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Regular Articles

A simple gold-coated microstructure fiber polarization filter in two communication windows

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ABSTRACT

A polarization filter is designed at two communication windows of 1310 and 1550 nm based on microstructured optical fiber. The model has four large diameter air holes and two gold-coated air holes. The influence of the geometrical parameters of the photonic crystal fiber on the performance of the polarization filter is analyzed by the finite element method. The numerical simulation shows that when the fiber length is 300 μm, the corresponding extinction ratio is 209.7 dB and 179.8 dB, the bandwidth of extinction ratio (ER) better than 20 dB is 150 nm and 350 nm at the communication wavelength of 1310 nm and 1550 nm.

1. Introduction

Photonic crystal fibers (PCFs) [1–6], which are also called microstructured optical fibers (MOFs). Compared with traditional fibers, it has some novel features such as low optical losses, high optical nonlinearity, ultra-negative dispersion, and polarization effects. Many functional devices based on PCF, including polarization splitters [7,8], sensors [9,10], rotators, wavelength division multiplexer (WDM), laser [11], and amplifiers, have been proposed. Liquid, liquid crystal, semiconductor, intelligent, oil and so on to fill the air bag, can change the characteristic of PCF. For example, by filling high refractive index fluid into the hole, index-guided PCFs whose transmission characteristics can in turn be tuned over a large range [12]. In the mental-filled PCF [13,14], the surface plasmon polariton (SPP) modes and the core-guided modes and the core-guided modes can be met.

With the development of technology, the rendering of photonic crystal fiber has been greatly improved. Microstructured optical fiber manufacturing technologies include extrusion, rod casting, ultrasonic drilling, and preform stacking. The method of filling or coating PCF is also developing rapidly. Wadsworth [15] have been developed the superposition and pumping methods of doped nuclear photonic crystal fiber. Sazio [16] show the variety of materials can be introduced into photonic crystal fibers by high pressure micro fluid chemical deposition.

Polarization filter is the key device in optical communication and optical sensing system. Microstructured optical fiber filter has the advantages of small size, tunable, large extinction ratio, good stability and wide wavelength range, which provides a better prospect for the development of the industry. A microstructured fiber is designed in this paper is proposed, through the selective polarization in Y direction of the air hole plating of nano gold film [17], the core mode and gold membrane coupled y polarization direction, thereby selectively at the resonant wavelength filter y polarized light, and then get the ideal result. In order to adjust the resonant wavelengths 1310 nm and 1550 nm in the y-polarization direction, we adjust the gold film thickness of 17.75 nm and 33.8 nm. When the fiber length is 300 μm, the extinction ratio values are reached at 1310 nm and 1550 nm 209.7 dB and 179.8 dB respectively.

1.1. The structure and basic theory

Fig. 1 shows the cross section of the microstructured optical fiber with two gold-coated air hole. The optical mode can be coupled out of the core into the gold layer. The lattice pitch is represented by $t = 2\,\mu m$. The diameters of white holes, green holes, blue holes, cyan holes, and yellow hole are represented by d, d_1, d_2, d_3, and d_4. And the position of the green hole is in the coordinates of the cross section (3.5, 3.0), (3.5, −3.0), (−3.5, 3.0), (−3.5, −3.0). The diameter of d is fixed to 1.4 μm. The blue hole is coated by nanoscale gold film. The red circle represents nanoscale gold film, the thickness of it is represents by δ. The background material is pure silica. The mode properties are studied by using the finite element method, the perfectly matched layer (PML) is used to absorb radiation energy at different angles without incident energy.

In this article, two stomata in the Y axis are coated to produce plasma resonance. The size of the six pores around the core and the X axis are larger in order to allow the pore leakage from the die field to

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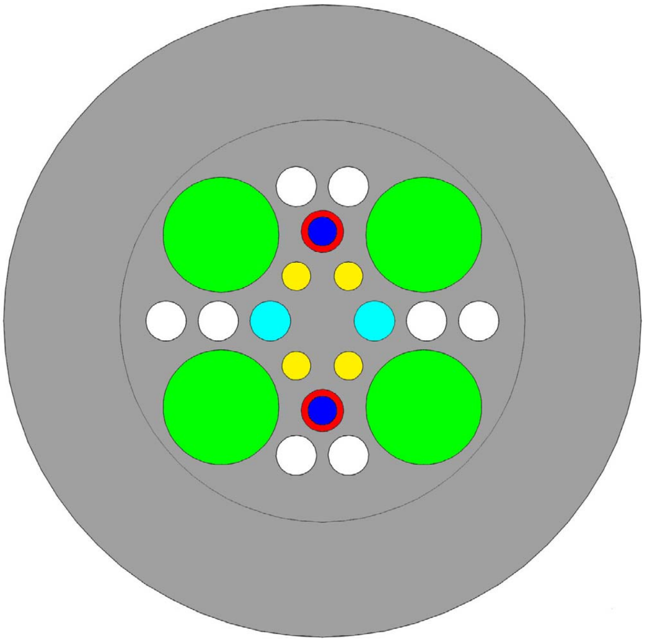

Fig. 1. Cross-section of the designed microstructured fiber.

the metal and increase the plasma resonance. In microstructure optical fiber under the condition of less total porosity, structure is simple, the distribution of the square four large porosity is in order to prevent the mode field leakage, reduce the loss of the limit of the fiber.

The chromatic dispersion of the background material, which is pure silica, and is calculated by the sellmeier equation [18]. Likewise, the dielectric constant of the gold is also characterized by the Drude-Lorentz model [19] and could be expressed as:

$$\varepsilon_m = \varepsilon_\infty - \frac{\omega_D^2}{\omega(\omega + j\gamma_D)} - \frac{\Delta\varepsilon\cdot\Omega_L^2}{(\omega^2 - \Omega_L^2) + j\Gamma_L\omega} \tag{1}$$

The physical meaning represented by the symbol has been marked out in the reference. The mode loss can be defined as:

$$L = 8.686 \times \frac{2\pi}{\lambda}\mathrm{Im}(n_{eff}) \times 10^4 \tag{2}$$

The units of the loss and wavelength are dB/m and μm respectively; the effective refractive index [20] represent the Im[neff].

2. Simulation results and analysis

Fig. 2 show the effective refractive index and energy loss in x-polarization and y-polarization directions. The SPP core mode is represented by a blue dotted line. In this part, d = 1.4 μm, d_1 = 4.0 μm, d_2 = 1.4 μm, d_3 = 1.4 μm, d_4 = 1.0 μm, the thickness of the metal film is δ = 33.8 nm. We found that from the picture, the effective refractive index decreases as the wavelength increases, and y-polarization has suddenly increased to 1310 nm. The loss of y-polarization varies regularly as the wavelength increases, and the largest loss at 1310 nm is 83235.7 dB/m. When the incident photon frequency matches the metal nanoparticles, the gold nanoparticles produce very strong photon energy absorption, and the surface plasmon resonance occurs, and the photon energy in the y-polarization direction is greatly lost. This is why polarization loss of y is greater than x-polarization loss.

As far as we know, the resonance properties are susceptible to structural parameters, such as the thickness of the metal film, the diameter of a cladding layer, and so on. By modulating the structure parameters of PCF, we implemented the polarization filter PCF. By selectively filling nanoscale gold films, the y-polarized core pattern can be filtered out. In order to ensure the effective transmission characteristics of the fibers, the structure parameters must be set on the same order of magnitude as the wavelength of light wave. So the core effective refractive index pattern or SPP pattern varies with the parameters. We can adjust the parameters to meet different needs. In this paper, we looked at the effect of the filter effect by changing the thickness of the gold film and the diameter of d_1, d_2, d_3, d_4.

Fig. 3 is by changing the diameter of green hole d_1 from 3.6, 3.8 to 4.0 μm. As the wavelength increases, the wave peaks of the loss of the y-polarization are moves towards the short-wave length. The loss peak of y-polarization is reduced from 84325.1 dB/m to 83235.7 dB/m, and the corresponding wavelength is moved from 1335 nm to 1310 nm. We saw that the loss of the y-polarization direction and the peak position didn't change much. Since the green air hole is far from the fiber core, the changes in its diameter cannot strong affect the coupling of the core and the gold film. Although it has an effect on the performance of the polarization filter by changing the diameter of d_1, but it's not significant.

By changing the diameter of the blue air hole d_2, we have the effect shown in Fig. 4. In the part, the diameter of d_2 is 1.4, 1.5, 1.6 μm, and the peak loss of y-polarization is 83235.7, 61704.0, 41907.5 dB/m. As the diameter of the blue air hole increases, the peak of the loss decreases, and the peak position is like the short-wave strength. Although the diameter of the air hole is larger, the coupled area of the gold film with the core mode has not increased, so the loss is smaller than before. We can adjust the size of d_2 to get more of the effect of the y-polarization loss.

Fig. 5 is changing the diameter of air hole d_3 from 1.4, 1.6 to 1.8 μm. We can see from the picture, the y-polarization core mode loss is influenced the diameter of the d_3. The bigger the diameter of the d_3, the smaller the loss of the y-polarization core mode. The resonance wavelength of y-polarization direction moves to long wavelength. With the increase of the size of the d_3, the core optical pattern changes, and

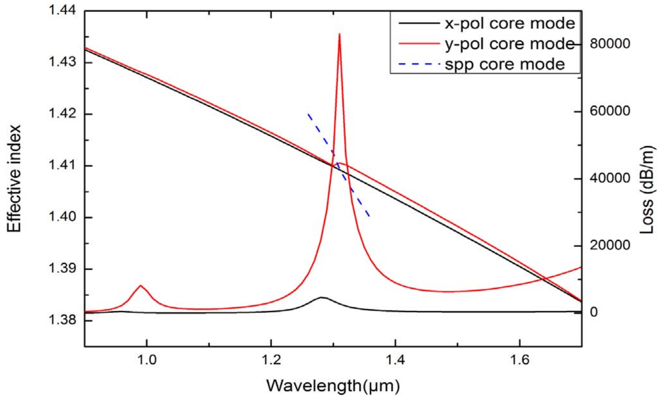

Fig. 2. Effective refractive index and energy loss in x-polarization and y-polarization directions.

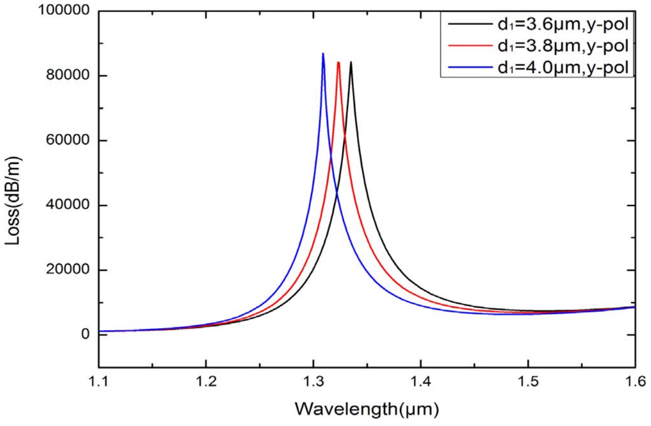

Fig. 3. Changing the effect of d_1 on device performance.