Sidelobes caused by polarization rotation in arrayed waveguide gratings

Citation for published version (APA):
Kleijn, E., Williams, P. J., Whitbread, N. D., Wale, M. J., Smit, M. K., & Leijtens, X. J. M. (2011). Sidelobes caused by polarization rotation in arrayed waveguide gratings. In *Proceedings of the International Conference on Information Photonics (IP), (2011 ICO), 18-20 May 2011, Ottoawa, Canada* (pp. 1-2). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/ICO-IP.2011.5953714

DOI:
10.1109/ICO-IP.2011.5953714

Document status and date:
Published: 01/01/2011

Document Version:
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Download date: 16. Nov. 2023

Sidelobes Caused By Polarization Rotation in Arrayed Waveguide Gratings

Emil Kleijn*, Peter J. Williams†, Neil D. Whitbread†, Michael J. Wale†, Meint K. Smit* and Xaveer J.M. Leijtens*
* COBRA Research Institute, Technische Universiteit Eindhoven, 5600 MB Eindhoven, The Netherlands (e-mail: e.kleijn@tue.nl)
† Oclaro Technology Ltd, Caswell, Towcester, Northamptonshire, NN12 8EQ, United Kingdom

***Abstract*—Polarization rotation within an Arrayed Waveguide Grating (AWG) is found to cause sidelobes in the response of the AWG. The devices in which this effect was observed are briefly discussed. Their measured responses are compared to a detailed simulation.**

***Index Terms*—Arrayed waveguide grating (AWG), integrated optics, optical planar waveguides, optical polarization, birefringence**

I. INTRODUCTION

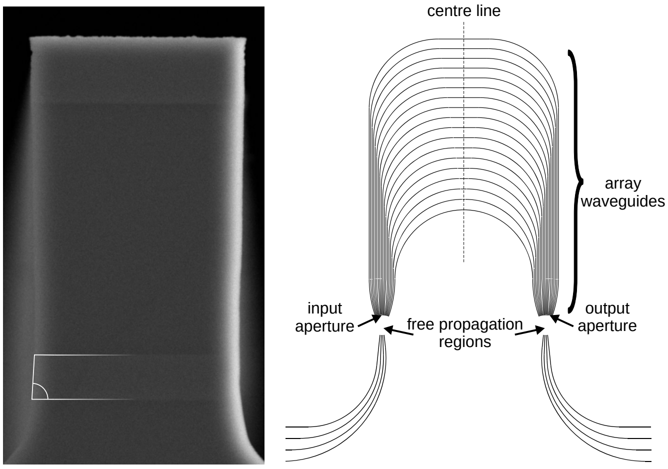
Arrayed waveguide gratings (AWGs) are standard components in integrated optics. In most applications the crosstalk performance offered by these devices is very important. Large sidelobes adversely affect crosstalk levels. In [1] Smit reports the a number of possible sidelobe causes, among which: finite array aperture sizes, phase errors due to fabrication imperfections and coupling between array waveguides. Here we report on a new cause: polarization rotation in the curved waveguides of the array. Sidelobes caused by this effect will be referred to as polarization rotation sidelobes or 'PR-sidelobes' for short. To the best of the authors' knowledge this is the first time PR-sidelobes are reported on.

In birefringent waveguides the TE and TM modes have different propagation constants. In an AWG this results in a different dispersion for both polarizations. As such the AWG pass band positions will be shifted in frequency with respect to each other.

First the devices in which the PR-sidelobes were measured will be briefly described. Section III treats the measurements and the results. Section IV describes a detailed simulation of an AWG subject to polarization rotation. We conclude in section V.

II. DEVICE DESIGN

The devices were designed for an indium phosphide layer stack from the company Oclaro. The stack consists of a lightly doped 2μm thick p-InP top cladding and a 0.36μm thick MQW core on a n-InP substrate. The resulting slab index is 3.246. All waveguides were 1.5μm wide and deep-etched with an etch depth of 3.6μm. The surrounding material is air. The resulting cross-section is shown in Fig.1a. The indicated angle in this figure equals 86.8 degrees.



(a) Cross-section (b) Layout

Fig. 1. (a): Electron microscope image of a waveguide cross-section of the manufactured AWG. The indicated angle is 86.8 degrees, which means the sidewall angle equals 3.2 degrees. (b): Layout of the manufactured AWG.

Fig.1b shows the layout of the device. The used bend radius was 150μm for all curved waveguides. Lateral offsets of 16nm were applied at junctions between straight and curved waveguides. The designed four channel AWG had a free spectral range of 1600GHz and a channel spacing of 400GHz. The devices were manufactured by Oclaro using their well established process.

III. MEASUREMENTS

The devices were characterized and sidelobes on one side of the transmission peaks were observed. These sidelobes are indicated by the arrows in Fig.2. Further measurements were carried out to determine the source of these sidelobes. The measurement setup used is shown in Fig.3. In this setup the light from a broadband light source is TE polarized by a polarizer. After the light has passed through the device under test a second polarizer can be set to transmit either TE or TM. Three measurements were performed. In the first measurement the output polarizer was set to transmit the TE part of the output signal. In the second measurement the TM part of the output was transmitted. In the last measurement the output polarizer was removed and the total transmitted power was recorded. The results of these measurements are shown in Fig.4. This figure clearly shows a sidelobe on the shorter wavelength side of the main transmission peak. This sidelobe is not present in the TE only output signal. It is present however in the TM part of the output. As only TE polarized light was launched, the TM output must be the result of polarization rotation in the sample.

This work was partly funded by the Dutch Ministry of Economic Affairs through the Smart Mix project Memphis, http://smartmix-memphis.nl.

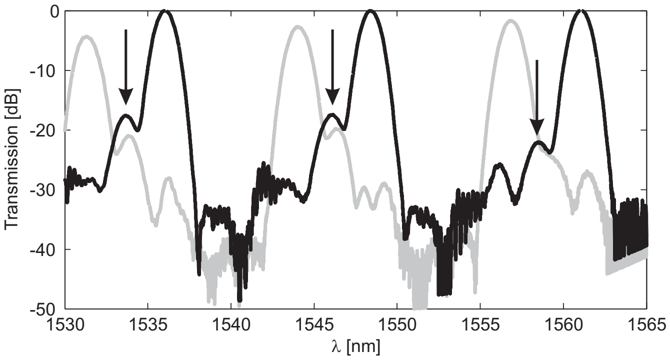


Fig. 2. Typical response of the characterized devices for TE input (black) and TM input (grey). The arrows indicate the PR-sidelobes.

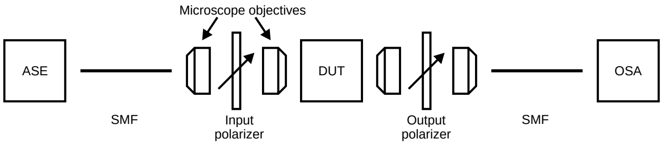


Fig. 3. Schematic of the experimental setup. The input polarizer is present in all measurement; in some measurements no output polarizer was used. ASE: Amplified Spontaneous Emission source, SMF: Single Mode Fiber, DUT: Device Under Test, OSA: Optical Spectrum Analyzer.

Fig.2 shows that the distance in wavelength between the sidelobe and main peak (≈ 2.4nm) is less than the observed shift between the TE main peak and TM main peak (≈ 4.3nm). This means that the polarization rotation occurs within the array itself and not in the input and output waveguides. The rotation most likely occurs in the curved array waveguides[2]. In the next section the measurements will be compared to detailed simulations to further support this hypothesis.

IV. SIMULATION

A simulation model of the AWG under test was constructed, which includes polarization rotation in the curved array waveguides. The model uses a Gaussian approximation of the modal fields in the waveguides. The star-couplers are modelled using a paraxial approximation. The slab and mode indices were calculated for both polarizations and fitted as a function of wavelength, using a 1D effective index method and a 2D Film Mode Matching method respectively. In the straight waveguides the mode index is used to propagate the TE and TM fields independently over the waveguide's length. The curved waveguides are modelled by two orthogonal hybrid modes with their principle axes rotated over an angle θ with respect to the straight waveguide TE and TM modes. The hybrid modes have different mode indices. At the straight and curved waveguide junctions the straight waveguide modes are coupled to the hybrid modes. Due to the accumulated phase difference between the hybrid modes after propagating through the curved waveguide, the coupling to the straight modes will change. This causes the state of polarization to rotate.

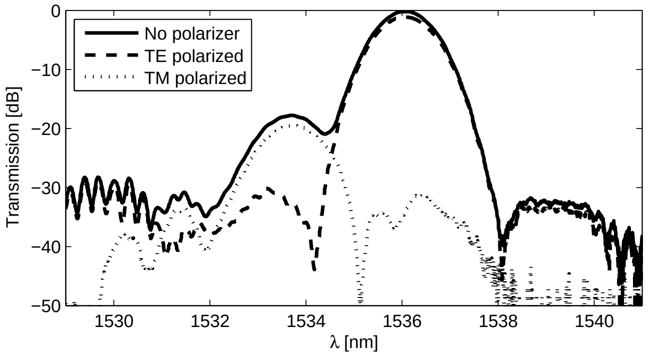


Fig. 4. Cutout of an OSA trace of the filtered, TE polarized ASE spectrum for: no output polarizer (solid), output polarizer set to TE (dashed), output polarizer set to TM (dotted). The traces have been normalized, correcting for the nonuniform shape of the ASE spectrum.

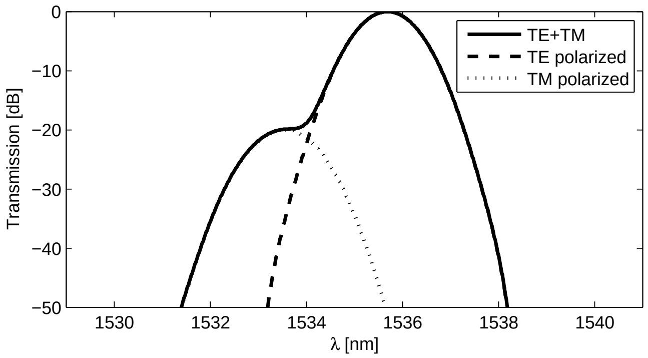


Fig. 5. Simulation of an AWG with polarization rotation occurring in the curved array waveguides.

The fitted TE and TM mode indices were changed slightly to match the measured polarization dispersion of 4.3nm in the array. This was done by subtracting 0.008 from the TM mode index. The need for this correction can be explained by the fact that the layer stack uses a MQW core, which can induce additional polarization dispersion. The polarization rotation angle θ was set to $2.7°$ to match the height of the measured polarization sidelobe.

A simulation was carried out with fully TE polarized light at the input. In the simulation result the PR-sidelobe is shifted 2.2nm with respect to the main lobe. In the measured response this is 2.4nm. Altogether the result of the simulation, shown in Fig.5, is very similar to the measured response.

V. CONCLUSION

It was shown through simulation and through measurements that polarization rotation in the curved waveguides of an AWG causes a sidelobe in the response of the device. Devices may be tested for the presence of this effect using a relatively simple setup.

REFERENCES

[1] M. Smit and C. van Dam, "PHASAR-based WDM-devices: principles, design and applications," *J. of Sel. Topics in Quantum Electron.*, vol. 2, no. 2, pp. 236–250, Jun. 1996.

[2] W. W. Lui, T. Hirono, K. Yokoyama, and W.-P. Huang, "Polarization rotation in semiconductor bending waveguides: A coupled-mode theory formulation," *J. Lightwave Technol.*, vol. 16, no. 5, pp. 929–936, May 1998.