Polarization-independent InP-based phased-array wavelength demultiplexer with flattened wavelength response

POLARIZATION-INDEPENDENT InP-BASED PHASED-ARRAY WAVELENGTH DEMULTIPLEXER WITH FLATTENED WAVELENGTH RESPONSE.

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Abstract

We have realized the first wavelength-flattened polarization-independent phasar demultiplexer. The device operates at 1.54μm with excess loss lower than 5 dB and crosstalk better than -14 dB over a range of 0.3 nm, and has four channels with 1 nm spacing.

1 Introduction

Wavelength Division Multiplexing (WDM) provides a simple and effective method for exploiting the large bandwidth of optical fibres. An important component in WDM-systems is the wavelength demultiplexer. Because of the undefined polarization state of the input signal from the optical fibre, polarization independent operation of this demultiplexer is an important feature.

Polarization independent phased array demultiplexers have been demonstrated using a number of different methods: A $\lambda/2$ plate inserted in the middle of the array waveguides [1], waveguides loaded with a birefringence-compensating film [2], non-birefringent waveguides composed of Q(0.97) material [3], and a phased array design with a free spectral range equal to the waveguide TE-TM shift [4].

The first approach fundamentally yields polarization independent behaviour through 90° polarization rotation halfway the completely symmetrical design. The other three depend on accurate waveguide design and fabrication technology to obtain the desired polarization independence. They have the advantage of being fully monolithical. Using these methods, the requirements on process control in order to tune TE and TM to each other are very tight. These requirements can be strongly relieved if the TE and TM response are flattened. We therefore combined the approach applied by [4] with the wavelength-flattening as applied in [5].

2 Design

A phased array demultiplexer consists of a dispersive waveguide array connected to input and output waveguides by two star couplers. The field from an input waveguide is reproduced in the output plane when the optical path length difference between adjacent array waveguides is an integral number of wavelengths. A change in the wavelength induces a tilt of the equi-phase plane at the array output, thereby sweeping the field distribution over the output waveguides and enabling spatial separation of different wavelengths.

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The array waveguide birefringence causes a spatial separation of the field distributions for TE and TM for the same wavelength *in vacuo* (see fig. 1). Because the birefringence of our waveguide structure cannot be reduced sufficiently to make the same array orders for TE and TM overlap, an array design has been adopted for which the mth order for TE overlaps with the $m-1$th order for TM [6]. This is obtained by choosing the distance of the orders (i.e. the FSR) equal to the waveguide TE-TM shift.

Because the TE-TM shift of our waveguide structure is 4.05 nm, the FSR of the phasar can accomodate four channels with a spacing of 1 nm. A slight deviation of the (calculated) TE-TM shift of only a few percent will, however, separate the overlapping TE and TM orders, and destroy the polarization independence of the device. To reduce the severity of the consequences of such a deviation, the phased array was equipped with wider, multimode output waveguides. This causes the focal spot in the image plane to couple efficiently to the output waveguides over a wider wavelength range [5] (see fig. 2). A limited deviation of the TE-TM shift can thus be tolerated, retaining polarization independent operation, over a slightly reduced wavelength range.

The demultiplexer designed consists of 39 waveguides, 2μm wide, with a path length difference of 153μm between adjacent arms. The radius of curvature varies from 500 to 1114μm. The input waveguides are also 2μm wide. The output waveguides are 6μm wide and are spaced 3μm apart in the output plane. The lateral contrast in the output section was increased with a second (non-critical) etching step in order to prevent the higher order modes in this section from radiating.

The total device size is 2.2×3.4 mm excluding the input and output branches, and 3.3×5.1 mm including them.

3 Fabrication

The demultiplexer was made on a SI-InP substrate with MOVPE-grown epilayers [7]: 660 nm InGaAsP(1.3) and 320 nm InP. The device was patterned in a 140 nm thick RF-sputtered SiO_2 masking layer and then etched 400 nm with an optimized RIE etching/descumming process [8]. In a second non-critical masking step the device was protected with photoresist and the output waveguides were etched an additional 50 nm. Finally, the chip was cleaved and AR-coated with a SiO_2 layer evaporated onto the waveguide facets.

4 Results

The chip was measured with light from an HP 8168A tunable laser source, which was coupled into the waveguides with a tapered fibre tip. The emanating light from the output waveguides was imaged onto a Ge-detector through a pinhole with a microscope objective. Fig. 3 shows the output power of the four receiver channels calibrated against straight reference waveguides. The excess loss of the device is 2.5–4.5 dB, and the crosstalk is below -14 dB. The attenuation of the reference waveguides is 1.5 dB/cm, both for TE and TM, measured with the Fabry-Perot method, before AR coating.

5 Discussion

As seen in fig. 3, the curves for TE and TM do not overlap completely. Instead of the calculated 4.05 nm TE–TM shift, a shift of 4.2 nm is observed. By virtue of the flattened response, however, there is still a range of at least 0.3 nm/channel over which the device performs with an excess loss less than 5 dB and crosstalk lower than -14 dB.

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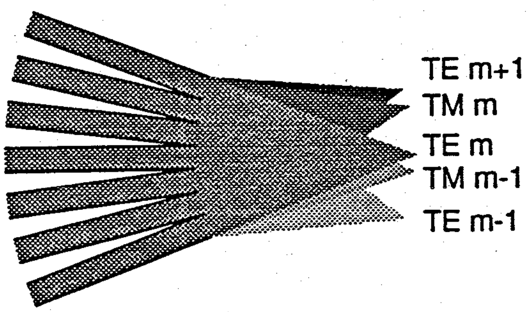

Figure 1: The differrent orders radiating from the waveguide array. The waveguide birefringence causes the TE and TM foci to be separated.

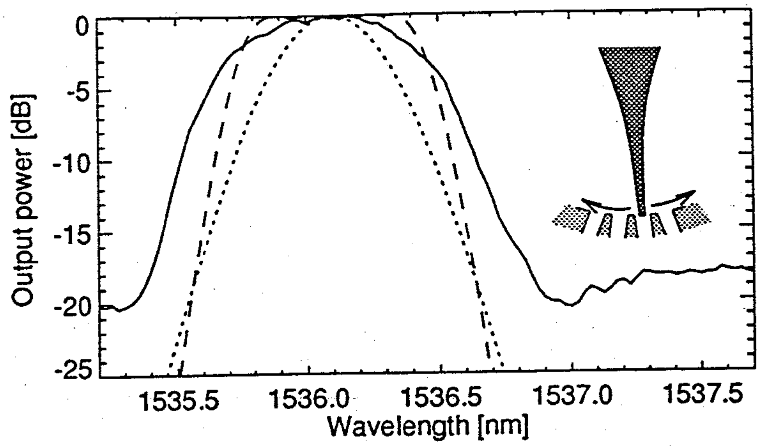

Figure 2: Calculated response of phased array with monomode (dotted) and multimode (dashed) output waveguides, and measured response of channel 2 of the realized phased array (solid). The inset shows a representation of the image plane of the flattened demultiplexer.

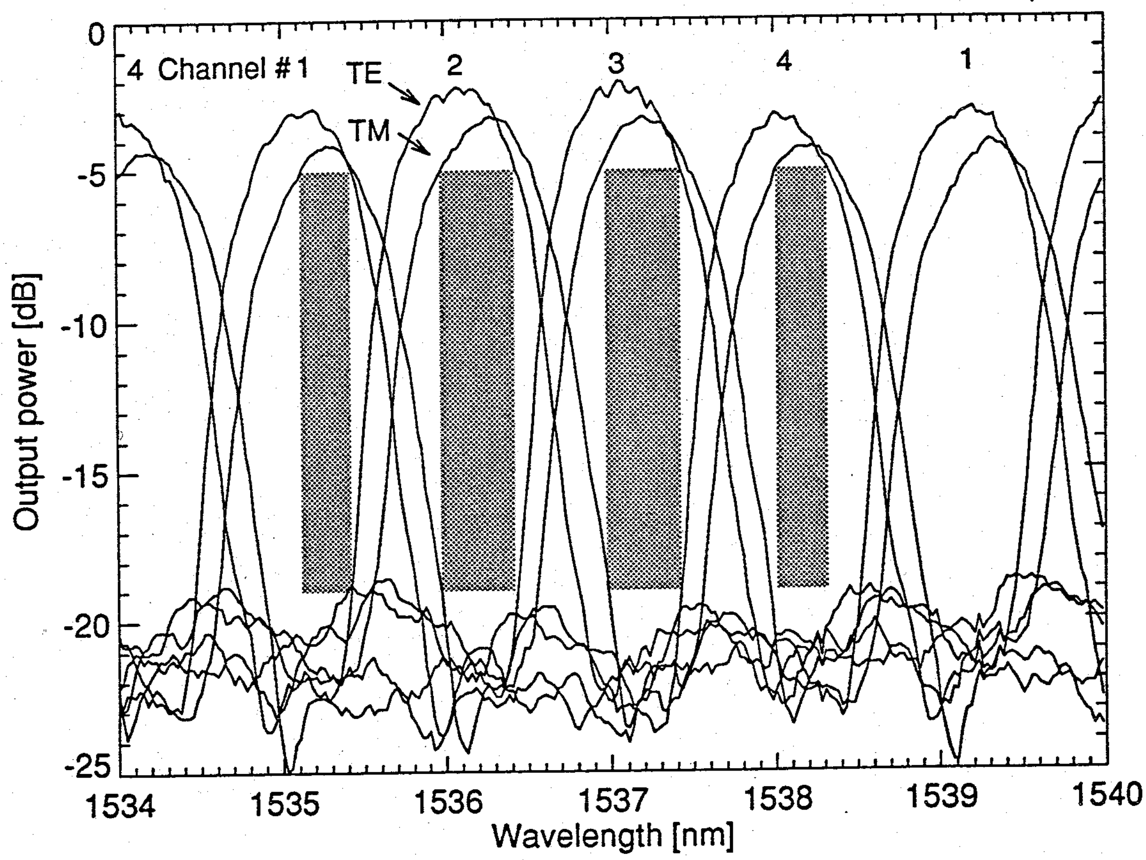

Figure 3: Spectral response of the phased array demultiplexer, calibrated against straight reference waveguides. The regions in which the device works with less than 5 dB excess loss and better than −14 dB crosstalk for both polarizations has been shaded. Adjacent orders are also visible.