IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 12, Issue 3, Ver. IV (May - June 2017), PP 09-12
www.iosrjournals.org

Dispersion and Effective Area of Air Hole Containing Photonic Crystal Fibres

Nagaraju Naddi[1], Eliyaz Mahammed[2], K.L.Naga Ksihore[3]
[123]*Department of ECE, Vardhaman College of Engineering, Hyderabad, Telangana, India*

Abstract: *Photonic Crystal Fibre (PCF) has zero dispersion at 1.55µm wavelength compared to the standard single mode fibre (18ps/nm/km) and also sometimes negative dispersion occurs for the telecommunication wavelength range of 1.2 to 1.8µm wavelength such as the effects of air holes. The PCF design parameters on the effective index, effective mode area (9.021 µm^2, confinement losses (0.0082 dB/m), and birefringence have been carefully investigated for the telecommunication wavelength range of 1.2 to 1.8µm wavelength.*
Keywords: *Photonic Crystal Fibres, confinement losses, Chromatic dispersion*

I. Introduction

Optical fibre with silica air microstructures called PCF' s have attracted a considerable amount of attention recently because of their unique properties that are not realized in conventional optical fibres. PCF's which are also called holey fibres or micro-structured fibres. This can be guide the light by total internal reflection between a solid core and a cladding region with multiple air holes.

The strongest wavelengths dependency of the effective refractive index and the inherently large design flexibility of the PCF' s allow for a whole new range of properties. Such properties include endlessly single mode fibres and fibres with anomalous dispersion in the visible wavelengths region. PCF have applications ranging from telecommunication field to metrology, spectroscopy, microscopy, biology &sensing. Because of its ability to confine light in hollow cores or with confinement characteristics not possible in conventional optical fibre, PCF is now finding applications in fibre optic communications fibre losses, nonlinear devices, high power transmission, highly sensitive gas sensors and other areas.

II. Proposed Model

The light guidance in PCF is obtained with the help of suitable array of air holes extending along the fibre propagation direction. The optical properties are related the fibre design, specifically the pitch(Λ) of the periodic array, the hole diameter(d) and the number of rings around the core. In this experiment we are designing the PCF with Λ=1.6µm, d1/ Λ =0.1312, d2/ Λ =0.43,d3/ Λ =0.419, d4/ Λ =0.92.

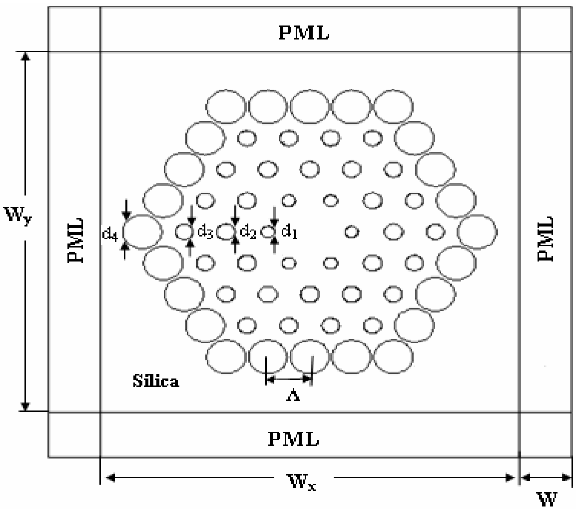

Fig 1: Schematic cross section of the PCF with four rings of 60 air holes

Figure 1 shows a schematic diagram of the PCF, consisting of four rings of arrays of air holes arranged in a silica background whose index of refraction is 1.45. The diameter of air holes and their pitch is denoted with d and Λ. In solid core photonic crystal fibres, where light is confined in a higher refractive region, modified total internal reflection is exploited, which is quite similar to the guiding mechanism of standard optical fibres.

The key factor in designing PCF is the effective mode area. The effective mode area A_{eff}, is related to the effective area of the core area, which is calculated by using

$$A_{eff} = \frac{(\iint E^2\, dx\, dy)^{\wedge}2}{\iint E^4\, dx\, dy}$$

The most important factor for any optical fibre technology is loss. The PCF is necessary to consider confinement loss. This is due to finite number of air holes which can be made in the fibre cross section. In solid core PCF the light is confined within a core region by the air holes. Light will move away from the core if the confinement provided by the air holes is inadequate.

$$confinement\ loss = 8.686 k_0 Im(n_{eff})\ (dB/m)$$

where $k_0 = \frac{2\Pi}{\lambda}$

where Im is the imaginary part of the n_{eff}

Dispersion is defined as the signal broadening or spreading while it is propagates inside the fiber. Light waves with different wavelengths travel at different speeds inside the material. The expression for the dispersion is given below

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

III. Results And Discussion

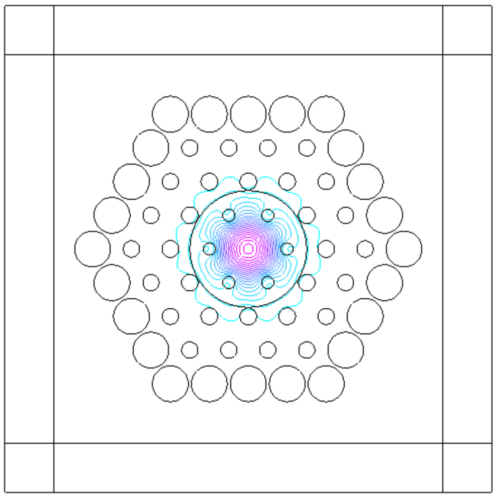

Fig 2: The field profile of the dominant E_x component of the fundamental HE_{11}^{x} mode ,whereΛ=1.6µm, d1/ Λ =0.312, d2/ Λ =0.43, d3/ Λ =0.419, d4/ Λ =0.92, at operating wavelengthλ=1.55 µm

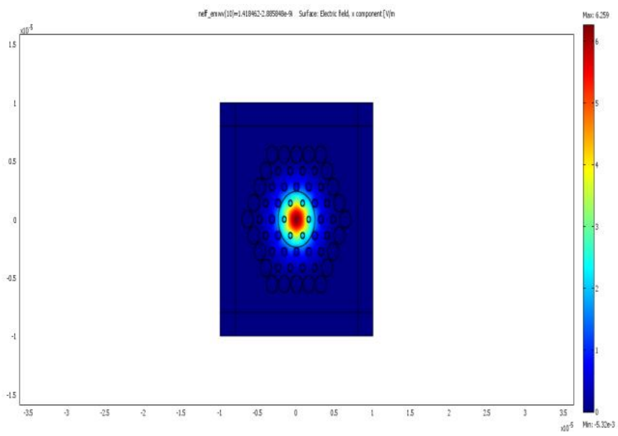

Fig 3: 2 dimensional view of the PCF

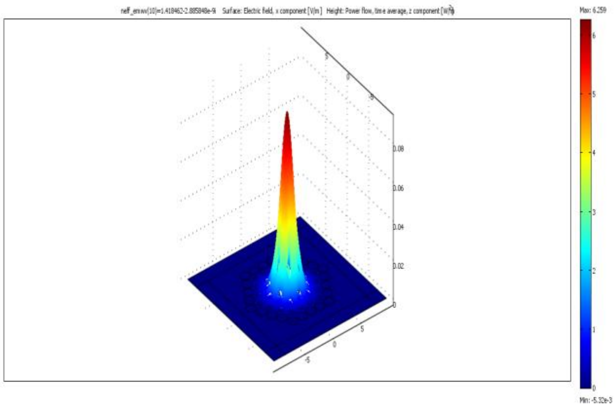

Fig 4: 3-D view of the PCF

Effective Mode Area

The variation of the effective mode area A_{eff}, with the wave-length. It can be noted that A_{eff} is **9.021**μm^2 at the communication window of 1.55μm. It is worth notifying that the effective area is smaller than that of conventional fibres at 1.55μm wavelength. The PCFs with nearly zero ultra flattened dispersion have relatively small effective area and would be useful for some nonlinear applications, such as super continuum generation. In the shorter operating wavelengths, mode is more confined into the core region than in the longer wavelengths.

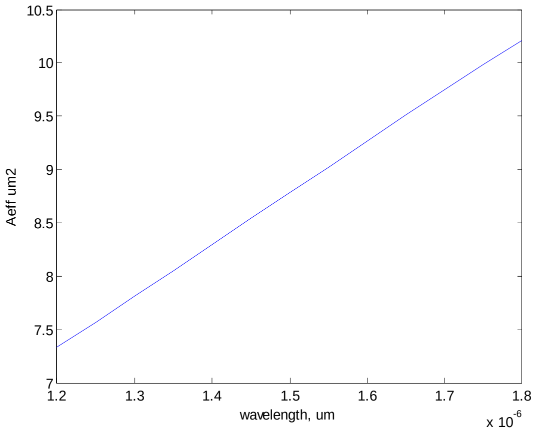

Fig5: Variation of effective mode area with wavelength

Confinement Loss

The fundamental mode is propagating in the core region. Due to a finite number of air holes, the optical mode leakage from the core region into the outer air hole region is inevitable and the confinement loss due to the extent of the cladding is taking place.

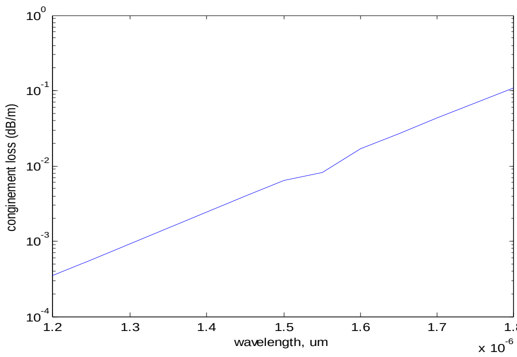

Fig6: Variation of confinement loss with the wavelength λ, Λ=1.6μm, d1/ Λ =0.312, d2/ Λ =0.43, d3/ Λ =0.419, d4/ Λ =0.92, λ=1.55 μm

The confinement loss of the fundamental mode has been computed from the imaginary part of the complex effective index n_{eff} and has been from.The confinement loss decreases rapidly when the operating wavelength decreases. The confinement loss is **0.0082dB/m** at communication wavelength **1.55μm.**

Dispersion

As may be seen from the fig 7 dispersion values between the wavelengths from 1.35µm to 1.8µm can be controlled by changing the size of the air holes of the **third** ring. In this case almost zero dispersion has been achieved at 1.55µmwavelength. It can also be observed that dispersion values for the wavelength from 1.5µm to 1.6µm changes between 0.4 and -0.11ps/km.nm. **Negative** dispersion has also been obtained around 1.55µm.

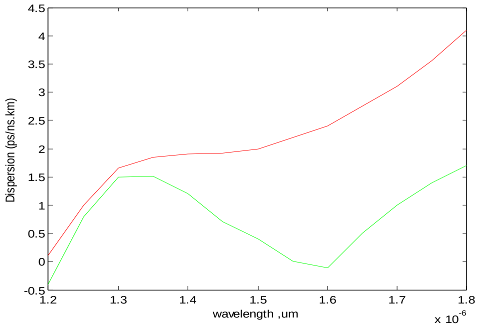

Fig 7: Variation of dispersion with wavelength where Λ=1.6µm, d1/ Λ =0.312, d2/ Λ =0.43, d3/ Λ =0.419, d4/ Λ =0.92(solid line) and d1/ Λ =0.312, d2/ Λ =0.43, d3/ Λ =0.468, d4/ Λ =0.92

wavelength(micro meter)	real	imag	real	imag	Aeff(x)	confinement loss
1.2	1.431185	-7.77E-12	1.431188	-7.81E-12	7.3352	-3.54E-04
1.25	1.43007	-1.30E-11	1.430073	-1.40E-11	7.5699	-5.69E-04
1.3	1.428961	-2.19E-11	1.428964	-2.51E-11	7.80869578	-9.22E-04
1.35	1.427859	-3.71E-11	1.427863	-4.50E-11	8.05044874	-1.50E-03
1.4	1.426766	-6.27E-11	1.42677	-7.98E-11	8.29423282	-2.45E-03
1.45	1.425684	-1.06E-10	1.425689	-1.40E-10	8.53906747	-3.98E-03
1.5	1.424614	-1.77E-10	1.424618	-2.41E-10	8.7839994	-6.46E-03
1.55	1.423543	-2.33E-10	1.423541	-4.28E-10	9.021	-8.20E-03
1.6	1.42251	-4.93E-10	1.422515	-6.84E-10	9.27059264	-1.68E-02
1.65	1.421478	-8.16E-10	1.421483	-1.13E-09	9.51063928	-2.70E-02
1.7	1.420459	-1.34E-09	1.420465	-1.84E-09	9.7475304	-4.32E-02
1.75	1.419455	-2.20E-09	1.41946	-2.95E-09	9.98066209	-6.87E-02
1.8	1.418464	-3.59E-09	1.418469	-4.69E-09	10.20944416	-1.09E-01

Table 1: Obtained values of effective area and confinement losses at different wavelengths

IV. Conclusion

The effective index, the confinement loss, the effective mode area and the chromatic dispersion of the fundamental mode of this structure have been successfully investigated. Low losses with ultra-low and desired chromatic dispersion in the telecommunication wavelength are reported. It was shown that it is possible to achieve zero dispersion at 1.55µm wavelength.

References

[1] NielsAsger Mortensen and Jacob Riis Folkenberg, "Low-loss criterion and effective area considerations for photonic crystal fibres," J. Opt. A: Pure Appl. Opt., vol. 5, pp. 163–167, 2003.

[2] NielsAsger Mortensen, "Effective area of photonic crystal fibres" Optics Express, vol. 10, pp. 341-348, 2002.

[3] Kapron, F. P. (1970). "Radiation Losses in Glass Optical Waveguides". Applied Physics Letters. 17 (10): 423. Bibcode:1970ApPhL..17..423K. doi:10.1063/1.1653255.

[4] Keck, D.B. (1973). "On the ultimate lower limit of attenuation in glass optical waveguides". Applied Physics Letters. 22 (7): 307. Bibcode:1973ApPhL..22.307K. doi:10.1063/1.1654649.

[5] Kaiser P.V., Astle H.W., (1974), Bell Syst. Tech. J., 53, 1021–1039

[6] Tajima K, Zhou J, Nakajima K, Sato K (2004). "Ultralow Loss and Long Length Photonic Crystal Fibre" Journal of Light-wave Technology". Journal of Light-wave Technology. 22: 7–10. doi:10.1109/JLT.2003.822143.

[7] P. Roberts, F. Couny, H. Sabert, B. Mangan, D. Williams, L. Farr, M. Mason, A. Tomlinson, T. Birks, J. Knight, and P. St. J. Russell, "Ultimate low loss of hollow-core photonic crystal fibres," Opt. Express 13, 236-244 (2005)

[8] Canning J, Buckley E, Lyttikainen K, Ryan T (2002). "Wavelength dependent leakage in a Fresnel-based air–silica structured optical fibre". Optics Communications. 205: 95–99. Bibcode:2002 Opt Co. 2095C doi:10.1016/S0030-4018(02)01305-6