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# Effects of Dispersion in Optical Fiber Communication

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**Abstract: This paper gives an overview of dispersion and its effects in optical fiber communication systems. Dispersion is the spreading of light pulse as its travels down the length of an optical fiber. This paper presents a review on various types of dispersions in optical fiber communication system.**

***Keywords:, Dispersion, Optical fiber, Polarization Mode Dispersion (PMD), Scattering, Intarmodal, Intermodal.***

## I. INTRODUCTION

The data that is carried in an optical fiber consists of pulses of light energy following each other rapidly. There is a limit to the highest frequency, i.e. how many pulses per second which can be sent into a fiber and be expected to emerge at the other end? This is because of a phenomenon known as pulse spreading shown in Fig.1, which limits the "Bandwidth" of the fiber. The pulse sets off down the fiber with a nice square wave shape. As it travels along the fiber it gradually gets wider and the peak intensity decreases. The cause of pulse spreading is dispersion. This means that some components of the pulse of light travel at different rates along the fiber.

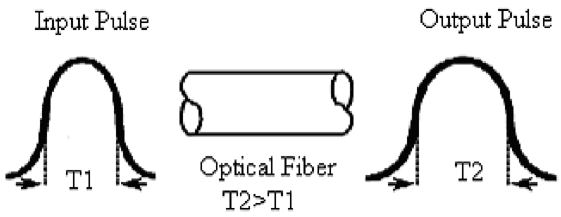


**Figure 1 Pulse Spreading in an Optical Fiber**

The is classified in to two types known as Intramodal and Intermodal dispersion

## II. INTRAMODAL/CHROMATIC DISPERSION

Chromatic dispersion is the pulse spreading that takes place within a single mode fiber. This spreading arises from the finite spectral emission width of an optical source There are two main causes of intramodal dispersion an these are material dispersion and waveguide dispersion. Material dispersion arises due to the variations of the refractive index of the core materials as a function of wave length. Material dispersion also referred to as chromatic dispersion, since this is the same effect by which a prism spreads out a spectrum as shown in Fig.2.

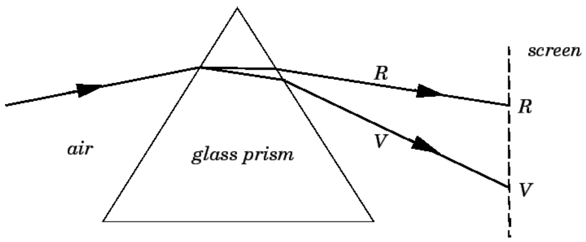


**Figure 2 Dispersion of Light through a Prism**

This refractive index property causes a wavelength dependence of the group velocity of given mode, that is pulse spreading occurs even when different wavelengths follow the same path .the wave guide dispersion causes pulse spreading because only part of the optical power propagation along a fiber is confined to the core. Dispersion arises because the fraction of light power propagating in the cladding travels faster than the light confined to the core, since the refractive index is lower in the cladding. Wave guide dispersion usually can be ignored in multimode fibers, but it's effect is significant in single-mode fibers.

## III. INTERMODAL DISPERSION/MODAL DISPERSION

In an optical fiber there is another type of dispersion called Intermodal dispersion which is also known as multimode dispersion. More oblique rays (lower order modes) travel a shorter distance. These correspond to rays traveling almost parallel to the centerline of the fiber and reach the end of fiber sooner. The more zig-zag rays (higher order modes) take a longer route as they pass along the fiber and so reach the end of the fiber later. For various reasons some components of a pulse of light traveling along an optical fiber move faster and other components move slower. So, a pulse which starts off as narrow burst of light gets wider because some components race ahead while other components lag behind, rather like the runners in a marathon race. Further the pulse travels in the fiber and worse the spreading gets. Pulse spreading limits the maximum frequency of signal which can be sent along a fiber. If signal pulses follow each other too fast then by the time they reach the end fiber they will have merged together and become indistinguishable as shown in Fig.3.

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This is unacceptable for digital systems, which depend on the precise sequence of pulses as a code for information. The Bandwidth is the highest number of pulses per second that can be carried by the fiber without loss of information due to pulse spreading.

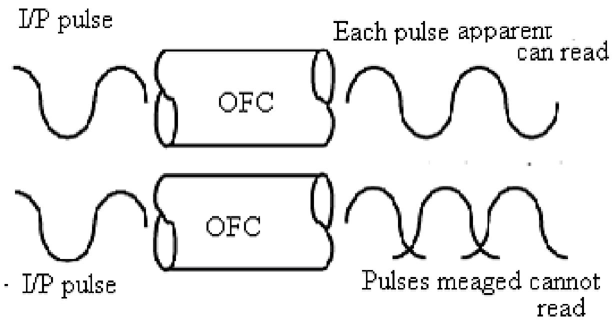


**Figure 3 Merging of pulses in fiber**

## IV. POLARIZATION MODE DISPERSION

Scientists and engineers for years have expressed the fear that as optical networking systems get faster and send signals to longer distances, major physics-related problems would become a limiting force. The technology for years had been given a free ride as it grew from 90 Mpbs to 270 Mbps to 435 Mbps to 2.5 Gbps. A problem began to manifest itself in 10 Gbps systems and threatens major dislocation at 40 Gbps networking. For the first time, the fiber-optics industry was faced with a networking killer. The problem, which itself was not even discovered until the early 1990s, is PMD. It can distort signals, render bits inaccurate, and destroy the integrity of a network. Approximately 20 percent to 30 percent of the single-mode fiber manufactured before the mid 1990s has a property that has become more problematic as bit rates and span lengths increase. Single-mode fibers support two perpendicular polarizations of the original transmitted signal. If a fiber were perfectly round and free from all stresses, both polarization modes would propagate at exactly the same speed, resulting in zero PMD.

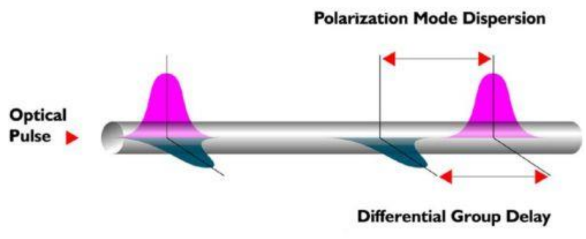


**Figure 4 Polarization mode dispersion**

However, practical fibers are not perfect; thus, the two perpendicular polarizations may travel at different speeds and, consequently, arrive at the end of the fiber at different times. Fig 4 illustrates this condition. The fiber is said to have a fast axis, and a slow excessive levels of PMD combined with laser chirp and chromatic dispersion, can produce time-varying composite second order (CSO) distortion in amplitude modulated video systems. This results in a picture that may show a rolling or intermittent diagonal line across the television Screen w-axis. The difference in arrival times, normalized with length, is known as PMD (ps/km0.5). For digital high bit rate transmission, this can lead to bit errors at the receiver or limit receiver sensitivity.

The major cause of PMD is the asymmetry of the fiber-optic strand. Asymmetry is simply the fact that the fiber core is slightly out-of-round, or oval as show Fig 5. Fiber asymmetry may be inherent in the fiber from the manufacturing process, or it may be a result of mechanical stress on the deployed fiber. The inherent asymmetries of the fiber are fairly constant over time, while the mechanical stress due to movement of the fiber can vary, resulting in a dynamic aspect to PMD. The mechanical stress on the optical fiber can originate from a variety of sources. One source that is very difficult to control is the diurnal (day/night) and seasonal heating and cooling of the optical fiber

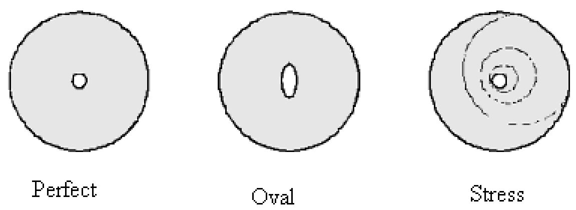


**Figure 5 Cross-Sections of optical fibers**

Although much fiber is deployed in the ground, subjected to temperature variation and mechanical stress. Another source of mechanical stress can originate from nearby sources of vibration. For example, much fiber is deployed alongside railroad tracks because of the ease of right-of-way and construction. However, vibration from passing trains can contribute to stress on the optical fiber. Fiber that is not buried next to railways and highways may be deployed aerially. In this scenario, wind can cause swaying of the fiber cable and can contribute to PMD. Because of the combination of these effects, and the random way these effects add up over a section of fiber, PMD does not have a single value for a given section of fiber. Rather, it is described in terms of average DGD (differential Group Delay), and a fiber has a distribution of DGD values over time. The probability of the DGD of a fiber section being a certain value at any particular time follows a Maxwell distribution given in Fig. 6. As an approximation, the maximum instantaneous DGD is about 3.2 times the average DGD of a fiber.

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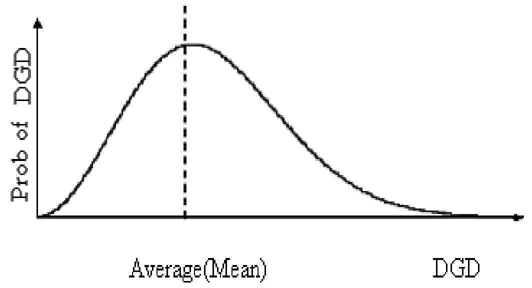


**Figure 6 Probability distortion of DGD levels in a typical fiber**

## V. NON LINEAR EFFECTS

An optical effect is called non linear if its parameter depends upon light intensity (power). Increasingly, people are talking about "nonlinear effects" and one may feel a little left out if he does not know what they are all about. In a linear system, the output is directly proportional to the input. As the input increases, the output grows to the same degree. Think of an unwanted guest. Each extra day of the visit will proportionally increase your irritation. The linear law is valid when optical power level inside the fiber are considerably low (<1mW).When any dielectric is exposed to light its response becomes non linear for intense electromagnetic fields. The nonlinear effects fall in two categories. One is the optical Kerr effect which is due to change in refractive index of with optical power and other is Scattering effect in the fiber medium due to interaction of the light with the molecules if silica medium.

## VI. CONCLUSION

Dispersion limits the bandwidth or information carrying capacity of a fiber. Linear characteristics are wavelength window, bandwidth, attenuation and dispersion. Non-linear characteristics depend on the fiber manufacturing, geometry etc. Dispersion can be avoided by using smaller core diameters which allows fewer modes. And also usage of single mode fiber permits no modal dispersion.

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