Abstract—In the modern world of Technology some application such as data video transmission and multimedia application require huge bandwidth. Optical fiber communication is promising technology. For such application Group velocity dispersion puts the limitation on the bit rate. Hence the different technique is used to compensate dispersion. If the power level in the fiber is increased then the nonlinear effects are generated. The power variation within the channel gives the variation in the Refractive index of fiber medium which give rise to Self phase modulation. Self Phase modulation gives positive chirp. This effect compensates the GVD if the wavelength is higher than zero dispersion wavelengths, which gives negative frequency chirp. Hence negative frequency chirp given by GVD is compensated by positive frequency chirp given by SPM. The Interaction of SPM and GVD give the pulse which maintains their pulse shape and amplitude such a wave is known as Soliton

Keywords— SPM, GVD

Introduction:

Light diffracts as it propagate in a medium. In linear homogeneous media (air, water), there is no physical phenomenon that restricts diffraction. However, in nonlinear media exhibiting Kerr effect, the diffraction can be controlled by a focusing effect that tries to literally squish the spatial extent of the beam. This rather special effect can be seen typically at very high intensities. According to the optical Kerr effect, the refractive index of non linear media increases proportional to the transverse intensity profile of the beam. For instance we have Gaussian profile the central part of the beam is more intense then the side, and hence the media transforms itself into a kind of a GRIN structure, whose refractive index in the central is higher than that of the edges. In other word media is transformed to a positive gradient index lens, and hence the focusing effect. If this focusing effect keeps converging a beam, the beam intensity per unit area of the non linear medium increases, and at some point this intensity goes beyond the maximum tolerable intensity level of the crystal thereby physically damaging the crystal. On the other hand, when the focusing effect is matched exactly to compensate the diffraction, the beam propagates without any change in the spatial profile.

Dispersion in optical fiber:

Ideally an optical pulse with a given FWHM and amplitude, transmitted into end of fiber should arrive at the far end of that fiber with its shape unchanged however the optical pulse not only loses power but the pulse broadens as it propagate the phenomenon of broadening of pulse during its propagation through the optical fiber is known as dispersion. The widened pulse may merge into its neighbouring pulse and cause transmission errors as shown in figure 1.

Chromatic dispersion:

Chromatic dispersion arises because different frequency components of light travel at different velocities in the same medium. A medium absorbs electromagnetic radiation through oscillation of bound of electrons at characteristics resonance frequency. Hence when an optical field is incident on the dielectric medium and interacts with the bound electrons, the response of the medium depends upon the frequency of the incident optical Field. Due to this phenomenon refractive index of the medium becomes function of frequency of the incident optical field that is n(ω). This property of the medium is called chromatic dispersion. Fiber dispersion plays important role in pulse propagation because different spectral components travel at different speeds, represented as c/n(ω), where n(ω) is frequency dependent refractive index of the fiber mathematically by using mode of Taylor series around the frequency ωo:

\[ \beta \omega = n_0 \omega + \frac{\omega^2}{2} c(n') = \beta_0 + \beta_1 (\omega_1 - \omega_0) + \beta_2 (\omega_1 - \omega_0)^2.1 \]
where \( n \) is the core refractive index, \( \omega_0 \) is the central frequency of the pulse spectrum and 
\[
\beta \omega = \left( \frac{d\beta_{m}}{d\omega} \right) (m=1,2,...) \cdot \omega_0 \\
\beta_1 = \frac{d\beta}{d\omega} = -\frac{1}{c} \frac{d}{d\omega} \left( \frac{\omega}{n} \right) 
\]
where \( \beta_1 \) is inverse group velocity \( v_g \) where \( ng \) is group index for \( \beta_2 \) named as a GVD parameter.

\[
\beta_1 = \frac{1}{c} \left( n + \frac{\omega dn}{d\omega} \right) 
\]

\[
\beta_2 = \frac{d\beta_1}{d\omega} = \frac{1}{c} \left( n + \frac{\omega dn}{d\omega} \right) 
\]

Figure 2 shows the variation of \( \beta_2 \) with wavelength around the region of interest.

From the figure it is clear that for the wavelength of 1.27\( \mu \)m denoted as \( \lambda_d \), the effect of \( \beta_2 \) vanishes. The values of \( \beta_2 \) are positive for wavelength less than \( \lambda_d \), while they become negative for wavelength greater than \( \lambda_d \). The region for \( \beta_2 > 0 \) is called normal dispersion regime while the region for \( \beta_2 < 0 \) is known as anomalous dispersion regime.

**Generation of optical Soliton**

If the relative effect of SPM and GVD are controlled just right, and the appropriate pulse shape is chosen the pulse compression resulting from SPM can exactly offset the pulse broadening effect of GVD. Depending on the particular shape chosen, the pulse either does not change its shape as it propagates. The family of pulse that do not change in shape are called fundamental solitons, and those that undergo periodic shape changes are called higher order solitons.

**Frequency chirp**

When a high intensity optical pulse is coupled to a fiber, the optical power modulates the refractive index seen by the optical excitation. This induces phase fluctuations in the propagating wave thereby producing a chirping effect in the pulse.

The intensity image clearly shows the energy spreading out as Sech propagate in \( Z \) direction. The Phase shows expanding spherical wavefront. The three apparent vertical discontinuities in the phase plot are not real. The 3D intensity plot shows the intensity draining out as it propagates. When pulse propagates through the non linear medium there is no spreading of pulse energy as the sech propagate the 3D Intensity plot of spectrum is shown in above.
Soliton Interaction

The Above figure illustrate the collision of two sech beams in a linear medium interference fringes can be seen the far field. we now implement a two soliton collision the intensity image clearly shows that the soliton remain unchanged after collision. It is interesting to see an on axis amplitude null exactly when the two solitons collide .The solitons destructively interfere in that region Due to the on axis null , there’s an on axis phase discontinuity in the phase plot .

Soliton through boundaries

When pulse propagates through boundaries having different refractive index n1 and n2 where n1 is non linear refractive index and n2 is linear refractive index. At the boundary of linear and nonlinear the phase of pulse gets dispersed as shown in figure 5 When the pulse propagates through non linear medium where n1 and n2 refractive index are nonlinear the spectrum of the pulse remain unchanged as shown in figure 5.

Effect of loss for high order Soliton

In order to see the effect of loss on high order solitons thepropogation of the first and second order soliton is simulated for a distance of 69 km with a loss of 0.5dB/km. As it can be seen from the figure the second order soliton compresses to the one fourth of the initial pulse width at the half period and then return to initial pulse width at the half period and when the propagation of the second order soliton under the effect of the loss which is shown in figure 6a and 6b

Figure 7 represent the propagation of two second order soliton through 28km lossless optical fiber. The time between the pulses is taken as 12psec in fig a and 6psec in fig b since the time between the pulse is much longer in fig a, there is no interaction between solitons and they propagate the same. As in fig a and fig b when the time between the pulse is reduced to 6psec as shown in fig b the interaction of soliton starts.
Conclusion:

Due to shape preserving property of soliton, it was considered as a candidate carrier for long distance and a high bit rate optical communication. The result obtained from computer simulation of the two second order soliton propagation through the optical fiber shows that soliton interact with each other depending on the time between the pulses if the loss of the optical fiber is neglected. It is also found that loss of optical fiber increases this interaction. It is observed that the interaction of the soliton can lead to lose the properties of the soliton.

References