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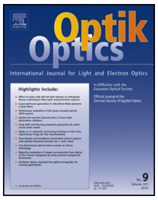

Octagonal photonic crystal fiber dual core polarization splitter

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ABSTRACT

An octagonal dual core polarization splitter based on highly birefringent photonic crystal fiber (PCF) is proposed and the full vector finite element method (FEM) is employed to analyze the impacts of structural parameters on birefringence and the coupling length, and simulation results show that high birefringence on the order of 10^{-3} can be achieved at 1.55 μm, moreover, the hole size and hole pitch both affect birefringence and the coupling length. Based on these results, the PCF's structure is optimized to realize a polarization splitter of 314 μm whose largest extinction ratio is around −50.5 dB at 1.55 μm. Meanwhile, the bandwidth at the extinction ratio of −10 dB is about 170 nm, and around 60 nm at −20 dB.

1. Introduction

Photonic crystal fibers [1,2] have attracted great research interest in recent years due to their unique and excellent optical properties, such as a wide wavelength range of single-mode operation [3,4], controllable effective modal area [5–7], tailorable dispersion [8,9] and high birefringence [10,11]. With the development of PCFs, polarization splitters based on PCFs have attracted more attention and they are of great significance for many optical applications, such as coherent optical communication systems and fiber optical sensors. Novel PCF polarization splitters with various structures have been reported in recent years. Rosa [12] proposed a polarization splitter based on a square lattice PCF, which comprises three asymmetrical cores. Mao [13] reported a polarization splitter based on all solid dual core PCF and the full vector finite element method was employed to analyze characteristics of the splitter. Lu [14] presented a three core PCF polarization splitter with a bandwidth of 400 nm, and two fluorine-doped cores and an elliptical modulation core are introduced in this structure. Shuo [15] put forward a polarization splitter in dual core hybrid PCF and their structure is composed of elliptical holes and comprises different materials.

In this paper, a novel dual core polarization splitter based on an octagonal PCF is proposed and the finite element method is used to calculate the effective indexes of the dual core octagonal PCF. Moreover, the impacts of structural parameters on birefringence and coupling length are numerically analyzed. By adjusting the structural parameters, high birefringence, high extinction ratios, small coupling lengths and large bandwidths can be achieved.

2. The proposed splitter's structure and theory

Fig. 1 illustrates the structure of the octagonal dual core PCF splitter whose cladding is composed of circular air holes arranged in octagonal configuration. A and B are two symmetrical cores of the PCF and d is the diameter of air holes. Λ_x and Λ_y denote the hole pitches along the x- and y-direction, respectively.

The effective index of the proposed PCF is calculated by FEM and birefringence can be expressed as [16]

$$B = |Re(n_{eff}^{x} - n_{eff}^{y})| \tag{1}$$

where B represents birefringence, Re stands for the real part of the effective index, n_{eff}^{x} and n_{eff}^{y} denote effective refractive indices of the x- and y-polarized fundamental modes, respectively.

According to the mode coupling theory, the total modes can be considered as a superposition of four modes, including the odd modes $E_{odd}^{x,y}$ and the even modes $E_{even}^{x,y}$. And their effective refractive indexes are $n_{odd}^{x,y}$ and $n_{even}^{x,y}$, respectively. The coupling length is defined as [17]

$$L_{x,y} = \frac{\lambda}{2(n_{even}^{x,y} - n_{odd}^{x,y})} \tag{2}$$

where λ is the optical wavelength.

When the power inputted into one core is $P_{in}^{x,y}$, the output power $P_{out}^{x,y}$ can be calculated from the following equation [18]

$$P_{out}^{x,y} = P_{in}^{x,y} \cos^2\left(\frac{\pi}{2}\frac{z}{L_{x,y}}\right) \tag{3}$$

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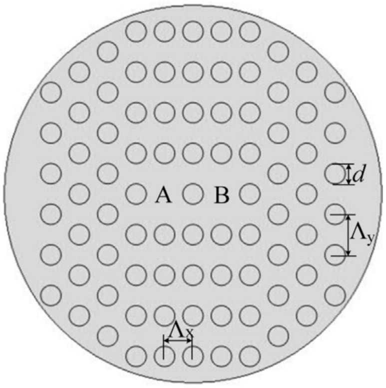


Fig. 1. Cross section of the octagonal dual core PCF polarization splitter.

where z is the propagation length along the fiber. With the $P_{out}^{x,y}$ obtained, the extinction ratio, ER, can be defined as follows [19]

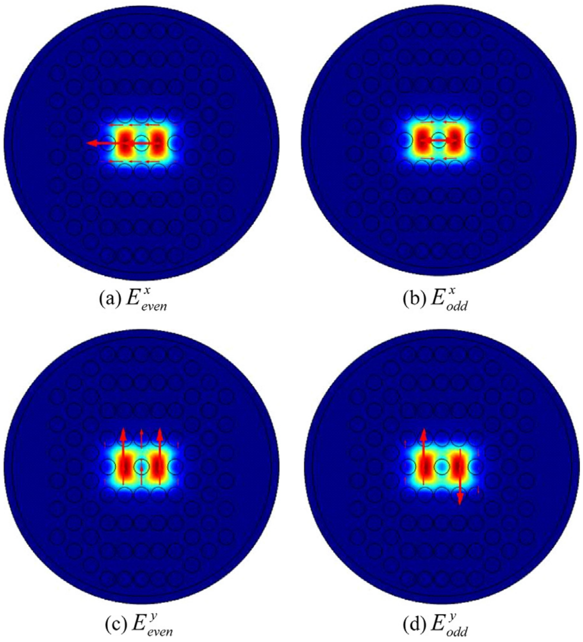
$$ER = 10\log_{10}\frac{P_{out}^{y}}{P_{out}^{x}} \tag{4}$$

3. Numerical results and discussions

The finite element method is applied to calculate the effective refractive index and simulate the distribution of fundamental modes of the PCF splitter, and the distribution of even modes and odd modes are shown in Fig. 2.

The coupling length is one of those important parameters for evaluating the performance of polarization splitters and birefringence has a big impact on the coupling length difference, so we calculate the coupling length and birefringence with altered structural parameters.

Fig. 3 shows birefringence as a function of Λ_y with different values of Λ_x/Λ_y and $d/\Lambda_y = 0.5$ at the wavelength of 1.55 μm, and we can see that with Λ_x/Λ_y fixed, birefringence decreases as Λ_y increases. This is because Λ_x increases along with Λ_y and the large hole pitch may reduce the structure's asymmetry, resulting in smaller birefringence. While Λ_y is fixed, the smaller Λ_x/Λ_y is, the higher birefringence becomes. This is because the smaller Λ_x can make the structure squeezed transversely, which enhances its asymmetry and leads to higher birefringence.


(a) E_{even}^{x} (b) E_{odd}^{x}

(c) E_{even}^{y} (d) E_{odd}^{y}

Fig. 2. Distribution of even and odd components of fundamental modes. (a) and (b) Even and odd modes of the x polarized mode. (c) and (d) Even and odd modes of the y polarized mode.

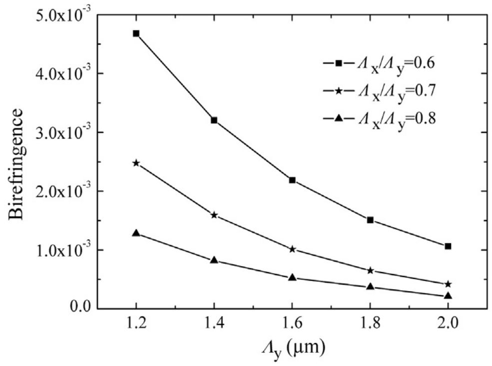


Fig. 3. Birefringence as a function of Λ_y for different Λ_x/Λ_y.

Fig. 4 illustrates the coupling length as a function of Λ_y with different values of Λ_x/Λ_y and $d/\Lambda_y = 0.5$ at the wavelength of 1.55 μm, and it is seen that with Λ_x/Λ_y fixed, the coupling length increases with Λ_y increasing, and the reason is while Λ_x and Λ_y both increase, the two cores can be further separated from each other and meanwhile modal fields are confined in the cores more intensely, so the coupling between two cores becomes more difficult, which results in the increased coupling length.

While the ratio is fixed as $\Lambda_x/\Lambda_y = 0.6$, we analyze the variation of birefringence and the coupling length with d/Λ_y at 1.55 μm, and in Fig. 5 we can see that with d/Λ_y fixed, birefringence decreases

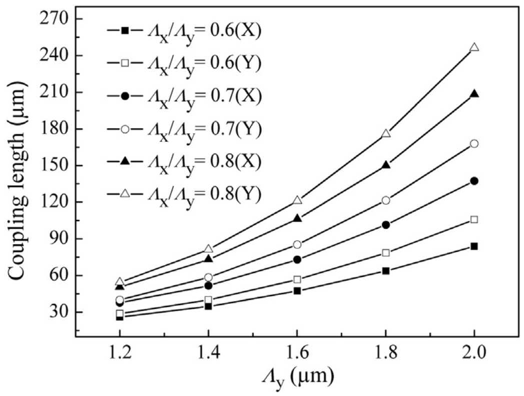


Fig. 4. Coupling length as a function of Λ_y for different Λ_x/Λ_y.

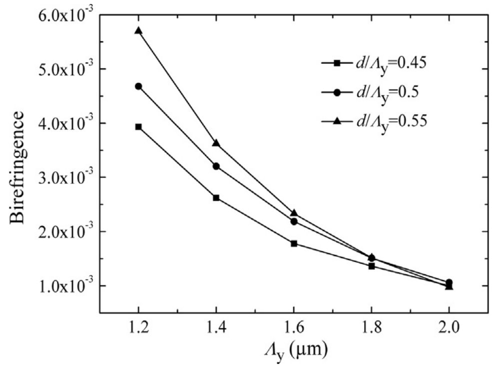


Fig. 5. Birefringence as a function of Λ_y for different d/Λ_y.