20GHz Channel Spacing InP-based Arrayed Waveguide Grating

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Abstract *We demonstrate a 10-channel InP-based Arrayed-Waveguide Grating (dimensions = 5.0x6.0* mm^2*) with a 20-GHz channel spacing. The excess loss of the AWG is 5.5-6.3 dB, and the crosstalk level is below -15 dB.*

Introduction

Arrayed waveguide Gratings (AWGs) are one of the key components for wavelength division multiplexing (WDM) applications, and narrow-channel-spacing AWG multi/demultiplexers are indispensable for ultrahigh-density WDM systems [1]. Even though silica-based AWGs are widely used and they have been demonstrated with channel separations down to 1 GHz [2], InP-based AWGs are attractive due to their compactness and potential for monolithic integration with active components, such as semiconductor optical amplifiers, and high-speed electro-optic modulators. However, InP-based narrow-channel-spacing AWGs are more challenging to realize than silica-based AWGs, due to the higher index contrast, the higher propagation loss, the less-mature fabrication technology, and the smaller waveguide dimensions. So far, the lowest channel spacing reported for an InP AWG is 50 GHz [3]. In this work, we report an InP-based AWG with 20 GHz channel spacing, which shows a crosstalk level below -15 dB, without any compensation of phase errors in the AWG arms. To the best of our knowledge, it is the narrowest channel spacing demonstrated with an InP AWG. This AWG can be used in many applications, such as in multi-wavelength lasers [4], and in optical arbitrary waveform generators [5].

Design

Phase errors, which are introduced in the AWG arms, can severely degrade the transmission of narrow-channel-spacing AWGs with large dimensions. These phase errors are caused by practical fabrication limitations, such as variations in the core-layer- composition and thickness, variations in the waveguide width, and an inhomogeneous filling of the gap near the apertures of the phase array, which results in small deviations in the propagation constant of the individual arrayed waveguides. We have come up with a fabrication-tolerant 20-GHz AWG design that minimizes the effects of these fabrication limitations on the AWG performance.

Fig. 1 shows the layout of the 20-GHz AWG. It contains 5 input waveguides, 10 output waveguides, and 42 array arms with a path length difference ΔL of 359.5 µm between the adjacent arms. The diffraction order at λ = 1.55 µm is 748, which gives a free spectral range (FSR) of 240 GHz and a channel spacing of 20 GHz. The gap between the adjacent arrayed waveguides at the edge of the slab region is 0.8 µm, which is the smallest lithographic resolution of our fabrication process.

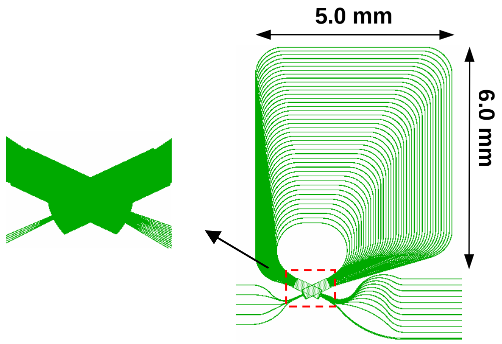


Fig. 1: Layout of AWG of 20 GHz channel spacing

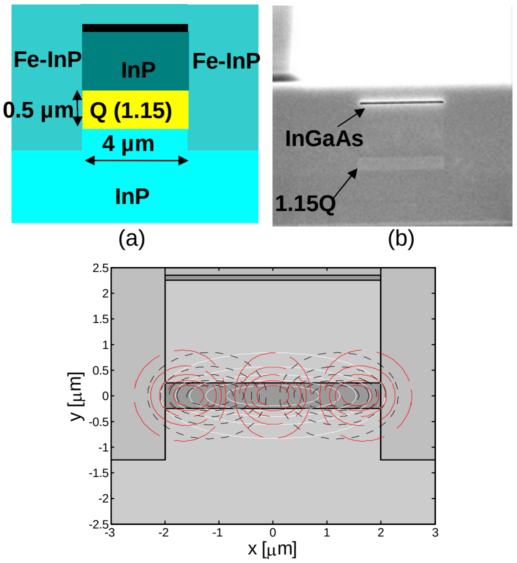
We have used the box geometry [6], which has an equal bending radius of 450 µm for all the arrayed waveguides, such that any phase errors introduced by the change in the propagation constant for different bending radii are reduced. Furthermore, for narrow-channel-spacing AWGs, the ΔL is so large that we can cross the two slab regions (shown in Fig. 1) and reduce the total dimension of the AWG.

The waveguides consist of buried heterostructure waveguides. This type of waveguide shows a high tolerance to core- width and thickness variations, due to the lower index contrast as compared to other types of waveguides (such as high-mesa waveguides).

In addition, we have chosen a waveguide width of 4 µm, because the width dependence of the propagation constant is smaller for wider waveguides [7]. Although the 4-µm-wide waveguides totally supports three guided modes (zero-, first- and second order) shown in Fig. 2c, the second-order mode is filtered when propagating through the curved waveguides. The excitation of the first-order mode can be suppressed by positioning the input fiber at the centre of the input waveguide.

Fabrication

The waveguide structure consists of a 1.5-µm InP layer, a 0.5-µm Q(1.15) waveguide core layer, a 2-µm InP top cladding layer, and a 0.1-µm InGaAs layer, which were grown on an InP substrate in a metal-organic vapour-phase-epitaxy (MOVPE) reactor. The InGaAs layer was added for testing purposes and does not influence the waveguiding properties. The 4-µm waveguides were etched in a Br_2/N_2 reactive beam etcher using a 550-nm SiO_2 layer as mask. Subsequently, the SiO_2 mask was selectively removed in a buffered hydrofluoric-acid solution. Finally, Fe-doped semi-insulating InP was regrown by low pressure hydride vapour phase epitaxy (HVPE) [8], resulting in the buried hetero-structure shown in Fig. 2.



(a) (b)

(c)

Fig. 2: Buried heterostructure waveguide: (a) cross section diagram, (b) SEM picture, and (c) mode profiles of the supported modes (solid: zero-order mode, dotted line: first-order mode, and dashed line: second-order mode).

Measurement Results

Fig. 3 shows the spectral response of the 20GHz channel spacing AWG for TE polarization. The excess loss of the AWG is 5.5-6.3 dB with a crosstalk level below -15 dB. The measurement setup is as follows. Light from a tunable laser source (TLS) is passed through a polarization controller, and launched into one of the inputs of the AWG with a lensed fiber. At the output of the AWG, the light is collimated by a microscope objective (MO) and passed through a pinhole, and a TE polarizer. After the polarizer, the light is focussed onto a photo detector (PD). The spectral response of the AWG is obtained by measuring the optical power in the PD, while sweeping the wavelength of the TLS. The measurements are calibrated against straight reference waveguides passing through the chip.

Fig. 4 shows the spectral response of one of the outputs for both TE and TM polarizations. Due to waveguide birefringence, the spectrum for TM polarization is shifted 0.1 nm, towards the longer wavelength, with respect to the TE polarization.

Conclusions

We have successfully realized an InP-based AWG with 20 GHz channel spacing using the buried heterostructure. We use equal bending radius for all arrayed waveguides, and wider core width to minimize the factors leading to phase errors. The size of the AWG is 5.0 mm × 6.0 mm, and the excess loss is 5.5-6.3 dB. The crosstalk is below -15 dB for all channels.

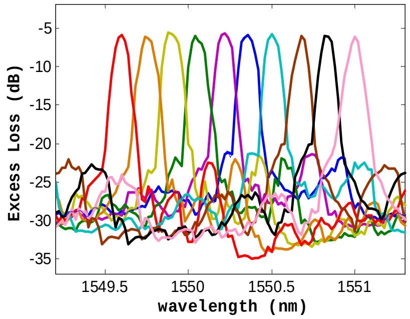


Fig. 3: Spectral response of the AWG for all 10 channels.

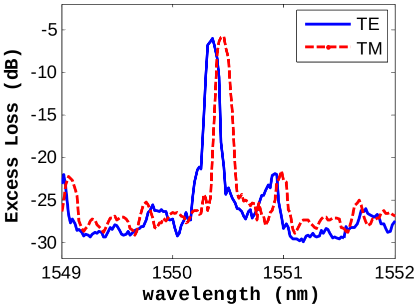


Fig. 4: Spectral response of one output for different polarizations.

Acknowledgement

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