Development of SS-WDM and High Speed SS-WDM

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Abstract— Multiplexing is a term used to refer the process where multiple analog or digital signals are combined and transmitted through same transmitting media. The technology of combining a number of such independent information carrying wavelengths onto the same fiber is called Wavelength Division Multiplexing (WDM). The conventional WDM system can hardly be applied to systems that require high data transmission rate regardless of short haul or long haul transmission line. But now-a-days, the demands for high data transmission are increasing and also the use of lasers as source in WDM systems had increased the overall cost. To overcome these issues a new technology called spectral slicing was developed which brings WDM technology one step more ahead of advanced technology. In spectral sliced WDM system, LED or ASE can be used as the low cost broadband source. These sources have high broadband spectrum, so it can be sliced spectrally into many independent signals with equal channel spacing. The main advantages of using Spectral Sliced WDM(SS-WDM) system includes low cost and high channel capacity. Here, in this paper the realization of spectral sliced WDM system using NRZ and RZ modulation formats is performed and evaluate the performance of the system for use in various optical access networks using Optisystem 12.

Key words: Wavelength Division Multiplexing (WDM), Passive Optical Networks (PON), Spectral Slicing.

I. INTRODUCTION

With the rising popularity of the internet and its applications, our life is dominated now a days by bandwidth-hungry services such as high-definition videos and live streaming. The explosive growth in the demand for higher bandwidth has triggered the introduction of Fiber-To-The-Home (FTTH) based broadband access networks. FTTH can be deployed using various architectures. The home run means Point-To-Point (P2P) fiber connection between the CO and a home, which is expensive to install and handle the numerous fibers. To reduce the installation related costs, Point-To-Multipoint (P2MP) architectures were investigated, where many subscribers share one fiber line through the Remote Node (RN). The RN performs function of active switching , or passive power splitting, or wavelength (de)multiplexing.

Among various FTTH implementations, Passive Optical Network (PON), which can provide very high bandwidths to the customers, appears to be an attractive solution to the access network. Other than offering high bandwidth, a PON system offers a large coverage area, reduced fiber deployment as the result of its Point-To-Multipoint (P2MP) architecture, and reduced cost of maintenance due to the use of passive components in the network. At present, most of PON deployments utilize Time Division Multiplexing (TDM) technique, in which dedicated time slots are assigned to each subscriber connected to the PON. However, most agree that TDM-PONs cannot cope with the requirements of future network evolution with respect to aggregated bandwidth and the allowable power budget. These problems can be mitigated with Wavelength Division Multiplexing (WDM)-PONs.

Incorporating Wavelength Division Multiplexing (WDM) in a PON allows one to support higher bandwidth compared to the standard PON since each wavelength is dedicated to a single subscriber. The WDM-PON offers other advantages such as ease of management and upgradability, strong network security, high flexibility with data and protocol transparency, so that it has been considered by many as a future-proof access technology and an ultimate next-generation FTTH network. Although a WDM-PON has many technical advantages, there have been several issues that have prevented it from being a suitable solution for access applications.

WDM PON requires transmitters that can be tuned to particular wavelengths. These transmitters are usually tunable lasers. Therefore, they require wavelength-stabilizing devices to control their wavelengths to match those of the wavelength-selective components in the networks. These tunable lasers and their necessary components have obstructed widespread installation of WDM PON due to their high cost although the advantages provided by WDM PONs are extremely attractive. This led to the introduction of SS-WDM PONs .Instead of employing expensive tunable lasers, SS-WDM PONs are equipped with less expensive LEDs. However, cost reduction is achieved with lower output power and slower speed LEDs[2]. The name "SS-WDM" is gained from the fact that these systems utilize LEDs whose output power spectra are considerably broader than conventional lasers, and the distinct operating wavelengths are obtained from wavelength-selective characteristic of components in networks. SS-WDM systems offer several technical advantages over laser-based WDM systems[3]. Identical LEDs are used in all transmitters; therefore, the systems are easy to maintain. They are more reliable because LEDs have longer lifetime than lasers. Additionally, components in the networks that have to be wavelength-controlled are only WDM multiplexers and demultiplexers located at each end of the PONs[4-8]. Since these devices are usually AWG multiplexers, which can be fabricated to have temperature insensitive property, the wavelength-control function might not be necessary.

II. SYSTEM ARCHITECTURE

A. *Basic block diagram of SS-WDM*

The basic block diagram (Figure 1) of a Spectral-Sliced WDM mainly comprises of a transmitter, fiber and a receiver. The transmitter section includes an optical source, a binary sequence generator and a pulse generator. Receiver section consists of a PIN photodetector[9] followed by a low pass filter.

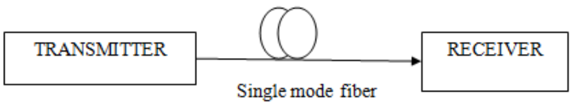

Fig. 1: Basic Block Diagram

B. *Design block of SS-WDM*

The design block diagram of a spectral sliced[8] WDM system is shown in figure 2.This system consists of three sections, namely the transmitter, fiber and the receiver. In the transmitter section, a low cost broadband light source Light Emitting Diodes (LEDs) is used as a light source for transmitting the signal. The broadband light source operation wavelength started from 1550 nm, and the total bandwidth is 5 nm. The DC power is used as the input power for the light source.

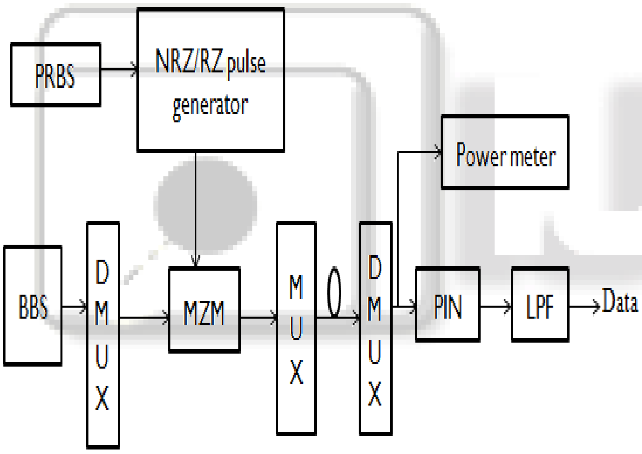

Fig. 2: Design block of SS-WDM

In the transmitter side, the LED's spectrum was sliced into four input signals using a de-multiplexer. Each sliced channel has spectral width of 0.2 nm .The sliced signal is then transmitted to the Point-To-Multipoint (P2MP) in each Optical Line Terminal (OLT), which consists of three components, such as pseudo random bit sequence generators, NRZ or RZ pulse generators[10-13] and Mach-Zehnder modulator. The modulated signal is combined by multiplexer, and a Single Mode Fiber (SMF) is used to transmit the modulated signal towards to the receiver.

In the receiver section, the transmitted signal from the fiber is divided by de-multiplexer. The de-multiplexer losses, such as the insertion losses, are considered as 2 dBm. A PIN photodetector followed by a LPF is used to detect the incoming signal. The optical power meter is connected with channel which is divided from de-multiplexer to measure the optical output power, which is considered as a received power of the system. Finally, eye-diagram analyzers are used to evaluate the performance of each channel signal.

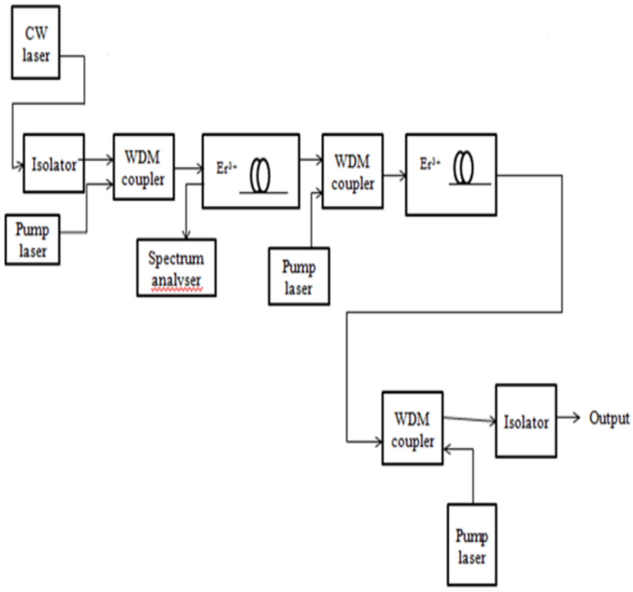

Fig. 3: Block diagram of ASE source

Figure 3 shows the block schematic for the generation of ASE source.Erbium doped fiber amplifier (EDFA) consist of erbium-doped fiber having a silica glass host core doped with active Er3+ ions as the gain medium. Basic elements of an EDFA schematically are shown in Figure 3. Erbium-doped fiber is pumped by semiconductor lasers at 980 or 1480 nm in wavelength. By pumping on 980 nm we get low noise figure and low optical gain but pumping on 1480 nm we can get higher optical gain and also higher optical noise. Useful optical signal propagates along short span of a special erbium doped fiber and is being amplified at that time.

Amplifier is pumped by a semiconductor laser (pump laser), which is coupled by a wavelength selective coupler, also known as WDM coupler. This WDM coupler combines the optical signal from pump laser with the transmitted optical signal which contains useful information need to been transmitted over the fiber optical link. The pump light propagates also in the same direction as the useful signal (co-propagation) or in the opposite direction (counter-propagation). Optical isolator is used to prevent laser oscillations and excess noise due to unwanted optical reflections.

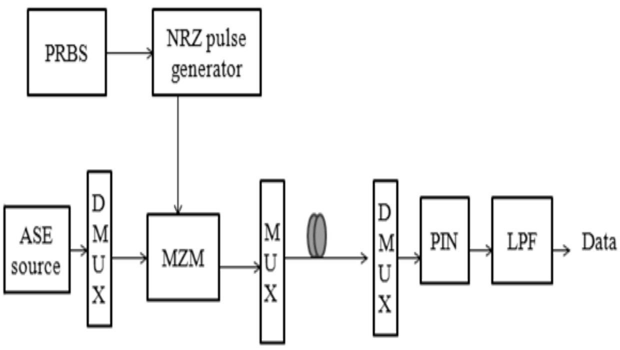

Fig. 4: Design block of High speed SS-WDM using NRZ format

III. SIMULATION OF SS-WDM

The simulation block diagram of SS-WDM using NRZ modulation format is shown in figure 5.Here three different bit rates such as 622Mbps,1Gbps and 1.5Gbps are used for simulation. The bit rates which are NRZ modulated is applied to a Mach-Zehnder modulator along with the signal generated from an LED. The signal is then combined by a multiplexer and transmitted towards the receiver section through a single mode fiber. The multiplexed signal is then divided by a de-multiplexer and photo detectors are used to convert the corresponding optical signal to electrical. At the receiver end eye-diagram analyzers are used to evaluate the performance of each channel signal.

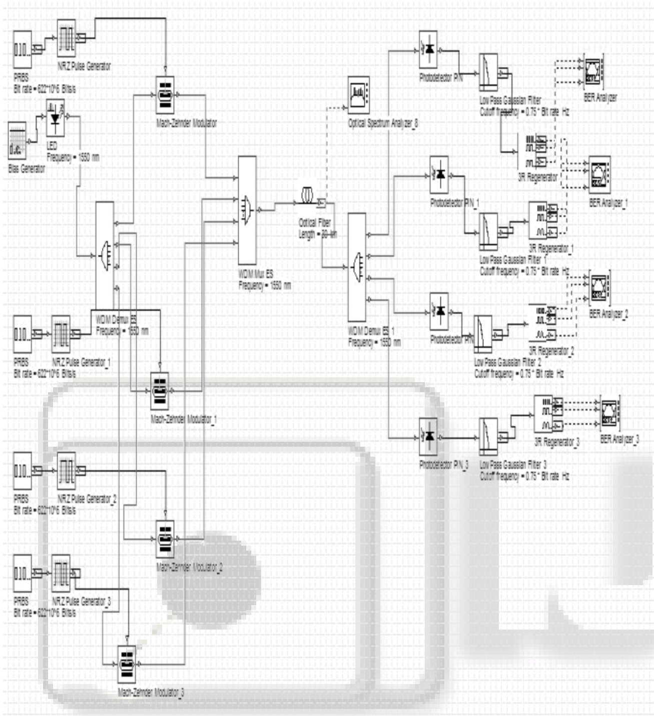

Fig. 5: Simulation layout of SS-WDM using NRZ format

Bit rate	Channels	Max: Q factor	Min: BER
622Mbps	1	6.830	$2.230*10^{-12}$
	2	7.025	$6.665*10^{-13}$
	3	7.534	$1.547*10^{-14}$
	4	6.543	$1.842*10^{-11}$
1Gbps	1	5.274	$3.883*10^{-8}$
	2	6.827	$3.025*10^{-12}$
	3	5.155	$7.545*10^{-8}$
	4	5.278	$3.676*10^{-8}$
1.5Gbps	1	3.355	$3.896*10^{-4}$
	2	4.970	$2.100*10^{-7}$
	3	4.969	$1.950*10^{-7}$
	4	4.615	$1.210*10^{-6}$

Table. 1: Results obtained from simulation of SS-WDM using NRZ format

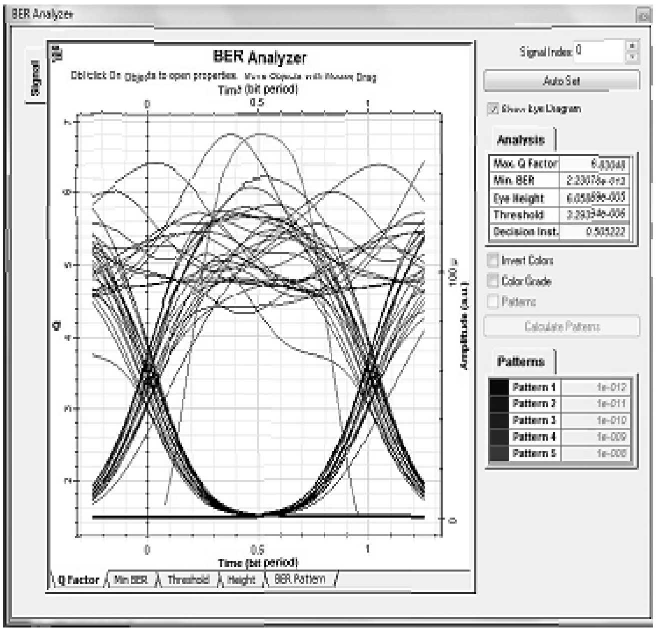

Fig. 6: Eye diagram at 622 Mbps using NRZ format

Figure 6 shows the eyediagram obtained from the first channel at 622Mbps using NRZ modulation format. Similarly eye diagrams are obtained from other channels also. The standard acceptable Bit Error Rate (BER) value will be $\leq 10^{-9}$. The result analysis from Table 1 shows that the quality factor increases with decrease in BER value. When the transmitted bit rate is 622 Mbps , the output obtained from the four channels is less than the standard acceptable BER..As a result the Quality factor increases. When the transmitted bit rate is 1 Gbps , the output obtained from the four channels becomes greater than the standard acceptable BER. As a result the Quality factor decreases. When the transmitted bit rate is 1.5 Gbps , the output obtained from the four channels is greater than the standard acceptable BER.As a result the Quality factor decreases. From these transmitted bit rates it is clear that as the bit rate increases, quality factor decreases and BER value increases.

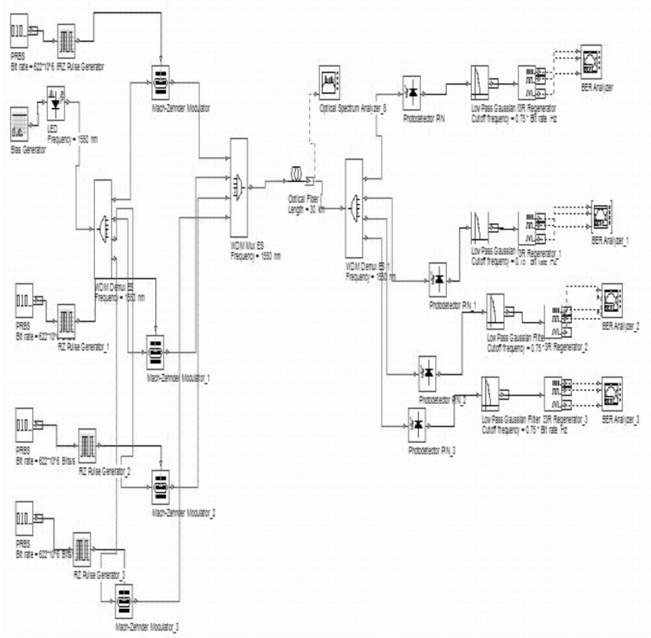

Fig. 7: Simulation layout of SS-WDM using RZ format

From this analysis, it is clear that the transmitted bit rate at 622Mbps can provide acceptable bit error rate at NRZ modulation format.

The simulation block diagram of SS-WDM using RZ modulation format is shown in figure 7.Here, three different bit rates such as 622Mbps,1Gbps and 1.5Gbps are used for simulation. The only difference is that here we replace NRZ modulation format by RZ format.

Bit rate	Channels	Max: Q factor	Min: BER
622Mbps	1	4.947	$2.939*10^{-7}$
	2	3.911	$3.866*10^{-5}$
	3	3.537	$1.660*10^{-4}$
	4	4.564	$2.131*10^{-6}$
1Gbps	1	5.005	$1.489*10^{-7}$
	2	5.557	$7.299*10^{-9}$
	3	3.904	$2.500*10^{-5}$
	4	4.804	$4.253*10^{-7}$
1.5Gbps	1	4.598	$1.179*10^{-6}$
	2	3.975	$1.909*10^{-5}$
	3	4.713	$6.808*10^{-7}$
	4	3.348	$2.281*10^{-4}$

Table. 2: Results obtained from the simulation of SS-WDM using RZ format

Here RZ modulation format is used. From this table it is clear that at three different bit rates (ie, 622Mbps, 1Gbps, 1.5Gbps) the BER value does not reach the standard acceptable range

Figure 8 shows the eyediagram obtained from the first channel at 622Mbps using RZ modulation format.Similarly eye diagrams are obtained from other channels at different bit rates.

From this analysis we can conclude that the BER value of NRZ modulation format is better than RZ modulation format at the lower bit rates as well as compared to the higher bit rates.

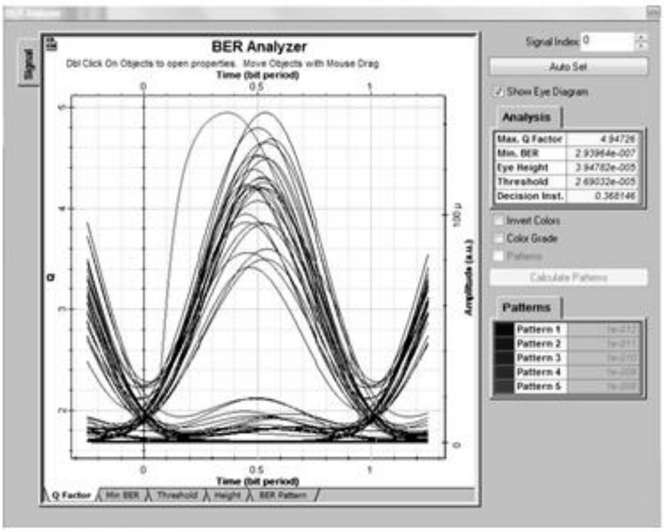

Fig. 8: Eye diagram at 622 Mbps using RZ format

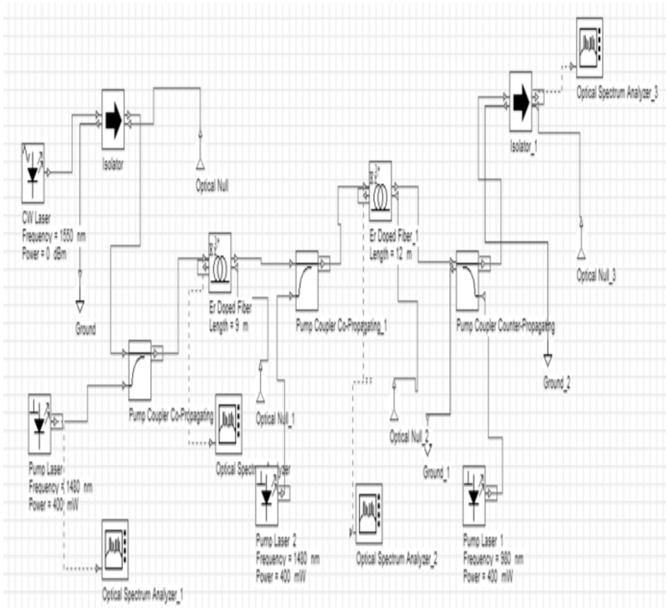

Figure. 9: Simulation layout for generation of ASE source

The simulation block for the generation of ASE source is shown in figure.9 and the simulation block for the generation of High speed SS-WDM is shown in figure.10. Here 10Gbps bit rate is used for the simulation. The output obtained from ASE source and the PRBS generator is modulated by using a Mach Zehnder Modulator(MZM). The modulated signal from MZM is combined using a multiplexer and is transmitted towards the receiver section through a single mode fiber. At the receiver a PIN photodetector converts the corresponding optical signal to electrical.

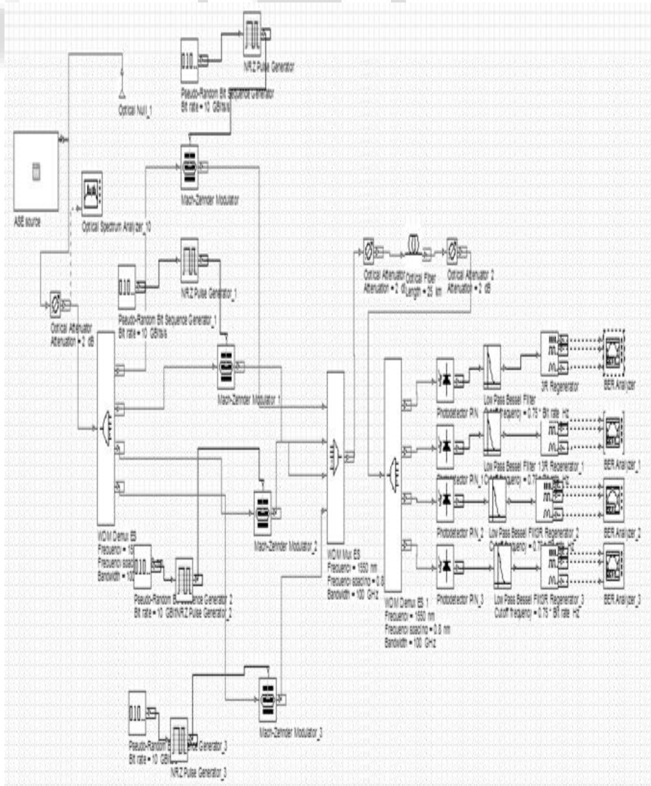

Fig. 10: Simulation layout of High speed SS-WDM

IV. CONCLUSION

Spectral-slicing is a powerful technique to establish a low cost narrow band channel spacing WDM system. Here the proposed narrow band spectral-sliced WDM system runs simultaneously on four channels with 0.2 nm channel spacing at 622 Mbps bit rate and High speed SS-WDM system runs simultaneously on four channels at 10Gbps bit rate. It is found by network simulation, that in SS-WDM the NRZ modulation format performs well at 622 Mbps system bit rates as compared to RZ modulation format and 1 and 1.5 Gbps system bit rates. But in High speed SS-WDM the system performs well at 10Gbps. The system performance has been investigated using simulator and its investigation was carried out by considering the system BER against received optical power at various system bit rates. Furthermore the signal quality of the received signal is investigated by using eye diagrams. The results obtained using NRZ and RZ modulation format were compared. The comparison results ascertained that the proposed system model provides better signal quality under NRZ modulation format at 622 Mbps and 10Gbps bit rates. Therefore, the proposed system would then be a promising solution to the next generation optical access networks.

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