A Ring Core Photonic Crystal Fiber with Hybrid Cladding Supporting High Quality Orbital Angular Momentum Modes

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ABSTRACT

A hybrid cladding ring core photonic crystal fiber is designed to support 26 high quality orbital angular momentum (OAM) modes spanning 7 OAM mode groups with weak spin-orbit coupling and wide bandwidth (C+L band).

INTRODUCTION

Mode division multiplexing (MDM) based on orbital angular momentum (OAM) modes is a good scheme to multiply the independent data channels. The ring core fiber and microstructure fiber with high refractive index contrast between core and cladding can break the degeneracy between HE and EH to ensure the stable transmission of OAM modes without coupling into LP modes. However, the large refractive index contrast of core-cladding will cause severe spin-orbit coupling, which can greatly increase the fiber loss and reduce the mode purity.

In this paper, we design a ring core photonic crystal fiber with hybrid cladding. The results show that the designed fiber can stably transmit OAM modes with high quality and weak spin orbit coupling

DESIGN OF OAM PCF

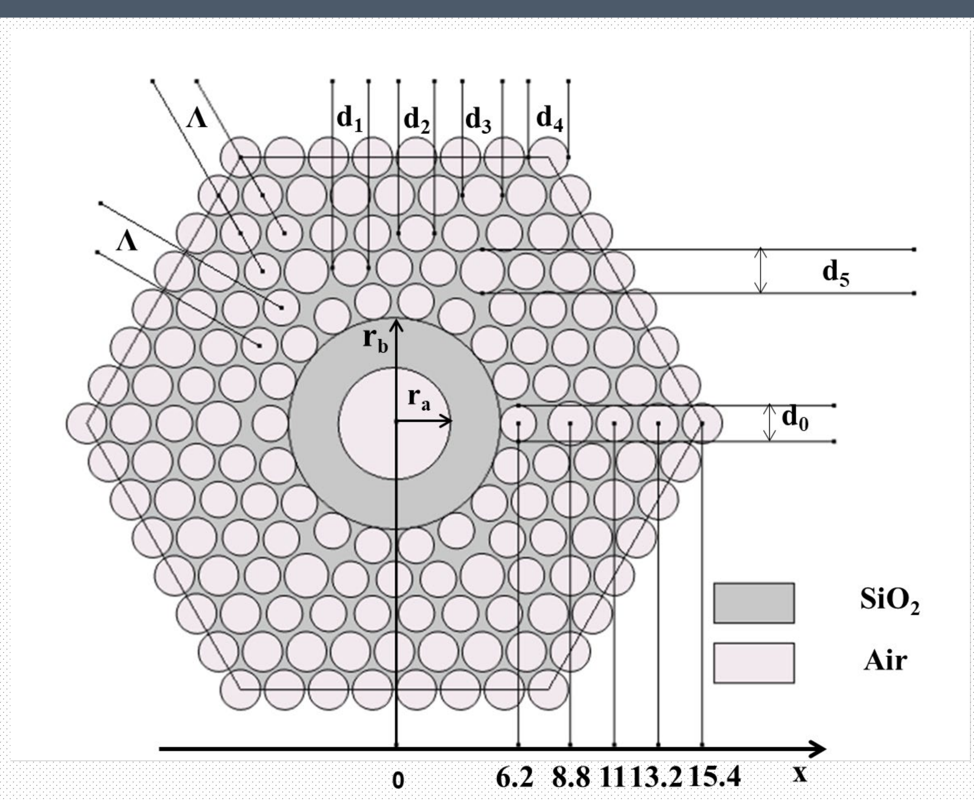

Fig.1. Cross-section of the designed hybrid cladding structure PCF.

Table 1
main parameters values

Parameter	Value
$d_0=d_1=d_2$	0.9um
$d_3=d_4$	1um
d_5	1.1um
r_a	2.8um
r_b	5.3um
Λ	2.2
$\rho(r_a/r_b)$	0.5283

In order to lift the index separation, triangular lattice is introduced to break the circular symmetry. However, air holes of the first ring must be arranged as a circular ring to ensure OAM modes excitation. So we mix the circular and triangular lattice as the fiber cladding.

PROPERTIES OF THE DESIGNED PCF

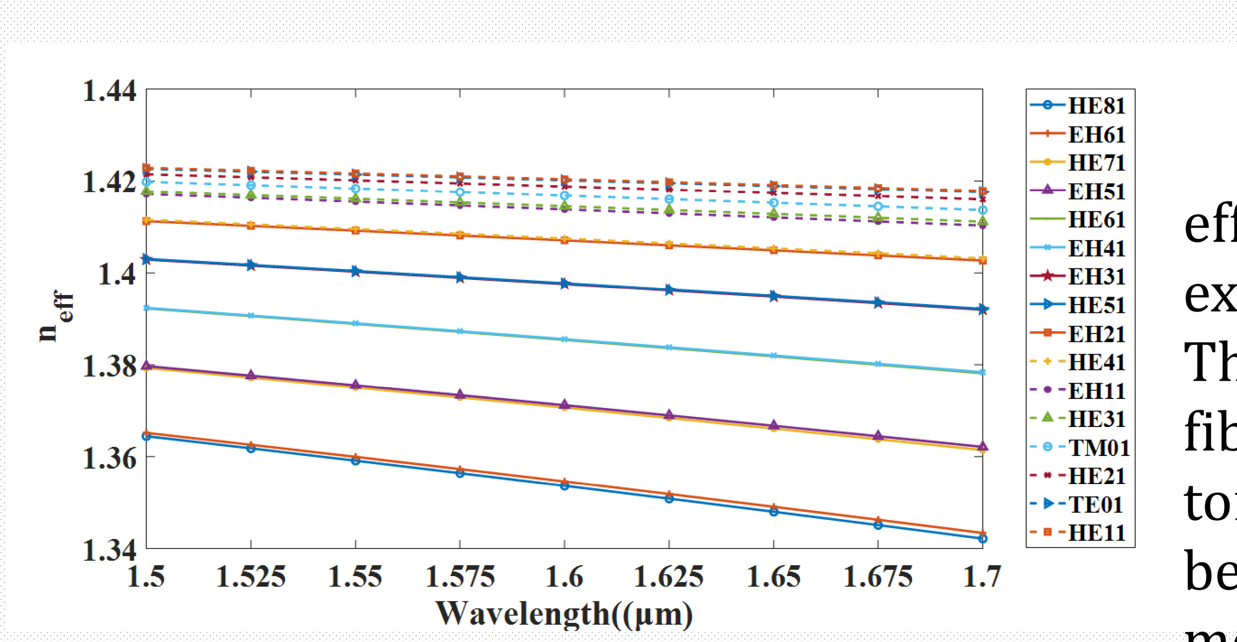

Fig.2. Effective refractive index of vector modes

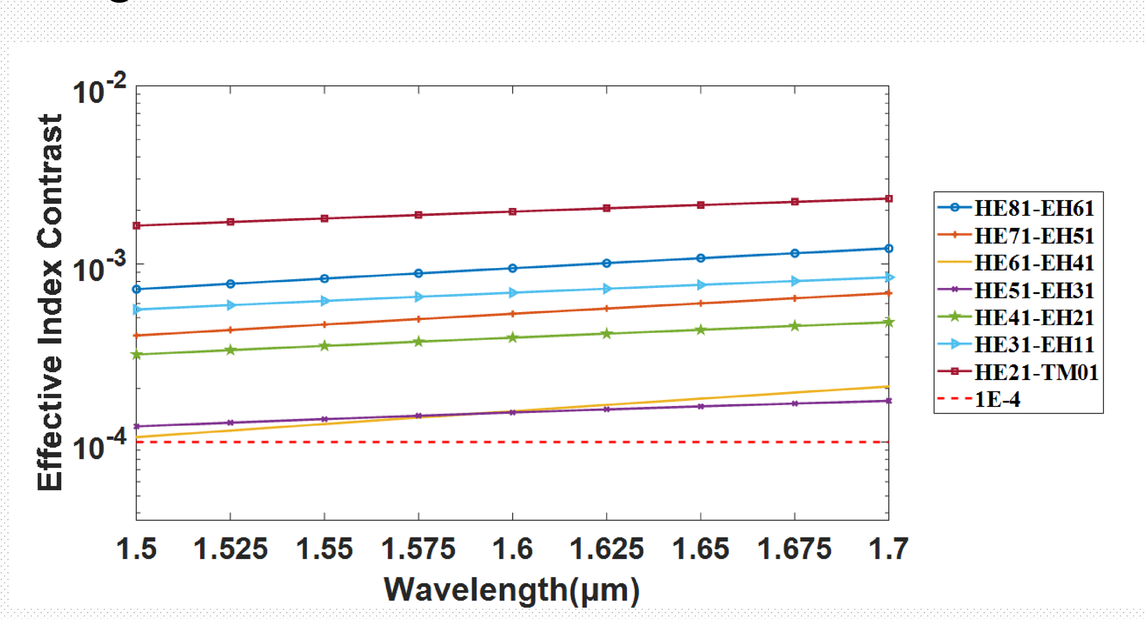

Fig.3. Refractive index difference of HE and EH modes from the same mode group.

Fig.2 exhibits the effective refractive index of the vector modes. The designed optical fiber supports 30 vector modes, which can be divided into 7 OAM mode groups. Fig.3 shows refractive index separation between adjacent vector modes from the same mode group which are larger than 10^{-4} from 1.55um to 1.7um which means the OAM modes can avoid coupling into LP modes during the process of transmitting in optical fiber..

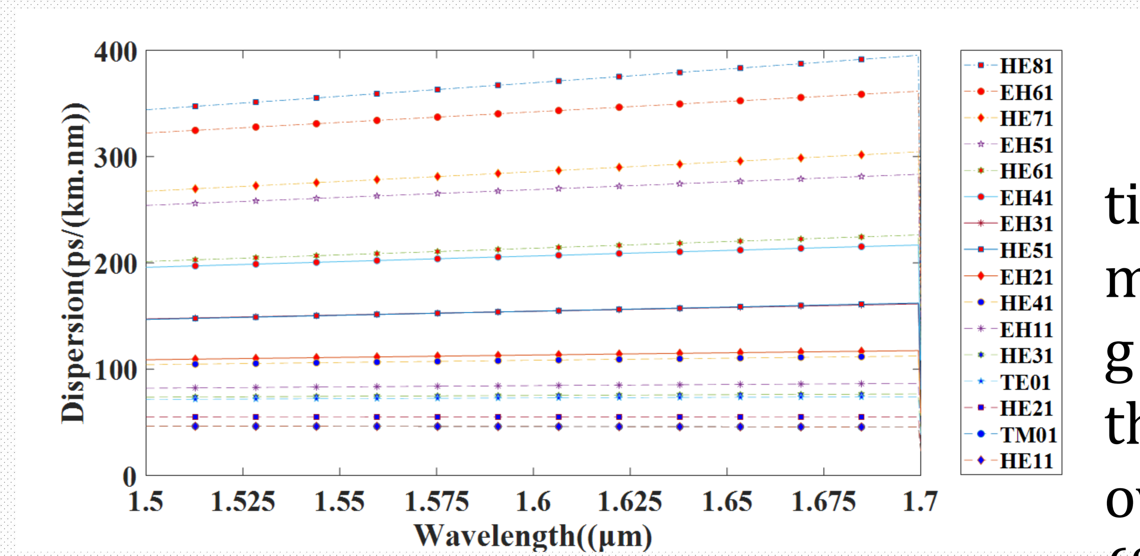

Fig.4. Dispersion characteristics of the vector modes

The dispersion variations for different OAM mode groups supporting by the fiber are lower than 50.0 ps/nm/km over 200 nm bandwidth (from1500 to 1700nm), which means dispersion curves are relatively flat. Except for higher order modes HE_{81} and EH_{61}, the confinement loss of other vector modes are lower than 3.6×10^{-9} dB/km.

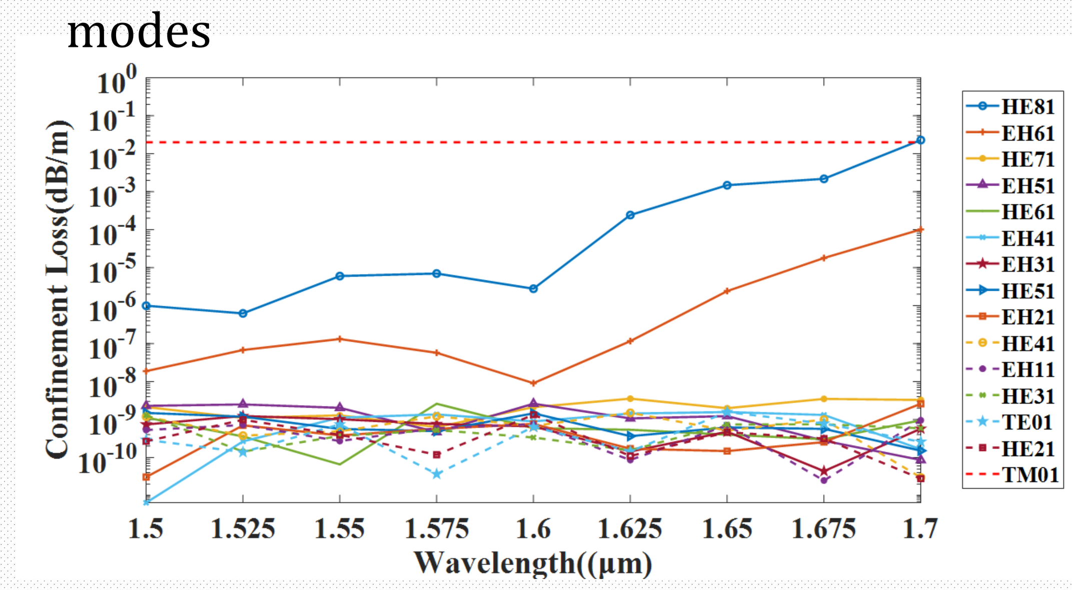

Fig.5. Confinement loss of different vector modes.

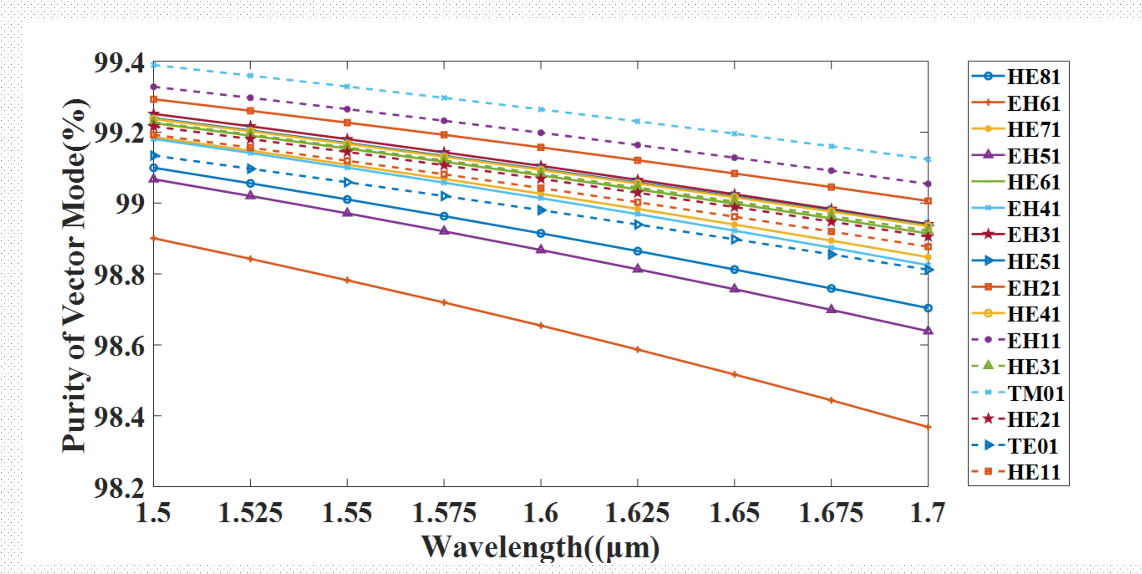

Fig.6. Purity of vector modes.

The vector mode EH_{61} with the lowest mode purity can also more than 98.3%. As shown in the Fig. 6, the purity of HE mode are greater than that of EH mode in the same OAM mode group. Fig. 7 shows OAM mode composition, intensity distribution and phase distribution. OAM modes have uniform intensity distribution and phase distribution in the ring core.

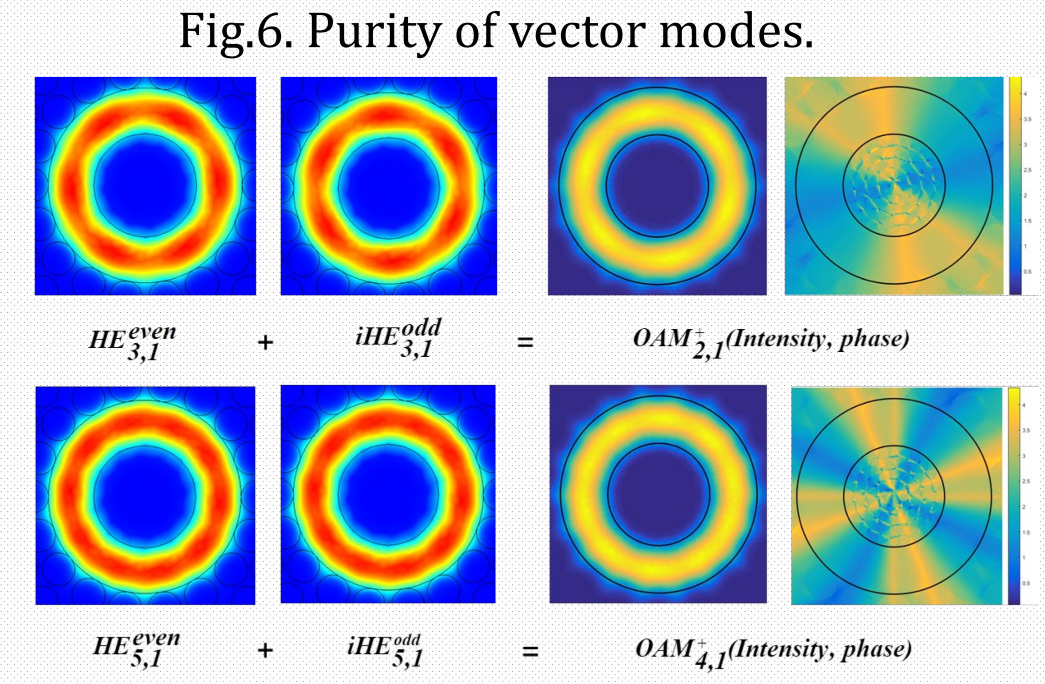

Fig.7. OAM mode composition, intensity distribution and phase distribution.

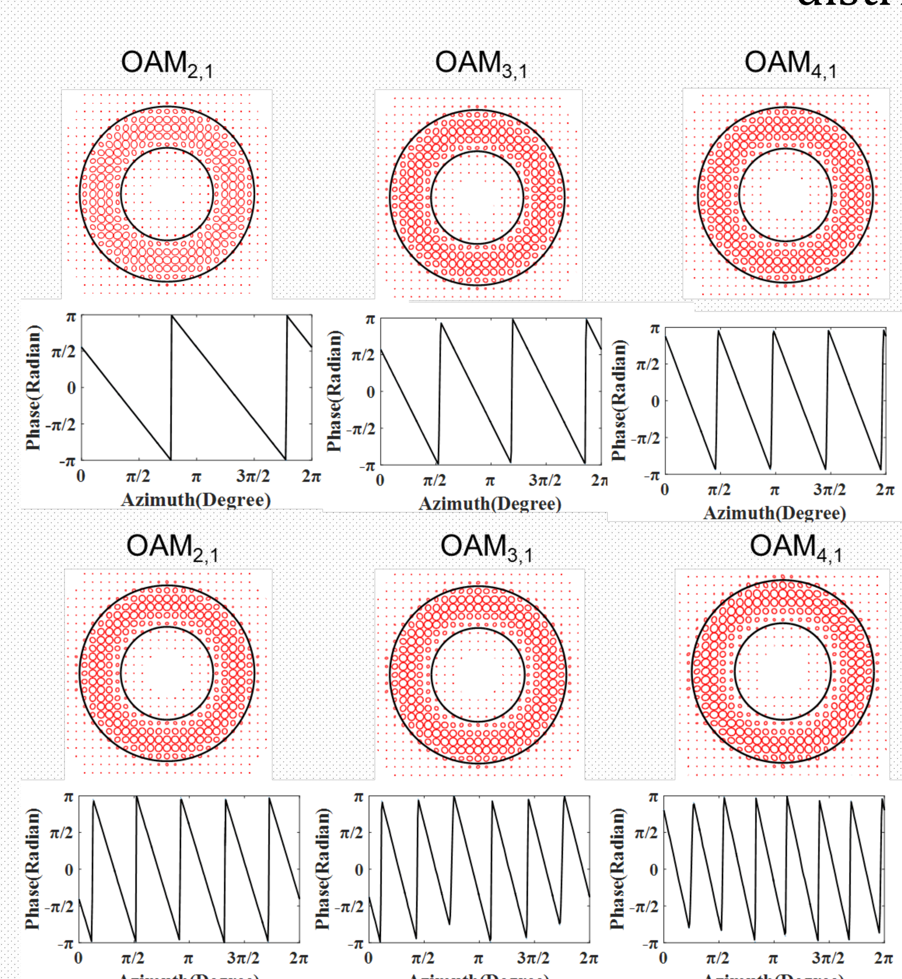

Fig.8. Polarization and phase distribution of OAM modes.

The polarization and phase of OAM modes are shown in Fig. 8. The polarization of OAM modes at each point in the ring core is near-circular polarization. The phase distribution of all OAM modes is periodic and uniform, which indicates that the designed fiber has weak spin-orbit coupling .

CONCLUSIONS

The thick ring fiber designed in this paper supports 26 OAM modes with high mode quality, weak spin-orbit coupling , flatten dispersion, low confinement cover C + L band. The effectives refractive index difference of vector modes reach the target (>10^{-4}) in the same OAM mode group which means high transmission quality. The purity of all vector modes is more than 98.3%. The polarization state of OAM modes in the ring core is near-circular polarization, and the phase distribution is periodic and uniform. Thus, the fiber can be used in the OAM-based MDM systems.

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