Performance Analysis Of An Ultra High Capacity 1 Tbps DWDM-RoF System For Very Narrow Channel Spacing

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***Abstract*— A RoF system can further be enhanced by incorporating the dense wavelength division multiplexing (DWDM) technique for bandwidth utilization and ultra high speed communication. In this paper the model for a high speed of 1Tbps, a 40-channel DWDM-RoF system has been designed and simulated where each channel carries data at a rate of 25 Gbps. The performance of and erbium doped fiber amplifier (EDFA) and semiconductor optical amplifier (SOA) for the system has been compared for extremely narrow channel spacing of 0.1 nm, and 0.2 nm at different transmission distance. The Q-factor and optical signal to noise ratio (OSNR) values have been reported for different cases and it is observed that SOA performs linearly and better than EDFA when employed as post amplifier.**

Keywords—ROF; DWDM; SOA; EDFA; OSNR.

I. INTRODUCTION

RoF was first proposed and demonstrated in 1990 by Cooper et al [1]. RoF systems have attracted much consideration latterly because of showing low loss and wider bandwidth [2]. RoF technology has drawn much interest for enhancing the capacity and mobility of high-speed wireless data transmission for the merging of wireless access systems with optical systems [3]. RoF is a state-of-the-art technology in which, light is modulated with radio frequency (RF) signals and then transmitted over an optical fiber to promote transmission as well as wireless access. It transmits RF signal between a central station (CS) and a base station (BS) and from the base station the signal is wirelessly transmitted to different users. RoF systems have surpassing capacity, larger bandwidth, enhanced coverage, reduced attenuation losses and better immunity to RF interference [4]. The burst in demand for network bandwidth is huge and for exploiting the higher band width of optical systems, multiplexed systems are favored for transmitting large information on a single fiber. DWDM is a multiplexed system with channel spacing less than or equal to 200GHz [5]. A signal-to-noise-and-distortion ratio (SNDR) has been investigated considering fiber dispersion and the results showed that the SNDR was adequately improved by EDFA in the noise-dominant case [6]. Normally a single fiber can import information in a single direction but with WDM it is possible to use a single fiber for two-way communication using distinct wavelengths. DWDM couples different wavelengths to be sent over the fiber optic network, thus utilizing bandwidth and maximizing total data. Thus, DWDM based RoF are aptly suitable for broadband wireless networks due to the capability of supporting huge number of distributed antenna stations . A cost competent 16 Channel DWDM-RoF link using SOA-MZI frequency up-conversion scheme has been proposed [7]. Multiplexing different types of data over optical wavelengths is an effective approach which can make long distance high data rate transmission possible. Two optical single side band configurations for RF transmission of data have been suggested established on the arrangements that have been created for baseband digital data transmission [8]. High speed RoF system that can carry large amount of data over a single fiber is the need of the hour. In this article, a 40 channel DWDM-RoF system is proposed for a data rate of 25 Gbps per channel. The performance of the system is analyzed at different transmission ranges for various extremely narrow channel spacing and a comparison of SOA and EDFA amplification has been done for the system. The orientation of this paper is as follows: Section 2 contains the model description, Section 3 discusses the result and model analysis, Section 4 concludes this paper.

II. MODEL DESCRIPTION

In this work, a DWDM-RoF system is designed, simulated and analyzed using OPTI-SYSTEM^{TM} 11 simulator by Optiwave. The system consists of a linear multimode fiber, a transmitter and an optical receiver. The fiber parameters used in the system model are as given in Table 1.

Table 1. Fiber parameters.

Attenuation	2.61 dB/km
Dispersion	-100 ps/nm/km
Dispersion slope	0.5 ps/nm^2/km
Spectral width	0.38 nm
Modal bandwidth	1324 MHz.km

Transmitter consists of 40 channels and in each channel; the digital information signal is merged with radio signal of 10 GHz using the power combiner. Further the electrical signal is

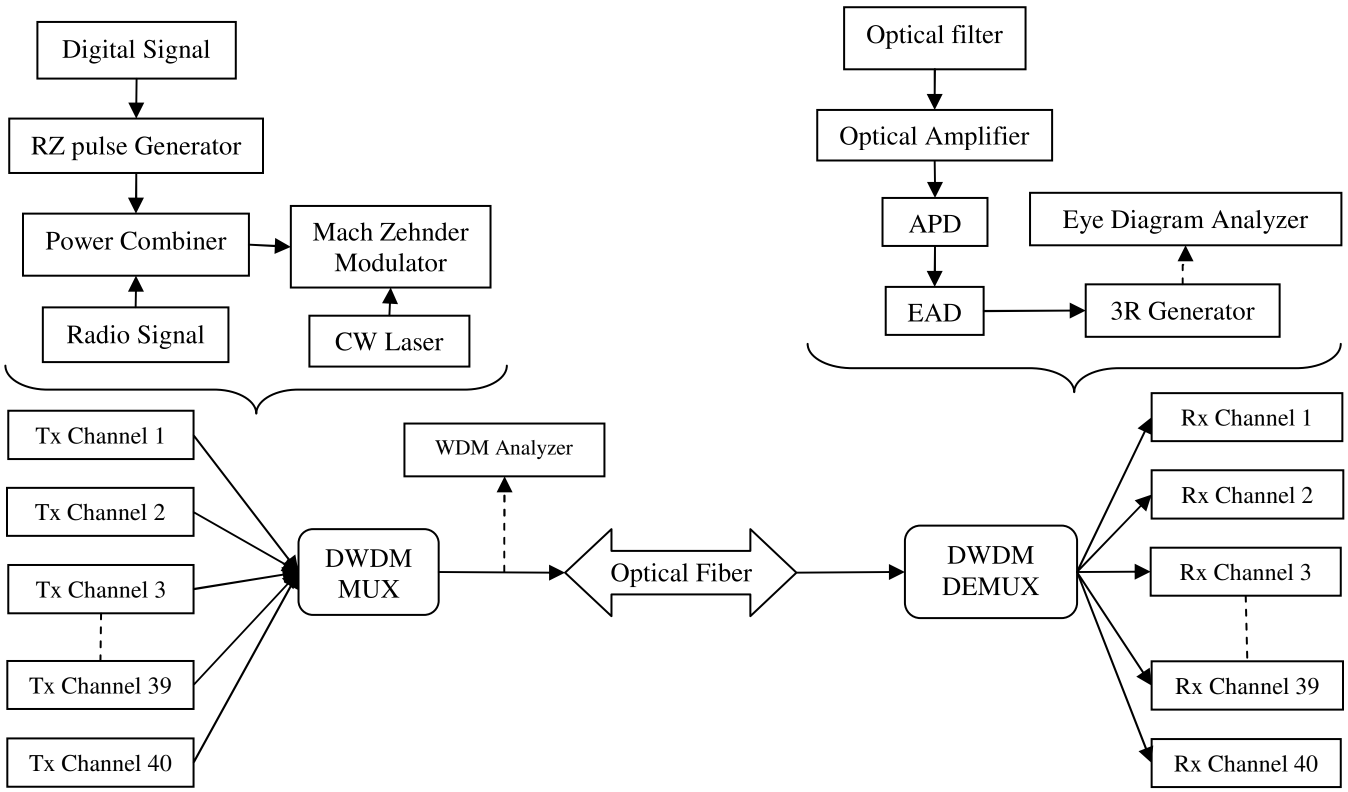


Fig. 1 Basic DWDM-RoF system.

modulated with an optical signal generated by a CW laser using Mach Zehnder modulator. 40 modulated optical signals get multiplexed with a DWDM multiplexer for different narrow frequency spacing. Then the multiplexed signal is transmitted through a multimode fiber for various transmission ranges. DWDM-RoF system is depicted in Fig. 1.

The frequency ranges used here are **a)** (1549.1-1553) nm **b)** (1546.02-1554) nm. The simulation parameters are given in Table 2.

Table 2. Simulation Parameters.

Operating Wavelength – 1550 nm
Bit rate – 25 Gbps
Sequence length – 128 bits
Samples/bit – 64
DWDM channel spacing – 0.1 nm, 0.2 nm
Capacity – 40-channel, 25 Gbps
CW Laser Power – 300 mW
Laser Linewidth - 5 MHz
Extinction ratio - 30 dB
Dark Current - 10 nA
Ionization ratio - 0.9

On receiver side, the received optical signal is first demultiplexed with a DWDM demultiplexer and then single channel signal is first pass through optical low pass filter to filter out high frequency noise signal. Further the weak filtered optical signal is amplified with a post optical amplifier (EDFA or SOA). The amplified optical signal is the converted into electrical signal with APD photodetector followed by an electrical amplitude demodulator (EAD). For analysis, the information signal is regenerated by 3R Regenerator and the Q-factor and eye diagram are observed by using Eye Diagram Analyzer. The focus of this paper is to analyze system performance due to post amplification on each channel for different wavelength spacing.

III. RESULTS AND DISCUSSION

Eye diagram analyzer displays multiple traces of a modulated signal to produce what we know as an eye diagram. An open eye pattern corresponds to a minimal signal distortion of the signal waveform due to ISI and noise appears as a closure of the eye pattern. A 40 channel DWDM-RoF system is designed for 25 Gbps per channel. For narrow wavelength spacing the impact of EDFA and SOA is analyzed in terms of OSNR, Q-factor and eye diagram for different transmission distances. The value of Q-factor represents the quality of signal. The OSNR is used to predict system impairment due to narrow channel spacing.

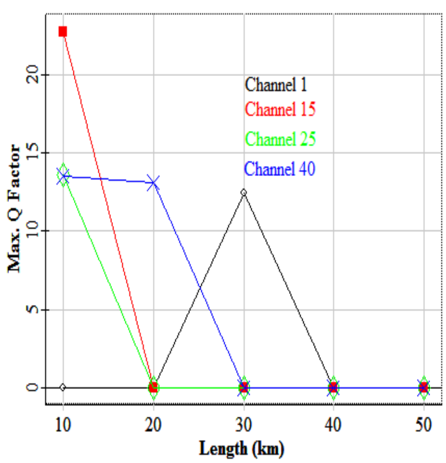
a) For 0.1 nm wavelength spacing (1549.1 nm - 1553 nm):

Fig. 2 show the power values obtained after multiplexing for 0.1 nm wavelength spacing. The maximum signal power is at channel 11 and the minimum signal power is at channel 15.

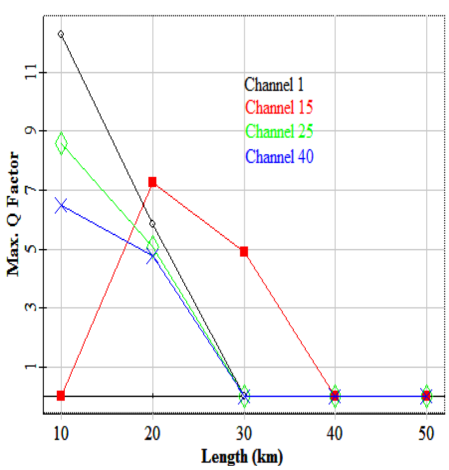
The maximum OSNR is at channel 38 and the minimum SNR is at channel 33.

	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
Min value	21.147595	18.169896	-0.11951379
Max Value	21.415595	21.360704	3.1216062
Total	37.280617	36.707031	
Ratio max/min	0.26800035	3.1908078	3.1908078
	(THz)	(THz)	(THz)
Frequency at min	193.35212	193.06573	193.12791
Frequency at max	193.40201	193.16524	193.06573

Fig. 2 WDM Analyzer results after multiplexing.



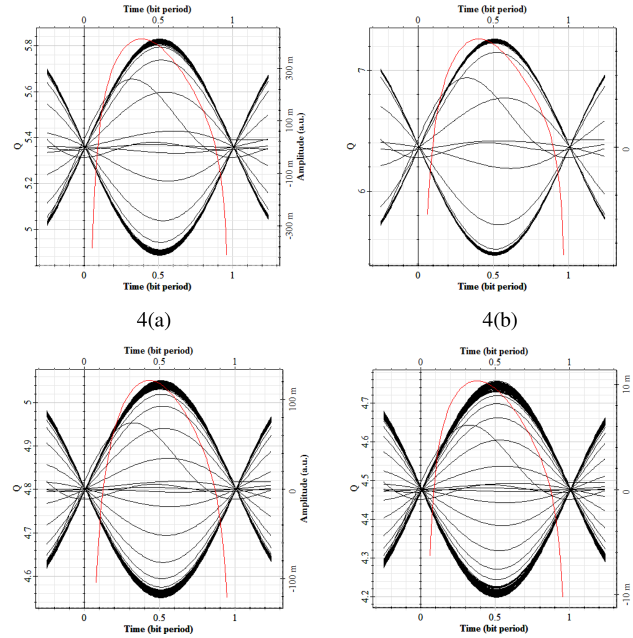
3(a)



3(b)

Fig. 3 Max. Q factor achieved for different transmission range (a) with EDFA (b) with SOA.

The comparison between Q-factor achieved with EDFA and SOA for different transmission ranges is shown in Fig. 3(a), 3(b). The Q-factor obtained at Channel 1, 15, 25 and 40 in case of SOA is better than EDFA for 0.1 nm wavelength spacing. The SOA based system able to perform linearly as compared to EDFA based system as shown in Fig. 3(a) and 3(b).



4(a) 4(b)

4(c) 4(d)

Fig. 4 Eye Diagram obtained with SOA for 20 km transmission (a) Channel 1 (b) Channel 15 (c) Channel 25 (d) Channel 40.

Fig. 4(a), 4(b), 4(c) and 4(d) shows the eye diagram obtained with SOA for 20 km transmission range of Channel 1, Channel 15, Channel 25 and Channel 40. The non clear eye center at end channel represents the non-linear characteristic of fiber that is four wave mixing (FWM) effect.

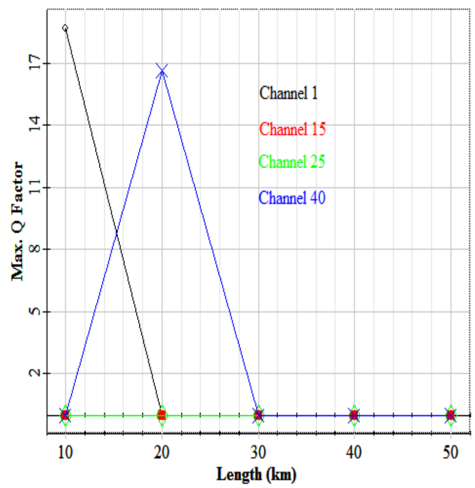
b) For 0.2 nm wavelength spacing (1546.02 nm - 1554 nm):

	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
Min value	21.126486	2.4553355	14.662236
Max Value	21.238961	6.5070779	18.690051
Total	37.188678	21.303015	
Ratio max/min	0.11247455	4.0517425	4.0517425
	(THz)	(THz)	(THz)
Frequency at min	193.78957	192.91664	193.73947
Frequency at max	193.61435	193.73947	192.91664

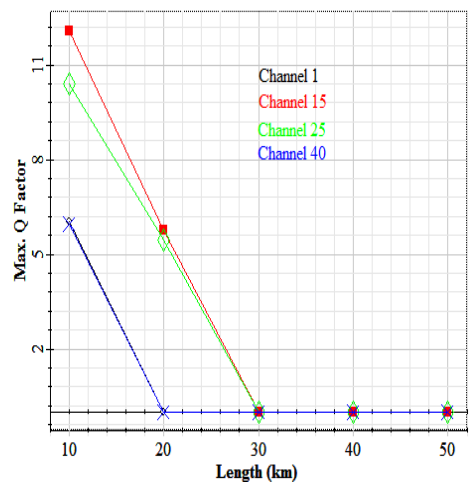
Fig. 5 WDM Analyzer results after multiplexing.

Fig. 5 show the power values obtained after multiplexing for 0.2 nm wavelength spacing. The maximum signal power is at channel 12 and the minimum signal power is at channel 5. The maximum OSNR is at channel 40 and the minimum SNR is at channel 7.

The comparison between Q-factor achieved with EDFA and SOA for different transmission ranges is shown in Fig. 6(a), 6(b). The Q-factor obtained in case of SOA is better than EDFA for 0.2 nm wavelength spacing. Again SOA based DWDM-RoF system performs linearly as compared to EDFA based system.



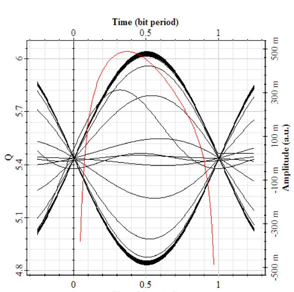
6(a)



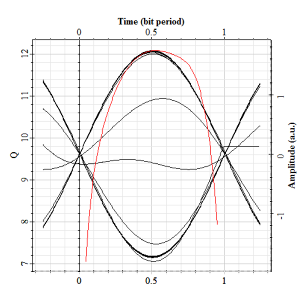
6(b)

Fig. 6 Max. Q factor achieved for different transmission range (a) with EDFA (b) with SOA.

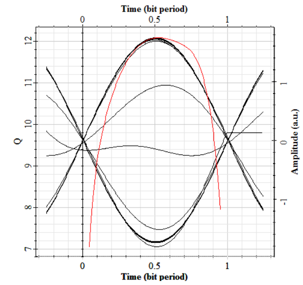
Fig. 7(a), 7(b), 7(c) and 7(d) shows the eye diagram obtained with SOA for 10 km transmission range of Channel 1, Channel 15, Channel 25 and Channel 40. In this case, the FWM effect can be seen in the eye diagram of end channel.



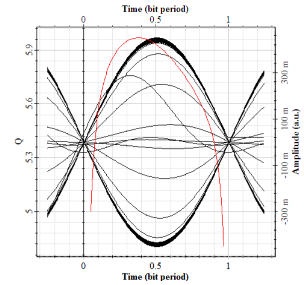
7(a)



7(b)



7(c)



7(d)

Fig. 7 Eye Diagram obtained with SOA for 10 km transmission (a) Channel 1 (b) Channel 15 (c) Channel 25 (d) Channel.

The values of Q-factor values obtained at different channel spacing and distinct transmission distances using EDFA and SOA separately are shown in Table 3.

Table 3. Q-Factor values.

Different channels spacing and transmission distance.		
(a) For 0.1 nm wavelength spacing (20km)	**EDFA**	**SOA**
Channel 1	0	5.82
Channel 15	0	7.26
Channel 25	0	5.05
Channel 40	13.08	4.76
(b) For 0.2 nm wavelength spacing (10km)	**EDFA**	**SOA**
Channel 1	18.64	6.04
Channel 15	0	12.07
Channel 25	0	12.08
Channel 40	0	5.97

From this analysis we obtained that, performance of EDFA based DWDM-RoF system is observed to degrade which is not the case in SOA based DWDM-RoF system. Also the SOA based performs linear as compared to EDFA based system.

IV. CONCLUSION

An ultra high capacity 40 channels DWDM-RoF system with extremely narrow channel spacing has been successfully designed and simulated. It is concluded that SOA based system performs better in terms of eye diagram, OSNR, signal power as well as linear in terms of Q-factor then EDFA based system. Hence it can be concluded that SOA will be more beneficial for future RoF based wireless broadband systems where an ultra high speed communication is needed along with bandwidth utilization. The performance of proposed DWDM-RoF system may further be analyzed with Vertical-Cavity SOA (VCSOA) as post amplifier.

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