Optimal SOA-based Noise Reduction Schemes for Incoherent Spectrum-Sliced PONs

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OUTLINE

• Motivation
• SOA-based noise reduction Experiment
  – What is the best noise suppression scheme?
  – What is the best SOA to use?
• Results
• Conclusion
Motivation

SNR proportional

Excess intensity noise on the 1 and 0 logical levels

Noise causes:

(-) BER floors.

(-) Trade off: Bit rate Vs spectral efficiency & QOS.
MOTIVATION

We are interested in several functions SOA:

- Noise cleaner
- Amplifier
- Modulator

Experiment

3 different SOAs
- SOA1: Fast
- SOA2: Medium
- SOA3: Slow

BPF1 = 0.24 nm
BPF2 = W/out Bo
- 1.2 nm
- 0.24 nm
Gain Recovery

Experiment

SOA1: Fast
SOA2: Medium
SOA3: slow

Recovery time
Fast  = 30 ps
Medium = 250 ps
Slow   = 650 ps


ASE Power & frequency modulation

Experiment

SOA1: Fast
SOA2: Medium
SOA3: slow

Input saturation Power
SOA1: -19 dB
SOA2: -14 dB
SOA3: -10 dB
Results

SOA1: Fast
SOA2: Medium
SOA3: slow

• The fastest gain recovery SOA is the best for noise cleaning
• Optical filtering significantly reduces performances
  1 McCoy et al., Noise suppression of incoherent light using a gain-saturated SOA: implications for spectrum-sliced WDM systems, JLT, AUG. 2005
  2 Actual systems need filtering at the receiver !!!

Noise suppression due to 2 contributions:

- Correlation induced by the SOA
- Larger Bo due to ASE bandwidth
Results

(B) SOA can be used as a booster & noise cleaner

- Noise cleaning less efficient than in (A), however SOA can be also used to boost the power in the link.
- To the contrary of (A), ASE does not contribute to noise cleaning
  - ASE contribute to Eye closing since it is modulated with inverted data through XGM.
  - Eye closing penalty depends on the ASE power & modulation bandwidth hence depends on the SOA used.

![Graph showing Q factor vs. received optical power for different SOA types.](image)

SOA1: Fast
SOA2: Medium
SOA3: slow

![Waveforms showing signal and ASE for different SOA types.](image)

Fast SOA:
Important ASE modulation.

The ASE degrades both Extinction Ratio and Eye Opening

Slow SOA
ASE is quasi-CW signal

Less Eye opening penalty
Results

SOA1: Fast
SOA2: Medium
SOA3: slow

- Slow SOA3 has performance comparable to fast SOA1 because of the small penalty introduced by its ASE.
Results

- SOA1: Fast
- SOA2: Medium
- SOA3: slow

Conversion needs a high input saturating power.
- SOA1, fastest SOA has best performances
- Noise suppression by conversion is comparable to (A)

Conclusion

- If the SOA is placed in the OLT before the electro-optical Modulation:
  - Fast SOAs are the most efficient for almost total noise suppression.
  - Poor spectral efficiency and no amplification.
- If the SOA is placed after the modulation:
  - Moderate noise cleaning.
  - Slow SOAs introduce less penalty.
  - The SOA could also be used as a booster.
- If the SOA is placed at the ONU in conversion scheme:
  - Fast SOAs realize almost total noise suppression.
  - Using the SOA in conversion is very spectrally efficient.
  - Need to saturate the SOA.
Gain Saturation & bandwidth expansion

- **SOA1**: SOA-NL-OEC-1550:
  - InP/InGaAsP 10 Quantum Well structure.
  - Operating Current IOP 300 mA
  - Central Wavelength $\lambda_C$ 1550 nm
  - Noise Figure NF 7.6 dB
• **SOA2: Optospeed SOA1550MRI:**
  - Bulk SOA.
  - Operating Current IOP 500 mA
  - Central Wavelength 1560 nm
  - Noise Figure NF 10.8 dB
  - PDG 5.6 dB

• **SOA3: Covega BOA-1004:**
  - InP/InGaAsP Quantum Well (QW) layer structure and a ridge waveguide design.
  - Operating Current IOP 500 600 mA
  - Central Wavelength $\lambda C_{1530\ 1550\ 1570\ \text{nm}}$
  - ASE Optical 3 dB Bandwidth BW 80 85 nm
  - Saturation Output Power @ -3 dB PSAT10 dBm
  - Small Signal Gain across BW @ Pin = -20 dBm
    - $G_{20\ 24\ \text{dB}}$
  - Gain Ripple (p-p) @ IOP$\delta G_{0.05\ 0.2\ \text{dB}}$
  - Polarization Extinction Ratio PER 18 dB
  - Noise Figure NF 7.5 9 dB