Design and Simulation of Dispersion Compensated DWDM System based on Hybrid Amplifier

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ABSTRACT
In this paper, the design of dispersion compensated DWDM system using Hybrid Amplifier is presented. The evolution of fiber-optic systems in communication bears the properties of enhanced bandwidth, enormous capacity and robustness.However from the practical point of view, the vast benefits of DWDM system cannot be fully utilized. The main performance degraders include linear factors and non-linearity metrics. Among these undesirable parameters the dispersion and loss of optical fiber itself are most critical. So the reduction and elimination of these unwanted factors becomes essential to accomplish optimum utilization of the system. The evolution of EDFA has significantly miniaturized the loss of optical fiber.However dispersion is severely affecting the performance of fiber-optic systems. The fed light signal is severelydistorted by dispersion, due to which signal quality, data rate and distance covered are greatly lessened. Therefore the techniques for effectively controlling the dispersion become burning concern in these systems.

Optisystem 11.0 is used for designing the proposed system and carries out simulations. Chirped FBG and EDFA – RAMAN hybrid amplification instead of EDFA alone is used to achieve acceptable signal at the receiver withimproved Q-Factor and BER. Special focus is given to CD which is compensated using chirped FBG.

General Terms

Fiber-optic communication system, Dispersion and Optical amplifiers.

Keywords
Dense Wavelength Division multiplexing (DWDM), Chromatic Dispersion (CD), FBG, Hybrid Amplifier.

1. INTRODUCTION
With the evolution of optical technology in communication, increasing demand for higher capacity and transmission over long distance is boost up. Dense Wavelength Division Multiplexing (DWDM) is the optimum technology to meet this demand. DWDM has the features of (a) Compatibility with the present communication systems (b) Reliability in performance (c) Massive increase in bandwidth and (d) Enormous increase in transmission capacity [1].

Most advanced technology used in 1.5~1.6μm band for amplification is Erbium-doped fiber amplifier (EDFA); conversely in ultra-long transmission an accumulation noise occurs in EDFA. On the other hand Raman amplifier performs better than EDFA due to the characteristics of enlarging the gain bandwidth, eliminating the accumulation noise and also better noise and gain characteristics. So the hybridization of EDFA and Raman amplifier is currently hot research topic. Utilization of huge resources of optical bandwidth and up-gradation of capacity of optical fiber communication system is an important technical and theoretical research area [1, 2].

In the design of a DWDM system, the implementation of some direct modulation schemes produces deterioration in the light pulse mainly because of the chirp included to the dispersion of fiber. Therefore external modulation schemes are preferred due to their ease in production, reduced insertion loss and large extinction ratio. In the DWDM systems operating at data rate beyond 40 Gb/s/channel, the lethalinfluences of nonlinearities and dispersionneed to be compensated when transmission over long distance is desirable. Due to the presence of dispersion and other nonlinear effects the performance of DWDM system is rigorously limited [2 – 5].

The dispersion of most commonly used ITU-T G.652 fibers in DWDM systems is relatively high which greatly affects the performance of the system. Therefore some dispersion compensation scheme should be used to achieve the enormous benefits of DWDM system. To improve the system performance and compensate dispersion some fibers like ITU-T G.655, G.656were designed, but manufacturing process of producing such low dispersion fibers is complicated and also the cost of these fibers were not reasonable [6].

2. DCF AS DISPERSION COMPENSATOR
Most commonly incorporated method for the compensation of dispersion especially CD is the employment of specially designed optical fiber having negative dispersion. The conventionally employed SMF have positive dispersion. Hence DCF of particular length is inserted along the span of optical fiber which tends to minimize or cancel the dispersion properties of optical fiber. By proper distribution of refractive index and carefully designed core of optical fiber, DCF having various negative coefficients are easily to manufacture. However using DCF for dispersion compensation imposes penalties in terms of enhanced ASE, non-linear effects and increased cost of system. Also in long haul optical communication systems, length of DCF required to compensate the accumulated dispersion is quite large which makes the system bulky and also huge terminal space is required which is quite expensive [7].

3. PROPOSED DISPERSION COMPENSATION SCHEME (FBG)

Fiber grating is most robust scheme for compensation of Chromatic dispersion (CD). Two major variations of fiber grating are uniform FBG and chirped FBG. Chirped FBG is used in this proposed system. The working principle of chirped FBG is shown in figure 1.

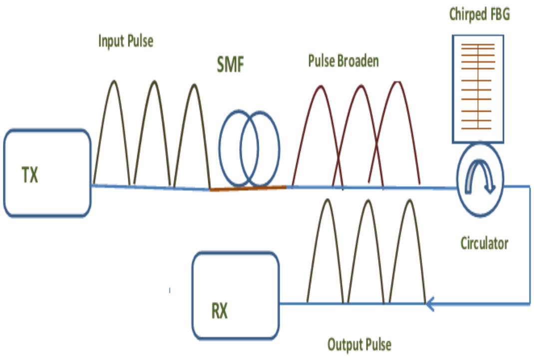

Fig 1: Working principle of chirped FBG

4. 32-CHANNEL PROPOSED DWDM SYSTEM DESIGN

The proposed design has been divided into three parts:

- Transmitter Design of 32-channel DWDM system
- Transmission link Design
- Receiver Design

4.1 Transmitter Design of 32-channel DWDM system

Externally modulated transmitter is used in this design in order to achieve stability. This also poses the benefits of reduced chirps and reduced non-linear effects. Pseudo-Random Bit sequence generator, NRZ pulse generator and Mach-Zehnder modulator are used in this design, as shown in figure 2. 32 such modulators are used and equally spaced laser array is deployed to feed laser signals. Frequency spacing of 200GHz is used with bandwidth set to 20GHz. This modulator also has the benefit of reducing the spacing among the neighboring channels.The MUX used in our system consists of 32 input ports and 1 output port.

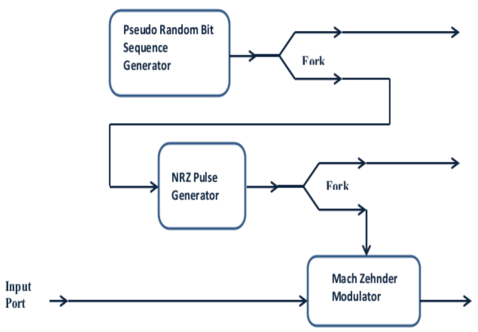

Fig 2: Externally Modulated Transmitter

4.2 Transmission link Design

EDFA is used before feeding the signal to RAMAN and SMF. Length of EDFA is set to 16m. Then average power model of RAMAN employed with length of 60Km. This RAMAN fiber is pumped with laser array with pumping powers of 400 mW. The pumping laser array consists of 6 lasers. Equally spaced WDM multiplexer is deployed for pumping the laser array. SMF of length 50 Km is used and then Chirped FBG along with optical circulator is employed with gratinglength set to 6m and the linear chirping parameter of 0.0001µm. The effective refractive index of FBG is set to1.45. Then another EDFA is used to further amplify the attenuated signal. The length of this EDFA is set to 9m whichprovides better signal. The reference wavelength is set to 1550 nm. Forward pumping is used for RAMAN fiber. Further increasein the length of FBG reduces the performance of the system in terms of Q-Factor and BER. Apodization function of FBG is also used but no improvement is observed. The transmission link is shown in figure 3.

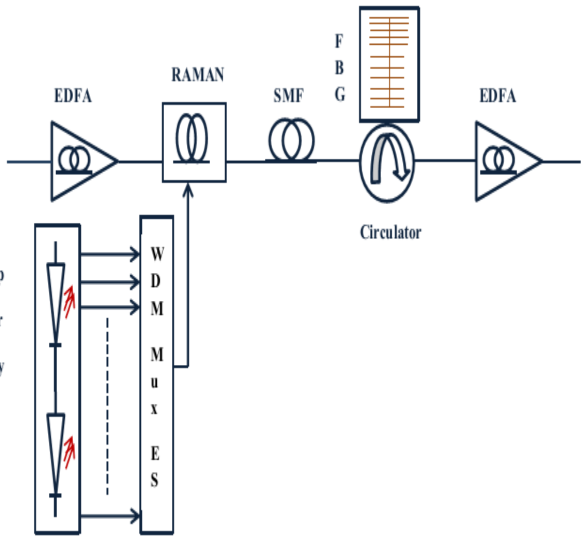

Fig 3: Transmission link

4.3 Receiver Design

Optical receiver is used with cutoff frequency set to 0.75*Bit rate.WDM de-multiplexer receives the composite signal and diverts to 32 different detectors. Each signal is then analyzed using BER analyzer.

5. SIMULATION RESULTS

Signal at the multiplexer output is shown in figure 4 starting at 193.1 THz. The power used at the transmitting side is set to -26 dBm. This optical signal is transmitted over a span of 110Km. Optical spectrum analyzer is used to visualize this optical signal. Frequency spacing among the neighboring channels is set to 200GHz. The data rate used for simulation is 10 Gb/s. Sequence length of 128 Bits, sample per bit equal to 64 and number of samples equal to 8192 are used for simulations. The visualizers used in our simulation are optical spectrum analyzer (OSA) and BER analyzer.

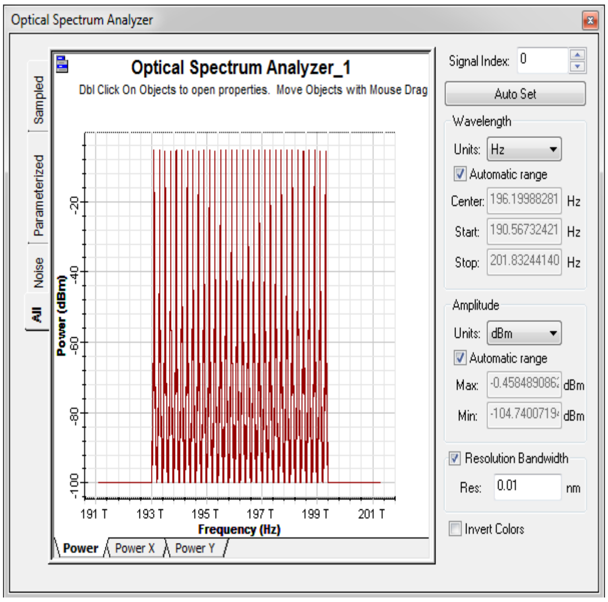

Fig 4: Input Signal to fiber span

The signal shown in figure 5 is taken without using FBG just before the de-multiplexer. The spectrum clearly dictates that signal is severely degraded without any dispersion compensator. This signal is extended towards left of its original position and now starting from 191.1 THZ. So due to chromatic dispersion signal is broadened over a larger bandwidth than the transmitted one. This resulted in decreased Q-Factor and increased BER. With these results it becomes quite difficult to distinguish the data contained by various transmitted channels. Q-Factor of 6.27 has been observed with minimum BER reaches to the order of 10^{-10} as shown in figure 6. SNR is also decreased as shown by eye-diagram. In order to achieve Q-Factor and BER in acceptable range, some dispersion compensation technique is needed to use. Eye opening is decreased due to dispersion which needs to be cured.

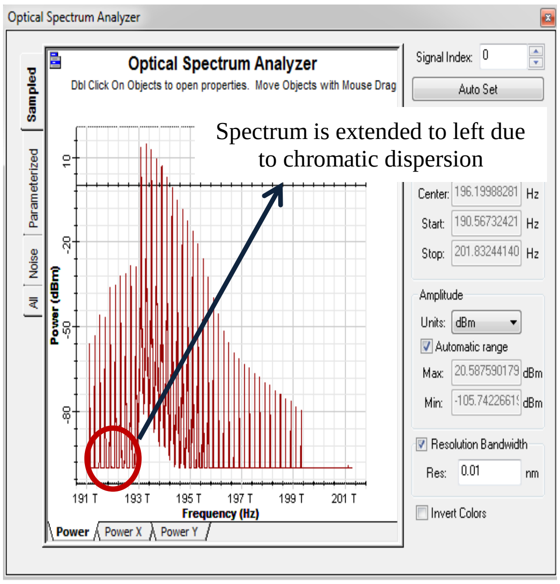

Fig 5: Dispersed Signals without Dispersion Compensator (FBG)

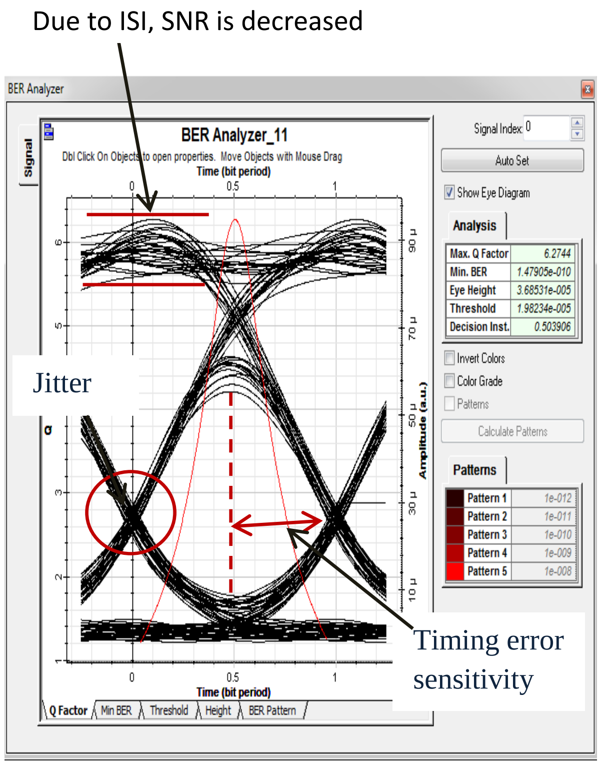

Fig 6: Eye diagram without Dispersion Compensator (FBG)

Figure 6 clearly dictates that without deploying dispersion compensator, the ISI introduced by fiber decreases SNR of the received signal.

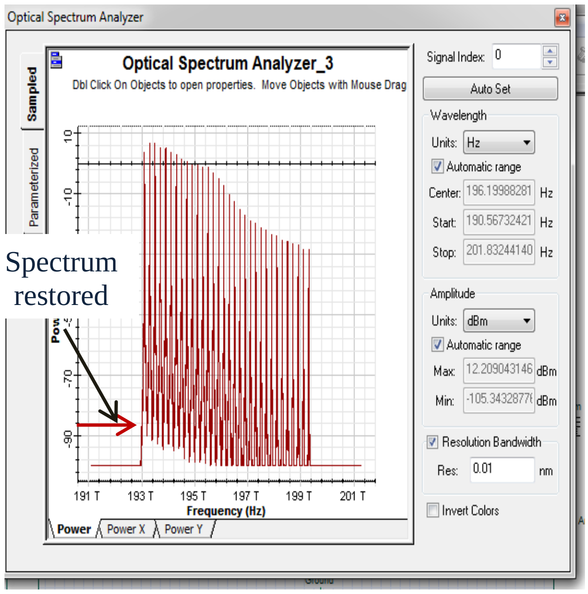

Fig 7: Spectrum after compensator

Figure 7 shows the spectrum after dispersion compensator. As shown that signal is restored to its original frequency. Hence the dispersion induced by fiber is canceled out. We have not taken into account other non-linear effects such as FWM, XPM and SRS etc. This design only focuses on chromatic dispersion. Figure 8 shows Q-Factor of dispersion compensated signal.

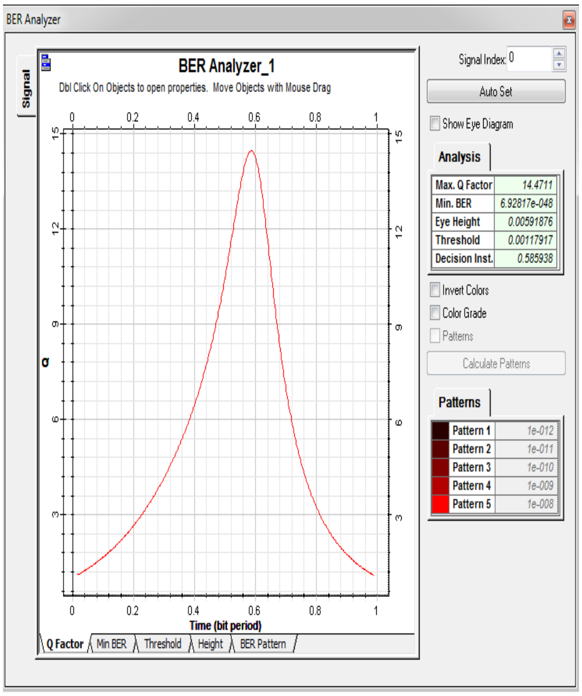

Fig 8: Improved Q-factor after Dispersion compensator (FBG)

Eye-diagram after deploying FBG is shown in figure 9. Q-Factor has been increased to 14.47 while min BER hasbeen decreased to 10^{-48}. Also eye opening has been broadened. Jitter has also been reduced.

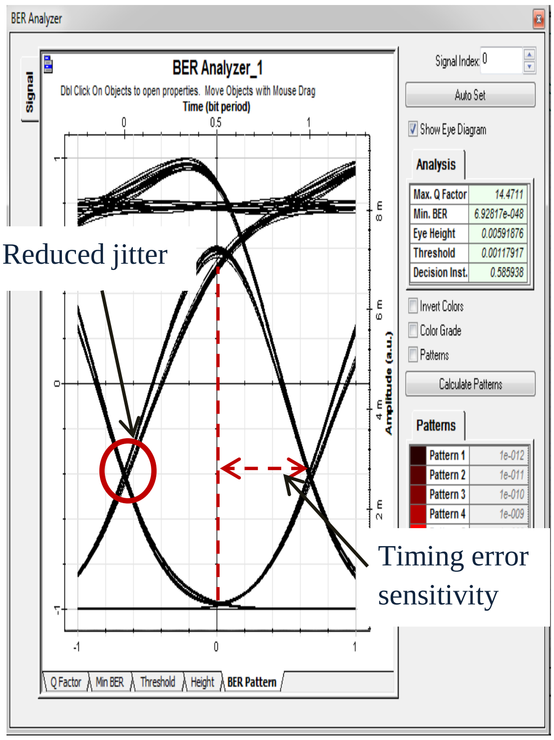

Fig 9: Eye diagram with FBG

Figure 9 represents the eye-diagram after deploying FBG and clearly shows that due to dispersion compensator SNR of received signal is increased as well as jitter is also decreased.Also timing error sensitivity is improved as compared to eye-diagram obtained without employing FBG.

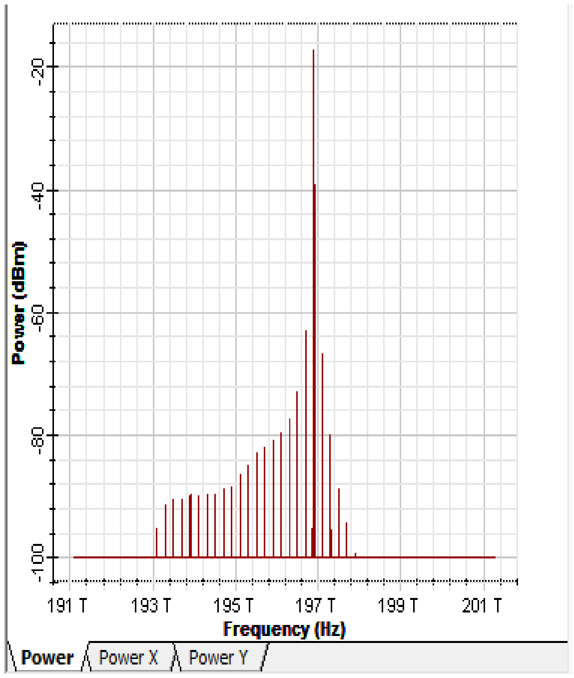

Fig 10: Output Spectrum for 32-channels

Figure 10 clearly depicts the output spectrum after de-multiplexing. Ideal de-multiplexer is used at the receiver side to de-multiplex the transmitted signals.

6. CONCLUSION

The designed DWDM system clearly depicts that hybridization of EDFA and RAMAN amplifier outperforms the design using only EDFA or using any other hybridization of optical amplifiers. The parameters of pumping laser array are carefully chosen because number of iterations while simulating the system is higher and a lot of time is needed for performing simulation. Also use of FBG along with optical circulator as compensator for chromatic dispersion is quite successful for achieving acceptable Q-Factor and minimum BER. We have not taken into account the non-linear effects such as FWM, XPM and SRM which is depicted by figure 6 & 10,which severely degrades the signal spectrum. Non-linear factors reduce the performance of communication system in terms of quality and performance.

7. Future Recommendations

Further improvements may be made to compress the non-linear factors without compromising over the signal quality. We have used only forward pumping. Better results may be obtained by using counter-pumping or bi-directional pumping. Also system utilizing higher data rates may be designed by using bi-directional pumping or some other pumping combinations. The design may be extended by keeping in view the gain and noise figure (NF) along with dispersion management.

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