Multimode fiber matched arrayed waveguides grating-based (de-)multiplexer for short distance communications

S. Musa, A. Borreman, G. Pandraud[1], P. Knijn, G. Sengo, M. B. J. Diemeer, and A. Driessen
Lightwave Devices Group
MESA⁺ Research Institute, University of Twente, P.O. Box 217,
7500 AE Enschede, e-mail: s.musa@el.utwente.nl
(1) OpsiTech, 15, rue des Martyrs - 38054 - Grenoble Cedex 9 - France

Abstract: *A multimode fiber matched arrayed waveguides grating-based (de-)multiplexer has been demonstrated for the first time. The device has been fabricated using low-cost polymer waveguide technology.*

I Introduction

Multimode optical fiber is predominant in many building and campus backbone links of local area networks. Although compared to single-mode fiber, multimode fiber has the advantage of relaxed alignment tolerances, its bandwidth is much narrower. The limit in the bandwidth of the multimode fiber is set by the modal dispersion. With the advent of bandwidth-demanding applications in local area networks such as the 10 Gb/s ethernet, this limited bandwidth of the multimode fiber becomes a serious problem. Among various solutions that have been proposed to improve the bandwidth-distance product of multimode fiber, wavelength division multiplexing (WDM) is the most promising.

Despite the appealing characteristics of WDM schemes, multimode fiber-compatible WDM devices pose serious challenges to the designer because of the competition between spectral and modal dispersion. The difficulty increases further when the low-cost and compact size requirements for short-distance applications are imposed.

Here, we demonstrate a novel design of multimode fiber-matched wavelength (de-)multiplexers using arrayed waveguide gratings (AWG). This design is superior to all so far realized multimode wavelength division multiplexers for it has relaxed fabrication tolerances and can be fabricated with simple planar polymer waveguide technology and hence can be produced potentially at very low cost. It can be easily scaled-up for a large number of wavelength channels.

In the following section the design of the multimode fiber-matched AWG and its fabrication method will be presented. Experimental results will be shown and discussed in section III. The conclusions will be given in section IV.

II Design and fabrication

The operation principles of AWG's are explained in great details elsewhere [1,2]. Fig. 1 shows a schematic layout of an AWG, which consists of the input and output waveguides and two focusing slab regions connected by a dispersive array of waveguides. For the array channels an oversized rib waveguide structure as given in Fig. 1, was used. The structure has been carefully optimized for single mode operation by using the following conditions [3]:

$$\frac{w}{h} \le 0.3 + \frac{t/h}{\sqrt{1-(t/h)^2}} \qquad \text{and} \qquad t/h \ge 0.5 \qquad (1)$$

where *w* is the waveguide width, *h* is the guiding layer thickness, and *t* is the slab height as indicated in the figure. In our design a layer thickness *h* = 40 μm and a channel width of *w* = 15 μm were chosen. In that case Eqs (1) predict that, single mode operation can be obtained for a ridge height *r* = 20 μm.

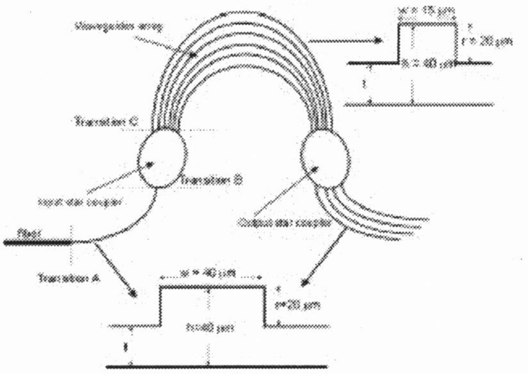

Figure 1: A schematic layout of an arrayed waveguides grating and the proposed waveguide structure.

The insertion loss and general performance is largely determined by the transition losses (see Fig. 1) between multimode fiber and the multimode access waveguide (A), the transition between the multimode access waveguide and the multimode slab region (B) and the multimode slab region and the oversized single mode dispersive waveguides (C). The loss at transition (A) has been shown for a 50-μm-diameter graded-index multimode fiber and a multimode waveguide with dimensions of 40 x 40 •m and refractive index contrast of 1.4886/1.471 to be as low as 0.05 dB [4]. In this paper we demonstrate the feasibility of the device by concentrating on transition

(B) and especially (C), the transition between the multimode slab region and the oversized single mode waveguide array. Because of the technological ease of a single mask process we have used for the output/input access channels a rib waveguide structure with width of 40• m and ridge height of r = 20 •m. The coupling loss between this waveguide structure and the 50 •m graded index multimode fiber is experimentally determined to be ~ 1 dB/facet.

Using these waveguides structures, we have designed a 1x4 (de-)multiplexer. The device operates at a central wavelength λ_c = 670 nm with spectral channel separation of 2 nm and a free spectral range (FSR) of 10.5 nm. The array consists of 30 rib waveguides and operates at grating order m = 64. The slab has a focal length of 11.9 mm and the output waveguide pitch was designed to be 50 µm. Using a bend radius of ~ 23 mm, which is a very conservative figure with regard to low bend losses, one ends up with a total device area of 60 x 30 mm^2.

The device was realized in polymer waveguide technology. The structures were fabricated using spin coating, photolithography and reactive ion etching. The waveguide structure consists of a 40-µm-thick UV curable epoxy resin UV15 [5] with a refractive index of 1.516 at λ = 670 spun on a 9µm SiO_2 layer thermally grown on a Si wafer. A PMMA layer with refractive index of 1.49 at λ = 670 nm was used as a top cladding. Details of the fabrication process can be found in [6,7].

III Experimental results and discussion

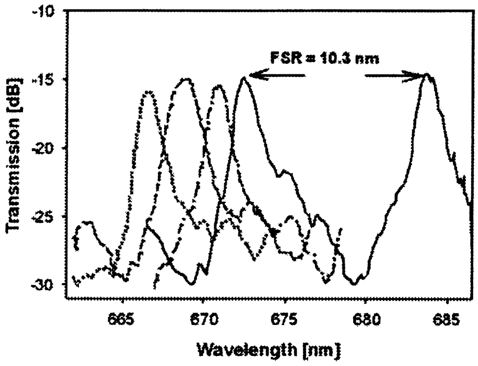

Figure 2: Spectral response of the 4-output channels.

Fig. 2 shows the measured spectral response of the 1x4 (de-)multiplexer. The measurements were done using a tunable dye laser pumped by an Ar laser. The light was coupled into the input waveguide by a microscope objective and coupled out of the device with a multimode fiber. The results show that the channel spacing is 2 nm and the FSR is 10.3 nm in good agreement with the designed values. The obtained excess loss is ~ 14 dB and a best wavelength rejection of −15 dB. The relatively high losses are largely originating at the interface between the slab and the array. An irregularity in the photolithography process makes the gaps between the array channels at the array apertures wider than in the design and thus increases the losses. The wavelength rejection can to be further reduced by optimizing the fabrication technology. Because the measured 3-dB bandwidth of 1.6 nm is close to the designed channel separation, it results in high adjacent channel cross talk. This cross talk can be reduced by using a course WDM grid. Devices with channel spacing suited for multimode fiber networks, with channel spacing ranging from 10 to 100 nm, have been designed and are currently in process of fabrication. Our results indicate among others that for the first time single mode operation of oversized bent waveguide with such large cross section dimension could be demonstrated.

IV Conclusion

The feasibility of a multimode fiber-matched (de-)multiplexer based on arrayed waveguides grating has been demonstrated. The design has very relaxed fabrication tolerances and has been fabricated using low cost polymer waveguide technology. Single mode operation of extremely large cross section oversized bent waveguides has also been demonstrated.

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