Use of SOAs in NG-EPON

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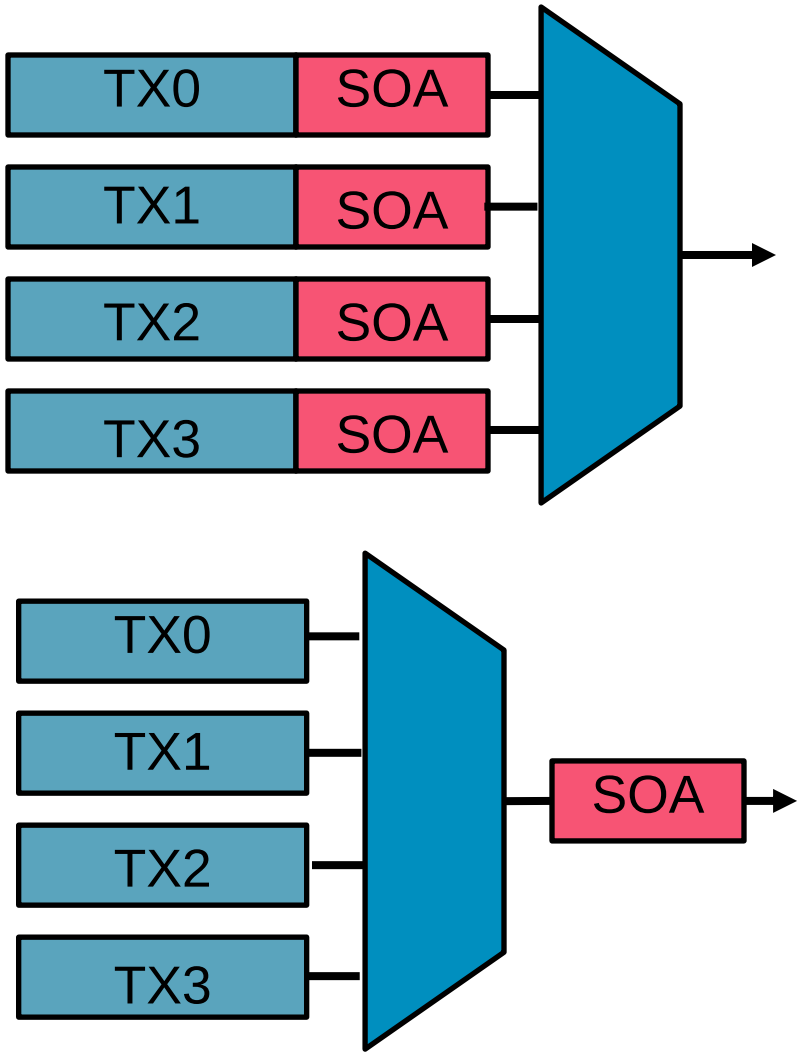
Some SOA facts

- SOA properties:
  - Lower output saturation powers (Psat) relative to EDFAs: ~17dBm max
  - Higher noise figures than EDFAs: typical 7-9dB vs 4-5dB.
  - Must be operated 3-5dB below Psat to avoid signal impairments
    - (Self) Gain saturation produces overshoot, undershoot and other ISI
    - Self-phase modulation (SPM) alters the chirp of the signal
    - Cross-gain modulation (XGM) modulates the amplitude of other signals
    - Cross-phase modulation (XPM) modulates the chirp of other signals
  - Fast carrier dynamics make SOAs well suited for burst-mode operation.
  - Uncooled or semi-cooled SOAs have been reported, but have inherent large variation of the gain spectrum over temperature.
- SOA availability:
  - Commercially available for all telecom wavelength bands
  - Typical packaging is 14-pin butterfly, but smaller options are possible
  - Current offerings are cooled to maintain high gain and output power
  - SOAs operating at higher temperature are in development but may have lower gain and Psat than current SOAs operating at 25 ºC.

Transmission performance using SOAs

- This contribution will not discuss the performance of specific SOA implementations in NG-EPON – for future study.
- Analysis of SOA amplification for 4x25G transmission was done as part of HSSG/802.3ba for 100GBASE-ER4:
  - 100GBASE-ER4 PMD was developed with SOA-PIN RX in mind.
  - Gutierrez_02_1107 and Gutierrez_04_1107 concluded that booster amplification alone did not provide good BER performance, but pre-amplification at the receiver was an effective solution.
  - Cole_01_0507 includes a preliminary sensitivity and power dissipation analysis.
  - Vandyshev_01_0708 estimates -24dBm sensitivity is possible for LR4 SOA-PIN RX and looks at crosstalk effects
  - R. Teranishi, “SOA module for 100GBASE-ER4,” SEI Technical Rev., No. 78, p. 53, April 2014.
- Many research publications have demonstrated the use of SOAs as in-line amplifiers to extend the range of optical transmission.

SOA booster configurations



Single-channel Booster SOAs

+ Can be integrated with EML/DML
+ Can be single-polarization
+ Requires modest Psat ~ 11dBm
- SPM at optical power near Psat
- High power dissipation must be inside the pluggable module
- Optical feedback issues

Shared Booster SOA

+ Lower total power, inside or outside the pluggable module
+ Requires higher Psat ~ 17dBm
- XGM/XPM at total optical power near Psat
- More difficult to integrate, but allows single-polarization

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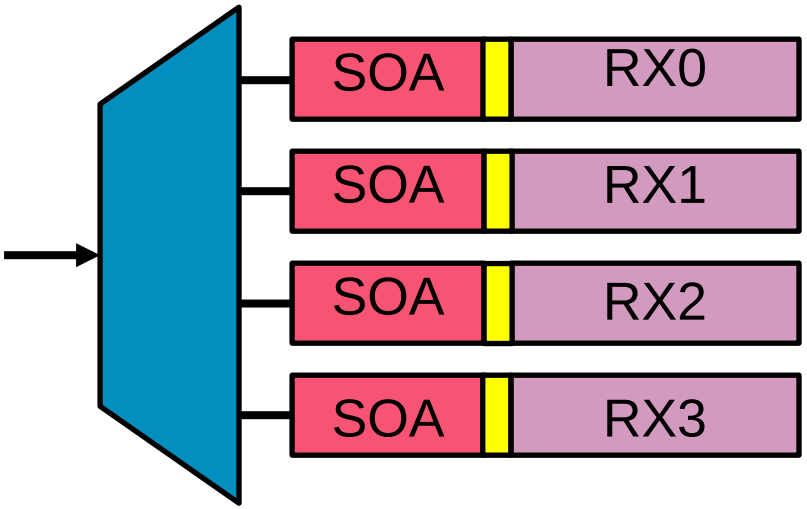
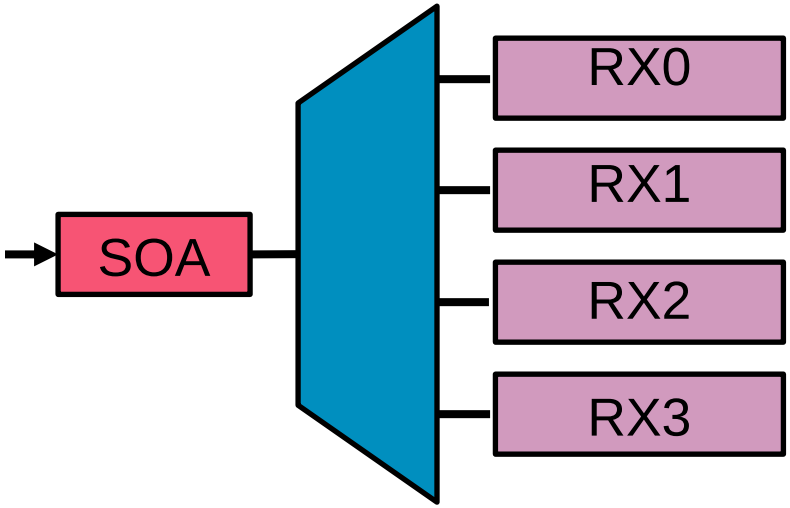
SOA preamp configurations





Single-channel Preamp SOAs

+ Requires low Psat and high gain
+ Can be integrated with waveguide photodetectors
- Polarization insensitive SOA
- High power dissipation must be inside the pluggable module
- ASE filters required between SOA and photodiode

Shared Preamp SOA

+ Requires low Psat and high gain
+ Lower total power, inside or outside the pluggable module
+ Demux serves as the ASE filter
- Polarization insensitive SOA
- More difficult to integrate

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Estimated power dissipation for SOAs

	Single-λ Booster, Psat~11dBm	Shared Booster, Psat~17dBm	Shared Preamp, Psat~7dBm
Bias current (mA)	300	600	200
Forward voltage (V)	1.6	1.8	1.5
SOA Power (W)	0.48	1.08	0.30
	0.48	1.08	0.30
TEC*			
Efficiency	50%	50%	50%
TEC Power (W)	0.96	2.16	0.6
Total Power/Ch. (W)	1.44		
25G TOSA	1.44		
50G TOSA	2.88		
100G TOSA/ROSA	5.76	3.24	0.90

* TEC powers are optimistic estimates, requiring SOA operation at temperatures higher than current commercially available SOAs (~50 ºC vs 25 ºC). Operation at 50 ºC may require higher bias current.

SOA integration in pluggable modules

- Cooled SOAs are not compatible with the limited TEC capacity of micro-TEC cooled TO-cans. Hermetic planar packaging is required – not ideal for low cost.
- Per-channel booster SOA configuration is less power-efficient than a shared SOA.
  - 5.8W total for four channels is too high to be integrated into QSFP28 (3.5W max) or CFP4 (6W max). CFP2 (12W max) is possible but an undesirable form factor.
  - Even if uncooled SOAs were available, they would require ~1.9W which is too high to integrate into QSFP28. CFP4 might be possible, but difficult.
- Shared WDM booster SOA has high power consumption due to the high Psat needed for total four-channel launch power > 13dBm.
  - 3.2W for cooled SOA. Not practical to integrate into QSFP28 or CFP4.
  - Development of uncooled SOAs with sufficiently high saturation power appears unlikely based on existing publications.
- Shared WDM pre-amp SOA is a more practical solution.
  - 0.9W for cooled SOA will be a stretch to fit into QSFP28 but CFP4 could be used.
  - Pre-amplification looks like the best approach from a system standpoint based on analysis of Gutierrez_02_1107.
- For ONU with BOSA-on-board construction, the SOA can be a separate component on the board (14-pin butterfly or other package TBD).
- For OLT with pluggable optics, the SOA may be implemented as a separate module, possibly integrated with the WDM optics and DCF (if any).

Thank you!