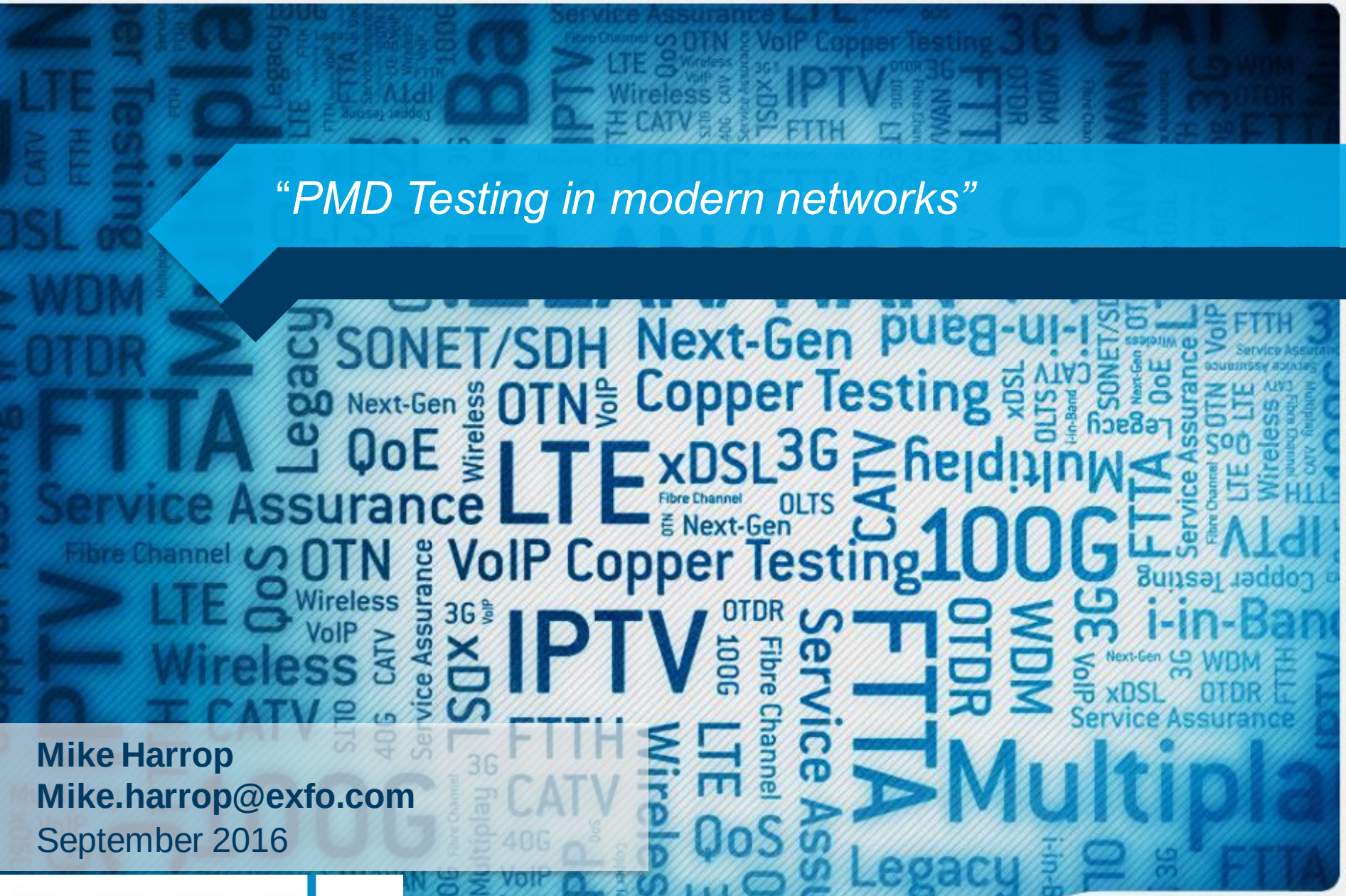
"PMD Testing in modern networks"



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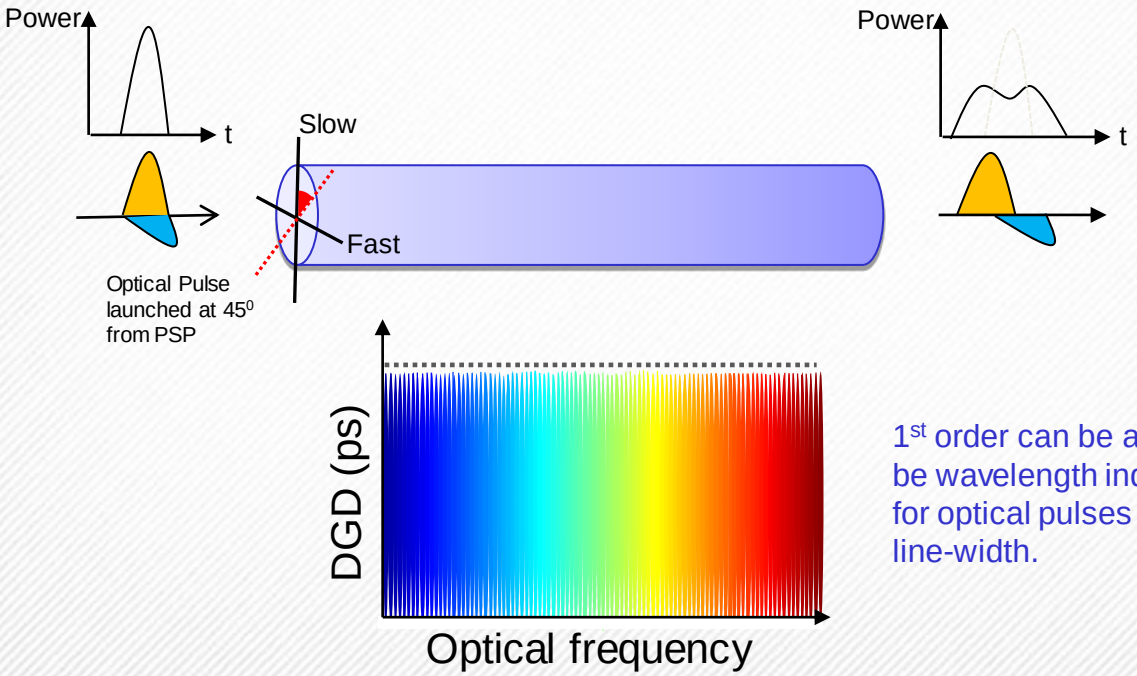
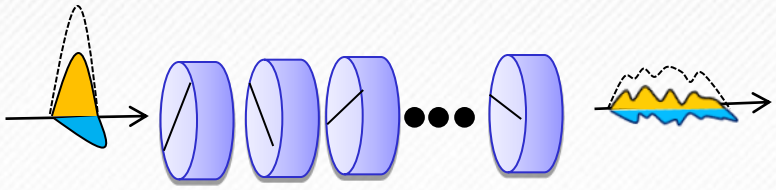
Polarization Mode Dispersion Basics: DGD (1st order PMD)

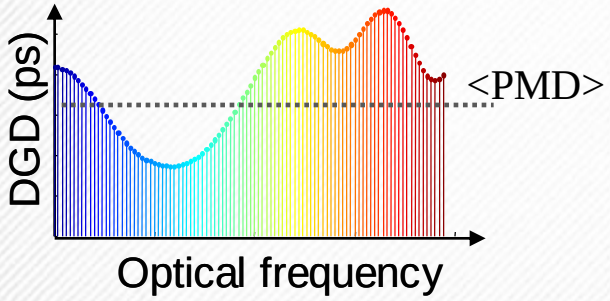
When an optical pulse with two equal polarization components propagates through a fiber, the birefringence causes differential group delay (DGD) between the polarization states which results in pulse distortion/broadening.



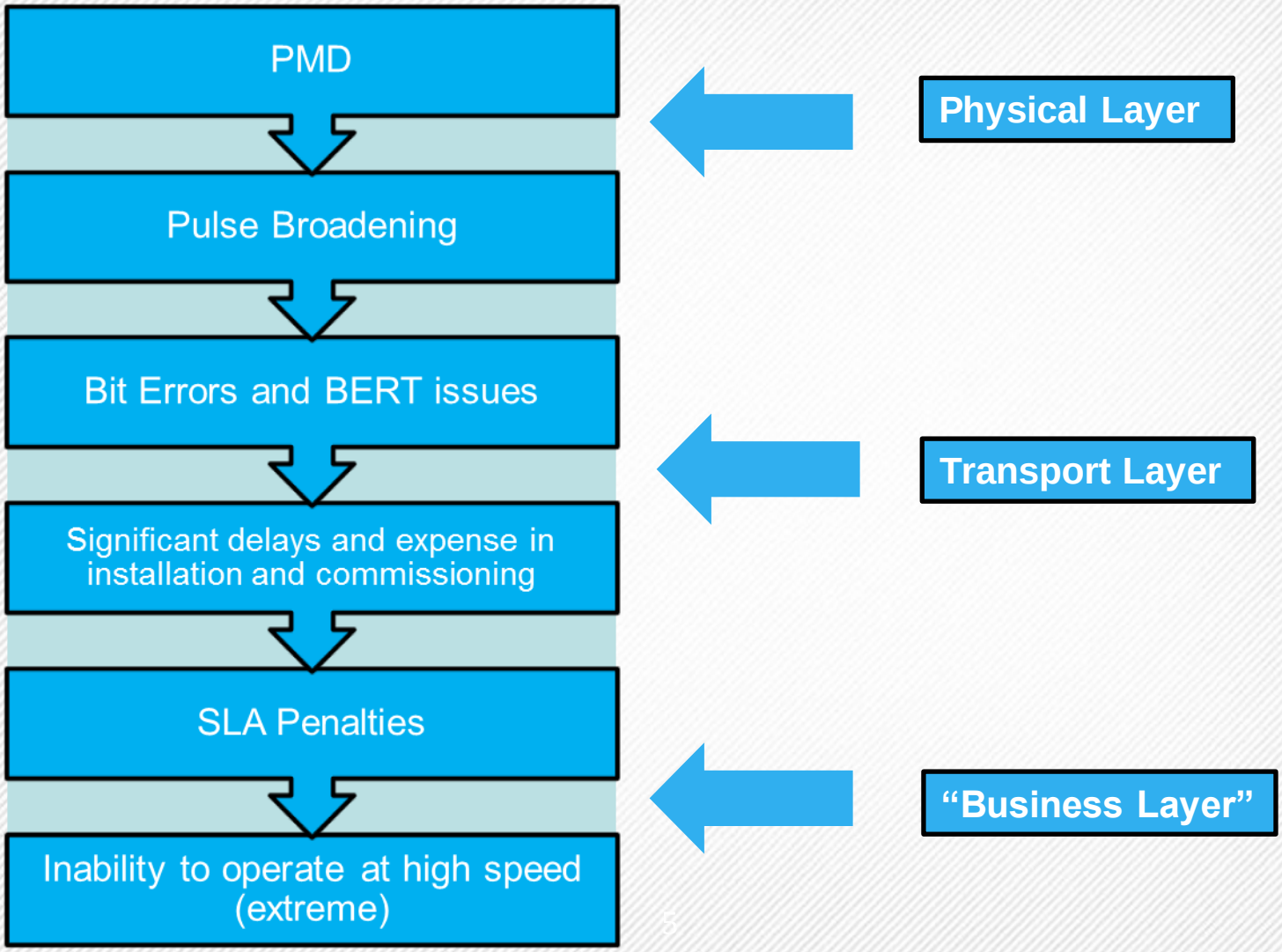
1st order can be assumed to be wavelength independent for optical pulses with narrow line-width.

Polarization Mode Dispersion Basics: 2nd order PMD

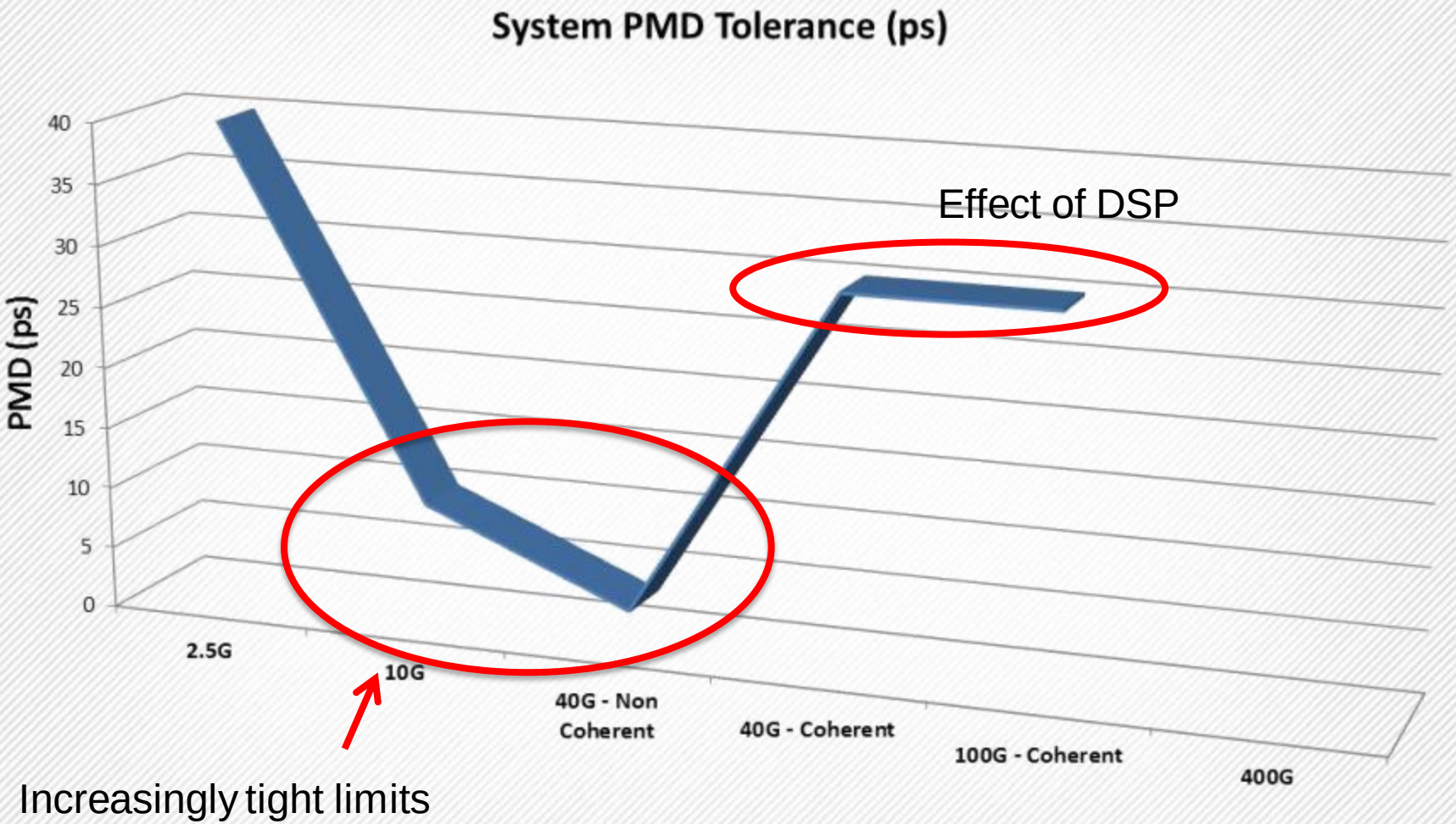




Impact of PMD on BER



System Limits

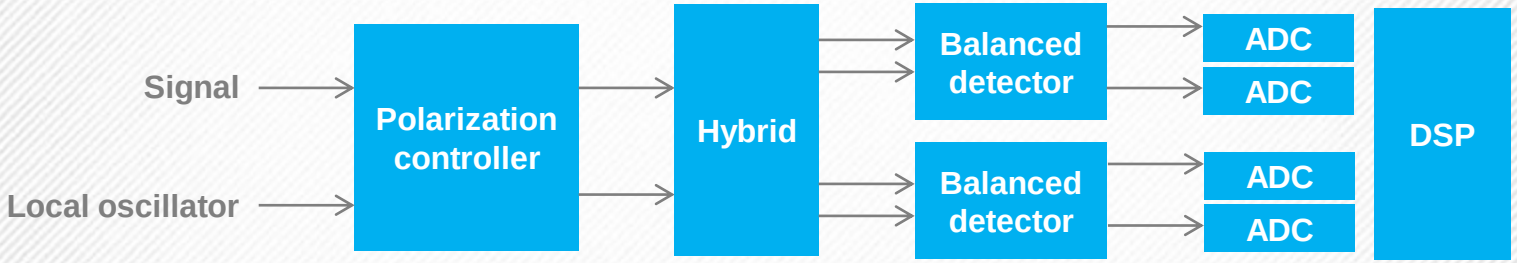


Increasingly tight limits

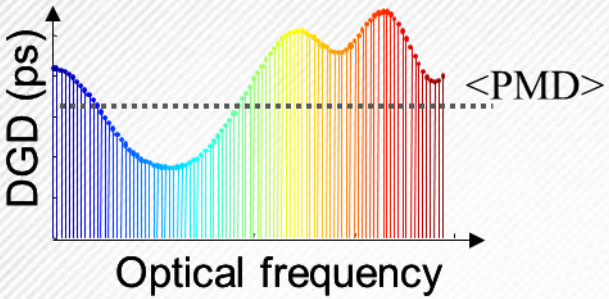
Coherent v/s Noncoherent

Direct detection (noncoherent): contains a photodiode for on-off keying signals

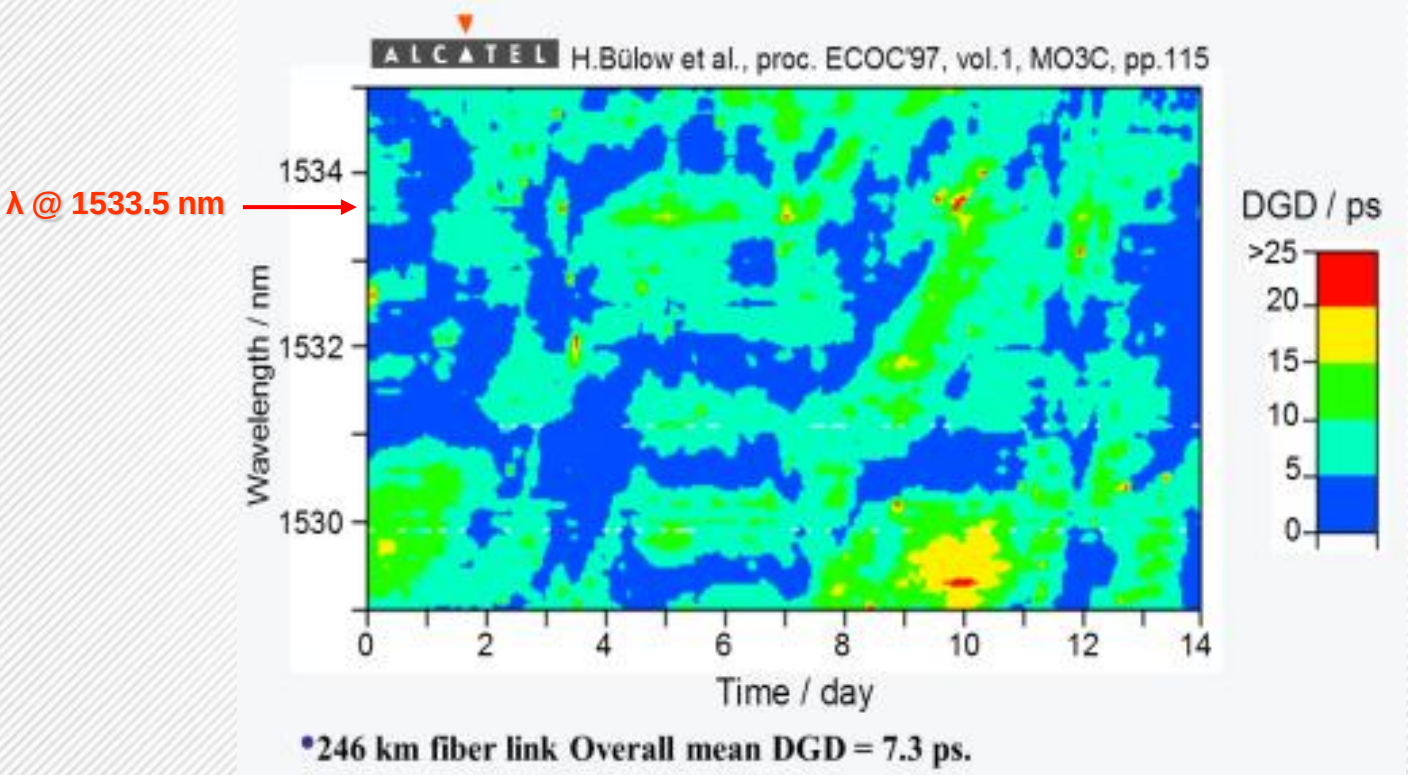
Coherent Receiver: contains a local oscillator (laser) for phase modulated signals (like DP-QPSK)



PMD is also Random and not Deterministic in Real Fibers



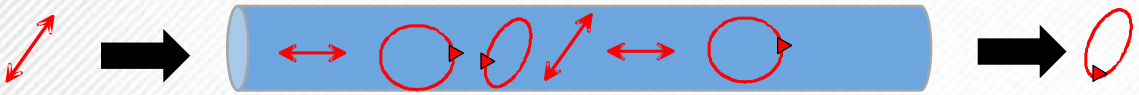
Because of the dynamic nature of PMD, it doesn't have a single fixed value for a given section of fiber.



Polarization Varies with Time in Fiber-Optic Systems

Free space: Polarization does not change with time

Fiber: Stresses ⟶ fiber birefringence variation ⟶ State of polarization variations



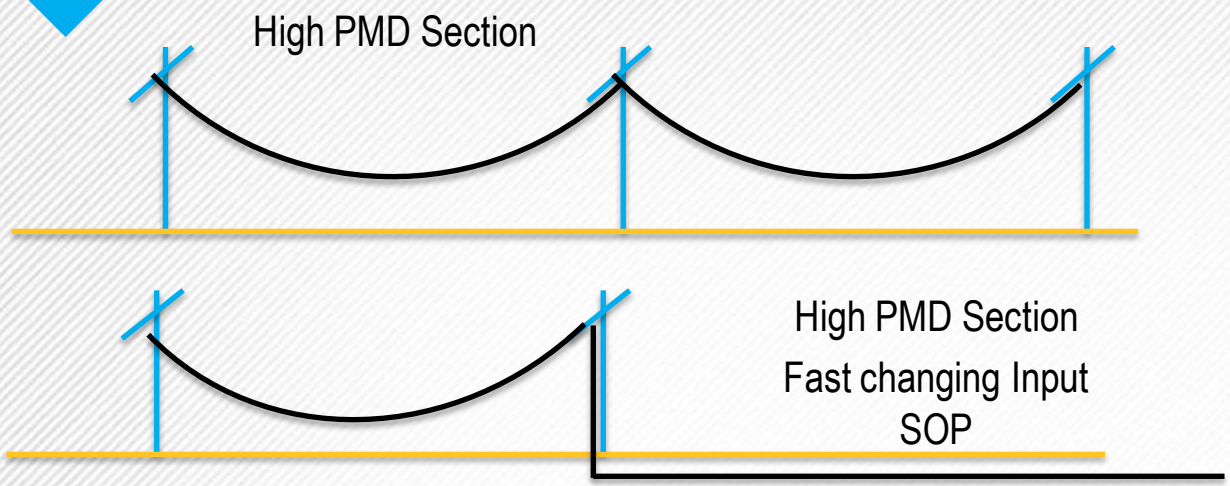
Sources of fiber stress

- Inherent asymmetry from manufacturing
- Temperature (Slow)
- Pressure (Slow)
- Macro/Micro bending (Slow)
- Wind-caused vibration (Fast)
- Mechanically induced acoustic vibration (Fastest)

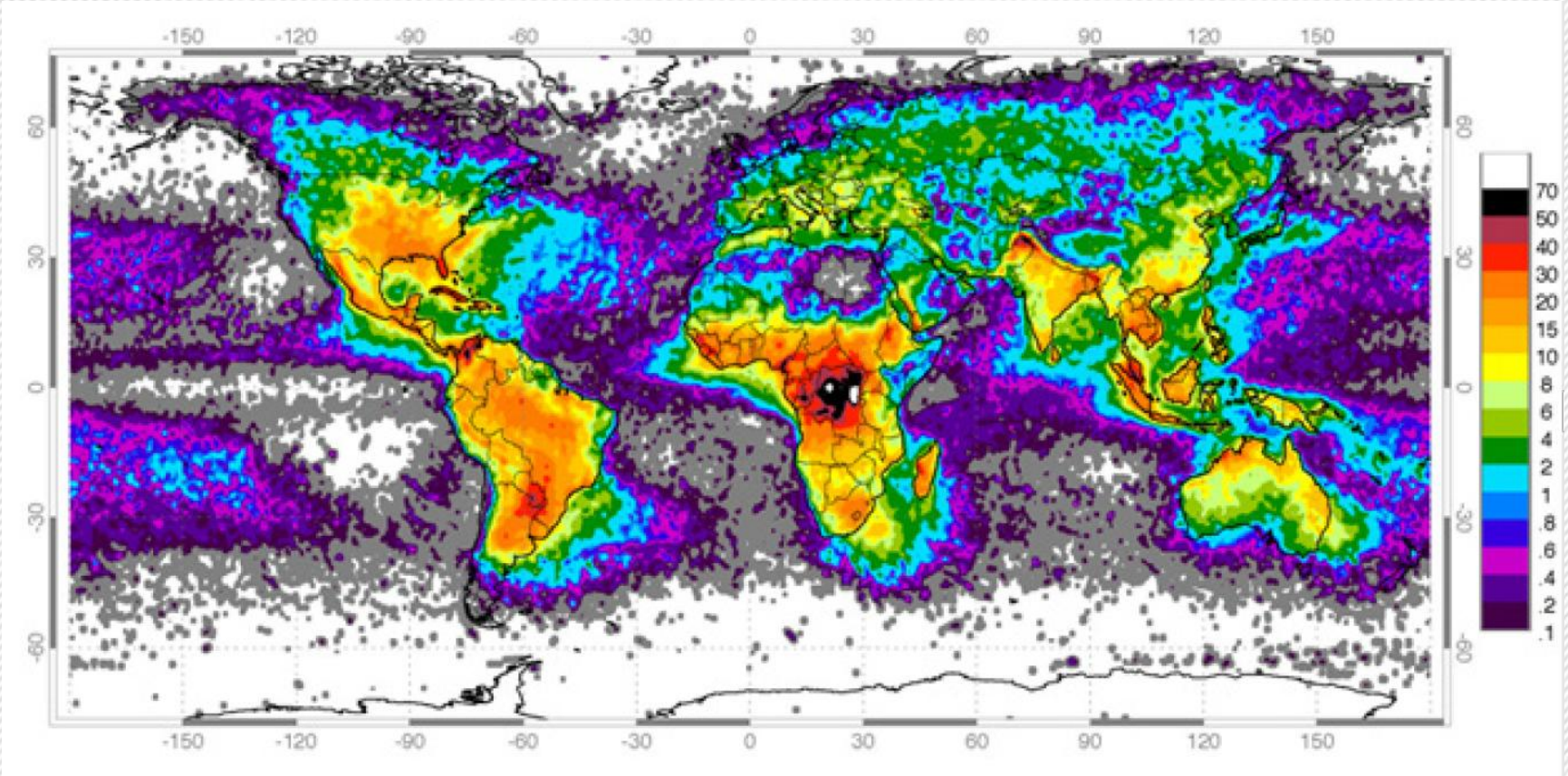
Fairly constant

Dynamic and random

Vibration examples



Vibration examples

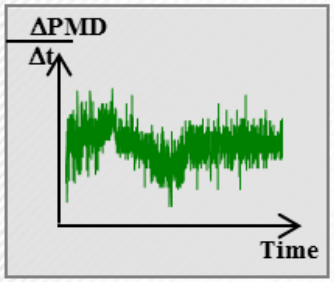


In central Europe ~30 strikes/100

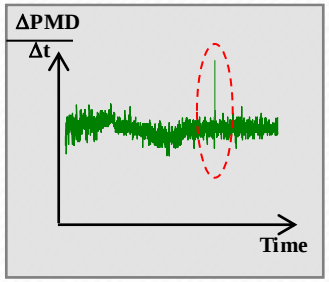
Effect of vibration & shock

- Vibrations, thermal & mechanical shock may induce
  - A very fast rate of change of PMD which the PMD tracking is unable to keep up with.

Fast PMD Change

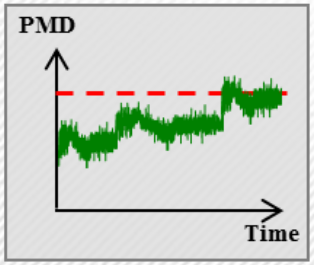


Sudden PMD Jump



  - A PMD greater than the system can tolerate.

PMD > PMDC range



Reducing the risk

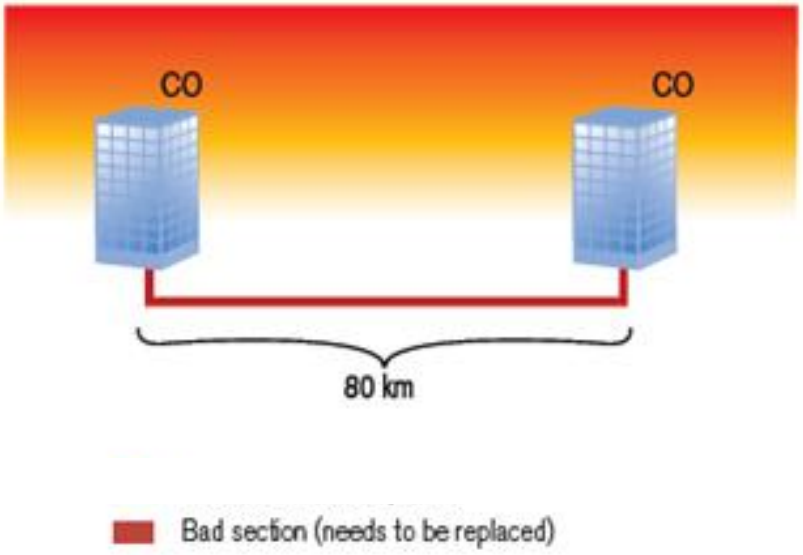
- Plenty of 10G still being used and also now being used in new application spaces (mobile back haul & Front haul, Metro, Broadband access)

- Even coherent systems are susceptible to fast PMD (changes) & very high PMD.

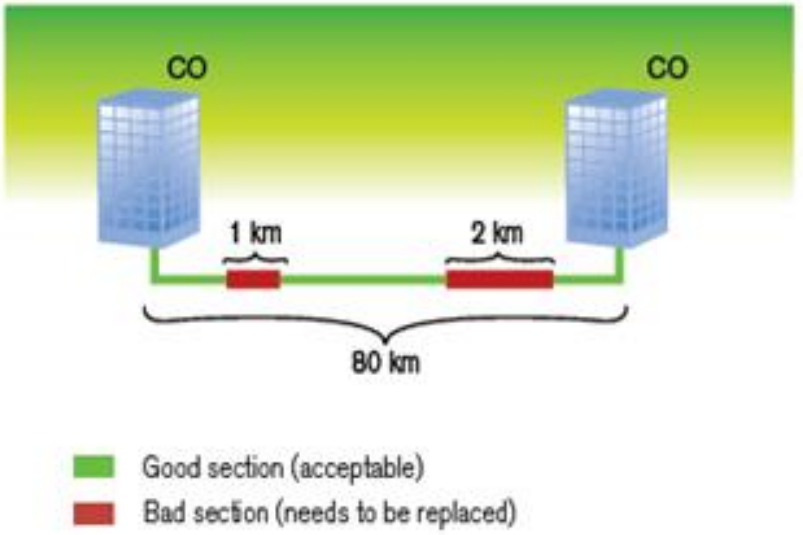
Start with a low PMD network the probability of a PMD related impact is much reduced.

Testing PMD is still vital as part of a links characterization.

The Situation



Traditional PMD measurement techniques provide a total link PMD value but do not enable locating which spans are causing the link to fail the test.

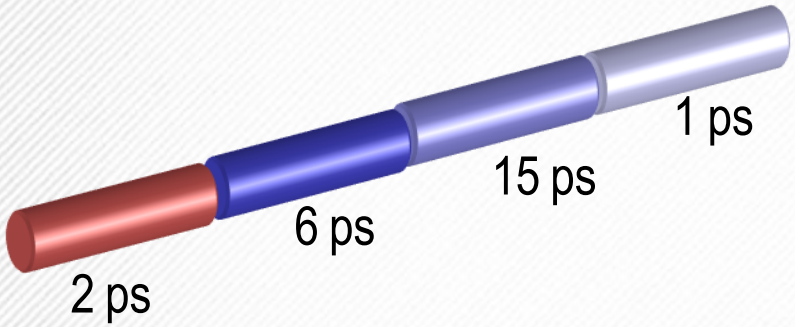


Contrary to the traditional approach, distributed PMD analysis breaks down the measurement results, effectively pinpointing the high-contributing sections of the link.

PMD Accumulation

Example: link built from concatenation of 4 fiber sections.

PMD for each section is: 15ps, 2ps, 1ps and 6ps.



$$PMD_{total} = \sqrt{\sum_i PMD_i^2}$$

$PMD_{total}^2 = 225ps^2 + 4ps^2 + 1ps^2 + 36ps^2 = 266ps^2$

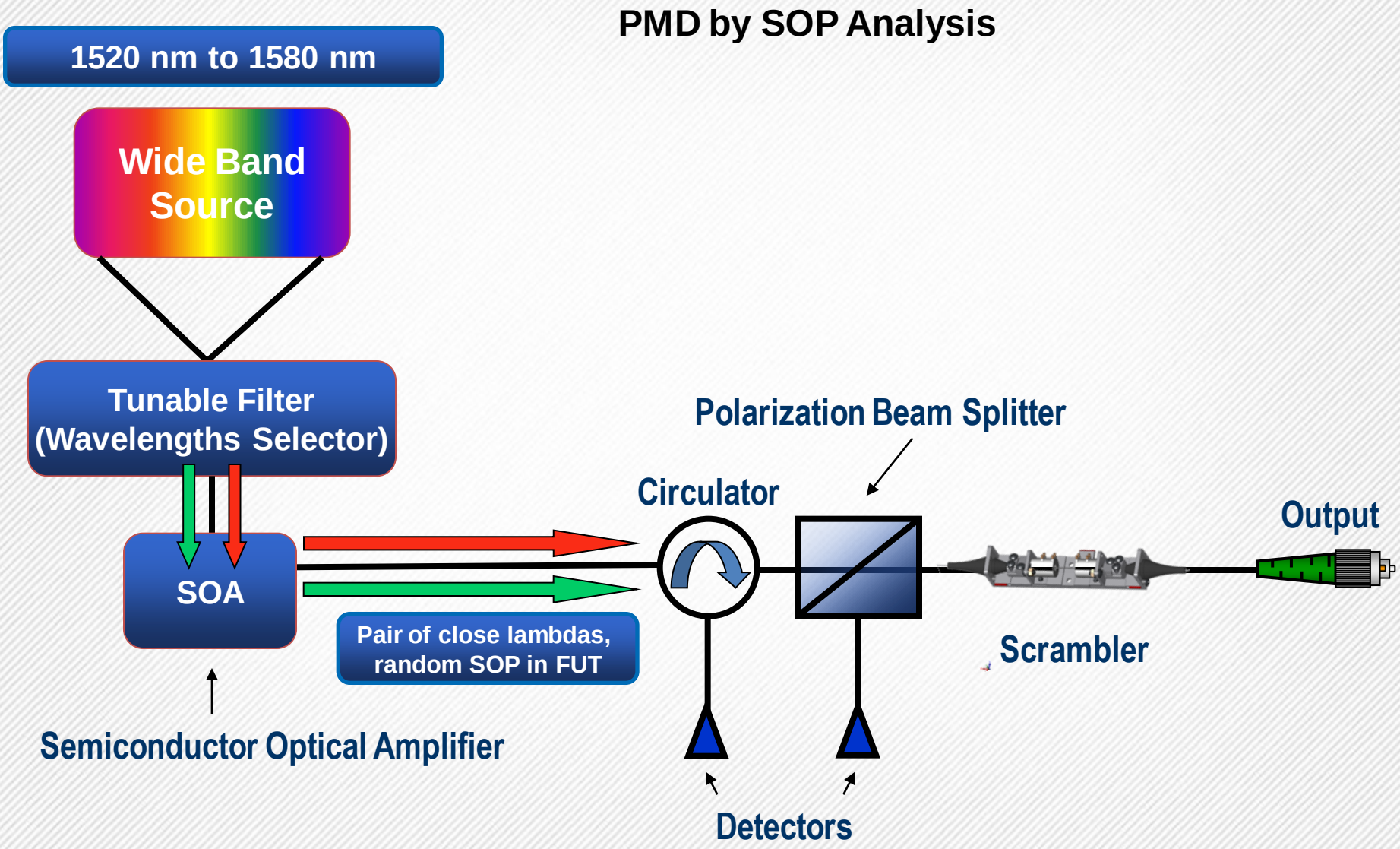
$PMD_{total} = sqrt(266) = 16.3ps$

Remove 6 ps section … PMD = 15.2 ps **(BAD)**

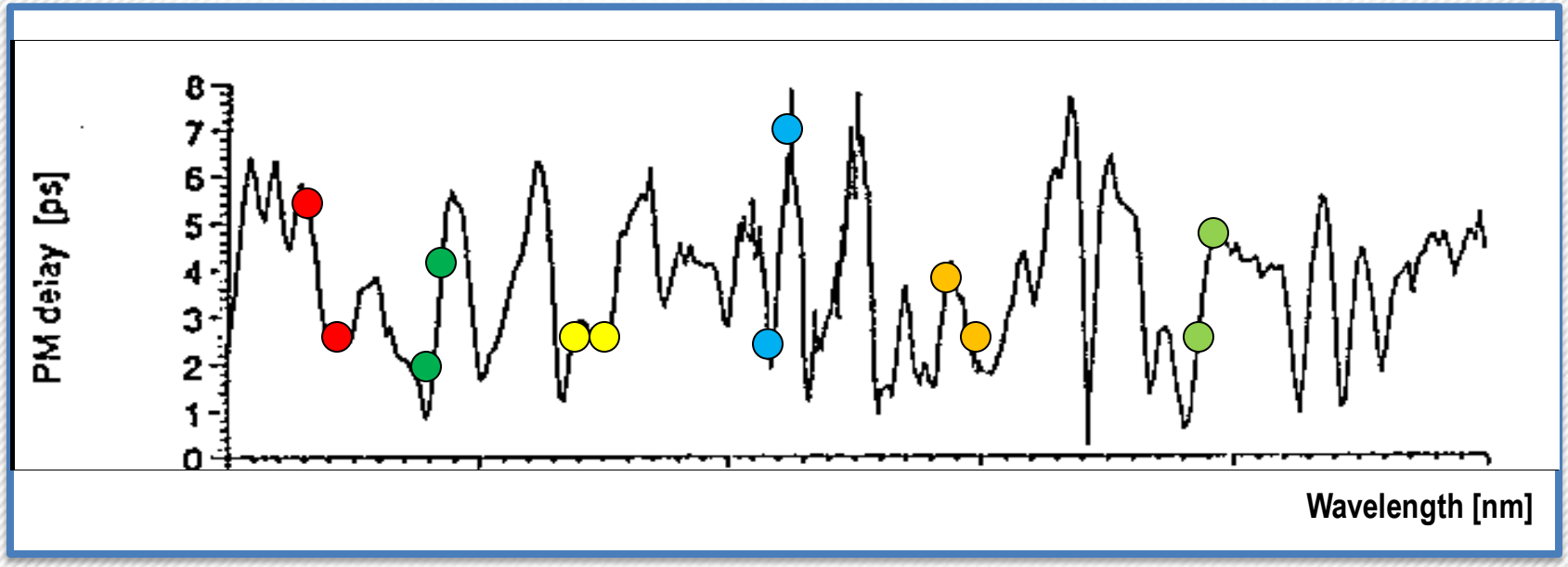
vs.

Remove 15ps section … PMD = 6.4 ps **(GOOD)**

Distributed PMD: Inside The Equipment

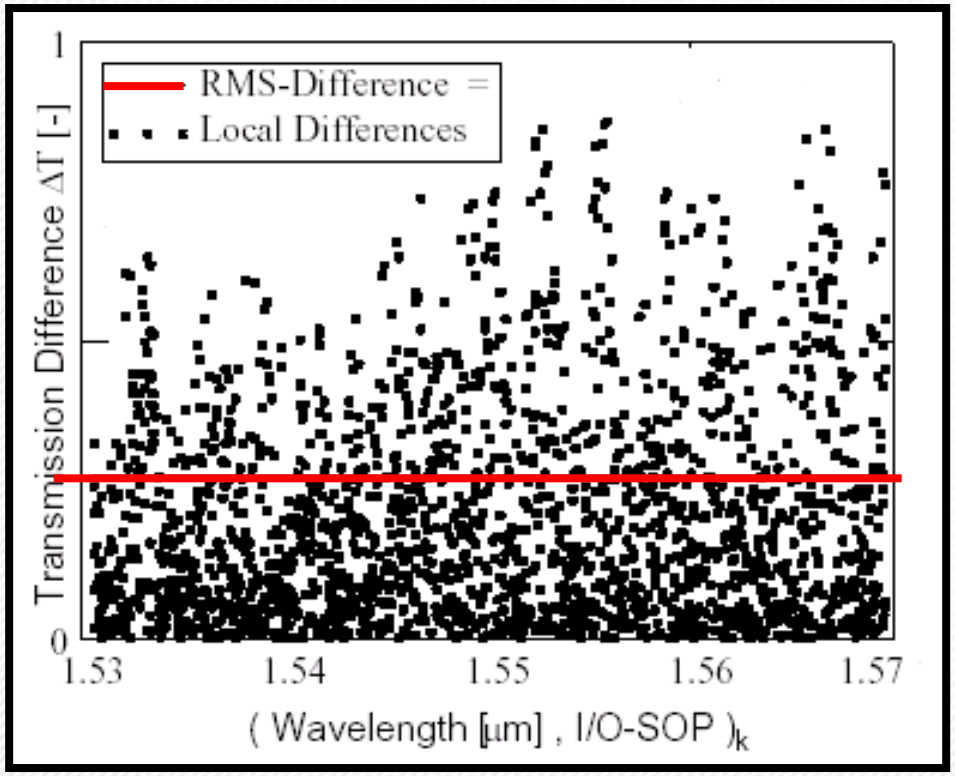


Inside The Equipment



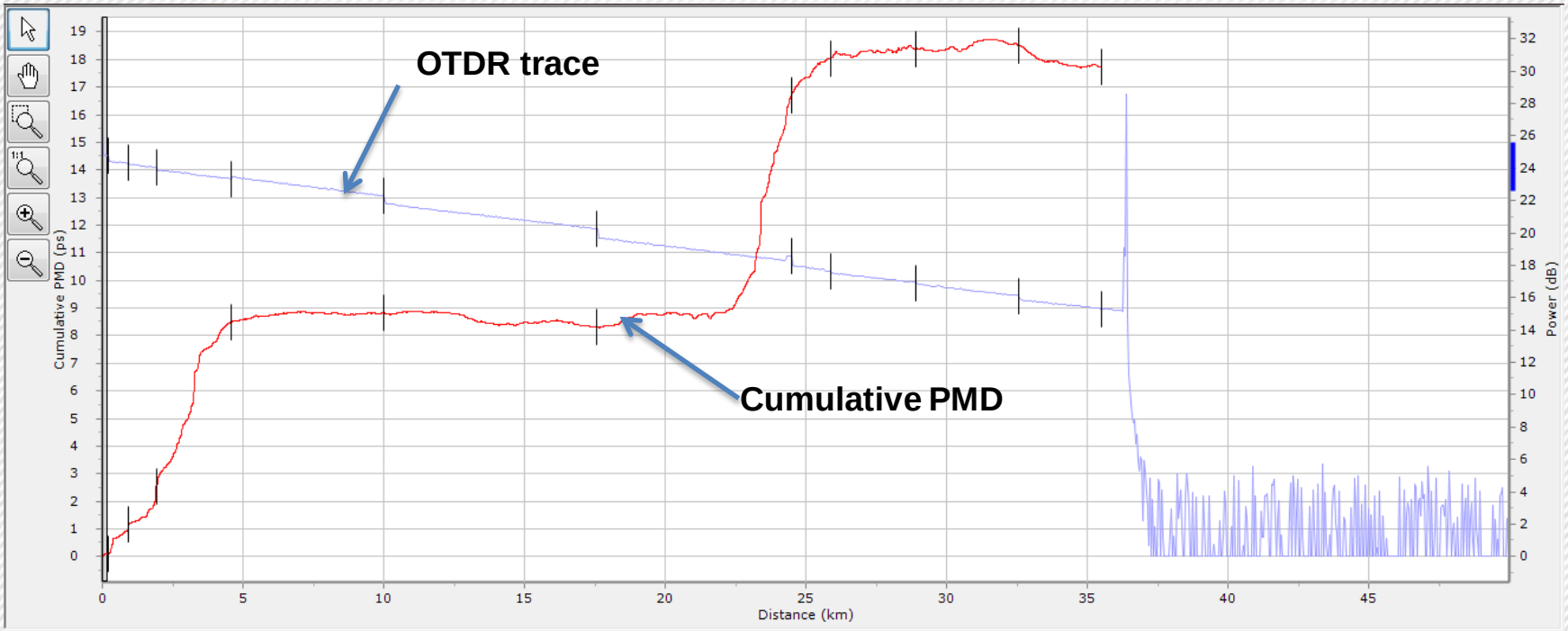
Inside The Equipment

- Repeat process at other Lambda Pairs & SOP's
- Compute RMS Difference



- Uses Rayleigh Backscattering instead of end reflection
- And LOTS of data processing…!

Output - Graph



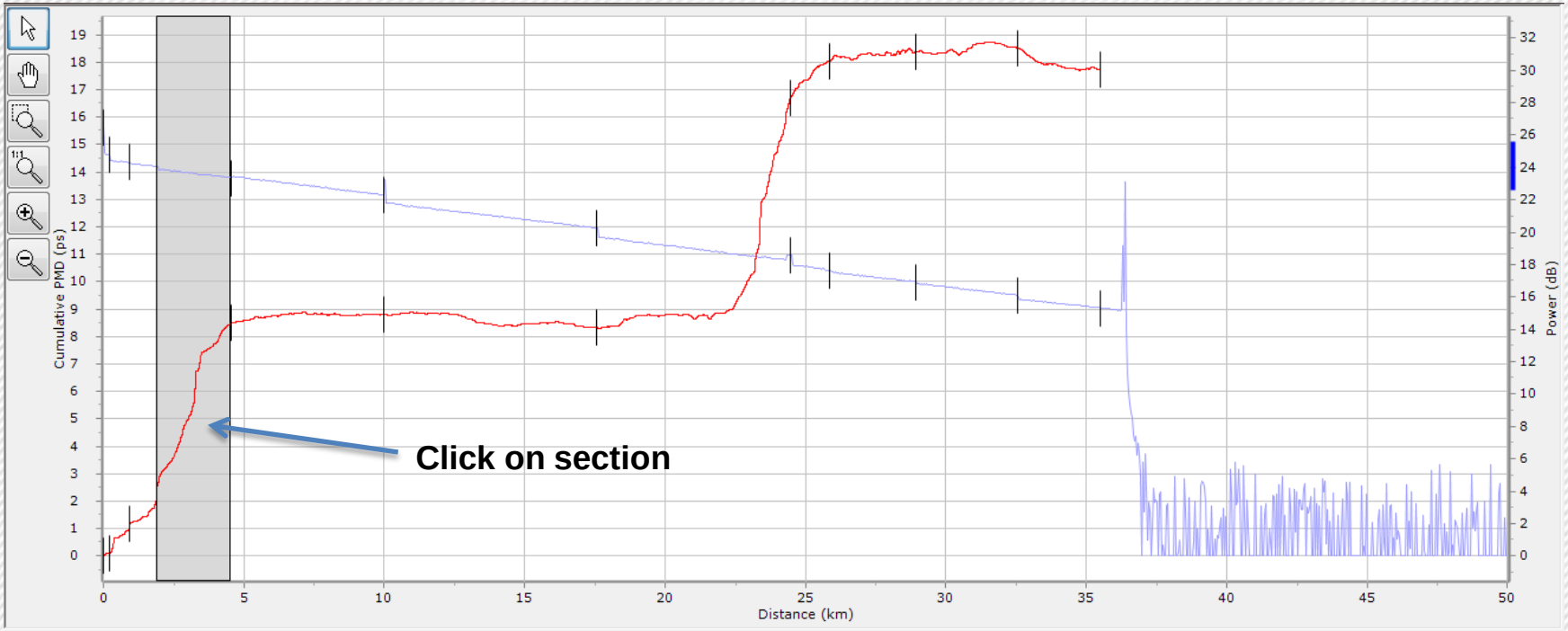
Section Edition | Estimation | Δ PMD | Trace Info.

No.	Loc. (km)	Len. (km)	PMD (ps)	PMD (ps²)	Cumul. PMD (ps)	Cumul. PMD (ps²)	PMD Coef. (ps/√km)	Contr. (%)	Status
1	0.0000	0.2118	0.100	0.010	0.100	0.010	0.218	0.00	Valid
2	0.2118	0.7274	1.173	1.376	1.177	1.386	1.375	0.44	Valid
3	0.9392	0.9749	2.256	5.088	2.544	6.474	2.285	1.62	Valid
4	1.9141	2.6440	8.098	65.571	8.488	72.045	4.980	20.83	Valid
5	4.5582	5.4285	2.365	5.594	8.811	77.639	1.015	1.78	Valid

Cumulative PMD: 17.741 ps

Split | Merge With Previous | Edit Length | Edit Comments | Reanalyze

Output - Graph



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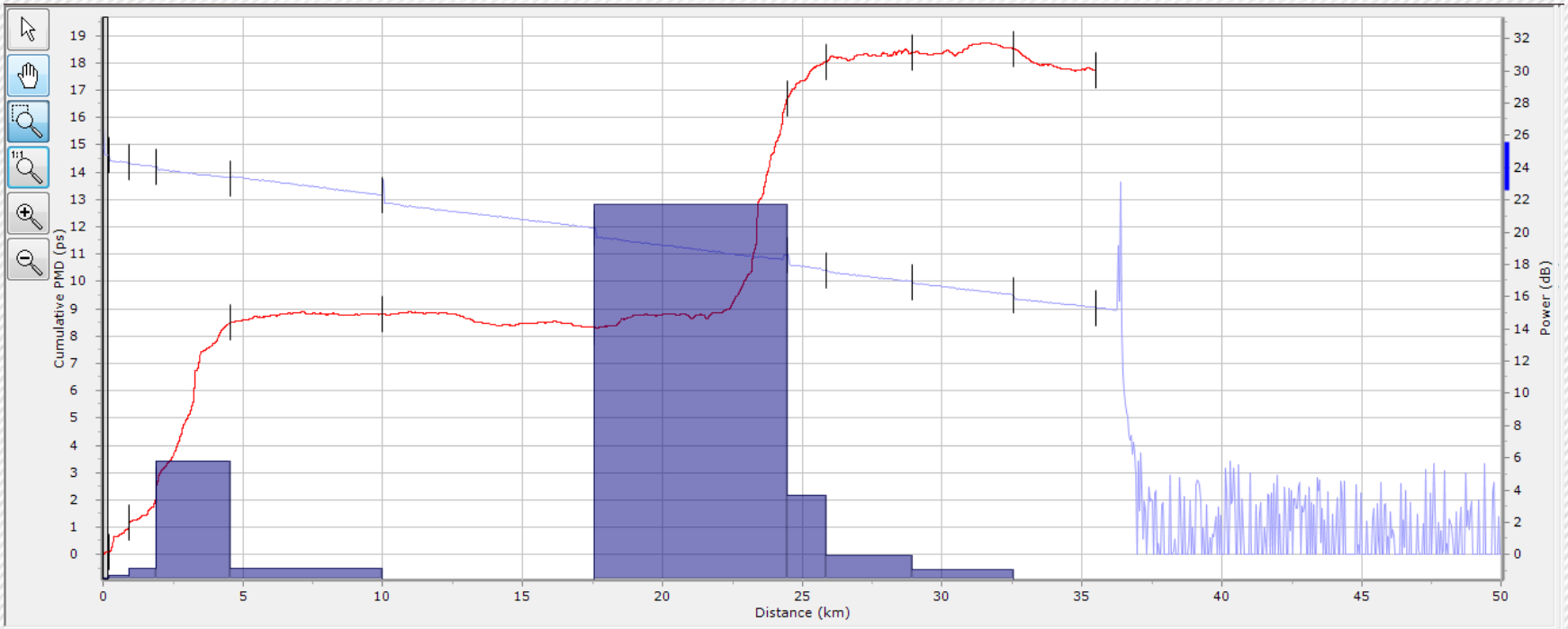
Details for that section

Cumulative PMD: 17.741 ps

Split | Merge With Previous | Edit Length | Edit Comments | Reanalyze

Output – Contribution Histogram



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Split | Merge With Previous | Edit Length | Edit Comments | Reanalyze

Conclusion

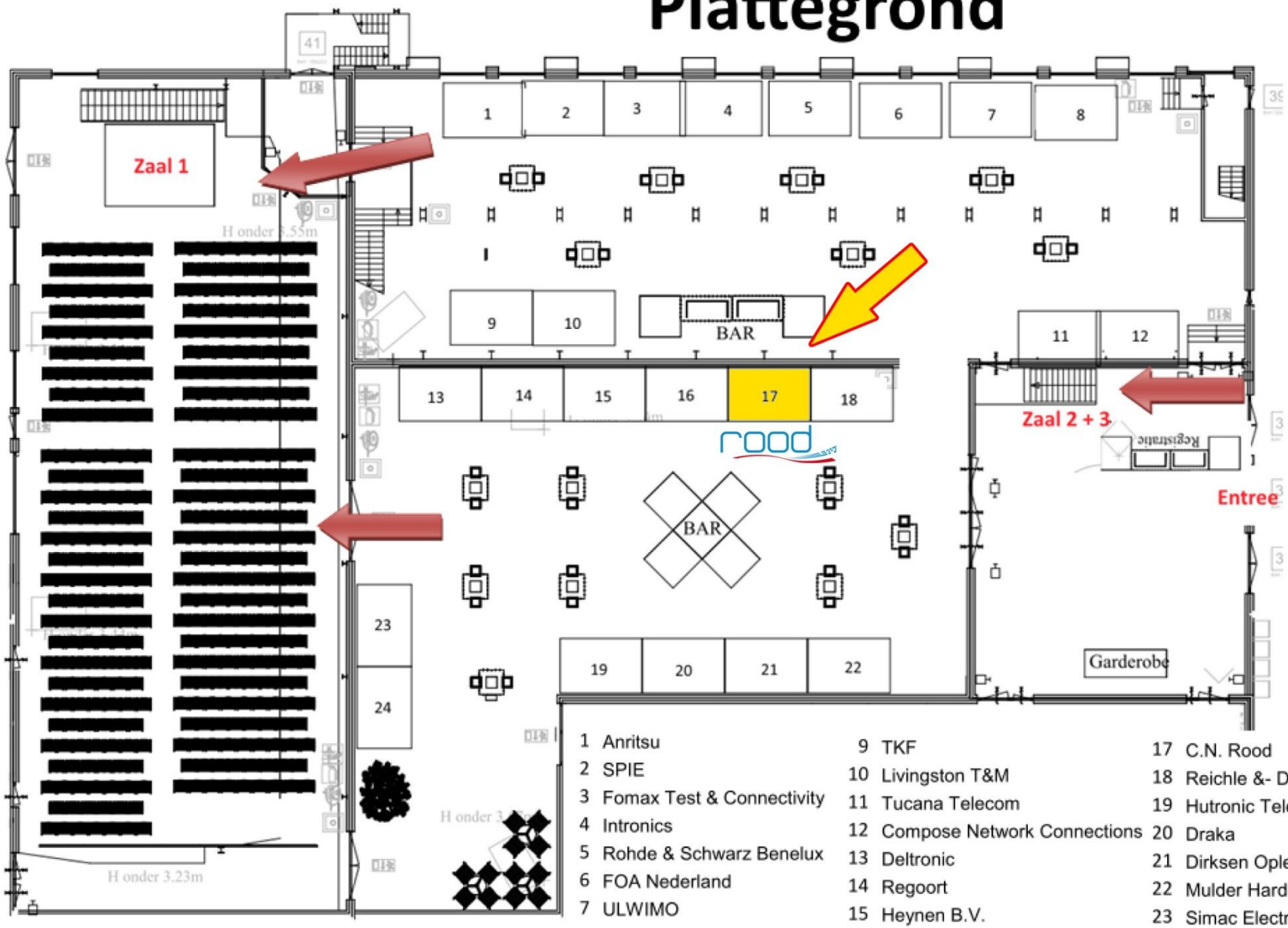
- Modern coherent systems are very tolerant of PMD, but fast changing or large abrupt changes may still cause problems.
- Plenty of 10G being used and still being deployed.

- Start with a low PMD network the probability of a PMD related impact is much reduced.
- Several tests in field can help identify PMD issues before they happen and therefore reduce outage probability

- Using standard PMD test equipment gives total PMD but no indication where high PMD may be
- Using distributed PMD equipment will help pinpoint any problems.

Thank You

Plattegrond



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