Interleave-chirp arrayed waveguide grating on InP generic technology

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Abstract

In this paper the design, fabrication and characterization of an Interleave-chirp Arrayed Waveguide Grating on generic InP technology is reported. The device operates for two wavelength channels spaced 0.8 nm, with a chirp pattern of P=4, unfolding the operation in each wavelength channel to 4 different phases and 2 polarizations, and a free spectral range of 3.2 nm. Polarization splitting is attained through birefringent waveguide cross-sections in the IC-AWG arms. The results show excellent match on the channel spacing, free spectral range, and close to designed targets on the birefringence.

I. Introduction

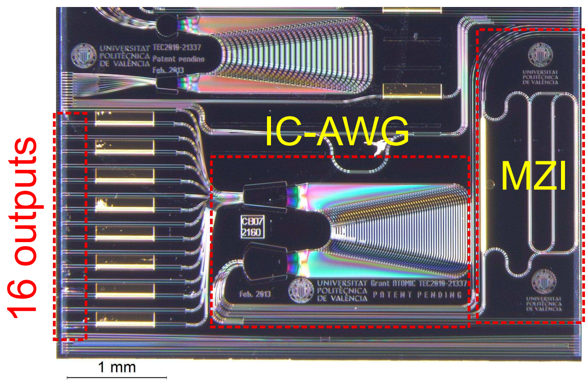
Coherent optical communications have revived in the recent years [1] and high performance photonic integrated circuits (PICs) with real-time operation at aggregate speeds of up to 500 Gb/s have been demonstrated [2]. Currently, the core of integrated optics based coherent receivers are Multi-Mode Interference (MMI) couplers, designed to operate as 90° hybrids. Similar to conventional Intensity Modulated Direct Detection (IM-DD) systems, Wavelength Division Multiplexing (WDM) has been recently brought into PICs for coherent optical communications. The natural combination of on chip demultiplexers, as the Arrayed Waveguide Grating, and optical MMI 90° hybrids have been demonstrated in [2], whereas off-chip optical polarization splitters are used to feed the PIC. Nonetheless, the solution demonstrated by Doerr e.a. [3], in a custom Indium Phosphide (InP) technology platform, in which the AWG arms are modified to enable three fold operation (demultiplexer, polarization splitter, 90° hybrid), is envisaged as the most compact solution for these future on-chip architectures. This device is named Interleaved-Chirp AWG (IC-AWG). In this paper we report on the fabrication of a IC-AWG coherent receiver on generic InP technology.

II. Design, fabrication and characterization

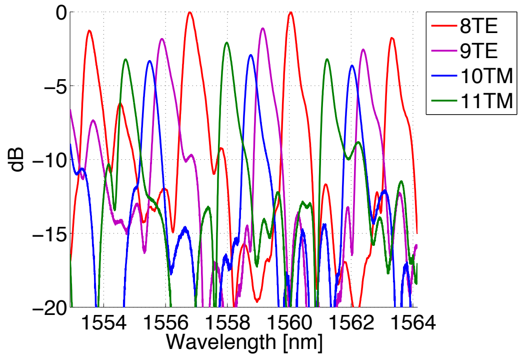
The IC-AWG was designed for the InP technology of JePPIX at the COBRA fab [4]. The technology enables the integration of passive waveguides and active areas, for amplifiers and photo-detectors, on the same chip using a butt-joint regrowth integration scheme. For the design, we followed our methodology described in [5]. Design parameters for the IC-AWG are chirp parameter P=4, channel spacing 0.8 nm, 16 outputs -i.e. 2 wavelength operating channels, P=4 phase relations, and 2 polarizations, TE and TM-, and FSR of 3.2 nm. This resulted in a slab coupler focal length of 384.6 μm, arm length increment of 51 μm, grating order m=107. The waveguides in the array to slab interface were spaced by 2.75 μm, and the curvature radius was 162 μm. The arm waveguide width to attain a birefringence of 1.6 nm, was 2.1 μm on a deeply etched cross section [4]. The chirp pattern was $\{0, 3\pi/4, 0, -\pi/4\}$. The center wavelength was set to 1550 nm. Therefore, each sub-array had a small base incremental length according to this wavelength and the chirp pattern [5]. No optimizations for the i/o waveguides regarding aberrations were done. An auxiliary 2x2 Mach-Zehnder interferometer (MZI) was connected to the input of the IC-AWG, in order to asses on the phase relations of the sub-arrays, similar to [6] for MMI-based 90° hybrids. The MZI has a length increment between arms of 8.124 mm, corresponding to a FSR of 80 pm. The two outputs of the MZI were connected to input positions of the IC-AWG separated corresponding to a spectral separation of the FSR. A microscope picture of the fabricated device is shown in Fig. 1-(a).

The chip was soldered to a submount, that was placed on top of a holder. A temperature controller (TEC) was used to keep the sample at 25° C during the experiments. Light was coupled in/out the chip using edge coupling with lensed fibers. An optical broadband source was used as input, and output traces were recorded with an Optical Spectrum Analyzer (OSA) with 10 pm resolution. All the spectral traces shown are normalized to the maximum value of all traces in the same graph.

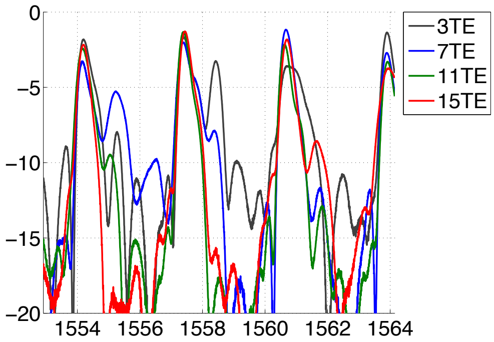
Firstly, in order to asses on the birefringence of the IC-AWG arm waveguides, the spectra of 4 consecutive outputs, 8, 9 for TE and 10, 11 for TM, was recorded. The result is shown in Fig. 1-(b). The results show the channels for the same polarization are correctly spaced 0.8 nm as per design. Starting at channel 8TE and looking to shorter wavelengths, channel 10TM should be placed by design at 1.6 nm away, however it appeared at 1.2 nm, confirming the birefringence designed does not match the obtained after fabrication. The obtained FSR is 3.2 nm.



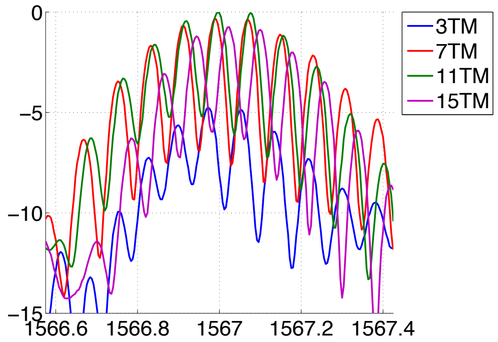
(a) Chip optical microscope image



(b) IC-AWG, in 3



(c) IC-AWG in, 3 to TE outs



(d) MZI+IC-AWG in 3, to TM outs

Fig. 1. Optical microscope image of the fabricated device (a) spectra of 4 consecutive channels to illustrate the birefringence (b), IC-AWG TE outputs (c) and MZI+IC-AWG TM outputs (d).

Secondly, in order to check the interleave-chirp operation, the spectra of 4 outputs spaced the chirp interval P=4 was recorded, i.e. 3, 7, 11 and 15, for TE polarization. The result is shown in Fig. 1-(c). As per design, the same wavelength range is collected at all the outputs. Nonetheless, severe pass-band degradation is observed for channels 3, 7. We attribute this to a very aggressive design, i.e. very narrow channel spacing (0.8 nm) and to the fact no i/o position corrections were done to account for optical aberrations [7] for the present large slab coupler aperture obtained layout. Analog results are obtained for TM, as shown in (d).
Finally, to asses on the phase relations of the IC-AWG, the spectra for a group of 4 outputs spaced the chirp interval P=4 was recorded, but using as input to the IC-AWG the MZI, instead of a directly connected waveguide from the chip facet. The results are shown in Fig. 1-(d). Phase relations are not the designed ones (90,0,180,270). We attribute this either to phase errors in the sub-arrays, or to imprecision's during measurements due to the fact the small FSR MZI (80 pm) might drift between the time required to reposition the output lensed fiber, albeit we are using a TEC.

III. Conclusion

In conclusion we report on the experimental demonstration of an Interleave-Chirp Arrayed Waveguide Grating on generic InP integration technology. The device feature a chirp pattern P=4, 16 channels, with 0.8 nm channel spacing, and had a targeted birefringence of 1.6 nm, therefore allowing to process simultaneously 2 optical channels, with 4 phase relations and 2 polarizations each. The birefringence obtained after fabrication was 1.2 nm. Some channels exhibit considerable pass degradation, that may be corrected using less aggressive layouts and i/o waveguide position corrections to minimize optical aberrations. The transfer function of the joint MZI+IC-AWG allowed to check the different phases provided by each sub-array in the IC-AWG. Finally, we acknowledge funding from the MINECO TEC2010-21337 & TEC2013-42332-P, FEDER UPV 10-3E-492 & 08-3E-008 and FPI BES-2011-046100.

References

[1] K. Kikuchi, in High Spectral Density Optical Communication Technology, Chap. 2, Springer (2010).
[2] R. Nagarajan e.a., Semiconduct. Science and Tech. **27,** 094003 (2012).
[3] C. R. Doerr, L. Zhang and P. J. Winzer, J. Ligthwave Technol. **29,** pp. 536–541 (2011).
[4] E. Bente and M.K. Smit, in Integrated Optoelectronic Devices, pp. 612419-612419 (2006).
[5] B. Gargallo and P. Muñoz, Optics express, **21**(6), pp. 6928–6942 (2013).
[6] L. Zimmermann e.a., IEEE Photon. Technol. Lett, **21**(3), pp. 143–145 (2009).
[7] G. Beelen and H.F. Bulthuis, Gemfire Corporation, US Patent 7,492,991, (2007).