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Hybrid InP-SiGe photoreceiver for the access network

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***Abstract*— In this paper, we present a low cost and polarization independent photoreceiver which is part of the optical network unit (ONU) for the fiber access network. It consists of one InP-photodetector and a low cost SiGe amplifier. It operates error free with $2^{23}-1$ PRBS word length at 1.25 Gbit/s with -13 dBm input optical power before the fiber chip coupling whose loss is about 5 dB. From the rise and fall time shown in measured eyediagram, it is estimated that it will also operate up to 2.5 Gbit/s.**

I. INTRODUCTION

WITH the ever-increasing demands on the bit rate from the users to exchange information, fiber-to-the home (FTTH) has been proven worldwide to be one of the most promising solutions. Currently the maximum widely available bitrate of installed optical network units (ONU) at the user side is 156 Mbit/s for upstream data carried by a 1310 nm Fabry-Pérot laser, and 656 Mbit/s downstream data carried by 1550 nm in a TDM-BPON system in Japan [1]. The ONU investigated in Dutch Broadband Photonics project (BBP) [2] aims for Gigabit Ethernet operation while keeping low cost, first up to 1.25 Gbit/s, and finally target at 10 Gbit/s.

The ONU in BBP consists of three parts: an optical transceiver [3] based on InP, an amplifier receiver chip based on SiGe and a transmitter burst mode driver chip based on Si. In this paper, we will present the design and measurement results of the photoreceiver chip of the ONU which consits of one InP-photodetector, and an amplifier chip comprising a transimpedance amplifier (TIA) and a variable gain amplifier (VGA) which is a three stage amplifier with two tuning voltages, based on SiGe. The two chips are wire bonded together. The block functionality diagram and the photograph of the fabricated chip are shown in Fig. 1. The photodetector was fabricated based on InP because the photodetector will be monolithically integrated with a semiconductor optical amplifier (SOA) acting as a reflective modulator at 1.55 μm. The amplifier circuit is based on SiGe. When the downstream data carried by the light is detected by the photodetector, the generated photocurrent will be pre-amplified and converted into a differential output voltage. The amplifier circuit also provides a DC bias voltage to the photodetector. The measured bandwidth of the InP-photodetector is more than 20 GHz [4], and the bandwidth of the photoreceiver is mainly limited by the TIA which was measured with a transimpedance gain of approximately 1500 Ω and a bandwidth of 3 GHz. The equivalent input noise current is 4.5 pA/$\sqrt{\text{Hz}}$. The final measurement results show that the photoreceiver can operate error free at 1.25 Gbit/s with -13 dBm input optical light before fiber-chip coupling.

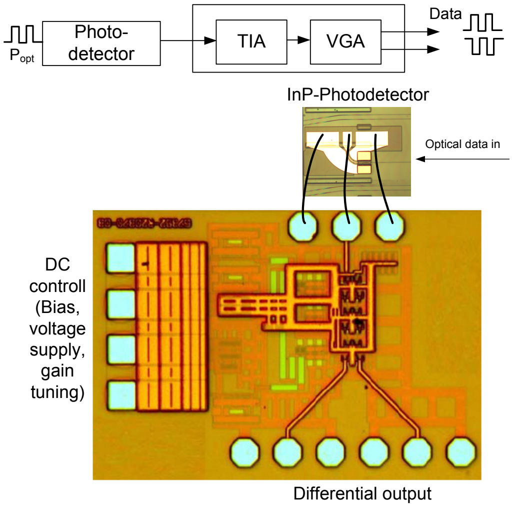

Fig. 1: Block functionality diagram (above) and the photograph of the fabricated photoreceiver consisting of an InP-photodetector and a SiGe amplifier connected with bonding wires (below).

II. FABRICATION

The InP photodetector is a ridge waveguide photodetector based on semi-insulating InP-substrate with lateral ground contacts. The photodetector shares the same layer stack as that for the SOA for future monolithic integration. It has a 120 nm active layer (Q1.55 InGaAsP, $\lambda_{\text{gap}} = 1.55\,\mu$m) sandwiched between two 190 nm thick Q1.25 film layers. The photodetector is 2 μm wide and 100 μm long. The waveguide was etched by

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reactive ion etching (RIE). Polyimide was spun for passivation and planarization. Before metallisation, firstly we etched back the polyimide in a barrel etcher to expose the p-InGaAs contact layer. To form the metal contact, Ti/Pt/Au were evaporated on the top p-InGaAs and the lateral grounds (n-InP) and patterned through lift-off. The access side of the finished photodetector is a cleaved facet with about 33% (26%) reflectivity for TE (TM) polarized light. The total fiber-chip coupling loss was estimated about 5 dB due to the reflection at the facet and the mode mismatch between the fiber and the input waveguide of the photodetector.

The amplifier circuit is implemented in the AMS 0.35 μm-SiGe BiCMOS process that includes high-speed SiGe Heterojunction Bipolar Transistors. Finally these two chips were bonded together through wires with 20 μm diameter.

III. CHARACTERIZATION

The measurement results on the amplifier circuit is shown in Fig. 2, in which V1 and V2 are the tuning voltages. The purpose of the tuning voltage V1 is to vary the gain in the VGA depending on the input voltage swing. A second tuning voltage V2 is present to compensate for process variations. The VGA is designed to achieve a constant output voltage swing of 80~90 mV at the output. The bandwidth of the amplfier circuit is about 3 GHz.

To measure the performance of the hybrid photoreceiver, we inject the light at 1546 nm from the tunable laser which was modulated by a 10 GHz commercial Mach Zehnder modulator driven by the pulse pattern generator (PPG) up to 1.85 GHz. The modulated light was coupled into the photoreceiver chip through a lensed fiber. The light was absorbed by the photodetector which was reversely biased at -3 V. and the generated photocurrent was converted into voltage and amplified by TIA and VGA. The output differential voltage from the photoreceiver was directly input to a digital communication analyzer without additional electrical amplifier to record the eye diagram. The tuning voltage V1 was set at 1.5 V, corresponding to about 30 dB gain in Fig. 2. The recorded eye diagrams for PRBS with $2^{23}-1$ word length at 1.25 Gbit/s and 1.85 Gbit/s are shown in Fig. 3 when the input optical power is -14 dBm before the fiber chip coupling. The measured Q factors are more than 19 and 17. Due to the frequency limitation in the PPG, we only measured the eye diagram up to 1.85 Gbit/s. We estimate that this photoreceiver will also operate at 2.5 Gbit/s based on the rise and fall time shown in the eye diagram. The measurement results on the eyediagram and BER were not dependent on the polarization state of the light.

IV. CONCLUSION AND DISCUSSION

A low cost and polarization independent photoreceiver which consists of InP-photodetector and a SiGe amplifier developed for Gigabit Ethernet ONU has been presented. The measurement results show that it operates error free at 1.25 Gbit/s for the input optical power of more than -13 dBm. The performance could be further improved by increasing the gain of the amplifier circuit.

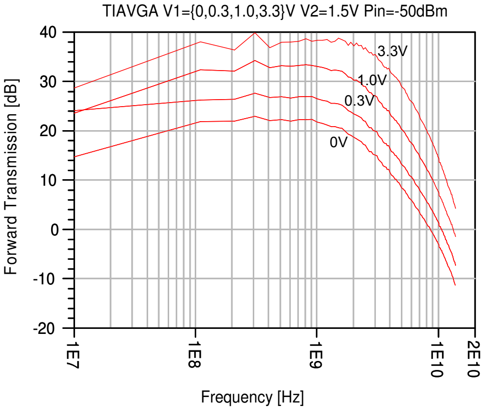

Fig. 2: Gain of the amplifier circuit.

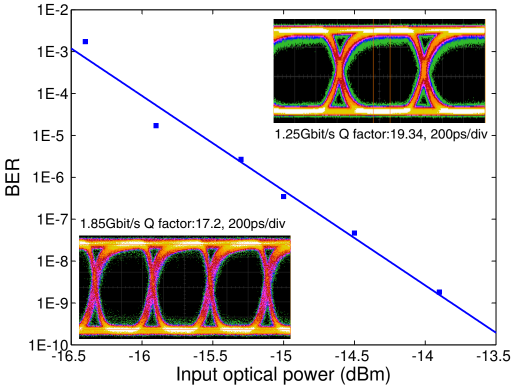

Fig. 3: The BER measurement at 1.25 Gbit/s for different input optical power level before fiber-chip coupling when the gain of the amplifier is about 30 dB. Eye diagrams for 1.25 Gbit/s (above) and 1.85 Git/s (below) with -14 dBm input optical power.

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