

Differential Group Delay Requirement for SMF Optical Cable

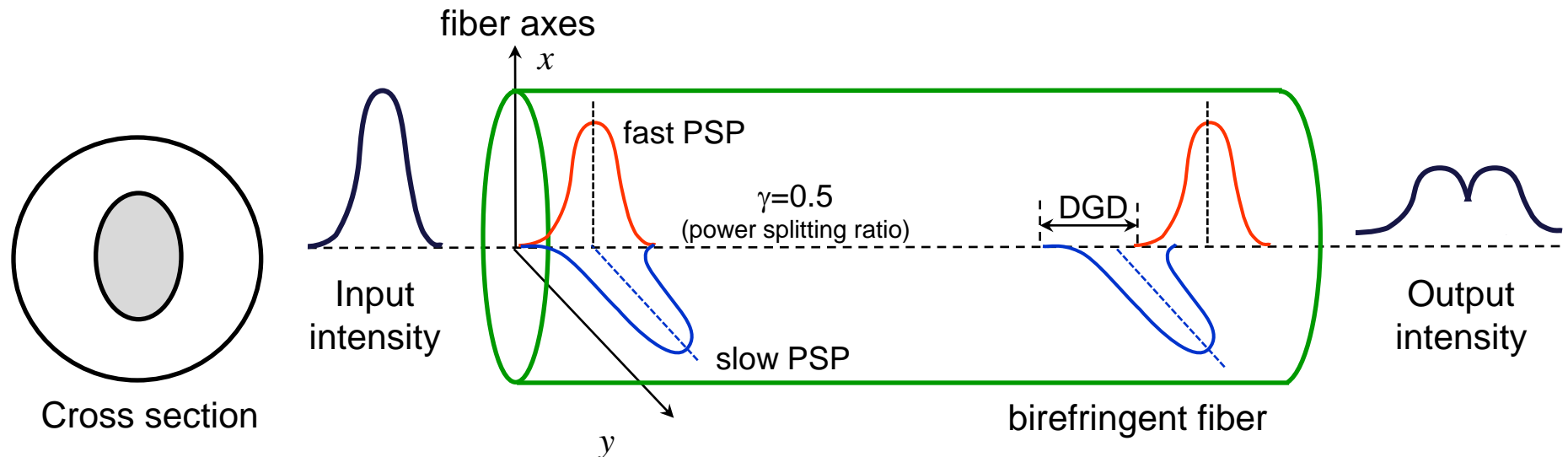
IEEE 802.3ba Task Force
9-13 November 2008

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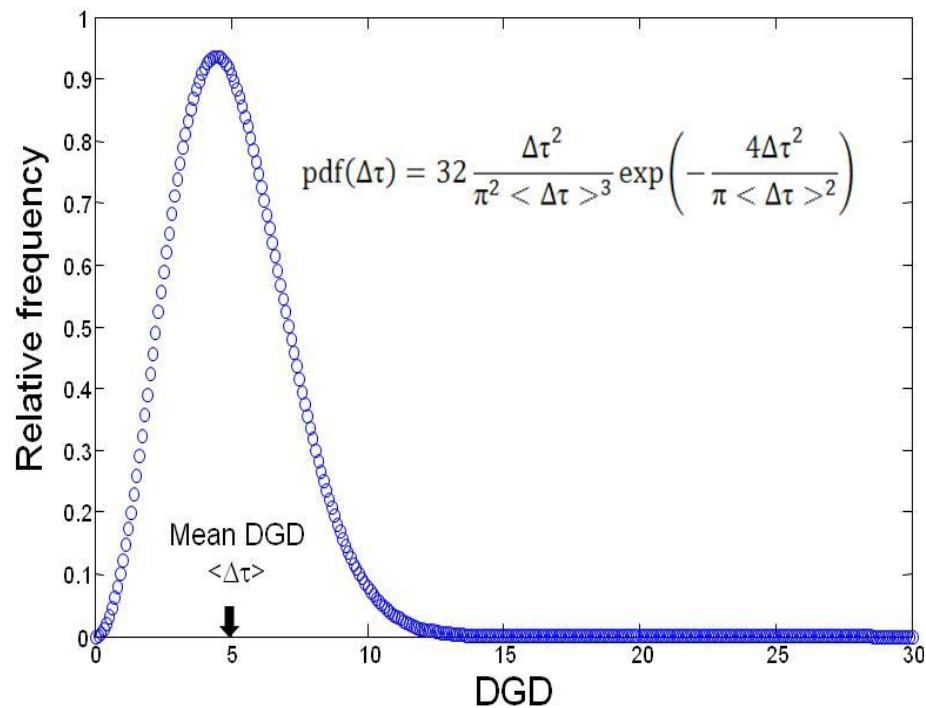


Differential Group Delay (DGD)

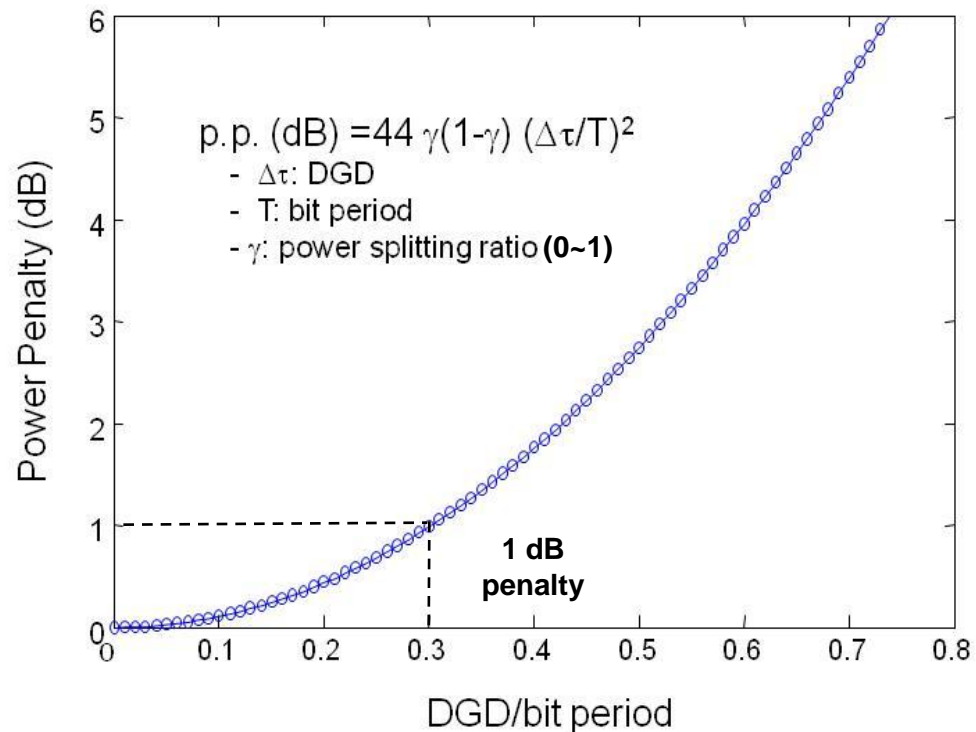
- Asymmetry in the refractive index creates a delay between the PSP (DGD).
- DGD causes an optical pulse to spread in time domain
- DGD varies randomly with wavelength and time



● DGD distribution



● DGD induced power penalty



- IEC TR-61282-3 document outline two statistical methods
- Method 1 (PMD_Q)
 - produces a statistical upper bound based on a number of concatenated fibers and an associated probability
 - 99.99 %-tile of the link $< 0.5 \text{ ps}/\sqrt{\text{km}}$, up to 20 cables in series
 - conservative estimate of PMD of concatenated fiber link
 - best descriptive metric for fiber distributions
- Method 2 (DGD_{max})
 - provides a probability of exceeding DGD which can be related to system down time
 - convolution of link PMD & Maxwell variation
 - probability $< 1.3 \times 10^{-7}$
 - system design purposes

- In Table 52-24, the DGD limit for 10 km and 40 km single mode 10 GbE is **10 ps** and **19 ps**, respectively.
- Calculated by Method 2 (see P802.3ae, Equalization Ad Hoc, [T. Hanson](#))
- Link Length: up to 40 km
 - cable section lengths: 10 km
- Probability: 1.3×10^{-7}
 - no need to allocate for components DGD

40GbE/100GbE DGD Limit

- IEC 60793-2 has two fiber attenuation categories: with/without low water peak
- ITU-T G.652 has two categories of PMD_Q Limit: 0.5 ps/ $\sqrt{\text{km}}$, 0.2 ps/ $\sqrt{\text{km}}$
- DGD at 1 dB power penalty: 30 ps (@10 Gb/s), 12 ps (@25 Gb/s)

IEC Fiber Type	ITU-T Fiber type	Maximum PMD_Q (ps/ $\sqrt{\text{km}}$)	Link length (km)	Implied fiber induced DGD_max(ps)	40GBASE-LR4 (10Gx4), Power Penalty	100GBASE-LR4/ER4 (25Gx4)
B1.1 (dispersion un-shifted) or B1.3 (low water peak)	G.652.A/C	0.5	10	10	O (0.11 dB)	O (0.69 dB)
			40	19	O (0.40 dB)	X (2.48 dB)
	G.652.B/D	0.2	10	4	O (0.02 dB)	O (0.11 dB)
			40	7.6	O (0.06 dB)	O (0.4 dB)

- Fiber optic cabling requirement for 40GbE/100GbE

Description	40GBASE-LR4	100GBASE-LR4	100GBASE-ER4		Unit
Operating distance	10	10	30	40	km
DGD_max	10	10 ^a	7.6 ^b	7.6 ^b	ps
Power penalty	0.11	0.69	0.40	0.40	dB

^a The 10 ps DGD_max for 100GBASE-LR4 is derived from ITU-T G.652 A/C.

^b The 7.6 ps DGD_max for 100GBASE-ER4 is derived from ITU-T G.652 B/D. Using ITU-T G.652 A/C may not support operation of 100 GBASE-ER4.

- We propose the 802.3ba task force to adopt DGD_max specifications of SMF.
 - DGD spec. was calculated from IEC 61282-3 and ITU-T G.652 fiber
- References
 - IEC 61282-3: fiber optical communication system design guides
 - ITU-T G.652: Characteristics of a single-mode optical fiber and cable
 - ITU-T G.650.2: Definitions and test methods for statistical and non-linear related attributes of single-mode fiber and cable
 - TIA TSB-107: Guideline for the statistical specification of polarization mode dispersion on optical fiber cables