10Gb/s Four Fiber Parallel Transmission Array

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Parallel PMD Objectives

1. Demonstrate 10G parallel transmission capability for 100/300m targets.
2. Establish optical interface parameters supporting both 100/300m distances.
3. Coordinate with 10GFC technical committee to create a protocol independent parallel optical standard.

Parallel 10Gb/s Applications

100m Link Distance

- OEM rack-to-rack switch connection.
- Server point-to-point connection.
- Network storage attachment.
- Back plane link extension.

300m Link Distance

- LAN Backbone

Multi Protocol Solution

One Parallel transceiver design for:

- 10G Ethernet
  - Optional XAUI interface
- Fibre Channel 10G
  - Supports 8B/10B encoding
- ATM (OC-48)x4 cross connect
  - Scrambled data (PRBS 2^{31}-1)
- Infiniband®
  - 4x 2.5Gb/s parallel data

Parallel Interface Characteristics

- Supports bi-directional 4x 2.5Gb/s MMF and SMF.
- Rate Independent
  - 8B/10B block coded serial rate of 3.125GBaud/3.1875GBaud (each fiber).
- Connector Independent
  - Ferrule Array Connector (FAC).
  - Ribbon Fiber Connector (RFC).

Parallel 10Gb/s Distances on MMF at 850nm

- 100m over installed base of 200MHz-km 62/125µm MMF*.
- 225m over 500MHz-km 50/125µm ribbon fiber*.

*Reference FC-PI rev 8.1Table 25 - Multimode Fiber Bandwidth

Parallel 10Gb/s Distances on MMF at 1310nm

- 300m over installed base of 500MHz-km 62/125µm MMF*.
- 300m over installed 500MHz-km 50/125µm MMF*.
- MMF conditioned launch eliminates patchcord.

*Reference FC-PI rev 8.1Table 25 - Multimode Fiber Bandwidth

850nm Transmitter Characteristics

Description	Unit	50µm MMF	62.5µm MMF
Type		850nm Laser	
Nominal Signaling Speed	GBaud	**3.125**	
Rate Tolerance	ppm	**+2,-.01%**	
Wavelength range (λ)	nm	830-860	
RMS Spectral Width	nm	0.85	
Average Launch Power (max)	dBm	-4	
Average Launch Power (min)	dBm	**-9**	
Rise/Fall, max (20%-80%)	ps	105	
Optical Modulation Amplitude (OMA), min	mW	**0.250**	
RIN_{12} (OMA), max	dB/Hz	**-120**	

Note: Assumes 8B/10B encoded data.

Note: Bold text indicates suggested value.

850nm Receiver Characteristics

Description	Unit	50µm MMF	62.5µm MMF
Nominal Signaling Speed	Gbaud	**3.125**	
Wavelength range (λ)	nm	830-860	
Average Receive Power, max.	dBm	0.0	
Optical Modulation Amplitude,min	mW	**0.050**	
Stressed Receiver Sensitivity (OMA), min.	mW	0.096	0.109
Receiver electrical 3dB upper cutoff frequency, max.	GHz	(2.5)	
Stressed Receiver ISI test, min.	dB	1.26	2.03
Return Loss, min.	dB/Hz	12	

Note: Blue text indicates suggested new value.

Discussion: Requirement to specify upper 3dB cutoff frequency

1310nm Transmitter Characteristics

Description	Unit	62.5/125, 50/125μm MMF
Type		1310nm Laser
Nominal Signaling Speed	Gbaud	**3.125**
Rate Tolerance	**%**	**+2,-.01**
Wavelength range (λ)	nm	1280-1340
RMS Spectral Width	nm	4
Average Launch Power (max)	dBm	-3
Average Launch Power (min)	dBm	**-10**
Rise/Fall, max (20%-80%)	ps	105
Optical Modulation Amplitude, min	mW	**0.200**
RIN_{12} (OMA), max	dB/Hz	**-120**

Note: Blue text indicates suggested new values.

1310nm Receiver Characteristics

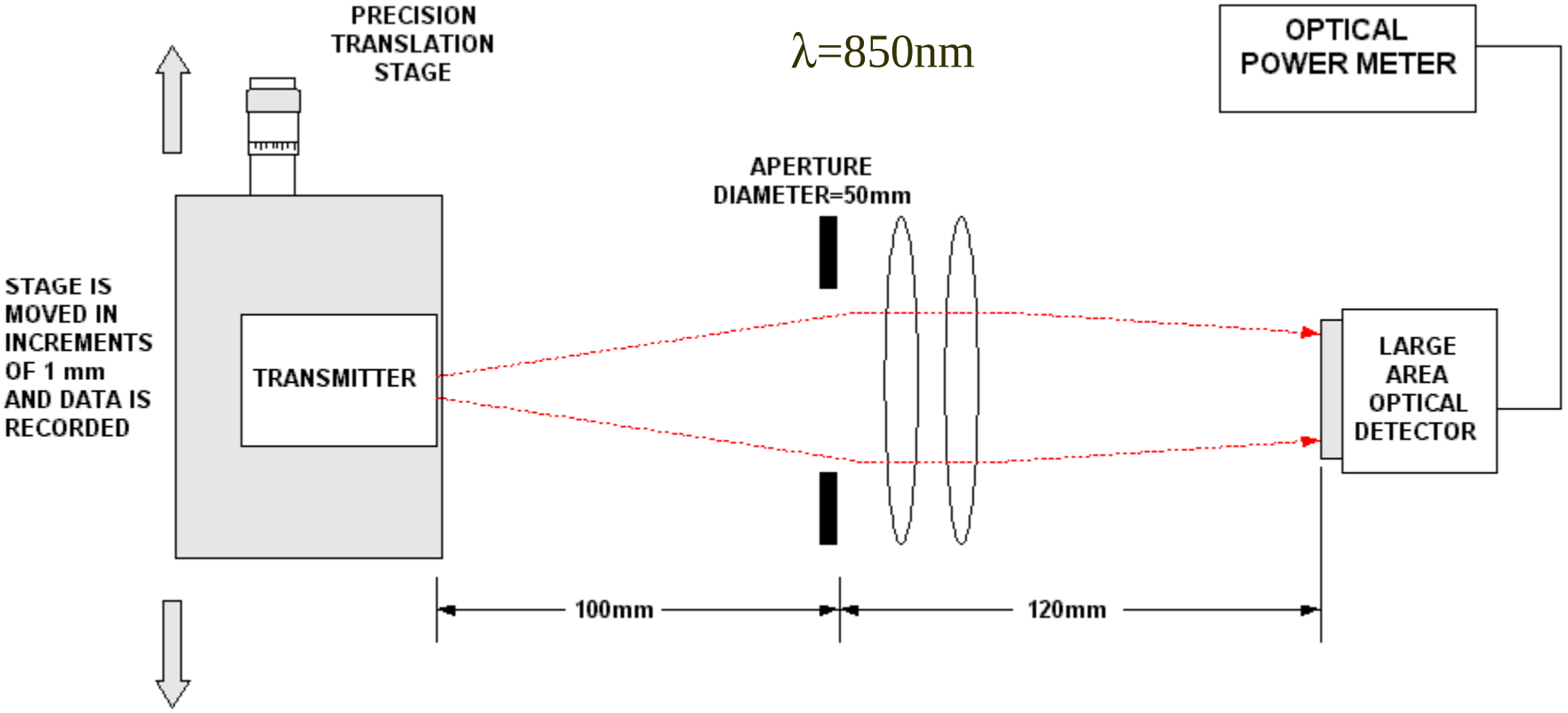
Description	Unit	62.5/125, 50/125µm MMF
Nominal Signaling Speed	Gbaud	**3.125**
Wavelength range (λ)	nm	1270-1355
Average Receive Power, max.	dBm	**-3**
Optical Modulation Amplitude,min.	mW	**0.020**
Return Loss, min.	dB/Hz	12

Note: Blue text indicates suggested new value.

Jitter (pk-pk), max.

	Unit	α_T	δ_T	γ_T	γ_R	δ_R	α_R
Deterministic (DJ)	UI	0,13	0,14	0,26	0,28	0,39	0,40
Total (TJ)	UI	0,25	0,26	0,44	0,48	0,64	0,65

IEC-825 Class 1 Compliance Test Setup



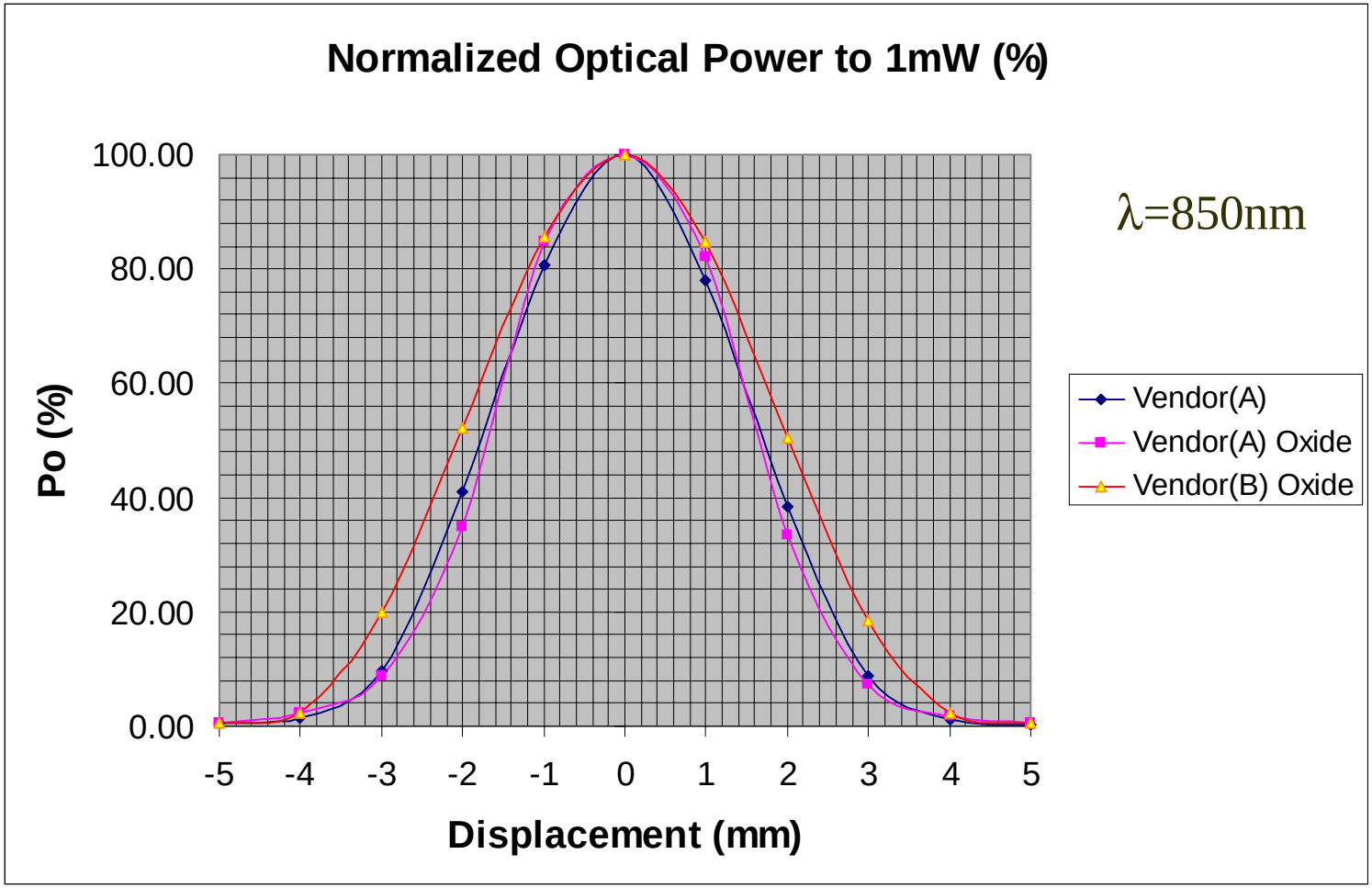
Note: Large area detector is equivalent to 6mm diameter of human body model.

Free Space Optical Output Power

λ=850nm

DISPLACMENT	Normalized Optical Power to 1mW (%)		
(mm)	VENDOR A	VENDOR A (OXIDE)	VENDOR B (OXIDE)
-5	0.49	0.52	0.71
-4	1.38	2.32	2.42
-3	9.65	8.81	20.09
-2	40.94	34.88	52.28
-1	80.51	84.69	85.75
0	100.00	100.00	100.00
1	78.05	82.00	84.62
2	38.48	33.39	50.57
3	8.76	7.42	18.52
4	1.18	1.86	2.28
5	0.39	0.56	0.57

Free Space Optical Output Power



Free Space Connector Choice

- 3.125mm pitch multi-Ferrule Array Connector (FAC) allows for a Non-OFC application.
- 250µm pitch Ribbon Fiber Connector (RFC) will require OFC or reduced optical power for IEC-825 and CDRH Class 1 Laser safety compliance.

Maximum Differential Delay Computation

$$\Delta T_{max} = \Delta T_{chro} + \Delta T_{fl} + \Delta T_{tx} + \Delta T_{rx}$$

Where;

ΔT_{chro} = Max. Chromatic Differential Delay
ΔT_{f} = Max. Fiber Length Differential Delay
ΔT_{tx} = Max. Transmitter E/O Differential Delay
ΔT_{rx} = Max. Receiver O/E Differential Delay

Chromatic Differential Delay Test

- **Objective**
  - **To test chromatic differential delay over 100m fiber using transmitters with varying wavelengths.**
- **Procedure**
  - **Transmit PRBS 2^7-1 through a 100m fiber using a transmitter with a known wavelength and record data from oscilloscope.**
  - **Replace transmitter with a different wavelength and record delay.**

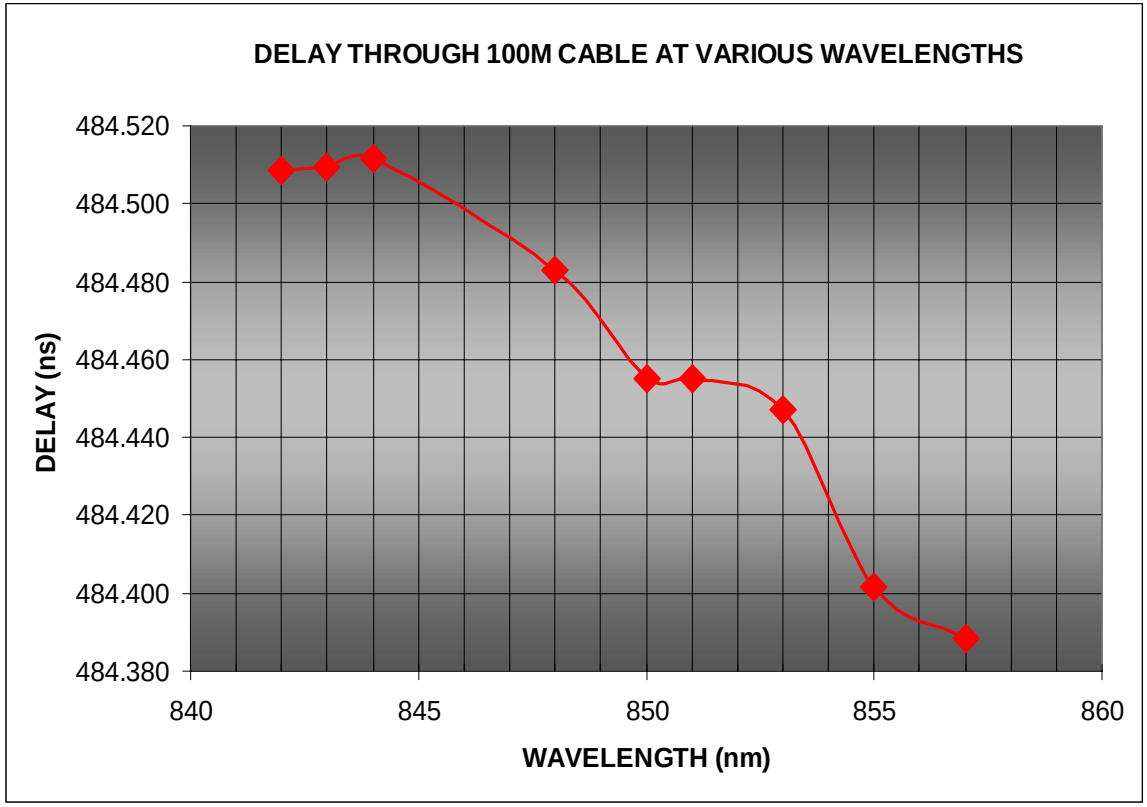
Chromatic Differential Delay

wavelength(nm)	Delay (ns)
842	484.508
843	484.509
844	484.512
848	484.483
850	484.455
851	484.455
853	484.447
855	484.402
857	484.388

Mean = 484.462(ns)

Variance = 0.002081(ns)

Std.Deviation = 0.046(ns)



Differential Fiber Delay Test

- Objective
  - To test differential delay over 100m parallel fiber
- Procedure
  - Transmit PRBS 2^7-1 through a 3m fiber and record data from oscilloscope.
  - Replace the 3m fiber with 100m trunk cable and record delay through 12 individual fibers.

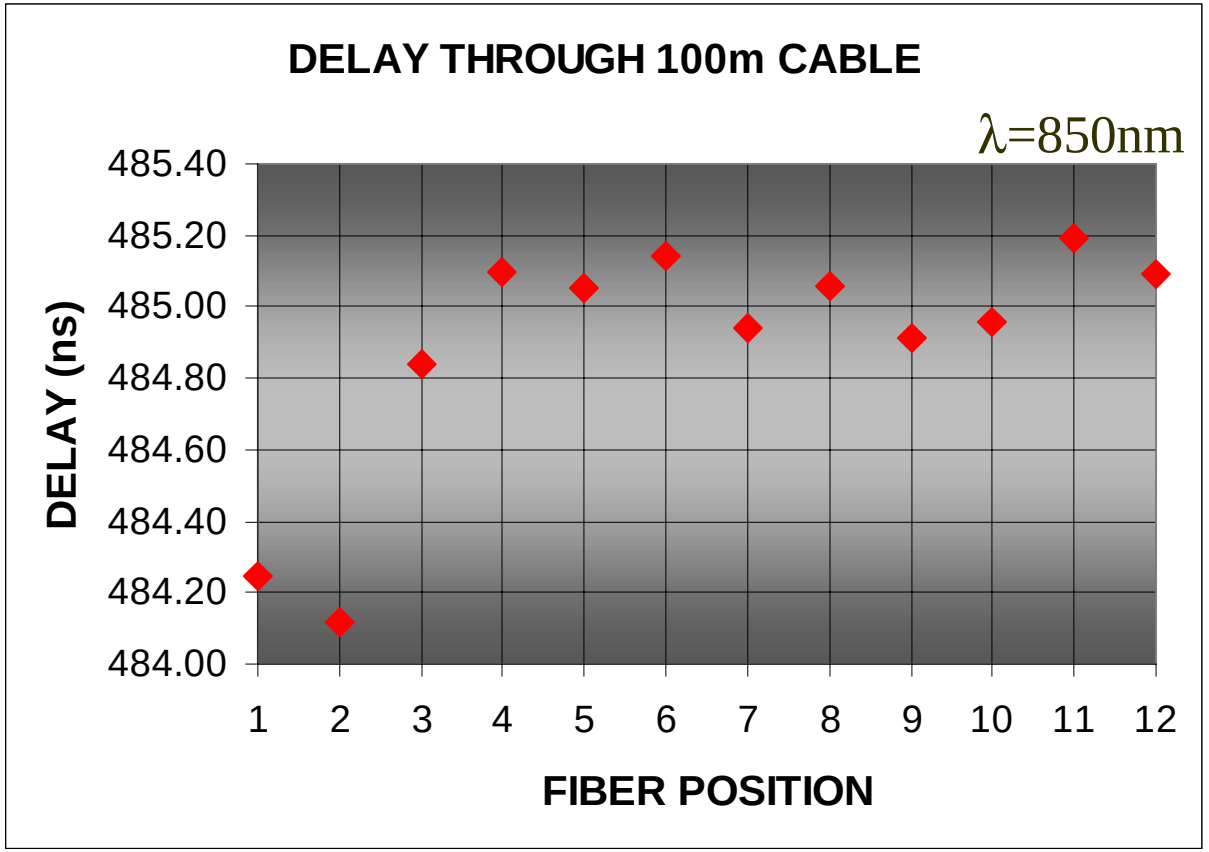
Delay by Fiber Position

FIBER POSITION	DELAY(ns)
1	484.244
2	484.118
3	484.839
4	485.096
5	485.052
6	485.141
7	484.941
8	485.061
9	484.910
10	484.955
11	485.194
12	485.092

Mean = 484.887(ns)

Variance = 0.119793(ns)

Std.Deviation = 0.35(ns)



Transmitter Differential Delay Test

- **Objective**
  - **To test variation in delay among individual transmitters.**
- **Procedure**
  - **Use a transmitter to send PRBS 2^7-1 and record data from oscilloscope.**
  - **Replace the transmitter and record delay.**

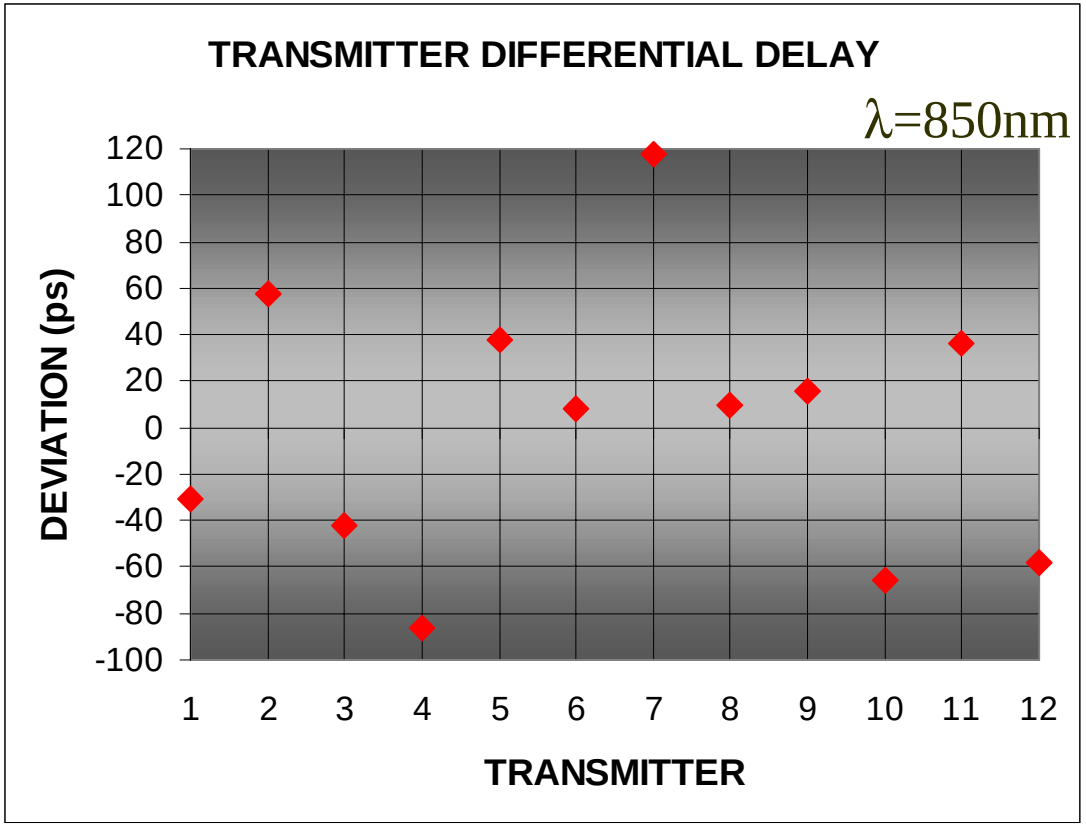
Transmitter Differential Delay

Transmitter	Deviation (ps)
1	-31.083
2	57.917
3	-42.083
4	-86.083
5	37.917
6	7.917
7	117.917
8	9.917
9	15.917
10	-66.083
11	35.917
12	-58.083

Mean = 236.555(ns)

Variance = 0.003481(ns)

Std.Deviation = 0.059(ns)



Receiver Differential Delay Test

- **Objective**
  - **To test variation in delay among individual receivers.**
- **Procedure**
  - **Receive a PRBS 2^7-1 and record data on an oscilloscope.**
  - **Replace the receiver and record delay.**

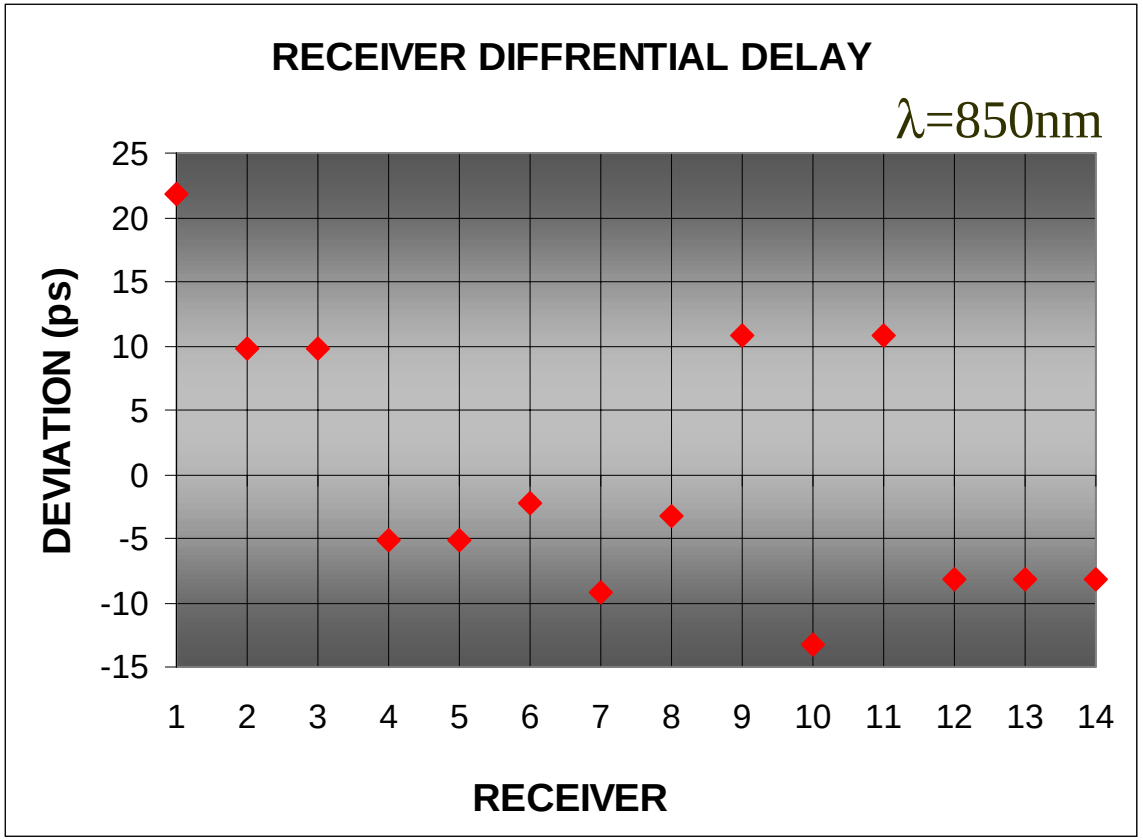
Receiver Differential Delay

Receiver	Deviation (ps)
1	21.786
2	9.786
3	9.786
4	-5.214
5	-5.214
6	-2.214
7	-9.214
8	-3.214
9	10.786
10	-13.214
11	10.786
12	-8.214
13	-8.214
14	-8.214

Mean = 251.839(ns)

Variance = 0.00011(ns)

Std.Deviation = 0.01049(ns)



System Total Differential Delay Computation

$$\sigma_{tot} = \sqrt{\sigma^2_{chro} + \sigma^2_{fl} + \sigma^2_{tx} + \sigma^2_{rx}}$$

$$\sigma_{tot} = 0.358 ns$$

$$6\sigma_{tot} = 2.148 ns$$

Where;

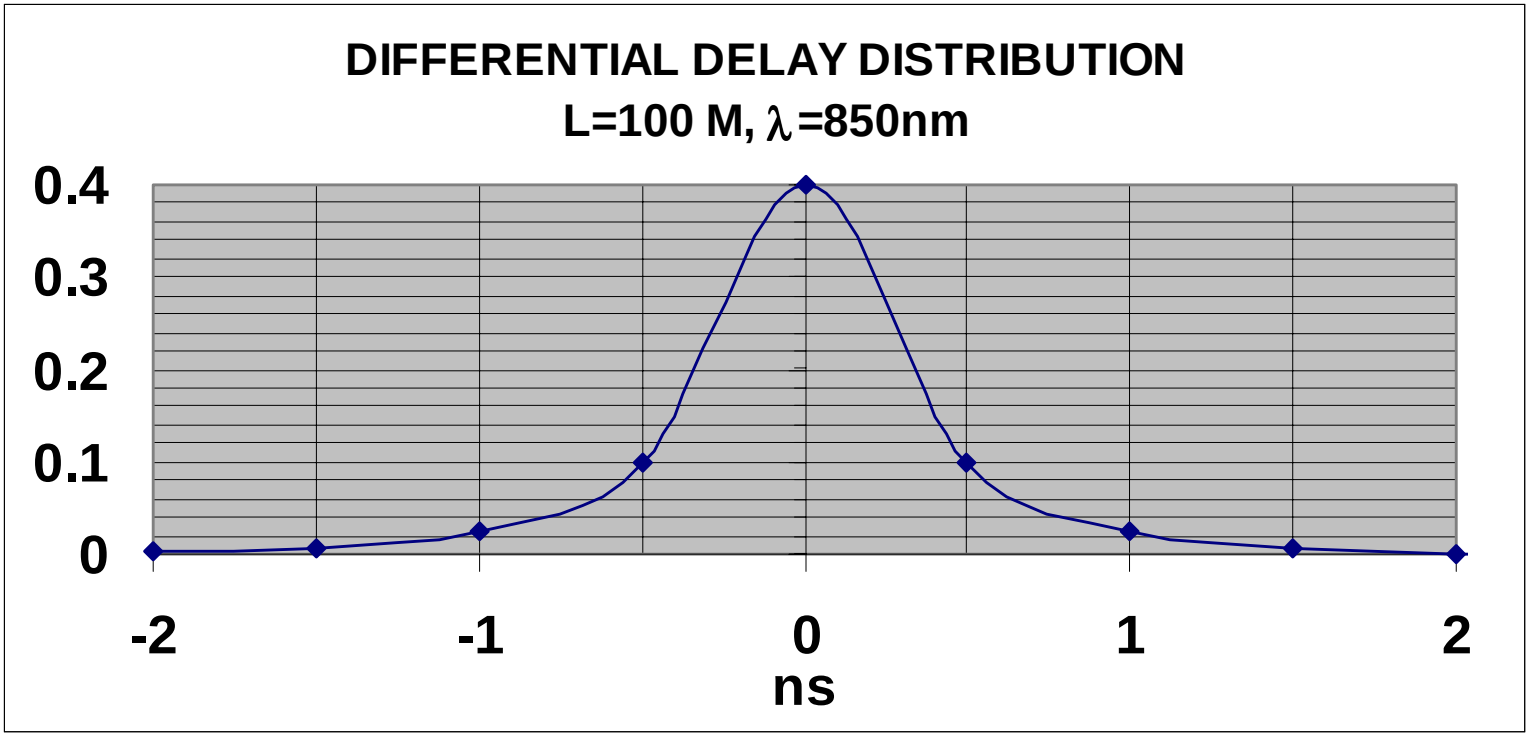
σ_{chro} = Chromatic Differential Delay

σ_{fl} = Fiber Length Differential Delay

σ_{tx} = Transmitter E/O Differential Delay

σ_{rx} = Receiver O/E Differential Delay

System Total Differential Delay



Conclusions

1. Addressed 300m LAN backbone parallel fiber transmission solution.
2. Established advantage of 3.125mm spacing for non-OFC applications.
3. Demonstrated differential delay characteristics enabling 10GbE four fiber parallel transmission over installed MMF.

This multi-protocol standard will address 10GbE, 10G Fibre Channel, Infiniband®, and ATM.