THE SOLITON TRANSMISSION IN OPTICAL FIBRES

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ABSTRACT

The objective of this paper is to familiarize readers with the basic analytical propagation model in optical fibres. It is the propagation model of short optical pulse in optical fibre, and that special type of pulse is known as soliton. A soliton transmission is a very efficient and attractive type of transmission in the fibre optics telecommunication system as it does not change the pulse shape during propagation through fibre link to the receiver. It basically travels down the fibre several thousands of Km without any change or without any dispersion when the loss in the system is taken care ,it delicately balances the nonlinear and linear effects in the medium during transmission .This model of very short pulse propagation is based on the numerical solution of the nonlinear Schrodinger equation (NLSE) ,although in possible cases it can be analytically proven .

KEYWORDS: *SOLITON, PULSE, NLSE, DISPERSION….*

1. INTRODUCTION

What is a optical fibre?

Fibre-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fibre. The light forms an electromagnetic carrier wave that is modulated to carry information. Fibre is preferred over electrical cabling when high bandwidth, long distance, or immunity to electromagnetic interference are required. Optical fibre is used by many telecommunications companies to transmit telephone signals, Internet communication, and cable television signals. Optical fibres are made of extremely pure optical glass. We think of a glass window as transparent, but the thicker the glass gets, the less transparent it becomes due to impurities in the glass. However, the glass in an optical fibre has far fewer impurities than window-pane glass.

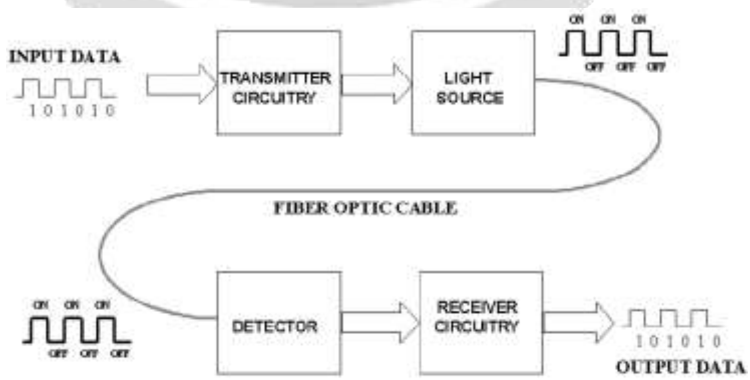


Fig 1 Block diagram of fibre optic cable

The communication using optical fibre involves some basic steps:

1) Firstly, transmitter creates the optical signal from an electrical signal.
2) Relay the signal through optic fibre.
3) Checking /ensuring so that signal does not get distorted, disturbed or becomes weak.
4) Receive the optical signal.
5) Finally converting the received signal into electrical signal.

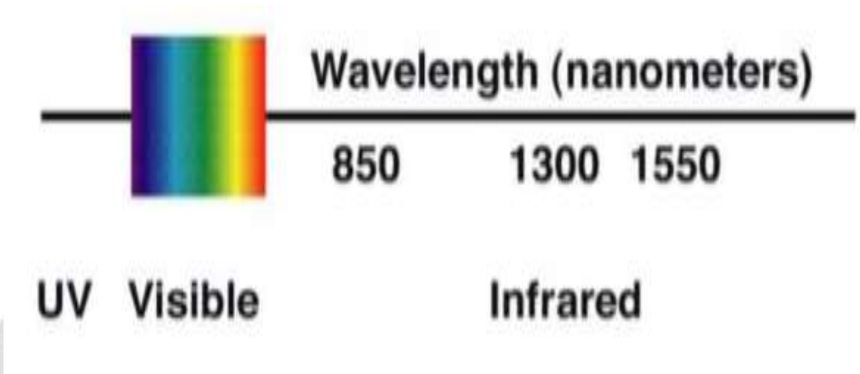


Fig.2: Light Used In Fibre Optics [1]

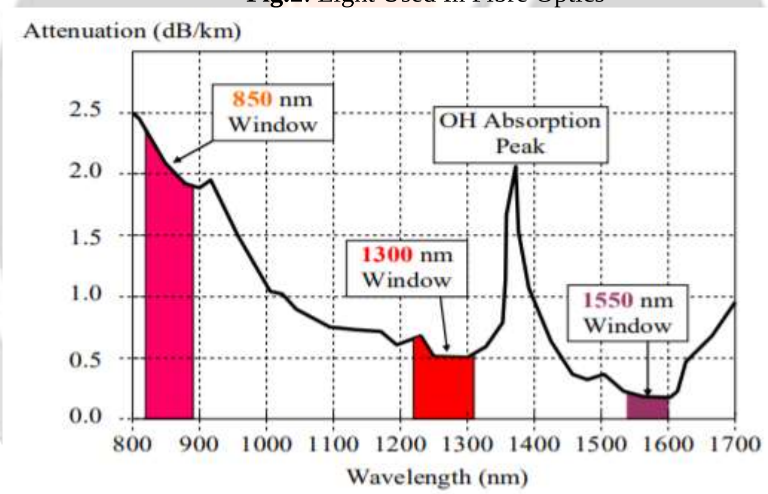


Fig.3: Optical fibre windows [1]

1.1 Advantages of optical fibre communication

1) As it has wider bandwidth more/larger information can be carried.
2) Transmission is possible over long distance with low attenuation (order of 0.2dh/Km).
3) In consideration of installation it is small size and less weight.
4) Compared to copper it is of low cost as it is made of glass which requires sand as raw material.
5) Due to dielectric medium, there no problem of electrical interference.

1.2 Disadvantages of optical fibre communication

1) Most delicate part is the OFC which is to be handled safely.
2) Repeated electrical -optical – electrical conversion is needed.

2.SOLITARY WAVES

Solitary waves also called as soliton sometimes, was a main topic for analysis over years both theoretically and experimentally .Historically ,the first person to observe soliton wave was James Scott Russel in 1834 he noticed the narrow water canal a smoothly shaped water heap was able to propagate in canal without any changes in the shape a few kilometre apparently.

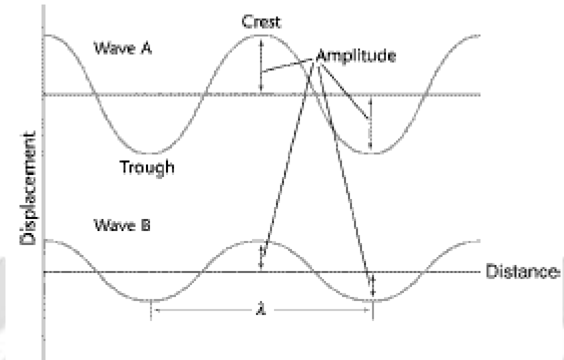


Fig 4: solitary waves

This concept of solitary wave was a big confusion over year, people did not understand this concept over a long time until a appropriate mathematical model was conceived in 1960's together with the way of solving nonlinear equation (inverse scattering method).

There are two types of soliton depending on light being confined with time or space:

1) Spatial soliton
2) Temporal soliton

The formation of soliton phenomenon comes from nonlinear properties of medium where a wave is propagating. In the case of spatial soliton the natural property of light to disperse in space is being proactively compensated by the nonlinearity of the medium in such a way that higher intensity part of an optical beam (typically in the centre of Gaussian beam) increase a value of refractive index of medium forming de facto a core of waveguide that is responsible to confine in reverse a dispersed light to the middle of the beam itself. This can be easily understood that if induced nonlinearity is very high beam gets focused towards this and if induced nonlinearity is less or none then beam gets spatially dispersed.

3.DISPERSION PHENOMENON

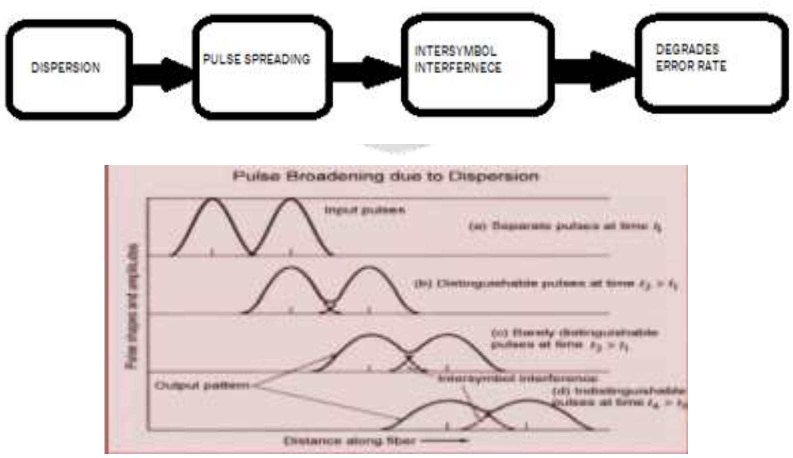


Fig 5: Dispersion effect in optical fibres

Dispersion is phenomena in which the wavelength depends on the velocity of propagation of electromagnetic wave. In telecommunication the term dispersion is used to describe the process electromagnetic wave carrying the signal and propagating in optical fibre is degraded as a result of dispersion phenomena. Degradation is caused radiation of different components having different frequencies propagate with different velocity

The types of dispersion:

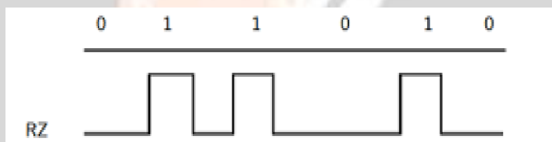
1) Modal dispersion
2) Chromatic dispersion
3) Wavelength dispersion
4) Material dispersion
5) Polarization dispersion

This dispersion phenomena is very difficult and problematic for long range communication. So solution to this problem is soliton based pulse transmission which helps in preserving their shape over long distance of several thousands of kilometre.

4. SOLITON BASED TRANSMISSION

The term soliton refers to special type of waves which travel over long distance without any disturbance or distortion in the signal and remain unaffected after collision with each other

There are various modulation formats for information transmits in fibres.



1) Here 1 represents one pulse and 0 represents zero pulse .in the above 1 pulse is designated to represent one pulse this format is called RZ (return to zero).

2) If the two pulse are connected to each other representing 1 in a sequence, then this format is called NRZ (not return to zero).
3) If 1 pulse is represented by two types pulse wave with opposite phase, then it is called duo binary.

5 MATHEMATICAL MODELLING OF SOLITARY WAVE

The propagation of light wave can be described mathematically using Maxwell equations. When equations for magnetic and electric fields are combined, we get [1][2]:

$$\nabla^2 \bar{\bar{E}} - \frac{1}{c^2}\frac{\partial^2 \bar{E}}{\partial t^2} = 1/\varepsilon c^2 \frac{\partial^2 P}{\partial t^2} \quad (1)$$

Where, c=speed of light

ε0=vacuum permittivity

Induced Polarization consists of two parts ε

$\overline{P}(\overline{r},t) = \overline{P}_L(\overline{r},t) + \overline{P}_{NL}(\overline{r},t)$ (2)

the linear part …and nonlinear part …are related to the electric filed by the general relations [1][2] [3][4]

$$\bar{P}L(\bar{r},t) = 1/\varepsilon \int_{-\infty}^{\infty} X^1(t-t').\bar{E}(\bar{r},t')dt' \quad (3)$$

$$\bar{P}L(\bar{r},t) = \varepsilon \iiint_{-\infty} X^3(t-t1,t-t2,t-t3)\ X\ \bar{E}(\bar{r},t1)\ \bar{E}(\bar{r},t2)\bar{E}(\bar{r},t3) \quad (4)$$

6 PROPAGATION OF SOLITON PULSE IN OPTICAL FIBRES

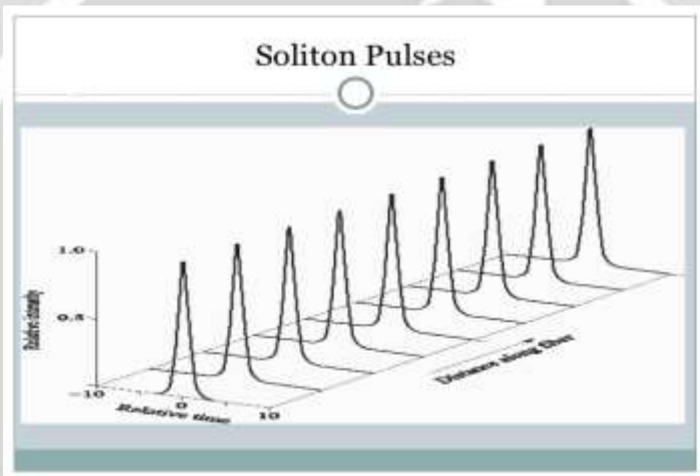


Fig 6 : soliton pulse

To better understand the process of propagation of soliton pulse it is necessary to setup a mathematical modelling expression (1) solution for electric filed E have a form [1]:

$E(r,t) = A(Z,t)F(X,Y)\exp(i\beta Z)$

where F(X,Y) is transverse field distribution of single mode fibre.

A(Z,t) is along propagation axis Z and

T=time.

The equation that governs pulse propagation in optical fibres [1]:

$$\frac{\partial A}{\partial z} + \beta_1 \frac{\partial A}{\partial t} + \frac{i\beta_2}{2}\frac{\partial^2 A}{\partial t^2} = i\gamma|A|^2 A \quad [1]$$

The parameters β1 a β2 include the effect of dispersion to first and second orders, respectively.

β1=1/vg, vg is group velocity associated with the pulse and β2 is called the group velocity dispersion (GVD) parameter.

The relation between D (ps/nm/km) and β2 is

$$D = \frac{d}{d\lambda}\left(\frac{1}{v_g}\right) = \frac{-2\pi c}{\lambda^2}\boldsymbol{\beta_2}$$

As we know, dispersion parameter D is a monotonically increasing function of wavelength, crossing a zero point at wavelength λZD, which is called a zero chromatic dispersion wavelength.

Soliton propagates without changing its shape but also it is a lack of energy in a continuous time beam. For the short time intensity will be constant during which it jumps to zero back again, thus generating a 'dark pulse'. So, solitons can actually be generated with dark short pulse in much longer standard pulses as these pulses have shown more stability and less losses. But these dark short pulses are very difficult to handle.

6.1 ADVANTAGES OF SOLITON TRANSMISSION IN OPTICAL FIBRE

1) Quality of 'soliton wave' is more efficient as it does not breakup, spread out or become weak over long distance.
2) Dispersion are reduced
3) Speed of transmission over long distance can be increased.
4) Makes the way for ultrahigh speed highways.
5) Cost efficient.

6.2 DISADVANTAGES OF SOLITON TRANSMISSION IN OPTICAL FIBRE

1) The main issue is the proper maintenance of power.
2) OFC is very delicate so it must be handled with care.

7. PROGRESS IN SOLITON TRANSMISSION IN OPTICAL FIBRES

Recent progress in fibre dispersion management technologies to enhance the transmission rate of soliton-based wavelength division multiplexing (WDM) and time division multiplexing (TDM). WDM is a technology which multiplexes the number of optical carrier signal onto a single optical fibre by using different wavelength parallelly TDM is a technology which transmits and receive the independent signals over a common signal path by means of synchronised switches at each end as a line so that signal appears on the line only a fraction of time in alternating pattern. In this type of soliton transmission dispersion management plays an important role in increasing the power margin and dispersion tolerance. With small dispersion swing also system can be called as average soliton suing nonlinear equation but for the large dispersion swing the soliton steady state pulse becomes a chirped gaussian pulse .We describe an inline modulation scheme up to 80Gbit/s per channel and its 2 channel WDM transmission over 10000Km.

8 .APPLICATION OF SOLITON TRANSMISSION

1) **SOLITON AMPLIFIERS**
   There is fibre loss which occurs due to loss of energy which is observed by the fibre as the pulse wave propagates through a fibre. Such losses cause broadening on solitons. These losses are compensated using amplification.
   There are two types of amplification
   a) Lumped amplification
      In this method after propagation of soliton through a certain distance the amplifiers boost the soliton energy to input level
   b) Distributed amplification
      - Stimulated Raman scattering

- Erbium doped fibres

2) PULSE COMPRESSION

Pulse compression is a process in which optical pulse gets compressed. dispersive and nonlinear effects in optical fibre helps in producing pulses less than 5fs.

There are 2 types of pulse compressor:

- Soliton effect compressor
- Grating fibre

3) SOLITON BIT RATE

Most of the commercial wavelength division multiplier (WDM) systems replace the traditional nonzero (NRZ) and return to zero (ZR) modulation.

The WDM system enhances the power as much as possible without nonlinearity

4) TIMING JITTER

Each soliton a carry a bit of information which ae separated with each other, this separation is only possible when soliton pulse width becomes much shorter than bit rates. Soliton jitter as the result of amplified noise which is responsible for bit rate error. This error can be compensated by reducing dispersion close to zero

9.CONCLUSION

Soliton transmission in optical fibre played a very important and useful role in communication system, soliton based optical communication is very useful communication for long distance transmission without any attenuation and very high information carrying capacity. In this paper a very basic analysis of soliton transmission is explained. However, the application of soliton transmission is not entirely without problems, the application of optical solitons is getting technological advancement. We do hope that further research in this field can yield the future of optical transmission in furthermore amazing and advance Technologies.

10. ACKNOWLEDGEMENT

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[6] Vol. 3, Issue 2, February 2014 Copyright to IJAREEIE www.ijareeie.com 7100 Soliton Transmission in Fiber Optics for Long Distance Communication Mehul G.Patel1 , S. B. Khant2 PG Student [SP&C], Dept. of ECE, A.D.Patel Institute of Technology,V.U.Nagar,Gujarat, India1 Assistant professor, Dept. of ECE, A.D.Patel Institute of Technology, V.U.Nagar,Gujarat, India2

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