Mitigation of cross-gain modulation in OLT booster amplifier

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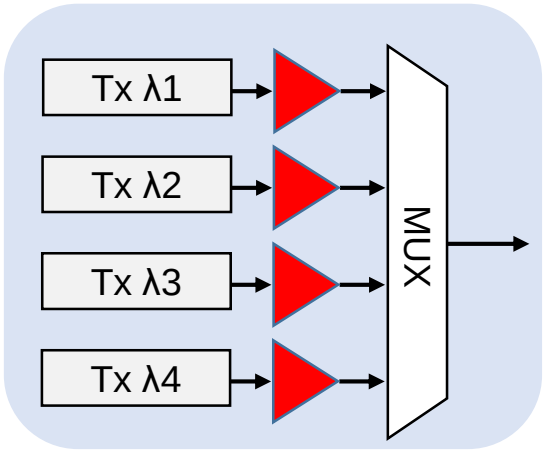
Motivation

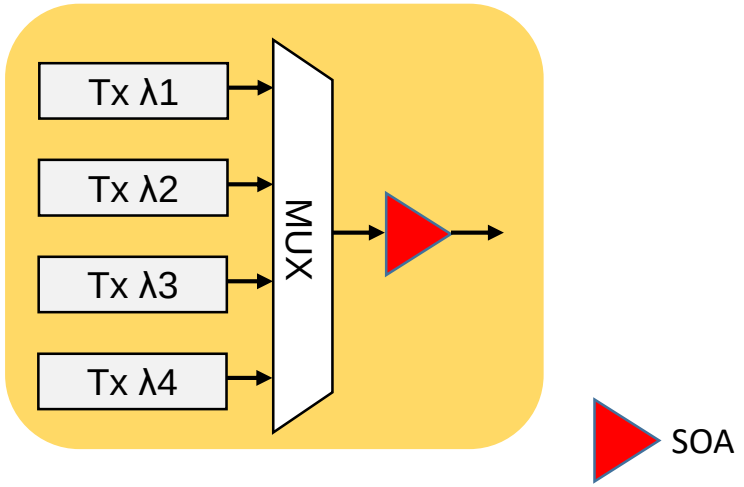
- 100G-EPON OLT must use a booster amplifier to overcome additional losses of optical components to configure WDM channels transmission.
- A semiconductor optical amplifier (SOA) is an excellent candidate for increasing a power of downstream signal considering their size, cost, and especially their flexibility in operating wavelength.
- In the previous meetings, some contributions reported feasibility of SOA as the preamplifier for upstream signals.
  - http://www.ieee802.org/3/ca/public/meeting_archive/2017/03/liudekun_3ca_1_0317.pdf
  - http://www.ieee802.org/3/ca/public/meeting_archive/2017/03/yang_3ca_1_0317.pdf
  - http://www.ieee802.org/3/ca/public/meeting_archive/2017/05/lee_3ca_1_0517.pdf
  - http://www.ieee802.org/3/ca/public/meeting_archive/2017/05/liudekun_3ca_1_0517.pdf
- But, no reports about a booster amplifier. It needs to discuss about the booster amplifier for downstream signals to archive PR30 link budget.
- In this contribution, we report experiment results about the SOA booster amplifier for downstream signals.

Configuration of booster amplifier for downstream

Case A: SOA for single λ

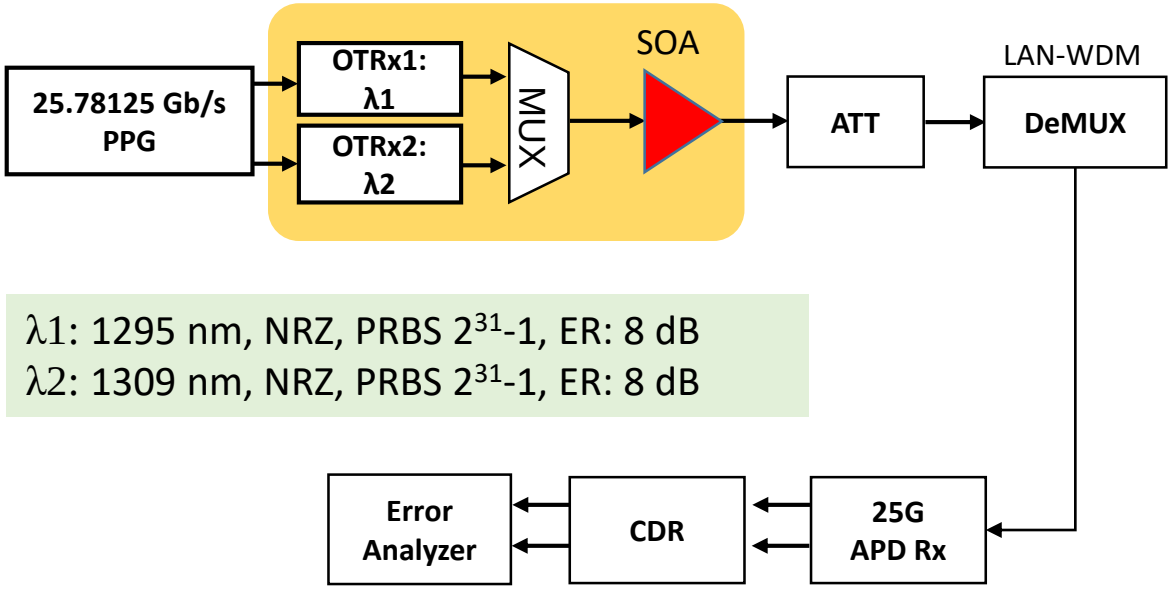


Case B: SOA for multi-λ

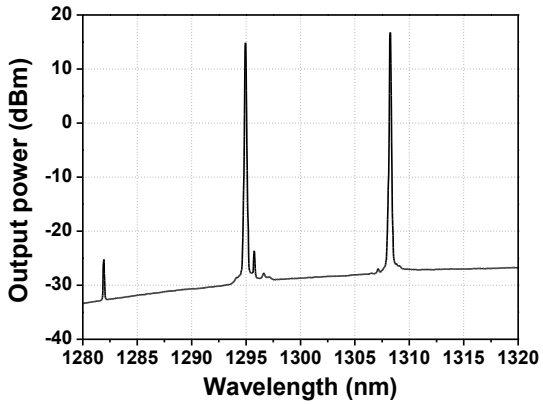


- A SOA can be applied to the OLT for amplifying each downstream signal (case A) or multiplexed WDM downstream signals (case B).
- Case A would be no problem since there is no cross-gain modulation. But, it is not cost-effective.
- Case B is simple and cost-effective. But, saturation-induced cross-gain modulation is a major obstacle.

Experiment setup



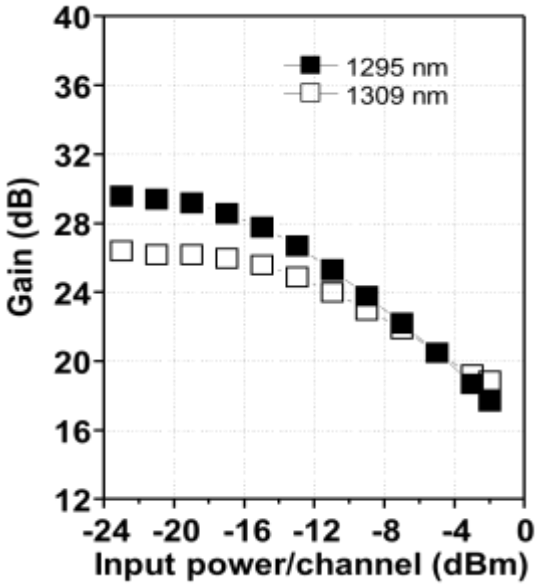
λ1: 1295 nm, NRZ, PRBS 2^{31}-1, ER: 8 dB
λ2: 1309 nm, NRZ, PRBS 2^{31}-1, ER: 8 dB

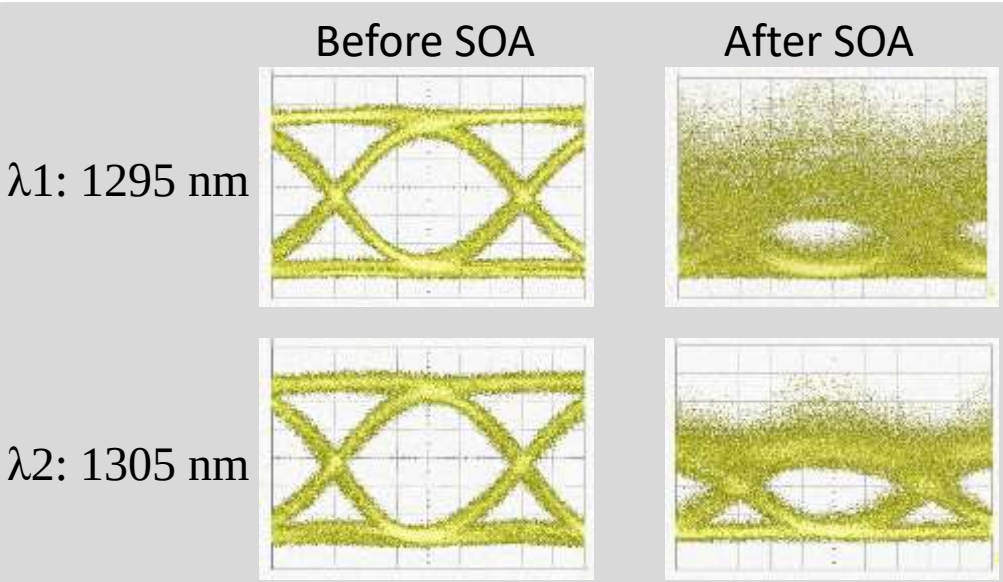


[Output spectrum]

- To test WDM signals amplification, 2 x 25 Gb/s NRZ signals in O-band , and 25 Gb/s APD based Rx were used.
- Output powers of amplified signals were over +15 dBm per λ.

Performance of amplified WDM downstream signals

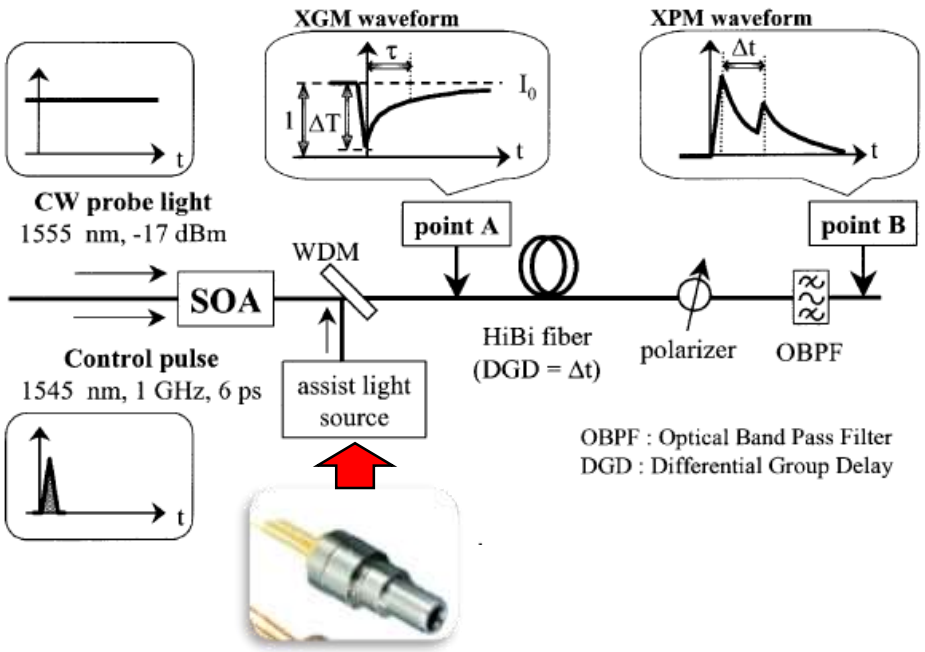


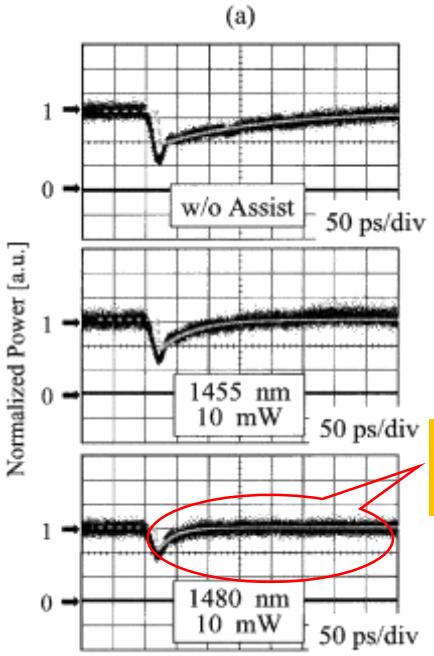


- A high power SOA had been reported and is commercially available with over +18 dBm of saturated output power [1].
- However, closed eye diagrams after the SOA were measured when the input power was -2 dBm/channel even the output powers were over +15 dBm/channel.
- It is because of slow gain recovery time due to decrease of carrier density in the SOA gain medium when the SOA has the high input power

[1] S. S. Saini, et al., "A semiconductor optical amplifier with high saturation power, low noise figure and low polarization dependent gain over the C-band," LEOS 2004, pp. 102-103.

Method to mitigate cross-gain modulation



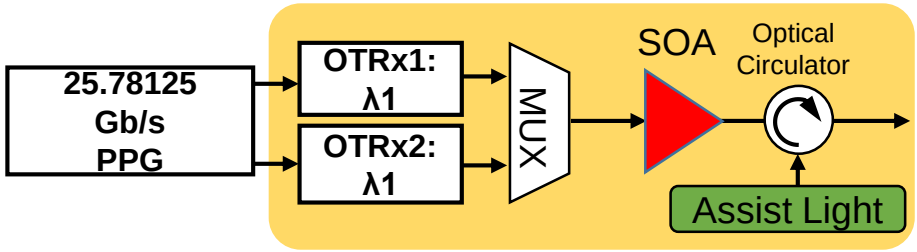


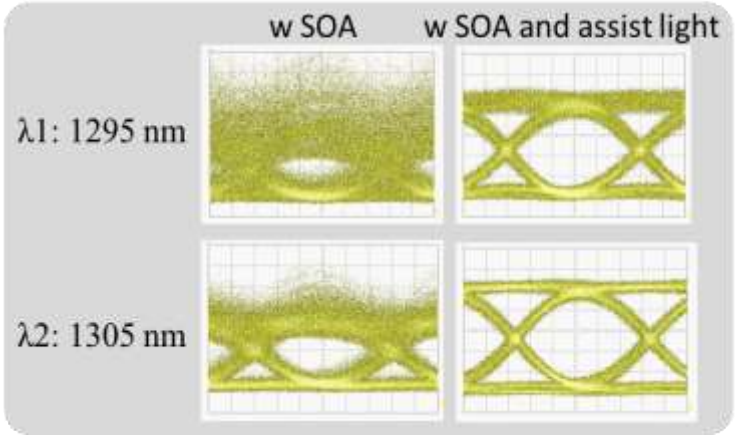
Enhancing gain recovery time

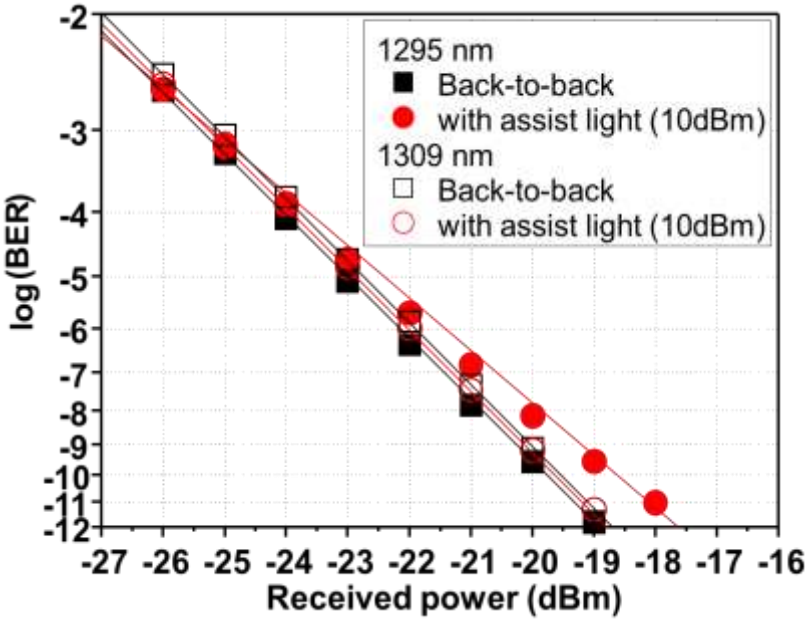
- An assist light injection scheme was proposed and the effect of accelerating a gain recovery time in SOA was confirmed[1].
- The assist light is creating new carriers and enhancing the gain recovery, rapidly.
- For 100G EPON application, a cooled DFB-LD TOSA can act as an assist light source.

[1] R. Inohara, et al., "Experimental Analysis of Cross-Phase Modulation and Cross-Gain Modulation in SOA-Injecting CW Assist Light," IEEE PTL, vol. 15, no. 9, (2003)

BER Performance of amplified WDM downstream signals

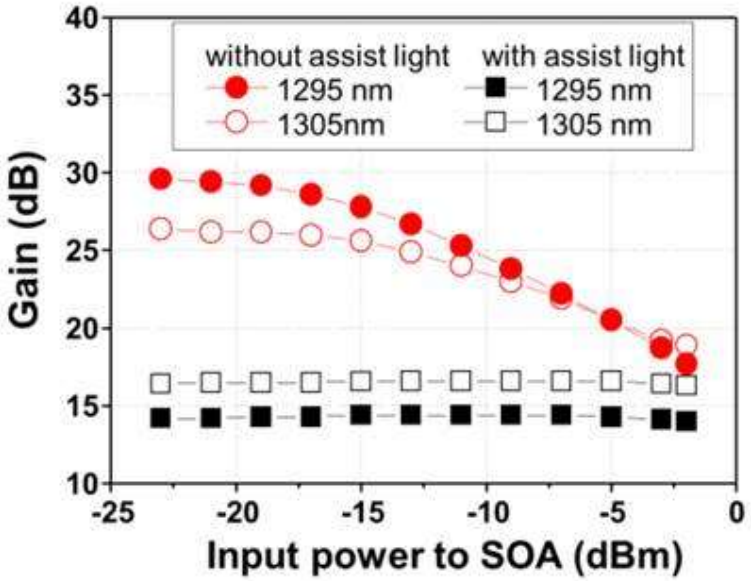


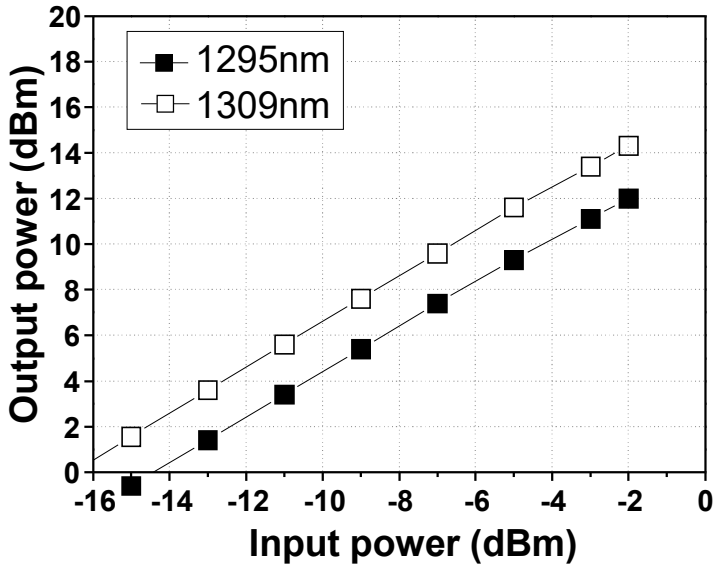




- We used a backward assist light with 10-dBm power to the booster amplifier.
- Eye diagrams with injecting the backward assist light were significatly improved and measured power penalty was negligible for both the signals.
- It is because the backared assist light enhances the gain recovery time of SOA by optically injecting a carrier.

Output power per channels





- The gains of signals were clamped at 14 dB and 16 dB by injecting the assist light. Then, a maximum input power of linear gain regime increased from -13 dBm to over 0 dBm. The output power per channel was +12 dBm and +14dBm when the input power was -2 dBm.
- If the SOA has four input signals an output power per channel would be 3 dB decreased so that it would be +9 dBm/channel. +9 dBm/channel of downstream will be satisfied to support the downstream link budget.
  - 0.7 dB of coexsistance filter loss, 29 dB of link loss, 1.5 dB of TDP, -24.2 dBm of sensitivity of ONU Rx and 2 dB of DeMUX loss.

Conclusions

- It was known that amplification of WDM signals by using a single SOA was not easy due to saturation induced cross-gain modulation when the input signal power located in the gain saturation regime.
- The simple method with using the assist light to the SOA can solve the crosstalk problem.
- We confirmed technical feasibility of a high-power booster amplifier for 100G-EPON multi-channels downstreams and observed that power penalty was negligible.