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A Comparative PerformanceAnalysis of WDM DEMUX with Fiber Bragg Grating

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Abstract—**Ccommunications using Optical fiber is preferred nowadays due to its wide bandwidth, long-distance transmission capability and lightweight property compared to conventional methods. In this paper, an alternative approach for WDM receivers has been discussed. In place of traditional WDM DEMUX here Fiber Bragg Grating (FBG) with Power Splitter is used at the receiving end of a WDM channel. It is observed that using Fiber Bragg Grating with splitter has improved reception performance in compare to WDM DEMUX. The Q-factor is found to be improved up to 37.096 with 1.6000e-301 BER for 50km optical fiber length and 15dBm input power. Proposed concept and its circuit aredeveloped and tested in Optisystem-14 simulator.**

Keywords-BER, Q-factor, WDM system, WDM MUX, WDM DEMUX, FBG, Power Splitter.

I. Introduction

Q-factor and BER are one of the most important factors that limiting the transmission distance in optical communication systems. In order to transmit signals over long distances, it is necessary to have a low BER and high Q-factor within the fiber. Wavelength Division Multiplexing (WDM) is most widely used technology in optical fiber communication for efficient utilization of an optical channel. It combines a number of optical signals each having different wavelength onto a single optical fiber and then transmit them at the same time. In addition to transmission attenuation and channel noise, these combined signals often went through interference with each other and result in degrading the quality of transmission.But WDM systems are very popular for telecommunication companies because it is impractical to add an additional channel for each optical signal having specific wavelength it will increase the system cost as well. Here WDM permits them to extend the capacity of the system without laying more fibers. The capacity of a given system can be expanded simply by upgrading the multiplexers and De-multiplexers at each end without having to overhaul the backbone network.For further increasing the performance of a WDM system this paper introduces an alternative approach for a WDM receiver.

II. Bit Error Rate and Q-Factor

In communication system, the bit error rate (BER) shows the ratio of total no of error bits to the totalnumber of bits involved or received in a transmission. For example, inadata transmission if 1000000 bits are transferred and out of which 1 bit was in error then BER for this transmission will be 10^{-6}[2].Another variable i.e. Q factor tell us the quality of atransmission signal in terms of its signal-to-noise (SNR) ratio. Q-factor of a transmission varied when change in parameters such asnoise, chromatic dispersion, and any polarization or non-linear effects which can reduce the signal quality and ultimately cause bit errors. In other words, the higher the value of Q factor enhances the SNR and therefore lowers the probability of bit errors [5].

III.Fiber Bragg Grating

A **Fiber Bragg grating (FBG)** is a type of smalloptical reflectors arranged in an array. All of them constructed in a short portion of an optical fiber that reflects specific wavelengths of light and transmits all others. This is done by creating a periodic variation in the refractive index of the fiber core by exposing it to UV-Rays, which creates a wavelength-specific mirror[3]. A FBG can be used as an inlinewavelength specific optical filter or wavelength-specific reflector[3].

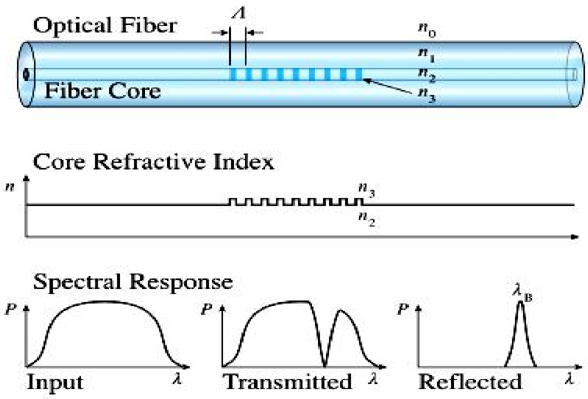

Fig.1 A Fiber BraggGrating structure,with

refractive index profile and spectral response.

The basic working principle behind anFBG is Fresnel reflection, where light traveling through different media of different refractive indicesmay undergo partial reflection and refraction at the interface.Generally,refractive index has alternate variation over a defined length. At each interface,a small amount of light is reflected and refracted forward. Finally, after large reflection from each interface light signals combines coherently with each other at a particular wavelength. This phenomenon happens when the grating period is approximately half the input light's wavelength. This is referred as the Bragg condition, and the wavelength at which reflection occurs is known as the Bragg wavelength. Light signals at wavelengths other than the Bragg wavelength, does not show much reflection property in an FBG.

Because of low insertion loss, high return loss or extinction, and potentially low-cost Optical Fiber Bragg Gratings (FBG) is used to compensate dispersion.

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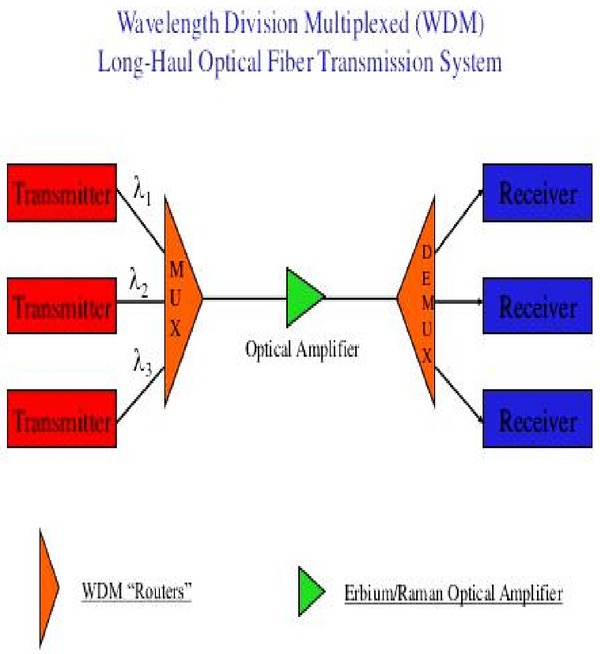
IV. WDM SYSTEM

Wavelength Division Multiplexing (WDM) is one of the most widely used method for a high capacity optical communication system. WDMcombines multiple signals with different frequencies or wavelengths in a single optical fiber. It is similar to Frequency Division Multiplexing (FDM). Instead of using Radio Frequencies (RF), WDM requires IR portion of the electromagnetic spectrum for propagating in an optical fiber. Each multiplexed IR channel is separated or de-multiplexed into the original signals by WDM-DEMUX at the destination.
WDM is used for gaining high capacity channel and effectively utilization of the bandwidth. For improving the transmission quality in WDM system, dispersion compensators and amplifiers are required.The first WDM systems had combined only two optical signals. Modern systems can effectively control up to 160 signals [3].



V. SIMULATION MODEL

For the simulation work, Optisystem Simulation software is used. In transmitter section 8-bit User Defined Bit Sequence generator is used along with NRZ coding and Mach-Zender Modulation technique. Non-return zero (NRZ) pulse generator is used to convert a digital signal into electrical signal. After that modulator mixes the electrical signal with the light source input and generates an optical output signal which is then sent to the multiplexer. In this design two transmitters are used of equal channel spacing of 50GHz starting from 193.1Thz. In this transmission link design, Single Mode Fiber (SMF) is used which has an attenuation of 0.2 dB/km. Uniform Fiber Bragg Grating (FBG) is used with Power Splitter to construct the working of an ideal WDM DEMUX.

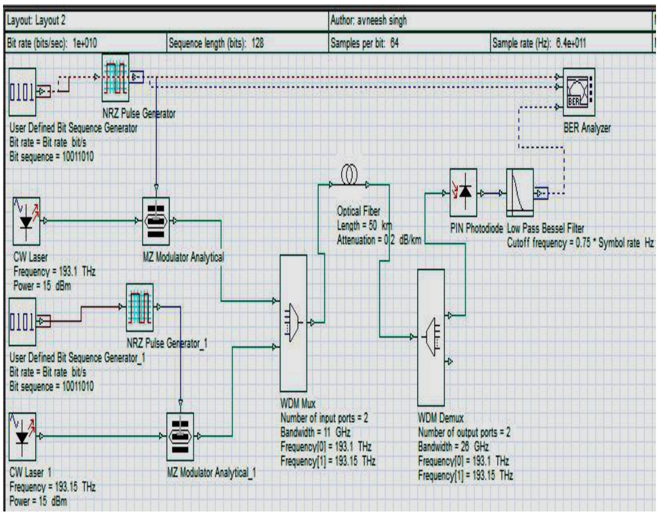


Fig. 2 WDM circuit using WDM DEMUX at the receiver end.

First a simple WDM circuit that consist of 2 input channels (193.1 THz, 193.15THz), NRZ coding, Mach-Zehnder modulators, a multiplexer, CW lasers (193.1 THz, 193.15THz), optical fiber (50Km, 0.2dB/km attenuation), de-multiplexer, PIN photo-detector, low pass Bessel filter and BER analyzer as in figure 1 starts to operate with 8-bit user-defined data (10011010), 15dBm power and at 11GHz bandwidth of WDM-MUX.At fixed 11GHz MUX bandwidth the bandwidth of WDM-DEMUX is varied from 0 to 40 GHz, It is observed that at the 26GHz bandwidth of DEMUX and 11GHz bandwidth of MUX maximum Q-factor 30.695 and minimum BER 3.2677e-207 is obtained for this circuit while observing from BER Analyzer.For different bandwidth's of DEMUX the Q-factor and BER responses of this simple WDM circuit is shown in Table 1.

TABLE1

	Data-bits	Power (dBm)	MUX Bandwidth (GHz)	DEMUX Bandwidth (GHz)	Max Q-factor	Min BER
1	10011010	15	11	0	0	1
2	10011010	15	11	5	2.5259	0.0055126
3	10011010	15	11	10	7.7081	5.6319e-015
4	10011010	15	11	15	17.367	6.9764e-068
5	10011010	15	11	20	26.219	7.8958e-152
6	10011010	15	11	25	28.780	1.8797e-182
7	10011010	15	11	26	30.695	3.2677e-207
8	10011010	15	11	27	28.826	8.852e-182
9	10011010	15	11	30	27.676	6.6508e-169
10	10011010	15	11	35	22.658	5.7697e-114
11	10011010	15	11	40	18.916	4.1103e-080

Table 1 shows when using WDM DE-MUX at receiver maximum Q-factor 30.695 & min BER 3.2677e-207 is obtained at DEMUX Bandwidth 26 GHz.

However, ideally the Bandwidth of WDM MUX and DEMUX should be same but in practical scenario Trains of Data bits while traveling through a long distance(50Km)

optical fiber undergoes with noises, dispersion & attenuation, as a result the bandwidth of these incoming Data bits widens. Hence at the receiver's end, the receiver (i.e. De-mux) should be tuned at wider bandwidth than transmitter for reception of all the data bits correctly.
The eye diagram & Q-factor response of this circuit at 26GHz De-mux bandwidth is shown below.

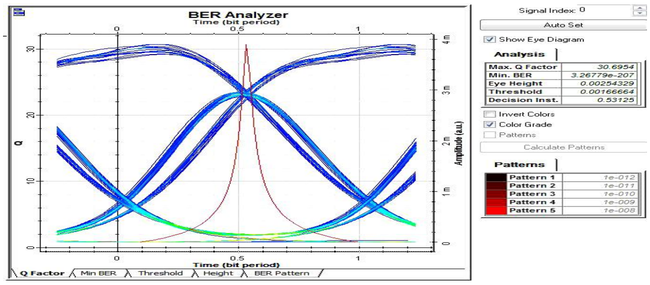


Fig. 3:BER Analyser output .

Since High Q-factor and low BER is required for a good communication through an optical fiber network.To obtain these requirements for a good communication, receiver's performance plays an important role. An ideal receiver should not add any additional noise and attenuation in the received data bits.
For this purpose, to increase receiver's performance further in a WDM network this paper introduces an alternative approach to a WDM DEMUX at receiver'send. This approach utilizes Uniform Fiber Bragg Grating(FBG) for their property of reflection to a specific frequency.
In this approach, an incoming optical signal at the receiver is split into two halves of equal powers, by using Power Splitter component from Optisystem library. Next, these split signals are separately filtered by Uniform Fiber Bragg Grating(FBG) having frequency of reflection equal to individual Channel frequency (i.e. 193.1 THz, 193.15THz etc.).
The schematic of the modified circuit is given below:

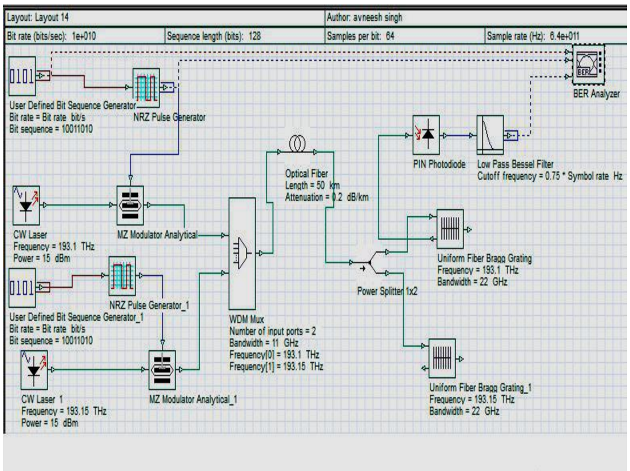


Fig. 4 WDM circuit using Fiber Bragg Grating with Power splitter at the receiver's end

Similar to previous circuit here all the working environment of the transmitter section is same only receiver side has modifications. At the receiver side Uniform FBG is used and similar analysis is performed by varying FBG's Bandwidth at a fixed operational bandwidth of transmitter section i.e. WDM MUX.
For different – different bandwidth of Uniform FBG, the Q-factor and BER responses of this modified WDM circuit is shown in table II.

TABLE 2

	Data -bits	Power (dBm)	MUX Bandwidth (GHz)	FBG Bandwidth (GHz)	Max Q-factor	Min BER
1	10011010	15	11	0	0	1
2	10011010	15	11	5	0	1
3	10011010	15	11	10	1.706	0.03591
4	10011010	15	11	15	22.316	1.2482e-110
5	10011010	15	11	18	24.752	1.2568e-135
6	10011010	15	11	21	33.334	5.8445e-244
7	10011010	15	11	22	37.096	1.6000e-301
8	10011010	15	11	23	34.407	9.8879e-260
9	10011010	15	11	30	26.401	6.4683e-154
10	10011010	15	11	35	22.121	9.6536e-109
11	10011010	15	11	40	24.145	4.1482e-129

Table 2 shows when using FBG in place of WDM DEMUX maximum Q-factor 37.096& min BER1.6000e-301is obtained at FBG Bandwidth 22 GHz. The variation of Q-factor and BER is shown in Fig 5 eye diagram.

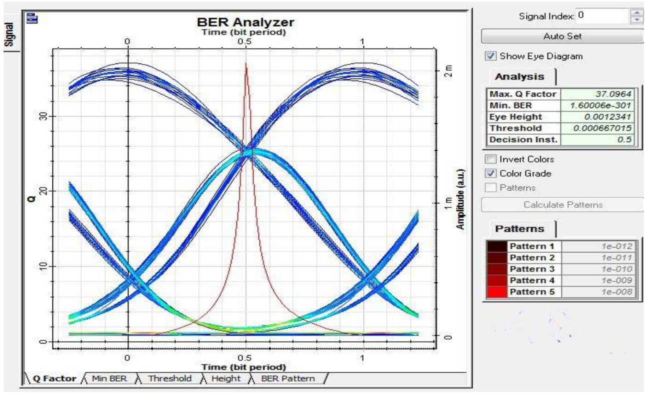


Fig. 5BER Analyser output

VI. RESULTS

On changing the bandwidth of receivers the Q-Factor and min BER vary because increasing the bandwidth adds more noise to the channel from adjacent channels and environments.
When considering highest channel capacity, the max Q-factor and min BER is found to be 30.695 & 3.2677e-207 respectively at 26GHz bandwidth in case of WDM DEMUX.
And in case of Uniform FBG Q-factor and min BER is 37.096& 1.6000e-301 respectively at 22GHz bandwidth,

which is much better than DEMUX performance for 50km fiber length in 15dBm input power.

Hence, FBG saves channel bandwidth equals to the difference in the bandwidth of WDM DEMUX and FBG i.e. 26-22=4 GHz.

VII. Conclusion

In this paper, a Wavelength Division Multiplexing (WDM) system using FBG is introduced. This circuit is designed for 50km optical fiber length. At 22 GHz receiver's bandwidth min BER 1.6000e-301 with a high Q-factor of 37.096 is achieved.

This observation offers a huge advantage in terms of cost, results, reliability and processing effort. Numerical simulation shows a noticeable improvement of the system BER and Q-factor after implementation of the suggested processing operation on the received optical signals at fixed transmission bandwidth. This work can provide a low cost modified WDM-DEMUX device with increased channel capacity and reduced bandwidth of each channel, as a result more channel can be multiplexed within the saved bandwidth.

The operation of optical transmission networks will be most important features in the near future to serve the ever-increasing demand for Bandwidth in Internet Protocol (IP) networks.

VIII. Future Aspects

Other parameters of FBG such as no. of Grating, Grating Interval, Grating length can be further varied for improvement in performance of an FBG based DEMUX or other devices.An array of FBG, where each FBG islocated at different geo-locations andeach having different reflection frequency and connected to a common WDM channel. Since FBG has frequency specific response, A Datastream can be sent separately to a specifically chosen FBG by tuning the transmitter carrier frequency equal to reflection frequency of that FBG located at a distant place.

In future, this solution can be utilized for improving Internet Routers, which are used for guiding an Internet Data Packet between different Client or locations.

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