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36 Gb/s OPERATION OF A BiCMOS DRIVER AND InP EAM USING FOUNDRY PLATFORMS

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Abstract

We demonstrate a clear eye-diagram at 36 Gb/s of a BiCMOS driver directly wire-bonded to an InP electro-absorption modulator (EAM) both fabricated through foundry platforms. The driver is fabricated in a 0.25 µm SiGe:C BiCMOS technology and delivers a maximum of 2 V_{p-p} amplitude when single-ended. The driver is DC-coupled to the modulator, simplifying the electronic-photonic assembly. The EAM operates in the L-band at 1590 nm, with a DC bias set at –1.6 V for on-off keying non-return to zero modulation. We measure the operation from 10 to 40 Gb/s, recording the dynamic extinction ratio from 5 to 3 dB, respectively. The use of foundry platforms does not require any fabrication process change and offers a wide spectrum of high-performance photonic-electronic integrated circuits.

1 Introduction

High capacity photonic integrated circuits (PICs) have been demonstrated, showing a total capacity of 2.25 Tb/s on 40 different channels – a 50 Gb/s per wavelength operation [1]. Their assembly with the electronic driver has been studied in different platforms [2, 3]. Ultra-high bandwidth InP IQ modulator for 100 GBd transmission is shown in [4], and an optical frontend module operating at 192 GBd in [5]. All of the demonstrated state-of-the-art ASICs were fabricated in an in-house technology process. In this work we demonstrate an electronic-photonic assembly using a commercially available foundry processes, thus eliminating the need for the process development on both electronic and photonic side.
Photonics foundries enable the use of externally modulated lasers, using small footprint modulators with operation at 50 Gb/s per channel [6, 7]. In Si-platform recent results show 70 Gb/s operation of a SiGe BiCMOS driver and GeSi EAM [8] and an all silicon transmitter operating at 34 GBd [9]. To the best of our knowledge this is the first time foundry enabled InP PIC and BiCMOS driver are assembled together.
The characterisation of the InP electro-absorption modulator integrated with passive waveguides is described in [10], showing a 100 µm-long EAM operating at 64 Gb/s. A first attempt of chip-on-carrier (CoC) is presented in [11], maintaining its E/O bandwidth and improving the reflection parameter, while still driving the EAM with an external discrete driver. This work shows a wire-bonded driver-EAM assembly. Open eye-diagram is demonstrated at 36 Gb/s, and both the electronic and the photonic chip were fabricated through foundry platforms, facilitating the direct use of both without a need for the whole fabrication optimization process.

2 EAM characteristics

The electro-absorption modulator in the InP generic integration platform was integrated with passive waveguides and electrical isolation sections (Fig. 1a). The EAM cross section uses the available p-i-n InP active layer stack in the multi-project wafer run offered by SMART Photonics [12] through the JePPIX service [13], fabricated in an experimental run on a semi-insulating substrate. A compromise between its E/O bandwidth and extinction ratio (ER), presented in [10], gives the EAM length of 150 µm. Its static extinction ratio is 12 dB (Fig 1b), and the bandwidth 32 GHz (Fig. 1c) when measured directly on-chip (bare-die) with a 50 Ω parallel termination inside the RF probe.

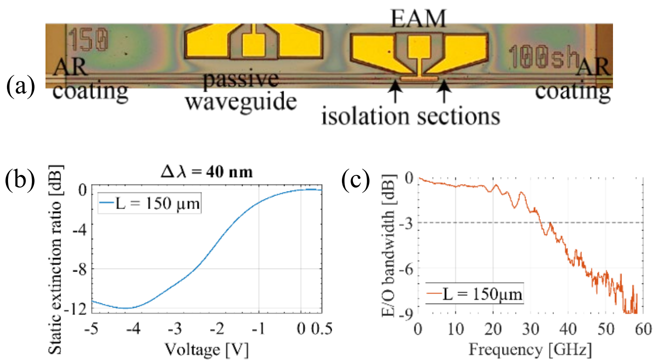

Fig. 1 (a) Photonic integrated chip comprising of an electro-absorption modulator (EAM), passive waveguides and electrical isolation sections. (b) 12 dB static extinction ratio of a 150 µm-long EAM, and its (c) E/O bandwidth of 32 GHz.

3 Driver characteristics

The electronic IC driver is designed for a 4 V_{pp} differential output voltage swing or 2 V_{pp} single-ended, fabricated in a 0.25 µm SiGe:C BiCMOS technology [14]. It is designed as a two stages linear amplifier topology, with an emitter follower as input and a cascade amplifier as output stage. It has an on-chip 50 Ω termination, so that it can operate in either single-ended or differential mode. The differential S-parameter measurement of the driver IC is shown in Fig. 2. It has a differential gain $S_{dd}21$ of 13.7 dB with a 3-dB bandwidth of 31.5 GHz. Its design is made to compensate the E/O bandwidth of an electro-optic modulator in the photonic foundry platform, limited around 25 GHz. The group delay variation is ±7.5 ps in the whole measured bandwidth range. The output stage draws 80 mA current from a 4 V power supply, resulting in a total DC power consumption of 364.5 mW.

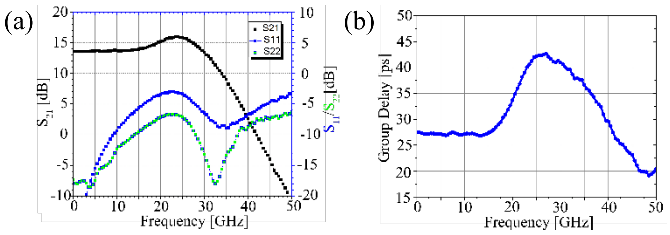

Fig. 2 (a) Measured driver IC differential S-parameters, and (b) its group delay.

4 Driver-EAM assembly

The driver-EAM assembly can be divided into three parts: the driver, the EAM submount and the broadband biasing circuit, whose electrical circuit is presented in Fig. 3.

4.1 EAM submount

The EAM chip-on-carrier submount consists of a decoupled 50 Ω termination load, to increase its E/O bandwidth and reduce the reflection loss, shown in Fig. 3 (orange). Since the EAM is fabricated on a semi-insulating substrate, its biasing is done from the top, applying the voltage difference between the ground (G) and signal (S) pad. The resulting voltage drop on the EAM is V_s–V_{DC}, V_s indicating the output driver voltage.

4.2 Broadband biasing circuit

A broadband biasing circuit is shown in Fig. 3 (blue) and consists of two stages: 1) a capacitance of 50 pF serves to decouple high frequency components and 2) RC series network (5 Ω in series with 100 nF) serves to decouple very low frequency components. The parameter values in the broadband biasing circuit are chosen for the presented EAM.

4.3 Driver-EAM submount

The driver and the EAM PIC were mounted on a CuW carrier, shown in Fig. 4. The ground of the driver and the EAM submount are connected through the metallized carrier. The driver output is directly connected with a wire-bond to the signal pad of the EAM, and further connected with a ribbon-bond to the EAM submount scheme. The driver is biased with a DC and RF probe, biasing both of its inputs, and using it in a single-ended configuration. For the EAM DC bias, a voltage difference between the ground, delivered from V_{DC} (see Fig. 3), and signal pad, delivered from the driver, results in a voltage of –1.6 V.

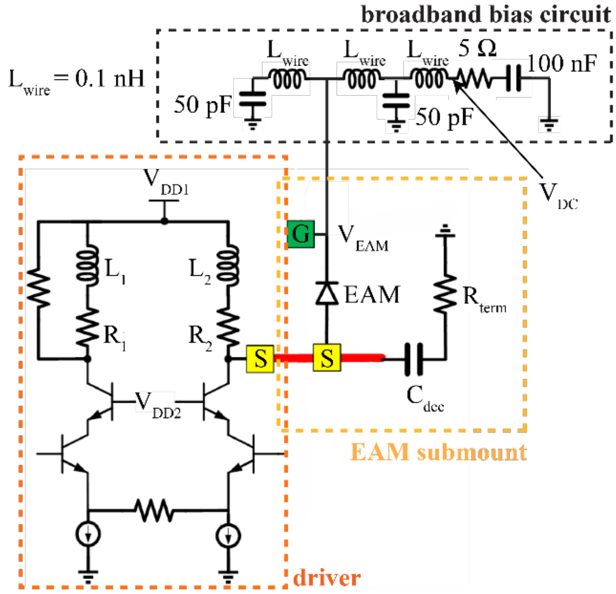

Fig. 3 Driver and EAM biasing scheme.

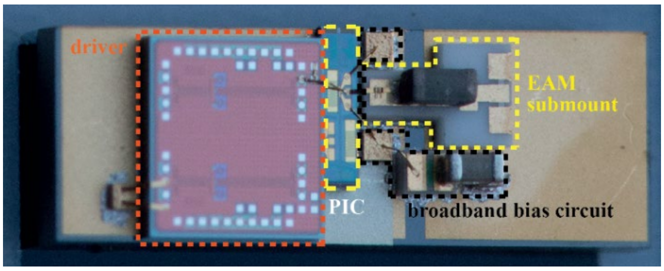

Fig. 4 Realization of the wire-bonded BiCMOS driver and the EAM sub-assembly.

4.4 Measurement setup

A commercial external laser (ID Photonics) is set at 1590 nm, for 40 nm detuning from the EAM bandgap. Its output power is set to 13 dBm. The input TE polarization is controlled with a polarization controller. Both input and output of the photonic integrated chip are edge-coupled to an anti-reflection coated lensed fibre, introducing ~4 dB loss at each facet. The EAM on-state insertion loss (V_{DC} = 0V) is 3 dB. The output fibre leads to an erbium-doped fibre amplifier operating in C + L band. A bandpass optical filter (Santec OTF-320) is used to supress the amplified spontaneous emission from the C-band. A PRBS generator (SHF 11100B) provides data and data bar signals at 10–40 Gb/s, with a sequence length 2^{31}-1, and an amplitude of 230 mV. The driver is used in a single-ended configuration, terminating the second output into a 50 Ω on-chip resistor. The optical signal is fed to the oscilloscope photodiode (HP-83480A) for eye-diagram recordings in back-to-back configuration. All the measurements are done at room temperature without a thermoelectric cooler.

4.5 Measured eye-diagram

The measured eye diagram for different bit rates is shown in Fig. 5. The measured dynamic extinction ratio is 4.76 dB at 10 Gb/s, and 3.38 dB at 36 Gb/s. An open eye-diagram is observed up to 36 Gb/s.

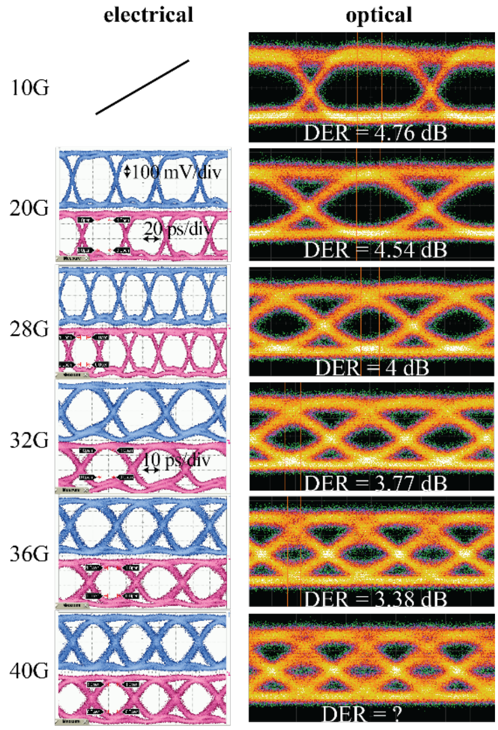

Fig. 5 Electrical (left) and optical (right) eye-diagram for bit rates 10–40 Gb/s and measured dynamic extinction ratios.

5 Conclusion

An integrated electronic differential driver is designed and fabricated in a SiGe:C BiCMOS technology with 31 GHz bandwidth, and wire-bonded to an electro-absorption modulator designed and fabricated in an InP foundry platform, showing 32 GHz bandwidth. The EAM submount is realized with an off-chip broadband decoupling capacitance and a 50 Ω termination load. Further driver-EAM assembly involves a broadband biasing scheme, all placed on a common carrier. The dynamic measurements show a clear eye-diagram up to 36 Gb/s, exhibiting 3.38 dB dynamic extinction ratio with the EAM DC bias at –1.6 V and a swing voltage of 2 V. The presented work illustrates the potential of using a mature and readily available technology for the driver circuit and an open-access InP multi-project wafer platform, and their capabilities towards transceiver circuits for 50 Gb/s per wavelength operation.

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