A 25G Burst-mode Receiver with –27.7-dBm Sensitivity and 150-ns Response-Time for 50G-EPON Systems

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Abstract *A 25Gbit/s-class burst-mode receiver for 50G-EPON systems with a 25G APD and 25G burst-mode TIA, fabricated by 0.13-µm SiGe BiCMOS technology, achieves record high sensitivity of –27.7 dBm (OMA) at BER = 10^{-2} and record settling time of 150 ns.*

Introduction

Passive optical networks (PONs) are mainly used to provide cost-effective broadband services to residential and business users. Recently, PON application to mobile networks is being discussed[1-2]. Fig. 1 shows a use case of the PON application to a mobile network. For such an application, a line rate of over 10Gbit/s will be needed for it[3], so IEEE and ITU-T are working to standardize the 50G-EPON and a higher speed PON, respectively.

The 25-Gbit/s-class burst mode receiver (BM-Rx) is a key component, and a 50G-EPON consisting of 25G-EPON with two wavelengths requires 25.78125 Gbit/s. The first 25-Gbit/s-class BM-Rx complying with IEEE specifications was reported in [4]. The sensitivity and response time of the BM-Rx are very important. High sensitivity improves the loss budget for long reaches and high splitting ratios, and a fast response improves bandwidth utilization efficiency, so a 25G BM-Rx with both high sensitivity and a fast response can expand the 50G-EPON application area.

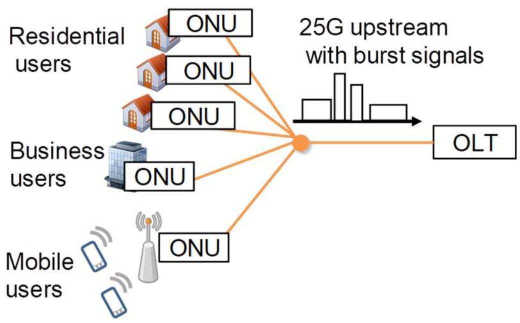

Fig. 1: 25G-bit/s-class PON application.

In this paper, we report a 25G BM-Rx which combines a 25G burst-mode TIA (BTIA) and a high-sensitivity 25G APD[5] to achieve the highest sensitivity and the fastest response time ever.

Circuit design

A block diagram of our 25G BTIA is shown in Fig. 2. A large feedback resistor Rf was used to increase the transimpedance gain of the TIA core. It reduces noise, and hence improves sensitivity, but it reduces the bandwidth of the TIA core. A large emitter-bypass-capacitor C_E recovers the degraded bandwidth but causes a series resonance problem with a bonded ground wire. The use of through silicon vias (TSVs) reduces the inductance between VEE and GND (L_{TSV}) and avoids the resonance problem. Thus, a wide-bandwidth and low-noise TIA core is achieved.

Series-inductor peaking is also used to enhance the bandwidth of the BTIA. It is implemented not only at the inter-stages of the three-stage differential amplifier but also at the input and output ports with impedance-matched inductors. The BTIA design includes the frequency-

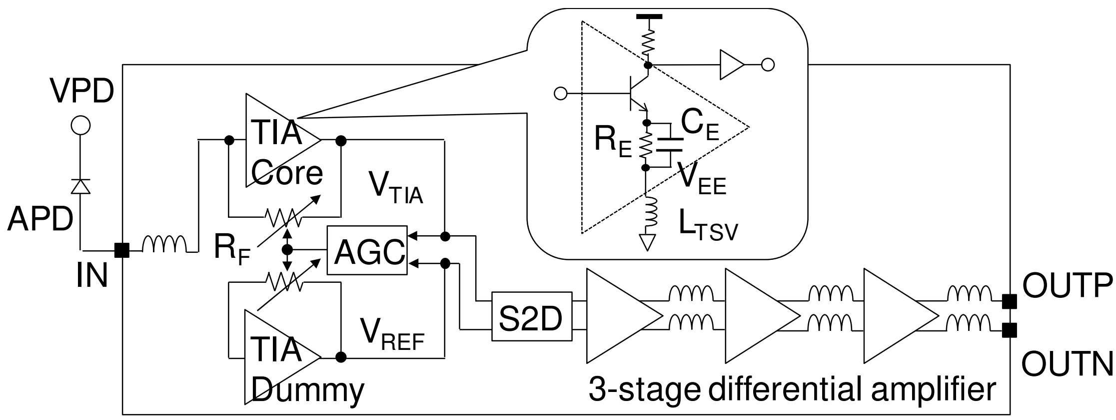

Fig. 2: Block diagram of 25G BTIA.

response model of our 25G APD for a 25-Gbit/s-class receiver.

An automatic gain control circuit (AGC) adjusts the gain of the TIA core so that its output swing equals that of a given reference. A single-ended to differential converter (S2D) converts the TIA core output V_{TIA} to a differential output. The time constants of the AGC loop were optimally designed by taking account of the tradeoff between the response and tolerance to consecutive identical digits (CIDs).

Fabrication and Characterization

The BTIA was fabricated by using 0.13-µm SiGe BiCMOS technology (f_T/f_{max} = 200 / 265 GHz). Fig. 3 shows a microphotograph of the chip, whose footprint is 1.31 x 0.92 mm^2 . Fig. 4 shows the frequency response of the transimpedance gain Zt, which we calculated from the measured

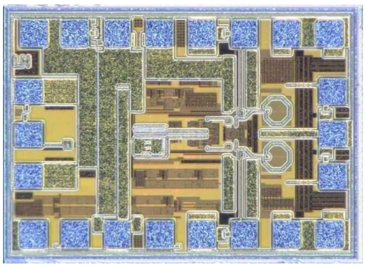

Fig. 3: Chip photograph (1.31 x 0.92 mm^2).

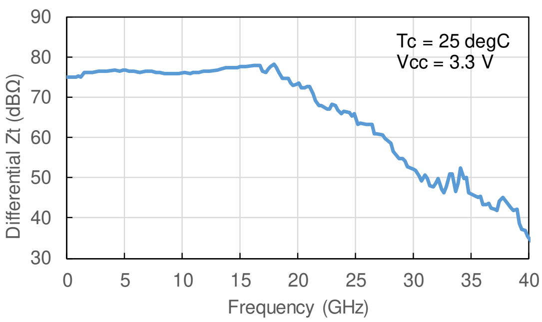

Fig. 4: Frequency response of BTIA.

S parameters of the BTIA in combination with the parameters of our 25G APD. A differential transimpedance gain of 76 dBΩ with a 3-dB frequency bandwidth of 19.4 GHz was obtained. Input referred noise current density was derived from the S-parameter and noise figure measurement, and was 9.8 pA/√Hz on average. The power consumption was 209 mW with the supply voltage of 3.3 V at room temperature.

An optical receiver module was assembled by connecting the BTIA and APD and mounting them in a butterfly package, as shown in Fig. 5.

Experimental Results

Fig. 6 shows the experimental setup for burst bit-error-ratio (BER) measurement of the BM-Rx. As an optical source, we used an EADFB laser with a semiconductor optical amplifier (SOA). A 25.78125-Gbit/s burst optical signal was generated by modulating the electro-absorption modulator (EAM) with data signals from the pulse pattern generator (PPG) and turning the SOA on and off with Tx-enable signals from the PPG. By swinging the SOA off current negatively, a high transmitter on/off average output ratio of more than 40 dB was obtained. Two burst signals, Tx #1 (λ=1295 nm) and Tx #2 (λ=1300 nm), were multiplexed and alternately input to the BM-Rx. The optical power of Tx #1, a loud burst signal as

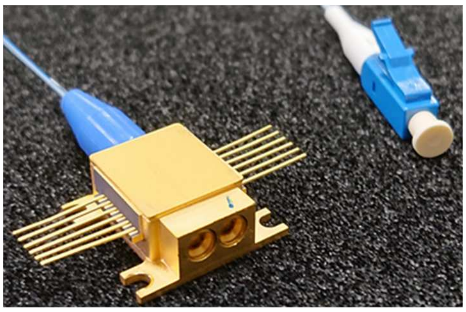

Fig. 5: Photograph of BM-Rx.

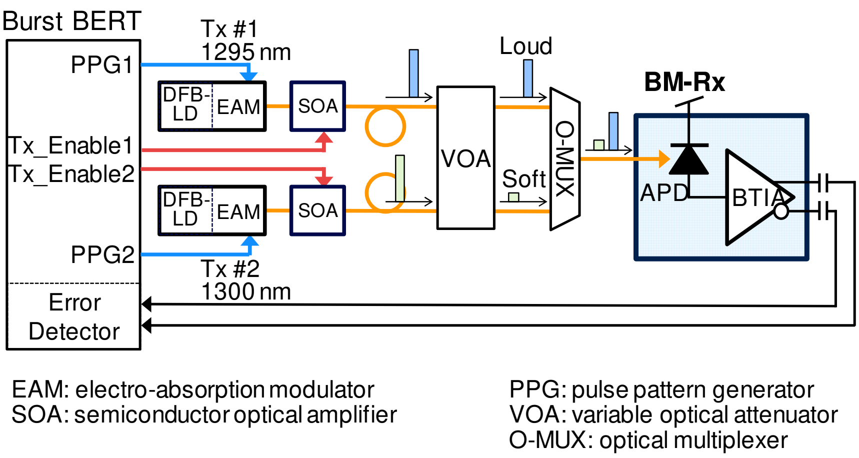

Fig. 6: Setup for burst BER measurement of BM-Rx.

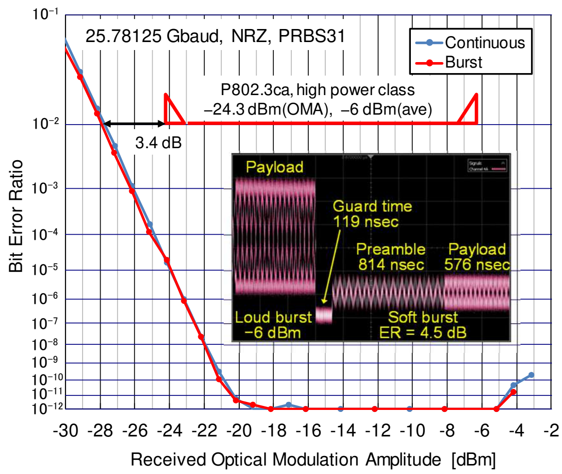

Fig. 7: BER performance of BM-Rx.

an aggressor, was −6 dBm, and the extinction ratio of Tx #2, a soft burst signal as a victim, was 4.5 dB.

Fig. 7 shows the BER performance of the BM-Rx with built-in equalization in the error detector and our target range in optical modulation amplitude (OMA). The input optical format of the measurement is also shown in Fig. 7. The minimum OMA sensitivities at BER=10^{-2} of −27.7 dBm for continuous inputs and for burst inputs, were successfully achieved. The minimum burst sensitivity has a wide margin of more than 3 dB with respect to the 25G-EPON high-power-class specification[6]. Input overload which was more than −3 dBm, is also compliant with the specification.

We also evaluated the settling time of the BM-Rx to burst data, as shown in Fig. 8. The BER performance was measured with different values of the preamble length of the soft burst signal that followed the loud burst signal. The preamble length shows the settling time of the BM-Rx. It can be reduced to 150 ns while maintaining the receiver sensitivity, which is much smaller than the settling time of 800 ns, specified by the IEEE P802.3ca 50G-EPON Task Force[6].

Tab. 1 summarizes the measurement results compared to the specs and prior art. It shows that our BM-Rx is well enough to satisfy the 50G-EPON requirements.

Conclusions

As far as we know, we achieved a highest-sensitivity and fastest-response 25G burst-mode APD-TIA receiver far exceeding the IEEE specifications. The minimum OMA sensitivities at BER=10^{-2} for continuous inputs and burst inputs are −27.7 dBm. The settling time is 150 ns. Our receiver with these performances can expand the 50G-EPON application area.

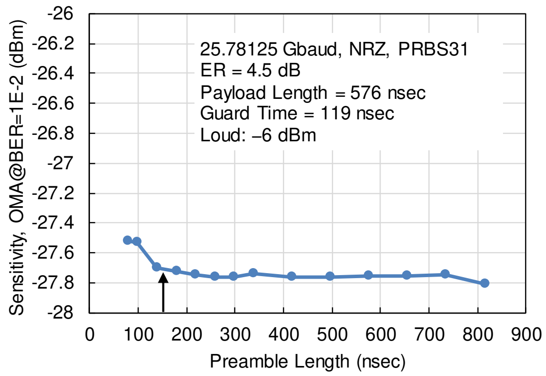

Fig. 8: Settling time of BM-Rx.

Tab. 1: Measurement results and the specs

Parameters	P802.3ca spec.1)	[4]	Our result
Trans-impedance gain (differential), Zt (dBΩ)		66	76
Frequency bandwidth (GHz)		18	19.4
Input referred noise current density, Ieq (pA/√Hz) 2)		-	9.8
Min. sens. (OMA) (dBm)	−24.3	−26.0	−27.7
Overload (P_{ave}) (dBm)	−6	> −6	> −3
Settling time (nsec)	800	600	150

1) High-power class.
2) Average Ieq from 1 GHz to Zt.

References

[1] ITU-T Recommendation G.sup 66: "5G wireless fronthaul requirements in a passive optical network context," Oct. 2018.

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[6] IEEE P802.3ca, "Physical layer specifications and management parameters for 25 Gb/s and 50 Gb/s passive optical networks," D3.1, 2020.