Characterization of Effective Area in FM-MCF with Diverse Liquid Dopants

Anastasia Ivanova[*1], Dmitry Kozlov[2]
***Department of Electronics & Telecommunication, Moscow Institute of Technology, Moscow, Russia.**

ABSTRACT
This paper is the analysis of effective area of the Multicore fiber when the structural parameter like wavelength is varied between 1.32µm to 1.54µm. Different structures of the MCF are used for this analysis viz., hexagonal, octagonal and decagonal structure. The analysis is done by doping few inner ring holes of the MCF with different liquids having refractive index lower than that of the actual core. The software used for this process is COMSOL Multiphysics and the graphs are plotted using MATLAB. It has been noted that by varying structural parameters change in effective area is found.

KEYWORDS: Multicore fibers (FM-MCF), Space Division Multiplexing (SDM), Photonic Crystal Fiber (PCF), Refractive Index (RI), Effective area.

1. INTRODUCTION
With the new technologies emerging and to cope up the demand for larger bandwidth and internet traffic various optical components are leveling up. This includes optical fiber, which has low loss and large capacity transmission and plays the crucial role in communication. It is made up of transparent core, surrounded by a transparent cladding material having lower refractive index [1]. Heterogeneous Multicore fiber (MCF), new type of fiber developed recently solves many limitations caused by the previous optical fibers. The technique MCF uses is Space division multiplexing (SDM) which enhances the capacity of transmission of the fiber [5]. With the help of SDM various signals can be transmitted simultaneously by using multiple spatial paths into the fiber [4]. It has been noted that in the field of MCF work are done on the variation in number of cores, modes and geometrical structures. Likewise, previous work done in Photonic Crystal Fiber (PCF) includes the different materials used to fabricate the core of the optical fiber [12]. Few air holes are replaced with different mediums and the variations are analyzed and discussed [12]. The variations are in the terms of confinement loss, effective area, dispersion etc [18].

In this paper, the holes of the different geometries are initially filled with silica. And then it is compared with holes filled with three different liquids having refractive indices lower than that of the core material. These liquids used are ethanol (refractive index (n)=1.361), diethyl ether (refractive index (n)=1.3526), and water (refractive index(n)=1.333) considering few parameters to be constant such as humidity, atmospheric temperature and pressure [12]. Only few holes are selected because the large amount of these liquids may turn core into the cladding [12].

2. OBJECTIVES
The major objective of this paper is to analyze the effective area of hexagonal, octagonal and decagonal structured MCF. It is done by varying the structural parameters like diameter of hole (d), pitch length (Λ) and wavelength (λ).

3. GEOMETRICAL STRUCTURE
The proposed MCF structures are designed in COMSOL Multiphysics. The background material used is silica, having RI 1.4443. And other holes except selectively filled holes have RI 1.4445. The liquids are filled in the inner ring of the structure. The holes are selected alternatively. Figure 1 shows the mentioned structures with selective holes filled with given liquids i.e. ethanol, water and ether.

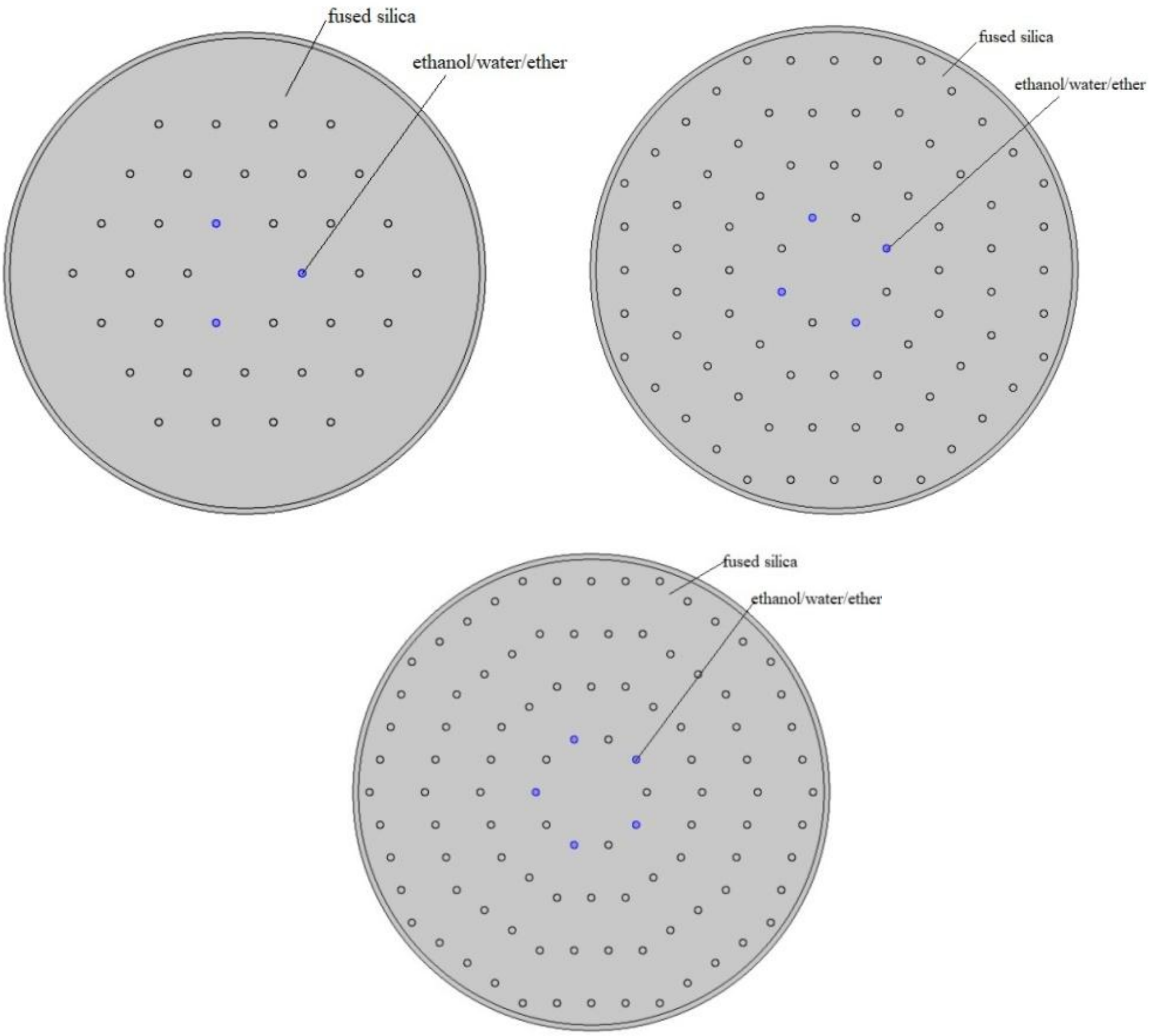

Figure 1: Hexagonal Structure Figure, Octagonal Structure and Decagonal Structure.

4. RESULTS AND DISCUSSION

Effective Area may be defined as the ratio of electric field of fundamental mode, confined during the propagation in optical link. Effective area is calculated by:

$$Aeff = \frac{|\iint |E|^2 dxdy|^2}{\iint |E|^4 dxdy}$$

where E is the normalized electric field.

***Variation in Effective Area when wavelength is changed in**:*

- ***Hexagonal structure.***

When the wavelength is varied from 1.32 µm to 1.54 µm, the variation in effective area of hexagonal MCF is nearly constant and not has slope for each liquids. The figure 2 shows the changes in the form of graph and table 1 show the values obtained through simulations.

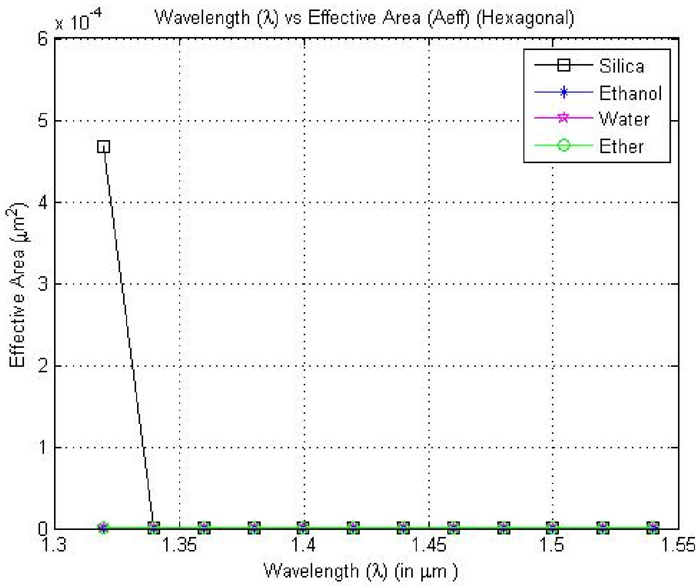

Figure 2: Graph plotted for wavelength vs effective area for hexagonal MCF.

lambda	Aeff(Silica)	Aeff(Ethanol)	Aeff(Water)	Aeff(Ether)
1.32	0.000467	5.3867E-10	5.525E-10	5.43E-10
1.34	4.55E-10	5.3855E-10	5.525E-10	5.43E-10
1.36	4.56E-10	5.3839E-10	5.524E-10	5.43E-10
1.38	4.58E-10	5.383E-10	5.522E-10	5.43E-10
1.4	4.59E-10	5.3819E-10	5.522E-10	5.43E-10
1.42	4.6E-10	5.3807E-10	5.521E-10	5.43E-10
1.44	4.61E-10	5.3805E-10	5.521E-10	5.43E-10
1.46	4.62E-10	5.3804E-10	5.52E-10	5.43E-10
1.48	4.63E-10	5.3803E-10	5.52E-10	5.43E-10
1.5	4.64E-10	5.3797E-10	5.52E-10	5.43E-10
1.52	4.64E-10	5.38E-10	5.52E-10	5.43E-10
1.54	4.67E-10	5.3806E-10	5.52E-10	5.43E-10

Table 1: Values of Effective Area for Hexagonal Structure

- ***Octagonal Structure***

When the wavelength is varied form given range, from the graph shown in figure 3 it can be seen that silica has highest value of the entire tried medium. And among liquids water has lowest effective area. Table 2 shows the values used for plotting graph given below.

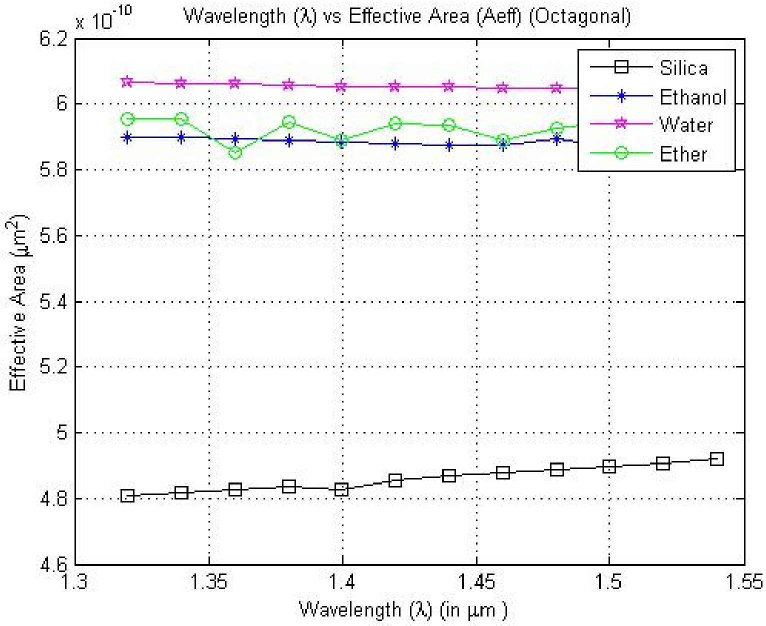

Figure 3: Graph plotted for wavelength vs effective area for octagonal MCF

lambda	Aeff(Silica)	Aeff(Ethanol)	Aeff(Water)	Aeff(Ether)
1.32	4.81E-10	5.90E-10	6.06E-10	5.96E-10
1.34	4.82E-10	5.90E-10	6.06E-10	5.95E-10
1.36	4.83E-10	5.89E-10	6.06E-10	5.85E-10
1.38	4.84E-10	5.89E-10	6.06E-10	5.95E-10
1.4	4.83E-10	5.88E-10	6.05E-10	5.89E-10
1.42	4.86E-10	5.88E-10	6.05E-10	5.94E-10
1.44	4.87E-10	5.88E-10	6.05E-10	5.93E-10
1.46	4.88E-10	5.87E-10	6.05E-10	5.89E-10
1.48	4.89E-10	5.89E-10	6.05E-10	5.93E-10
1.5	4.90E-10	5.87E-10	6.04E-10	5.94E-10
1.52	4.91E-10	5.85E-10	5.99E-10	5.92E-10
1.54	4.92E-10	5.86E-10	6.04E-10	5.92E-10

Table 2: Values of Effective Area for Octagonal Structure

- ***Decagonal Structure***

From the graph shown in figure 4, it can be seen that silica has the highest effective area whereas among liquids, like in octagonal structure water has the least effective area. Table 3 shows the values calculated for plotting the graph mentioned in figure 4.

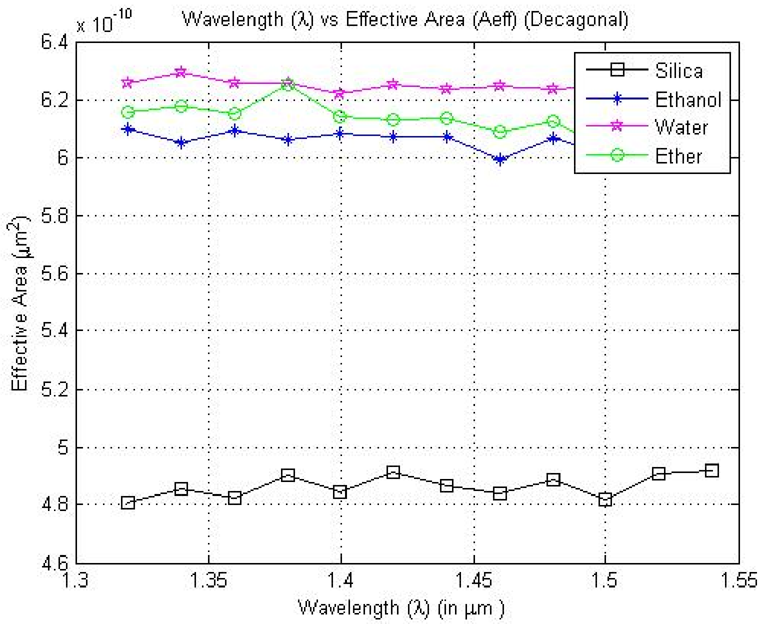

Figure 4: Graph plotted for wavelength vs effective area for decagonal MCF

lambda	Aeff(Silica)	Aeff(Ethanol)	Aeff(Water)	Aeff(Ether)
1.32	4.81E-10	6.0981E-10	6.256E-10	6.15E-10
1.34	4.85E-10	6.052E-10	6.294E-10	6.17E-10
1.36	4.83E-10	6.0899E-10	6.255E-10	6.15E-10
1.38	4.9E-10	6.0608E-10	6.253E-10	6.25E-10
1.4	4.85E-10	6.0809E-10	6.219E-10	6.14E-10
1.42	4.92E-10	6.0735E-10	6.251E-10	6.13E-10
1.44	4.87E-10	6.0726E-10	6.234E-10	6.13E-10
1.46	4.84E-10	5.9934E-10	6.247E-10	6.09E-10
1.48	4.89E-10	6.0645E-10	6.236E-10	6.13E-10
1.5	4.82E-10	6.0155E-10	6.243E-10	6.03E-10
1.52	4.91E-10	6.0575E-10	6.248E-10	6.12E-10
1.54	4.92E-10	6.0531E-10	6.24E-10	6.1E-10

Table 3: Values of Effective Area for Decagonal Structure

5. CONCLUSION

After various simulations and analysis of heterogeneous Multicore fiber (MCF) with different geometries like hexagonal, octagonal and decagonal structures using three different liquid materials viz. ethanol, diethyl ether and water, following conclusions can be drawn out.

- In all the structures, silica has the highest effective area when compared with liquids used.
- Among the liquids used for doping the holes of the MCF of the different geometries, water has the lowest effective area.
- Ethanol tends to have highest effective area when compared among the liquids used.

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REFERENCES

1. Anshu, Mr. Sharad Mohan Shrivastava, Mr. Vikas Sahu, August (2017), International Science Community Association Research Journal on Engineering Sciences, Research Paper- "MODELING OF CAPACITY ENHANCEMENT OF HETEROGENEOUS FEW MODE MULTI-CORE FIBER", ISSN - 2278 - 9472, Volume 6(7).

2. Jun Sakaguchi, B. J. Puttnam, Y. Awaji, T. Nakanishi, T. Watanabe, T. Takahata, (2015), Journal of Lightwave Technology, “LARGE SPATIAL CHANNEL (36-CORE × 3 MODE) HETEROGENEOUS FEW-MODE MULTI-CORE FIBER
3. K. Saitoh, S. Matsuo (2013), Nanophotonics 2.5-6:441-454, “MULTICORE FIBERS FOR LARGE CAPACITY TRANSMISSION”
4. K. Saitoh, S. Matsuo (2016), Journal of Lightwave Technology, vol. 34, “MULTICORE FIBER TECHNOLOGY”
5. M. Koshiba, K. Saitoh and Y. Kokubun, (2009), IEICE Electronics Express, Vol.6, No.2, 98-103, “HETEROGENEOUS MULTICORE FIBERS: PROPOSAL AND DESIGN PRINCIPLE
6. Shoichiro Matsuo et al. (2016), Journal of Lightwave Technology, Vol. 34, No. 6, “HIGH-SPATIAL-MULTIPLICITY MULTICORE FIBERS FOR FUTURE DENSE SPACE-DIVISION-MULTIPLEXING SYSTEMS”
7. Nirmala et al. (2017), BITCON, “SIMULATION OF SPATIAL MULTILICITY ENHANCEMENT FOR DENSE SPACE DIVISION MULTIPLEXING”
8. Yusuke Sasaki et al. (2015), Journal of Lightwave Technology, Vol. 33, No. 5, “FEW MODE MULTICORE FIBER WITH 36 SPATIAL MODES (THREE MODES (LP_{01}, LP_{11a}, LP_{11b}) ×12 CORES)”
9. Priyanka Arora, Mayank Joshi (2015), IJETR, Vol.3, Issue-12, “COMPARATIVE STUDY OF H-PCF STRUCTURE ON DISPERSION AND CONFINEMENT LOSS AT DIFFERENT PITCH OF AIR HOLES”
10. Sakhi Gopal Panda, Aakash Joshi, Vikas Sahu (2018), i-manager’s Journal on Electronics Engineering, Vol.8, No.4, “ANALYSIS OF SELECTIVELY FILLED ETHANOL HOLES IN OCTAGONAL RING OF PHOTONIC CRYSTAL FIBER”
11. A. Joshi et al (2017), i-manager’s journal on Electronics Engineering, Vol. 7, No. 4. 7-13, “MODELING OF HEXAGONAL AND OCTAGONAL PHOTONIC CRYSTAL FIBER”
12. S. G. Panda, A. Joshi, V. Sahu (2018), i-manager’s Journal on Wireless Communication Networks, Vol.6, No.4, “COMPARATIVE ANALYSIS OF CONFINEMENT LOSS AND DISPERSION FOR H-PCF STRUCTURE DOPED WITH SPECIFIC LIQUIDS”
13. S. M. Abdur Razzak et al (2007), Journal of Microwaves, Optoelectronics and Electromagnetic Applications, 6(1), 44-49, “GUIDING PROPERTIES OF A DECAGONAL PHOTONIC CRYSTAL FIBER”
14. A. Joshi, S.M. Shrivastava, V. Sahu (2017), National Conference on Research Challenges in Science, Technology and Management for National Development, BITCON-2017, “SIMULATION OF VARIOUS STRUCTURES OF PHOTONIC CRYSTAL FIBERS”
15. Anshu, Mr. Sharad Mohan Shrivastava, Mr. Vikas Sahu, (March - May 2017), i-manager's Journal on Electronics Engineering, Research Paper- "SIMULATION OF HETEROGENEOUS FEW MODE MULTI-CORE FIBER FOR CAPACITY ENHANCEMENT", ISSN - 2229 - 7286, Volume - 7, No. - 3.
16. Y. E. Monfared et al. (2013), Optik 124 (2013) 7049– 7052, “CONFINEMENT LOSS IN HEXAGONAL LATTICE PHOTONIC CRYSTAL FIBERS”
17. E. K. Akowuah et al. (2012), IEEE 4th ICAST, 114-120, “DESIGN AND ANALYSIS OF PHOTONIC CRYSTAL FIBERS FOR BROADBAND APPLICATIONS”
18. J. Sheng Chiang et al (2006), Optics Communications, 2589(2), 170-176, “ANALYSIS OF PROPAGATION CHARACTERISTICS FOR AN OCTAGONAL PHOTONIC CRYSTAL FIBER”
19. Philip St J Russell (2006), Journal of Lightwave Technology, Vol. 24, No. 12, 4729-4749, “PHOTONIC-CRYSTAL FIBERS”
20. Aakash Joshi et al. (2016), i-manager’s Journal on Electronics Engineering, Vol. 7, No. 1, “MODELING OF POLARIZATION FILTER BASED ON PHOTONIC CRYSTAL FIBER USING SURFACE PLASMON RESONANCE: A REVIEW”