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Measurement of Material Dispersion for 850nm wavelength using FiberSim Simulator

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Abstract*—Dispersion in the optical fibre is critical issue in case of optical fibre communication. Dispersion is broadening of the pulse which affect the inter symbol interference of the pulse. This ISI effect limits the length of fibre, data rate of transmission and strength of the signal in optical fibre. Basically there are three types of dispersions material dispersion, waveguide dispersion and polarisation mode dispersion. Dispersion depends on types of optical source, spectral width of the optical source and type of fibre. Study of measurement and compensation of dispersion is very necessary to improve the quality of optical communication. In this paper study of dispersion is completed. We have been measured material dispersion for 850nm wavelength signal of Light Emitting Diode (LED) source. We have taken 20nm width of the pulse and measured dispersion at different distances. Results show that the data rate and broadening of the pulse at various length of optical fibre.

Keywords— *Dispersion, Inter symbol Interference, Material Dispersion, Optical communication*

Introduction

The high bandwidth of today's communication increases exponentially every year. For high speed communications, we can optical communication which supports terabits bandwidth and high data rate transmission. As the ultimatum of bandwidth rises, the spacing between successive pulses and ISI effect of the pulse should be minimum. Any signal in optical contain more number of frequencies or wavelength,. As we know these different components travels with different speed in optical channel and they arrives at different time at the receiver. Due to delay between these different components pulse broadening occurs which is called dispersion[1]. Dispersion depends on the source type, spectral width of the source, material utilized in optical etc. Dispersion is very important parameter which degrades quality of optical communication system. LASER optical source having the narrow spectral width compared to the LED so it create less dispersion compared to LED source. In multi-mode fiber effect of dispersion is more compared to single mode fibre. Different mode having different velocity of pulse in multimode fibre so delay occurs on output and dispersion occurs which is called intermodal dispersion. Intermodal dispersion occurs only in multimode fibre. In single mode fibre dispersion occurs because of material or reflective index of material which is called material dispersion [2]. In this paper we have studied material dispersion and measured it at 850nm wavelength signal by using Fibre Sim simulator.. As a pulse of light proceeds through the fibre, it widens in the time domain. This spreading is caused by dispersion. To improve the optical communication we should study some dispersion compensation techniques [3].

I. Material Dispersion

Material dispersion is produced by the speed of light existence a utility of wavelength. If the wavelength of the signal is higher, the signal arrives faster than the lower wavelength optical signal so that pulse is broadened. This happens in same material fibre this is called material dispersion. This broadening of the pulse is expressed by following equations [4]

$$T = \frac{L}{V_g} \qquad (1)$$

Where V_g is the group velocity of fiber given by,

$$V_g = 1/(\frac{d\beta}{d\omega}) \qquad (2)$$

We then have, $$T = L\frac{d\beta}{d\lambda}\frac{d\lambda}{d\omega} \quad (3)$$

On further approximation will give,

$$T = L\frac{d\beta}{d\omega}(-\frac{\lambda}{\omega}) = -L\frac{\lambda}{2\pi c}^{2}\frac{d\beta}{d\lambda} \quad (4)$$

We know that,

$$\beta = 2\pi n(\lambda)/\lambda \quad (5)$$

So, $$T = -L\frac{\lambda}{2\pi c}^{2}\frac{d\beta}{d\lambda} \quad (6)$$

$$T = -L\frac{\lambda}{2\pi c}^{2}\left[\frac{2\pi n}{\lambda^2} + \frac{2\pi n'}{\lambda}\right] \quad (7)$$

The pulse dispersion ΔT due to a source line width of $\Delta\lambda$ is

$$\frac{\Delta T}{\Delta\lambda} = \frac{dT}{d\lambda} = \frac{L}{C}\left[\frac{dn(\lambda)}{d\lambda} - \lambda\frac{d^2n}{d\lambda^2} - \frac{dn}{d\lambda}\right] = -\frac{L\lambda}{C}\frac{d^2n}{d\lambda^2} \quad (8)$$

Multiplying by $\Delta\lambda$, we find the desired expression for the material dispersion

$$\Delta T = -\frac{L\lambda\Delta\lambda}{C}\frac{d^2n}{d\lambda^2} = \frac{L\Delta\lambda}{C\lambda}\left(\lambda^2\frac{d^2n}{d\lambda^2}\right) \quad (9)$$

$$\Delta T = -\frac{L}{c}\frac{\Delta\lambda}{\lambda}\left(\lambda^2\frac{d^2n_1}{d\lambda^2}\right) \quad (10)$$

This is the final expression of the pulse spreading due to material dispersion. Where $\Delta\lambda$ the spectral width of the source is, λ is the nominal wavelength of the source, and $\frac{d^2n_1}{d\lambda^2}$ is the second derivative of the core index of refraction with respect to wavelength[5].

FiberSim Simulator

Material dispersion is caused by the velocity of light (or, equivalently, the index of refraction) being a function of wavelength. In single-mode fibres operating at shorter wavelengths (i.e., 800-900 nm), this will be the dominant source of dispersion. All sources of light have some degree of spectral width to their output. A laser source has a considerably narrower spectral width than an LED[6]. This nonzero spectral width implies that, even with single-mode propagation, the longer wavelengths with their faster velocities will arrive at the receiver before the shorter wavelengths, thereby stretching the pulse.

FiberSim simulator allows us to analyse how a pulse becomes distorted while traveling through a medium. It is a very easy to use simulator which gives you not only the amount of pulse broadening but also the complete detail of all the concern parameters with pulse shapes at every point in the fibre. The view of the simulator is look like as shown in figure 5.1.The simulator consists of four variables which we can readily vary in order to completely understand the effect of material dispersion on the shape of the pulse as it propagates through the optical fibre. These are: input pulse width (in ns), spectral width of the source (in nm), and distance travelled by the pulse (in km), and wavelength of operation (in km). The four section of the simulator is explained as under in figure 1:

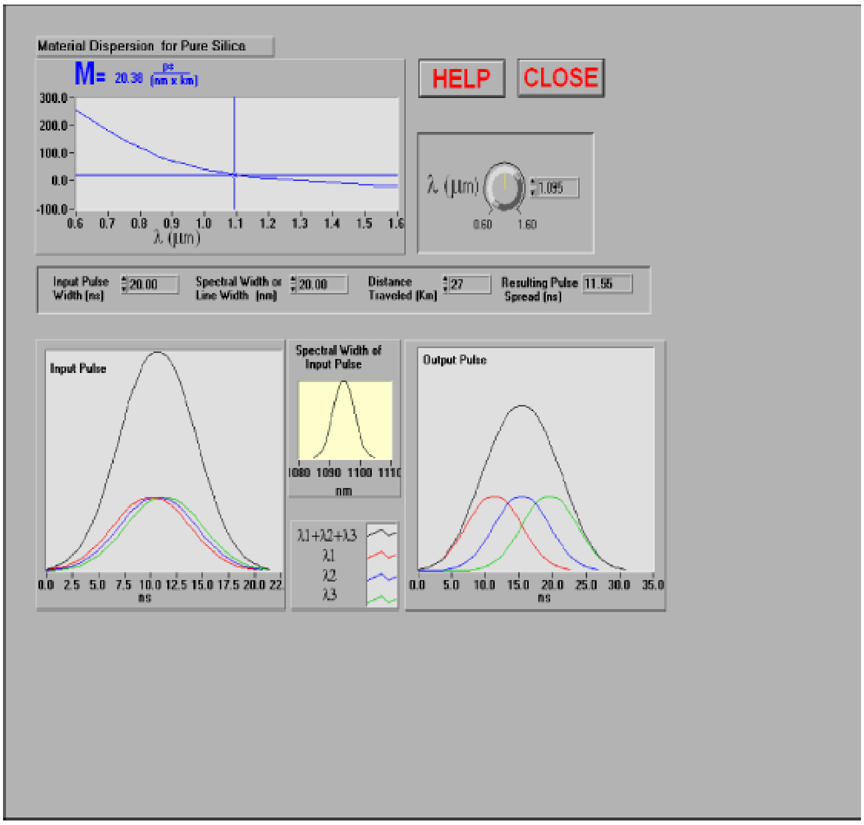


Fig1 FiberSim simulator desktop view

II. RESULTS AND DISCUSSION

As we know the material dispersion depends on wavelength [7]. We have measured material dispersion for wavelength 850nm for different distances and analysed the effect of dispersion on distance as well as data rate[8].

Initial parameters:

Input pulse width: 20 nm.

Spectral width: 0.1nm (Laser source).

Wavelength of operation: 850nm.

The result obtained after the simulation with the given initial parameter is shown in Table 1. Table consists of seven columns. Column II corresponds to the initial input pulse width, Column

III corresponds to the spectral width of the source (here it is 0.1nm for Laser) initial input pulse, Column

IV corresponds to the distance in kilometer a pulse travels through the silica fiber, Column V corresponds to the amount of pulse spread in the pulse with the distance at a given parameter of consideration, Column VI corresponds gives the maximum allowable bit rate for dispersion free transmission at corresponding pulse spread up to that distance. Column VII corresponds to the amount of distortion in the width of the received pulse.

Where,

Maximum allowable bit rate is calculated by formula:

$$T = \frac{1}{4T_p} \qquad (11)$$

Pulse width distortion PWD is calculated by formula:

$$PWD\% = \frac{(t_{out} - t_{in})}{t_{in}} \times 100 \qquad (12)$$

Theoretical value of material dispersion calculated by formula

$$\Delta T_{mat} = -\frac{L}{c}\frac{\Delta\lambda}{\lambda}(\lambda^2 \frac{d^2 n_1}{d\lambda^2})ps \qquad (13)$$

Or,

$$\frac{\Delta T_{mat}}{\Delta\lambda L} = -\frac{1}{\lambda c}\lambda^2 \frac{d^2 n_1}{d\lambda^2} ps.nm^{-1}.km^{-1} \qquad (14)$$

$$\lambda^2 \frac{d^2 n_1}{d\lambda^2} = 0.022 \qquad (15)$$

The calculated (theoretical) value of material dispersion found to be,

$$\Delta T_{mat}\text{(Theoritical)}=91.66\ \text{ps}\times\text{nm}^{-1}\times\text{km}^{-1}$$

While the simulated value of material dispersion is found to be,

$$T_{mat}\text{(Simulated)}=88.64\ \text{ps}\times\text{nm}^{-1}\times\text{km}^{-1}$$

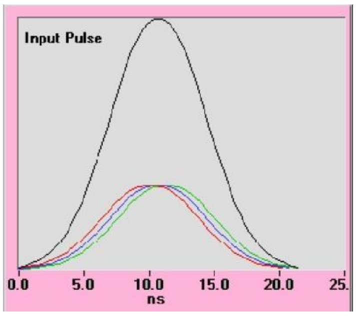
The theoretical and the simulated value of material dispersion found to be nearly equal, this

shows, we can use this simulator for the analysis of material dispersion. And the result obtained by the simulator will be near to what theoretically calculated results at wavelength 850*nm*

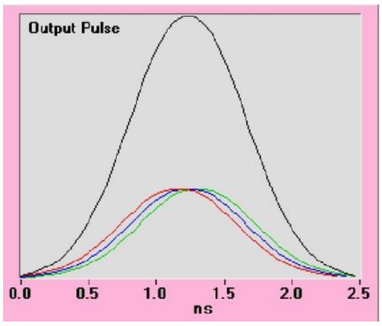
Table 1 shows the amount of pulse broadening due to material dispersion with the distance when operating at 850nm wavelength.

Table 1: Pulse spreading at a wavelength of 850nm

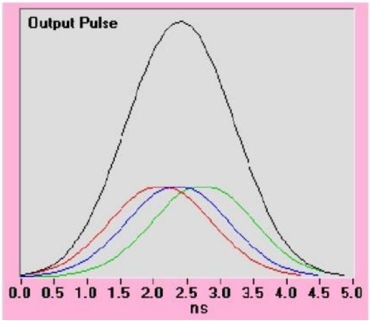
S. No	Input Pulse Width (t_{in})	Spectral width of source (Laser) ($\Delta\lambda$)	Distance traveled (L)	Pulse spread $t_P=(t_{out}-t_{in})$	Max. Allowable Bit rate (B)	Pulse width distortion $(t_{out}-t_{in})/t_{in}\times 100$
1	20 ns	0.1 nm	1 km	0.1ns	2500Mbps	0.50%
2	20 ns	0.1 nm	2 km	0.2 ns	1250Mbps	1.00 %
3	20 ns	0.1 nm	3 km	0.29 ns	860 Mbps	1.45 %
4	20 ns	0.1 nm	4 km	0.39 ns	640 Mbps	1.95 %
5	20 ns	0.1 nm	5 km	0.49 ns	510 Mbps	2.45 %
6	20 ns	0.1 nm	10 km	0.98 ns	250 Mbps	4.90 %
7	20 ns	0.1 nm	15 km	1.46 ns	170 Mbps	7.30 %
8	20 ns	0.1 nm	25 km	2.44 ns	100 Mbps	12.20%
9	20 ns	0.1 nm	50 km	4.88 ns	50 Mbps	24.40 %
10	20 ns	0.1 nm	75 km	7.31 ns	34 Mbps	36.55 %
11	20 ns	0.1 nm	100 km	9.75 ns	25 Mbps	48.75 %
12	20 ns	0.1 nm	125 km	12.19 ns	20 Mbps	60.95 %
13	20 ns	0.1 nm	130 km	12.68 ns	19 Mbps	63.40 %
14	20 ns	0.1 nm	140 km	13.65 ns	18 Mbps	68.25 %
15	20 ns	0.1 nm	150 km	14.63 ns	17 Mbps	73.15 %
16	20 ns	0.1 nm	175 km	17.06 ns	14 Mbps	85.30 %
17	20 ns	0.1 nm	200 km	19.50 ns	12 Mbps	97.50 %
18	20 ns	0.1 nm	225 km	21.94 ns	11 Mbps	109.70 %
19	20 ns	0.1 nm	250 km	24.38 ns	10 Mbps	121.90 %
20	20 ns	0.1 nm	300 km	29.25 ns	8 Mbps	146.25 %



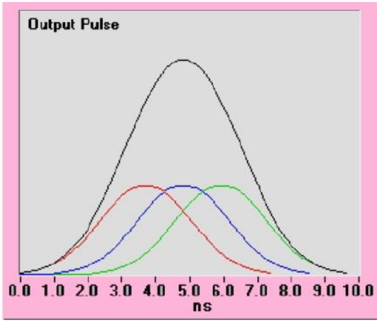
Input Pulse



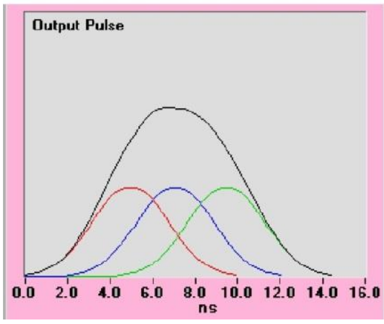
Pulse after 25km



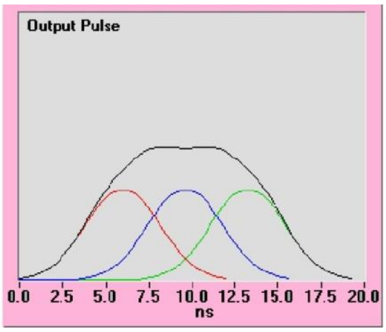
Pulse after 50km



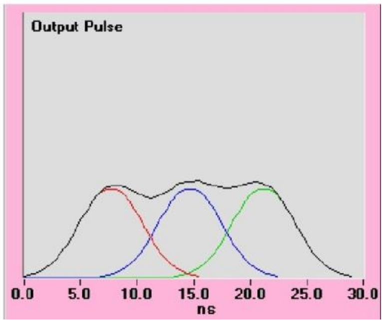
Pulse after 100km



Pulse after 150km



Pulse after 200km



Pulse after 300km

Fig 2. Input and output pulses at wavelength of 850nm

It is clear from the figure 2 that the shape of the pulse deteriorates with the distance. The graph between the pulse spread and distance is shown in figure 3. The pulse spread increases linearly with the distance. Initially the amount of spreading is more but after considerable distance, it begins to saturate down. Figure 4 shows that the graph between maximum allowable data rate with the distance a hyperbola. As the distance increases the data rate decreases

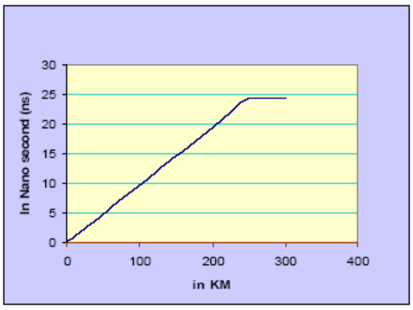


Fig 3 Pulse spread vs. distance graph at 850nm

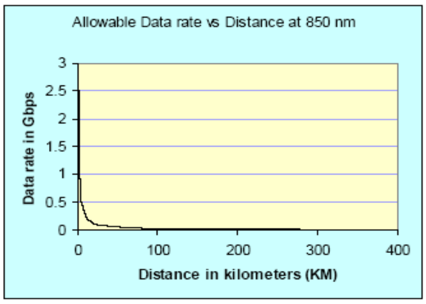


Fig 4 Data rate vs. distance graph at 850nm

III. CONCLUSIONS

We have analysed the material dispersion occurrence in optical fiber communication. In this paper we have successfully measured material dispersion by using FibreSim simulator. We have used 850nm wavelength for the required measurement. We can conclude that If we increase pulse travelling distance, the pulse broadening increases and pulse is distorted. We have also seen that data rate decreases with increasing of pulse dispersion. We can say that material dispersion limits the travelling distance and decrease the data rate of the pulse. Results show that dispersion decreases the performance of optical communication. In future we can develop some dispersion compensation techniques which minimize the effect of dispersion so we can improve the quality of optical communication.

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