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اثر تغییر در پارامترهای مؤثر بر اتلاف حبسی در فیبرهای کریستال فوتونی

مریم حسین پور و اکبر زنده نام

دانشکدهٔ فیزیک، دانشگاه اراک

چکیده – در این پژوهش ، تأثیر افزایش تعداد ضلع در ناحیهٔ غلاف (از چینش مربعی تا آرایش نه ضلعی) ،اثر افزایش تعداد حلقه های هوا و همچنین تغییر در طول موج مخابراتی به کار گرفته شده بر اتلاف حبسی به ازای مقادیر بالای کسرپرشدگی بررسی شده اند . نتایج نشان می دهند افزایش بیش از حد تعداد ضلع در ناحیهٔ غلاف نمی تواند سودمند باشد زیرا منجر به افزایش اتلاف می شود. همچنین ، افزایش کسرپرشدگی ، مقادیر اتلاف را در تمامی چینش های مفروض به طور قابل ملاحظه ای کاهش می دهد.

کلید واژه – اتلاف حبسی ، تعداد حلقه های هوا، تعداد ضلع در ناحیهٔ غلاف ، مقادیر بزرگ کسرپرشدگی

The Influence of Variation in Effective Parameters on Confinement Loss In Photonic Crystal Fibres

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Abstract: In this research , the impressions of both rising the number of edges in cladding region (from square – lattice up to Nano structure) and the number of air rings as well as variation in the used telecomm wavelengths on the confinement loss for large amounts of air-filling fraction are studied . The achievements show extra increasing the number of edges cannot be beneficial so that it raises the loss. Also, it is obtained that the increment of the air – filing fraction can reduce and revise the amount of loss considerably for all considered structures.

Keywords**:** confinement loss, large air – filing fraction (d/Λ) values, number of air rings, number of edges in cladding region confinement loss

1 Introduction

Photonic crystal fibres (PCFs) are an innovative class of fibres which express unique characteristics [1, 2] in comparison with conventional fibres and are classified according to their core which is air or silica.

It is possible to promote the facilities of PCFs in aspect of delivery intensity with the least amount of loss by changing the diameter of air holes (d) or the constant lattice (Λ) which result in the variation in the effective index (n_{eff}) .

It is important to examine the performance of PCFs with various configurations when other effective parameters like air-filling fraction (d/Λ), the number of air rings (N) as well as the employed wavelength (λ) are varied.

Since the inspection of variation in the PCF ' configuration is so complicated, researchers have often tried to focus on studying only one or two usual structures [3, 4, and 5].

Loss in PCFs occurs because of such reasons as intrinsic material absorption loss, structural imperfection loss, Rayleigh scattering, confinement loss (CL), etc. [6]. Confinement loss is an additional form of loss that occurs in single-material fibers. PCFs are usually made from pure silica; hence, the guided modes are inherently leaky because the core index is the same as the index of the outer cladding without air holes.

Indeed, CL happens since the number of air rings in cladding region cannot be endless.

According to [6], it is obtained that rising the number of air rings reduce amount of loss exponentially.

In our early work on PCFs, the confinement loss and group velocity dispersion (GVD**)** of two types of MOFs against wavelength were investigated. As far as we know, most of previous and recent articles have been investigated the influences of changing the air-filling fraction or the number of air rings on confinement loss while the configuration type of the PCF has been supposed to be one specific structure. However, in this study, we used the COMSOL Multiphysics v3.4 software to simulate different air-hole designs of the PCF (the PCF with square-lattice up to the PCF with Nano structure) and to calculate the values of confinement loss under diverse conditions including various amounts of d/Λ, N as well as λ. Finally, the CL plots as a function of the number of edges in the cladding region are depicted.

2 Results and discussions

According to [7], confinement loss can be calculated by Equation (1):

$$L_c = 8.686\, k_o\, Im[\, n_{eff}\,] \qquad (1)$$

where L_c signifies confinement loss, Im [n_{eff}] is the imaginary part of effective mode index and $K_0 = 2\pi/\lambda$. All results are classified into four sections.

2.1 The influence of the increment in the number of edges

As mentioned, we simulated six various air-hole arrangement of PCF which commences from the PCF with square-lattice and carried on up to the PCF with Nano structure. For instance, the cross section of the PCF with Nano configuration is shown in Fig.1.

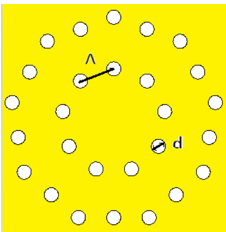

Fig.1. the cross-section of the solid core PCF with Nano structure of air-holes (nine edges) in the cladding region

Fig.2 summarizes the relationship between the C.L and the number of edges in the cladding when N= 4, for large d/Λ values (d/Λ= 0.5, 0.6, 0.7, 0.8) and λ = 1.35, 1.55, 1.65μm.It should be noted when d/Λ = 0.7 and 0.8, respectively, we enconter the tangentional or intersected air holes in the cladding region of the PCFs with square-lattice or pentagonal desgin (see Fig.3).

Fig.3 indicates obviously to the fact that makes us ignore the investigation of the PCFs with these structures when d/Λ is greater than 0.6.

According to Fig.2 , It is evident that for each of the supposed value for d/Λ , by increasing the number of edges (moving towards such PCFs with more edges like Nano-lattice) , the amounts of loss rise at the two long studied wavelengths (λ = 1.55, 1.65μm) .It can be due to in configurations with more edges in the cladding, not only the diameter of air holes (d) but also the hole pitch (Λ) reduce together. In other words, in these structures, the parameter d becomes smaller than the employed wavelength, especially when λ = 1.55 and 1.65μm.

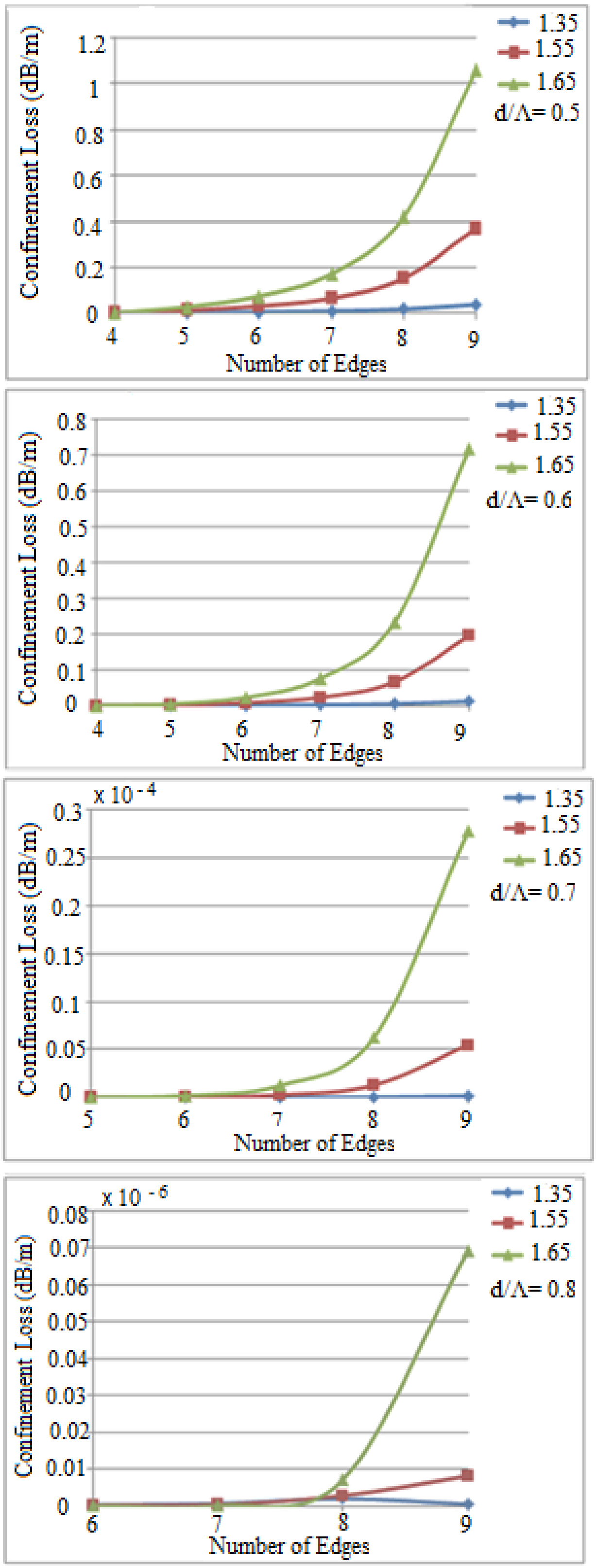

Fig.2 Plots of C.L as a function of the number of edges when N = 4 for various d/Λ

2.2 The effect of the rise in the air – filing fraction

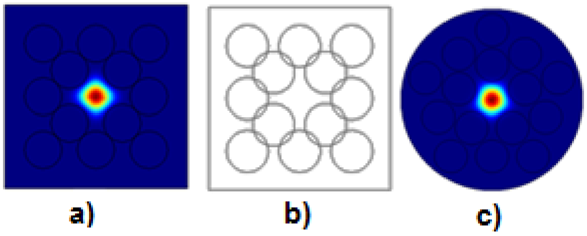

Fig.3 The 2D (two dimensional) intensity distribution of PCFs with square and penta – lattice while a) d/Λ= 0.7, b) and c) d/Λ = 0.8, respectively

Fig.2 shows that increasing the parameter d/Λ from 0.5 to 0.8, which results from the rise in the diameter of air holes, can be so influential in decreasing the amount of loss in all of the considered PCFs.

It can be due to when the diameter of air holes are increased , especially in structures with more edges , it causes the mode field to confine and trap completely in the core , hence, the amount of loss reduces . Indeed, rising the diameter of air holes, particularly when the PCFs with more edges are employed (the PCF with heptagonal design up to the PCF with Nano-lattice), can improve the performance of these fibers in aspect of achieving the least amount of loss.

2.3 The impression of the variation in the employed wavelength

Fig.1 indicates that when used wavelength is varied from 1.35μm to 1.55 or 1.65μm (λ > 1.35μm), the rise of the number of edges increases the amount of loss noticeably.

In fact, when λ = 1.35μm (the least assumed value of wavelength), as can be seen in Fig.2, the plots of C.L against the number of edges express nearly the linear behavior, for all of the considered configurations. Moreover, all of the supposed structures show the least loss (0 dB/m) at λ = 1.35μm, hence, this wavelength is suitable for performing all of the studied PCFs even when d/Λ = 0.5.

However, while larger values are opted for wavelength (λ= 1.55μm or 1.65μm), the plots of C.L against the number of edges illustrate the exponential behavior.

Also, for each of the large d/Λ values, the maximum amount of loss belongs to the longest used wavelength (λ = 1.65μm).

2.4 The effect of the rise in the number of air rings

In order to investigate this effect, the number of air rings (N) are increased from N= 4 to N= 6 while d/Λ = 0.5 and λ = 1.55µm.

In Fig.4, the plots of the C.L as a function of the number of edges are shown.

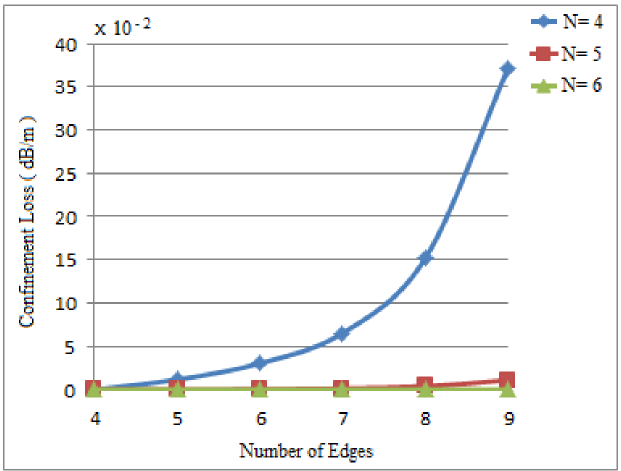

Fig.4 Plots of C.L against the number of edges for d/Λ = 0.5 at λ = 1.55µm

By comparing the results in Fig.2 with the results in Fig.4, It is evident that increasing the number of rings causes the amount of loss to reduce considerably to the minimum amount (0 dB/m) in all of the considered PCFs (from square-lattice up to Nano structure.

As can be seen in Fig.4, when the number of air rings are risen even to N= 5 (or N= 6), the plot of C.L demonstrates the linear behaviour as a function of the number of edges.

Indeed, when d/Λ = 0.5, even five number of air rings (N= 5) is sufficient to achieve the minimum value of loss (0dB/m).

It should be noted that our results cannot be comparable to the other works [4, 7], since they have used a special arrangement for their optical fibers (a PCF with square-lattice or hexagonal configuration).

3 Conclusion

In this work , the influences of the increment in the number of edges (from the PCF with square-lattice up to the PCF with Nano – lattice) , also, the rise in the parameters air – filing fraction and the number of air rings as well as the effect of variation in the employed wavelengths (λ = 1.35,1.55,1.65µm) are investigated .

It is obtained that the rise in the number of edges increase amount of loss at the long used wavelengths (λ = 1.55µm and 1.65µm) . On the contrary, at λ= 1.35µm, all of the studied PCFs show 0 dB/m.

Also, it can be inferred that rising d/Λ can reduce C.L noticeably but extra increment of the diameter of air holes cannot be beneficial because it makes some common and favourite configurations (square and pentagonal structures) to remove.

Moreover , when d/Λ= 0.5 , five rings of air holes (N=5) are enough to achieve the least amount of loss (0 dB/m) . Hence, rising the number of air rings to N=5 or 6 can be more suitable for deceasing the C.L since it provides the possibility of employing the PCFs even with square or pentagonal structures when d/Λ = 0.7 and 0.8.

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