

Soliton Based Optical Fiber Communication



PHYSICS

KEYWORDS : soliton, self phase modulation and group velocity dispersion.

Dr.Brijesh.N.chawda

Professor, Department of Humanities and sciences, Jayaprakash Narayan college of Engg, Mahaboobnagar, Telangana, India.

ABSTRACT

To overcome the various disadvantages in fiber optic system which uses laser and glass material one can use optical solitons pulses which can preserve their shape by balancing the mechanism called self phase modulation (SPM) resulting from the Kerr non-linearity and pulse broadening effect of GVD (Group velocity dispersion). This is important, because to any pulse travelling through a fiber is affected by both the Kerr nonlinearity effect and group velocity dispersion effect.

1.1.1: INTRODUCTION:

Solitons are very narrow laser pulses of pulse width 10 14 second with high peak powers more than 100 mW. Solitons are mainly used to increase the bit rate or transmission capacity of the fiber by reducing the losses and dispersion effects. Soliton propagation means the propagation of laser pulses through the optical fiber without undergoing any loss or dispersion. That is the pulses are transmitted without change in their shape as they travel down the fiber [2].

Today soliton fiber lasers are available. Soliton type propagation is achieved by the nonlinear property of the silica fiber when the intensity of the light pulses is more than 15 mW. In the case of single mode silica fiber, when the power level of optical pulses is more than 15 mW, then its refractive index is dependent on intensity such that

$$n = n_0 + n_2 I$$

If the effective area of the fiber mode is about 50 mm² and the power of the optical pulse is about 100 milliwatt, then $n_2 = 6.4 \times 10^{-11}$ for silica fiber. So inside the optical fiber, the high intensity portion of the pulse will propagate in a high refractive region of the fiber compared with the lower intensity portion of the pulse. This intensity dependent refractive index leads to a phenomenon called self phase modulation (SPM). Due to this phenomenon the distance traveled by the optical pulse inside the fiber is continuously increased due to lower speed of the high intensity portion of the pulse[3]. Thus there is a generation of additional frequencies and hence the broadening of the spectrum of the pulse while keeping the temporal shape unaltered. Further SPM leads to a chirping of the pulse with lower frequencies in the leading edge and high frequencies in the trailing edge of the pulse. So one can conclude that even though the distance traveled by the high intensity optical pulse is greater than the distance traveled by the low intensity optical pulse inside the fiber having negative nonlinearity, the optical pulse travels down the fiber without any dispersion.

When the operating wavelength is about 1.3 mm there is zero dispersion. But when the operating wavelength is greater than 1.3 mm, then the fiber has positive group velocity dispersion. So the low frequency components of the pulse will travel at a lower speed than the high frequency components of the pulse. But in the case of self phase modulation, we get the opposite effect. That is due to SPM the low frequency components of the pulse will travel faster than the high frequency components. Thus the broadening of the spectrum by SPM is properly compensated by the compressions of the spectrum by group velocity spectrum, and then the pulse will propagate without change in the temperate shape and without broadening of the spectrum of the pulse. Even though there is no dispersion effect, still there is some loss in the fiber due to scattering and absorptions. To compensate this small loss in the transmissions link, for every 100 km or 150

km length, an optical fiber laser amplifier of length 10 m is connected. Due to sufficient amplification at the receiver end one can get the signal without loss of power. Thus during the propagation of the optical pulse through the fiber, there is no change in pulse shape and height and width. Such propagation is called soliton propagation.

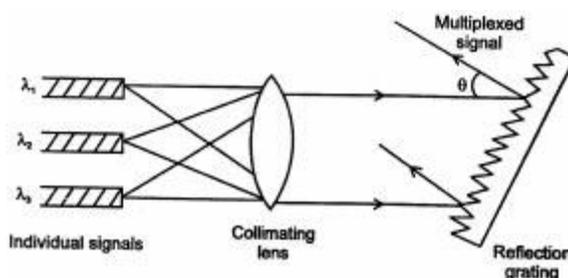


Figure 10. Grating multiplexer.

1.1.2: Soliton laser

Soliton laser is an optical source used to deliver soliton pulses. Since this laser is in the form of number 8, it is also called figure 8 laser (figure 11). It consists of an output fiber loop and nonlinear fiber loop amplifier which are connected by a 50 : 50 coupler. The wavelength division multiplexer which is a T-coupler passes the light from the optical pumping source at a wavelength of 0.98 mm into the nonlinear fiber loop amplifier which is a mode locked single mode fiber laser[1]. The fiber laser is doped with erbium impurity and acts as an optical amplifier. The 50 : 50 coupler is a directional coupler as well as a four-port coupler. This connects the signal at 1.535 mm from the output fiber loop to the nonlinear fiber loop amplifier as well as the amplified signal from the non linear fiber loop amplifier to the output fiber loop. Through the 20 : 80 coupler, the output soliton pulses of 1.535 mm can be obtained. The purpose of the optical isolator in the output fiber loop is to propagate the light in one direction in the output fiber loop. Polarization controllers in both fiber loops are used to maintain the same phase shifts during the propagation of light through the loops[4]. The phase shift between the signal coupled into the non linear fiber loop amplifier and the amplified light in that loop is always an integral multiple of 0 or 2π .

2.1.1: RESULT AND DISCUSSION

Actually, there are many modes with different frequencies, generated in the erbium doped fiber by the spontaneous emission[6]. But whenever the generated frequency is different from the signal frequency then the time taken by that light (noise) to go around the loop once is different from $2\pi r/n$ where r is the radius of the loop, n is the refractive index

C

of core of the fiber loop and C is the velocity of light in air or vacuum. Hence its amplitude gradually decreases due to destructive overlap. After few circulations, these noises are completely suppressed. For the signal, the time taken to go around the loop once is exactly $2\pi r/n$ so that its amplitude gradually increases due to constructive overlap. After few

C

circulations, the amplitude of the signal is increased to a greater extent so that the output light has high power, more than 100 milliwatt, and high coherence[5].

Further, there is self phase modulation in the nonlinear fiber loop so that the output pulses from the soliton laser cannot undergo any dispersion. Thus the pulses coming out from the soliton laser are behaving as solitary waves having no dispersion and no loss during their transmission through optical fibers.

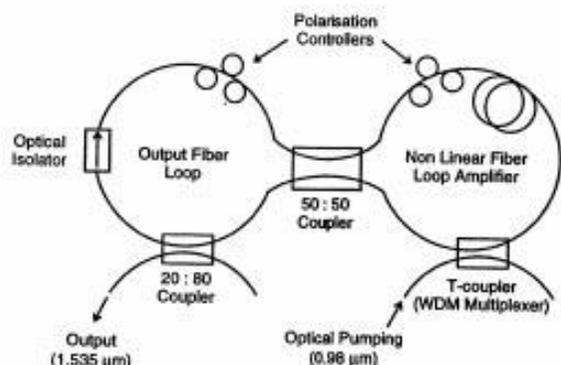


Figure 1. 8- laser.

6. Conclusion

At present there are many optical fiber communication links throughout the world without using optical solitons. When we introduce optical solitons as light pulses through the fibers, we can achieve high quality telecommunication at a lower cost. We can expect a great revolution in optical fiber communication within a few years by means of solitons. Solitons pulses which can preserve their shape by balancing the mechanism called self phase modulation (SPM) and Group velocity dispersion (GVD).

Acknowledgments: I'm grateful to the chairman Shri K.S Ravi Kumar, Sri V. Venkata Rama Rao Garu, Secretary and principal of JPNCE institution for all the possible support extended to my work.

REFERENCE

- 1) Agrawal G.P. (1997) "Fiber Optic Communication Systems", 2nd edition, Wiley, New York. | 2) Biswas A and S. Konar (2005) "Soliton-solitons interaction with Kerr law non-linearity," Journal of Electromagnetic Waves and Applications, Vol. 19, No. 11, 1443–1453. | 3) Biswas A et al (2006) "Soliton-soliton interaction with parabolic law nonlinearity," Journal of Electromagnetic Waves and Applications, Vol. 20, No. 7, 927–939. | 4) Hasegawa A and Y. Kodama (1995) "Soliton in Optical Communication", Clarendon Press, Oxford. | 5) Haus H and W. S. Wong (1996) "Soliton in optical communications," Rev. Mod. Phys., Vol. 68, 432–444. | 6) Haus H. A. (1993) "Optical fiber solitons: Their properties & uses", Proc. IEEE, Vol. 81, 970–983. |