SOA / PIN based OLT receiver update

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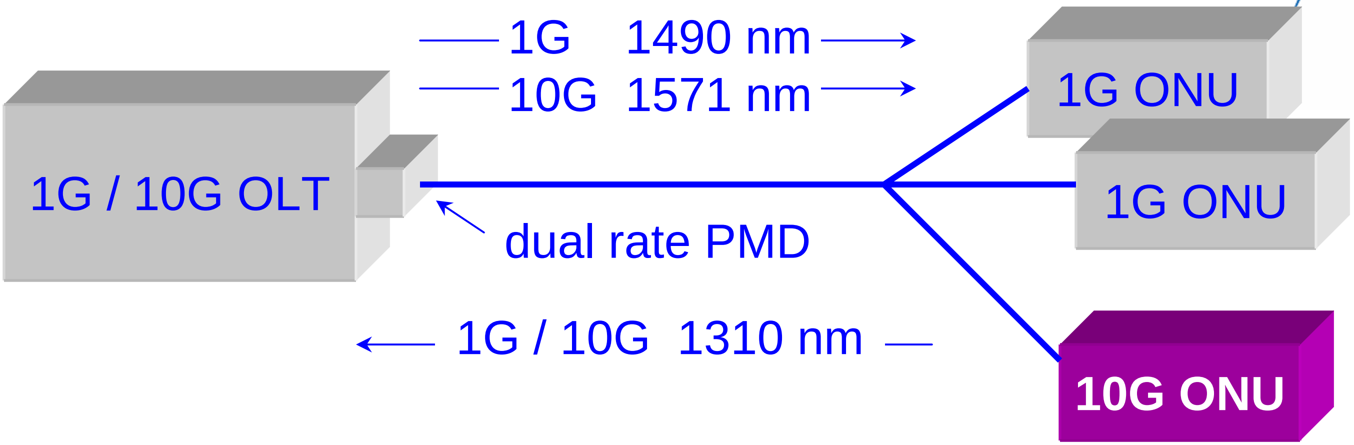
SOA/PIN OLT receiver

- New since last time (3av_0705_piehler_1.pdf):
  - Calculations now use same assumptions as 3av_0705_takizawa_1.pdf
    - 6 dB extinction ratio for the upstream.
    - 4 dB FEC gain for 10 G upstream signal
- We review simpler SOA / PIN devices
  - No "soft" filter, but with gain flattening filter.
- We address issues raised on the exploder.

Basic Idea: Coexistence – 10G/1G TDMA upstream



1310 nm 10G/1G TDMA in upstream

Constraints

(1) Existing OSP has 29 dB link budget

(2) Legacy 1G upstream receiver must have -30 dBm sensitivity at BER = 10^{-12} (no FEC)

(3) Legacy1G upstream wavelength specification is 1260 – 1360 nm

10G/1G upstream problem-1

10GEPON U/S Power Budget

λ : 1310 nm

	PX10	PX20	B++	Mean power(dBm)
CH IL (dB)	20	24	29	
Path Penalty (dB)	1	1	1	
Tx (ONU)	DFB	DFB	DFB	
Rx (OLT)	APD[Note]	APD	APD	
ER (dB)	6	6	6	
OLT Sensitivity	-20 (-19)	-26 (-25)	-26 (-25)	BER<10^{-2} or 10^{-3} (BER<10^{-4})
ONU Launch (min)	+1 (+2)	-1 (0)	+4 (+5)	
ONU Launch (max)	+6 (+7)	+4 (+5)	+9 (+10)	
OLT Overload	+1 (+2)	-6 (-5)	-6 (-5)	

Note : APD parallel PMD (ATT inserted) is assumed for 1G/10G dual-mode Rx

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From 3av_0705_takizawa_1.pdf

On one hand if an APD is at the OLT, its sensitivity of -26 dBm (which includes 4dB of FEC gain)

means that

a +4 dBm EML at 1310 nm (*not commercially available*) is needed at the ONU

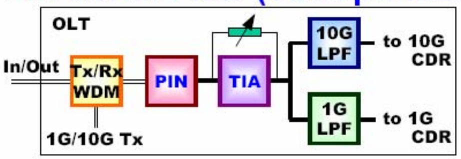
to get a Class B++ system to work in the upstream **at 10G only.**

10G/1G upstream problem - 2

Alphion

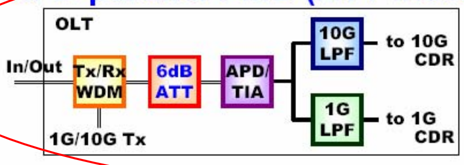
PX10 U/S 1G/10G Dual-mode RX

PIN serial PMD (TIA optimized)



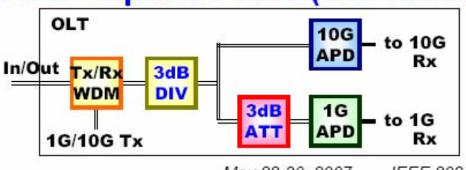
Mean power (dBm)	OLT in	APD in
1G Sens.	-24	
1G Over.	-1	
10G Sens.	-19	
10G Over.	0	
10G Launch (ONU)	+2	

APD parallel PMD (ATT inserted)



Mean power (dBm)	OLT in	APD in
1G Sens.	-24	-30
1G Over.	-1	-7
10G Sens.	-20	-26
10G Over.	+1	-5
10G Launch (ONU)	+1	

APD separate Rxs (DIV inserted)



Mean power (dBm)	OLT in	APD in
1G Sens.	-24	-30
1G Over.	-1	-7
10G Sens.	-23	-26
10G Over.	-2	-5
10G Launch (ONU)	-2	

E-FEC assumed for sensitivities

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From 3av_0705_takizawa_1.pdf

Now consider a 1G/10G dual mode Rx:

The best solutions for a dual-mode receiver gives a -20 dB sensitivity at 10G (with 4dB FEC) and -24 dB at 1G.

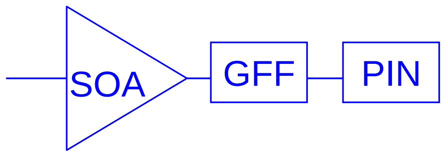
This is good enough for a the PX 10 (20 dB) link budget, but not good enough for PX20 (24 dB), and B++ (29 dB)

Best conceivable result with present technology (requires two APDs):
-23 dBm @ 10G with FEC
-24 dBm @ 1G

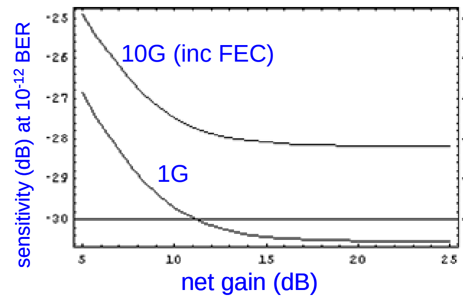
SOA alternatives

- In previous talk (3av_0705_piehler_1.pdf) we focused on the *soft* filter concept.
- Simpler SOA / PIN based also are also advantageous compared to the traditional approaches.
  - We consider here, in addition to the *soft* filter
    - An SOA with a simple gain flattening filter
    - A splitter and a pair filters located after the SOA and before a pair of PINs

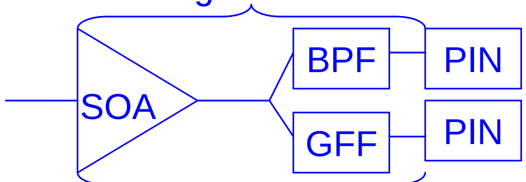
Alternate solutions



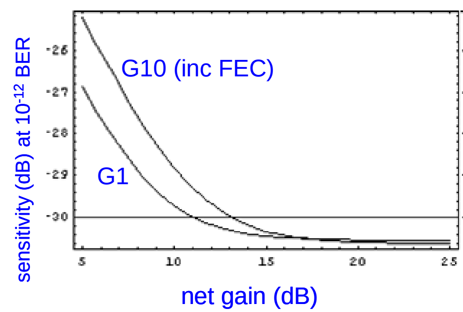
Net gain = G

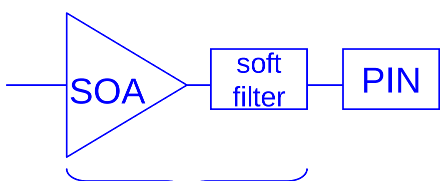


Net gain = G10



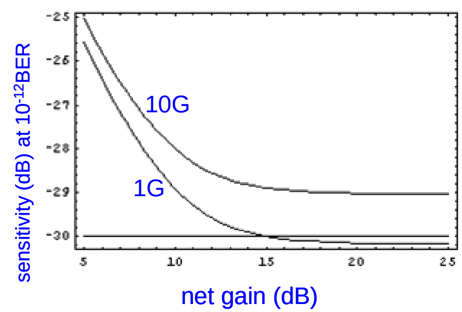
Net gain = G1





Net 10 G gain = G

L_{oob} = 1.5 dB



Calculation

ER (1G) = 9 dB
ER (10 G) = 6 dB
NF = 7 dB

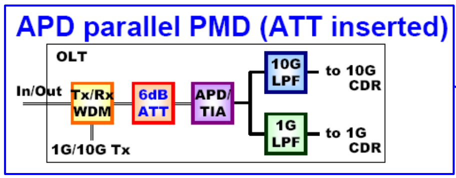
GFF = gain flattening filter
BPF = bandpass filter

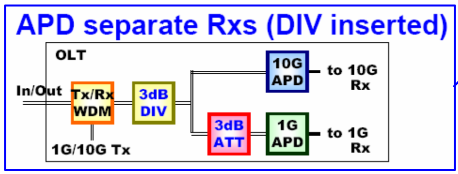
BPF = 20 nm*
GFF = 100 nm

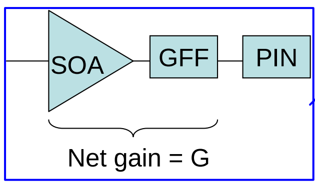
4 dB of FEC gain is included in the 10 G calculations.

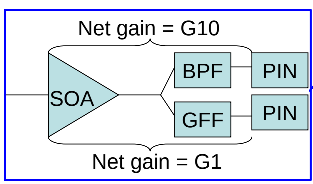
* At the meeting the group voted for a 20 nm passband for the upstream.

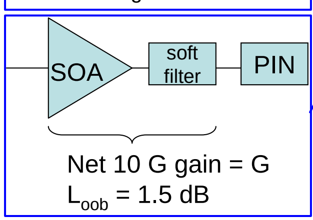
SOA vs. non-SOA solutions











	Ps 1G (dBm)	required 1G overload at Rx (dBm)	required 1G overload at PIN/APD (dBm)	Ps 10G (dBm)	required 10G overload at Rx (dBm)	required 10G overload at PIN/APD (dBm)
best traditional solution 1APD	**-24.0**	-1	-7	**-20.0**	1	-6
best traditional solution 2APD	**-24.0**	-1	-7	**-23.0**	-2	-5
GFF only net gain = 5 dB	**-26.9**	-7	-2	**-24.9**	-5	0
GFF only net gain = 10 dB	**-29.7**	-10	0	**-27.5**	-8	3
GFF only net gain = 15 dB	**-30.4**	-10	5	**-28.1**	-8	7
GFF (G1 = 12 dB) BPF (G10 = 10 dB)	**-30.1**	-10	2	**-28.8**	-9	1
GFF (G1 = 12 dB) BPF (G10 = 12 dB)	**-30.1**	-10	2	**-30.3**	-10	2
soft filter (Loob = 1.5 dB, G = 10 dB)	**-28.9**	-9	1	**-28.0**	-8	2
soft filter (Loob = 1.5 dB, G = 15 dB)	**-29.6**	-10	5	**-28.9**	-9	6

Even the most straight forward SOA solutions give vastly better results than traditional APD solutions.

Overload is a very key issue. For a dual mode receiver there is concern that an APD may not be able to handle < -10 dBm.

Our key point on the overload issue is this: There are numerous 10 / 2.5 / 1 G receivers on the market today with +3 dBm overload. There are TIAs with an overload of +6 dBm. (These numbers are at 1550 nm – to translate to 1310 nm add 0.7 dB.)

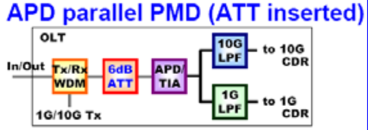
Soft filter does not seem to have much advantage here. Would be advantageous at smaller filter bandwidth

SOA solutions - summary

- Several SOA solutions outperform traditional solutions by several dB when 1G/10G coexistence is considered.
- SOA solution give even better results if the band for the 10G upstream is lowered.
- Use of SOAs could enable a single ONT for all classes.
- Use of SOAs eliminate the 1G/10G receiver penalty.

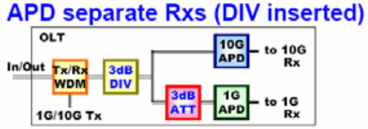
Traditional Approaches

APD parallel PMD (ATT inserted)



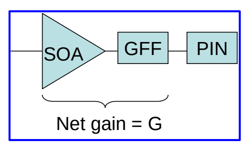
Ps(1G) = -24 dBm
Ps(10G) = -20 dBm

APD separate Rxs (DIV inserted)

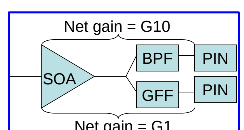


Ps(1G) = -24 dBm
Ps(10G) = -23 dBm

SOA Approaches



Ps(1G) = -30 dBm
Ps(10G) = -28 dBm



Ps(1G) = -30 dBm
Ps(10G) = -30 dBm

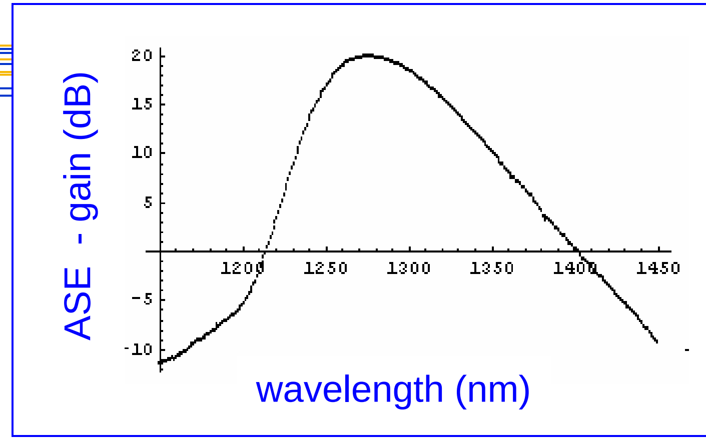
B++ Goal

Ps(1G) = -30 dBm
Ps(10G) = -30 dBm

Appendix

Why a gain flattening filter?

Assume an SOA with the following gain ~ ASE profile (Taken from Alphion data, assuming gain ~ ASE)



The sp-sp beat noise for a signal at λ_0 is approximately

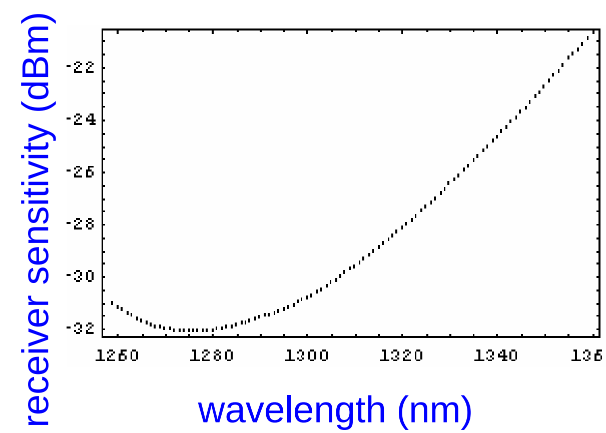
$$\sigma^2_{sp-sp} \propto \frac{\int ASE(\lambda)^2 d\lambda}{ASE(\lambda_0)^2}$$

So, unfiltered, one would expect the following Ps (for 1.25Gb/s, ER= 9 dB, NF = 7, BER= 10^{-12})

Best Ps at peak of the ASE / gain curve, worsening Ps as one move away

A gain flattening filter will make flat not only the gain, but also the Ps vs wavelength

Note: This is a much greater variation than one would see in Ps if one used a narrow BFP and measured Ps vs. wavelength.

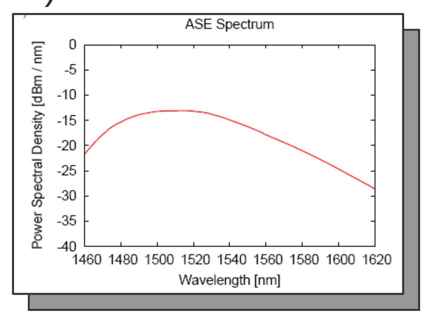


A request

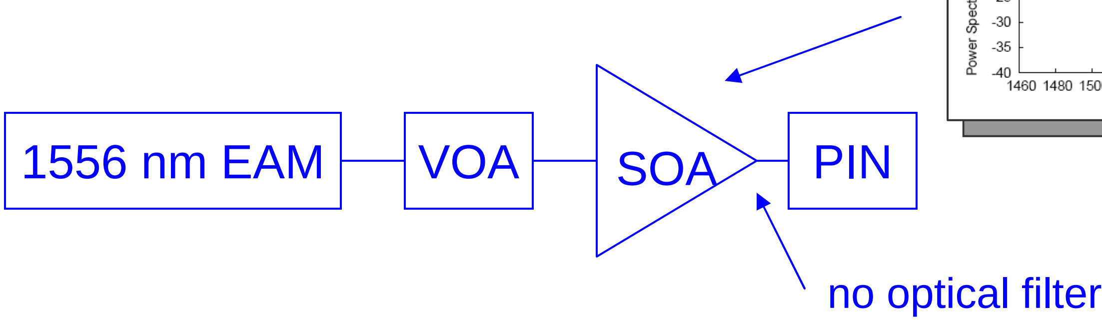
Suzuki-san of NTT suggested in the email exploder.

(1)To provide some results (if possible, both experimental and numerical) of BER curve measurements including BERs below 10E-12 to confirm whether there are error floors because I think "error floor" means that the SNR does not linearly improve with the optical input power and stay around an insufficient SNR value.

(2)To provide some results of "Q" measurements to experimentally confirm whether there are error floors because I think it is hard (or takes a very long time) to measure sensitivities at low bit-error rates.



We preformed the following experiment



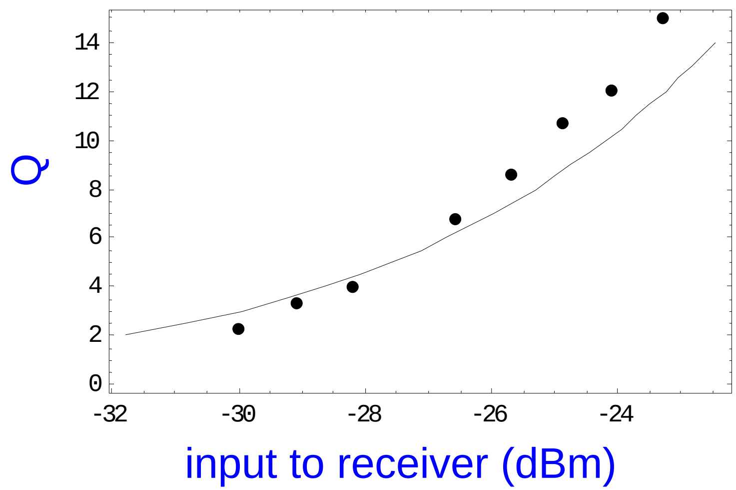
G = 20 dB

NF = 7 dB

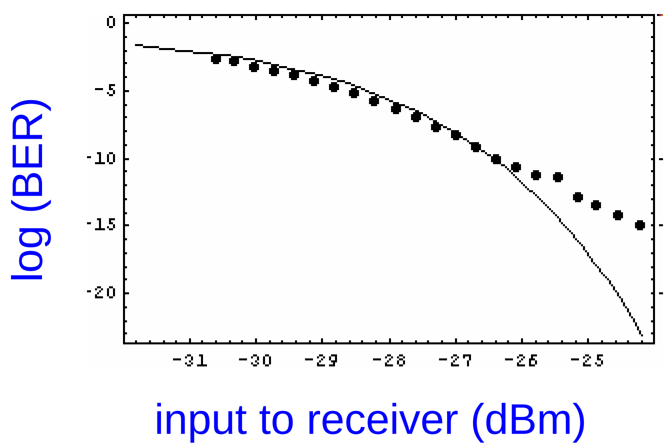
ER = 10 dB

Experiment preformed at 1556 nm due to lack of quality 1310 nm 10G Tx

Results



Q measurements are somewhat better than calculation at higher input power



BER measurements are somewhat worse than calculation at higher input power

Questions from

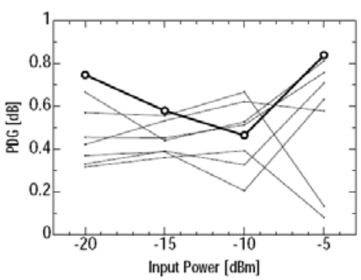
From: Seigo Takahashi

Sent: Thursday, May 24, 2007 8:39 AM

To: STDS-802-3-10GEPON@listserv.ieee.org

Subject: Re: [8023-10GEPON] [POWER_BUDGET] SOA/PIN for 10G/1G OLT receiver

PDG fluctuation



The PDG value depends on input power, injection current and signal wavelength.

Because, it is affected by carrier density in SOA waveguide.

Our response:

As long as polarization stays below the PDG limit (we believe that +/- 0.50 dB is reasonable, and is met in the above data) There is no problem because PDG is taken into account in the PIN/filter/SOA design.

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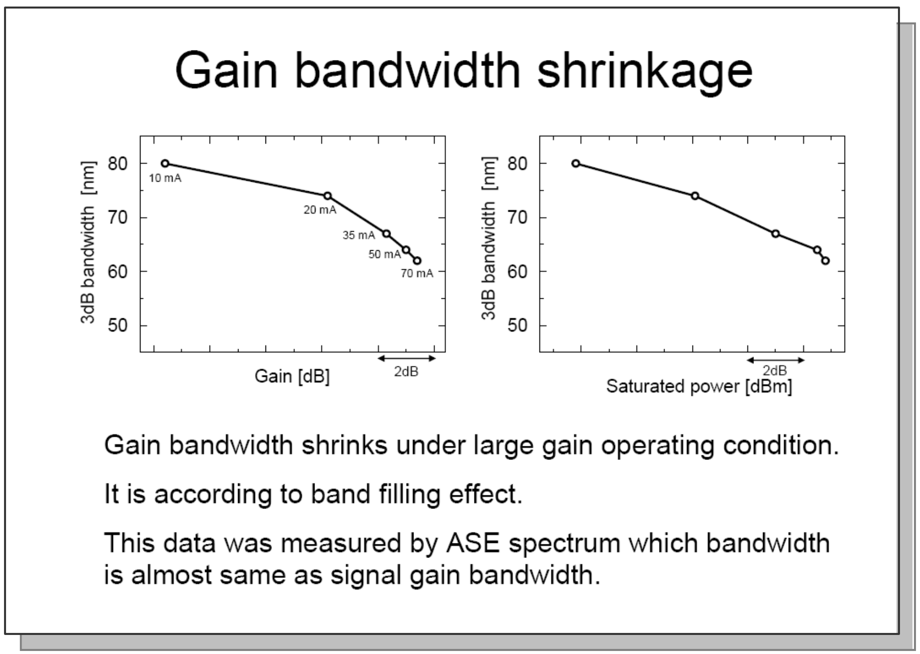

Our response:

It is not unusual that gain bandwidth decrease increasing injection current. However, we propose to operate the SOA at a constant current – therefore gain shrinkage is not an issue

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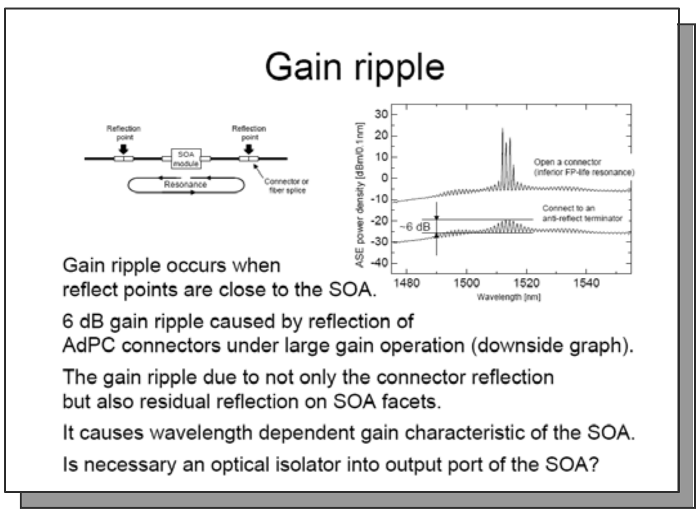

Our response:

The data shown shows a very poor SOA. The free spectral range of the ripples (0.8 nm @ 1520 ~ 86 GHz = c/(2nL) -> L = 790 microns.) implies that these reflections are coming from the SOA cavity. Today, commercial SOAs are commonly made with angled facets and do not show such ripples in the gain spectrum. I would guess that that SOA in the diagram had facts normal to the waveguide, and had poor anti-reflective coatings. It is not surprising at all that the SOA illustrated should be sensitive to external reflection, since it appears to be acting as a FP laser diode just under threshold. The effects illustrated are not seen in commercial SOAs.