Optimization of The Residual Radius of The Side-Polished Photonic Crystal Fiber Coupler

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***Abstract*-In order to design couplers based on side-polished photonic crystal fiber (SPPCF), we made the simulation and calculated the optimum residual radius. A model of coupling region of SPPCF coupler was established. By using Rsoft software, optical propagation characteristics of SPPCF coupler was calculated with different residual radius. The simulation showed that light field appeared alternately between two optical fibers of coupler and there was coupling effect. When the residual radius was 2.85 μm or 3.99 μm, coupling effect was more obvious.**

I. INTRODUCTION

Optical couplers, which are used to combine or split the power of different channels, are components of extreme importance in optical communication systems [1]. The side-polished photonic crystal fiber (SPPCF) is fabricated from the photonic crystal fiber (PCF) with the cladding part removed[2]. The “window” of transmission light in PCF is formed on the polished area [3-6].

Due to the intensive interest of PCF application, a tunable photonic crystal fiber coupler based on a side-polishing technique was made by Hokyung Kim [7], but there is no analysis of the optimum residual radius. It is necessary to simulate and analyze the optical propagation characteristic of SPPCF coupler with different residual radius.

II. MODEL OF SPPCF COUPLER

Fig.1 shows the model of SPPCF coupler. In the model, d indicates the distance diameter of the air hole, Λ indicates the distance between centers of adjacent air hole, n_{air} and n_{cl} indicate the refractive index of air hole and that of PCF's materials, respectively [8], D indicates the residual radius (the minimum distance between side-polished surface and the center of PCF). Let the cross section of SPPCF coupler to be the x-y plane, and the transmission direction of light to be the direction of z axis.

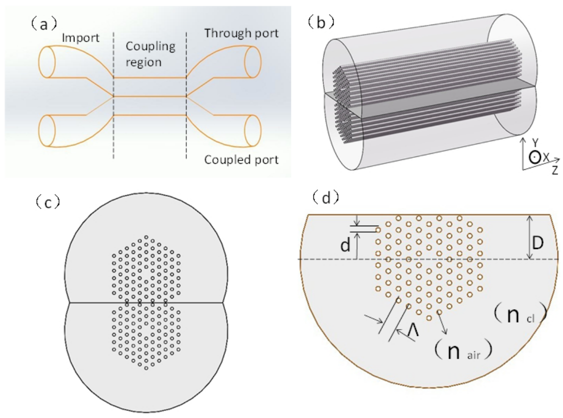

Fig.1. Model of SPPCF coupler: (a) Structure of SPPCF; (b) Model of coupling region of SPPCF coupler; (c) Cross section of the model; (d) Parameters introduction

In the simulation, d = 2.28μm, Λ= 5.7μm, n_{cl} = 1.45, and the outer diameters of the PCF is 125μm. The free space wavelength of light is 1.55μ m.

III. RESULTS AND ANALYSIS

In the simulation, the beam propagation method simulations are performed using a commercial software package, Rsoft-Beamprop (RSoft Design 2010). Full transparent boundary condition (FTBC) is used. The light is launched with LP_{01} mode at the import, and propagates along the z direction [8]. Because of single-mode transmission characteristic of PCF, there is only LP_{01} mode on the cross section of through port. But the side-polishing of PCF

978-1-4799-3682-3/14/$31.00 ©2014 IEEE

destructs the symmetric periodical configuration in cross section of PCF. Hence single-mode transmission characteristic of PCF is changed [9]. In the simulation, we monitor the optical power of LP_{01} mode only.

We set the value of D to be 2.85μm, 3.99μm ,5.7μm and 6.84μm, respectively. 2.85μm is half of the distance between centers of adjacent air hole, 3.99μm is the distance of radius of air hole added on the basis of 2.85um, 5.7μm is the distance between centers of adjacent air hole and 6.84μm is the distance between centers of adjacent air hole added on the basis of the radius. The optical power in two fibers of SPPCF coupler is calculated in the four cases. SPPCF1 is through port, and SPPCF2 is coupled port.

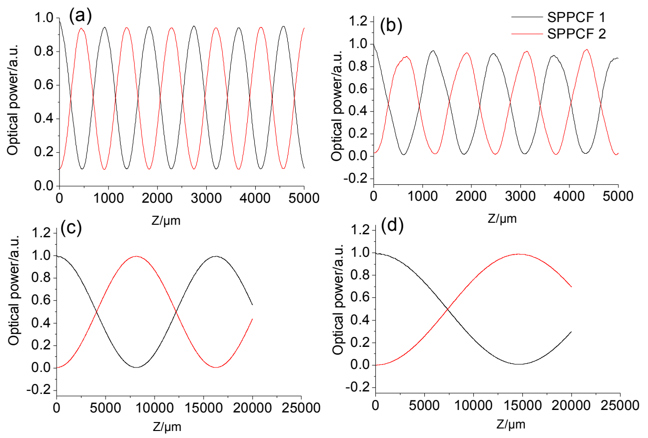

Fig.2. Optical power in two fibers of SPPCF coupler: (a) D=2.85μm; (b) D=3.99μm; (c) D=5.7μm; (d) D=6.84μm

The optical power in two fibers of SPPCF coupler changes as shown in Fig.2. The coupling period is about 1000μm, 1250μm, 16000μm and 30000μm, respectively.

The fact that power alternately distributes between two fibers in the coupling region can be concluded from Fig.2. When D is 2.85μm, coupling period is the minimum, the optical field propagates frequently between two fibers. When D=2.85μm, optical power of the through port and coupled port can transform completely. When D=5.7μm or 6.84μm, coupling period is very long.

IV. Conclusions

The greater D is, the greater coupling period is, and the smaller times of coupling per unit length is. When D=2.85μm or D=3.99μm, the power in two fibers transforms frequently which provides higher success rate for coupling. When D=5.7μm and D=6.84μm，because of longer coupling period, two parameters are not suitable practically. Hence the value of D can be 2.85μm or 3.99μm.

Acknowledgment

This work was supported by the National Natural Science Foundation of China (No. 61177075, 61008057, and 11004086), the Core Technology Project of Strategic Emerging Industries of Guangdong Province (No.2012A032300016,2012A080302004,2011A081302002), Special Funds for Discipline Construction of Guangdong Province (No. 2013CXZDA005), and the Fundamental Research Funds for the Central Universities of China (No. 21614313, 21613325, and 21613405), and the Open Research Fund of State Key Laboratory of Bioelectronics, Southeast University(No. 2014H09).

References

[1] A. Lord, I. J.Wilkinson, A. Ellis, D. Cleland, R. A. Garnham, and W. A.Stallard, “Comparison of WDM coupler technologies for use in erbiumdoped fiber amplifier systems,” *Electron. Lett.*, vol. 26, pp. 900–901,Jun.1990.

[2] Birks, T. A., et al. "Dispersion compensation using single-material fibers,"*Photonics Technology Letters, IEEE,* vol.11, pp.674-676,Jun.1999.

[3]Chen Z, Cui F, and Zeng Y, "Theoretical analysis on optical propagation characteristics of side-polished fibers," *Acta Photonica Sinica,* vol.37, pp.918-923, May2008.

[4] JIANG Pei-fan，CHEN Zhe，ZENG Ying xin，et a1． "Optical propagation characteristics of side polished fibers," *Semiconductor Optoelectronic*, vol.27, pp. 578~581 , Jul. 2006.

[5] Liu, L., Chen, Z., and Bai, C., "The effect of refractive index of material overlaid side polished area of FBG on Bragg.Wavelength," *Acta Photonica Sinica,* vol.**36**, pp.865–868, May2007.

[6] Zeng, Y., Chen, Z., and Jiang, P.,"Optical propagation characteristics of side polished fibers," *Appl. Laser* , vol.**26**, pp.29–34, May.2006.

[7] Kim, Hokyung, et al. "Tunable photonic crystal fiber coupler based on a side-polishing technique," *Optics letters,* vol.29, pp.1194-1196,Jun.2004 .

[8] He, Xiaoli, et al. "Numerical analysis of optical propagation characteristics of side-polished photonics crystal fiber," *Optical and Quantum Electronics*, pp.1-8,Sep.2013.

[9]Daozhu Hua and Ling Fu,"Numerical Analysis of Coupling Characteristics of Tunable Photonic Crystal Fiber Coupler for Nonlinear Optical Microscopy,"*Photonics Technology Letters*, vol. 24, pp. 125~127 ,Jan. 2012.