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Micro-optic MZI filter composed of a dual-fiber collimator and a reflective beam-splitting plate

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Abstract

We demonstrate a micro-optic MZI filter composed of an optical collimator with dual fiber-pigtails and a reflective optical plate with a periodic mirror pattern. The insertion loss and the PDL of the implemented filter were less than 1.52 dB and 0.12 dB, respectively.

1 Introduction

Mach-Zehnder interferometric(MZI) filters are widely used in fiber-optic communication systems since they have wide pass-bands and linear phase characteristics[1]. Especially, micro-optic MZI filter shows excellent optical performances such as a low insertion loss, a very low polarization dependent loss (PDL) and offers a high design flexibility[2]. However, the micro-optic MZI filter requires a strict alignment process, which increases manufacturing difficulties. In this paper, we propose and demonstrate a novel micro-optic MZI filter structure to alleviate the optical alignment requirements of the convention micro-optic MZI filter.

2 Configuration and principles

The proposed MZI filter is composed of an optical collimator with dual fiber-pigtails and a beam-splitting optical plate as shown in Fig. 1 (a). The pigtail-fibers of the collimator are used as an input port and an output port of the MZI filter, respectively. The optical plate has mirrors on its both facets. The rear facet of the optical plate has a uniform mirror pattern while its front facet has a periodic mirror pattern, a stripe mirror pattern. We assume that the width of the optical plate, the length of the stripe pattern in y-direction, is much longer than the beam diameters of the collimated beam when the beam propagates in ±z-direction. The centers of the input and the output fibers of the collimator are aligned as shown in Fig. 1 (b) so that the position deviation of the plate in y-direction does not affect on the characteristics of the filter.

The optical beams entering through the input fiber are expanded by the collimator and reflected by the mirror on either facets of the optical plate. Since the mirror area and the open areas are interleaved on the front facet, some beams are reflected by the front facet mirror while the other beams by the rear facet mirror after passing through the open areas of the front facet. The optical collimator and the optical plate are placed so that the reflected beams are coupled into the output fiber through the collimator. The optical plate split the beams and the beams reflected by the rear facet of the optical plate propagate relatively longer optical paths before they arrive at the collimator. Namely, the optical plate induces the optical path length difference between the beams reflected by the front facet and the beam reflected by the rear facet. The Mach-Zehnder interference occurs between the beams with different phases during they are collimated into the output fiber, which leads to a wavelength-dependent spectral response of the filter.

3 Fabrication and experiment

We fabricated the optical plate by implementing mirrors on both facets of a glass substrate. The pyrex glass with a 500 ㎛ thickness is used as the substrate. We deposited Aluminum (Al) on the front facet of the Pyrex glass substrate through an E-beam evaporation process to form the optical mirror pattern. We used etching process to implement a periodic stripe mirror pattern on the front facet of the optical plate. The thickness of the deposited Al mirror region on the front facet of the glass substrate was about 2000 Å. The period of the stripe mirror pattern was 100 ㎛ and the width of the etched region was about 50 ㎛, which means the width of the Al mirror pattern on the front facet was also 50 ㎛.

Fig. 2 shows the microscopic picture of the front facet of the fabricated optical plate. The white regions are the Al-deposited mirror areas while the dark regions are the etched open areas. The stripe mirror pattern was well defined and has clear open areas. The measured reflectivity of the mirror pattern of the front facet was higher than 85% over the wavelength range from 1520 nm to 1580 nm. The uniform mirror of the rear facet of the plated was implemented by evaporating Al thermally on the rear side of the glass substrate and the thickness of the deposited Al region was about 8000 Å. We used a conventional optical collimator with a 500 μm beam diameter and about 2 degree of crossing angle between in-out beams. We aligned the fabricated optical plate and the optical collimator as shown in Fig. 1 (a). The working distance between the collimator and the optical plate was about 2 mm.

Fig. 3 shows the measured spectral response of the implemented MZI filter using a tunable laser and power meter. The free spectral range (FSR) of the filter was about 1.6 nm (about 200 GHz). The insertion loss of the implemented MZI filter was less than 1.52 dB and the extinction was greater than 24 dB over 1510 nm to 1640 nm. We also measured the spectral responses of the implemented micro-optic MZI filter by changing the relative position of the optical plate from 0 μm to 50 μm in x-direction to ensure the constant spectral responses irrespective to the position deviation in lateral direction. The collimator and the plate were aligned as shown in Fig. 1 (b) in the initial state (x = 0 μm). The extinction ratio variation due to the change of the relative position of the optical plate was less than 0.2 dB and the measured insertion loss variation at the peak wavelength was less than 0.05dB. This means that the location error due to a misalignment between the optical plate and the collimator does not affect on the characteristics of the MZI filter. Thus the only parameter one should care in the alignment process to implement MZI filter is the tilt angle of the optical plate, which simplifies the manufacturing process of the optical filter.

Fig. 4 shows the spectral response and the PDL of the implemented MZI filter measured with a tunable laser and a PDL meter in the wavelength range from 1545 nm to 1555 nm. The measured PDL of the filter was less than 0.12 dB within the 3 dB passband of the filter.

4 Summary

In this paper, a novel micro-optic MZI filter has been proposed and demonstrated to overcome the alignment and the fabrication difficulties of the micro-optic filter. It is composed of a collimator with dual pigtail-fibers and a reflective optical plate with a periodic mirror pattern on the front facet. We implemented the MZI filter with a 1.6 nm FSR. The maximum insertion loss and the minimum extinction ratio of the filter were 1.52 dB and 24 dB, respectively. We also show that the lateral alignment error does not affect the characteristics of the filter.

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References

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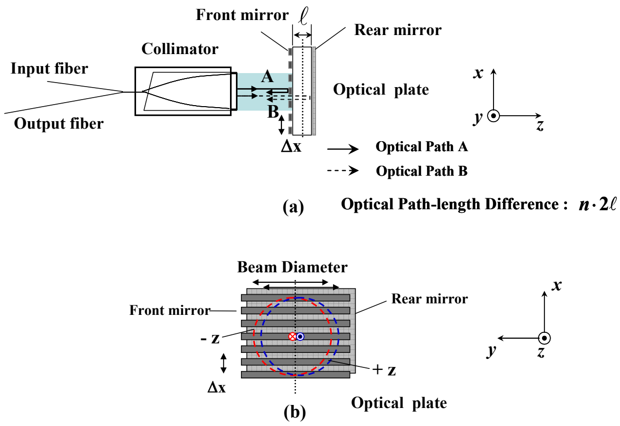

Fig. 1. The configuration of the proposed MZI filter (a) and the comprehensive plots of the beam profile, the beam diameter of the collimator and the stripe pattern of the optical plate (b)

Fig. 2. Microscopic picture of implemented optical plate with periodic stripe mirror pattern

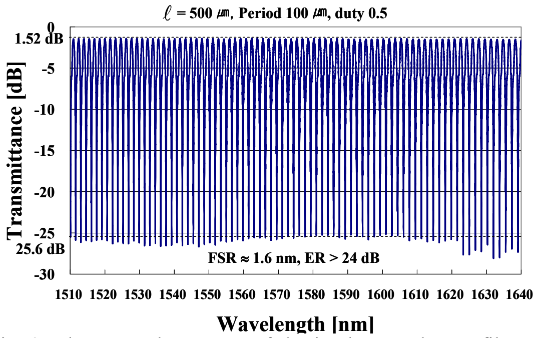

Fig. 3. The spectral response of the implemented MZI filter measured with a tunable laser and optical power meter

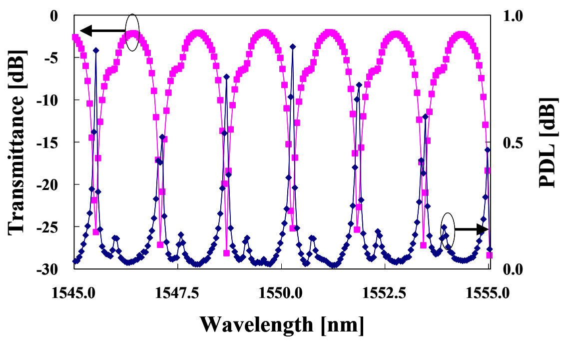

Fig. 4. The spectral response and PDL of implemented MZI filter measured with a tunable laser source and a PDL meter