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10GB/S NRZ BASED ON SELF-PHASE MODULATION IN ALL OPTICAL 2R REGENERATION

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ABSTRACT

We demonstrated 10Gb/s NRZ signal regeneration based on self-phase modulation (SPM) in a single highly nonlinear fiber (HNLF). The optical signal has been degraded by 2500 km length of transmission and has passed through the regeneration section. During the regeneration, the significant improvement of BER 10^{-6} to BER 10^{-12} is recorded. The simulation result for transmitter, degradation and regeneration sections are discussed to prove the effectiveness of the proposed system.

Keywords: self-phase modulation, highly non linear fiber (HNLF), degradation section, regeneration section.

INTRODUCTION

All-optical signal processing devices based on highly nonlinear fibers (HNLFs), dispersion shifted fibers (DSFs), and photonic crystal fibers (PCFs) have attracted wide attention in the past two decades (Wen *et al*. 2014), (Vukovic *et al*. 2014), (Ito and Cartledge 2008). All-optical 2R regeneration (re-amplifying and re-shaping) can directly improve degradation signals resulting from fiber loss, dispersion, nonlinearity, and amplified spontaneous emission (ASE) noise (Wen *et al*. 2014). Moreover, 2R regeneration is a key technique for minimizing impairments and achieving long transmission distances (Yu *et al*. 2010). In addition, by using self-phase modulation (SPM), cross-phase modulation (XPM) or four-wave mixing (FWM), all-optical 2R regenerators can be achieved (Hnaung, 2014).

In this paper, we demonstrated 10Gb/s NRZ based on self-phase modulation in a single highly nonlinear fiber. SPM may occur whenever a signal having time-varying amplitude is propagated in a nonlinear material (Bass *et al*. 2002). NRZ encoding technique has been used in this simulation to perform the regeneration. The frequencies source of signal is 1550nm.

TRANSMISSION SYSTEM

The transmission system consists of three (3) sections which are transmitter, degradation and regeneration.

A. Transmitter

Optical transmitter is used to transmit signal data information in optical transmission system. In this simulation, pseudo random bit sequence generator is used whose output in turn is given to a pulse generator to generate NRZ pulse. Mach-Zehnder modulator (MZM) is used for electrically controlling the output amplitude or the phase of the light wave passing through the device. In addition, continuous wave (CW) laser is used as a source of signal power. Figure-1 shows the block diagram of the transmitter section.

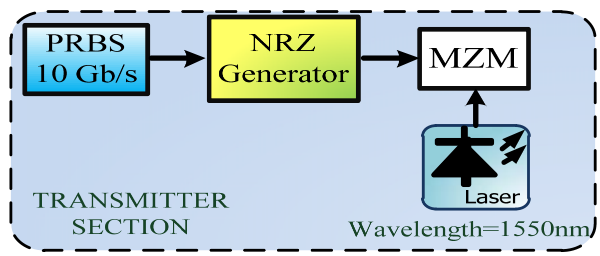

Figure-1. Block diagram of the transmitter section.

B. Degradation

In degradation section, dispersion compensation is performed by dispersion compensating fiber (DCF) after single mode fiber. A couple of amplifier and optical bandpass filter is used after each type of fiber length to recover the fiber losses and to reject ASE noise respectively. Then the signal becomes distorted because of the ASE noise from the EDFA. Each transmission consists of 100km-long single mode fiber and the signal is degraded by 8 transmission loops (2500km-long SMF). Figure-2 illustrates the block diagram of the degradation section.

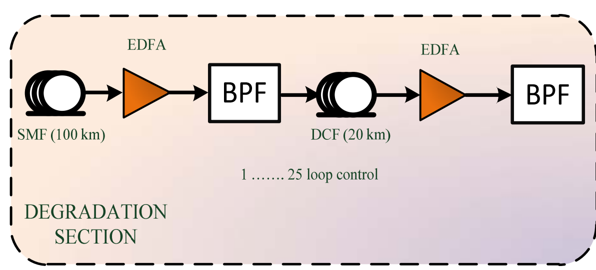

Figure-2. Block diagram of the degradation section.

C. Regeneration

In regeneration section, the degraded optical signal is launched into amplifier. An additional optical filter is inserted after the amplifier to reject the out of band ASE noise. The amplified signal is passed through the

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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. Figure-3 shows the block diagram of the regeneration section.

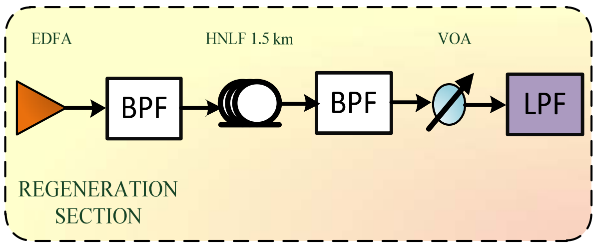

Figure-3. Block diagram of the regeneration section.

SIMULATION SETUP FOR TRANSMISSION SYSTEM

The simulation is done for 10Gb/s NRZ based on self-phase modulation in a highly nonlinear fiber. The CW laser and 10Gbps NRZ pseudo random bit sequence signal is modulated by Mach-Zehnder modulator and then is sent to the transmission span. The transmission span is considered as a circulating loop. Each loop is composed of 100km-long single mode fiber (SMF) with an anomalous dispersion of 16ps/nm/km, a dispersion slope of 0.08ps/nm^2/km, and attenuation of 0.2dB/km. Total loss is recovered by EDFA with 20dB gain. Dispersion is compensated by using dispersion compensating fiber with a length of 20km, a normal dispersion of -80ps/nm/km, a dispersion slope of -0.5ps/nm^2/km. To recover the fiber loss, EDFA with 12dB gain is used. Both amplifiers have noise figure of 4dB. These two amplifiers are followed by OBPF with a bandwidth of 200GHz to remove ASE noise added by amplifiers. The signal is passed through in circulating loop for 25 times in order to degrade the signal. In generation section, EDFA with 32.3dB gain and 4dB noise figure was used. Followed by OBPF with frequency 1550nm and 100Ghz bandwidth. The length of HNLF is 1.5km. Dispersion of -72ps/nm/km, a dispersion slope of 0.0075ps/nm^2/km, and attenuation of 0.47dB/km. By using the optical time domain analyzer and optical spectrum analyzer component, the output waveform for each section can be measured.

RESULT AND DISCUSSIONS

In what follows, the outcomes from transmitter section are firstly measured. Followed by degradation section and lastly regeneration section. In transmission section, NRZ signal combine with CW Laser with power 2dBm. The launched power is an important design parameter as it indicates how much fiber loss can be tolerated. Wavelength of 1550nm is used and the transmitter output waveform signal which is modulated by NRZ generator as shown in Figure-4.

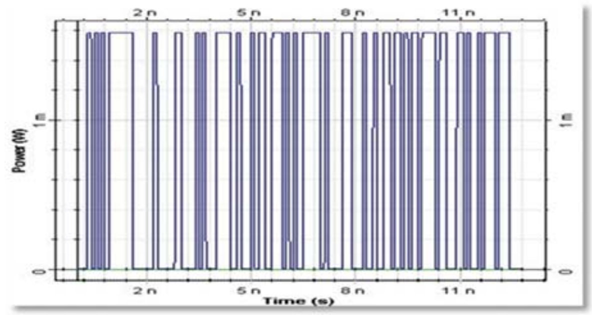

Figure-4. Waveform of the transmitter signal.

In the degradation section, the output waveform of degraded signal after 2500km transmission fiber is shown in Figure-5. Both amplifiers and optical bandpass filters is used in this section, to recover the fiber losses and reject the spontaneous noise. The results showed that the signal is distorted after 2500km transmission length. Figure-6 shows the spectrum of degradation section before HNLF. The spectrum in the degradation section is smaller compared to the spectrum in the regeneration section because EDFA is inserted at the beginning of the regeneration section.

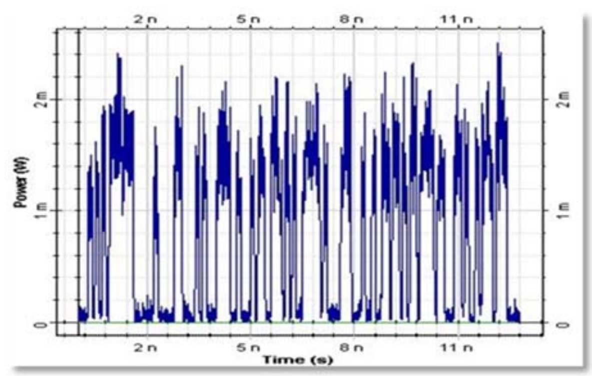

Figure-5. Waveform of the degradation section.

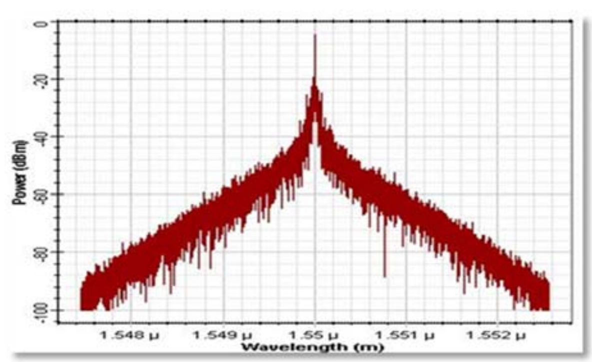

Figure-6. Spectrum of the degradation section.

In the regeneration section, the degradation data signal is amplified and then the signal is filtered by using

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OBPF to suppress out ASE noise. After filtering, the amplified signal is launched into HNLF where signal spectrum is broaden depending on power due to PM effect. At the output of the HNLF, OBPF is used again but with shifted centre wavelength to remove spectral for regeneration. Figure-7 shows regenerated waveform after the signal passed through the degradation process. Figure-8 shows the spectrum after the regeneration section is wider compared to the degradation section because there are SPM effects inside the HNLF. Figure-9 and Figure-10 show the eyes diagram before and after the signal regeneration respectively. The min BER after the degradation section is 10^{-6} and 10^{-12} after the regeneration section. The Q-factor before and after the regeneration are 4.456 and 6.829 respectively. The large eyes opening is the better quality of data transmitter. Figure-11 and Figure-12 shows the comparison of BER and Q-factor performance between the degradation section and the regeneration section as a function input power. The results of BER and Q-factor show significant improvement of the signal regeneration section.

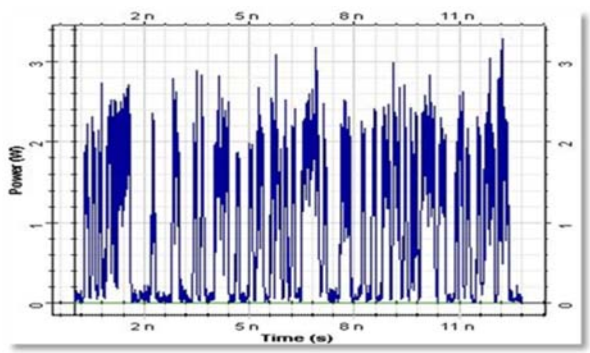

Figure-7. Waveform of the regenerated section.

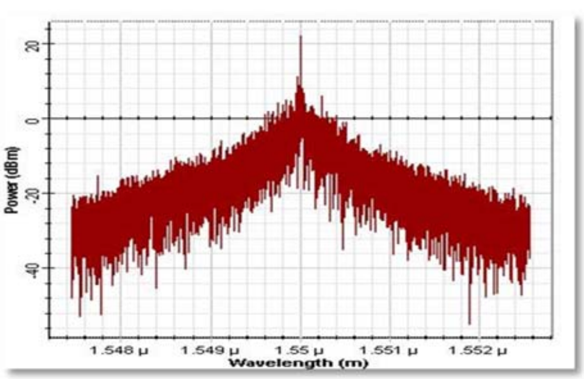

Figure-8. The spectrum of the regenerated section.

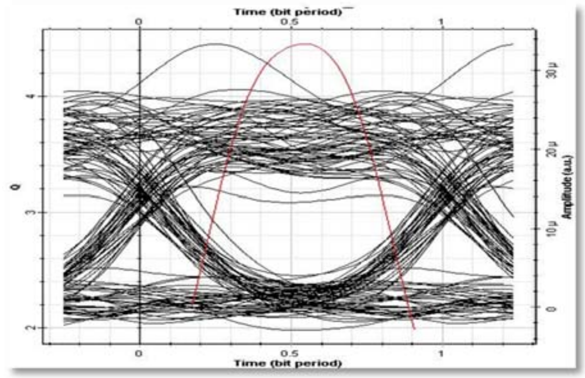

Figure-9. Eye diagram after passing through 2500km transmission fiber.

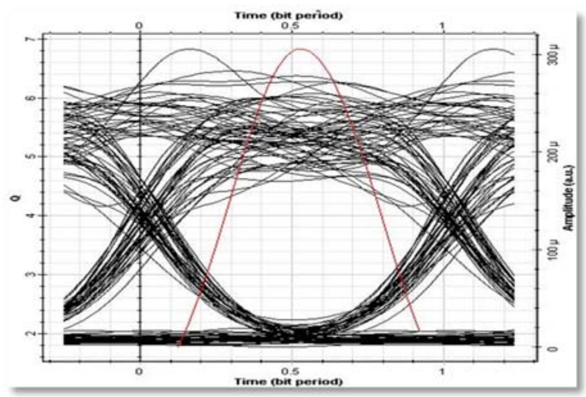

Figure-10. Eye diagram after the regeneration process.

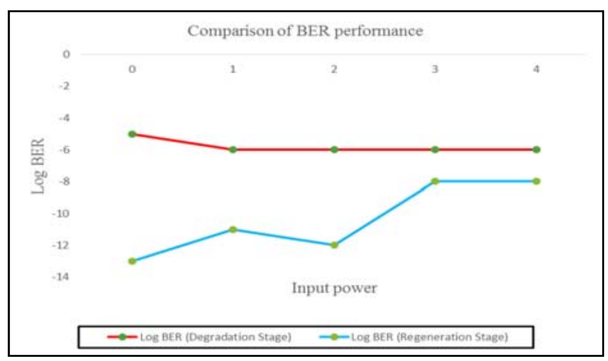

Figure 11. BER performance in 2R regeneration.

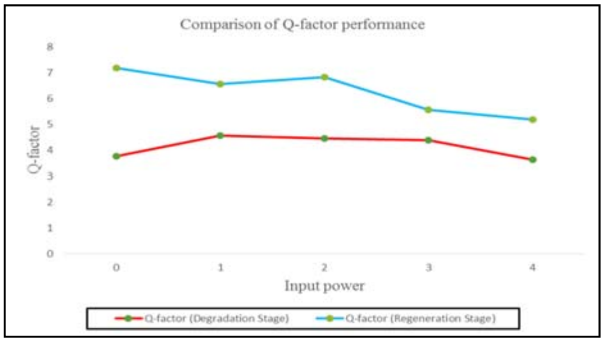

Figure-12. Q-factor performance in 2R regeneration.

CONCLUSIONS

In this work, we have demonstrated all optical signal regeneration for 10Gb/s NRZ degradation signal by 2500km DCF. We conclude that, min BER and Q-factor are improved after the signal regeneration by using the proposed system. This type of system can be utilized for high speed long distance transmission for future network.

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