Silicon Photonics and RF Hybridization Approach for Optical Solutions

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1. Abstract

This paper presents an experimental study of the main blocks for a silicon photonics and RF integration, with external laser, for high bit rate transceiver used for optical communications and interconnection. The Electrical-Electrical small-signal bandwidth characterization is presented for a single-wavelength chip-to-chip optical interconnection based on the coupling of light to a silicon ring modulator and into a second chip with an integrated germanium photodetector, both devices integrated in SOI waveguides.

2. Introduction

Opto-Electronic interconnections present many advantages over pure electrical solutions [1].

Optical fiber is the dominant transmission medium for long distance communication, and is quickly replacing copper cables for short-haul high-speed datacom. Optical waveguides are also a potential candidate to replace copper both in the inter-chip and intra-chip interconnects [2,3].

More and more photonic integrated circuits (PIC) are becoming the technological core of the optical transceivers' subsystems in communication links. The most complex building blocks are those dedicated to the modulation and photodetection functions (Fig.1).

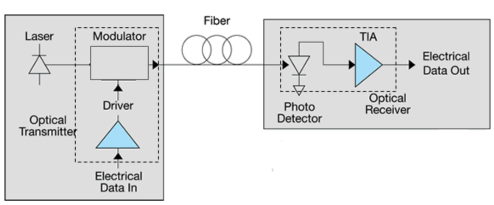

Fig.1. Basic optical transceiver

In this paper, each block of highlighted in Fig.1 of a single wavelength optical inter-connection for the silicon-on-insulator (SOI) platform is demonstrated, including the RF electronics and integration platform.

3. Characterization of Main Blocks

A. Ring Modulator

A silicon photonic ring modulator for operation in the C-band was fabricated by OpSis-IME [4] and is presented its operation at λ_0 = 1542 nm, with O-E bandwith in excess to 32 GHz (Fig.2). It was packaged using soft substrates as described here. In this case, the RF input of the modulator was connected to GCPW that was terminated with end launch connectors. The chips were connected by 1 mil gold wirebonding, as shown in Fig. 3. The bottom PCB is a standard DC bias structure.

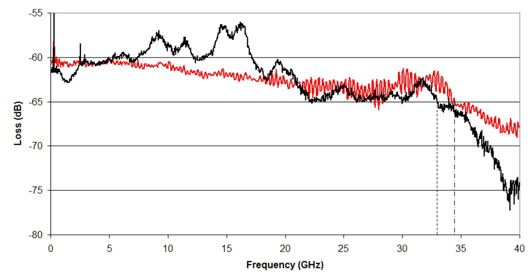

***Fig.2.** Optical ring modulator EO bandwidth - on-chip (red) and packaged (black) measurements*

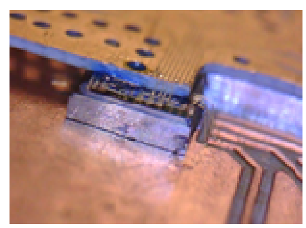

***Fig.3.** Ring Modulator packaging (detail wirebonding)*

B. Driver Modulator

We studied a commercial GaAs MMIC pHEMT Distributed Driver Amplifier - HMC870LC5 from Analog Devices (Hittite), with surface mount package which operates between DC and 23 GHz. The amplifier provided 17 dB of gain (Fig. 4), 8Vp-p saturated output swing and features output swing cross point adjustment. The assembled device is shown in the Fig. 4(b).

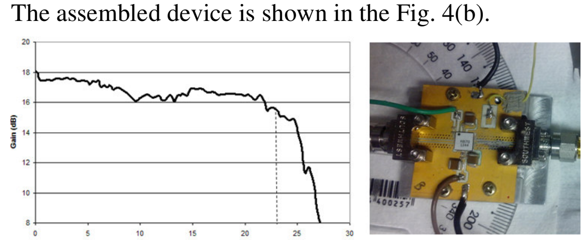

***Fig 4.** Driver packaged and curve – Gain x frequency*

C. Photodetector

The photodetectors were also fabricated in Opsis-IME [4] and are built using evanescently coupled germanium p-i-n diodes with the absorption section of germanium grown on top of a silicon waveguide. The p-i-n junction is defined by an n-type implant in the germanium and a p-implant in the silicon directly below the germanium. The photodetectors present an average responsivity of 0.55 A/W and a dark current of 10 uA at 4 V reverse bias. The RF performance was measured and the O-E bandwidth obtained was 27 GHz (Fig. 5).

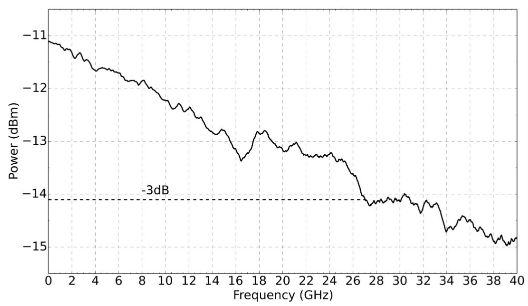

Fig 5. *Photodetector O-E bandwidth*

Optical-electrical conversion in a diplexer filter (1490 nm/1550 nm) was characterized with the output ports terminated by a photodetector. The Fig. 6 shows the response for the 1550 nm port, showing rejection for 1490 nm, and the PIC used for the measurements.

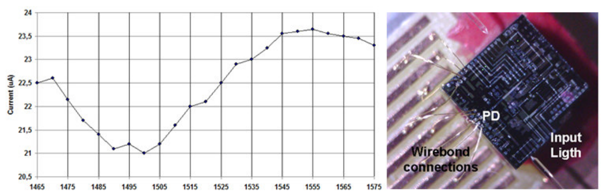

Fig 6. *Typical optical-electrical response and PD test board*

D. Transimpedance Amplifier (TIA)

A 10 Gb/s IC TIA developed at CTI [5] was mounted with GCPW and end launched connector. The inputs and outputs on the circuit are GSG (ground-signal-ground) structures connected by 1 mil gold wirebondings. Bandwidth @ 3 dB obtained was 7.4 GHz enough to 10 Gb/s receiver (Fig. 7), presenting noise figure of 3.5 dB. Another TIA was developed with bandwidth in excess of 40 GHz and is under evaluation.

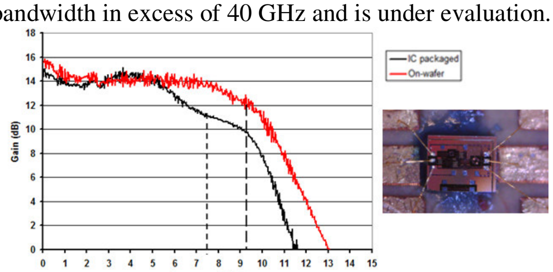

Fig 7. *TIA measurements – Gain x frequency*

D. Inter-chip Link

The chip-to-chip transmission measurement was carried out by connecting the optical output of a silicon ring modulator (chip#1) to the optical input of a waveguide-integrated germanium photodetector circuit (chip#2) [1].

Figure 8 shows the RF S21 measured with the VNA. The response exhibits a 6 dB E/E bandwidth of 26 GHz.

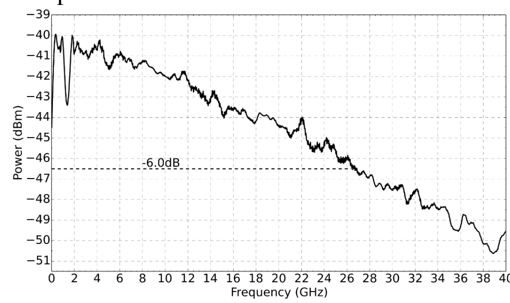

Fig.8*. E-E bandwidth – Interchip link*

4. Conclusions

We reported on our study of the main blocks for TX/RX high bit rates using silicon photonics ICs in the optical cores. The RF packaging and electronics for the electrical-optical-electrical conversions was also studied. The next step of the work is to integrate all blocks in TX and in RX. Considering these results we expect good performance for communication at rates greater than 10 Gb/s.

Acknowledgments

Special thanks to technical staff at CTI, CNPq (project PRJ02.101 PCI and CITAR) and SMART Modular Technologies Ltda for financial support. We acknowledge the use of EMU Fapesp 09/54045 multiuser equipment.

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