High Non-Linear Fiber Length Verification in Optical Regeneration using Non-Return Zero and Return Zero Signal

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Abstract—In this paper, the effect of high nonlinear fiber length in optical regeneration are investigated. To address the goal of this paper, there are two part need to fulfilled which are input pulse part and regeneration part. This work is focus on simulation by using OptiSystem Software. The simulated results show that the effective length for NRZ signal are starting from 0.5km to 2km while for RZ signal are 0.5km to 1km that suitable for optical regeneration. The comparisons of Max Q-factor and Min. log of BER for different signals are recorded.

Keywords— Non-Return Zero (NRZ); Return Zero (RZ); Highly Non-Linear Fiber (HNLF); Q-Factor; Bit Error Rate.

1. INTRODUCTION

All-optical signal processing devices based on Highly Non-Linear Fibers (HNLFs) [1], Dispersion Shifted Fibers (DSFs) [2], and Photonic Crystal Fibers (PCFs) [3] have attracted wide attention in the past two decade. Optical regeneration [4-5] can directly improve degradation signals resulting from fiber loss, dispersion, nonlinearity, and amplified spontaneous emission (ASE) noise as in [2]. The signal regeneration is conventially performed by Optical-Electrical-Optical (O-E-O). On the other hand, another type of regeneration that does not rely on the OEO conversion is optical regeneration [6] which can achieve high data rate. Optical nonlinearities can be classified into two general categories which are the nonlinear inelastic scattering processes. These are Stimulated Raman Scattering (SRS) and Stimulated Brillouin Scattering (SBS) [7]. The second category of nonlinear effects arises from intensity-dependent variations in the refractive index in a silica fiber, which is known as the Kerr effect including Self-Phase Modulation (SPM), Four-Wave Mixing (FWM) and Cross-Phase Modulation (XPM) [8].

2. Principle of Transmission System

In order to verify the HNLF length in optical regeneration in term of max. Q-factor and min BER, both NRZ and RZ signal are used. The simulation setup for NRZ and RZ signal modulation was illustrated in Figure 1. In this paper, a 10Gbit/s pseudo random bit sequence generator is used whose output in turn is given to a pulse generator to generate NRZ signal modulation and RZ signal modulation. Then, the oscilloscope is used to display the signal amplitude while the RF spectrum to display the signal intensity and power spectral density.

Next, the power transfer function is illustrated in Figure 2. The input signal consists of 1550nm wavelength. The signal is first amplified through an erbium-doped fibre amplifier (EDFA) which is to filter out the wavelength. The amplified signal is passed through the highly nonlinear fiber (HNLF). At the output of the HNLF, an optical filter which is Optical Gaussian Filter is used to provide pulse shaping element. In this simulation, the power is varied from 10dBm to 50dBm with 1550nm wavelength. Figure 3 shows the saturated power transfer function for the proposed system. It shows that, the power is saturated around 30dBm until 50dBm that indicates 1.956dBm output power. The saturated regime of the power transfer function curve can determined the performance of optical regeneration.

3. Simulation Setup for Transmission System

In this simulation, 2dBm input power with 1550nm wavelength are used for both NRZ and RZ signal. Figure 4 illustrates the HNLF setup for the proposed system. The NRZ and RZ signal is launched into amplifier through the Mach-Zehnder Modulator. An additional optical filter is inserted after the amplifier to reject the out of band ASE noise. The amplified signal is passed through the highly nonlinear fiber (HNLF). At the output of the HNLF, an optical filter which is Optical Bandpass Filter (OBPF) is used as a regenerate element. By using the Bit Error Rate (BER) analyzer, the min. log of BER and max Q-Factor can be measured. The HNLF parameters for the proposed system is referring the HNLF standard fiber module which are normal dispersion is -2.5ps/nm/km, an attenuation is 0.47 dB/km and a length is varies from 0.5km to 3.0km. The nonlinear coefficient inside the HNLF can be calculated by using eq (1). The criterion of the selection A_{eff} parameter is based on the value of fiber nonlinearity equal to 19.885×10^{-9}/W/km.

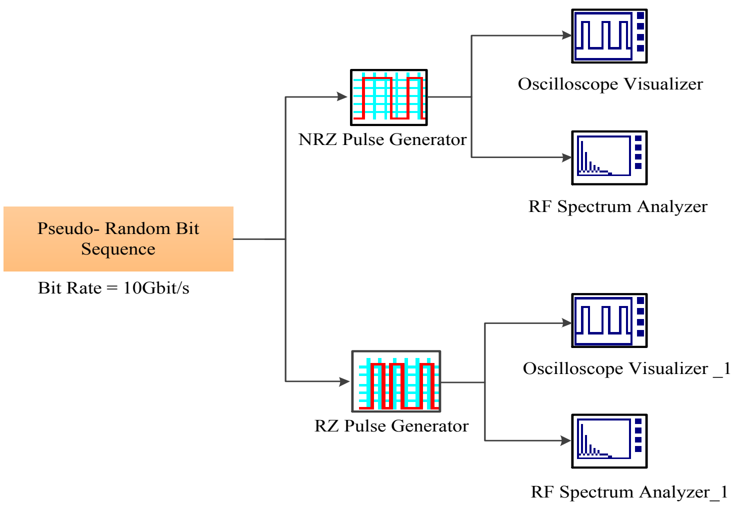


Figure 1: Simulation setup for NRZ and RZ signal modulation

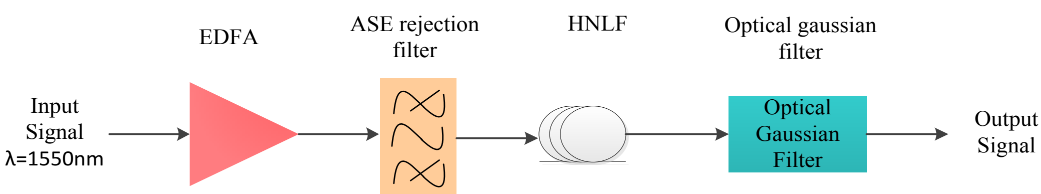


Figure 2: Simulation setup for power transfer function

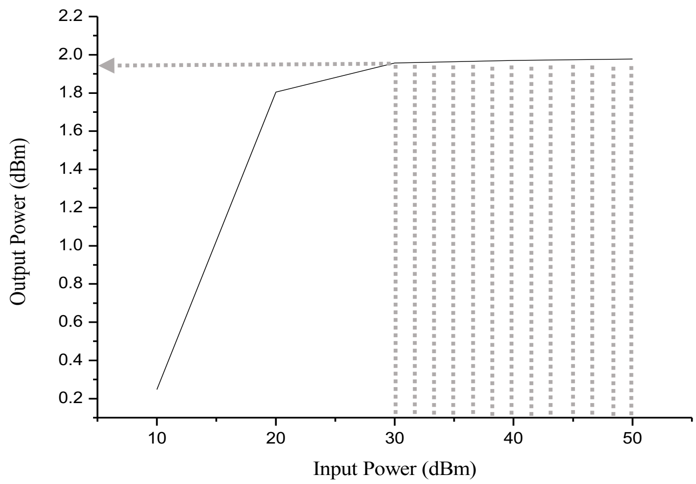


Figure 3: The saturated power transfer function

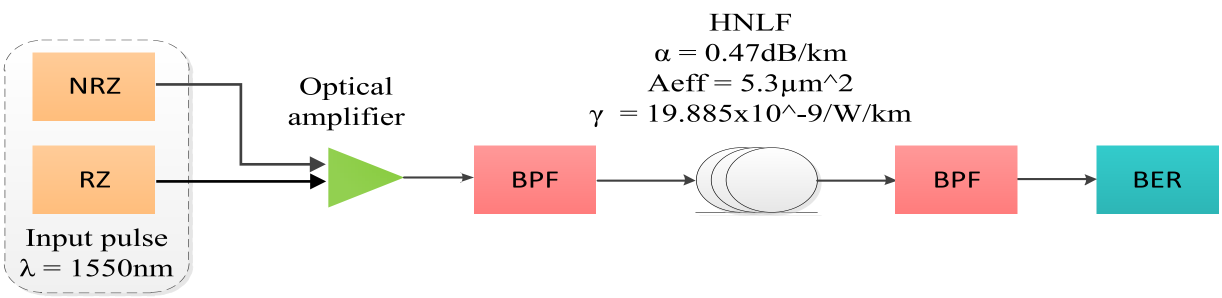


Figure 4: The simulation setup in Optiwave Software

$$Fiber\ nonlinearity, \gamma = \frac{2\pi}{\lambda}\frac{\eta_2}{A_{eff}} \tag{1}$$

$$\gamma = \frac{2\pi}{1550n}\frac{2.6 \text{ x } 10^{-20}\ \frac{m^2}{W}}{5.3\ \mu m^2}$$

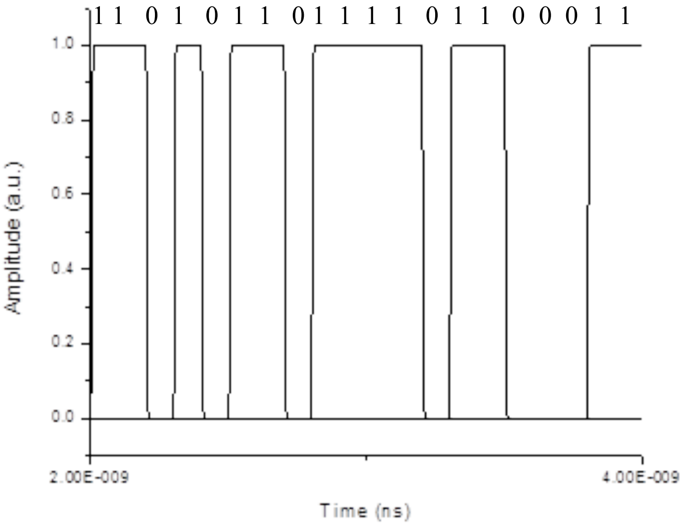
$$\gamma = 19.885 \text{ x } 10^{-9}\ \text{W}^{-1}\ \text{km}^{-1}$$

where λ is a wavelength, η_2 is a nonlinear index coefficient and A_{eff} is an effective area.

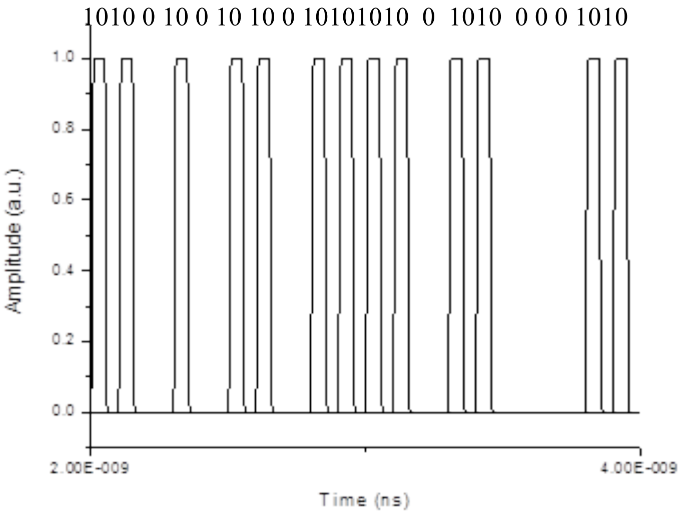
4. Result and Discussions

Figure 5(a) shows the NRZ signal amplitude. The pulse remains on throughout the bit slot and its amplitude does not drop to zero between two or more successive 1 bits. As a result, pulse width varies depending on the bit pattern. In contrast, the RZ signal amplitude as show in Figure 5(b), each pulse representing bit 1 is shorter than the bit slot and its amplitude returns to zero before the bit duration is over. Figure 6(a) shows the NRZ signal spectrum while Figure 6(b) shows the RZ signal spectrum in the proposed system. The advantage of the NRZ format is the bandwidth associated with the bit stream is smaller than that of the RZ format by about a factor of 2, because on-off transitions occur fewer times.

In the simulation, the length is varied from 0.5km to 3km. In optical regeneration, the acceptance value for min. log of BER is between 10^{-9} and 10^{-13}. Figure 7 shows the comparisons of Max. Q. Factor versus Length (km) for NRZ and RZ signals. It shows that, NRZ signal give a higher Q. factor compare to RZ signal which are 7.396 and 6.446 respectively at 1km length of transmission. Moreover, Max. Q. Factor for both signal is decreased when the length is longer. While, Figure 8 shows the comparisons Min. log of BER versus Length (km) for NRZ and RZ signals. It shows that, NRZ signal give a higher Min. log BER compare to RZ signal which are -13 and -10 respectively at 1km length of transmission. In the same way, Min. log BER for both signal is increased when the length is longer.



(a)



(b)

Figure 5: Signal amplitude of (a) Non Return Zero (b) Return Zero in Optical Regenerator

5. CONCLUSION

In conclusion, HNLF length play an important role in order to analyze the performance of Max Q-factor and Min. log BER in optical regeneration. In short, NRZ signal the 0.5km to 2km length of HNLF are valid in order to get the min. log of BER in acceptance range that suitable for optical regeneration while for RZ signal, only 0.5km to 1km length of HNLF are inside the acceptance range and the rest is out of range.

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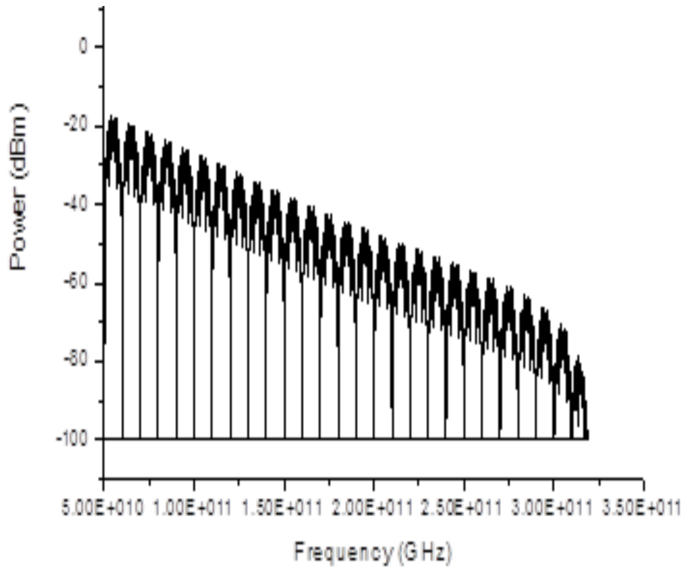
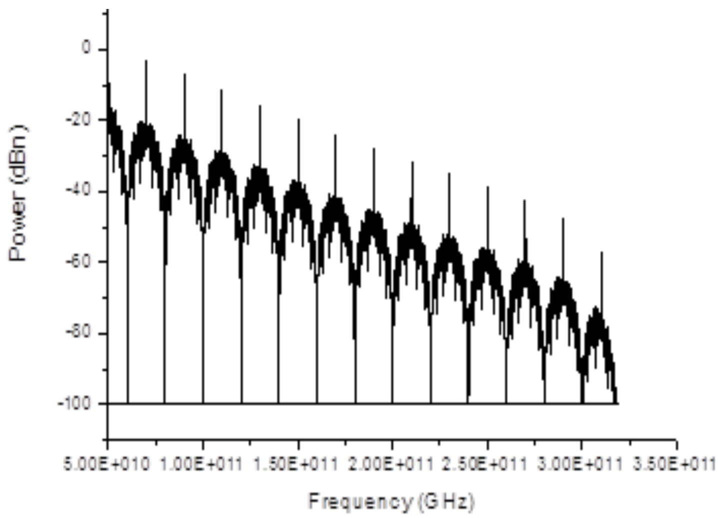


(a)



(b)

Figure 6: Signal spectrum of (a) Non Return Zero (b) Return Zero in Optical Regenerators

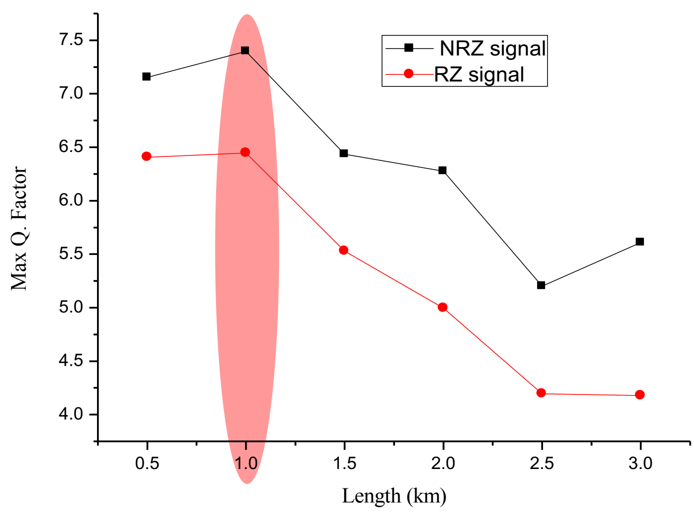


Figure 7: Comparisons Max. Q. Factor versus Length (km) for NRZ and RZ signals

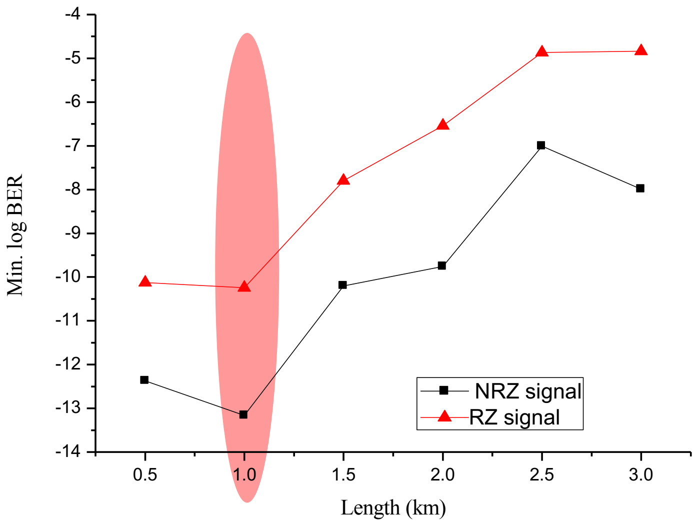


Figure 8: Comparisons min. log of BER versus Length (km) for NRZ and RZ signals

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