

PUBLICATION IV

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AWG Based DWDM Multiplexers Combined with Attenuators on SOI

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Abstract We report on the design, fabrication and optical characteristics of SOI based AWG multiplexers combined with attenuators. The AWG devices and attenuators comprised 8 channels with 200 GHz channel spacing around 1550 nm wavelength.

Introduction

Silicon-on-insulator (SOI) is regarded as an attractive platform for integrating optical and electronic functions, since it can utilize the mature materials processing and extensive electronic functionality of silicon technology [1]. It also has some important features for integrated optical components too, such as e.g. good optical properties at telecommunication wavelengths around 1.3 μm and 1.55 μm . Arrayed waveguide grating (AWG) structures and variable optical attenuators (VOA) are essential building blocks of such an optical board technology to serve e.g. as optical multiplexer and optical wavelength division multiplexer (WDM) filters, respectively, with equalization functionality.

In this work we present SOI based AWGs [2] with combined attenuators to act as optical multiplexers. The related AWGs were designed for the launched laser polarisation and had 8 channels in the C-band. VOAs relying on thermally controlled Mach-Zehnder interferometers (MZI) were integrated with the AWGs.

Simulation and Design

The AWGs were designed as 8 channels devices with 200GHz (1.6 nm) channel spacing on the ITU grid around 1.55 μm centre wavelength. The optical simulation was performed on AWGs relying on ridge waveguides in 4 μm SOI with 2.0 μm ridge height and 3.2 μm ridge width. The simulations of the AWGs included the input and output star couplers with the associated input and output ports of the device and the array waveguide ports, respectively. The waveguide array itself was introduced by appropriate phase shift terms. One of the results obtained from 3D BPM simulation is shown in fig. 1, where the grating order was chosen to be $m=70$. The insertion loss can be seen to be below 1 dB. The contribution of the waveguide propagation loss was neglected in these calculations.

The VOAs were implemented as symmetrical Mach-Zehnder interferometer structures with 2 mm long and 15 μm wide heaters on top, fig. 2. For the MZI-VOAs 3 dB couplers are required and these were realised by 1x2 multi-mode interference (MMI) couplers. They were also evaluated using 3D BPM calculations. The input and output waveguide ports of the MMI were

designed as tapers at the waveguide-to-body interfaces. This structural layout was designed to ensure smooth optical transition and improve mode matching. Based on the dimensional optimisation an MMI structure with a length of 470 μm and a body width of 19.75 μm was chosen. The 3D BPM simulation results of this MMI are shown in fig. 3.

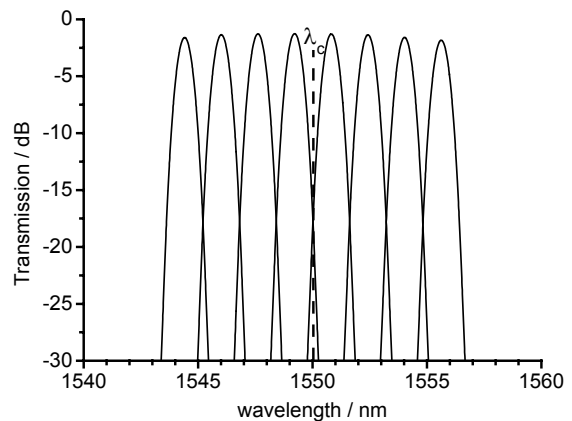


Fig. 1 Simulated transmission characteristics (3D BPM simulation) of an 8-channel, 200GHz AWG.



Fig. 2 Mach-Zehnder Interferometer with two 3-dB 1x2 MMIs. The grey areas represent the heaters.

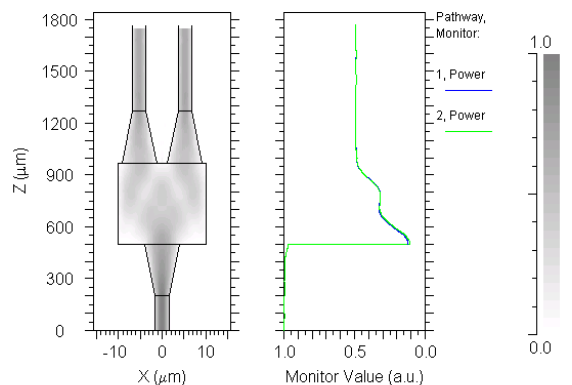


Fig. 3 BPM simulation (3D) of a 3 dB 1x2 MMI coupler at 1550 nm wavelength.

Fabrication

The device structures were fabricated on an epitaxially thickened smart-cut SOI wafer with a 4.5 μm thick SOI layer and a 1 μm thick buried oxide layer (BOX). The waveguides were defined by standard photolithography and dry Si etching. The etching was done using an inductively coupled plasma type reactive ion etcher [3]. The etch depth was 2.2 μm . After the etch, a 0.46 μm thick thermal oxide was grown to reduce the roughness of the waveguide sidewalls. The thermal oxide was removed with wet etching in buffered hydrofluoric acid before growing a cladding oxide layer. The 1 μm thick cladding oxide was deposited with the tetra-ethyl-ortho-silicate (TEOS) process in a low-pressure chemical vapour deposition (LPCVD) furnace. For the VOA structures metal heaters were formed on top of the waveguide structure using molybdenum. A thin layer of silicon nitride was used as passivation layer on Mo. Finally, the wafer was diced and the AWG chip facets were polished.

Results

In fig. 4 the measured characteristics of an 8-channel AWG with integrated VOAs are shown. The loss of the combined device was 7 dB. The excess loss of the VOAs can be estimated to be 1.5 dB from the difference to the measured loss of 5.5 dB of an identical AWG without the VOAs.

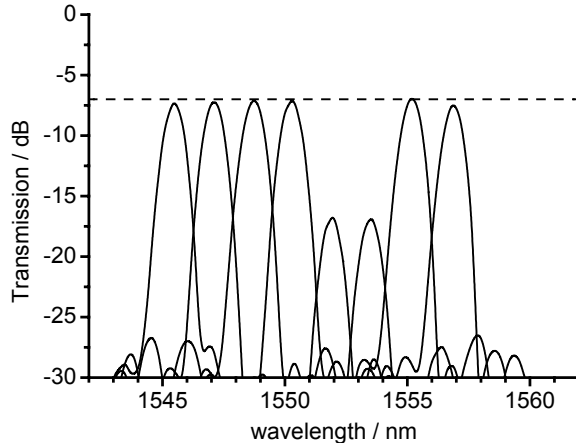


Fig. 4 Measured characteristics of an 8-channel 200 GHz AWG with directly attached MZI-VOAs. Ch.5 and Ch.6 are attenuated in this case by 10 dB.

Fig. 5 shows the VOA attenuation versus the applied heater power. For each VOA the electrical power corresponding the maximum optical attenuation is approx. 160 mW, where the dynamic range is about 15 dB. The transition times of the VOAs were measured at the optical chip output using an HP11982A Amplified Lightwave Converter and with the aid of an electrical pulse generator. Fig. 6 shows the transfer characteristic indicating a maximum attenuation of some 15 dB. The transition times for

rise and fall were found to be smaller than 10 μs .

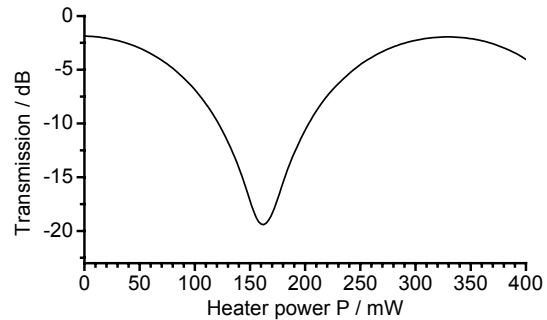


Fig. 5 Measured optical attenuation due to powered heater electrode.

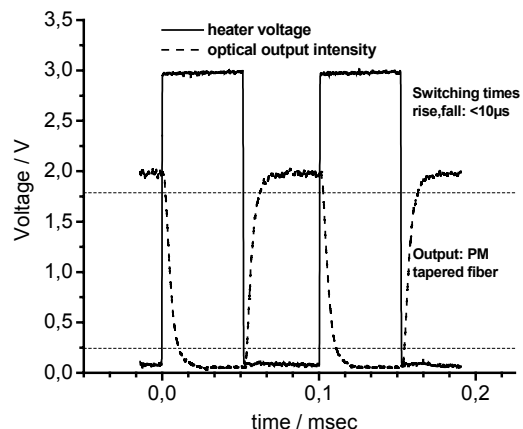


Fig. 6 VOA heater voltage and corresponding optical output intensity.

Conclusions

Simulation, component design, fabrication, and characterisation of AWGs integrated with thermally controlled VOA structures were performed. The AWG was designed for the launched laser polarisation with 8 channels in C-band. The channel spacing was chosen to be 200 GHz. The insertion loss of the fabricated AWG was measured as 5.5 dB. The VOAs were based on MZIs incorporating 1X2 MMI couplers. The VOAs showed an excess loss of 1.5 dB and had a dynamic range of 15 dB on the average. The maximum attenuation was achieved at 160 mW power consumption of the heaters and the rise and fall times were below 10 μs .

Acknowledgement

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