



# **32dB of Optical Budget with DSP-free real time experimentation up to 50Gbit/s NRZ using O-band DFB-EAM and SOA-PIN for Higher Speed PONs**

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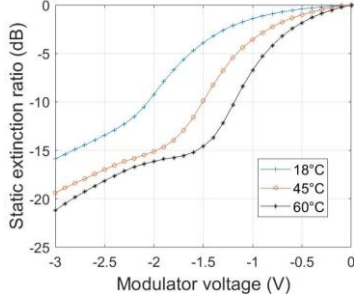
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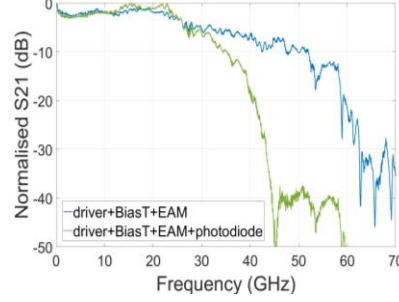


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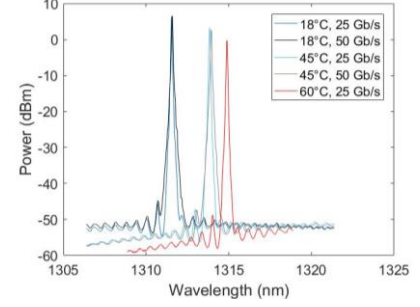
Figure 1 presents our experimental setup of a physical layer transmission of HSP with a Non Return to Zero (NRZ) modulation at 50Gbit/s. An EML was used, as it presents a lower chirp than Directly Modulated Lasers (DML) commonly used in PONs. We also chose to avoid the complexity and extra cost of a Mach Zehnder Modulator and we designed an EML based on a single chip Distributed Feedback Laser integrated with an Electro-Absorption Modulator (DFB-EAM). The device, detailed in [9], is optimized to provide high output power and steep modulator



**Fig.2** DFB-EAM static extinction



**Fig.3:** EO bandwidths measured at 18°C



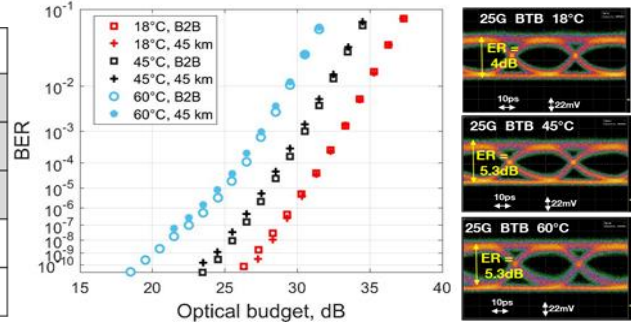
**Fig. 4:** EML optical spectra

extinction curve as shown in Fig. 2, with 15dB extinction at -2V at 45°C. The EML is also designed for semi-cooled performances and the EAM length is optimized to limit the applied modulation voltage for easier integration. At the output of the chip (picture on Fig.1), a micro-lensed fibre [10] is used to couple the laser beam. As usual with PON transceivers, an isolator is placed at the output of this fiber to avoid back reflections. Measured electro-optical bandwidths of the modulator associated to its bias tee and linear driver are presented in Figure 3, presenting 25GHz bandwidth at -3dB and 48GHz at -10dB.

The affordable optical budget is measured in Back-to-Back (B2B) or by inserting 45Km of Standard Single Mode Fiber (SSMF) before a Variable Optical Attenuator (VOA). After this transmission span, we used a PIN photodiode associated with a TransImpedance Amplifier (TIA). The overall electro-optical bandwidth is represented in Figure 3, showing more bandwidth limitation when the photo receiver is added (35GHz at -10dB).

	$I_{bias}$ (mA)	$V_{EAM}$ (V)	$V_{mod}$ (Vpp)	$P_{out}$ (dBm)	$\lambda$ (nm)	$ER_{outEML}$ (dB)	$I_{SOA}$ (mA)	$ER_{outSOA}$ (dB)
25G 18°C	90	-1.4	1.5	7.3	1311.5	5.9	116	4
25G 45°C	102	-0.94	1.5	4.5	1314	7.8	116	5.28
25G 60°C	98	-0.63	1.5	1.5	1314.8	8.35	116	5.3
50G 18°C	90	-1.13	2.8	7.3	1311.5	7.9	110	4.35
50 45°C	102	-0.94	2.4	4.4	1314.1	8.4	102	5.23

Tab. 1: Optimized and measured parameters at 25Gbit/s and 50Gbit/s



**Fig. 5:** BER at 25Gbit/s vs Optical budget with SOA, for BTB (B2B) and 45Km reach, at 18°C, 45°C and 60°C, at 25Gbit/s and Corresponding Eye Diagrams in BTB

The EAM section is driven by a  $2^{31}-1$  Pseudo Random Bit Sequence at 25Gbit/s or 50Gbit/s. An Error Detector (ED) was placed after the reception to measure the Bit Error Rate (BER) of this transmission in real time. The optical spectra of the modulated laser are represented in Figure 4 for each tested cases. Table 1 summarizes the laser currents, EAM voltages and modulation amplitudes that were optimized to reach the lowest BER for 25Gbit/s and 50Gbit/s. This table also reports the measured EML output powers, peak wavelengths ( $\lambda$ ) and Extinction Ratios (ER). The EML is experimented at 18°C, 45°C and 60°C to show uncooled capabilities.

Since no commercial burst mode receiver at 25Gbit/s or 50Gbit/s are available yet [11-13], no impact of burst mode is presented in this paper. First, the BER versus the received optical power was measured for Back To Back (BTB) transmissions (0km) at 25Gbit/s and 50Gbit/s. The transmission is mainly limited by the sensitivity of the PIN receiver at -12dBm in BTB at 25Gbit/s for a targeted BER of  $10^{-2}$  which is the BER threshold defined in HSP before Forward Error Correction (FEC) [6]. At 50Gbit/s, a sensitivity of only -9dBm was reached, giving a maximum optical budget of 16.3dB at 18°C.

To improve the optical budgets, integrated SOA-PIN or Avalanche PhotoDiode are commonly used with ongoing competition on the market for ER40 and ZR4 transceivers. Thus, we inserted a commercial low polarization dependent gain SOA as a pre-amplifier to the PIN photodiode. The SOA's Amplified Spontaneous Emission (ASE) spectrum is centered at 1290nm and the SOA presented a small signal gain of 18dB and a Noise Figure of 5.9dB when biased at 110mA and at 20°C. We used an isolator between the SOA and the PIN to avoid amplification of back reflections due to optical connectors. Spectrally filtering the ASE noise is not possible in PON systems since the transmitted wavelength windows can be as large as 20nm. Therefore, no optical filter was present in our

experiments. A polarization controller is used at the SOA input to maximize the output power. Without polarization controller, a maximum power penalty of 1dB was measured to reach the same performances for a BER of  $10^{-2}$ .

The optical budget is now measured according to the SOA input power and BER results are presented in Figure 5 and 6, for transmissions at 25Gbit/s and 50Gbit/s respectively. For each case, the ER is reduced at the output of the SOA due to the ASE which increases the zero level of the eye diagram. The SOA permits to reach error free transmissions at FEC threshold with fibre length up to 45km. Very negligible penalties were due to transmission over fiber since the EML wavelength is close to the zero dispersion. At 25Gbit/s, optical budgets of 29.3dB at 60°C, 32.1dB at 45°C and even 35dB at 18°C are demonstrated. This shows the feasibility to reach the N1 class (14-29dB), with 6dB of margin at 18°C which might be enough to overcome penalties due to burst mode, in the case of HSP upstream transmissions. At 50Gbit/s, optical budgets of 29.4dB at 45°C and 32.3dB at 18°C are obtained. This corresponds almost to the same Optical Modulation Amplitude (OMA) of -23.5dBm, because the temperature variation is affecting both the EML output power and the extinction ratios.

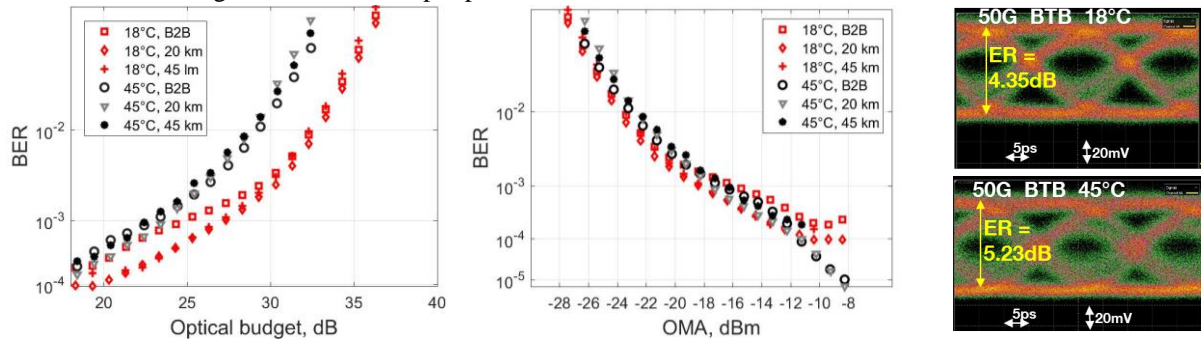


Fig. 6: BER at 50Gbit/s vs Optical budget with SOA, for BTB, 20km and 45Km reach, at 18°C, 45°C and 60°C, at 50Gbit/s (left) ; Same results vs OMA (middle) ; corresponding Eye Diagrams at 50Gb/s in BTB (right)

### 3. Conclusions

To the best of our knowledge, we experimentally demonstrated, for the first time a DSP-free NRZ transmission in real time at 50Gbit/s and 25Gbit/s using a semi-cooled O-band DFB-EAM transmitter and SOA-PIN receiver. At 50Gbit/s, optical budgets of 32.3dB (-23.5dBm OMA) were achieved for 0, 20 and even 45km. At 25Gbit/s, up to 36dB of optical budget was reached with 45km of fibre. All those results cope with the targets of HSP for co-existence with legacy PONs based on N1 classes (14-29dB) and with 0 to 40km reach. This experiment also shows the possibility to use simple NRZ transmissions for point to point long reach applications [14], offering a solution to avoid 4-level Pulse Amplitude Modulation (PAM4) and DSP for bitrates above 10Gbit/s.

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### 4. References

- [1] G.9804.1 : Higher Speed Passive Optical Networks: Requirements; online : <https://www.itu.int/rec/T-REC-G.9804.1-201911-I/en>
- [2] J. S. Wey, “The outlook for PON standardization: A tutorial”, *Journal of Lightwave Technology*, Vol. 38, Issue 1, pp. 31-42; (2020)
- [3] F. J. Effenberger, “The future of higher speed PONs”, 2018 Asia Communications and Photonics Conference (ACP), Hangzhou, 2018, pp. 1-4, doi: 10.1109/ACP.2018.8595908.
- [4] D. van Veen et al, “Bi-directional 25G/50G TDM-PON with extended power budget using 25G APD and coherent amplification,” 2017 Optical Fiber Communications Conference and Exhibition (OFC), Los Angeles, CA, 2017, pp. 1-3.
- [5] Rosales Ricardo et al, “First Demonstration of an E2 Class Downstream Link for 50Gb/s PON at 1342nm”, ECOC 2020, paper Tu2J-5
- [6] A. Mahadevan et al, “50G PON FEC Evaluation with Error Models for Advanced Equalization”, OFC 2020 San Diego, CA, USA, 2020
- [7] L. A. Neto et al, “Considerations on the Use of Digital Signal Processing in Future Optical Access Networks,” in *Journal of Lightwave Technology*, vol. 38, no. 3, pp. 598-607, 1 Feb.1, 2020, doi: 10.1109/JLT.2019.2946687
- [8] Gael Simon et al, “50Gb/s TDM PON Digital Signal Processing Challenges: Mining current G-PON Field Data to Assist Higher Speed PON”, 2020 European Conference on Optical Communications, ECOC 2020, Brussels, paper Tu2J-7
- [9] Xing Dai et al, “Versatile Externally Modulated Lasers Technology for Multiple Telecommunication Applications”, *IEEE Journal of Selected Topics in Quantum Electronics*, Year: 2021 Volume: 27, Issue: 3 | Journal Article | Publisher: IEEE.
- [10] M. Thual et al, “Appropriate micro-lens to improve coupling between laser diodes and single mode fibres”, *Electronic Letters*, 16th October, 2003, vol. 39, N°21, pp. 1504-1506.
- [11] R. Borkowski 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,” 2017 Optical Fiber Communications Conference and Exhibition (OFC), Los Angeles, CA, 2017, pp. 1-3.
- [12] G. Coudyzer et al., “Study of burst-mode adaptive equalization for >25G PON applications [Invited],” in *IEEE/OSA Journal of Optical Communications and Networking*, vol. 12, no. 1, pp. A104-A112, January 2020, doi: 10.1364/JOCN.12.00A104.
- [13] N. Tanaka et al, “25.78-Gbit/s Burst-mode Receiver for 50G-EPON OLT,” in OFC 2020, OSA Technical, paper M1F.5.
- [14] ITU-T recommendation G.9806 : Higher-speed bidirectional, single fibre, point-to-point optical access system, June 2020