Numerical analysis of independent light propagation in a photonic crystal fibers

م . د. ميامي عبد اللطيف محمد

- Recently, PCF with two or more adjacent cores called multicore PCFs (MCPCF) [1, 2]. It is a possibility to use it as an optical fiber coupler [3-9]. Destroying the symmetry of the PCF couplers is the key method to obtain anisotropy in the structure. In general, one can introduce asymmetry in the structure by using different dimensions of the coupler or variation between the cores or using different index profiles [10, 11].
- In our study, we design different geometrical structures, such as two-, three-, and seven-core PCFs coupler to predict the mode behavior in several of coupled MCPCF. Which have the potential to affect the coupling properties between coupled cores, such that reduction of the coupling significantly, so that the coupling non-existent between the cores and then the cores become decoupled, consequently propagates the light independently essentially in all cores, as individual cores in isolation.
- By assuming that the propagation constant of each core is β0; the coupling coefficient between the cores is κ_0, the evolution of the modal field amplitudes in MCPCF coupler as U0 can be described ‘as in equation (1) [10, 11]:

$$\boldsymbol{i\frac{dU_0(z)}{dz} + \beta_0 U_0(\mathrm{z}) + \kappa_{0n} \sum_{n=1}^{N} U_n = 0} \quad (1)$$

The coupling coefficients with non-identical become

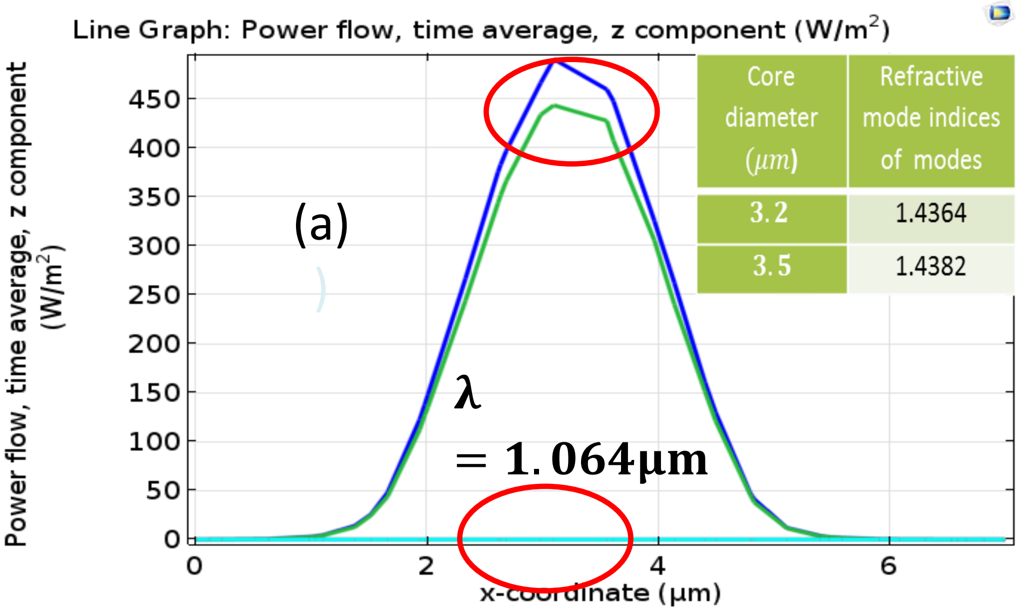
$$\boldsymbol{\kappa_{0n} = \sqrt{2\Delta_n}\frac{\mathrm{U}U_0U_n}{R_0V_0} \times \frac{K_0(W_0D_{0n}/R_0)}{K_1(W_0)K_1(W_n)} \times \left\{\frac{\overline{W}_0K_0(W_n)I_1\overline{W}_{n+}\overline{W}_0K_1(W_n)I_0\overline{W}_0}{{W_0}^2\,{U_n}^2}\right\}} \quad (2)$$

The power flow in each core as a function of z is described as [12]:

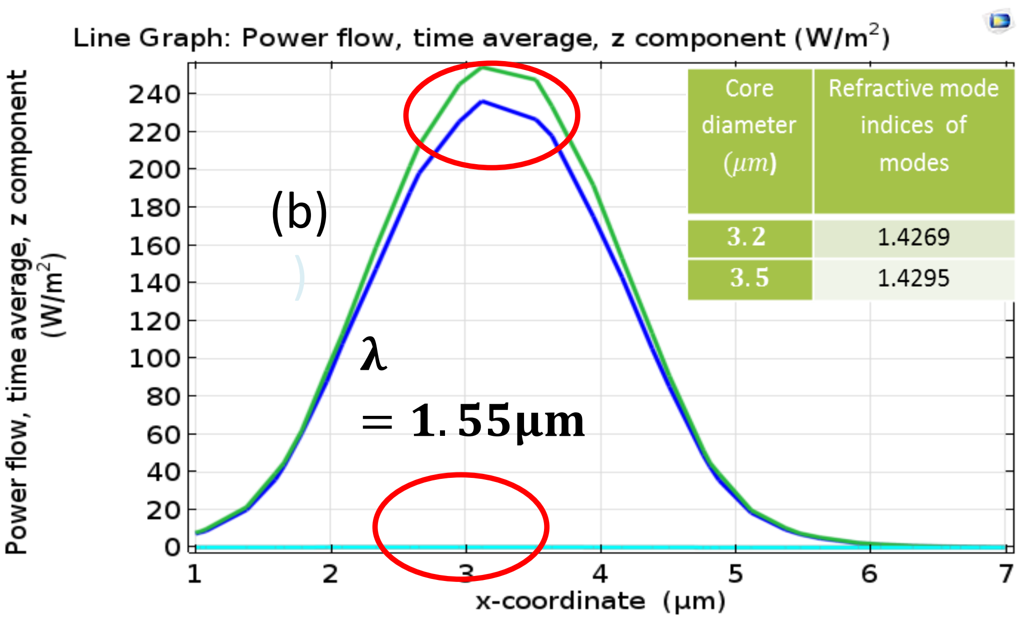
$$P_{core} = \frac{1}{2}\mathrm{Re}\iint \vec{E}(\mathrm{x,y})\vec{H}^*(\mathrm{x,y}).\hat{z}\ \mathrm{dx\ dy} \quad (3)$$

E and H are the electric and magnetic fields with a complex conjugate ($*$)

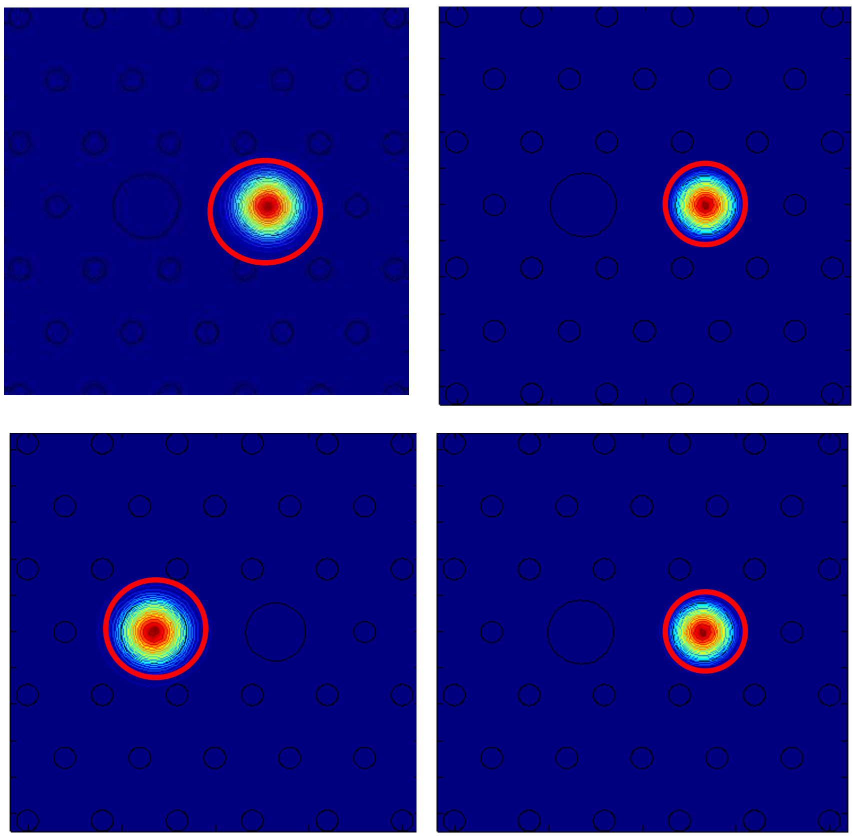
The effect of anisotropy in all diameters of two core on the coupling properties



Core diameter (μm)	Refractive mode indices of modes
3.2	1.4364
3.5	1.4382

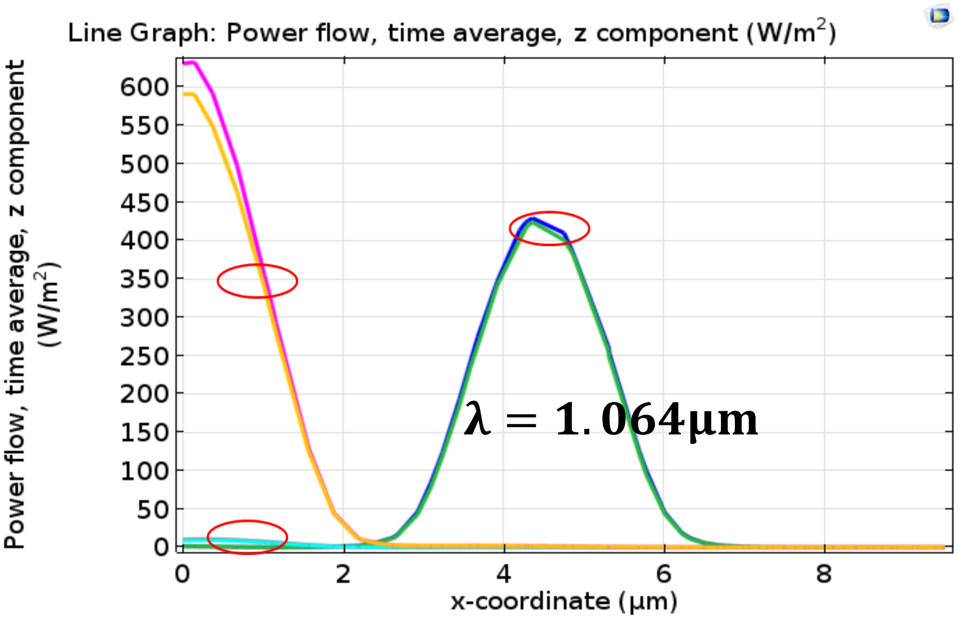


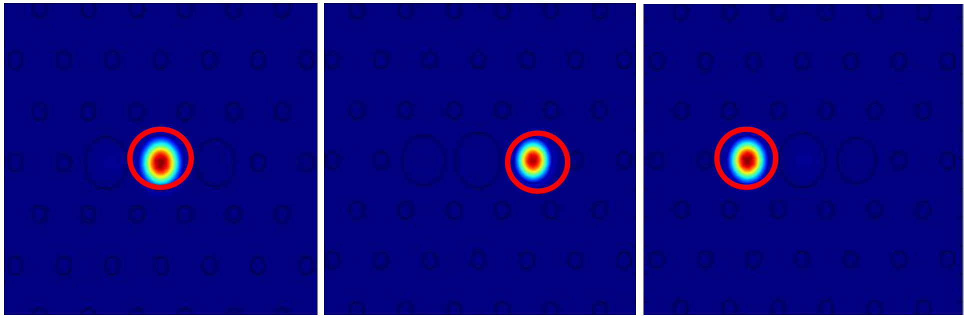
Core diameter (μm)	Refractive mode indices of modes
3.2	1.4269
3.5	1.4295

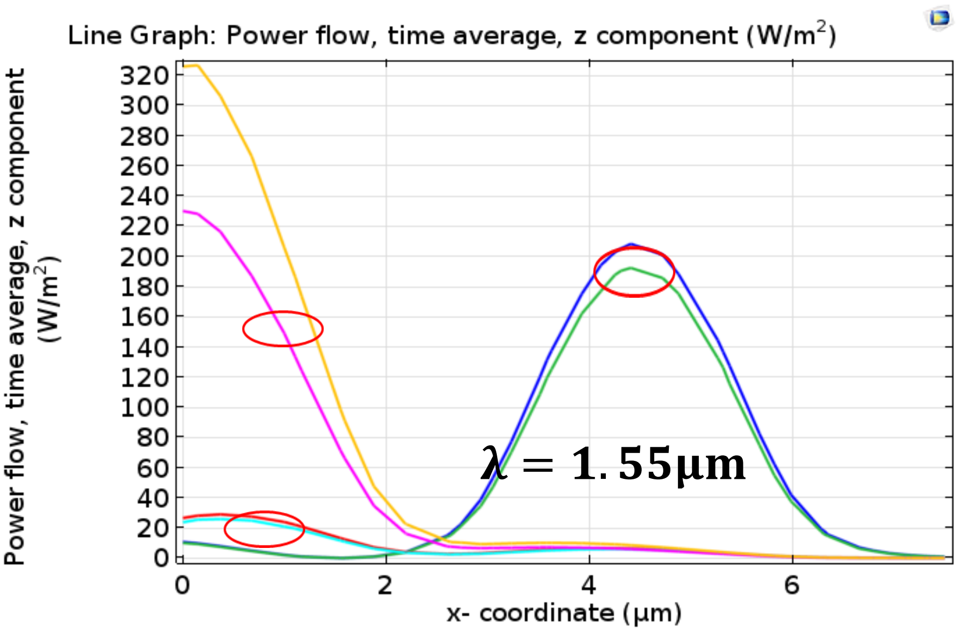


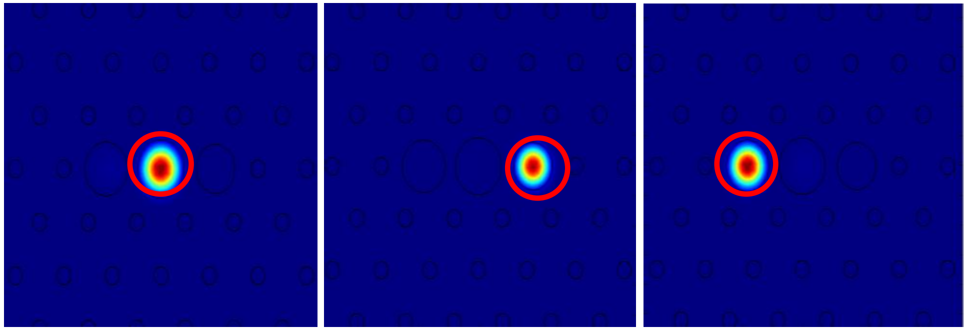
3

The effect of anisotropy in all three core diameters on the coupling properties



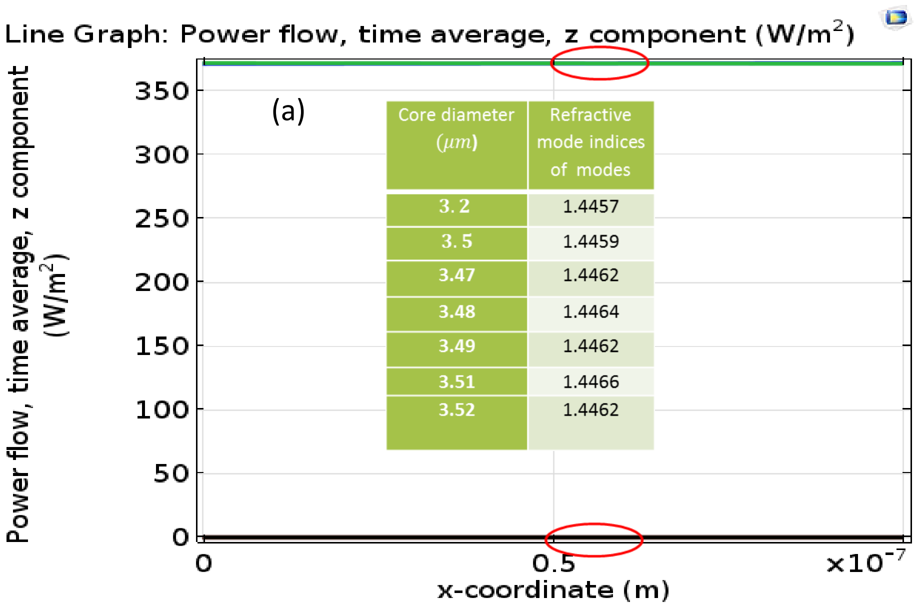




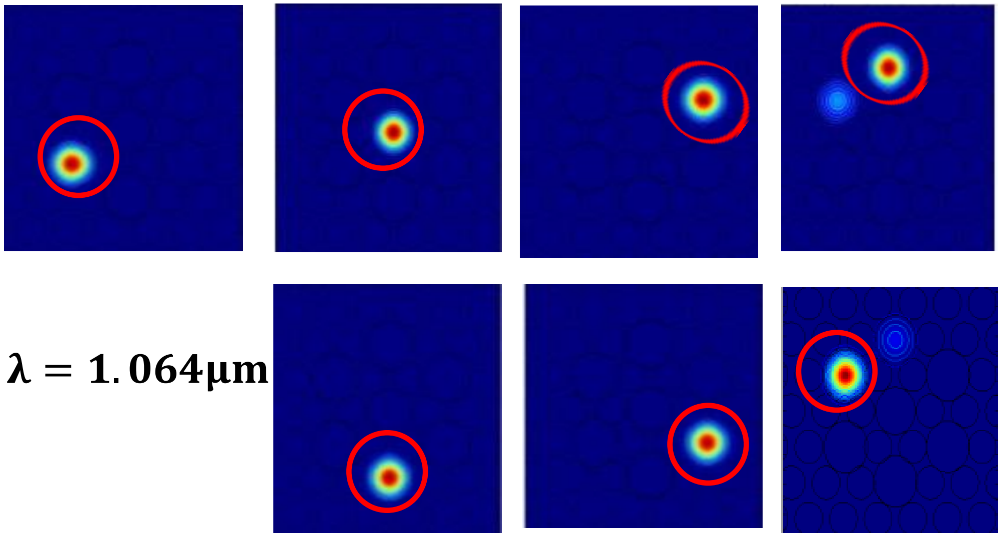


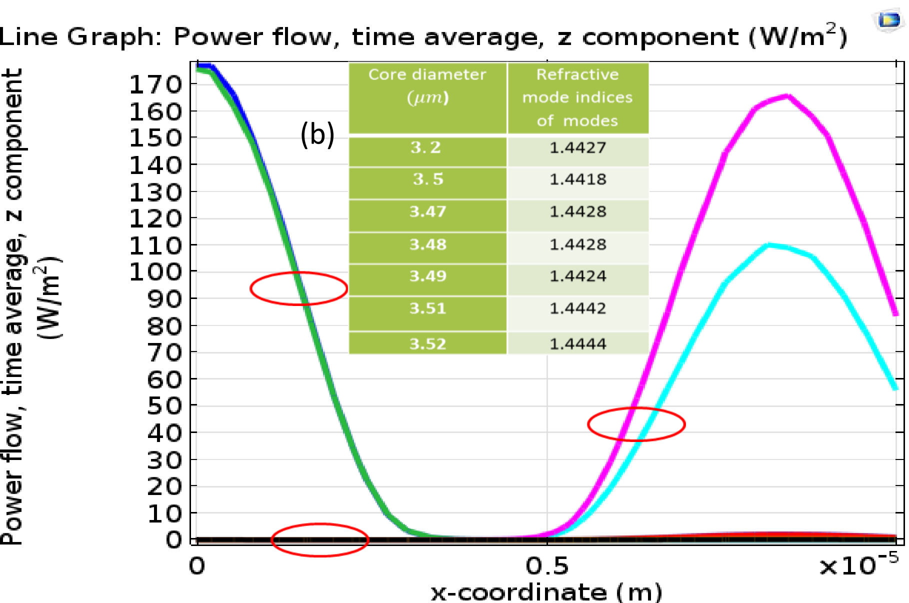
4

The effect of anisotropy in all seven core diameters on the coupling properties

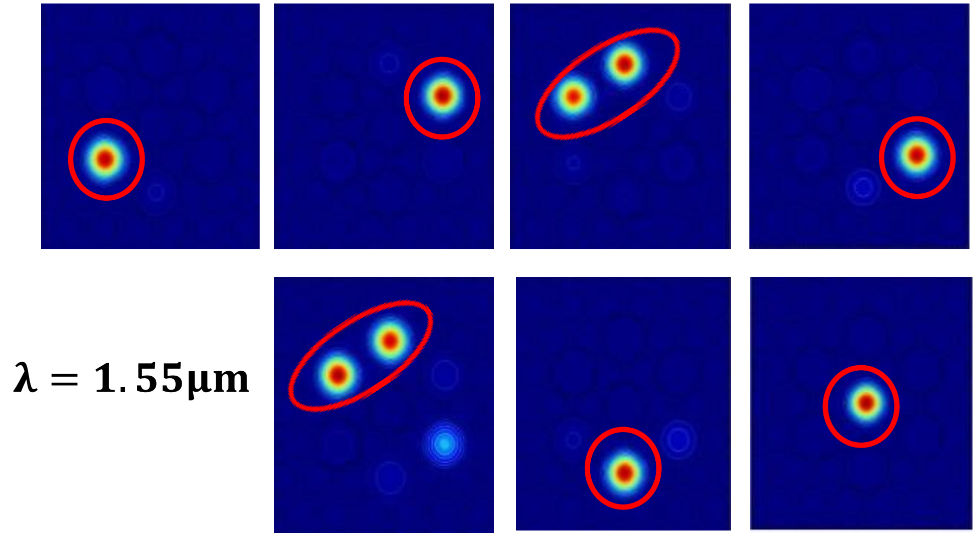


Core diameter (μm)	Refractive mode indices of modes
3.2	1.4457
3.5	1.4459
3.47	1.4462
3.48	1.4464
3.49	1.4462
3.51	1.4466
3.52	1.4462





Core diameter (μm)	Refractive mode indices of modes
3.2	1.4427
3.5	1.4418
3.47	1.4428
3.48	1.4428
3.49	1.4424
3.51	1.4442
3.52	1.4444



Conclusion

- 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.

- **This design structural can be used in applications as**

Multiplexing

Multiplexing

6

Thank you for attentions

References

[1] J. C. Knight, "Photonic crystal fibres," Nature, vol. 424, no. 6950, p. 847, 2003.

[2] F. K. Kamalia, M. E. Heidarib, and M.K. M. Farshi , " Designing a dual-core photonic crystal fiber coupler by means of microfluidic infiltration ", (IJOP), 6, 2012.

[3] K. R. Khan and T.X. Wu , " Finite element modeling of dual-core photonic crystal fiber ", ACES,23, 2008.

[4] A. W. Snyder, "Coupled-mode theory for optical fibers," JOSA, vol. 62, no. 11, pp. .1972 ,1277–1267

[5] A. Yariv, "Coupled-mode theory for guided-wave optics," IEEE Journal ofQuantum Electronics, vol. 9, no. 9, pp. 919–933, 1973.

[6] K. Saitoh, Y. Sato, and M. Koshiba, "Coupling characteristics of dual-core photonic crystal fiber couplers," Optics Express, vol. 11, no. 24, pp. 3188–3195, 2003.

[7] M. Mohammed, "Fem analysis of two-core photonic crystal fiber coupling characteristics," in Computational Methods in Engineering Science, CEMS Conference 2019, no. ISBN:978-83-7947-386-1, (Kazimierz Dolny, Poland, November (2019)), pp. 74–87, 2019.

[8] D. S. K. Priya, "Modeling of twin core liquid filled photonic crystal fiber coupler with elliptical air holes," Advanced Research Trends in Engineering and Technology (IJARTET), II, XXIII, p. 168190, 2015

[9] H. He and L. Wang, "Numerical analysis of birefringence and coupling length on dual core photonics crystal fiber with complex air holes," Optik, vol. 124, no. 23, pp. 5941–.2013 ,5944

[10] C. Xia, M. A. Eftekhar, R. A. Correa, J. E. A. Lopez, A. Schülzgen, D. Christodoulides, and G. Li, "Supermodes in coupled multi-core waveguide structures," IEEE Journal of Selected Topics in Quantum Electronics, vol. 22, no. 2, pp. 196–207, 2016.

[11] M. Parto, M. A. Eftekhar, M.-A. Miri, R. Amezcua-Correa, G. Li, and D. N. Christodoulides, "Systematic approach for designing zero-DGD coupled multi-core optical fibers," Optics Letters, vol. 41, no. 9, pp. 1917–1920, 2016.

[12] K. L. Reichenbach and C. Xu , "Independent core propagation in two-core photonic crystal fiber resulting from structural nonuniformities ,". Optical Express 25, 10336-10348 (2005).