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Analysis of Dispersion and Effective Refractive Index in Decagonal Structure of Photonic Crystal Fiber having Circular Hole within Core

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Abstract- **In this paper we have introduced an efficient design of photonic crystal fiber i.e. decagonal 4 ring structure with circular hole in core. Perfectly matched layer has been applied outside the cladding to prevent reflections. We have analyzed this design in COMSOL Multiphysics simulation tool. We have calculated effective refractive index and dispersion for this design by varying pitch keeping diameter constant and by varying diameter keeping pitch constant. Core is filled with glycerol and optimum values of pitch and diameter are found.**

Index Terms- **Cladding, Photonic Crystal Fiber, Dispersion, Air-hole, Core.**

I. INTRODUCTION

Photonic crystal fibers (PCFs) are new class of optical fiber based on the photonic crystals properties. They are fabricated with hollow air holes running parallel with the fiber which acts as cladding and directs the light. The optical analog possesses the photonic crystal, which provides support in replacing the atoms or molecules with the help of macroscopic media with different dielectric constants, and the dielectric material function here helps in replacing periodic potential. The Photonic crystals in combination with photonic-band gaps are generated to avoid light propagation in definite directions at certain ranges of wavelengths. Photonic crystal fibers are an unorthodox form of normal fiber optics, often utilize the total internal reflection or light detention in hollow-core methods to transmit the light.

In reality, such a fiber was first urbanized in 1996 in the form of a photonic-crystal cladding with a interrupted range of hollow air holes. It was later noticed that the periodic character of air holes is not vital for silica-core fibers only if the cladding has several air holes that efficiently reduce its index of refraction below of the silica core. In such case, light is directed by the total internal reflection, and the air holes are used to decrease the index of the cladding region. The air holes which are periodic in nature become important in the so-called photonic bandgap fibers, in which the optical form is restricted to the core by periodic variations of the refractive index inside the cladding. The core of such kind of fibers frequently holds air to which light is cramped by the photonic band gap. Such accurate PCFs can operate as an extremely nonlinear medium if air is replaced with an appropriate gas or liquid.

1.1 Index Guiding PCF

While the cladding contains air holes there is better index contrast with a refractive index of 1 in similar with the normal silica cladding index of 1.457 which is close enough to germanium-doped core index of 1.462. However there is fundamental physical difference exists between the index-guided PCFs and conventional fibers due to the method in which the guided mode interacts with the cladding region.

For shorter wavelengths the effective cladding index is somewhat lower than the core index, and hence they stay put tightly confined to the core. However for longer wavelengths, the mode sample is more than the cladding and the effective index contrast is larger.

1.2 Bandgap Guiding PCF

Optical fibers structure completely dissimilar from the conventional fibers, the reason behind this is that the photonic crystal cladding has gaps in the ranges of the supported modal index β/k where at hand are no transmission modes. These are the PBGs of the crystal, which are related to the two dimensional bandgap, their main characteristic is planar light wave circuits, but in this case they are propagated with a non-zero value of β. It is significant to underline that gaps can emerge for values [4] of modal index both larger and slighter than unity, enabling the arrangement of hollow core fibers with bandgap material as a cladding. These fibers are normally difficult to made using conventional optics, are related to Bragg's fibers, because they are not rely on TIR to direct light. In reality, in order to guide light through TIR, it is compulsory a lesser index cladding material adjoining the core, but there are no fitting low loss material with a refractive index lower than air at optical frequencies. It is noticed that its core is created with an additional air hole in a honeycomb lattice. This PCF can only guide light in silica that is in the higher index material. The foremost hollow core PCF had a simple triangular lattice of air holes, and the core was created by removing seven capillaries in the axis of the fiber cross section. Because of the production of relatively large core, the probability of finding guided mode was much improved.

II. PCF DESIGN SIMULATION

We have designed and analyzed decagonal structure of photonic crystal fiber having circular hole in core. The core is filled with glycerol. Effective refractive index and dispersion are calculated based on different pitch values and different air hole cladding diameter values.

DECAGONAL PCF WITH CIRCULAR HOLE IN CORE

In this design we have made 4 decagonal air hole rings in cladding region and core in center of PCF. Circular hole is inserted within core. Material for core is silica whose refractive index is 1.46 and for air hole is air whose refractive index is 1. Diameter of air hole is d and circular hole is d1. Perfectly matched layer is applied across the cladding. This design is analyzed based on different pitch and different air hole diameter. Design of decagonal PCF is shown in Fig-1 and electric field distribution is shown in Fig-2.

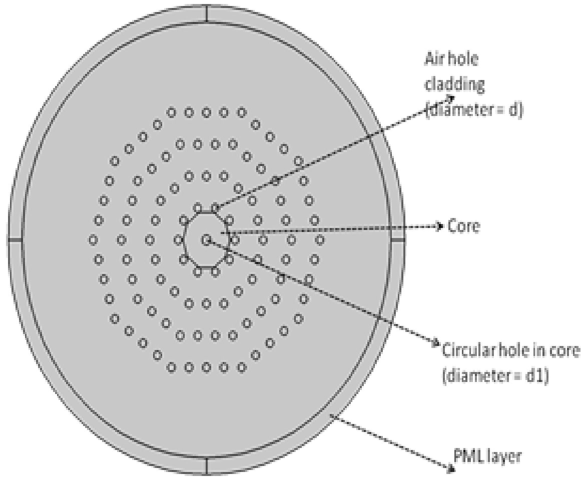

Fig-1: Decagonal PCF with circular hole in core

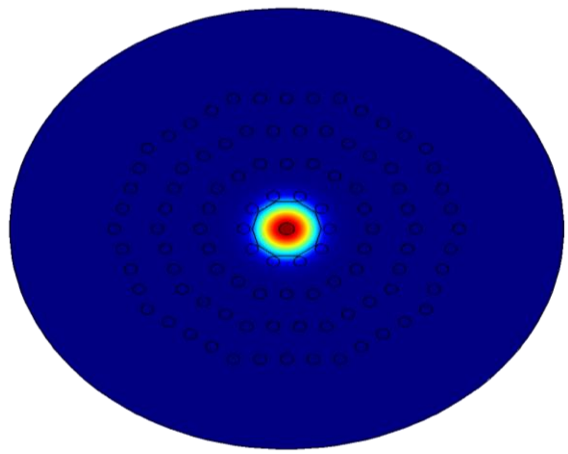

Fig-2: Electric field distribution

This design is simulated in COMSOL Multiphysics simulation tool. Effective refractive index and dispersion are calculated for different pitch values as shown in Table-1 & Table-2 respectively. In this analysis air hole diameter (d) and circular hole diameter (d1) are kept constant and pitch is varied at different values of wavelength.

Effective refractive index and dispersion for different air hole diameter are calculated and mentioned in Table-3 & Table-4 respectively. In this analysis pitch and circular hole diameter (d1) are kept constant and air hole diameter is varied at different values of wavelength.

Table -1: Effective refractive index for different pitch

	d = 0.5μm & d1 = 0.6μm		
	Pitch = 1.5μm	Pitch = 1.75μm	Pitch = 2μm
Wavelength (μm)	η_{eff}	η_{eff}	η_{eff}
1.0	1.4384	1.4483	1.4542
1.1	1.4306	1.4427	1.4504

1.2	1.4258	1.4385	1.4465
1.3	1.4175	1.4324	1.4426
1.4	1.4103	1.4267	1.4386
1.5	1.4021	1.4210	1.4345
1.6	1.3963	1.4166	1.4306
1.7	1.3913	1.4127	1.4283
1.8	1.3869	1.4083	1.4267
1.9	1.3831	1.4039	1.4255
2.0	1.3778	1.3993	1.4245

Table -2: Dispersion for different pitch

	d = 0.5µm & d1 = 0.6µm		
	Pitch = 1.5µm	Pitch = 1.75µm	Pitch = 2µm
Wavelength (µm)	D (ps/nm.km)	D (ps/nm.km)	D (ps/nm.km)
1.2	-600.00	-280.00	20.00
1.3	288.89	173.33	7.22
1.4	127.22	46.67	15.56
1.5	117.50	30.00	20.00
1.6	-134.22	-94.22	-3.56
1.7	-161.75	-111.98	-132.22
1.8	-174.64	-51.43	-157.50
1.9	-184.00	-42.22	-157.55
2.0	-54.20	-22.22	-145.93

Table -3: Effective refractive index for different diameter

	pitch = 2 µm & d1 = 0.6 µm		
	d = 0.4µm	d = 0.5µm	d = 0.6µm
Wavelength (µm)	η_{eff}	η_{eff}	η_{eff}
1.0	1.4551	1.4542	1.4532
1.1	1.4526	1.4504	1.4488
1.2	1.4487	1.4465	1.4451
1.3	1.4455	1.4426	1.4414
1.4	1.4402	1.4386	1.4378
1.5	1.4363	1.4345	1.4342
1.6	1.4312	1.4306	1.4291
1.7	1.4294	1.4283	1.4236
1.8	1.4278	1.4267	1.4191
1.9	1.4263	1.4255	1.4146
2.0	1.4254	1.4245	1.4102

Table -4: Dispersion for different diameter

	pitch = 2 µm & d1 = 0.6 µm		
	d = 0.4µm	d = 0.5µm	d = 0.6µm
Wavelength (µm)	D (ps/nm.km)	D (ps/nm.km)	D (ps/nm.km)
1.2	160.00	20.00	-140.00
1.3	86.67	7.22	-52.00
1.4	45.00	15.56	-37.33
1.5	17.50	20.00	-25.00
1.6	19.11	-3.56	115.00
1.7	-136.75	-132.22	120.00
1.8	-155.36	-157.50	21.86
1.9	-134.58	-157.55	15.13
2.0	-153.33	-145.93	7.41

Graphical representation for Table 1, 2, 3 and 4 is shown in Fig-3, 4, 5 and 6 respectively.

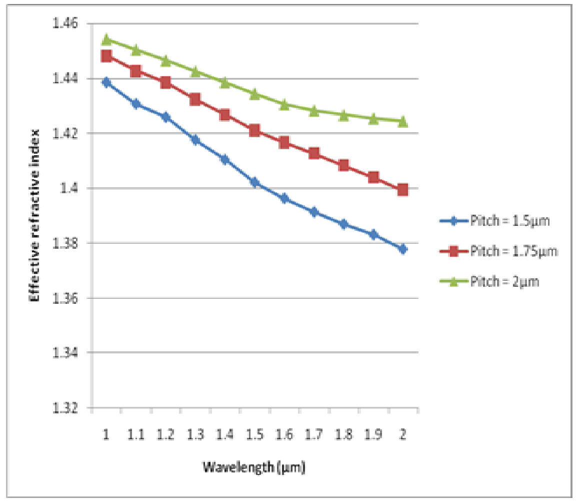

Fig-3: Effective refractive index for different pitch

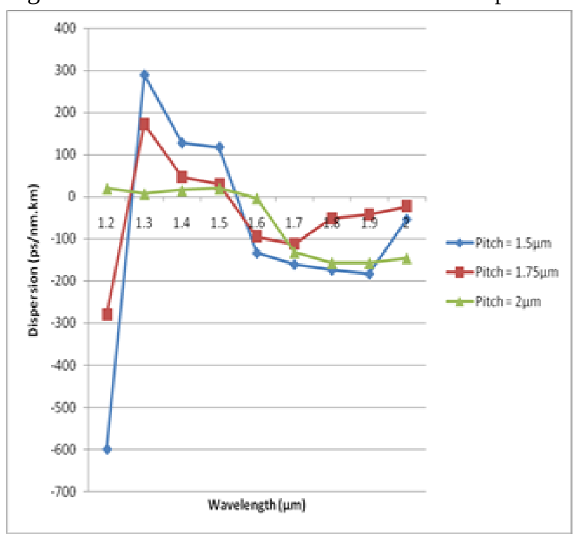

Fig4: Dispersion for different pitch

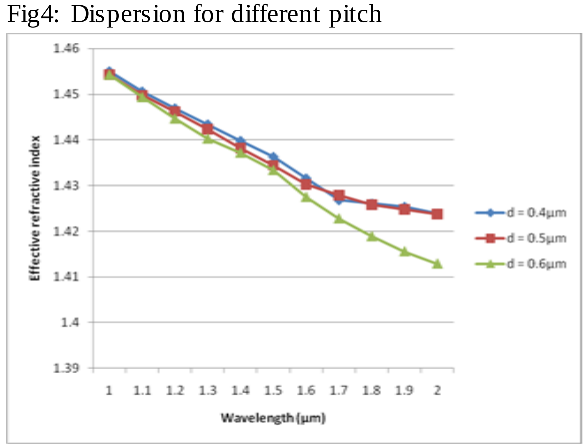

Fig-5: Effective refractive index for different diameter

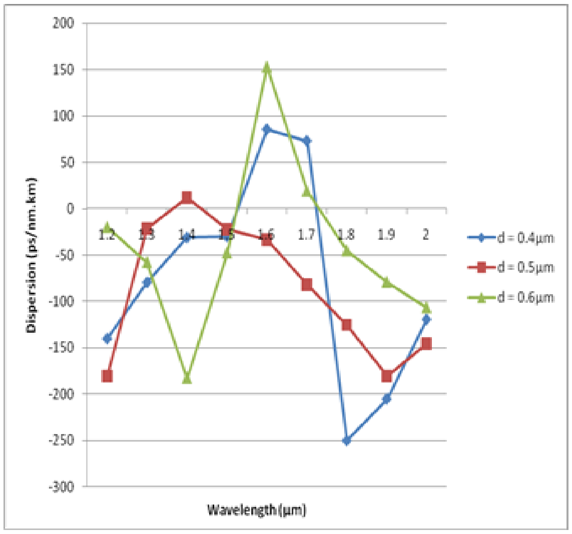

Fig6: Dispersion for different diameter

III. CONCLUSIONS

In conclusion, when we increase the pitch, photonic crystal fiber shows better results i.e. high effective refractive index and low dispersion at different values of wavelength but when we increase air hole diameter keeping pitch constant at 2 µm then effective refractive index decreases and dispersion increases. Best results are obtained for pitch = 2 µm and air hole diameter = 0.5 µm

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