Designing of 2.5 GBPS WDM-PON using Mach-Zehnder Modulator

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ABSTRACT
The propose design is for a cost effective Full Duplex Wavelength Division Multiplexed Passive Optical Network. This system can transfer data up to 2.5 Gbps to up to 10 Gbps over a 20km of a single feeder fiber using single light source per Optical Network Unit. Here, a Non-return to zero (NRZ) downstream signal is first frequency up-converted to around 20 GHz before being fed to Mach-Zehnder Modulator for downstream transmission. CW DFB Laser Array is used as a carrier for optical signal. After transmission over feeder fiber, a portion of this signal is detected at the Optical Network Unit and one of its signal is up streamed with the help of Optical Transmitter at a frequency of 1550nm. For amplification EDFA is used. To overcome the bandwidth limitation, we apply a Buffer Selector at upstream receiver. At receiver side Photo detector PIN is used to detect the optical signal.

Keywords
WDM-PON, EDFA, ONU, CW DFB Laser.

1. INTRODUCTION
Users of today's voice, video, and data networks are be-coming more complex – requiring more bandwidth and faster data transmission rates over farther distances. To meet these demands, network managers are relying more and more on fiber optics. But the reality that many Service Providers and Enterprise Corporations are facing is that once their available fiber infrastructure is exhausted, laying more fiber is no longer an economical or feasible option.

Many are turning to Wave Division Multiplexing (WDM) technologies in order to increase capacity on the fiber links that are already in place. WDM is a technology which multiplexes multiple optical signals on a single fiber by using different wavelengths, or colors, of laser light to carry the different signals. By utilizing bidirectional communications over a single fiber, network managers can realize a multiplication effect in their available fiber's capacity.

A quick study of WDM yields three major options: Bidirectional Wave Division Multiplexing (BWDM), Coarse Wave Di-vision Multiplexing (CWDM) and Dense Wave Division Multiplexing (DWDM). The modern WDM systems can handle up to 160 signals and can thus expand a basic 10 Gbit/s system over a single fiber pair to over 1.6 Tbit/s. In this we, proposed a designed of cost effective full duplex Wavelength-Division-Multiplexed Passive Optical Network. This system can transfer data up to 2.5-10 Gbps over 20km of single feeder fiber using a single light source per Optical Network Unit. Here, a Non-return to zero (NRZ) downstream signal is first frequency up-converted to around 20GHz before being fed to Mach-Zehnder Modulator for downstream transmission. CW DFB Laser Array is used as a carrier optical signal. After transmission over feeder fiber portion of this signal is detected at the ONU and one of its signal is up streamed with the help of Optical Transmitter at a frequency of 1550nm. For amplification EDFA is used. To overcome the bandwidth limitation, we apply a Buffer Selector at upstream receiver. At receiver side Photo detector PIN is used to detect the optical signal.

2. PROBLEM DEFINATION
We have switched to WDM-PON technology instead of TDM-PON in this particular project. The previous generation Network Communication systems deployed the technology of Time Division Multiplexing i.e. TDM Technology. In TDM, data packets are time multiplexed and are transmitted using the same radio carrier frequency. Hence if say, there are 2 channels, each operating at 4.8 Kbps and they are time multiplexed, then resulting capacity of these 2 channels is aggregate of two channels i.e. 9.6 Kbps. But there were many demerits in TDM which can be overcome by the use of an alternate technology called Wavelength Division multiplexing i.e. WDM. In TDM, resulting capacity is the aggregate or sum of all the input signals/channels whereas in WDM, each signal is transmitted independent of the others and hence each channel will have its own dedicated bandwidth. In WDM, all signals will arrive at the same time while in TDM they will arrive one after the other. This is because in TDM the signals are broken up and multiplexed time wise before transmission. This is same as TDMA frame, where in data from various stations are multiplexed and then transmitted. Thus the trend for next generation access is totally based on Passive Optical Networks.

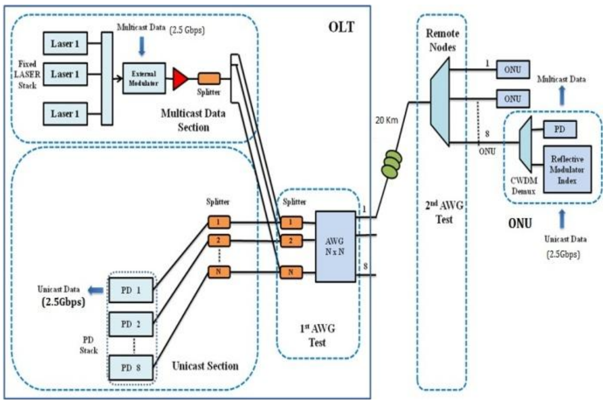

Fig 1: Block Diagram

Block diagram description
Figure 1 represents the overall block diagram of the system we have proposed. This system is divided into three major

blocks namely an Optical Line Termination Unit (OLT), Optical Network Unit (ONU) and Remote Node Section. An optical line termination (OLT), also called an optical line terminal, is a device which serves as the service provider endpoint of a passive optical network. It provides two main functions: To perform conversion between the electrical signals used by the service provider's equipment and the fiber optic signals used by the passive optical network. To the multiplexing between the conversion devices on the other end of that network. This Optical Line Termination Unit comprises of three main sections. The first section is called as the Multicast Data Section. This comprises of Fixed Laser Stack, External Modulator and a Splitter.

The Laser Stack is nothing but a fixed arrangement of Lasers that provide very high input power. This has a bit rate of 2.5 Gbps and the signal is multiplexed and given to the modulator. This modulated output signal is then given to the splitter where the power is evenly split and passed on to the second section (Arrayed Waveguide). The second section is called as first Arrayed Waveguide. Arrayed waveguide gratings (AWG) are commonly used as optical (de)multiplexers in wavelength division multiplexed (WDM) systems. These devices can multiplex a large number of wavelengths into a single optical fiber, thereby increasing the transmission capacity of optical networks considerably. The devices are based on a fundamental principle of optics that light waves of different wavelengths interfere linearly with each other.

This means that, if each channel in an optical communication network makes use of light of a slightly different wavelength, then the light from a large number of these channels can be carried by a single optical fiber with negligible crosstalk between the channels. The AWGs are used to multiplex channels of several wavelengths onto a single optical fiber at the transmission end and are also used as de multiplexers to retrieve individual channels of different wavelengths at the receiving end of an optical communication network. This splitted signal is again fed to another set of splitters and given to an Arrayed Waveguide Grating (AWG) of order N X N. This data signals enter the third section called the Unicast Section. This comprises of Splitters and PD Stack. The output of AWG is now feeded to a 20km single feeder fiber and the remaining 7 terminals are made optically null. This data travels through the 20km single feeder fiber and enters the Remote Nodes of second Arrayed Waveguide Gratings. (AWG). The data is de multiplexed and given to the Optical Network Unit. An optical network terminal (ONT),is used to terminate the Fiber Optic Line, Demultiplex the signal into its component parts and provide power to customer telephones. as the ONT must derived its power from the customer premises electrical supply, many ONTs have the option for battery backup, to maintain the service in the event of a power outage. Here the Optical Network Unit Block comprises of a Reflective Modulator Index and CWDM multiplexer. A part of the signal from first Arrayed Waveguide Grating is taken and directed to another stack of PDs with a data rate of 2.5 Gbps.

3. SIMULATION SETUP

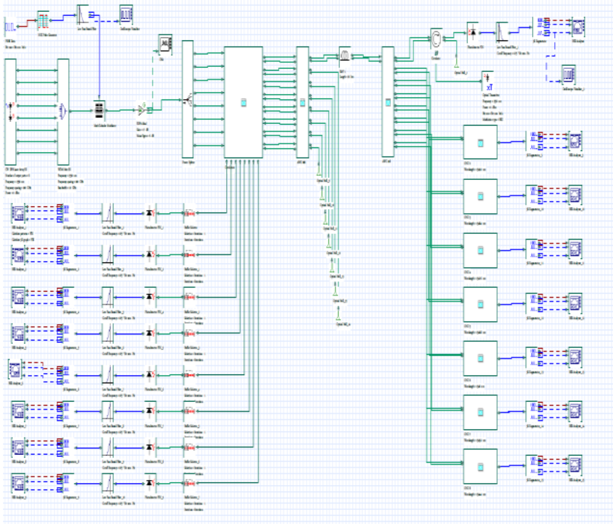

Fig 2: Simulation setup for Designing of 2.5 Gbps WDM-PON using Mach-Zehnder Modulator

We have proposed a cost effective Full Duplex Wavelength Division Multiplexed – Passive Optical Network. This system can transfer data up to 2.5 Gbps – 10 Gbps over a 20km single feeder fiber using a single light source per ONU.

3.1 Simulation setup description

PBRS is a Pseudorandom Binary Sequence (PRBS) binary sequence that, while generated with a deterministic algorithm, is difficult to predict and exhibits statistical behavior like a truly random sequence. PRBS are used in telecommunication encryption, simulation, correlation techniques and time-of-flight spectroscopy.

3.1.1. Low Pass Bessel Filter

In electronics and signal processing, a Bessel filter is a type of analog linear filter with a maximally flat group/phase delay (maximally linear phase response), which preserves the wave shape of filtered signals in the pass band. Bessel filters are often used in audio crossover systems. The Bessel filter is very similar to the Gaussian filter, and tends towards the same shape as filter order increases. The Bessel filter has better shaping factor, flatter phase delay, and flatter group delay than a Gaussian of the same order, though the Gaussian has lower time delay. The time-domain step response of the Bessel filter has no overshoot. It is likely unique among filter types by this characteristic.

3.1.2. Oscilloscope

An oscilloscope, previously called an oscillograph, and informally known as a scope, CRO or DSO is a type of electronic test instrument that allows observation of constantly varying signal voltages, usually as a two-dimensional plot of one or more signals as a function of time. Other signals can be converted to voltages and displayed. Oscilloscopes are used to observe the change of an electrical signal over time, such that voltage and time describe a shape which is continuously graphed against a calibrated scale. The observed waveform can be analyzed for such properties as amplitude, frequency, rise time, time interval, distortion and others. Modern digital instruments may calculate and display these properties directly. Originally, calculation of these values required manually measuring the waveform against the scales built into the screen of the instrument. Storage oscilloscopes used special storage CRTs to maintain a steady display of a single brief signal. CROs were later largely superseded by digital storage oscilloscope switch this panel displays, fast analog to digital converters and digital signal processors.

3.1.3. Ber

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference distortion or bit synchronization errors. The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage. The bit error probability is the expectation value of the bit error ratio. The bit error ratio can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a longtime interval and a high number of bit errors.

3.1.4. 3r Regenerators

In long-distance communication systems, wave distortion and relative time delay deviation (lack of synchronization) are accumulated even when optical amplifiers that regenerate signal amplitude are used. This is why periodic regeneration is usually required to regenerate the original waveform and synchronization of signals. Complete (3R) regeneration includes three regenerating operations with a signal: regeneration of amplitude (amplification), regeneration of signal waveform and regeneration of synchronization. In modern communication systems, these three operations are completed by an opto-electro-optical (OEO) converter. Such optical regenerators are called optical repeaters. Optical repeaters detect optical signals, convert them into electric signals, completely regenerate the signal in its electric waveform and transmit it in the form of an optical signal. Optical repeaters are quite complex and expensive systems, as they are comprised of an optical receiver, electric regenerator and a transmitter.

3.1.5 Arrayed Waveguide Grating (Awg)

Arrayed waveguide gratings are commonly used as optical demultiplexers in wavelength division multiplexed (WDM) systems. These devices can multiplex many wavelengths into a single optical fiber, thereby increasing the transmission capacity. The devices are based on a fundamental principle of optics that light waves of different wavelengths interfere linearly with each other. This means that, if each channel in an optical communication network makes use of light of a slightly different wavelength, then the light from many these channels can be carried by a single optical fiber with negligible crosstalk between the channels. The AWGs are used to multiplex channels of several wavelengths onto a single optical fiber at the transmission end and are also used as demultiplexes to retrieve individual channels of different wavelengths at the receiving end of an optical communication network.

3.1.6 Edfa

EDFA is an optical repeater device that is used to boost the intensity of optical signals being carried through a fiber optic communications system. An optical fiber is doped with the rare-earth element erbium so that the glass fiber can absorb light at one frequency and emit light at another frequency.

3.1.7 Mach Zehnder Modulator

A Mach-Zehnder modulator is used for controlling the amplitude of an optical wave. The input waveguide is split up into two waveguide interferometer arms. If a voltage is applied across one of the arms, a phase shift is induced for the wave passing through that arm.

3.1.8 Cw Laser

In laser physics and engineering, "continuous wave" or "CW" refers to a laser that produces a continuous output beam, sometimes referred to as "free-running," as opposed to a q-switched, gain-switched or mode locked laser, which has a pulsed output beam.

4. RESULTS AND DISSCUSSION

Noise Factor

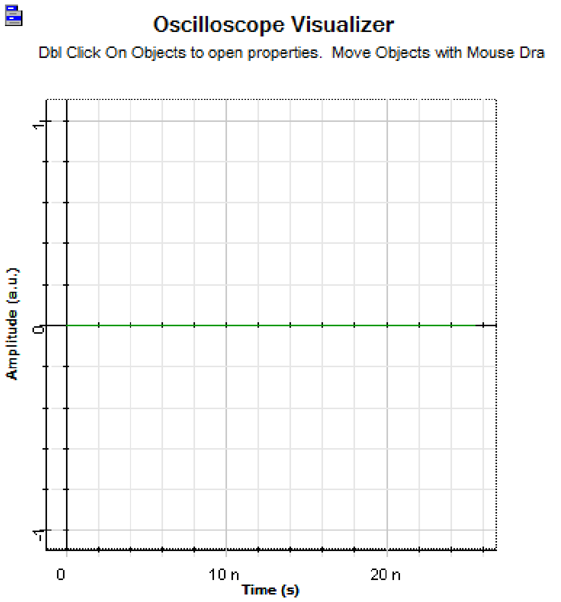

Fig 3: Noise at Transmitter side

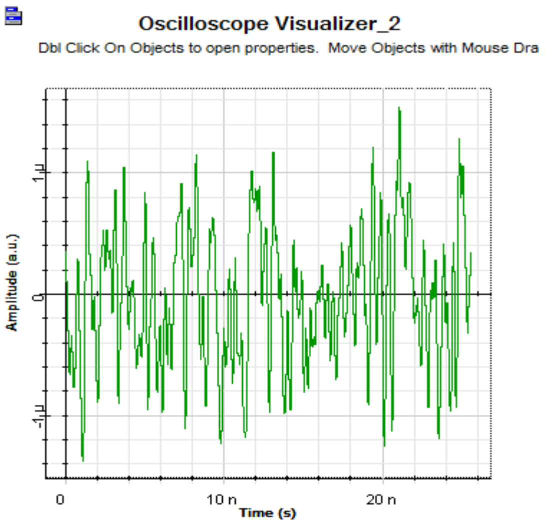

Fig 4: Noise at Receiver Side

The signal Noise at Transmitter side is 0 dB. As shown in Fig.5.1.9. the signal then transmitted over 20 Km SMF (Single Mode Fiber). The Fiber having an attenuation 0.24 dB/Km at reference wavelength of 1550nm which is very negligible. The signal gets attenuated and receive at receiver with an attenuation of 4.8 dB. The attenuated signal at receiver side is as shown in Fig.5.1.10. For proper data transmission Noise, should be as low as possible

Signal to Noise Ratio

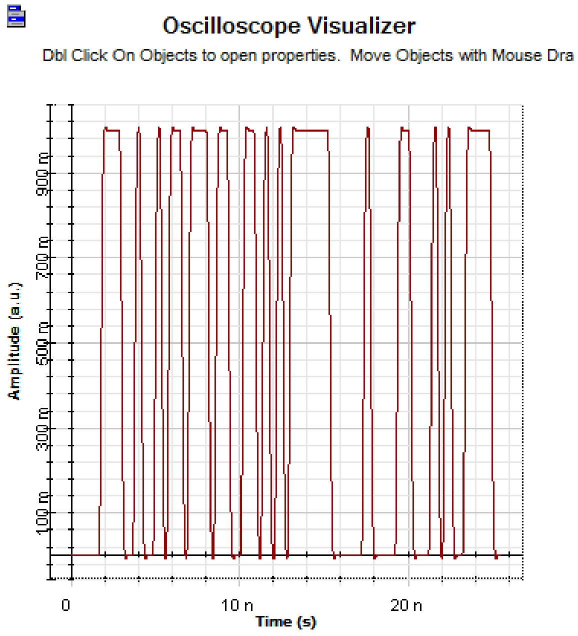

Fig 5: Transmitted Signal

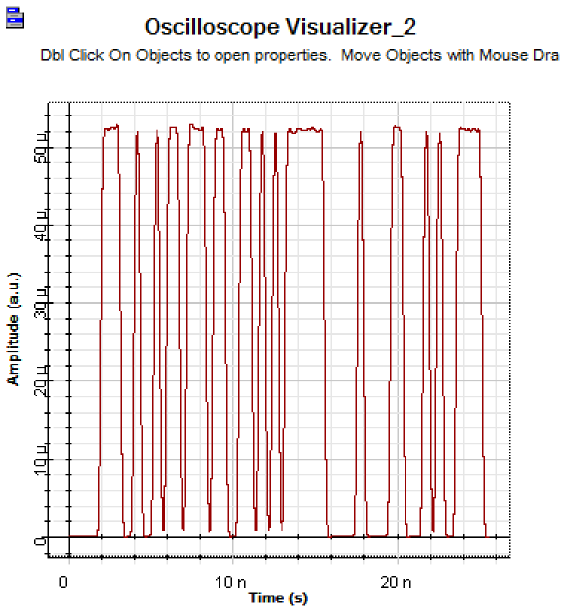

Fig 6: Received Signal

The signal which is transmitted is in the form of Pulse form. This pulsed signals we are getting from NRZ pulse generator at a bit rate of 2.5Gbps with order of 6. The transmitted & received signal we can see in oscilloscope visualizer as shown in Fig.5 and Fig.6

BER Analyzer Output

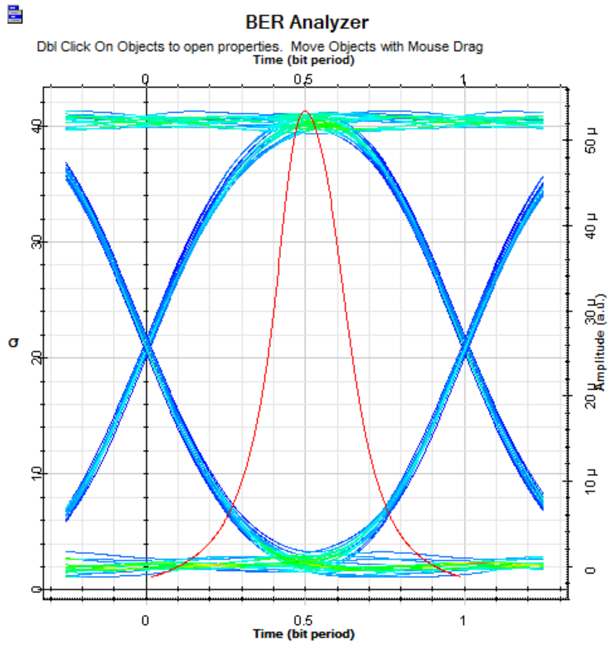

Fig.7: Eye Diagram

4.1 Advantages

1. WDM can increase the capacity of fiber network dramatically.

2. Maximum bandwidth for WDM-PON is 1-10 Gb/s per channel.

3. A single Fiber -optic cable can handle dozens of channels instead of using 12 cables, you only use 1.

4. This system is Flexible and Scalable so addition of any component or up-gradation for future demands is possible.

5. Effective use of fiber up to 64 subscribers.

6. A key advantage of WDM-PON is the use of completely separate downstream wavelength for each of the subscribers.

4.2 Disadvantages

1. Not cost-effective for low channels, low channel recommends CWDM Complicated transmitter and receivers.

2. The frequency domain involved in the network design and management, increase the difficulty for implementation.

3. Cost of implementation of proposed system is high.

4.3 Applications

As the new-generation access network, WDM-PON makes it possible to transmit multiple wavelengths instead of one wavelength in the PON over the same fiber, thus greatly meet the bandwidth requirements of users. In addition to its efficient use of wavelengths, the WDM-PON also has advantages in its use of optical-transmission power. The network management is much simpler than a TDM-PON, and all future services can be delivered over a single network platform.

1. It is used as a back transmission of 3G and LTE base station, thus becoming the optimal technology for the back transmission of mobile station to meet the bandwidth requirement.

2. WDM-PON also can be used to support reach extension and the transition of existing EPON networks to improve the

scalability as well as protect the existing network investment.

3. This technology is used in submarine cables and extending the lifetime of cables where all fibers are being used. For submarine cables, DWDM enhances the capacity without adding fibers, which create larger cables and bulkier and more complicated repeaters. Adding service in areas where cables are now full is another good application. But this technology may also reduce the cost on all land-based long distance communications links and new technology may lead to new network architectures.Adding fibers, which create larger cables and bulkier and more complicated repeaters. Adding service in areas where cables are now full is another good application. But this technology may also reduce the cost on all land-based long distance communications links and new technology may lead to new network architectures.

5. FUTURE SCOPE

In technology. future, it is used in, High bandwidth applications such as storage networking, video streaming, cloud-based software as a service (SaaS), collaborative computing, and online gaming and video sharing will also be contributing factors driving greater demand for ultra-high bandwidth connections with low latency and differentiated QoS. Furthermore, in the case of the enterprise market, symmetrical traffic patterns will also be required. In future, we can implement this for 80 channels by using WDM.

6. CONCLUSION

In this paper, we have considered both the benefits and drawbacks of WDM-PON technology, in the context of Optical fiber communication. We proposed a designed of cost effective full duplex Wavelength-Division-Multiplexed Passive Optical Network. This system can transfer data up to 2.5-10 Gbps over 20km of single feeder fiber using a single light source per Optical Network Unit. WDM-PON has many characteristics such as high Bandwidth, providing multiple carrier over single feeder fiber, High speed data transmission and Low Noise that make the technology appealing for application in Optical fiber communication. Unfortunately, the system is not cost-effective for low channels, low channel recommends CWDM Complicated transmitter and receivers.

These eye mask definitions specify transmitter output performance in terms of normalized amplitude and time in such a way to ensure far end receiver can tell the difference between '1' and '0' levels in the presence of timing, noise, and jitter.

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