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Field analysis based on the smoothly deformed Bragg fiber

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ABSTRACT

A new kind of smoothly deformed Bragg fiber structure has been proposed in this paper, and the mode field characteristics about this fiber have been analyzed. By comparing the field at different coordinates along the propagation direction, the evolution of the field for the elliptical transverse faces and the circular one is obtained. The method has also been used to detect the behavior of the elliptical Gaussian beam. This research method can be used to analyze the thermal deformation of fiber.

1. Introduction

Bragg fiber was proposed by Yeh et al. at 1978 [1]. This kind of fiber and its relevant devices possess more attractive characteristics than the conventional ones [2]. For some reasons, such as partial sun shine, causes partial thermal deformation (thermal expanding), the shape of the fiber is often distorted, typically into an ellipse-like one. There are various methods to deal with laser beam [3–7]. So in the paper we try to find the relationship between the elliptical Bragg fiber and the circular one and deal with Gaussian beam. This research method can be used to analyze the thermal deformation of fiber, and it can be widely used to fiber communication system.

2. Derivation of electromagnetic field

The structure of this kind of fiber is shown in Fig. 1.

At the top of the fiber, the traverse face is elliptical structure, and along the propagation direction, it is smoothly deformed into a circular one at the bottom of the fiber, that is, the shape of every transverse face is elliptical except the circular bottom face. Bragg fiber consists of a low index air core surrounded by high and low refractive index layers alternatively.

The transverse refractive index distribution of elliptical Bragg fibers is:

$$n(\xi) = \begin{cases} n_c, & 0 < \xi < \xi_1 \\ n_1, & \xi_{2v-1} < \xi < \xi_{2v} \\ n_2, & \xi_{2v} < \xi < \xi_{2v+1} \end{cases} \quad (1)$$

where $v = 1, 2, 3, \ldots, \infty$.

It is convenient to analyze the field of the elliptical transverse faces in the elliptical coordinate system, shown as Fig. 2.

In terms of the rectangular coordinates (x, y, z), the elliptical cylinder coordinates (ξ, η, z') are defined as follows

$$\begin{aligned} x &= c\cosh(\xi)\cos(\eta) \\ y &= c\sinh(\xi)\sin(\eta) \\ z &= z' \end{aligned} \quad (2)$$

where c is foci of the core.

In Bragg fiber, the propagation satisfies $0 \le \beta/k_0 \le n_{core}$. Then, at a general cladding interface $\xi = \xi_0$, the axial electromagnetic field can be expressed as

$$\{ \quad (0 < \xi < \xi_0) \quad (3)$$

and

$$\{ \quad (\xi_0 < \xi < \infty) \quad (4)$$

where $q = (c^2(p^2 - \beta^2))/4, p^2 = k_i^2 - \beta^2, k_i^2 = \omega^2 \mu_i \varepsilon_i, \beta$ is the propagation constant and Ce, Se, Fey, Gey are radial Mathieu functions of the first and second kind and ce, se are the angular Mathieu functions of the first kind in accordance with [5].

3. Analysis FOR results

In this paper, to simplify our simulation and at the same time get a fairly good result, we suppose that the electromagnetic field propagates along the negative z direction, that is, from the top to the bottom .In terms of the refractive index of the core and the first and second claddings are predefined as $n_{core} = 1, n_1 = 25$, and $n_2 = 1.5$. At the bottom, the thickness are 0.2214 μm and 0.1 μm respectively. The radius of the core is $r_{core} = 0.75$ μm. For the top

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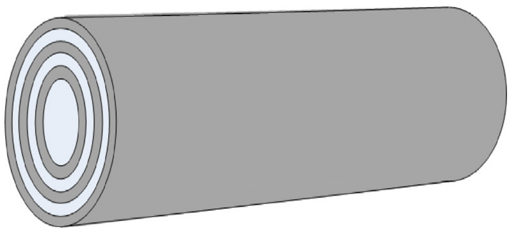

Fig. 1. The structure of deformed fiber.

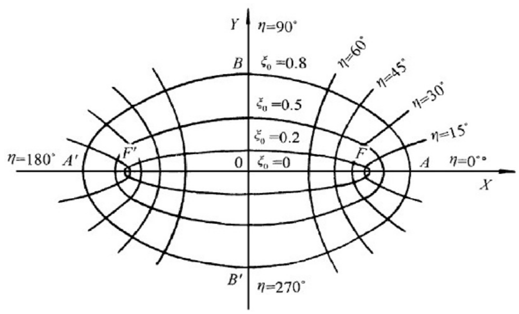

Fig. 2. The elliptical coordinate system.

face, the length of the major and minor semi axis are $a = 1.167$ μm and $b = 0.075$ μm.

Fig. 3(a) and (b) shows the HE_{11} mode and HE_{21} mode at the bottom face.

It indicates that this kind of fiber has confined the field within the core effectively and $HE_{m,n}$ mode has m angular nodal lines and n radial nodal lines including the boundary line as expected, which resembles the circular Bragg fiber.

Fig. 4(a)–(c) indicates how the corresponding core electric field behaves at different transverse faces along the propagation direction, that is, the negative z direction.

We can find that the electric field is split into more parts gradually as the transverse face degenerates from an ellipse to a circle. We have also simulated the field distribution of different incident wave frequencies, which reveals the same phenomenon.

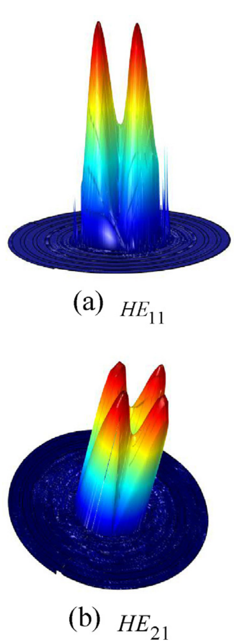

Fig. 3. Electric field of HE_{11} and HE_{21} mode at the bottom.

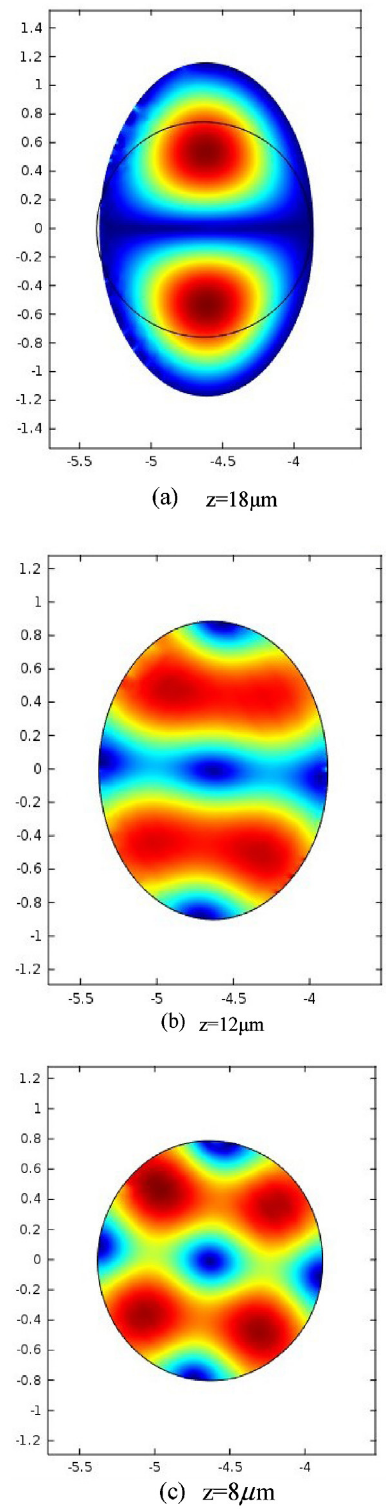

Fig. 4. Electric field distribution at the air core.

4. Analysis about the elliptical Gaussian beam

Here, we suppose that the wavelength of the incident elliptical Gaussian beam is 1170 nm shown in Fig. 5 and it propagates along the negative z direction.

Fig. 6 shows the electric field distribution at the output face (the bottom face).