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Solutions for Budget Increase of Optical Access Network using amplification to design Hybrid Cable TV/GPON system integration working with 1.31/1.49/1.55 pm WDM trans-receiver module

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Abstract: In this article our discussion focused on application of different types of amplifications as the solutions of budget increase for Passive Optical Network (PON) by which the system become useful to work for hybrid Cable TV/ Gigabit capable Passive Optical Network (GPON) system integration. PON is used as last mile access. Several types of amplifiers are employed in order to upgrade PON systems. With the need for increased bit rate, splitting ratio, as well as the reach extension, more optical budget is also required for PON system. The solutions for this budget increase are optical amplification which can ensure the evolution of the access network. Optical network are the best technology which may be deployed to support high bandwidth requirement for transmission of video signal for cable TV. Here, three wavelengths Wavelength Dance Modulation (WDM) transceiver module with a pigtail fiber designed for GPON and Cable TV specifications working integrally are also described which brings good optimum result for the necessary signal communication, especially Video signal. The discussion about Cable TV/ GPON integration system is addressed on duplex transmission measurement of gigabit-capable data and multi-channel video signal. Finally it is shown that use of different amplification may be useful for budget solution to provide service of cable TV through optical network.

Keywords —Cable TV, GPON, WDM, Central Office (CO), optical amplification, optical access network

I. INTRODUCTION

The GPON technology enables us to provide high bandwidth with the facilities of sharing of cost of the infrastructure and so, this technology is cost-effective in terms of civil engineering. The network can meet efficiently with the potential demand for more bandwidth. It also has another advantage that, with the development of new services, it is easily upgradeable with the new technique. Gigabit-capable Passive Optical Network (GPON) is the most useful technology as broadband access network because of unlimited bandwidth characteristic of the PON, having the capability to exploit for high rate data communication used for video signal. Various advantages of GPON like low infrastructure deploying cost, bandwidth efficiency utilization and network service extended capability of GPON make it the automatic choice for the area of application in the field like cable TV transmission.

This kind of application meets a transmission distance of 20 km with complete Fiber to the Curb (FTTC), Fiber to the Building (FTTB) or Fiber to the Home (FTTH) technology. GPON optical network unit (ONU) transceiver used to works on burst mode transmission with ability for upstream data processing and it combines Cable TV applications by Ethernet Internet Protocol data networking for downstream data communication. This article shows the three wavelengths WDM transceiver module and verifies data and video transmission character with current standard specification [1] [2]. Our present work mostly deals with the evaluation of amplification performance of PON system which connects different Remote Nodes (RNs) at various distances [4]. In order to maximize the fiber capacity and full-duplex bidirectional transmission of 1.31/ 1.49/ 1.55 μm WDM signals modulated at around 1.25 Gb/s are employed for GPON with multi channel video transmission system. This paper presents a standard beforehand three wavelengths WDM transceiver module and related parameters especially burst mode items. One of the major issues is the need for more optical budget. Indeed, in order to be cost effective, one specification of the next generation access network is the increased splitting ratio in order to have more users, which implies a higher loss of the system. Moreover, in a migration scenario where the number of

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central offices has to be decreased with metro-access convergence, there is a need for increased optical budget in order to compensate for the losses brought about by the extended reach. There have been several works ongoing for identifying relevant solutions for the access network ([5]-[7]). In this work, we propose to compare amplification solutions based on different technologies, namely the Erbium Doped Fiber Amplifier (EDFA), the SOA (Semiconductor Optical Amplifier), the Remote Optical Pumped Amplifier (ROPA) and the Erbium Doped Waveguide Amplifier (EDWA). The EDFA and ROPA solutions are quite mature and have been deployed in the long haul transmission network for the C band amplification. The SOA is also well developed and adapted for the 1.3µm, 1.49µm and C band windows. However, it has not been a widely used technology since it has much less power than the EDFA and also since it has the disadvantage of having crosstalk when several signals are amplified. The EDWA is only emerging as a potentially compact solution since it can be integrated with couplers. These solutions are analyzed in a GPON migration scenario.

II. CHARACTERIZATION OF AMPLIFIERS

The gain and noise factor of the amplifiers are given on Fig. 1 to 4. For the ROPA, the pumping was performed in a co-propagating mode. It can be seen that the maximum gain is available from the EDFA which can be as high as 45 dB. For all the amplifiers the noise factor is close to 5 dB except for the SOA where the NF is more than 8 dB. The wavelength dependence of the gain is observed for all the amplifiers, as well as gain saturation when the input power increases. The ROPA gain (25 dB) is not as high as the EDFA gain due to the attenuated pump power incident on the erbium doped fiber. The EDWA and SOA have a gain of 20-25 dB. The curves show that all four amplifiers are suitable for amplification from 1530-1570 nm where Coarse Wavelength Division Multiplexing (CWDM) can be applied for upstream and downstream transmission. Now from the Fig. 1 to 4 the comparison of the amplification of the four different amplifier components may be observed and in the next section we will discuss about the architecture for the budget extension.

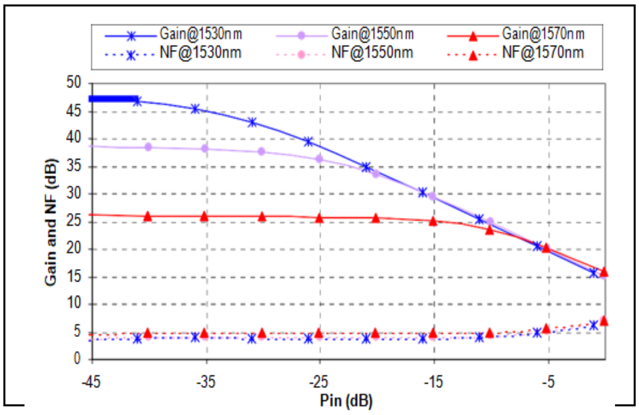

Figure 1. Gain and noise factor of EDFA

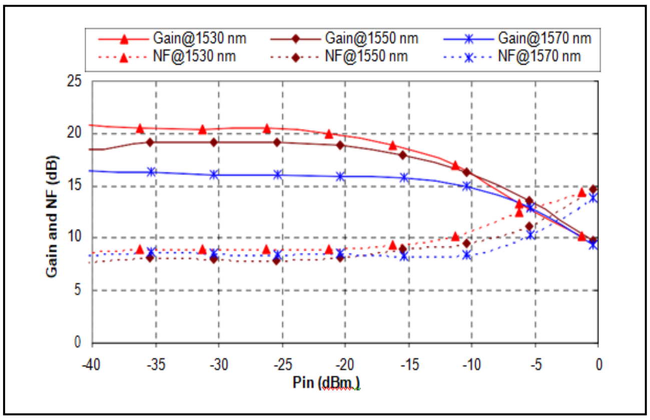

Figure 2. Gain and noise factor of SOA

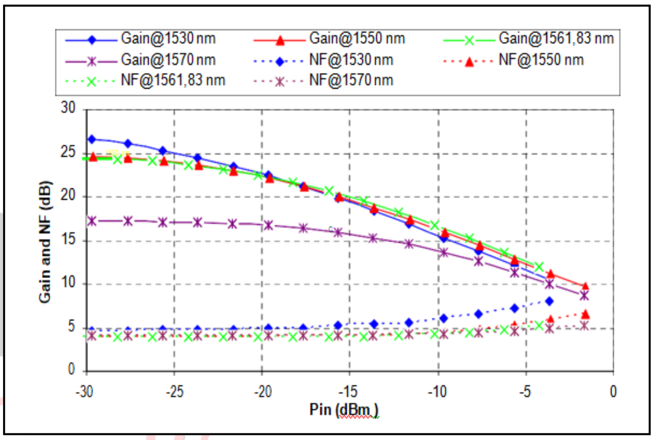

Figure 3. Gain and noise factor of ROPA.

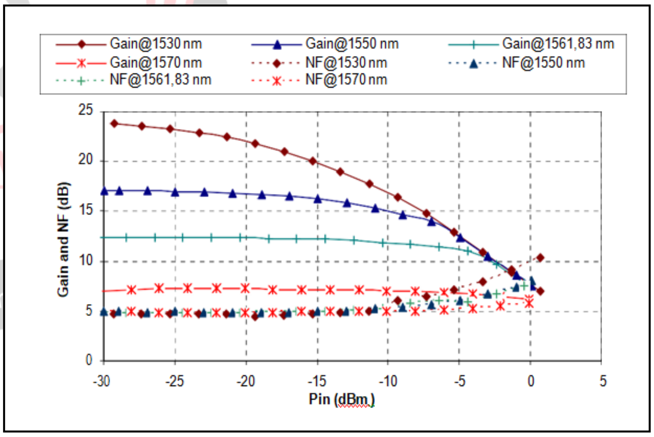

Figure 4. Gain and noise factor of EDWA.

III. ARCHITECTURES FOR BUDGET EXTENSION

Here Fig. 5 shows a GPON architecture which can be implemented with a splitting ratio of 64 obtained by two 1x8 coupling stages. The reach of this architecture is 20 km and the optical budget available is 13 – 28 dB which corresponds to the class B+ standardized GPON. Figure 6 shows the same architecture but with the implementation of amplifiers as booster and pre-amplifier at the central office location. This scheme enables optical budget increase with the advantage of keeping the network passive. Fig. 7 and 8 show in-line amplification schemes, namely unidirectional amplification where two amplifiers

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are required one for each direction of transmission and bidirectional transmission scheme where a single amplifier can perform bidirectional transmission. The ROPA enable the network to remain passive also in the in-line amplification scheme. The amplifiers were tested in all configurations, except for the ROPA which was evaluated only in the in-line configuration. Also, the bidirectional architecture was only applicable to the SOA. The experiment was carried out using a directly modulated DFB laser as emitter with continuous 2^7-1 pseudorandom binary sequence and with an extinction ratio of 13 dB. The bit rates of the upstream and downstream transmissions were 1.25 and 2.5 Gbit/s respectively. The receiver was an avalanche photo diode with a sensitivity of -30 dBm at a bit error rate (BER) of 10^{-9}. The signal wavelengths were 1550 nm downstream and 1570 nm upstream

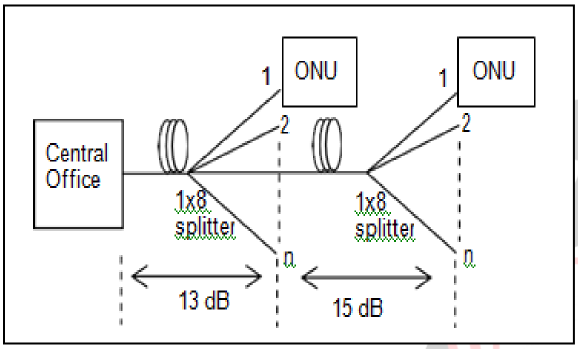

Figure 5. GPON architecture with 28 dB losses.

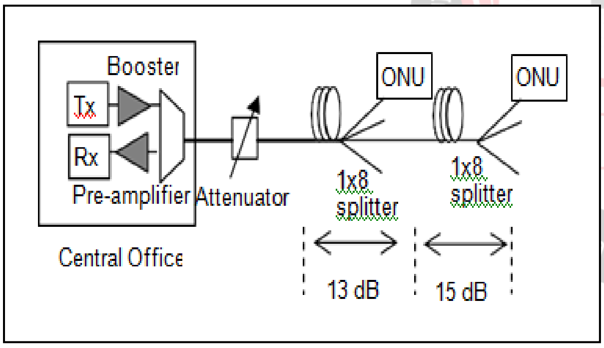

Figure 6. Booster and pre-amplifier configuration.

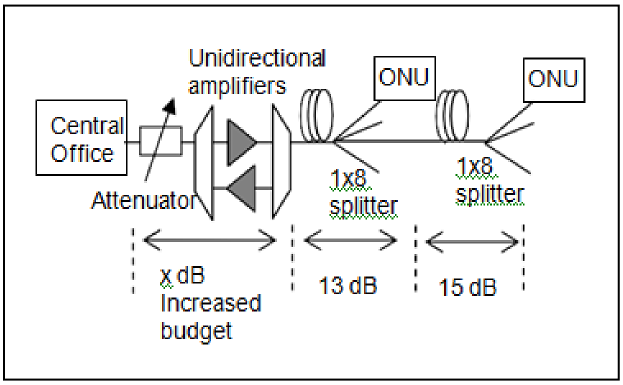

Figure 7. In-line amplification with unidirectional solution.

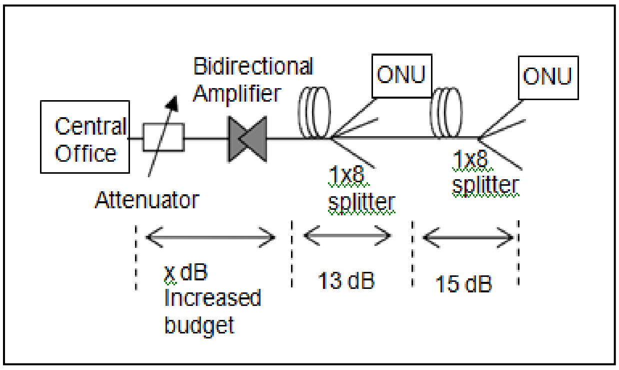

Figure 8. In-line amplification with bidirectional solution.

In this paper, we also deploy the three wavelengths WDM transceiver module as GPON ONU triplexer transceiver module. The transceiver module package outline and footprint are based on the industry standard 2*10 Pin-Through-Hole (PTH) and 75 ohm SMB connector. The transceiver module that consists a burst mode optical transmitter, continuous mode optical receiver, and optical CATV receiver with a SMB output. The GPON Trans- receiver module setup for measurement is shown in Fig. 9.

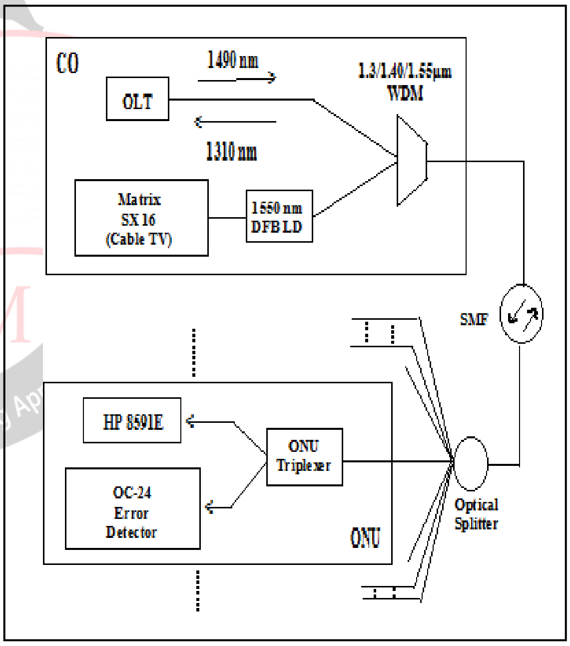

Figure 9. The GPON Trans- receiver module setup

The 1.31 km wavelength light is used for transmitting the signals from user's homes to a CO. On the other hand, the analog (graphic/video) and digital (voice/data) signals are transmitted from the CO to the user's homes with 1.55 pm and 1.49 pm light respectively. The optical transport networks make use of wavelength- division multiplexing (WDM) technology. The use of different types of splitters (splitters having different split ratio) and erbium doped fiber amplifiers (EDFAs) enables long-reach PON to provide enormous bandwidth over large distance [8, 9], but this may also deteriorate receivers bit error rate (BER)

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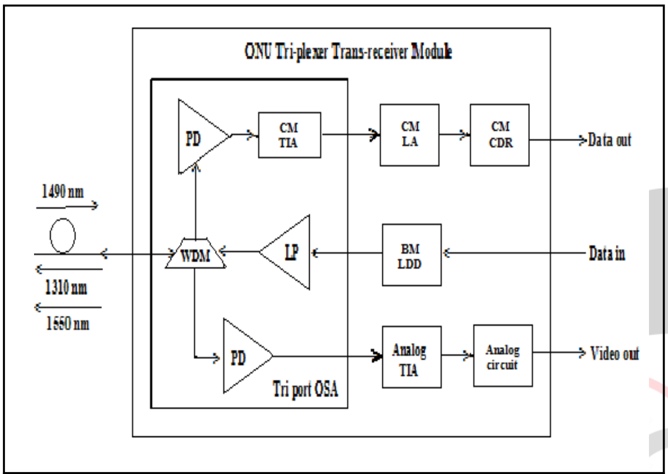
performance. By the way, upstream power penalty due to branches and simultaneously transmission of the on/off performance challenges light source and driving technique.

To achieve all criteria, the GPON ONU tri-plexer transceiver module consists of a bidirectional tri-port optical subassembly (OSA), a burst mode laser diode driver (LDD), a continues mode limiting amplifier (LA), a continues mode clock data recover (CDR), a system burst mode control mechanisms, an analog trans-impedance amplifier (TIA) and an analog circuits all compact integrated as illustration in Fig. 10.



CDR: Check and Data recovery LA: Limiting Amp.
CM: Continue Mode control LD: Laser Diode
LDD: Laser Diode Driver PD: Photo Diode
BM: Burst Mode control; TIA: Trans-impedance Amp.

Figure 10. Functional block of the GPON ONU tri-plexer Trans- receiver module setup.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

PON system consists with the optical line terminal (OLT) at the CO, distribution fiber, optical distribution network (ODN) and an ONU at the subscriber's premises. The maximum range of the network lies from 20 km and 64 physical ONU's can be supported by deployment of the optical splitter. Communication from the CO towards the subscribers is entitled as downstream traffic, the opposite direction is called as upstream traffic and both direction communications are possible using Time Division Multiple Access (TDMA) transmit signals towards CO at a wavelength of 1310 rim. In PON system specific time slots are allocated for the transmission and reception of data by a subscriber. A Cable TV having an extra downstream channel in the 1550-1560 rim range is possible to be used to bring high capacity video services towards the customers. In between two data burst, the ONU transmitting power (Tx) must keep silent and may not launch any optical power into the channel and avoid disturbing signals transmitted by other ONU's. To balance the BER among ONUs and to reduce the variance the BER performance of the channel need to be calculated and applied in the system

In order to keep the upstream transmission efficiency high, the ONU Tx must be able to switch on/off the laser within a few nanosecond or bits preceding the upstream data [4]. In other words, the transmitter in the upstream direction must turn on/off quickly enough to be equal to the burst envelope signal. Here, the main problem is the ability of laser driver's that can drive the laser up to the bias level in a sufficient duration. Fig. 3 shows the burst envelope signal (upper pattern sequence in the figure) that enables the bias level (lower pattern sequence in the figure) is applied to enable the driver to test the transmitter actual T_N timing. The turn on and turn off of the burst are shown in Fig. 11.

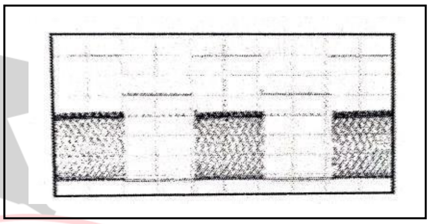


Figure 11: Burst Envelope Signal.

The budget extension obtained from the different amplifiers is shown in table 1. With central office localized amplifiers as well as the in-line configuration, the EDFA was the most interesting solution giving the highest gain. This is due to the higher saturation power and low NF. The SOA is advantageous in that it can be used in a bidirectional mode offering 15.5 dB gain even though cross gain modulation is a source of noise. Despite the fact that the ROPA was based on EDFA technology, the gain obtained was only 11.5 dB since the pump power was attenuated in the link in the same way as the signal. The EDWA was interesting as an in-line amplifier with 11.5 dB gain and can be implemented in the same way as the ROPA. Moreover, it has the additional advantage of being compact and can potentially be integrated with couplers.

Table 1. Budget extension for the amplifiers.

	Booster and pre-amplifier	Unidirectional in-line Amplifier (dB)	Bidirectional in-line Amplifier (dB)
SOA	2	16	15.5
EDFA	10.6	32.8	NA
EDWA	3	11.5	NA
ROPA	NA	11.5	NA

It must be noted that the amplifier used were not optimized for booster and preamplifier configuration. Still they gave an indication of the possible problems arising while used in these configurations. The EDFA gave the best result in the

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booster and preamplifier configuration due to higher saturation power and also due to low noise figure which is a prerequisite in the preamplifier configuration. Both the SOA and the EDWA gave a budget increase of only 2 and 3 dB respectively. In the in-line configuration, the EDFA provides the best result as the booster and preamplifier configuration because of the higher saturation power and also due to low noise figure which is an essential prerequisite in the preamplifier configuration. Both the SOA and the EDWA gave a budget increase of only 2 and 3 dB respectively. In the in-line configuration, the EDFA gave also the best results due to the higher value of the gain. Though SOA and EDFA as amplifier solutions are interesting for the above-mentioned reasons, they need in-line powering which can be a drawback in case there has been no provision for electric power. In that case, the ROPA solution becomes attractive and can offer a gain of 11.5 dB. Though the technology is the same as the EDFA, the limited gain arises from the fact that the pump power incident in the erbium doped fiber is attenuated as the signal power. In case of the migration preview, where the metro and access networks are merged together to avoid central offices (CO), the previous CO location may be an amplifier site. In that case, power supply considerations may no longer be major hurdles so that EDFA offering the best gain value can be installed.

Based on the analysis result, the delay of modulation signal needed to be as long as 16-bits in 1.25 Gb/s (12.8 ns) to let the transmitter turn on fully. In addition, the transmitter just needs 16-bits time in 1.25 Gb/s (12.8 ns) to turn off completely. The bias level is reached within 12 pre-bias bits (9.6 ns).The disabling of the bias takes about 10 ns. The maximum allowed enabling and disabling time of the transmitter are specified in ITU-T G.984.2 as 16 bits each at 1.25 Gb/s. The measured results in the system are provided in Table II. Note that The sensitivity of the receiver was -25 dBm.

Table II. Specifications of GPON – ONU trans-receiver module

Parameter	Unit	OES	Specifications Reference [1]
Bit Rate (Upstream and Downstream)	Gb/s	1.25/ 1.25	1.25/ 1.25
Transmission Distance	km	20	20
Minimum Extinction Ratio	dB	>10	10
Burst Transmission turn ON/ OFF time	ns	<12/12	12.8/ 12.8
Bit error ratio	N/A	10^{-12}	10^{-12}
Minimum sensitivity	dBm	-25 (Typ)	-25
Minimum overload	dBm	-2 (Typ)	-4
CSO/ CTB/ CNR	dB	60/63/48	53/53/43

In Fig. 9, a NTSC Matrix SX-16 signal generator was used to feed 80 subcarriers into a directly modulated Tee-bias transmitter with a central wavelength of 1550 rim and an optical modulation index (OMI) of ~3.5 % per channel. Fig. 11 shows the measured CNR, CSO and CTB values for AM-VSB Cable TV under NTSC channel number (CH2CH75).

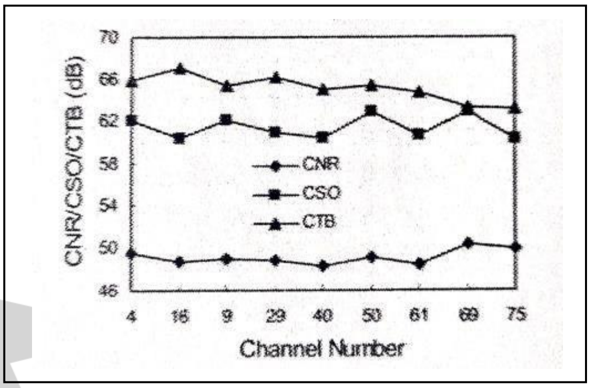

Figure 11: CNR, CSO, CTB values of cable TV.

The CNR values of 48 dB for the system can satisfy the fiber optical CATV specifications, it can be attributed to the appropriate received optical power at the receiver site. For the better performance of the AM-VSB optical receiver, the received optical power need to be kept (-3 ~ +3) dBm, whereas the received optical power for the analog optical receiver is -1.3 dBm. As to CSO and CTB performs the CSO values (≥63 dB) for the system also can satisfy the fiber optical cable TV specification.

V. Conclusion

In conclusion this can be stated that with a view to upgrade the GPON by budget increase, several solutions for the amplifier have been compared here namely as EDFA, ROPA, SOA and EDWA. First we characterized the amplifiers with respect to the gain and NF with showing their implementation in different architectures: in-line, booster and pre-amplifier, and bidirectional schemes. The extended optical budgets in different scenarios have been measured. The appropriate solution depends on the availability of power supply and gain needed. Further to serve the purpose of service provides to cable TV, the three wavelength module for GPON and cable TV applications including the systemic evaluation on burst mode data transmission in PON network is practicable. With verification of the amplification performance of the communication line the video signal or the three wavelength hybrid WDM transport system with cable TV and GPON video and digital applications can be demonstrated with excellent performance.

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