Prototyping of high speed optical front ends for realization of a GigaPON uplink

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Two prototypes were developed for the challenging physical layer uplink of a GigaPON demonstrator were developed. One prototype contains an intelligent optical transmitter together with high-speed network termination functions at ONT (Optical Network Termination) side. Another consists of a DC-coupled APD-TIA (Transimpedance amplifier) module, a high sensitivity with a wide dynamic range burst-mode receiver with a wide dynamic range, and a fast clock phase alignment device with critical line termination functions at the OLT (Optical Line Termination) side. A high performance 1.25 Gbit/s uplink has been successfully integrated with a complete set of innovative burst-mode Physical Media Dependent (PMD) chips, which is publicly demonstrated for the first time.

Introduction

Sharing the enormous capacity of an optical fiber among a group of subscribers via TDMA (Time Division Multiple Access), PONs (Passive Optical Network) can offer economical broadband access [1]. A recent research activity within the INTEC_design Lab concerns critical high speed building blocks such as 1.25 Gbit/s burst-mode transmitters and burst-mode receivers at both the OLT (Optical Line Termination) and the ONT (Optical Network Termination) side, and their integration and testing together with the high speed digital parts of the NT (Network Termination) and the LT (Line Termination). This work also includes the Burst-Mode Data Recovery (BM-DR), and the Optical Front Ends (OFEs) needed to demonstrate the end-to end performance of an innovative 1.25Gbit/s GPON (Gigabit Passive Optical Network) uplink.

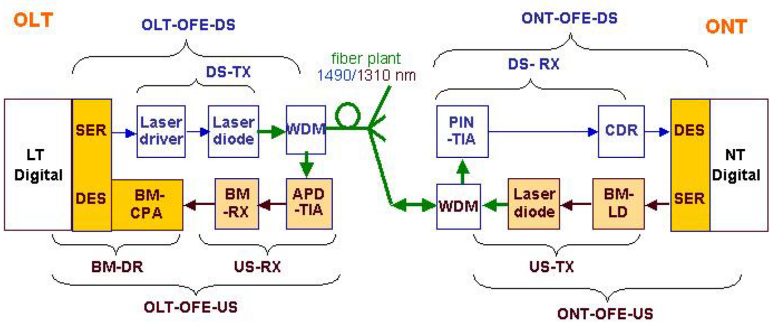

Figure 1 The physical layer building blocks/components

Figure 1 depicts the GPON physical layer as a set of Physical Media Dependent (PMD) building blocks, forming the demonstrator of the EU funded IST-GIANT project. At the ONT side, it consists of a CW Downstream Receiver (DS-RX), an Upstream Transmitter (US-TX) containing a laser diode and Burst-Mode Laser Driver (BM-LD), and a Serializer and Deserializer (SERDES). At the OLT side, it consists of a CW Downstream Transmitter (DS-TX), an Upstream Receiver (US-RX) containing both an

Avalanche Photo Diode-Transimpedance Amplifier (APD-TIA) module and a Burst-mode Receiver (BM-RX), and a BM-DR consisting a Clock Phase Aligner (CPA), a delimiter detector/byte aligner and a SERDES.

Prototype integration

An ONT-OFE daughter board integrating the DS-RX and the US-TX with the SERDES (on the left of Figure 2) was functionally tested at 1.25 Gbit/s. The ONT US part accepts 8 pairs of 155 Mbit/s LVDS (Low Voltage Differential Signalling) parallel data from an FPGA in the GIANT Lab Test Bed (LTB) via a 120-pin connector. The serializer combines the data of these 8 line pairs into a serial 1.25 Gbit/s CML (Current Mode Logic) data stream. Meanwhile, a 1.25 GHz clock together with a burst envelope signal are also generated. The configuration registers inside the chips can be set via an SPI (Serial Peripheral Interface). The BM-LD produces drive current to the laser according to the configuration, and the laser output optical power will be quickly stabilized and accurately tracked on a packet basis.

The OLT-OFE daughter board integrates the DS-TX, the APD-TIA module, the BM-RX and the BM-DR. The OLT-OFE (on the right of Figure 2) was tested successfully. For the OLT US part, the BM-DR sends a time reference signal to the BM-RX to indicate the start of a new burst. Then the BM-RX recovers the amplitude of the input signal from the APD-TIA module and generates an “activity-detected” signal to the BM-DR as well. The CPA of the BM-DR aligns the clock phase with the data on packet-by-packet basis and also performs the byte alignment. After that, the 1.25 Gbit/s data is de-serialized into 8 pairs of 155 Mbit/s LVDS signals.

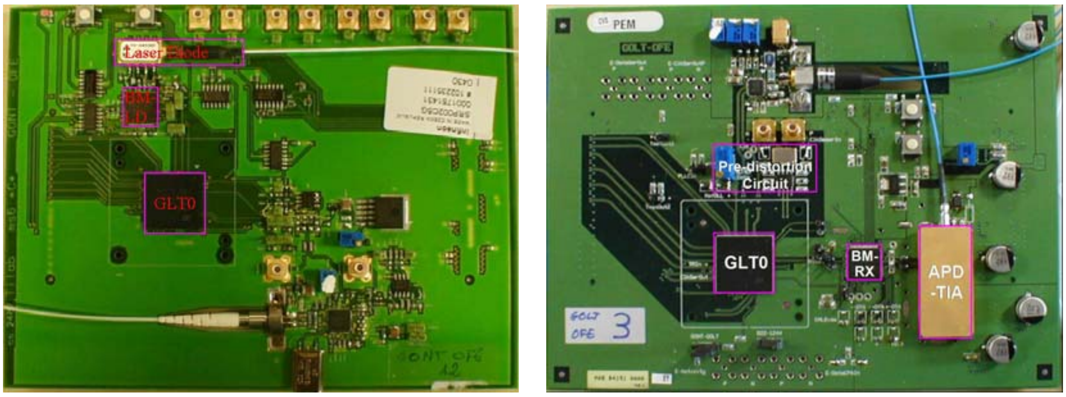

Figure 2 The ONT-OFE and the OLT-OFE prototype

We developed the GIANT LTB for testing burst-mode data transmission at 1.25 Gbit/s speed over an upstream passive optical link. It consists of a DSP board, 2 FPGA boards, a Graphic User Interface (GUI) and the physical layer prototypes under test. Figure 3 depicts the LTB set up to test a complete upstream link. No BER lab instruments are needed for the testing. The upstream link performance was evaluated emulating the real uplink part of the GPON system. The inputs from an FPGA burst pattern generator are serialized to generate both the 1.25 Gbit/s data stream and the burst envelope signal driving the US-TX. To avoid collisions of bursts originating from different ONTs, the ONT Serializer adds a programmable delay with bit accuracy until the launched bursts are aligned with the ongoing traffic at the OLT. The 1.25 Gbit/s data packets are recovered after the BM-DR block and de-serialized to feed an FPGA burst analyzer performing Burst-mode Bit Error Ratio (BBER) measurements.

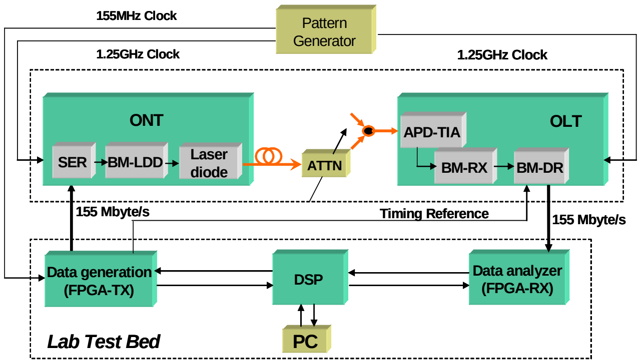

Figure 3 The GIANT Lab Test Bed setup

Evaluation of the prototype performance

The oscilloscope screenshot on the left in Figure 4 shows, from top to bottom, the data and the envelope signal entering the US-TX, and the corresponding optical output generated by the US-TX. It shows that the high-speed serializer and the BM-LD function correctly. According to the ITU-T G984.2 standard [2], the launched optical power is stabilized and an extinction ratio larger than 10 dB is ensured. The screen shot on the right of Figure 6 shows that the eye diagram is compliant with the mask defined in [2]. It was obtained under the condition that the “0” power level was around –13.5 dBm and the “1” around –2.5 dBm.

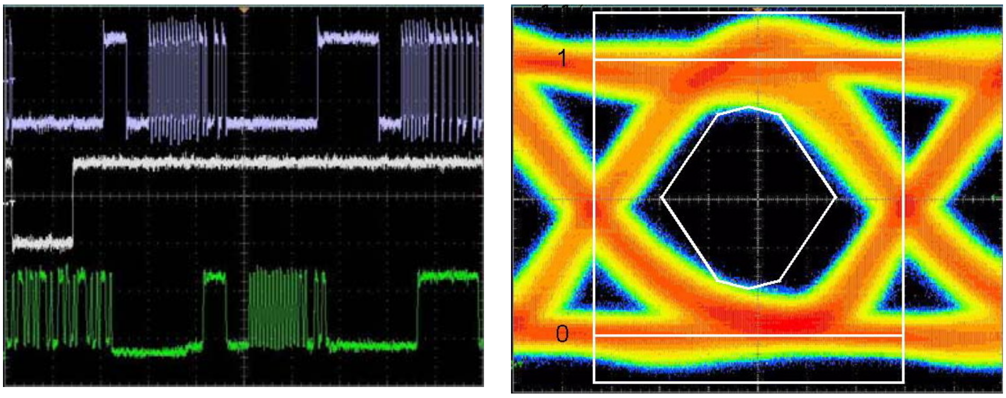

Figure 4 Testing of ONT-OFE

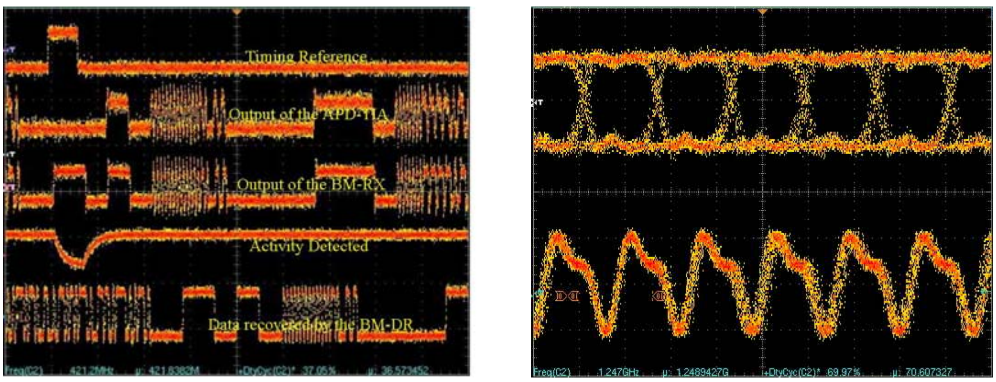

Figure 5 Testing of OLT-OFE

From top to bottom, the screenshot on the left (Figure 5) shows the timing reference signal regenerated by the BM-DR, the APD-TIA output, the BM-RX output and ‘activity-detected’ signal to the BM-RD. The right screenshot shows how the BM-DR correctly recovered the data with a phase-aligned 1.25 GHz clock reference. Figure 6 summarizes the excellent performance obtained from these BBER measurements on the complete link including the ONT-OFE and OLT-OFE prototypes and an Optical Distribution Network (ODN). A sensitivity of –31.7 dBm is achieved with an average launched power of 0.5 dBm, which emulates the case of maximum ODN loss including 15km fiber. An overload of –12 dBm is measured with an average launched power of –5.5 dBm, emulating the case of minimum ODN loss without fiber. When an average optical power of –2.5 dBm is launched into 15km fiber, about 20.9 dB dynamic range (-10 ~ -30.9 dBm) is obtained. Without fiber, this is 21.6 dB (-10 ~ -31.6 dBm).

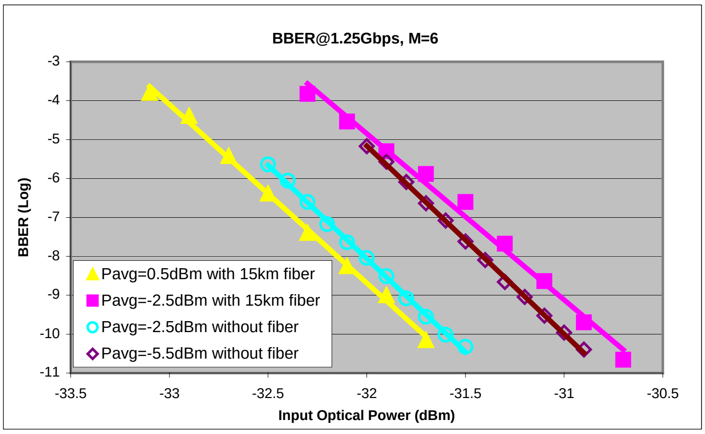

Figure 6 BBER measurement results of the complete uplink @1.25 Gbit/s (APD gain=6)

Conclusion

The test results show that the GPON uplink prototypes exceed the specifications (sensitivity @ –28 dBm and overload @ -13 dBm) recently standardized in ITU-T Recommendation G.984.2 [2] under all conditions.

Acknowledgement

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References

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[2] Gigabit-capable Passive Optical Networks (GPON): Physical Media Dependent (PMD) layer specification, ITU-T Recommendation G.984.2.

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