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Fabrication of Silicon-on-Insulator arrayed waveguide grating and monolithic power monitor array

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Abstract: *The design, fabrication and initial testing of a pair of silicon-on-Insulator arrayed waveguide gratings (SOI AWG) integrated with a monolithic power detector array for power monitoring is described.*

The use of reconfigurable optical add-drop multiplexers (ROADM) is attractive for cost effective networks [1]. However changes in the number of channels will affect amplifier performance and produce dynamic gain tilt and gain transient. In this paper, we describe a potentially low-cost compact channel optical power monitor formed by the use of a pair of silicon-on-insulator (SOI) arrayed waveguide grating (AWG) and an integrated photodetector array. The photocurrent is measured by silicon photodectors made sensitive to the below bandgap energy light via the use of helium implantation. The proposed device thus avoids the need for space consuming waveguide taps and hybrid integrated III-V photodetectors [2].

Fig. 1 shows the design simulation of a typical channel in a Gaussian AWG multiplexer with 40 channels. The target channel spacing was 100GHz (0.8nm).

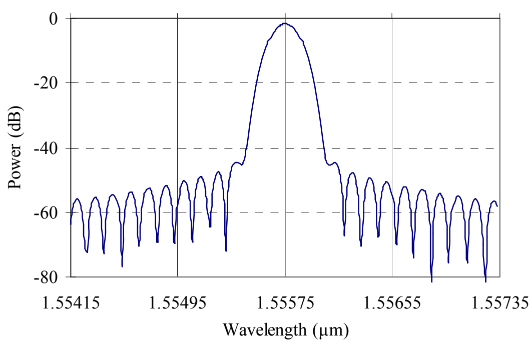


Fig 1 Spectral response of a typical channel in the AWG

For the monolithically integrated power monitor, two AWGs were arranged in the folded geometry as shown in Fig. 1. The input channels are first demultiplexed by the first AWG. The demultiplexed signals are individually monitored by individual waveguides which form an array of helium implanted photodetectors. Finally the signals are recombined by the second AWG and coupled to the transmission link. The whole device comprising two 40-channel AWGs and 40 waveguide photodetectors occupy an area of less than 2x2 cm^2 in size.

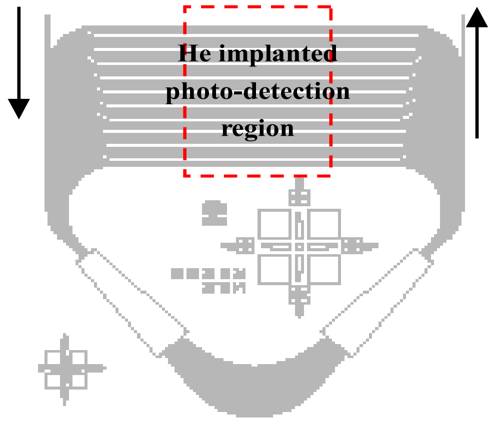
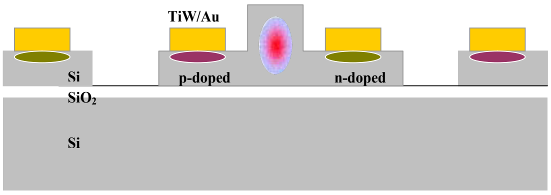


Fig. 2 Bidirectional AWG with power monitoring He implanted region.

The waveguide photodetectors were formed by rib waveguides of 2.4um width and 2.3um etch depth. The waveguides were fabricated using deep reactive ion etch (DRIE) at room temperature using a continuous mixture of C_4F_8 and SF_6 gases. To minimize electrical crosstalk between photodetectors, electrical isolation trenches were etched on either side of each waveguide photodetector as shown in the schematic cross section diagram in Fig. 3.



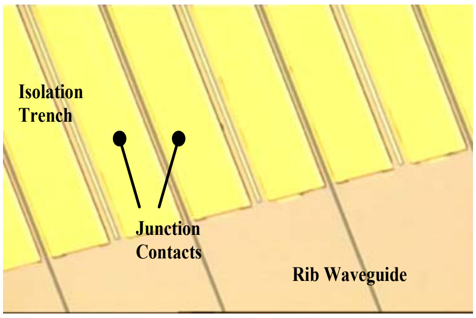


Fig. 3 (Above) Schematic cross-section of SOI rib waveguide. (Bottom) Fabricated arrayed waveguide grating (AWG) with contacts and isolation trenches.

The array of waveguide photodetctors were produced by fabricating lateral p-n diodes with boron and phosphorus implantation respectively on either side of each waveguide. The dose of boron and phosphorus dopants were $5x10^{15}/cm^2$ and the implanted diodes underwent rapid thermal annealing at 950^oC for 1 minute. Metal contacts (Ti/W/Au) were deposited onto the doped regions. A picture of the fabricated device after liftoff of the TiW/Au contacts is shown at the bottom of Fig. 3. The current-voltage characteristic of a single diode in the array is shown in Fig. 4.

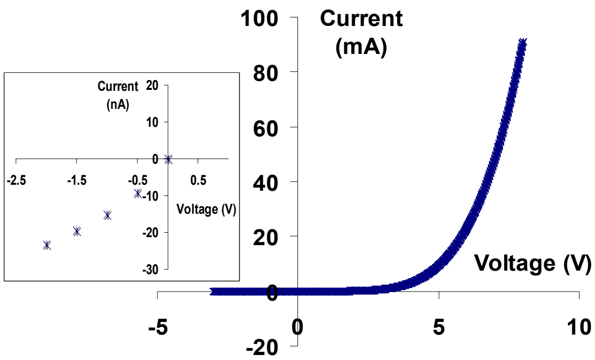


Fig. 4. Forward bias characteristics of p-n diode across rib waveguide.

Since the photon energy at wavelengths in the 1.55μm wavelength band are insufficient to excite electrons across the indirect bandgap of silicon, it is necessary to enhance the absorption of below bandgap energy photons by helium implantation into the array of waveguides [2]. The target dose of helium ion implantation was $5x10^{13}cm^{-2}$ and the implanted samples were annealed. Absorption via traps in the bandgap introduced by the ion implantation, together with the thermal excitation of electrons from these defect states into the conduction band energy allowed the generation of photocurrent from the helium implanted waveguides for power monitoring. Although responsivities as high as 64mA per watt of absorbed optical power and low excess losses in the waveguide photodetectors were previously achieved with single waveguide photodetectors [2], the response was limited in the case of the present monolithically integrated device because of the higher dark currents in the reverse biased diodes. The high dark current limited the reverse bias currents to only a few volts (Fig 4 inset). We speculate that the higher dark currents may be caused by currents flowing via surface states [3].

Work on further optimizing the diodes to improve the diode performance is ongoing. We believe the device will have potential for low-cost in-line channel power monitoring and may find important applications in broadband reconfigurable networks which need individual channel power monitoring in order to allow effective compensation of EDFA gain transients or gain tilt after optical add-drop.

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