Analysis of Overcoming Independent Core Light Propagation in Multicore Photonic Crystal fibers with Non-identical Cores Coupling

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Abstract

Multicore photonic crystal fibers with non-identical cores are analyzed numerically using Comsol Multiphysics software. Anisotropy in all cores diameters of multicores photonic crystal fibers leads to different coupling behavior. Such anisotropy causes suppressed the coupling between the core modes at some wavelengths. Then the core modes become uncoupled, and this leads to the light mode propagate independently of their neighbors, by increasing the wavelengths, possibly overcoming this problem. These properties could be a novel candidate for multiplexer and demultiplexer applications.

1. Introduction

Recently, developments have revealed that multicore photonic crystal fiber (MCPCF), which has attracted interest from researchers for the flexibility of its design, uncomplicated manufacturing process [1]. And many research interests are shown towards MCPCF, such as couplers [1, 2], splitter [3], and multiplexer-demultiplexer MUX-DEMUX [4]. Generally, one can happen the difference between the diameters of the cores of MCPCF and become non-identical; this leads to unequal power distribution in each core.

In our study, we have numerically investigated the possibility of designing to overcome on the decoupler. And suppression between mode cores in non-identical MCPCF structure.

2. Theory and Design methodology

We start our analysis by designing a seven-core as MCPCF system, see Fig. 1. We suppose that the propagation constant of each core is β_0 , the coupling coefficient between different cores is κ_{0n} and U_0 is the local modal field amplitude in the MCPCF coupled system, can describe as [4, 5]:

$$i\frac{dU_0}{dz} + \beta_0 U_0 + \kappa_{0n} \sum_{n=1}^{6} U_n = 0 , \qquad (1)$$

By entering a gauge, transformation $U_n = u_n \exp(i\beta_0 z)$ is the eigenvalue equation. The coupling coefficients κ_{0n} between the mode 0 and *n*, when the diameter of the neighbor cores are changed relative to the central core diameter that represents as (0), can describe in Equation (2). The normalized index difference is $\Delta_n = (n_{1,n} - n_{2,n}) / n_{1,n}$, where the refractive indices of the core and cladding are $n_{1,n}$ and $n_{2,n}$, the dimensionless *V* number for the central core is $V_0 = k_0 R_0 n_{1,0} \sqrt{2\Delta_0}$ core $W_0 = R_0 (\beta_0^2 - k^2 n_{2,0}^2)^{1/2}$,
$U_0 = R_0 (k^2 n_{1,0}^2 - \beta_0^2)^{1/2}$
$\overline{W}_0 = W_0 R_n / R_0$. $I_n(x)$ and $K_n(x)$ represent the modified Bessel functions of the first and second kind, the D_{0n} is the distance between the core centers for *0* and *n*, R_0 are the core radii., and k is the free-space wavenumber.

$$\kappa_{0n} = (2\Delta_n)^{1/2} \frac{U_0 U_n}{R_0 V_0} \times \frac{K_0(W_0 D_{0n} / R_0)}{K_1(W_l) K_1(W_m)} \times \frac{\overline{W}_0 K_0(W_n) I_1(\overline{W}_0) + W_n K_1(W_n) I_0(\overline{W}_0)}{\overline{W}_0^2 + U_n^2} , \qquad (2)$$

3. Discussion

To illustrate our method by introducing anisotropy in all seven-core diameters, such as *3.2um*, *3.47um*, *3.48um*, *3.49um*, *3.5um*, *3.51um* and *3.52um*. The structural parameters are the hole diameter d=*4.48um*; the pitch is *Λ=5.6um*, core separation D= 2Λ, and the refractive indices for core and cladding 1.45and 1.4, respectively, see Fig. 2. (a) at the wavelength *1.064um* and When increasing the wavelength to *1.55um*, see Fig. 2. (b). The results showed that the anisotropy in cores diameters, leads to a small mode mismatch, and in turn, impedes the coupling between these cores, the cores become independent of light propagation of their neighbors. Increasing the wavelength to *1.55um*, we found that the coupling efficiency improves, where the coupling occurs between two cores with a little penetration to other cores. Otherwise, each core remains independent of its neighboring.

4. Conclusions

The significant effect of anisotropy in all core diameters of MCPCF is a mode mismatch, which in turn, impedes the coupling between these cores, such that the cores become independent of their neighbors. By increasing the wavelength, it is possible to overcome the problem of suppression of coupling between cores, even if all cores with different diameters; these results may be useful in applications, such as multiplexing, and demultiplexing.

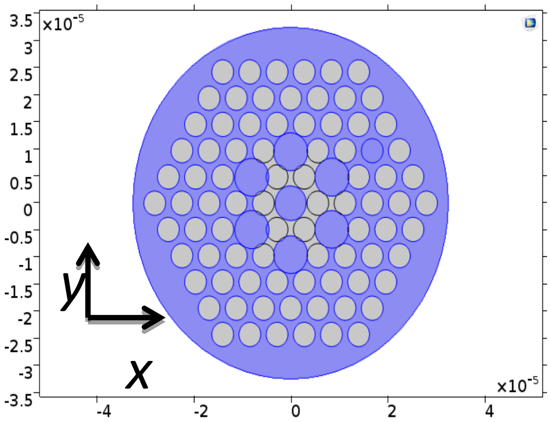
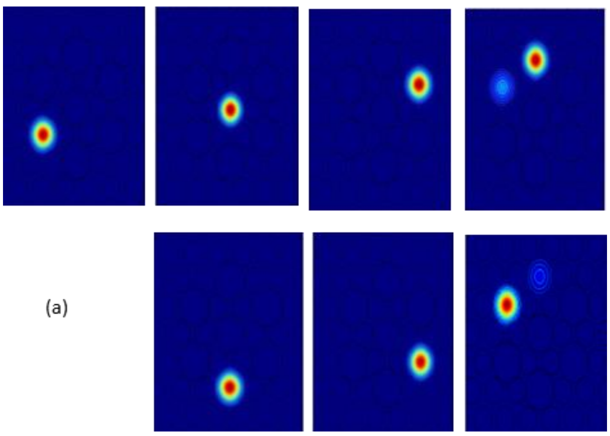
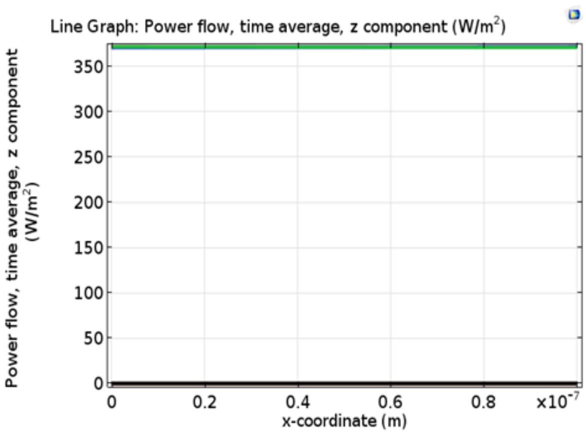
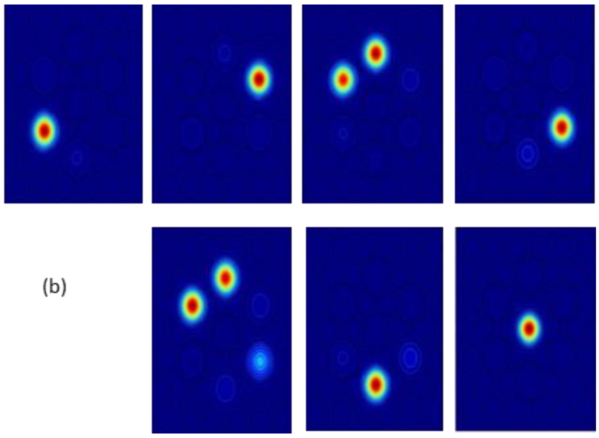


Figure 1: Cross-section of seven-core PCF with five-ring hexagonal lattice modeled using COMSOL MULTIPHYSICS software-based finite element method







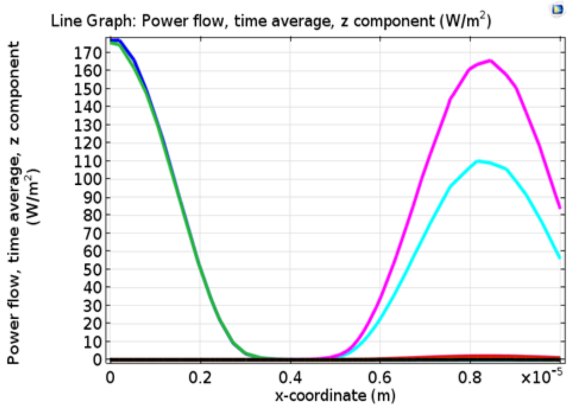


Figure 2: Distributions of the unique power for the seven-core with different wavelengths, such as *1.064um* (a) and 1.55um (b).

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