SBS Mitigation in Digital Transmission for 10G EPON Standards Development

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Outline

- Motivation
- SBS in previous contributions on high power
- SBS thresholds and mitigation in digital transmission
  - CW SBS threshold
  - Impact of modulation
  - Suppression by FM dithering
- Strategy for Dealing with SBS in 10G EPON

Need For High Power Tx

CH IL (dB)	Tx Pen. (dB)	Power Budget (dB)	PIN Rx Sens. w/ 3dB FEC (dBm)	Min Launch (dBm)	Max Launch (dBm)
29	~2	~31	-20 (avg) -18.4 (OMA)	11 (avg) 12.6 (OMA)	14-15 (avg) 16.6-17.6 (OMA)
24	~2	~26	-20 (avg) -18.4 (OMA)	6 (avg) 7.6 (OMA)	11 (avg) 12.6 (OMA)

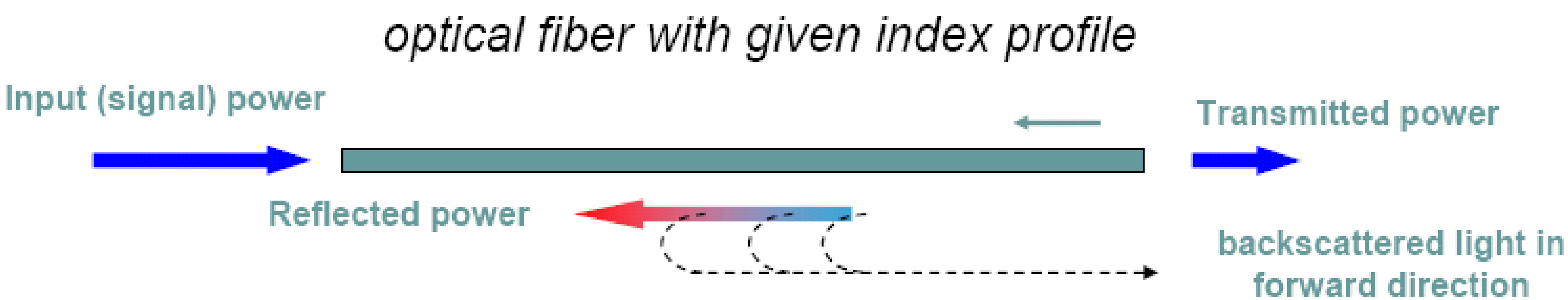
Assume ER > 8.2 dB

Previous Contributions

Contributor	Tx + Amp	Fiber Length (km)	Max Power (dBm) w/o SBS mitigation for <= 0.5 dB penalty	Max Power (dBm) w/ SBS mitigation for <= 0.5 dB penalty
Murata_1_0706	EML+ EDFA	20	13*	“higher”
3av_0611_doussiere_1	EML + EDFA	25	13	> 17
3av_0701_gokhale_1	EML + EDFA	20	~ 12.5*	> 17
3av_0701_ten_1	MZM+ EDFA	20	~ 11	

* Estimation, based on conversations with authors

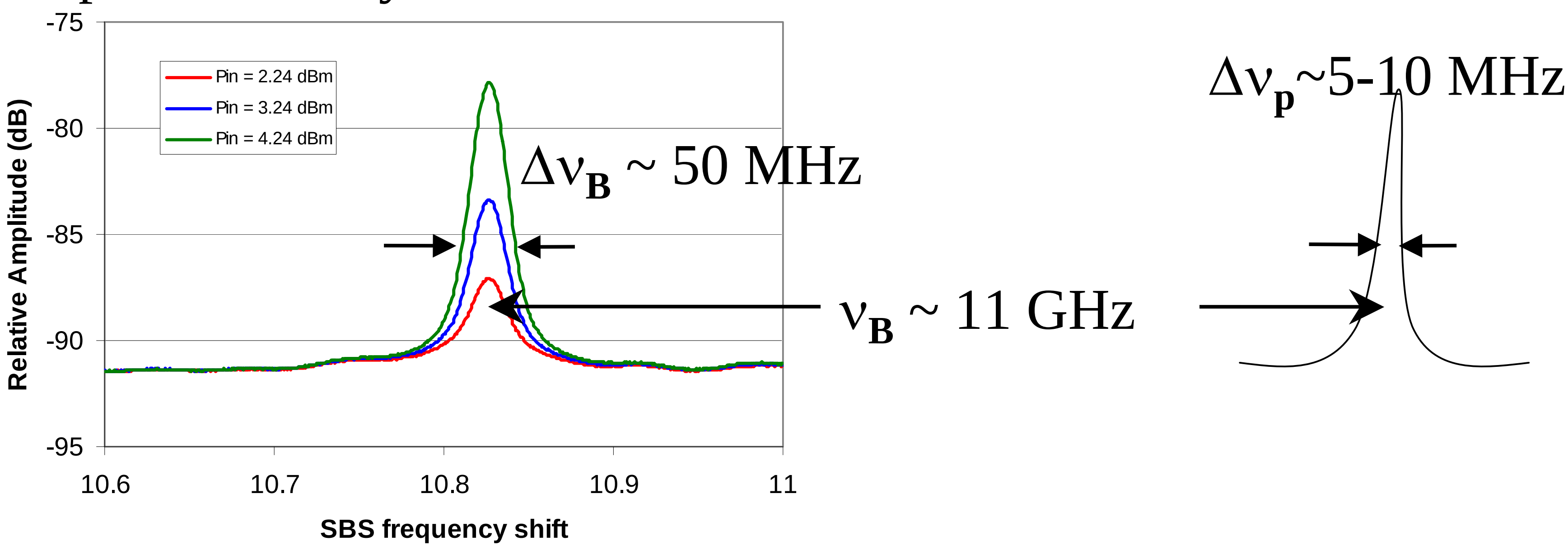
Stimulated Brillouin Scattering



$$P_{thr}^{CW} \approx 42 \frac{A_{eff}}{g_0 L_{eff}} \left(\frac{\Delta \nu_B + \Delta \nu_p}{\Delta \nu_B} \right)$$

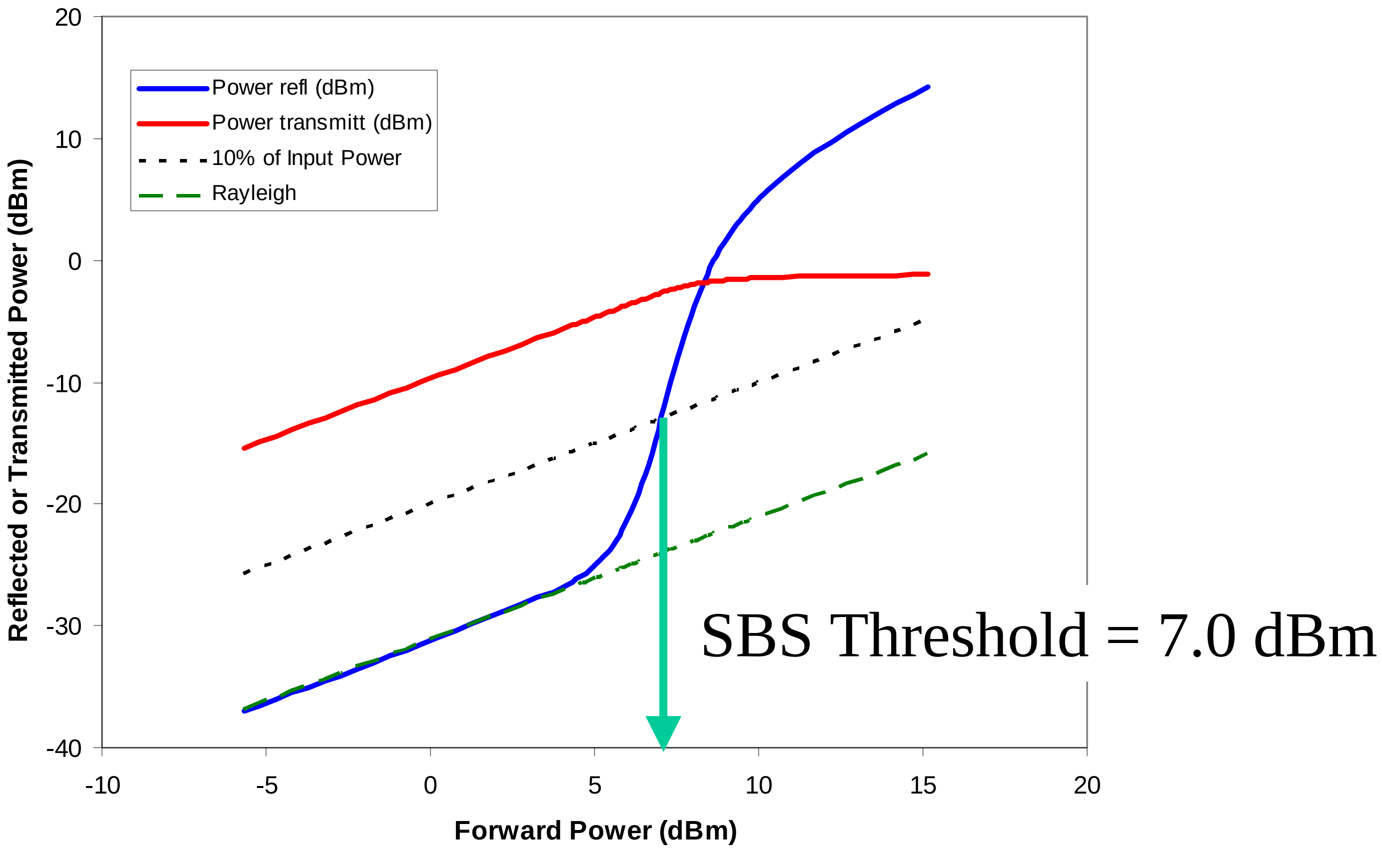
Ref: Aoki et al., JLT, v6, p710 (1988)

SBS measured on RF spectrum analyzer



SBS Threshold Definitions

•Pick some point where the backscatter power is rapidly rising with input power.
•There are advocates for various threshold definitions, but the impact on system performance is what matters.



SBS 1% CW Threshold Power for various G.652 fibers

(values normalized to 20 km length)

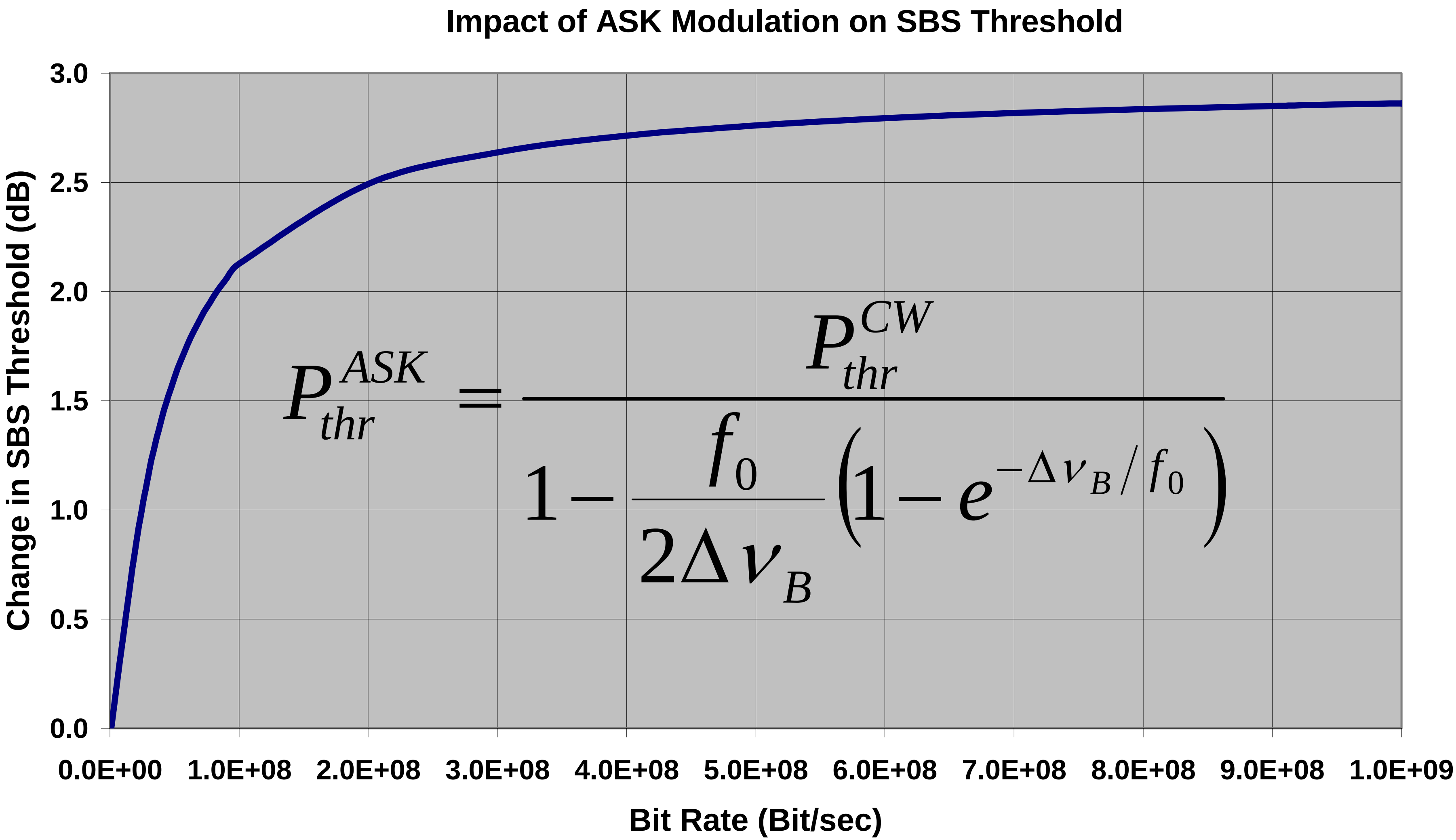
Fiber Type	Threshold Range (dBm)	# Tested
A	7.04 – 8.23	≥ 8
B	7.24 – 9.65	≥ 8
C	5.8 – 6.7	3
D	5.91 – 7.2	≥ 8

- Measured with ECL, linewidth ~ 100kHz
- Represents different 1) manufacturers, 2) core fabrication technologies, and 3) designs within G.652

SBS Suppression by Data Modulation

- The wider line width of a modulated signal will increase the SBS threshold.
- However, the effect saturates because half the total pump power is contained in the spectrally narrow carrier for ASK.
- Thus the effect saturates at 3 dB, and most benefit is already obtained at a data rate of 500 Mbps .
- Above comments apply to external modulation. SBS can be ignored in the case of DMLs.

Impact of Digital Modulation



$$P_{thr}^{ASK} = \frac{P_{thr}^{CW}}{1 - \frac{f_0}{2\Delta\nu_B}\left(1 - e^{-\Delta\nu_B / f_0}\right)}$$

f_0 is the bit rate, Eq 3 of Fishman & Nagel, JLT 11, p1721 (1993).

SBS Suppression by FM Dither of Tx Center Wavelength

Fishman & Nagel, JLT, v11, 1721 (1993).

FM dithering of the laser wavelength at 10’s of kHz broadens the effective linewidth of the source

$$P_{thr} \propto \left(\frac{\Delta\nu_B + \Delta\nu_p^{Eff}}{\Delta\nu_B} \right)$$

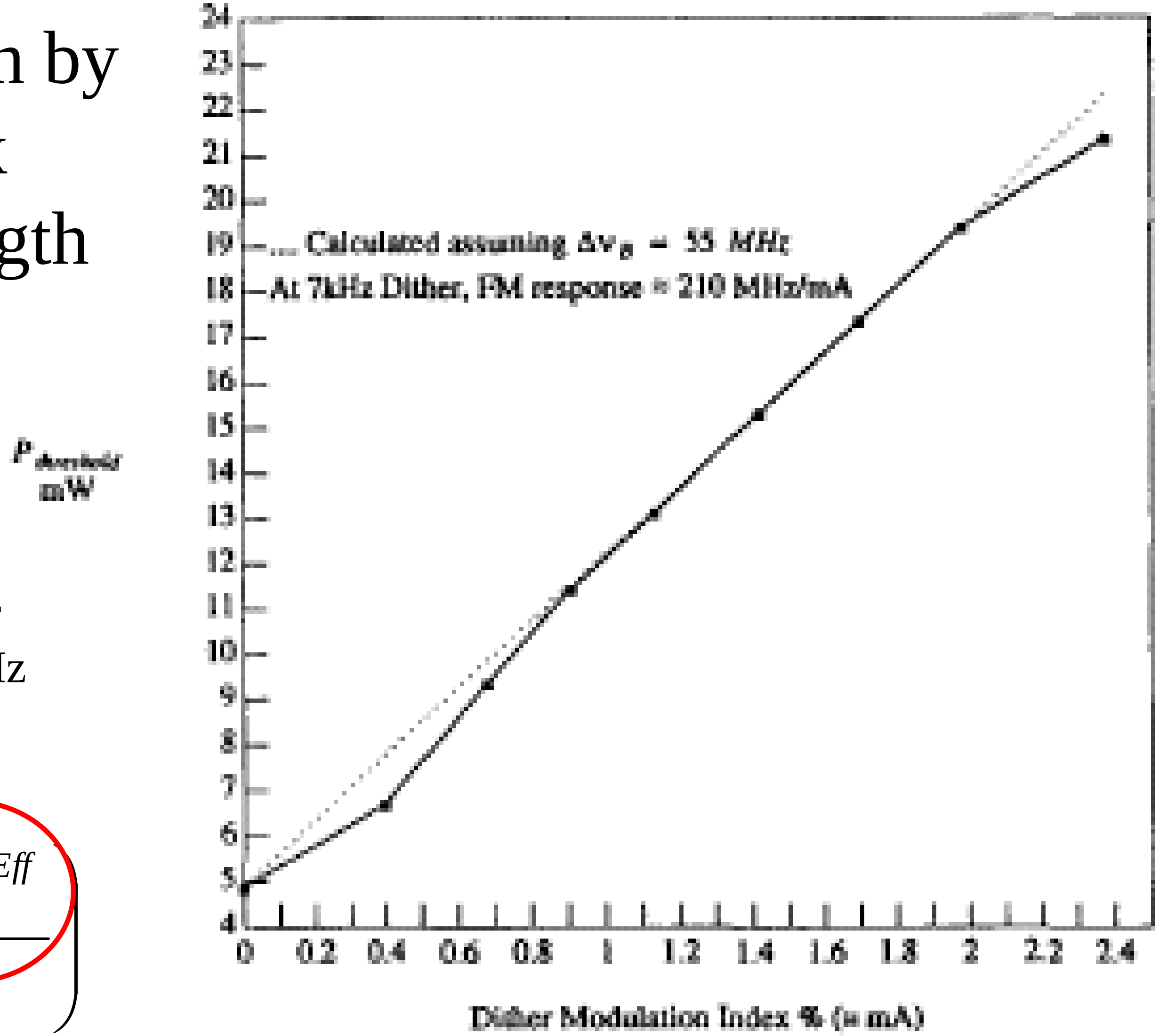


Fig. 9. Plot showing the effect of FM dither on CW SBS threshold. The MQW-DFB laser is biased at 100 mA, with a nominal FWHM linewidth of 25 MHz. The dotted line is a result of the threshold calculated using (2), assuming that $\Delta\nu_B = 55$ MHz and that the dither effectively broadens the linewidth.

FM Dithering of Digital Tx

- It is typical for EMLs for DWDM transmission to have an input for a 1-100 kHz signal to drive frequency dithering for SBS control
- The solution is straightforward, common, and “practically free.”
- Tx dithering can solve any SBS problem that may occur in 10G EPON systems, without adding dispersion penalties.

Suggested Strategy for Handling SBS in 10G EPON

- Determine the limit where SBS suppression is required to keep impairments less than a few tenths of a dB for worst case fiber + amplified EMLs, from experimental data
- Require that SBS suppression be employed for an EML Tx operating in a range that overlaps the determined limit
- If isolation is good at the amplifier, SBS suppression *may* only be an issue for the 29 dB CH IL case