Dispersion Compensated Optical Fibers for Long Haul Communication

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Abstract

Optical fibers are the quintessential transmission lines in modern day communication system, which have enabled Terabit data transfers and long haul inter-continental internet networks. A key requirement in such systems is to have optical fibers that can transmit data over long distances with least attenuation and dispersion. Dispersion is broadening of light pulses due to varying arrival times of different spectral components of light launched in fiber, which in turn leads to corruption of information being conveyed.

Total dispersion parameter in single mode optical fibers measured as pulse broadening in picoseconds per km of fiber length per nanometer source wavelength (ps/km-nm) is the sum of material dispersion and waveguide dispersion. Material dispersion is inevitable in optical fibers while waveguide dispersion is negative, and hence offers a way to tailor the refractive index profiles, to get zero overall dispersion at a particular wavelength, resulting in Dispersion Shifted Fibers (DSF), and else low overall dispersion over a range of wavelengths, giving Dispersion Flattened Fibers (DFF).

In COMSOL Multiphysics software , the optical fiber was modeled using 2-Dimensional Electromagnetic Waves-Frequency Domain interface. The electromagnetic mode analysis study was configured to simulate fundamental EM mode of light propagation. Within this, mode analysis study was used to compute effective refractive index for different excitation wavelength as well as fiber refractive index profile. The "Effective refractive index" is an important parameter calculated by Mode Analysis study, which greatly simplifies our calculations and dispersion compensation design. The COMSOL mode analysis also shows the Electric field and magnetic field distribution, helpful for visualizing energy confinement. We modeled 2 different DFF profiles (Figure 2 and Figure 3) and a DSF profile (Figure 4), and obtained optimum total dispersion results.

For each fiber, the 2-D cross section was built in COMSOL, with silica as the fiber material and appropriate refractive index values that emulated the required index profiles. Material dispersion for different wavelengths was calculated manually from Sellemier's formula. Parameters were defined to obtain Waveguide dispersion value as a function of wavelength (Figure 1), from the corresponding effective refractive index computed by COMSOL Multiphysics.

For DFF fibers to obtain dispersion value over a range of wavelengths, parametric sweep feature was used to change the wavelength from 1.3 um to 1.7 um in small steps and run the simulation for each of them automatically. The total dispersion for each fiber and its plot versus wavelength was obtained and thus by tailoring the fiber profiles, dispersion was kept within an optimum ±3 ps/km-nm.

Thus this study enables us to design the DSF and DFF fibers which help in reducing the dispersion in optical fibers. These single mode dispersion compensated fibers are of great importance in long distance communication, since they offer very low attenuation and low dispersion around 1.5 micrometer ranges. It is essential to avoid inter symbol interference arising due to dispersion, and hence offer reliable error free communication. These are therefore used for Intercontinental internet transmission and long distance underwater telephony and telemetry.

Reference

1.Ajay Ghatak, K. Thyagarajan,Introduction to Fiber Optic, 1/e.
2. Gerd Keiser, Optical fiber Communication ,2/e.
3.COMSOL Multiphysics 4.4 Reference manual.
COMSOL Step Index Fiber simulation tutorial notes.

Figures used in the abstract

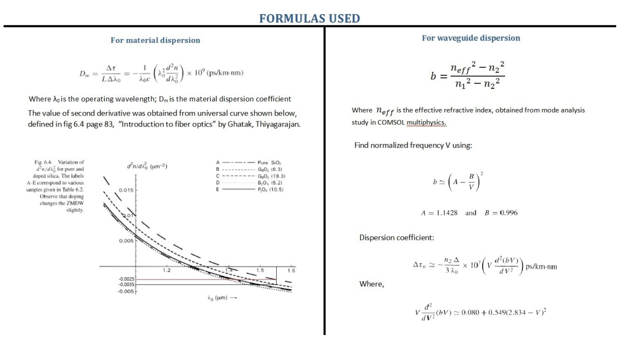


Figure 1: Important Formulas Used for Arriving at the Results.

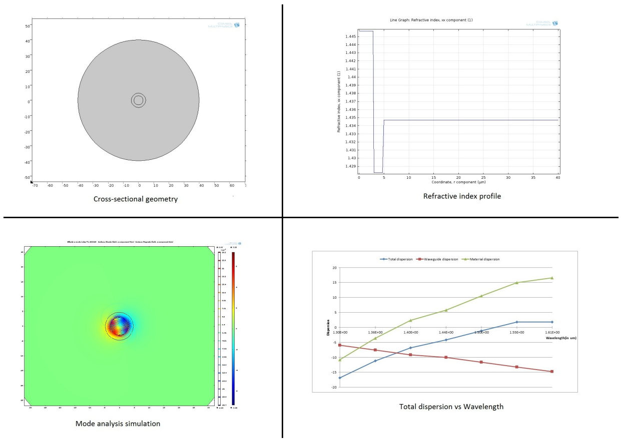


Figure 2: Modelling and Results:Dispersion Flattened Fiber-Profile 1.

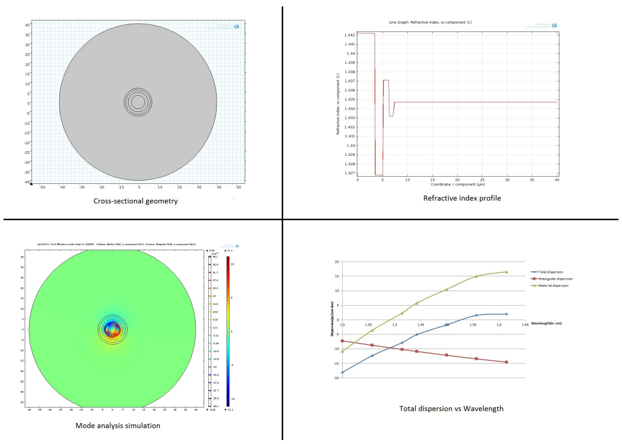
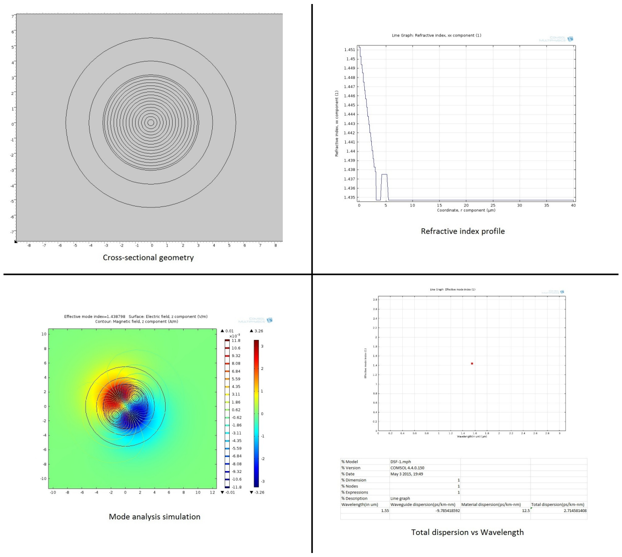


Figure 3: Modelling and Results:Dispersion Flattened Fiber-Profile 2.



% Model	DSF-1.mph		
% Version	COMSOL 4.4.0.150		
% Date	May 3 2015, 19:49		
% Dimension	1		
% Nodes	1		
% Expressions	1		
% Description	Line graph		
Wavelength(in um)	Waveguide dispersion(ps/km-nm)	Material dispersion(ps/km-nm)	Total dispersion(ps/km-nm)
1.55	-9.785418592	12.5	2.714581408

Figure 4: Modelling and Results:Dispersion Shifted Fiber