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Implementation of 4* 10Gbps-DWDM System in the presence of Four Wave Mixing (FWM)

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ABSTRACT
The focus of this paper is to implement four channel- dense wave length division multiplexing (DWDM) system, with each channel of 10Gbps over optical span of 100Km in the presence of Four Wave Mixing (FWM) under the impact of equal- and unequal- channel spacing. In this proposed work, the comparison of DWDM system with equal- and unequal-channel spacing varying from 0.24nm to 0.26nm is carried out in conjunction with the fiber dispersion controlled by means of Fiber Bragg grating and achieved affordable BER, Q-parameter along with jittering required in practical DWDM systems.

General Term

Simulative Modeling

Keywords
Dense wavelength-division-multiplexing (DWDM), Four wave mixing (FWM), Channel spacing

1. INTRODUCTION
Dense wavelength-division-multiplexing (DWDM), a key technology, comes into the picture to enable the ultra high-capacity photonic networks required by our communication thirsty society. The dispersion and fiber nonlinearities are the parameter which restricts the transmission distance and bandwidth of DWDM systems. Fiber nonlinearities become a problem, when several channels are co-propagating in the same fiber. Nonlinear effects arose as data rate, repeater-less transmission length, number of wavelengths, and optical power levels are increased. The interaction of propagating light with fiber leads to interference, distortion, or excess attenuation of the optical signals. The nonlinear effects tend to manifest themselves when optical power is very high and become prominent in WDM/DWDM systems. The fiber nonlinearities fall into two categories. One is the stimulating scattering (Raman and Brillouin) responsible for intensity dependent gain or loss and is generated due to stimulated process. The second types of nonlinearities are Self Phase Modulation (SPM), Cross Phase Modulation (XPM) and FWM [1-4]. The FWM is one of the key limiting factors in DWDM systems and third-order nonlinearity in silica fibers, which is analogous to inter-modulation distortion in electrical systems. It is due to change in the refractive index with optical power called the optical Kerr effect. FWM generates new optical frequencies or FWM products that may cause channel crosstalk. The occurrence of FWM depends on several factors, such as the frequency spacing between channels, the input power per channel, the dispersion characteristics of the optical fiber, and the distance along which the channels interact [5]. The FWM is one of the substantial and significant degrading factors in WDM and DWDM optical communication systems [6-8]. There have been many reports offered on different methods for mitigating the impact of fiber nonlinearities on WDM/DWDM systems including different channel allocation techniques like equal-channel spacing and unequal-channel spacing techniques [7] and [9-13], dispersion management schemes [14] and the use of nonzero dispersion fibers [15]. In this paper, we have evaluated BER, Q-parameter and jittering of 4*10Gbps-DWDM system over an optical span of 100Km in the presence of FWM under the impact of equal channel spacing varying from 0.24nm to 0.26nm in conjunction with the fiber-dispersion controlled by means of Fiber Bragg grating. The section II describes the simulation setup of 4*10Gbps-DWDM system followed by section III that concludes our results.
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2. SIMULATION SETUP & RESULT DISCUSSION
The simulation setup to evaluate the impact of varying channel spacing between the input channels of a DWDM system in the presence of FWM as shown in Figure 1 is demonstrated. The simulation setup consists of four CW lasers externally modulated by 10Gbps NRZ data for each channel with equal channel spacing varying in the range of 0.24nm-0.26nm.

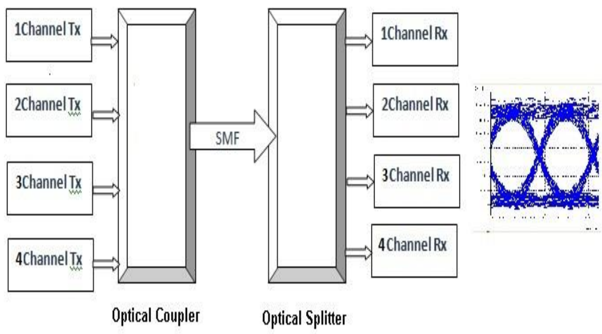
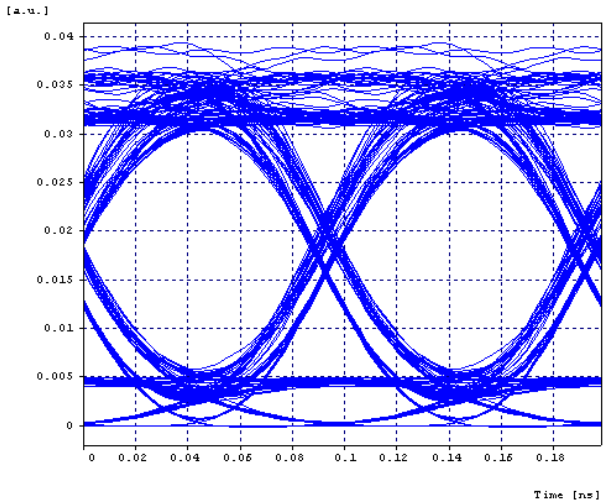
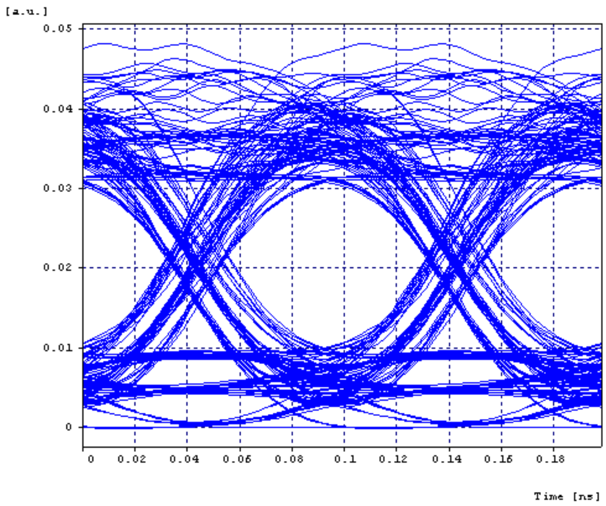


Fig: 1 Simulation Setup of 4*10Gbps-DWDM system

The results are calculated for an optical span of 100Km having two spans of 50Km of 0.25dB/Km attenuation factor and fiber dispersive property is controlled by incorporating fiber Bragg grating. To examine the eye diagram to compute BER, Q-factor, eye opening and jittering effect, an electrical scope is kept at the receiver output. In Figure 2, eye diagrams of 4*10Gbps-DWDM system with equal channel 0.26nm after optical span of 100Km in the presence of FWM has been observed.



Channel 1



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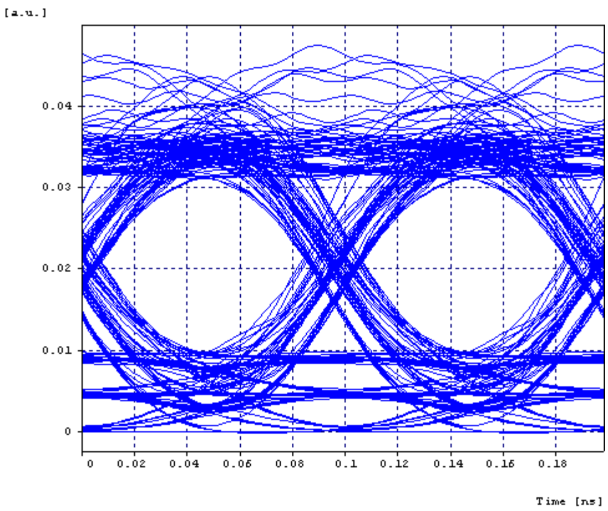

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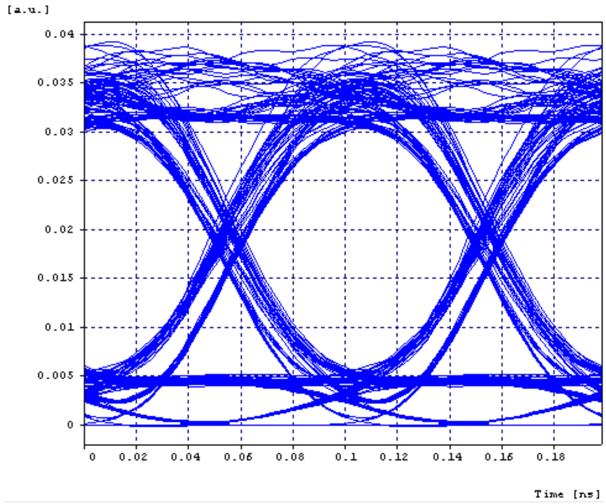
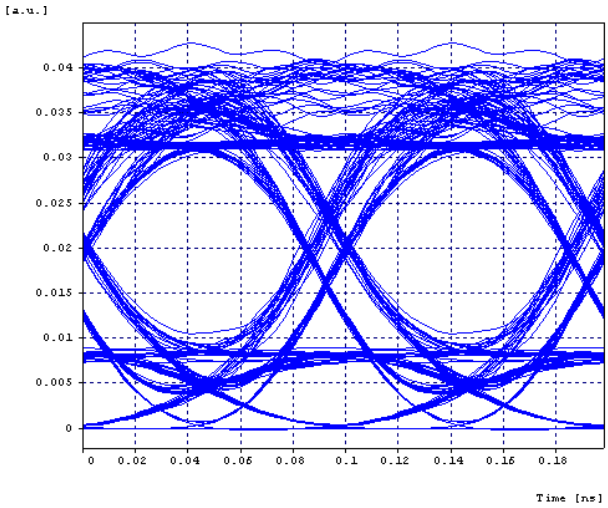


Channel 4

Fig: 2 Eye Diagrams 4*10Gbps-DWDM system with equal channel spacing of 0.26nm with optical span of 100Km in the presence of FWM



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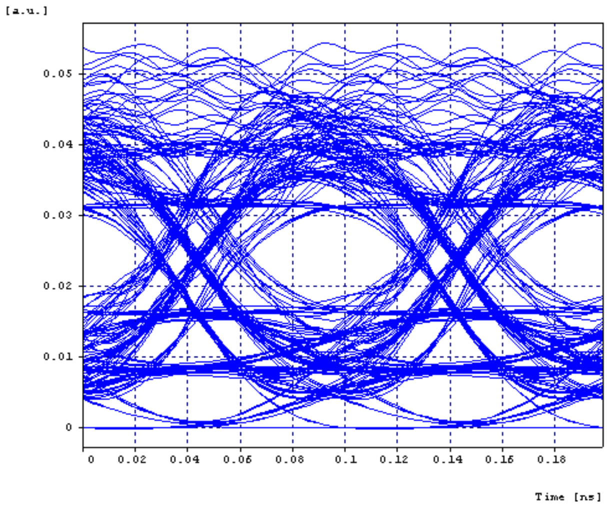

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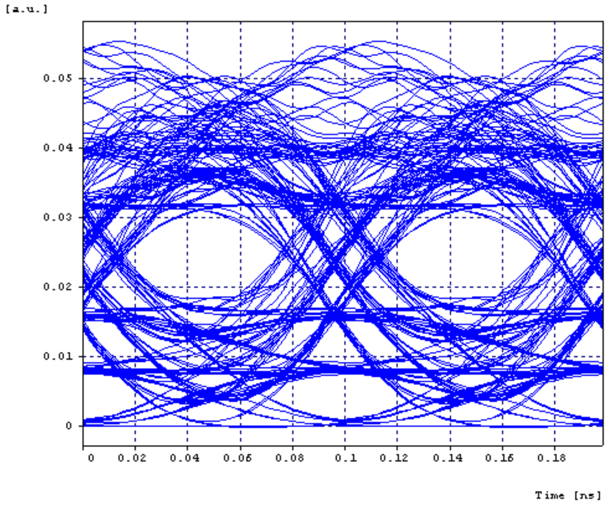

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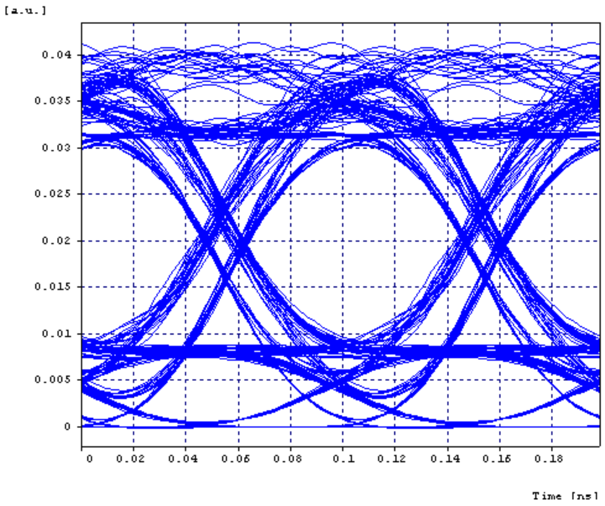
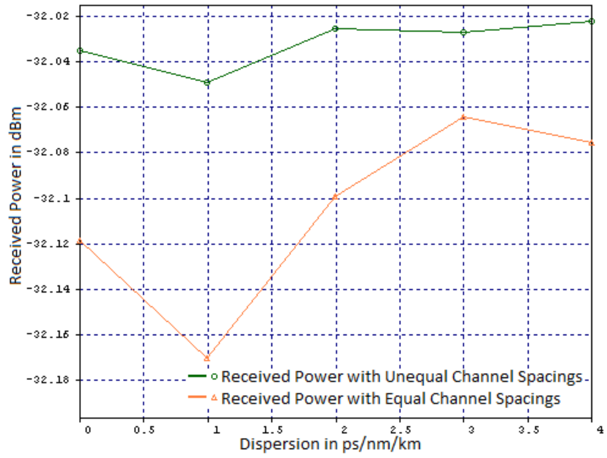


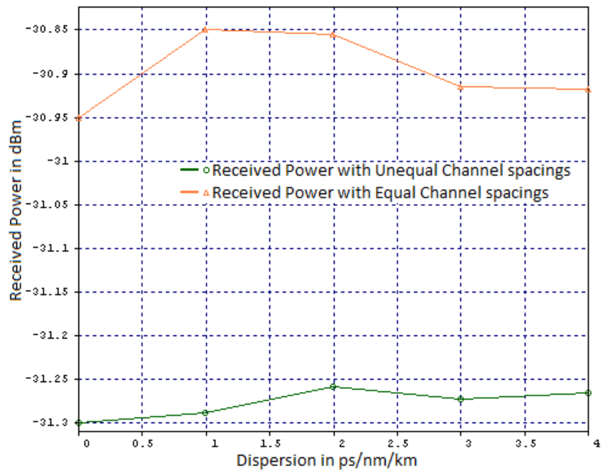
Channel 4

Figure 3: Eye Diagrams of 4*10Gbps-DWDM system with equal channel spacing of 0.24nm with optical span of 100Km in the presence of FWM

It has been observed that the Q-parameter is computed as [14.61, 10.54, 10.05, 14.35] with jittering [0.022, 0.018, 0.022, 0.021] for channels first (1552nm), second (1552.26nm), third (1552.52nm) and fourth (1552.78nm) respectively with BER as [6.32×10^{-8}, 4.53×10^{-4}, 7.79×10^{-4} and 1.00×10^{-7}]. Further, the results are evaluated for equal channel spacing of 0.24nm as shown in Figure 3 and observed Q-parameter as [14.40, 11.52, 13.28, 18.35] with jittering [0.021, 0.019, 0.021, 0.019] for channels first (1552nm), second (1552.24nm), third (1552.48nm) and fourth (1552.72nm) respectively with BER as [8.25×10^{-8}, 9.08×10^{-5}, 2.03×10^{-6} and 6.80×10^{-17}].



Channel 1



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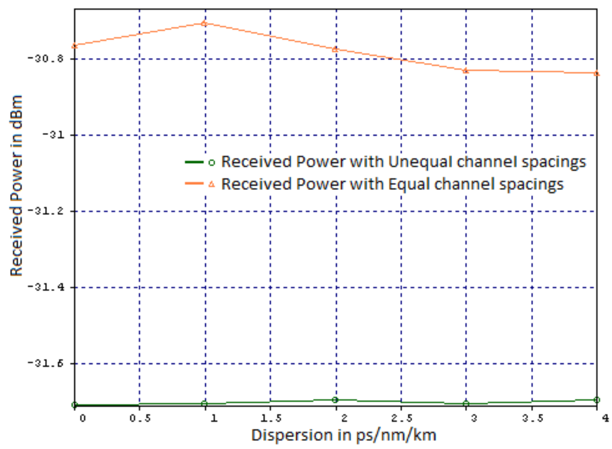

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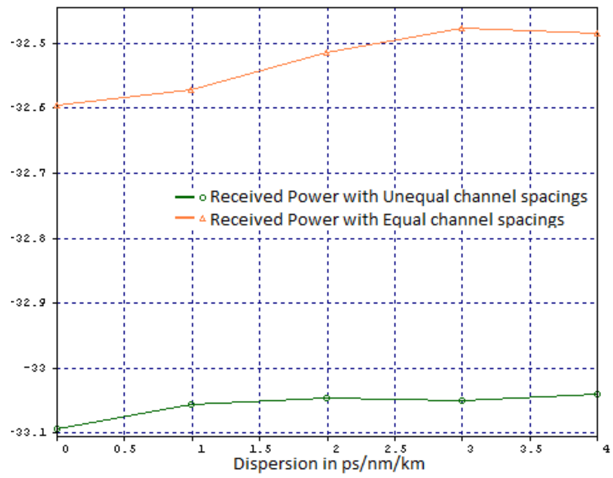


Channel 4

Figure 4: Received Power 4*10Gbps-DWDM system with equal- and unequal channel spacing with optical span of 100Km in the presence of FWM

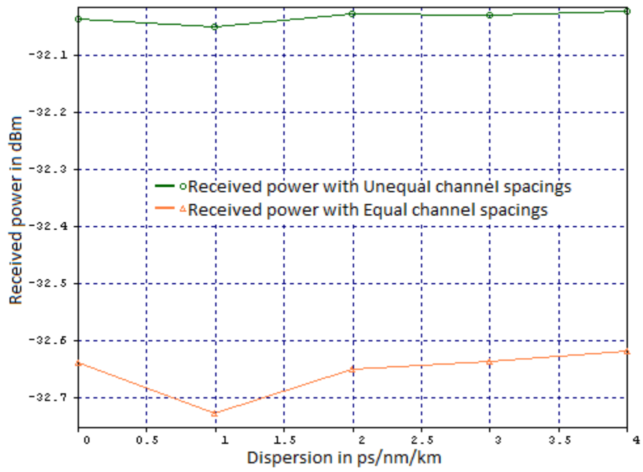
In Figure 4, received power of 4*10Gbps-DWDM system with equal channel of 0.24nm and unequal channel spacing varying from 0.24nm to 0.26nm distributed among 4-channels as spacing between channel 1 and 2 = 0.24nm, between channel 2 and 3 = 0.25nm, between channel 3 and 4 = 0.26nm, after optical span of 100Km in the presence of FWM has been observed. It has been observed that an improvement in received power is achieved with unequal channel spacing as compare to equal channel spacing. The same behavior is also obtained for received power of 4*10Gbps-DWDM system with equal channel of 0.26nm and unequal channel spacing varying from 0.24nm to 0.26nm distributed among 4-channels as spacing between channel 1 and 2 = 0.24nm, between channel 2 and 3 = 0.25nm, between channel 3 and 4 = 0.26nm, after optical span of 100Km in the presence of FWM has been observed as shown in Figure 5. The simulated observations reveals that unequal channel spacing comes out as an good candidate in improving the performance of ultra high speed long haul DWDM systems. Further, it is also observed that the intermediate channels are more affected by fiber nonlinearity i.e. FWM. The different values calculated of 4*10Gbps-DWDM system at varied values of equal channel spacing from 0.24nm to 0.26nm is given in tabular form in Table 2 and Table 3.

Table 2: Measuring Values with Equal Channel Spacing of 0.24nm

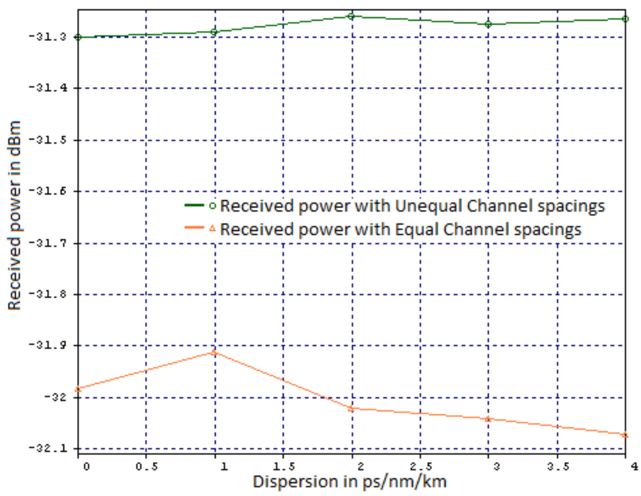
Parameters	**Channel-1**	**Channel-2**	**Channel-3**	**Channel-4**
BER	6.32×10^{-8}	4.53×10^{-4}	7.79×10^{-4}	1.00×10^{-7}
Q-factor	14.61	10.54	10.05	14.35
Eye Opening	0.020	0.013	0.012	0.020
Jitter	0.022	0.018	0.022	0.021

Table 3: Measuring Values with Equal Channel Spacing of 0.26nm

Parameters	**Channel-1**	**Channel-2**	**Channel-3**	**Channel-4**
BER	8.25×10^{-8}	9.08×10^{-5}	2.03×10^{-6}	6.80×10^{-17}
Q-factor	14.40	11.52	13.28	18.35
Eye Opening	0.021	0.015	0.018	0.024
Jitter	0.021	0.019	0.021	0.019



Channel 1



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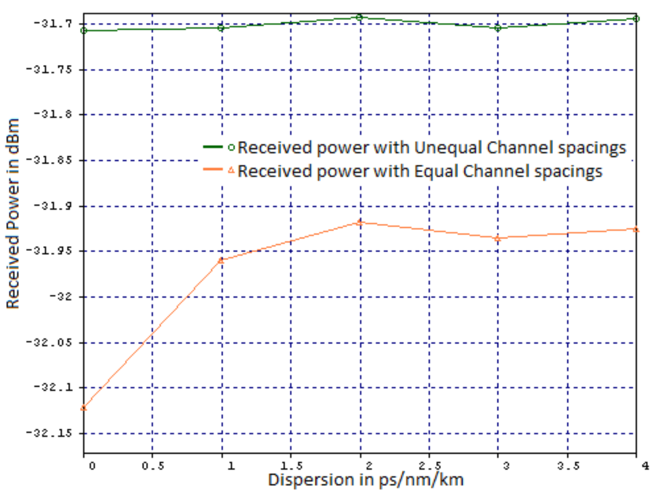
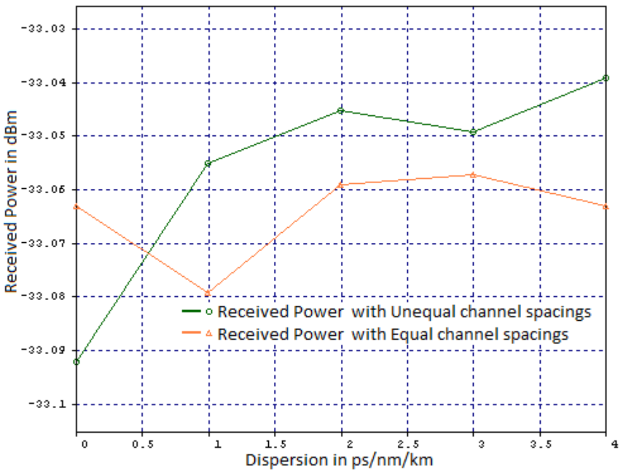


Channel 3



Channel 4

Figure 5: Received Power of 4*10Gbps-DWDM system with equal- and unequal Channel spacing of 0.26nm with optical span of 100Km in the presence of FWM

3. CONCLUSION

An implementation of 4*10Gbps-DWDM system have been reported over an optical span of 100Km in the presence of Four Wave Mixing with acceptable BER, Q-parameter and jittering under the impact of equal channel spacing varying from 0.24nm to 0.26nm in conjunction with the fiber-dispersion controlled by means of Fiber Bragg grating. It is observed that the intermediate channels are more affected by FWM. Further, it is recommended to implement ultra speed long haul -DWDM system with unequal channel spacing FWM suppression method and has been also observed that the suggested technique is simpler to implement and better to the presented methods.

4. REFERENCES

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