Single contact double-waveguide SOAs in AWG-based lasers fabricated on InP generic photonic integration platform

K. Ławniczuk,[1,2] M. J. Wale,[1,3] P. Szczepański,[2,4] R. Piramidowicz,[2]
M. K. Smit,[1] and X. J. M. Leijtens[1]

[1] Photonic Integration Group, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, the Netherlands; *k.lawniczuk@tue.nl*
[2] Institute of Microelectronics and Optoelectronics, Warsaw University of Technology, Koszykowa 75 Str. 00-662 Warsaw, Poland
[3] Oclaro Technology Ltd., Caswell, Towcestrer, Northamptonshire, NN12 8EQ, United Kingdom
[4] National Institute of Telecommunications, Szachowa 1, 04-894 Warsaw, Poland

By implementing SOAs that guide two waveguides through a single contact active section, we can reduce dimensions of photonic integrated circuits (PICs) and decrease the number of electrical contacts of current injection. In this paper we demonstrate linear 4-channel and 8-channel AWG-based lasers that take advantage of such SOAs. This resulted in a reduction of the required number of active regions and contacts by a factor two. Measurements showed that these sources operate with an output power of 1 mW per AWG-channel and side-mode suppression ratio better than 40 dB. The lasers were fabricated in a multi-project wafer run on an indium phosphide (InP)-based generic photonic integration platform.

AWG-based lasers

Multiwavelength sources that emit light simultaneously at different wavelengths can be successfully realized using arrayed waveguide gratings (AWGs) [1-2]. While AWG-based lasers (AWGLs) can be realized in many configurations, the most common is the linear configuration. In this configuration a separate semiconductor optical amplifier (SOA) is dedicated to each generated wavelength and thus for each AWG passband [3]. Biasing more than one SOA at the same time will result in simultaneous lasing at several channels. The AWG acts as an intra-cavity filter in the lasers and might be used as a multiplexer of the generated optical signals. In these devices the number of SOAs in the laser array scales linearly with the number of required operational channels.

One of the methods to reduce the number of SOAs in the array by a factor two and reduce the size of PICs is by implementing single contact double-waveguide SOAs. These components guide two waveguides, corresponding to two AWG passbands, through a single active section. The operation principle of the sources remains unchanged. In this configuration we obtain compact multiwavelength sources with

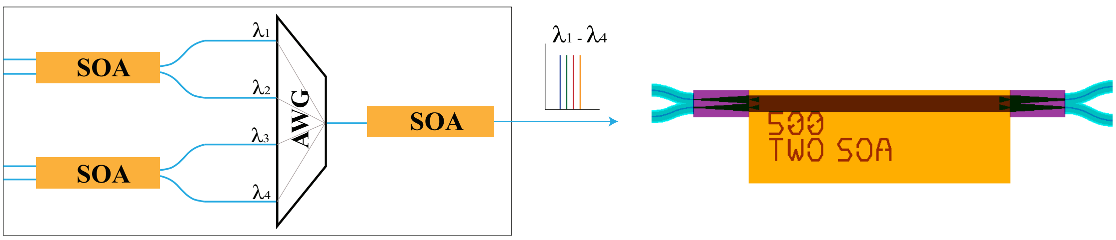

Fig. 1. Schematic of an AWG-based laser (*left*) and mask layout of the double-waveguide SOA (*right*).

easier driving mechanism, due to the reduction of the number of contacts requiring current injection.

In this paper we present linear 4-channel and 8-channel AWGLs that take advantage of a novel design with single contact double-waveguide SOAs. The devices were processed on an InP-based platform that allows for monolithic integration of active and passive components. The sources were realized following the generic integration concept [4] and fabricated in cooperation with an industrial foundry partner [5] in a multi-project wafer (MPW) run [6].

Design and fabrication of AWG-based lasers

Generic integration on InP-based photonics platforms enables designing and fabricating of functionally advanced photonic integrated circuits (PICs), yet utilizing only a limited set of components called building blocks (BBs) [4], [6]. We developed our AWGLs using three elementary BBs: (1) deeply etched passive waveguide structures, (2) shallowly etched SOAs and (3) low-loss deep-shallow transition elements that were inserted between the SOA and each waveguide. The SOAs with double-waveguide geometry were offered by the foundry [5] as parameterized BBs. The schematic of such AWGL and the mask layout of the single contact double-waveguide SOA are presented in Figure 1. As can be seen, two lasing channels operating in two AWG-passbands can be activated using only a single contact on the double-waveguide amplifier.

The fab that carries out the MPW runs, such as the one in which the AWGLs were fabricated, uses integration processes that were developed over many years and that are used commercially for the fabrication of devices such as tunable laser-Mach-Zehnder PICs employed in tunable XFP-format transceivers [5]. The technological process utilizes six MOVPE epitaxial growth stages for: source wafer growth with InGaAsP multi-quantum well (MQW); bulk quaternary Q1.42 tuning section infill; strong waveguide infill; spot-size converter (SSC) and upper confinement layer overgrowth. Gain regions are defined by dielectric patterning and subsequent etch processes. Infill stages use a selective growth approach, where a dielectric mask is used as a non-growth barrier. The waveguide ridge for the amplifier is formed by dry and wet etching following the overgrowth stage. The etch depth is controlled by the material structure and is limited by an etch-stop layer. Strong ridge formation is done by dry etching. Following deposition and definition of a dielectric isolation layer, the p-contact metal is sputtered and annealed in order to provide low contact resistance. Gold bond pads are deposited onto the p-metal to enable efficient current injection and heat dissipation.

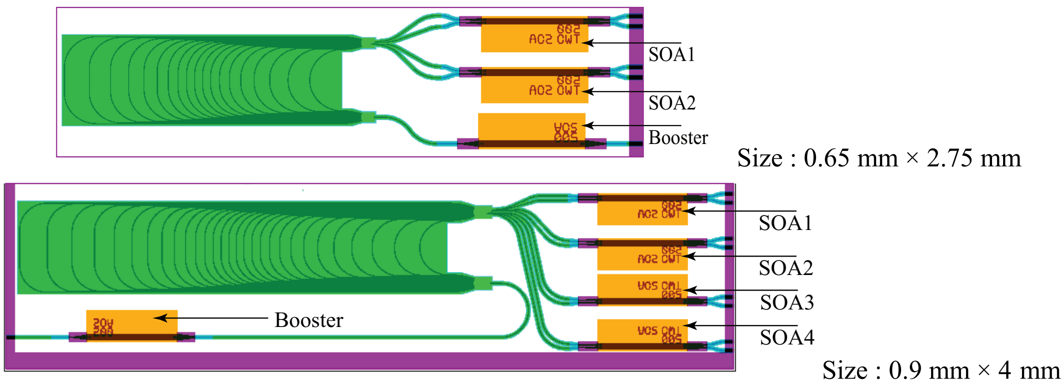

Fig. 2. Mask layout of 4-channel (*top*) and 8-channel (*bottom*) AWG-based lasers.

The layouts of the 4-channel and 8-channel AWGLs are presented in Figure 2, with indicated SOAs and boosters. Both AWGs were designed for a central wavelength λ_c = 1550 nm with a channel spacing $\Delta\lambda$ = 200 GHz (1.6 nm) in case of the 4-channel device and $\Delta\lambda$ = 100 GHz (0.8 nm) in case of the 8-channel device. The free spectral ranges (FSRs) of the 4-channel and 8-channel sources are 800 GHz and 900 GHz respectively. The length of each SOA is 500 µm. The AWG laser dimensions are 0.65 mm × 2.75 mm (4-channel device) and 0.9 mm × 4 mm (8-channel device).

Fig. 3. Wire-bonded 4-channel AWGL on measurement setup. The device was placed in a 2 mm × 4 mm cell.

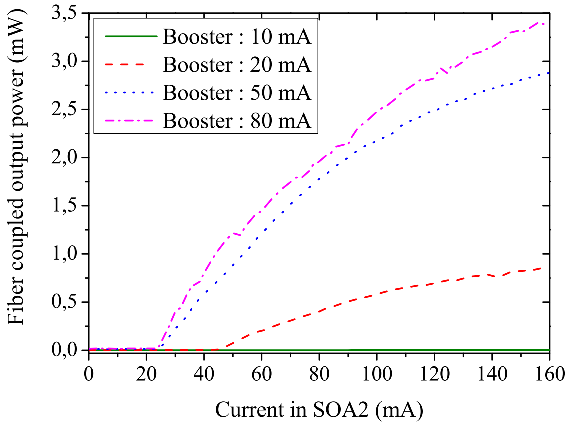

Fig. 4. *LI* characteristics of 4-channel AWGL, for SOA2, and for different currents in the booster.

Measurement results

The devices were mounted on a ceramic submount and wire bonded to external DC pads to ease access to the SOA contacts. A lensed fiber was used to couple the light out from the chip. A high resolution (0.16 pm) Optical Spectrum Analyzer, APEX P2041A, was used to record the spectra. The devices were measured at room temperature. A photograph of the 4-channel AWGL on a measurement setup is presented in Figure 3.

The threshold currents of the AWGLs depend on the current applied to the booster amplifier. This is because the booster was implemented within the laser cavity and at the output waveguide coupler. The results of experiment performed on SOA2 of 4-channel AWGL are shown in Figure 4. The threshold current is less than 25 mA while biasing the booster with 50 mA. The threshold currents measured for each SOA of the 8-channel AWG laser are less than 35 mA, while biasing the booster with 50 mA.

The spectral characteristics of 8-channel AWGL measured while biasing the booster with 80 mA are demonstrated in Figure 5. During our first experiments we obtained a single-mode operation for AWG passbands in the case of 3 out of 4 double-waveguide SOAs. By biasing one double-

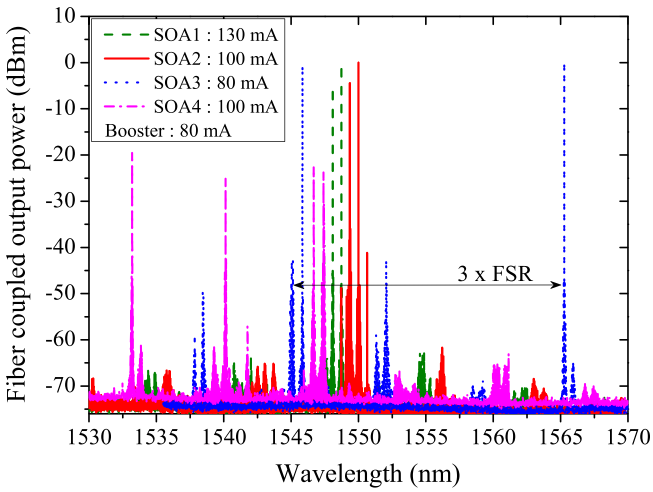

Fig. 5. Spectral characteristics of the 8-channel AWGL. By activating one double-waveguide SOA we obtain laser operation on two AWG passbands.

waveguide SOA we achieved double AWG channel operation of the lasers. The detected output power in the fiber was in the range of 1 mW per AWG passband with a side mode suppression ratio (SMSR) better than 40 dB. The channel spacing between adjacent signals ranged from 0.64 nm to 0.85 nm. The variation is caused by the relatively long cavity resulting in closely spaced longitudinal modes. The presented source also reveals operation on FSR orders different than the central FSR, which can be suppressed for example by introducing wavelength selective mirrors, such as distributed Bragg reflector (DBR)-based gratings.

Summary and further work

We demonstrated novel AWG-based lasers that use single-contact double-waveguide SOAs. The devices were fabricated on a generic InP-based platform. The obtained size of the array of the SOAs is twice smaller when compared to other linear configurations of AWG sources, which makes these components and devices promising for further utilization. The first characterization results show a good performance of the multiwavelength sources. The detected output power is in the range of 1 mW per activated AWG passband with a SMSR better than 40 dB. Operation in a single order of the AWG can be ensured in a next design, by using wavelength-selective mirrors or by chirping the waveguide grating.

Future work concerns a detailed spectral characterization of the sources and focuses on a theoretical analysis of single contact double-waveguide SOAs in lasers.

Acknowledgement

The authors would like to thank Christophe Kazmierski from Alcatel-Thales III-V labs (Marcoussis, France) for mounting and wire-bonding of the AWG-based lasers.

The research leading to these results has received funding from EU FP7/2007-2013 grant agreement no 228839: EuroPIC [7] and from the Dutch Ministry of Economic Affairs through the Smartmix project Memphis [8].

References

[1] M. Zirngibl and C. Joyner, "12 frequency WDM laser based on a transmissive waveguide grating router," *Electron. Lett.*, vol. 30, no. 9, pp. 701–702, 1994.

[2] K. Ławniczuk, R. Piramidowicz, P. Szczepański, P.J. Williams, M.J. Wale, M.K. Smit and X.J.M. Leijtens, "8-channel AWG-based multiwavelength laser fabricated in a multi-project wafer run," *Proc. 23rd Int. Conf, Indium Phosphide and Related Materials,* Berlin, Germany, 22-26 May (2011).

[3] C. Doerr, C. Joyner, and L. Stulz, "40-wavelength rapidly digitally tunable laser," *IEEE Photon. Technol. Lett.*, vol. 11, no. 11, pp. 1348–1350, Nov. 1999.

[4] M. Smit, X. Leijtens, E. Bente, J. van der Tol, H. Ambrosius, D. Robbins, M. Wale, N. Grote, M.Schell, "Generic foundry model for InP-based photonics," *IET Optoelectron.*, vol. 5, no. 5, pp.187-194, 2011.

[5] Oclaro Technologu Ltd., http://www.oclaro.com/.

[6] X. Leijtens, "Jeppix: the platform for indium phosphide-based photonics," *IET Optoelectronics*, vol. 5, no. 5, pp. 202–206, 2011.

[7] EuroPIC,European Manufacturing Platform for Photonic Integrated Circuits, http://europic.jeppix.eu.

[8] Memphis, Merging Electronics and Micro & Nano-Photonics in Integrated Systems, http://www.smartmix-memphis.nl.