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Super-high-Δ silica-based flat-passband filter using AWG and cascaded Mach-Zehnder interferometers

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Abstract

A super-high-Δ silica-based multi/demultiplexer consisting of a multi-input AWG combined with cascaded MZIs is demonstrated. Very flat passband response and low loss penalty due to the passband flattening were obtained.

1 Introduction

In metropolitan and access-area networks, multi/demultiplexers should have a flat spectral response to allow the concatenation of many filters. To flatten the passband of arrayed waveguide gratings (AWGs) with low intrinsic loss, a technique using a combination of two synchronized routers [1-3] is a promising approach. Low-loss and flat-passband characteristics can be achieved with a Mach-Zehnder interferometer (MZI) or a three-arm interferometer for the input of an AWG [1,2]. Also, back-to-back AWGs [3] can be used to obtain wider spectrum although slab-to-array transition loss is twice that of a single AWG. Aiming at achieving both low-loss and flat response, we proposed a flat-passband filter that consists of a multi-input AWG combined with a cascaded MZI structure, and numerically analyzed its optical performance with a theoretical model of a multi-input AWG [4,5]. In this paper, we demonstrate a super-high-Δ multi/demultiplexer with the proposed structure utilizing silica-based planar lightwave circuit (PLC) technology.

2 Circuit structure

The optical circuit of our proposed flat-passband filter is shown in Fig. 1. It consists of a multi-input AWG and a cascaded MZI structure connected to the AWG input waveguides. Reflecting the results in our previous report [4,5], we proposed two stages of cascaded MZIs to achieve a small chip size as well as sufficient flatness. To obtain an appropriate demultiplexing function, the FSR of the first stage MZI was set to half of the channel spacing of the AWG, and that of the second-stage MZIs was set to the same value as the channel spacing. The signals with four equally spaced frequencies $f_1, \ldots, f_4$ within a channel spacing are first divided by the first-stage MZI into two groups f_1, f_3 and f_2, f_4, and next divided by the second-stage MZIs into individual signals. The lower port of the upper second-stage MZI and the upper port of the lower second-stage MZI should cross each other so that the signals $f_1, \ldots, f_4$ are spatially arranged in this order at the input side of the AWG.

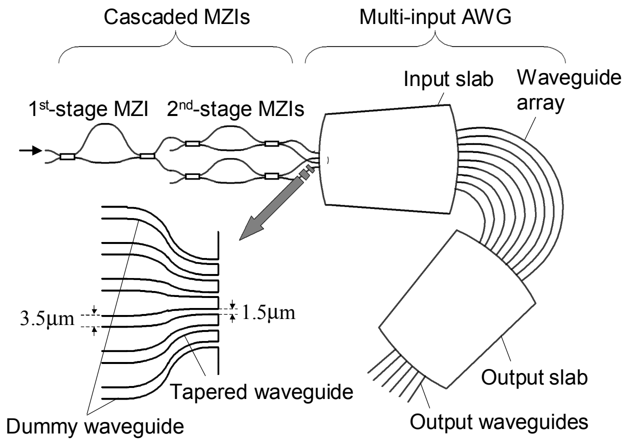


Fig. 1 Optical circuit

We found that insertion loss can be reduced if the input waveguides just before the input slab have narrower core and gap widths [5]. However, they lead to larger coupling between input waveguides. The coupling can cause non-zero chromatic dispersion due to the phase shift in coupled light. To reduce the coupling, we introduced curved waveguides, as shown in Fig. 1, that have a tapered core such that the core width gradually decreases from 3.5 μm to 1.5 μm as the core approaches the slab. The waveguide interval also gradually decreases from 12 μm to 4.8 μm to narrow the core and gap widths. By using this structure, the coupling can be reduced compared with constant core width of 1.5 μm because smaller bending radius is allowed while keeping the bending loss small. Moreover, dummy waveguides were arranged on both sides of four input waveguides to reduce chromatic dispersion by adjusting the phase of input field to the slab.

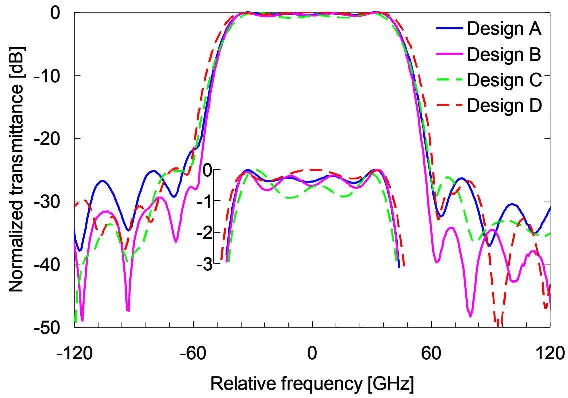
3 Demonstration

We demonstrated flat-passband filters with 100-GHz channel spacing using multi-input AWG and cascaded MZIs. The relative index difference Δ of 2.5% between the core and cladding was used to significantly reduce the chip size from a conventional Δ (0.8%). The minimum bending radius was 0.8 mm. Consequently, the typical chip size was 38.5 x 17 mm^2, which allows us to arrange seven chips on a 4-inch wafer. We fabricated chips with several different design parameters (the number of arrayed waveguides, input waveguide interval, and core widths of input/output waveguides at the edges of slabs).

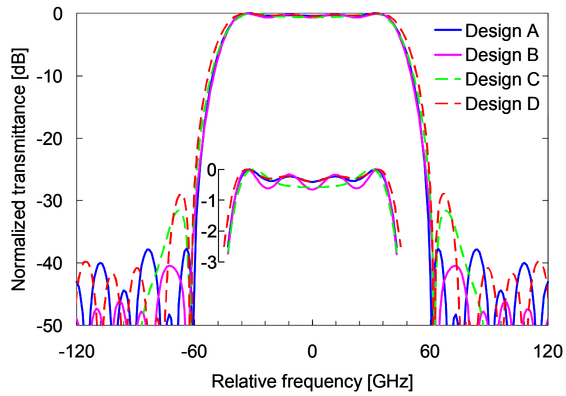
The spectral responses measured by TE-polarized light are shown in Fig. 2(a) for different design parameters, and the simulation results are shown in Fig. 2(b). The passband shape for the measured results generally agrees well with that for the calculated one in each design. For example, ripples in the passband increased when we compare designs A and B, and the passband width was slightly widened when we compare designs A and D. The spectral responses for the central eight output ports of design D are shown in Fig. 3. We obtained very flat responses for all eight output ports. The 1-dB and 20-dB bandwidths were 0.645–0.658 nm and 0.944–0.960 nm, which correspond to figure-of-merit [2] values of 0.68–0.70. The minimum insertion loss was 5.7–5.8 dB. Comparing with the result of a normal-AWG input port that was not cascaded with MZIs, the increase in insertion loss due to the passband-flattening was estimated to be as small as 0.9–1.0 dB. The total insertion loss also contains fiber-to-chip transition loss of 3.4–3.7 dB that can be reduced by applying spot-size converters to the edges of the chip.

4 Conclusion

We demonstrated a multi/demultiplexer with a very flat passband and small excess loss, which consists of a multi-input AWG combined with a cascaded MZI structure using 2.5%-Δ silica waveguides. We obtained a very flat passband response (1-dB bandwidth of 0.645–0.658 nm and 20-dB bandwidth of 0.944–0.960 nm) with a loss penalty due to the passband flattening of 0.9–1.0 dB. The measured passband shape generally agreed with the simulation results.



(a) Measured



(b) Calculated

Fig. 2 Measured and calculated spectral response for different design parameters

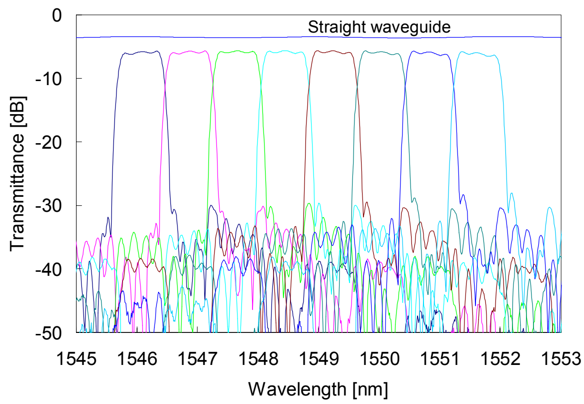


Fig. 3 Measured spectral response for central eight output ports of design D

Acknowledgments

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