IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 19, Issue 2, Ser. I (Mar. – Apr. 2024), PP 01-05
www.iosrjournals.org

Optimization Of Dispersion In Optical Fiber Using Solitons Through The Nonlinear Schrodinger Equation (Nse)

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Abstract

Optical fibers have created a revolution in the field of telecommunication and have become the back bone of today's global communication networks. Optical fiber communication is considered to be more advantageous because, it has large channel handling capacity, high signal to noise ratio due to presence of low noise, no electromagnetic interference. In the most recent telecommunication engineering, it is known to use optical fibers for sending optical signals of a predetermined frequency to carry information to be remotely communicated. It is also known that the optical signal sent through an optical fiber undergoes an attenuation during its travel, which necessitates amplification by means of respective amplifiers disposed at predetermined intervals along the line. The major disadvantages are information loss and cross talk because of optical loss and dispersion. The problem of dispersion can be over come with the help of generating soliton pulses. In soliton communication the pulse broadens neither in the time domain nor in the free domain. This material is non crystallric and nonlinear in nature.

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Keywords: *Soliton, Optimization ,Dispersion , Optical fiber ,Nonlinear schrodinger equation, Optical time division multiplexed (OTDM) transmission system, etc.*

Date of Submission: 22-02-2024 Date of Acceptance: 02-03-2024

I. Introduction:

Solitions are very stable solitary waves in a solution of those equations. As the term "soliton" suggests these solitary waves behave like "particles". When they are located mutually far apart, each of them is approximately a traveling wave with constant shape and velocity. As two such solitary waves get closer, they gradually deform and finally merge into a single wave packet; this wave packet, however, soon splits into two solitary waves with the same shape and velocity before "collision" as shown in fig. 1.

The stability of solitons stems from the delicate balance of "nonlinearity" and "dispersion" in the model equations. Nonlinearity drives a solitary wave to concentrate further; dispersion is the effect to spread such a localized wave. If one of these two competing effects is lost, solitons become unstable and, eventually, cease to exist. In this respect, solitons are completely different from "linear waves" like sinusoidal waves. As shown in fig. 2.

An Raman amplifier which pumps a wavelength of 1545nm was designed to provide a distributed gain for investigation of soliton properties over distances of 100 dispersion lengths. The pump source developed for the amplifier was a super fluorescent amplified spontaneous emission source capable of delivering upto 1300mW of power in a 0.5nm bandwidth. The investigations of the behaviour of soliton pulse pairs reveals several limitations to high bit rate soliton communications over such long distances. These restrictions are caused by pulse energy fluctuations in combination with the soliton self frequency shift and the build up of dispersive radiation emitted by the solitons [1-3].

II. Importances Of Invention Of Soliton.

To solve this problems, using fundamental soliton train with relatively short pulse width instead of sinusoidal signal at the input section of the DDF has been suggested, making the adiabatic compression scheme applicable to low repetition rate. It has been proposed a new scheme for generating a pedestal-free, femtosecond soliton pulse train from sinusoidal input signal by utilizing quasi-adiabatic pulse compression in two stage dispersion decreasing fiber, to achieve a high compression factor > 250[4]. Fig.3.

The optical fibers used for transmission have a chromatic dispersion, which is due to the material that forms them and the refractive index profile, that varies with the wavelength of the transmitted signal and that goes to zero at a given value of the wavelength itself. This chromatic-dispersion phenomenon substantially consists of a widening in the duration of the pulses forming the signal during their travel through the fiber. This widening is due to the fact that the different chromatic components of each pulse are characterized each by its own wavelength and travel in the fiber at different speeds. Following this widening, temporarily successive pulses that are well separated at the transmitter, can partially overlap at the receiver, after their travel through the fiber. They may even be no longer distinguishable as separate values, cause an error in the reception[4-6]...

Therefore, Step-Index fibers at wavelengths close to 1500nm, which is used for telecommunication, have an important value of chromatic dispersion capable of constituting a limit to the transmission speed. That is, SI fibers limit the possibility of sending a high number of successive pulses in a predetermined unit time without incurring errors at the receiver.

The need of sending of increased amounts of information over the same transmission line has led to the sending of more transmission channels over the same line by a “Wavelength Division Multiplexing” (WDM) process. According to this technique, more channels consisting of analog or digital signals are simultaneously sent over the line consisting of a single optical fiber, and the channels are distinguished from each other in that each of them is associated with its own wavelength in the employed transmission band. This technique enables the number of the transmitted pieces of information per unit time to be increased, where the pieces of information are distributed among several channels and the transmission speed on each channel is the same[7-10]..

That a WDM transmission through dispersion-shifted single-mode optical fibers gives rise to an intermodulation phenomenon between the channels, known as “Four Wave Mixing” (FWM). This phenomenon arises, in general, when the presence of three optical signals in the fiber gives rise to a fourth signal which can overlap the others, thereby reducing the system performance[11]. The effect is due to non-liner third order phenomenon that can become very strong due to the high field intensity in the fiber core and at the high interaction lengths between the signals[12]. The greatest generation efficiency of the fourth wave (that is the noise effect in the system) is reduced by increasing the differences between the signal frequencies, the chromatic dispersion or the transmission length, due to the increased phase shift between the signals. In the case in which the optical fiber is a low-chromatic dispersion fiber and has a small efficient area of interaction between the optical frequencies, the non-linearity resulting from generation of the fourth wave can become a limit to transmission, in that the intermodulation products can fall with in the receiving band and give rise to a noise source[13-18]

III. Non-Linear Schrodinger Equation [Nse]

The equation that describes the propagation of soliton pulses in periodically amplified systems with variable dispersion is:

$$i\frac{\partial u}{\partial \xi}+\frac{1}{2}d(\xi)\frac{\partial^2 u}{\partial \tau^2}+|u|^2u=$$

$$-\frac{i}{2}\,\Gamma+i(\sqrt{G}-1)\sum_{m=1}^{N_A}\delta(\xi-m\xi_A)u \qquad \ldots\ldots.1$$

Where N_A is the number of cascaded amplifiers, $\xi_A=Z/L_D$, $\Gamma=\alpha L_D$ is the normalized loss coefficient (α is the loss coefficient and L_D is the dispersion length), $G=exp(\Gamma\xi_A)$ is the gain provided to compensate for the losses, δ is the Dirac function, which indicates the periodic nature of the amplification, and $d(\xi)$ is the variable dispersion profile given by :

$$d(\xi)=\begin{cases}\dfrac{\beta_2^{DCF}}{\beta_2^{ave}} & \text{, for the DCF, and}\\[2ex] \dfrac{\beta_2^{DCF}}{\beta_2^{ave}} & \text{, for the DSF}\end{cases}$$

…2

Where DCF and DSF stand for dispersion compensating fiber and dispersion shifted fiber, respectively, and

$$\beta_2^{ave}=\frac{\beta_2^{DCF}Z_{DCF}+\beta_2^{DSF}Z_{DSF}}{Z_A}$$ ...3

is the average dispersion coefficient.

In order to analyse the propagation of the pulse envelopes, it is convenient to write the amplitude *u* as a function of a fast component, due to loss and periodic amplification, and a slow component, the envelope through the transformation:

$$u(\xi,\tau) = a(\xi)v(\xi,\tau)$$ …4

By applying this transformation to equation 1. the following equations are obtained:

$$i\frac{\partial u}{\partial \xi}+\frac{1}{2}\,d(\xi)\frac{\partial^2 u}{\partial \tau^2}+a^2(\xi)|u|^2u=0$$ …5

$$\frac{da}{d\xi}=-\frac{1}{2}\;\overset{A}{\underset{m-1}{\Gamma a+(\sqrt{G}-1)^N\sum\delta(\xi-m\xi_A)a}}$$ …6

Equation 6 has the following solution

$$a(\xi)=\begin{cases}a_0\exp\left(-\frac{1}{2}\Gamma(\xi-m\xi_A)\right), & \text{for } m\xi_A<\xi<(m+1)\xi_A\\ a_0 & \text{For } \xi=m\xi_A\end{cases}$$ …7

with

$$a_0=\left(\frac{\Gamma\xi_A}{1-\exp(-\Gamma\xi_A)}\right)^{1/2}$$ …8

It should be noticed that, if the amplifier spacing Z_A is chosen much smaller than the dispersion length L_D. then $\xi_A=Z_A/L_D \ll 1$ and $a(\xi)$ is a function of the fast variation in each interval between amplifiers. With a suitable choice of the input power, the soliton shape will deviate very little from its shape in a lossless medium and may be amplified hundreds of times with a behavior very close to ideal propagation. The energy of the soliton in this propagation regime is the average energy in one amplification stage, and is therefore called average soliton regime[19]..

IV. Optimization Of Dispersion

The dispersion compensation scheme is reported where the uniform DCF is replaced by fiber with decreasing and increasing dispersion profiles. In this study, three cases were considered for the dispersion coefficient of the compensating fiber: uniform (conventional DCF), exponential decreasing, and exponential increasing. In order to do a fair comparison as general as possible, the average dispersion of the dispersion-varying compensating fiber (DVCF) was set to be equal to the dispersion of the uniform fiber[20-21].

V. Result And Discussion

In one aspect, the analytic method presents invention relates to an optical telecommunication system having at least two sources of optical signals modulates at different wavelengths, included in a predetermined transmission wavelength band, at a predetermined transmission speed; means for multiplexing said signals for input to a single comprising optical fiber; and optical-fiber line connected at one end to said multiplexing means; and means for receiving said signals comprising optical demultiplexing means for the signals themselves depending on the respective wavelength.

In particular, the wavelength value bringing the chromatic dispersion to zero is lower by at least 10 nm than the minimum wavelength to the transmission band. Preferentially, the wavelength value bringing the chromatic-dispersion to zero is lower than or equal to 1520 nm and, more preferably, the chromatic dispersion value in the fiber is lower than 3 ps/(nm.km) in the predetermined transmission band. Also preferably, the predetermined optical power value in at least one portion of the line is not lower than 2 mW per channel.

In a second aspect, the invention relates to an optical fiber for transmitting at least two optical signals in a predetermined transmission wavelength value included in a predetermined interval. The maximum zero for a wavelength value included in predetermined interval. The maximum value of the interval is lower than the minimum wavelength of the band by such an amount that substantially no local wavelength value bringing the local chromatic dispersion to zero include in the band, but which is present in the fiber over a length portion capable of generating intermodulation peaks of said signals. In particular, each of the wavelength zero values of the local chromatic dispersion differs by less than 10 nm from the wavelength zero value of the overall chromatic dispersion in the fiber. Also in particular, the optical fiber according to the invention has a chromatic dispersion lower than 3 ps (nm.km) in the transmission band, and it becomes zero for a transmission value lower by at least 10 nm than the minimum wavelength value of the band.

In another aspect, the optical fiber consistent with the invention is characterized in that, for an overall fiber length greater than 100 km, it has a chromatic dispersion of such a value that intermodulation peaks are not generated in the presence of at least two optical signals over several channels of different wavelengths, the power of which being at least 3 mW per channel fed to a fiber end, and the intensity of which causing a signal/noise ratio lower than 20.

The minimum wavelength value of the transmission band is higher by a given amount than the wavelength value bringing the chromatic dispersion to zero, which amounts to have such a value that in no efficient fiber portion the chromatic value in the band becomes zero. The wavelength value brining the chromatic dispersion to zero is included between 1500 and 1520 nm. Preferably, the predetermined transmission speed is higher than or equal to 2.5 Gbit/s.

In particular, the optical fiber has a chromatic dispersion lower than 3 ps/(nm.km) in the transmission band, which becomes zero for a wavelength lower by at least 10 nm than the minimum wavelength value of the band. Preferably, the predetermined transmission wavelength band ranges from 1530 to 1560 nm.

In material dispersion for silica, at wavelength 1550 nm, with dispersion obtained is 22 ps/km-nm. Whereas in waveguide dispersion process for the same wavelength in silica the dispersion obtained is 22 ps/km-nm. In general it has been observed that the dispersion is optical fiber is equal to 1.6dB for distance of 11 km. In the second aspect the dispersion is 0.8 db/km ,where the wavelength of the source is 10^{-6}m at a temperature of 140^0 K. In another aspect the dispersion is 0.5 dB/km when the wavelength is equal to 1.3μm in the stimulated Raman Scattering process where as in the silica silica glass and germanium doped silica glass the dispersion 0.1dB/km when the wavelength of the source is 1.2 μm.

The transmission fiber of 50 km length is either DSF with dispersion d=1 ps/km/nm, dispersion slope d”=0.06 ps/nm$_2$/km, loss α=0.21 dB/km, and effective area A_{eff} =55 μm^2, or SMF with d=17 ps/km/nm, d”=0.06 ps/nm^2/km, α=0.21 dB/km, and A_{eff}=26 ps/nm/km, d”=-0.2 ps/nm^2/km, α=0.5 dB/km, and A_{eff} = 26 μm^2. The length of DCF is adjusted to provide residual dispersion around zero. As nonlinear fiber, we considered the HNF with d=1.8 ps/nm/km, d”=0.03 ps/nm^2/km, α=0.5 dB/km, and nonlinear coefficient $n_2/A_{eff}=2x10^{-9}W^{-1}$. The erbium-doped fiber amplifier (EDFA) with a nose figure of 6 dB is installed after the DCF for both systems.

We first apply stability analysis to the DM line with a weak map strength operating at 10 Gb/s and 40 Gb/s in order to validate the accuracy of the stability analysis for different transmission regimes. Here, the DSF is used as a transmission fiber; the average dispersion is 0.05 ps/nm/km, and the pulse energy is 0.15 pj.

First numerical results demonstrating 40-GB/s transmission over 20000 km of SMF using modified modulation technique have been reported in 6H8. However, comprehensive investigation of the stable regimes in multidimensional parameter space is limited by the computational time required for a single optimization run. New effective approaches are then highly desirable for further system optimization. The combined action of the filters, modulators.

Figure 1-.2 shows the 10GHz sinusoidal input signal at 21 dBm average power evolving into the compressed pulse train with 1.76ps full width at half maximum (FWHM) pulse. The first DDF has the total length of 13.6km and linearly decreasing dispersion profile, from 10ps/nm/km at the input to 3.2ps/nm/km at the output. Note that the length of the first DDF is much shorter than that of a DDF required in Mamshev’s analysis, where the sinusoidal input evolves into a fundamental soliton.

VI. Conclusion

An analytic theory describing the equal for nearly equal spacing of pulses in harmonic passively mode-locked depletion of the gain across the soliton pulse causes a group-velocity drift proportional to the spacing between pulses. An analytic model capturing the effect of the time dependant gain on the pulses by including a phenomenological perturbation to the nonlinear Schrodinger equation have been developed.

.The system model of the proposed idea and the pulse shapes at each stage are illustrated for the precise analysis of pulse propagation, the nonlinear Schrodinger equation [NSE] was solved numerically using variation approach. It has been shown that the soliton in fiber links employing compensating fiber with variable dispersion suggesting the possibility of an optimal dispersion compensating profile for soliton transmission in a periodically amplified system. Here it is proposed to find an optimal dispersion based on the variational approach for the solution of the non-schrodinger equation (NSE) by using simple system criterion.

In this work it is concluded that dispersion in optical fiber is 0.21dB/km for an effective area of d=1ps/km/nm and as the length of DCF is adjusted to reduced dispersion around zero. In nonlinear fiber the dispersion can be reduced to 0.5db/km by adjusting the length of DCF. From these results it is further stated that, for this type of propagation, the amplitude of the envelope of the slow variation function is constant, the soliton frequency is constant the phase varies linearly with propagation distance.

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