5 x 20 Gb/s III-V on Silicon Electroabsorption Modulator Array Heterogeneously Integrated with a 1.6nm Channel-Spacing Silicon AWG

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Abstract: We demonstrate a five-channel wavelength division multiplexed modulator module that heterogeneously integrates a 1.6nm channel-spacing arrayed-waveguide grating and a 20Gbps electroabsorption modulator array, showing the potential for 100 Gbps capacity on a 1.5x0.5 mm^2 footprint.

OCIS codes: (250.3140) Integrated optoelectronic circuits; (250.7360) Waveguide modulators

1. Introduction

Wavelength division multiplexing (WDM) systems have attracted much attention in recent years for achieving ultra-high speed optical networks and optical interconnects. WDM transmitters and receivers require low cost and high performance devices for maximal bandwidth usage and high energy-efficiency. For the active components in a WDM system, both silicon and III-V based materials are available. Potentially low-cost, monolithic silicon WDM modulator chips have been reported [1, 2]. However, an optically broadband silicon-based modulator usually has a large footprint and requires a relatively high driving voltage for sufficient extinction ratio, compared to III-V devices. The hybrid silicon platform combines the advantages of indiumphosphide-based materials and silicon. Hybrid active devices with excellent performance, such as hybrid silicon narrow linewidth lasers [3], high-speed modulators [4], and high-speed detectors [5] have already been demonstrated.

In this paper, a silicon AWG and array of 5 III-V EAMs are heterogeneously integrated using adhesive bonding technology [6]. An ultracompact size (1.5x0.5 mm^2), a low driving voltage (~2.5Vpp), and a large extinction ratio (4.9-6.9dB) are obtained with 100Gbps capacity in our device.

2. Device Structure

Figure 1(a) shows the schematic of the chip layout. On each channel of the arrayed waveguide grating (AWG), a separate electro-absorption modulator (EAM) is integrated. In Fig.1(b), the cross-section of the modulator is sketched. The InGaAlAs MQW stack with a width of 2µm is sandwiched by two separate confinement heterostructures (SCHs). According to the simulation results, the coupling efficiency from the passive silicon waveguide (380nm thick) to the III-V waveguide using a 45µm taper can be as high as 98%. The length of the active modulator section is 100µm. Benzocyclobutene (DVS-BCB) is used for passivation and for decreasing the parasitic capacitance. A lumped electrode structure is adopted. The size of the whole device (see Fig.1(c)) is 1.5x0.5 mm^2.

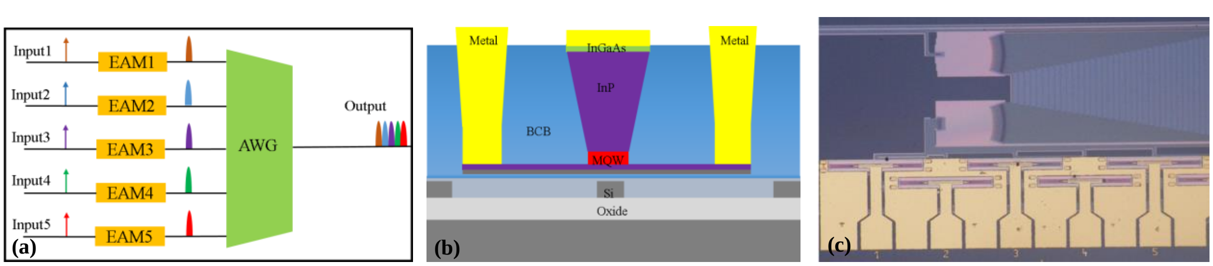

Fig. 1. (a) The schematic diagram of the layout. (b) Cross section of the hybrid modulator section. (c)Top-view of the fabricated EAMs+AWG.

3. Device Characteristics

The normalized transmission spectrum of the 5-channel AWG is shown in Fig. 2(a). The channel spacing is 1.6nm. Figure 2(b) illustrates the measured static extinction ratio of the 100µm-long EAMs under different reverse biases. More than 12 dB extinction ratio can be achieved when the bias is changed from 0 V to -2.5 V. The insertion loss of the EAM at 0V bias is measured to be less than 3dB.

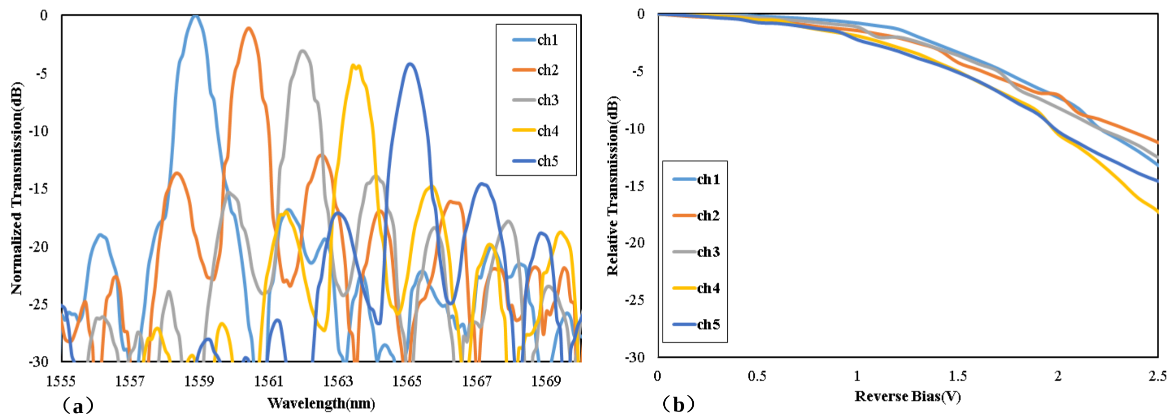

Fig. 2. (a) Normalized Spectrum of the AWG. (b) DC characteristics of the modulators on each channel.

For the eye diagram measurement, a tunable continuous wave (CW) laser was aligned to each channel of the AWG. A Tektronix pattern generator followed by a driving amplifier and a bias tee produces a PRBS signal with 2.3 to 2.6Vpp with a DC offset of -1.5V to -2V to drive the EAMs. The modulated light was then boosted by an erbium-doped fiber amplifier (EDFA) to compensate the loss from the AWG. A narrow optical filter is inserted to remove the amplified spontaneous emission (ASE) noise generated by the EDFA. Finally, the eye diagrams are obtained with an 8300A digital series analyzer. Figure 3 shows the eye diagrams at 20Gbps for the different channels. The dynamic extinction ratios are between 4.9dB and 6.9dB. The EAMs can even reach 30Gbps by adjusting the bias.

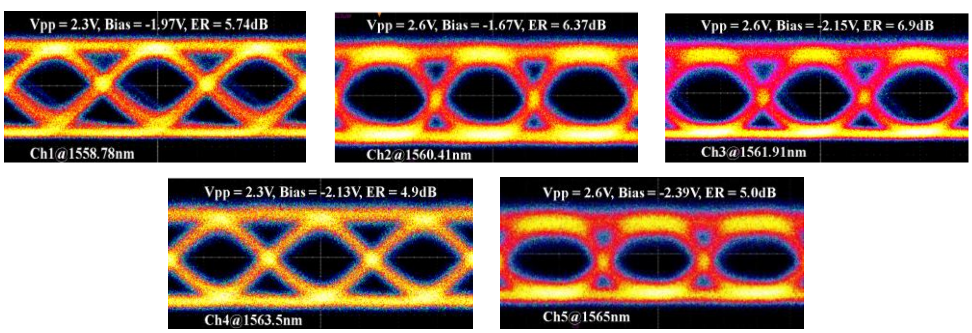

Fig.3 Optical eye diagrams at 20 Gbps for each channel.

4. Conclusion

We report a five-channel WDM modulator module that heterogeneously integrates a 1.6nm channel-spacing arrayed waveguide grating and a 20Gbps electroabsorption modulator array reaching 100Gbps capacity. The total size of the device is 1.5x0.5 mm^2. The realization of the module on a hybrid silicon photonic platform allows in a next step to co-integrate the laser sources as well. It can also be used as WDM receiver by strongly reverse biasing the devices.

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