COUPLING CHARACTERISTICS OF MULTI-CORE PHOTONIC CRYSTAL FIBERS

م . د. ميامي عبد اللطيف محمد
م. لمياء علي لطيف

1. Introduction

Coupling characteristics of two-core photonic crystal fiber are analyzed using COMSOL MULTIPHYSICS software that depended on the finite element method. The effective mode indexes, the electric field distributions, and the coupling length for different geometrical designs evaluated. The results show the coupling length dependence the wavelengths to realize significantly short coupling lengths of two-core photonic crystal fiber in um at the telecom wavelength 1.55um and 1.31um compared with the traditional fiber coupler. The geometrical parameters of two-core photonic crystal fiber play an essential role in the dependence of the mode characteristics between cores of a photonic crystal fiber coupler, such as the hole diameter, hole pitch, air- filling fraction, and core separation. Increasing the core separation leads to a drastic reduction in the coupling strength between the cores of photonic crystal fiber or may lead to suppression of the coupling between the cores of photonic crystal fiber. Our proposed is an excellent device for the coupler, and power splitter, multiplex and de-multiplex applications.

2. Design methodology

Photonic crystal fiber coupler consists of two identical cores of PCF, and these cores are placed close to each other with cores separation in (um). The light guides via one of two cores so that they can exchange energy with each other by the excitation of the evanescent part of the fundamental modes of each guide during the propagation [6, 12]. These evanescent modes depended on the wavelength, which is used [12]. The structural parameters are the hole pitch Λ=4 um, hole diameter d=1.16 um, the air-filling fraction is d ⁄Λ=0.29, and core separation D=3 um at the wavelength λ=1.55um, respectively. The refractive index of the core 1.45 is slightly larger than the refractive index of the cladding 1.4, modeled to the light guiding by total internal reflection mechanism (MTIR) between the cores and the cladding region. Fig.1 shows the designer by using COMSOL MULTIPHYSICS software-based FEM with a perfectly matched layer (PML) as a boundary.

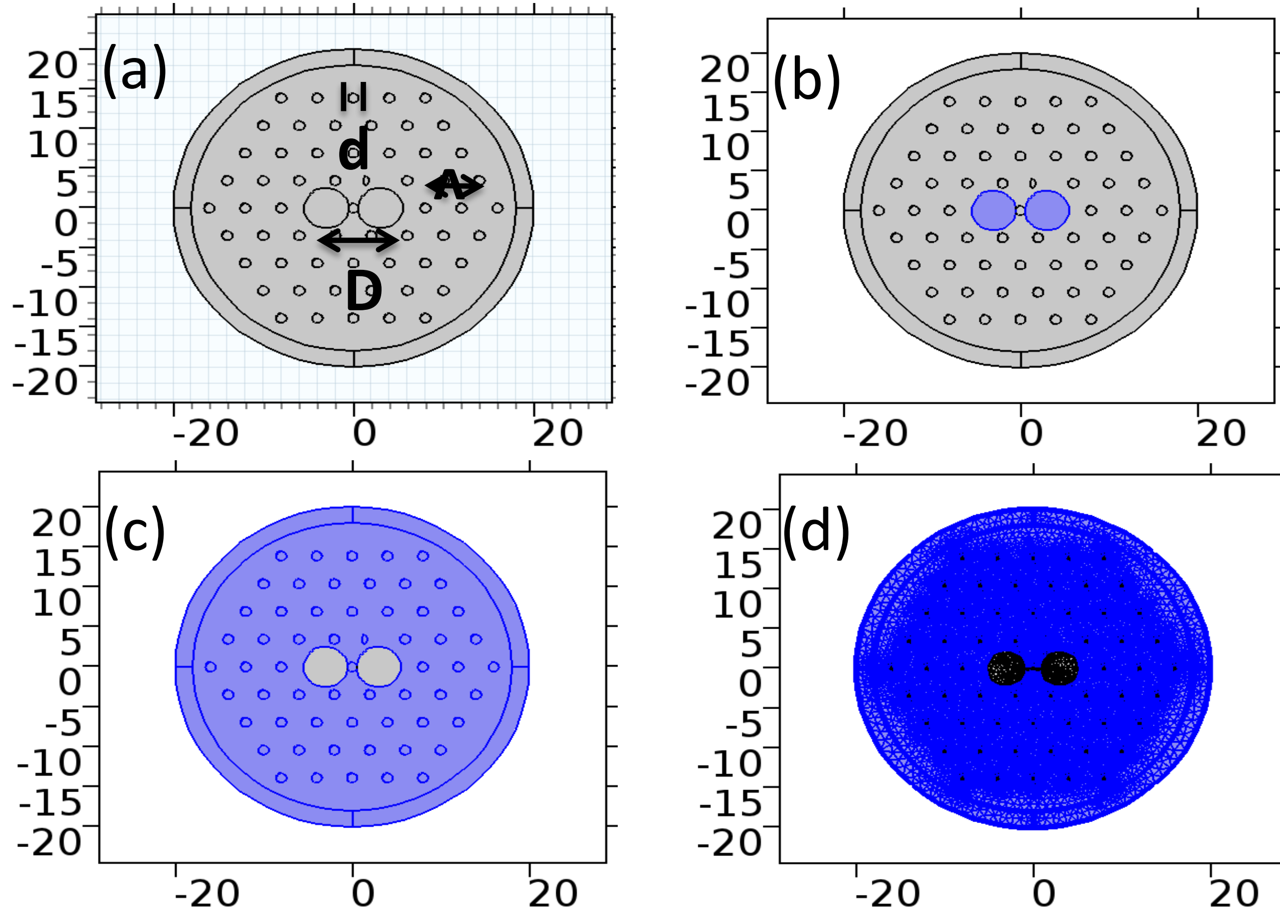


Fig 1. Cross-section of two-core PCF coupler. The geometry of PCF design characterized by the structure parameters, such as the core diameter=5um, the hole pitch Λ=4 um, hole diameter d=1.16 um, the air-filling fraction d /Λ=0.29, and core separation D=3 um, at the wavelength λ=1.55um, respectively (a). Insert cladding material (b), Insert core material (c), Mesh triangular finite element (d).

3. Supermode theory

According to the supermode theory, that depends on mode coupling, there are four modes with different propagation constants; either two modes propagate with the same phase called even (symmetric) modes. Or two modes propagate with a different phase called odd (anti-symmetric) modes along x-and y-polarization fields [3, 9]. The coupling length (L_c) can describe as the single power exchanged between two cores; as a result, the weak overlap of the adjacent electric field. A part of the light is confined into one core, then transfer to the other core after propagation distance called coupling length. As a result of the difference in propagation constants of even and odd modes and their refractive indexes shown in equation (1). The coupling length determined as bellow [3, 5, 8, 12]:

$$L_c = \frac{\pi}{\beta_{even} - \beta_{odd}} = \frac{\lambda}{2(n_{even} - n_{odd})}$$

$$\kappa = \frac{\pi}{2L_c}$$

The coupling coefficient relates to coupling length

4. Simulation results and discussion

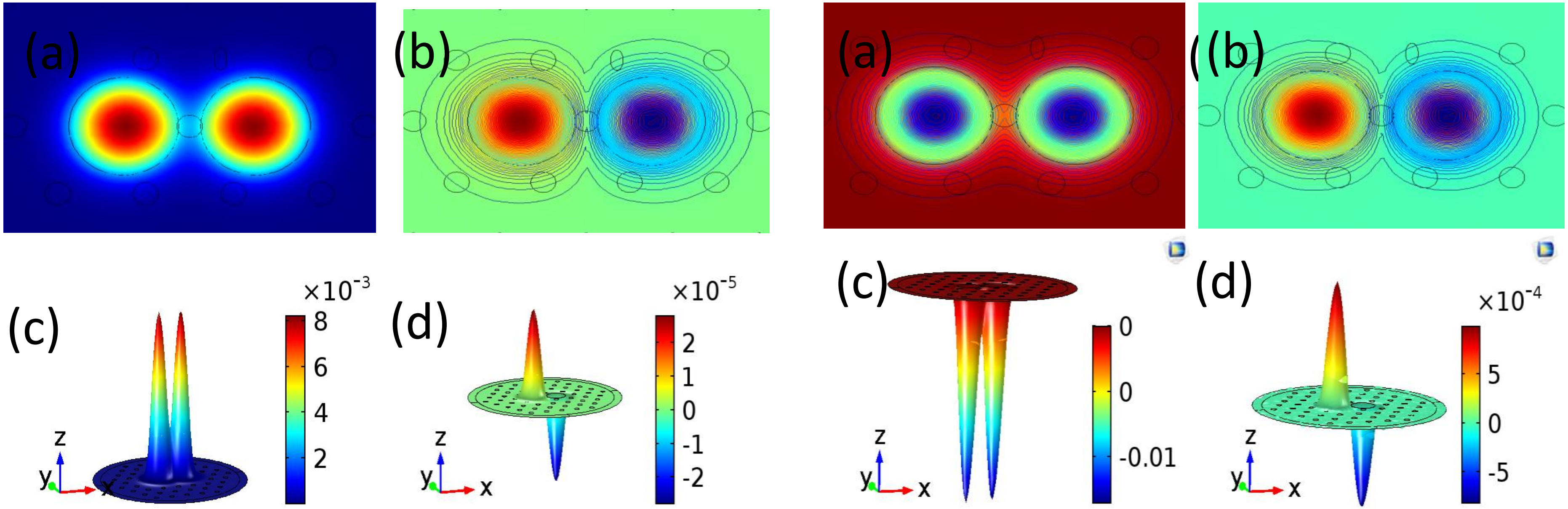
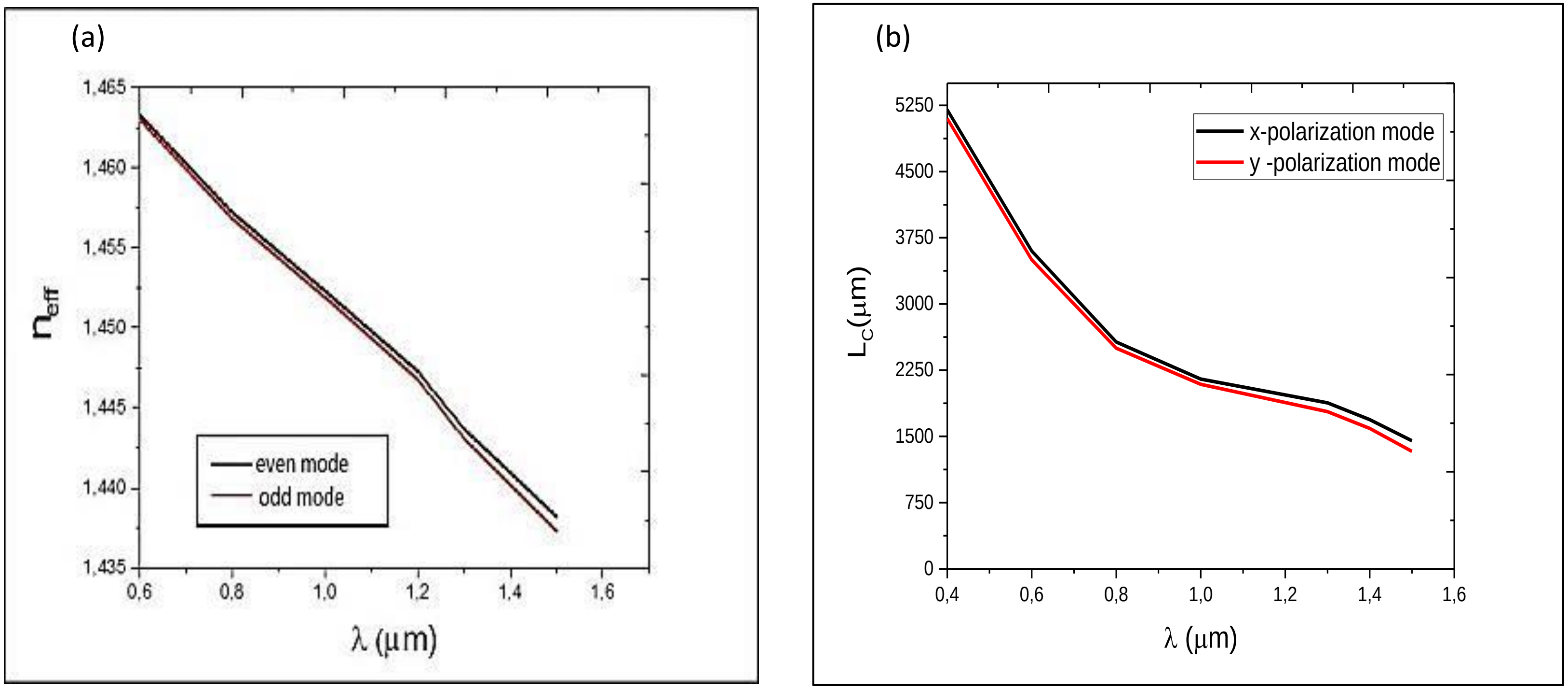


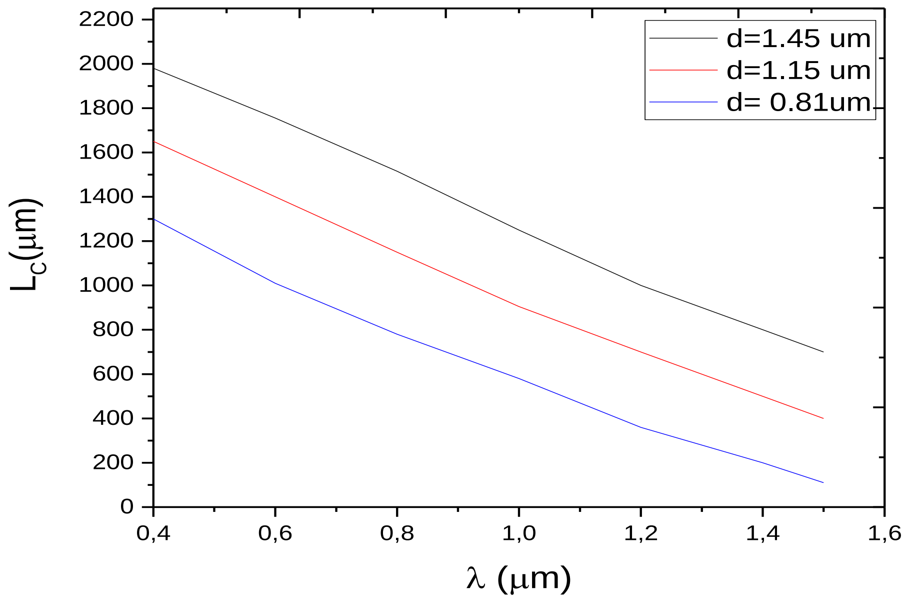
Fig 3. A cross–section of two–core PCF represents the even supermodes in (a) and odd supermodes in (b) of the electric field distributions along the x-polarization field in (a and b), the profile of the electric field for even and odd supermodes along the x-polarization field in (c and d) at wavelengths 1.55 *u*m (left) and 1.31*u*m (right).

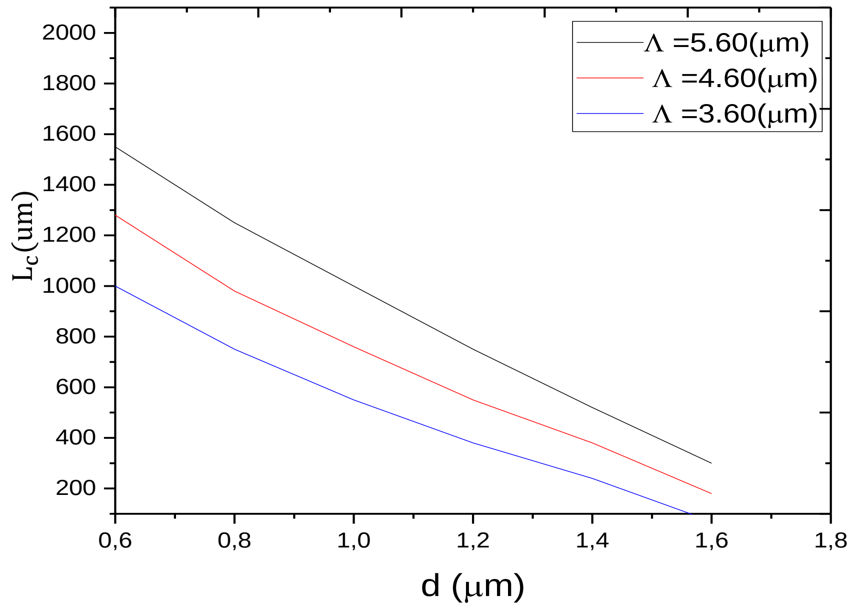
The effective mode indexes along the x-polarized field are for even and odd modes 1.4382 and 1.4375 and for the 1.55um. Moreover, for the wavelength 1.31um are 1.4409 and 1.4406. Then, the difference in the effective refractive index for even and odd modes are 0.0007 and 0.0003, and coupling lengths are L_c =1,107um and 2166um for the wavelength 1.55um and 1.31um. It is possible to design multicore PCF coupler with the coupling lengths of (um) much shorter than the traditional optical fiber couplers in (mm), which could be useful for multiplexer-demultiplexer .



The sudden decrease in the coupling length with increased the wavelengths, this can attribute to the material dispersion of silica glass, which plays an essential role in evaluating the difference between the effective refractive index of the even and odd modes.

5. Effect of the geometricalparameters of the two-core PCF on the coupling length

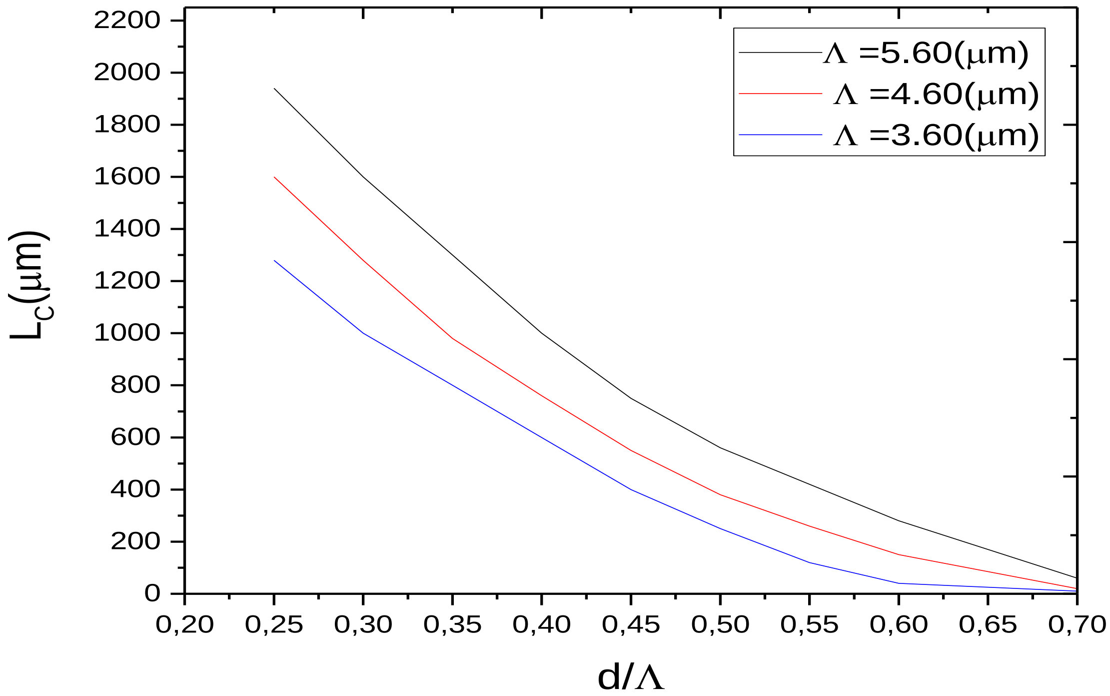




To investigate the influences of the geometric structural parameters of two-core PCF on the coupling length.

- **By increasing the hole diameter, the coupling length L_c increased, as a resulte in a decrease in the difference between even and odd modes**

- **Increase in hole diameter for different hole pitch (Λ), and this corresponds to the rise of the core radius. large hole diameter is more likely to decoupling because the mode confined to one of the cores. Therefore, the coupling length decreases with the hole diameter increasing**

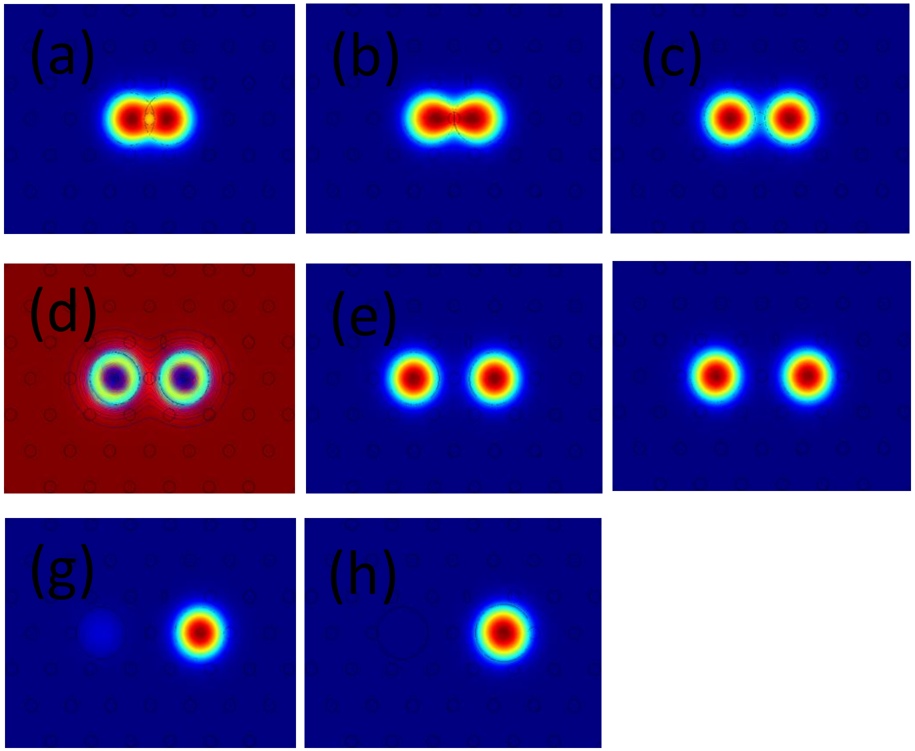


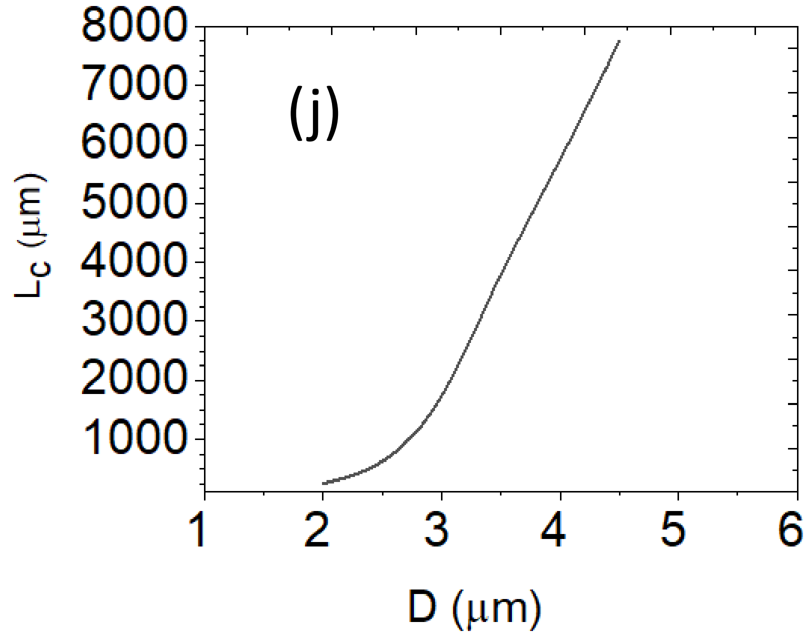
- **With decreasing the air–filling fraction d/Λ or increasing of the hole pitch Λ, the coupling length L_c increaseed. Show that the coupling length becomes less than 1000 um at increasing the value of air–filling fraction d/Λ to greater than 0.4. The structure becomes multimode.**

While decreasing the value of air–filling fraction d/Λ to less than 0.4 into the endlessly single-mode regime, the structure a single-mode will realize.

Therefore, changes in d/Λ of multicore PCF appear coupling lengths extremely low, and the mode field area becomes more extensive.

Core separation





At wavelength 1.55um

The coupling strength between the two-core PCF coupler is strong at small cores separation as 2um (coupling length is 203.94 um), and reduce or suppression when increased the core separation as 4.5 um (the coupling length increased to 7750 um). Or 5 um, and 5.5 um, the coupling length id suppression.

Conclusions

- Coupling characteristics of a two-core PCF have been numerically analyzed with different designs using COMSOL MULTIPHYSICS software-FEM

- The study aimed to show it is possible to design a two-core PCF coupler with different wavelengths as 1.55um and 1.31um to realize short coupling lengths in (um) are much shorter than the optical fiber couplers that have designed with the coupling lengths in several tens of (mm).

By changing the geometrical parameters of the PCF coupler, such as the hole diameter, hole pitch, air–filling fraction d/Λ. These characteristics of multi-cores PCF couplers have potential in several applications such as:
Multiplexer-Demultiplexing, Wavelength division mode system (WDM), Coupler, Polarized splitter.

By changing the core separation between two cores leads to reduce in the coupling strength then the coupling suppression between them.

- This result give us possibly for designing coupling lengths short or considerable of PCF coupler to the decrease or increase of the rate of data transmitted in close or in far distance telecommunication.

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THANK YOU FOR ATTENSION