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Efficiency Checking of Advanced Modulation Formats and Amplifiers in IsOWC Link

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ABSTRACT: Optical communications systems have evolved from lengthy fibres to powerful wireless system. Inter satellite optical wireless communication systems (IsOWC) are one of the important applications of FSO technology that will expand in space in the near future. These systems provide high bandwidth, small size, light weight, low power and low cost to present microwave satellite systems. In the future systems, the satellite to satellite communication will be governed by optical wireless links. This paper analyzed the performance of IsOWC link using advanced modulation format such as CSRZ, DRZ and DPSK and also different amplifiers such as EDFA, Raman amplifier, SOA amplifier are used. It is investigated that CSRZ modulation with EDFA amplifier scheme gives better performance than any other modulation scheme at long range in IsOWC link. Q factor and BER is used for the performance analysis. The IsOWC system is modelled and simulated by using commercial optical system software named Optisystem 12.0 by optiwave.

KEYWORDS: Amplifiers, CSRZ (Carrier Suppressed Return to Zero), DRZ (Duobinary Return to Zero), DPSK (Differential Phase Shift Keying), IsOWC (Intersatellite Optical Wireless Communication), FSO(Free Space Optics), Q factor.

I. INTRODUCTION

The application of laser technology to communications, particularly space communications, was envisioned in the very early days of laser development around 1962, described a method for secure communications between a satellite and a submarine. In the 40 years since, government agencies, companies, universities, and individuals in many countries have made tremendous technical progress in optical space communication [1]. The present satellite communications system uses microwave technology for space-to-ground and geosynchronous satellite to low earth orbiting vehicles. In the future system, the satellite to ground links would remain in the microwave regime but satellite-to-satellite communication will be governed by optical wireless links i.e. InterSatellite Optical Wireless Communication [2]. The technology uses laser light of infrared wavelengths to transmit optical signals between two points via free space. This requires devices similar to those used for the transmission through fibre-optic cable, except that the signal is transmitted through free space and not via optical cable capable of transmitting data, voice or video. IsOWC can be used to connect one satellite to another, whether the satellite is in the same orbit or in different orbits the data can be sent at speed of light with-out much delay and with minimum attenuation since the space is considered to be vacuum. The advantages of using optical link over radio frequency of thousands of kilometers using small size payload [2]. By reducing the size of the payload, the mass and the cost of the satellite will also be decreased. Another reason of using OWC is due to wavelength. RF wavelength is much longer compared to lasers hence; the beam width that can be achieved using lasers is narrower than that of the RF system [2]. Due to this reason, OWC link results in lower loss compared to RF but it requires a highly accurate tracking system to make sure that the connecting satellites are aligned and have line of sight. In this paper the performance of IsOWC link is analysed by using some advanced modulation format such as CSRZ, DRZ, and DPSK and compare its performance over a range of 2000km at bit rate of 10 Gb/s. Q factor analysis is taken for comparing the performance of IsOWC link using different modulation formats.

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II . LITERATURE SURVEY

Satellite orbits with orbital height of approximately 1000 km or less are known as Low Earth Orbit (LEO). LEOs tend to be in general circular in shape. . LEO satellites take from 2 to 4 h to rotate around earth. This orbit is commonly used for multi-satellite constellations where several satellites are launched up to space to perform a single mission [1]. Satellite orbits with orbital heights of typically in the range of 5000 km to about 25,000 km are known as Medium Earth Orbit (MEO)/Intermediate Circular Orbit (ICO). MEO and ICO are often used synonymously, but MEO classification is not restricted to circular orbits. In Geosynchronous Earth Orbit (GEO) the satellite is in equatorial circular orbit with an altitude of 35,786 km and orbital period of 24 hr. Three satellites in GEO placed 120◦ apart over equator cover most of the world for communications purposes [3]. At present there are 6124 satellites orbiting earth and this number increases year by year. At the same time the optical wireless communication (OWC) technology has grown and advanced throughout the year. Laser communication is now able to send information at data rates up to several Gbps and at distance of thousands of kilometres apart.

1. IsOWC LINK WITH DIFFERENT MODULATION FORMAT

A. Non Return to Zero (NRZ)

A non-return-to-zero (NRZ) line code is a binary code in which ones are represented by one significant condition, usually a positive voltage, while zeros are represented by some other significant condition, usually a negative voltage, with no other neutral or rest condition. The intensity of the carrier light wave is modulated by the applied electric field which voltage varies with a determined function. The Mach zehnder modulator (MZM) is driven at the quadrature point of the modulator power transfer function with an electrical NRZ signal.

B. Return to Zero (RZ)

Return-to-zero (RZ or RTZ) describes a line code used in telecommunications signals in which the signal drops (returns) to zero between each pulse. The main characteristic of RZ modulated signals is a broad optical spectrum, resulting in a reduced dispersion tolerance and a reduced spectral efficiency.

C. *Carrier Suppressed Return to Zero (CSRZ)*

CSRZ is a special form of RZ where the carrier is suppressed. The main target of this modulation format is a reduction of the nonlinear impairments in a channel and an improvement of the spectral efficiency in high bit rate systems. The difference between CSRZ and conventional RZ is that the CSRZ signal has a π phase shift between adjacent bits. This phase alternation, in the optical domain, produces no DC component; thus, there is no carrier component for CSRZ. It can be expected that the dispersion tolerance of CSRZ modulation can be improved due its reduced spectral width compared to RZ modulation.

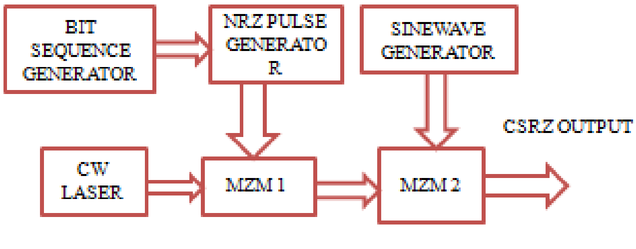

Figure: 1 CSRZ signal generation

Generally speaking, the formulation of CSRZ optics signal demands two electro-optic modulators as the Figure 1. It is the first MZM modulator that encodes NRZ data. After that, the generated NRZ optical signal is modulated by another MZ modulator to produce a CSRZ optical signal.

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D. Duo binary Return to Zero (DRZ)

Figure: 2 illustrates the schematic of a duo-binary transmitter. The duo binary was generated by first creating an NRZ duo binary signal using a duo binary precoder, NRZ generator and a Duo binary pulse generator

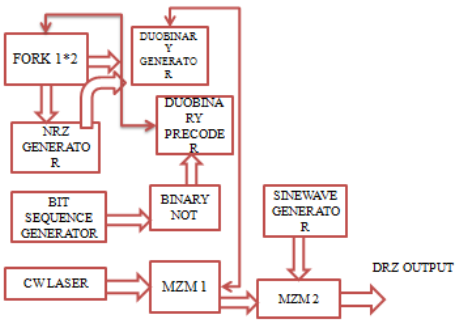

Figure: 2 Schematic of DRZ modulation format

. The generator drives the first MZM, and then cascades this modulator with a second modulator that is driven by a sinusoidal electrical signal with the given frequency. The duo binary precoder used here is composed of an exclusive-or gate with a delayed feedback path. DRZ formats are very attractive, because their optical modulation bandwidth can be compressed to the data bit rate that is, the half-bandwidth of the NRZ format.

E. Differential Phase Shift Keying (DPSK)

It is a common form of phase modulation conveys data by changing the phase of carrier wave. In Phase shift keying, High state contains only one cycle but DPSK contains one and half cycle. For generating a DPSK signal machzehnder modulator is needed. The DPSK pulse generator drives the MZM at a given frequency and get a DPSK signal.

2. AMPLIFIERS

Optical amplifier is an analog device. Most of the optical amplifiers amplify incident light by stimulated emission. Its main ingredient is the optical gain realized when the amplifier is pumped (optically or electrically) to achieve population inversion. The optical gain, in general, depends not only on the frequency (or wavelength) of the incident signal, but also on the local beam intensity at any point inside the amplifier. Optical amplifiers (OAMP) were classified on the basis of device characteristics, whether it is based on linear characteristics (semiconductor optical amplifier and rare-earth doped fiber amplifiers) or nonlinear characteristic (Raman amplifiers). By using optical amplifiers the range of transmission can be improved.

A. Doped Fibre Amplifier (DFA)

Doped fibre amplifiers (DFAs) are optical amplifiers that use a doped optical fiber as a gain medium to amplify an optical signal. They are related to fibre lasers. The signal to be amplified and a pump laser are multiplexed into the doped fiber, and the signal is amplified through interaction with the doping ions.

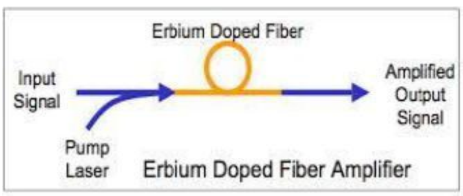

Figure: 3 Erbium Doped Fiber Amplifier

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The most common example is the Erbium Doped Fiber Amplifier (EDFA), where the core of a silica fibre is doped with trivalent erbium ions and can be efficiently pumped with a laser at a wavelength of 980 nm or 1480 nm, and exhibits gain in the 1550 nm region. An erbium-doped waveguide amplifier (EDWA) is an optical amplifier that uses a waveguide to boost an optical signal. Amplification is achieved by stimulated emission of photons from dopant ions in the doped fiber.

III.PROPOSED METHODOLOGY

The IsOWC system consists of three main communication parts which are transmitter, propagation channel and receiver as shown in Figure:4 where the transmitter is in the first satellite and the receiver is in the second satellite. Optical-wireless communication uses light at a near-infrared frequency to communicate. The IsOWC system is not much different from free space optics. The free space between two connecting satellites is considered as OWC channel, which is the propagating medium for the transmitted light. The OWC channels modeled between an optical transmitter and optical receiver with a 15cm optical antenna at each end by using optisystem software. The OWC channel is considered to be free space where it is assumed to be a vacuum and free from atmospheric attenuation factors.

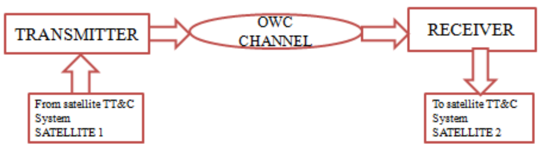

Figure: 4 General diagram of IsOWC system

The transmitter consists of four subsystems. The first subsystem is the pseudo-random bit sequence generator. This subsystem is to represent the information or data that wants to be transmitted. The data usually come from the satellite's TT&C system. In this project the bit rate and link distannce is varied to observe the system performance and the relationship between bit rate and distance. The second subsystem is the NRZ pulse generator. This subsystem encodes the data from the pseudo-random bit sequence generator using the non-return zero encoding technique. The third subsystem in the satellite IsOWC transmitter is the CW laser. CW stands for continuous wave where the output signal of the laser is nonstop and un-modulated. Lasers are used instead of LED for this system because of its ability to transmit at further distance. The frequency of the light is chosen to be 1550nm or 193.1THz with input power of 10dBm. The last subsystem in the transmitter is the Mach-Zehnder Modulator. It is an optical modulator that functions is to vary intensity of the light source from the laser according to the output of the NRZ pulse generator. The input optical signal from the laser will split in to two and go through phase shifting process in the waveguides. Phase-shifting happens due to the electro-optic effect where the output electrical pulse from the NRZ pulse generator will vary the voltage hence varying the refractive indices of the waveguides. The output of the Mach-Zehnder modulator will be transmitted to the other satellite through the space of OWC channel. Block digram of 1TX/1RX IsOWC system is shown in Figure:5

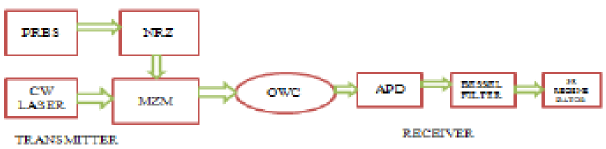

Figure: 5 Block diagram of 1TX/1RX IsOWC system.

The receiver of the data consists of an APD photodiode, low pass filter and 3R regenerator. The photodiode acts as a frontend receiver that receives the optical signal and converts it into electrical signal. APD photodiode is useful in low, weak or reduced light applications because of the avalanche phenomenon utilized by the device provides high amplification. Hence it is ideal to be used in this system where the long distance transmission reduces the intensity of

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the light. APD photodiode used in the OptiSystem model has a multiplication factor of 3 and default dark current used is 10nA. The frequency of the photodiode is set to 193.1THz.

IV.SIMULATION DIAGRAM

In this section the IsOWC system is designed and modelled by using optisystem software and is then presented and finally explains each and every subsystems of the model. The OWC channel provided in the software is specifically designed to suit the Intersatellite environment.

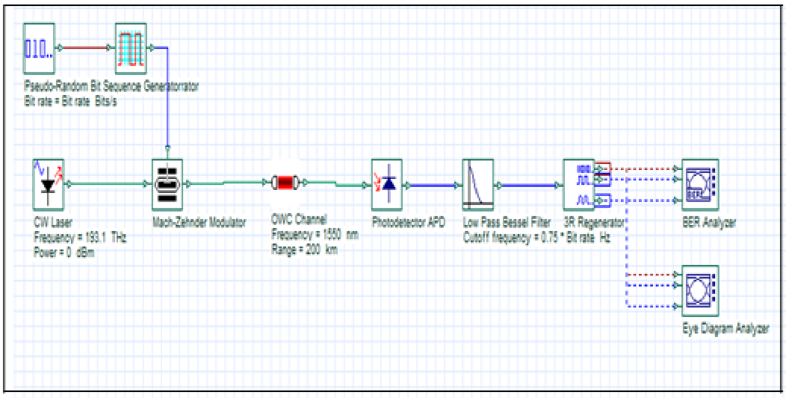

Figure: 6 simulation diagram of IsOWC simplex model

Figure:6 shows the simulation diagram of simplex IsOWC simplex model. The signal from the TT&C converts it into optical signal by using a machzehder modulator. Here the propagation medium is the OWC channel and it reaches the receiver apart, optical signal is converted back to electrical signal by the use of a photodetector. And eyediagram and BER analyzer was used to analyze the performance of IsOWC link. Q factor from the eyediagram is the main part to optimizing the IsOWC (Intersatellite Optical Wireless Communication) link. The system is worked under different power levels and notice the change in Q factor and also bitrate is varied according to the power levels.

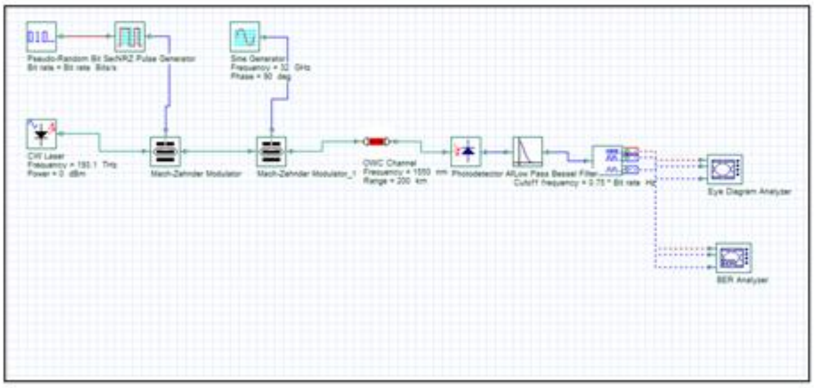

Figure:7 simulation diagram of IsOWC link using CSRZ modulation

Above figure:7 shows the simulation diagram of IsOWC link using advanced modulation format such as CSRZ modulation . Different modulation formats are used for optimizing the IsOWC link. DRZ and DPSK are also advanced modulation format, after analysing the IsOWC link using modulation format, different amplifiers are used in the receiver part to enhance the performance of OWC link.

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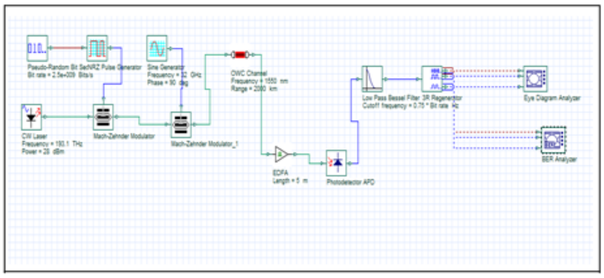
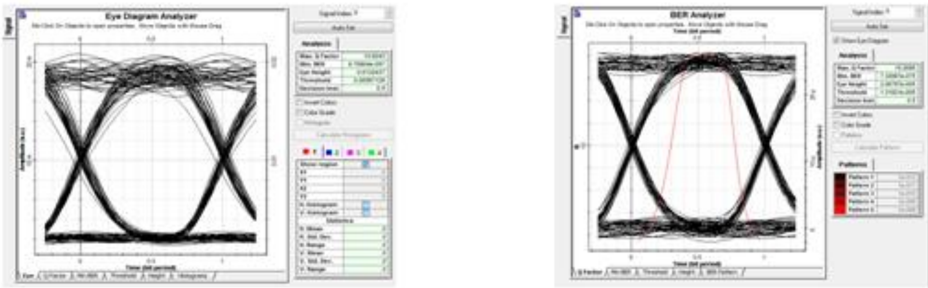


Figure :8 simulation diagram of IsOWC link using CSRZ modulation format using EDFA amplifier

Figure:8 shows the simulation diagram of IsOWC link using CSRZ modulation format and also the EDFA amplifier is used in the receiver part. And check how these factors affect the IsOWC link.
And different amplifiers are used such as Raman amplifier and SOA and anlayzed the performance differences in IsOWC link by using these amplifiers.

V. RESULT AND DISCUSSIONS

IsOWC link is simluated and modeled by using optisystem software and obtained eyediagram was analyzed for a link distance varied from 200km to 10000km at a bit rate of Gb/s range at a power range from 10dBm to 35 dBm.



(a) (b)

Figure: 9 shows the Eyediagram of (a) simplex model IsOWC link (Q Factor= 14.924) and (b) using CSRZ modulation format (Q factor=18.2688)

Figure: 9(a) shows the eyediagram of simplex IsOWC model. And the amplifiers are used at the receiver section and obtained eyediagram was analyzed. Different pulse generator are also used and checked the signal strength and the output power reached in the receiver section. Figure:9(b) shows the Eyediagram of IsOWC link using Carrier Suppressed Return to Zero(CSRZ) modulation scheme. It can be observed and verified that Q factor of IsOWC link using CSRZ is higher than IsOWC simplex model.

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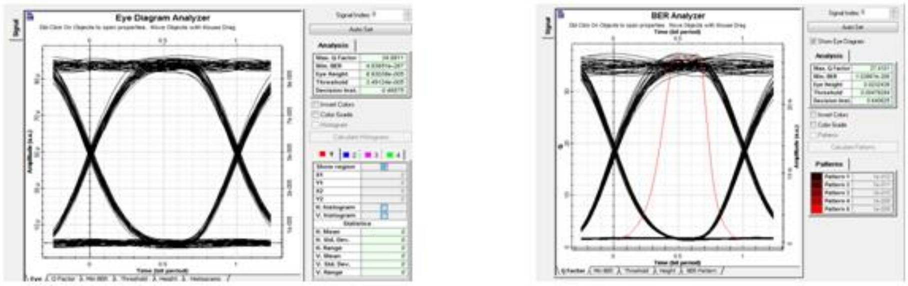
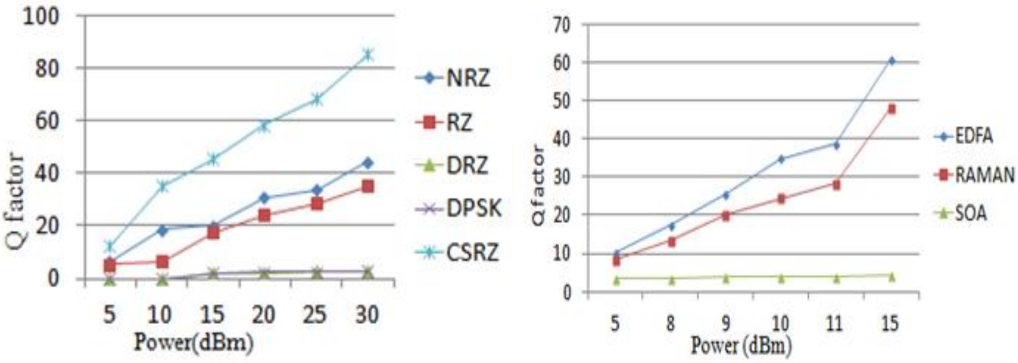


(a) (b)

Figure:10 Eyediagram of IsOWC link using (a) EDFA amplifier(Q factor=34.8911) and (b) using CSRZ modulation with EDFA amplifier (Q factor=37.417)

Above figure 10 shows the Eye diagrams of IsOWC link using EDFA amplifier and compare the eye diagram with other two amplifiers such as Raman amplifier and SOA(Semiconductor Optical Amplifer) amplifier. And it is analysed that EDFA amplifier gives better performance than other two. Figure 10 (b) shows the Eye diagram of CSRZ modulation with EDFA combination in IsOWC link.

Graphical analysis gives a better information about the different modulation format and EDFA amplifier and how these two factors affect the Intersatellite Optical Wireless Communication link.. We can analyze how each and every parameter (link distance, bit rate, power) is affected the IsOWC link. Here the aperture diameter is taken as 15 cm. Aperture diameters have an important place in designing the IsOWC link.



(a) (b)

Figure: 11 graphical representation of effect of (a) different modulation formats and (b) amplifiers.

By analysing the figure 11(a) we can understood that CSRZ modulation format is better than other modulation format. At very low power CSRZ modulation gives better Q factor and also shows the graphical representation of the effect of different amplifiers such as EDFA, Raman amplifier, SOA in IsOWC link. Analysis was done at different power levels range varies from 10dBm to 30dBm and also varies the link distance and bit rate. EDFA amplifier gives better performance in low power. After that CSRZ modulation format with EDFA amplifier was used in IsOWC link.

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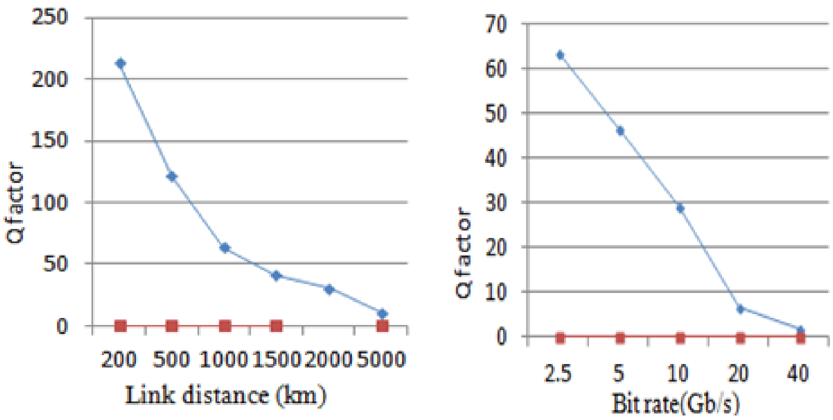

Figure: 12 shows the effect of link distance and bitrate of IsOWC link using CSRZ with EDFA amplifier

It is clear that from the figure 12 the Q factor is decreased that we increase the link distance at constant power at same bit rate. If we increase the bitrates shown in the figure 12 , the Q factor will decreases. It will affect the entire performance of the IsOWC channel. Then high power laser is needed. It will increase the cost. Q factor could be obtained for a higher link distance (5000km) only when using high power lasers.

VI. CONCLUSION

Intersatellite Optical Wireless Communications (IsOWC) can provide intersatellite communication at high speed and achieve farther distance compared to RF links. In this paper it is investigated that CSRZ (Carrier Suppressed Return to Zero) modulation format with EDFA(Erbium Doped Fiber Amplifier) amplifier gives better performance than any other modulation format and amplifier combination. It is possible to communicate between the satellites in LEO orbits using low power lasers. LEO- MEO communication is possible with high power lasers. Signal transmission at a link distance of 5000km at higher bit rate(10-40Gb/s) is achieved by using the source power range around 15-20dBm. For LEO- LEO communication only low power lasers is needed ie, for achieving below 500km link at a bit rate of 2.5Gb/s with CSRZ modulation.

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