MC1 (Invited)
3:30pm - 4:00pm

Wafer Fused Optoelectronics for Switching

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Major requirements for photonic switching elements are scalability, low loss and low crosstalk. In high speed packet switched networks, there is a need for large size waveguide switches that incorporate fiber loop memories and integrated semiconductor optical amplifiers. Wafer fusion techniques can be used to combine planar waveguides fabricated on two different substrates into a 3D structure in which there is vertical coupling between arrays of single mode waveguides through the fused regions (Figs. 1,2) [1]. In addition, application of a bias at fused regions will allow a change of gain or index for switching purposes.

The Fused Vertically Coupled (FVC) waveguide structure shown in Fig. 2, was analyzed by 3D finite difference Beam Propagation Method (BPM). A single-mode ridge-loaded waveguide structure based on InP substrate, with 0.5 μm InGaAsP (λ=1.3 μm) core region, 0.1 μm cladding and 0.1 μm ridge height, is vertically coupled through a fused gap layer to an identical waveguide. The gap layer thickness is varied from 0.1 to 0.6 micron with its index ranging from InP to InGaAsP (λ=1.4 μm). Fig. 3 displays the calculated coupling length for different parameters of the gap layer. Ultra short couplers with 40-220 μm coupling length and 20-32 dB extinction ratio can be realized. A passive vertical coupler with 0.4 μm InP gap layer was fabricated by fusing two $8\times10\text{mm}^2$ samples under pressure and at a temperature of 630 °C in a hydrogen atmosphere for 30 minutes. Fig. 2 shows the stain etched SEM picture of a finished FVC. The fused interface is not visible, which is an indication of the high quality of the fusion process. The near field pattern at the output of a FVC, 5.5 mm long, is recorded by an IR camera and it is shown in Fig. 5. It can be seen that by changing the input wavelength, light is switched from the upper to the lower waveguide. Since the shapes of the two waveguide modes are very similar, one can get a high extinction ratio. Our measurement shows the extinction ratio is about 15 dB. Fig.4 shows the intensities of the upper and lower waveguides as a function of wavelength. From the oscillation period (about 12 nm) and considering material and waveguide dispersions, coupling length is calculated to be 62 μm at 1.55 μm which is very close to BPM result of 58 μm.

The optical loss at the fused interface is an important factor in the design of coupler and switch structures. This was investigated using single mode InGaAsP-based fused waveguide structures. Comparison of the transmission loss in ridge-loaded waveguide structures with and without a fused layer near the core region, reveals an excess loss of 1.1 dB/cm at 1.55 μm wavelength. Finally a PIN FVC was fabricated and characterized. It can be seen in Fig. 6 that with a bias of 2.3V the light is switched from the top to the bottom waveguide. In conclusion, fused couplers and switches can give the added advantage of vertical integration by separating the input and output waveguides and create compact and scalable 3D photonic integrated circuits.

This work is supported by the DARPA center MOST.

References:

[1] B. Liu, A. Shakouri, P. Abraham, B.-G. Kim, and J. E. Bowers, submitted to Appl. Phys. Lett..

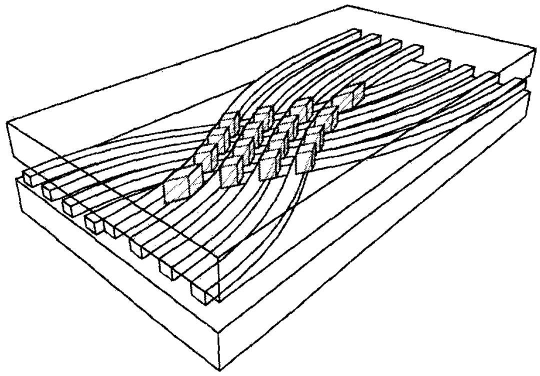

Fig. 1 InP Crossbar switch based on coupling between independent arrays of waveguides on each substrate.

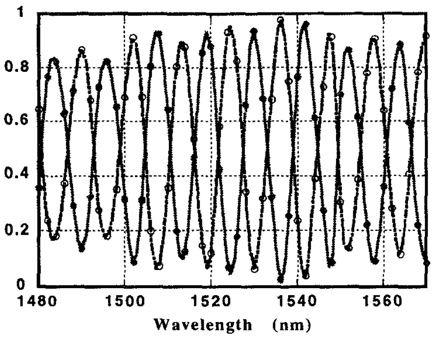

Fig. 4 Measured intensity of the upper and lower waveguides as a function of wavelength.

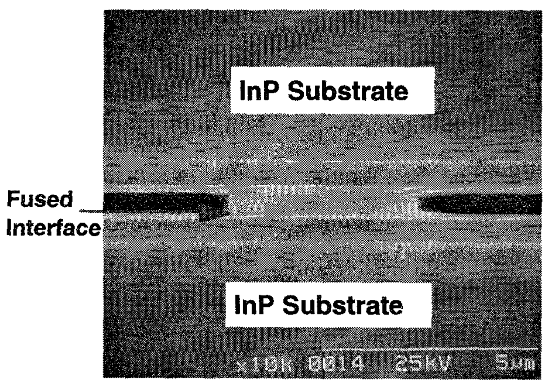

Fig. 2 Stain etched SEM picture of a fused vertical coupler

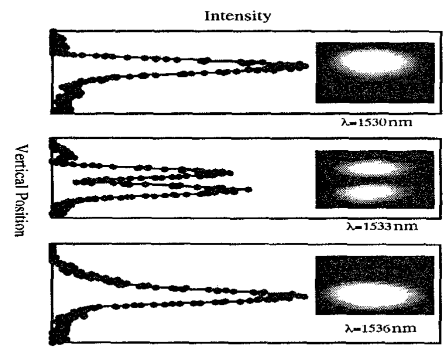

Fig. 5 Photograph of the near field pattern at the coupler output at 1530, 1533 and 1536nm wavelengths.

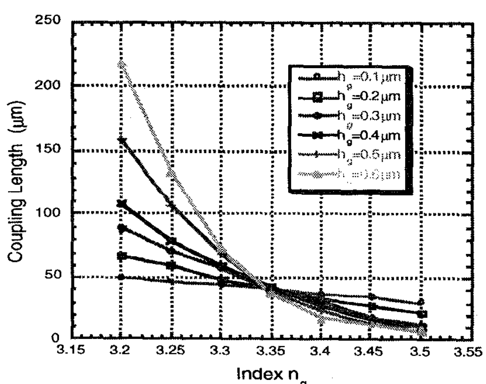

Fig. 3 Coupling length as a function of gap layer index for different thicknesses of the gap layer.

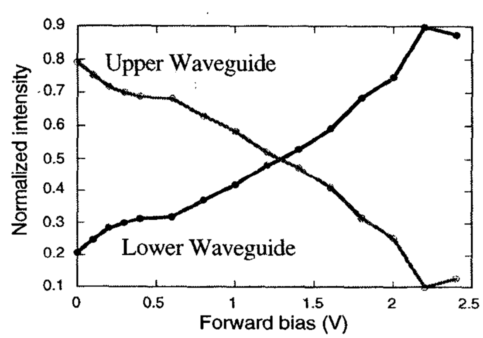

Fig. 6 Measured bias dependence of the output intensity for a 3.5mm fused vertical switch.