Hybrid Cladding Ring-Core Fiber with Weakly Spin-Orbit Coupling for OAM Mode Division Multiplexing Transmission

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ABSTRACT

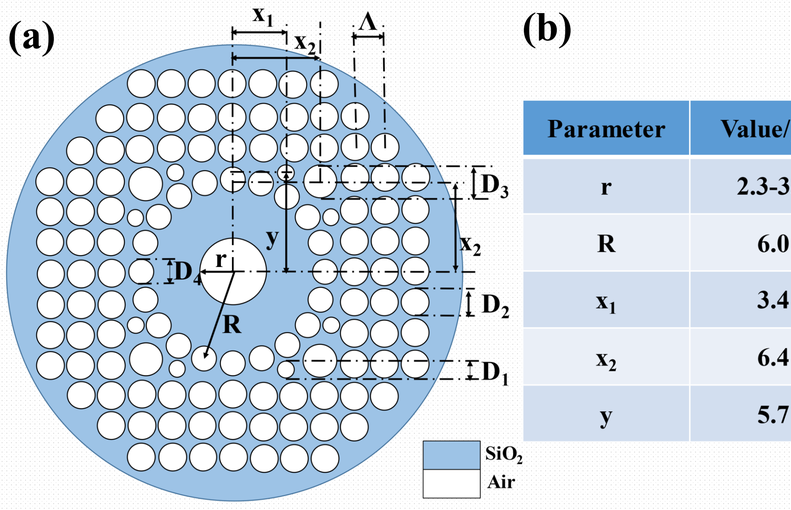
We design a hybrid cladding ring-core fiber which can transmit 22 orbital angular momentum (OAM) modes. In addition, OAM modes exhibit weak spin-orbit coupling, which will greatly reduce the complexity of MIMO at the receiver.

INTRODUCTION

To overcome the emerging capacity crunch, space division multiplexing (SDM) exploiting space domain is considered as a very potential method. Mode division multiplexing (MDM) as one form of the space division multiplexing, which adopts multimode fiber supporting linearly polarized (LP) modes or orbital angular momentum (OAM) modes to increase independent data channel.

In this paper, we propose a hybrid cladding ring-core fiber with cladding composed of circular and square lattice to weaken the spin-orbital coupling and obtain the large index separation. The refractive index difference between the core and cladding can be adjusted by changing the fiber structure parameters without doping, which will reduce the difficulty of the fiber fabrication and fiber loss. The simulation results show that the proposed fiber can support 22 high quality OAM modes with weak spin-orbit coupling and the wide bandwidth from 1450nm to 2000nm, when the radius of the middle air hole is set as 2.7μm. Therefore, it can be used in MIMO-less MDM systems with long distance.

OPTICAL FIBER DESIGN

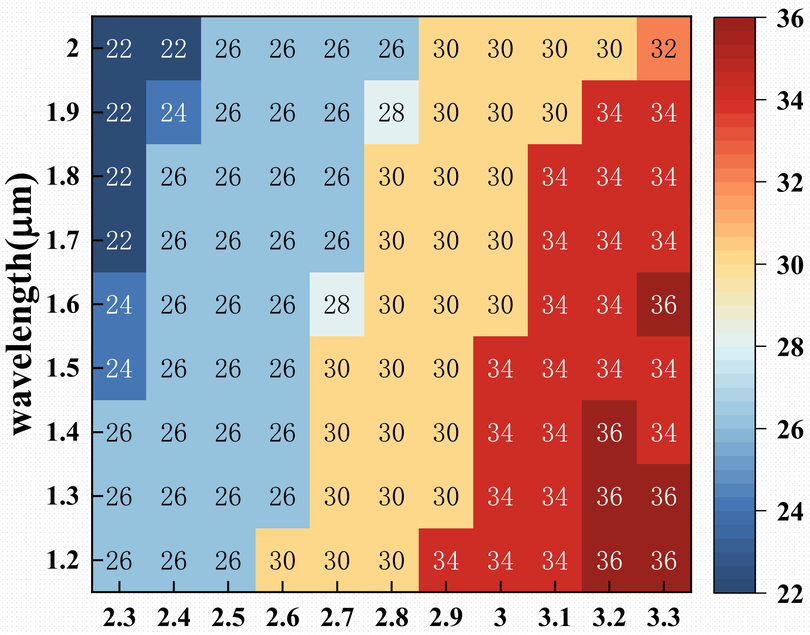


Parameter	Value/μm	Parameter	Value/μm
r	2.3-3.3	D_1	1.2
R	6.0	D_2	1.8
x_1	3.4	D_3	2.4
x_2	6.4	D_4	1.6
y	5.7	Λ	2.0

Fig.1. (a) Cross-section, and (b) main parameters values of the designed hybrid cladding structure PCF.

The ring-shaped fiber and ring microstructure fiber with high index contrast between ring core and cladding are proposed to support OAM modes. However, thinner ring cores are adopted in these fiber designs to suppress the high radial order modes and achieve the large refractive index difference between adjacent vector modes, which leads to severe spin-orbital coupling.

RESULT AND DISCUSSION



We analyzed the guided OAM modes in the proposed fiber shown in Fig.2, which the value of r from 2.3μm to 3.3μm. The figure indicates that with the increasing value of r, the number of OAM modes also increases in a step-type trend.

Fig.2. The number of modes varies with the radius of the central circular hole

As shown in Fig.3, we listed the effective refractive index difference at r = 2.4μm, r = 2.7μm and r = 3.0μm. The reason is that the thick ring will inhibit the coupling of spin-orbit and obtain better mode field quality.

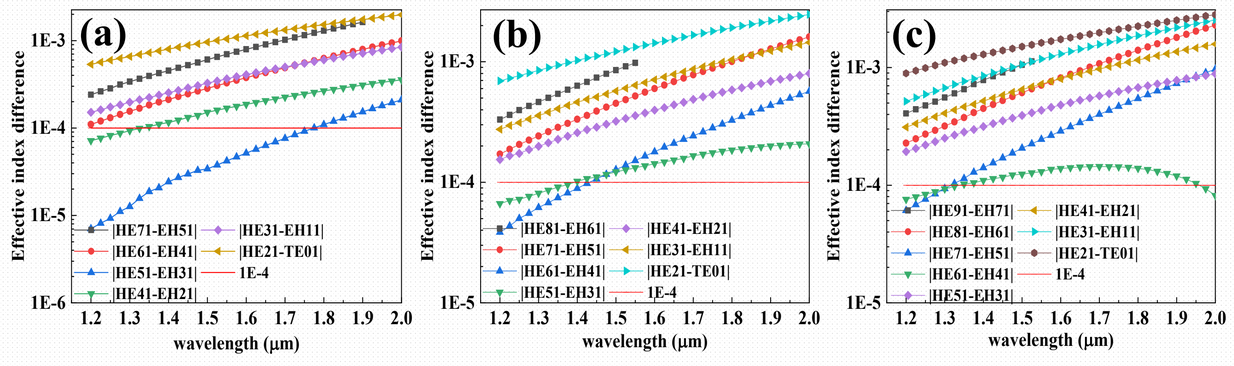


Fig. 3.Effective refractive index difference at different center hole radius (a) r = 2.4 μm (b) r = 2.7μm and (c) r = 3.0μm

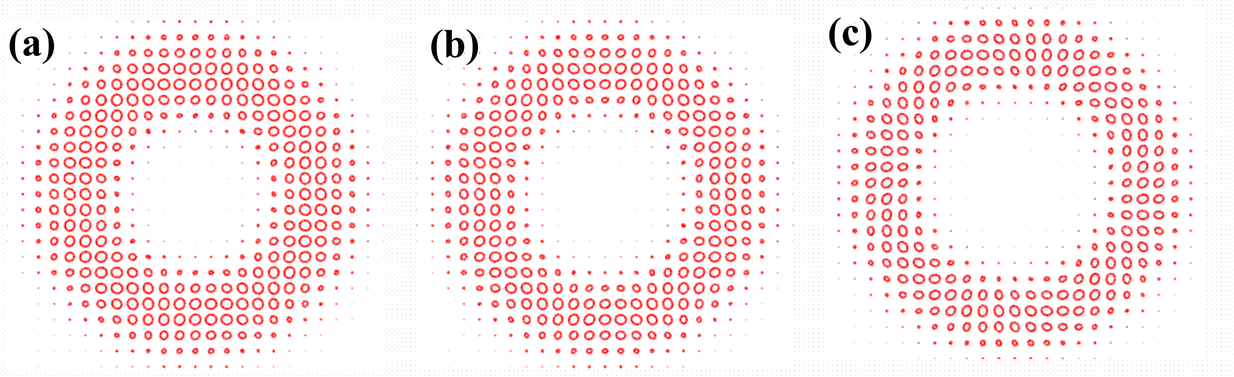


Fig.4 Spin-orbit coupling effect of OAM_{21}^{+} at different center hole radius (a) r = 2.4 μm (b) r = 2.7μm and (c) r = 3.0μm

In Fig.4, we display a group of the spin orbit coupling effect under different radius, what we show is the OAM_{21}^{+} mode, which is obtained by the composed of the HE_{31} mode. Combined with the model numbers, we choose that r = 2.7μm, which can ensure spin-orbit coupling is weak, also can support enough model number.

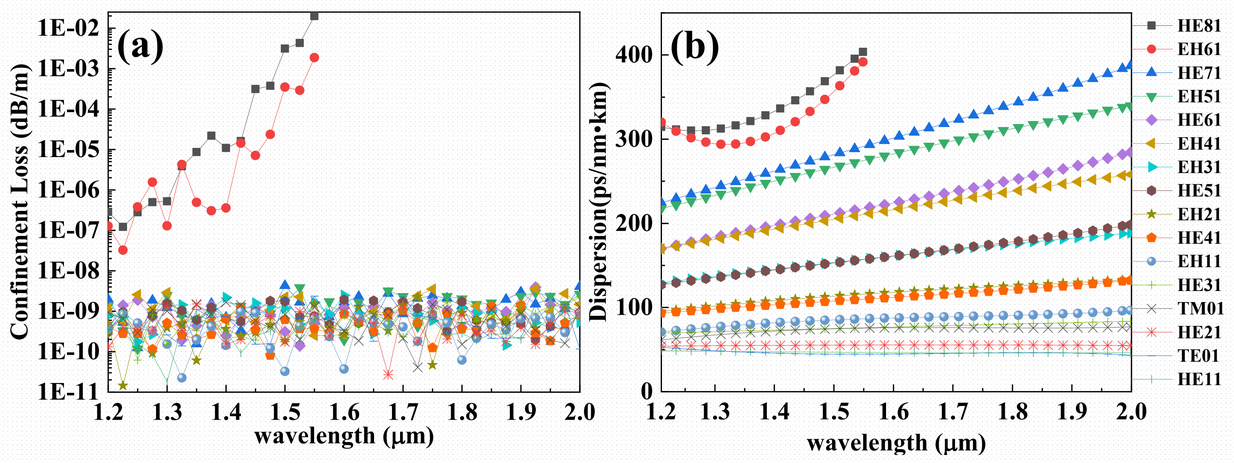


Fig.5. r=2.7μm (a) The relationship between confinement loss and wavelength (b) The relationship between dispersion loss and wavelength

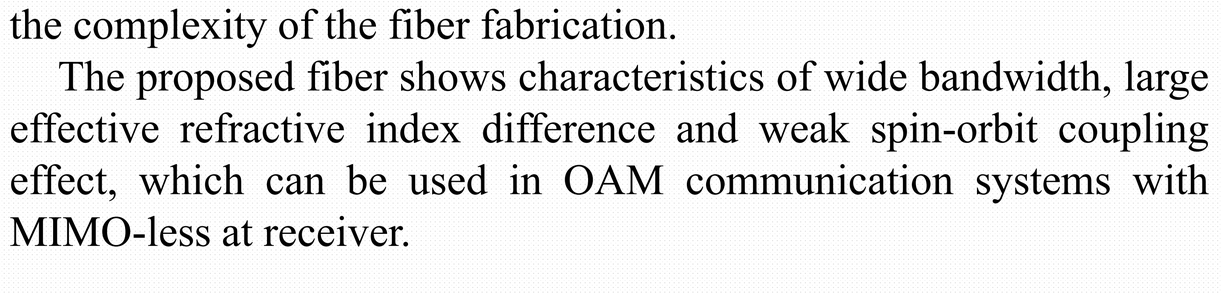


Fig.6. (a) the intensity distribution of HE_{31}^{even} (b) the intensity distribution of HE_{31}^{odd} (c) the intensity distribution of OAM_{21}^{+} and (d) the phase distribution of OAM_{21}^{+}

As shown in Fig.5, the confinement loss of all modes is less than 10^{-8} over the whole wavelength range. except for HE_{81} and EH_{61}. The dispersion of most modes increase when the wavelength increases. It can be seen in Figure. 6 that after the odd and even modes of HE_{31} are superimposed, the central dark spot becomes more round and the quality of the mode field becomes better, and its phase period is 2.

CONCLUSIONS

We propose a hybrid cladding fiber that can support 22 OAM modes with weak spin-orbit coupling effect from. In addition, we use single material SiO_2 as the substrate material, which greatly reduces the complexity of the fiber fabrication.

The proposed fiber shows characteristics of wide bandwidth, large effective refractive index difference and weak spin-orbit coupling effect, which can be used in OAM communication systems with MIMO-less at receiver.

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