25Gb/s 3-level Burst-Mode Receiver for High Serial Rate TDM-PONs

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Abstract: We report the first 25Gb/s 3-level modulated BM-RX employing a ¼-rate linear BM APD-TIA and a custom decoder IC. We successfully demonstrated burst-mode sensitivity of -20.4dBm with 18dB dynamic burst-to-burst for 25Gb/s upstream links.

OCIS codes: (060.2360) Fiber optics links and subsystems; (060.0060) Fiber optics and optical communication.

1. Introduction

Access network infrastructure plays a key role in fulfilling the ever-increasing traffic demand and emerging service requirement. Among those solutions, passive optical networks (PONs) are being widely recognized as the most cost-effective technology for access networks. Various time division multiplexing PON (TDM-PON) standards, e.g. GPON and GE-PON, have been proposed by two standard bodies, international telecommunications union (ITU) and institute of electrical and electronics engineers (IEEE) respectively. Meanwhile upstream burst-mode receivers (BM-RX), the most critical physical media dependent (PMD) component of PON systems, have been recently developed up to 10Gb/s [1,2] in parallel with both of the standardization processes.

Due to technology and cost challenges associated with further increasing the serial date rate, current NG-PON2 standard from ITU focuses the development on a time and wavelength division multiplexed (TWDM) PON, i.e., by basically stacking 10Gb/s XG-PONs at 4 or 8 wavelengths. Still, a low-cost single-wavelength upstream beyond 10Gb/s has the potential to serve as a per-wavelength upgrade path for NG-PON2, in line with recent researches on 40Gb/s high serial rate downstream for PONs [3,4].

In this paper we present a first 25Gb/s 3-level modulated BM-RX for high serial rate TDM-PONs. Instead of using non-return to zero (NRZ) format, 3-level BM detection is proposed by employing a ¼-rate APD-based linear BM trans-impedance amplifier (TIA) and a custom duo-binary decoder chip. The proposed 25Gb/s BM-RX relaxes the bandwidth requirement on optical components, esp. the high-speed APDs, and can support a high loss budget of 25.4dB without optical pre-amplification.

2. 25Gb/s 3-level modulated BM-RX

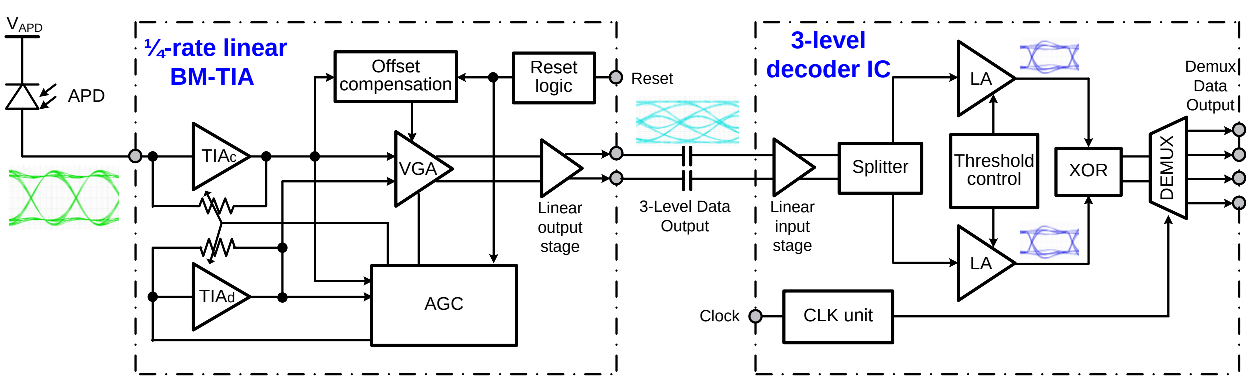


Fig. 1. Block diagram of the 25Gb/s 3-level modulated BM-RX

Figure 1 shows the block diagram of the proposed 25Gb/s BM-RX. The BM-RX consists of two blocks: a linear BM APD-TIA and a 3-level duo-binary decoder IC. Both blocks were designed and fabricated in a 0.13µm SiGe BiCMOS process. The linear BM-TIA is based on the design in [5] but with a trans-impedance gain adapted for the decoder IC and a fine-tuned bandwidth (one-fourth of the upstream data rate). The ¼-rate small-signal bandwidth and linear operation are required for optimal 3-level signal generation. The linear BM-TIA consists of a core TIA TIAc, a dummy TIA TIAd, a variable gain amplifier (VGA), and a linear output stage. At the start of each burst, the automatic gain control (AGC) senses the output amplitude of the TIAc core and set its transimpedance gain within 10ns.The linear BM-TIA also performs a fast offset compensation process. This minimizes the DC offset in the output 3-level signal, and helps reduce the settling time of the decoder IC. The output of the linear BM-TIA is a 3-level current-mode signal and ac-coupled to the 3-level decoder IC.

The subsequent custom decoder IC combines a 3-level signal decoding function and a 1 to 4 deserializer. It first amplifies the input signal linearly to partly compensate the internal loss of the RF splitter. After the splitter the upper and lower eyes are separated and amplified to their logic levels by two limiting amplifiers (LA). No threshold feedback has been realized in this first version decoder IC, so a feed-forward threshold control was implemented instead. The upper and lower logic signals then enter a high-speed digital XOR gate to regenerate the data in NRZ format. Finally the received NRZ data is deserialized into 4 CML outputs for interfacing with lower-speed components off-chip, e.g. FPGAs.

3. Experimental setup and results

The performance of the 3-level APD BM-RX was evaluated using the 25Gb/s experimental set-up as shown in Fig. 2. Two 1.3 μm burst-mode transmitters (BM-TXs) named TX #1 and TX #2, are alternately sending burst packets. At the OLT, the linear BM APD-TIA was integrated with the 3-level decoder IC and the upstream BER was measured at one of the 4 CML output channels at 6.25Gb/s. Finally two branches of BM-TXs were built to emulate the worst TDMA scenario: a strong burst followed by a weak burst with a short guard time. The output optical power of the two BM-TXs can be adjusted by two variable optical attenuators (VOAs), namely VOA #1 and VOA #2 for respectively TX #1 and TX #2. A gated semiconductor optical amplifier (SOA) was used to increase the optical output power of the TX #2 to +5dBm, in order to generate a sufficiently large loud/soft ratio for this experiment. A 10nm coarse wavelength division multiplexing (CWDM) filter was used to remove out-of-band amplified spontaneous emission (ASE) noise from the SOA. The two TX outputs are combined by a 2x2 splitter, and fed to the BM-RX.

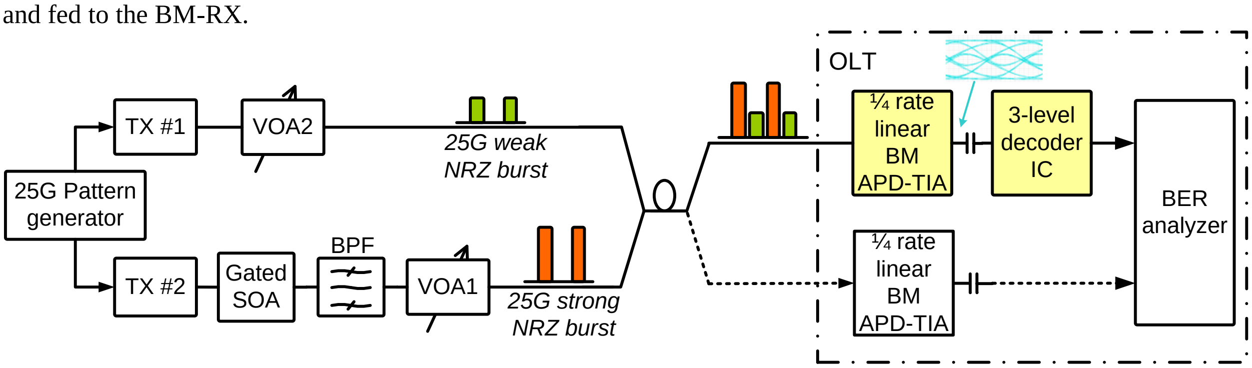


Fig. 2. Experimental setup used to characterize the BM-RX

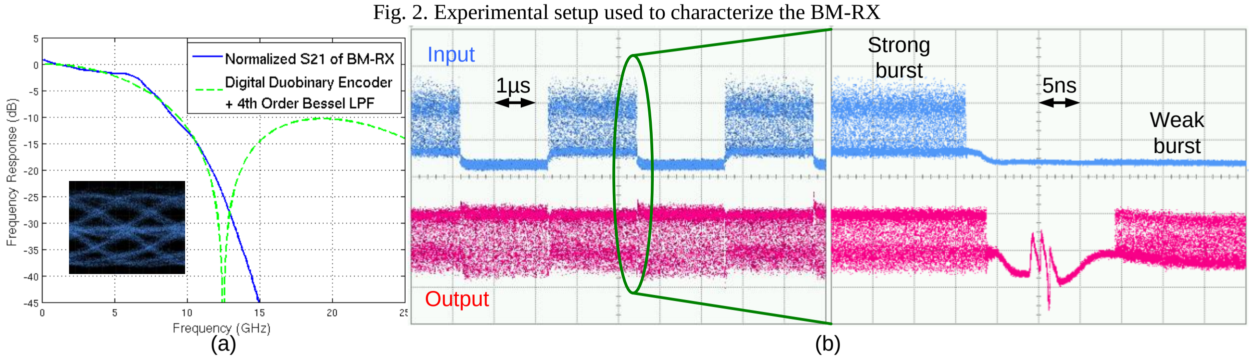
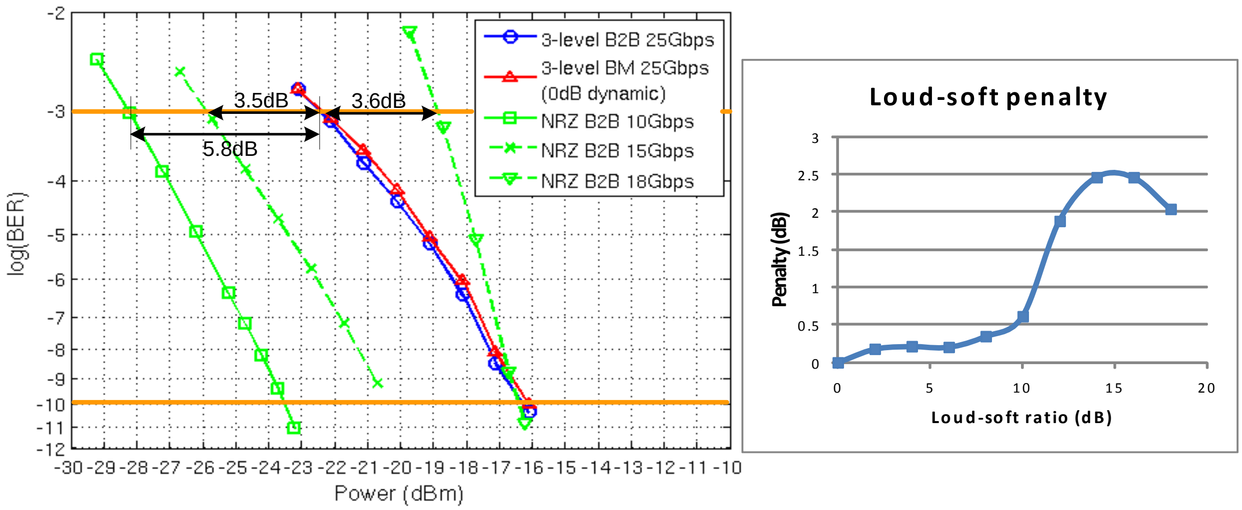


Fig. 3. (a) Measured RF frequency response and 25Gb/s eye-diagram (b) input and output waveforms of the BM APD-TIA

To generate 3-level modulation, the linear BM-TIA should have a bandwidth of roughly one-fourth of the data rate, i.e., ~6.25GHz for 25Gb/s. We measured the differential O/E response of the linear BM APD-TIA assembly with a lightwave analyzer and it shows a 3dB bandwidth of 6.7GHz. The measured BM-TIA S21 response is plotted in Fig. 3(a), together with simulated frequency response of cascading a digital duobinary encoder and a 4^{th}-order half-rate Bessel LPF. Both frequency responses agree nicely in the roll-off shape up to the Nyquist frequency. The measured 25Gb/s eye-diagram (Fig. 3(a)) at the output of the BM-TIA shows clearly the 3-level signal with two open eyes. Fig. 3(b) shows the measured received bursts and the output signal of the BM APD-TIA. The applied 25Gb/s burst packets consist of a 245ns preamble and a 1800ns payload of 2^7-1 pseudo random bit sequence (PRBS) patterns. The guard time between bursts is set to 15ns. As shown in Fig. 3(b) the received weak burst following a strong burst has been recovered within ~10ns.

The measured B2B and BM BER curves are presented in Fig. 4. The APD multiplication factor M was set to ~7. The linear BM APD-TIA was initially characterized with a NRZ signal in a back-to-back (B2B) configuration for various data rates. The BM APD-TIA cannot directly support 25Gb/s NRZ without equalization. We measured the BER curves for 10Gb/s, 15Gb/s and 18Gb/s NRZ, and we found that there was ~9.4dB penalty at 18Gb/s with respect to the 10Gb/s case for a pre-FEC BER of 1E-3. We then measured the BER performance of the proposed 3-level modulation in both B2B and BM scenarios. The measured 25Gb/s B2B sensitivity at a pre-FEC BER of 1E-3 is -22.4dBm and the sensitivity at a BER of 1E-10 is -16.3dBm. We took the pre-FEC threshold of ~1E-3 as the reference because FEC coding is mandatory in NG-PON2 systems in order to maintain its compatibility with existing ODNs. With respect to 18Gb/s NRZ transmission, the 25Gb/s 3-level detection experiences a sensitivity improvement of 3.6dB, which is primarily explained by the reduced 18Gb/s NRZ eye openings due to the higher bandwidth requirement. With two branches of BM-TXs, the BM-RX sensitivity measured on the weak packet emitted by BM-TX #1 was -22.4dBm with a static optical power level (0dB loud/soft). The BM-RX was also assessed in different loud/soft ratios and the measured BM-RX penalties due to the preceding loud burst are shown in Fig. 4(b). There was ≤0.6dB penalty for a loud/soft ratio up to 10dB. The BM penalty was 2dB for the maximum loud/soft ratio of 18dB.



(a) (b)

Fig. 4. (a) Comparison of BER between NRZ and 25Gb/s 3-level modulation (b) BM loud-soft penalty

4. Conclusions

We presented, for the first time, a 25Gb/s upstream BM-RX that utilizes 3-level detection at OLTs. Using a low-cost ¼-rate linear BM APD-TIA and a custom decoder IC, it achieved an excellent RX sensitivity of -22.4dBm without optical pre-amplifier or power-hungry DSP. In the worst case of 18dB power difference between strong and weak bursts, we successfully demonstrated BM sensitivity of -20.4dBm and a loss budget of 25.4dB is therefore compatible for 25Gb/s upstream in high serial rate TDM-PONs.

5. Acknowledgement

The authors would like to thank the support from the European Union FP7 under grant agreement n. 318137 (Collaborative project "DISCUS"), IWT, Special Research Fund of Ghent University, and Sumitomo Electric Devices Innovations, Inc for their professional linear BM APD-TIA Assembly.

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