UNIVERSITÉ LAVAL

Silicon Nitride Arrayed Waveguide Grating with a Waveguide Superlattice

Qi Han, Michaël Ménard, and Wei Shi

IEEE/OSA Conference on Lasers and Electro-Optics (CLEO 2020)

Silicon Nitride Arrayed Waveguide Grating with a Waveguide Superlattice

Qi Han[1]**, Michaël Ménard**[2]**, Wei Shi**[1*]

[1]*Centre d'optique, photonique et laser (COPL) and Département de génie électrique et génie informatique, Université Laval, 2375 rue de la Terrasse, Québec G1V 0A6, Canada*

[2]*Microtechnology and Microsystems Laboratory, Université du Québec à Montréal, C.P. 8888 succursale Centre-ville Montréal, Québec, H3C 3P8, Canada*

wei.shi@gel.ulaval.ca

Abstract: A compact 100-GHz 1×8 arrayed waveguide grating with 3 dB insertion loss and -20 dB crosstalk, enabled by a novel concept of waveguide superlattice, is experimentally demonstrated.

OCIS codes: (060.1810) Buffers, couplers, routers, switches, and multiplexers, distributed feedback; (060.4230) Multiplexing;(080.1238) Array waveguide devices.

1. Introduction

Arrayed waveguide gratings (AWGs) are the important components in dense wavelength division multiplexing (DWDM) systems. Silicon nitride (SiN) platforms are promising for compact, high performance AWGs [1, 2]. Compared to silicon-on-insulator (SOI), SiN waveguides have a lower refractive index contrast and thus better tolerance to fabrication errors. Conventional AWGs use identical waveguides inside the array, requiring a sufficiently large gap in-between them to supress inter-waveguide coupling. In our previous work [2], a large gap of 10 μm was used, which prevented us from further shrinking the footprint of the AWG.

Here we use the concept of waveguide superlattice based on the asymmetric directional coupler theory [3, 4]. The waveguide superlattice consists of a number of waveguides with different widths with none or little parasitic couplings between adjacent waveguides. Using such a superlattice for arrayed waveguides in SiN, we experimentally demonstrate a 1×8 AWG for 100 GHz DWDM.

2. Device Design and Fabrication

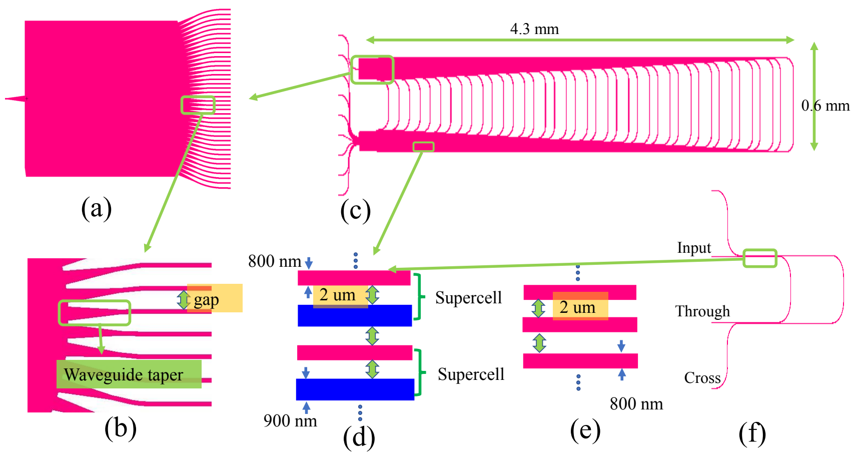

Fig. 1. Schematic of (a) the input star coupler, (b) waveguide tapers, (c) AWG, (d) arrayed waveguide superlattice, (e) conventional arrayed waveguides, and (f) MZI for coupler characterization.

To demonstrate the performance improvement enabled by the proposed superlattice structure, we designed two 1×8 AWGs: a conventional design with identical waveguides and another using a waveguide superlattice. In both cases, an array of 40 waveguides with a separation of 2 μm between adjacent waveguides is used, as shown in Fig. 1. In the superlattice, the width of the waveguides alternates between 800 nm and 900 nm (Fig. 1(d)), whereas in the conventional AWG, all the waveguides have a width of 800 nm. Both devices have a center wavelength of

1550 nm and a channel spacing of 100 GHz. Waveguide tapers are used to reduce the uncoupled loss between the star coupler and arrayed waveguides. A large radius of 100 μm is used for the waveguide bends to minimize bending losses. The footprint of both AWGs is 4.3 mm $\times$ 0.6 mm.

In order to characterize the anti-coupling effect of the waveguide superlattice, we designed two MZIs: one with a conventional directional coupler and the other with a waveguide supercell (i.e. asymmetric directional coupler), as shown in Fig. 1(f). The first MZI uses a single waveguide width of 800 nm, whereas the supercell design uses different widths for two arms that are 800 nm and 900 nm, respectively, Both MZIs have a coupling gap of 2 μm and 600 μm length imbalance between the two arms.

The devices were implemented on AEPONY's SiN platform with a waveguide core thickness of 440 nm. The fabrication began with the deposition of 3.2 μm of SiO_2 on a Si wafer followed by that of SiN. The SiN waveguide pattern was defined using electron beam lithography and dry etching. In the final step the wafer was covered with another 3.4 μm of SiO_2 to form the top cladding.

3. Experimental Results

The normalized transmission spectrums of the MZIs are shown in Fig. 2(a). The interference pattern is clearly seen in the conventional MZI, while little interference effect is shown in the MZI with the asymmetric couplers. This indicates that the waveguide superlattice can effectively prevent parasitic coupling between adjacent waveguides. At the center wavelength (1550 nm), the insertion loss is approximately 3 dB for the superlattice AWG; the crosstalk across all channels is around -20 dB, as shown in Fig.2(b). The insertion loss at the center wavelength is around 5 dB for the conventional AWG; the crosstalk across is around -16 dB, as shown in Fig.2(c). These results prove that the use of a waveguide superlattice significantly improves the performance of compact AWGs.

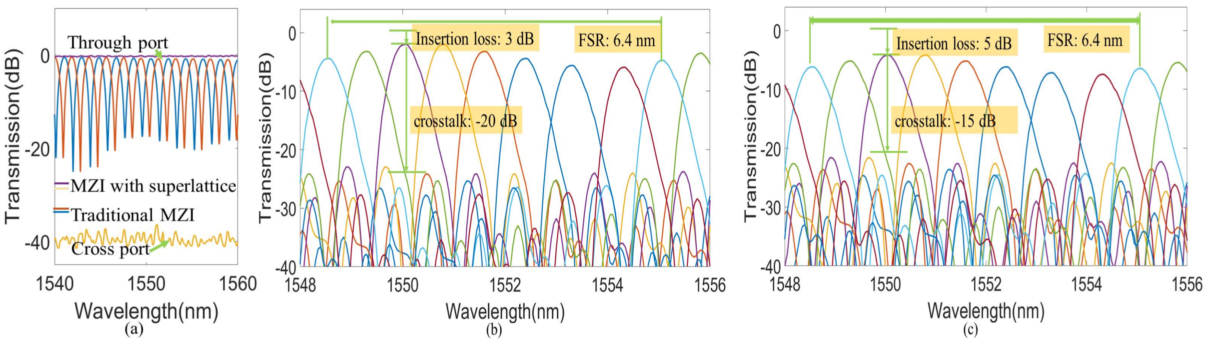

Fig. 2. Measured spectra of (a) MZIs with symmetric and asymmetric directional couplers (supercells), (b) the superlattice AWG, and (c) the conventional AWG.

4. Conclusion

In summary, we have proposed and experimentally demonstrated a compact (4.3 mm $\times$ 0.6 mm) AWG with a waveguides superlattice. The device shows considerable improvement in both insertion loss (by 2 dB) and crosstalk (by 4 dB) compared with the conventional design with identical arrayed waveguides thanks to the drastic reduction in parasitic coupling in the waveguides array.

Acknowledgement

We thank the AEPONYX Inc team for the device fabrication and many useful discussions. This research was funded by Mitacs, AEPONYX Inc., TELUS Corp., PROMPT Québec, and the Natural Sciences and Engineering Research Council of Canada (CRDPJ 499664).

References

1. P. Gatkine, S. Veilleux, Y. Hu, T. Zhu, Y. Meng, J. Bland-Hawthorn, and M. Dagenais, "Arrayed waveguide grating spectrometers for astronomical applications: new results," Optics Express 25, 17918 – 17935 (2017).
2. Q Han, J St-Yves, Y Chen, M Ménard, W Shi, "Polarization-insensitive silicon nitride arrayed waveguide grating" Optics Letters,44,16,3976-3979 (2019).
3. W Song, R Gatdula, S Abbaslou, M Lu, A Stein, W. Lai, J. Provine, R. Fabian W. Pease, Demetrios N. Christodoulides and W.Jiang,"High-density waveguide superlattices with low crosstalk",Nature Communications,6, 7027 (2015).
4. G.Assanto, A.Laureti-Palma, C.Sibilia, M.Bertolotti,"All-optical switching via second harmonic generation in a nonlinearly asymmetric directional coupler",Optics Communications, 110, 5–6,599-603(1994).