Period Adapted Bragg Mirror Multimode Interference Device

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Abstract: A direct UV-written multimode interference device is constructed with a pair of Bragg mirrors that have adaptively manipulated period to minimise excess loss. Excess loss achieved is comparable to that of a regular MMI device.

OCIS codes: (130.3120) Integrated Optics Devices; (130.1750) Components

1. Introduction

Multimode interference (MMI) devices are effective building blocks in photonic integrated circuits [1], due to their simple structure, low loss, compact size, polarization insensitivity, low cross talk and good fabrication tolerance. These structures provide power splitting/combining and have found many applications in 3dB couplers, Mach-Zehnder interferometers (MZI), ring lasers, and optical switches [2].

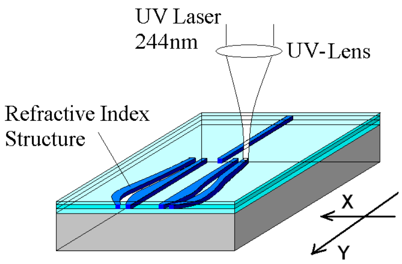

Fig. 1. Direct UV writing of an adaptive period MMI device

Direct UV written MMI devices were first reported in 2003 by Knappe et al [3]. This was done by raster scanning a laser to define the device. As with the majority of optical waveguides in solid state optoelectronics this raster scanned device operated in a total internal reflection (TIR) regime. By moving away from this TIR regime and towards an interference based regime that consist of a pair of Bragg mirrors it is possible to create a MMI Antiresonant Reflecting Optical Waveguides (ARROW) device [4]. The device proposed here uses an adaptive period technique to construct the Bragg mirrors. This is necessary as the index contrast in DUW devices is low compared to that in standard ARROW devices. This work introduces the Locally Optimised ARROW (LO-ARROW) concept (Figure 1) that has comparable loss to a device that has been raster scanned.

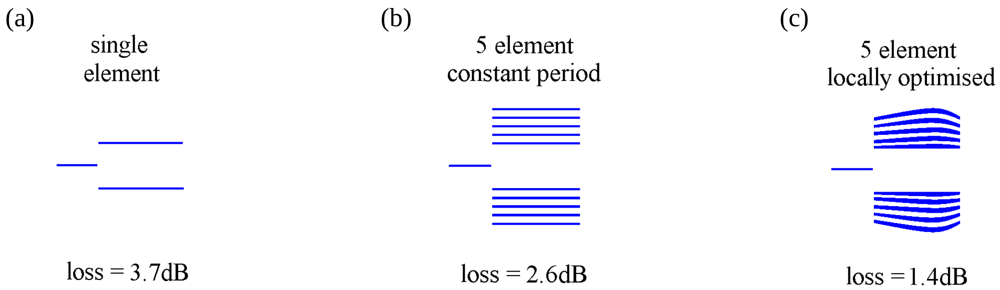

Fig. 2. Direct UV written structures of (a) single element (b) standard ARROW and (c) LO-ARROW devices

Direct UV Writing (DUW) is a well understood technique for defining waveguides [5]. DUW makes use of three silica layers on a silicon substrate, the second layer of which is doped with germanium. The germanium makes the planar layer photosensitive to UV light such that on illumination it acquires an index increase. A focused UV beam is used as a writing stylus and the photosensitive layer is moved laterally by a computer-controlled translation stage (Figure 1). The main advantage of this technique is its high speed and flexibility in defining refractive index structures. Using DUW a proof of concept single element device (Figure 2(a)) has been fabricated.

The excess loss of a single element device has been calculated by BPM simulation to be 3.7dB. Similar BPM modelling shows that optimising the period for a standard ARROW device (Figure 2(b)) results in a loss of 2.6dB. By adapting locally the Bragg period of the walls (LO-ARROW Figure 2(c)) this can be further reduced to 1.4dB.

2. Methodology

Before DUW each silica-on-silicon wafer is hydrogen loaded in an atmosphere of 140bar at room temperature for over 14 days. This acts to increase the photosensitivity of the germanium doped core.

The DUW optical system consists of a cw frequency doubled argon ion laser that outputs 50mW of 244nm wavelength light. This is focused into the wafer's photosensitive core layer by a UV-lens to a diameter of about 5µm. For our proof of concept device the DUW fluence was set to give an index change of 5×10^{-3}. The sample is translated under the exposure using high precision xy stages, allowing the device pattern to be written in the core.

The LO-ARROW structure can be realized by either multiple passes per channel or defocusing the writing spot along the traversed trajectory.

3. Results

As proof of concept a single element 1x5 splitter has been fabricated. The device has a width of 100µm and a length of 1.5mm. Figure 3 (a) depicts the end-face image directly visualized by an IR-CCD camera. A small fraction of the light is coupled into the single elements, seen as two small intensities either side of the image.

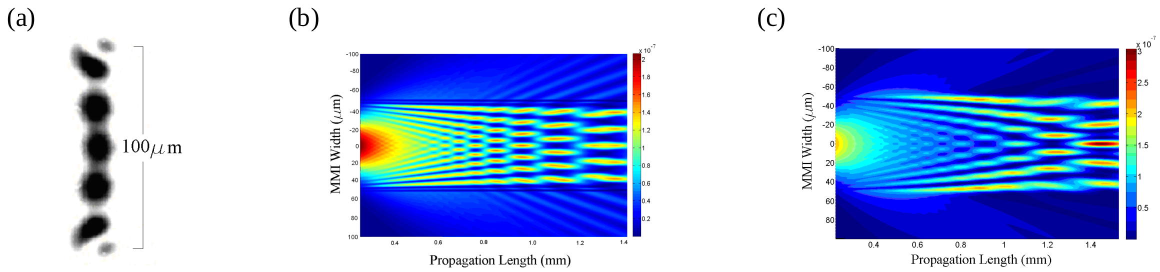

Fig. 3. (a) Interference pattern at 1550nm wavelength of a direct UV written single element device directly visualized by an IR-CCD camera and BPM simulations of a center-fed MMI couplers with a width of 100µm and an index difference of 5×10^{-3} at the wavelength of 1550 nm for (b) single element device (c) LO-ARROW

Using BPM modelling excess loss for a LO-ARROW device has been minimised. Comparing Figures 3(b) and (c) this reduction in loss compared to a single element device can be visualised. The single element case (Figure 3(b)) has rays of light radiating away from the MMI device at positions between its n-fold and (n+1)-fold images. Each radiated position corresponds to a different wavevector. The adaptive period technique (Figure 3(c)) matches the radiated wavevector to a particular period so that it is funnelled back into the device, reducing excess loss.

4. Conclusion

We have demonstrated for the first time the concept of a LO-ARROW device. A proof of concept single element device was fabricated and observed to have an excess loss of 3.7dB. An optimised LO-ARROW device reduces the excess loss to 1.4dB. It should be noted that the LO-ARROW device can also act as a filter as the Bragg mirrors are optimised for a particular wavelength.

Fabricated devices with single and constant period elements ranging from 5 to 40µm shall be present alongside LO-ARROW devices. In addition the effect of wafer geometry and composition shall be addressed.

5. References

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