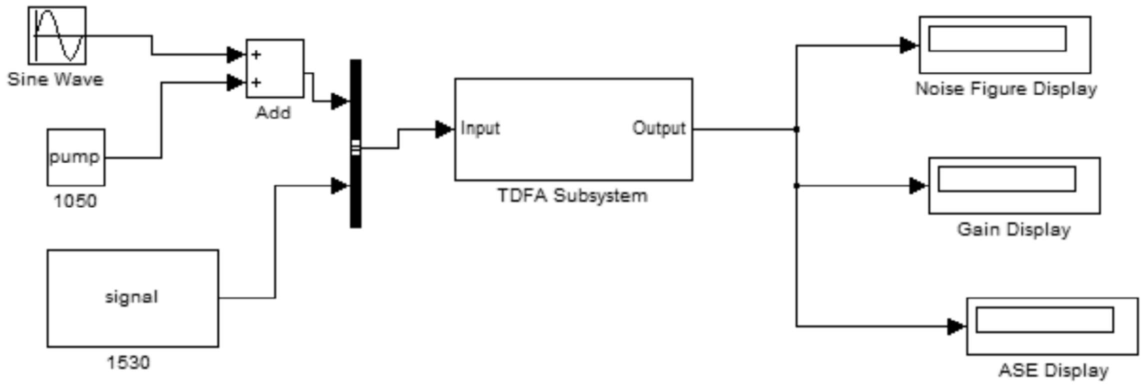

Figure 2: Block diagram of TDFA

Steps involved in modeling of TDFA are in Table 1.

Table I
Algorithm_sim_TDFA

STEP I: Starting with initial value of n0, N1 and N3 (Mt+3 ion densities at basic level, balanced and unbalanced states), addition of impurity, power at input end, number of channels, area of cross section, the(length of fiber), Pp &PS (power of pump and signal), λp &λs (wavelengths) and designated input signal.
STEP II: n1, n1 , N3 are constants and L is taken as variable
STEP III: Finding the value of peak gain and length at which it is achieved along with range of wavelengths
STEP IV: Determine power of injected power
STEP V: Determine gain along with power of ASE along with fiber length.
STEP VI: Optimize fiber length for higher gain and lesser power of ASE
STEP VII: Plot gain, NF for optimum length of TDF with respect to wavelength.

III. RESULTS AND DISCUSSIONS

A model is designed with a purpose to study dynamics of TDFA. The results are being analyzed in terms of noise level and gain considering length of fiber. The results are being demonstrated from figure 3 to Figure 7.

(A) Selection of optimum length of TDF

Considering equation (6) and steps involved in Table I, it is concluded that length of TDF significantly affects the performance of TDFA as metastable population is concerned. A result depicts also emphasis that injection power through pump can control inversion of population in metastable state which is similar to EDFA as both are doped. It is shown from the graph that length of fiber is chosen selectively to improve the said performance. The power has been chosen selected as 200mW and range of length of fiber has been selected from 8m to 16m [6]. While performing simulation, optimum length need to be selected in order to get less interdependency of TDFA at ASE and gain at maximum value can be achieved at lesser length of fiber.

(B) Variation of Gain versus wavelength

The objective to find optimal length of TDF to analyze the performance of TDFA, in order to evaluate; graphical view is analyzed for various wavelengths plotted for gain. The range of length is varies from optimal value to maximum value [1] as shown in figure 3[1]. This graph implies that the 16m as optimum length, at this value, peak gain is achieved while for 10m STIS value is 26dB and for 8M STIS value is 22dB. The aim of the evaluation is to find as much as closest optimum value of TDF length to have maximum value of gain with less value of ASE in maximum range of wavelength

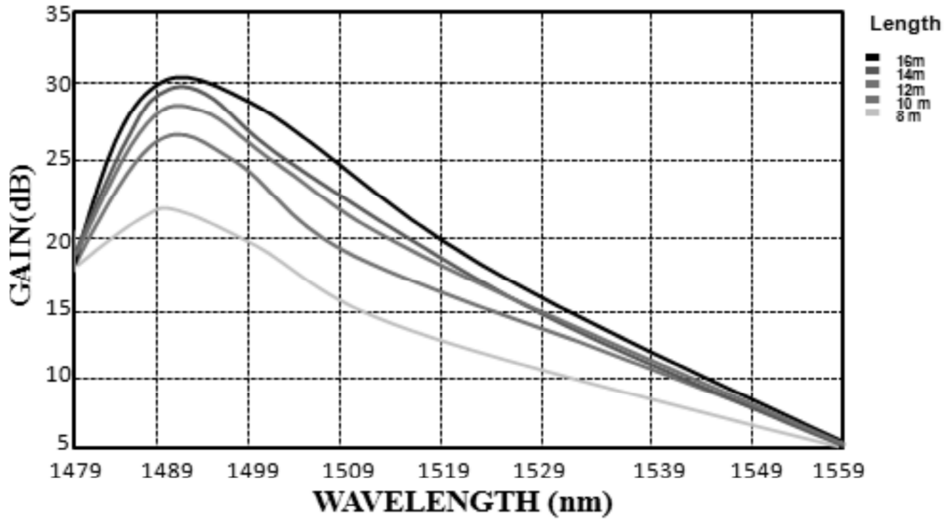

Figure 3: Variation of Gain and Wavelength for Different Lengths without ASE

(C) Variation of ASE versus Length of TDF

In this work, ASE is also considered in form of co-propagation (6). Different lengths of TDFA are plotted which has been shown in Figure 4. From results, it is concluded that ASE noise is directly proportional with length, as soon as length will increase, they avalanche and emitted which stimulates and generate more photons and leads to distorted noise.

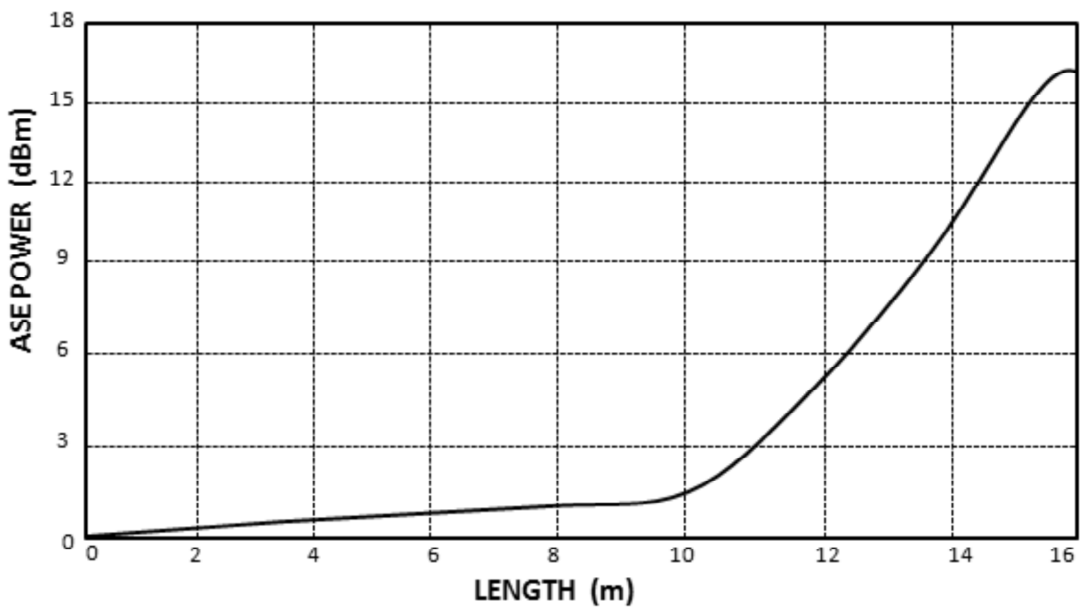

Figure 4: Variation of ASE with respect to TDF

The Figure 4 depicts that ESA is 16.5dBm for amplify length of 16m, for amplify length of 10m STIS value is 1.5dBm and value of ase still lowers at shorter length of TDF.

(D) Variation of gain (with ASE) versus wavelength

For optimum length of fiber, gain of TDFA is plotted as shown in Figure 5 by considering the effect of co-propagating ASE for length of TDF ranges from lowest to highest. To obtain gain at lowest length, as length will increases noise too. It has been observed that the gain peak is reduced from 30.5dB to 26dB for 16m length, from 26dB to 24dB for 10m length and from 22dB to 13.5dB for 8m length. It has been clear from Figure 5.13 That while considering the effect of co-propagating ASE, there is a very small difference in gain peaks for 16m length and 10m length. So, it is concluded from Figure 3, 4 and 5 that 10m length of TDF is considered as the optimum length of TDFA for pump power of 200mW.

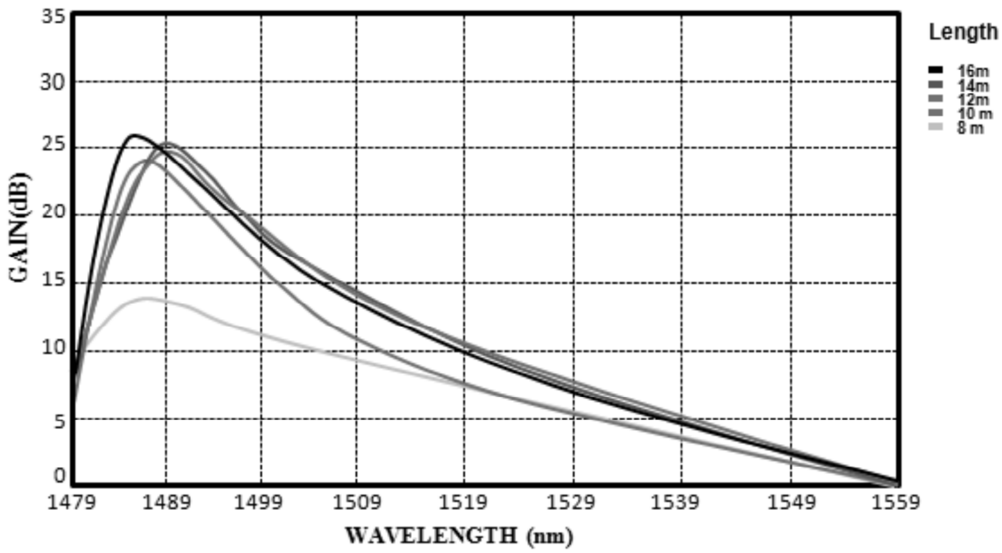

Figure 5: Gain versus Wavelength for Different Fiber Lengths of TDF with ASE

From Figure 4 it can be depicted that as power imposes a direct effect on length of fiber. This is well concluded that length will superimpose decrease in gain and optimal length also reduces as can be seen that 10m length of TDF can be the optimum length to be chosen as at 10m length the ASE is much lesser as compared to 16m length. However at the same time it is comparable to ASE at 8m length. As also the gain at 10m is much higher as compared to 8m and comparable to gain at 16m. The results that are presented in Figure 3, 4 and 5 are summarized in Table II and shown in Figure 6.

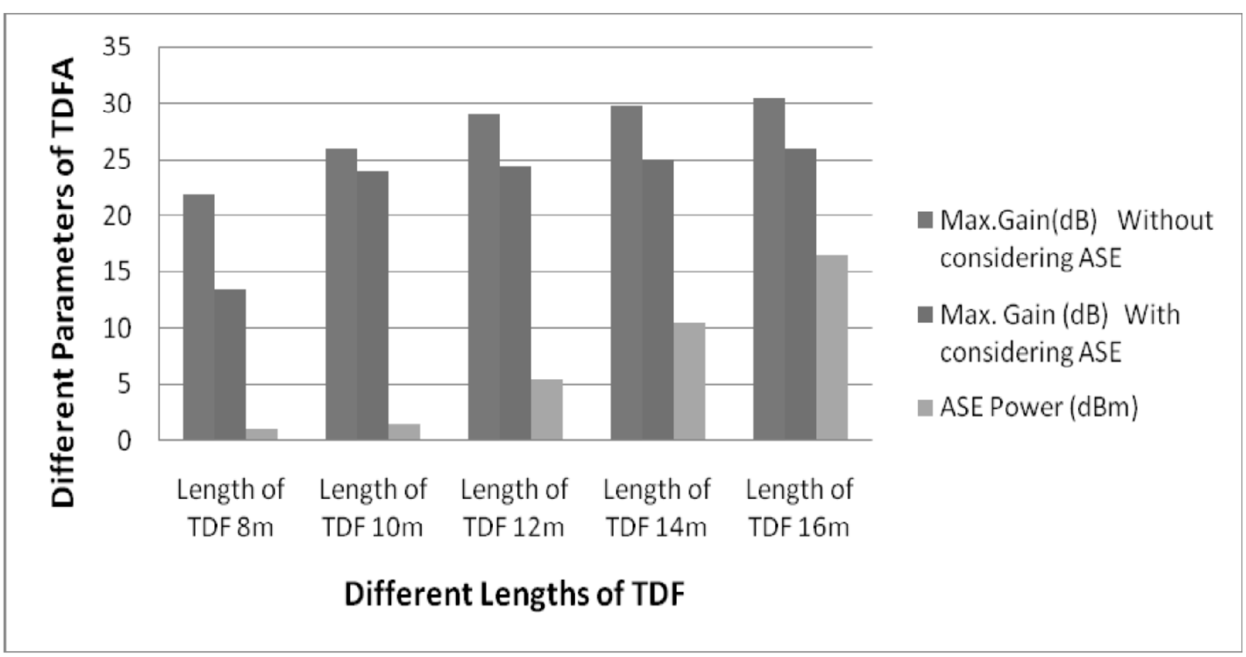

Figure 6: Gain (with and without ASE), ASE Power of TDFA at different lengths of TDF

Table II
Summarized Results of TDFA

Without considering ASE			*Considering ASE*	
Length(m)	*Max. Gain(dB)*	*Length (m)*	*Max. Gain (dB)*	*ASE Power (dBm)*
8	22	8	13.5	1
10	26	10	24	1.5
12	29	12	24.5	5.5
14	29.8	14	25	10.5
16	30.5	16	26	16.5

From Figure 6, it is observed that as the length of fiber directly proportional to ASE power. This is also seen from above that with increase in length decreases the gain (with ASE) of TDFA as compared to gain (without ASE).

IV. CONCLUSIONS

Modeling has been simulated and equation has been improvised to analyze the dynamics of TDFA. The model is designed considering metastable population; with basis of population inversion where injection of power is considered with similar to EDFA. The observations are being analyzed for noise pattern, optimal length of fiber, possible range of wavelengths and gain of a system.. It is observed that 10m length of TDF can be the optimum length to be chosen as at 10m length the ASE is much lesser as compared to 16m length. However at the same time it is comparable to ASE at 8m length. As also the gain at 10m is much higher as compared to 8m and comparable to gain at 16m.

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