Reflective Arrayed Waveguide Grating with Sagnac Loop Reflectors in Silicon-on-Insulator with Gaussian Pass-band

B. Gargallo$^1$, P. Muñoz$^{1,2}$, R. Baños$^1$, A.L. Giesecke$^3$, J. Bolten$^3$, T. Wahlbrink$^3$
and H. Kleinjans$^3$

$^1$Universitat Politècnica de València & $^2$VLC Photonics S.L.
Camino de Vera sn, 46022 Valencia, Spain - pmunoz@iteam.upv.es
$^3$AMO GmbH, Otto-Blumenthal-Straße 25, 52074 Aachen, Germany - kleinjans@amo.de

Abstract

In this paper the experimental demonstration of a Silicon-on-Insulator Reflective Arrayed Waveguide Grating (R-AWG) is reported. The device employs one Sagnac loop mirror per arm in the array, built with a 1x2 input/outputs, 50:50 splitting ratio, Multimode Interference coupler, for total reflection. The spectral responses obtained are compared to those of regular AWGs fabricated in the same die.

Wavelength multi/demultiplexers are central components in optical communications. Their cost when implemented as an integrated circuit is closely related to its footprint [1]. Reflective multiplexers as the Echelle Diffraction Grating (EDG) achieve considerable size reduction [2]. One issue with EDGs is to maximize the reflection on the grating, in order to minimize the overall insertion losses, with the deposition of metal layers at the edge of the grating [3], or the addition of other structures as Bragg reflectors [4]. Metal deposition provides broadband reflectors, but it requires additional fabrication steps. Conversely, Bragg reflectors can be manufactured in the same process, but the reflection bandwidth is inversely proportional to their strength [5]. Reflective Arrayed Waveguide Grating (R-AWG) with reflectors implemented in similar ways exist, with coatings on the facet of the chip [6], [7], photonic crystals [8], external reflectors [9] and Bragg reflectors [10]. A common issue of all the described approaches for the reflector is that broadband full reflectivity requires additional fabrication steps, increasing the cost. In [11] a configuration for a R-AWG, where Sagnac Loop Reflectors (SLRs) are used at the end of the arrayed waveguides, was demonstrated in silica. These reflectors are broadband, supply total reflection, and can be fabricated in the same lithographic process as the AWG. Moreover, the reflection of a SLR depends on the coupling constant of the coupler. Hence, it can be different for each of the waveguides in the array. In this paper we report on the experimental demonstration of a Silicon-on-Insulator (SOI) R-AWG with Gaussian response, based on SLRs with 50:50 coupling ratio. This opens the door to further research on non Gaussian response R-AWGs, using MMIs with coupling ratios other than 50:50 as we describe in [12].

Following the model and methodology from [12], regular and reflective AWGs were designed for target polarization TE on SOI substrates consisting of a 3 µm thick buried oxide layer and a 220 nm thick Si layer, with no cladding. The effective indexes, calculated using a commercial software, are 2.67 in the arrayed waveguides ($n_c$) - waveguide with 0.8 µm to minimize phase errors [13]- and 2.83 in the slab coupler ($n_s$). The R-AWG parameters are: center wavelength 1550 nm, 7 channels with spacing 1.6 nm and free spectral range of 22.4 nm, focal length 189.32 µm, length increment 36.03 µm and the number of arms is 49. The R-AWG footprint is 350x950 µm$^2$ with an orthogonal layout. The fabricated devices are shown in Fig. 1-(a). Each waveguide in the R-AWG array is terminated by a SLR built with a 1x2 Multimode Interference coupler, with 50:50 splitting ratio for ideally full reflectivity. The input/output waveguides are equipped with focusing gratings couplers (FGCs).

The waveguides are fabricated by Electron Beam Lithography (EBL) and dry etching in a two-step process. First, using hydrogen silsesquioxane negative tone resist in combination with a high contrast development process [14] all device features are defined and fully etched to the buried oxide using an HBr-based ICP-RIE process [15]. In a second step, a positive tone ZEP resist mask is carefully aligned to those features, exposed and used to define the shallow etched parts of the devices using a C4F8/SF6-based dry etching process. For both process steps a multi pass exposure approach is used to further reduce the sidewall roughness of the photonic device, hence minimizing scattering losses in those devices. Furthermore, special care is taken to guarantee accurate critical dimensions of all parts of the device by applying a very accurate proximity effect correction in combination with a well-balanced exposure dose [16].

For spectral characterization, a broadband source was employed in the range of 1525-1575 nm, and traces were recorded using a Optical Spectrum Analyzer with 10 pm resolution. All the traces were normalized with respect...
(a) Optical microscope image of the fabricated devices

(b) AWG spectra

(c) R-AWG spectra

(d) Comparison R-AWG vs AWG

Fig. 1. Optical microscope image of the fabricated AWGs (a) and spectral traces, (b) regular AWG, (c) R-AWG and (d) comparison.

to a straight waveguide. The results are shown in Fig. 1. Panel (b) shows the spectra for the seven channels of the AWG, from the central input. Peak insertion loss is approximately 3 dB. Note this value is subject to small variations in the performance of the FGCs (expected ±0.4 dB). The highest side lobe level is 12 dB below the pass band maximum. Panel (c) shows the spectra for the three inner channels from the central input, for the R-AWG. The other three channels were not designed to be measured, as they end in the same side of the chip. Finally, (d) shows the comparison of both AWG and R-AWG. Two main differences are clearly visible in the figure, between the AWG and the R-AWG. These can be seen in (d) comparing for instance traces A0 and R0. First, the shape of the pass band is slightly degraded towards longer wavelength, for the R-AWG, where broadening happens at 6 dB below maximum. Second, the side lobe level is increased by 4 dB in the R-AWG as compared to the AWG. Being the only difference between both devices the presence of SLRs, these degradations are likely to be due to phase/amplitude imperfections in the reflectors.

In conclusion, we have reported the experimental demonstration of a SOI reflective Arrayed Waveguide Grating, with Sagnac mirrors and Gaussian spectral response. The performance of this first prototype is comparable to that of a regular twin AWG in the same die. Differences, likely due to dissimilarities between reflectors, are subject of current on-going research. Finally, we acknowledge funding from the Spanish MINECO TEC2010-21337 & TEC2013-42332-P, FEDER UPV 10-3E-492 & 08-3E-008, and FPI BES-2011-046100.

REFERENCES


Powered by TCPDF (www.tcpdf.org)