JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

PERFORMANCE EVALUATION AND COMPARISON OF OPTICAL AMPLIFIERS USING PUMPING FOR HIGH PRIVACY OPTICAL COMMUNICATION LINKS

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Abstract **:** This paper demonstrates the review of performance comparison of optical amplifiers EDFA, SOA and RAMAN amplifiers for secured optical communication systems. The optical amplifiers such as single stage EDFA(SSEDFA), Dual stage EDFA(DSEDFA), tri stage EDFA(TSEDFA), Eight stage EDFA(ESEDFA), single stage SOA(SSSOA), dual SOA stage(DSSOA), tri SOA stage(TSSOA), single stage RAMAN(SSRAMAN), dual stage RAMAN(DSRAMAN), tri stage RAMAN(TSRAMAN) and Eight stage EDFA(ESEDFA) with backward pumping separately simulated with wavelength of 980nm and the input and output parameters of each model measured the input optical power, output optical power, input noise and output noise, Gain, noise figure, Quality factor, BER(Bit Error rate), Eye height and received electrical power values are tabulated, compared and analyzed. The Eight Stage optical amplifiers use only two stage pumping of wavelength 980nm to overcome the wastage of pumping power compared to other optical amplifiers. Single stage optical amplifier uses one pumping wavelength, dual stage uses two pumping wavelengths, Tri stage optical amplifier uses three stage pumping wavelengths and etc., For cascading model, Eight stage EDFA with 128 channels identified as the best and used as repeater gives input multiplexed optical power 9dBm, output optical power 27dBm and receive electrical power 22dBm and quality factor of 3.116 and Eye height 0.005 for long distance world's telecommunication link

Keywords: **SSEDFA, DSEDFA, TSEDFA, SSSOA, DSSOA, TSSOA, SSRAMAN, DSRAMAN, TSRAMAN, ESEDFA, ESRAMAN, BER, Quality factor, Optical power, Eye height and Electrical Output.**

I. INTRODUCTION

In the recent days the information transmitted from one place to another using optical fiber to a long distance by repeaters used in the world's telecommunication link. To overcome the demand of very long distance information transmission requires the cascaded optical amplifier. EDFA acts as optical amplifier in optical communication systems used as repeaters easily without any regeneration of optical signal, repeaters amplifies the optical signal directly by the fiber itself. Many repeaters used in guided media applications to carry the information to a long distance communications compared to other optical amplifiers. The general optical Amplifiers EDFA, SOA and RAMAN used as repeaters in fiber optic communications.

1.1 EDFA

EDFA used as an optical amplifier to amplify the optical signal by stimulated emission principle as well as to transmit to a fiber optic communication using the erbium doped fiber. EDFA optimize the gain and output amplified optical power and obtained less noise figure and less output noise compared to input noise power. EDFA uses temperature 20 degree centigrade, erbium meta stable lifetime 10ms, core radius 2.2µm, erbium doping radius 2,2µm, erbium ion density 1e+025m^{-3}, Numerical aperture 0.24.

1.2 SOA

SOA is the semiconductor optical amplifier acts as a amplifier by stimulated emission principle and also used as information source transmits to a fiber optic communications. Many SOA's are cascaded to gives the moderate gain and less noise. SOA uses the injection current 0.1A, Input and output coupling loss 2dB, Active length 0.0006m, optical confinement factor 0.45, active area 1.6e-013^2 and temperature 200K.

1.3 RAMAN Amplifier

RAMAN is the optical amplifier to amplify the signal by scattering of light signal principle and also transmit the optical signal to a long distance. RAMAN uses effective interaction area 72μm^2 , temperature 300K, rayleigth back scattering 5e-005/km and upper pump reference 1450nm.

II. Background

The paper[1], analyzes the gain and noise figure using EDFA. The paper [2] discusses the multi stage SOA superior in noise and gain saturation performances used in short range applications. The paper [3] discusses the SOA strong in noise in long haul applications, attractive features, high speed processing, high bias current and moderate input signal power recommended. The paper [4] discusses the Telecommunication traffic (voice, data etc.) is increasing day by day. So to meet the capacity demand, in this paper we have designed and verified a high capacity optical fiber communication system through simulation.. The paper[5] The characteristics of EDFA investigated, EDFA amplification depends upon the signal power, EDF length, Pump power and configuration of pump laser. The paper[6] There is an increasing demand for Dense Wavelength Division Multiplexing systems to support a set of network requirements like span length, total distance, capacity etc. The capacity increase in fibre optic communication systems has been achieved mainly by deploying more fibre links, populating more wavelength channels per fibre link through Dense Wavelength Division Multiplexing (DWDM). [7] This paper simulated using OptSim and their Qfactor, output power, eye opening, eye closure and bit error rate are compared by varying transmission distances from 60 to 180 km and keeping the dispersion constant at 2 ps/nm/km both in the presence and absence of non-linearities.. The paper[8] dense wavelength division multiplexing (DWDM) for upgrading optical communication systems capacity can be used with different modulation formats that are namely: NRZ (non return to zero), RZ (return to zero) and on-off keying and change the number of channels then show the effect of this on the three different optical pumping techniques. Here optiwave simulation program version 7 can be used with changing the following parameters: EDFA length, pumping power, pumping wavelength, input signal power and also fiber length then we measure the quality factor, BER, input power, output power, Gain, noise figure and bit rate.

III. PROPOSED WORK

The proposed ESEDFA (Eight stage EDFA) shown in Fig.1. gives the optimized gain and less noise figure, good quality factor, less BER (Bit error rate), less transmitter output noise compared to other simulated model techniques such as SSEDFA (Single stage EDFA), DSEDFA (Dual stage EDFA), TSEDFA(Tri stage EDFA), SSSOA (Single stage SOA), DSSOA (Dual stage SOA), TSSOA(Tri stage SOA), SSRAMAN(Single stage RAMAN), DSRAMAN(Dual stage RAMAN) and TSRAMAN(Tri stage RAMAN). The ESEDFA consists of eight channel information sources multiplexed as well as 128 channels sources also get multiplexed separately and simulated with added the authorized Pseudo noise random sequences for secured optical communication and send to Eight stage EDFA to amplify using the two stage backward pumping wavelengths of 980nm and to transmit the signal to a long distance. EDFA got output using multiple channel sources compared to SOA and RAMAN, cascaded (up to three stages only) SOA produces less gain and less noise used for short haul applications after that it cannot be produce any output. Cascaded RAMAN also uses up to the three stages and produce very less gain and less noise, it also used for short haul applications. Moreover the eight stage optical amplifier uses only two pumping stages compared to dual stage and tri stage optical amplifiers, therefore eight stage optical amplifier reduces the wastage of pumping power. EDFA, SOA and RAMAN uses the multiple wavelength ranges from 1100nm to 1620nm. Cascaded optical amplifiers transmit multiple channel sources increases the transmission capacity for that the bandwidth broadened.

EDFA consists of two input ports and two output ports. The secured and multiplexed input signal connected to the first input port and pumping signal with the wavelength 980nm connected to the second input port. The first output port of EDFA connected to the second stage EDFA, the output connected to the third stage EDFA and so on, and the output connected to the receiver input. The second output port of EDFA connected to the Ground signal to bypass the unwanted reflected signals. The receiver input starts from the Secured authorized PRBS receiver input codes given and the 8 channel demultiplexer to split all the eight signals and each connected to optical receiver. It consists of APD (Avalanche Photo diode) to detect the electrical signal from the original optical signal and measured the quality factor, Eye height, BER and Receiver sensitivity or the electrical output power.

EDFA cascades into a single stage, two stages(dual), three stages (Tri) connected together to get the transmitter output, like that SOA cascades into a single, dual and tri stages similarly RAMAN cascades into a single, dual and tri stages to analyze the transmitter and receiver output. Transmitter consists of Information sources with eight channels of each 1Tb/s. multiplexed into a single channel by 8:1 WDM multiplexer and coupled the secured codes using PRBS sequences converted to a optical signal. Channel guided media consists of EDFA or SOA or RAMAN, Receiver consists of secured codes coupled to the channel output and send to the demultiplexer WDM 1:8 splits the eight channels and measures the output Quality factor, BER and Eye height. Transmitter input measures the input optical signal power, input noise and channel output or Receiver input measures the output signal power, output noise, Gain and noise figure and OSNR. The proposed 128channels ESEDFA with two backward pumping gives optimized gain and reduced noise compared to eight channels TSEDFA shown in Fig 2.and other optical amplifier types mentioned above.

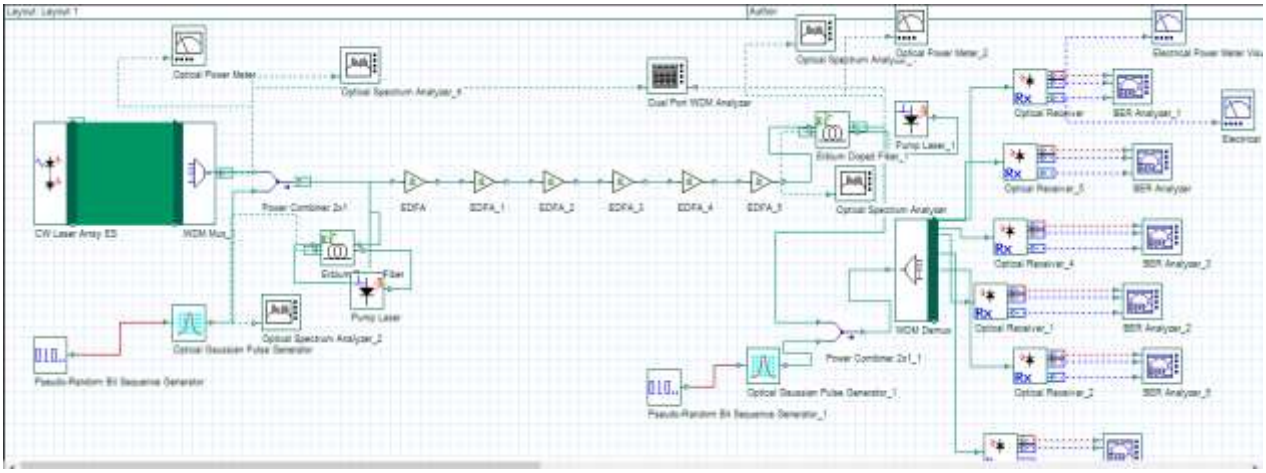

Fig 1. Secured 128 channels Eight Stage EDFA with two stage backward pumping using the wavelength 980nm

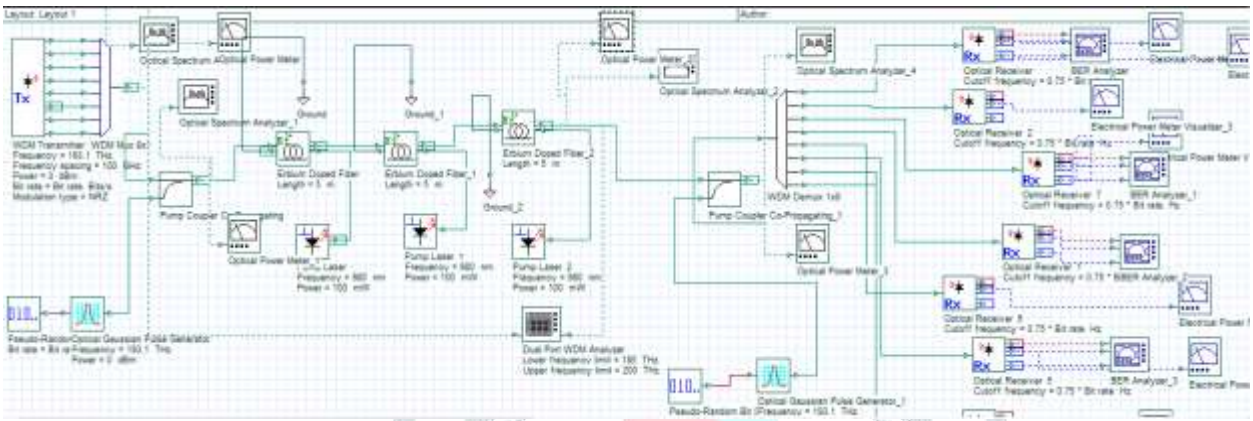

Fig 2. Secured Eight channel Tri Stage EDFA with three stage backward pumping using the wavelength 980nm

IV. RESULTS AND DISCUSSION

The Parameter visualize the Optical power meter, OSA (Optical spectrum analyzer), BER(Bit Error Rate) analyzer, Electrical power meter used to measure the values taken from each input and output part of the components connected in the simulation model. The Proposed Eight stage EDFA(ESEDFA) gives maximum gain, less noise figure, optimum output optical power in the transmitter and high quality factor, less BER and maximum Output Signal to noise ratio and less output noise compared to other simulated models like SSEDFA, DSEDFA, SSSOA, DSSOA, TSSOA, SSRAMAN. DSRAMAN, TSRAMAN.

Dual Port WDM Analyzer

Frequency (THz)	Gain (dB)	Noise Figure (dB)
193.1	24.185156	7.98228
193.2	19.965411	9.34886
193.3	17.391708	11.9203
193.4	14.671601	11.7032
193.5	11.920318	11.5349
193.6	9.0381572	11.5714
193.7	6.1178438	11.9006
193.8	3.134918	14.8813
193.9	-0.074390189	15.8074
194	-3.2984638	17.2212
194.1	-6.6006109	19.1756

Analysis | Details

Signal Index: 0

Frequency
Units: THz

Power
Units: dBm

Resolution Bandwidth
Res: 0.10000 nm

Fig.3. Dual port 128 channels WDM analyzer

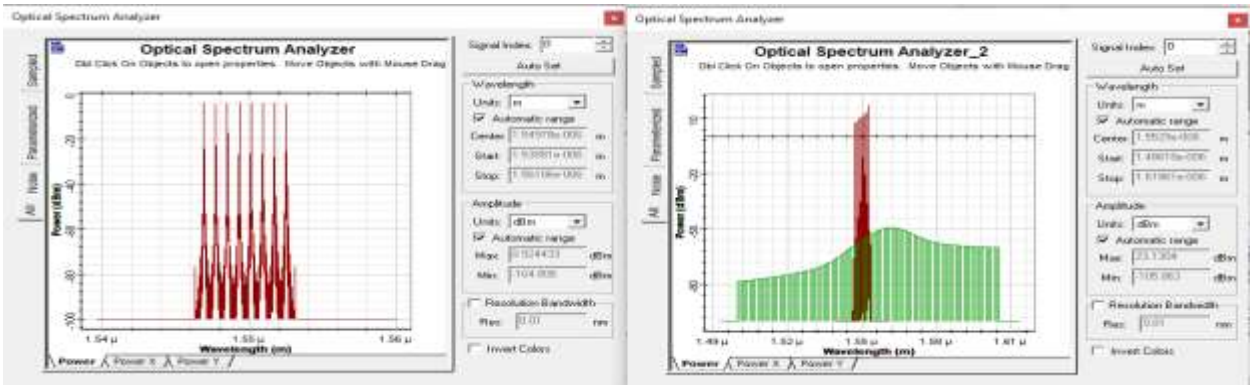

Fig. 4. OSA output of Multiplexed signal output and Third stage EDFA output.

From all the simulation models, DSEDFA and TSEDFA gives maximum electrical output, ESEDFA with 128 channels gives maximum optical output power 27.15dBm, Gain 24.18dB and Eye height of 0.005. In SSRAMAN Less Transmitter output noise -95,04dBm, less noise figure -1.25 and gives maximum OSNR 7.9e+001 dB and maximum quality factor 4.91. EDFA gives maximum output power and gain RAMAN gives less noise.

Table I. Performance comparison of optical amplifiers

Transmitter : Input optical multiplexed power=6.14dBm, input noise=0.924dBm and input SNR:9dB									
Optical Amplifiers (8 channels each)	**Receiver Input or Channel output**					**Receiver output**			
	Optical Power (dBm)	**Noise (dBm)**	**Gain (dB)**	**Noise Figure (dB)**	**OSNR (dB)**	**QF**	**BER**	**Eye height**	**Electrical Power (dBm)**
SSEDFA	17.9	-58.2	15.08	4.46	5.06e+001	4.83	6.18e-007	0.0109	26.99
DSEDFA	20.8	-51.9	18.8	4.76	5.03e+001	4.83	6.18e-007	**0.0064**	**29.3**
TSEDFA	22.5	-46.6	21.25	4.84	5.02e+001	4.83	6.18e-007	0.0034	**29.3**
ESEDFA	**26.7**	**-23.3**	**23.73**	**8.9**	**5.092e+001**	**3.09**	**0.000867**	**0.004**	**22**
SSSOA	7.8	-67.2	5.05	5.63	5.19e+001	3.05	0.0011	7.15e-005	17.3
DSSOA	7.86	-60.9	5.38	8.78	4.64e+001	2.37	0.0088	-0.0026	14.9
TSSOA	7.87	-55.4	4.8	11.8	4.32e+001	2.44	0.0059	-0.021	13.69
ESSOA	1	10	-100	100	1	0	1	0	-1
SSRAMAN	4.75	**-95.04**	1.33	**-1.25**	**7.39e+001**	**4.91**	6.28e-007	0.0005	26.9
DSRAMAN	2.7	-93.98	-0.66	0.76	7.10e+001	**4.91**	**4.06e-007**	0.0001	26.9
TSRAMAN	0.75	-94.2	-2.66	2.75	6.92e+001	**4.91**	4.10e-007	6.86e-005	26.9
ESRAMAN	-1.186	-70	-9.16	16.9	4.97e+001	2.14	0.0153	-0.000185	29.9

Fig 3 shows the WDM port analyzer output displays the 128 channels output of gain and noise figure in dB from minimum and maximum wavelength 0f 128 channels. Fig 4 shows the OSA output of TSEDFA eight channel input multiplexed stage. Table I. displays the input and output of transmitter, channel and receiver of EDFA, SOA and RAMAN with single, dual and tri pumping stages and also ESEDFA(8 and 128 channels), ESRAMAN(8 channels) connected individually simulated and analyzed the tabulated output values. Fig 5 shows the Optical meter output of multiplexed input and channel output. Fig 6. Shows the OSA input optical power and output noise of ESEDFA with 128 channels. Fig 6. Shows the BER output of TSEDFA with Eye diagram. Fig.7. Shows the Electrical meter output

OSA denotes the optical spectral analyzer to display the spectal characteristics of EDFA multiplexed Signal input and signal output, input and output noise and etc, BER analyzer displays the Minimum Bit error rate, quality factor, Eyeheight and Eye diagram of eight channels demultiplexed and detected by the optical receiver uses APD detector. Fig 8 shows the line chart

graph denotes the performance analysis of various parameters like gain, noise figure, optical output power, quality factor and electrical output power.

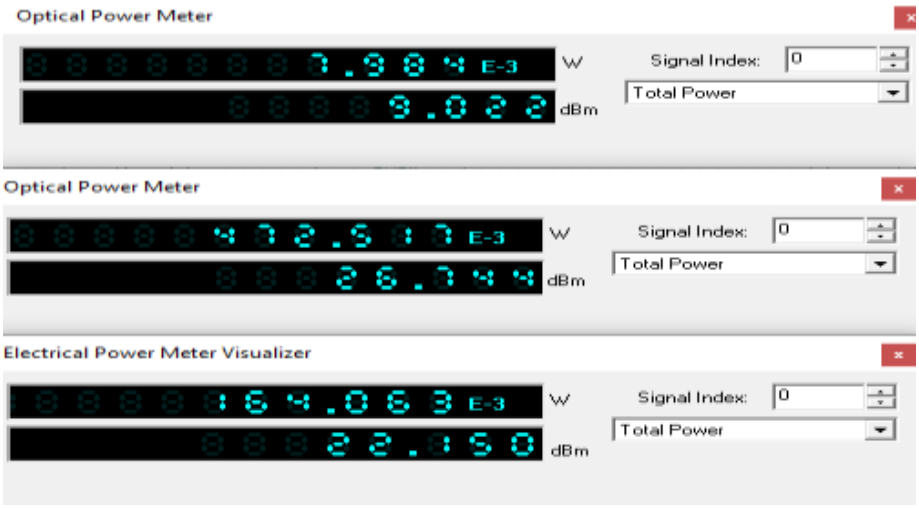

Fig 5. Optical power meter output of multiplexed input, optical Eight stage EDFA output with 8 channels and electrical power meter output of optical receiver

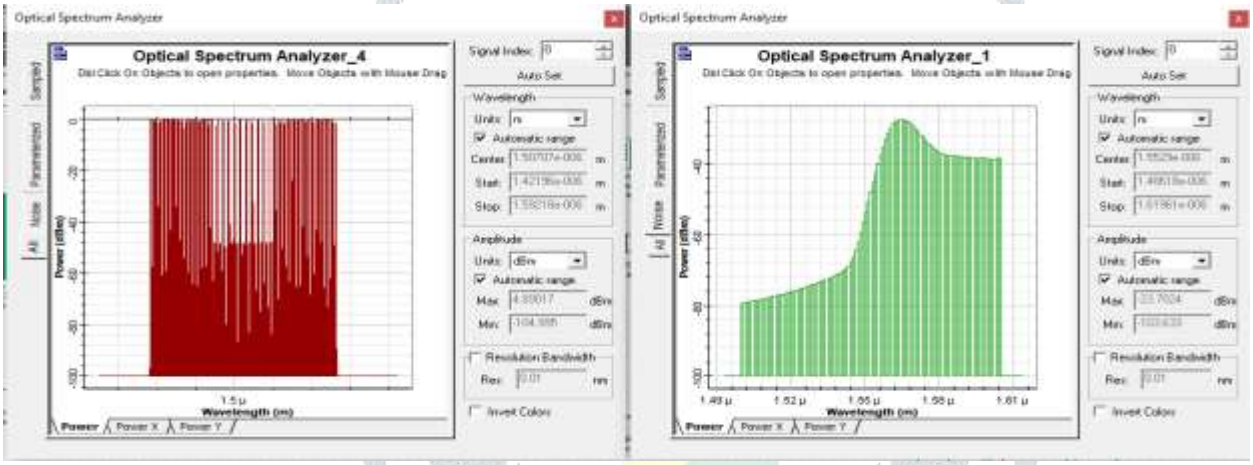

Fig..6. OSA input optical power and output noise of ESEDFA with 128 channels

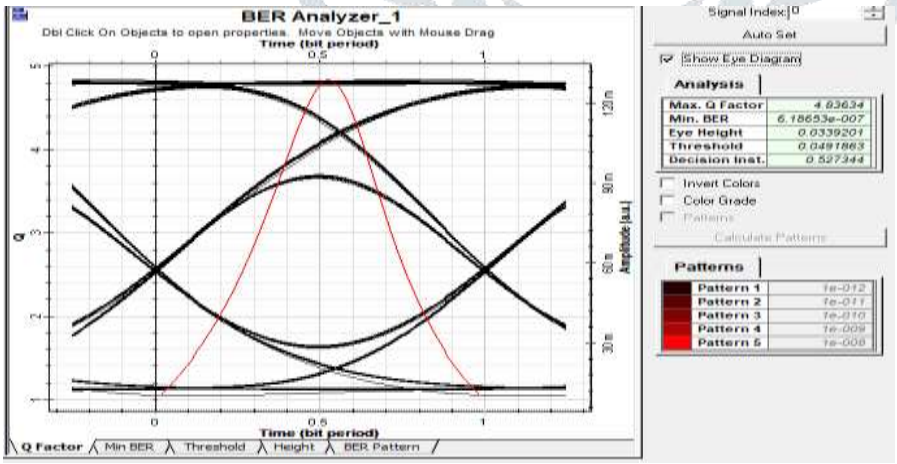

Fig 7. BER Output

Table II. Performance comparison of amplifiers with variation of number of channels

Transmitter : Input power 1mw(0dB) and Multiplexed input 20dB, Channel: OA using two stage pumping									
Optical Amplifiers	Receiver Input or Channel output					Receiver output			
	Optical Power (dBm)	Noise (dBm)	Gain (dB)	Noise Figure (dB)	OSNR (dB)	QF	BER	Eye height	Electrical Power (dBm)
ESEDFA (128 channels)	**27.15**	**-23.7**	**24.18**	**7.9**	**5e+001**	**3.116**	**0.0008**	**0.005**	**22**
ESEDFA (64 channels	26.9	-23.5	23.99	8.5	4.9e+001	3.1	0.00082	0.005	22
ESEDFA (32 channels)	26.8	-23.2	23.8	9.7	4.88e+001	3.12	0.00079	0.005	22
ESSOA(128Channels)	-1	10	-100	100	1	0	1	0	1
ESSOA (32 channels)	8.28	-31.175	-25.6	52.55	4.3e+001	2.49	0.0062	-7.4e-007	10
ESRAMAN (128 channels)	10.5	-69.55	-7.85	16.4	4.9e+001	2.3	0.0098	-0.000169	26

Table II denotes the performance comparison of optical amplifiers with the variation of number of channels line 32, 64 and 128 channels used in the transmitter with all the parameters For the analysis of optical amplifiers eight stage EDFA with 128 channels gives good result compared to all other optical amplifiers used in high gain long distance applications with many worst channels,

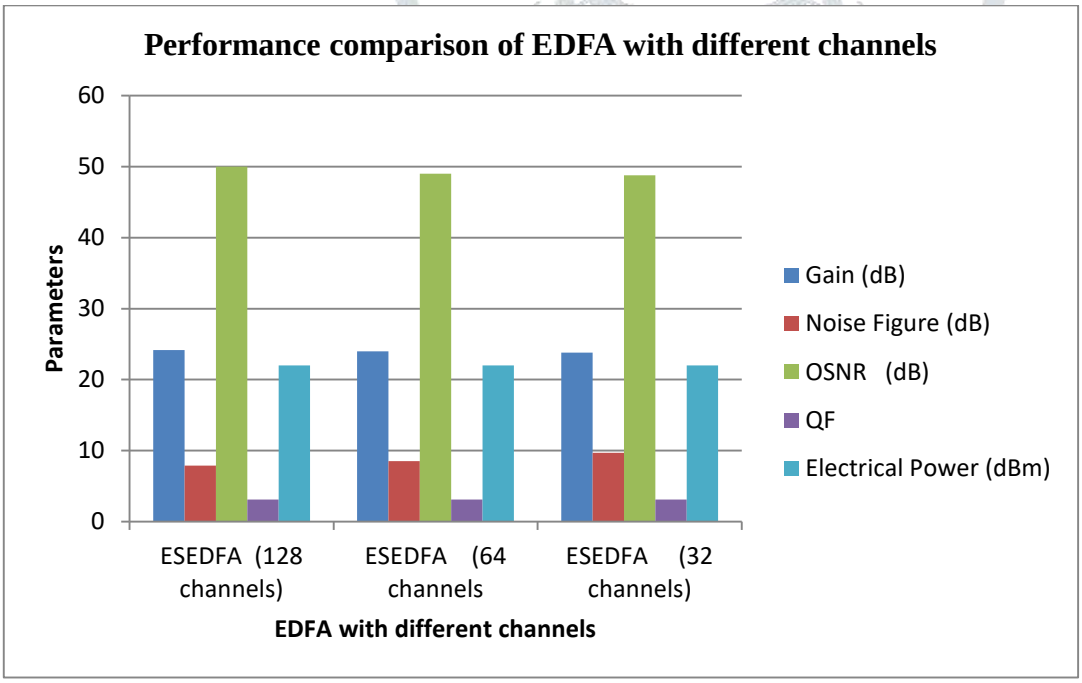

Fig 8. Performance comparison of various parameters of Eight stage EDFA

V. CONCLUSION

We summarize the models like SSEDFA, DSEDFA, TSEDFA, ESEDFA (8 and 128), SSSOA, DSSOA, TSSOA, SSRAMAN, DSRAMAN, TSRAMAN and ESRAMAN simulated separately with eight channels each of 1Tb/s data rate and multiple wavelength ranges from 1500nm to 1600nm and measured the values from the output of each model, tabulated and analyzed. From the above models ESEDFA with 128 channels shown the optimized results compared to other simulation models. The parameters Optical power, Noise, Gain, noise figure, OSNR, QF, BER, Eye height and Receiver sensitivity measured from the output of each simulation model. After analyzing all the results, ESEDFA (128) gives maximum output power and Gain and SSRAMAN gives less noise and maximum OSNR and high quality factor. This model will be applicable in telecommunication link using optical fiber in communication systems. The security provided by the PRBS codes given to the transmitter and receiver separately for that the authorized person access the information with high privacy. Moreover multiple cascaded EDFAs most

suitable for multiple wavelength optical communication repeaters in broad bandwidth long distance applications due to high gain, high transmission capacity and less noise compared to multiple cascaded SOAs and multiple cascaded RAMAN amplifiers suitable for short haul applications in fiber optic communication systems

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