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Monolithically Integrated Waveband Selective Switch Using Cyclic AWGs

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Abstract

We propose a novel waveband-selective switch that uses cyclic Arrayed-Waveguide Gratings. The device is fabricated on one chip using Planer Lightwave Circuit technologies. Tests demonstrate that the designed performance is successfully realized.

Introduction

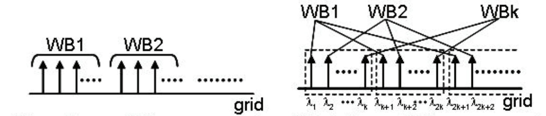
Broadband access is being rapidly adopted throughout the world and, as a result, traffic is increasing rapidly. Further traffic expansion will occur in the near future with the introduction of new broadband services including IP-TV/VoD services using super-/ultra- high definition TV (6/72 Gbps/ch). In order to cope with the envisaged traffic growth effectively, the introduction of higher order optical paths, wavebands (WBs), which consist of multiple wavelength paths, are being intensively studied [1]. The introduction of WB path routing (waveband cross-connect) has been shown to significantly decrease the total switch scale/cost of optical cross-connect nodes [2]. Efficient WB path routing algorithms have also been proposed [3], which assures significant network cost reduction.

To develop single-layer optical path cross-connect systems that handle wavelength paths, one of the key components is the wavelength selective switch (WSS). In order to realize the multi-layer optical path (WB and wavelength path) cross-connect, the waveband selective switch (WBSS), an extension of WSS, will also play a key role [4]. The introduction of WBSS has been shown to greatly reduce the total amount of switch element needed [5].

In this paper, we propose a new WBSS architecture that consists of cyclic AWG wavelength filters and optical switches that are fabricated with PLC (Planar Lightwave Circuit) technology; it effectively suppresses the channel loss deviation by a new AWG arrangement. We demonstrate the effectiveness of the device as realized monolithically on one chip. The device has no moving mechanical parts, requires no adjustment, and is very compact, which will lead to high reliability and low cost.

Waveband Arrangement

Different WB arrangements are possible as shown in Fig. 1 [6]. One integrates wavelength paths in a sequential manner (a) whereas the other integrates them in a periodic manner (b). Which WB arrangement is used has virtually no impact in terms of network provisioning and OA&M(Operation, Administration and Maintenance).



(a) continuous WB arrangement (b) interleaved WB arrangement

Figure 1: Waveband Arrangement

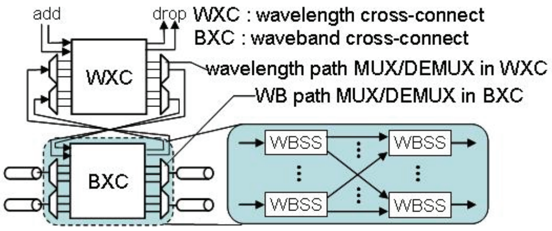


Figure 2: Generic multi-layer optical path cross-connect node architecture and an example of BXC implementation using WBSS

In this paper we adopt the interleaved WB arrangement, since the periodicity potentially allows us to use cyclic AWGs for WB MUX/DEMUX in the BXC part in Fig. 2, and to use cost-effective wide channel spacing AWGs as MUX/DEMUX in WXC. Here, cyclic means that the free spectral range (FSR) of the 1 x M AWG corresponds to a width that covers M consecutive channels.

Proposed WBSS

A. WBSS Architecture

We used forty C-band channels on an ITU-T grid with a channel spacing of 100 GHz; they are divided into five WBs, each WB consists of eight individual channels as shown in Fig. 3. The proposed 1x5 WBSS consists of six 1x5 cyclic AWGs and five 1x5 optical switches (Fig. 3). The cyclic AWG has periodic transmission response whose period equals the FSR [7], 500 GHz. This enables the 1st AWG to demultiplex the input signal into the interleaved WBs. Each WB output from the 1st AWG can be routed to any of the five output AWGs (2nd AWGs) through 1x5 switches. Finally, the 2nd AWGs multiplex the WBs and output them.

B. Joint Optimization of the Two AWGs

While the logical implementation explained above does physically achieve the desirable optical operation, there is an issue to be cleared up. The

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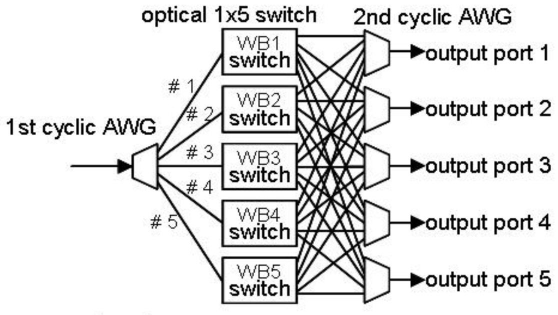
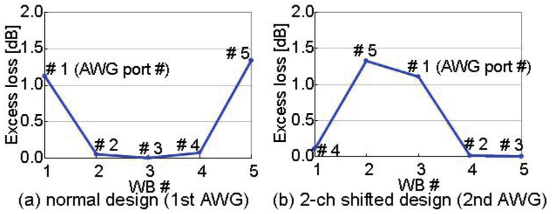


waveband arrangement

WB1	$\lambda_1, \lambda_6, \lambda_{11}, \lambda_{16}, \lambda_{21}, \lambda_{26}, \lambda_{31}, \lambda_{36}$
WB2	$\lambda_2, \lambda_7, \lambda_{12}, \lambda_{17}, \lambda_{22}, \lambda_{27}, \lambda_{32}, \lambda_{37}$
WB3	$\lambda_3, \lambda_8, \lambda_{13}, \lambda_{18}, \lambda_{23}, \lambda_{28}, \lambda_{33}, \lambda_{38}$
WB4	$\lambda_4, \lambda_9, \lambda_{14}, \lambda_{19}, \lambda_{24}, \lambda_{29}, \lambda_{34}, \lambda_{39}$
WB5	$\lambda_5, \lambda_{10}, \lambda_{15}, \lambda_{20}, \lambda_{25}, \lambda_{30}, \lambda_{35}, \lambda_{40}$

Figure 3: Generic WBSS Architecture



(a) normal design (1st AWG) (b) 2-ch shifted design (2nd AWG)

Figure 4: Excess Loss of Test Samples

channel loss of a cyclic AWG for the outer ports is larger than that for the inner ports. Figure 4 (a) depicts an excess loss measured with a test sample of the 1st cyclic AWG for WB1-WB5. As shown in the figure, the excess loss deviation was 1.3 dB. In the proposed WBSS, each channel passes through the 1st and 2nd AWGs, and hence the total AWG loss and the loss deviations are doubled. To overcome this problem, we propose a new idea, that is, shifting centre wavelength of the 2nd AWG so that the offset relative to the 1st AWG equals 2ch (200 GHz), as shown in Fig. 4(b). With this scheme, the resulting excess loss deviation after passing through the two AWGs is reduced to 1.3 dB while it is 2.8 dB without this channel shift approach (also total maximum excess loss of the two AWGs is almost halved). Note that with this arrangement, waveguide connections between WB switch and the 2nd AWG shown in Fig. 3 are changed accordingly.

Experiment

The proposed WBSS was fabricated using PLC technology on one chip; the chip size is 34 x 64 mm as shown in Fig. 5. It includes six AWGs and five 1x5 switches. The device is designed to accommodate forty 100-GHz spaced channels (195.6 + 0.1 x n [THz]; n=0 to 39) on the ITU-T grid. Figure 6 shows an example of WB channel spectra at output port 1 when WB1 and WB2 are routed, respectively. We repeated the same measurements for all the output ports and the results are summarized in Table 1. It is confirmed that the loss deviation is reduced as intended. Its small size, no adjustment requirement, and good performance further strengthen the benefit of the multi-layer optical path cross-connect.

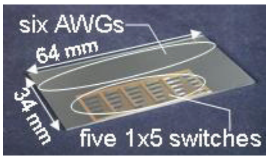
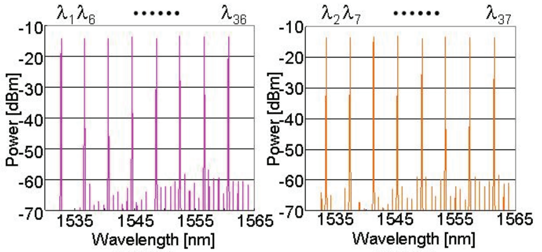


Figure 5: WBSS Chip



(a) WB1 (b) WB2

Figure 6: Output Channel Spectra at Output Port 1 When WB1 and WB2 are routed

property	measured value
center wavelength error	-0.023 to 0.033 [nm]
insertion loss	6.9 to 9.2 [dB]
channel loss deviation in each output port	1.5 to 2 [dB]
1dB channel bandwidth	> 0.15 [nm]
3dB channel bandwidth	> 0.3 [nm]
adjacent crosstalk	> 37.1 [dB]
non-adjacent crosstalk	≥ 38.6 [dB]

Table 1: Transmission characteristics of fabricated WBSS

Conclusions

We have proposed a novel 1x5 waveband selective switch (WBSS) that minimizes the excess loss deviation by optimizing AWG frequency response. The device was fabricated on a single chip thanks to the interleaved wavelength banding. Its routing capability and performance were successfully confirmed. The device is expected to play a key role in the development of cost-effective multi-layer optical path cross-connect.

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