Reflective Arrayed Waveguide Grating in Silicon-on-Insulator with flattened spectral response

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In this paper the simulations and design of a Reflective Arrayed Waveguide Grating in Silicon-on-Insulator with a flattened spectral response are reported. The device operates using two different groups of arrayed waveguides, each of these groups focusing the same wavelengths in slightly shifted spatial positions. The combination of the two Gaussian passbands for each channel determines the resulting channel width and ripple. 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.

Introduction

The Arrayed Waveguide Grating (AWG) [1, 2] is a well-known passive and fully integrated device used to separate the input wavelengths in different spatial positions or to combine different wavelengths in the same spatial position. A regular AWG is formed by a group of input waveguides connected to the input of a first slab coupler o free propagation region (FPR), a group of arrayed waveguides connected to the output of the first FPR and the input of the second FPR, and a group of output waveguides connected to the output of the second FPR. Typically, the arrayed waveguides are designed with a constant incremental length, obtaining a wavelength-dependent lineal phase front that, in combination with the FPR, focuses different wavelengths to the different output waveguides.

During the last years, there has been a lot of interest in improving this component. The reduction of size of the final device, strongly related to the cost and losses due to fabrication, is one of the necessary improvements. A feasible configuration to obtain the reduction of size with the same functionality is the reflective AWG (R-AWG). In this case, the device is half of a regular AWG, using reflectors at the middle of the arrayed waveguides. In the literature it is possible to find different ways to implement the reflector, using the chip facet [3], multimode interference reflectors [4], external reflectors [5], Bragg reflectors [6] or Sagnac loop reflectors [7] at the end of the arrayed waveguides.

There are also different techniques to customize/flatten the spectral response of the AWG, as for example using multimode interference couplers (MMIs) at the input waveguides [8], parabolic waveguide horns [9], interferometers [10], using different focal points [11] or modifying the amplitude and phase at the arrayed waveguides [12]. In this paper, a R-AWG configuration using Sagnac loop reflectors (SLR) is used, since it can be fabricated in one lithographic process without using external structures, and the response is flattened by means of two different focal points (two different groups of arrayed waveguides).

Principle of operation

A schematic view of a reflective AWG (R-AWG) can be seen in Fig. 1. The R-AWG consist of a group of input and output waveguides connected to the input of the slab coupler, and two different groups of arrayed waveguides (AWs) connected to the end of the slab coupler, each of these groups with a constant incremental length between consecutive waveguides, and a Sagnac loop reflector (SLR) at the end of each arrayed waveguide. The SLR has been implemented by means of a 1x2 multimode interference coupler (MMI) with the outputs by-passed. This configuration enables to modify the amplitude in each a AW independently through each SLR. In the most general case presented in this paper, all the SLRs are similar with a 100% reflectivity.

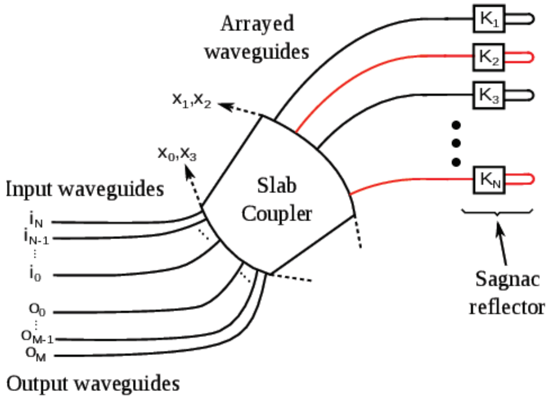

Fig. 1: Reflective AWG schematic. There exists an incremental length between arrayed waveguides in the same group. Different colors stand for different AW groups. Abbreviations: K stands for coupling constant and x stands for spatial AWG planes.

To obtain the flattened spectral response, two different groups of arrayed waveguides are used. Each of these groups have a different incremental length ($\Delta L_1, \Delta L_2$), and then a different central wavelength (λ_1, λ_2) will be focused at the central position of the output plane. The response of each array analysed independently has a Gaussian shape [13]. If the two central wavelengths are slightly different, the final spectral response obtained as the addition of both responses will be flattened, as can be seen in Fig. 2.

Design and simulations

The design provided is for Silicon-on-Insulator (SOI) technology, with a 220-nm-thick Si guiding layer on a SiO_2 substrate with no cladding, and TE polarization. The effective indexes, calculated using a commercial software, are 2.667 in the arrayed waveguides (n_c) when using a width of 0.8 μm and 2.83 for the slab coupler (n_s). The R-AWG parameters are the following: 7 channels with a spacing of 1.6 nm and a FSR of 22.4 nm. The calculated focal length is 306.2 μm, the incremental lengths between arrayed waveguides are 13.366 and 13.375 μm for each group of arrayed waveguides, respectively, and the grating order m is 23. The total number of AWs is 105. Using Eq. 1 that relates the different incremental lengths with the central wavelength focused at the central position

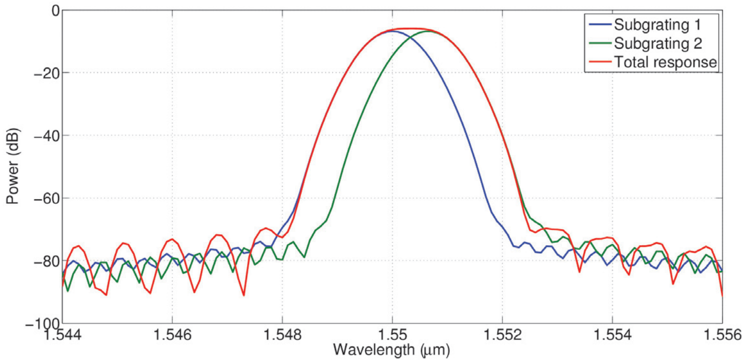

Fig. 2: Simulated AWG as two subgratings and using both AW groups at the same time

at the output plane, the focused wavelengths will be 1550 and 1550.65 nm for each group of AWs.

$$\lambda_1 = \frac{\Delta L_1 n_c(\lambda_1)}{m}, \quad \lambda_2 = \frac{\Delta L_2 n_c(\lambda_2)}{m} \tag{1}$$

It can be seen in Fig. 2 where the central channel has been simulated for each group of AWs independently and for both groups at the same time. Figure 3 shows the simulations for all the output waveguides when using the aforementioned parameters.

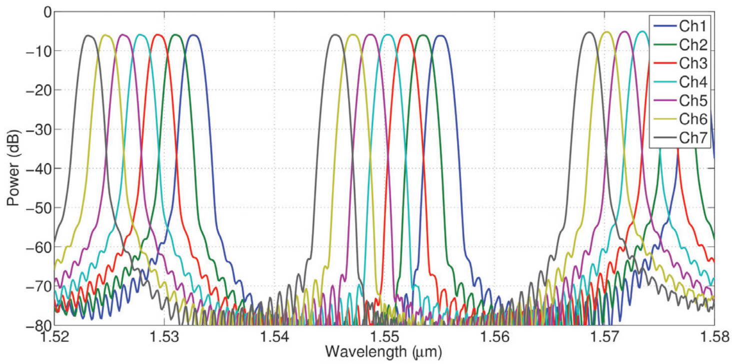

Fig. 3: Transfer function from central input waveguide to the output waveguides

The most important parameters can be obtained from Fig. 4, where the output central channel is shown in more detail when using the flattened R-AWG. In this case, the losses are approximately 6 dB and the 1dB and 3dB bandwidths are 1.0 and 1.4 nm, respectively.

Conclusion

This paper provides the proposal for the use of reflective Arrayed Waveguide Gratings to obtain a flattened spectral response. It has been based on the two-focal-point method where two different groups of arrayed waveguides are used with slightly different central

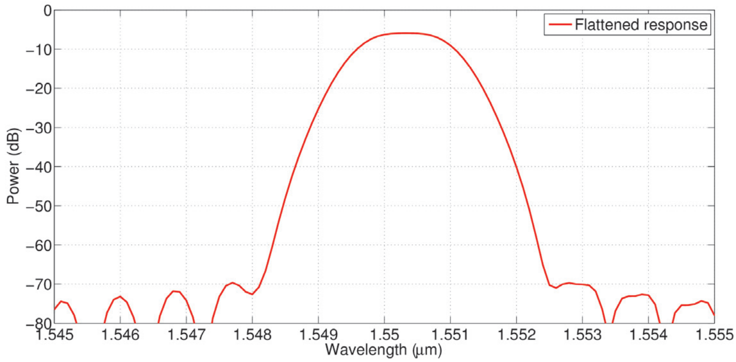

Fig. 4: Central output waveguide response

wavelengths. This method has been used with real parameters to provide an example of design and the corresponding simulations using the model in [7].

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