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PWE approach to MSOF for beam splitting application

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ABSTRACT

Simulation studies for electric field distribution in micro structured optical fiber (MSOF) using plane wave expansion (PWE) technique is reported in this paper, where the outcomes of electric field distribution leads to beam splitting application. Here MSOF is realized by 5×5 air holes on silicon substrate with defect at centre. PWE method is employed to envisage a number of spectrally distinct output beams with respect to single input beam. Simulation result revealed that electric field mode of propagation varies nonlinearly with respect to radius of air hoes at lattice constant of 500 nm, for example the proposed MOSF allows 1,2, 3,4,5,6 and 7 number of modes of propagation at radius of air holes of 110 nm,120 nm, 210 nm 150 nm, 162 nm, 165 nm and 230 nm respectively. Finally simulation is also carried out for output power emerging from MSOF. And present result divulges that the power emerging from micro structure fiber depends on both structure parameter and configuration along with nature of material.

1. Introduction

Now-a-days optical technology is a major research in the field of science and technology owing to different theoretical and practical applications [1–8]. Apart from above applications, beam splitter is a special type of optical device that splits a beam of light into two or more. Nevertheless the splitting of beam depends on the nature of material as well as the configuration of the devices. For an example; dichroic optical coating device splits different output beams, where metal coating device splits of two instead of many [9,10]. Apart from this; as far as literature survey on beam splitter is concerned, some works related to the same have found in literature [11–14].In reference[11],authors discuss the beam splitter application using Mach-Zehnder interferometer, where in reference [12] the broadband beam splitter plate is made by BK7 material. Similarly, reference [13] realizes polarization beam splitter under different constraint condition. Aside this, recently a beam splitter application is discussed using photonic crystal structure by employing finite difference in time domain method [14]. Though several works have been done for realizing beam splitting application, we in this paper present a beam splitting application using microstructure fiber with the help of plane wave expansion method. The microstructures fiber is shown in Fig. 1.

As far as definition of microstructure optical fiber is concerned, it is nothing but optical fiber waveguide where guiding is obtained through manipulation of waveguide structure rather than its index of refraction. Fig. 1 represents the microstructure fiber allows multiple beams with respect to single input beam. Here we have considered silicon as background material and 5×5 holes are on square lattice optical fiber. In this case output signal depends on power emerging from air holes; for example if light will be transmitted through single hole only then it is treated as single beam splitter device. Similarly if light will be coming out from two holes then it will be treated as two beams splitter. Using above concept, multiple output

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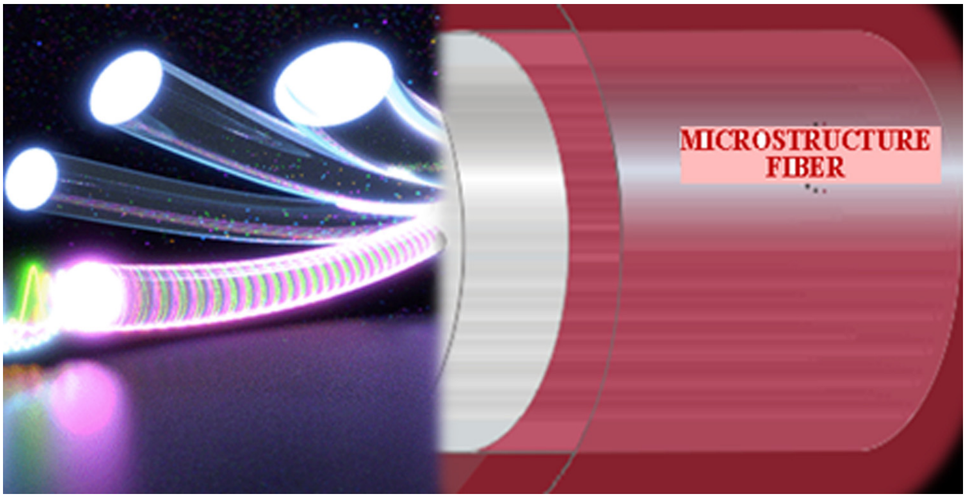

Fig. 1. Schematic diagram of microstructure showing multiple output beams.

beams can be realized. As far as present work is concerned, here we have dealt with the same for single beam splitter to seven beam splitter. These beams splitting are realized with respect to different values of both lattice spacing and air holes, which is discussed in Section 3.

This paper is organized as following: Section 2 gives mathematical treatment for PWE method, where results and discussion are made in Section 3. Finally, conclusions are given in Section 4.

2. Mathematical treatment

The electric field distribution in microstructure optical fiber is computed using, Helmholtz equation, which is given by [15]

$$\frac{1}{\in(r)}\nabla X\left\{\nabla XE(r)\right\} = \frac{\omega^2}{c^2}E(r) \tag{1}$$

The solution of eqn is expressed as

$$E(r) = E_{k,r}(r).e^{i.k.r} \tag{2}$$

Where $E_{k,r}$ is the periodic function with periodicity of lattice.

The wave functions are represented in terms of Bloch wave and expanded in to Fourier series over lattice vector, which is expressed as

$$E_{kr}(x, y) = \sum Ekr(Gr)\,expi(kx + Gx, r).x + (ky + Gy, r).y \tag{3}$$

Here E'kr(Gr) are Eigen vectors to be found during the Eigen problem solution. Gx and Gy are called Fourier coefficients for harmonics. Using above equations, we solved Eigen value problem and compute the field distribution in the microstructure optical fiber.

From above field distribution, the peak electric field corresponding to each diagram is computed and then power for each peak is found by the following expression [16]

$$P = \frac{C\in_0\eta A}{2}|E_0|^2 \tag{4}$$

Where 'c' is velocity of light, ε_0 is permittivity of free space, η is the refractive index of the material, 'A' is the area of the lattice structure, E_0 is the peak electric field.

3. Simulation result and discussion

To realize beam splitter, here we have considered 5×5 air holes on silicon substrate at lattice constant of 500 nm. The reason for choosing such lattice structure is that beam splitting application can be realized at this lattice spacing only. In this case we try to envisage number of output spectral beams with respect to single beam. So to realize the same, here the radius of air holes is varied at lattice constant of 500 nm. The reason for variation of radius of air holes is that splitting ratio (output: input) changes with changing the radius of air holes. To obtain so, we use the plane wave expansion to find out