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Pulse Width Reduction Efficiency of Different Modules in Dense WDM Systems

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A B S T R A C T

In this work, Pulse width reduction efficiency (PWRE) of different hybrid modules at 10 Gbps is calculated in dense wavelength division multiplexed (DWDM) systems. Hybrid PWR units are Fiber Bragg Grating (FBG) and Dispersion Compensation Fiber (DCF), Optical Phase Conjugation (OPC) and DCF, FBG-DCF-OPC. It is observed that proposed DWDM system with 32 channels is capable to cover 300 km link distance. Results revealed that maximum PWRE is seen in FBG-DCF-OPC i,e. 70% but other two modules provide PWRE less than 55%.

Keywords: WDM, FWM, SPM, Q factor, BER

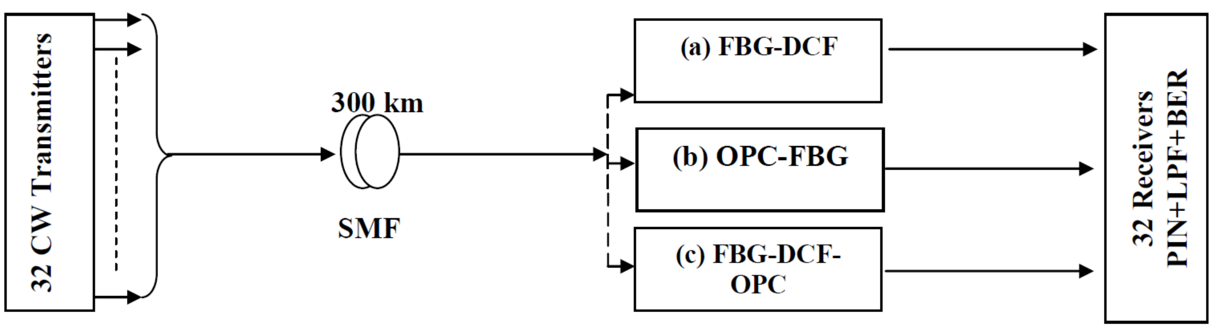
1. Introduction

Users need an excellent way out of fast signal transmission these days, with the unstable increase in web applications. Service providers face difficulties in meeting the demands of bandwidth-thirsty applications [1]. Today, high-speed and high-capacity systems are required, and fibre optics has emerged as an ultimate solution to meet the ever growing demands [2]. In most long distance high-speed communication networks, traditional systems made use of copper and coxial cable which are not appropriate due to high signal loss, more dispersion, electromagnetic interference (EMI), less protection and thus optical fibre is integrated [3]. Dispersion and attenuation are linear degradations in optical fiber systems but former is real issue than later one. Also there are nonlinear effects in optical fiber due to high input power such as Four wave mixing (FWM), Cross Phase Modulation (XPM), and Self Phase Modulation (SPM) etc [4] [5] [6]. In past, numerous studies are reported to compensate dispersion effects or pulse width broadening effects such as using FBG, DCF, and OPC [7] [8] [9]. However, each module has their own advantages and disadvantages like efficiency, cost, complexity etc. DCF is excellent candidate for PWR with great efficiency but it costly for the optical communication systems [10]. On contrary, FBG is cheaper module but provide less efficiency of PWR [11]. In OPC, nonlinear effects can be compensated along with PWR, but increase complexity. Later on, hybrid module of FBG and DCF were analyzed to find out high PWRE and moderate cost [12]. The cost of the module, however, was still high, so OFCS needs more economical PWR modules with better performance.

In this work, Pulse width reduction efficiency (PWRE) of different hybrid modules at 10 Gbps is calculated in dense wavelength division multiplexed (DWDM) systems over 300 km link distance.

2. System Setup

Optiwave optisystem 7 was used in this research work for the realisation of the proposed work. To verify which of the techniques has the best performance, three hybrid modules have been simulated. The PWRE was taken to determine the efficiency of the techniques as the decisive factor. Three different modules are tested in 32 channel 25 GHz spaced as shown in Figure 1. For the transmission purpose, SMF-28 optical fiber is taken which is having 17 ps/nm/km dispersion and 0.2 dB/km attenuation. An array of 32 lasers is used to produce different wavelengths each having 1 MW power. Binary data at 10 Gbps rate line encoded with non-return to zero (NRZ) is fed to a Mach Zehnder modulator to modulate data. After transmission, the signal enters the receiver section via a PWR module and amplification unit. The receiver consists of a PIN, low pass filter and BER analyzer for the assessment of Q factor and BER. System parameters are given in Table 1



PIN: Positive intrinsic negative LPF: Low pass Filter BER: Bit error rate analyzer

Figure 1 A Block Diagram of Proposed DWDM System

Table 1 System Parameters

Parameter	Values
Number of WDM channels	32
Frequency Spacings	25 GHz
Power per channel from transmitter	1mW (0 dBm)
SMF's Attenuation and Dispersion respectively	0.20 dB/km and 17 ps/km/nm
length of SMF	300 km
DCF's Attenuation and Dispersion respectively	0.5 dB/km and -80 ps/nm/km
DCF's length in each PWR module	FBG-DCF 51.6 km, OPC-DCF 70 km, FBG-DCF-OPC 51.2 km

3. Results and Discussions

In order to find an ideal PWR module for long distance communication systems, the proposed 32 channel ultra dense WDM system is being investigated. The optical spectrum of a single channel at 193.1 THz is shown in Figure 2 (a). Figure 2 (b) displays optical spectrum analyzers (OSA) for 32 channels and it is obvious that the carrier power and centre frequencies are shown by OSA. The input power of each wavelength is 1 MW (0 dBm), but the power of the carriers varies from -6 dBm to -4 dBm due to the insertion loss of the components.

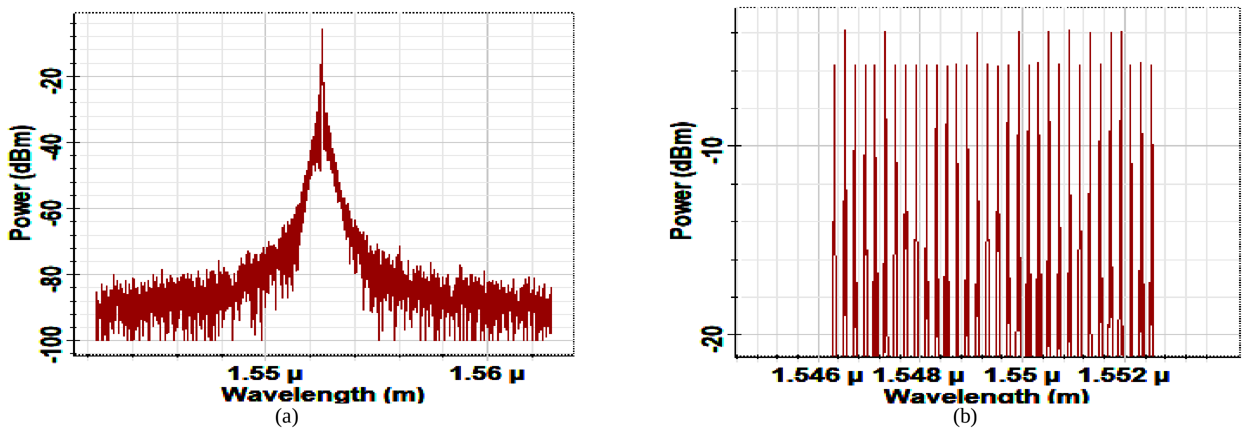


Figure 2 Optical spectrum analyzer output for (a) single channel (b) 32 channels after multiplexer

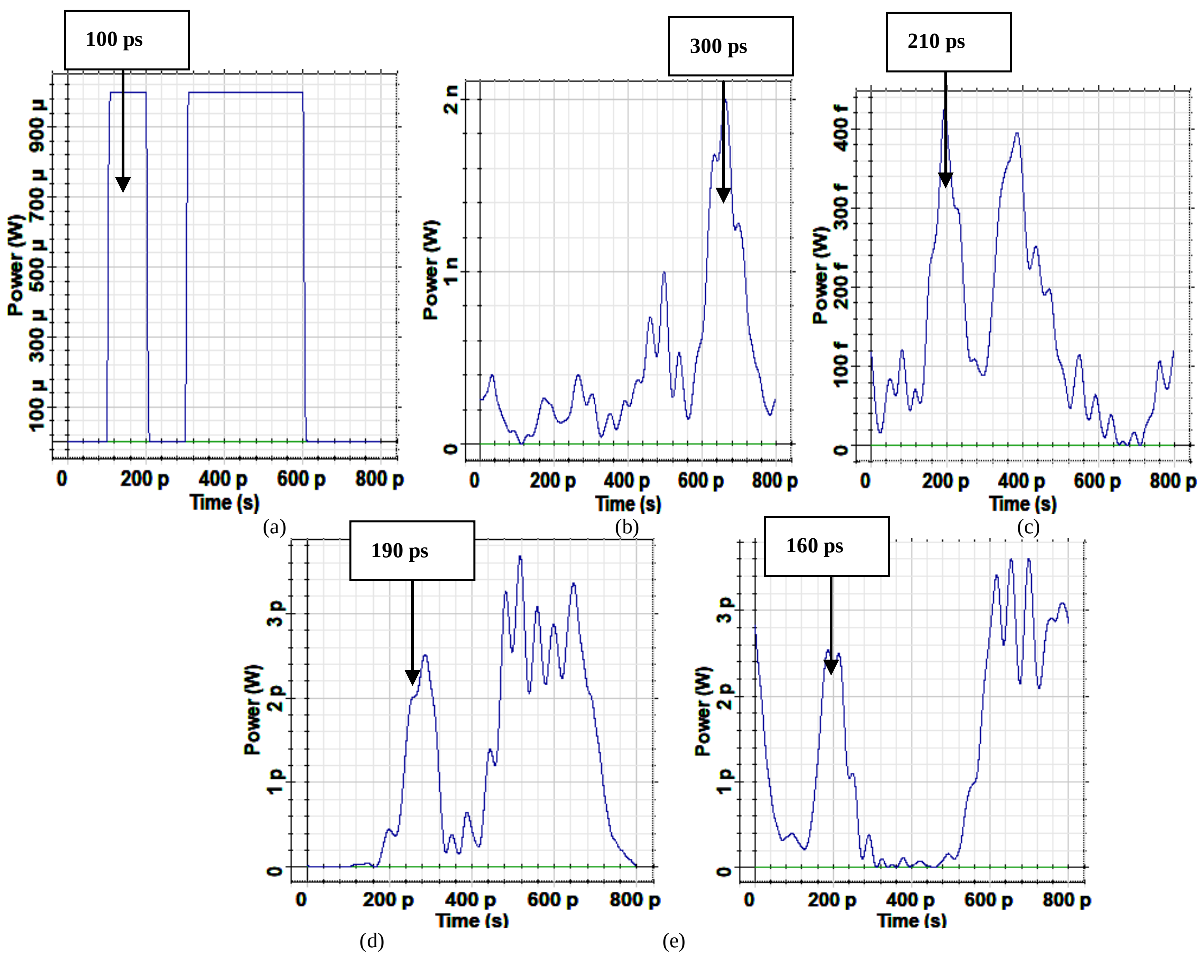


Figure 3 Optical time domain analyzer output after (a) transmitter (b) SMF of 300 km (c) Module OPC-DCF (d) Module FBG-DCF (e) Module FBG-DCF-OPC

The optical time domain visualizer (OTDV) is used to search the bits with regard to the time slot. The OTDV outputs are shown in Figure 3 (a), (b), (c), (d) and (e) for 100 ps pulse transmission, 300 ps pulse expansion, and 190 ps pulse reduction after FBG-DCF, 210 ps afterwards OPC-DCF, and 160 ps after incorporation of FBG-DCF-OPC. Compared to other modules, the PWR performance of FBG-DCF-OPC is higher. Pulse size in FBG-DCF-OPC is reduced from 300 ps to 160 ps and in case of FBG-DCF, it is 190 ps. For the calculation of PWRE, pulse size of the bits is measured after SMF, PWR module and after transmitter. Formula to calculate PWRE is given as

$$\mathbf{PWRE} = \frac{Y-Z}{Y-X}\ \mathbf{X\ 100} \quad (1)$$

It is observed from equation (1) that PWRE of FBG-DCF-OPC is 70%, FBG-DCF 55%, and OPC-DCF 45%. Least DCF fiber length i.e. 51.2 km is used in FBG-DCF-OPC, maximum in OPC-DCF i.e. 70 km.

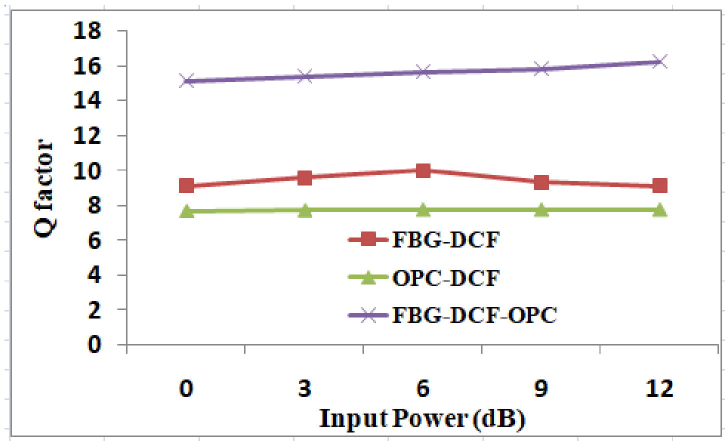


Figure 4 Performance comparisons of three PWRP modules in terms of Q factor

Figure 4 represents the system's Q factor when various PWR modules are incorporated with respect to the launched power into the system. In general, the launch power increases, the system's Q factor increases. More power inside the fibre, however, causes nonlinear effects that exacerbate the Q factor internally. The starting power ranges from 0 dBm to 12 dBm in this work, and it is observed that different power effects occur on each module. In the FBG-DCF-OPC module, the Q factor is greatest and each module has nonlinear effects. Using 6 dBm of input power for the maximum Q factor is recommended. It is obvious that the Q factor first increases with power in the case of FBG-DCF and decreases after 6 dB due to nonlinear high-power incidence effects. On the opposite, in OPC-FBG and FBG-DCF-OPC, OPC does the job of nonlinear compensation. Therefore, for these modules, the Q factor increases with the increase in input power.

The difference in input power is shown in Fig 5 and the increase in power is observed by BER when different PWR techniques are implemented into the device. In the case of FBG-DCF-OPC, the Q factor and BER differ inversely and the results showed that the minimum BER is seen. Increase the input power and decrease the system's BER. More power within the fibre, however, induces nonlinear effects that add more bit errors. It is perceived that BER first decreases with power increase in the case of FBG-DCF and increases after 6 dB because of nonlinear high-power incidence effects. In the case of OPC-DCF and FBG-DCF-OPC systems, however, BER decreases with power increase.

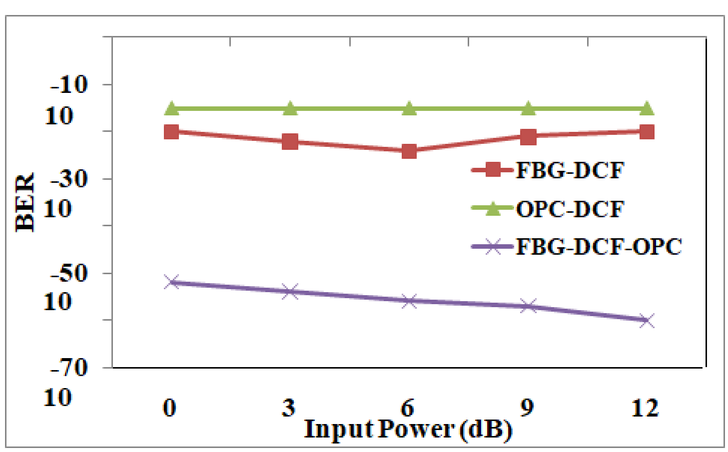


Figure 5 Performance comparisons of three PWRP modules in terms of BER

Figure 6 For optical fibre communication systems, the eye diagram is the decision representation and is the end part of the device that provides data on eye opening, jitter, signal to noise ratio, Q factor, BER, etc. Figure 6 (a) of the Eye diagram shows the output of the device without a PWR module. It becomes apparent from the eye diagram that the system is very sensitive to noise and dispersion. In the device, a dispersion compensation module is integrated and is shown as an eye diagram for various cases such as OPC-DCF, FBG-DCF, FBG-DCF-OPC in Figure 6 (b), (c), (d). A compensator is used after fibre to generate a dispersion index equal to but with the opposite dispersion (DCF) to that generated in fibre, of which the former will eventually inactivate the latter. In addition, by changing the SMF duration, the effect of distortion increases. Results have shown that in the case of FBG-DCF-OPC and maximum in OPC-DCF, distortions are least.

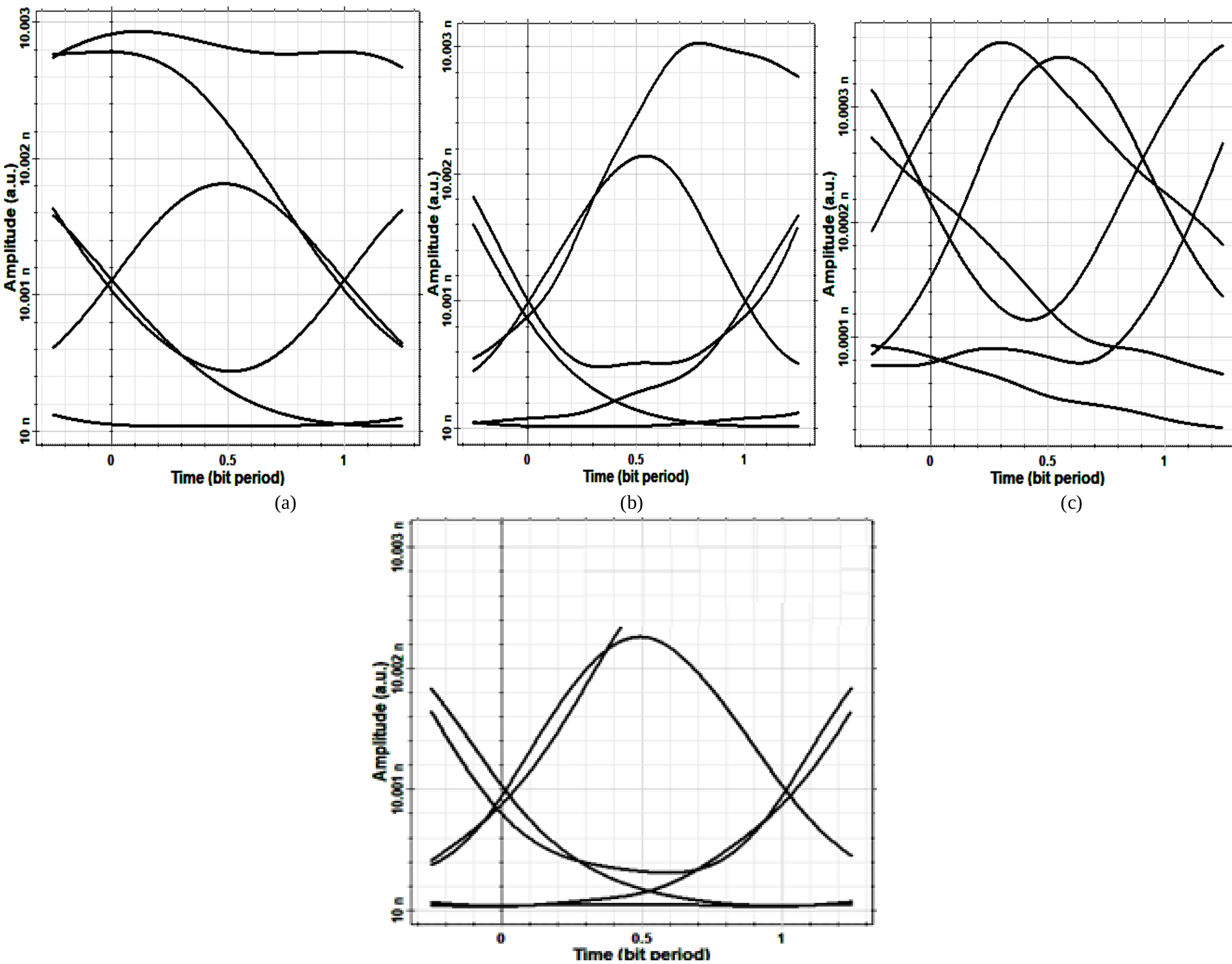


Figure 6 Eye diagrams of (a) without PWR (b) with PWR using FBG-DCF (c) using OPC-DCF (d) FBG-DCF-OPC

4. Conclusion

PWR schemes are proposed in this work by integrating various techniques such as FBG-DCF, OPC-DCF, FBG-DCF-OPC into the ultra dense 32-channel WDM system to observe PWR performance and module expenditure. The proposed investigation is conducted at 10 Gbps over 300 km SMF and the PWR module is further investigated in order to achieve an efficient hybrid PWR module and amplification unit. The performance of all modules is evaluated in terms of output Q factor, BER, at various input power levels. FBG-DCF-OPC is found to be the highest PWRE (70 percent) and Q factor 15.16 at 1 MW (0 dBm) with the minimum DCF duration module (51.2 km for 300 km SMF-28). Q factor output at 1 MW is represented as: FBG-DCF-OPC depicts Q factor=15.16, FBG-DCF depicts Q factor of 9.12 and OPC-DCF depicts Q factor=7.68. Therefore, due to its optimal performance in terms of PWRE and cost, the recommended hybrid module is FBG-DCF-OPC.

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