25.78-Gbit/s Burst-mode Receiver for 50G-EPON OLT

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Abstract: We report the world's first receiver optical sub-assembly equipped with 25G burst-mode TIA which is applicable for 50G-EPON OLT transceiver. We demonstrate its 25G/10G dual-rate burst-mode receiver characteristics.
OCIS codes: (130.0250) Optoelectronics; (130.1750) Components

1. Introduction

Passive optical networks (PONs) have been widely used as cost-effective internet access networks for FTTH. Along with the increase of huge contents such as 4K/8K video streaming, the demand for access speed is being rapidly increased not only from home uses but also business uses. As a next generation high speed PON system, ITU-T has standardized 40G access networks NG-PON2 [1] which employs time and wavelength division multiplexed (TWDM) PON. Thus, all the physical media dependent (PMD) components such as a laser diode, an avalanche photodiode (APD), a driver and a trans-impedance amplifier (TIA) are still 10G grade.

As for further high speed PON, IEEE started a task force to standardize 50G-EPON [2] from 2016. Fig. 1 shows the system overview of 50G-EPON upstream. 50G-EPON upstream is composed of 2-wavelength TWDM which means 25.78-Gbit/s/λ. Besides, conventional 10G-EPON [3] coexists with 50G-EPON. In particular case where 10G time division multiplexed signals coexists with 25G signals in the same wavelength, 50G-EPON optical line terminal (OLT) has to receive both 10G and 25G burst signals from optical network units (ONUs), and PMD components have to satisfy both 10G-EPON and 50G-EPON upstream specifications. The optical receiver for 50G-EPON OLT needs to receive the optical signals with wide dynamic range after the short guard time. While 25Gbit/s NRZ burst-mode receiver is reported [4], so far no report has presented the optical receiver module complied with 50G-EPON specification to satisfy requirements above mentioned.

We successfully developed the world's first burst-mode optical sub-assembly (BM-ROSA) which is applicable for 50G-EPON OLT transceiver and demonstrated its 25G/10G dual-rate burst-mode receive characteristics.

2. Design of Receiver for 50G-EPON OLT

We newly developed 25.78-Gbit/s burst-mode trans-impedance amplifier (BM-TIA) IC chip to satisfy requirement above mentioned. Fig. 2 shows the block diagram of BM-TIA. It includes the architectures to realize the fast settling time and wide dynamic range to meet 50G-EPON specification even without an external reset control signal and the low input referred noise as mentioned in the previous study [5].

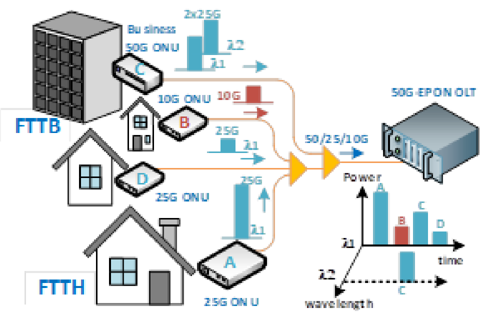


Fig.1 System overview of 50G-EPON

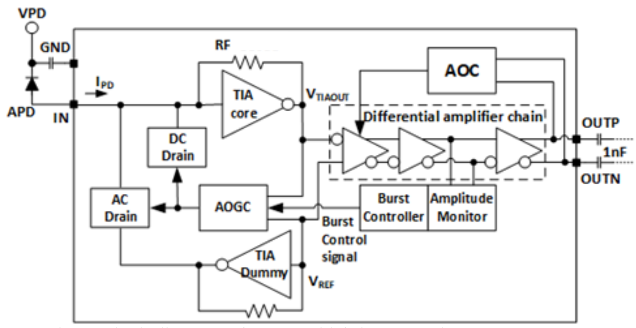


Fig.2. Block diagram of 25.78-Gbit/s burst-mode TIA

Fig.3 (a) shows the external view of BM-ROSA which uses conventional coaxial packaging technologies. Its coaxial diameter of 3.15 mm is small enough to be implemented in transceivers with the general form factor like SFP28. It is also suitable to be integrated to bi-directional optical sub-assembly with optical transmitter. TIA and PD are mounted on a low cost coaxial package and electrically connected together by gold bonding wires. Fig.3 (b) shows the photograph of BM-TIA fabricated by 0.13um SiG:C-BiCMOS technology (fT/fmax =300/500 GHz). Newly developed 25.78-Gbit/s BM-TIAs were assembled with 25G class PIN-PD and APD.

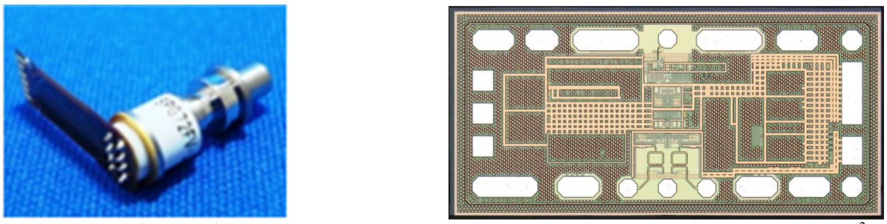


Fig.3. (a) External View of BM-ROSA (b) TIA chip photograph (size: 1.60 × 0.75 mm^2)

3. Measurement results

Herein we report the high frequency characteristics of BM-TIA using PIN-PD and APD, and then demonstrate burst-mode bit error ratio performances with APD BM-ROSA to confirm its compliance to both 10G-EPON and 50G-EPON upstream specification.

3.1. Receiver high frequency performance

Fig.4 shows the measured opto-electric trans-impedance $Z_{T(O\text{-}E)}$ of BM-ROSA that includes an evaluation board loss. The 3dB bandwidth of $Z_{T(O\text{-}E)}$ was 14GHz for PIN-PD BM-ROSA and 11.8GHz for APD BM-ROSA. The 3dB bandwidth of APD is around 10GHz in case its multiplication factor is 6 as reported in [6]. Therefore, the additional peaking function in TIA was activated to overcome APD's bandwidth limitation for APD BM-ROSA. The estimated 3dB bandwidth of $Z_{T(O\text{-}E)}$ without the evaluation board loss is about 18GHz that is good enough for 25.78-Gbit/s operation in case of PIN-PD BM-ROSA, and about 14GHz for APD BM-ROSA. The eye diagrams of 25.78-Gbit/s PRBS2^{31}-1 signal are shown in Fig.5. Optical input signal with diagram shown in Fig.5 (a) was applied for APD BM-ROSA. Then, the single-ended electrical eye diagrams of APD BM-ROSA are captured at the output of evaluation board via 1nF capacitors as shown in Fig.5 (b), (c) and (d). We observed enough eye openings without pattern dependent jitter from -21dBm to -3dBm as a receiver input optical power.

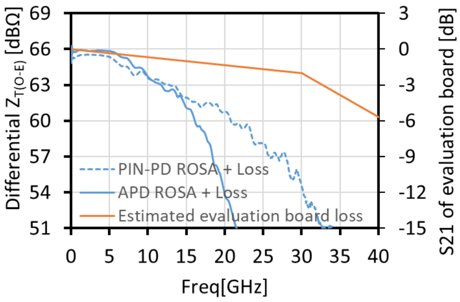


Fig.4. Measured opto-electric impedance $Z_{T(O\text{-}E)}$

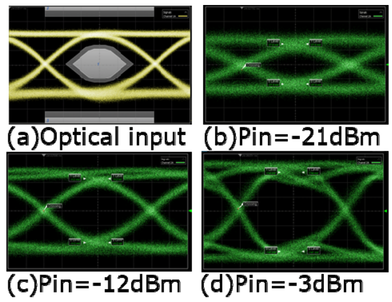


Fig.5. Measured eye diagrams of 25.78-Gbit/s (APD BM-ROSA)

3.2. Receiver burst-mode bit error ratio performance

A setup outlined in Fig.6 (a) was used to evaluate the burst-mode bit error ratio (BER) in back to back configuration. Tx1 is a soft burst transmitter with a wavelength of 1309nm. The extinction ratio of Tx1 is set to 5.0dB for 25.78-Gbit/s and 6.0dB for 10.31-Gbit/s. Tx2 is a loud burst transmitter with a wavelength of 1270nm and extinction ratio of 6.0dB. Two burst signals from both transmitters are combined by a power combiner after these signal powers are adjusted by optical attenuators, and eventually received by BM-ROSA. Fig.6 (b) shows the test format of burst signals. A tested soft burst as a victim follows a loud burst as an aggressor. BER is measured during the payload portion of the soft burst. At the beginning of the soft burst, a fixed preamble pattern is used for the assistance of CDR lock. The period from the end of the loud burst to the beginning of the payload is defined as settling time Ts. Generally, burst-mode receivers have to recover from a signal power transition between two bursts within settling time and receive next payload signal properly. The interval time between two burst signals is defined as a gap time Tg. The maximum Ts is specified as 800ns in 10G-EPON and 50G-EPON. The following all burst bit error performances are measured under Ts=600nsec, Tg=0nsec, PRBS2^{31}-1 as payload pattern and room temperature. A loud burst power is fixed to -3dBm.

Fig. 7(a) shows BER for 25.78-Gbit/s. In this measurement, an output differential signal of BM-ROSA is AC coupled to a bit error detector by 1nF capacitors. Scattered circles and solid lines are measured BERs of APD BM-ROSA and their least squares approximation lines, respectively. A continuous and a burst-mode results are colored in yellow and blue, respectively. Although the settling time Ts is 600nsec, almost zero burst BER penalty was achieved. The minimum optical modulation amplitude (OMA) sensitivity at BER=10^{-2} was -26.0dBm that meets the minimum sensitivity specification of 50G-EPON high power class with at least 1.5dB margin. BER was less than 10^{-12} when input OMA is greater than -18dBm. There was no error even at the highest OMA of -3.0dBm that is equivalent to overload specification of 50G-EPON middle power class. Red triangle marks in Fig.7 (a) show receiver sensitivity specifications in 50G-EPON upstream. The burst dynamic range (loud/soft ratio) to satisfy a pre-FEC error condition of BER<10^{-2} was greater than 23dB for 25.78-Gbit/s.

BER for 10.31-Gbit/s is also measured as shown in Fig.7 (b). In this measurement, we used the same APD BM-ROSA for 25G and added a limiting amplifier between the BM-ROSA and the bit error tester to limit total receiver bandwidth by 10GHz. The definition of a graph legend is the same as Fig.7 (a). As well as 25G BER, almost zero burst BER penalty was confirmed. The minimum average power sensitivities at BER=10^{-3} and 10^{-2} were -30.3dBm and -32.0dBm, respectively. All receiver sensitivity can satisfy both 10.31-Gbit/s upstream specifications of 50G-EPON (red triangle) and 10G-EPON (blue triangle), which are specified at BER=10^{-2} and 10^{-3}, respectively. BER was less than 10^{-12} when the input average power is greater than -24dBm. 26dB burst dynamic range to satisfy a pre-FEC error condition of BER<10^{-2} was confirmed for 10.31-Gbit/s.

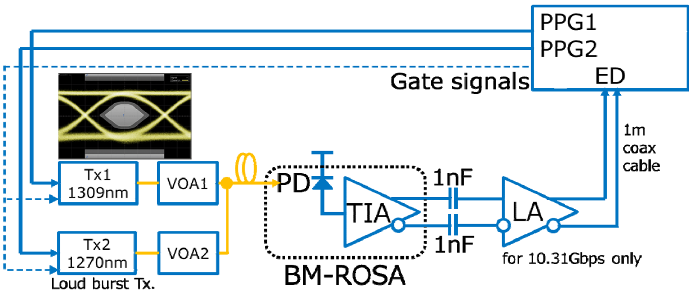
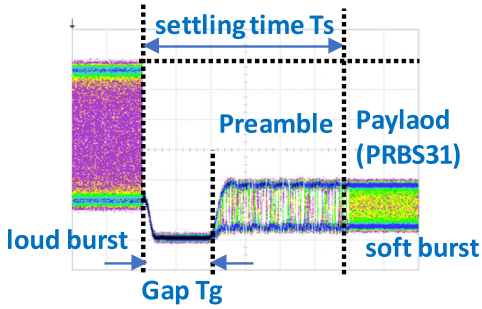


Fig. 6. (a) Experimental Setup for burst BER measurement



(b) Test format of burst optical signals

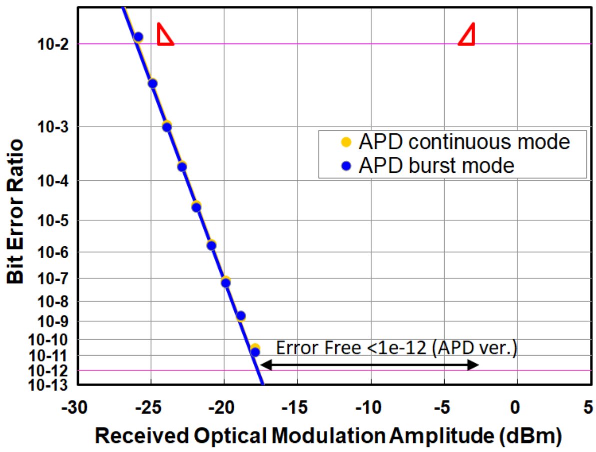
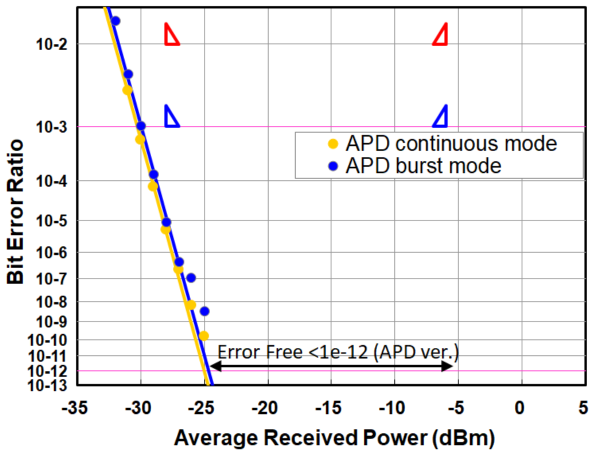


Fig.7. (a) 25.78-Gbit/s BER results



(b) 10.31-Gbit/s BER results

4. Conclusion

In this paper, the 25.78-Gbit/s burst-mode receiver design and burst-mode optical receiver performances in 10G and 25G dual rate operation were presented. The minimum receiver sensitivities at BER=10^{-2} were -26.0 dBm(OMA) for 25.78-Gbit/s and -32.0dBm(ave) for 10.31-Gbit/s, respectively. In addition, very wide burst dynamic range (loud/soft ratio) of more than 23dB for 25.78-Gbit/s and 26dB for 10.31-Gbit/s was achieved, respectively. We have confirmed that these performances satisfy both high and middle power class 50G-EPON upstream specifications for OLT.

5. References

[1] ITU-T G.989.1, "40-Gigabit-capable passive optical networks (NGPON2): General requirements," 2013.
[2] IEEE 802.3ca,"Physical Layer Specifications and Management Parameters for 25 Gb/s and 50 Gb/s Passive Optical Networks",D2.0, 2019
[3] IEEE 802.3, "Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks," 2009.
[4] R. Borkowski1 et al, "Real-Time Burst-Mode Operation of an Integrated SOA-PIN/TIA Receiver for 25 Gbit/s/λ and Faster T(W)DM-PON," ECOC'2017, Tu3G.6, Sept. 2017.
[5] K. Tanaka et al, "25.78-Gbit/s Burst Mode TIA for 50G-EPON OLT," BCICTS 2019 277-FM854.
[6] T. Endo et al, "Highly reliable grown-junction InP/InGaAs avalanche photodiodes for high-speed integrated optical receivers," IPRM 2018, paper Fr3A9-6, (2018).