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Bandwidth Length and Dispersion Effect in Optical Networks

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Abstract - This paper discuss the influence of dispersion on the data rate and on optical power loss in transmission channel of free space optical communication link is presented. Compared to the other, previously published works, the paper review simulations based on very complex link model containing all important parts of an optical communication system. The another link model allows setting of the basic parameters of dispersion like bit duration , loss and dispersion parameters based on two mirror and beam splitter. For modeling the dispersion effect on the link performance the modified dispersion theory have been used. The paper discuss analysis of data rate and band width the propagation loss and dispersion. Communication link performances like data rate and length of fiber called bandwidth and length product has been reviewed.

Keywords—optical fiber ; power loss; dispersion; chromatic dispersion , propagation los

1.Introduction

A optical fiber is a flexible element of very clear and thin glass capable of carrying information bits in the form of light. Optical fibers are cylindrical and hair-thin structures manufactured by forming pre-forms cylindrical structure , which are like glass rods. Then optical fiber structure consists of core and cladding. The core is the heart of optical fiber in which light propagates. The core of optical fiber is made of silica glass , it is the light transmission area of the fiber. The outer layer of core is “cladding” which is the layer completely surrounding the core. An **optical fiber** can be a flexible, transparent fiber made of special glass (silica) or plastic. It is slightly thicker than a human hair. It is used as a waveguide, or it can be called “light pipe”, to transmit light along the two ends of the fiber. Light is guided by total internal reflection in the core of the optical fiber by total internal reflection

Optical fibers are widely used in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data rates) than wire cables. Fibers are used instead of metal wires because signals travel along them with less loss and are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces.

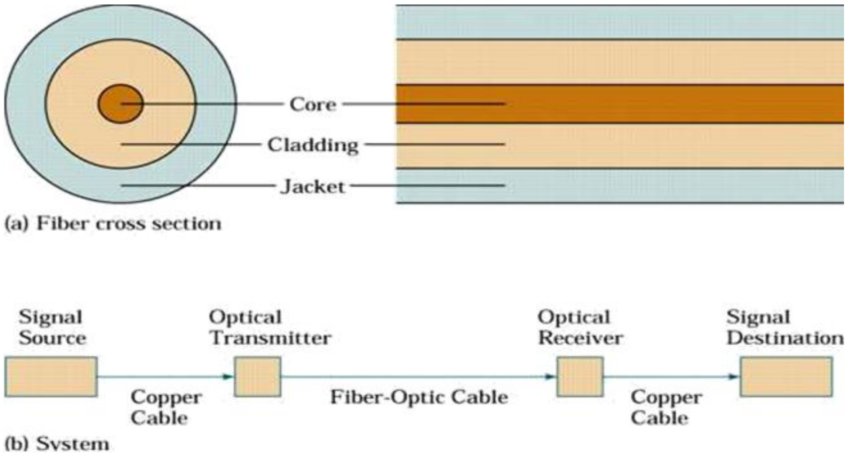


Figure1 a) Optical fiber Cross section b)Optical fiber Link

2. Literature Review on optical fiber Dispersion

The Nonlinear effects in optical propagation and dispersion in optical fibers have become an area of academic and industrial research and of great importance in the optical fiber based communication systems because it limits the link performance [4].. Presence of these nonlinear effects and soliton and dispersion in the optical fiber communication systems adversely affect the performance of communication between two receiving ends and data rate is affected .The effects of nonlinearity and dispersion can be considered separately but if are considered together, the situation changes. In some circumstances, the nonlinearity could counteract the dispersion [1] this is called dispersion shift.. There are several techniques for dispersion compensation, DCF is the most widely deployed dispersion compensator, as they are cascadable, commercially available and compatible with all optical network concepts [2].Inside each DCF span, the pulses of a longer wavelength channel travel faster than pulses of a shorter wavelength channel , whereas the opposite is the case inside each SMF span [3] .The condition for perfect dispersion compensation is that effective dispersion , for a pulse to regain its original shape, is given by $D_1L_1 + D_2L_2 = 0$, where D_1 and D_2 are dispersion coefficients of SMF and DCF, L1 and L2 are the corresponding length respectively. The effective dispersion is zero. For practical reasons, L2 should be as small as possible. [1,2,3,5]. The most dominant fiber nonlinear effect in a standard SMF is the self-phase modulation (SPM), the refractive index $n(\lambda)$ depends on the wavelength and velocity depends on $n(\lambda)$ which is caused by the nonlinear dependence of the refractive index on pulse intensity [6].Deepak Gupta etal reported that appropriately choosing the pulse profile and the pulse power, SPM and GVD can be made to exactly compensate for each other [6]. It is known that fiber has lowest loss at 1550nm and also that efficient amplifiers operate around this wavelength. So it is desirable to operate around 1550nm [5].With increased bitrates it has been shown that Return-to-Zero (RZ) modulation formats offer certain advantages over NRZ, as they tend to be more robust against distortions [8]

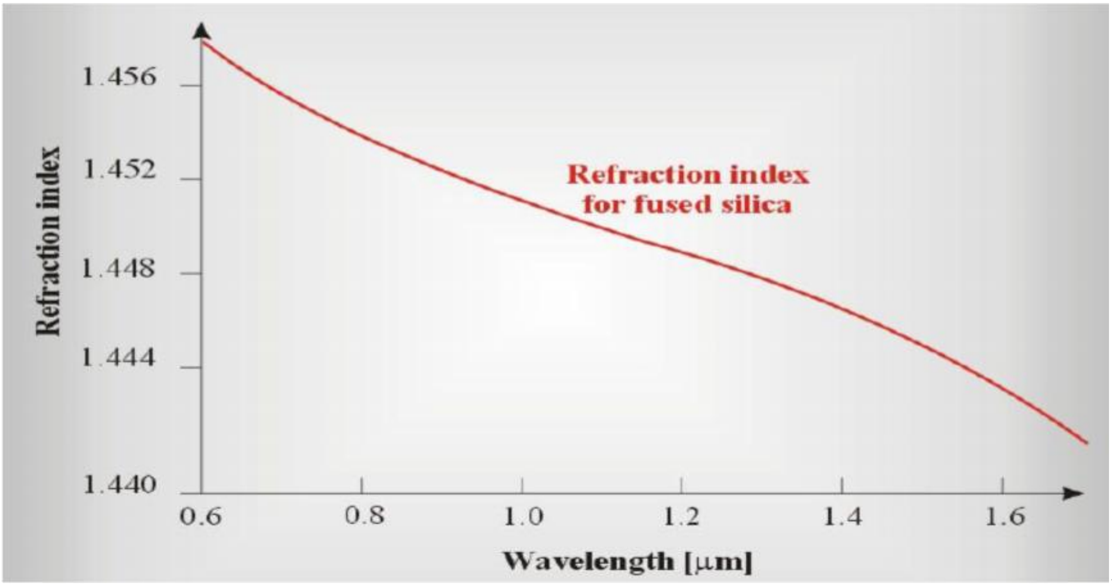


Figure 2. Refractive index dependency on wavelength

3. Types of Dispersion in Optical Fiber

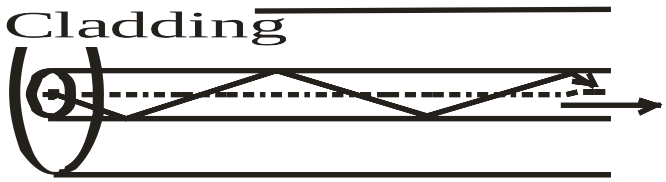
Dispersion represents a broad class of phenomena related to the fact that the velocity of the electromagnetic wave depends on the wavelength and each color have different wavelengths . In optical network the term of dispersion is used to describe the processes which cause that the signal carried by the electromagnetic wave and propagating in an optical fiber is degraded due to different delays and different time delays at output which is dispersion phenomena[5] . This degradation occurs because the different components of radiation having different frequencies propagate with different velocities as velocity depends on refractive index[6].

The optical fiber in two categories: 1. Step Index fiber a) Single Mode fiber
b) Multimode fiber and 2. Graded Index fiber

Modes of propagation -- Two main categories of optical fiber used in fiber optic communications are multi-mode optical fiber and single-mode optical fiber.

1.Single-mode fibers – used to transmit one signal per fiber (used in telephone and cable TV). They have small cores(9 microns in diameter) and transmit infra-red light from laser.Single-mode fiber's smaller core (<10 micrometres) necessitates more expensive components and interconnection methods, but allows much longer, higher-performance links.

2. **Multi-mode fibers** – If more than one mode is transmitted through optical fiber, then it is said to be a multimode fiber. The larger core radii of multimode fibers make it easier to launch optical power into the fiber and facilitate the end to end connection of similar powers. V-number is greater than 2.405. They used to transmit many signals per fiber (used in computer networks). They have larger cores(62.5 microns in diameter) and transmit infra-red light from LED. Multimode fiber has a larger core (≥ 50 micrometres), allowing less precise, cheaper transmitters and receivers to connect to it as well as cheaper connectors. However, multi-mode fiber introduces multimode distortion which often limits the bandwidth and length of the link. Furthermore, because of its higher dopant content, multimode fiber is usually more expensive and exhibits higher attenuation.



Single mode fiber

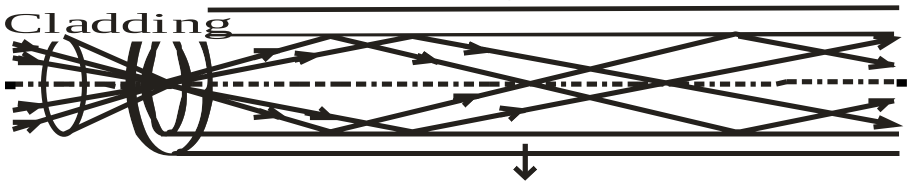


Figure 2. Single mode and Multi mode fiber

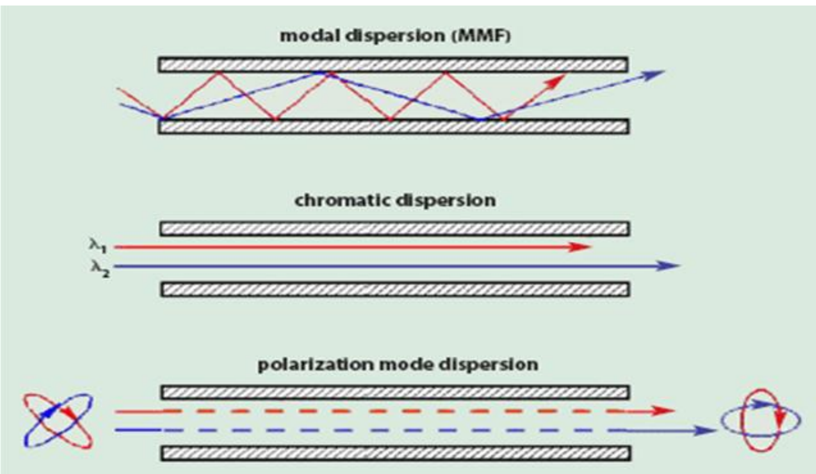


Figure 3 Types of Dispersion in Optical fiber

4.Chromatic Dispersion Measurements

Dispersion is defined as pulse spreading in an optical fiber. Dispersion increases along the fiber length. Modal dispersion- Pulse spreading caused by time delay 7]. Chromatic dispersion-Pulse spreading caused by different wavelength of light propagate by different velocities. Material dispersion-Wavelength dependency on index of refracting of glass. Waveguide dispersion is Due to physical structure of the waveguide [11] . The following block diagram in figure4 is proposed to measure the chromatic dispersion. The fiber under test is situated between len1 and lens2.

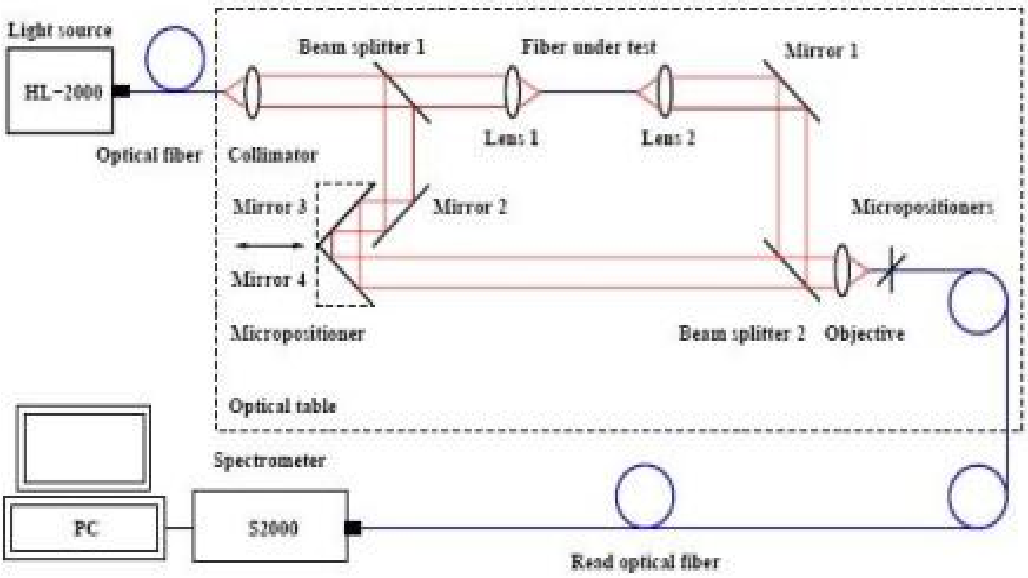


Figure4- Experimental set up for chromatic Dispersion Measurements

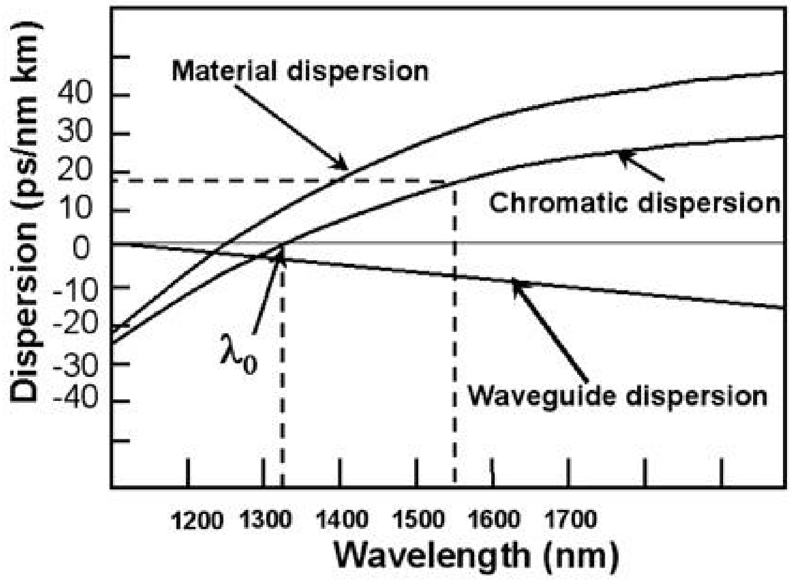


Figure 5 Material , waveguide and total Dispersion in optical fiber Ref[Halina et al]

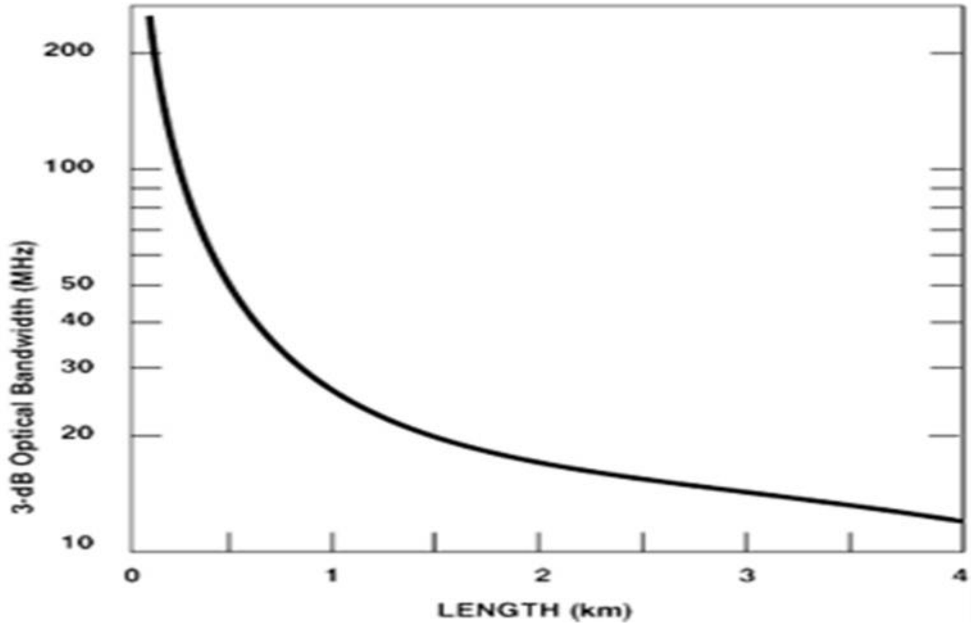


Figure 6- Optical band width dependency on length (L)

5. Conclusion

This paper discuss the phenomenon of dispersion in fiber optical communication is only about non-chromatic dispersion and chromatic dispersion due to different velocity depending on refractive index. The latest trends in data rate i.e optical 3 dB bandwidth and dispersions have been discussed . The material dispersion has the highest delay effect. The dispersion limits the bandwidth and length product of the optical fiber as length increases the bit rates or bandwidth degraded.

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