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Dispersion Analysis in Single Mode and Multimode Fiber

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Abstract-

A cylindrical-shaped dielectric waveguide is what an optical fibre is. The core cladding interface confines electromagnetic energy in the form of light within its surface and directs light through a number of internal reflections if the angle of incidence is larger than the critical angle c. The dispersion of the transmitted optical signal causes distortion in both digital and analogue transmission across optical fibres. When optical fibre transmission is widely employed and some sort of digital modulation is applied, dispersion mechanisms inside the fibre cause the transmitted light pulses to broaden as they move along the channel.

Keywords- Dispersion; singlemode fiber; multimode fiber; light; optical fiber;

Introduction-

Dispersion is the process through which a light pulse spreads out over time as it moves down the fibre. Dispersion in optical fibre can take the forms of model dispersion, material dispersion, and waveguide dispersion. Material dispersion results from the refractive index of fibre optic materials changing with wavelength. Higher indexes cause light to move more slowly. Waveguide dispersion results from light being split between the waveguide's core and cladding. [6]

Similar to attenuation, dispersion shortens the distance a signal must travel through optical fibres. Dispersion, as opposed to attenuation, distorts the signal rather than making it weaker. For example, a pulse with duration of one nanosecond at the transmitter will have duration of 10 nanoseconds at the receiver. Signals are not properly received and decoded as a result. [6]

The waveguide dispersion is calculated using a simple curve fitting method. The dispersion analysis for single mode fibre is carried out by modifying the wavelength in respect to various types of dispersion, including material dispersion, waveguide dispersion, and total dispersion. [8,9]

1. Dispersion in optical Fiber-

The process by which an input signal broadens/spreads out as it propagates/travels down the fibre is referred to as optical fibre dispersion. Modal, chromatic, and polarisation mode dispersion are the typical types of dispersion in fibre optic cable.

In multimode fibres and other waveguides, a distortion mechanism known as modal dispersion causes the signal to be spread out in time as a result of the various modes' varying rates of propagation. As is common knowledge, light rays entering a fibre at various angles of incidence will follow various routes or modes. As shown below with a step-index multimode fibre, some of these light rays will travel directly through the fiber's centre (axial mode), while others will continually bounce off the cladding/core barrier and zigzag their way through the waveguide.

As far as we are aware, dispersion is a phenomenon that occurs when light travels from one medium to another. Light of different wavelengths will bend at various angles and cause dispersion. One common illustration is how a transparent prism would divide white light into a spectrum of colours, with red light bent at the lowest angle and blue light bent at the greatest angle. As a result, red light is at the top of the spectrum while blue light is at the bottom. We just use our secondary understanding of light dispersion to support our explanation [14]. To fully comprehend dispersion and how it applies to fibre optics, more research must be done. [10]

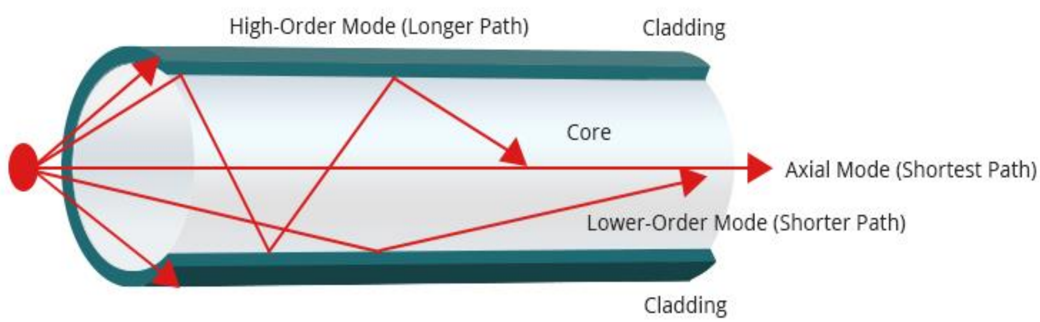

Figure 1- Modes of optical Fiber

Combining material and waveguide dispersion in a way that results in zero chromatic dispersion at a desired operating wavelength is a practical application of both (normally between 1530 and 1620 nm). Since material dispersion is typically unpleasant to change due to desirable inherent features of the chosen material for optical fibre, this can be accomplished by altering waveguide dispersion (most likely silica). The following figure illustrates how nonzero dispersion-shifted fiber's material, waveguide, and chromatic dispersion fluctuate with wavelength and exhibits zero chromatic dispersion at 1.5 micrometre wavelength.[1,2,7]

The wavelength dependence of the refractive index on the fibre core material is what leads to material dispersion. Waveguide dispersion happens as a result of the mode propagation constant's dependency on the signal wavelength, core radius, and difference in refractive indices between the fibre core and cladding. These two effects may cancel one another out at a specific frequency, producing a wavelength with nearly zero chromatic dispersion.

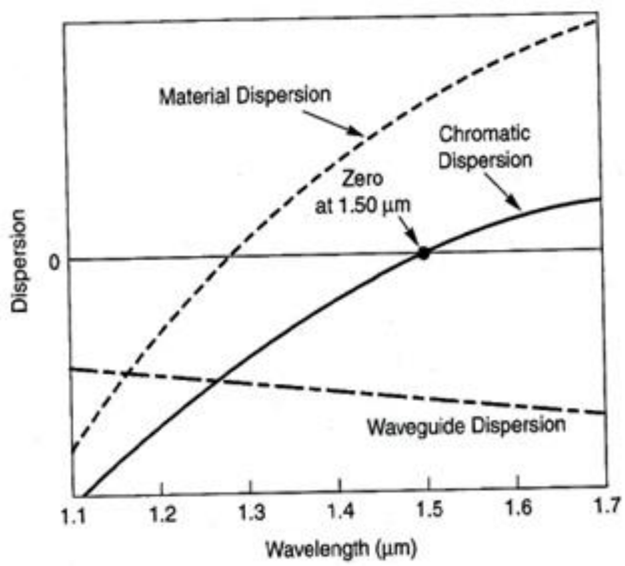

Figure 2- Combine waveguide and material dispersion.

The varying speeds of light rays cause a phenomena known as chromatic dispersion, which is the spreading of a signal across time. The effects of material and waveguide dispersion combine to create chromatic dispersion.

Additionally, chromatic dispersion need not always be a negative thing. When travelling through various materials or wavelengths, light moves at varying rates. It is feasible to tailor the index of refraction profile to create fibres for various uses by causing pulses to either spread out or compress as they travel along the fibre. For instance, this is how G.652 fibres are made.

2. Measurement Methodology-

Measurements of dispersion reveal how optical signals are distorted as they travel across optical fibres. The capacity of the fibre for conveying information is constrained by delay distortion, which, for instance, causes the spreading of transmitted light pulses. We implement the system using MATLAB , the optical fiber toolbox.

Functions for quick, automatic guided mode calculations in basic optical fibres are provided by the Optical Fibre Toolbox (OFT). Designed with tapered microfibres in mind (also known as nano-fibres). For both weak and strong guidance scenarios, exact answers are given. Dispersion of the material is considered.

The main feature is

- To locate the guided modes.
- Determine each mode's effective refractive index for the specified diameter and wavelength or in the presence of changeable diameter or wavelength (modal dispersion).
- Determine the modes' electric and magnetic fields (only two-layer modes).
- Locate phase-matching fibre spots for harmonic production.

By directly fitting the curve, the waveguide dispersion is calculated. By adjusting the wavelength in relation to various types of dispersion, such as material dispersion, waveguide dispersion, and total dispersion, one may analyse the dispersion of single-mode fibre.

3. Results-

Sr. No.	Wavelength in µm	Dispersion for single mode fiber in ps/nm.km		
		Material Dispersion	Waveguide Dispersion	Total Dispersion
1	1.2	- 3.5	- 2.68	- 6.2
2	1.25	- 1.15	- 3.35	- 4.5
3	1.3	1.2	- 4	- 2.8
4	1.35	3.82	- 4.6	- 0.76
5	1.4	6.3	- 5	1.27
6	1.45	9.37	- 5.4	4
7	1.5	12.3	- 5.62	6.68
8	1.55	15.6	- 5.7	9.9
9	1.6	19	- 5.8	13.16

Table 1- Dispersion characteristics in singlemode fiber

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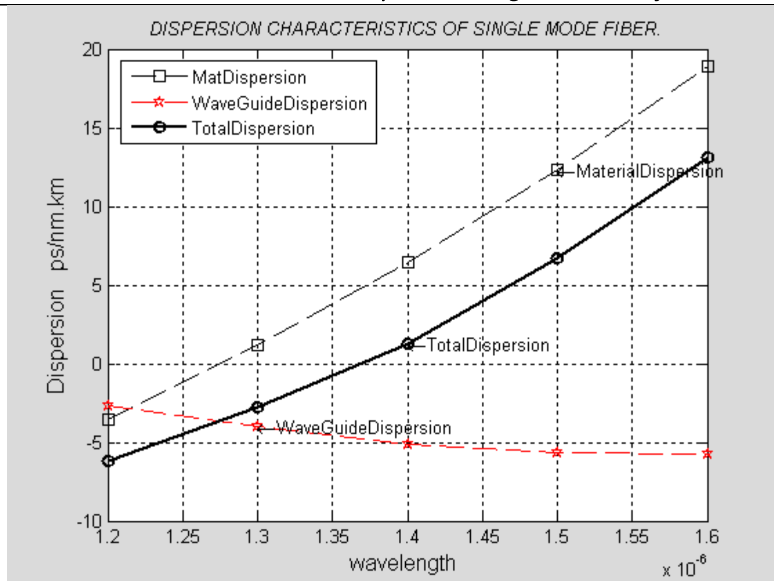

Figure 3 - Dispersion characteristics for singlemode fiber

Sr. No.	Wavelength in µm	Dispersion for multimode fiber in ps/nm.km Material Dispersion	Waveguide Dispersion	Total Dispersion
1	1.2	-3.5	0	-3.5
2	1.25	-1.15	0	-1.15
3	1.3	1.2	0	1.2
4	1.35	3.82	0	3.82
5	1.4	6.44	0	6.44
6	1.45	9.37	0	9.37
7	1.5	12.3	0	12.3
8	1.55	15.6	0	15.6
9	1.6	18.92	0	18.92

Table 1- Dispersion characteristics in Multimode fiber

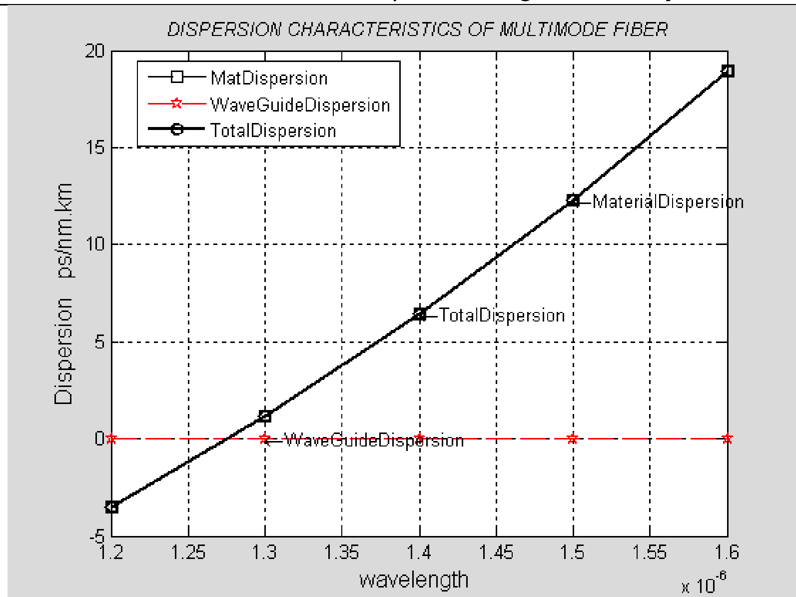

Figure 4- Dispersion characteristics for multimode fiber

Conclusion-

Waveguide dispersion in single mode fibre is not zero, as the aforementioned figures demonstrate. Waveguide dispersion in multimode fibre, however, is 0 percent. Total dispersion includes both material dispersion and waveguide dispersion. Furthermore, it can be demonstrated that there is no material dispersion at 1.27 mm. Between single mode and multimode optical fibres, there are differences in chromatic dispersion.

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