Loss Uniformity Improvement of Arrayed-waveguide Grating Router using Interleaved Chirped Array

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Abstract: An arrayed-waveguide grating router using interleaved chirped array (IC-AWGR) is proposed. We designed 32 x 32, 50-GHz channel spacing IC-AWGR. The minimum loss of the IC-AWGR is 4.75 dB with a loss variation of 1.08 dB.

Introduction: An arrayed-waveguide grating router (AWGR) is a planar lightwave circuit which enables N frequency channels to make strictly nonblocking N x N interconnections.[1] The free spectral range (FSR) of the conventional N x N AWGR is equal to the product of N and the channel spacing. The conventional AWGR has large loss variation and the center frequency deviations of wavelength channels, depending on the combination of the input and the output ports.[2] To improve these characteristics, an uniform-loss and cyclic-frequency (ULCF) configuration or an interconnected multiple AWG configuration were reported.[1] These configurations showed good characteristics, however, the former requires a lot of couplers and waveguide crossings, the latter requires a lot of AWGs. An AWG using interleaved chirped array has been reported as multiplexer of optical cross connect.[3] However, a configuration of AWGR using interleaved chirped array has never be reported.

In this paper, we propose AWGR using interleaved chirped array (IC-AWGR) which has improved loss uniformity characteristics. We designed AWGR for newly developing thousand-band (T-band, 1000 –1260 nm) communication[4].

Principle: An IC-AWGR consists of input waveguides (1a, 2a,… 8a), slab waveguides, an arrayed-waveguide with interleaved chirping, and output waveguides (1b, 2b,… 8b). The length of the shortest waveguide in the arrayed-waveguide is L_0. The length of i-th interleaved chirping waveguide in the arrayed-waveguide, L_i, is derived by eq. (1) [3].

$$L_i = L_0 + (i - 1)\Delta L + \lambda_0/(4n_c) * \mathrm{Modulo}_2(i + 1),\ i = 1, 2, 3,\ldots \quad (1)$$

ΔL is path difference of arrayed-waveguide, λ_0 is center wavelength of the AWGR, and n_c is effective index of the arrayed-waveguide. Figure 1 shows transmission spectra of the IC-AWGR and a normal AWGR when the center input waveguide and the center output waveguide are used. The FSR of the IC-AWGR is one-half compared to the FSR of the normal AWGR. The peak transmittance is 3 dB lower than that of the normal AWG. Table 1 shows output wavelength channel relation of connection between input waveguides and output waveguides. 1a, 2a, …, and 8a are input waveguide number, 1b, 2b, …, and 8b are output waveguide number. Arabic numerals (1, 2,…, 8) mean wavelength channel number. Two wavelength channels are output, when one input waveguide and one output waveguide are used. A gray part of table 1 satisfies cyclic condition and operates as AWGR when 3rd, 4th, 5th, and 6th wavelength channels are used.

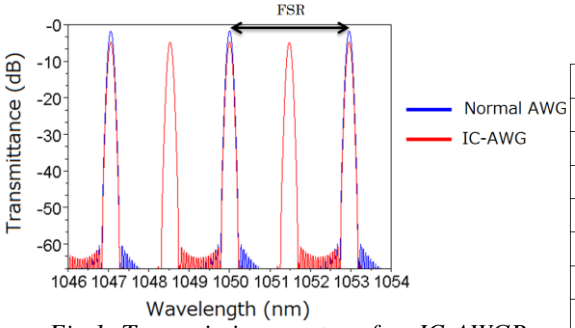

Fig.1: Transmission spectra of an IC-AWGR and a normal AWGR.

Table.1: Channel relation of connection.

In/Out	1b	2b	3b	4b	5b	6b	7b	8b
1a	2, 6	3, 7	4, 8	1, 5	2, 6	3, 7	4, 8	1, 5
2a	3, 7	4, 8	1, 5	2, 6	3, 7	4, 8	1, 5	2, 6
3a	4, 8	1, 5	2, 6	3, 7	4, 8	1, 5	2, 6	3, 7
4a	1, 5	2, 6	3, 7	4, 8	1, 5	2, 6	3, 7	4, 8
5a	2, 6	3, 7	4, 8	1, 5	2, 6	3, 7	4, 8	1, 5
6a	3, 7	4, 8	1, 5	2, 6	3, 7	4, 8	1, 5	2, 6
7a	4, 8	1, 5	2, 6	3, 7	4, 8	1, 5	2, 6	3, 7
8a	1, 5	2, 6	3, 7	4, 8	1, 5	2, 6	3, 7	4, 8

Design: The 32 x 32 IC-AWGR was designed, the center wavelength was 1050 nm, the FSR was 3200 GHz, and the channel spacing was 50 GHz. We used silica waveguides with a relative index difference of 1.5 %, and the core dimension of 4.5 μm x 4.5 μm. At the center wavelength, the effective index in arrayed-waveguide, n_c, was 1.46633, and the group index of effective index, N_c was 1.48697. The number of waveguide in arrayed-waveguide was 192, and the diffraction order was 87. The path difference, ΔL is 63.3 μm, and the length of slab waveguide was 14.8 mm.

Simulation results: Transmission characteristics of three types of AWGR were calculated. One is the IC-AWGR, and the others are normal AWGRs which have FSR equal to the product of 32 channels and 50-GHz channel spacing. The normal AWGR, which is named AWGR-A, has the same diffraction efficiency[5] as that of the IC-AWGR. The other normal AWGR, which is named AWGR-B, has low diffraction efficiency to improve loss uniformity. The AWGR-B has wide gap of 14 μm between waveguides in boundary between slab waveguide and arrayed-waveguide to reduce diffraction efficiency. The parameters of the normal AWGRs are 32 x 32, and 50-GHz channel spacing. The number of waveguide in arrayed-waveguide is 96, the diffraction order is 175, and the path difference is 125.3 μm. The former has a slab waveguide with a length of 7.4 mm, and the latter has a slab waveguide with a length of 14.8 mm. Figure 2 shows simulation results of loss characteristics. The maximum loss and the minimum loss in 32 wavelength channels for each output waveguide are indicated. In all combinations of input and output waveguides, the minimum losses of the IC-AWGR, the AWGR-A, and the AWGR-B are 4.75 dB, 1.74 dB, and 7.76 dB, respectively. The maximum losses are 5.83 dB, 6.05 dB, and 8.84 dB, respectively. Loss variations of the IC-AWGR, the AWGR-A, and the AWGR-B, which are the ratio of the maximum loss to the minimum loss, are 1.08 dB, 4.31 dB, and 1.08 dB, respectively. The loss variation of the IC-AWGR is as same as that of the AWGR-B, but the loss is smaller than it by about 3 dB. The AWGR-A has smaller loss but the loss variation is larger.

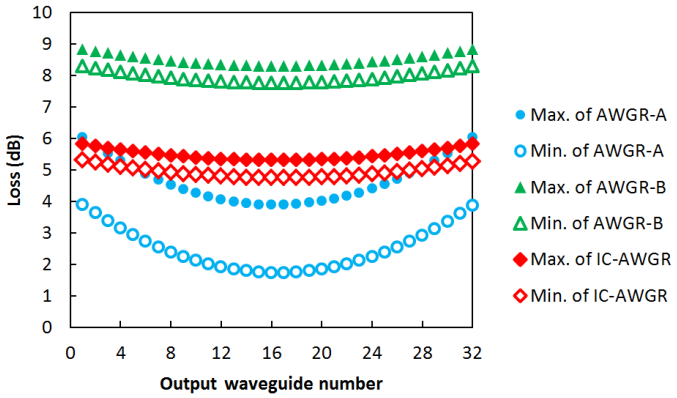

Fig. 2: Loss characteristics of AWGRs.

Conclusions: The 32 x 32, 50-GHz channel spacing AWGR using interleaved chirped array is designed. The minimum loss of the IC-AWGR is 4.75 dB with a loss variation of 1.08 dB. The IC-AWGR has better loss uniformity than that of a normal AWGR.

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