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Polarization splitter based on dual-core photonic crystal fiber with tellurite glass☆

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ABSTRACT

A polarization splitter based on dual-core photonic crystal fiber (PCF) with tellurite glass was proposed. The birefringence of the splitter was improved by introducing elliptical air holes. The full vector finite element method is used to analyze the impacts of structural parameters on the coupling length. The results show that the elliptical size is reasonably changed, the extinction ratio can reach 107.21 dB at the wavelength of 1.55 μm, the length of the splitter is 89.05 μm, and the bandwidth is 150 nm when the extinction ratio is more than 20 dB. Besides, we also compare the characteristics of tellurite glass and silica glass photonic crystal fiber polarization beam splitters with the same structural parameters.

1. Introduction

High-speed, high-capacity all-optical network has become the trend of future communications. All-optical network with large capacity and ultra-high speed needs the support of high-performance optical devices, and all-optical devices with excellent performance and low price have become the research hotspots. Polarization splitter is an important optical device in all-optical network, which can separate one light beam into two orthogonal polarization states, the long length of a polarizing splitter made by a conventional optical fiber limits its application, so it is necessary to design a high-performance polarizing splitter.

Photonic crystal fiber (PCF), because of its unique and excellent optical properties, which include endlessly single-mode [1], ultra-low loss [2], high-birefringence [3], extremely effective mold field area [4], chromatic dispersion [5] and great nonlinearity [6] has attracted a large amount of interests since 1996. The flexible design of the structure and high birefringence provide the basis for high performance polarization splitter. So polarization splitter based on photonic crystal fiber has attracted research interest. At present, polarization splitters based on PCF have been reported. Rosa et al. [7] presented a polarization splitter consisting of square-lattice PCF, with the length being 29 mm, and the bandwidth being 90 nm when the extinction ratio is more than 23 dB. Rajeswari [8] designed a polarization splitter with dual-core PCF, with the length being 2 mm, and the bandwidth of the x, y-polarization modes being 100 nm and 55 nm. Saitoh et al. [9] proposed a three-core polarization splitter based on PCF, with the length being 1.9 mm, and the bandwidth being 37 nm. Jiang et al. [10] presented a dual-core polarization splitter based on PCF, whose length is only 119.1 μm.

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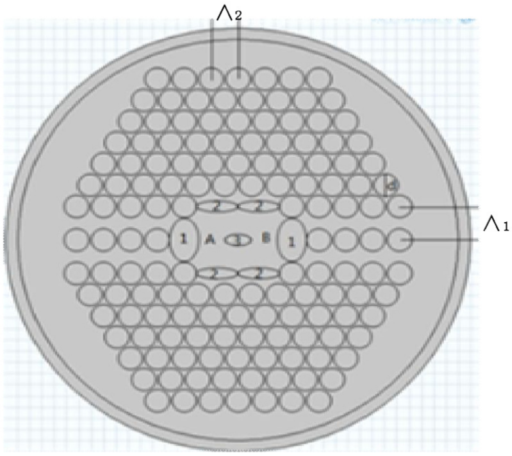

Fig. 1. Cross section of the polarization splitter.

Because the tellurite glass has a high linear and nonlinear refractive index and a wide transmission spectrum, especially, their typical melting temperature is much lower than that of silica, it has attracted researchers interests again. Liu [11] analyzed high extinction ratio PCF polarization splitter based on ZnTe glass, with the length being 1.1452 mm at the wavelength of 1.55 μm, the extinction ratios being 92.16 dB and 29.56 dB in A and B cores respectively, and the bandwidth of the x, y-polarization modes being 100 nm and 45 nm. Liu et al. [12] analyzed a total solid three-core PCF polarization splitter based on tellurite, with the length being 1.14 mm, the extinction ratio being up to −101.27 dB, the bandwidth being 100 nm. Liu [13] simulated a short and broadband polarization splitter based on PCF filled tellurite glass, with the length being 510 μm at the wavelength of 1.55 μm, the extinction ratio being 71.2 dB. Rui [14] proposed highly birefringent PCF polarization splitter made of soft glass, with the length being 252 μm at the wavelength of 1.55 μm, the extinction ratio being −44.42 dB, the bandwidth being 32 nm. The above designs have their advantages, but they do not have the characteristics of short length, high extinction ratio and wide bandwidth, so the performance of polarization splitter should be further optimized.

In this paper, we proposed a polarization splitter based on dual-core photonic crystal fiber (PCF) with tellurite glass. The effective refractive index is calculated by the commercial package Comsol Multiphysics based on the full vector finite element method (FEM) with perfectly matched layer. Moreover, we analyzed the impacts of structural parameters on the coupling length, and by optimizing the structural parameters, a polarization splitter with ultra-short length, high extinction ratio and wide bandwidth is obtained. Besides, we also compared the characteristics of tellurite glass and silica glass photonic crystal fiber polarization beam splitters with the same structural parameters.

2. Model and theory

The cross section of the polarization splitter based on dual-core PCF with tellurite glass is shown in Fig. 1. The middle three rows of air holes are arranged in a rectangular lattice, the horizontal pitch is $\Lambda_2 = 1.1\,\mu$m and vertical pitch is $\Lambda_1 = 1.5\,\mu$m, the remaining circular air holes are arranged in a common hexagonal lattice and the diameter of circular air holes is $d = 1.0\,\mu$m and a lattice constant is Λ_2. The minor and major half-axis length of the ellipse 1 are $b_1 = 0.60\,\mu$m and $a_1 = 0.97\,\mu$m, respectively. The distance between the ellipse 1 and the ellipse 3 in the horizontal pitch is 2 Λ_1. The minor and major half-axis length of the ellipse 2 are $b_2 = 0.25\,\mu$m and $a_2 = 0.85\,\mu$m, respectively. The distance between the ellipse 2 and the ellipse 3 in the vertical pitch is Λ_1, and the horizontal direction between the two ellipses 2 is tangent. The minor and major half-axis length of the ellipse 3 are $b_3 = 0.25\,\mu$m and $a_3 = 0.53\,\mu$m, respectively. The background material of the whole fiber is ZnTe tellurite glass, the refractive index can be calculated from the Sellmeier formula [15], the material dispersion is negligible. The refractive index of the air is 1.

$$n(\lambda) = \sqrt{A + \frac{B\lambda^2}{\lambda^2 - C} + \frac{D\lambda^2}{\lambda^2 - E}} \tag{1}$$

where A = 2.4843245, B = 1.6174321, C = 0.053715551, D = 2.4765135, E = 225.0. λ is the free-space wavelength of the incident light and its unit is micrometer [15].

According to the mode coupling theory, there are four modes in the dual-core PCF, which are the odd-mode E_{xo}, E_{yo} and even-mode E_{xe}, E_{ye} in x, y-polarization directions, respectively [16]. Their field distributions of even modes and odd modes are shown in Fig. 2.

The same polarization mode that satisfying the interference conditions will cause the core power coupling, that is, the core power coupling is caused by the even and odd modes interference in the x, y-polarization directions [17]. When the energy of a polarized light is completely transferred from one core to another, that is, the optical power of the polarized