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Optical Solitons Simulation Using DSF and Optical Pulse Generator in Single Mode Optical Fiber

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Abstract: ***This report indicates about the optical solitons simulation in single mode optical fiber. Optical Solitons are now used in long distance communications, because of its elemental property of maintaining its pulse shape. This project develops the optical solitons modeling and simulates the signal propagation by using OptiSystem software. Dispersion Decreasing Fiber and optical pulse generatrors are being used in the simulation. The effect of nonlinearity and dispersion in the optical fiber is investigated using optical pulse generators such as sech and Gaussian pulse generators. In addition, the pulse generators will be simulated at different distances varied by the nonlinear dispersive fiber total field. Then the data achieved from the simulation is analysed. Optical soliton generated using sech pulse generator is idle and has less data loss. This project is significant for the ultrafast communication system that is using optical fiber as it simulates optical solitons for over 40 Gbps.***

Keywords: DSF, EDFA, Four wave mixing, Multisoliton compression, Pump Laser, Spectral enrichment, Sech Pulse Generator

1. Introduction

Now we have a technology that revolutionizes the way the world communicates. It is a combination of glass and light-it is optic fiber. Many countries are using optical fiber for internet connection, phone telecommunication or internet protocol. In optical fiber huge amount of data is transfer though a small, narrow glass cable. The data will convert to the signal before it's transmitting as optical pulses in tiny glass cable-optical fiber. The pulse travel in the cable is like waveguide propagation and it has certain limit to transfer high data rate in long distances. A solution for this is the use of optical solitons which is a very narrow pulse with high peak power. This means that ultrafast optical solitons are in demand, as it means higher speed of communication, lower losses and provides stability. In fact, the bandwidth increases exponentially after the millennium due to overwhelming demand of internet users and the broom of information technology (IT).

Solitons are special type of optical pulses that can travel through an optical fiber undistorted for tens of thousands of kilometers. These pulses are in the stable shape and velocity is preserved while travelling along the medium. This means that solitons pulses do not spread in optical fiber even after thousands of kilometers. In an optical fiber, solitons pulses are generated by counter balancing the effect of dispersion by self-phase modulation.

2. Generation of Soliton Pulses

2.1 Soliton Generated Using DSF

Soliton pulse train is generated by combination of spectral enrichment in Dispersion Shifted Fiber (DSF) and multisoliton compression in a standard fiber and then passing them through DDF.

In an inhomogeneous optical fiber medium there is a compression in pulse of the signal whereas amplitude increases and similarly whenever there is transmission of multisoliton it is also compressed i.e. width of the signal decreases with increase in amplitude whereas its opposite is spectral enrichment in DSF where a signal is flattened (increase in width) when it passes through the DSF. Four wave mixing is a phenomenon in which propagation of two wavelengths results in formation of two new wavelengths (because of scattering of incident photons new photons are generated) and these new wavelengths are called sidebands and this can be the reason of signal flattening in DSF.

2.2 Soliton Generated Using Optical pulse generator

Pulses are generated by the pulse generator at user defined bit sequence generator. This generator is simulated at different length of distances using the nonlinear dispersive fiber total field in order to examine the effect of the nonlinearity and dispersion in optical solitons wave propagations. The simulation is done by using two types of optical generators which are the optical Gaussian pulse generator and optical sech pulse generator.

3. System Design

3.1 System Design Using DSF

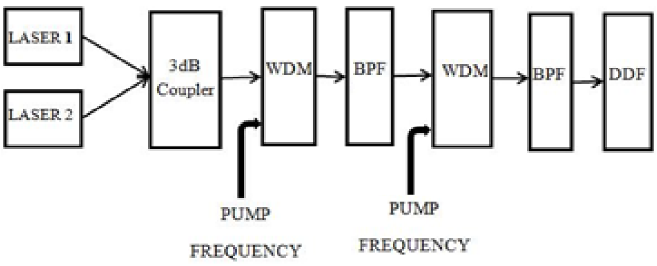

Figure 1: Block diagram for generation of Soliton

Figure1.Represents block diagram for generation of a SOLITON Pulse Train where two single frequency laser

sources work at 1550 nm and then their outputs are combined through 3 dB coupler. This is done to obtain a beat signal. This signal is then combined with a pump frequency of 1064 nm (wavelength) through wavelength division multiplexer and then the resultant signal is amplified by Erbium-Ytterbium Doped Fiber Amplifier. Then a Band Pass Filter is used to shape the signal and then amplified again through another EDFA. Now the signal is passed through a dispersion shifting fiber which is responsible for sideband generation by four waves mixing.

The signal is then passed through a standard fiber for multisoliton compression. At last is a DDF with standard parameters. What we get as a result is a soliton train which is not similar to ideal one but can be approximated to an ideal one by use of another DSF. The total loss of the system was 5.6 db. This circuit however has acute environment instability and requires additional chirp compensation at the system output.

The circuit for the generation of soliton pulse train was simulated using “OPTISYSTEM V.12”. A Gaussian optical filter is used as a BPF.The simulation set up is shown in Figure 3

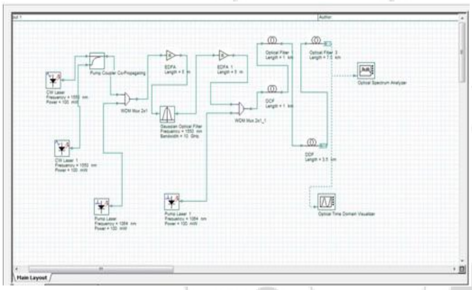

Figure 2: Simulation Setup for generation of Soliton

3.2 System Design Using optical pulse generator

The input pulse is generated using user defined bit sequence generator. It is given to an optical pulse generator such as optical sech pulse and an optical Gaussian pulse as shown in Figure 2 and Figure 3.The output pulse from the nonlinear optical fiber is an optical pulse.

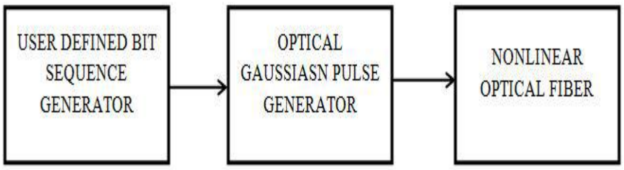

Figure 3: Block diagram for generation of Soliton using optical Gaussian pulse generator

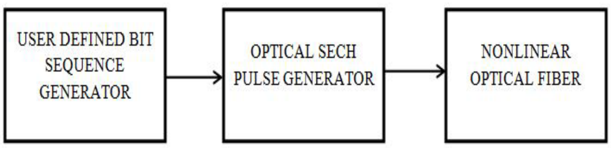

Figure 4: Block diagram for generation of Soliton using optical Sech pulse generator

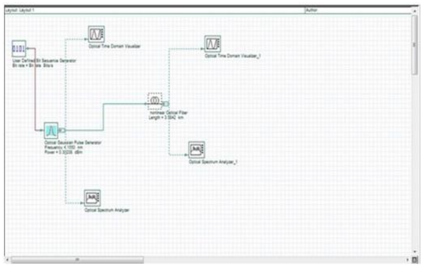

Figure 5: Simulation Setup for generation of Soliton using Gaussian Pulse Generator

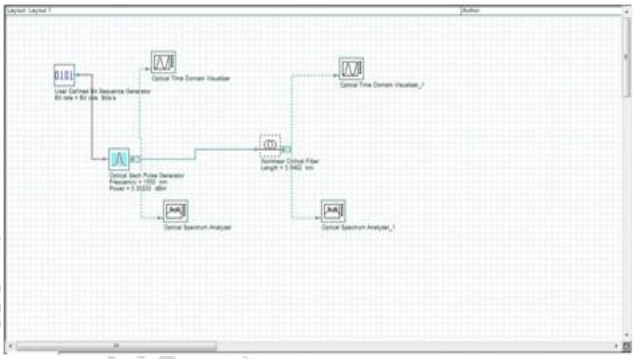

Figure 6: Simulation Setup for generation of Soliton using Sech Pulse Generator

Figure 5 and Figure 6 shows the optical solitons modeling circuit, simulated using optical sech and gaussian pulse generator. While varying the nonlinear dispersive fiber from 3.9482 km to 30km. All the optical soliton pulses obtained at each distances of the nonlinear dispersive fiber from the simulation are then captured and from the data obtained the results are being calculated, compared and analyzed.

From the simulation result of the optical solitons by using both optical Gaussian pulse generator and optical sech pulse generator at different lengths firstly the bit slot could be determine from the graph of the one cycle pulses obtained. Then from the bit slot the full width half maximum time, T_{FWHM} is calculated. Then the relation between T_0 parameter and T_{FWHM} can be finding by using the formula of:

$$T_0 = \frac{T_{FWHM}}{1.763} \tag{1}$$

The parameter for the values of nonlinear reference index, n_2 = 2.6 x 102 m^2/ W and cross-section area of optical fiber A_{eff} = 80 $\mu m^2$is used. The power value, P_N is then calculated by using the formula of:

$$P_N = N^2 \frac{|\beta|^2}{\gamma T^2} \tag{2}$$

The parameter for the value of the group velocity dispersion, β_2 is set to -20$ps^2/\mu m$. Next, the value for the dispersion length, L_D of the optical soliton pulse is calculated by using the formula of:

$$L_D = \frac{T_0}{|\beta_2|^2} \tag{3}$$

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4. Simulation and Results

4.1 Simulation using DSF

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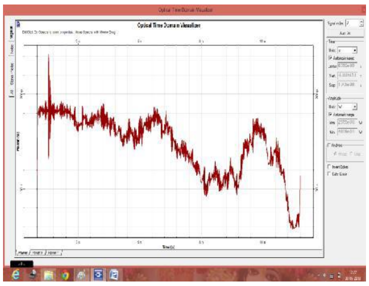

Figure 7: Curve of signal vs. time

Figure 7. is the curve of the signal vs time and it is clear that signal is very good but not same as that of an ideal soliton. and is already stated in theory

Figure 8. is the spectrum analyser graph of signal vs. wavelength and as is very much clear that at our operating wavelength of 1550 nm we are getting a very good peak of approximately -51 dBm power.

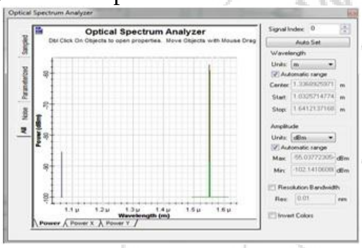

Figure 8: Curve of noise vs wavelength

As it is very much clear by the results that if anyhow we can remove various anomalies we can get a very good soliton pulse train which can then result in dispersion free communication.

4.2 Simulation using Optical Pulse generator

Figure 10 to Figure 13 Shows the overall output graph for simulation of the optical solitons when using the optical Gaussian pulse generator after travel for 3.9482 km, 10 km, 20 km, and 30km

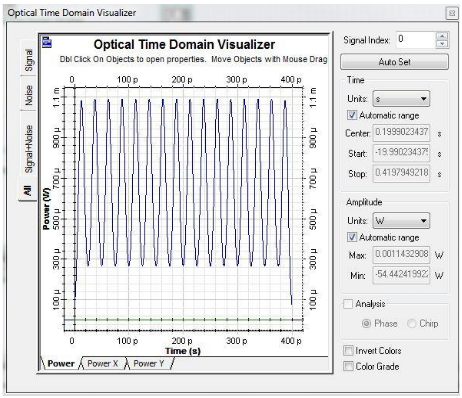

Figure 9.Input Pulse for optical generators

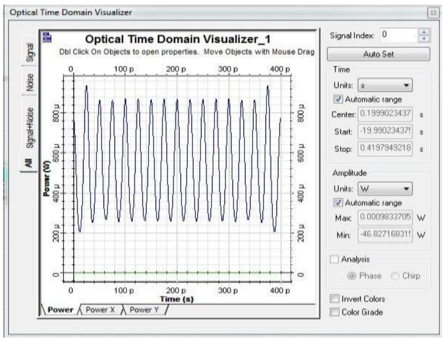

Figure 10.Output Pulse of Gaussian pulse generator after 3.9km

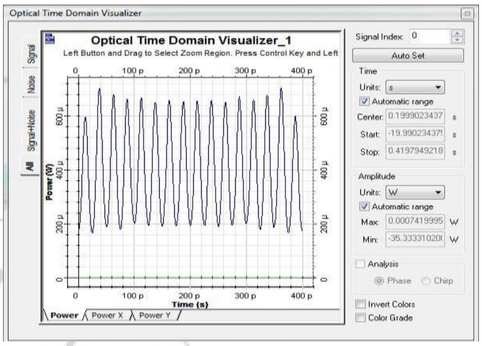

Figure 11.Output Pulse of Gaussian pulse generator after 10km

After travel for 3.9482 km the signal propagates without changing it shapes and almost have the same peak value and period except at the starting and ending of the pulses where they could be neglected as they are affected by noises. It shows that from the signal after travel 10 km are still propagates without changing it shapes but the peak values and periods are slight different as the length of the nonlinear dispersive fiber is increased. The signal pulses have started to be slightly different in shapes so as the peak values and

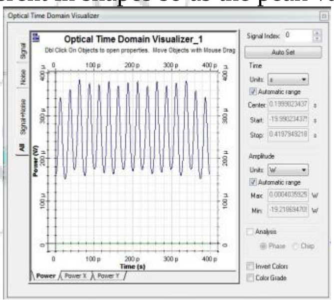

Figure 12.Output Pulse of Gaussian pulse generator after 20km

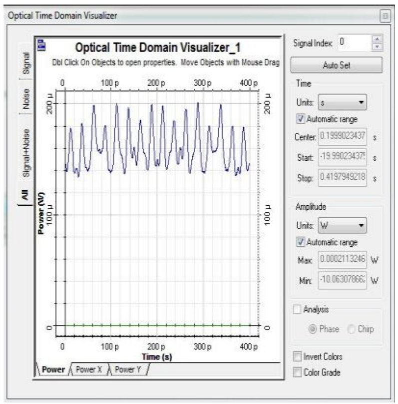

Figure 13.Output Pulse of Gaussian pulse generator after 30km

periods are different from one pulse to another after 20 km. Some pulses have undershoots. Most of the pulses are noticed to have undershoots after travel 30 km.

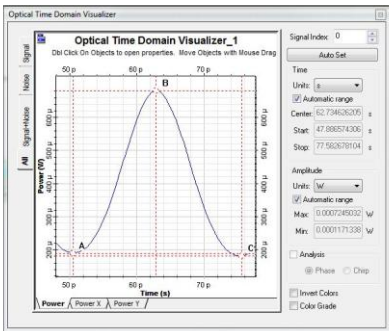

Figure14.One cycle input obtained from pulse after travel 10km

Figure 14 shows one complete cycle of the third pulse from the optical solitons pulses propagation taken from Fig12. It is observed that from the graph, there is no distortion happening at the pulse. The peak value obtained for this optical pulse is 681µW obtained from marker B at y-axis and the period for this one cycle pulse is 24.9 ps thus the bit slot calculated is 12.45 ps. Then from the bit slot the full width half maximum time, T_{FWHM} calculated as 6.2 ps. After that, the relation between T_0 parameter and T_{FWHM} can be find by using the formula of:

$$T_0 = \frac{T_{FWHM}}{1.763} = \frac{6.21}{1.763} = 3.5163$$

The power value P_N is then calculated as,

$$P_N = N^2 \frac{|\beta|^2}{\gamma T^2} = \frac{20^2}{1.317(3.15)^2} = 1.218 N^2 W$$

Next, the value for the dispersion length, L_D of the soliton pulse is calculated,

$$L_D = \frac{T_0}{|\beta_2|^2} = \frac{3.512^2}{20} = 0.617 km$$

Similarly, by using the above equations T_0, L_D and P_N for other distances can be calculated and tabulated below:

Table 1: Tabulated data for Optical Gaussian Pulse Generator simulation output

Nonlinear Dispersive Fiber Length(km)	T_{FWHM}	*Power Value,* P_N	*Dispersion Length,* L_D	*Peak Value (µW)*
3.983	6.5	1.075	0.69	862
10	6.6	1.2	0.72	681
20	6.2	1.07	0.65	384
30	-	-	-	-

From Table 1. it is observed that when using optical Gaussian pulse generator and varying the nonlinear dispersive fiber total field length from 3.9482 km to 10 km, 20 km and 30 km the T_{FWHM} indicates a reduction from 6.586 ps to 6.225 ps but then increases back to 6.625 ps respectively. For the power value initially it is increasing from 1.053(N^2{W}) to 1.218(N^2{W}) and then it decreased to 1.075(N^2{W}). On another note, the dispersion length decreased from 0.691 km to 0.623 km and then increased to 0.715 km. Next, it is noticed that shortening occurred for the solitons as it keep decreasing from 862.2µW to 681µW and then to 384.2 µW. When at 30 km, all the values for parameters T_{FWHM}, power value, dispersion length and soliton period couldnt be traced because the output bit slot could not determined.

Similarly the outputs from sech pulse generator are also obtained and the above values are calculated.Calculation and pulses are not included. Obtained values are tabulated below.From the Table 2 it is observed that when using optical sech pulse generator when the distance increases T_{FWHM}) indicates a reduction from 6.5253 ps to 6.19 ps but then increases back to 6.87 ps respectively.

Table 2: Tabulated data for Optical SechPulse Generator simulation output

Nonlinear Dispersive Fiber Length(km)	T_{FWHM}	Power Value,P_N	Dispersion Length, L_D	Peak Value (µW)
3.983	6.5	1.1	0.67	1046
10	6.19	1.2	0.61	820
20	6.8	1.03	0.75	482
30	-	-	-	-

For the power value initially it is increasing and then it decreased .It is noticed that shortening occurred for the solitons as it keep decreasing from 1046 µW to 820 µW and then to 482.5 µW.

From the signals obtained it is observed that the optical solitons signal when travel over 3.9482 km and 10 km distances either using sech or Gaussian pulse they propagate without changing their shape and even propagate at almost the same peak power undistorted.

But then, the optical solitons signal started to differ slightly in shape and peak power when they travel over 20 km be it with the sech or Gaussian pulse. However when the optical solitons signal travel at 30 km the signals could no longer preserve their shape and peak power and at this rate they have overshoots and undershoots.

But then, the optical solitons signal started to differ slightly in shape and peak power when they travel over 20 km be it with the sech or Gaussian pulse. However when the optical solitons signal travel at 30 km the signals could no longer preserve their shape and peak power and at this rate they have overshoots and undershoots.

Dispersion length obtained for optical solitons propagation output when using optical Gaussian pulse generator is higher than optical sech pulse generator. When relate to communication system, optical solitons that have higher dispersion length, will results in higher data losses due to the scattering effect. Therefore optical sech pulse generators are suited for generating solitons.

5. Conclusion

Optical solitons could be modeled and simulated by using OptiSytem software either by multiplexers or by optical pulse generators such as optical Gaussian pulse generator and optical sech pulse generator in single mode fiber.Based on the analysis it could be said that it is better to use optical sech pulse generator compared to optical Gaussian pulse generator and multiplexers as it have lower dispersion length and thus have lower losses in communication system due to the scattering effects.

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