A Review Paper on Long Distance Dispersion Measurement in Optical Fiber

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Abstract---Optical fibers are used widely with the development of the telecommunication. It has the characteristics are long distance transmission and a large capacity. Dispersion can be divided into some types. The Mode dispersion plays a major role in the multimode fiber, where as chromatic dispersion or the intra modal dispersion are the main things in single mode fiber. Basically it is quite important to test the dispersion and also to know the characteristics of dispersion. The device is used for the measurement of the fiber dispersion characteristics of the optical fiber and results show the validity of theory.

Keywords: Optical fiber, dispersion, modified method, measurement

I. INTRODUCTION

In optical fiber, different lights usually travel at different speeds usually known to be dispersion. It is an important optical characteristic in the optical fiber. Dispersion will broaden the optical pulse and because serious limit on transmission capacity and the bandwidth optical fiber. For the multimode fiber, mode dispersion will play a major role, it meant that different modes travel at different velocities to lead to the dispersion. For the single mode fiber, chromatic dispersion or the intra modal dispersion is one of the main mechanism, and this is to say that dispersion is caused by the different frequencies on different speeds of transmission. Due to the limitation of mode dispersion, this transmission rate cannot be exceeded 100Mb/s.After all single-mode fiber is more superior to multimode fiber. But in the practical applications single-mode fiber is widely been used and it is more important to consider fiber dispersion of single mode. Dispersion in single mode is the material dispersion and the waveguide dispersion. The Material dispersion is the variation of frequency transmission which leads to variation of the refractive index and cause the variation of the transmission constant an also group velocity. The waveguide dispersion is due to variation of frequency resulted in changes of the waveguide parameters and cause variations in transmission constant and the group velocity. Now the intra mode dispersion causes mainly due to polychromatic source. Into add, two orthogonal linear polarization modes exist in the single-mode fiber transmission. Due to non-circular symmetry, edge stress, optical fiber, fiber bending and so on, the polarization mode dispersion will appear in transmission.

Dispersion has been an important feature in optical structure fiber. Various types of methods have been developed for the numerical calculation in dispersion characteristics for microstructure, but experimental methods in measurement of micro structural fiber dispersion have been still inadequate. The results of the theoretical calculations should be validated by the experimental test.

For the reason of not perfect in production of optical fiber, the actual properties should be studied. In order to express the performance of the optical performance, characterization of the optical fiber is urgently needed.

From the view of summarizing the existing methods and put forward new Methods to measure fiber dispersion. The main contribution is establishment of a measurement method for dispersions, and thus remainder of the paper is shown as the following: optical fiber and its model is introduced. Some measurement methods are Summarized. New method is proposed. The experiment is shown and the conclusion is described..

2. DISPERSION AND COMPENSATION METHODS

Fig 1 Scanning Electron Micrographs of PCF,

Fig 2 Transmission Effect of PCF,
The basic equations of pulse transmission in single mode fiber can be described as;

\[
\frac{\partial A}{\partial z} + \frac{i}{2} \beta_2 \frac{\partial^2 A}{\partial T^2} - \frac{1}{6} \beta_3 \frac{\partial^3 A}{\partial T^3} = 0
\]

Here \( A \) is the slowly varying amplitude and \( z \) is the transmission distance. \( \beta_2 \) is the group velocity dispersion (GVD) or the second order dispersion coefficient and is the main factors of pulse broadening and \( \beta_3 \) is the coefficient of the high order dispersion (also called third order dispersion). When we Compare with the second order dispersion, effect of the third order dispersion on the pulse is usually very small. When ps/ km, The solution of function can be obtained as,

\[
A(z, T) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} A(0, \omega) \exp\left[\frac{i}{2} \beta_2 \omega^2 z\right] d\omega
\]

Dispersive of the single-mode optical fiber per unit length can be obtained as.

[dispersion equation]

\[
\delta = -\frac{\lambda}{c} \frac{d^2 n(\lambda)}{d\lambda^2} - n_0 \frac{V}{c} \frac{d^2 V}{d\lambda^2}
\]

c is the light velocity, \( V \) is the normalized frequency of the optical fiber transmission, 
\( n_0 \) is the normalized propagation constant. The First item at the right of the formula depends on the refractive index of the material, which is known as material dispersion, second item is related to fiber waveguide properties which is called waveguide dispersion. Chromatic dispersion coefficient of the common single-mode optical fiber in 1550nm and window is about 16 ps/nm and its dispersion can reach 1600 ps/mm. For a system with a capacity of 10Gbit/s, the tolerance of maximum dispersion is 1000 ps/mm. Therefore, in order to make the system to run normally it must be compensated.

3. MEASUREMENT METHODS

The Photonic Crystal Fibers (PCF), which are also called Micro-Structured Fibers (MSF), are widely paid attention in the recent years. Complex refraction rate distribution exists on cross section of PCF. In PCF, stomata with different arrangements are included, and their size is in roughly the same order of magnitude with the wavelength of light wave and throughout the entire length of the optical devices. The light wave will be limited in center region of the fiber with a low a refractive index. This concept of the photogenic crystals first appeared in 1987. Some researchers proposed that electronic band gap of semiconductor has similar periodic dielectric structure with optic, and one of the promising fields is the applications of photonic crystal in optical fiber. It is mainly relating to the periodic high refractive index optical fiber with the microstructure, which is normally consists of stomata with silicon dioxide as the background material. This new type of the optical waveguide has two types: 1 fiber with high index refractive core layer and surrounded structure by the 2-dimensional photonic crystal cladding. These fibers have similar properties with the conventional optical fiber and its principle is that the waveguide is formed by the total internal reflection (TIR). Compared to the conventional reflection index guiding, it is allowed for the photonic crystal cladding with higher refractive index. Therefore, it is the important to note that the internal total reflection photonic crystal fiber (TIR-PCFs) is actually not depend on Photonic Band Gap (PBG) effect. 2fiber with the Photonic Band Gap (PBG) effect. The fiber controls the beam in core layer with this effect. The optical fiber (PBG-PCFs) exhibits a considerable performance, and the most important is the controlling and guiding the beam transfer in core layer with a lower refractive index than that of cladding refractive index. Dispersion measurement of the fiber dispersion is measuring the time delay of different frequencies light pulse travel the same distance, or measuring pulse phase of different frequencies with corresponding frequency domain. There are many methods in measuring the fiber dispersion, which mainly include the pulse delay method, phase shift method and the interferometric method.

Pulse Delay Method

The time delay method is one of the simplest methods. Generally in this method, the dispersion value will be acquired according to the polynomial fitting by measuring time delay of different frequencies light pulse.

[Delay equation]

\[
D = \frac{1}{L} \frac{d\tau_2}{d\lambda} = \frac{d}{d\lambda} \left( \frac{1}{V_2} \right) = -\frac{2\pi}{\lambda^2} \frac{d^3 \beta}{d\omega^2} = -\frac{2\pi}{\lambda^2} \beta_2
\]

\( D \) is the dispersion coefficient, and it means that the time delay of light signal with unit wavelength interval transmitting unit distance difference. Its unit is ps/mm·km. Factor \( \beta_2 \) is group velocity dispersion parameter:

[Dispersion coefficient]

\[
\beta_2 = \frac{d^2 \beta}{d\omega^2}
\]
Fig shows typical time delay measurement device. Where, the DUT is fiber [equipment]. Under the test, VOA is adjustable optical attenuator. Light source is laser diode or fiber Raman laser with a series of different wavelengths. Fiber Raman laser stimulates the Simultaneously several different wavelengths of light pulse according to Raman scattering effect. First pulse signal delay will be set as a reference value. Time delay difference and the corresponding wavelength would be fitted and dispersion parameters would be acquired.

In all practical applications, the time delayed method, which is based on the optical time domain reflect meter (OTDR), is used to measure delay dispersion. It has a time resolution of 50ps. It has the advantages of its simplicity method, and a low cost device, long measurable fiber distance, while disadvantages are inaccuracy time delay and corresponding wavelength. In add due to limitation of the light source, number of the sampling points is not enough and it also affects the precision of measurement.

Interferometric Method

This interferometric method is a measurement of dispersion without expensive instruments. Use of the Mach-Zehnder Interferometer or its arm as the under tested optical fiber arm and reference arm. According to the changing the reference arm length, intensity information of the interference fringes of light from the two arms will be obtained.

\[ I(d) \propto FT^{-1} \left[ R(\omega)e^{-i(\beta(\omega)L)} \right] \left( d / c \right) \]

\( d \) is the length variation of reference arm and \( L \) is the length of optical fiber under tested. \( R(\omega) \) is the parameter relevant to the transfer function of arms. \( \beta(\omega) \) is the transfer constant for different frequencies.

4. TEST RESULTS

From the fig below the difference shows the error, and main reason may be the fiber structure is not perfect. This error includes structural asymmetry and heterogeneity lead to the calculation error and test accuracy. However the measured and calculated results are very similar. This determines the validity of the proposed test device.

5. CONCLUSIONS

The Main Phenomenon called Dispersion exists in the optical fiber in the telecommunication. It is one of the important optical characteristics in optical fiber and will broaden the optical pulse. Mode dispersion plays a major role in multimode fiber, while the chromatic dispersion or intramodal dispersion are main mechanism in the single mode fiber. So, this paper introduces a test method and designs a test device. The theoretical basis and the experimental device have been introduced in detail. The device is used to measure the fiber dispersion characteristics of optical fiber and results show the validity of theory and the designed test device.

REFERENCES