International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 5, Issue 10, pp 65-69, October-2021

https://doi.org/10.47001/IRJIET/2021.510011

Performance Improvement of VCSEL based 8-Channel WDM Optical Link

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***Abstract* - In this paper, a Vertical Cavity Surface Emitting Laser (VCSEL) based 8-channel WDM link has been established. VCSEL's operating at 850 nm in optical networks is very popular due to broad range of applications. The conventional and dispersion compensated optical links have been established for data transmission at the bit rate of 20Gbps with 200 meter fiber length. The phase conjugator has been employed for dispersion compensation. The performance comparison of two optical links has been carried out using fiber length, Q factor and Eye Diagram.**

Keywords: VCSEL, Dispersion compensation, Phase conjugator, Optical Link.

I. INTRODUCTION

Vertical Cavity Surface Emitting Laser (VCSEL) is a semiconductor laser diode emitting laser beam perpendicularly from the top of the surface. VCSELs are ideal light sources for a wide range of applications due to their high productivity, cost-effectiveness, reliability, low power consumption, and compact size[1]. VCSEL's are a potential candidate to be used in advanced generation optical networks such as radio over fiber (RoF), fiber to the home (FTTH), free space optics (FSO). The transmission of signals at high speed and larger distance requires low bit error rate (BER) and high quality factor (Q-factor). Multi-mode VCSELs with optimized bandwidth and minimized noise have been engineered for efficient 100 Gb/s data communication over multi-mode fiber. A 100 Gb/s PAM-4 signal transmission over a 100m OM4 fiber is demonstrated leveraging equalization at both the transmission and reception stages [2].

The dispersion is defined as pulse broadening leading to erroneous reception and high BER. The dispersion needs to be taken care as it hampers the maximum data rate. There are various techniques or devices that are employed to compensate the dispersion including dispersion compensation fiber, fiber bragg gratings and optical phase conjugator[3-6].

Mid-span dispersion compensation was successfully achieved using a silicon waveguide-based optical phase conjugator. A successful transmission of wavelength-multiplexed 4×10 Gb/s data over 320 km of standard fiber was achieved, resulting in a power penalty of less than 0.3 dB at a bit error rate of 10-9[4]

An optical transmission system with a bit rate of 10 Gb/s was implemented for a distance exceeding 50,000 km. The key conclusion from the results is that placing a single optical phase conjugator (OPC) at the fiber's midpoint effectively compensates for dispersion [5].

It was successfully demonstrated that a bandwidth-efficient OPC module placed at the midpoint of a field-installed 800 km non-dispersion-managed link effectively compensates for both chromatic dispersion (CD) and nonlinear distortion in a six-channel polarization-division multiplexed (PDM) 16-QAM signal [6].

In this work, we have established an optical link for high-speed data transmission over 200 meter multimode fiber length for attaining good Q-factor and better performance at room temperature with a bit rate of 20Gb/s. In this paper, we have compared the improvement in Q-factor and eye diagram performance when the system is incorporated with optical phase conjugator (OPC) to compensate for optical dispersion. All these investigations have been carried out on 850nm wavelength range.

II. SIMULATION SETUP

The VCSEL based model is designed to transmit the data at bit rate of 20 Gbps with 200 meter fiber length at 850 nm wavelength by employing OPC. Our proposed model is consisting of basically three sections, namely, transmitter, channel and receiver.

Figure 1 represents the simplified block diagram of the designed model that consists of conventional link and dispersion compensated link. In transmitter section, Pseudo Random Bit Sequence (PRBS) produces digital data and it is encoded by pulse generator in Non-Return Zero (NRZ) format. The encoded data is superimposed on eight optical frequencies with channel wavelength 850 nm and channel spacing 0.8 nm generated by corresponding VCSELs. The optical combiner multiplexes these eight different wavelengths.

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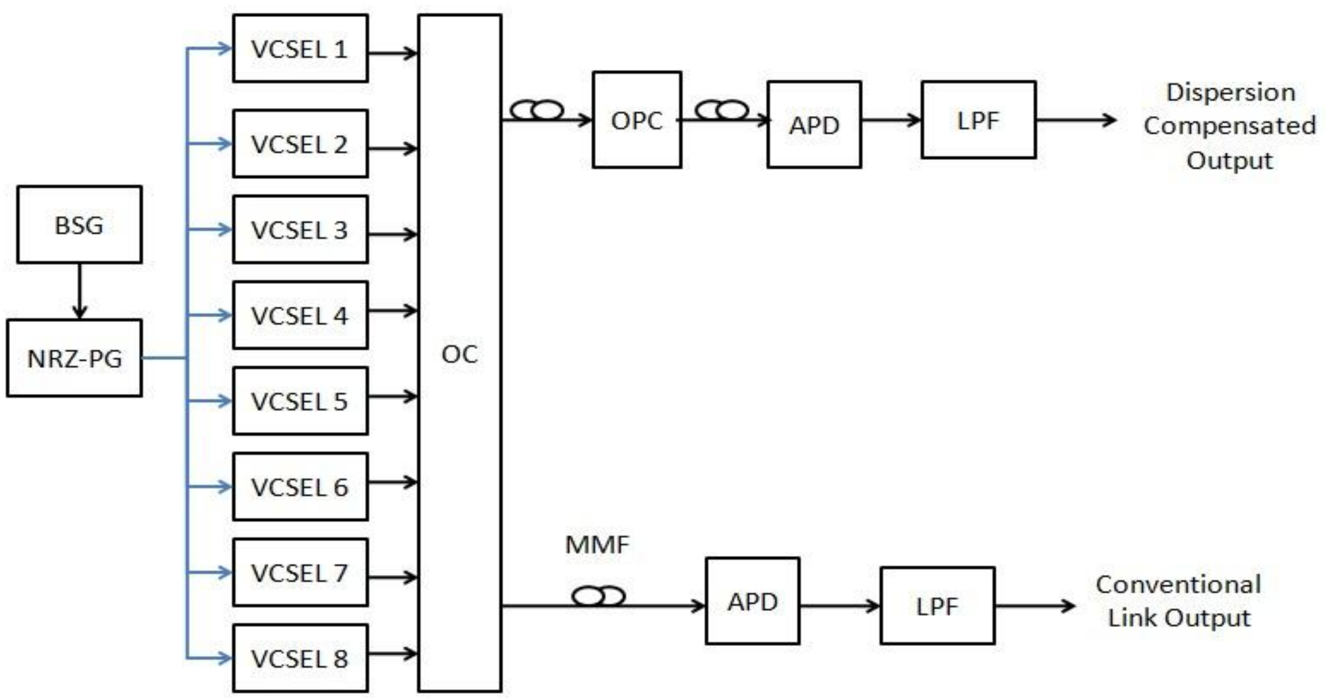

Figure 1: Block diagram of proposed 8-channel WDM link; BSG: Bit sequence Generator; NRZ-PG: Non return to zero-pulse generator; OC: Optical combiner; APD: Avalanche photodetector; LPF: Lowpass filter

The output signal of optical combiner is further processed through two different channels namely conventional link and dispersion compensated link. In Channel Section, the conventional link employs multimode optical fiber of length 200 meter while dispersion compensated link employs optical phase conjugator between two multimode optical fibers of 100 meter length. The output of conventional link and dispersion compensated link are received by separate Avalanche photo detectors (APD) in receiver section. The optical signal detection is performed by APD and its output is applied to the low pass Bessel filter which then passes the low frequency signals and rejects the high frequency signals. The processed outputs of conventional and compensated links are compared using fiber length, BER values and Eye diagrams.

Figure 2: Simulation set up for proposed link

Table 1: Simulation Parameters involved in system design

Parameter	Value		Parameter	Value
Laser wavelength	850 nm		Optical Conjugator Angle	90 degree
Channel spacing	0.8 nm		MMF length	200 meter
VCSEL Input Current	40 mA		MMF chromatic dispersion	17 ps/nm km
VCSEL Bias Current	14 mA		PD Dark current	10 nA
Data Rate	20 Gbps		PD Responsivity	1 A/W

III. RESULTS AND DISCUSSION

The model shown has been simulated and the different outputs are observed. The outputs were taken from conventional link and dispersion compensated link and then both the results were compared. This section compares various results obtained for conventional and compensated link. The transmitted optical signal spectrum in figure 3 includes eight dominating frequencies generated by eight lasers while the received optical spectrum in figure 4 also includes intermodulation (IMD) components in addition to original dominating frequency components.

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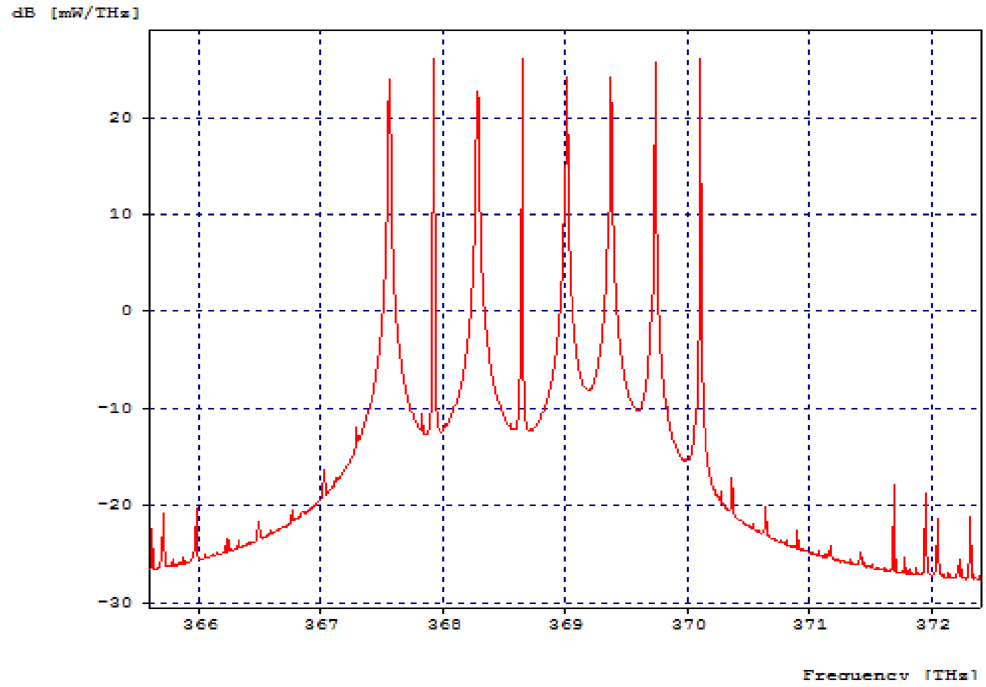

Figure 3: Transmitted Optical Spectrum

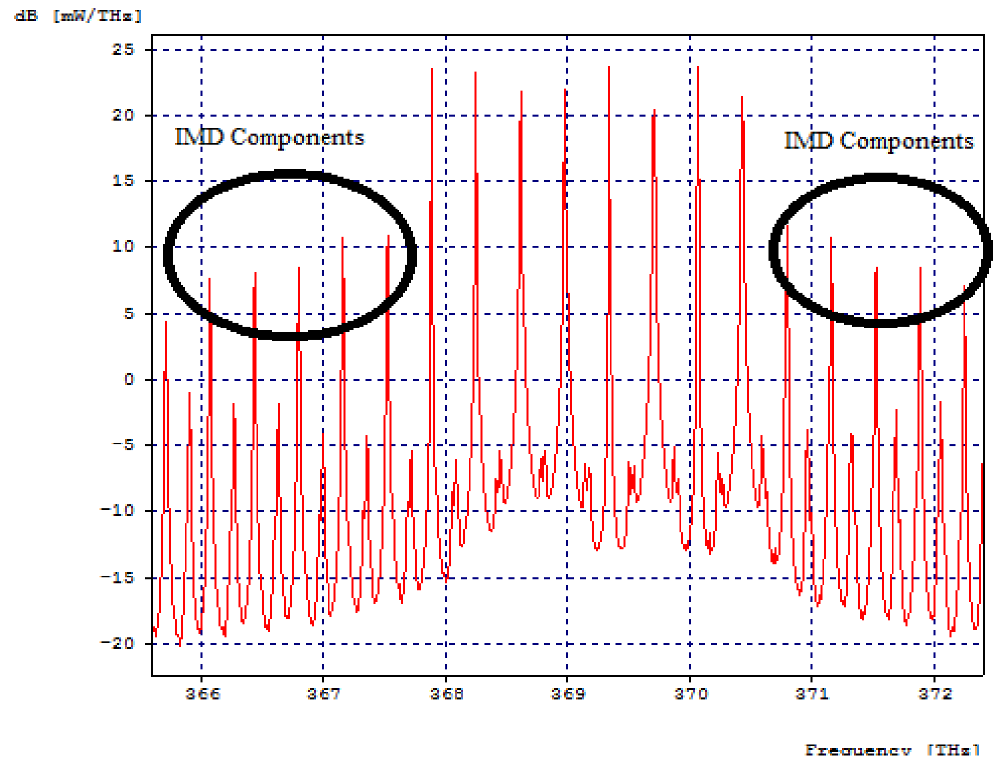

Figure 4: Received Optical Spectrum

The figure 5 depicts, for BER less than 10-10, the conventional link can be extended up to 140 meter of fiber length while compensated link can be extended up to increased fiber length of 160 meter. The Q factor value is 13 for 140 meter fiber length at conventional link in figure 6 while the compensated link offers higher Q factor value of 14 even at increased fiber length of 160 meter. The eye diagram in figure 7 reveals that conventional link doesn't offer a clear eye opening. It has been observed in eye diagram of figure 8 that the compensated link results into clear and symmetrical eye opening even for 160 meter fiber length.

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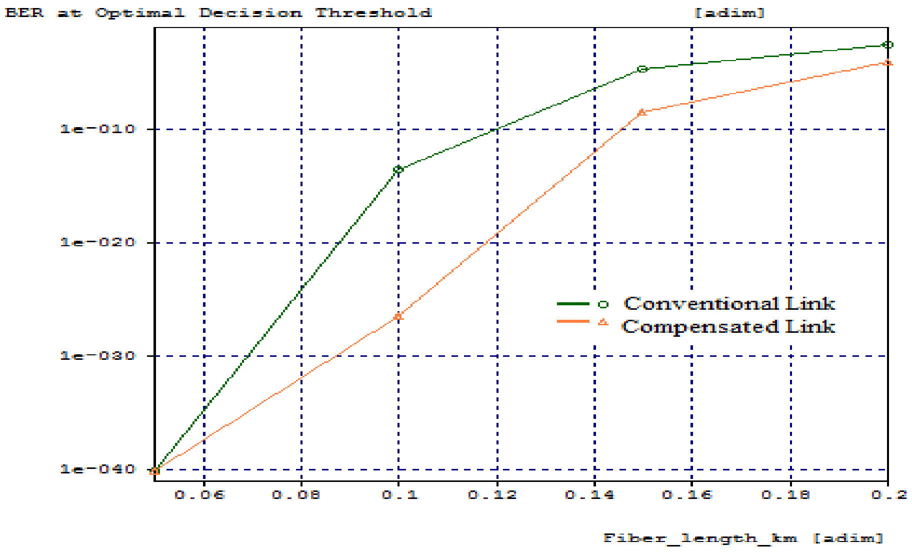

Figure 5: Fiber Length vs BER for conventional & compensated link

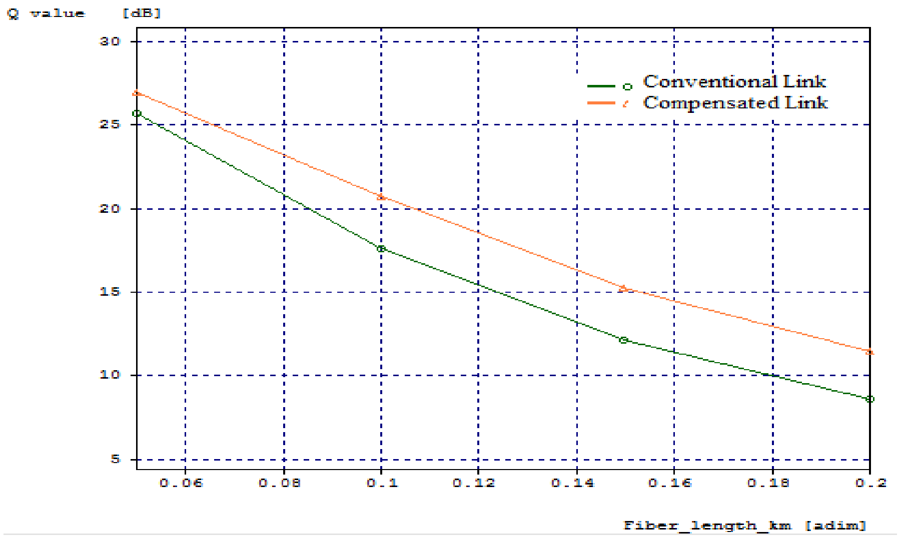

Figure 6: Fiber Length vs Q value for conventional & compensated link

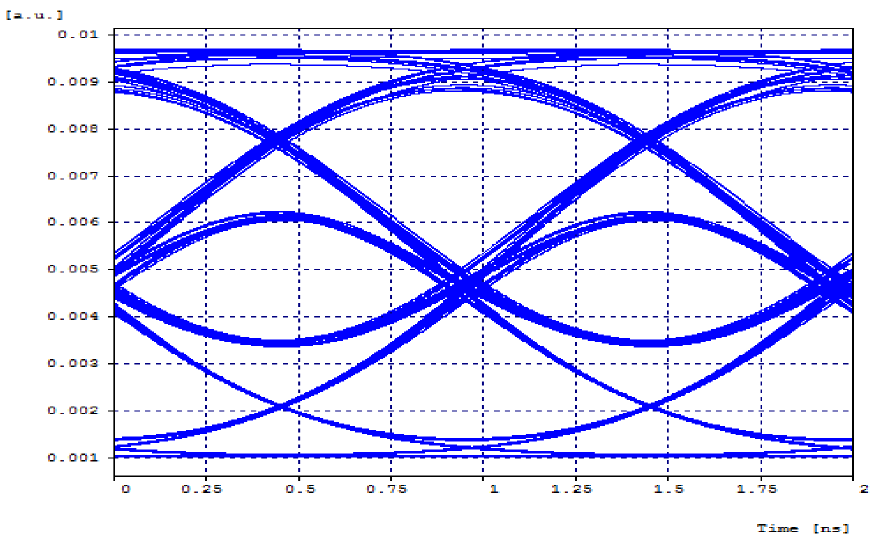

Figure 7: Eye diagram of Conventional link at 140 meter

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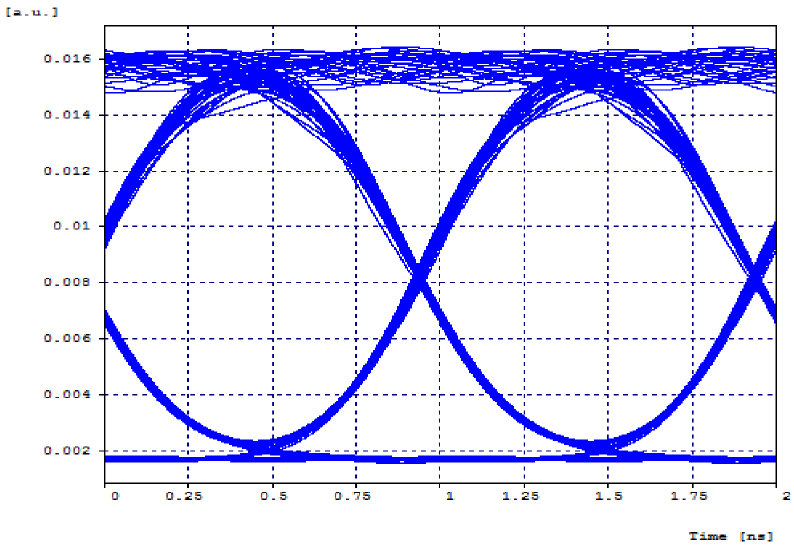

Figure 8: Eye diagram of Compensated link at 140 meter

IV. CONCLUSION

VCSEL based 8-channel WDM conventional optical link and dispersion compensated optical link were established. It was observed that phase conjugator based dispersion compensated link displays better performance as compared to conventional link. The dispersion compensated link has higher Q factor and clear eye opening. The conventional link operates at maximum fiber length of 140 meter while compensated link operates at an extended fiber length of 160 meter.

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Citation of this Article:

Ajay Kumar, & Avinash Kumar, "Performance Improvement of VCSEL based 8-Channel WDM Optical Link" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 10, pp 65-69, October 2021. Article DOI https://doi.org/10.47001/IRJIET/2021.510011

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