Chromatic Dispersion Limited Link Lengths for SWL and LWL Fiber Systems

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Outline

- Two basic effects of chromatic dispersion
- Pulse broadening
- Mode partition noise
- Penalties
- Additional effect of other noise terms
- Summary

Two basic effects of chromatic dispersion

Chromatic dispersion is caused by the different propagation velocities of light components having different colours.

It leads to two different effects:

- pulse spread, resulting in ISI;
- Mode Partition Noise (MPN)

Pulse broadening

The value of the ISI-caused chromatic dispersion penalty (in dB) can be estimated as follows[1]:

$$\alpha_{ISI} = 5 \log [1 + 2 \pi (B D L \sigma)^2]$$

where B is Baud rate, D is fiber chromatic dispersion coefficient, L is link length and σ is the RMS spectral width of laser

Mode partition noise

Partitioning of laser power between laser modes does not change the total transmitted power and does not cause additional noise at the laser output.

However, different laser modes travel at different velocities in the MMF.

As a result, power fluctuations between modes lead to MPN at the fiber output.

Mode partition noise penalty

The power penalty in dB due to MPN can be estimated as [1]:

$$\alpha_{mpn} = 5 \log [\, 1 / (1 - Q_a^2 \, \sigma_{mpn}^2) \,]$$

where Q_a is the desired argument of

$$BER(Q) = [\, Q (2 \pi)^{1/2} \,]^{-1} \exp(- Q^2 / 2)$$

and

$$\sigma_{mpn} = (k / 2)[\, 1 - \exp\{ - (\pi \, B \, D \, L \, \sigma)^2 \} \,]$$

σ_{mpn} is the MPN variance and the other terms as previously defined.

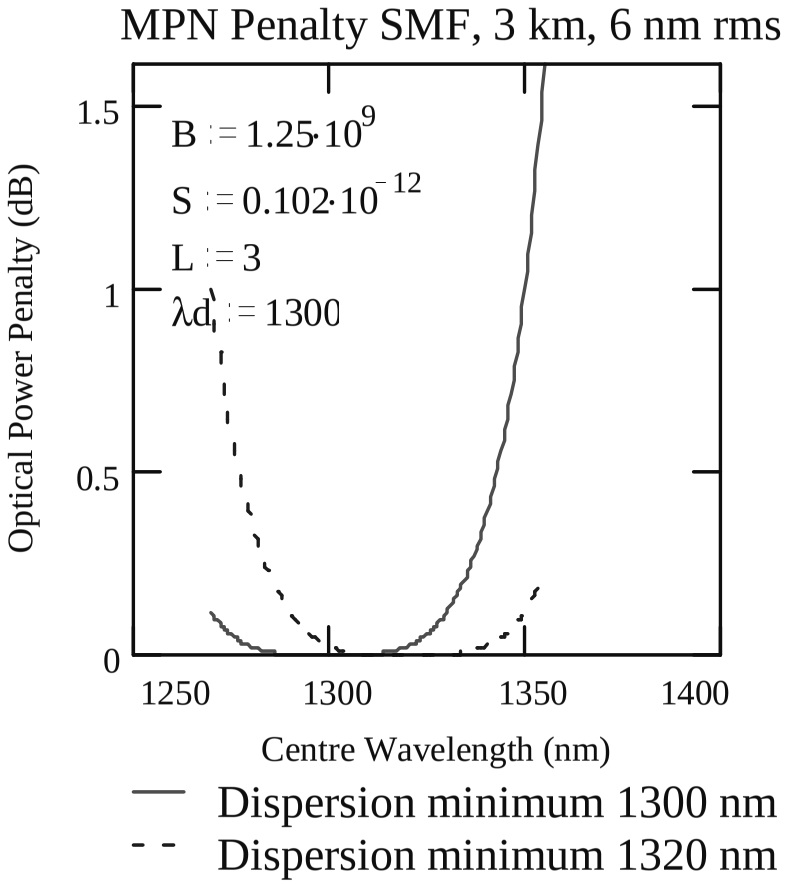
Penalties: Long Wavelength Lasers

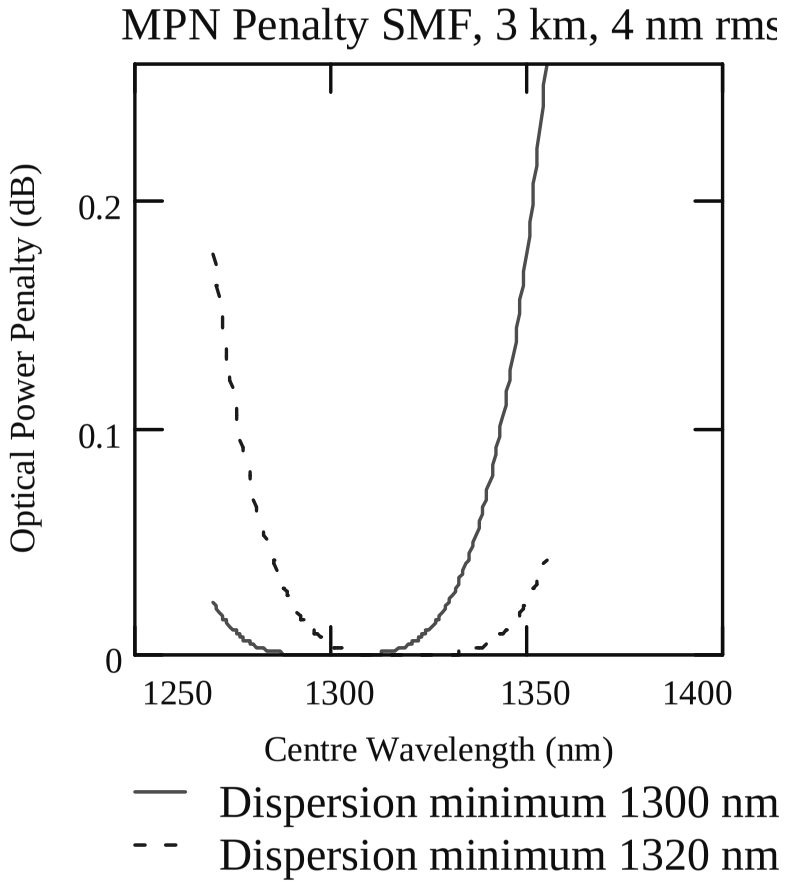
Near 1300nm D is approximately zero so D is estimated using:

$$D = S (\lambda_0 - \lambda_d)$$

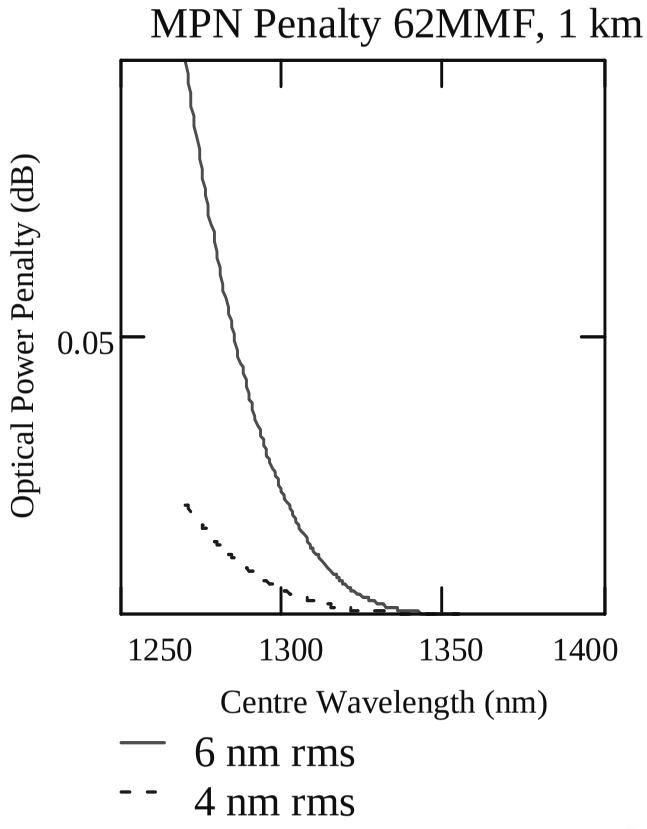
where S is the dispersion slope, λ_0 is the source mean wavelength and λ_d is the MMF zero dispersion wavelength.

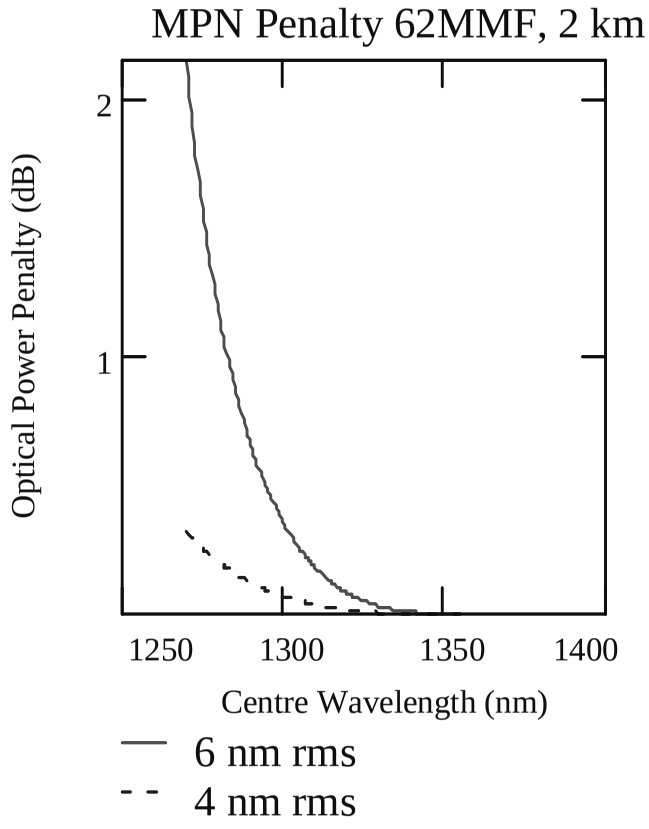
Penalties: Long Wavelength Lasers, SMF, k=1





Penalties: Long Wavelength Lasers, 62MMF, k=1





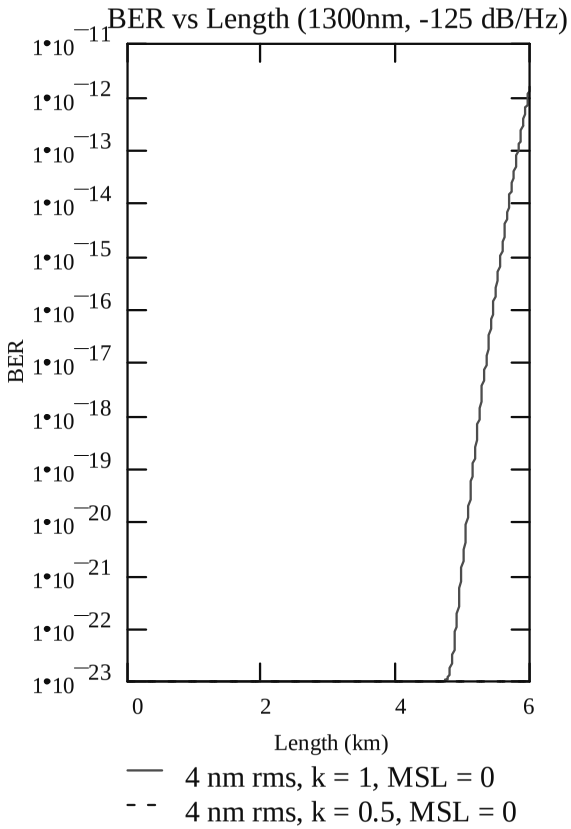
$B := 1.25 \cdot 10^{9}$

$S := 0.093 \cdot 10^{-12}$

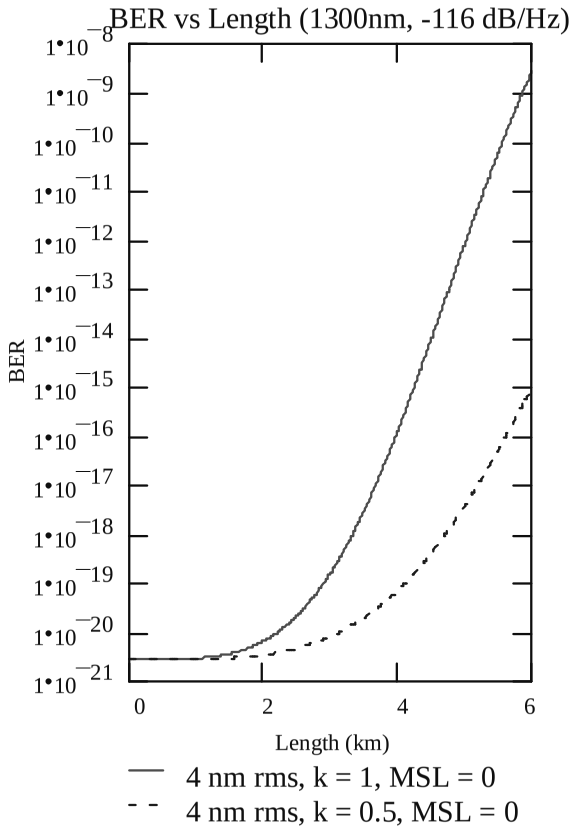
$\lambda d := 1365$

$\lambda 0 := 1270, 1270.5 .. 1355$

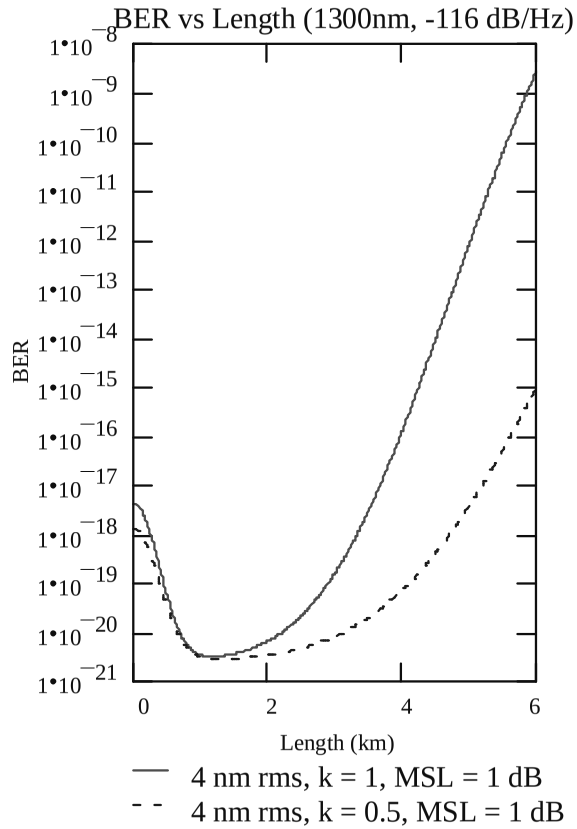
Additional effect of other noise terms



MPN

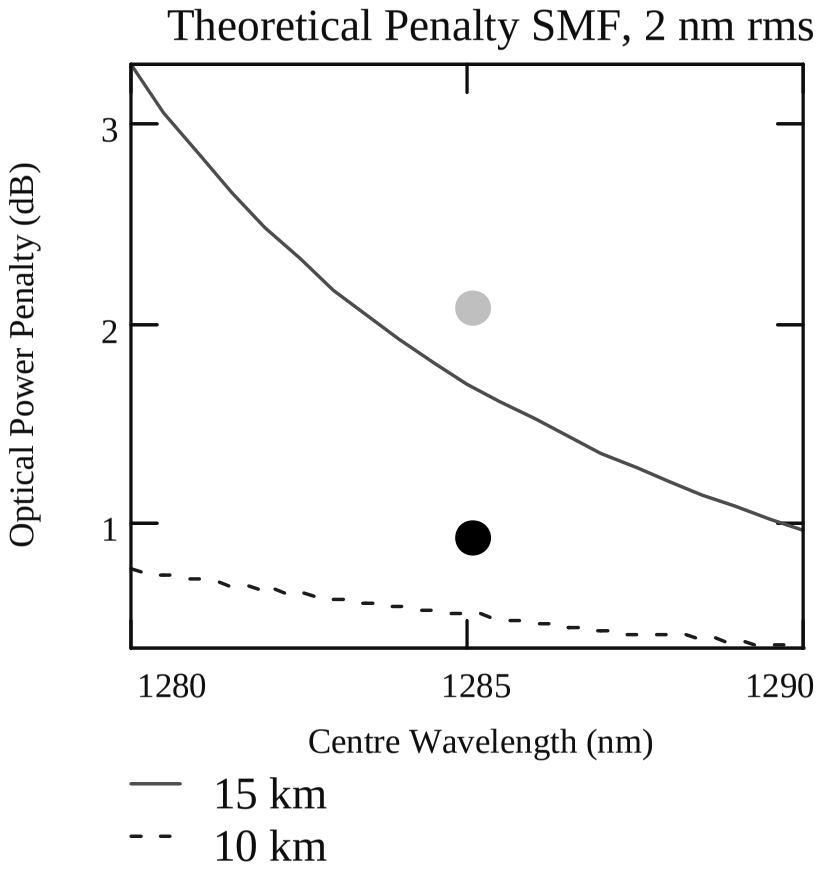


MPN & RIN



MPN, RIN & modal noise

Penalties: Long Wavelength Lasers, SMF, k=1



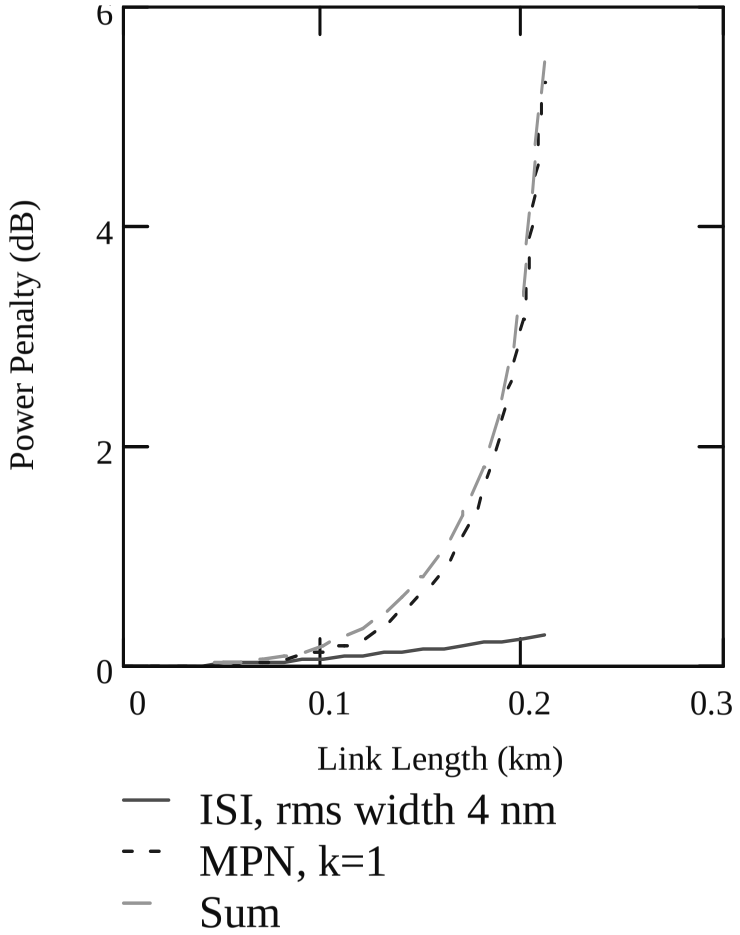
Experimental results at a centre wavelength of 1285 at 1 Gb/s:

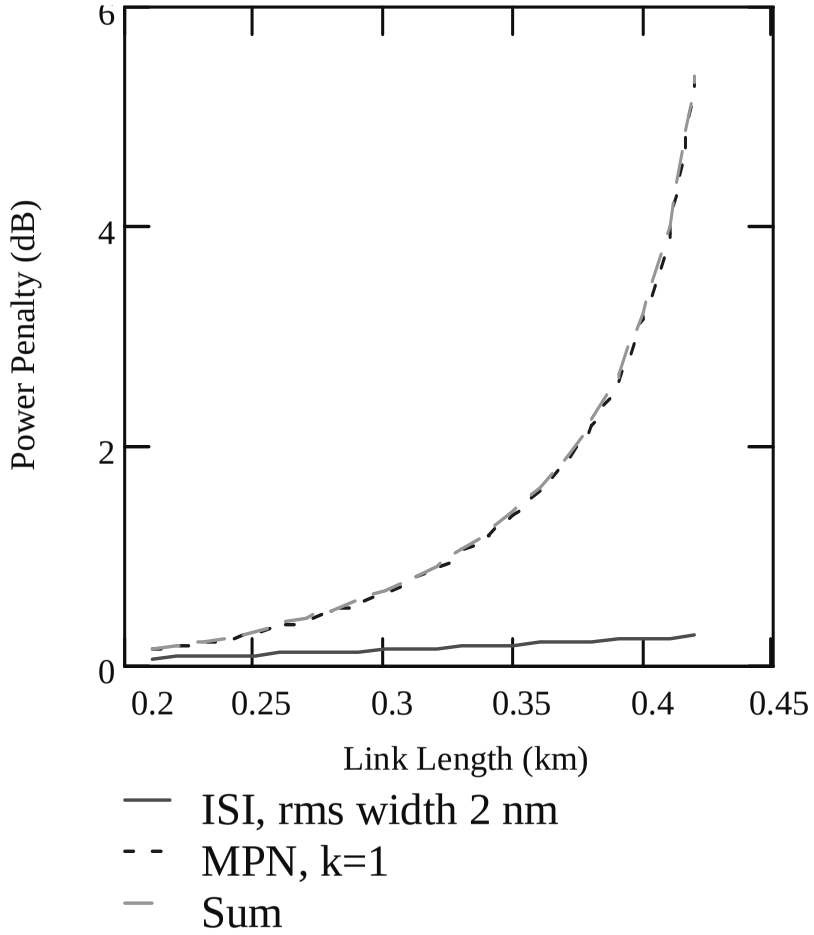
1 dB penalty for 10 km of SMF
2 dB penalty for 15 km of SMF

Bit rate increased to 1.4 Gb/s and a BER floor at 10-12 observed.

Penalties: Short Wavelength Lasers (770 nm), 50MMF, k=1, B = 1.25 Gb/s, D = 140 ps/nm

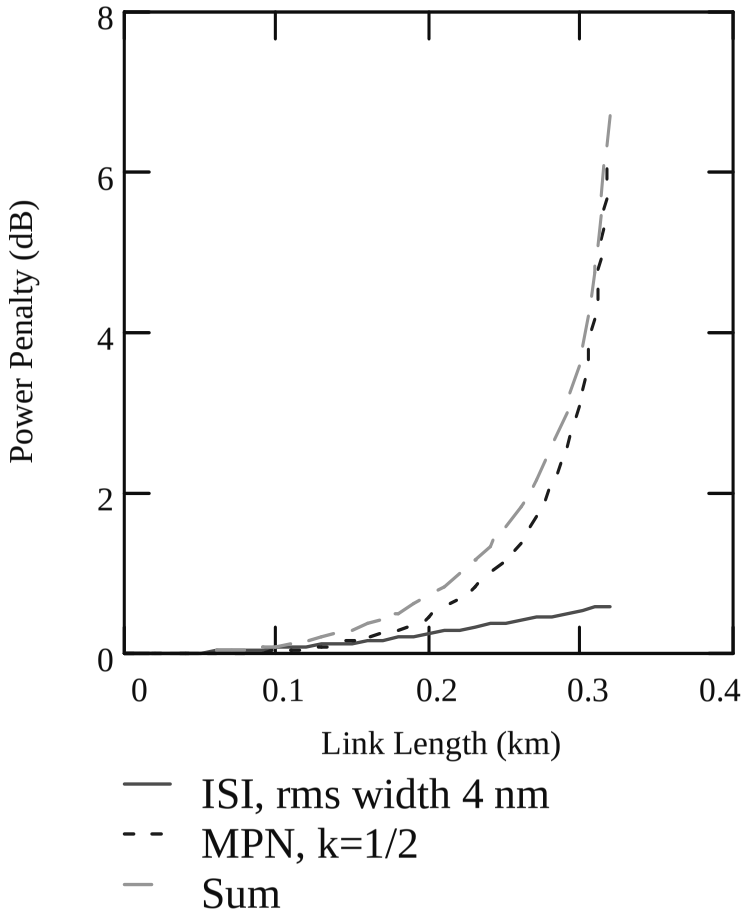
Dispersion Penalties versus length

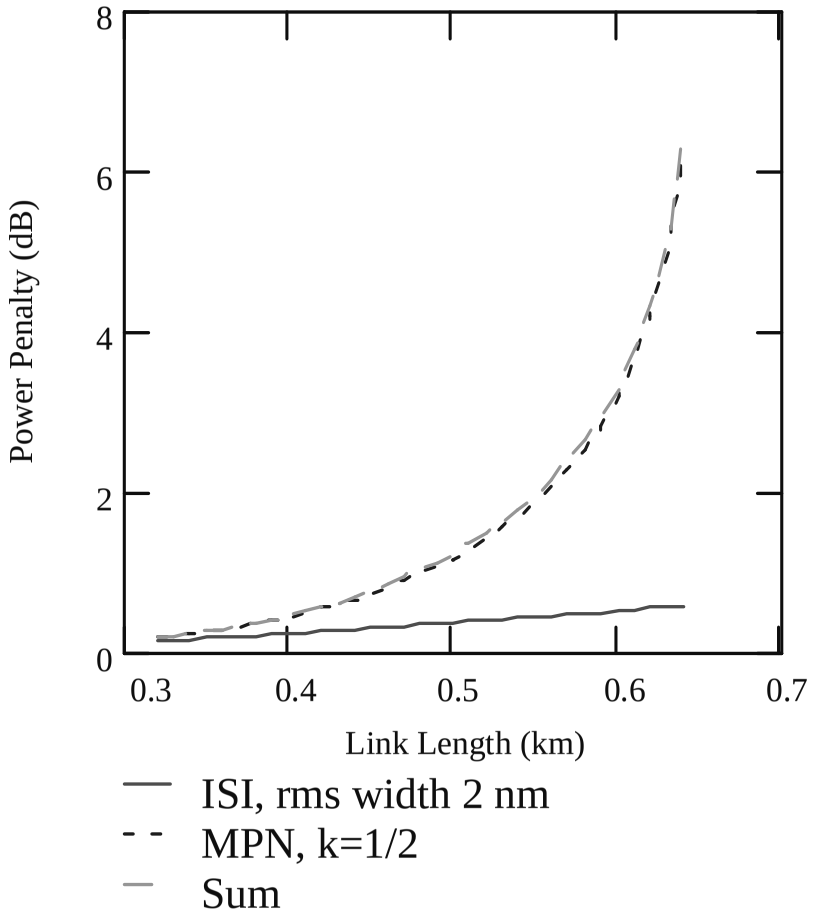




Penalties: Short Wavelength Lasers (770 nm), 50MMF, k=0.5, B = 1.25 Gb/s, D = 140 ps/nm

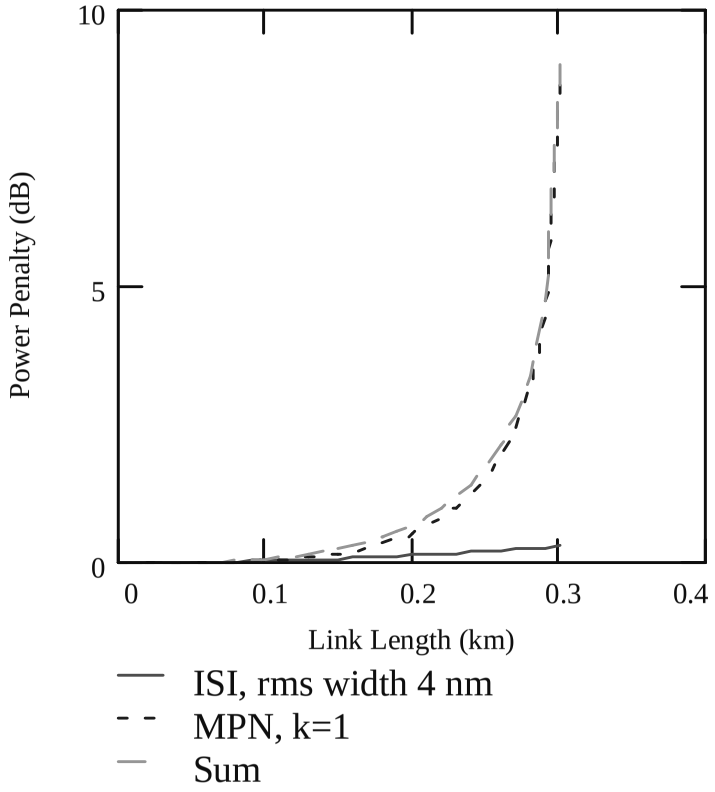
Dispersion Penalties versus length

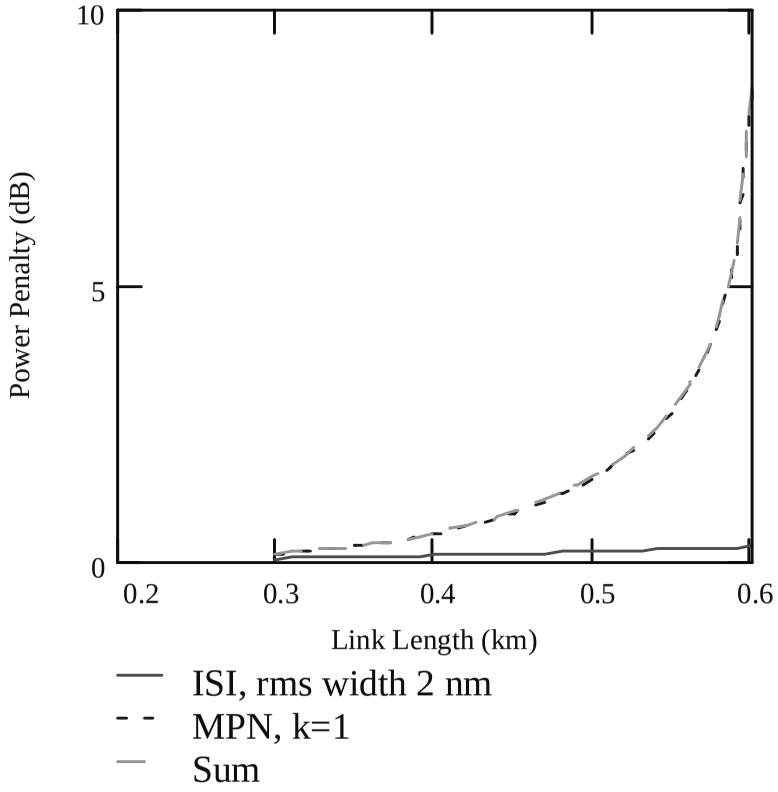




Penalties: Short Wavelength Lasers (840 nm), 50MMF, k=1, B = 1.25 Gb/s, D = 100 ps/nm

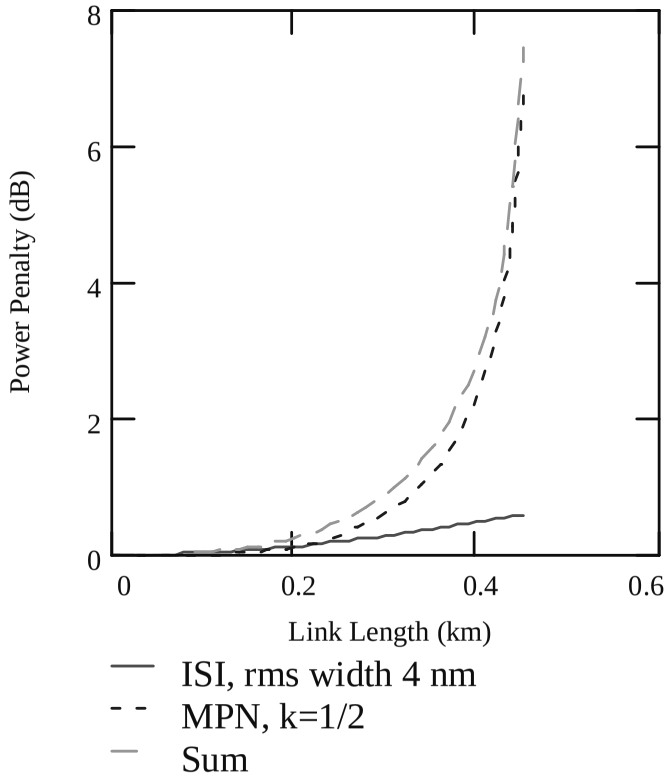
Dispersion Penalties versus length

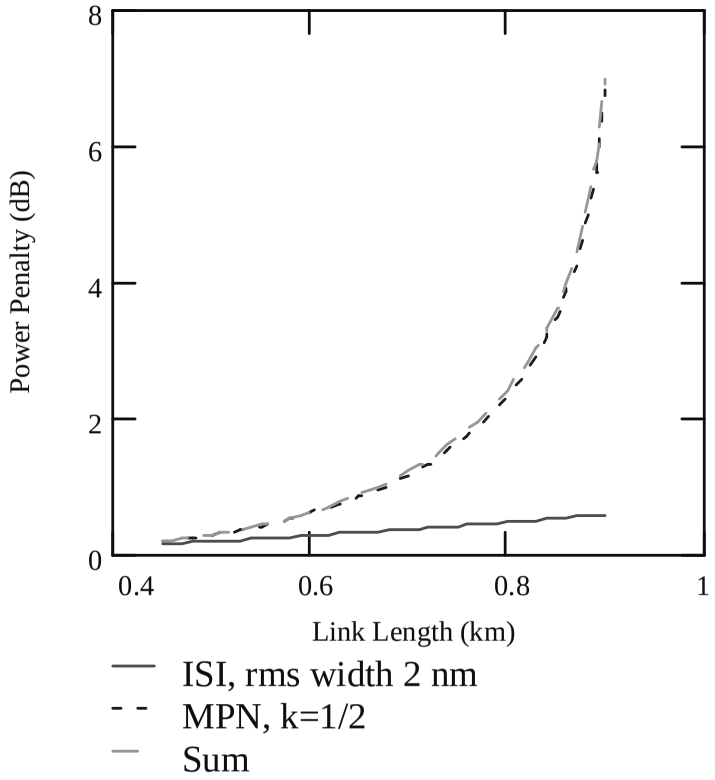




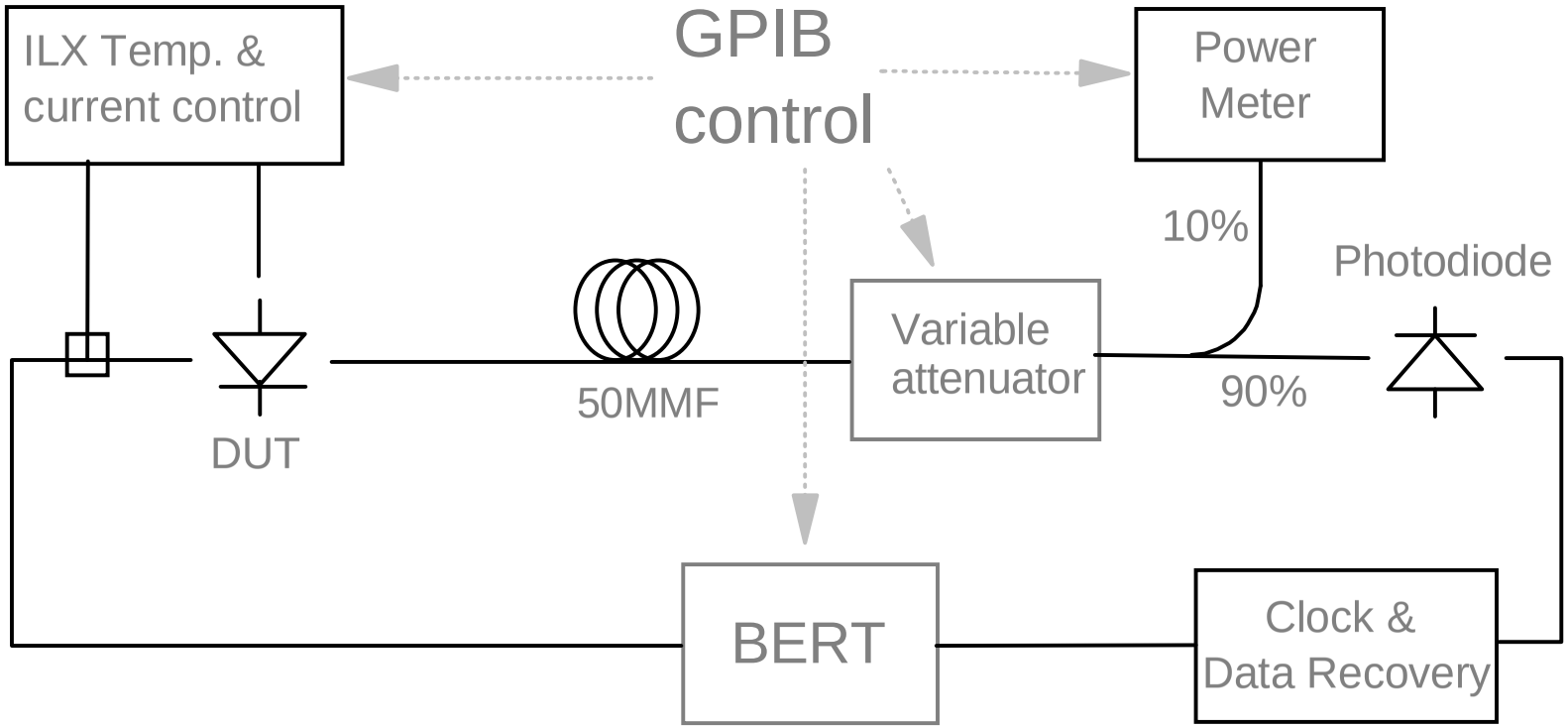
Penalties: Short Wavelength Lasers (840 nm), 50MMF, k=0.5, B = 1.25 Gb/s, D = 100 ps/nm

Dispersion Penalties versus length





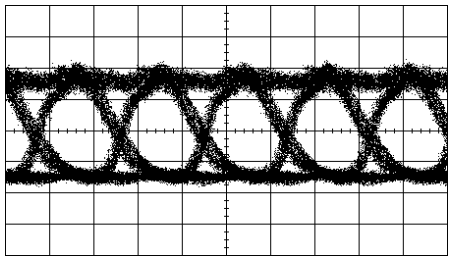
Mode Partition Noise - Experimental Set up



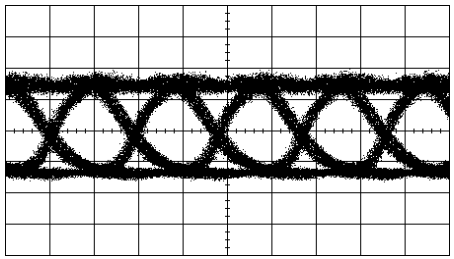
Laser temperature could be ramped or held constant

Experimental results

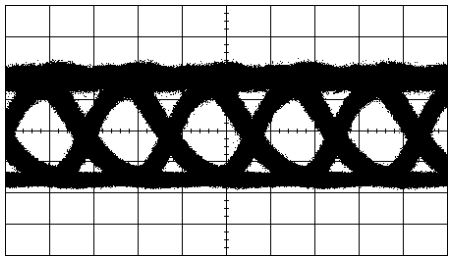
50MMF had high modal BW to ensure low ISI penalty.



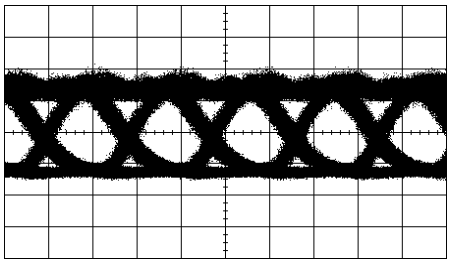
300m



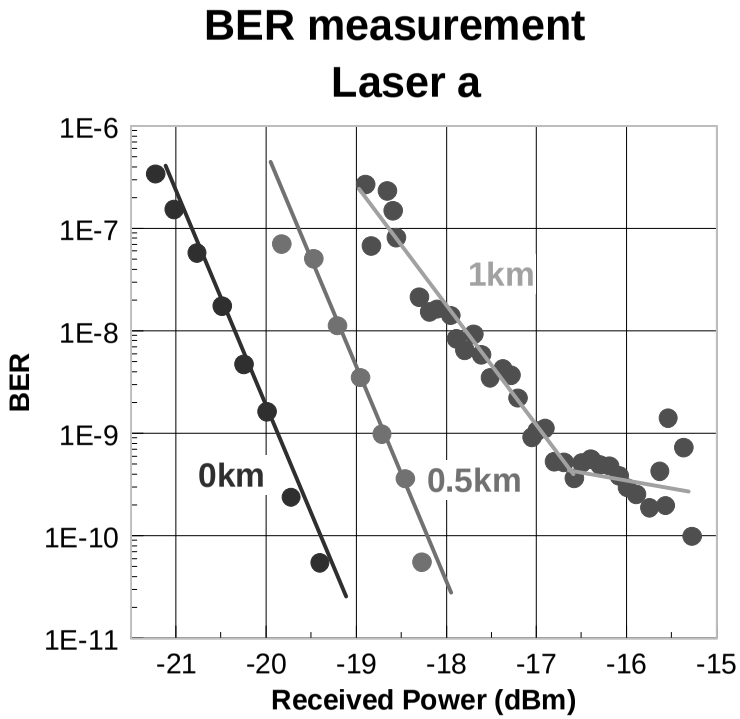
500m



700m



1km

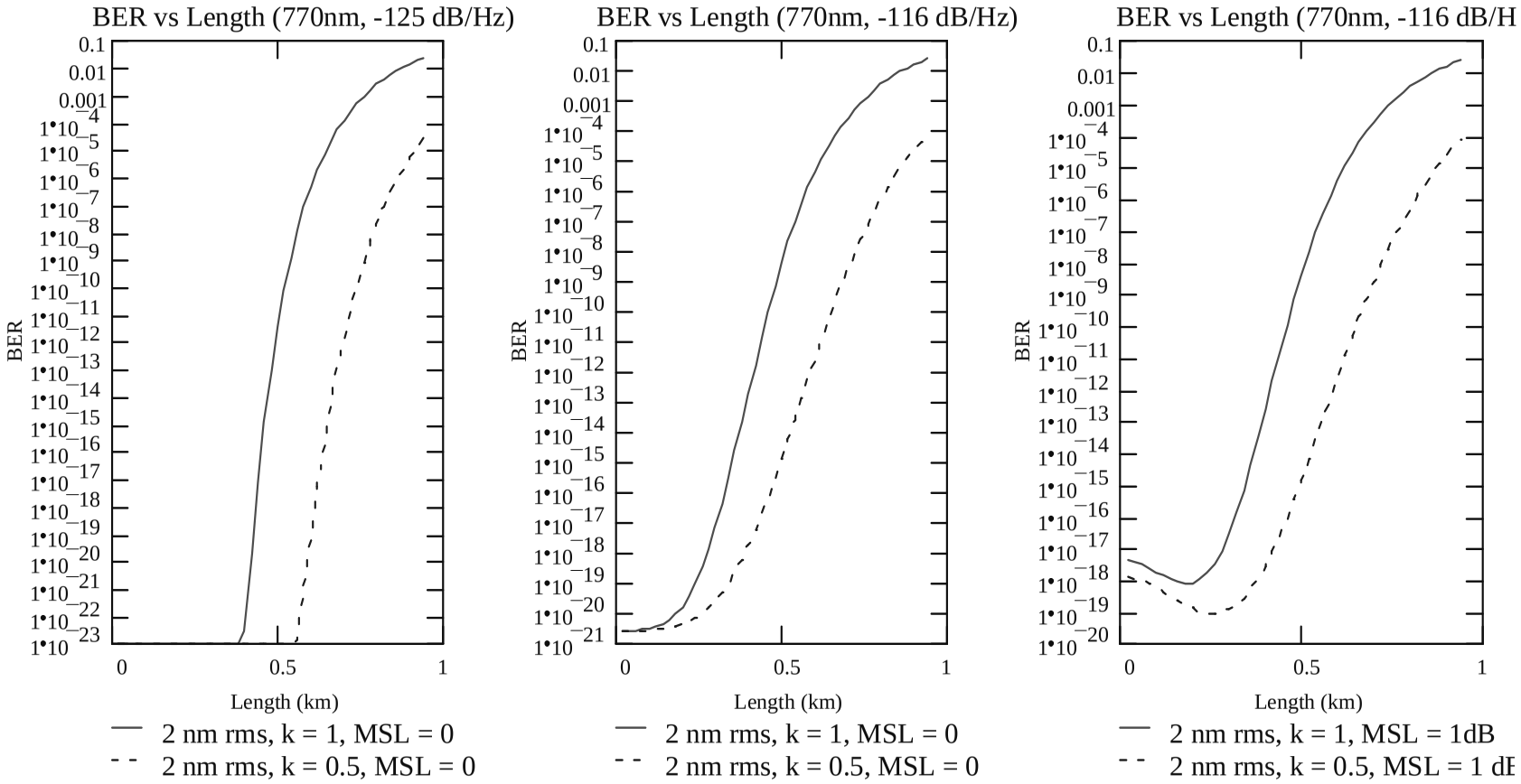


Experimental Penalties: Short wavelength Lasers

laser	λ	RMS width	300m 50MMF	500m 50MMF	700m 50MMF	1km 50MMF
a	**780nm**	0.79nm	-	1 dB penalty	-	**floor @ 10^-10**
b	**850nm**	0.85nm	-	-	-	**<1dB penalty**
c	**850nm**	1.13nm	-	**-**	**1dB penalty (floor@10^-11 when MSL present)**	**floor @ 10^-11**
d	**850nm**	0.62nm	**floor @ 10^-11**	**floor @ 10^-9**	-	**floor @ 10^-6**
e	**850nm**	0.49nm	-	**>1dB penalty (floor @ 10^-11 when MSL present)**	-	**floor @ 10^-9**

- Not measured

Additional effect of other noise terms



MPN **MPN & RIN** **MPN, RIN & modal noise**

Summary

- 6 lasers from different manufacturers for MMF data communication at Gb/s rates were tested:
  - lasers were all edge emitters (Fabry-Perot)
  - all exhibited penalties due to MPN and chromatic dispersion induce ISI
- **Preliminary Recommendations:**
  - ***MPN must be taken into account in specifications***
  - ***LWL maximum RMS width of 4nm for 3km SMF links***
  - ***SWL maximum RMS width < 2nm for 500m links***