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Design and Profile Optimization for Dispersion Shifted Fiber (DSF)

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Abstract— **In designing of SM fibers, dispersion behavior is a major distinguishing feature which limits long distance and high speed transmission. Dispersion of SMF is lowest at 1.3 um, but the attenuation is minimum at 1.55 um. At 1.55um dispersion is higher. For achieving maximum transmission distance in a high capacity link ,dispersion null should be at the wavelength of minimum attenuation .This may be achieved by mechanisms like reduction in fiber core with an accompanying increase in the relative RI to create Dispersion Shifted Fibers (DCF) [3].**

In the proposed work by optimizing the fiber profile a fiber with minimum dispersion slope at the desired wavelength will be carried out.

Index Terms— Optical Fiber, Dispersion, DSF, MFD.

I. Introduction

Optical fiber is a dielectric waveguide or medium in which information (voice, data or video) is transmitted through a glass or plastic fiber, in the form of light. It consists of a transparent core with one refractive index n_1 surrounded by a transparent cladding of a slightly less refractive index n_2. The refractive index of cladding is less than 1%, lower than that of core. Typical values for example are a core refractive index of 1.47 and a cladding index of 1.46. The cladding is used in the waveguide structure to protect the core from absorbing surface contaminants and to guide light internally for total internal reflection. Glass core fibers tend to have low loss in comparison with plastic core fibers.

Optical fibers are not only used in the telecommunication but also used in the Internet and Local Area Networks (LAN) to achieve high signaling rates. Optical networks, based on the emergence of the optical layer in transport networks, provide higher capacity and reduced costs for new applications such as the Internet, video and multimedia interaction, and advanced digital services. But the linear and nonlinear Characteristics of the optical fiber are the limiting factors to reach the goals. In the standard single mode fibers, the Polarization Mode Dispersion is the phenomenon that causes the hurdles to achieve the high bit-rate-distance product of amplified light wave communication system. The detailed study of impacts of various fiber irregularities, temperature, stress, bending radius, Ellipticity on PMD is done [9], [10]. The experimental study showed that bit rate increases if various fiber irregularities are controlled to control PMD which is created by fiber irregularities and thus causes dispersion and distortion of the light pulse, thus increasing BER and limiting data rate [9],[10]. There are various types of irregularities in fiber, which arise due to an asymmetric fiber core or can be introduced through internal stresses during fiber manufacture, or through external stresses during cabling and installation. Optical fiber manufacturing processes are designed to yield fibers with a circular cross-section. Any deviation from this form will generally result in an elliptical core, which in turn will result in a refractive index difference between the X and Y-axes of the elliptical core [9], [10]. Even if the fiber core is manufactured with an ideal circular cross-section its refractive index can be asymmetric across its cross-section due to stresses built into the fiber during the manufacturing process or stress that is externally applied during deployment or operation [9],[10].

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Fiber attenuation, which triggers the use of amplification systems, is caused by a combination of material absorption, Rayleigh scattering, Mie scattering, and connection losses. Although material absorption for pure silica is only around 0.03 dB/km (modern fiber has attenuation around 0.3 dB/km), impurities in the original optical fibers caused attenuation of about 1000 dB/km. Other forms of attenuation are caused by physical stresses to the fiber, microscopic fluctuations in density, and imperfect splicing techniques. The transmission loss or attenuation of the signal in an optical fiber is a very important quantity to consider in optical fiber communication. The attenuation of the signal transmitting through the fiber results from absorption and scattering and is measured in decibel/km and is a function of wavelength as shown in figure 3. The optical communication wavelengths are 0.8, 1.3 and 1.55 mm. Attenuation can be classified into two types, namely, intrinsic losses and extrinsic losses.

Mechanisms generating intrinsic losses are listed below:

i. Infrared absorption by Si-O coupling which is present at higher wavelengths around 1.4 mm to 1.6 mm.
ii. Ultraviolet absorption due to electron transition which is present at lower wavelengths near 0.8 mm. This will produce a loss of 0.3 dB/km.
iii. Rayleigh scattering due to spatial fluctuation of refractive index. It produces a maximum loss in the ultraviolet region only. In the wavelength region around 0.8 mm to1 mm, it gives a loss of 0.6 dB/km.
iv. Absorption by molecular vibration of OH impurity. It is the fundamental absorption due to hydroxyl (OH) ions.

Mechanisms generating extrinsic losses are listed below:

i. Geometrical non-uniformity at the core-cladding boundary.

ii. Imperfect connection or alignment between fibers.
iii. Micro-bending.
iv. Radiation of leaky modes.

Extrinsic losses are very small when compared to intrinsic losses and can be minimized by proper care during the manufacturing and installation of the fibers.

Dispersion-shifted fiber (DSF) is a type of optical fiber made to optimize both low dispersion and low attenuation. DSF is a type of single-mode optical fiber with a core-clad index profile tailored to shift the zero-dispersion wavelength from the natural 1300 nm in silica-glass fibers to the minimum-loss window at 1550 nm. The group velocity or intramodal dispersion which dominates in single-mode fibers includes both material and waveguide dispersion. Waveguide dispersion can be made more negative by changing the index profile and thus be used to offset the fixed material dispersion, shifting or flattening the overall intramodal dispersion [1]. This is advantageous because it allows a communication system to possess both low dispersion and low attenuation. However, when used in Wavelength division multiplexing systems, dispersion-shifted fibers can suffer from four-wave mixing which causes intermodulation of the independent signals. As a result nonzero dispersion shifted fiber is often used [2]. The DSF fiber has a low dispersion slope, moderate dispersion, low attenuation, and excellent bend resistance performance. It is suitable for a high-speed (10 Gbits/s and 40 Gbits/s), large capacity, and long distance DWDM system. Therefore, not only the non-linear problem that limits high-speed communication is solved effectively, but also the DWDM transmission at 10 Gbits/s can be realized within a wider wavelength range. In addition, low dispersion slope is advantageous for comprehensive management of dispersion, so that the requirement for long distance non-electric relay can be fulfilled [5].

II. FIBER PROFILE

The goal of our study is to design new DSFs with low dispersion slope and small negative dispersion to maintain the merits of original DSFs in combating dispersion and nonlinearities, while extending DWDM operating window through low dispersion slope and improving dispersion management ability through negative dispersion design.

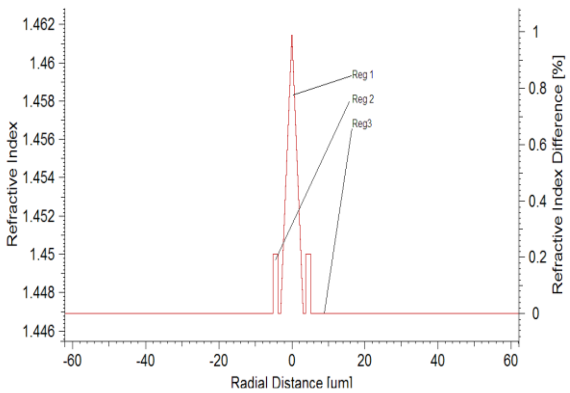

Fig 1: Fiber Profile

Here the triangular geometry of the fiber profile is designed. The profile of the projected fiber is shown in the fig 1.

The minimum group delay is found to be 4.9024E6 ps/Km at the wavelength of 1.51429 µm. The Mode Field Diameter is found to be 7.94350 µm at the wavelength of 1.51429 µm, as shown in fig.3.

III. ZERO DISPERSION FIBER DESIGN 1: (WITH WIDTH 0.6 UM)

Figure 1 shows the variation of refractive indices with respect to radial distance from the core. For the region 0 shown in fig. 1, refractive index varies from 1.4615 to 1.44692 and has a linear profile. Regions 1, 2 and 3 of fig.1 have almost constant profile with fixed refractive index. Initially the width of the region 1 is kept at 0.6 µm. For the width of 0.6µm the various parameters like group delay, mode field diameter (MFD) and dispersion are found out. Fig. 2 shows the group delay for the designed fiber.

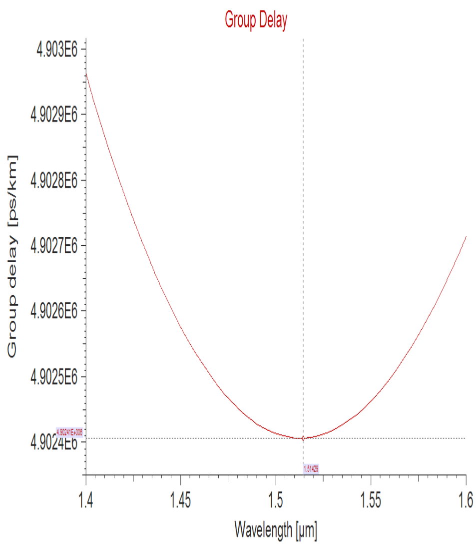

Figure 2: Group Delay

The minimum group delay is found to be 4.9024E6 ps/Km at the wavelength of 1.51429 µm. The Mode Field Diameter is found to be 7.94350 µm at the wavelength of 1.51429 µm, as shown in fig.3.

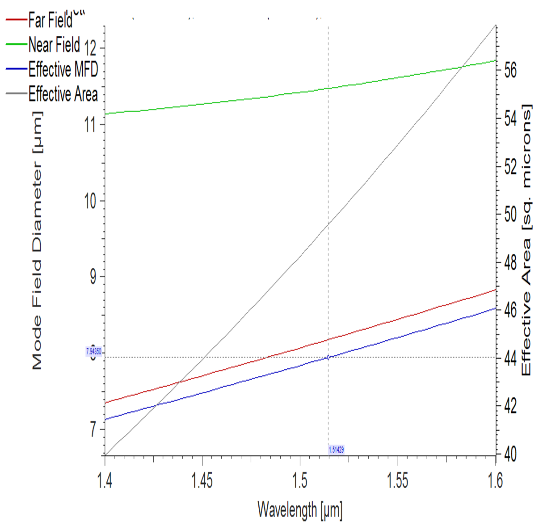

Figure 3: MFD Calculations

In the same way, the zero dispersion for this fiber at the width of 0.6 µm, is found at 1.5134 µm with the slope of 0.07468, as shown in fig.4.

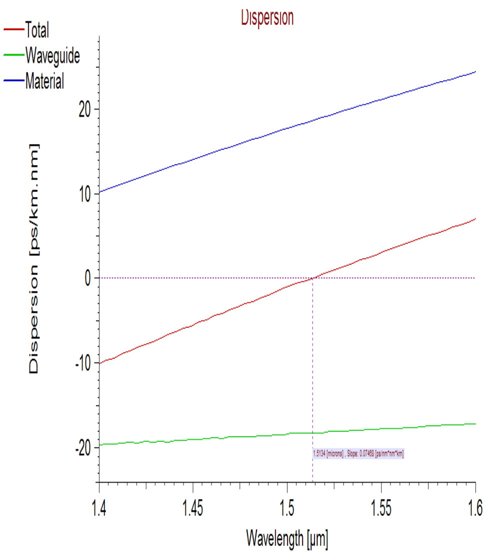

Fig 4: Zero dispersion at 1.5134 µm when core width is 0.6 µm

Summery for the core width of 0.6 µm is given in Table 1.

Table-1

Group Delay (ps/km)	MFD (µm)	Zero dispersion wavelength (µm)	Zero dispersion slope
4.9024E6	7.94350	1.5134	0.07468

Here, the zero dispersion is obtained at the wavelength of 1513.4nm. As the dispersion in the 1550nm window is less, zero dispersion wavelength of 15134nm can be shifted to 1550nm window by changing the region 1 width.

IV. SERO DISPERSION FIBER DESIGN 4: (WITH WIDTH 1.3 UM)

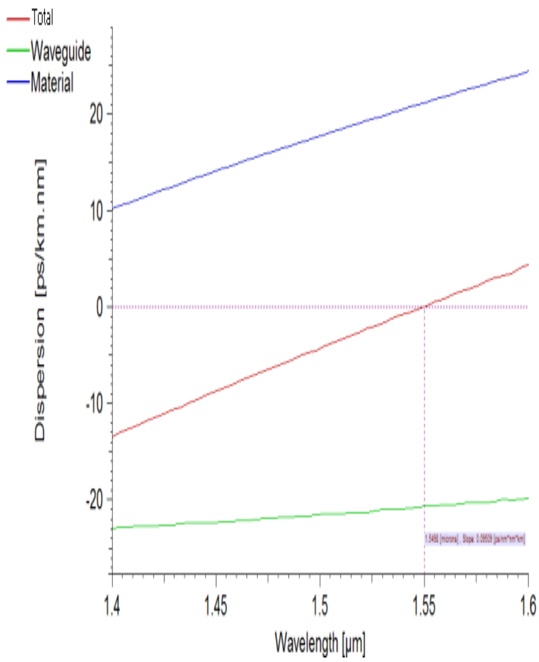

Fig 5: Zero dispersion at 1.5502 µm when core width is 1.3 µm

V. RESULT AND CONCLUSION

Simulation results are tabulated below in table 2 for zero dispersion wavelengths for Fiber1, Fiber2, Fiber3, Fiber4, and Fiber5.

Table- 2

Parameters	Fiber1	Fiber2	Fiber3	Fiber4
Zero Dispersion Wavelength (µm)	1.5134	1.5238	1.5340	1.5502
MFD (µm)	7.94350	NA	NA	8.25297
Group Delay (ps/km)	4902410	NA	NA	4901950
Slope	0.07468	0.07920	0.08533	0.07370
Width	0.6um	0.8um	1.3um	1.5um

From table 2, it is found that there is a shift in the zero dispersion wavelengths from 1.5134µm to 1.5502µm. This shift in the wavelength is obtained by changing the core width. It is thus observed that for a defined fiber parameter such as MFD, group delay and slope, the zero dispersion wavelengths can be shifted by changing the core width from 0.6µm to 1.33µm. In this work the zero dispersion wavelengths is obtained at 1.5502µm for the core width of 1.33µm. Thus, in nutshell, the authors have observed the effect of change in the core geometry on the wavelength to obtain the zero dispersion wavelengths. The various parameter of the fiber are calculated. The Average effective area is found to be 0.54 with MFD 0.825297. The Zero dispersion wavelengths are obtained at 1.5502µm with a dispersion slope of 0.07370 only.

VI. ACKNOWLEDGEMENT

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