Analysis Of 8 Channel WDM Network With EDFA

Divya Rajan

Abstract— Optical fiber communication is preferred nowadays due to its long distance transmission capability and available bandwidth compared to conventional techniques. The scope of this work is to analyze the performance of EDFA in Wavelength Division Multiplexing (WDM) network using Return-to-zero (RZ) and Non-Return-to-zero (NRZ) modulation format. A WDM network forms the backbone of optical communication. EDFA plays a significant role in optical communication for long haul purposes. For several reasons, especially for long haul communication, amplifiers are needed for improving the efficiency of transmitted data through communication medium which is typically optical fiber. The specified optical virtual environment is created in optisystem-7 software. Quality factor (QF), and Bit Error Rate (BER) have been observed to analyze the performance.

Index Terms— WDM, EDFA, QualityFactor, BER, Optisystem, Optical Communication, Optical amplifier

1 Introduction

ONE of the biggest challenges of modern day's communication system is the requirement of huge bandwidth. This high bandwidth demand is fulfilled by the evolution of optical communication system [1]. The rapid expansion of optical network created a need to increase the transmission capacity. One of the most popular techniques used to increase capacity is Wavelength Division Multiplexing (WDM). The key feature of modern optical communication system is WDM [2]. WDM uses multiple light sources operating at slightly different wavelengths to transmit several independent information streams over same fiber. By the mid of 1990's,combination of amplifiers and WDM was used to boost fiber capacity to higher levels and to increase the transmission distance [3].

The optical amplifiers directly amplify the transmitted optical signal without converting it into electric form as in-line amplifier. Amplifiers regenerate an optical signal, amplify and then re-transmit it. As the optical signal propagates over an optical fiber, it necessarily gets attenuated along the fiber path. Among various optical amplifiers, a great preference is given to EDFA because of its high gain and low noise insertion. EDFA is very much reliable for long distance transmission due to their wide bandwidth and optimum BER [4].

2 WAVELENGTH DIVISION MULTIPLEXING

WDM in optical communication is a technology which carries a number of optical carrier signals on a single fiber by using different wavelengths. WDM is done in IR region of electro-magnetic (EM) spectrum. Fig.1 shows basic WDM technology.

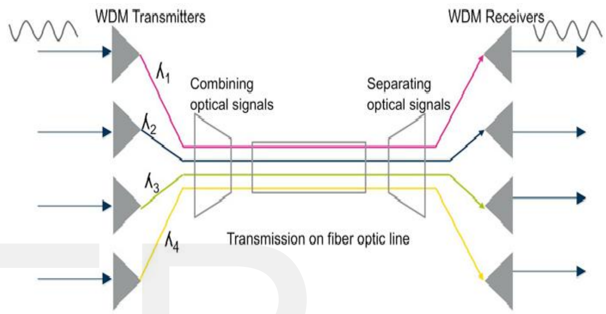

Fig. 1. Wavelength Division Multiplexing

The transmitter in figure 1 is individual optical transmitters. The output signal from these transmitters at corresponding wavelength is multiplexed by wavelength multiplexer in wavelength domain in accordance to ITU G.692 standard. The wavelength multiplexer combines all the output signal and combined output is transmitted along optical fiber to reach receiving end. At the receiver section, the combined transmitted signal is received and then de-multiplexed by a wavelength de-multiplexer and the respective receivers receive their intended data signal and before the signal is actually delivered to end user, further processing takes place on these receivers.

WDM system is of more popular with telecommunication infrastructures because they permit them to expand the capacity of system without laying more fiber. WDM systems are classified into three different wavelength patterns: normal (WDM), course (CWDM) and dense (DWDM). Normal WDM uses the 2 normal wavelengths 1310nm and 1550nm. CWDM provides upto 16 channels across multiple transmission windows of silica fibers. DWDM uses C- band (1530 nm – 1560 nm) transmission window, but with denser channel spacing. WDM, DWDM and CWDM are based on the same concept of using multiple wavelengths of light propagating on a single fiber, but they differ in wavelength spacing, channel number and ability for amplifying multiplexed signal in optical space.

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3 ERBIUM DOPED FIBER AMPLIFIER

Erbium Doped Fiber Amplifier (EDFA) is an optical amplifier that consists of a length of silica fiber whose core is doped with ionized atoms, Er^{3+}, of rare earth element erbium. Fig.2 shows principle of EDFA.

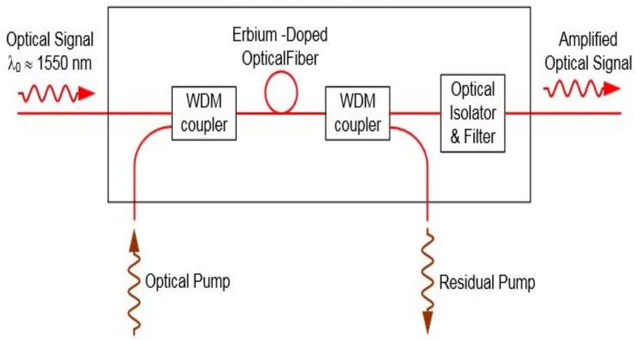


Fig. 2 . Principle of EDFA

The fiber is pumped using a pump signal from a laser, typically at wavelengths of 980 nm or 1480 nm. The doped fiber is precceeded by a wavelength selective coupler to combine ouput of pump laser with input signal. At output, another wavelength selective coupler may be used if needed to separate amplified signal from any remaining pump signal power. Isolator is used at input and or output of amplifier to prevent reflections into amplifier.

Fig.3 shows energy level diagram of EDFA. In case of erbium ions, set of frequencies that can be amplified by stimulated emission from E_2 to E_1 band corresponds to wavelength range 1525 – 1570 nm, a bandwidth of 50 nm, with a peak around 1532 nm. The energy difference between E_1 and E_3 levels corresponds to a wavelength of 980 nm. So , if optical power at 980 nm is injected into amplifier, it will cause transitions from E_1 to E_3 and vice versa.

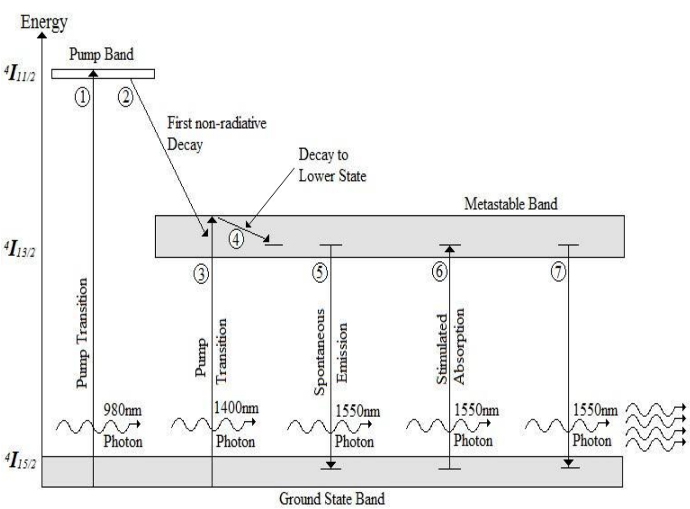


Fig. 3. Erbium energy level diagram

The ions that have been raised to level E_3 by this process will quickly transmit to level E_2 by spontaneous emission process. The lifetime for this process τ_{32}, is about 1μs [5]. Atoms from level E_2 will also transmit to level E_1 by spontaneous emission process, but lifetime for this process,τ_{21} is about 10 ms, which is much larger than E_3 to E_2 lifetime. If the pump power is sufficently large, ions that transmit to level E_1 are rapidly raised again to E_3 level only to transmit to E_2 level again. The net effect is that most of the ions are found in level E_2, and thus have population inversion between E_2 and E_1 levels. Therefore if simultaneoulsy a signal in 1525 – 1570 nm band is injected into fiber, it will be amplified by stimulated emission from E_2 to E_1 level.

4 MODULATION FORMAT

The first step in the design of an optical communication system is to decide how the electrical signal should be converted into a bit stream. The optical communication system are used as high speed long haul communication system. Due to high data rates, dispersion and non-linearity limitations in the optical communication system is of great concern. An optical modulation format is used to impress data on an optical carrier wave for transmission over optical fiber. In long haul, high speed and WDM transmission links, the ideal modulation format is one that has a narrow spectral width, low susceptibility to fiber nonlinearity, large dispersion tolerance and good transmission performance.

The two possible modulation formats in Intensity-Modulated direct-detection (IM/DD) system are Non return-to-zero(NRZ), in which a constant power is transmitted during the entire bit period, and Return-to-zero (RZ), in which power is transmitted only for a fraction of the bit period [6].

For last years, NRZ was dominant modulation format because it requires a relatively low electrical bandwidth and minimum optical peak power per bit interval for given average power. But it is not suitable for high bit rates and longer distances. At higher bit rates, RZ modulation formats supersede NRZ. RZ is more tolerant to dispersion [7]. At higher bit rates, RZ are less susceptible to fiber non-linearity.

5 METHODOLGY

The system consist of 8 input channels, an ideal multiplexer, two isolators, pump laser, optical amplifier, optical fiber, de-multiplexer, PIN photodetector, low pass Bessel filter, 3R re-generator and BER analyzer as shown in fig. 4.

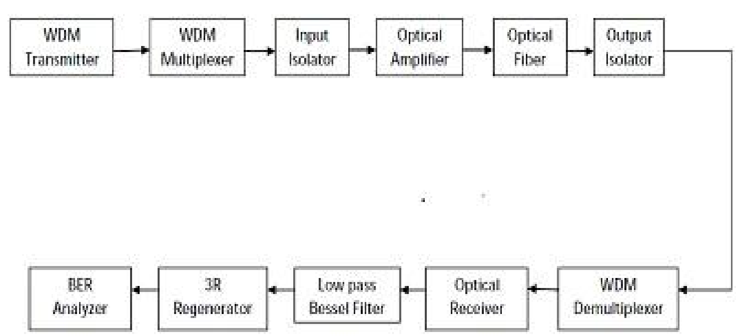


Fig. 4. Basic block diagram

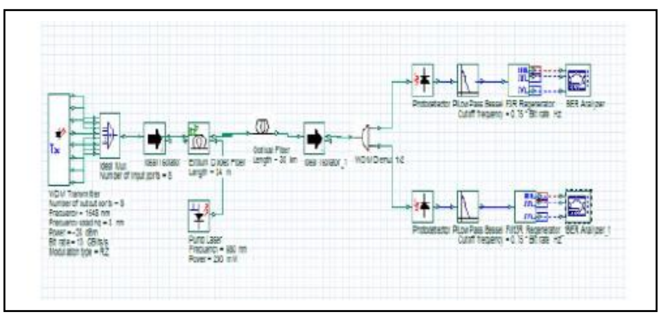
The input of the system is 8 wavelength multiplexed signal with 0.8 nm channel spacing. The power given to each channel is -28dBm. 980nm pumping is used to excite atoms to higher energy level. Use of two isolators is to prevent Amplified Spontaneous Emission (ASE) and signal from propagating in backward direction. Otherwise, reflected ASE would reduce population inversion. Pump laser is used for the excitation of doped atoms to excited energy level. Optical fibre acts as a transmission medium to carry optical signal. PIN photodetector is used to detect an optical information signal and convert it into the electrical signal. Low -pass Bessel filters are widely used in optical receivers since it produces only little overshoot and it limits noise power. Optical 3R regenerator is used for Re-amplifying, Re-shaping, Re-timing the optical signal. It is a key element in reducing the optical impairments arising from the long haul optical communication system. Results are obtained on BER analyzer.

5.1 OPTISYSTEM

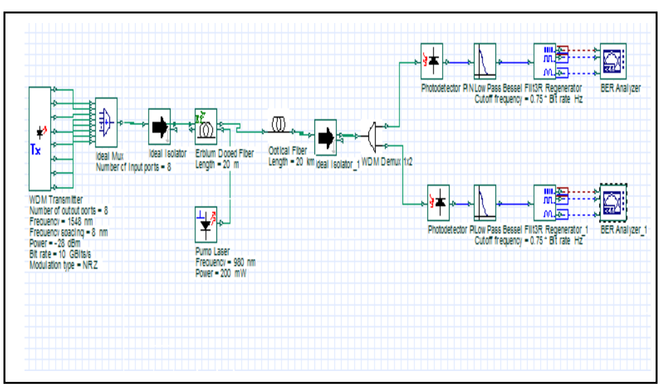
OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. A system level simulator based on the realistic modeling of fiber-optic communication systems, OptiSystem possesses a powerful simulation environment and a truly hierarchical definition of components and systems.

6 RESULTS AND DISCUSSION

6.1 SIMULATION LAYOUT OF EDFA USING RZ



6.2 SIMULATION LAYOUT OF EDFA USING NRZ



A. VARATION OF EDFA LENGTH

The length of the erbium doped fiber is varied from 6 to 24m.The Q-factor and BER is measured by varying the length of erbium doped fiber for constant pump power 200 mW. The optical fiber length is kept constant at 30 Km.Fig.7 shows variation of EDFA length Vs Q-factor. A plot of Q-factor Vs BER is also shown in Fig.8.

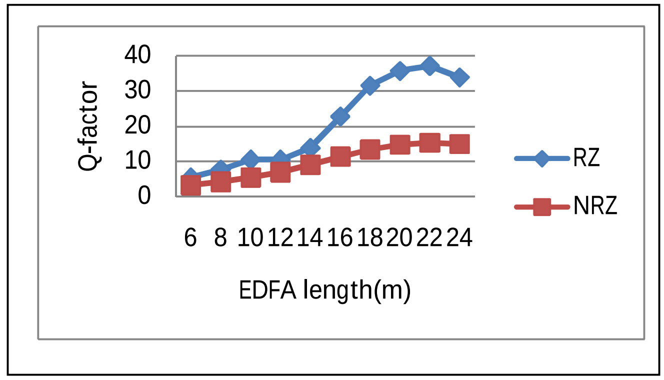


Fig. 7 Plot of EDFA length Vs Q-factor

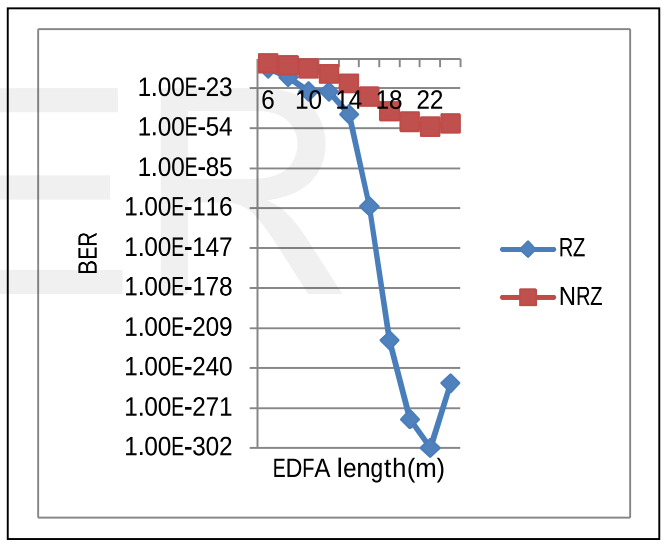


Fig 8. Plot of EDFA Length Vs BER

As the erbium doped fiber length increases, the erbium ions will excite to higher level but after reaching at certain length, the unexcited ions will cause decrease in Q-factor. The maximum Q-factor is obtained at 22 m length of amplifier. So this is the length of erbium doped amplifier where maximum Q-factor and minimum BER is achieved. It is clear from observations that Q-factor starts decreasing after attaining maximum value. RZ shows better results than NRZ.

B. VARIATION OF ERBIUM ION DENSITY

Erbium ion density is varied from 100 ppm-wt to 1000 ppm-wt. EDFA length is kept at a constant value of 24m. Pump power of 200 mW is provided.Fig.9 shows variation of erbium ion density Vs Q-factor.Also a plot of erbium ion density Vs BER is shown in fig.10.

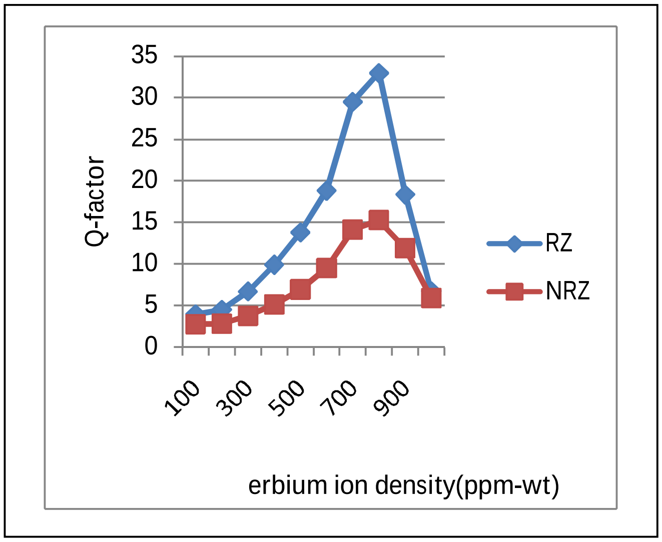


Fig 9. Plot of Erbium Ion Density Vs Q- factor.

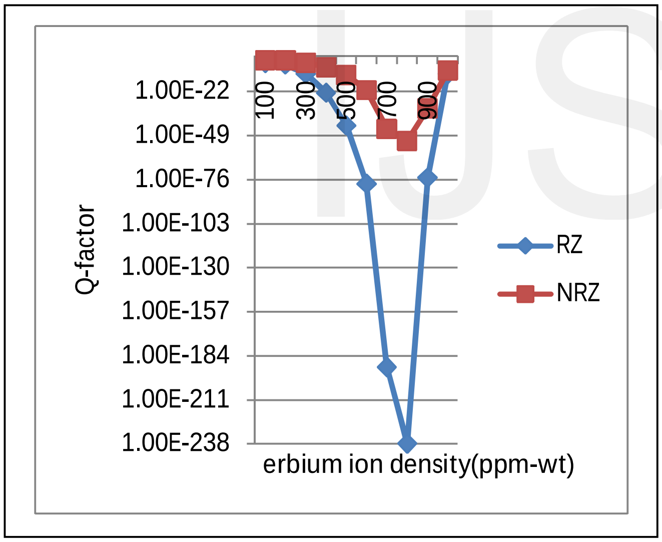


Fig 10. Plot of Erbium Ion Density Vs BER

It can be seen that for a given pump power, Q-factor increases linearly with increasing erbium ion density and after a certain level, it tends to decrease. At that point BER tends to increase. This is because once the amplifier reaches the maximum population inversion, after that the Q-factor decreases due to exhausted ions. It is found that Q-factor increases upto 800 ppm-wt erbium ion density value and after that it starts decreasing.

7 CONCLUSION

Due to continuous growth in the technology of optical fiber communication, the requirement of optical amplifiers increased.WDM techniques combined with EDFA provides high light wave transmission with high capacity and also provides flexible optical network technology. It can be concluded that WDM system integrated with EDFA using RZ modulation format gives better results than NRZ for all analysis. RZ is superior to NRZ as they are less susceptible to effects of non-linearities and Inter Symbol Interference (ISI).

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