PUMP SHARING HYBRID OPTICAL AMPLIFIER IN THE SCENARIO OF C+L BAND DENSE WAVELENGTH DIVISION MULTIPLEXED SYSTEM

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Abstract. In this work, we investigated C+L Band Hybrid optical amplifier (HOA) by pump sharing to provide cost efficient systems .Two different configuration of HOAs have been proposed to achieve better performance using pump sharing concept. One technique uses FBG in the system and other isolators in order to provide maximum gain and gain flatness. Further evaluation of 32 x 10 Gbps WDM system has been done in terms of maximum Gain and noise figure (NF) by utilizing different HOA. Evaluation of different techniques is carried out by analyzing Q-factor and bit error rate (BER) along with gain flatness and noise figure (NF).

Keywords:DWDM, HOA, pump-sharing, gainflatness, RAMAN-EDFA.

1. Introduction

Optical fibers have become an inevitable part of any high speed communication system due to its high information carrying ability, high bandwidth and extremely low loss. In the recent years, communication transport networks capability has been continuously increased. This has been achieved by increasing the number of optical channels per fiber. As the traffic increases, wavelength division multiplexing (WDM) used to enhance the transmission capacity by utilizing available bandwidth. Wavelength division multiplexing (WDM) has become the preferred transmission technology in transport network of long distance operators [1]. In order to support, broadband optical amplifiers like RAMAN, EDFA's are required. But the RAMAN only amplification has a serious drawback of its non linear effects [2] and only EDFA have its nonuniform gain spectrum [3] This, in turn, requires adaptable and broadband architectures which encourage the interest in hybrid amplification.

In HOA, Raman amplifier carried along with the high output power capacity Erbium-Doped Fiber Amplifier (EDFA) in order to increase efficiency for broadband applications[5]. It is striking because of its aptitude to increase the span length, minimize the impairments due to fiber nonlinearities, enhance the capacity of optical communication system[6]. In the literature, various optimization strategies are used to optimize the parameters of HOAs to enhance system performance in the terms of gain, noise figure and gain flatness. Carena et al. [7] proposed a mathematical optimization strategy to yield the performance of Raman –EDFA HOA for a desired optical signal-to-noise ratio for the span distance around 50-60 km in case of HOA while it was 30 km when only EDFA is used. As for as in mathematical model of HOA the total gain is the multiplication or addition of individual gains of cascaded amplifiers [8]. Singh et al. [9] designed a net gain mathematical model and optimizing the Raman-EDFA HOA using genetic algorithm which provides a flat gain > 17 dB with a gain variation of less than 1.5 dB and noise per channel < 7.7 dB. In this all optimization strategies two pump lasers are used one for

EDFA and one for Raman. Using two pumps makes the system complex and costly. So to overcome this S.N Padwal et al. [10] proposed RFA and EDFA using only one pump laser and concluded that the best result of HOA are obtained when EDFA used in C band and Raman in L band which make the system cost effective and attractive. Shein et al.[11] introduced Raman-EDFA HOA using a single pump. They obtain average gain of 20 dB and NF 6.5 dB by using several FBG, which make the system more complex.
So to make the system attractive , highly efficient , we proposed a Raman-EDFA HOA in C+L band by using two different pump sharing schemes 1) by using only one FBG 2) by using isolators

2. SIMULATION SETUP

2.1 Hybrid Optical Amplifier-FBG

The amplified concept of hybrid optical amplifier using fiber Bragg grating and using single wavelength pump LD, which is shared by both the amplifiers in C + L band is illustrated in fig.1. 32 Non return-to-zero (NRZ) data signals at rate $B = N \times R$ (N channels at base rate R) wavelength multiplexed signals starting from 189THz to 191.1THZ are used as inputs with 100GHz channel spacing. These signals modulated by data using PRBS each at 10Gb/s followed by NRZ line coding and MZM modulator multiplexed with WDM multiplexer, where power of each channel is initially set at -26 dBm. First, the pump LD injected into the front-ends of Raman amplifier and pump power transfer utilize Raman phenomenon to boost the signal of L band region. Here concept of single pump for gain equalization and saving cost has been introduced. FBG is used to reflect the pump signal and transmit the 32 channels for further amplification to EDF (Erbium doped fiber). So, EDF is also used the same pump. FBG has peak reflection wavelength at 1495nm and reflectivity is around 85%.C band wavelengths experience amplification in EDF and L band in DCF employing only one pump in order to obtain flat spectrum.

HOA has been realized using DCF due to its maximum Gain ability at 22um^2 effective area.EDF with 10 m length getting drive from FBG and counter pumped by residual pump operated at 1495 nm.A 32×10 Gb/s WDM system is used to analyze the Gain and noise figure of proposed HOA for different wavelengths.

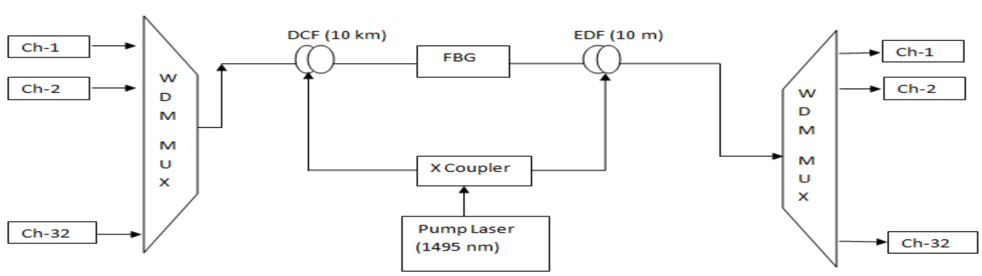

Fig. 1. System setup of HOA-FBG in 32 channel DWDM system

2.2Hybrid optical amplifier-isolator

Figure2 depicts the realization of HOA using isolators due to its ability to transmit signal in only one direction and block the other one in order to mitigate the effects of ASE. External pump is used to amplify the signal and

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operated at 1495 nm. In this setup also 32 Non return-to-zero (NRZ) input data signals at rate $B = N \times R$ (N channels at base rate R) wavelength multiplexed signals starting from 189THz to 191.1THZ are with 100GHz channel spacing. These signals modulated by data using PRBS each at 10Gb/s followed by NRZ line coding and MZM modulator multiplexed with WDM multiplexer, where power of each channel is initially set at -26 dBm. DCF and EDF of length 7m Km and 14m respectively connected by inserting isolator in middle and output and amplified signal fed to WDM demux. System Specifications are given in TABLE 1.

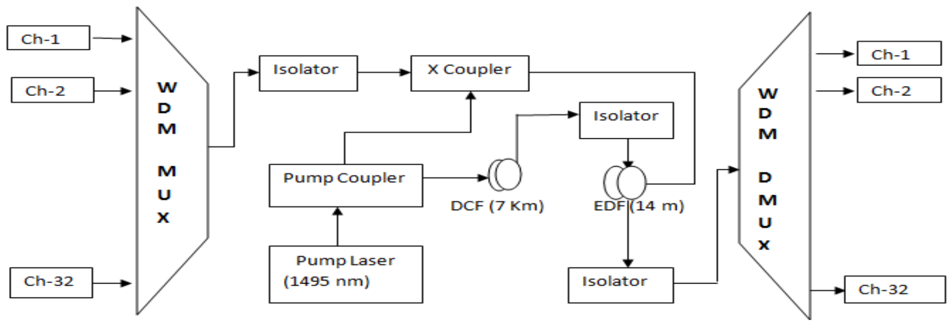


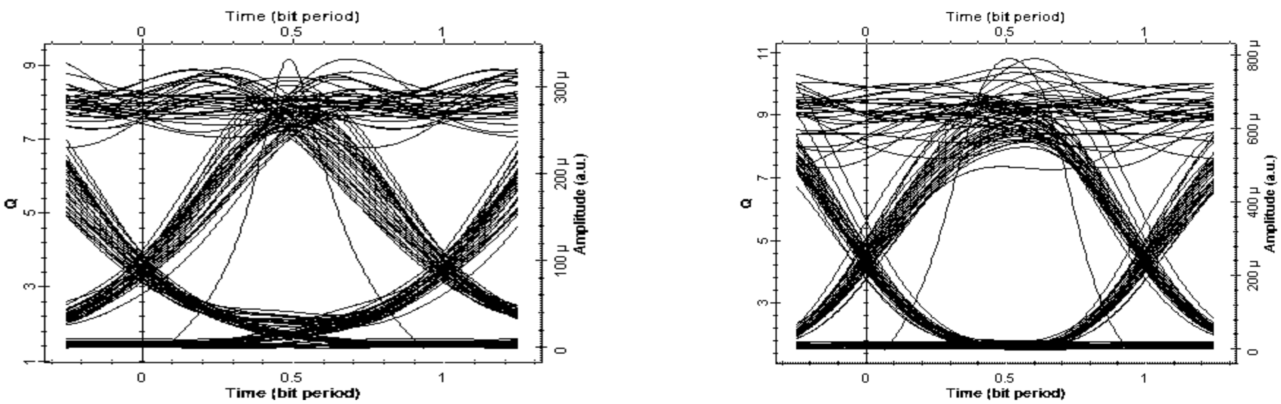
Fig. 2. System setup of HOA-ISOLATORS in 32 channel DWDM system

TABLE 1. Parameters of HOA'S

Parameter	Value (HOA-FBG)	Value (HOA-ISOLATORS)
DCF length	10 km	7 km
Effective interaction area	22 μm^2	22 μm^2
Attenuation	0.2 dB/km	0.2 dB/km
EDF length	10 m	14 m
Pump frequency	1495 nm	1495 nm
FBG frequency	1495 nm	_
Pump power	800 mw	600

3. Resultand Discussion

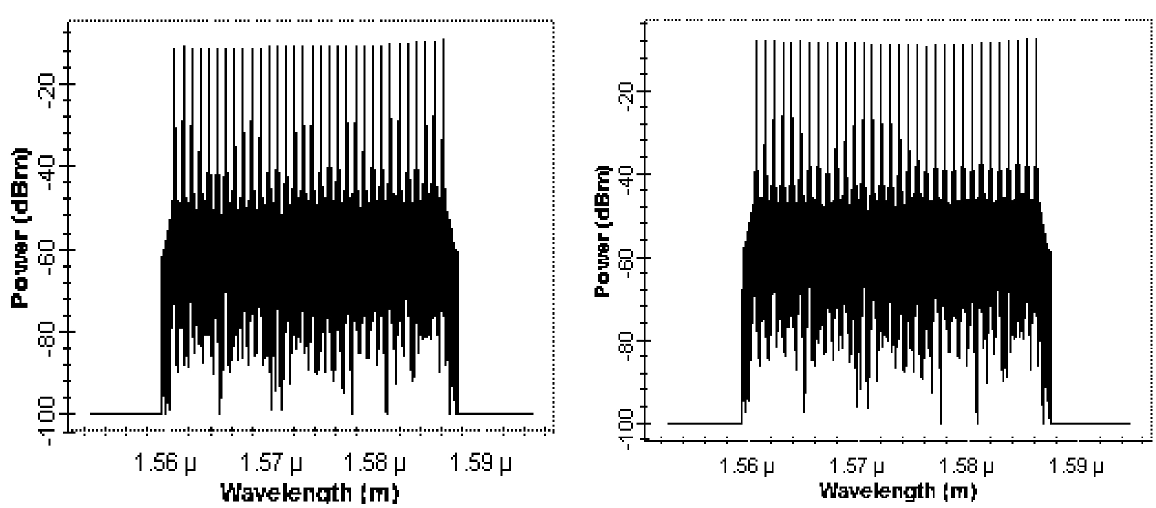
In order to evaluate the performance of proposed schemes in a transmission system, we performed eye diagram and BER measurements. 32 laser signals starting from 189THz to 191.1THZ are used with 100GHz channel spacing. These signals modulated by data using PRBS each at 10Gb/s followed by NRZ line coding and MZM modulator multiplexed with WDM multiplexer. Multiplexed stream of data then fed to both proposed HOA amplifiers differently in order to evaluate Gain variation over C/L band. Amplified signal passes through 1:32 demultiplexer, in order to evaluate bit error rate(BER) followed by BER analyzer. Evaluation of eye diagram has been done for first chanel assuming the uniform Gain at all the operating channels.Eye diagram examination carried out as depicted in fig.3, which shows the comparison among these. From eye diagram it is clearly observed that quality factor is best in scheme 2.



(a) (b)

Fig. 3. Evaluation of eye diagram for (a) HOA-FBG (b) HOA-ISOLATOR

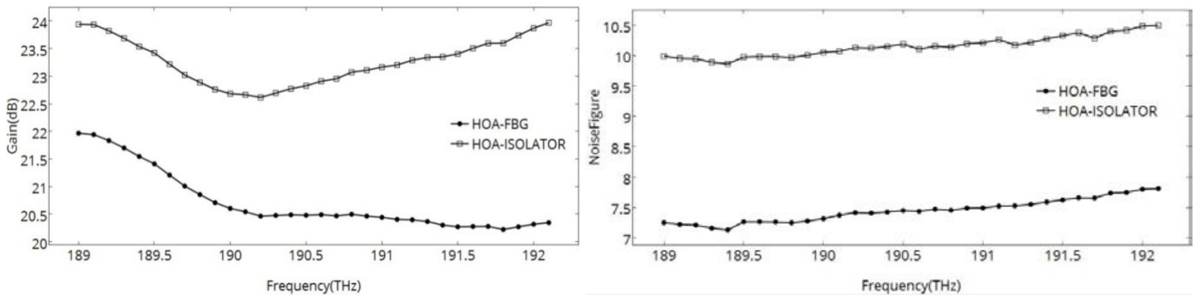
Hybrid optical amplifiers employing pump sharing for 32 WDM channels has been investigated in terms of power spectrum, gain and noise figure. Optical spectrum analyzer allows calculating optical signals in the frequency domain. It can display the signal intensity, power spectral density, phase, group delay and dispersion for polarizations X and Y for both the schemes as depicted in fig.4. Power spectrum of all the channels is observed and it has been observed that spectrum of all the channels in C and L band amplified with uniform gain using proposed schemes.



(a) (b)

Fig. 4. Optical spectrum analyzer for (a) HOA-FBG (b) HOA-ISOLATOR

Further study and investigation proceeded to evaluate performance of proposed HOAs in terms of overall Gain and noise figure in C/L band system and then compare the performance of both the schemes on the basis of gain and noise figure.The performance of proposed HOAs in terms of overall Gain and noise figureis illustrated in Fig. 5.



(a) (b)

Fig. 5. Variation of (a) Gain (b) NF (noise figure) over channel frequencies

From the graphical representation in Fig.5 (a), (b), it is clearly seen that hybrid optical amplifier incorporating FBG provide maximum Gain and Gain flatness. Reported values of Gain from the aforementioned schemes come out to be 23.16dB and 20.33dB in case of HOA-FBG and HOA-ISOLATOR respectively and noise figure are 7.4dB and 10.1 dB.

4. **CONCLUSION**

We successfully presented different hybrid optical amplifiers(HOAs) using FBG and Isolators for 32x10Gb/s WDM system by sharing laser pump in order to obtain maximum Gain with Gain flattening and minimum noise figure and concluded that HOA-ISOLATORS exhibit maximum Gain of 23.2dB and 10dB noise figure with 1.3dB Gain flatness. While HOA using FBG provide Gain of 19.8dB and noise figure 7.4dB with 4.7dB Gain flatness. Both the configuration tested by analyzing BER at receiver after demultiplexing. These results has been carried out withoutusing any gain flattening techniques, which is a cost effective solution.

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