



Article Lossless WDM PON Photonic Integrated Receivers Including SOAs

Pantea Nadimi Goki ^{1,*}, Muhammad Imran ¹, Claudio Porzi ¹, Veronica Toccafondo ², Francesco Fresi ², Fabio Cavaliere ³ and Luca Potì ²

- ¹ TECIP Institute Scuola Superiore Sant'Anna, 56124 Pisa, Italy; m.imran@sssup.it (M.I.); c.porzi@santannapisa.it (C.P.)
- ² CNIT Photonic Networks and Technologies Nat'l Lab, 56124 Pisa, Italy; veronica.toccafondo@cnit.it (V.T.); francesco.fresi@cnit.it (F.F.); luca.poti@cnit.it (L.P.)
- ³ Ericsson, 56124 Pisa, Italy; fabio.cavaliere@ericsson.com
- * Correspondence: p.nadimigoki@santannapisa.it; Tel.: +39-327-157-9141

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Abstract: The role of a semiconductor optical amplifier (SOA) for amplifying downstream traffic at optical network terminals (ONT) within a silicon-photonics integrated receiver in a high capacity passive optical network (PON) is investigated. The nearly traveling wave SOA effects are evaluated by considering fabrication and link loss constraints through numerical analysis and experimental validation. The impact of hybrid integration of a SOA chip on a silicon on insulator (SOI) photonic chip using the flip chip bonding technique on SOA design is evaluated through numerical analysis of a multi section cavity model. The performance of the proposed ONT receiver design employing twin parallel SOAs is evaluated experimentally on a 32×25 Gb/s OOK WDM transmission system considering cross gain modulation (XGM) and amplified spontaneous emission (ASE) constraints. The XGM impact is evaluated through 32 channel wavelength division multiplexing (WDM) transmission and a likely PON worst case scenario of high channel power difference (~10 dB) between adjacent channels. The impact of ASE is evaluated through the worst-case polarization condition, i.e., when all of the signal is coupled to only one. Successful transmission was achieved in both worst-case conditions with limited impact on performance. SOA results indicate that a maximum residual facet reflectivity of 4×10^{-4} for the chip-bonded device can lead to a power penalty below 2 dB in a polarization-diversity twin SOAs receiver.

Keywords: integrated semiconductor optical amplifier; 5G networks; passive optical networks

1. Introduction

Technological innovations are continuously introducing novel applications that greatly influence the way humans interact, make decisions and conduct businesses. It is estimated that traffic from wireless devices will account for more than 63 percent of total IP traffic by 2021 [1]. These applications demand enhanced capacity, coverage, low latency and high quality of service (QoS) from wireless as well as optical access networks. Optical fiber distribution networks (ODN) in already installed passive optical access networks (PON) can be exploited to cope with diverse traffic demands originated from 5G mobile fronthaul, backhaul and large capacity short reach point to point links [2]. Designing low cost, low complexity and high capacity short reach PON access links using ODNs is a challenging task due to high link loss, particularly for optical network terminals (ONTs) at the customer premises. ONT transmitter complex modulation formats can provide higher capacity (>10 Gb/s) but keeping conventional non-return-to-zero (NRZ) modulation is a better option for low complexity and cost. However, conventional PIN-TIA receivers have low sensitivity, therefore power budget and higher capacity cannot be managed at the same time. Alternatively, receivers employing avalanche photodiodes (APD) and TIA have been demonstrated for 25 Gb/s TDM-PON links, but these kinds of APDs are not yet widely commercially available [3,4]. In this scenario, optical amplification becomes essential. Erbium doped fiber amplifiers (EDFA) at the optical line terminal (OLT) can amplify all downstream traffic, but integrated semiconductor optical amplifiers (SOAs) are a better choice at the ONTs due to having a smaller footprint despite relatively higher noise. Moreover, SOA-PIN/TIA receivers have a relatively large margin in terms of bandwidth improvement compared to APDs and can be realized at any telecom wavelength [5]. A recent study about the applicability of SOAs in PONs concluded that managing the optical power budget (>29 dB) for greater than 10 Gb/s PON such as 25 Gb/s and 50 Gb/s while using state-of-the-art low-cost components is challenging and will require pre/booster or both amplifiers [6]. Monolithic III-V photonic integrated pre-amplified optical receivers that integrate SOA and photodiodes [7,8] and TIA [9] have already been demonstrated for up to 40 Gb/s high speed PONs. Among the different photonic integration technologies, silicon photonics is particularly promising for ONT transceivers due to large scale integration capability, low cost, and reliability. Hybrid integration of SOA and mode locked laser in an eight channel WDM silicon photonic transceiver using edge coupling was recently reported in [10]. Nevertheless, hybrid integration of InP-based SOAs on silicon-on-insulator (SOI) substrates using flip-chip bonding [11,12] techniques poses additional challenges in the design of SOA devices, as it affects important parameters such as effective reflectivity, coupling efficiency, and gain ripples.

Design of SOA devices combined in photonic integrated circuits (PICs) required precise numerical modeling and optimization of existing models. Several numerical models have been proposed for calculation/estimation of SOA parameters and operational behavior [13,14]. Vagionas et al. [15] presented experimentally validated SOA numerical modeling techniques applicable to a wide range of SOA devices by using the transfer matrix method (TMM). In [16], they reported an optimized SOA model using the transmission line matrix (TLM) method to simulate light propagation through the active region of SOA. Shawki et al. described a theoretical model of the SOA time domain oscillation dynamics, used for the simulation of the oscillation dynamics in the SOA-based random laser [17]. A wideband steady-state model of a strained MQW-SOA has been described in [18], which uses an asymmetric broadening function in the material gain and additive spontaneous emission calculations. In [19], a numerical model was reported for the simulation of all nonlinear effects of the SOA. All these models proposed to optimize the operating conditions and improve SOA design, either stand-alone or on chip, for different applications. Depending on the application, SOAs are operated either in linear regime, as in-line amplifiers in optical communication networks [20,21] or in nonlinear regime, as all optical logic gates [22], all-optical switching [23] and wavelength conversion [24]. SOA performance has been investigated in terms of input signal with different modulation formats, different input pulse shapes [25,26] and nonlinear pulse propagation [27].

In this paper, we propose an architecture of a lossless polarization insensitive hybrid photonic integrated WDM PON ONT receiver that employs SOAs. The proposed SOAs not only compensate the link loss but also compensate the on-chip losses. Dual polarization grating couplers and the twin parallel SOA structure provides polarization insensitive design. SOI based tunable micro-ring filters are proposed to drop the relevant wavelength. We investigate the design of a SOA device for bidirectional 32×25 Gb/s short reach optical access links through numerical simulation modelling. The optimum SOA device parameters and dimensions are evaluated under ODN link loss and integrated ONT receiver fabrication constraints on a reference architecture. Steady state and dynamic analysis are also performed to evaluate WDM transmission performance. We also validate our model experimentally, using commercial SOAs in realistic working conditions. The impact of cross gain modulation (XGM) and amplified spontaneous emission (ASE) on receiver performance is also evaluated experimentally in worst case power and polarization imbalance conditions.

2. Lossless WDM PON Architectural Model

The lossless WDM PON architectural model considered for simulation and experimental investigation in this work is shown in Figure 1. The architecture consists of generic PON network elements; OLT, ODN and ONT with an additional proposed photonic integrated receiver including twin parallel SOAs. The architecture can support 32 bidirectional C-band DWDM channels that are transmitted at 25 Gbit/s with 50 GHz-interleaved downstream/upstream channel spacing. The OLT consists of arrays of transmitters and receivers, mux/demux and pre- and booster-EDFAs. The ODN length is 15-20 km and split ratio is 32. To maintain compliance to safety class 1M, the maximum overall output power considered for the OLT booster amplifier is 21 dBm, corresponding to up to 6 dBm per channel. Considering 2 dB for circulator and band split loss, the reference launch power per channel is 4 dBm. The overall expected loss including the ODN, circulator and band splitter (at receiver) is expected to be about 25–30 dB considering the typical loss for fibers and passive components. The ONT has a tunable transmitter for upstream and an integrated receiver. At the receiver, the WDM multiplexed channels are coupled to the SOA and one of the channels is dropped using a relevant micro-ring resonator based tunable filter before detection and conversion into output electrical signal [28]. Receiver sensitivity is considered to be -16 dBm and target optical signal-to-noise ratio (OSNR) is 19 dB. A polarization insensitive scheme for the integrated receiver can be realized by exploiting twin parallel SOAs and filters: the optical signal is coupled to the photonic integrated chip through dual polarization grating couplers (GC) [29], separating the transverse electric (TE) and transverse magnetic (TM) modes over two different waveguides feeding two twin parallel SOAs. It is assumed that SOAs are placed in the SOI trench using the flip-chip technique. The light between the SOA and other silicon components is coupled through a spot size converter. The SOA is designed to compensate the link, coupling and on-chip losses.



Figure 1. Lossless WDM PON architecture with proposed photonic integrated receiver. All link, coupling and on-chip losses are compensated by twin parallel integrated SOAs in the receiver. OLT: optical line terminal, ODN: optical distribution network, ONT: optical network terminal, TF: tunable filter.

3. SOA Design, Modelling and Analysis

Due to unavoidable non-perfect mode matching at the interface between the spot-size converter and the SOA, the usual travelling-wave assumption for the amplifier is no longer strictly valid, and even small reflections need to be taken into account. In this work we consider a nearly traveling wave (NTW) semiconductor optical amplifier [30] design for 16.5 dB gain at peak wavelength, large gain bandwidth of around 150 nm, and <1 dB gain ripple. Both steady state and dynamic analysis is performed for optimum SOA design using a parabolic gain model.

Under proper forward biasing of the device, amplification occurs in the active region of the SOA, so that the signal experiences a single pass gain $G_{sp} = \exp(gL)$, where g is the net gain per unit length which includes the material gain coefficient per unit length $g_m = a(n - n_0) - a_2(\lambda - \lambda_p)^2$, being *a* and a_2 the differential gain coefficient and gain constant, respectively, *n* and n_0 the injected and transparency carrier densities, respectively, and λ_p the peak gain wavelength [31]. The amplification factor for a resonant amplifier is defined by [30,32]:

$$G = \frac{(1-R_1)(1-R_2)G_{sp}}{\left(1-G_{sp}\sqrt{R_1R_2}\right)^2 + 4G_{sp}\sqrt{R_1R_2}\sin^2(\phi)}$$
(1)

where φ is the total single-pass (carrier-dependent) phase shift, and R_1 and R_2 are facet reflectivities. The NTW regime of operation for the amplifiers is defined as the condition for which the gain ripples ΔG are below 3 dB, which requires residual facet reflectivities (RFR) such that $G_{sp} \sqrt{R_1 R_2} \le 0.17$ [30]. Figure 2 shows the simulated spectral characteristic of the amplifier gain, for which the gain ripples due to residual facet reflectivities are within about 0.3 dB. In this simulation, the SOA single pass gain G_{sp} is about 16.5 dB, and facet reflectivities are $R_1 = R_2 = 4 \times 10^{-4}$. The RFR is such that $G_{sp} \times R = 0.017$, corresponding to $\Delta G = 0.3$ dB, which is in good agreement with the experimentally measured gain profile.



Figure 2. Simulated semiconductor optical amplifier (SOA) gain profile, with inset showing a magnified ripple in the center part of gain profile with gain ripple (ΔG) of 0.3 dB, and FSR ($\Delta \lambda$) of 0.2 nm.

In order to extrapolate relevant parameters to be used in the simulation, we performed measurements from a real device. In particular, the active region length has been obtained from the measured free-spectral range (FSR) of the ASE ripples as [33]:

$$L = \frac{\lambda_0^2}{2\overline{n}\Delta\lambda} \tag{2}$$

where λ_0 is the central wavelength (1500 nm), \overline{n} is the average semiconductor refractive index and $\Delta\lambda$ is the FSR (0.2 nm). Since the ASE is proportional to the amplifier gain (*G*), the gain ripple can be directly measured on the ASE spectrum [34]. The active region length was obtained by measuring the wavelength spacing between two maxima of the ASE spectrum ripples. The gain profile is shown in Figure 3 together with the simulated one; the peak gain of 16.5 is measured at 1500 nm and the gain at 1550 nm is around 15 dB. The simulated curve is in good agreement with the measured one in the region above the peak wavelength (i.e., around the operating wavelength of 1550 nm), whereas there is little

difference between the measured and simulated gain profile below the peak wavelength. Besides the obvious approximation introduced by the parabolic model, this mismatch is also ascribed to the gain tilting effect in the SOA under the broadband light injection used for the measurement. Furthermore, as the wavelength is further lowered from the peak, the measurement is dominated by the noise floor and sensitivity of the system, due to the limited amount of spectral power from the broadband ASE source. This causes the observed inversion in the expected gain drop at short wavelengths.



Figure 3. Simulated (blue) and experimental (red) SOA gain profile.

The SOA gain as a function of input power was also investigated at a wavelength of 1550. The small-signal gain of the SOA device is measured to be 15.25 dB. The gain reduction characteristic as a function of input power due to carrier depletion in the active region has also been measured, providing a saturation input power P_{in}^{sat} , at which the gain is reduced by 3 dB, of 5.2 dBm. Signal distortion will occur when the output optical power becomes comparable to the saturation power of the amplifier (P_{sat}) [35,36], defined by:

$$P_{sat} = \frac{h\vartheta \ \sigma_m}{\Gamma \tau_c a} \tag{3}$$

where *h* is the Plank constant, *v* is the optical frequency, $\sigma_m = W.d$ is the active region cross section, where *W* and *d* are its width and thickness, respectively, Γ is the optical confinement factor, τ_c is the carrier life time and *a* is the already introduced differential gain coefficient. By using the following equation, the SOA gain as a function of input power was obtained [37]:

$$G = G_0 \cdot \exp\left((1 - G)\frac{P_{in}}{P_{sat}}\right) \tag{4}$$

where G_0 is the (small-signal) unsaturated amplifier gain, and P_{in} is the input amplifier power, which can be defined as a function of output power $P_{in} = P_{out}/G$ where P_{out} is the output amplifier power. Figure 4 shows the simulated and the experimentally measured gain saturation characteristics for a wavelength of 1550 nm at an injection current of 500 mA. The simulation results are in good agreement with the experimentally measured gain values. It should be noted that the device used in the experiment was a relatively dated one. Current SOA technology is able to provide similar values of small signal gain and output saturation power with driving current in the order of 200 mA.



Figure 4. SOA gain as a function of input power. Simulation (solid line) and measured (dots) for wavelength = 1550 nm.

The dynamic model used to simulate the NTW SOA is similar to the model used in [38], which is based on the numerical solution of the rate equation for carrier density. The model can be easily updated to include nonlinear gain compression terms [15] to investigate operation under strong saturation regimes as well. For the modal gain, a fitted parabolic model was used:

$$g = a(n - n_0) \left(1 - \left[\frac{\frac{c}{\lambda} - \frac{c}{\lambda_{gap}}}{c_v [n - n_0]} - 1 \right]^2 \right)$$
(5)

where c_v is a parameter related to the bandwidth of the modal gain, and λ_{gap} is the band-gap optical wavelength. To perform dynamic simulations, the SOA was divided into a sufficiently large number of sections, so that the carrier concentration density within each section can be considered constant. Starting from the first section, where the input signal is considered, the solution of the time-dependent carrier rate equation for each section is used to calculate the signal at the input of the subsequent section. To solve the rate equations of each section, a standard ordinary differential equation (ODE) is used. The SOA model parameters used for simulations are presented in Table 1.

Symbol	Description	Value	Unit
λ_p	Peak wavelength	1500	nm
λ_{gap}	bandgap wavelength	1655	nm
$R_1 = R_2$	Facet reflectivities	4×10^{-4}	_
\overline{n}	Average refractive index	3.45	_
а	differential gain coefficient	1.67×10^{-16}	cm ²
n_{tr}	Transparency carrier density	0.47×10^{18}	cm^{-3}
α	Internal loss coefficient	6	cm^{-1}
$ au_c$	Free carrier life time	200	\mathbf{ps}
L	Length of active region	1600	μm
w	Width of active region	0.45	μm
d	Thickness of active region	0.39	μm
E_{g0}	Band gap energy	0.74	ev
Ĭ	Inject current dc bias	500	mA
G_{sp}	Single pass peak Gain	16.5	dB

Table 1. SOA geometrical and material parameters used in the simulation.

In the present paper, the effect of the amplified spontaneous emission to the SOA output signal was added as Gaussian noise with variance equal to the ASE power. The spontaneous emission power can be written as [39]:

$$P_{ASE} = 2h\vartheta n_{sp}(G-1)BW_o \tag{6}$$

where n_{sp} is the spontaneous emission factor and BW_o is the optical filter bandwidth. The factor of two accounts for the unpolarized nature of ASE [40]. The effects of ASE on the carrier dynamics in the semiconductor optical amplifier can be accounted for by using the models presented in [41,42].

Equivalent Cavity and Reflectivity Design

A multi section cavity analysis has been performed to optimize the SOA model by incorporating flip chip technique assembly constraints in terms of its effective reflectivity. We took into account the multi-cavity effect due to discontinuities in the hybrid integrated SOA–SOI chip by using effective mirror model and scattering-matrix analysis [43]. In Figure 5, an equivalent mirror cavity is depicted, which replaces the SOI waveguide passive section by an effective mirror with reflectivity r_{eff} . In particular, the reflectivity from the spot-size converter taper between the SOA and SOI waveguide and from the input/output GC reflectivity have been considered in order to compute the effective complex facet reflectivity r_{eff} as:

$$r_{eff} = r_{tap} + \frac{t_{tap}^2 r_{gc} e^{-2j\beta_p L_p}}{1 + r_{tap} r_{gc} e^{-2j\widetilde{\beta}_p L_p}}$$
(7a)

$$\widetilde{\beta_P} = \left(\frac{2\pi}{\lambda}\right) n_{eff,P} + j \cdot 0.5 \cdot \alpha_P \tag{7b}$$

where r_{tap} and t_{tap} are the reflection and transmission coefficient at the spot-size converter taper part respectively, r_{gc} is reflection at GC, $\tilde{\beta_p}$ is the complex propagation constant, n_{eff} is the effective index and α_p is passive cavity internal loss. This yielded the value for the residual facet reflectivity $R = |r_{eff}|^2$ (assuming $r_{eff1} = r_{eff2}$) of the SOA that needs to be considered in Equation (1) for ensuring a reduced ripple amplitude of 0.3 dB. Figure 6 shows the contour plot for the calculated RFR versus GC and tapered section reflectivities. The plot has been obtained using SOA with an active region length of 1600 µm assembled to the SOI waveguide with 2600 µm passive cavity length from each side.



Figure 5. (a) Multi-section cavity model; (1): input grating couplers (GC) equivalent mirror (2): silicon on insulator (SOI)–SOA taper section (b) equivalent cavity.



Figure 6. Range of NTW_SOA operation versus the GC and tapered reflectivity. Lines separate the boundary with different residual facet reflectivities (RFR). The dot line marks the boundary with $G_{sp}R = 0.017$ which corresponds to the 0.3 dB-ripples limit for 16.5 dB single pass gain.

4. Results

4.1. Transmission Simulation

The performance of the designed SOA device in the reference DWDM architecture was evaluated through simulation of a 32×25 Gb/s NRZ transmission with 100 GHz channel spacing and 2^{11} -1 pseudo-random bit sequences (PRBS) data. The input power to the SOA was -20 dBm per channel.

The receiver scheme with twin parallel SOAs was considered: the incident signal is split into two orthogonal polarization states, TE and TM, and each one of them is amplified by separate SOAs. The transmission performance was evaluated under the worst case scenario, i.e., the incident signal has only one polarized state and all light is coupled to only one SOA while the twin SOA works in the absence of input signal. In this condition, the second SOA only emits ASE noise at the output which is coupled with the amplified signal from the first SOA. The transmission performance for a channel under test (Ch.u.t.) was evaluated through eye diagrams either in the presence or absence of the second SOA to assess the impact of the additional ASE noise. Clear eye opening shows successful transmission of 32 WDM channels (Figure 7) with a limited impact of the ASE due to the second SOA.



Figure 7. Simulated eye diagrams for a channel under test (Ch.u.t.) at SOA1 output (**left**) and after coupling with parallel SOA2 (**right**) for the case of 32×25 Gb/s transmission.

We also considered another potentially critical scenario where power differences of two adjacent input channels is about 10 dB in order to estimate the impact of XGM. Figure 8 shows the eye diagrams for the Ch.u.t. (left) and its 10 dB stronger side channel (right) for the case of input power of -16 dBm and -6 dBm respectively. There is no evidence of XGM and pattern effects are visible.



Figure 8. Simulated eye diagrams for the Ch.u.t. (**left**) and its 10 dB stronger side channel (**right**) for the case of input power of -16 dBm and -6 dBm respectively.

To evaluate the model for SOA operation in nonlinear regime (NL), we also simulated transmission of 32×25 Gb/s with -4 dBm input power per channel. Such a large input power causes the SOA to switch into the NL regime and represents a large cross gain modulation (XGM). The signal quality is affected by patterning due to gain saturation. The nonlinear effect on the data pattern and eye diagram of the Ch.u.t is depicted in Figure 9.



Figure 9. Simulated output data pattern and eye diagram for the Ch.u.t. with very high input power (–4 dBm per channel).

4.2. Experimental Results

The experimental setup for validation of the developed software model is shown in Figure 10. The 25 Gb/s NRZ signal for the Ch.u.t. was generated by exploiting an Mach-Zehnder modulator (MZM) fed with a continuous wave (CW) laser at 1552 nm and driven by a bit pattern generator (BPG) with a 2^{31} -1 PRBS. A second MZM was fed by 16 CW lasers spaced by 200 GHz and driven by a second bit pattern generator (BPG) with a 25 Gb/s 2^{31} -1 PRBS to generate the interfering channels. The channel allocation on the SOA gain curve is shown in Figure 11.

Ch.u.t. and interfering channels were coupled together and to emulate the effect of 32 channels, we reduced the power of the Ch.u.t. by 3 dB with respect to the interfering channels. The worst case for XGM has been considered here as the interfering channels are all modulated with the same data stream. Two identical SOAs have been used in the experiment to implement the polarization-diversity scheme with twin coupled SOAs.



Figure 10. Experimental setup for BER measurements with twin parallel SOAs; eye diagrams of the received signals are shown for the back-to-back case as well as after a single SOA and after coupling with the twin parallel SOAs. BPG: bit pattern generator, OBPF: optical band-pass filter, VOA: variable optical attenuator.



Figure 11. Channels (ch) used for the experiment and SOA gain profile in the wavelength region of interest.

To emulate the worst case polarization condition, the optical signal is fed to the first SOA only (with optimized polarization) while the second SOA works in the absence of input power and emits ASE noise only. Both SOAs are biased at 500 mA. Total input power for SOA1 is set to -5 dBm (corresponding to -20 dBm for Ch.u.t.). After the 3 dB coupler, the Ch.u.t. power is -8 dBm, far above the receiver sensitivity of -16 dBm of the reference architecture. A 1 nm optical band-pass filter (OBPF) was used to extract the Ch.u.t. for eye-diagram evaluation and bit-error-rate (BER) measurements. At the receiver, a 30 GHz photo receiver was used, followed by a 45 GHz oscilloscope and a 25 Gb/s error detector. Unfortunately, due to the high insertion loss (6 dB) of the OBPF used in the experiment and the receiver sensitivity of the available photoreceiver (-10 dBm), the thermal noise was dominating the ASE noise of the SOAs and hiding other possible impairments. This required the use of a pre-amplified receiver to accurately evaluate the impact of the SOAs in absence of the receiver thermal noise.

Figure 10 reports the eye diagrams of the Ch.u.t. in back-to-back, after SOA1 and after coupling with SOA2 cases. BER has been evaluated by varying the optical power at the input of the pre-amplified receiver.

To highlight the impact of the two SOAs, both cases of a single SOA and twin SOAs have been considered. Experimental BER results are shown in Figure 12. The curves show that at BER = 1×10^{-9} , there is only a 2 dB penalty for the twin SOAs scheme.



Figure 12. Experimental NRZ BER measurements in back-to-back configuration compared to single SOA BER and twin parallel SOAs.

In order to examine the device's nonlinear behavior performance in terms of cross gain modulation (XGM), we injected two signals to the SOA with -20 dBm (Ch.u.t at 1552 nm) and +5 dBm (3×0.8 nm from Ch.u.t) optical input power, respectively. Both signals were modulated to produce a 25 Gb/s 2^{11} -1 PRBS sequence. The results of the simulated and measured signal of the channel under test are depicted in Figure 13. Since the available SOA is linear with high saturation input power of +6 dBm, within this optical power range, the eye diagram does not exhibit a significant nonlinear effect.



Figure 13. Finding the cross gain modulation (XGM) point for the linear SOA (25 Gb/s NRZ), simulation data (top row) versus experimental (bottom row).

5. Conclusions

SOA is a promising approach to optimize performance for future PON due to the wide gain bandwidth, low-price and high integration capability. We proposed a practical scheme for a polarization-insensitive integrated receiver including twin parallel SOAs for the ONT receiver. We evaluated optimum design considerations for integrated WDM 25 Gb/s integrated ONT receivers exploiting SOAs under ODN loss. The SOA in the receiver are designed not only to compensate the

coupling and link losses, but also on chip losses to realize the lossless receiver design. We performed a multi section cavity analysis for optimum SOA model design to incorporate the flip chip technique constraints. The bonding constraints of SOA in the hybrid integrated SOA–SOI chip for obtaining lower gain ripples (ΔG) were evaluated. The effect of ASE noise as well as the XGM on an amplified optical signal using twin parallel SOAs was modeled for linear and nonlinear behavior investigation of the SOA construct. The XGM impact is investigated using 32 × 25 Gb/s channels as well as considering two adjacent input channels where the interfering channel is 10 dB higher, without significant impairments as long as the input power remains below approximately 6 dBm. Transmission performance and ASE effect were evaluated in the worst-case polarization condition, i.e., when all of the signal is coupled to one SOA, which resulted in the successful transmission of 32 WDM channels with a limited impact of the ASE due to the second SOA.

Author Contributions: P.N.G.; F.F.; and V.T.; designed and performed the experiments, C.P.; designed and modeled SOA simulations. P.N.G.; performed the simulations and with C.P.; analyzed the results. F.C.; provided vendor specifications. P.N.G.; M.I.; F.F.; and C.P.; wrote the paper. L.P.; conceived and developed the concept, reviewed the results and the manuscript.

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