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Optimal Design and Analysis of Ultra Compact 1.3/1.55μm Demultiplexer

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Abstract

Ultra compact 1.3/1.55μm demultiplexer was newly proposed based on the self-imaging phenomenon and the bandgap property of photonic crystal. The characteristics of the proposed device were analyzed and optimally designed by using the FDTD method.

1. Introduction

From a communication capacity point of view, the electron based conventional communication system has shown the physical limitation due to a rapid growth of the internet and multimedia. Therefore the solution should be found. One of the answers is optical communication system which has an extremely wide communication capacity. And one of the key components in the optical communication system is a wavelength demultiplexer. Especially, 1.3/1.55μm wavelength demultiplexer plays a very important role in the passive optical network systems. Therefore many researchers have tried to enhance the performance of a demultiplexer.

Multimode interference (MMI) based device is a good candidate for the wavelength demultiplexer. Since the length of the device using an interference phenomenon is determined to be a common beat length for the multiple wavelengths, however, the device is a quit long. Though some researchers used the Bragg gratings to resolve the size problem [1], it has very wavelength-sensitive characteristics by the Bragg grating's properties. In 2006, Chung et al. suggested the photonic crystal (PhC) instead of the Bragg gratings to enhance the isolation ratio [2].

Almost conventional dielectric waveguide devices can be realized with PhC devices having a very small size. In 2004, Kim et al. demonstrated that self-imaging phenomenon also was valid in the PhC waveguide as well as in the dielectric waveguide [3].

In this paper, we proposed an ultra compact 1.3/1.55μm demultiplexer based on the self-imaging phenomenon in the PhC waveguide and the photonic band gap (PBG) property of the PhC device. And the characteristics of the proposed device were analyzed and optimally designed by using the finite-difference time-domain (FDTD) method.

2. Design and Evaluation

The PhC is a kind of dichroic mirror. So the PhC device can transmit or reflect the light according to the wavelength of an incident light because of the PBG [4]. And a self-imaging phenomenon in the MMI device is the property that the profile of an incident wave is reproduced with a single or multiple images periodically along the propagation direction in the MMI device [5]. By using these two properties, an ultra compact demultiplexer can be realized.

In this study, 2D PhC structure consisting of a square lattice of dielectric rods in the air was used to get a wide band gap. The refractive index of the dielectric rods is set to be 3.4 and the radius(r) is $0.18a$, where a is the lattice constant of the crystal. In this structure, the band gap opens for the frequency ranges of 0.303-0.445 (a/λ) for the E-polarization (electric field parallel to the rods) where λ is the wavelength in free space.

Schematic diagram of the proposed 1.3/1.55μm demultiplexer is depicted in Fig. 1. In this structure, five consecutive rows were removed to form a multi-mode PhC waveguide. And as an access waveguide, one-line-defect PhC waveguide was introduced. This access PhC waveguide supports single-mode. We choose an operating frequency of 0.35 (a/λ) and 0.417 (a/λ), these are corresponded to the wavelength of 1.55μm and 1.3μm by setting the lattice constant as 542.5nm.

$L_{m,\ 1.3\mu m}$ and $L_{m,\ 1.55\mu m}$ is the length of the first mirrored image for the wavelength of 1.3μm and 1.55μm, respectively. The size defects of the rods(r = 0.33a) were formed in the position of $L_{m,\ 1.3\mu m}/2$ within the multi-mode PhC waveguide. In this structure, the band gap opens for the frequency ranges of 0.392-0.479 (a/λ). Therefore the wavelength of 1.3μm could be reflected from the defects and the wavelength of 1.55μm could be transmitted through the defects.

The characteristics of the proposed device were analyzed and optimized by using the FDTD method. Fig. 2 shows the steady-state electric field distribution for the frequency of 0.417 (a/λ) and 0.35 (a/λ), respectively. As we expected before, the wavelength of 1.3μm reflected and the wavelength of 1.55μm transmitted through the defect as shown in Fig. 2. The transmittance of the device is about 98.8% for 1.3μm and 87.7% for 1.55μm, respectively. The extinction ratio was defined as the ratio of the power at the desired output port to the power at an undesired port for a specific wavelength. In the optimally designed structure, the extinction ratios for 1.3μm and 1.55μm were less than about -21.7 dB and -16.3dB, respectively.

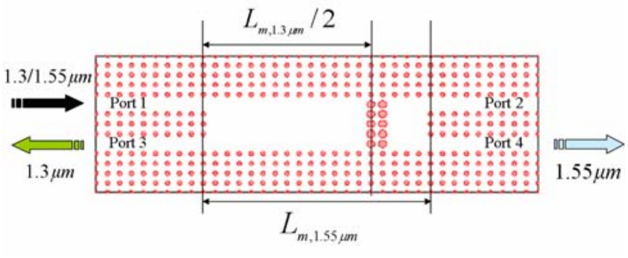

Fig. 1. Schematic diagram of the proposed 1.3/1.55μm demultiplexer. $L_{m,\ 1.3\mu m}$ and $L_{m,\ 1.55\mu m}$ are the length from end of the port1 to the first mirrored image for the wavelength of 1.3μm and 1.55μm, respectively.

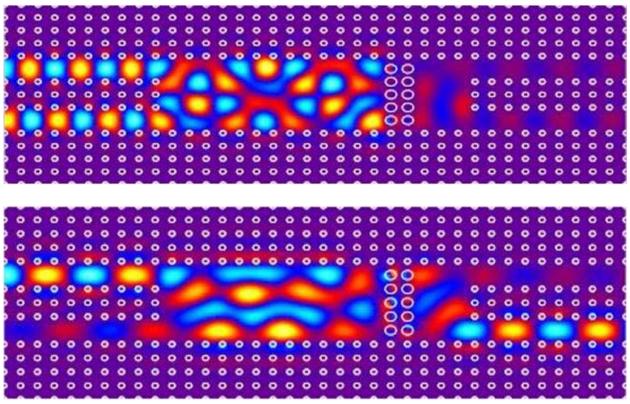

Fig. 2. Steady-state electric field distribution for the wavelength of 1.3μm (top) and 1.55μm (bottom).

3. Conclusion

Optimally designed 1.3/1.55μm demultiplexer has the size of 10.3 x 7.6μm^2, it is believed to be the smallest one in the state of the art to our knowledge. The transmittance of the device is about 98.8% for 1.3μm and 87.7% for 1.55μm, respectively. And the extinction ratio of the proposed device is less than about -21.7dB for 1.3μm and -16.3dB for 1.55μm, respectively. Now we are trying to enhance the extinction ratio for 1.55μm.

Acknowledgement

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