Numerical Analysis of Optical Propagation Characteristics of Side-polished Photonics Crystal Fiber

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***Abstract*—In order to design new all optical fiber devices based on side-polished photonics crystal fiber(SPPCF), a numerical model was established and analyzed by use of three dimension finite difference beam propagation method (FDBPM). The attenuation of optical power and the distribution of propagation mode in the device of SPPCF were calculated and analyzed with the variation of the three factors, such as: residual radius after side polishing, axial rotation angle, and the length of side-polished area. The numerical study shows: the shorter the residual radius is, the larger the attenuation of the optical power of SPPCF is; The optical power of LP_{01} in the SPPCF varies and oscillates along fiber in the side-polished area; When residual radius is small enough, the high order modes appear during the light pass through the side-polished area;After light pass through the side-polished area, some of the optical power of LP_{01} mode recove from higher modes; With variations of the residual radius, there is a small difference between the attenuations of optical power at different axial rotation angles; When the residual radius is longer than 1.5μm, the change of the side-polished length have little impact on the attenuation of optical power; when the residual radius is shorter than 1.5μm, the attenuation of optical power changes in oscillation as the the side-polished length changes from shorter to longer.**

Keywords—Side-polished fiber; Photonics Crystal Fiber; finite difference beam propagation method; Optical Propagation Characteristic; the attenuation of optical power; propagation mode;

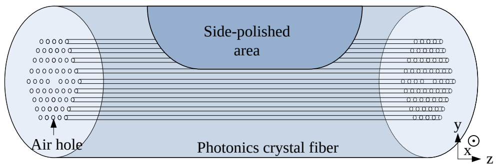
I. INTRODUCTION

The research of photonics crystal fiber and its device have become hot spots in the optical communications and optoelectronic field due to their excellent optical properties such as endlessly single mode transmission properties, adjustable dispersion property, high birefringence properties, large mode field area, and high nonlinear features and so on. Photonics crystal fiber has important applications in some fields such as optical fiber communication, fiber sensors, dispersion compensation, and optical integrated circuit [1].

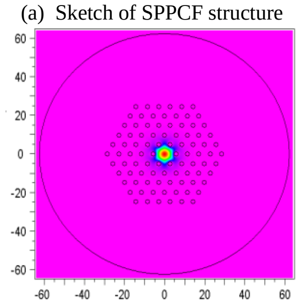
In recent years, side-polished fibers have been reported to analyze its optical characteristics [2, 3]. Side-polished fiber with two-dimensional photonic crystal lattice [4] was also reported. Many devices based on SPPCF were reported, such as Tunable Photonic Crystal Fiber Coupler for Nonlinear Optical Microscopy [5], tunable photonic crystal fiber coupler, fiber sensors, and surface plasmon resonance sensor [6]. It is necessary to simulate and analyze the optical propagation characteristic of SPPCF, because it is very important for the design and manufacture of new devices based on SPPCF. In this paper, the theoretical model of a SPPCF is established by three dimension finite difference beam propagation method**,** and the attenuation of optical power and the distribution of propagation mode about the SPPCF are analyzed.

II. THEORETICAL MODEL OF SIDE-POLISHED PHOTONICS CRYSTAL FIBER

The theoretical model of SPPCF is established as shown in Fig.1 (a). The cross-section at side-polished area likes a letter "D". The launch power of the theoretical model is the fundamental mode LP_{01} of photonics crystal fiber, as shown in Fig.1 (b).The residual radius R represents the distance between the center of fiber and the side-polished surface; the axial rotation angle θ means the angle with anti-clockwise turning around z axis along the fiber. There are five layers of air hole in the fiber, the diameters of the air holes is 2.28μm, and the distance between the center of neighboring air holes is 5.7μ m. Refractive index of optical fiber material is 1.45, the diameters of the fiber is125μm, free space wavelength is 1.55μ m, the side-polished length L is 8mm, the length of flat area with polishing L1 is 6mm, the length of transition area with polishing L2 is 1mm.



(a) Sketch of SPPCF structure



(b) LP_{01} of photonics crystal fiber

Fig.1. Sketch of SPPCF structure and LP_{01} of photonics crystal fiber

III. RESULTS AND DISCUSSIONS

In the simulation, optical transmission along the Z axis, and optical power transmittance T is the ratio of the output optical power to the input optical power when light pass through the side-polished PCF device.

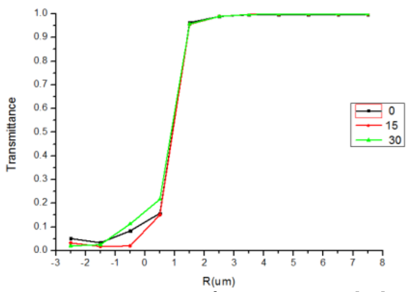


Fig.2. optical power transmittance T of SPPCF vs. residual radius R under different axial rotation angle θ

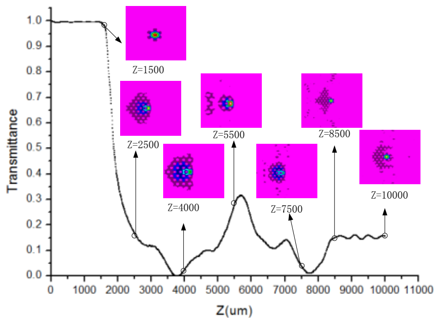


Fig.3. optical power transmittance T of SPPCF and the distribution of propagation mode when R is 0.5μm and $\theta = 0^o$

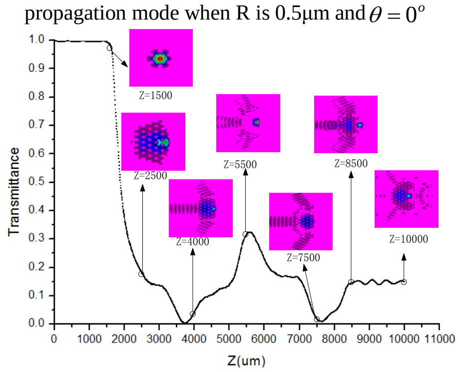


Fig.4. optical power transmittance T of SPPCF and the distribution of propagation mode when R is 0.5μm and $\theta = 30^o$

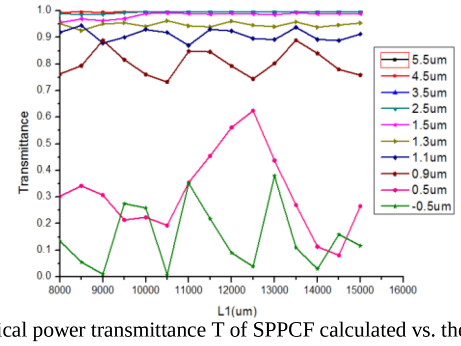


Fig.5. optical power transmittance T of SPPCF calculated vs. the length of flat area with polishing L1 when $\theta = 0^o$

Fig.2 shows that when the axial rotation angle θ are 0^o, 15^o and 30^o, the optical power transmittance T of SPPCF changes with the variation of the residual radius R. The shorter R is, the larger the attenuation of the optical power of SPPCF will be. When the residual radius is larger than 0.5μm, the change of the residua radius has little impact in the optical power transmittance T while the axial rotation angle changes.

Fig.3 and Fig.4 show that higher order modes appear in side-polished area at z=2500μm when the residual radius is 0.5μm. Because many higher order modes excite at z=4500μm, the optical power of fundamental mode have a large attenuation. After z>9000μm, some of optical power in high order modes is back to the fundamental mode.

Fig.5 shows that the optical power transmittance T of SPPCF changes with the variation of the length of polishing flat area. When the residual radius R is greater than or equal to 1.5μm, the optical power transmittance T changes little with variation of the side-polished length, only up to 0.04. When residual radius R is less than 1.5μm, the optical power transmittance T changes in oscillation as the change of the side-polished length, and the smaller the residual radius is, the greater the oscillation amplitude will be.

IV. Conclusion

Optical propagation characteristics of SPPCF have been analyzed .The attenuation of optical power and the distribution of propagation mode in the device of SPPCF were calculated and simulated with the variation of the three factors, such as: residual radius after side polishing, axial rotation angle, and the length of side-polished area. The results can be used to estimate the residual radius of SPPCF through the change of the optical power, and to choose the appropriate side-polished length and axial rotation angle according to the attenuation of optical power and the change of propagation mode.

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