



10GBASE-LX4: Technical Feasibility

Molex Incorporated
Blaze Network Products
Pine Photonics



Participating Companies

- ❖ Molex Fiber Optics
 - Representative: John Dallesasse
- ❖ Blaze Network Products
 - Representative: Eric Grann
- ❖ Pine Photonics
 - Representative: Bor-Long Twu





Presentation Outline

- ❖ Individual Vendor Data
 - Tx Operation
 - Rx Operation (New Data for Austin)
 - Link Data
- ❖ Inter-Vendor Operation Summary
 - Workshop Dates: September 5-7, 2001
 - BER < 10^{-12} At Rated Link Distances





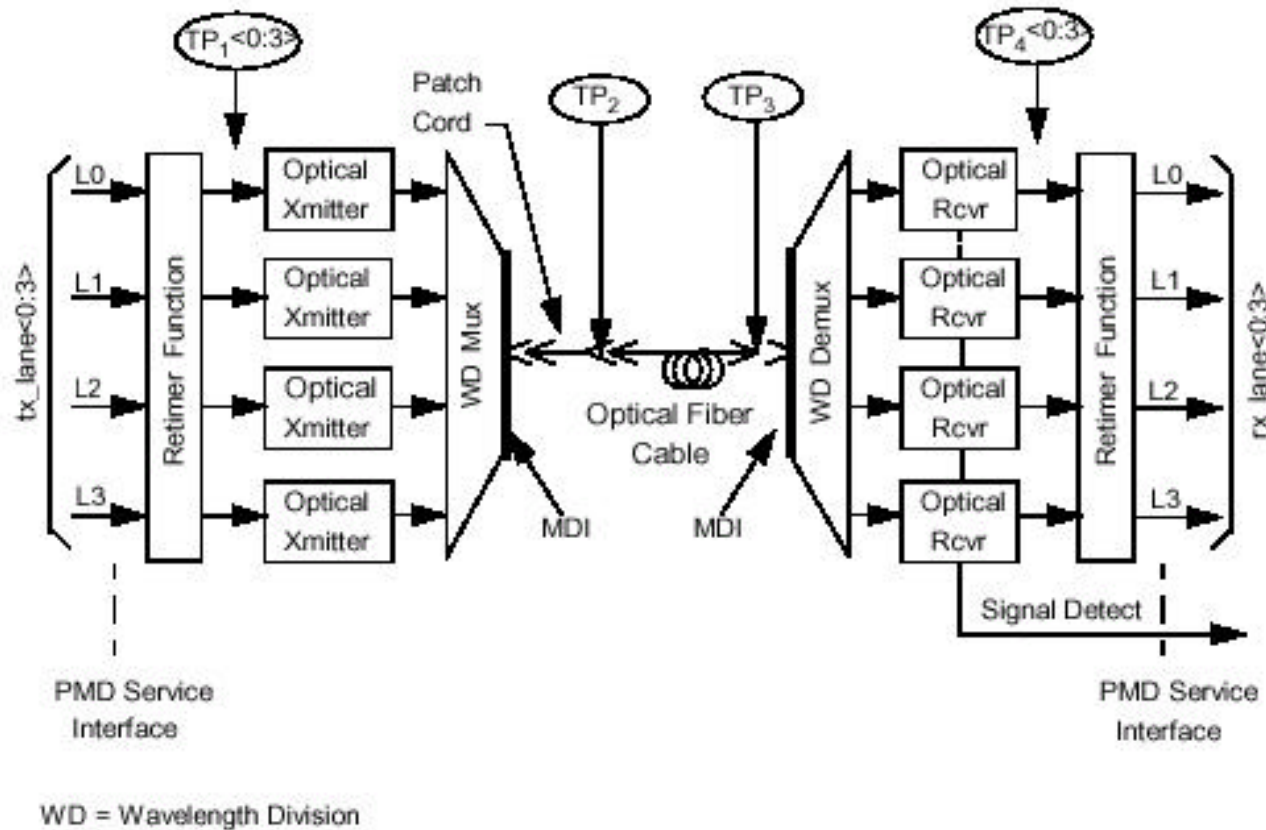
Summary

- ❖ Inter-Vendor Operation Has Been Demonstrated for All Link Distances and Fiber Types With a Less Than 10^{-12} Bit Error Rate Using Early Parts
- ❖ Full Compliance Has Been Shown By At Least One Vendor For Each Tested Parameter
- ❖ Technical Feasibility Has Been Demonstrated





Typical Link Under Test



Our Tests: Drive at TP1,
Test at TP2 and TP4





Component Availability

- ❖ Retimer ICs (XAUI-XAUI or XAUI-Other): Available Soon From at Least 3 Vendors
- ❖ Laser Drivers, TIAs, Limiting Amplifiers: Currently Available from Multiple Vendors
- ❖ Lasers and Photodiodes: Currently Available from Multiple Vendors
- ❖ Optical Multiplexing: Multiple Technologies and Multiple Vendors
- ❖ Optical Demultiplexing: Multiple Technologies and Multiple Vendors
- ❖ Summary: There are multiple sources of components and multiple transceiver manufacturers – multi-vendor support is demonstrated.





Individual Vendor Data

- ❖ Data From Three Companies
 - Presented as Vendors A, B, and C
- ❖ Data Presented
 - Tx TP2 Data
 - Optical Spectra, Rise/Fall Time, Optical Power, OMA
 - Rx Data (New Data for Austin)
 - Jitter Data (New Data for Austin)
 - Link TP4 Eye Diagrams
 - Link BER Testing





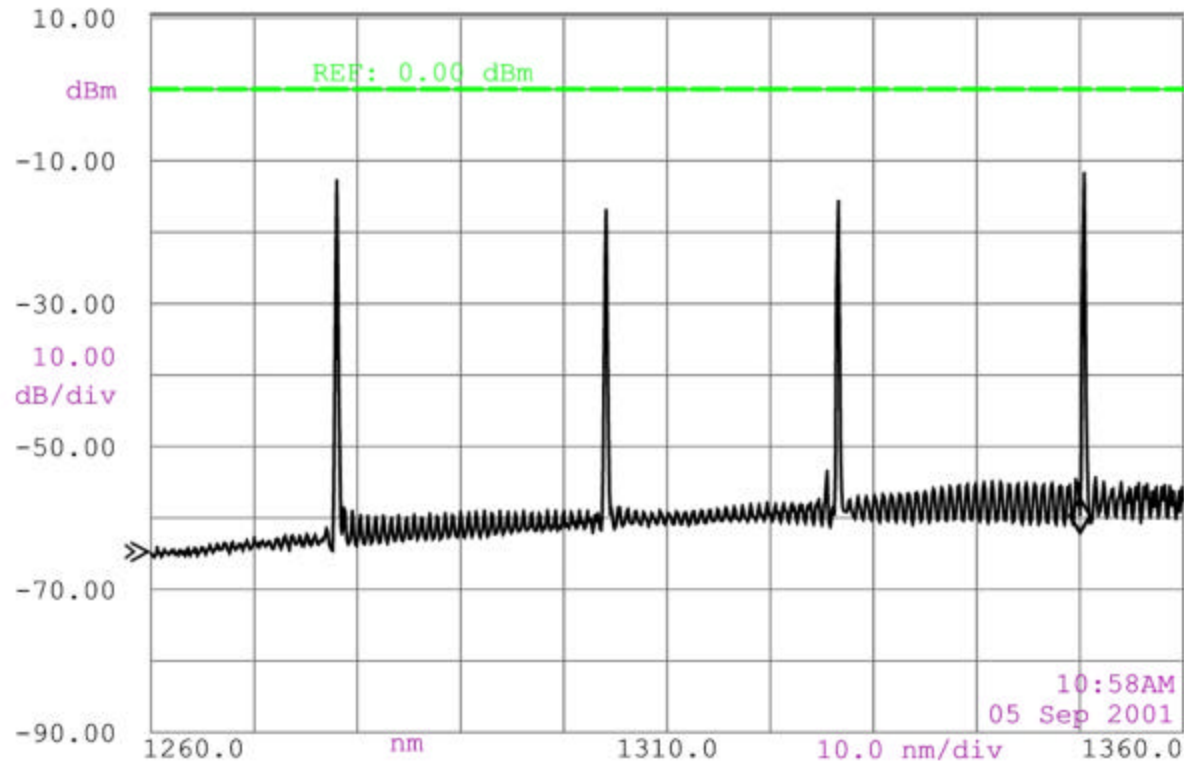
Transmitter TP2 Testing

- ❖ Optical Spectra:
 - Measured with All Channels Operating
 - Wavelength and Spectral Width are Compliant
- ❖ Average Optical Power, OMA, Rise/Fall Time
 - Measured at TP2 With Channels Not Under Test Disabled
 - Compliance Has Been Shown





Vendor A Optical Spectra



RBW: 0.06 nm
VBW: 2.1 kHz

Sens: -60.00 dBm
ST: 1.01 s

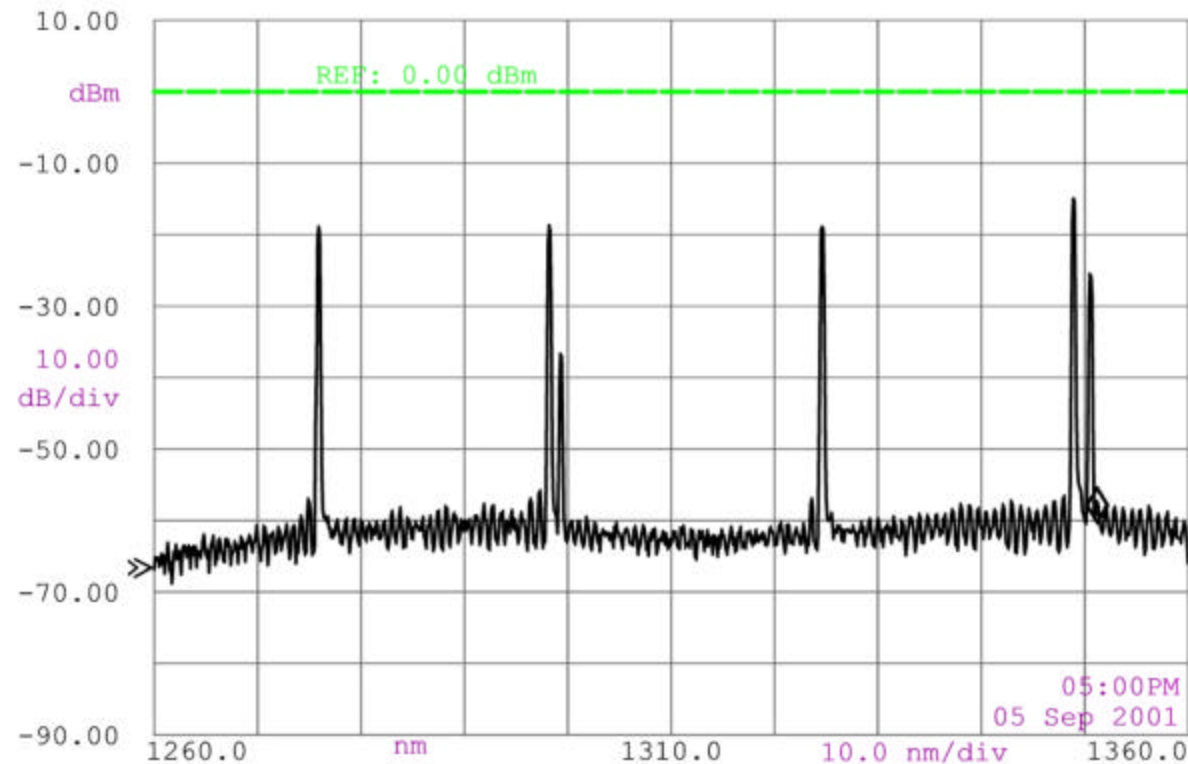
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In Vacuum
User Cal





Vendor B Optical Spectra



RBW: 0.2 nm
VBW: 19.3 kHz

Sens: -60.00 dBm
ST: 76.0 ms

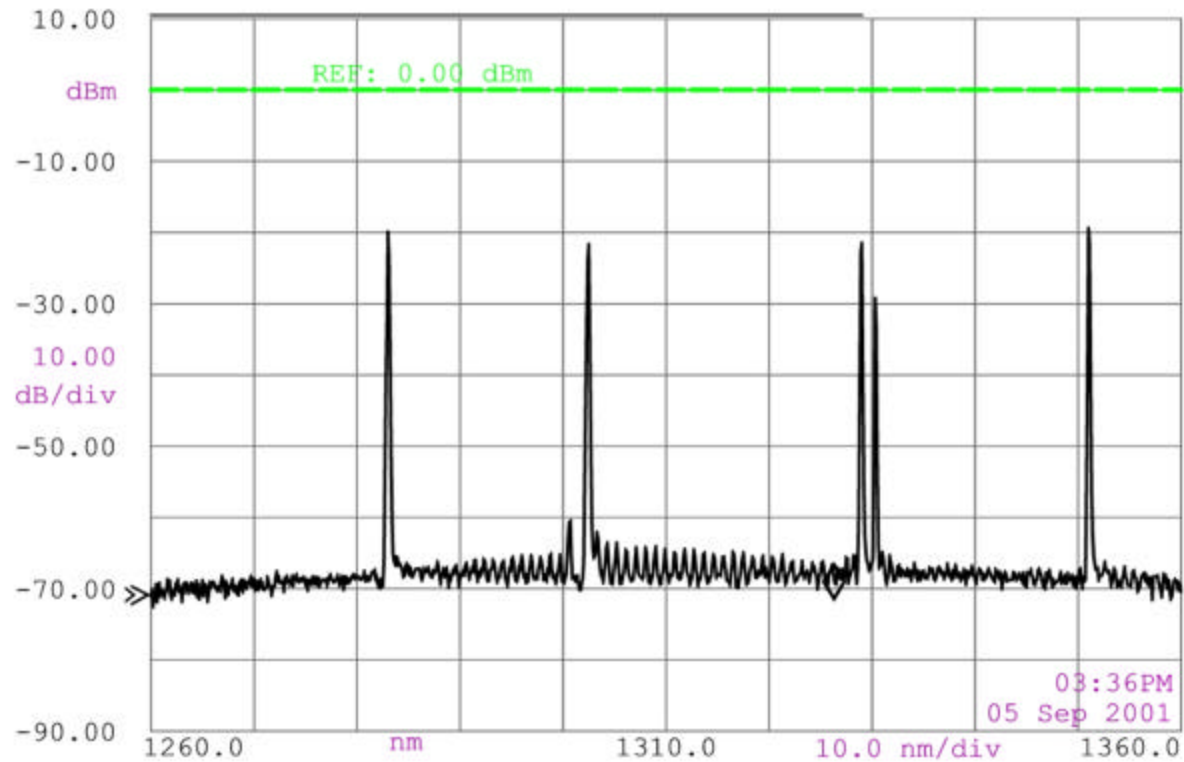
Avg: Off

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User Cal





Vendor C Optical Spectra



RBW: 0.06 nm
VBW: 2.1 kHz

Sens: -60.00 dBm
ST: 1.01 s

Avg: Off

In Vacuum
User Cal





Vendor A TP2 Data

	Channel 0 (1275)	Channel 1 (1300)	Channel 2 (1325)	Channel 3 (1350)
OMA	341 μ W	580 μ W	435 μ W	749 μ W
Average Power	-4.42 dBm	-2.8 dBm	-2.7 dBm	-0.5 dBm
Rise Time	145 ps	141 ps	153 ps	125 ps
Fall Time	177 ps	161 ps	167 ps	137 ps



Note: Subsequent Testing On Newer Transceivers
Has Shown Rise Times in the 60-65 ps Range
And Fall Times in the 91-96 ps Range
COMPLIANCE HAS BEEN DEMONSTRATED!





Vendor B TP2 Data

	Channel 0	Channel 1	Channel 2	Channel 3
OMA	290 μ W	238 μ W	260 μ W	238 μ W
Average Power	-6.34 dBm	-7.15 dBm	-6.35 dBm	-6.42 dBm
Rise Time	159 ps	124 ps	161 ps	139 ps
Fall Time	159 ps	138 ps	149 ps	125 ps





Vendor C TP2 Data

	Channel 0	Channel 1	Channel 2	Channel 3
OMA	478 μ W	446 μ W	405 μ W	439 μ W
Average Power	-4.56 dBm	-4.56 dBm	-5.30 dBm	-5.03 dBm
Rise Time	59 ps	48 ps	53 ps	96 ps
Fall Time	94 ps	87 ps	86 ps	96 ps



All Tested TP2 Parameters Compliant!





TP2 Test Result Comments

- ❖ At Least Two Vendors Currently Compliant With All TP2 Parameters
- ❖ Compliance Has Been Demonstrated!

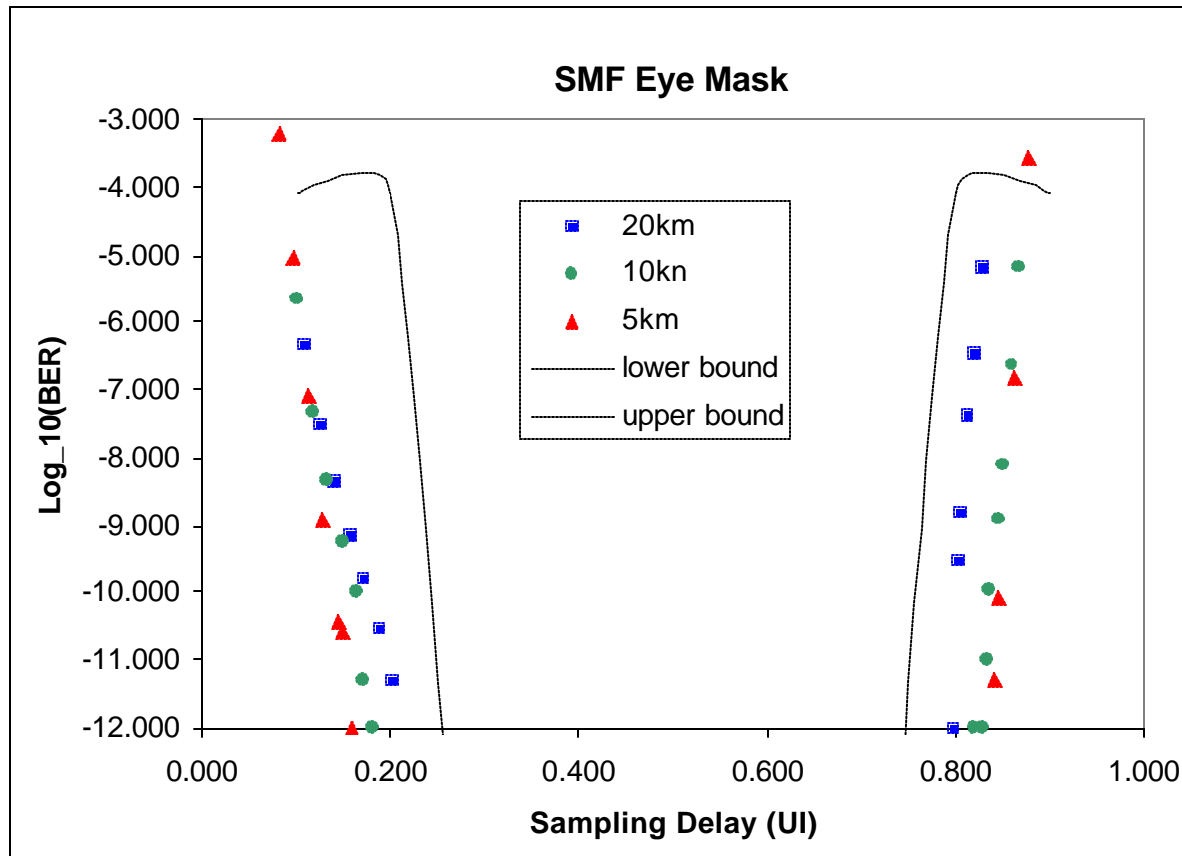


Transmitter TP3 Testing

- ❖ Conformance at TP3 Requires Measurement of Transmit Jitter Using “Bathtub Curve” Methodology
- ❖ To Replace “Golden Receiver,” Test Setup Uses Standard Receiver
- ❖ The Measurement Is More Conservative Than Required – Receiver Jitter is Not Removed

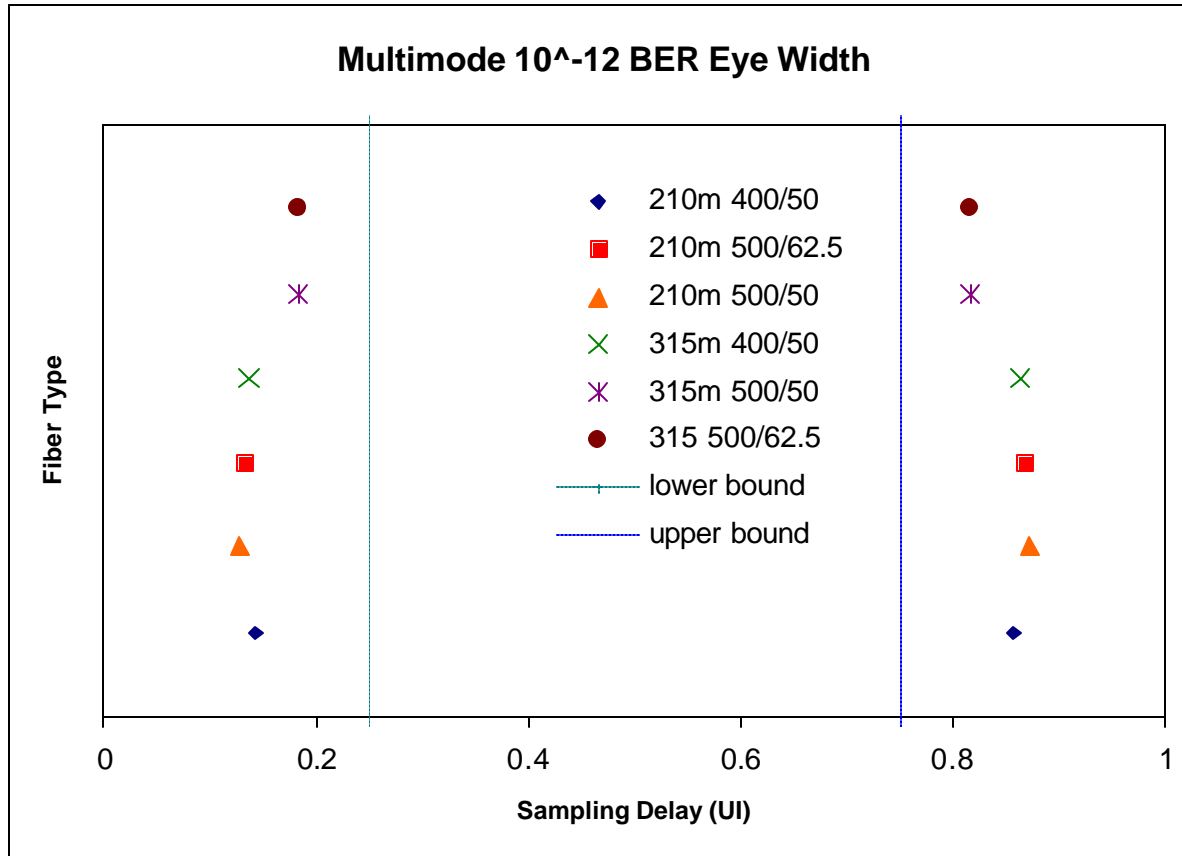


Vendor A Bathtub Curve: Single Mode Fiber



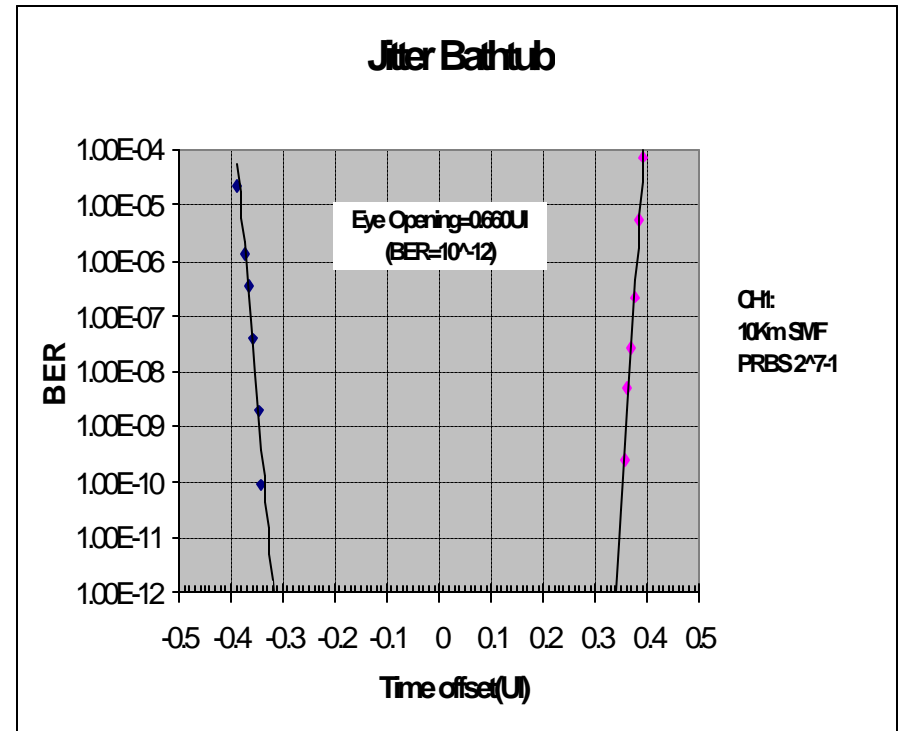
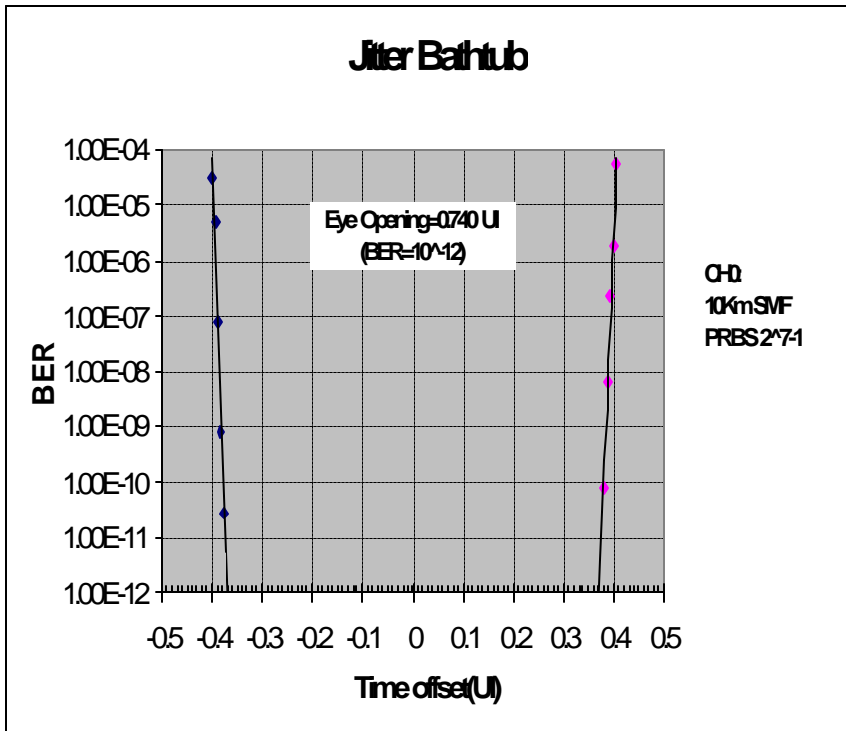


Vendor A Bathtub Data: Multimode Fiber



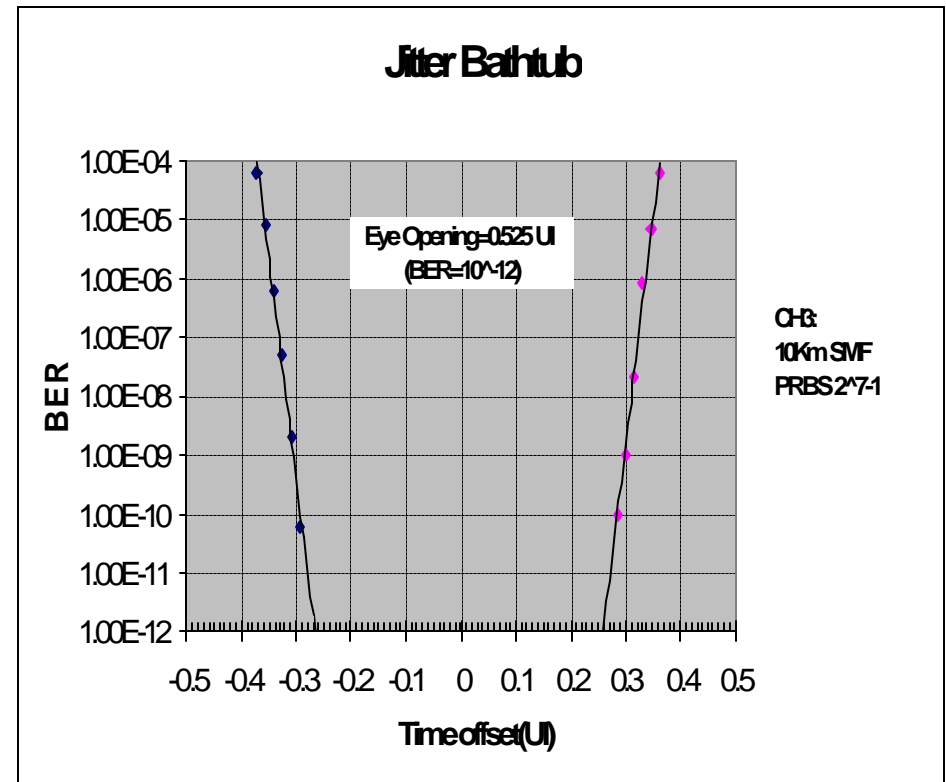
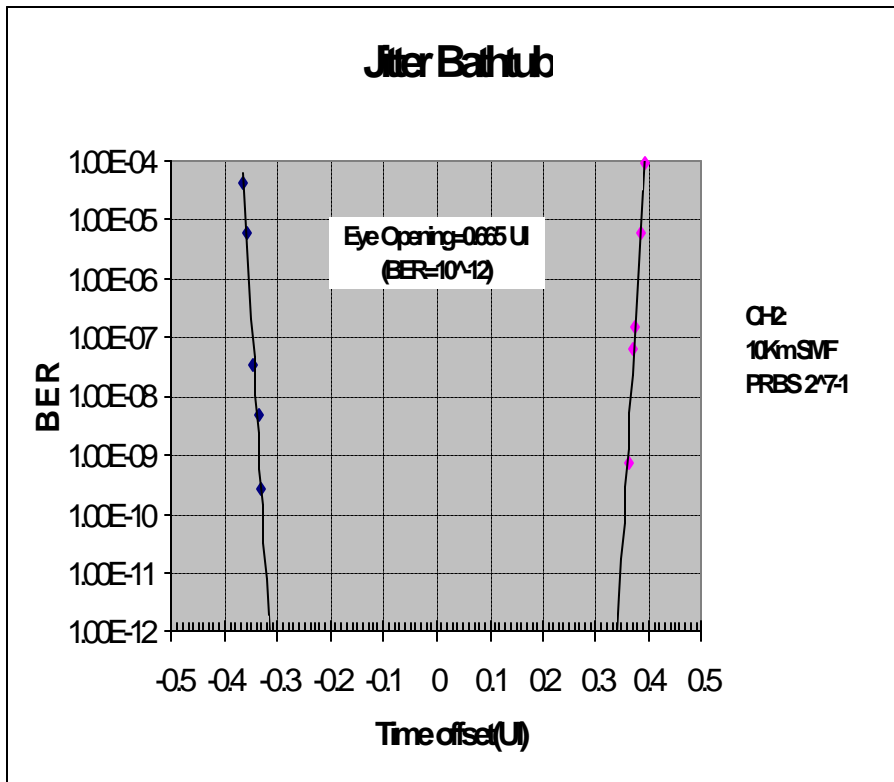


Vendor C Jitter Bathtub Curve: 10 km SMF (CHANNEL 0 and 1)





Vendor C Jitter Bathtub Curve: 10 km SMF (CHANNEL 2 and 3)





Summary of TP3 Testing

- ❖ At Least Two Vendors Have Demonstrated Conformance at TP3
 - Full Bathtub Curves for Single Mode Fiber
 - Data Shown For Multimode Fiber
- ❖ Jitter Methodology and Compliance Has Been Demonstrated!





Receiver Measurements

- ❖ Receiver Sensitivity
- ❖ Stressed Receiver Sensitivity
- ❖ 3dB Bandwidth
- ❖ Receiver Jitter Tolerance



Receiver Sensitivity

	Lane 0	Lane 1	Lane 2	Lane 3
Standard (μ W OMA) (MM/SM)	37.4/32.7	37.4/32.7	37.4/32.7	37.4/32.7
Vendor A	R1: 60 R2: 16	R1: 65 R2: 25	R1: 64 R2: 13	R1: 64 R2: 27
Vendor C	31.2	27.5	34.2	56.7

Note: R1 Used for Interoperation, R2 New Unit

Compliance Has Been Demonstrated!



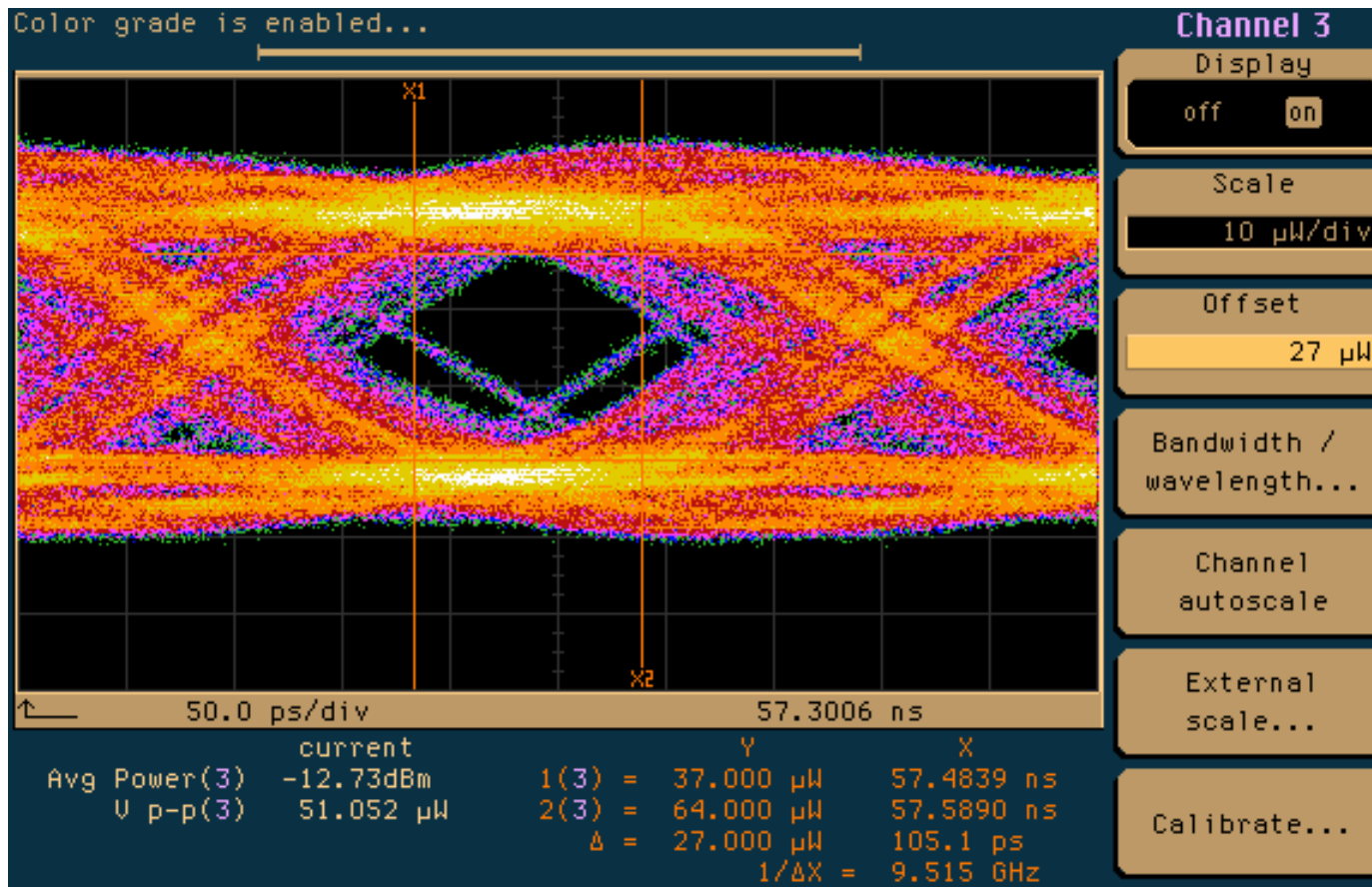


Stressed Receiver Sensitivity

- ❖ Measured By Vendor A and C With All Channels Running, No Wavelength Tuning
- ❖ Measured By Vendor B Using Full Methodology of Current Draft
- ❖ Compliance Has Been Demonstrated



Vendor A Stressed Eye

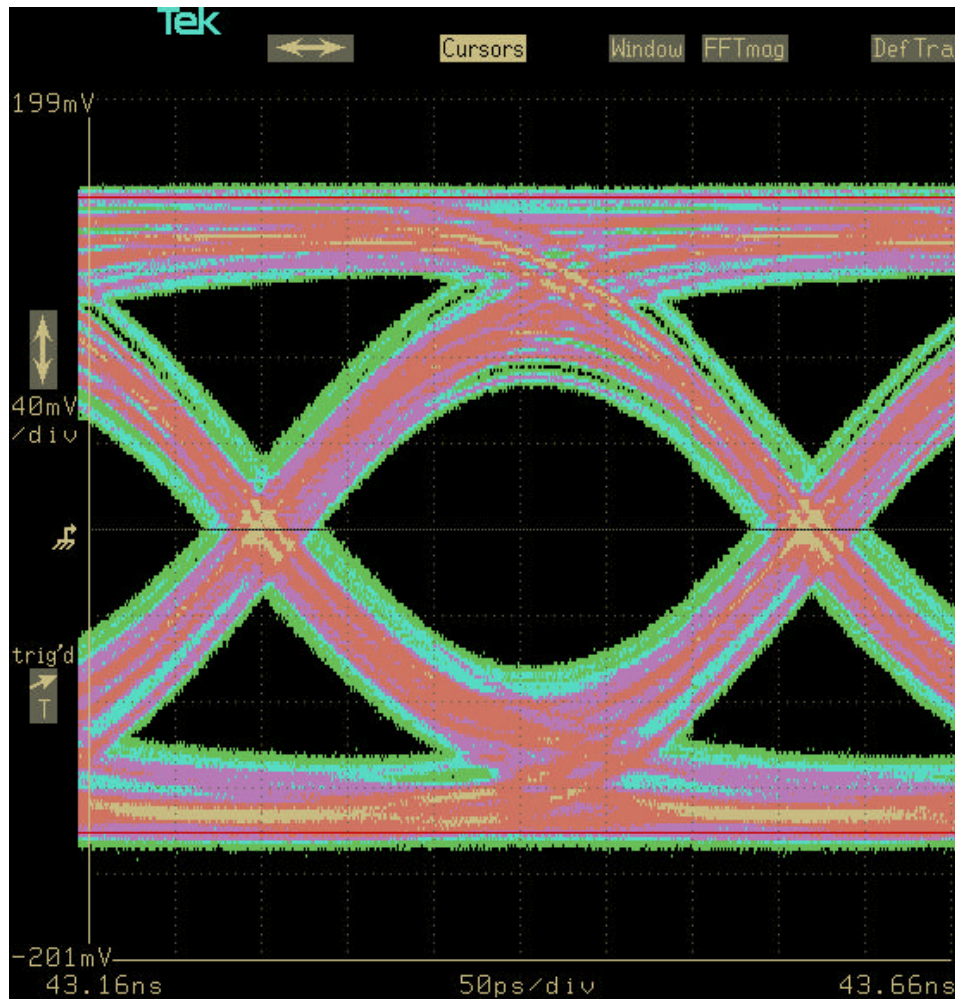


Lane 0: 15 μW , Lane 1: 27 μW , Lane 2: 32 μW , Lane 3: 60 μW



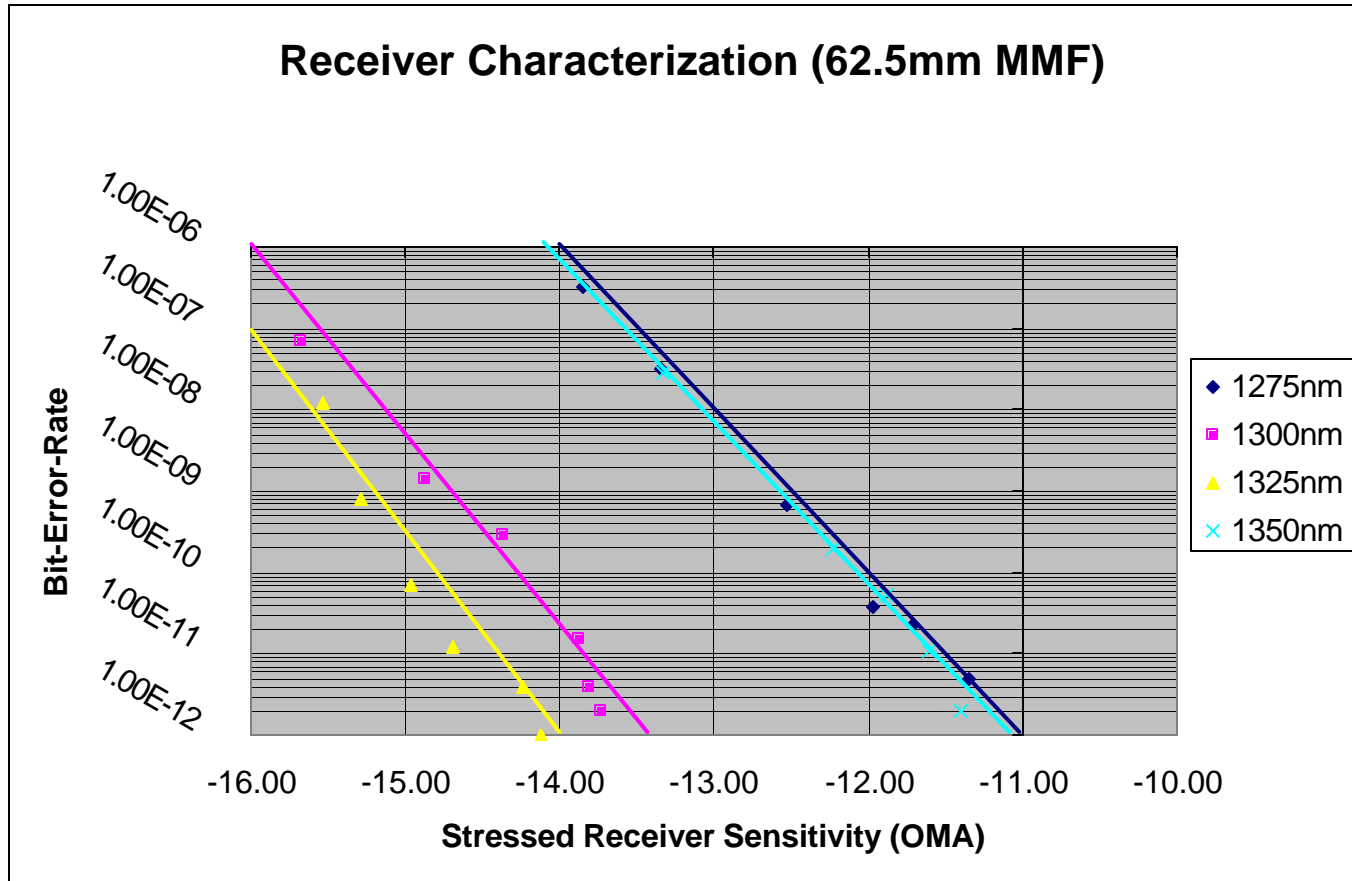


Vendor B Stressed Eye





Vendor B Stressed Receiver Data

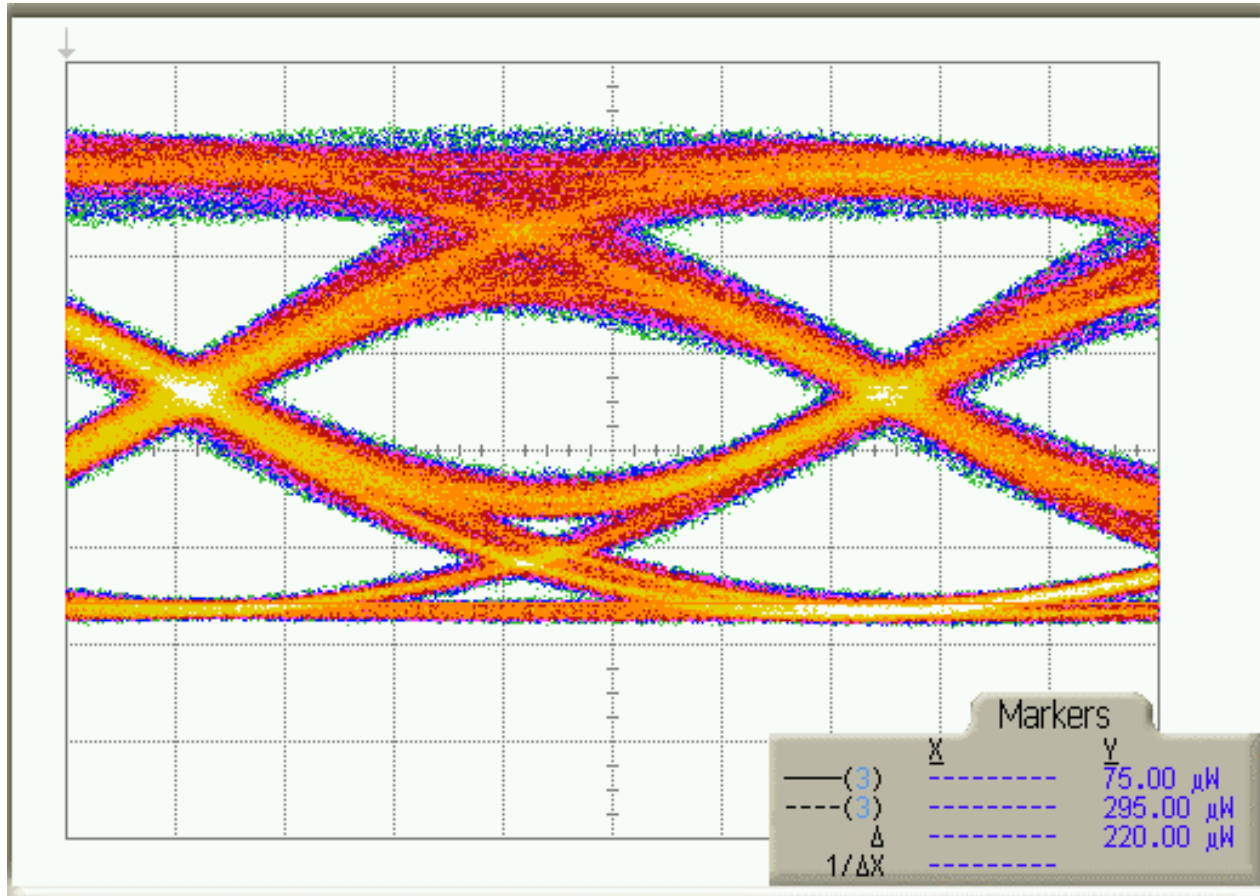


Compliant With Standard (-10.3 dBm)!





Vendor C Stressed Eye

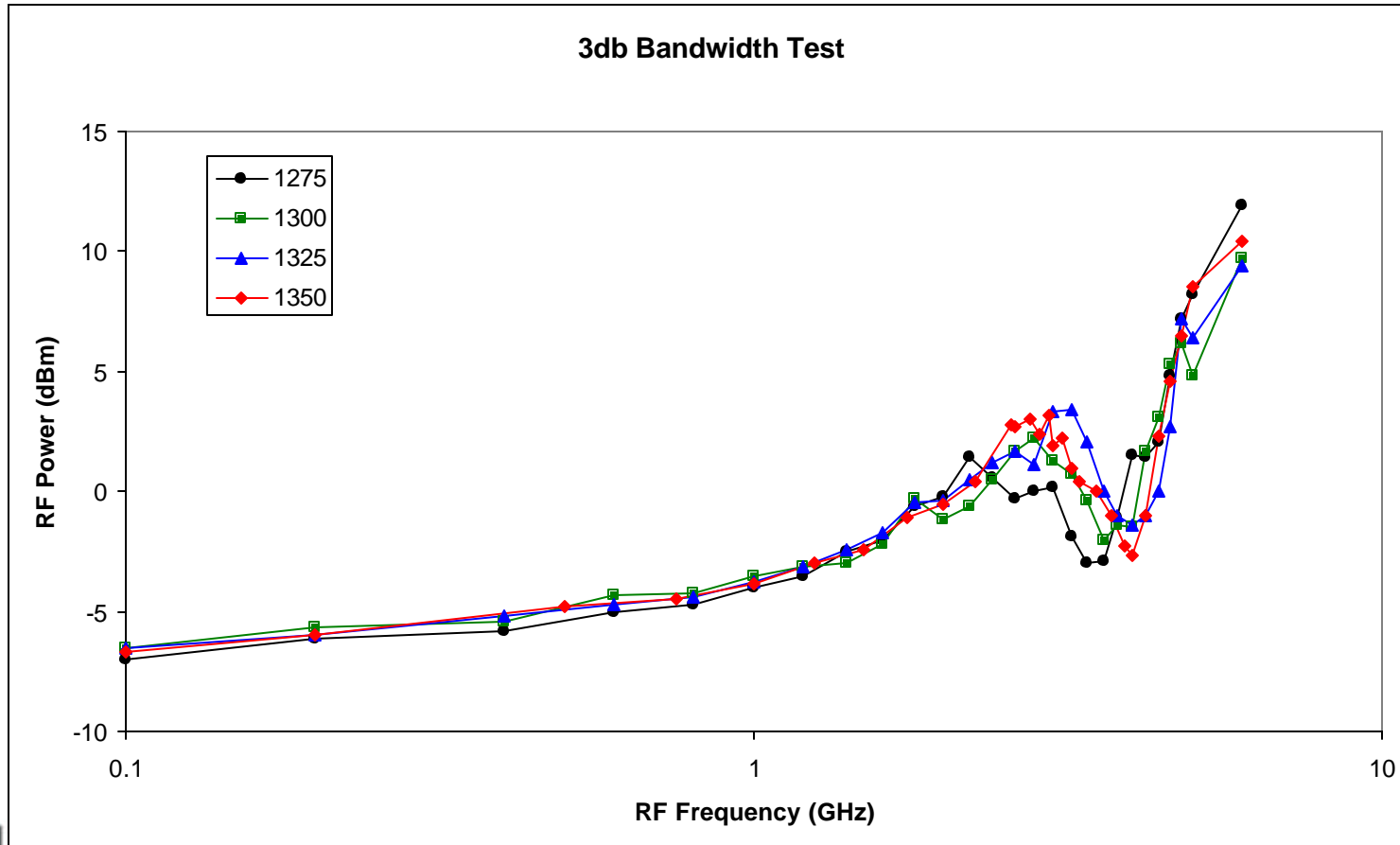


Multimode Sensitivity
Ranging From -6.7 to -7.2 dBm





Vendor A Receiver 3dB Bandwidth



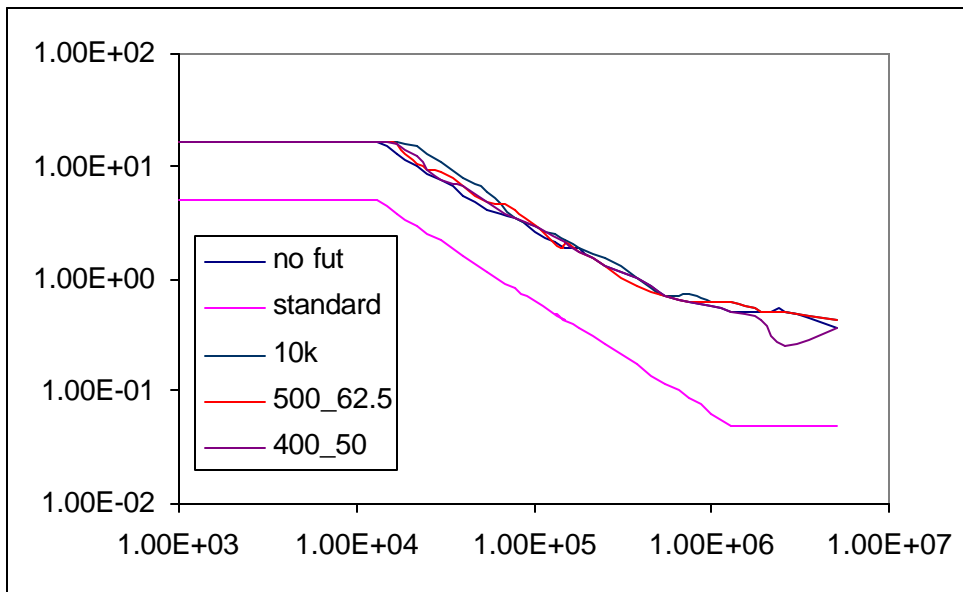
Receive Bandwidth < 3.75 GHz
Complies With Standard!





Vendor A Jitter Tolerance

- ❖ Data Taken Thus Far Looks Good
- ❖ Additional Testing Under Way





Transmitter Intra-Vendor TP4 Testing

- ❖ Goal: Demonstrate Data Transmission for All Fiber Types at Rated Distance
 - 10,000 meters SMF
 - 300 meters, 62.5 μm Core, 500 MHz•km MMF
 - 240 meters, 50 μm Core, 400 MHz•km MMF
 - 300 meters, 50 μm Core, 500 MHz•km MMF
- ❖ Summary: This Goal Achieved





Vendor A Link Testing

- ❖ 10,000 meters SMF
 - $< 10^{-12}$ BER for > 1 Hour With Up To 2.5 dB Attenuation
 - $< 10^{-12}$ BER for 20,000 meters SMF
 - Initial Tests at 30,000 meters Promising
- ❖ 330 meters, 62.5 μm Core, 500 MHz•km MMF
 - $< 10^{-12}$ BER for > 1 Hour With Up To 5 dB Attenuation
- ❖ 263 meters, 50 μm Core, 400 MHz•km MMF
 - $< 10^{-12}$ BER for > 1 Hour With Up To 2.6 dB Attenuation
- ❖ 300 meters, 50 μm Core, 500 MHz•km MMF
 - $< 10^{-12}$ BER for > 1 Hour With Up To 5.5 dB Attenuation



Rated Distance for All Fiber Types!





Vendor B Link Testing

- ❖ All Link Distances and Fiber Types Tested with $< 10^{-12}$ BER
- ❖ Data Not Available with Attenuation



Rated Distance for All Fiber Types!





Vendor C Link Testing

- ❖ All Link Distances and Fiber Types Tested with $< 10^{-12}$ BER
- ❖ 10,000 meters SMF
 - $< 10^{-12}$ BER With Attenuation (per Channel) of Up to 7.3, 7.6, 5.3, and 4.7 dB
 - Tested for Up to 3 Hours With No Errors
- ❖ 300 meters, 62.5 μm Core, 500 MHz•km
 - $< 10^{-12}$ BER With Attenuation (per Channel) of Up to 6.3, 6.7, 4.5, and 1.7 dB
 - Tested With BER $< 10^{-12}$ To 700 meters



Rated Distance for All Fiber Types!





Intra-Vendor Link Testing Comments

- ❖ Required Bit Error Rates ($< 10^{-12}$ BER)
Demonstrated Under “Stressed”
Conditions
 - Excessive Rise/Fall Times
 - Extra Fiber Length
 - Added Attenuation
- ❖ These Results are Very Good



Inter-Vendor Testing Goals

- ❖ Vendor A Tx – Vendor B Rx
 - Rated Distances, All Fiber Types
 - 10,000 (10,400) meters SMF
 - 300 (330) meters, 62.5 μm Core, 500 MHz•km MMF
 - 240 (263) meters, 50 μm Core, 400 MHz•km MMF
 - 300 meters, 50 μm Core, 500 MHz•km MMF
- ❖ Vendor A Tx – Vendor C Rx
 - Rated Distance, All Fiber Types
- ❖ Vendor B Tx – Vendor A, C Rx
 - Rated Distance, All Fiber Types
- ❖ Vendor C Tx – Vendor A, B Rx
 - Rated Distance, All Fiber Types





Test Details

- ❖ Data Source at TP1:
 - BERT Pattern Generators, 2^7-1 PRBS
 - All Channels Independently Driven
- ❖ Multiple Connections:
 - SC Optical Interface on Transmitters
 - 2 Patch Cords Prior to Fiber Under Test
 - 2 Patch Cords After Fiber Under Test
- ❖ CDR at TP4 for BER Testing Only (Needed Clock)
- ❖ Test For Minimum of 5 Minutes Per Channel
- ❖ Vendor B Tx to Vendor C Rx 10 km SMF Test With Additional 2 dB of Attenuation ⇒ No Problem!





Data Summary: Vendor A to Vendor C

	62.5 μ m Core MMF 500 MHz-km, 330 m	50 μ m Core MMF 400 MHz-km, 263 m	50 μ m Core MMF 500 MHz-km, 300 m	10 μ m Core SMF 10,400 m
Vendor A Tx - Vendor C Rx				
Channel 0	X	X	X	X
Channel 1	X	X	X	X
Channel 2	X	X	X	X
Channel 3	X	X	X	X
Vendor C Tx - Vendor A Rx				
Channel 0	X	X	X	X
Channel 1	X	X	X	X
Channel 2	X	X	X	X
Channel 3	X	X	X	X

“X” Indicates $< 10^{-12}$ Bit Error Rate



Rated Distance for All Fiber Types!
Full Demonstration of Inter-Vendor Operation





Data Summary: Vendor A to Vendor B

	62.5 μ m Core MMF 500 MHz-km, 330 m	50 μ m Core MMF 400 MHz-km, 263 m	50 μ m Core MMF 500 MHz-km, 300 m	10 μ m Core SMF 10,400 m
Vendor A Tx - Vendor B Rx				
Channel 0	X	X	X	X
Channel 1	X	X	X	X
Channel 2	X	I	X	X
Channel 3	X	X	X	X
Vendor B Tx - Vendor A Rx				
Channel 0	X	X	X	X
Channel 1	X	X	X	X
Channel 2	X	X	X	X
Channel 3	X	X	X	X

“X” Indicates $< 10^{-12}$ Bit Error Rate

“I” Indicates Incomplete Test





Data Summary: Vendor B to Vendor C

	62.5 μ m Core MMF 500 MHz-km, 330 m	50 μ m Core MMF 400 MHz-km, 263 m	50 μ m Core MMF 500 MHz-km, 300 m	10 μ m Core SMF 10,400 m
Vendor B Tx - Vendor C Rx				
Channel 0	X	*	X	X
Channel 1	X	*	X	X
Channel 2	X	*	X	X
Channel 3	X	*	X	X
Vendor C Tx - Vendor B Rx				
Channel 0	X	X	X	X
Channel 1	X	X	X	X
Channel 2	X	I	X	X
Channel 3	X	X	X	X

“*” Indicates Fiber Not Available at Time of Test

“X” Indicates $< 10^{-12}$ Bit Error Rate





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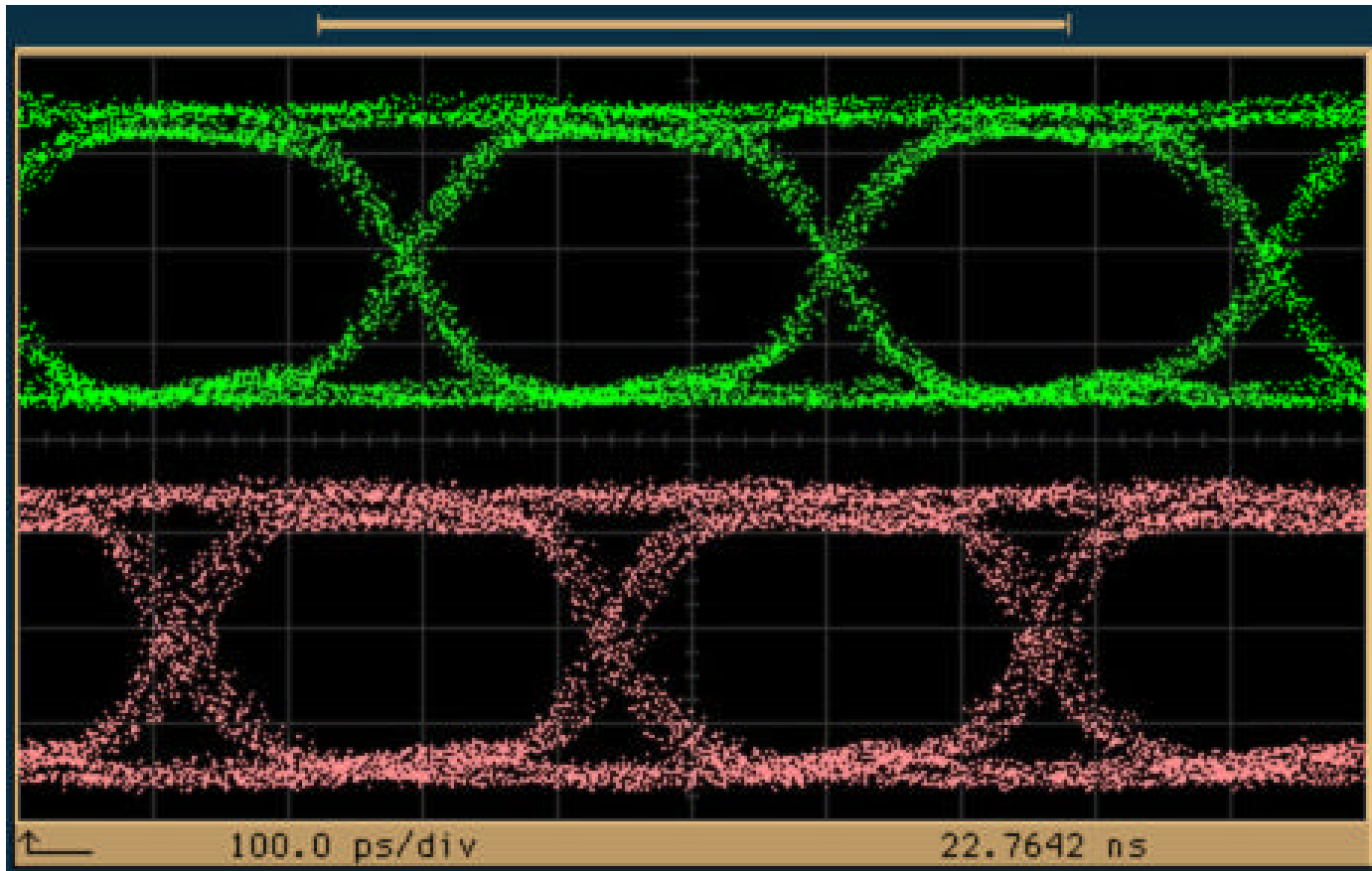
Representative Eye Diagrams





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Vendor A Tx – Vendor C Rx 10.4 km SMF



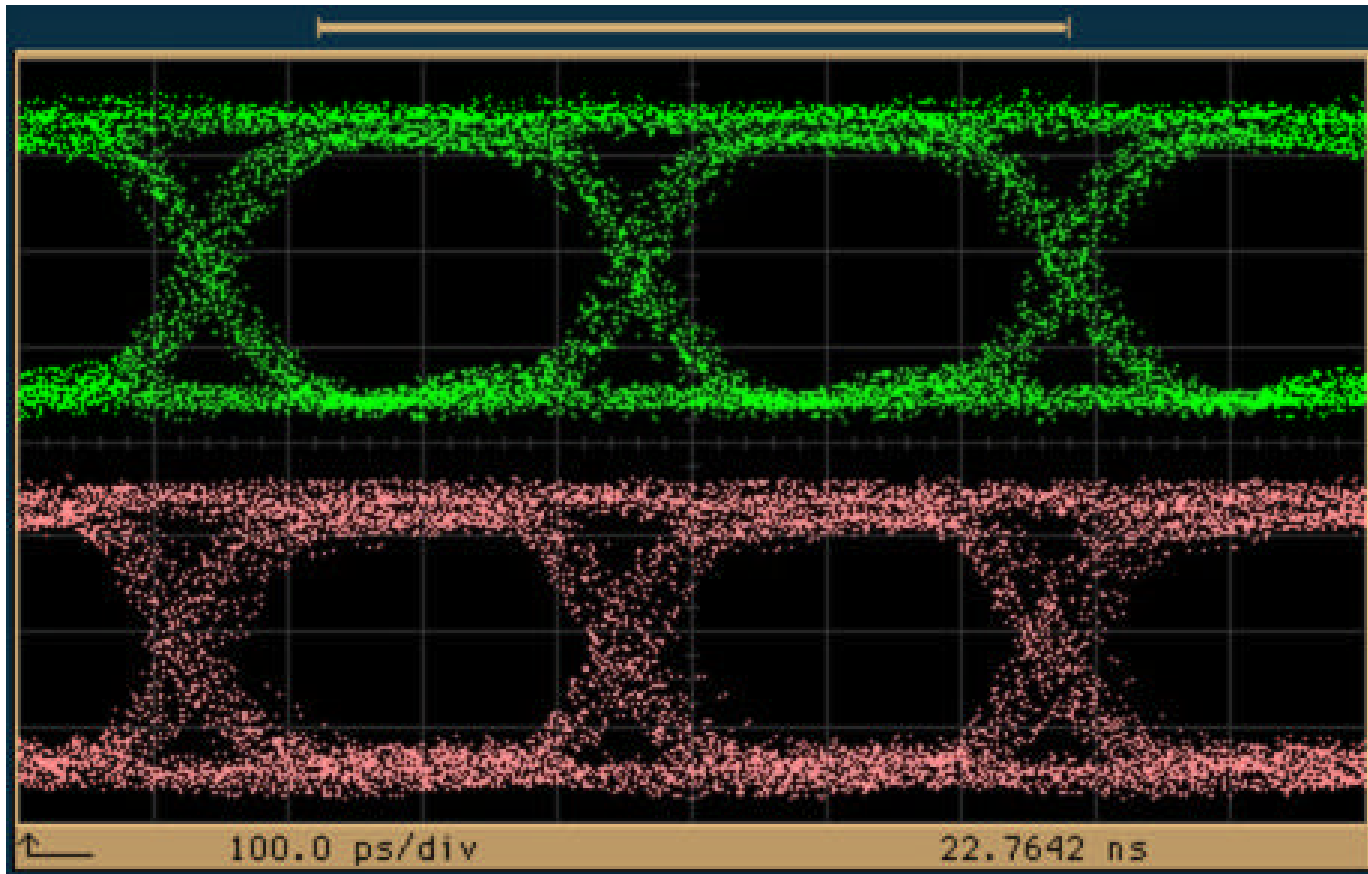
Note: Two Representative Channels Shown





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Vendor A Tx – Vendor C Rx
330 m, 62.5 μm Core MMF

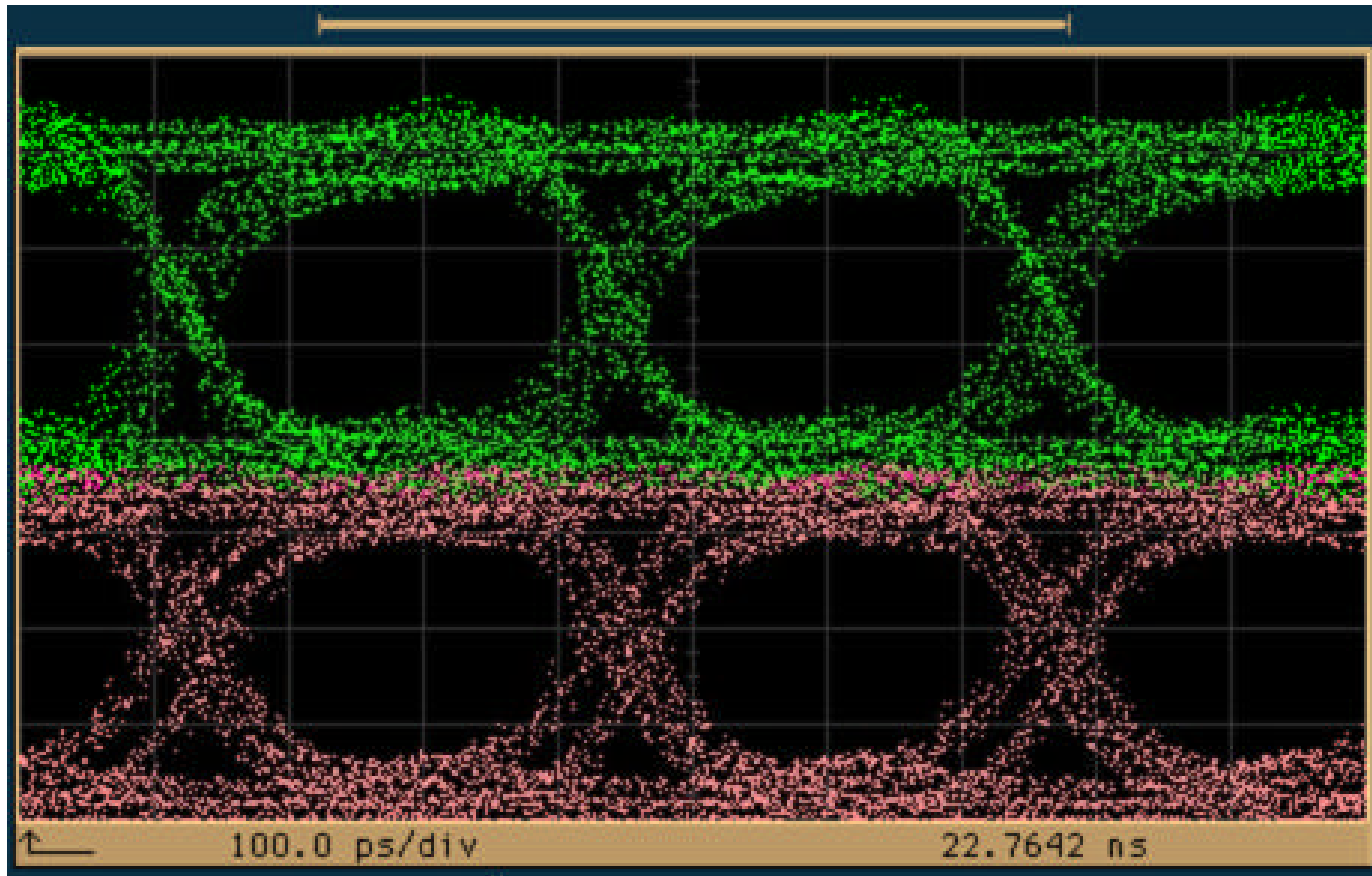




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Vendor A Tx – Vendor C Rx

263 m, 50 μm Core, 400 MHz•km MMF

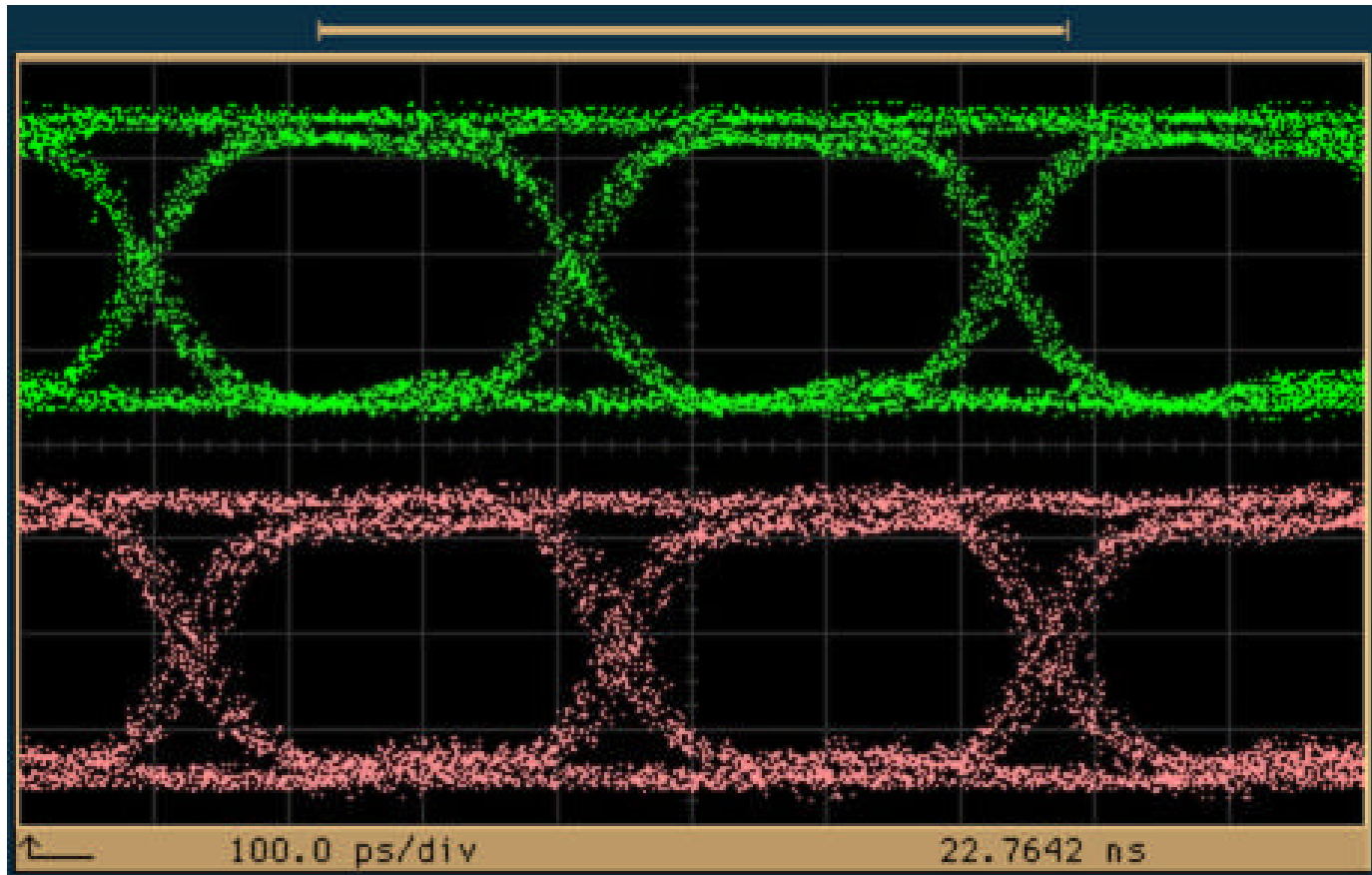




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Vendor A Tx – Vendor C Rx

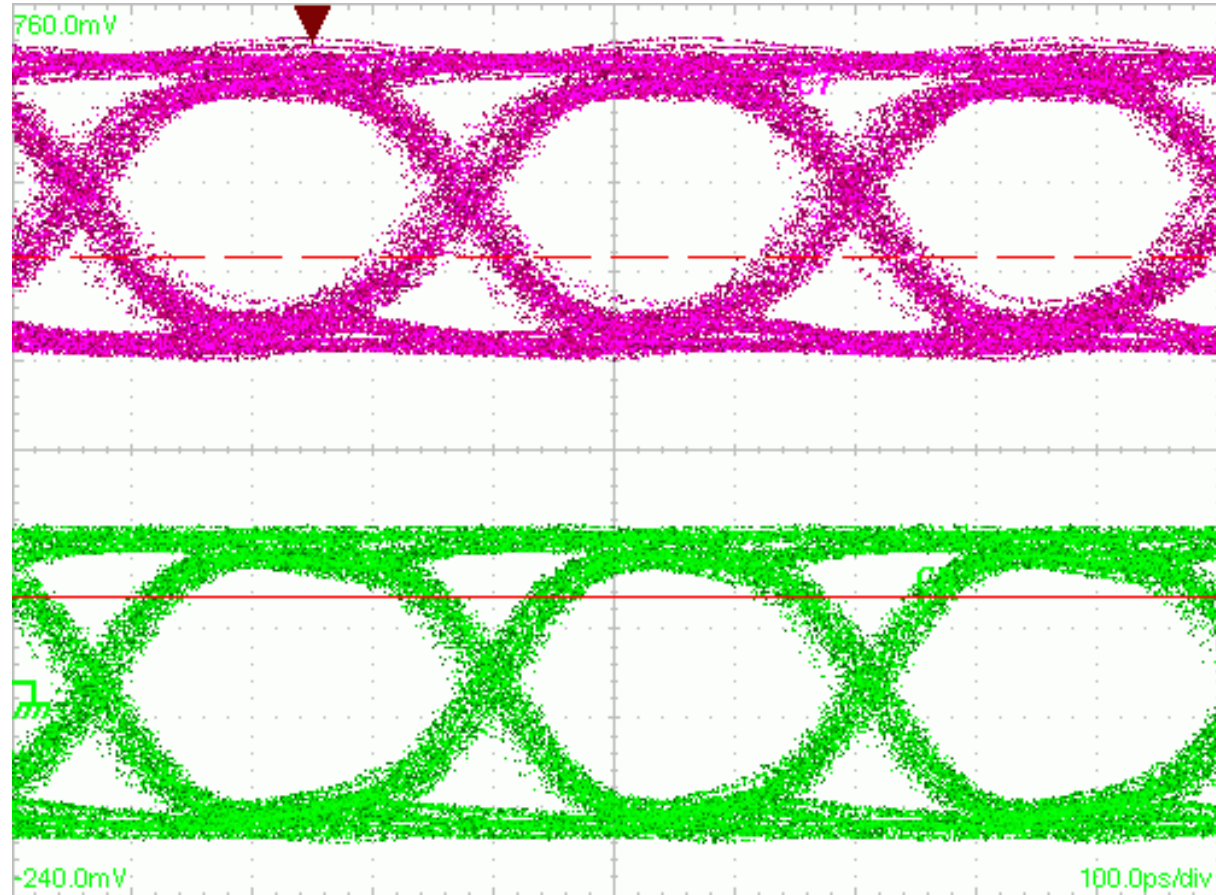
300 m, 50 μm Core, 500 MHz•km MMF





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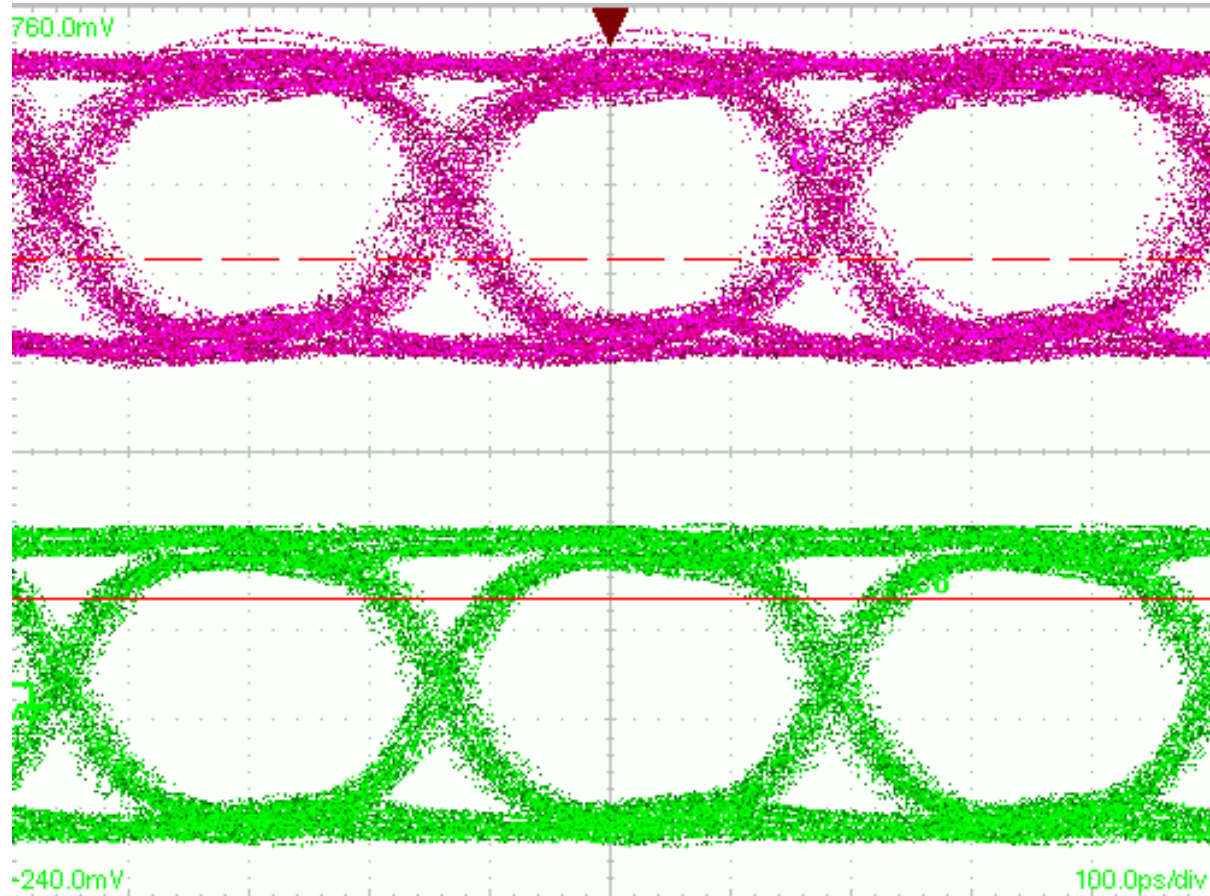
Vendor B Tx - Vendor C Rx 10 km SMF





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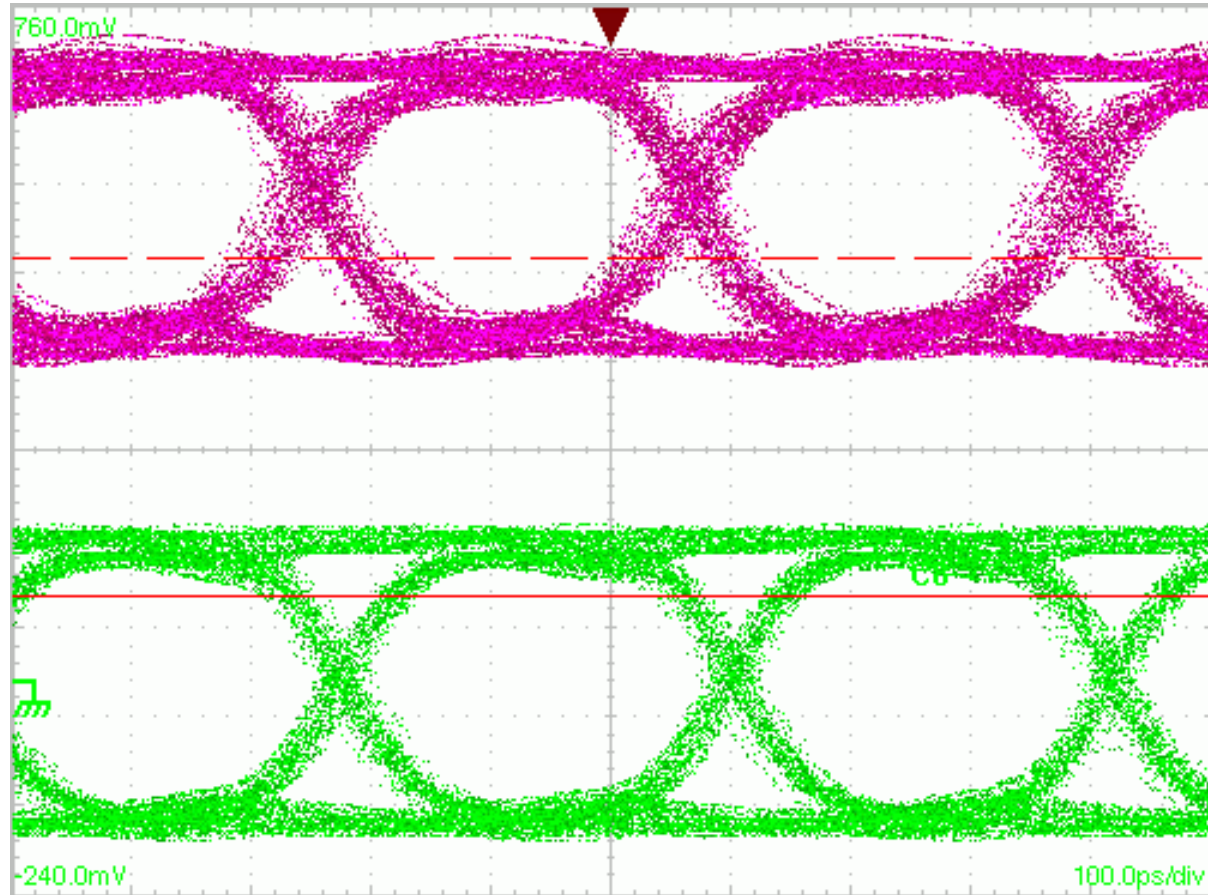
Vendor B Tx – Vendor C Rx 300 m, 62.5 μm Core MMF





Vendor B Tx – Vendor C Rx

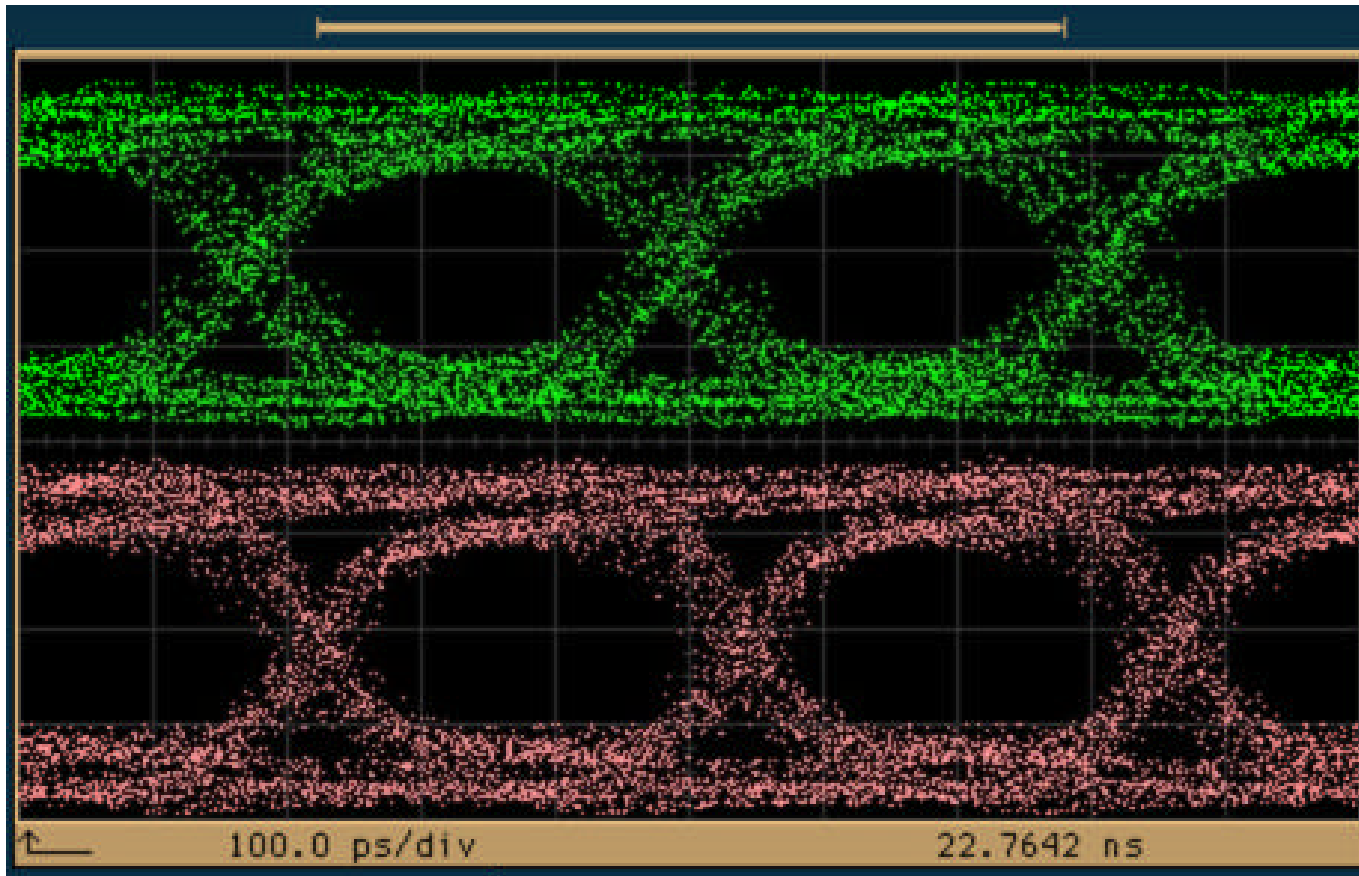
300 m, 50 μm Core, 500 MHz•km MMF





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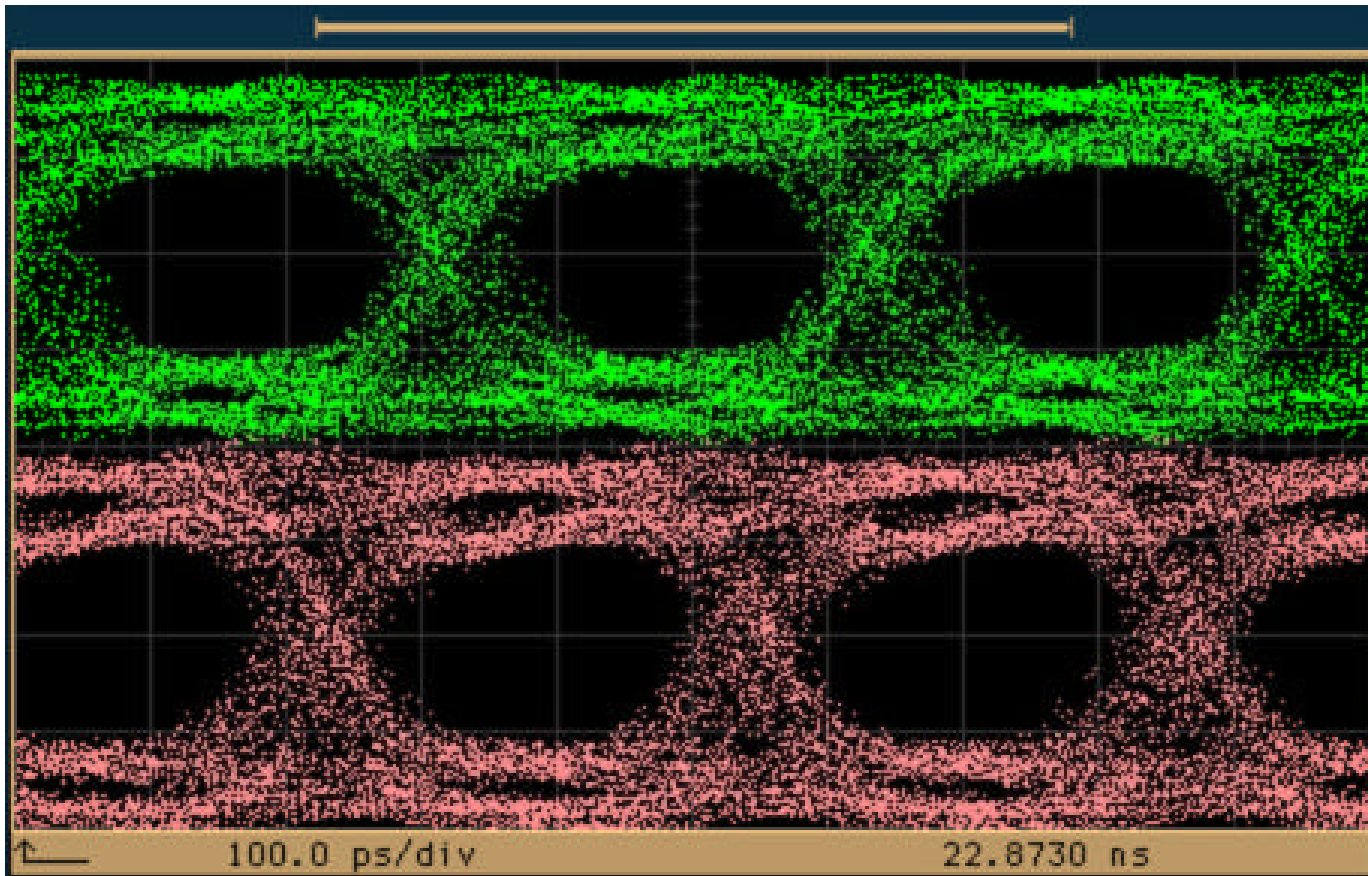
Vendor B Tx – Vendor A Rx 10.4 km SMF





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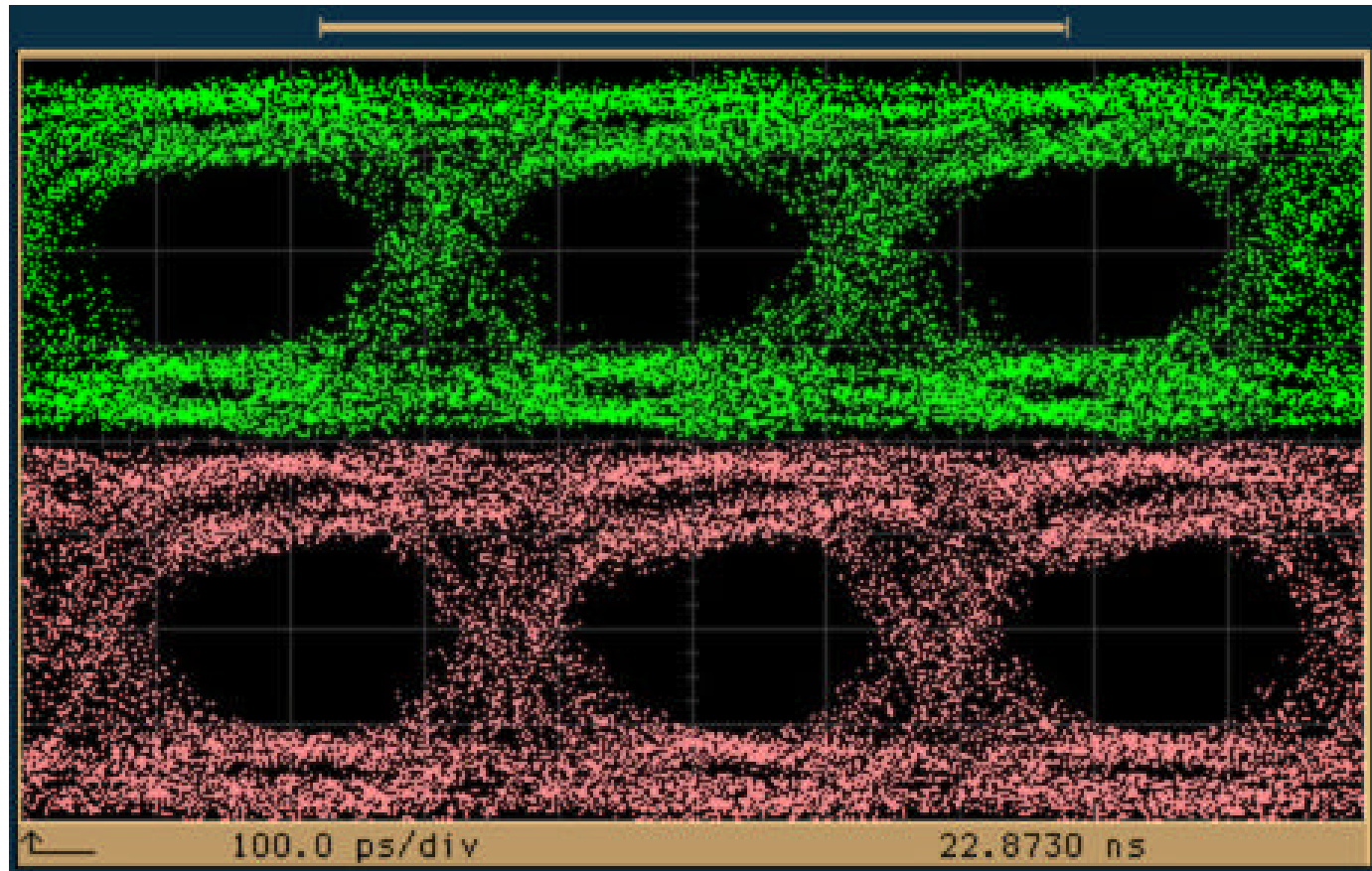
Vendor B Tx – Vendor A Rx 330 m, 62.5 μm Core MMF





Vendor B Tx – Vendor A Rx

263 m, 50 μm Core, 400 MHz•km MMF

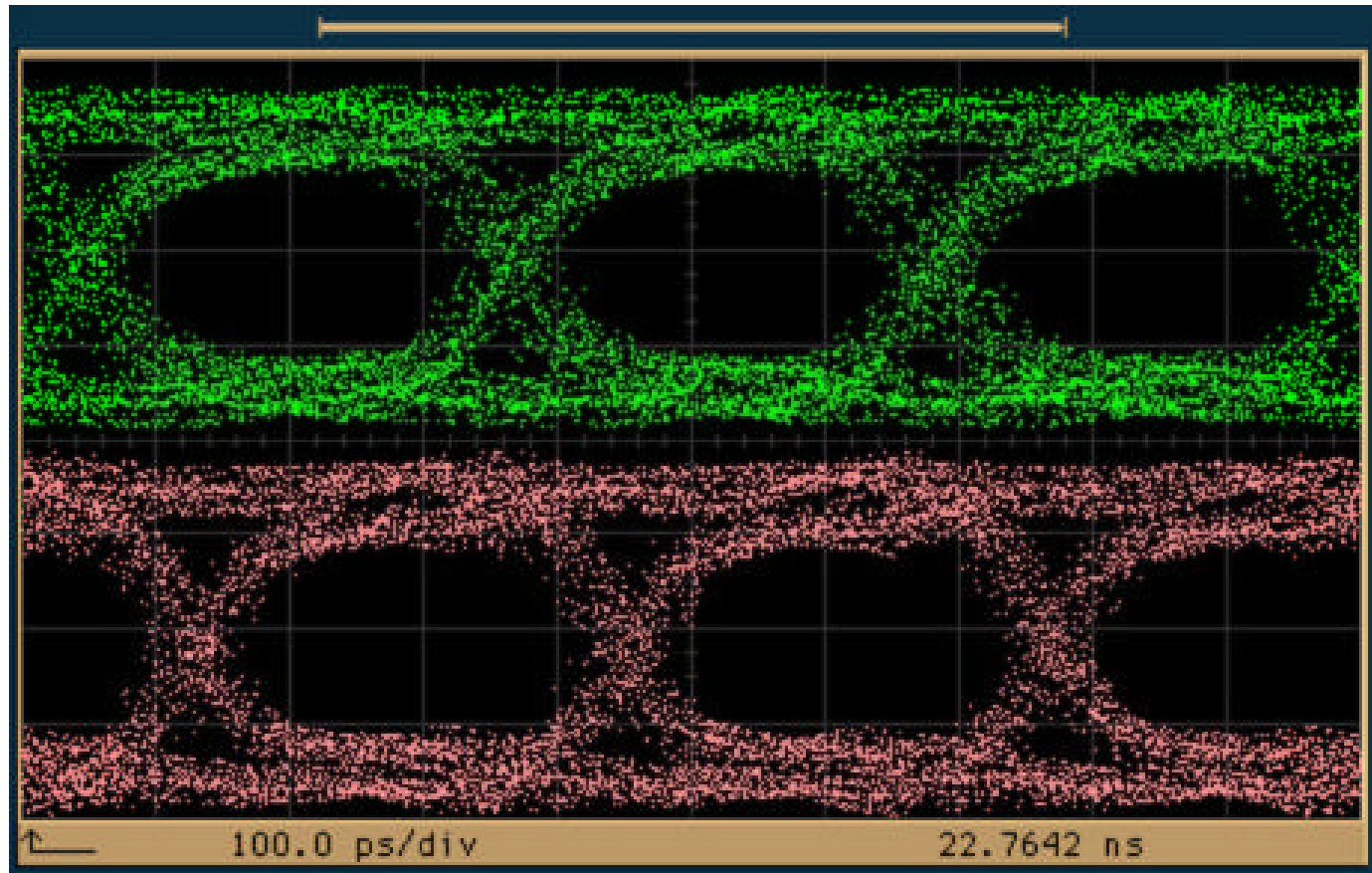




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Vendor B Tx – Vendor A Rx

300 m, 50 μm Core, 500 MHz•km MMF





Inter-Vendor Operation Testing Comments

- ❖ Required Bit Error Rates Demonstrated During Extensive 3-Way Testing
 - All Distances and Fiber Types Demonstrated for At Least Two Vendors
- ❖ Some Testing Under “Stressed” Conditions
 - Additional Fiber Length
 - Multiple Connections
 - Attenuation
- ❖ These Tests Were A Success in Demonstrating Inter-Vendor Operation





Conclusions

- ❖ Intra-Vendor Link Operation Has Been Demonstrated for All Link Distances and Fiber Types
- ❖ Inter-Vendor Link Operation Has Been Demonstrated for All Link Distances and Fiber Types
- ❖ Compliance Has Been Demonstrated For All Parameters, In Most Cases By Multiple Vendors
- ❖ Technical Feasibility Has Been Demonstrated





Motion

- ❖ Move that the IEEE 802.3ae Task Force agrees that technical feasibility of 10GBASE-LX4 PMD is technically feasible.

Moved: John Dallesasse

Seconded: Eric Grann

