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Analysis of EDFA-WDM Optical Network System

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Abstract- In WDM systems optical fibers are utilized to transmit data in type of light pulse between the transmitter and the receiver. WDM frameworks can possibly transmit multiple signals at the same time. However, the light signal decreases in power when they travel a long distance inside the fiber. So it is required to intensify all the light signals at the same time after a specific interval of light spread to recover the first signal. Optical amplifiers are for the most part used to regenerate the light pulses. There are numerous optical amplifiers. One of the normal amplifier utilized is Erbium Doped Fiber Amplifier. In this paper the investigation of WDM system is done on the basis of Erbium Doped Fiber amplification and dispersion compensation mechanism utilizing Optisystem programming.

Keywords – *EDFA, WDM, Optical Fiber, Gain and Noise Figure*

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I. INTRODUCTION

Erbium-doped fiber amplifier (EDFA) has assumed an exceedingly vital part in the optical fiber communication system. Propagation losses are the greatest concern for optical fibers. In any case, use of EDFA has helped hugely in compensating losses amid signal propagation. For wavelength division multiplexing frameworks EDFAs are to a great degree helpful in light of the fact that they give uniform gain over an extensive range of wavelengths. EDFAs have gain in the scope of 40–50 dB. The gain relies on upon different parameters like doping focus, dynamic fiber length, pump power, center range, erbium span, numerical gap, signal information power, signal data transfer capacity, pumping wavelength, and so forth . The EDFAs are pumped with laser diodes at a pumping wavelength of 980nm or 1480nm. There are diverse pumping strategies utilized for EDFAs which are clarified in the following area. The EDFA gain is one of the vital element for WDM systems, furthermore the Noise figure which characterizes the measure of noise is aggregated.

THEORY ON WAVELENGTH DIVISION MULTIPLEXING

Optical fibers can carry various light signals of different wavelength at the same time. The procedure which permits the optical fiber to carry various signals is called wavelength division multiplexing. So wavelength division multiplexing is the system of sending signals of a few unique wavelengths of light into the fiber simultaneously. In fiber optic technology, wavelength division Multiplexing (WDM) is an innovation which multiplexes different optical carrier signals on a single optical fiber by utilizing distinctive wavelengths of Laser light to carry different signals. This expands capacity furthermore and helps bi-directional transmission over a single fiber length for transmitter and receiver.

II. CIRCUIT DIAGRAM

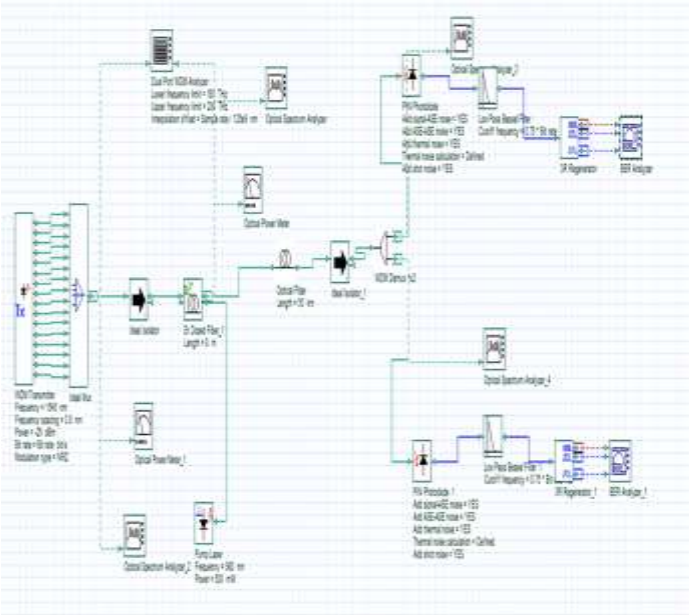


Fig 1: Circuit Diagram

III. SOFTWARE

The software used is Optisystem. It is a comprehensive simulation package developed by Optiwave
WDM Transmitter-The WDM Transmitter holds 16 equalized wavelengths that feed to Ideal Multiplexer.
Isolators - The 2 isolators are used to prevent Amplified Spontaneous Emission (ASE) and signals from propagating in backward direction.
Pump Laser - The pump power used is for the excitation of the doped atoms to a higher energy level
Erbium Doped Fiber - It is used to transmit or carry optical signals.
Photodetector PIN - As a photodetector, the PIN diode is reverse biased. Under reverse bias, the diode ordinarily does not conduct (save a small dark current or Is leakage). When a photon of sufficient energy enters the depletion region of the

diode, it creates an electron, hole pair. The reverse bias field sweeps the carriers out of the region creating a current.
Low pass Bessel filter - The Bessel filter is widely used in optical receivers since it produces only little overshoot.
3R regenerator - Optical 3R generator is used for Re-amplifying, Re-shaping, Re-timing the optical signal. It is a key element in reducing the optical impairments arising from the long haul optical communication system.

IV. SOFTWARE SIMULATION

Specifications	
Length of EDFA	8m
Reference Wavelength	1545 Nm
Pumping Wavelength	980 Nm
Pumping Power	120 mw
Pumping Technique	Forward
Length of Optical Fiber	50 km

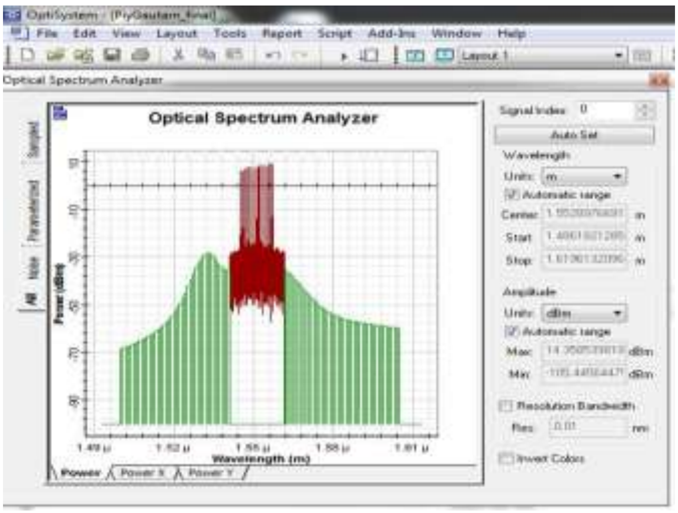
Parameters and Values

Parameters	**Values**
Pump Laser Frequency	980 Nm
Power of each channel	-26 dbm
Modulation Type	NRZ
Fiber Length	50 km
Bessel Filter Cut-Off Frequency	0.75×Bitrate (Hz)

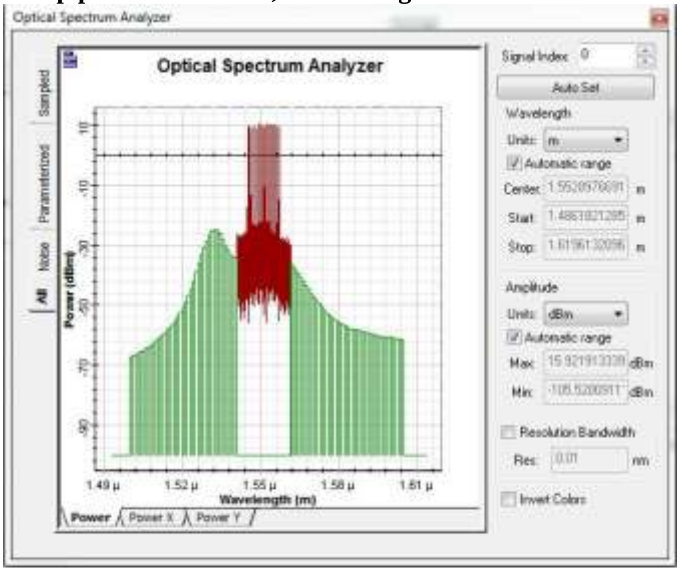
The desired gain is more than 30dB. Two parameters are selected to be optimized in achieving the desired gain under output power and gain flatness constraints are fiber length and pump power.

We can clearly see in the optical spectrum analyzer that on increasing the pump power the noise figure tends to decrease.

Pump power – 300 mW, EDFA length – 10 m



Pump power – 400 mW, EDFA length – 10 m



The parabolic wave represents the noise which shows that the noise is decreasing when the pump power is increasing while the red symbol in the graph represents the sample wavelength. Hence, it can be easily concluded that higher pump power will give a lower noise figure and higher gain and higher output.

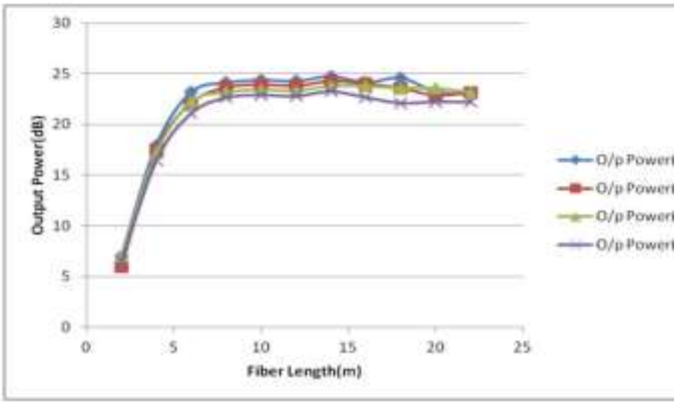


Fig 2: Output power variation with fiber length and pump Power

Length(m)	Output Power(W)	dBm
2	5.01	7
4	62.80	17.98
6	230.14	23.22
8	309.029	24.15
10	309.029	24.41
12	241.546	24.30
14	299.22	24.77
16	293.76	24.68
18	289.73	24.62
20	287.078	22.26
22	226.986	21.42

Table 1: Output power variation with fiber length and pump power

For each of the pump power, the output power increases and decreases after reaching a maximum value. Since the pump is at wavelength of 980nm, when the fiber length increases, the erbium ions will excite to the higher level where the lifetime of this higher level is approximately 1us. Therefore, it will cause the increasing of the output power. However, after a certain length when the pump power is exhausted, the unexcited erbium ions will results in the decreased of output power.

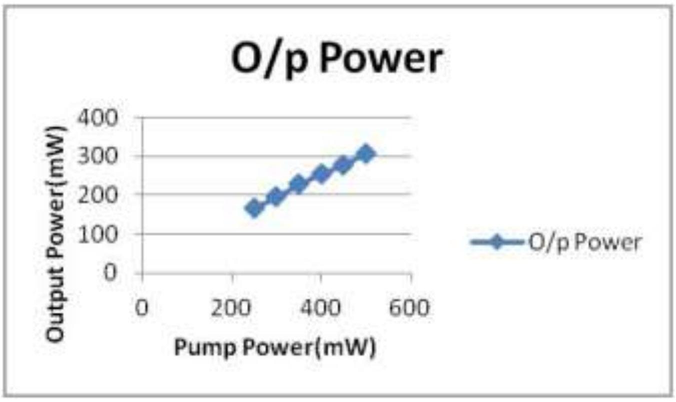


Fig 3: Output Power V/s Pump Power

Pump Power(mW)	Input Power(e-3)(W)	Output Power(e-3)(W)	dbm
250	21.959	168.391	21.938
300	21.959	195.521	22.647
350	21.959	227.727	23.235
400	21.959	254.099	23.783
450	21.959	277.724	24.172
500	21.959	306.653	25.557

Table 2: Output power and input power variation w.r.t to different pump powers

The increase of pump power will increase the output power at each meter of the length. This is because when the length of the amplifier is increased, there will be more power used to transmit the signal in the system

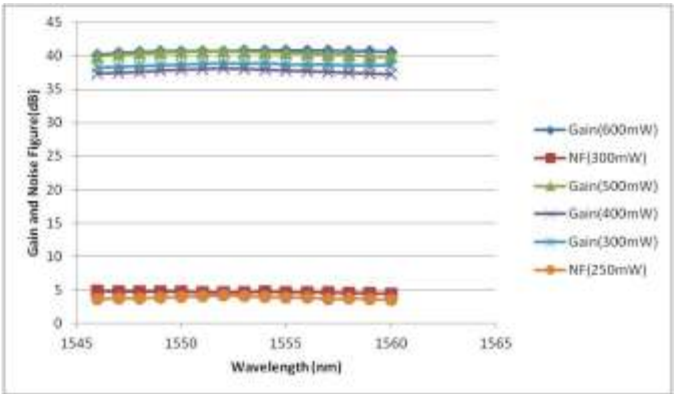


Fig 4: Gain and noise figure w.r.t. different values of input wavelengths

Wavelen-gth	Gain(600 mW)	Gain(500 mW)	Gain(400 mW)	Gain(300 mW)	NF(300 mW)	NF(250mW)
1546	40.13	39.96	38.25	37.39	4.82	3.65
1547	40.45	40.23	38.33	37.42	4.72	3.7
1548	40.54	40.34	38.45	37.57	4.73	3.76
1549	40.65	40.46	38.57	37.76	4.76	3.85
1550	40.73	40.59	38.64	37.89	4.71	3.98
1551	40.68	40.63	38.75	38.01	4.65	4.11
1552	40.73	40.69	38.9	38.15	4.66	4.21
1553	40.82	40.61	38.85	38.07	4.67	4.09
1554	40.85	40.53	38.87	37.91	4.7	3.95
1555	40.81	40.49	38.73	37.79	4.59	3.88
1556	40.84	40.33	38.66	37.67	4.64	3.79
1557	40.8	40.26	38.69	37.59	4.59	3.67
1558	40.71	40.11	38.58	37.45	4.56	3.75
1559	40.64	39.95	38.55	37.33	4.56	3.63
1560	40.6	39.81	38.57	37.21	4.44	3.56

Table 3: Gain and noise figure w.r.t. different values of input wavelengths

As the wavelength increases, the gain also increases but after reaching at the saturation point, it starts decreasing as shown in the above graph. Gain starts decreasing after a certain point because despite of increase in pump power, the population inversion decreases due to exhausted pump power. One can note that as the input signal power increases, the noise figure decreases achieving a minimum. For higher signal input power the noise figure increases drastically due to the lower population inversion in the beginning of the doped fiber. However, as the signal power continues growing, there will not be enough inverted population to keep the amplification processes, leading to higher noise figure values.

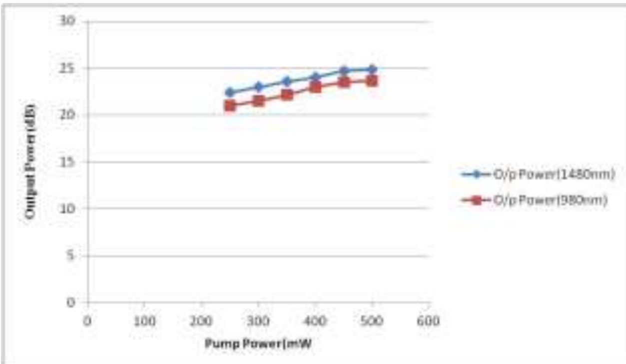


Fig 5: Output power w.r.t different pump powers for different pump wavelength

Pump Power(mW)	Output Power(1480nm)	Output Power(980nm)
0	0	0
250	22.37	21.01
300	22.95	21.53
350	23.54	22.15
400	24.02	22.97
450	24.68	23.47
500	24.85	23.65

Table 4: Output power w.r.t different pump powers for different pump wavelength

In case of 980nm pumping wavelength the output power is less as compared to 1480nm. As we increases the pump power the output power increases.

Channel 1

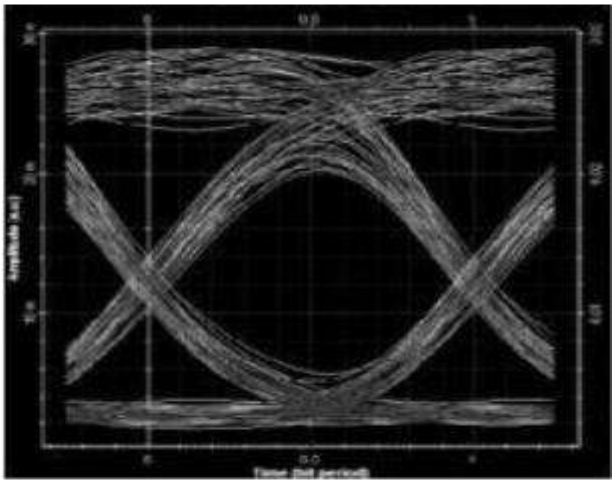


Fig 6: Eye diagram for channel 1

Channel 2

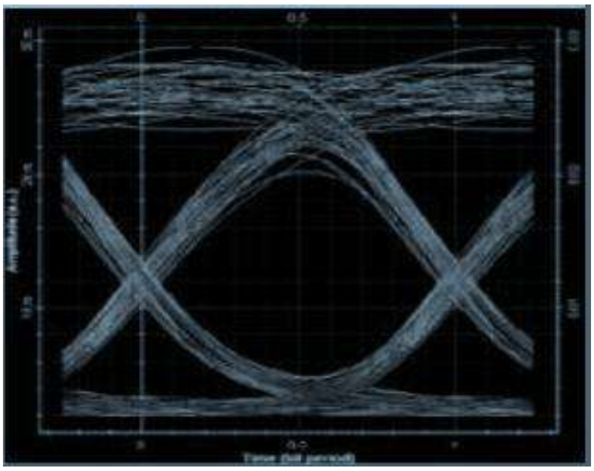


Fig 7: Eye diagram for channel 2

It can be clearly seen from the above eye diagram that the inter-symbol interference is very less while the width of the opening denotes the time for which the sampling is performed for coherent detection. Here, optimal sampling time corresponds to maximum Eye opening yielding greatest protection against noise.

From the simulation results, it is clear that as the pump power increases, the gain increases while the noise figure decreases.

V. CONCLUSION

The simulation and analysis of a WDM optical network with pump power and fiber length as the parameters is performed. Pump power and fiber length are optimized to achieve low gain flatness, low noise figure and low bit error rate. Different values of pump power give different output power depending upon the length of the fiber. The attenuation in EDFA at each stage was controlled. The output power and gain increases with the increase in pump power values while the noise figure decreases.

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