A Simulation Approach in Optical System for Dispersion Compensation Using a FBG

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Abstract: *Now a day's communication is major research section. We are work to transmit data in high distance without any noise so we are design different type of system. Optical fiber transmission systems are designed, analyzed and simulated to get long length of fiber. The performance of optical fiber on optical signals is characterized by chromatic dispersion, background*

Key Words: *The main constituents of an optical fiber communication link are information sources, optical transmitter, optical connectors, cabled optical fibers, optical amplifiers, passive or active optical devices and optical receivers. One of the most important elements in an optical fiber link is cabled fiber.*

1. INTRODUCTION:

Communication is major research section. We want to transmit data in high distance without any noise so we are design different type of system. Optical fiber transmission systems are designed, analyzed and simulated to get long length of fiber. The performance of optical fiber on optical signals is characterized by chromatic dispersion, background loss, polarization mode dispersion (PMD) and nonlinearity. Through an optical fiber, transmit information from one place to another by transmitting light pulses; this method is called fiber-optic communication. Electromagnetic carrier wave is modulated to carry information. In the 1970s first developed, fiber-optic communication systems have transformed the telecommunications industry and have played an important role in the advent of the Information Age. Chromatic dispersion and polar mode dispersion occurs in single mode fiber (SMF). In optical system dispersion can be compensated by also using erbium doped fiber amplifier (EDFA). Chromatic dispersion broadening the pulse of optical fiber and causes inter symbol interference (ISI). A preferable solution is that we can use Dispersion compensating fibers and they can provide broadband dispersion compensation. But there are several drawbacks of using dispersion compensating fiber, such as high nonlinearity and high insertion loss.

A. Fiber Bragg Grating

FBG is a type of common single mode fiber that is like a grating. The Bragg conditions satisfied propagated light, in a FBG core is resonated by grating structure and reflected wave. The gratings distance specifies the reflected wavelength, so that, from transmission spectra reflected light is removed in Bragg wavelength. A fiber Bragg grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others. This is achieved by creating a periodic variation in the refractive index of the fiber core, which generates a wavelength specific dielectric mirror. A fiber Bragg grating can therefore be used as an inline optical filter to block certain wavelengths, or as a wavelength-specific reflector.

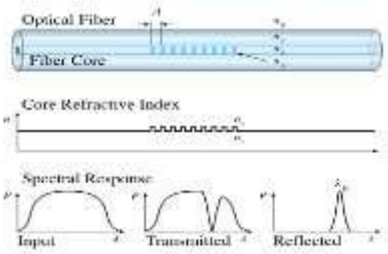


Fig. 1.1 FBG

This instrument performs some operations like reflection and filtering with high efficiency and low loses. Some variations are created in period of gratings (as result variations along the grating in a chirp FBG. There is a delay occurred in wavelength with different time intervals, along the axis the period of grating changes, different wavelengths are reflected by different parts of grating. In a communication link chromatic dispersion can be compensated and compression in incident pulse occurred finally. Most important reason to use chirp FBGs than all other suggested types, are cost efficiency and low internal lose nonlinear effects.

Dispersion compensation is the process of designing the fiber and compensating element in the transmission path minimize the total dispersion. In other sentence dispersion compensation can be referred as the control of overall chromatic dispersion of the system. dispersion needs to be compensated by various dispersion compensating techniques. They are usually one of two types. The first type is DCF or Dispersion Compensating Fiber and the second type is FBG or Fiber Bragg grating.

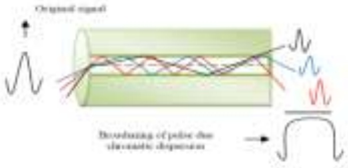


Fig 1.4. : broadening of pulse due to chromatic dispersion

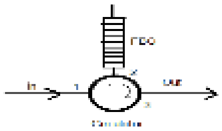


Fig.1.5: Dispersion

2. BACKGROUND & LITERATURE SURVEY

Simulation of a transmission system to compensate dispersion in an optical fiber by chirp gratings
Author: S. O. Mohammadi, Saeed Mozaffari and M. Mahdi Shahidi [4]
In this work, we simulated a communication system in information transmission. As soon as we observed dispersion, we decided to compensate it in order to receive data in receivers as they are. To this purpose, we employed chirp FBG and simulated it. Also, it can be obtained that increase in grating length leads to decrease in pulse extension, and also increase in its power. By considering the power of the output spectrum of modulator and the pulse shape in that point, the most suitable length which equals to 6 mm can be resulted. Apodization function is not very effective in FBG reflected spectrum, although the best shape is Tanh function because of its grating length. Finally, it can be understood that the pulse was broadened and its power increased as a result of the increase in chirp parameter which is the best amount.

A Simulation study on DCF compensated SMF using OptSim
Author: Sujith, Gopchandran[6]
"In this report an analysis of the performance limitations of SMF due to SPM effect is discussed. With the aid of OptSim simulation software a DCF has been employed with proper variation in length to tackle the nonlinear effects in the transmission system. Better performance was shown when a combination of SMF length 85km and DCF length 15km was chosen. The BER and Eye diagram technique have been used for evaluating the system performance."

Comparing FBG and DCF as dispersion compensators in the long haul narrowband WDM systems
Author: Gnanagurunathan, Rahman, F.A. [7]
In this paper proposed evaluated the chromatic dispersion compensation for a long-haul WDM transmission. A 4 channel optical network was modeled, simulated and analyzed at a 600 km distance using two chromatic dispersion compensators i.e. fiber Bragg grating (FBG) and dispersion compensated fiber (DCF). Subsequently the modulation scheme and also the traffic load are varied to determine the robustness of the compensators to sustain the changes imposed on the light wave optical system. This analysis concludes that the grating device seems to be the better compensating solution for the long haul narrowband transmission.

Optimization of Apodization profile of chirped fiber bragg grating for chromatic dispersion compensation
Author : Naqib Muhammad Faiyaz, Asif Iftekar Omi and Mohammed Faizal[3]
In this paper optimization of hyperbolic tangent profile is proposed for FBG as dispersion compensator. A suitable profile can be chosen for various parameters of FBG by coupled mode theory equations which can play more significant role in dispersion compensation. Many profile parameters have been varied as well as Apodization factor parameters and tabulated the data. This analysis has enabled us to choose the appropriate hyperbolic tangent profile to achieve low dispersion as low as possible. It is shown that a optimized profile for FBG can compensate for chromatic dispersion up to 2237 ps/nm at 1550nm. By varying the coupling profile, the dispersion in SMF can be managed efficiently.

Chromatic Dispersion Analysis in a Network WDM-PON Using FBG Compensators
Authors : P. X. Zumba, P. T. Cabrera, and E. J. Coronel [1]
In this paper, WDM is considered as the solution to the future on optical transmissions, there exist variations that allow an increase of performance in the network but keeping the Wavelength Division Multiplexing principle. However, the WDM-PON network transmissions may be affected by the Chromatic Dispersion (CD), found over long linked networks. One of the methods developed to solve the effects caused by CD is shown in this paper, specifically the application of post compensation using Fiber Bragg Grating (FBG) implementing a topology to be simulated on Optisystem and then analyze the result obtained under different parameters of link distance and fiber type. a topology WDM-PON to visualize the effects of the dispersion Over a fiber optic bay, and as these are reduced with the use of FBG post compensators. The simulation has determined the expected results.
It was verified that the distance affects the Quality of the transmission to the greater the chromatic dispersion, Although if we refer to the theory, this would be obvious, since The dispersion is measured in ps / nm / km indicating an increase For each kilometer, this dispersion value being plus the To be increased, different for each type of Fiber, where depending on the needs, should be governed by ITU standards to choose the most suitable fiber type.

Parameters	Paper 1	Paper 2	Paper 3	Proposed work
Data bit rate (Gbps)	10	10	40	10
Length of SMF (km)	10	75	600	80
Dispersion (ps/nm/km)	17	17	16	16.75
Dispersion slope(ps/nm 2/km)	0.050	0.08		0.075
Modulation format	NRZ	NRZ	NRZ	RZ
Attenuation index(dB/km)	0.20	0.25		0.20
Effective refractive index	1.45	2.5		1.45

Table 2.1: Literature Table

3. PROBLEM FORMULATION

In the base paper the distance is only 10 km. This means that the entire optical transmission process is to be repeated which will make the transmission system more complex and costlier. Thus distance between two optical stations must be increased within the suitable range of communication distractions and comparatively low losses.

4. PROPOSED ALGORITHM & TOOLS

A. *Methodology*

1. Theoretical analysis for selective coupling profile for FBG
2. Simulation Tool (Optisystem simulator)
3. Transmission system Using FBG Without FBG
4. Transmission system Using FBG With FBG

A. Theoretical Analysis of FBG parameters

Coupled mode theory can be easily evaluated for uniform grating. For non uniform grating we have to use some evaluation methods. One of them is transfer matrix method. The coupled mode equations are the main basis of analyzing the FBG and are solved using transfer matrix method. The coupled mode equations are given as

$$\frac{dB}{dz} + i\left[\kappa_{dc} + {}^{1}/_{2}\left(\Delta\beta - \frac{d\varphi(z)}{dz}\right)\right]B = -i\kappa_{ac}^{*}F \quad (1)$$

$$\frac{dF}{dz} - i\left[\kappa_{dc} + {}^{1}/_{2}\left(\Delta\beta - \frac{d\varphi(z)}{dz}\right)\right]F = i\kappa_{ac}B \quad (2)$$

Where,

$$B = A_1(z)e^{-i(1/2)(\Delta\beta z - \varphi(z))} \quad (3)$$

and

$$F = A_2(z)e^{i(1/2)(\Delta\beta z - \varphi(z))} \quad (4)$$

In these equations, F is a forward and B is backward travelling waves, A_1 and A_2 are amplitudes of forward and backward travelling waves, respectively z is the transmission distance, k_{ac} is the ac coupling coefficient and is defined as,

$$\kappa_{ac}(z) = \frac{\pi}{\lambda}vK(z) \quad (5)$$

B. Proposed Profile

We have varied i and have optimized the value to realize the desired dispersion. Our proposed profile is given by,

$$K(z) = 4 + \tanh\left[4\left(1 - 4\left(\frac{z}{L_g}\right)^{3}\right)\right] \quad (17)$$

This profile has the highest negative dispersion value at 1550nm. The parameters used for numerical calculations are listed in the table below,

Parameters	Values
Chirp, $\frac{d\lambda_D}{dz}$	−1 nm/cm
Effective refractive index, n_{eff}	1.46
Bragg wavelength, λ_D	1550 nm
Grating length, L_g	2 cm
Fringe visibility, v	5×10^{-4}

Table 4.1: Different parameters and their values used to generate the figures

After choosing the profile the spectral characteristics of FBG is investigated and for this we have selected eight different variations for hyperbolic tangent profile and checked them to find best profile.

The reflectivity of the chosen profiles are shown in fig. below

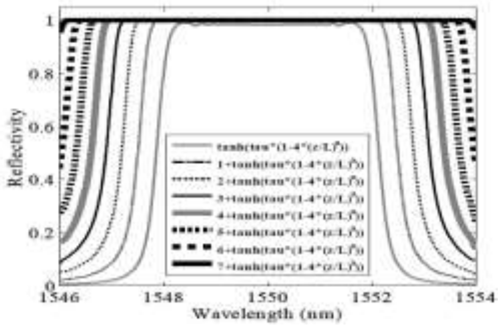


Fig4.1: Reflection versus wavelength for eight hyperbolic tangent profiles.

$$K(z) = i + \tanh\left[4\left(1 - 4\left(\frac{z}{L_g}\right)^2\right)\right]$$

i	Group delay (ps)	Dispersion (ps/nm)
0	96.94	-748.7
1	94.36	-1226
2	90	-1739
3	83.47	-2106
4	73.32	-2237
5	56.24	-2031
6	30.26	-1471
7	7.14	-632.6

Table 4.2: Group delay and Dispersion for various values of integer i

As shown in the fig when i remain within 4, the dispersion increases from almost -650ps/nm to -2200ps/nm. On further increasing i from 5 to 7 dispersion decreases and gets to as low as -632.6ps/nm for 7. According to table 2 it can be seen that when the value of i is 4 we get maximum dispersion of -2237ps/nm at 1550nm and the group delay is also fairly acceptable of 73.32 ps. And when the value of i is 2 the profile is suitable for dense WDM systems, as it has a moderate range of wavelength band and with -3660 ps/nm to -482 ps/nm dispersion. We can adjust the profile to achieve desired characteristics from FBG. We can show that FBG's with the proposed profile can be utilized to enhance the link length up to 100 km. that is the costing will be reduced considerably.

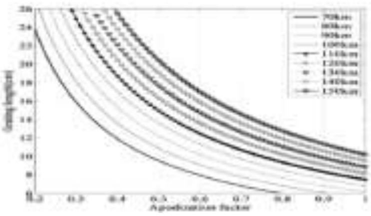


Fig 4.4: Grating length Vs Apodization factor for diff fiber link

When Apodization factor is calculated from equation 15 a graph between grating length against Apodization factor is plotted. According to fig 5 it is shown that we need longer grating for to support the FBG at longer link lengths. Tighter profile will need longer grating while weak profile will need shorter grating. Longer grating can increase the cost so we need to choose the Apodization factor wisely which depends on τ and α.

So we have found that by varying the coupling profile, the huge accumulated dispersion of SSMF's in optical fiber transmission line can be managed efficiently.

3. Optisystem simulator

OptiSystem is an optical communication system simulation package for the design, testing, and optimization of virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broadcasting systems to intercontinental backbones. Its capabilities can be easily expanded with the addition of user components and seamless interfaces to a range of widely used tools. OptiSystem is compatible with Optiwave's OptiAmplifier and OptiBPM design tools.

5. ANALYSIS & RESULTS

A. *Proposed Transmission System Analysis*

We designed the transmission system to achieve best output of optical system each system has best result. We designed firstly without FBG system which can provide communication only up to 60km without dispersion and then we used FBG and varied length of optical fiber with proposed profile and we successfully achieved length of 80km with no more losses.

Simulation of transmission system is done by using **Chirped Fiber Bragg grating** for compensation of dispersion.10Gbps data is transmitted for long distance of 80 km. The behavior of the system is defined by Q-factor and bit error rate (BER).By the proposed system the length is increased from 10 km to 80 km along with the increase in the q-factor .

The output of system1 is fed into optical fiber whose length is 80km, dispersion is 16.75ps/km/nm, dispersion slope is 0.050pm/nm2/km, and attenuation index is 0.20km. Now to get a better result or to achieve a better signal the dispersed wave goes into the chirp fiber Bragg grating. The parameters involved in chirp FBG are frequency, effective refractive index, length of grating, Apodization function, Tanh parameter, chirp function. Our Proposed transmission system show below in a figure.

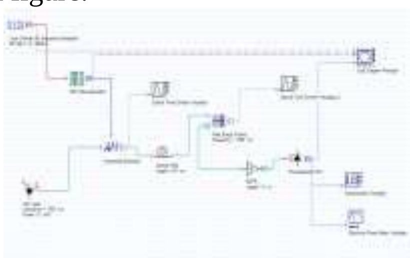


Fig.5.1: System With FBG

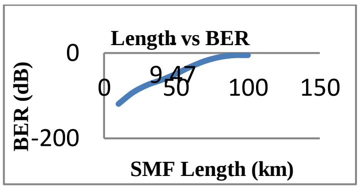


Fig.5.2: Graph of Comparison between Length of Single Mode Fiber and BER

B. Eye Diagram analysis

Below is the Eye diagram output of the base paper transmission sytem.

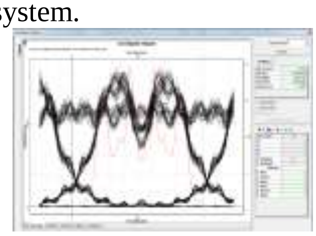


Fig 5.4: base paper system output

The final proposed system outputs are given below

Analysis	
Max. Q Factor	19.9719
Min. BER	4.8248e-089
Eye Height	0.0808518
Threshold	0.0455785
Decision Inst.	0.59375

Table 5.1: Output of proposed system

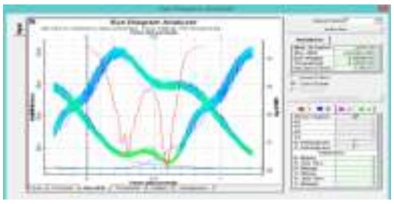


Fig 5.5 Min BER of final system

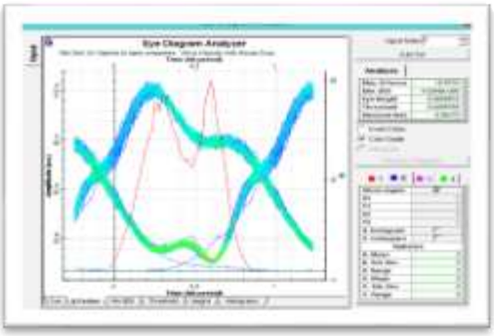


Fig 5.6 : Q factor of final system

C. Results Comparison

Parameters	Base Paper Design	Proposed Design
SMF Length	10 KM	80 KM
FBG Length	2 mm	27 mm
Q-Factor	15.61	19.97
Bit Error Rate	$1.85\ e^{-55}$	$4.82\ e^{-89}$
Eye Height	-0.00146	0.0712

Table 5.2 : Comparison of results

All below figure shows different variance result which is achieved during designing of upper figure.

Optical communication system without use of FBG show below on figure. It used single mode fiber length 60km for best output as show on figure. It's BER is 10^{-9} and below show in figure single mode fiber length and correspondence BER plot.

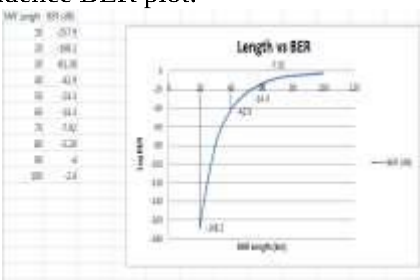


Fig.5.7: Transmission System without Use of FBG SMF Vs BER Plot

It shows output of the transmission system which is design use of FBG. It SMF length is 70km and very FBG length 1 to 20mm so it generate best output in 16mm length. It chirp grating is 00.00007.

Below figure show SMF length vs. SNR and SMF vs. Q factor plot. Best output is achieved on 70km SMF Length.

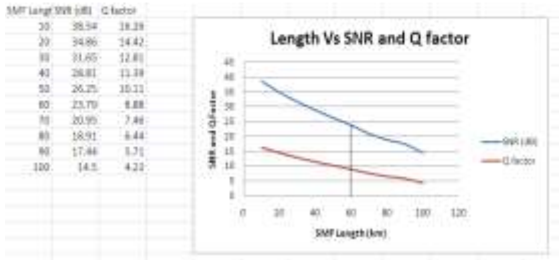


Fig.5.8: Transmission System using FBG and SMF Length 60km SMF Length vs. SNR and SMF vs. Q factor plot

Below figure shows best output where FBG length is 16mm.

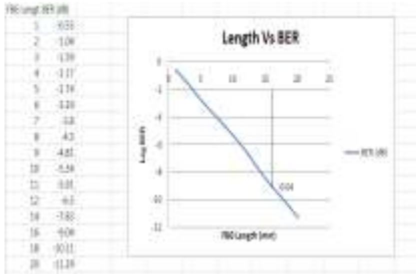


Fig.5.9: Transmission System Output FBG length Vs BER

Its show SMF length verses BER Plot

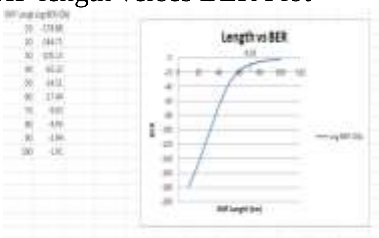


Fig.5.10: Transmission System SMF vs. BER Plot

Below figure is SMF 80km FBG length vs. BER.

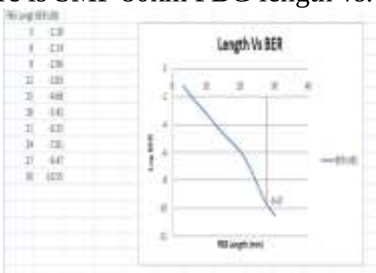


Fig.5.11: SMF 80km FBG Length vs. BER

Below figure is SMF 80km SMF length vs. BER

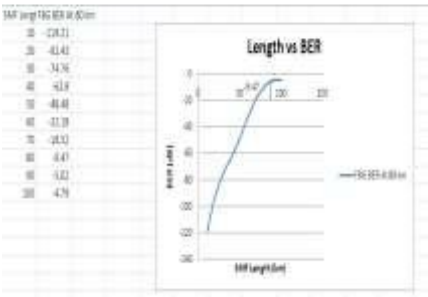


Fig.5.12: SMF 80km SMF Length vs. BER Plot

Below figure is SMF 70km which show chirp parameter vs. BER plot.

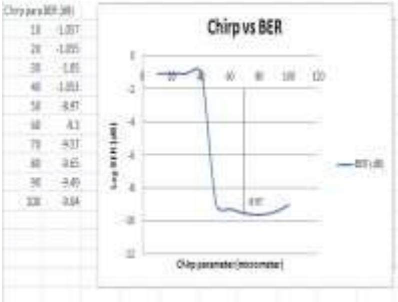


Fig.5.13: SMF 70km which show Chirp Parameter vs. BER Plot

Below figure is SMF 80km which show chirp parameter vs. BER plot.

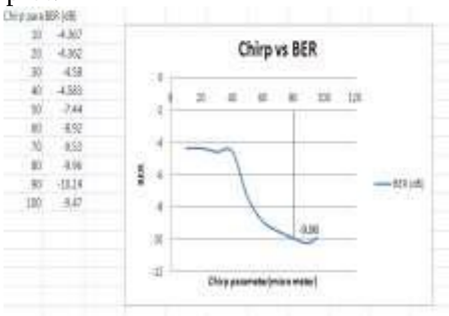


Fig.5.14: SMF 80km which show Chirp Parameter vs. BER Plot

Below figure which show BER comparison plot between without FBG, with FBG 70km SMF and With FBG 80km SMF

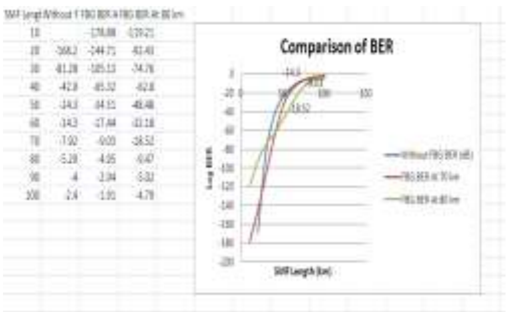


Fig.5.15: BER Comparison Plot between without FBG, with FBG 70km SMF and With FBG 80km SMF

Below figure is SMF 70km which show SNR vs. Q factor plot.

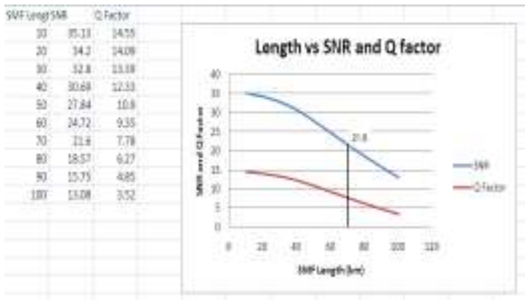


Fig.5.16: SMF 70km which show SNR vs. Q factor Plot

Below figure is SMF 80km which show SNR vs. Q factor plot.

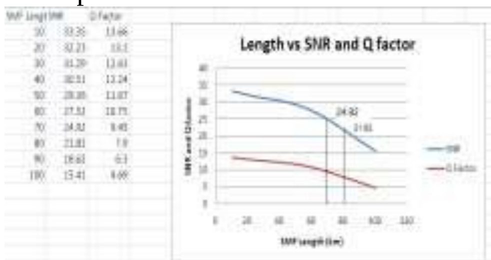


Fig.5.17: SMF 80km which show SNR vs. Q factor Plot

Below figure which show SNR comparison plot between without FBG, with FBG 70km SMF and With FBG 80km SMF

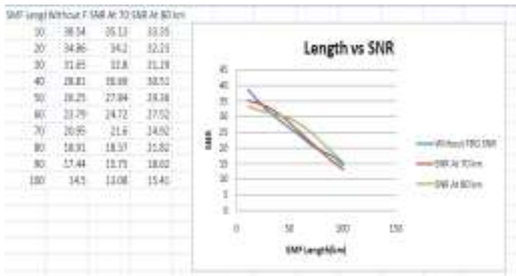


Fig.5.18: SNR Comparison Plot between without FBG, with FBG 70km SMF and With FBG 80km SMF

Below figure which show Q factor comparison plot between without FBG, with FBG 70km SMF and With FBG 80km SMF

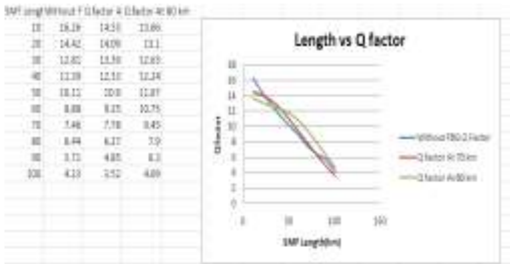


Fig.5.19: Q factor Comparison Plot between without FBG, with FBG 70km SMF and With FBG 80km SMF

D. Comparison of Different Dispersion Compensating Techniques

Optical fiber communication (OFC) provides us a very high bit rate data communication. There are different types of impairments and signal degradation

mechanisms involved with this high speed communication system. In case of long haul communication, the most effective impairment is dispersion. It affects the signal very badly when signal travels a long distance. Different techniques are available to compensate dispersion. Not all of them are the same in performance.
There are different types of dispersion in OFC. They can be compensated using different techniques. Fiber Brag Grating (FBG) and Dispersion Compensating Fiber (DCF) are two mostly used techniques in long haul communication.

Dispersion Compensating Fiber (DCF)

The DCF introduces a negative dispersion coefficient. Post compensation is achieved by adding the DCF onto an existing fiber. The fiber's dispersion can be manipulated by varying the refractive index profile and the relative index value. Very high negative dispersion is achieved by methods like depressed cladding or decreasing the core radius. However these could induce other penalties such as non-linear effects and insertion loss. A 30 km SMF which has a dispersion of 16ps/nm/km would encounter a total of (30 x 16) 480ps/nm of dispersion. Assuming the DCF has a negative dispersion of -80 ps/nm/km, and then 6km (480ps/nm ÷ 80ps/nm/km) of DCF is needed for the compensation. A matched-cladding type DCF has a positive dispersion slope similar to transmission fibers and the dispersion slope of the DCF is steeper than that of the conventional single-mode fiber . When this type of DCF is used for dispersion compensation, the dispersion slope for the whole transmission system including the DCF becomes larger than that for the transmission fiber alone and a wavelength region where the dispersion is well compensated is restricted to a narrow range. In a WDM system, multiple wavelengths are used to transmit information. DCF provides an "un-tunable" fixed negative dispersion for all the different channels in the WDM system. DCF is a good compensating device for its reference wavelength but it will leave residual dispersion at other wavelengths in a multi-channel transmission . In other words, it will only correct the center wavelength of a pulse causing shorter wavelength to be overcompensated and longer wavelength to be under-compensated. The magnitude of accumulated residual dispersion is dependent on the degree of DCF slope matching and the length of the transmission fiber link .

Advantages of FBG as dispersion compensator

For high speed communications, FBG has prospectively more advantageous than DCF, as it almost lossless, compact easily tunable and negligible non linearity. FBG's are found to be better negative response to dispersion as compared to DCF.
The most common advantage of FBG is low insertion loss (IL). Typically, a 120-km FBG-DCM has an insertion loss in the range of 3 to 4 dB, depending on type. Furthermore, the FBG-DCM holds an advantage is that it has virtually constant IL versus span length, whereas the IL of the DCF-DCM grows linearly with span length. Residual dispersion is another key parameter for compensators. Due to the very flexible grating process developed by approximation, the chirp characteristics can readily be chosen according to fiber specifications, i.e. dispersion level and dispersion slope can be tailored to fit any fiber type. The ability to tolerate high optical powers without any loss caused by nonlinear effects is also one prominent characteristic separating the FBG-DCM from the DCF-DCM. Although a DCF will display nonlinearity effects at rather low optical powers, the FBG-DCM won't introduce such effects even at the highest power levels present throughout optical network. Dispersion requirements increase with higher bandwidth, the focus on dispersion compensation is high. There's also increased use of longer fibers, which means higher expense associated with the placement of amplifiers along the fiber routes. FBG-based DCMs may be concentrated in a single location. That equates to fewer compensation points and fewer amplifiers to upgrade with the DCMs, which leads to cost savings.

CHARACTERISTICS	DCF	FBG
Bandwidth	Wide band, 20 nm	Narrow band, 0.1-5 nm
Fiber length	17-20 km	10-15 cm
Construction	Complex	simple
negative dispersion	+15 to +25 ps/nm/km	+2000 ps/nm/km
positive dispersion	−80 to −120 ps/nm/km	-2000 ps/nm/km
dispersion	16pm/km/nm	17pm/km/nm
Bending loss	0.4-0.6dB/km	0.14 dB/km
Reflectance ratio	99.99%	10-95%
attenuation	0.8 dB/km	0.2 dB/km
Non linear effects	Some limitations	no
Insertion loss	high	low
Overall Cost of system	high	low

Table 5.3: Comparison between FBG and DCF

Dispersion compensation is necessary to reduce losses and cost of the system. Dispersion compensation can be done through two different methods i.e dispersion compensation fiber and fiber Bragg gratings. By comparing the two methods we can see that Using DCF techniques increase the total losses nonlinear effects and costs of optical transmission system. FBG helps in decreasing the cost of the system and also have low insertion loss. Table 1 shows the comparison between DCF and FBG.

COMPENSATION TECHNIQUE USED	Q - FACTOR	Bit Error Rate (BER)
PRE USING DCF	12.8	2.077 e-38
POST USING DCF	15.5	6.192 e-055
MIX USING DCF	15.9	1.263 e-057
PRE USING FBG	16.0	2.328 e-058
POST USING FBG	16.3	2.478 e-060

Table 5.4: Q-factor and BER for each compensation technique (at 0 dBm input power).

In WDM systems, Q-factor is one of the most important features to measure the performance of the system. The readings are taken only for 193.1 THz frequency channel of the WDM system. The graph between Q-factor and input power of laser is plotted by increasing the power and measuring the Q-factor at each value. Input power is varied from 0-9 dBm and readings of Q-factor and BER are observed.

The graph in fig. 2 shows that FBG post compensation is better than all other techniques using NRZ format. It is followed by FBG pre, DCF mix, DCF post and DCF pre compensation techniques. FBG post has a highest Q-factor of 16.4 at 0 dBm and DCF pre has least Q-factor of 12.8. Another observation can be made that as the input power increases for NRZ format, the Q-factor also decreases. This means the performance of system degrades as input power increases.

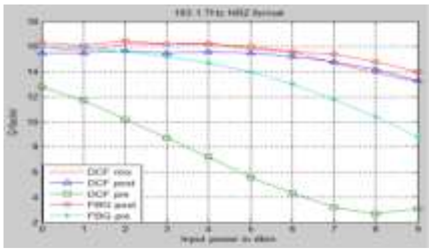
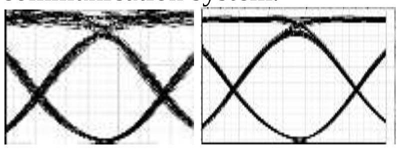
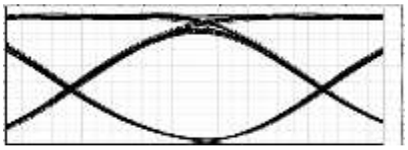


Fig 5.20 : Q-factor vs. Input power for NRZ format using different compensation schemes

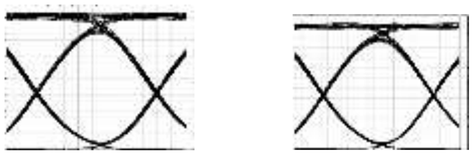
The fig.5.21 shows eye diagrams for all the five compensation techniques. Maximum is the opening of eye diagram, better is the performance of the communication system.



(a) DCF pre (b) DCF post



(c) DCF mix



(d) FBG pre (e) FBG post

Fig. 5.21 Eye diagrams for (a) DCF pre (b) DCF post (c) DCF mix (d) FBG pre (e) FBG post compensation techniques

6. CONCLUSION

Above Design in information transmission communication system is simulated. To get better result chromatic dispersion should be compensated in optical fiber. We increase the length of fiber to transmit the signal to long length with less dispersion. The length we gained is 80 km which is better for the system than the other.

Second Design we employed a chirp FBG to simulate and compensate the dispersion in a communication system in information transmission. Whenever we increase the length of grating the extension of pulse will be decreased because of that the signal will be cover more length without or less dispersion. So the quality of signal will be same at the receiver as the transmitter. The efficiency will be high and the cost will be low by using chirp fiber Bragg grating.

7. FUTURE WORK & APPLICATIONS:

A. Future Work

Instead of using fiber Bragg grating for compensating dispersion, other techniques like short period dispersion-managed fiber and dispersion compensation fiber component can be used. By using these techniques dispersion is reduced considerably by which even higher data rate can be transmitted over longer length fiber by keeping higher Q-factor and lower BER. Instead of using EDFA for amplification Raman Amplifier can be used.

B. Applications

- Chirped FBG not only helps in minimizing the cost of the transmission system but also has low loss insertion.
- EDFA amplifies optical signal because of their high gain and low noise.
- It can be provided high speed, better bandwidth and high capacity.
- Symmetric high capacity access network with high spectral efficiency, cost effective, good flexibility

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