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FLATTENED RESPONSE ENSURES POLARIZATION INDEPENDENCE OF InGaAsP/InP PHASED ARRAY WAVELENGTH DEMULTIPLEXER

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Abstract - A four channel polarization independent phased-array wavelength demultiplexer has been made by using different array orders for TE and TM. The insertion loss is 3.5 dB and the crosstalk is -16 dB. TE/TM peak position difference is only 0.2 nm. The response is flattened over 0.5 of the 1 nm channel spacing, yielding 0.3 nm of polarization independent flattened response for each channel.

Introduction

Wavelength Division Multiplexing (WDM) is a simple and effective way of exploiting the large bandwidth of optical fibres. The *Phased Array wavelength demultiplexer* has been shown to be the superior WDM demultiplexer for systems with a small number of channels [1].

Because of the undefined polarization state of the signal from an optical fibre, this demultiplexer must be polarization independent. For Phased Arrays (PA), this has been achieved in a number of different ways, i.e. by insertion of a half wave plate in the middle of the array waveguides [2], by use of non-birefringent waveguides composed of Q(0.97) material [3], or by a PA design in which the Free Spectral Range (FSR) equals the waveguide TE-TM shift, thus overlapping different orders of the TE and TM response [4].

The latter approach, which is adopted in our present work, is appealing because it requires no new technology. It will be shown, however, that the TE-TM shift depends heavily on the waveguide geometry. This imposes tight requirements on process control in order to make TE and TM response overlap, unless this response is flattened, as proposed earlier [5].

Design issues

A Phased Array consists of a dispersive waveguide array connected to input and output waveguides through two radiative couplers. Its operation is based on the imaging of the input field at the output plane. Due to the dispersion, the phase front at the output plane will tilt with varying wavelength, thus projecting the light onto different output waveguides. (See figure 1.)

Because of the slightly different effective indices for TE and TM, the wavelength response for TE polarized light will be slightly shifted with respect to the response for the TM polarization. The TE-TM shift $\Delta\lambda_{\text{TE-TM}}$ is defined as the shift between these two response patterns. It can be shown that

$$\Delta\lambda_{\text{TE-TM}} = \lambda\left(1 - \frac{N_{\text{TM}}}{N_{\text{TE}}}\right)\Big/\left(1 - \frac{\lambda}{N_{\text{TE}}}\frac{dN_{\text{TM}}}{d\lambda}\right),$$

taking the material dispersion into account [1]. Figure 2 shows the dependence of this waveguide property on different waveguide parameters. It is seen that practical fabrication tolerances can induce a change in the TE-TM shift of about 0.2 nm in either direction, and thus affect the polarization independence of the PA, unless the response can be flattened over a region of at least 0.2 nm. This is done by using multimode output waveguides [6].

In a previous design a conservative configuration of the receiver plane was used, i.e. wide multimode waveguides for a large flatness region and wide gaps for low crosstalk between channels [5]. This, in combination with the small channel spacing necessary to fit 4 channels in one FSR results in large devices, (i.e. 2.2×3.4 mm^2 excluding input/output waveguides) in which layer and lithographic nonuniformity pose difficulties for proper phase transfer through the array.

In the present design, an optimal balance was sought between device size and crosstalk/flatness region. This resulted in a device working in 327th order for TE and 326th order for TM, with 30 array waveguides, and 4.5 μm wide multimode output waveguides separated by 2.5 μm gaps. The device size is 2×2.7 mm^2.

Fabrication

The device was fabricated in a simple one step masking/etching process on a SI-InP substrate on which 600 nm of InGaAsP(1.3) and 300 nm of InP were grown with MOVPE [7]. It was first patterned in a 140 nm thick RF-sputtered SiO_2 masking layer and then etched 350 nm with an optimized RIE etching/descumming process [8]. Finally it was cleaved.

Measurement

The chip was measured by launching linearly polarized light from a single-mode source into the waveguides with an AR-coated microscope objective. The output light was picked up with a similar microscope objective and projected onto a Ge-detector.

First, Fabry-Perot measurements were done to establish the propagation loss in straight waveguides. This was 2.0±0.2 dB/cm for both polarizations.

Then, the demultiplexer response was measured by exciting the PA in the central input channel. The results are plotted in figure 3. The TM peaks are shifted 0.2 nm to longer wavelengths relative to the TE peaks, indicating a TE-TM shift 0.2 nm smaller than the theoretical 4.7 nm. Disregarding the Fabry-Perot ripple due to multiple reflections at the (not yet AR-coated) cleaving faces, the response is flattened over 0.5 nm, yielding 0.3 nm of polarization independent flattened response for each channel. The insertion loss and the crosstalk are 3.5 dB and -16 to -18 dB, respectively.

Figure 4 (left) compares the response of one channel with what is theoretically expected, i.e. the field of a monomode input waveguide sweeping over a multimode output waveguide. Agreement is excellent, indicating that phase transfer through the array and the focus in the receiver plane are good.

Discussion

In figure 4 the response of the presently considered device is compared with that of a previous one [5], that suffered from the problems discussed under "design issues". It is seen that the new optimized device considerably improves the flatness of the respone. Furthermore, the insertion loss is reduced from 5 to 3.5 dB for the complete range of flatness.

It has been shown that, notwithstanding various sources of uncertainty regarding TE-TM matching, fabrication of polarization independent Phased Arrays is feasible by using a flattened response. This has been done without requiring new technology and with very simple one step waveguide processing.

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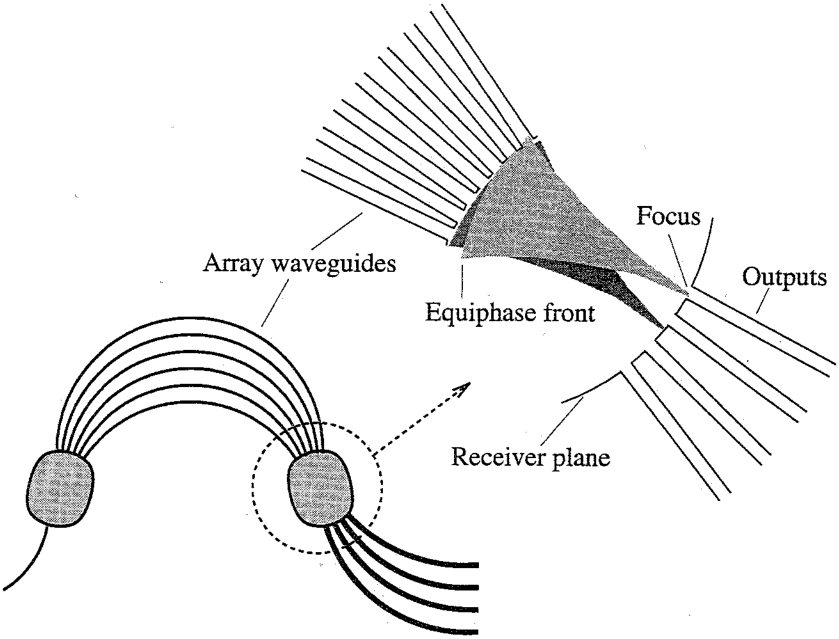

Figure 1 Operating principle of a phased array: The input field, coupled into the array, is projected onto the receiver plane. Tuning the wavelength tilts the phase front, and thus adresses different outputs.

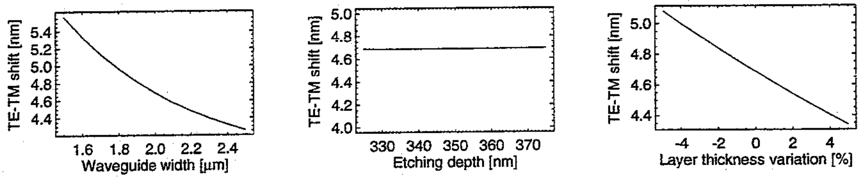

Figure 2 Dependence of TE-TM shift on several waveguide parameters. The unperturbed waveguide is 2 μm wide, and is etched 350 nm in a layerstack of 300 nm InP and 600 nm Q(1.3) on InP substrate.

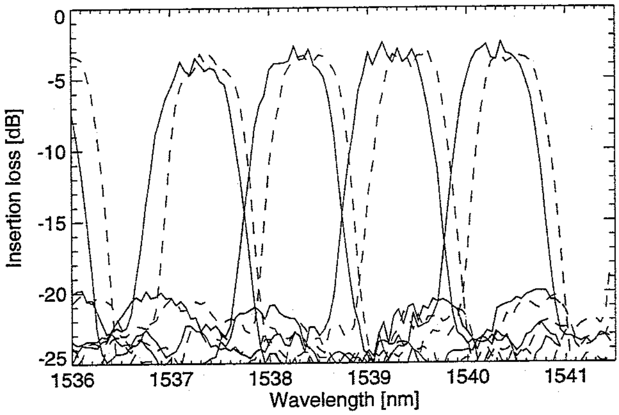

Figure 3 Response of each of the four output channels for TE (solid) and TM (dashed). Insertion loss is 3.5 dB, crosstalk is -16 dB (worst case). There is 0.3 nm of polarization independent flattened response per channel. The next higher order can just be discerned at the left. The cleaving faces have not yet been AR-coated, hence the Fabry-Perot ripple.

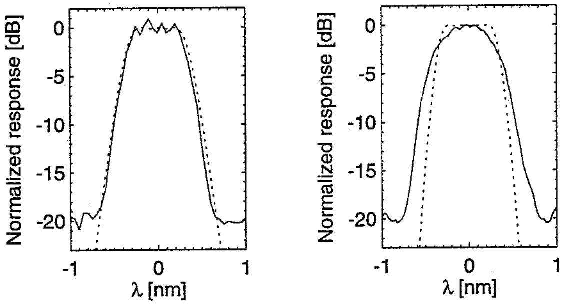

Figure 4 **Left** Simulated (dotted) and measured (solid) response for one channel (#3, TE). Excellent agreement indicates good focus and phase transfer through the array. **Right** Response of previous device [5] compared to its simulation.