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ANALYSIS OF FWM POWER AND EFFICIENCY IN DWDM SYSTEMS BASED ON CHROMATIC DISPERSION AND CHANNEL SPACING

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ABSTRACT

The objective of this paper is to analyze the Four Wave Mixing efficiency (FWM) in DWDM systems based on Channel Spacing and Dispersion Coefficient for different fiber lengths. The design of the FWM was simulated with the OPTISYSTEMv7.0 tool and analyzed using the eye pattern method with respect to BER. This paper also shows the effect of chromatic dispersion on FWM in terms of input/output spectrums and eye diagrams. Results of the simulation show that FWM effect can be reduced by using unequal channel spacing and it is reduced more when the dispersion coefficient is increased.

Index Terms—FWM, DWDM, BER, Optisystem

INTRODUCTION

Four Wave Mixing (FWM) is an important nonlinear effect in optical fibers, that is why it is very important to study FWM and its effects in optical fibers and minimize these effects to improve the system performance ([1],[2],[3],[4]). A fourth wavelength light is generated from three lights of different wavelengths in FWM interactions. The number of FWM light is increased when the number of channels is increased. When three light passes through an optical transmission system a fourth wavelength light is produced by the interactions between the three lights. This light is known as FWM light (or Idler light) and this phenomenon is known as Four wave mixing. The probe light (or signal light) is the light that was there before launching, and sandwiching the two pumping waves in the frequency domain. The frequency of the Idler can be determined by

fidler = fp1 + fp2 - fprobe

Where fprobe is the probe light frequency and fp1 and fp2 are the pumping light frequencies. This condition is called the frequency phase-matching condition.

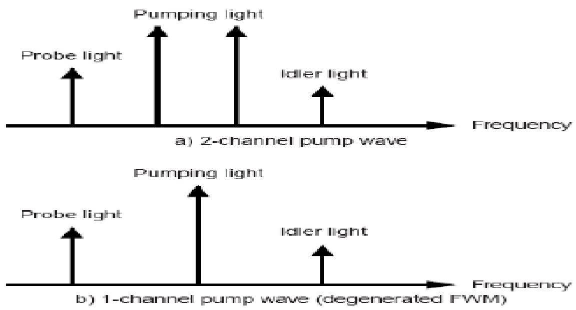

Fig. 1. Schematic of four wave mixing in frequency domain

Chromatic dispersion is a phenomenon that is an important factor in fiber optic communications. It is the result of the different wavelengths, arriving at their destination at slightly different times in a light beam. Chromatic dispersion is the result from the spectral width of the emitter. The spectral width basically determines the number of different wavelengths that are being emitted from the laser or LED. When the number of wavelengths that are emitted are fewer, the spectral width is shorter. Shorter wavelengths will arrive at the end of the fiber before of longer ones, which spreads out the signal.

Fig. 2. Pulse broadening due to chromatic dispersion

Chromatic dispersion basically broadens the pulses and can be reduced by using the dispersion shifted fibers at 1550 nm wavelength ([5],[6]). FWM can be suppressed by increasing the channel spacing between the channels but it has some drawbacks of increasing the overall system bandwidth. Another good approach is to use the unequal channel spacing between the channels. This is quite the good way to decrease the FWM effect in optical transmission system since it avoids overlapping between the channels [7].

In this Paper, We have analyzed the FWM Power and efficiency in Dense Wavelength Division Multiplexing (DWDM) systems based on Chromatic Dispersion and Channel Spacing. This is done using the Optisystem Software. We have designed the 3 Channel system and analyzed by changing the dispersion coefficient and channel spacing between the channels. We have also analyzed Eye diagram and BER for 4 Channel system.

METHODOLOGY

The whole paper has been divided into 3 sections which are as Transmitter, Fiber Section and Receiver.

2.1 TRANSMITTER

The transmitter section consists of data source that generates pseudo random bit sequence at the rate of 10 Gbps. The Pseudo-Random bit sequence output goes to NRZ coder that produces an electrical NRZ coded signal. This coded signal is modulated using Mach-Zehnder modulator. The Mach-Zehnder modulator is driven by a CW Lorentzian laser.

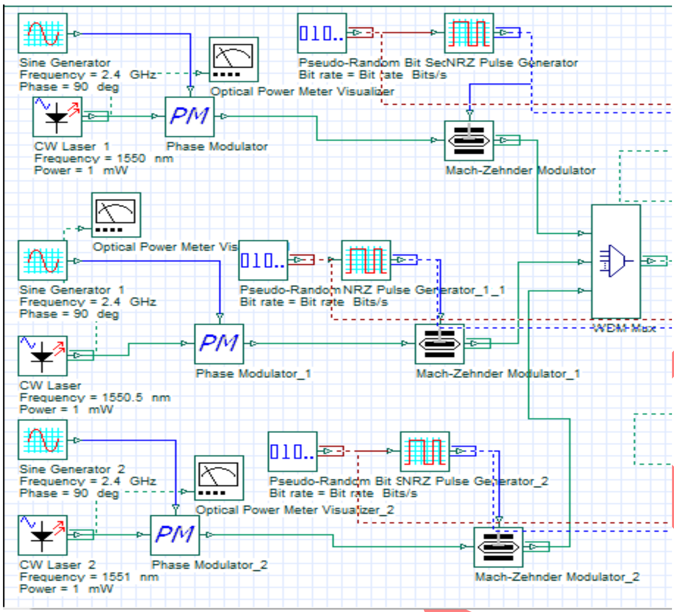

Fig. 3. Circuit diagram of the transmitter

2.2 FIBER SECTION

The three channels are multiplexed and the combined signal is fed into a fiber which is a single mode fiber. The nonlinearities are taken into account in this fiber. We can induce different nonlinearities (FWM in this case) using the Optisystem software. Different parameters like fiber length, attenuation, channel spacing and dispersion parameters can be adjusted. The output of the fiber is send to the receiver. Fiber is completely compensated at each span through Fiber Bragg gratings.

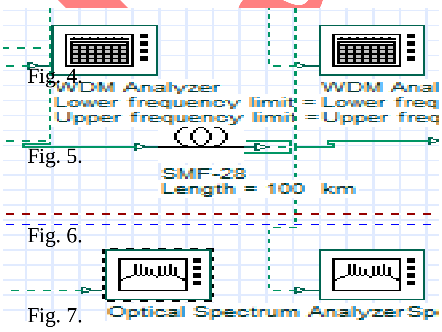

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8. Circuit diagram of the fiber section

2.3 RECEIVER

The output signal from the fiber is demultiplexed and individual signals are received at the receiver. For each signal, there is an electrical low pass Gausian filter followed by the PIN photodetector. At the output of the low pass filter, a Eye diagram analyzer is provided which is an electrical scope to display the eye diagrams, BER etc. A wide eye opening shows the minimum distortion.

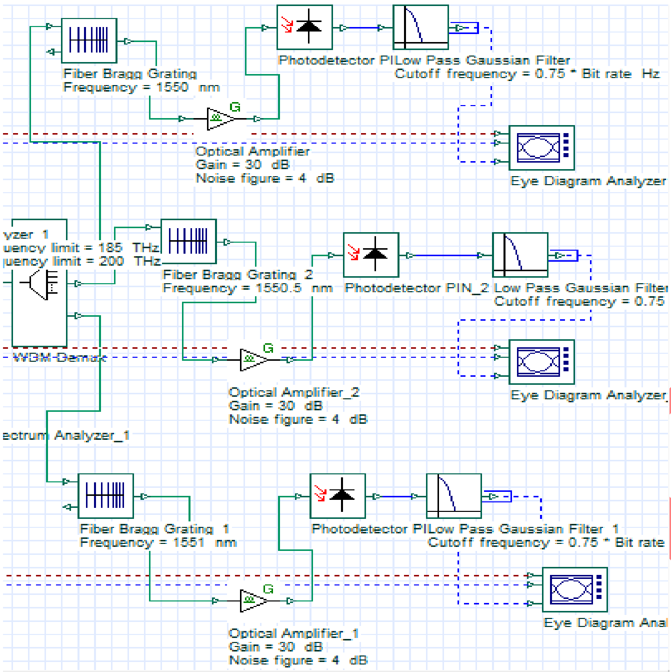

Fig. 9. Circuit diagram of the receiver

RESULTS & OBSERVATIONS

Various results have been deduced from the simulations which are given below under various sub-sections:

3.1 TRANSMITTED SIGNAL POWER

- ❖ The Optical Spectrum analyzer at the input says that we have the peak power at the frequency of 194.54 THz and the power is -4.06 dbm for 1 mW input power.
- ❖ The Optical Spectrum analyzer at the output says that we have the peak power at frequency of 194.54 THz and the power is -23.06 dbm for 1 mW input power and we find that the peak power has been amplified.
- ❖ The output also shows more channels. This shows basically the FWM effect.
- ❖ The power of the transmitted signals got increased as we increased the input power to 100mW.
- ❖ This shows that FWM effect increases as we increase the input power since FWM power is directly proportional to the input power.

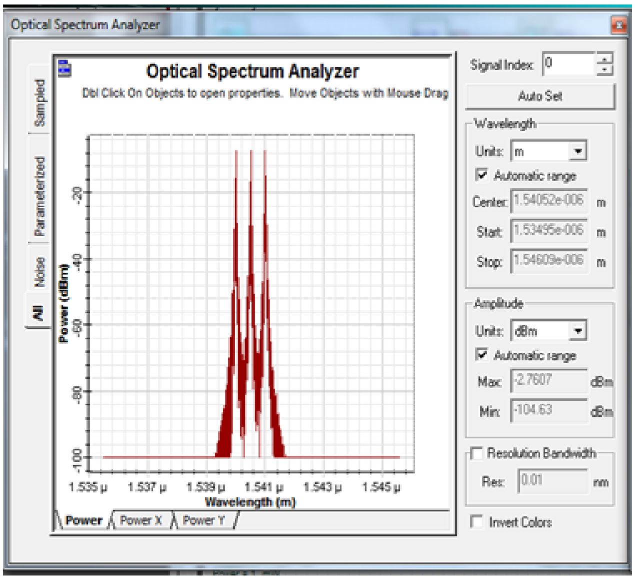

Fig. 10. Input Optical Spectrum when input power is 1 mW

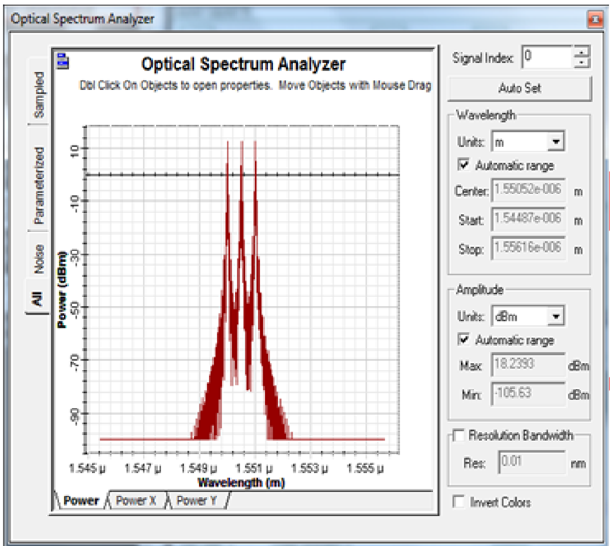

Fig. 11. Input Optical Spectrum when input power is 100 mW

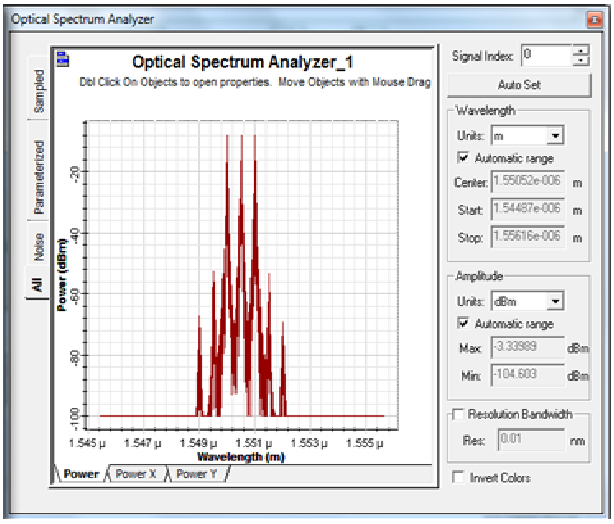

Fig. 12. Received Optical Spectrum when input power is 100 mW

3.2 Eye Diagram and BER Analysis on the Basis of Channel Spacing

- The three figures show that the FWM effect decreases as the eye diagram obtained at the receiver is getting clear when we have increased the channel spacing.
- This shows that there will be less signal distortion as we increase the channel spacing between the channels.
- Bit Error Rate (BER) also decreases as we increased the channel spacing between the channels. This shows that FWM effect is less for more channel spacing.

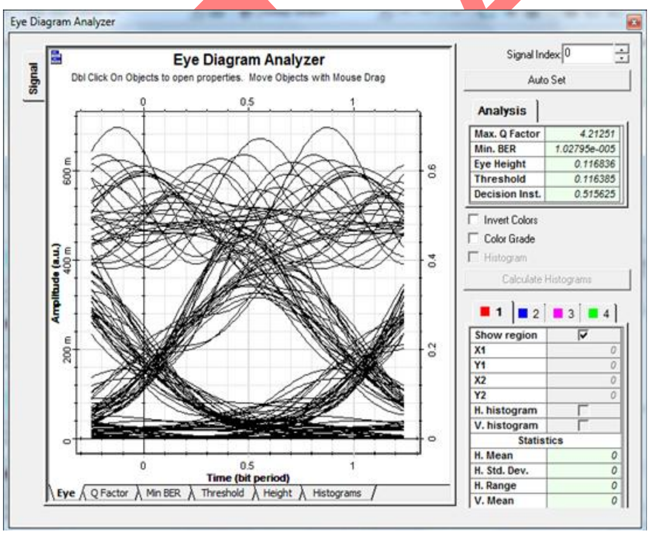

Fig. 13. Eye diagram when spacing is 0.1 nm and input power is 1 mW

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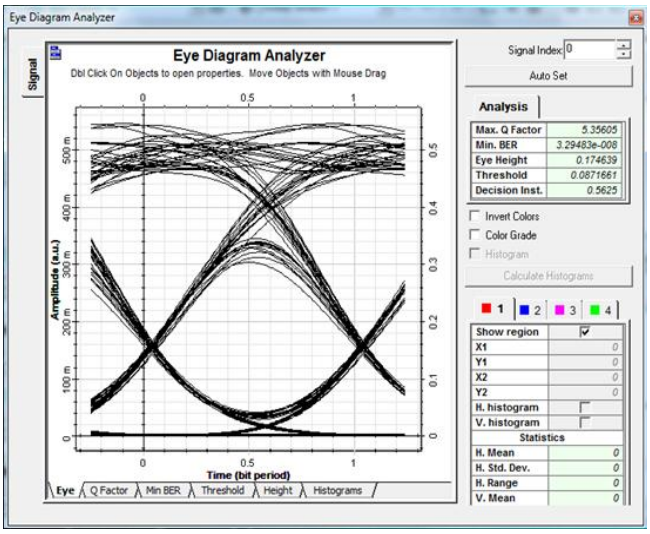

Fig. 14. Eye diagram when spacing is 0.2 nm and input power is 1 mW

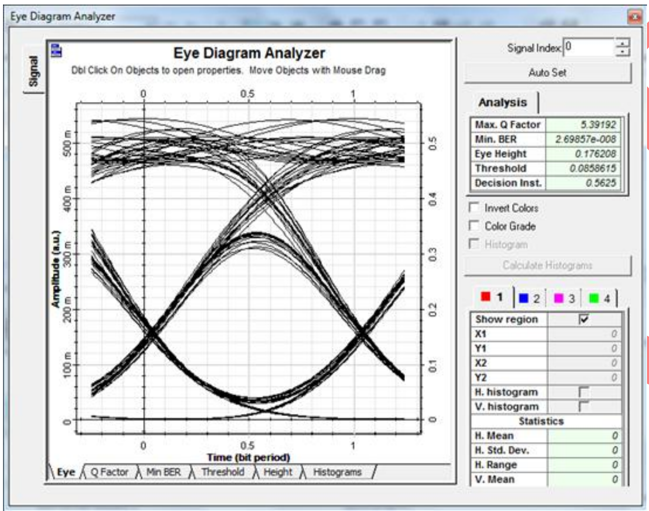

Fig. 15. Eye diagram when spacing is 0.5 nm and input power is 1 mW

3.3 BER Analysis & Eye Diagram on the basis of Chromatic Dispersion

- The BER analyzer shows that the BER is decreasing as we have increased the dispersion coefficient from 1 ps/nm/km to 16 ps/nm/km.

- We have a clear eye opening pattern which corresponds to minimal signal distortion when we increased the dispersion coefficient.

- This shows that FWM effect decreases as we increased the dispersion coefficient from 1 ps/nm/km to 16 ps/nm/km.

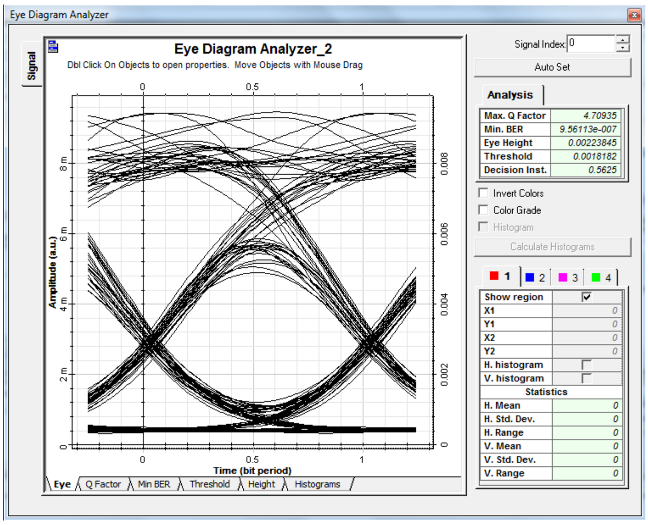

Fig. 16. Eye diagram when the dispersion coefficient is 1 ps/nm/km

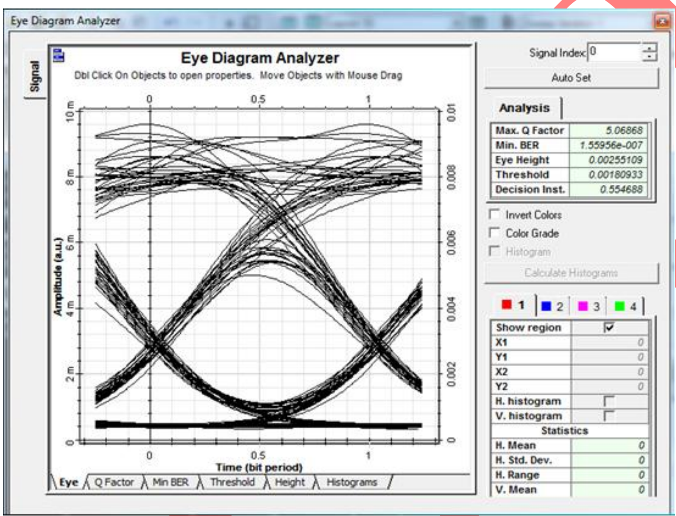

Fig. 17. Eye diagram when the dispersion coefficient is 4 ps/nm/km

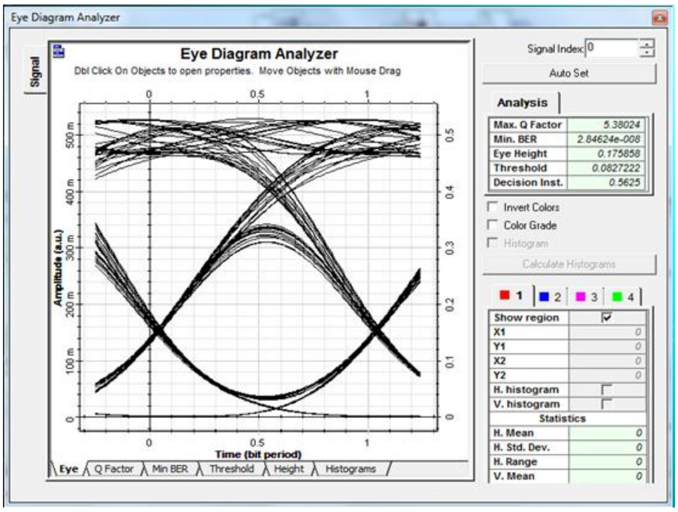

Fig. 18. Eye diagram when the dispersion coefficient is 16 ps/nm/km

3.4 BER ANALYSIS AND EYE DIAGRAM FOR 4 CHANNEL SYSTEM

On increasing number of channels that is here are 4 channels, Eye diagram is clear as compared to 3 channel DWDM system and BER also decreased. This shows that FWM effect decreases as we increase the number of channels.

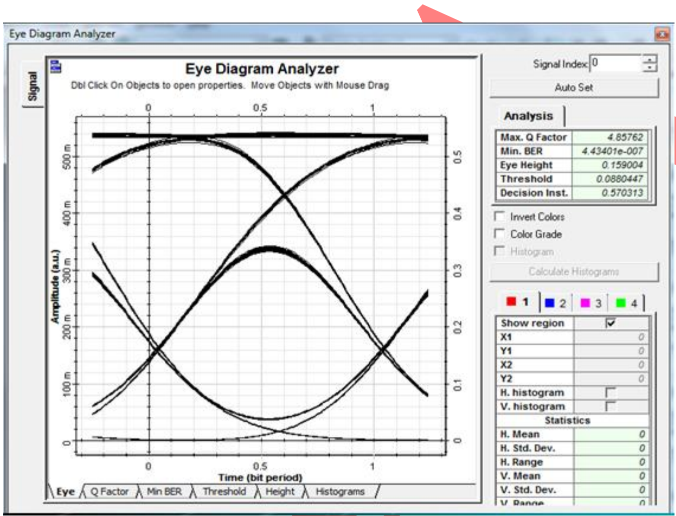

Fig. 19. Eye diagram when spacing is 0.5 nm and input power is 1 mW

3.5 TRANSMITTED SIGNAL POWER AND EYE DIAGRAM FOR UNEQUAL CHANNEL SPACING

When the spacing between the channel is unequal, the four wave mixing (FWM) effect is reduced slightly. Due to equal channel spacing, some of the FWM components overlap DWDM channels. But here in unequal channel spacing there is no overlapping of DWDM channels and thus wavelength conversion occurs.

The BER for Unequal Channel Spacing is less as compared to Equal Channel Spacing. Also the Eye Diagram is clear and open as compared to equal channel spacing.

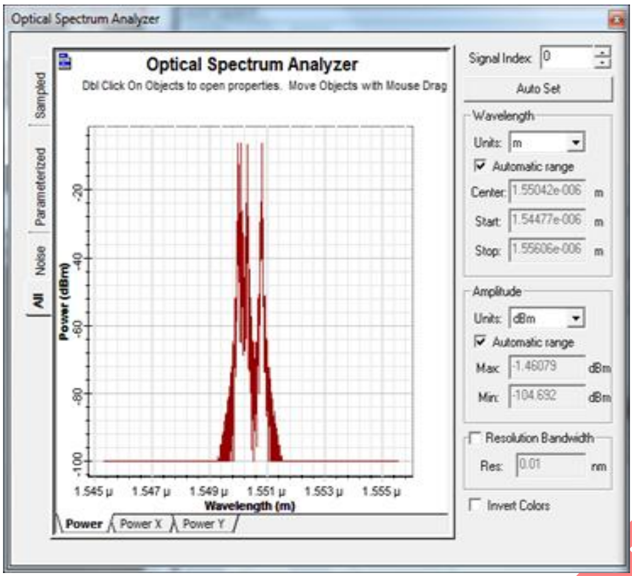

Fig. 20. Input Optical Spectrum for Unequal Channel Spacing

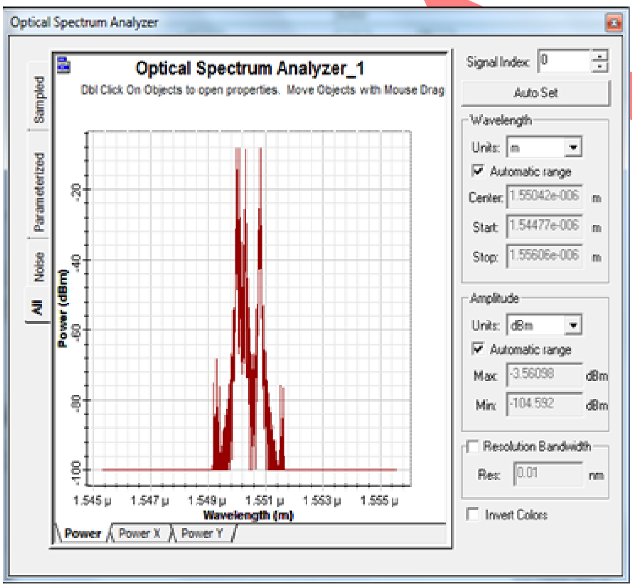

Fig. 21. Output Optical Spectrum for Unequal Channel Spacing

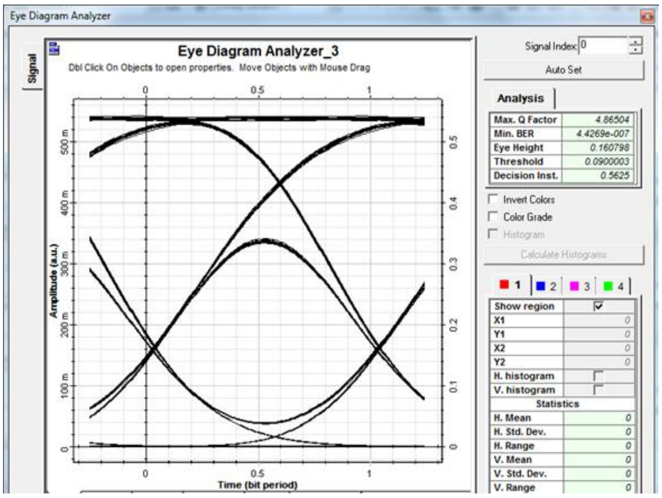

Fig. 22. Eye diagram for Unequal Channel Spacing

3.6 BER ANALYSIS & EYE DIAGRAM ON THE BASIS OF FIBER LENGTH

When the length of the fiber is increased, the four wave mixing (FWM) effect is increased. BER is increased and the eye diagram is showing more signal distortion when we increased the fiber length from 10 km to 100 km.

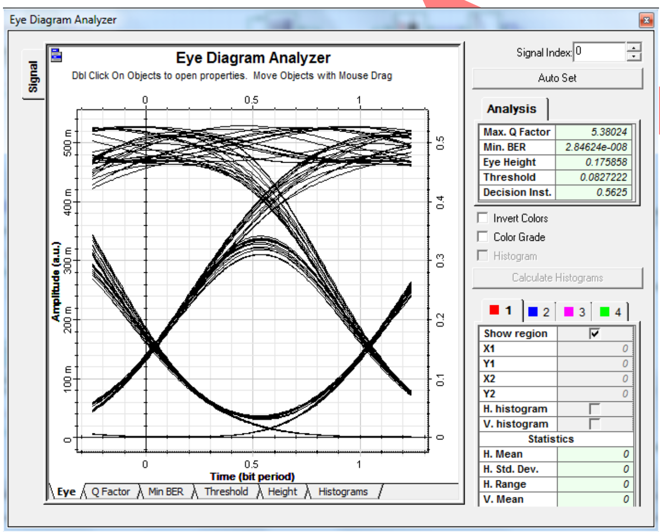

Fig. 23. Eye diagram when the length of fiber is 10 km

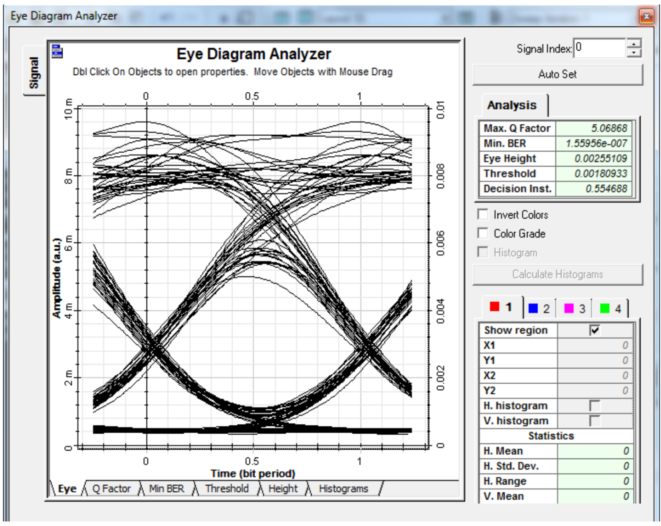

Fig. 24. Eye diagram when the length of fiber is 50 km

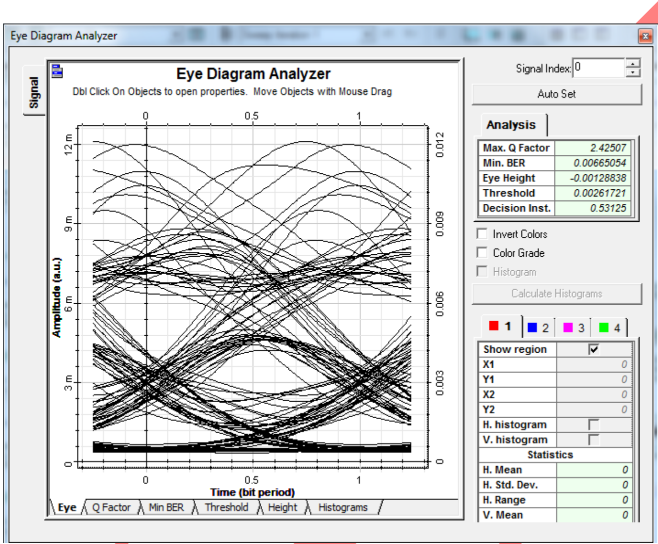

Fig. 25. Eye diagram when the length of fiber is 100 km

CONCLUSION

- The impact of dispersion coefficient on FWM in a 3-channel and 4-channel DWDM system has been demonstrated in this paper. The effect has been shown for both equal and unequal channel spacing.
- Results show that FWM effect is maximum when dispersion coefficient is minimum and the FWM effect reduces as the dispersion coefficient is increased.
- Also the performance of the system is found to be better with unequal channel spacing. Therefore in a DWDM system in order to improve performance, unequal channel spacing is recommended with an optimized level of chromatic dispersion.
- Results also show that FWM effect is maximum when the length of the fiber is maximum and the FWM effect reduces as the length of the fiber is reduced. It is because the FWM power is exponentially dependent on the length of the fiber.

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