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EYCDFA IN 8 CHANNEL WDM SYSTEM

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Abstract: *As the optical signal travels in a fibre, it suffers attenuation. In order to counterbalance the attenuation losses in optical fibre, optical fibre amplifiers came into existence. Optical fibre can be doped with rare earth element such as erbium, ytterbium. Wavelength Division multiplexing technology is attractive for large capacity transmission system. In Erbium ytterbium co-doped fibre amplifier (EYCDFA), the major concentration is ytterbium element. The scope of this work is to analyze the performance of EYCDFA in Wavelength Division Multiplexing (WDM) network using Return-to-zero (RZ) and Non-Return-to-zero (NRZ) modulation format. 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.*
Keywords – *BER, EYCDFA, Optical amplifier, Optical communication, WDM*

I. INTRODUCTION

The Information revolution implies that multimedia networks need high bandwidth for real- time communication services. At present, optical fiber is the only transmission medium offering such large bandwidth with low loss communication links. In fiber optic communication, there is degradation of transmission signal with increased distance [1]. By the use of optoelectronic repeater, this loss limitation can be overcome. In optoelectronic repeater, optical signal is first converted into electric signal and then after amplification it is regenerated by transmitter. But such regeneration becomes quite complex and expensive for wavelength division multiplexing systems. So, to remove loss limitations, optical amplifiers are used which directly amplify the transmitter optical signal without converting it into electric forms. With the use of optical fiber amplifiers the performance of the optical system is boost up to increase the repeater spacing and bit rate.

Optical amplifiers are a key enabling technology for optical communication networks. Together with wavelength-division multiplexing (WDM) technology, which allows the transmission of multiple channels over the same fiber, optical amplifiers have made it possible to transmit many terabits of data over distances from a few hundred kilometers and up to transoceanic distances, providing the data capacity required for current and future communication networks [2].

II. WAVELENGTH DIVISION MULTIPLEXING

Optical fibers can carry multiple light signals of different wavelength simultaneously. The technique which allows the optical fiber to carry multiple signals is called wavelength division multiplexing. So wavelength division multiplexing is the technique of sending signals of several different wavelengths of Light into the fiber simultaneously [3]. In fiber optic communications, wavelength division Multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths of Laser light to carry different signals. This helps to increase capacity and also helps bi-directional transmission over a single fiber length for transmitter and receiver.

WDM systems are popular with telecommunications companies because they allow them to expand the capacity of the network without laying more fiber. By using WDM and optical amplifiers, they can accommodate several generations of technology development in their optical infrastructure without having to overhaul the backbone network. Capacity of a given link can be expanded simply by upgrading the multiplexers and demultiplexers at each end.

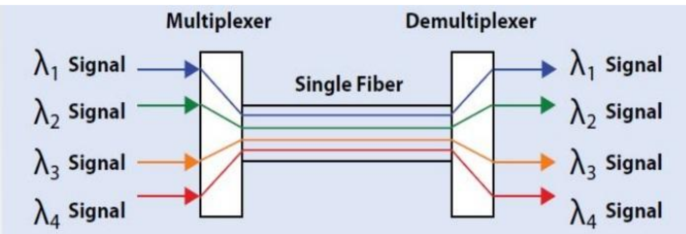

Fig 1: WDM Architecture

Fig.1 shows WDM architecture. The transmitter in the figure are the individual optical transmitters.. The transmitter block may consist of time division multiplexed type of system where the data signals to be transmitted is multiplexed in the time domain. The output signals from these transmitters at their corresponding wavelengths are then multiplexed in the wavelength domain in accordance to the ITU G.692 standard by the Wavelength Multiplexer. The wavelength multiplexer combines all the output signals and combines them to be transmitted along the optical fiber to reach the receiving end. At the receiver side, the multiplexed transmitted signal is received and then de-multiplexed by a wavelength de-multiplexer and the respective receivers receive their intended data signals and further processing takes place on these receivers before the signal is actually delivered to the end-user.

III. ERBIUM YTTERBIUM CO-DOPED FIBRE AMPLIFIER

The optical fibre can be doped with any rare earth element to provide large gain such as Erbium(Er), ytterbium (Yb), Neodymium (Nd) or Praseodymium (Pr). The host fibre material can be either silica or fluoride based glass. Amplification is achieved by stimulated emission of photons from dopant ions in the doped fibre. The pump laser excites dopant ions present in the doped fiber to a higher energy level from where they decay to a lower energy state (level) by 3 methods. Firstly, the excited ions decay via stimulated emission of a photon at the signal wavelength, which is requirement of amplification. Secondly, the excited ions can also decay by spontaneous emission or thirdly by non-radioactive (without light radiations) processes which involves interactions of phonons with the glass matrix which compete with stimulated emission reducing the overall efficiency of amplification of an amplifier. This spontaneous emission amplified along with signal when travels through doped fiber and becomes amplified spontaneous emission (ASE) which is major source of noise. The amplification window or operating regions of an optical amplifier is the range of optical wavelengths for which the amplifier provides a useful gain. The operating regions of an optical amplifier are determined by the spectroscopic properties of the dopant ions, the glass matrix of the optical fibre, power of the pump laser, and the wavelength of pump source. The most popular material for long haul telecommunication applications is a silica fibre doped with Erbium and Ytterbium, which is known as Erbium Ytterbium Co-doped Fibre Amplifier (EYCDFA).

Ytterbium (Yb)-sensitized erbium (Er)-doped fiber amplifiers (EDFAs) have recently demonstrated high and broad gain, comparable to the performance of conventional EDFAs. In addition, the pump efficiency of Yb^{3+} co-doped EDFAs is significantly improved, as well as spectrally broadened. Furthermore, the incorporation of Yb^{3+} minimizes the quenching process when high Er^{3+} concentrations are necessary, e.g., in short-fiber or waveguide amplifiers. In Yb -codoped EDFAs, the Yb^{3+} ions absorb most of the pump power and cross correlation between adjacent Yb^{3+} and Er^{3+} ions ensures the energy transfer. The introduction of Yb^{3+} allows for higher Er^{3+} concentrations, as stated, resulting in higher gain for a given pump level. Moreover, Yb^{3+} offers a wide variety of pump wavelengths to utilize different high power sources in the range from 800 to 1100 nm [4].

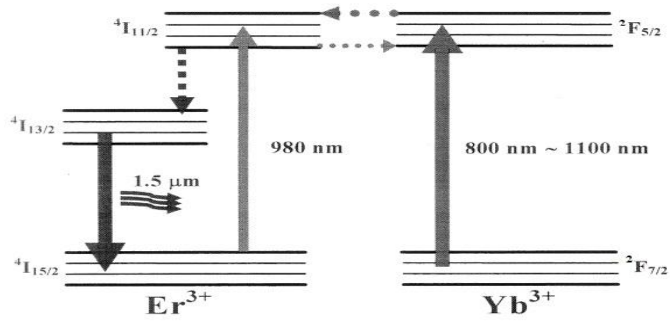

Fig 2: Energy-level diagram of the Erbium Ytterbium Co-Doped system

Fig.2 shows the simplified energy level transitions for Er^{3+}/Yb^{3+} co-doped fiber amplifiers (EYCDFAs). Yb^{3+} ions in silica fiber have just one broadband laser transition, between 970 nm and 1200 nm, pumped continuously between 800 nm and 1100 nm as shown in Figure. The absorption peak is at 975 nm. In the short wavelength region, Yb^{3+} has a unique two-level structure. In the long wavelength region, the transition is rather similar to the three-level system of Er^{3+}. Even if Yb^{3+} doped fiber amplifiers exist, Yb^{3+} ions are often combined with Er^{3+}, as sensitizers. The Yb^{3+} ions absorb the pump power and, due to cross relaxation between adjacent ions of Er^{3+} and Yb, the energy transfer efficiency from Yb^{3+} to Er^{3+} can be as high as 95% because of the large spectral overlap between Yb^{3+} emission spectrum ($^2F_{5/2} \rightarrow ^2F_{11/2}$) and Er^{3+} absorption spectrum ($^4I_{15/2}2 \rightarrow ^4I_{11/2}$). This process allows having strong absorption of the pump. Without signal absorption due to the Er^{3+} concentration, this helps to obtain very high power amplifiers and lasers [5].

IV. MODULATION FORMAT

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.

V. SYSTEM DESIGN

The proposed block diagram of EYCDFA on WDM system is shown in fig. 3. The WDM Transmitter holds 8 equalized wavelengths that feed to Ideal Multiplexer. The input of the system is 8 equalized wavelength multiplexed signals with 8nm channel spacing. The power of each channel is -28dBm.The pumping at 980nm is used to excite the doped atoms to a higher energy level. The 2 isolators are used to prevent Amplified Spontaneous Emission (ASE) and signals from propagating in backward direction. In fiber optic network, most of the reflections are harmful to the stability of the system. If back reflected and scattered light enter into the laser, the lasing process will fluctuate and the output power of the laser will varied. This problem will be avoided with the proper isolation between the components by use isolators. Optical isolators are device which transport light only in one direction and prevent the reflections and scattered light from sensitive components, particularly lasers. The pump power used is for the excitation of the doped atoms to a higher energy level. Optical Fiber is used to transmit or carry optical signals. As a photodetector, the PIN diode is reverse biased. Under reverse bias, the diode ordinarily does not conduct (save a small dark current or is leakage). When a photon of sufficient energy enters the depletion region of the diode, it creates an electron-hole pair. The reverse bias field sweeps the carriers out of the region creating a current. Low pass Bessel filter is widely used in optical receivers since it produces only little overshoots. Optical 3R generator 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. This can be simulated and modelled using OptiSystem as shown in fig.4 and fig.5.

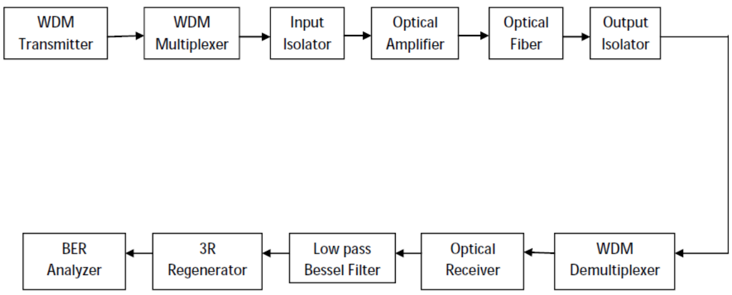

Fig 3: Basic block diagram

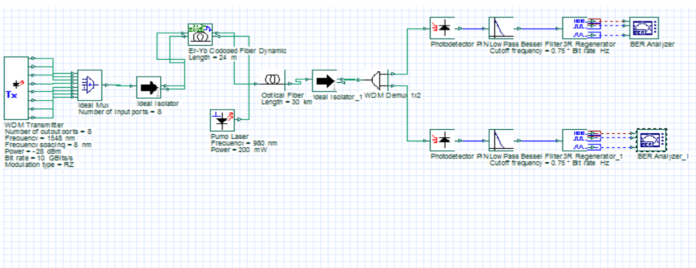

Fig 4: Simulation layout for EYDFA using RZ

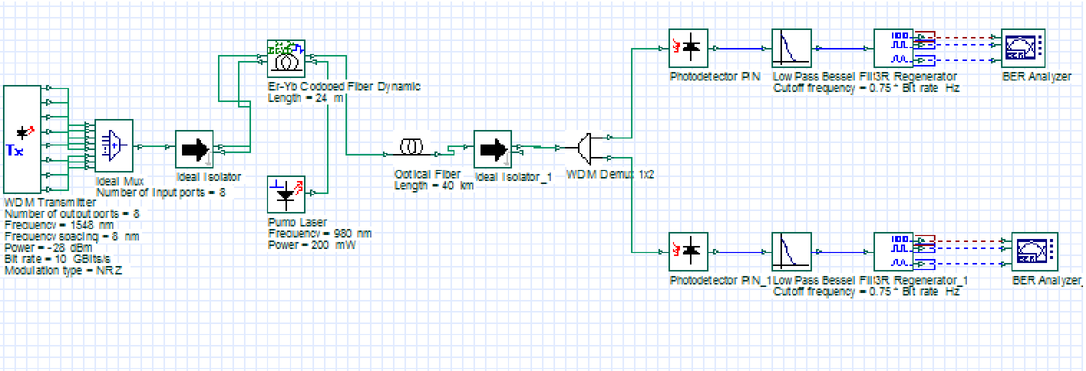

Fig 5: Simulation layout for EYDFA using NRZ

VI. RESULTS AND DISCUSSION

Variation of Er-Yb length:

The length of the ErYb 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 and fiber length 30 Km. As the erbium ytterbium doped fiber length increases, the ions in the ground state 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 24 m length of amplifier. So this is the length of 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. Plot of Er-Yb Vs Q-factor and BER is shown in fig. 6 and in fig.7.

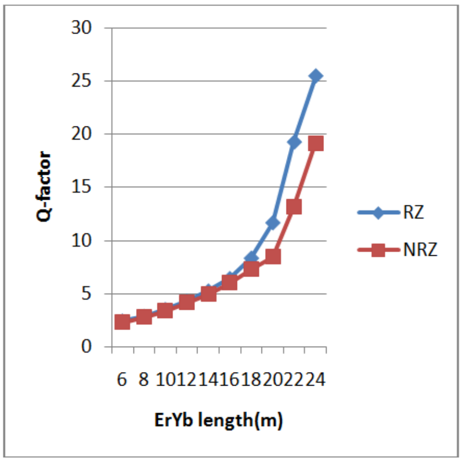

Fig 6: ErYb length Vs Q-factor

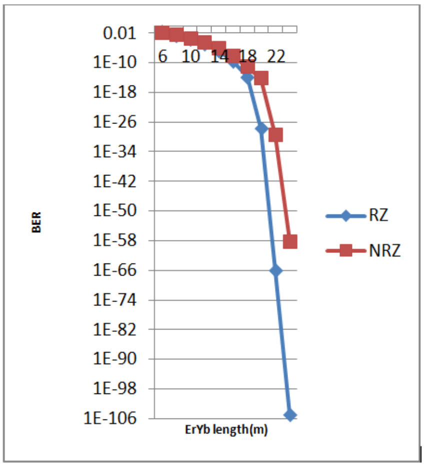

Fig 7: ErYb length Vs BER

Variation of pump power:

For a given length of doped fiber, as pump power increases, Q-factor increases initially. At the same time, as pump power increases, it creates more and more population inversion and once all the ions in fiber are excited, no more excited ions are available and Q-factor would decrease resulting in larger BER. After this saturation condition, Q factor again increases resulting in minimum BER. Plot of pump power Vs Q-factor and BER is shown in fig. 8 and in fig. 9.

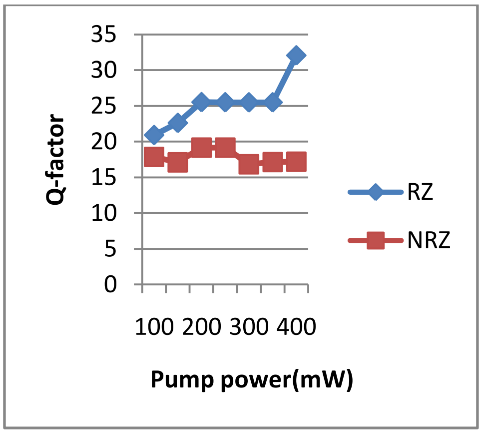

Fig 8: Pump power Vs Q-factor

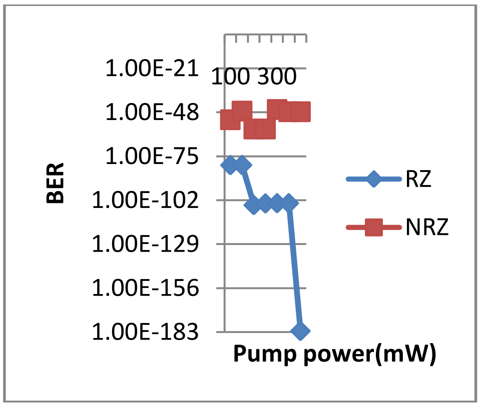

Fig 9: Pump power Vs BER

Variation of fiber length:

As the fiber length is increased, Q-factor decreases because performance of the system is degraded due to attenuation and dispersion effects. Decrease in quality factor of system experiences greater amount of noise resulting in larger BER. Plot of pump power Vs Q-factor and BER is shown in fig. 10 and in fig. 11.

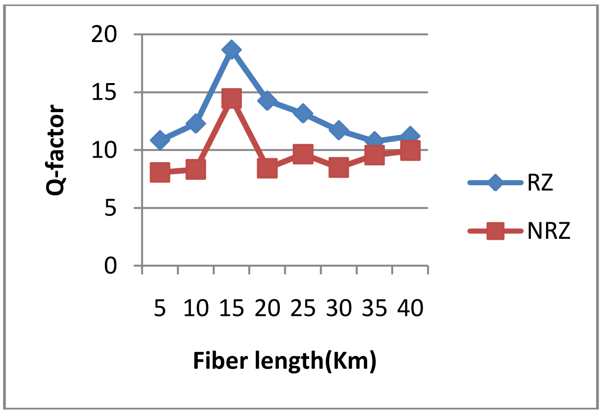

Fig 10: Fiber length Vs Q-factor

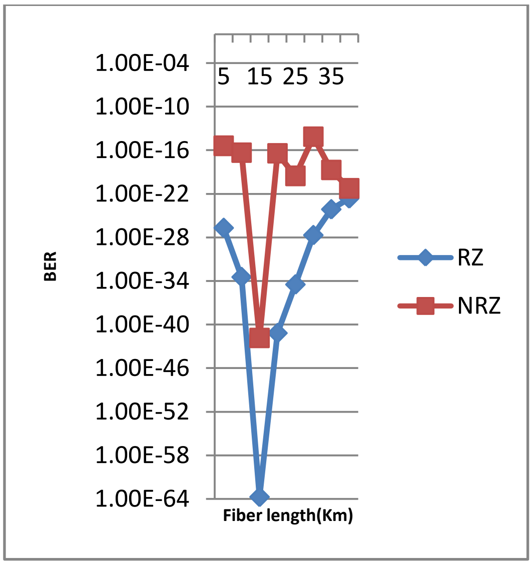

Fig 11: Fiber length Vs BER

VII. CONCLUSION

Due to continuous growth in optical fiber communication technology, the need of amplifiers increased and the reason being the amplifiers enhances the gain-bandwidth and also reduces the noise figure which arises in optical fiber. In this paper, performance of EYCDFA has been examined with various parameters. It is found that RZ modulation format shows better performance than NRZ for all the analysis. This is because RZ is less susceptible to ISI. Thus, RZ is better for long haul communication system and it shows low BER at high rates.

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