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Non-Symmetric Mach-Zehnder Interferometer Wavelength Filter

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Abstract – **A non-symmetrical Mach-Zehnder configuration with corrugated waveguide at one of its arm which acts as an interferometer is presented. The interference output intensity of the input light power depends on the operating wavelength, hence acting as a wavelength filter. The function of this wavelength filter is demonstrated by beam propagation method within range from 1000nm to 1800nm.**

I. Introduction

Passive integrated optical devices, such as optical add-drop multiplexer (OADM), wavelength demulitiplexers and multiplexers (WDM), and power dividers fabricated by ion exchange techniques have considerable potential use in fibre-optic communication systems [1]. Three-wavelength demultiplexers operating at 980 nm, 1310 nm and 1550 nm are great important for the application in WDM optical fiber telecommunication systems [2].

A typical choice for WDM component has been a symmetric directional couplers. It is a simple structure and has the advantage of small size and low optical losses [3]. Based on this simple structure, optical filter such as OADM can be designed using cascaded symmetric directional couplers [4]. However, the spectral transmission characteristics of the combination of cascaded symmetric directional couplers are very sensitive to fabrication conditions and it seems difficult for reproducibly with the desired centre wavelengths and low crosstalk.

OADM function can also be realized through Mach-Zehnder interferometer (MZI), by allowing and filtering certain wavelengths at its output port.

In this paper, a non-symmetric Mach-Zehnder interferometer with one corrugated arm is being studied. It is a simple device, but offers the advantage of high tolerances for fabrication process deviations.

II. Mach-Zehnder Interferometer Optical Filter

Mach-Zehnder interferometer (MZI) optical filter is composed of a non-asymmetric Y-branch and connected to each other by two waveguides with a different length (L and $L + \Delta L$). The input power is splitted into P_1 and P_2 at the Y-branch and propagating through the upper and lower arms of the MZI, respectively, and with phase shift between the two optical path, $\Delta\phi$, the output power can be written as [5]:

$$P_{out} = \frac{1}{2}\left\{P_1(t) + P_2(t) - 2\sqrt{P_1(t)P_2(t)}\cos(\Delta\phi)\right\} \tag{1}$$

where,

$$\Delta\phi = \frac{2\pi L}{\lambda}\Delta n_{eff} \tag{2}$$

The phase shift is depending on the effective refractive index of the propagating mode, n_{eff}. Phase shift also depends on the wavelength, λ, and the length of the phase shifter, L [6].

III. Non-Symmetric MZI Wavelength Filter Design

In this paper, the design of non-symmetric MZI structure consisted of two parths, and a phase difference is introduced by increasing one of the path lengths with respect to the other. As shown in Fig. 1, the upper arm consists of one straight waveguide connected with one S-bend waveguide at both end, whereas the lower corrugated arm consists of a numbers of U-bended waveguides, where each of them is a combination of two S-bended waveguides. It is designed in such a way that it can be sufficiently increased the optical path for a miniature structure.

The length of the S-bended waveguide in its y-component is about 1000 μm, and with path difference of 310 nm compares to it straight counterpart, with a bending angle of 1.43^0

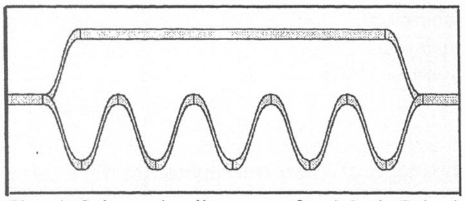

Fig. 1 Schematic diagram of a Mach-Zehnder with five U-banded waveguides.

The structure is designed for glass substrate with refractive index 1.515 and the waveguide refractive index 1.545. The guide width is 3 μm. Eight U-bended waveguide is included which is equivalent to a length difference of 4.96 μm.

IV. SIMULATION RESULT AND DISCUSSION

The power output is calculated through simulation using beam propagation method in an ideal case, with power input is equally split at the Y-branch so that the field is scaled down by a factor $\sqrt{2}$ going into each arm, with wavelength in the range between 1000 nm to 1800 nm.

Four variables have been identified to study the characteristic of the MZI wavelength filter. These variables are waveguide length difference *ΔL*, refractive index different *Δn*, waveguide width, and operational wavelength.

Spacing between the two nearest peak output powers from MZI is becoming smaller when the optical path difference is larger, as shown in Fig. 2. With 15 U-bended waveguides which is equivalent to a difference length of 9.3 μm, the wavelength of 1310 nm can be effectively filtered out while keeping the wavelength 1550 nm go through the output.

Wavelength selection resolution can be further increased with greater refractive index difference between waveguide and substrat, as shown in Fig. 3. The output power for a single mode waveguide with the width between 3 μm to 7 μm do shows significant change, as shown in Fig. 4. It can be estimated that the MZI structure is tolerable to fabrication variation of about 0.3 μm. In our previous work on directional coupler, we found that the design parameters, the guide width and the separation in the coupling region are very sensitive [4].

Propagation mode of TE and TM do not have significant variation in a single mode waveguide, as shown in Fig. 5.

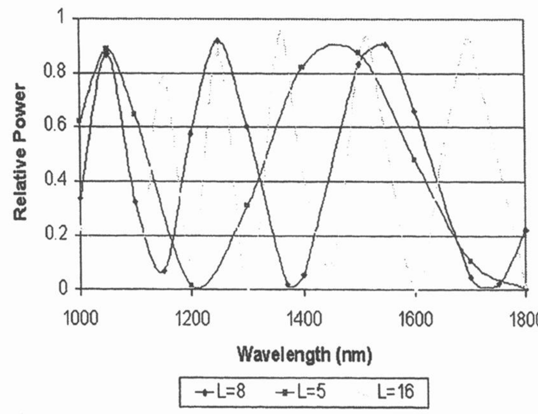

Fig. 2 Wavelength selection resolution can be increased with bigger optical path difference.

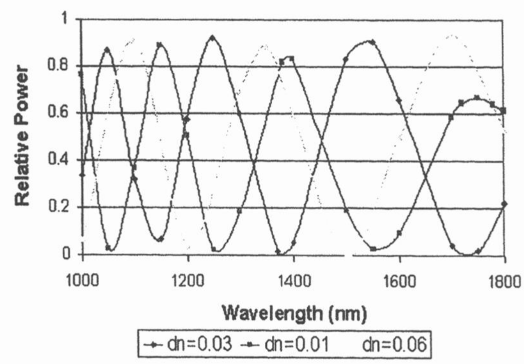

Fig. 3 Wavelenght selection depends on refractive index different

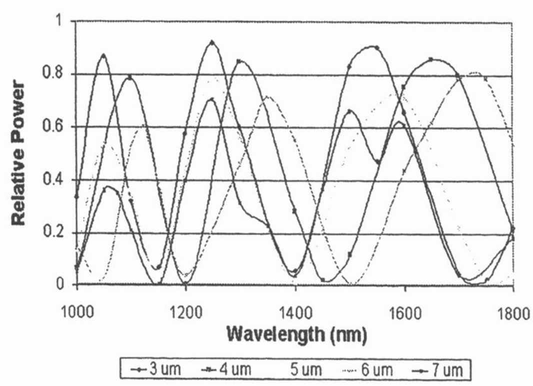

Fig. 4 Variation of waveguide width within single mode do not drastically change the selective wavelenght pattern.

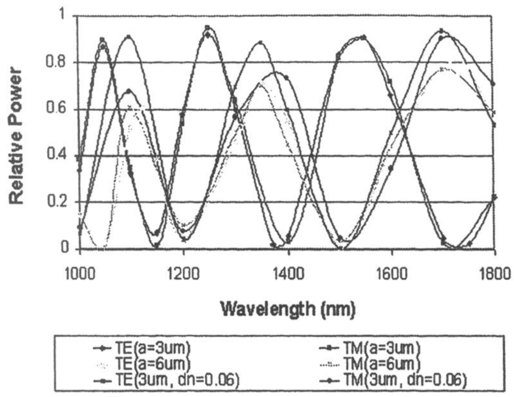

Fig. 5 TE and TM mode is maintaining the wavelength pattern within a single mode waveguide.

V. CONCLUSION

By modifying refractive index difference and optical path difference for a non-symmetric Mach-Zehnder structure waveguide, an optical filter with desired output wavelengths can be produced. This work demonstrates that the structure has good tolerance to fabrication variation and this offers good reproducibility.

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