Design and Integration of an O-band Silicon Nitride AWG for CWDM Applications

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***Abstract* — Experimental demonstration of an O-band four channel CWDM silicon nitride AWG is reported. Specificity of low order array has been explored through multiple devices among which insertion loss below 2.3dB, crosstalk level as high as 37dB and polarization insensitive flat spectral response is obtained.**

Keywords* — *Arrayed Waveguide Grating; Silicon Nitride; Coarse Wavelength Division Multiplexing; Photonics

I. INTRODUCTION

Silicon photonics technology provides unreached data densities and integration level while taking benefits from low cost and industrial manufacturing infrastructure of CMOS electronics[1]. This is of particular interest for the implementation of Coarse Wavelength Division Multiplexing (CWDM), which enables transmission of multiple high speed data channel onto a single fibre with low-cost uncooled lasers.

However, the relatively high propagation losses, temperature dependence and roughness-induced phase error of silicon makes it not relevant to implement the multiplexer/demultiplexer (MUX/DEMUX) function. In recent years another common CMOS material, silicon nitride (SiN), appears as an interesting optical medium[2]. Indeed, SiN has a thermo-optical coefficient lower than seven times[3] and its moderate index contrast leads to a more suitable platform for passive devices requiring a good control of the phase, while maintaining a reasonable footprint [2].

In this paper, the design and experimental demonstration of two O-band four channel CWDM silicon nitride Arrayed Waveguide Grating (AWG) is presented. A first « standard design » is reported as a reference, the second one, « flattened spectral response », show polarisation insensitive channel flattening.

II. DESIGN CONSIDERATION

A. Standard design

AWG principle has been extensively described in the last decades[4,5]. This AWG was designed in order to fulfil O-band CWDM standard defined by ITU-T, which set channel spacing to 20nm and channel centres to 1271, 1291, 1311 & 1331nm. Considering these specifications, the design procedure started from a Free Spectral Range (FSR) higher than 80nm to avoid channel overlapping. The FSR can then be linked with the array waveguide order:

$$m = \frac{n_{effWG}(\lambda_c) * \lambda_c}{n_{gWG}(\lambda_c) * \lambda_{FSR}}$$

With m array waveguide order, λ_c central design wavelength (nm), $n_{effWG}(\lambda_c)$ array waveguide effective index, $n_{gWG}(\lambda_c)$ array waveguide group index and λ_{FSR} free spectral range (nm). This relation set an upper limit to the array order m, which leads to the length difference between arrayed waveguide ΔL:

$$\Delta L = \frac{\lambda_c * m}{n_{effWG}(\lambda_c)}$$

This design procedure is summarised in Fig. 1 (a).

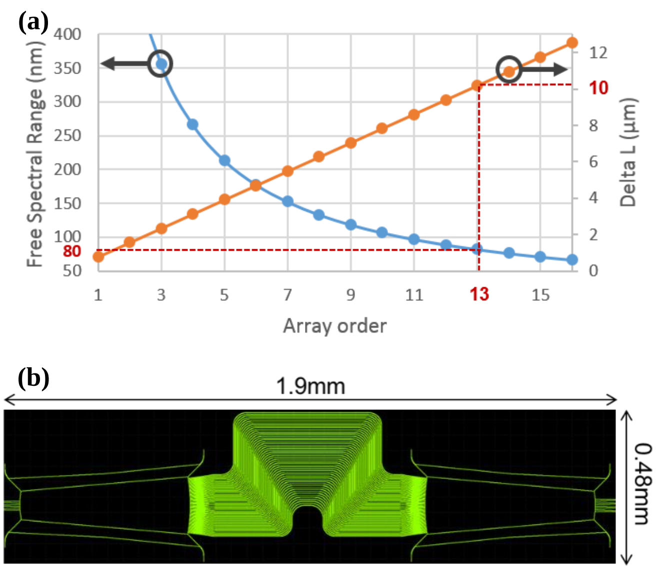

Figure 1: ***(a) Graphic showing dependence between FSR, array order and array waveguide length difference, (b) AWG layout.***

Once the upper limit on m and ΔL was set, the final values were chosen according other parameters including channel bandwidth, crosstalk level and device footprint. In our configuration, the array order was five, and the number of waveguides in the array 52.

With such a short ΔL the usual « U-shape » is not suitable since it will lead to waveguide overlapping in the array. An interesting alternative is the « S-shape ». Its major drawback, additional delay length, is acceptable due to low propagation losses of SiN. In addition, the use of straight waveguides avoid layout grid mismatch which can drive phase errors and thus higher floor crosstalk level. The final AWG footprint is less than 1mm^2 as shown in Fig. 1(b).

B. Flattened spectral response design

Another condition that must be fulfilled to complain with CWDM standard is a flattened spectral response to ensure constant power level transmission on the whole channel bandwidth. This was achieved using a Multi-Mode Interferometer (MMI) as an input waveguide of the AWG[6]. Moreover, by choosing an appropriate MMI width[7], beating length for both transverse electric (TE) and transverse magnetic (TM) polarisations can be equal, leading to polarisation insensitive channel broadening as shown in section III. B.

III. Experimental Demonstration

Both AWG presented in the following parts were fabricated on 300mm wafers in ST Crolles, Fr. Fig. 2 presents standard design measurements using grating coupler (GC). As GC only worked for TM polarisation this impose to switch on edge coupling for TE measurements of the flattened spectral response device shown on Fig. 3. The larger channel non-uniformity came from the variation of coupling efficiency at the waveguides facet.

A. Standard design

Fig. 2 shows the spectral response of the standard AWG design. The central channel losses were between 1.91 to 2.29dB giving a channel non-uniformity of 0.38dB. The crosstalk level was better than 36dB for all of the four channels.

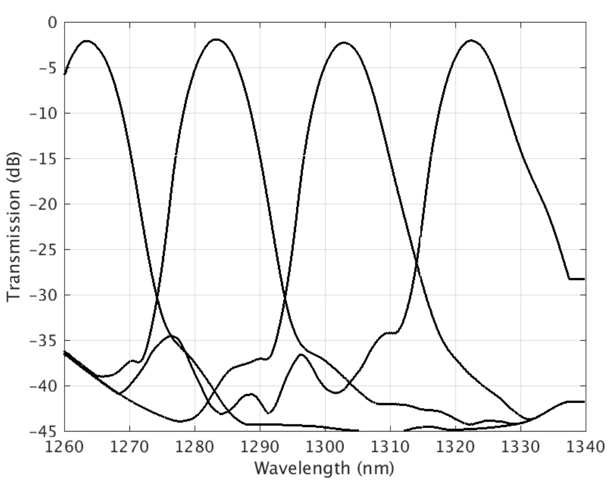

Figure 2: ***Standard AWG experimental spectral response for TM polarisation. (Characterisation by grating coupler.)***

Individual channel shape shown on Fig. 2 were slightly asymmetric. This small widening at the right part of the channel came from residual TE polarisation that was not correctly filtered during measurements.

B. Flattened spectral response design

As mentioned in section II. B, CWDM standard requires a constant power level transmission on the whole channel bandwidth, which have to fall from 8 to 13nm. This has been demonstrated experimentally as shown on Fig.3. Both polarisations show the same loss level and the 1dB channel bandwidth was 9.2nm for TE and 9 nm for TM demonstrating polarisation independent flattening.

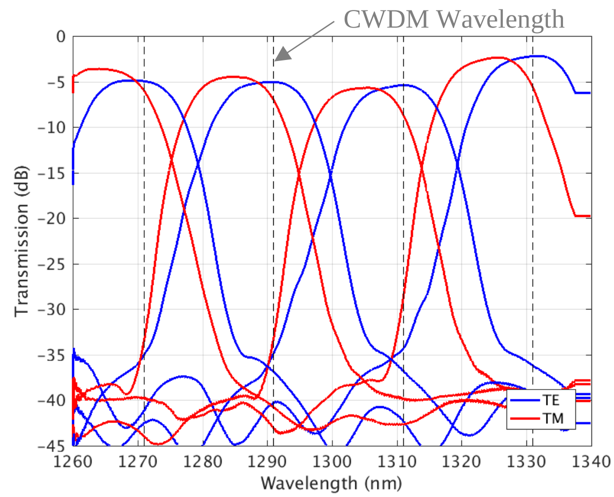

Figure 3: ***AWG experimental spectral response for TE and TM polarisation. (Characterisation by edge coupling.)***

IV. Conclusion

O-band four channel CWDM SiN AWG have been designed, fabricated and characterised. Polarization insensitive channel flattening have been demonstrated with appropriate MMI design. Future work will be focused on spectral polarisation dependence reduction, temperature sensitivity measurements and statistical characterisation for integration in ST 300mm photonic platform.

V. Acknowledements

This work was partially funded by DGE Nano2017 program and by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (ERC POPSTAR – grant agreement No 647342).

We also acknowledge financial support to this work by the European Commission through the H2020-ICT-27-2015 COSMICC project under grant agreement n°688516.

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