معرض الابتكارات العلمي الثالث (2021) دائرة الرعاية العلمية - وزارة الشباب والرياضة

Numerical investigation of light propagation in photonic crystal fiber

براءة اختراع

د. ميامي عبد اللطيف محمد

***ABSTRACT:** 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.*

The main aim of the study is:

- To develop the possibility to design different structures of multicore PCFs with very short coupling lengths in a unit of micrometer.
- Overcome the problem of coupling suppression in anisotropy structures of multicore PCFs with high efficiency.

Methodology design & Theory

Using COMSOL MULTIPHYSICS 5.5 software that dependent on full vectorial Finite Element Method (FEM) to model the PCF structures

- FEM is a numerical simulation used to find approximate solution of complex partial differential equations (PDEs), reducing the problem to a set of LES to form eigen value matrix equation that is solved to find the propagation modes of the field

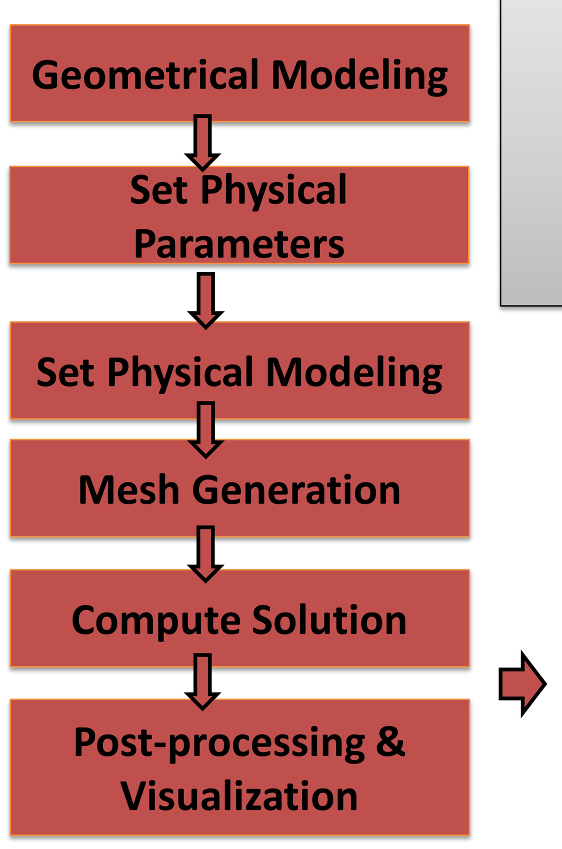


Fig.1 Flowchart for modeling PCF structure in Comsol Multiphysics

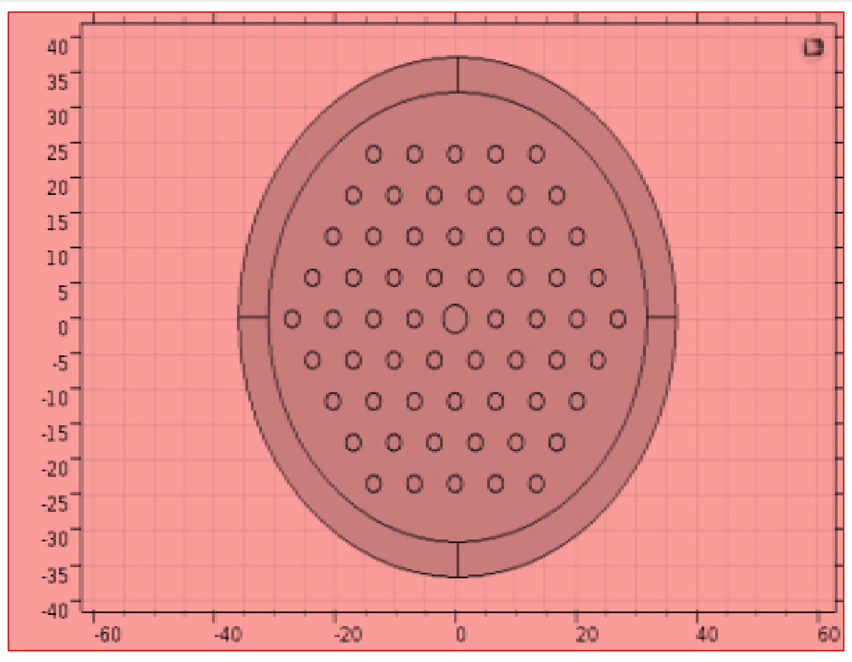


Fig.2 Solid – core PCF structure

FEM allows us to divide the cross-section PCF into small finite elements by using mesh-free triangular and chose the study as the mode analysis study and directly solve the Maxwell equations to obtain an approximate value of the effective refractive indexes of mode.

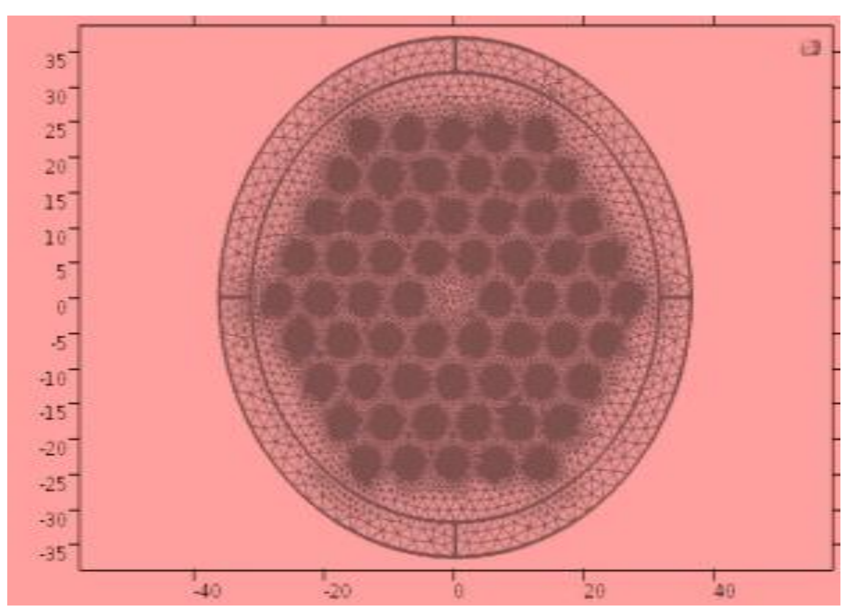


Fig.3 Triangular finite mesh of solid – core PCF structure

Coupling

Two modes propagate with a different phase called odd (anti-symmetric) modes along x-and y-polarization fields. 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:

$$L_c = \frac{\pi}{\beta_{even} - \beta_{odd}} = \frac{\lambda}{2(n_{even} - n_{odd})} \qquad (1)$$

The coupling length is affected mainly by the core diameter of the coupler, cores separation, and the wavelength. The coupling coefficient relates to coupling length as in equation (2) follow below:

$$\kappa = \frac{\pi}{2L_c} \qquad (2)$$

Simulation results and discussion

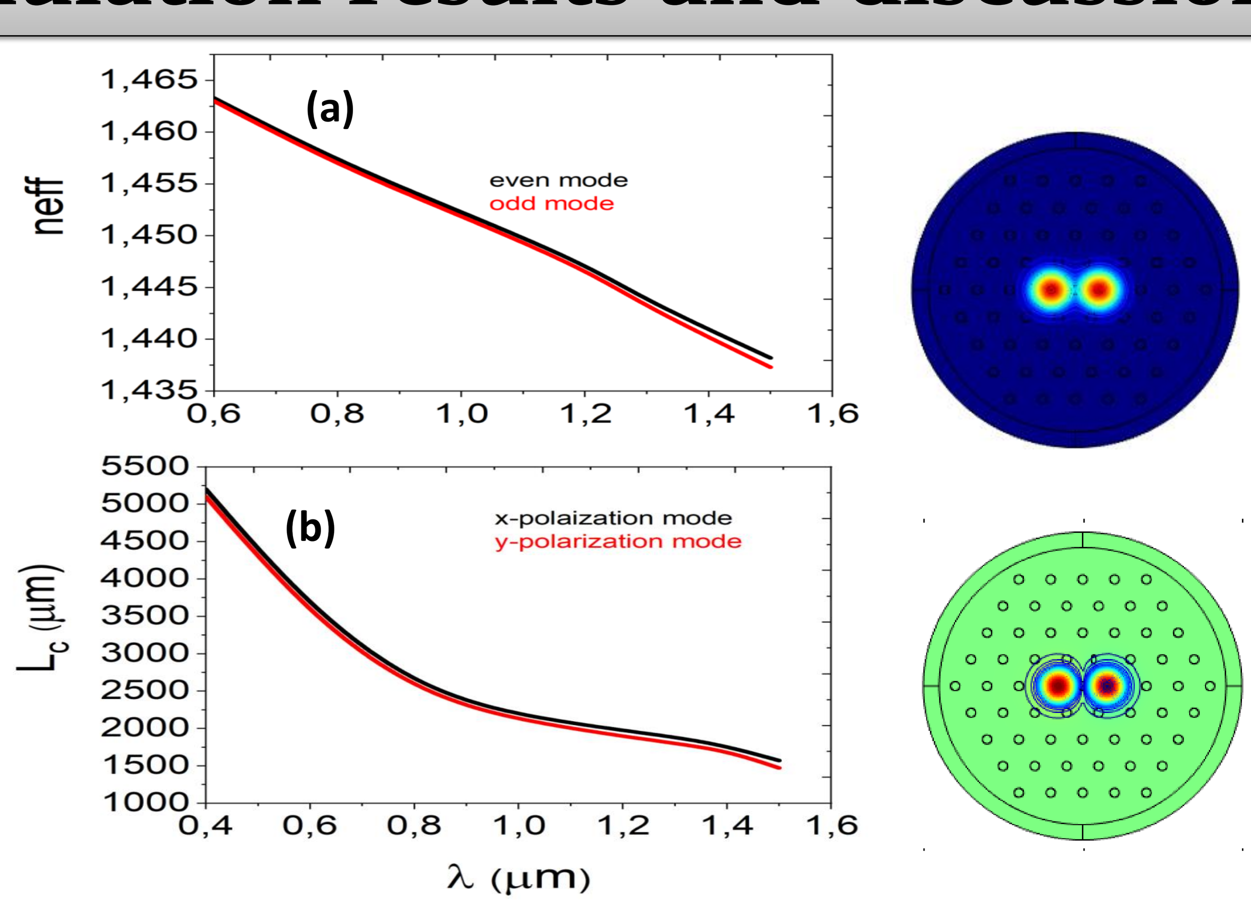
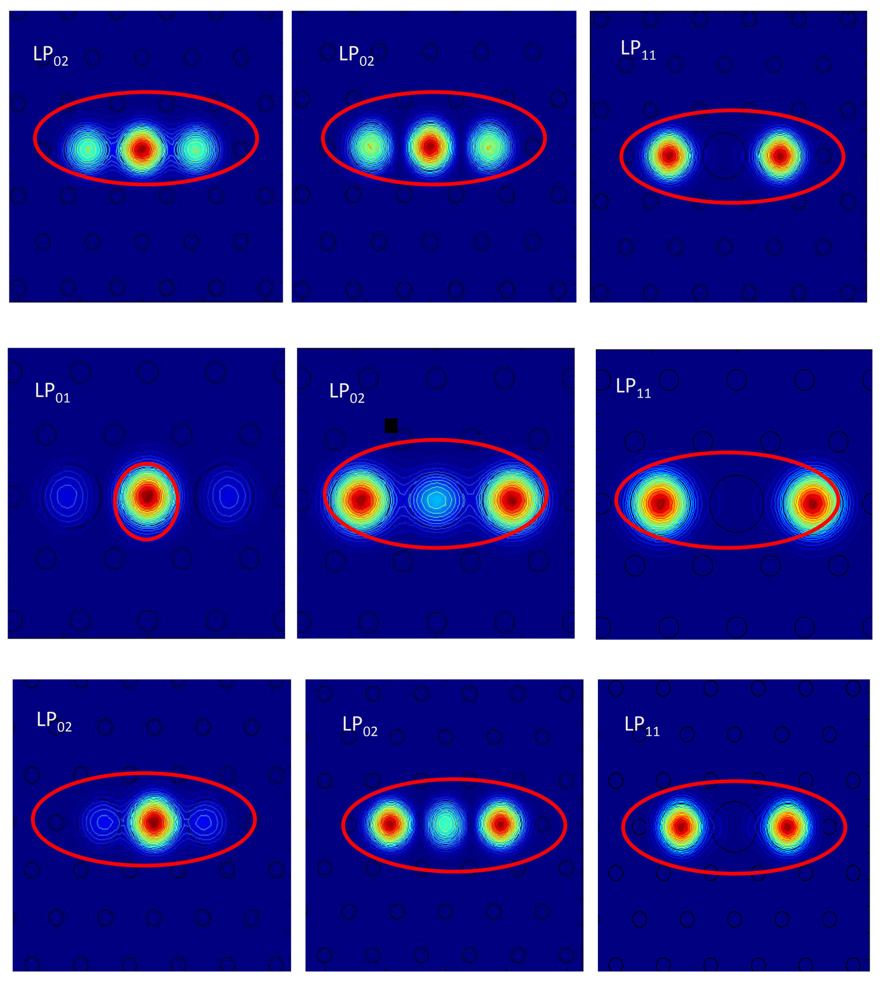
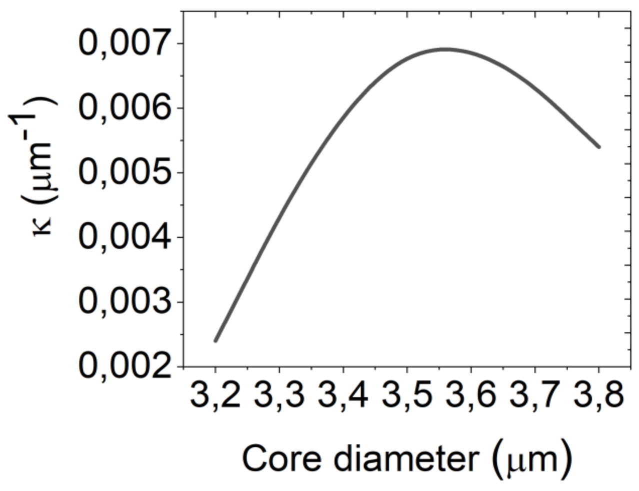
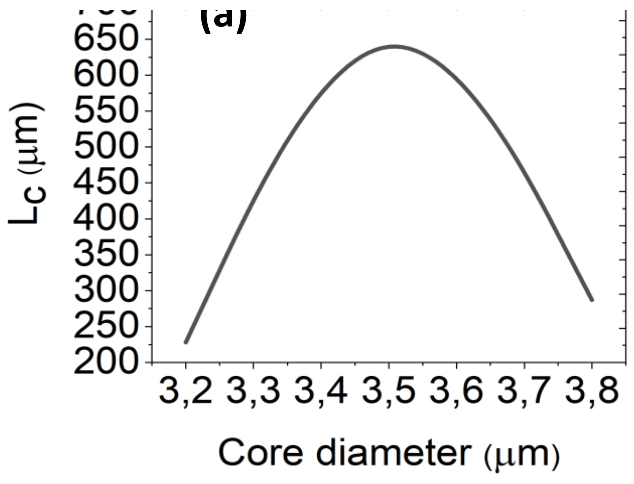
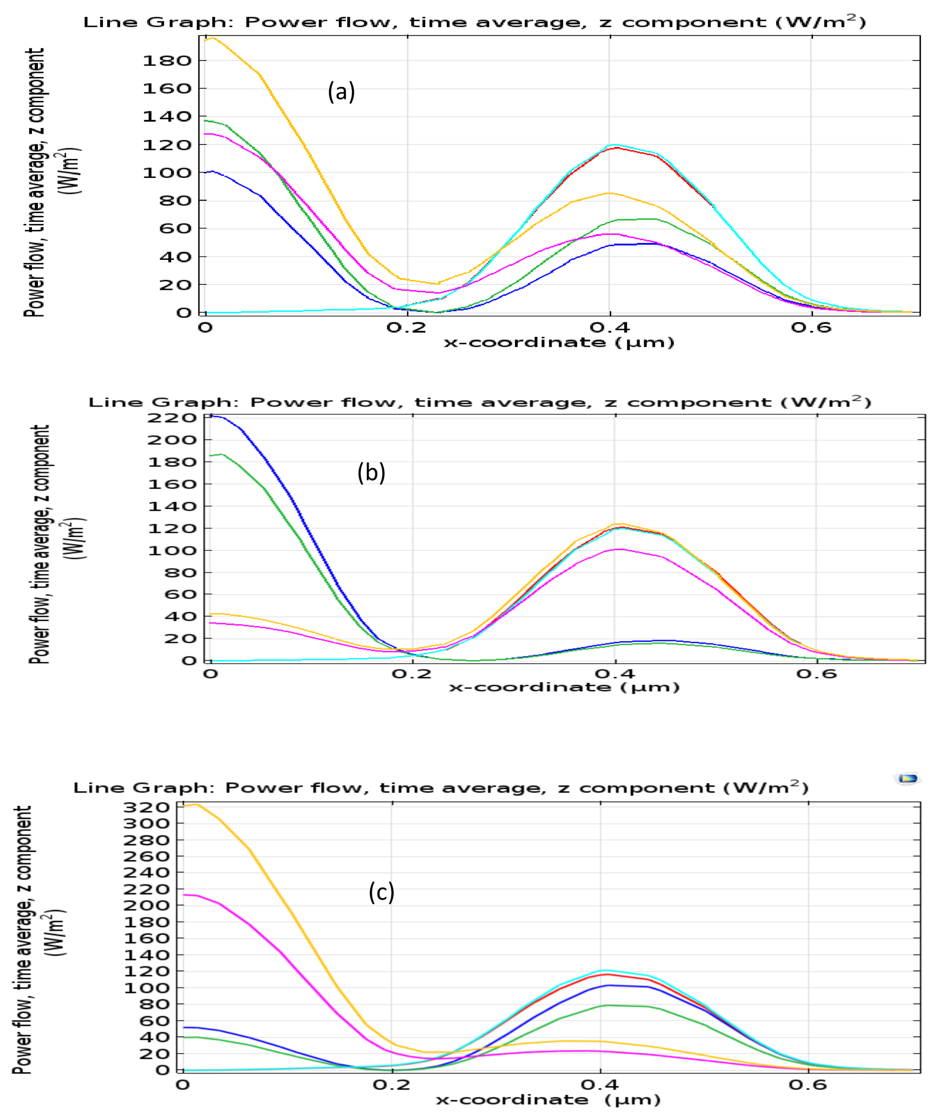


Fig 4. Cross-section of two-core PCF coupler (even modes from up and odd modes from down). The geometry of PCF design characterized by the structure parameters, such as the core diameter=5um, the hole pitch Λ=4 um, hole diameter d=1.16 um, the air-filling fraction d/Λ=0.29, and core separation D=3 um, at the wavelength λ=1.55um, respectively. Figs show the refractive index (up) and coupling length (down) related with wavelength.

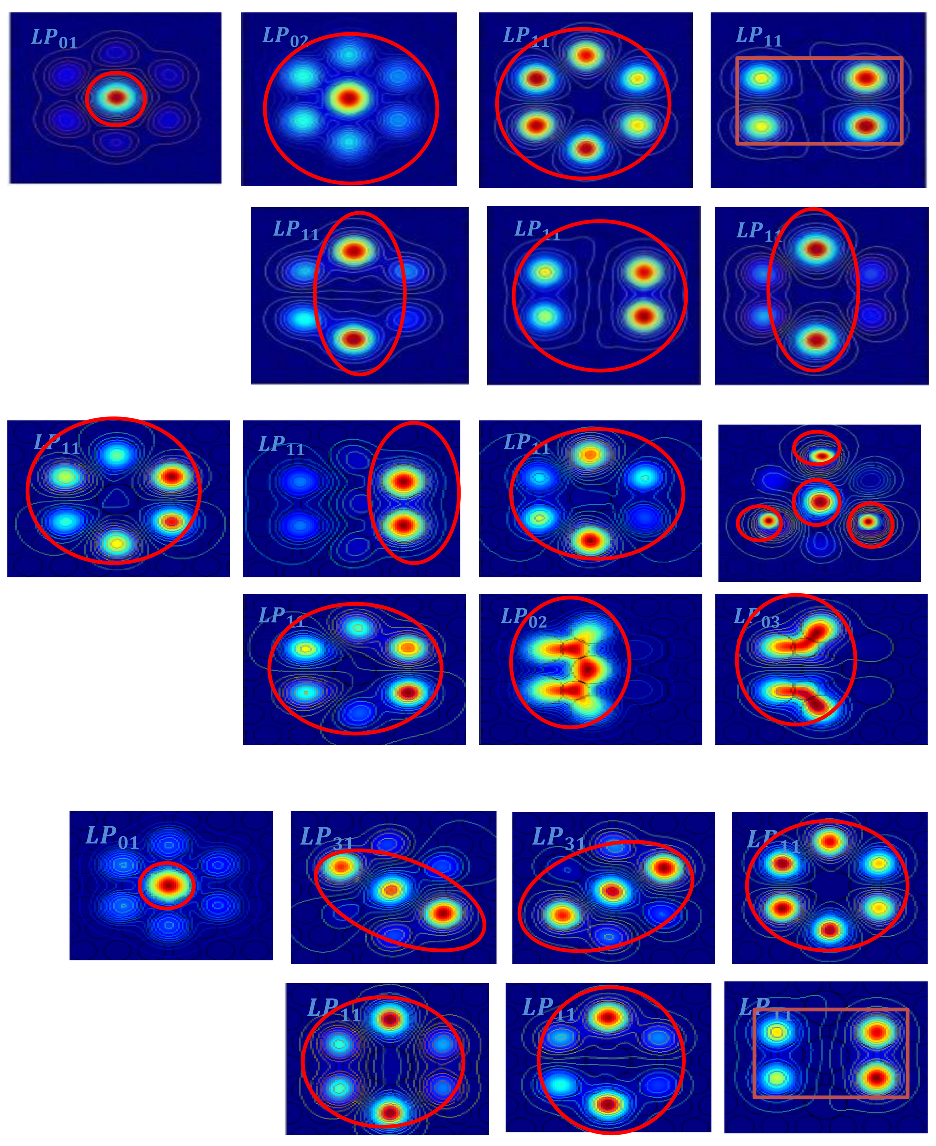


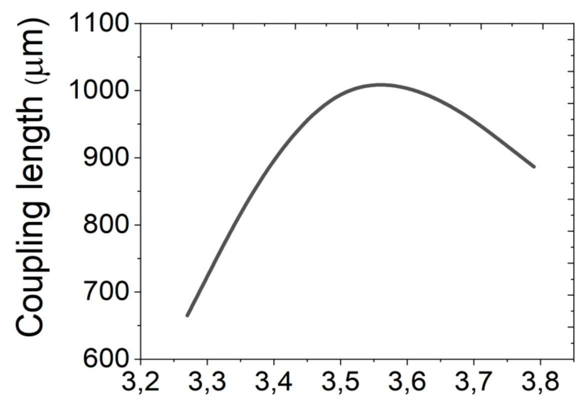


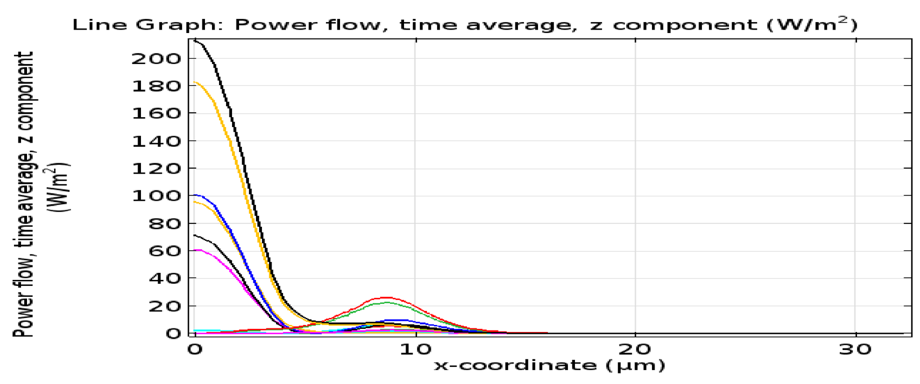


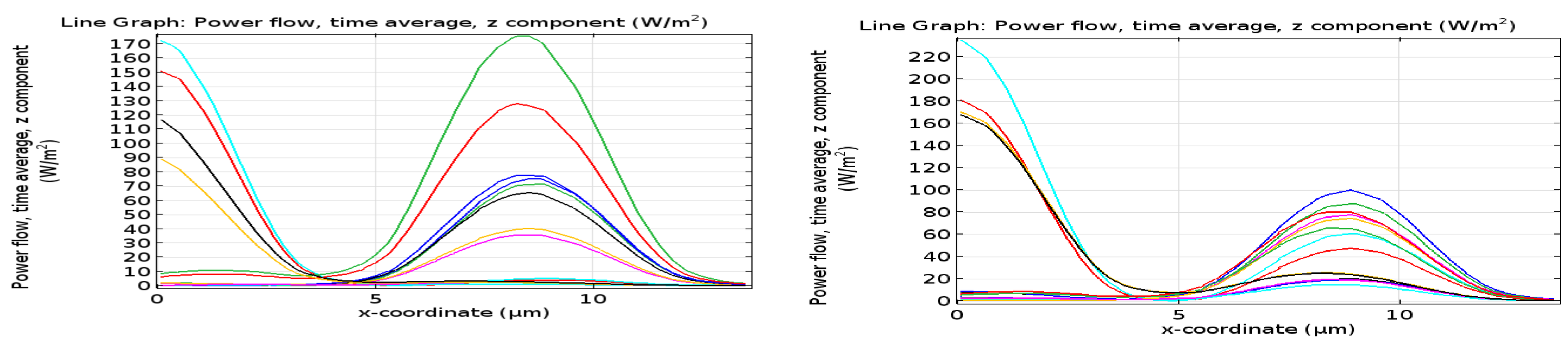


Coupling between three identical and non-identical cores: $3.5\mu m$ identical, $3.2\mu m$ identical and $3.8\mu m$ *non* − identical at $1.55\mu m$



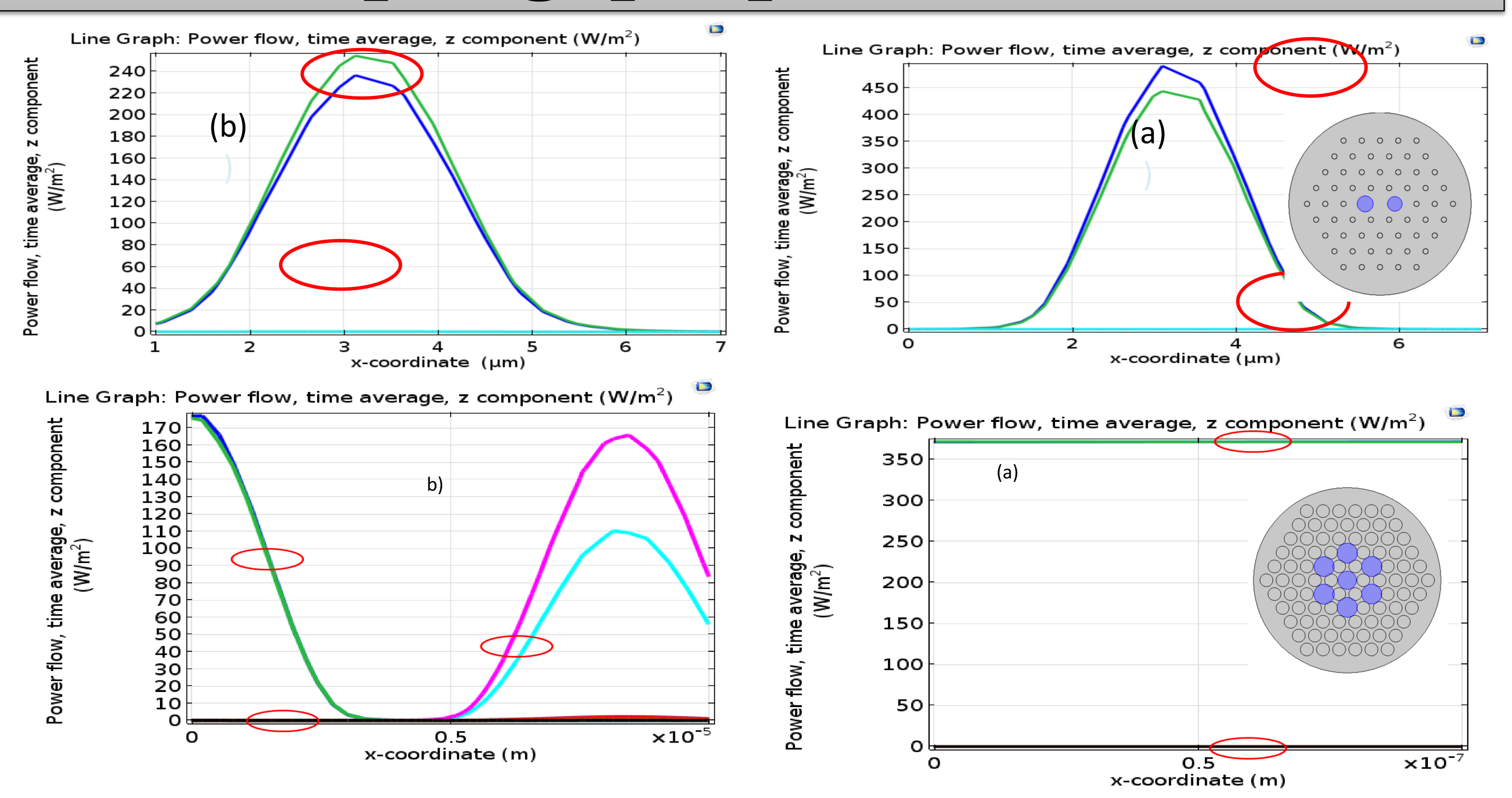






Coupling between seven identical and non-identical cores: $3.5\mu m$ identical, $3.2\mu m$ identical, $3.8\mu m$ *non* − identical at $1.55\mu m$

Anisotropy in all three core diameters on the coupling properties



$1.55\mu m$ $1.064\mu m$

Conclusion

- Analysis of the supermode Opens up new possibilities for designing different structures of MCPCF with Complex field distribution and prediction of mode propagation in these structures
- **Coupling length and the strength of coupling** between cores can be manipulated by control to the structural engineering parameters such as **core diameters, core separation, wavelength and design to achieve better transmission properties for coupled modes**
- **The advantage of designing coupling lengths in (μm) for PCF coupler is much shorter than the traditional optical fiber couplers that have designed with the coupling lengths in several tens in (mm), The device becomes more miniaturized.**
- **Designing very Short coupling lengths with a system consists of non-identical cores than identical cores,, and this result is useful in optical communication systems even if their cores of somewhat different sizes**
- **Introduce anisotropy in all core diameters causes suppression the coupling between the cores, as a result the modes of these cores become decoupled and the light independently propagation in each core.**
- **By increasing the wavelength It is possible to overcome the problem of suppression the coupling between cores even if all cores different**
- **The coupling efficiency** between the cores **improves** by Increasing both of the **wavelengths** and **the number of coupled cores** inside the structure.

Splitter

Coupler

Multiplexing

Demultiplexing