Effect of different transmission medium on the performance of 4x20 Gbps OTDM system operating in C-band

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Optical time-division multiplexing (OTDM) updates the well-known technique of electrical time-division multiplexing into the optical domain. In OTDM, optical data streams are constructed by multiplexing a number of low bit-rate optical streams in time domain. In this paper, Optical Time Division Multiplexed System has been investigated with different transmission medium such as Single Mode Fiber (SMF) and Optical Wireless Communication (OWC). The performance of 4x20 Gbps has been evaluated on the basis of Q factor, BER and Eye diagram at different transmission distance. It is found that signal is successfully transmitted to a distance of 100 km in SMF with Q factor of 6.63 and BER of 1.27e-011 and 172 km in OWC with Q factor of 6.05 and BER of 4.69e-010. It has been observed that OWC exhibits good performance as compared to SMF.

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1. Introduction

Optical Networks are expanding speedily now days due to tremendous advantages like huge bandwidth, reliability, low cost transmission and security [1]. Multiplexing is becoming one of the key technologies capable of satisfying the growing demand of large capacity for optical transmission system [2]. Development of different multiplexing technology designed optical communication networks with very high capacity that offer transmission over many thousands of kilometers without using any electronic repeater [3]. The bandwidth of optical systems can be increased either through Wavelength Division Multiplexing (WDM) or optical time division multiplexing (OTDM) or by a combination of both. Less network management efforts make OTDM more economic than WDM and there is no need of replacement of existing single band and narrow-band erbium-doped fiber amplifiers (EDFAs) with broadband amplifiers, as they still work [4]. Erbium-doped fiber amplifiers (EDFAs) are designed in order to reduce the impairments due to fiber nonlinearities [5-6].

Optical time division multiplexing (OTDM) has attracted much attention in recent years for achieving high transmission rates on a single wavelength [7]. The principle of this technique is to optically combine a number of lower speed electronic baseband digital channels to extend time division multiplexing [8].In optical time division multiplexing (OTDM), low bit rate channels are multiplexed in time domain and transmitted using a single wavelength. Ultra-high bit rate transmission (>100 Gbps) is attained by sending packets composed of very short duration pulses. The benefits of these systems are its flexibility of allowing for variation in the number of signals being sent along the line, as well as its capability to adjust the time intervals to make best use of the available bandwidth [9].Proper signal recovery must be achieved with synchronization between the transmitter and the receiver as OTDM is a time synchronized system [10**].** It has been observed that the chromatic dispersion and optical Kerr effect limits the performance of the system and transmission length of a single mode fibre at high bit rates in high speed OTDM transmission system [11-12].

Sanmukh Kaur et al. [13] evaluated the performance of OTDM system at different data rates up to 160 Gbps using SOA-MZI as a demultiplexing switch for RZ and NRZ modulated signals. Ming Chen et al. [14] demonstrated the demultiplexing for OTDM system exploiting two concatenated electro-absorption modulators (EAMs). OTDM signal of 80 Gbps was successfully demultiplexed to base rates of 20 Gbps and 10 Gbps using the pair of EAMs, respectively. Jyotsana et. al [2] investigated the performance of 40 Gbps OTDM transmission system with pre-, post-, and symmetrical-dispersion compensation techniques for different fibre standards.

The previous work [10] was carried out for optical time division multiplexing using SMZ switching at 40Gbps with distance of 75km.The work is extended here with 80 Gbps using different transmission medium such as SMF and OWC with reachable distance of 100 km and 172 km in the presence of losses.

This paper is organized into four sections. In section 1, Introduction to OTDM system is described. In section 2, simulation setup for 4x20 Gbps OTDM is described. In section 3, results in terms of Q factor and BER for proposed system have been reported. The Section 4 presents the conclusion about the feasibility of the system.

2. Simulation setup

The proposed system set up of 4×20 Gbps Optical Time Division Multiplexing (OTDM) system is shown in Fig. 1. The transmitter consists of Laser, PRBS, Pulse generator, modulators and power combiner. Continuous wave (CW) laser with linewidth 10 MHz, Input Power 5 dBm is used as optical source which operates at 1550 nm. Optical output signal of laser is then splitted using 1x4 optical splitter into four channels. Each channel is modulated with an external amplitude modulator driven by RZ pulse generator with a pseudo random bit sequence (PRBS) and generates a data stream of 20 Gbps. The modulated signals are delayed with different time intervals. The time delays used are D0 = 0 ns, D1 = 0.0125 ns, D3 = 0.025 ns, D4 = 0.0375 ns as shown in Fig. 1. The four 20 Gbps modulated signals are combined together to produce 80 Gbps signal using optical combiner. The optical Splitter/Combiner has insertion loss of 0.1 dB.

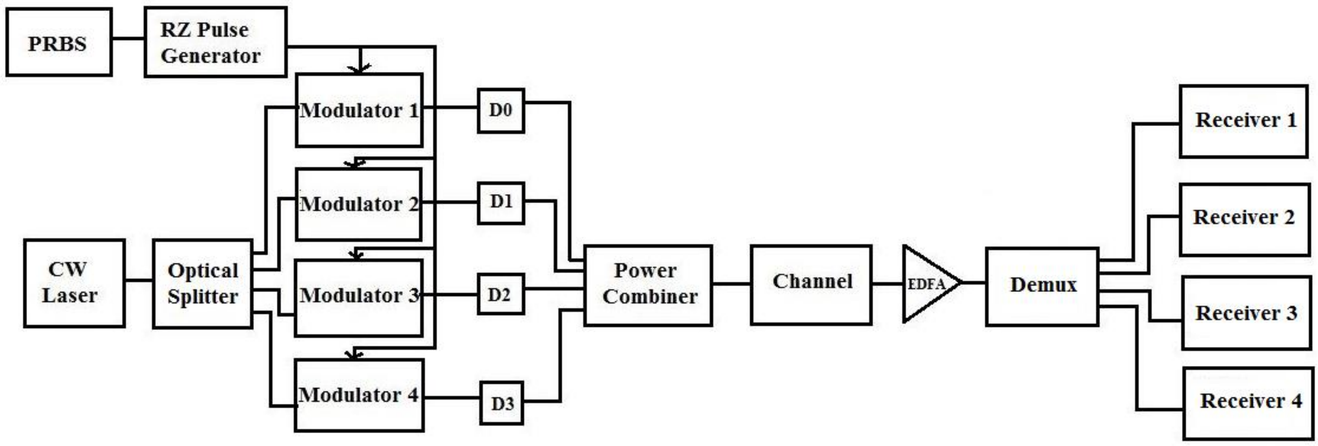

Fig. 1. System setup for OTDM system

The 80 Gbps OTDM signal is transmitted through the different optical medium under investigation i.e. SMF and OWC. The SMF has dispersion of 16.75 ps/nm/km and attenuation of 0.2 dB/km. OWC exhibits attenuation of 0.2 dB/km. To compensate the losses caused by medium an optical amplifier with gain of 25 dB is used to amplify the incoming signal. The issue of medium losses such as dispersion, nonlinearities, crosstalk and attenuation are taken into account.

After that 80 Gbps optically modulated signal is demultiplexed into four channels of 20 Gbps using clock demultiplexing. In clock demultiplexing, incoming signal is given to a modulator driven by base electrical clock of 20 Gbps. Clock demultiplexing reduces the system complexity. Clock recovery is used to provide synchronization between transmitter and receiver. The demultiplexed output is fed to the receiver. Receiver consists of Photo detector, filter, regenerator and BER analyzer. The photo detector converts the optical signal into electrical signal. Avalanche photodiode is used as a detector at the output side due to its better performance characteristics than PIN photodiode. Low pass Bessel filter removes the higher frequency components. The output of each LPF is given to the 3R Regenerators followed by BER (Bit Error Rate) analyzer to visualize the eye diagram, BER, Q factor of the system.

3. Results and discussion

The performance of 4x20 Gbps OTDM with different transmission medium i.e. SMF and OWC is defined in terms of Q-factor, BER and Eye diagram. The losses of optical medium such as dispersion, nonlinearities, crosstalk and atmospheric turbulence are taken into account. The results are reported for each channel by varying the distance. The spectrum of the multiplexed signal is shown in the Fig. 2.

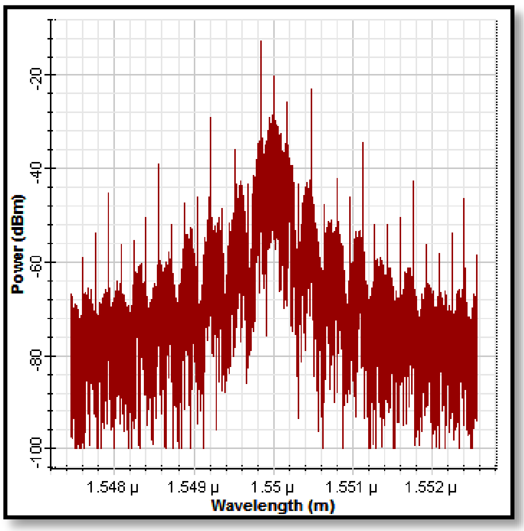

Fig. 2. Spectrum of multiplexed signal

The graph between Q factor and transmission distances for OWC as shown in Fig. 3. It is evident from the graph that with increase in distance from 115 to 190 km, Q factor decreases. The Q factor is varying from 35–3.32, 21.02–3.61, 21.14–3.52 and 23.76–3.55 with Channel 1, Channel 2, Channel 3 and Channel 4, respectively. It is observed that acceptable Q factor i.e. 6 is obtained at 172 km transmission distance. Hence signal is transmitted up to 172 km distance with the acceptable performance.

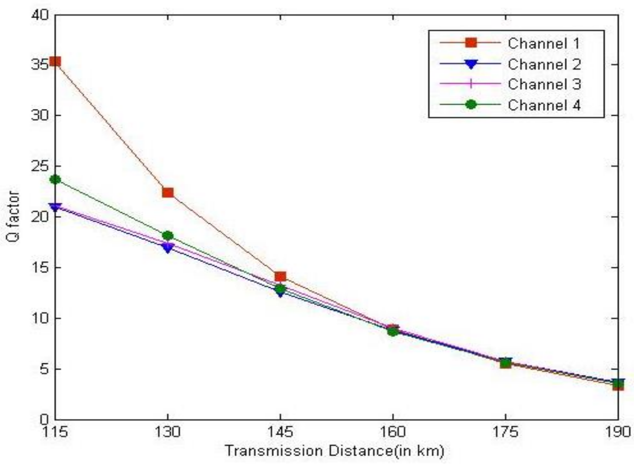

Fig. 3. Q factor versus transmission distances for OWC

The effect of transmission distance on Q factor for SMF is shown in Fig. 4. The acceptable Q factor is achieved up to 100 km distance with SMF in the presence of fiber nonlinearities. After that Q factor decreases means signal gets degraded. It is observed that the acceptable Q factor of 6.63, 7.26, 7.44 and 6.81 are achieved at 100 km transmission for Channel 1, Channel 2, Channel 3 and Channel 4 respectively. Hence data is transmitted up to 100 km distance with the acceptable performance.

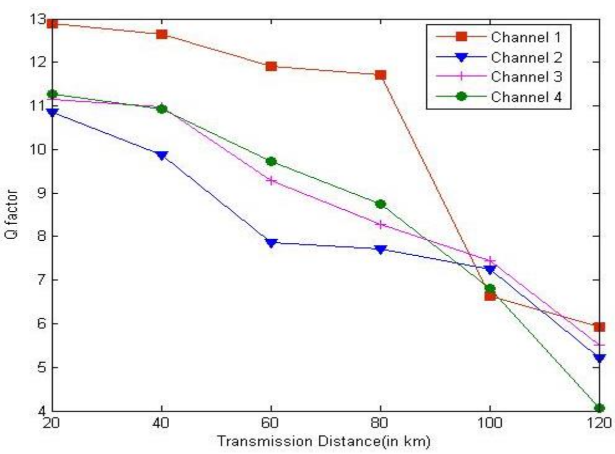

Fig. 4. Q factor v/s transmission distances for SMF

As shown in Fig. 5, the effect of transmission distance on BER for OWC is observed. It is analysed that there is a significant variation of BER when distance increases due to attenuation loss. The acceptable BER (i.e 4.69×10^{-10}) is achieved up to 172 km distance. The BER varies from 3.84×10^{-274} to 3.1×10^{-5} for channel 1. Channel 2 and Channel 3 exhibits variation in the range of 1.06×10^{-98}–1.15×10^{-6}, $8.10\times\times10^{-100}$ – 1.6×10^{-6} at 115km and 190 km. The variation of channel 4 is in the range of 2.18×10^{-125} to 1.32×10^{-6}.

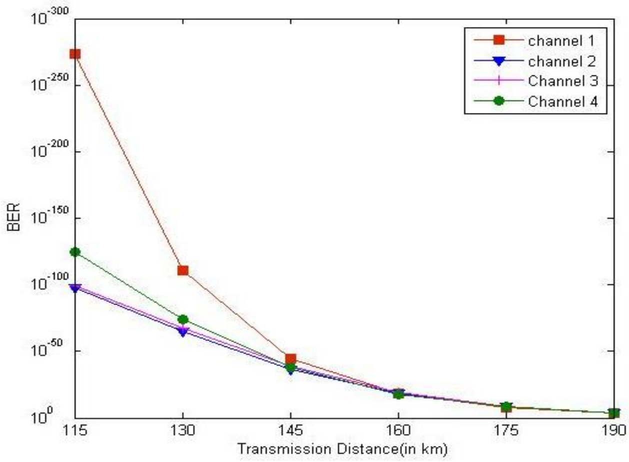

Fig. 5. BER v/s Transmission distance for OWC

Fig. 6 shows the BER versus transmission distance for SMF. It is observed that with increase in distance, BER increases due to fiber losses such as dispersion, crosstalk and attenuation. For Channel 1, BER at 20 km distance is 1.81×10^{-38} and increases to 1.46×10^{-9} at 120 km. The variation is from 9.73×10^{-28}–1.58×10^{-9}, 5.62×10^{-29} – 1.12×10^{-9} and 1.07×10^{-30}–2.04×10^{-5} for Channel 2, Channel 3and Channel 4 respectively.

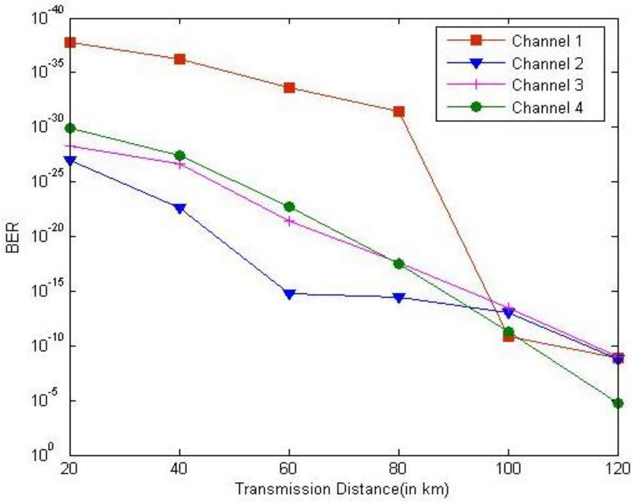

Fig. 6. BER v/s Transmission distance for SMF

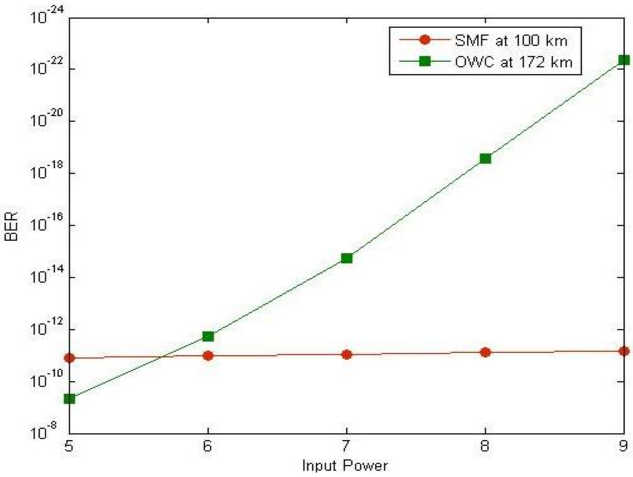

Fig. 7. Input Power versus BER [at channel 1]

Fig. 7 shows the variation of BER with change in input power. The BER gets improved when the value of power increases from 5 dBm to 9 dBm, respectively. There is a slight variation of BER in SMF due to the fiber losses such as dispersion, attenuation and crosstalk etc.

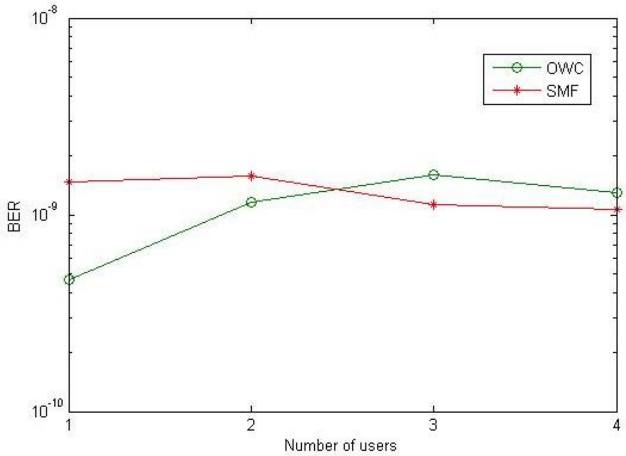

Fig. 8. Number of users versus BER

Fig. 8 depicts the graph between the number of users and BER. In this paper, each channel is of 20 Gbps and there are four channels. Thus, the number of users for this OTDM system is four with bit rate of 20Gbps for SMF and OWC. The values of BER for all the users are 4.69×10^{-10}, 1.15×10^{-9}, 1.6×10^{-9} and 1.3×10^{-9} for OWC at 172 km whereas the BER for SMF at 100 km for all the users are 1.46×10^{-9}, 1.58×10^{-9}, 1.12×10^{-9} and 1.07×10^{-9}.

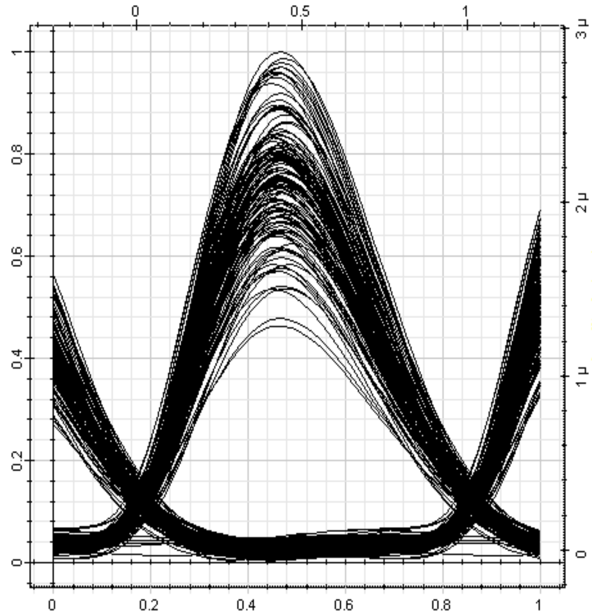

Fig. 9. Eye diagram of SMF at 100 km

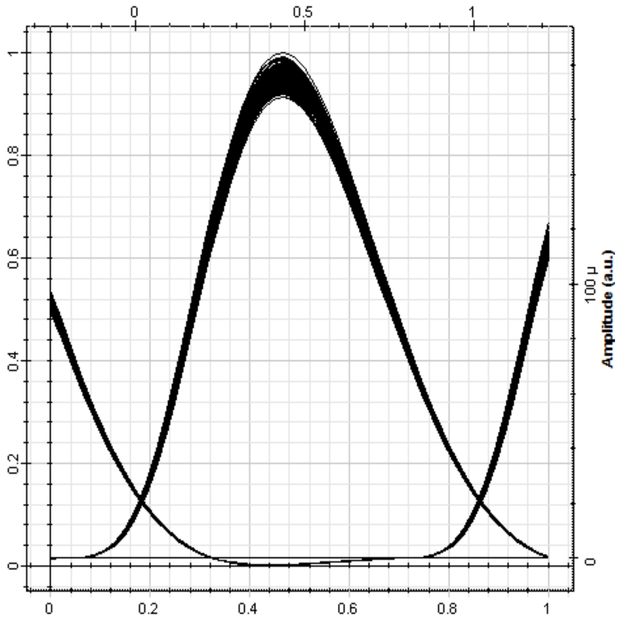

Fig. 10. Eye diagram of OWC at 100 km

Fig. 9 & Fig. 10 shows the eye diagrams for SMF and OWC at 100 km respectively. It is clearly visible from Fig. 9 that the performance of SMF goes on decreasing due to signal distortion i.e. decreasing the Q factor due to the fiber non linearities and OWC shows maximum eye opening as shown in Fig. 10.

4. Conclusion

In this paper, the feasibility and performance of Optical Time Division Multiplexed System for 4×20 Gbps bit rate using Single Mode Fiber and Optical Wireless Communication as transmission medium has been investigated. Moreover, OTDM system is simple and cost-effective. The benefit of this system is its flexibility as well as its capability to adjust the time intervals to make best use of the available bandwidth. It is observed that OWC provides acceptable Q factor of 6.05 and BER of 4.69e-010 up to 172 km distance with attenuation loss and SMF provides acceptable Q factor of 6.63 and BER of 1.27e-011 up to 100 km distance in the presence of fiber nonlinearities. It is observed that the OWC channel gives better performance than SMF in OTDM system.

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