Maximum Tx Power Limits for 25GBASE-ER

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Supporters

Overview

- Currently the maximum Tx power for 25GBASE-ER is +6dBm average power
- This is close to the Stimulated Brillouin Scattering (SBS) threshold on single mode fiber
- Propose reducing the maximum Tx launch power to avoid SBS

Stimulated Brillouin Scattering (SBS)

- SBS is an interaction between the photons and the glass lattice → generates acoustic phonon + reflected wave
- Caused by non-regular glass matrix (randomness of glass molecules)
- Reflected wave takes energy from the forward travelling wave (signal) → reduces signal power, increases signal noise
- Caused by the $\chi^{(3)}$ non-linearity in glass
- Reflected wave is ~11GHz lower in frequency
- Brillouin gain is a narrowband effect
  - Typically 50-100MHz optical bandwidth
  - Affects single wavelength systems

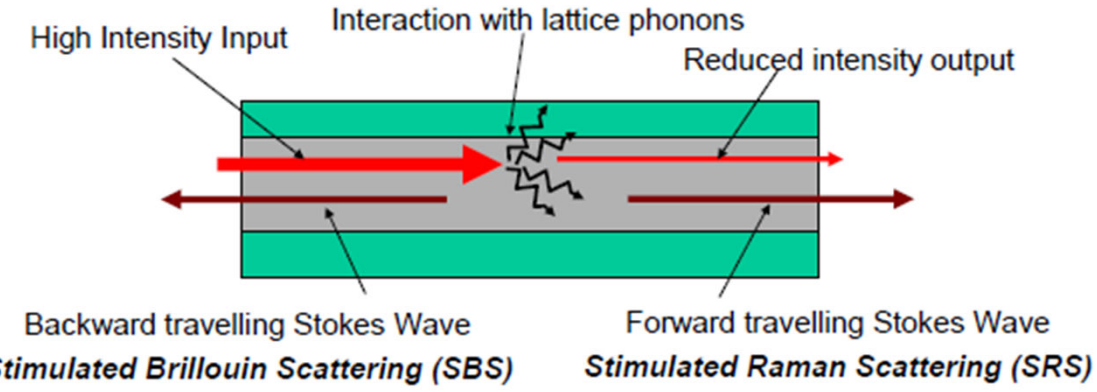


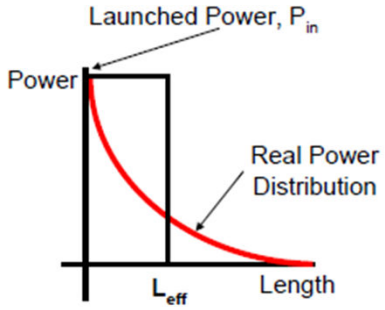
Diagram from Dr Tom Brown
Uni of St Andrews

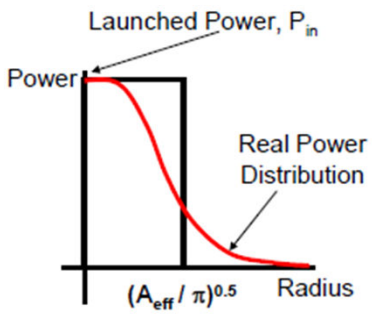
SBS Effects

- Limits transmit power
  - Hard upper limit
  - Critical power threshold to keep below
- Increases noise as reflected signal is pattern dependent
  - Reflection occurs in narrow optical band (<100MHz)
  - Acoustic phonons have long lifetimes
    - Not instantaneous compared to data rate
  - Highest power for NRZ is the CW optical carrier and low frequency data spectral lines
  - Back reflection can induce laser instabilities if laser has insufficient isolation
- SBS effect depends on fibre loss, effective area of fibre and effective length of fibre

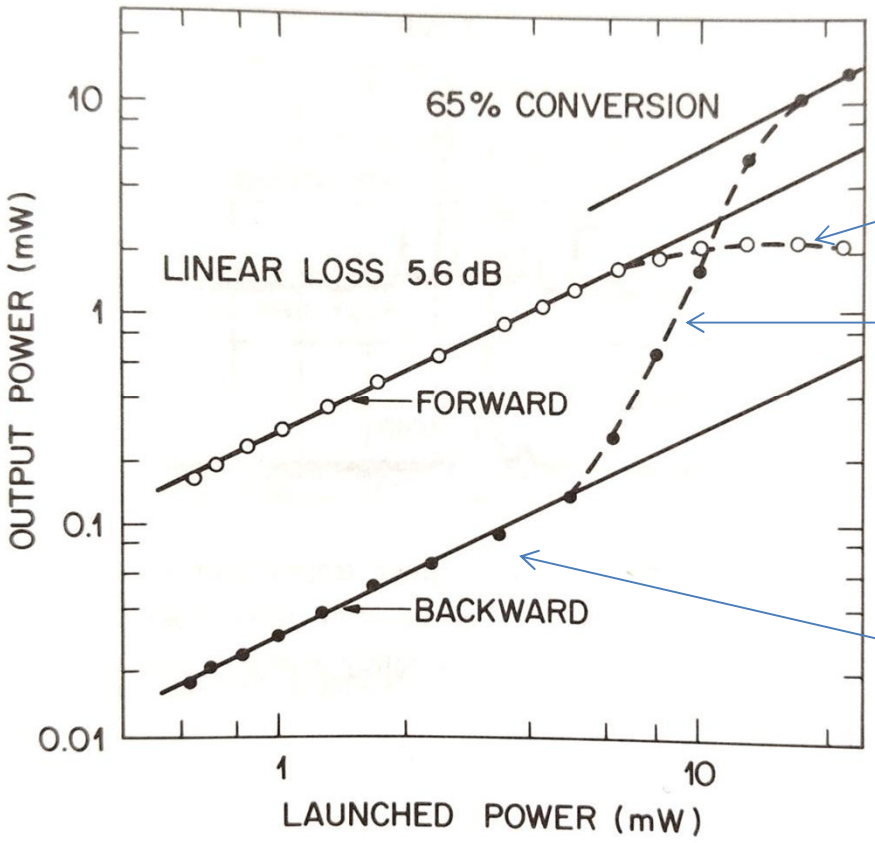
$$P_{thres} = \frac{21A_{eff}}{g_B L_{eff}}$$

A_{eff} = effective area of fibre
g_B = Brillouin gain co-efficient
L_{eff} = effective length of fibre





SBS Threshold Power



Forward optical power

Reflected optical power due to SBS

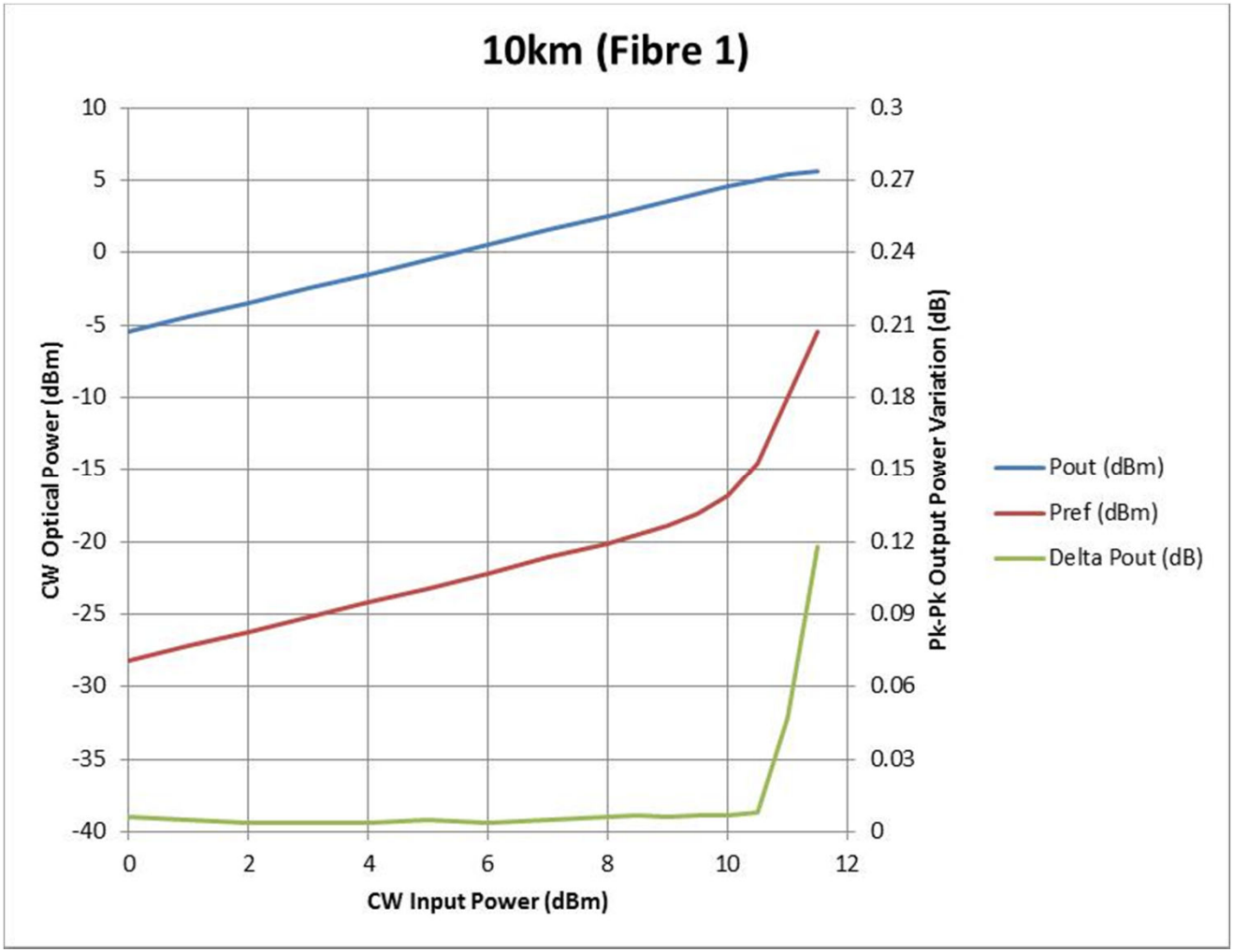
Reflected optical power due to Rayleigh Backscatter

From “Non-linear Fiber Optics”, G.P. Agrawal, p387

Explanation of Measurements

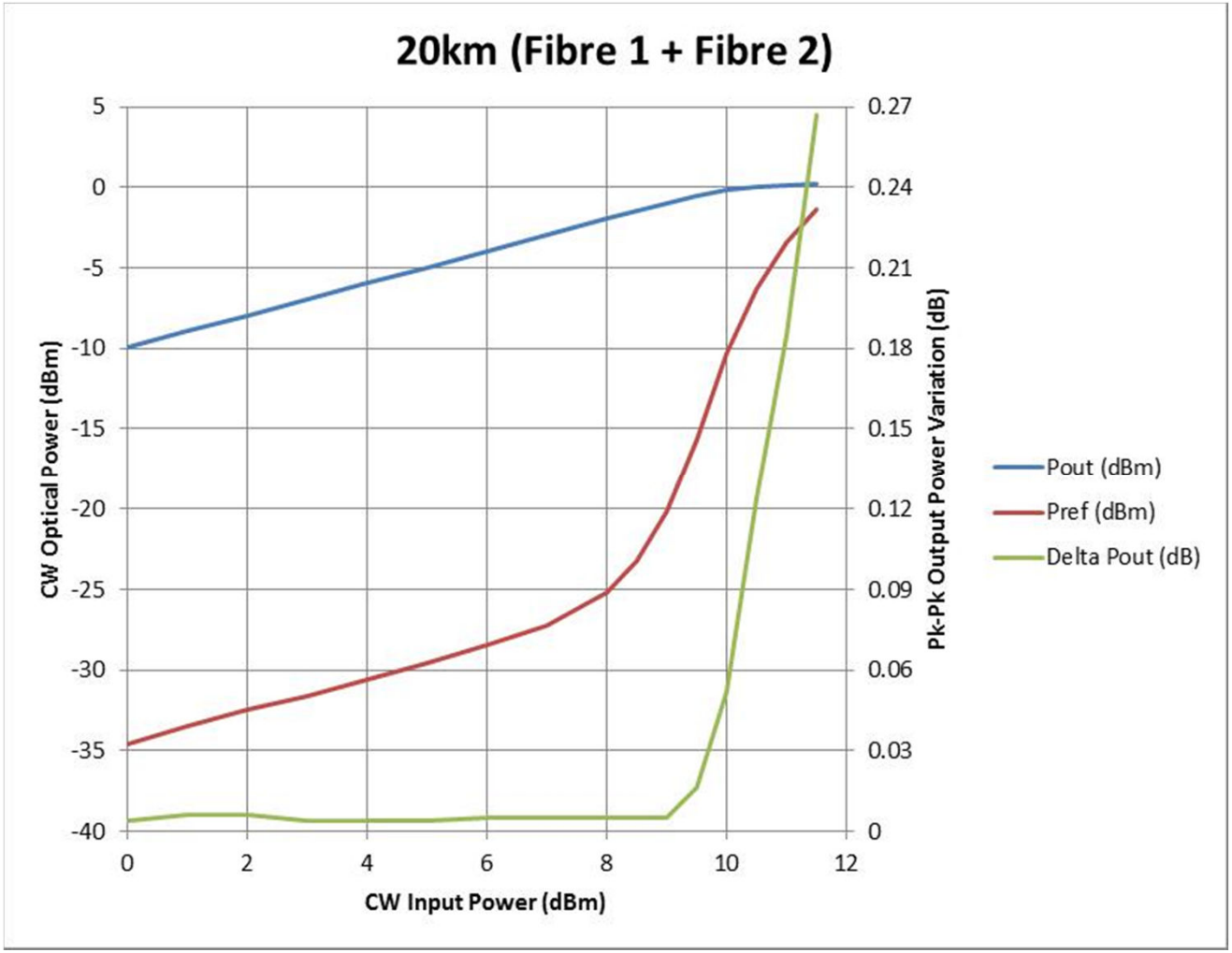
- Pout = optical power out of fibre (ie power into Rx)
- Pref = optical power reflected back to fibre input (ie power reflected back to Tx)
- Delta Pout = pk-pk variation of optical power at the output of the fibre (ie noise at Rx)
- Measurements made with CW power
- No attempt to control or vary polarisation of input optical power

Measured Results 1



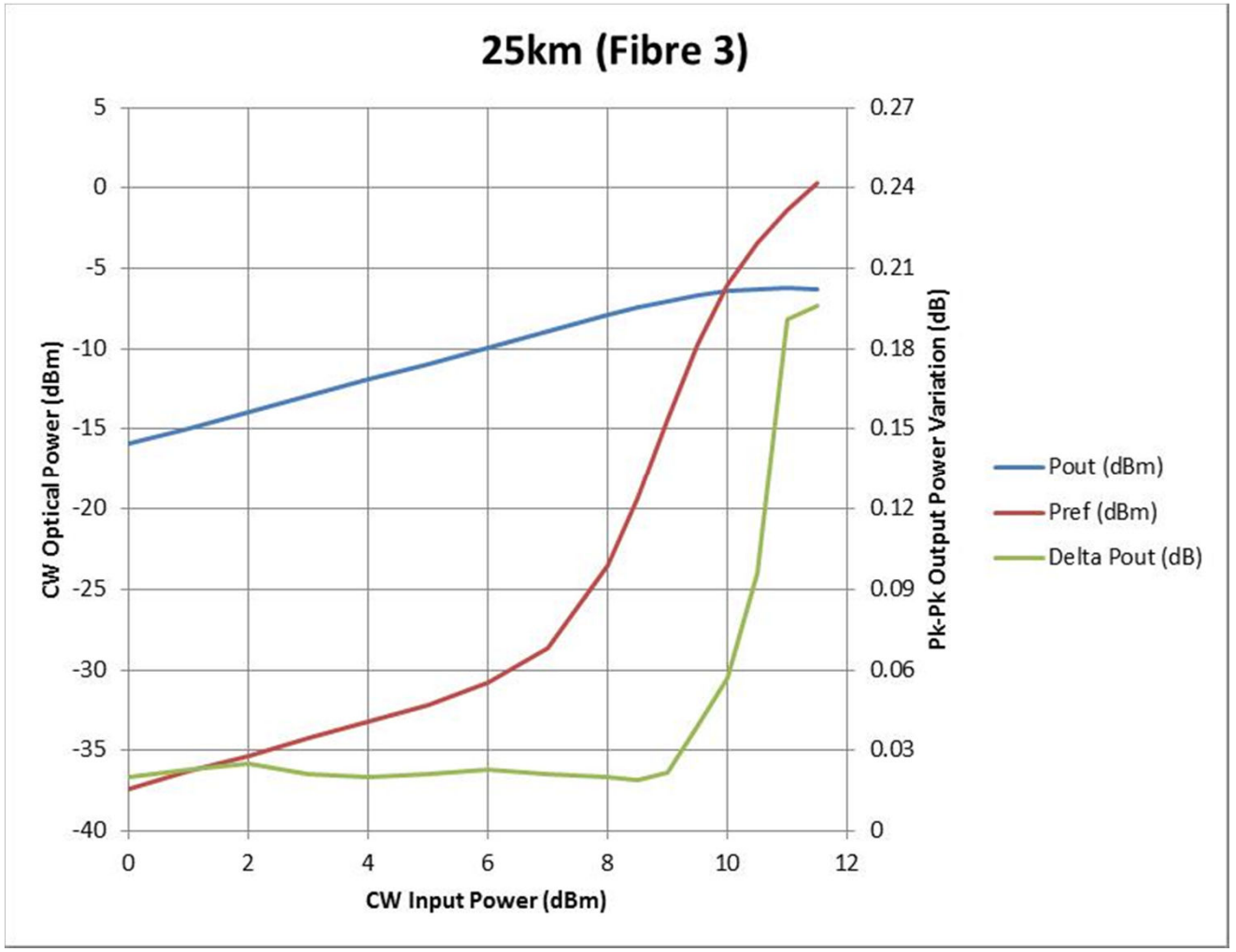
Fibre loss = 5.45dB

Measured Results 2



Fibre loss = 9.92dB

Measured Results 3



Fibre loss = 15.9dB

Fitting parameters to measured 25km link

Brillouin parameters										
b	2		PMF=1, SMF=2							
Ae	4.18539E-11	m^2	Effective area of overlap between Stokes wave and pump wave (~0.73 x actual)							
Gb	4.00E-14	m/mW	Maximum steady-state Brillioun gain (4e-9cm/W)					(1cm/W=1e-5m/mW)		
Fibre_Loss	6.00E-01	dB/km	Fibre loss							
alpha	0.000138153	neper/m	Fibre loss							
Lfibre	25000	m	Fibre length							
Le	7009.42709	m	Effective length = (1-exp(-alpha*L))/alpha							
f_B	1.10E+10	Hz	Brillouin bandwidth							
Bitrate	2.50E+10	b/s	Bitrate							
Ka	0		Intensity modulation depth 0<=Ka<=1 (0=CW, 0.5=50%)							
A	0									
G	4E-14		Modified Brillouin gain							
Pc	6.269636729	mW	Critical power - onset of Brillouin							
	7.97242378	dBm								

Assumptions:

Fibre loss = 0.6dB at 1310nm

CW - no modulation

No polarisation control

Aeff and Brillouin Gain coefficient

Modelling ER 40km link

- Worst case is low loss fibre – extends L_{eff}
  - Assume 0.25dB/km for lowest loss fibre
- NRZ modulation

Assumptions:
Minimum fibre loss = 0.25dB at 1310nm
NRZ modulation
No polarisation control
Aeff and Brillouin Gain coefficient

Brillouin parameters										
b	2		PMF=1, SMF=2							
Ae	4.18539E-11	m^2	Effective area of overlap between Stokes wave and pump wave (~0.73 x actual)							
Gb	4.00E-14	m/mW	Maximum steady-state Brillioun gain (4e-9cm/W)					(1cm/W=1e-5m/mW)		
Fibre_Loss	2.50E-01	dB/km	Fibre loss							
alpha	5.75639E-05	neper/m	Fibre loss							
Lfibre	40000	m	Fibre length							
Le	15634.74918	m	Effective length = (1-exp(-alpha*L))/alpha							
f_B	1.10E+10	Hz	Brillouin bandwidth							
Bitrate	2.50E+10	b/s	Bitrate							
Ka	0.5		Intensity modulation depth 0<=Ka<=1 (0=CW, 0.5=50%)							
A	0.292893219									
G	2.9306E-14		Modified Brillouin gain							
Pc	3.836522184	mW	Critical power - onset of Brillouin							
	5.839377138	dBm								

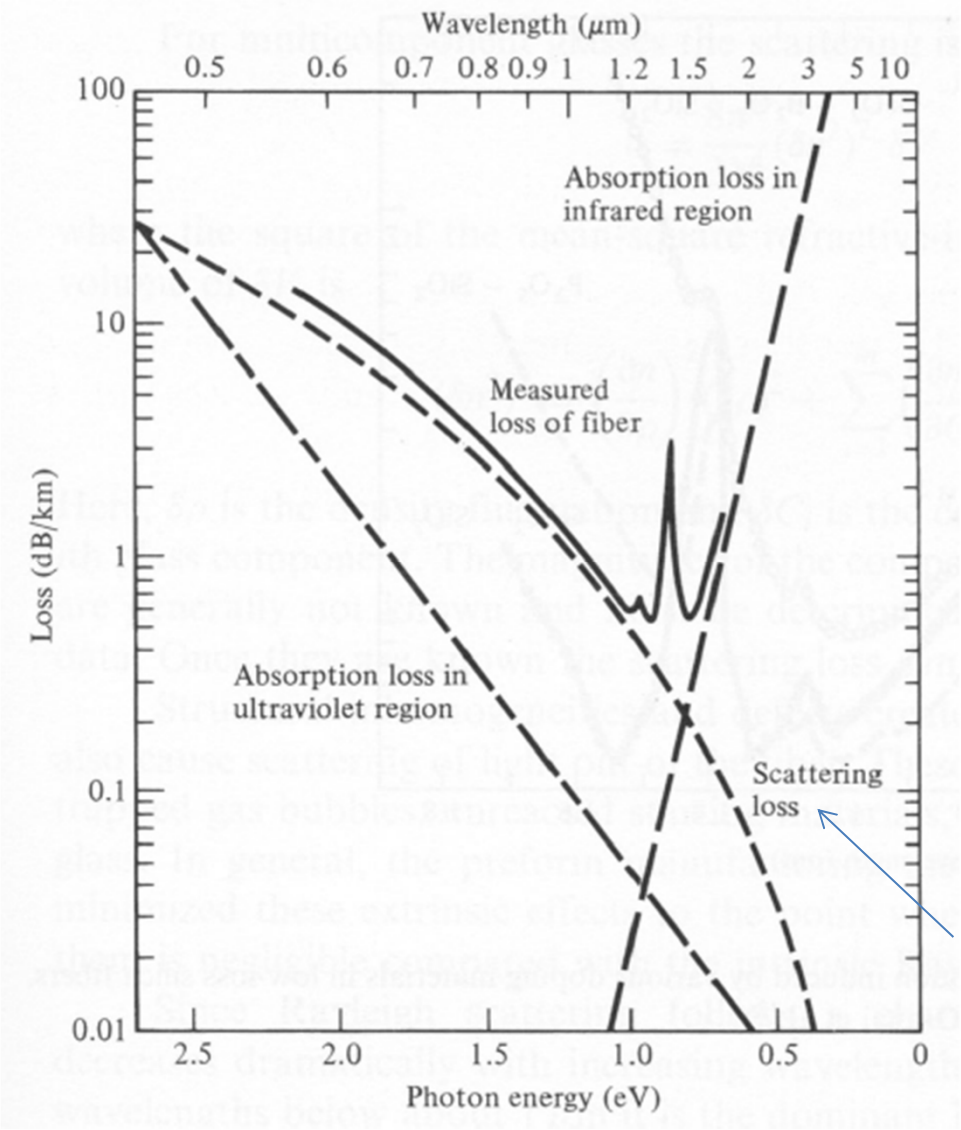
P_{thres} < +6dBm (max transmitter power) – Recommend keeping >1dB from P_{thres}

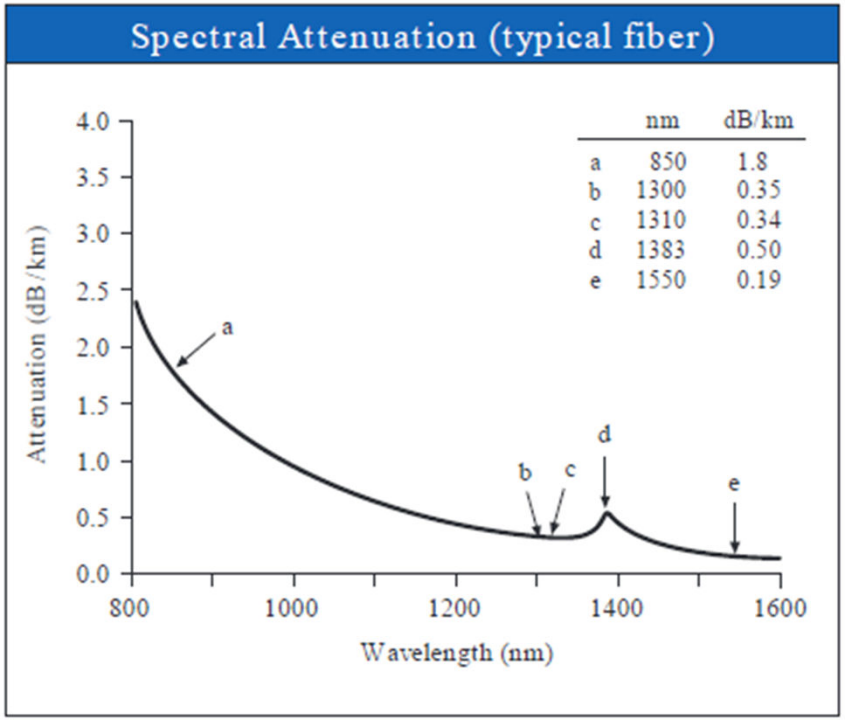
Proposal

- To avoid potential SBS and using SBS suppression techniques recommend keeping maximum transmitter power about 1dB lower than lowest P_{thres}
- Recommend changing maximum transmitter power to +5dBm

Back-up

Fibre Loss





SMF28 (circa 2002)

Rayleigh Backscatter