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Dispersion resulting from wide passband shape in 50-GHz-spaced wavelength router

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Abstract. We report dispersions resulting from a slot device (SD) in silica-based arrayed-waveguide grating (AWG). A SD is used to produce flattened passbands and we show the dependence on the bandwidth, the crosstalk, the ripple, and the chromatic dispersion (CD) of the passband in the presence of such a device. A comparison with other known techniques is also given. The device has been developed on a high index silica-based PLC platform but can be implemented on higher index contrast platforms. [DOI: 10.1117/1.1759332]

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1 Introduction

As optical communications advances, more and more passive optical components are needed; e.g., broadband multiplexers are needed to deliver voice and data to the home. Silica-based arrayed waveguide gratings (AWG) have been extensively studied[1] and manufactured to satisfy that need because of their low insertion loss. However, crosstalk and dispersion in such a system are still an issue as they need to be carefully controlled.

To reduce the need for accurate control of the central frequencies of transmitted wavelengths, a rectangular response is currently required. For optimal system performance, it is essential that the passband flattened AWG has a low dispersion or at least lower than the already deployed fibers.

A pulse transmitted in a dispersive medium will suffer a spread, limiting the transmission bandwidth and distance. Moreover, in the next generations of wavelength-division-multiplexing (WDM) systems, optical signals will pass through devices, placed at nodes, more frequently than in point-to-point applications. The cumulative passband width of a channel becomes less than that of a single-stage demultiplexer and chromatic dispersion (CD) is accumulated. In this paper, we describe a new method to produce flat-top passband in AWG and will show that good dispersions are expected using this method.

Table 1 Simulated bandwidth, crosstalk, ripple, and CD for different SD.

L_r	130	150	160	170	180	190	210
BW (GHz)	28.95	27.9	27.7	27.5	27.3	27.3	28.3
AXT (dB)	22	25	24.7	24.8	24.8	23.2	17.5
Ripple (dB)	0.2	0.2	0.2	0.15	0.12	0.1	0.1
CD max (ps/nm)	1	0.4	0.4	0.2	0.4	0.5	6

2 Interleaver Design and Fabrication

We designed and fabricated an 8-channel $\times$50-GHz spacing interleaver fixing the free spectral range (FSR) to 400 GHz in the C band. Silica layers have been deposited using a plasma enhanced chemical vapor deposition (PECVD) process. To reduce the losses around 1.55 μm due to Si-H bonds, a high temperature annealing step is performed after the cladding has been deposited. At $\lambda=1.55$ μm the cladding index is 1.444 and the core index 1.454 (i.e., the relative refractive index difference $\Delta=0.69\%$). The input/output core layer height is 4.5 μm and the width defined by lithography as 6.5 μm. To reduce losses due to the coupling into the phased array and to the bends, the waveguide at the beginning of the array are spaced at 8 μm and the minimum bend radius kept higher than 8 mm. Each array arm is carefully designed according to Ref. 2 to manage slight transition (i.e., low loss) between straight sections and bends. The output waveguides are 24 μm apart. For an 8$\times$50-GHz interleaver, the length of both star couplers is $R=1405$ μm and the total chip area is 5 cm^2. The high path length difference between adjacent waveguides in the array (fixed by the current design) as well as the high minimum radius of curvature impose such a big size. Size reduction will imply changing Δ (Ref. 3). To have a perfect control of the wavelength on the International Telecommunication Union (ITU) grid, the group index (i.e., the order) should be chosen carefully. From a first design (with a guessed group index), we measured the channel spacing and corrected the group index in order to be precisely positioned on the grid. We considered a group index of 1.013107.

3 Band Shape Study

While AWG demultiplexers have no CD in principle, the phase fluctuation in the arrayed waveguide region caused by fabrication errors and the flattening mechanism has been reported to induce CD in AWGs. The phase fluctuation in the array can be reduced with precise fabrication technique and a precise control of the refractive index of the core.[4] The design of the AWG itself can also be improved. A reflection type AWG (Ref. 5) for example provides good crosstalk performances because it has no extra curved waveguides, lowering the phase fluctuation. However, we choose here the AWG's shape presented in Fig. 1, but we still had to study the CD and the dispersions generated by the SD itself.

In order to individuate the set of parameters that corresponds to the device's best performances, the proposed SD

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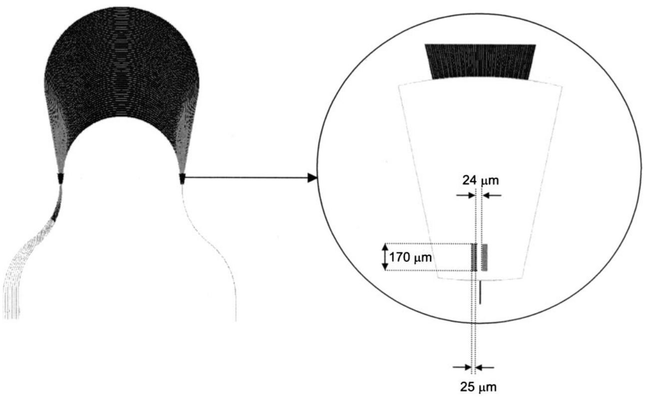

Fig. 1 Waveguide grating router with a slot device.

has been analyzed and designed using commercial simulators: Olympios—Integrated Optics Software.[6] We calculated both the phase and amplitude of the wave at the end of the SD. The power coupled into the output waveguide is determined by the overlap between the focused field (i.e., the field at the end of the SD as the star couplers act as lenses) and the Gaussian-like output guide-mode. From the calculated passband shape, we can easily extract common specifications[7] on bandwidth (at 1 dB), ripple (defined as the difference between the maximum and the minimum loss within the 1-dB bandwidth; it characterizes passband tilt), adjacent crosstalk (AXT defined as the contribution of solely the first neighbors within the 1-dB bandwidth), and CD (also measured in the 1-dB bandwidth).

The chromatic dispersion is obtained from the calculated phase response as follows:

$$D = -[\sigma^2/(2\pi c)] \cdot d^2\phi/d\sigma^2 \tag{1}$$

where c is the speed of light, ϕ the phase, and σ the wavenumber ($1/\lambda$). In our simulations, the slot is placed at 80 μm from the input waveguide. The distance between the grooves is 24 μm, their length 170 μm, and they are 25 μm wide. Table 1 shows for different SD lengths the considered specifications. The CD best performance is obtained for a 170-μm-long SD but from 120 μm until 200 μm the performances remain quiet close.

As a final point, it is worth comparing our device with the other flattening techniques proposed in the literature. It is interesting to point out that a multimode interference (MMI) device[8] gives a measured CD, when the phase in the array is perfectly controlled (i.e., the MMI remaining the cause of CD), as low as 3 ps/nm within the 1-dB bandwidth. Simulations performed on such a MMI show even smaller figures within the range of lengths of Table 1.

The CD when using a parabolic horn waveguide[9] can be reduced to 3 ps/nm in a 100 GHz-spacing 16-channel AWG, as long as the multimode section added to the horn has the required length. As the CD is inversely proportional to the square of the channel spacing, this value is comparable to the CD of the newly developed SD (i.e., 12 ps/nm presented in Section 4). The total length of the device is 340 μm, a bit-longer than the proposed SD or MMI.

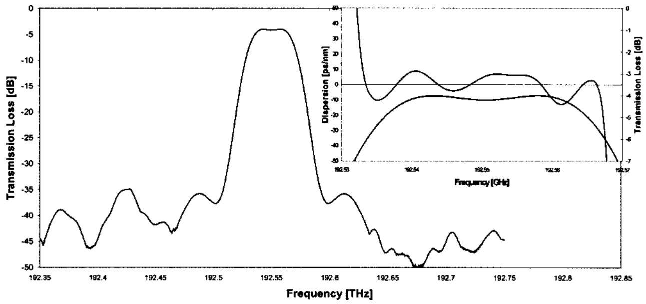

Fig. 2 Demultiplexing (central frequency) and dispersion properties of AWG with an optimized slot device.

4 Results

Figure 1 is a schematic diagram of the router including the SD. The slot is deeply etched by reactive ion etching after the deposition of the cladding. Because of the deep etching process used to produce the SD optimized in Section 3, we designed a mask with smaller windows. The average offset for the deep etching process was ± 2 μm.

Figure 2 shows the transmission of the router using the optimized SD. The total losses (worst case) are 5.5 dB and the insertion loss uniformity over the high channels is 1.2 dB. The 1-dB bandwidth of TM polarization mode has been confirmed to be the same as the TE polarization mode and equals 27 GHz. The CD shown in Fig. 2 has a maximum value of 12 ps/nm. The CD can be attributed to the deep etching process, but also to the control of the phase in the array. The path length difference in the array is greater for a 50-GHz-spaced interleaver than for a 100-GHz-spaced multiplexer used in Refs. 8 and 9, making a control of the phase in the array more difficult.

5 Conclusion

We designed, fabricated, and tested a low CD flat-top 8 channel interleaver on a PLC platform. We have shown that the SD used to flattened the passband does incorporate a dispersion in agreement with other flattening techniques developed in silica-based photonic circuits. Further improvements in controlling the phase in the multiplexer as well as in manufacturing the SD are required to lower the CD.

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