Impact of High Speed Differential Quadrature Amplitude Modulation using Hybrid Optical Amplifier for Super Dense Wavelength Division Multiplexing System

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In this paper, a Differential Quadrature Amplitude Modulation (DQAM) technique for 200 x100 Gbps Super Dense Wavelength Division Multiplexing (SD-WDM) system is proposed. Optimized rating outcome in terms of the quality factor, bit error rate, crosstalk, and acceptable minor effect of the channel spacing with the support of RAMAN-EDFA-RAMAN Hybrid Optical Amplifier (HOA) is reported.

Keywords: Differential Quadrature Amplitude Modulation, Hybrid Optical Amplifier, quality factor, bit error rate (BER), crosstalk, output power

1 Introduction

Transmission of high spectral efficiency optical signal from one place to another place with less loss and good rating of quality factor is also an interesting challenge for a researcher. Many researchers have proposed the different modulation techniques such as Amplitude Modulation (AM), Frequent Modulation (FM), Phase Modulation (PM) and much more. But these are the basic modulation technologies which have some limitations in term of optical signal transmission. In fact, low power signal is converted into a high power signal with the help of the carrier signal. Moreover, the optical carrier signal is generated from the CW laser and boost up the level of the optical signal in terms of the modulation signal for long haul distance. Many researchers are focusing to raise the transmission speed up to 100 Gbps or more with the support of different advanced modulation technology for optical communication such as M-ary Differential Phase Shift Keying (DPSK)$^1$, Optical Differential Quadrature Phase Shift Key (ODQPSK)$^2$, Differential Quadrature Phase Shifting Keying (DQPSK)$^3$ and Symmetrical Differential Phase Shift Keying (SDPSDK)$^4$ etc. Unfortunately, the effect of the hybrid optical amplifier is not considered in the literatures, which is an important consideration for long haul optical communication. Super dense wavelength division multiplexing system is the advanced technology to transmit the higher capacity optical signal$^{5,7}$. In the multiple play services, a number of channels are packed to provide the services such as high-quality video and communication$^8$. But the effect of the fiber nonlinearity and amplified spontaneous (ASE) emission can be dismissed with the help of different Hybrid Optical Amplifiers (HOAs)$^9$.

High spectral efficiency is the hot demand for the optical network. Chung et al.$^{10}$ have explored the new technology for 16 x 10 Gbps for the transmission distance of 1040 km with the help of RAMAN amplifier, but this model only highlighted the data transmission speed up to 10 Gbps which does not fulfill the demand of high capacity transmission. Downie et al.$^{11}$ have evaluated the error free data transmission of 43Gbps for the transmission distance of 1200 km with 50 GHz channel spacing, but the effect of the hybrid amplifier is not shown in this literature which is an important effect in terms of low bit error and good rating quality factor for single span optical communication system.

In this paper, we have used a very advanced modulation (DQAM) technology for optical transmission. Transmission of 100 Gbps is shown by the support of RAMAN-EDFA-RAMAN hybrid optical amplifier (HOA). Moreover, the layout of the

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paper is represented in the five sections. Literature review and evaluation of existing technology are shown in section one, description of proposed modulation transmitter and receiver are given in section two, description of simulation setup is given in section three, results and discussion are given in section four and paper is ceased with the analysis in section five respectively.

2 Description of proposed transmitter and receiver

The transmitter of proposed DQAM is shown in Fig. 1. The differential quadrature amplitude modulator delivers the transmission of two data streams of 50 Gbps from the data sources and provides the best outcome in terms of spectral efficiency and enhanced dispersion tolerance\(^1\). In this way, the resultant bit rate is coming out with the rate of 100 Gbps. Modulation is accomplished with the help of two MZM (Mach-Zehnder) modulators. Each of the MZM is fed with the data (generated from the data source and NRZ electrical drive) and further modulated with the carrier signal. The carrier signal is generated from CW laser, which is further applied to MZMs with the help of an optical splitter (OS). The resultant signals in phase and quadrature arms are combined with the phase difference of \(\pi/2\) to generate the DQAM modulated signal. Further, this modulated signal is transmitted through the optical fiber with the help of the HOA.

To detect such a high capacity signals, we required a very advanced receiver which is shown in Fig. 2. The received optical signal is applied to two parallel Mach-Zehnder demodulator with the help of an optical splitter. The optical delay is set with the period of 2/B. To remove the intersymbol interference (ISI), the phase difference of \(\pi/4\) and \(-\pi/4\) are set to upper and lower arms respectively. Each MZM demodulator received the balanced bit rate of 50 Gbps. Two PIN photodiodes with low pass filters are placed after the MZM demodulator for optical-to-electrical (O-E) conversion. The input signal is in the form of \(E_0 [\cos(w_0 \delta_1) + j \sin(w_0 \delta_2)]\) and output after the PIN photodiodes are in the form of \(\cos(\delta_1) + \sin(\delta_2)\) and \(\cos(\delta_1) - \sin(\delta_2)\) respectively. In this way, high rating signal of 100 Gbps is received at the receiver side.

3 Simulation setup

Our complete proposed simulation setup including high spectral efficiency transmitter and receiver for 200 x 100 Gbps are shown in Fig. 3.

Simulation is going to establish with the help of 200 CW laser sources. The beam of laser sources is generated at 180.9 to 193.4 THz. 200 channels are placed with 12.5 GHz channel spacing and input signal spectrum occupies the bandwidth of 6.4 THz.
RAMAN amplifiers are pumped by 1480 nm at 760 mW. EDFA is set to fix output power of 32mW and noise figure of 4.5 dB to amplify the signal. The total gain of cascade amplifier is given by equation (1) \[ G_{RER} = G_{Raman1}G_{EDFA}G_{Raman2} \]

PIN photodiodes with the quantum efficiency of 0.875 and dark current of 0.1 nA are used on the receiver section. Parameters of RAMAN amplifier are given as 12 km of Raman fiber length, 0.2 dB/km of Raman loss, 1453 nm of pump wavelength, 600 mW of pump power, 0.2 dB/km of pump attenuation, 2.15 ps/nm/km is set for reference frequency of dispersion, and 300 K of operating temperature respectively. In a similar manner, the parameters of EDFA amplifier are already explained in this paper. The evaluated rating of the received signal in terms of eye diagram is given as eye closure of 0.11570 dB and eye opening of 0.0106989 (a.u.) for channel 1, eye closure of 0.104414 dB and eye opening of 47.5934 (a.u) for channel 200 respectively. It is observed that insertion of data bits from the data source (which means more number of users or data bits induce more eye closure).

4 Result and discussion

The impact of channel spacing of 50 GHz and 100 GHz on the hybrid optical amplifier in terms of power variations is shown in fig. 4 (a) & 4 (b). The recorded values for the 50 GHz channel spacing lies between 7 dBm to 7.1 dBm for 0 dBm power, and -0.4 dBm to -0.6 dBm for -7 dBm power. In a similar way, the recorded values for 100 GHz channel spacing lies between 5 dBm to 5.3 dBm for 0 dBm power, and -0.3 to -0.02 dBm for -7 dBm power respectively. It is analyzed that the variation in power for 50 GHz channel spacing is greater than 100 GHz channel spacing due to degradation in power level. So it can be concluded that RAMAN-EDFA-RAMAN hybrid optical amplifier provides the best accepted rating outcome for 100 GHz channel spacing.

The illustration to show, the effect of crosstalk induced by RAMAN-EDFA-RAMAN HOA with respect to applied input power is shown in Fig. 5. The variations in crosstalk are given as -22 dB to -11 dB for the 50 GHz channel frequency, and -24 to -13 dB for 100 GHz channel spacing respectively. It is evaluated that variation in crosstalk is increasing with respect to increasing input power just because of internal gain saturation. Further, the recorded results have shown that the accepted rating outcome are better than the results obtained by Oberg et al. 14

To illustrate the performance of the proposed model in term of quality factor with respect to bit rate is shown in Fig. 6. It is observed that proposed HOA delivers the best outcome for 50 GHz channel spacing.
in terms of 50 Gbps bit rate. Moreover, the performance of the system is degraded with 100 GHz channel spacing at 45 Gbps due to non usage of any dispersion compensation techniques.

Variations of bit error rate with respect to bit rate for different channel spacing is shown in Fig. 7. The observed values lies between 1.3e-13 to 3.1e-1 for 50 GHz channel spacing, and 1.4e-14 to 2.5e-1 for 100 channel spacing. So it is observed that the performance of proposed modulation shows the accepted BER (> 50) Gbps with the quality factor (> 30) dB.

The variation in gain and quality factor for different channel spacing and input power are shown in Table 1. It is observed that the quality factor of received signal is affected by increasing the channel spacing. It occurs due to the addition of its own nonlinearity and crosstalk by each amplifier in the arrangement of HOA. But it can also be resolved by placing the isolator in the middle of two optical amplifiers.

5 Conclusion

We have evaluated the impact of DQAM modulation technology for the 200 x 100 Gbps SD-
WDM system with the help of RAMAN-EDFA-RAMAN HOA in term of varying channel spacing, the influence of crosstalk, quality factor, and bit error rate respectively. The accepted rating outcome is reported with the comparison of references\textsuperscript{15-20} in the scenario of reduction in crosstalk, improvement in quality factor, channel spacing, gain ripple, cost, and speed, etc. Moreover, it has also observed that proposed model has shown the better outcome in terms of higher spectral efficiency (> 100 Gbps) with fiber (>200 km) for the commercial research.

References