Optimization of Silica Glass Micro Fiber for Zero Dispersion Wavelength

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ABSTRACT

We report theoretical investigations regarding the silica glass micro-optical fiber for its mode field, dispersion, bending loss and Splice loss characteristics.

Keywords

Single mode optical fiber, micro fiber, silica glass.

1. INTRODUCTION

Optical fibers have revolutionized areas of telecommunications, medical, sensing applications, etc. A fiber generally comprises a core and cladding as a part of its construction. Typical optical fiber devices include remote current sensors [1], nonlinear switching devices [2], super-continuum generators [3] etc. With regards to super-continuum generators, where the broadband light containing wavelengths from 200 nm to 2000 nm or above is generated, nonlinear properties (related to phase) of the optical fiber are utilized to get the super-continuum.

However, the nonlinear properties of the silica glass fiber can be be masked by the presence of dispersion (unless utilized properly, for example, for solitons) and then generating super-continuum in the presence of dispersion becomes a costly task due to requirement of very large pumping power. A simple alternative to control dispersion is to change the dispersion properties of the optical fiber. Very cost effective high power laser sources are available at the wavelength of 600 nm, 800 nm 980 nm and 1064 nm.

However, using commercial optical fibers at these wavelengths pose problem due to high negative dispersion at these wavelengths, which mars the super-continuum generation. If one wants to use the dispersion shifted fiber, most of the reported dispersion shifted fibers have been optimized for 1550 nm operation and if we are looking to use the commercial single mode fibers, the dispersion control is possible only by means of changing the core diameter. In the current communication, we simulated the micro-optical fiber for the zero dispersion wavelength near the available pumping wavelength and analyzed its optical properties.

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2. THEORY

A few definitions of parameters have been listed here for the ease of reading. Optical power loss at the splicing point of two ends of optical fiber is known as splice loss.

$$\alpha(dB) = 4.34(u/w)^2$$

Macro bending is caused typically by poor handling or installation. Ray diagram view used with multimode fiber provides approximate explanation.At a sharp bends light rays which propagate by TIR on straight fiber are lost into
the cladding. Result is optical power loss and thus attenuation. The empirical relation for bending loss is given by,

$$\propto\left(\frac{dB}{m}\right) = 4.343 * \sqrt{\frac{\pi}{4aR}} * \left(\frac{U}{VK(W)}\right) * \left(\frac{1}{\sqrt[3]{W}}\right) * e^{(2W^3R/3K^2a^3n^2)} \quad (2)$$

Dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency, or alternatively when the group velocity depends on the frequency. Media having such a property are termed *dispersive media*. Dispersion is sometimes called *chromatic* dispersion to emphasize its wavelength-dependent nature, or group-velocity dispersion (GVD) to emphasize the role of the group velocity. The chromatic dispersion *D* is computed from the equation:

$$D = \frac{-\lambda}{c}\frac{d^2 n_{eff}}{d\lambda^2} \quad (3)$$

where λ is the wavelength, n_{eff} is an effective index and c is speed of light in the vacuum.

3. RESULTS AND DISCUSSION

We used OptiFibers code to simulate the micro-fiber. The commercial single mode optical fiber parameters with dimensions squeezed proportional to the decreased core size were chosen for simulation. As at a very narrow core size, silica is the dominating factor rather than GeO_2 to determine the propagation characteristics, the core itself was approximated to be of silica glass. The fiber diameter (i.e. core diameter) was varied from 0.8 µm to 4 µm, and the cladding was assumed to be of air; these parameters were then used to solve the scalar wave equation for the fundamental mode and resulting radial variations of electric fields were used to compute other parameters, such as dispersion, splice loss, etc.

Initially to understand the optical parameters of the micro-fiber, we show typical results for the specific micro-fiber. A refractive index profile of the micro-fiber under consideration is shown in Fig. 1 for the fiber diameter of 1 µm. Fig. 2 shows the optical confinement obtained for the above fiber showing large leakage in the cladding region; corresponding fundamental mode field pattern is shown in Fig. 3. Splice losses for this typical profile as well as for simulation were obtained for following parameters:

(a) Matching mode size = 9µm (Single mode fiber)

(b) Medium refractive index = 1
(c) Transverse offset = 0.12 µm
(d) Longitudinal separation = 1000µm
(e) Angular misalignment = 0.6 deg

Resulting splice losses for the fiber are shown in Fig. 4, showing the angular misalignment to be the prominent contributor towards the splice loss. The zero dispersion wavelength was obtained at 610 nm as shown in Fig. 5, indicating that the change in fiber size can effectively shift the dispersion.

Finally, we show the simulated data for the optimized fiber diameter to obtain the zero dispersion wavelength. The fiber diameter was varied from of 1μm – 4 μm. Table I shows the optimum fiber radius for the prominent pumping wavelengths where zero dispersion can be obtained.

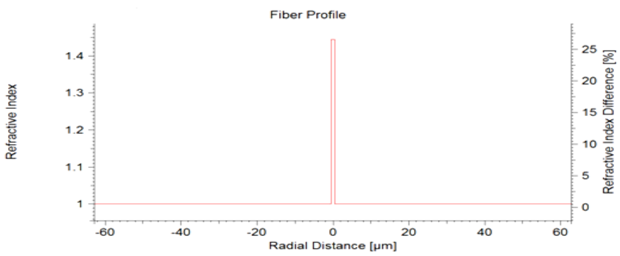

Fig: 1: Refractive Index profile of the micro fiber

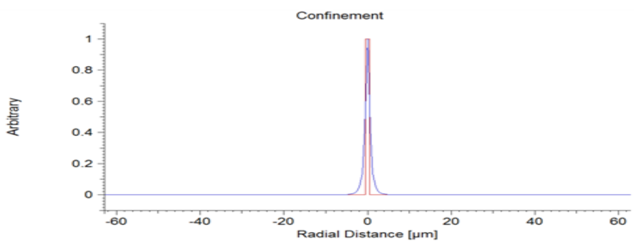

Fig: 2: The optical confinement within the fiber

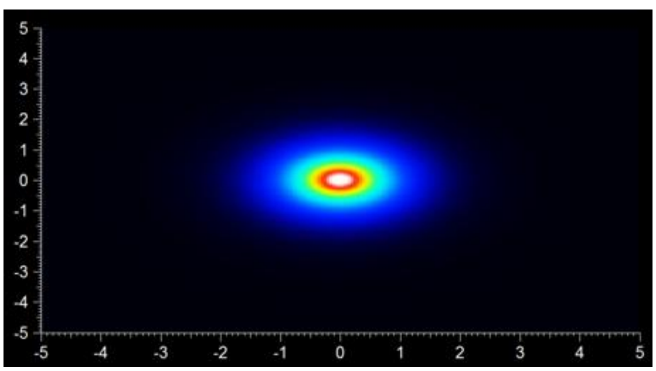

Fig: 3: The LP_{01} mode field pattern propagating within the fiber

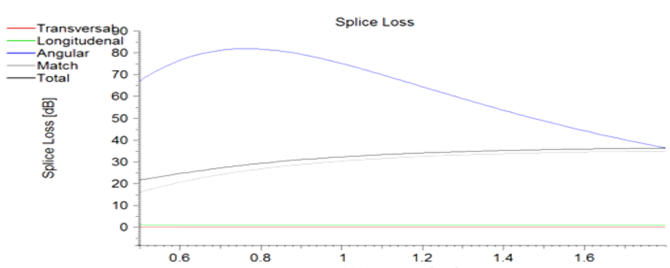

Fig: 4: Total splicing losses that can occur for splice between the micro-fiber and the commercial single mode fiber.

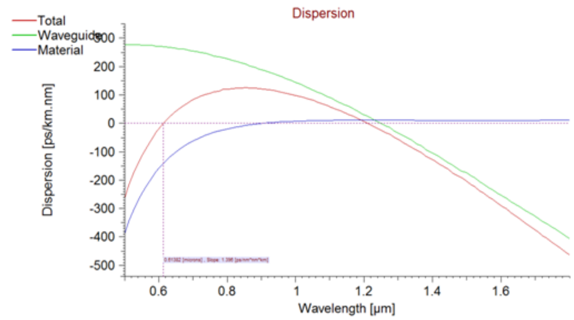

Fig: 5: Total Dispersion losses in the fiber.

λ(μm)	Micro-fiber radius(μm)
0.6	0.4
0.8	1.2
0.98	2.2
1.064	3.1

Table 1: Zero dispersion wavelength and microfiber radius variations.

4. CONCLUSION

We simulated the micro-fiber to obtain the optimum diameter of the fiber where dispersion coefficient is zero at various pumping wavelengths.

5. REFERENCES

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