Multi-Band Gap Electro-Absorption Modulator Array in a Generic Integration Platform using Selective Area Growth

(Student paper)

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ABSTRACT

We demonstrate the integration of 4 electro-absorption modulators (EAM) with shifted band gaps by combining selective area growth (SAG) with a generic photonic integration platform. The designed, fabricated and characterized EAMs operate in the wavelength range 1490–1550 nm, and the process allows mask layer specification of four band-gaps with 20 nm spacing. Static extinction ratio over a 2 V peak-to-peak voltage swing is beyond 10 dB for all EAMs with a variation of only 1.7 dB from device to device over the 60 nm wavelength range.

Keywords: Selective Area Growth, Generic photonic integration platform, Electro-Absorption Modulator

1 INTRODUCTION

Electro-absorption modulators (EAM) are key devices in optical communication operating at high bit-rate [1], [2] with a low drive voltage and small footprint. They have been recently introduced into the TU/e generic integration platform [3]. Using the generic integration enables the combination of active and passive devices in complex circuits, as it has been shown for a high capacity transmitter [4]. The modulation of EAM being wavelength dependent, their integration in a coarse wavelength division multiplexing (CWDM) configuration requires a control over their band gap.

Selective area growth (SAG) is a technology enabling band gap control for active devices with a single epitaxy step. With this technology, a four channels CWDM transmitter with a total of 13 different band gaps was demonstrated [5]. Previous work shows the successful combination of SAG with generic photonic integration to enable complex photonic chips with the example of a widely tunable laser source [6]. To the best of our knowledge a multi-band gap EAM array has not been integrated in a generic photonic platform.

This paper presents the integration of 4 EAMs with band gap shift by combining SAG with a generic platform fabrication process. The variation of static performance with band gap tuning is characterized and compared to EAMs from the standard generic integration platform for benchmarking.

2 EAM STRUCTURE

The active layer stack used in this work contains 6 quantum wells in order to integrate both lasers, semiconductor optical amplifiers and EAMs with a single epitaxial step. Prior to the multiple quantum wells (MQW) growth, pairs of dielectric SAG mask stripes are deposited on the wafer to locally control the MQW band gap. After the active layer stack growth, a butt-joint process is used to co-integrate active and passive devices. To characterize the variations of EAM static performance with band gap tuning, arrays of four 200 µm-long EAMs were fabricated on a 2-inch wafer. The Fig. 1 a) shows the layout of an EAM and Fig. 1 b) shows a photograph of the EAM array. The input and output waveguides are incident at the facet with an angle of 7° and the facets are anti-reflection coated. The SAG mask widths used for the EAM 1, 2, 3 and 4 are 6.4, 9.1, 12.0, and 15.3 µm respectively, providing peak photoluminescence (PL) emission wavelengths of 1503, 1524, 1545, and 1566 nm respectively. A wavelength step of 20 nm is aimed to follow the CWDM standard.

3 EXPERIMENTAL SETUP

To measure the EAM absorption as a function of bias, the chip was placed on a copper holder at room temperature without temperature stabilization. An electrical probe was used to bias the EAM and an external tunable laser was used to inject light in the EAM with 0 dBm power in fiber. A polarization maintaining fiber was used to inject the laser signal into the waveguide to excite the TE mode. The optical power transmitted through the EAM was collected at the chip output and measured with a power-meter. Lensed fibers were used to couple the light in and out of the chip, introducing a coupling loss of 3–4 dB at each facet. The absorption was recorded while sweeping the EAM bias from 0 to −8 V with a 0.1 V step.

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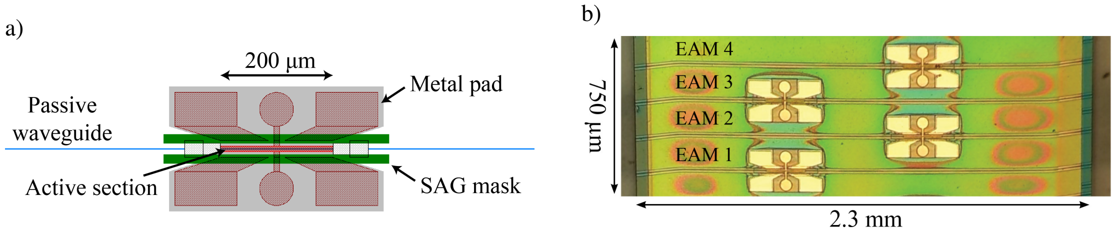

Figure 1: a) EAM layout with the SAG mask stripes. b) Picture of a fabricated EAM array.

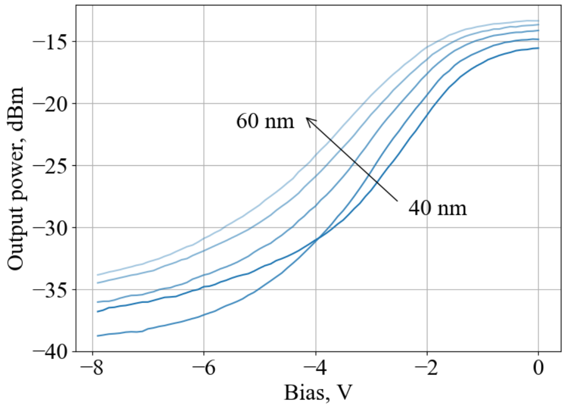

Figure 2: Transmitted optical power of the EAM 3 as a function of bias for different wavelength detuning. A laser input power of 0 dBm is used at wavelength detuning from 40 to 60 nm with a 5 nm step.

4 STATIC EXTINCTION RATIO ANALYSIS

The EAM performance analysis is performed in two steps. First, for each EAM the absorption as a function of bias is recorded for different wavelength detuning between the laser and the EAM PL peak wavelength. Then, the variation of performance with band gap tuning is measured after choosing one wavelength detuning for each EAM. To compare the EAM performance, three parameters are considered: 1- the measured transmitted optical power at 0 V EAM bias, called total insertion loss (IL), 2- the measured optical power normalized to the total IL, called static extinction ratio (ER), and 3- the bias of the inflexion point of the logarithmic ER characteristic, called optimal DC bias.

Wavelength detuning variation

In order to identify the best wavelength detuning for each EAM, we analyze the variation of EAM absorption for different laser wavelengths. The Fig. 2 shows the absorption measurement of the EAM 3 for different wavelength detuning values. The laser source was swept from 1585 to 1605 nm with a 5 nm step to provide wavelength detuning values from 40 to 60 nm. The measurements show total IL from −13.3 to −15.6 dB, maximum static ER from 20.4 to 23.9 dB and optimal DC biases from −2.2 to −3.4 V. The highest static ER is found with a wavelength detuning of 45 nm.

EAM band gap variation

The Fig. 3 shows the ER of each EAM at the wavelength detuning providing the highest static ER at −8 V. The inflexion point of the static ER in logarithmic scale are −2.5, −3.0, −2.9 and −2.8 V for the EAMs 1, 2, 3 and 4 respectively. By considering a 2 V peak-to-peak voltage swing around a bias of −2.8 V, the corresponding static ER are 10.3, 12.0, 11.2, and 11.7 dB respectively. These values are similar to the performance reported with a 200µm-long device in the standard integration platform [3].

The total IL measured for the 4 EAMs in the configuration presented in Fig. 3 ranges from 15 to 18 dB. Considering a fiber-to-chip coupling loss of 7 dB, it corresponds to an on-chip IL from 8 to 11 dB. This value is 1 to 4 dB higher than the on-chip IL reported with the standard integration platform.

5 CONCLUSION

In this paper we present for the first time the integration of electro-absorption modulators by combining selective area growth with the TU/e generic integration platform. Modulators are fabricated with photolumi-

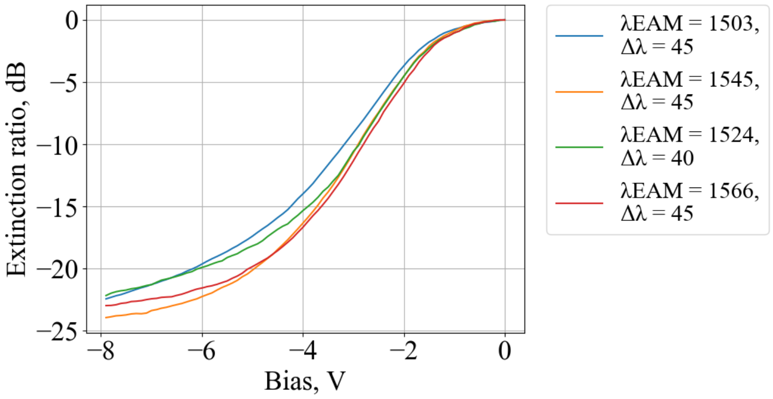

Figure 3: Extinction ratio for 4 EAMs with different band gaps in logarithmic scale from 0 to to −8 V. λEAM refers to the photoluminescence peak wavelength and Δλ refers to the wavelength detuning used for the measurement.

nescence wavelengths from 1490 to 1550 nm with a 20 nm spacing. The influence of wavelength detuning is studied for each EAM to find the conditions of operation for maximum static extinction ratio. A 2 V peak-to-peak voltage swing around a bias of −2.8 V provides a static extinction ratio beyond 10 dB for all EAMs. The success of the generic integration of EAMs with band gap choice over a 60 nm wavelength range paves the way to the integration of complex circuits for coarse wavelength division multiplexing transmitters.

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