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大数据光网络测试技术及展望

刘剑 应用工程师

2014-04

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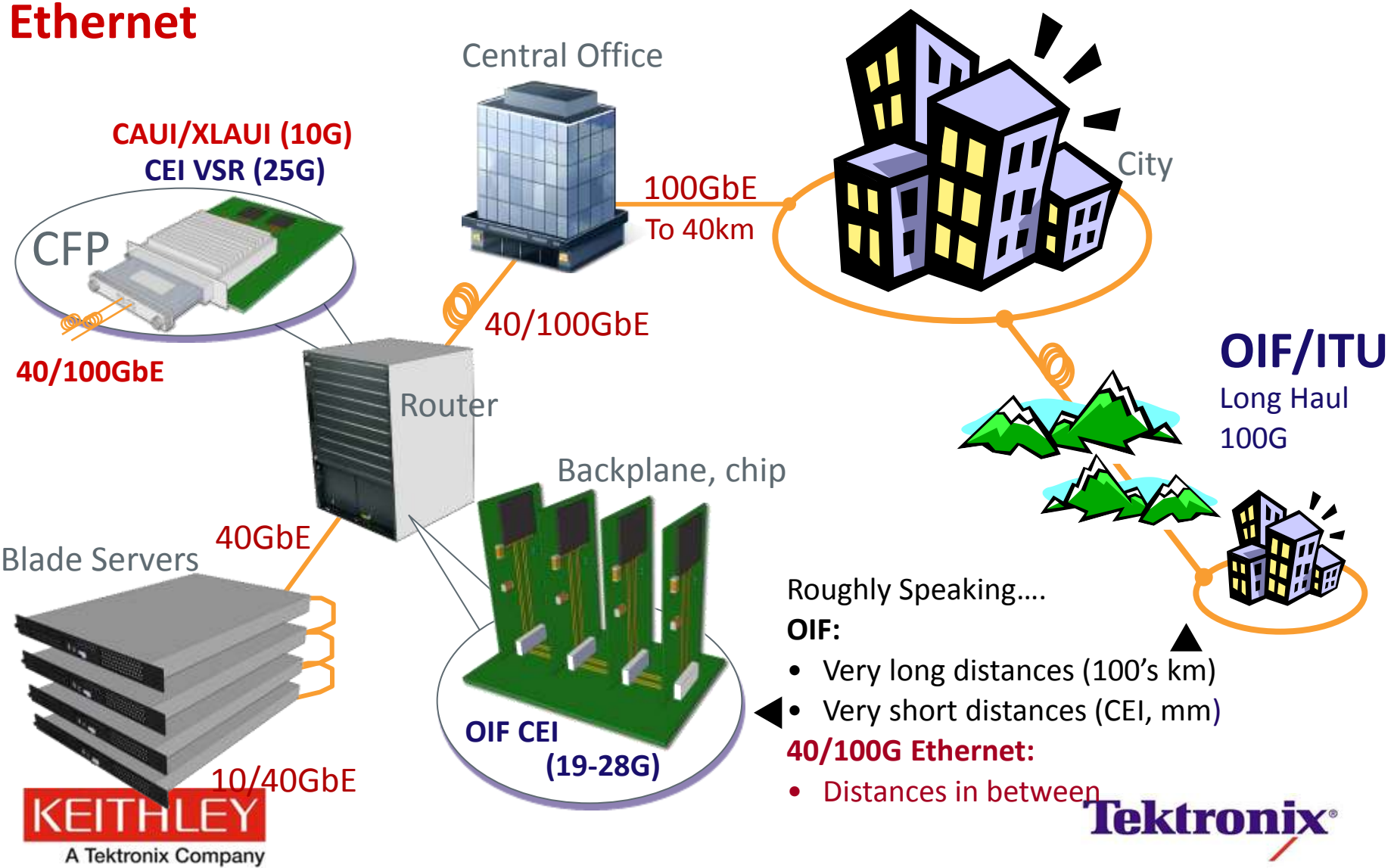
High Speed Networks & Standards

Ethernet



Roughly Speaking….

OIF:

- Very long distances (100's km)
- Very short distances (CEI, mm)

40/100G Ethernet:

- Distances in between

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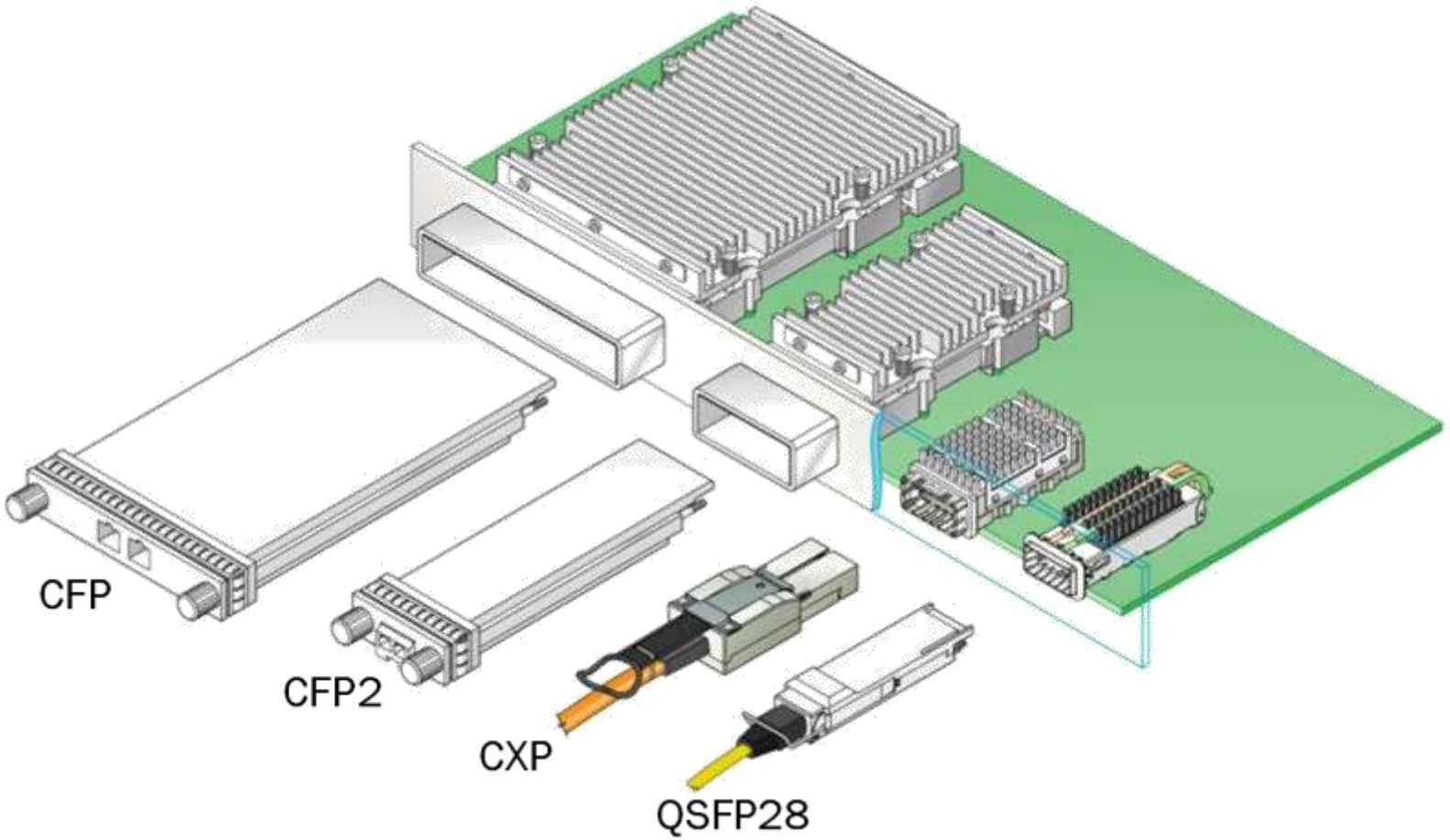
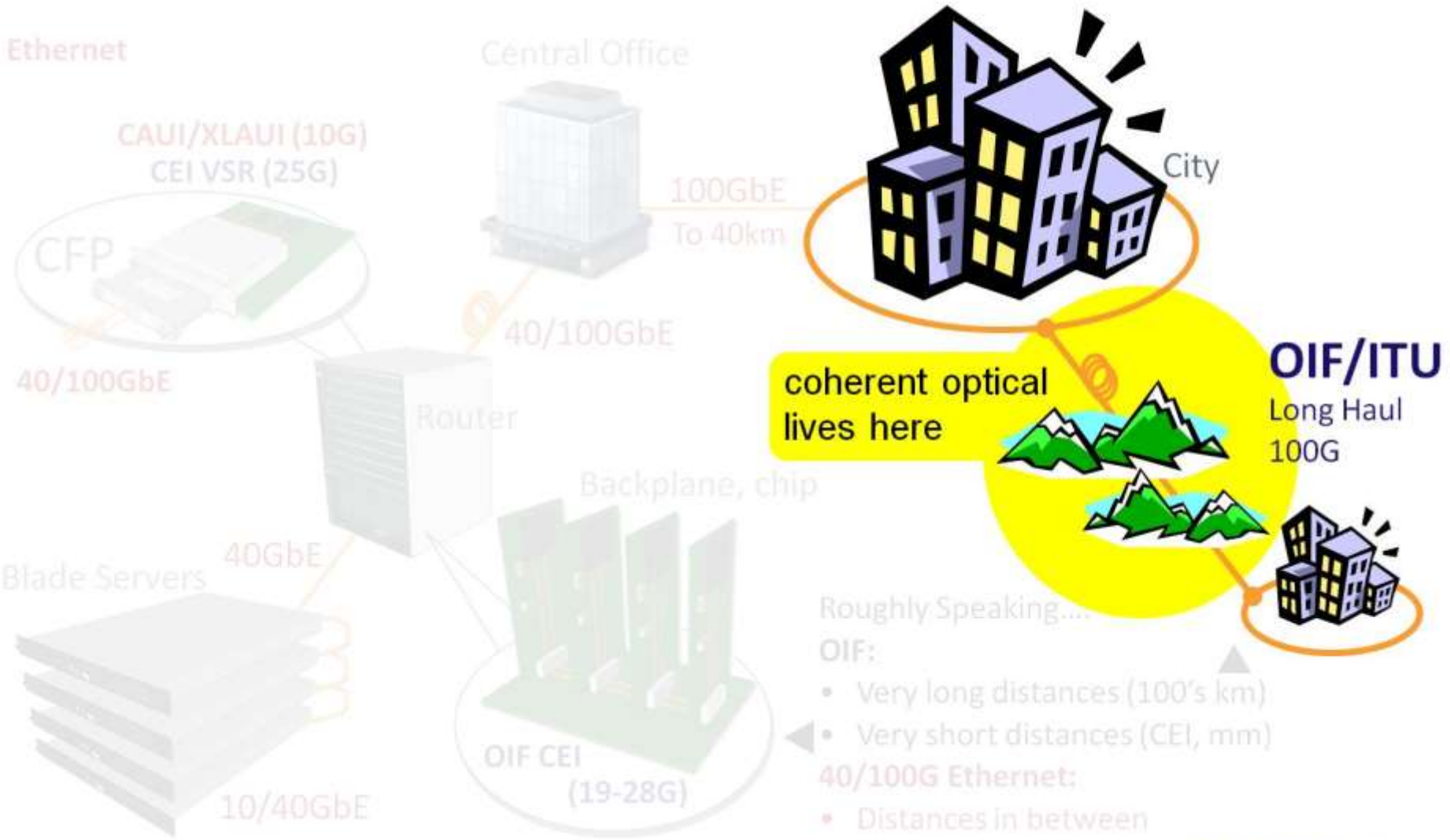
The top-to-bottom of 100G standards

Distance	Standard	Modulation/signaling	Companies playing	Tek solution
X,000 km	OIF, OTN, ITU <no set name>	Complex optical	Alcatel, Ciena, Cisco, Huawei, Fujitsu	OM4000, MSO73304DX
10 to 40 km	Ethernet 100GBASE-LR4, -ER4	NRZ Single-Mode	Cisco, Finisar, Oclaro, JDSU, Juniper, ZTE	DSA8300+80C10C; BSA286CL, CRU286A
100 m to 2km	Ethernet	NRZ MM and SM	*As above*	DSA8300+80C15C; BSA286CL, CR286A
10 m	Ethernet	NRZ over cable or el.<->opt. cable	Avago, Altera, Broadcom, Fujitsu, Cisco, Hitachi, Huawei, IBM, NEC, Xilinx, ZTE,	DSA8300+ 80E09B/10B+80A08; BSA286CL, CR286A,
Backplane < 1m	Ethernet, OIF CEI	NRZ, PAM4,		
Interconnect module to chip, chip to chip	OIF CEI Ethernet	NRZ		*As above*, + CEIVSR Sol. SW

100G Transceiver Size and Complexity



High Speed Networks & Standards



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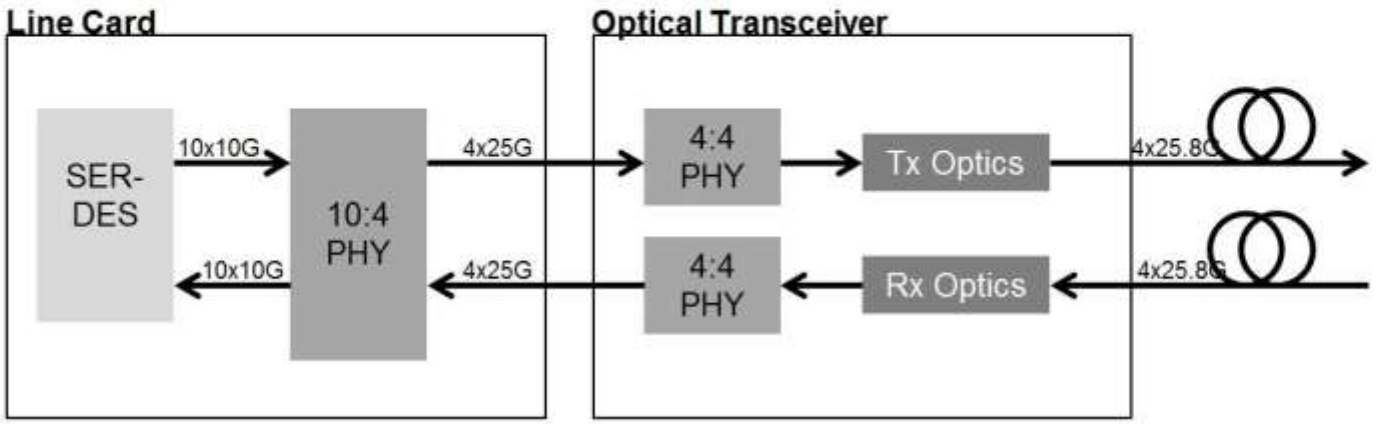
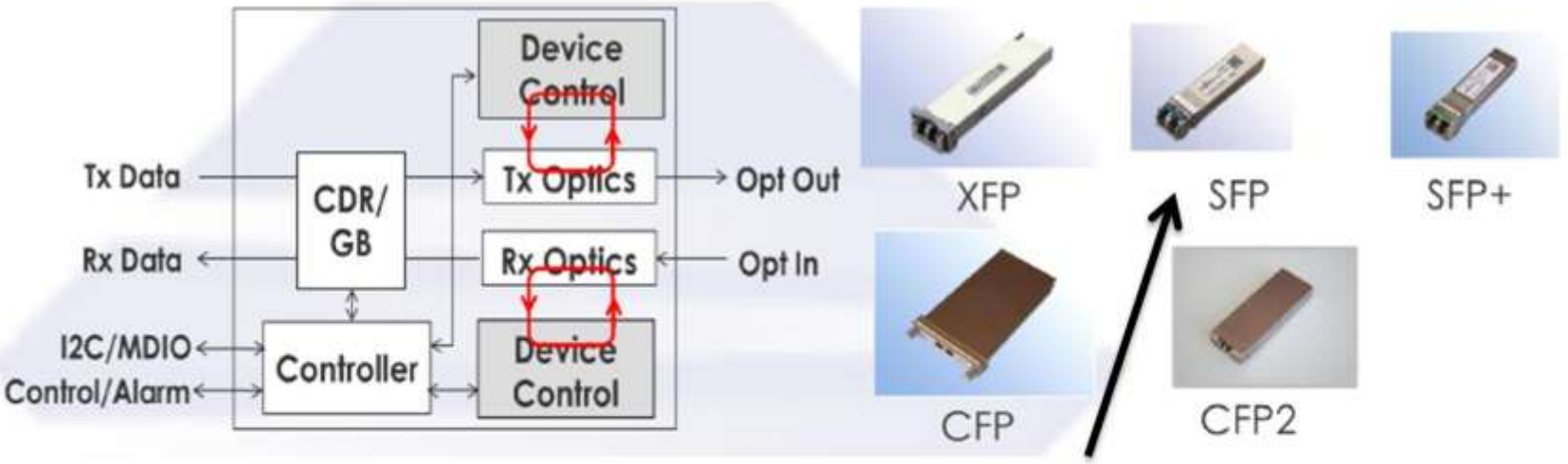
Optical Long-Haul Block Diagram 100GBase-ER4, LR4





About 2” long

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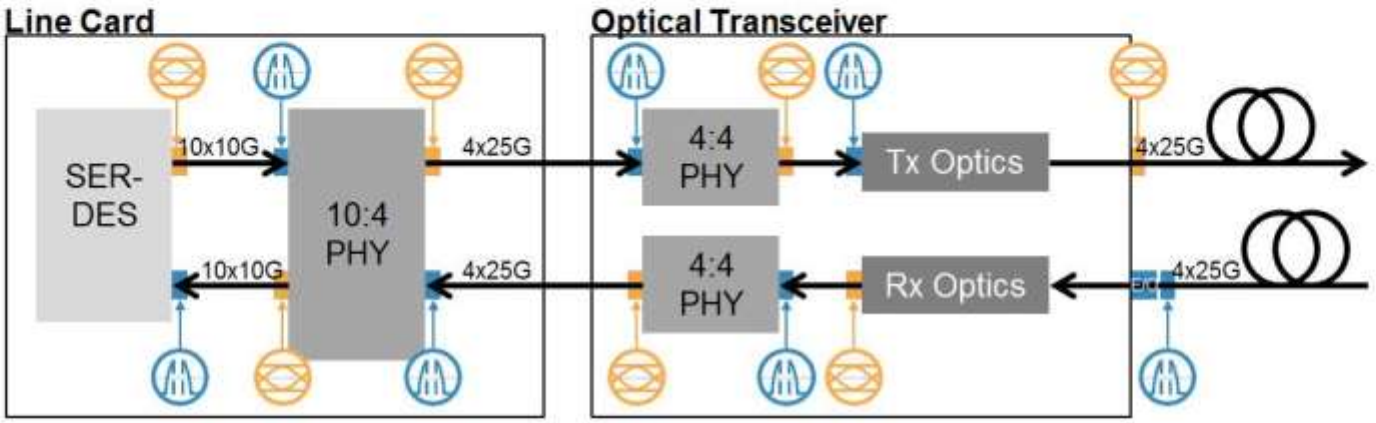
Optical Long-Haul Block Diagram
100GBase-ER4, LR4



BERTScope BSA-series
Bit Error Rate Tester

DSA8300-series
Equivalent Time Oscilloscope

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100 (4×25) Gb/s Single-mode Solution

80C10C-F1 Optical Module

Performance Specifications	
Single-mode	9μm core
Supported wavelengths	1310, 1550 ± 20 nm
Maximum Optical Bandwidth	**70 GHz**
Optical Reference Receivers	**All 25 Gb/s standards**
Sensitivity	**-8 dBm**
Buffered electrical data pick-off to support external clock recovery instrument	Recommended Tektronix CR286A

Standards Supported

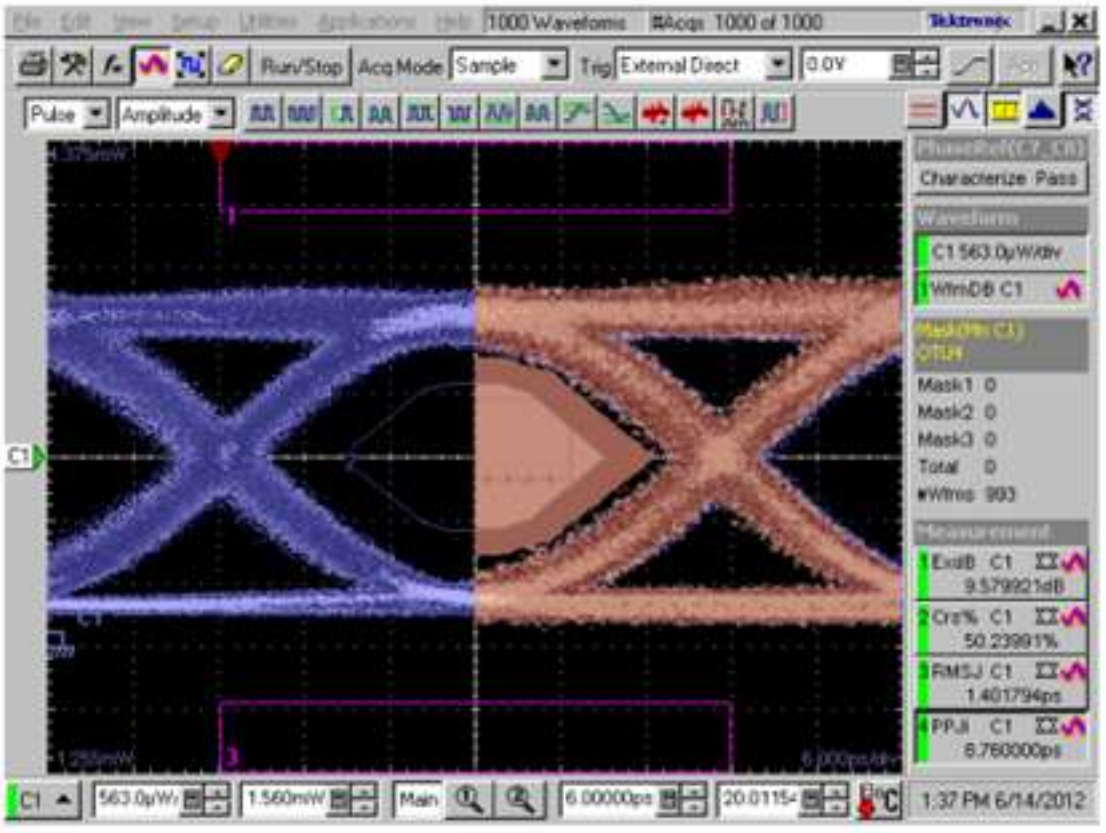
Standard	Data Rate
100GBASE-ER4	25.781 Gb/s
100GBASE-LR4	25.781 Gb/s
OTU-4	27.952 Gb/s
OC-768/STM-256	39.813 Gb/s
VSR-2000 G.693	39.813 Gb/s
40G NRZ G.959.1	39.813 Gb/s
(40GBASE-FR)	41.25 Gb/s
OTU3	43.018 Gb/s
VSR-2000 w/ FEC	43.018 Gb/s
4x10G LAN PHY OTU3	43.018 Gb/s

80C10C Optical Module

Unmatched Sensitivity for 100G (4 x 25G) Applications

OTU4 transceiver: 3.5 dBm, 1310nm, 27.95 Gb/s, 9µm SMF

New Tektronix 80C10C



Alternative Solution

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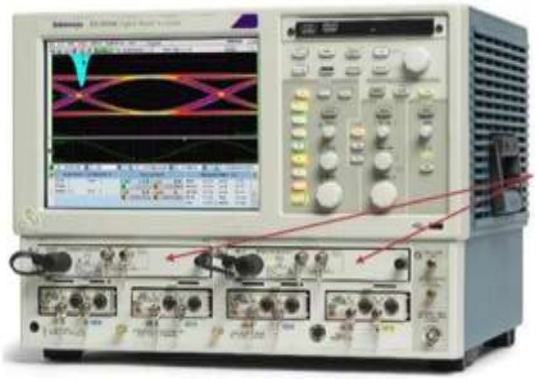
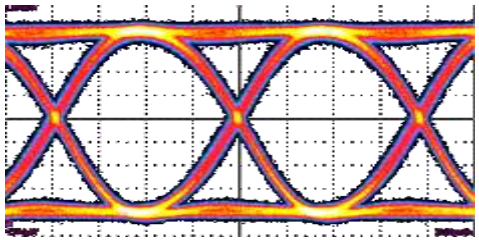
Tektronix 80C15 Optical Sampling Module Highlights

80C15 NEW

- Single-Channel Optical Plug-in Module for DSA8300
- Unfiltered Optical Bandwidth >32GHz
- 62.5/125 µm **Multi-Mode** Fiber Input
- **Short-** and Long-Wavelength Support (800 -1600 nm)
- 200 kS/s Acquisition Rate
- **Jitter Floor <150 fs RMS (with 82A04B)**
- Optical Receiver Filters:
  - **32G Fibre Channel (28.05 Gb/s)**
  - OTU-4 (4 x 27.95 Gb/s)
  - 100Gbase-LR4/ER4/SR4 (25.78 Gb/s)
  - 26G EDR Infiniband (25.78 Gb/s)





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Coherent Optical Modulation

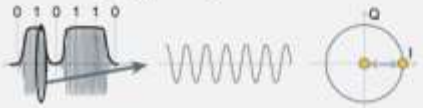
Why/What/How is it Tested?

Why coherent modulation?

Demand for long-haul network bandwidth is growing at an exponential rate due to the increased consumption of video content on mobile devices, streaming media to the home, and the transformation of the internet. Coherent technology allows 40G and even 100G transmission over existing 10G infrastructure. This allows network operators to increase their network capacity with a relatively small capital investment.

What is coherent modulation?

Traditional 10G transmissions modulate the amplitude of the light, a.k.a. or on-off keying (OOK). Direct detection is used in the receiver.



OOK
On-Off Keying
1 bit/symbol

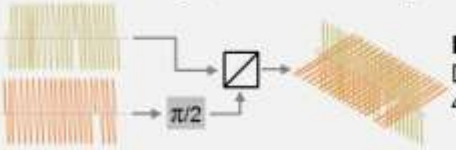
Coherent transmissions modulate the phase of the light, the simplest case is phase shift keying.

PSK
Phase Shift Keying
1 bit/symbol

By doubling the number of phase states, the bit/symbol rate is also doubled.

QPSK
Quadrature Phase Shift Keying
2 bits/symbol

Rotating the polarization of one QPSK signal, and combining it with a second QPSK signal, doubles the bit/symbol rate again.



DP-QPSK
Dual-Polarization QPSK
4 bits/symbol

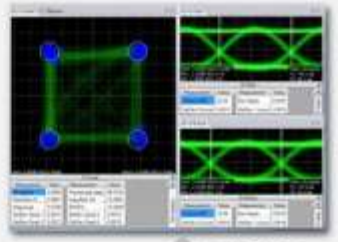
Other formats are also used such as Differential QPSK (DQPSK), 8-PSK, and Quadrature Amplitude Modulation (QAM).

What are the **benefits** of coherent modulation?

- The channel bit-rate can be quadrupled (when using DP-QPSK), without increasing bandwidth, through existing fiber infrastructure.
- Linear digital filtering can now compensate for major sources of degradation such as Chromatic Dispersion (CD) and Polarization Mode Dispersion (PMD).
- 4.3dB improvement in noise tolerance compared to direct detection.

How is coherent modulation **tested**?

❸ The OM4106D software transforms the digitized electric field and displays the original tributary waveforms. The SW provides specialized visualization tools and measurements.



waveforms via Ethernet

❷ A scope (RT or ET†) digitizes the electric field.

coherent optical input (fiber)

electric field to scope

❶ An Optical Modulation Analyzer (OMA), such as the OM4106D converts the optical signal into a dual-polarization electric field.

†For more information on how to choose an RT or ET scope, see the *Choosing an Oscilloscope for Coherent Modulation Analysis* technical brief.

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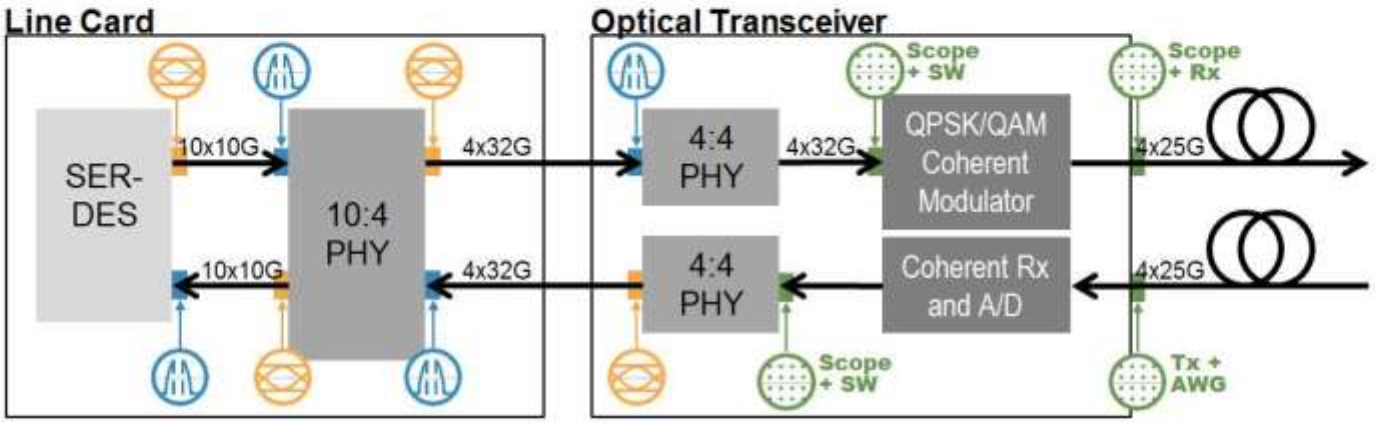
Optical Long-Haul Block Diagram
Coherent Optical



Tx + AWG

OM5110
Multi-format Optical Transmitter
AWG70000-Series
Arbitrary Waveform Generator

Scope + Rx

DPO70000-Series
Digital Phospor Oscilloscope

OM4000-Series
Optical Modulation Analyzer

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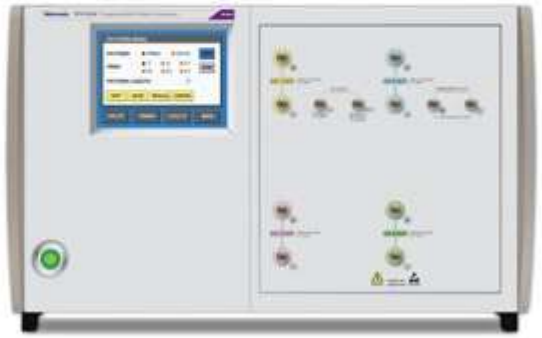
Signal Generation: PPG-Series

PPG benefits for coherent optical

- Up to 4 channels in a single instrument – necessary for dual polarization for I and Q.
- Data rate up to **40 Gbps** covers all 100G test requirements.
- Very fast risetimes.
- Simple to set-up and use.
- Multi-level signals (such as 16QAM) can be created using external devices



PPG3204 Programmable Pattern Generator

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Signal Generation: AWG

AWG benefits for coherent optical

- Ability to customize waveform to compensate for system losses.
- Ability to create impairments.
- Easier to create arbitrary multi-level signals than PPG.
- Single-channel instrument supports sample rate up to 50GS/s

AWG70001A Arbitrary Waveform Generator

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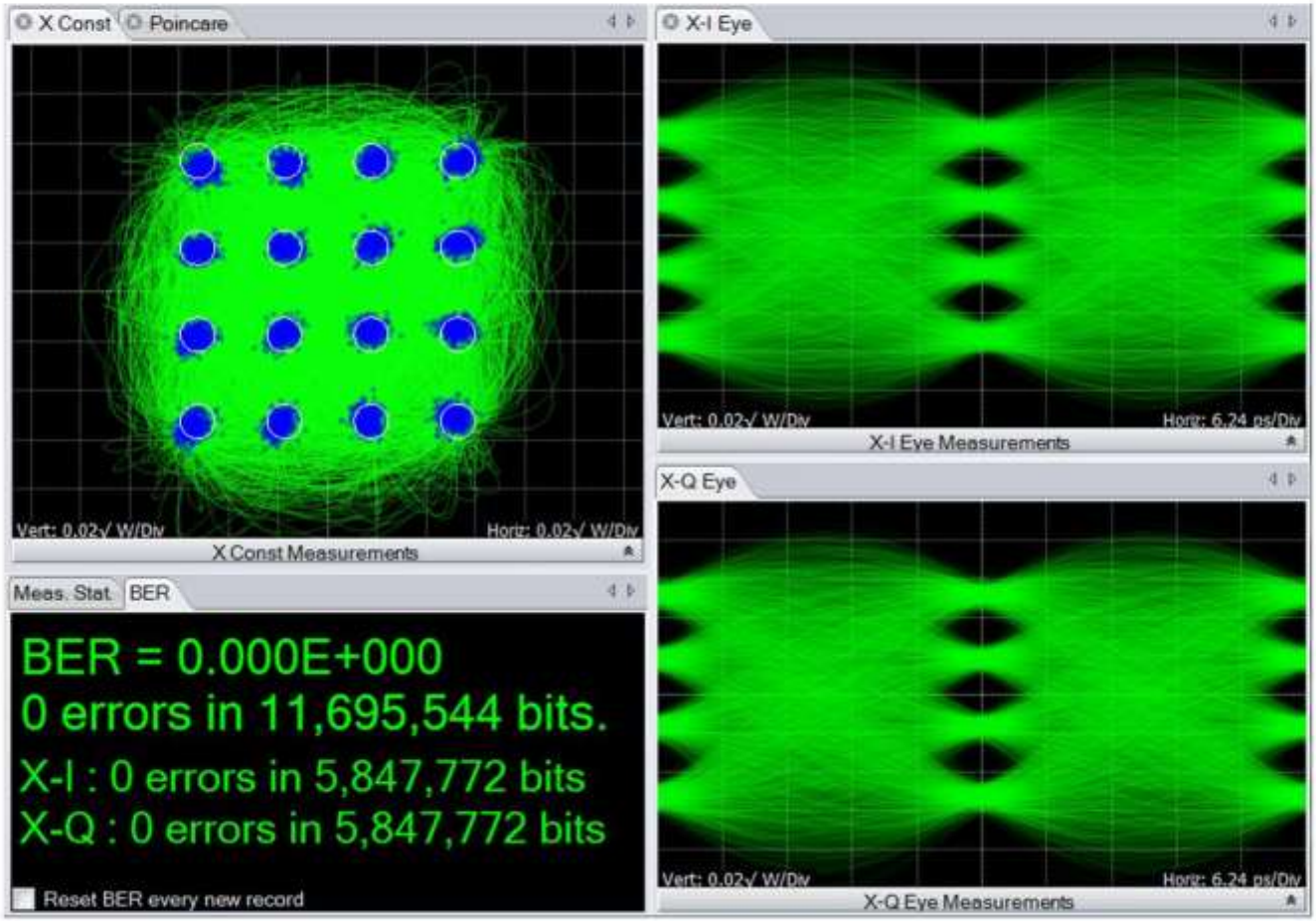
Equalized OM5110 optical output

- 32 Gbaud 16-QAM optical signal
- EVM = 6.5%



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Coherent Detection: OM4106D

- 33GHz optical modulation analyzer supports all common coherent optical modulation.
- Supports both real-time and equivalent-time scopes.
- Provides built-in local oscillator and support external LO.
- Dynamic Matlab interface provides unique and streamlined flexibility and customization.
- Capable of analyzing multi-carrier systems such as 400G and 1Tb/s.

OM4106D Coherent Lightwave Signal Analyzer

also known as:
Optical modulation analyzer
OMA
Coherent O/E converter

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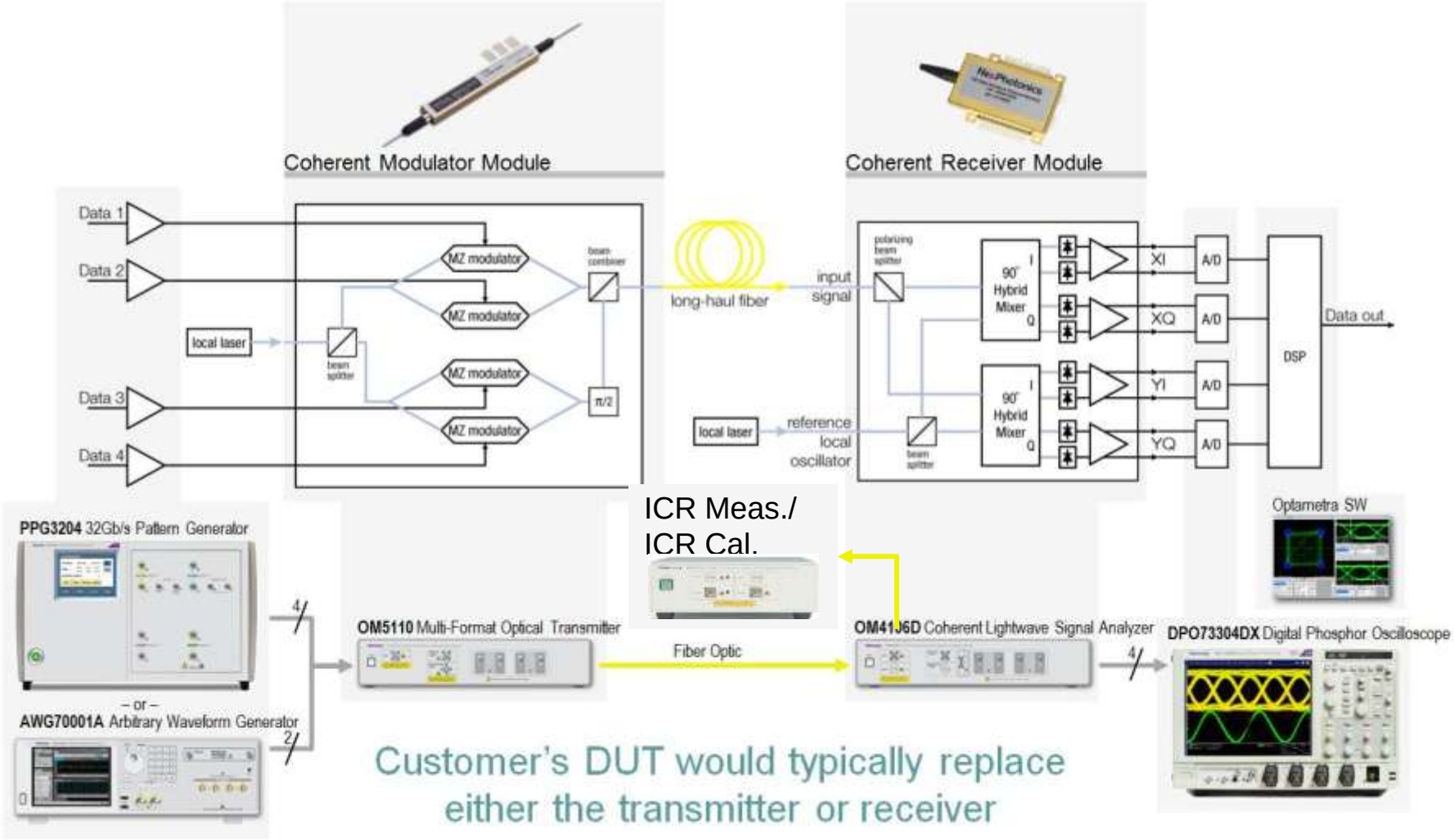
Coherent Optical Modulation Overview



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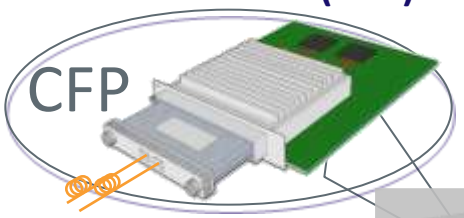
High Speed Networks & Standards

Ethernet

CAUI/XLAUI (10G)
CEI VSR (25G)



40/100GbE

Central Office

100GbE
To 40km

City

40/100GbE

Router

OIF/ITU
Long Haul
100G

Backplane, chip

Blade Servers

40GbE

10/40GbE

Roughly Speaking….

OIF:

- Very long distances (100's km)
- Very short distances (CEI, mm)

40/100G Ethernet:

- Distances in between

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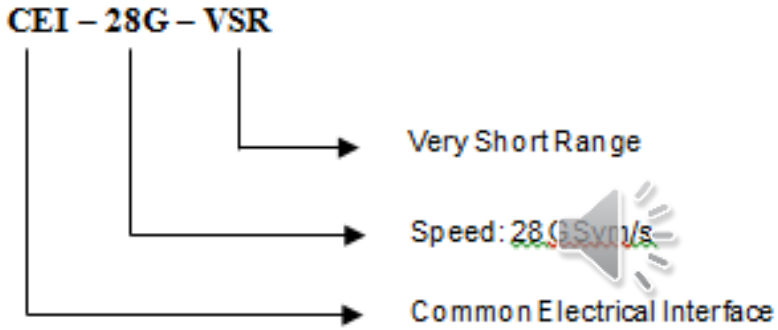
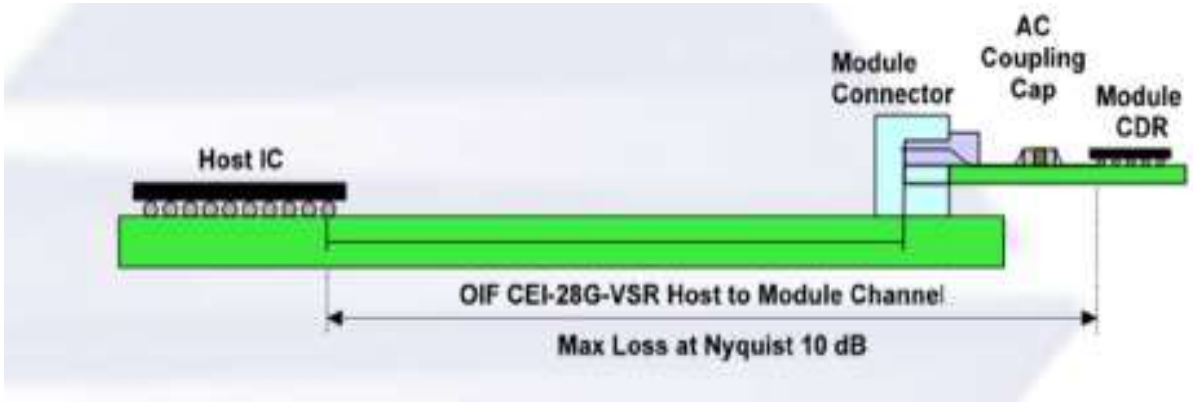
CEI-28G-VSR Technology Evolution

OIF-CEI-VSR - Optical Internetworking Forum - Common Electrical Interface -28G-VSR (CEI-28G-VSR)





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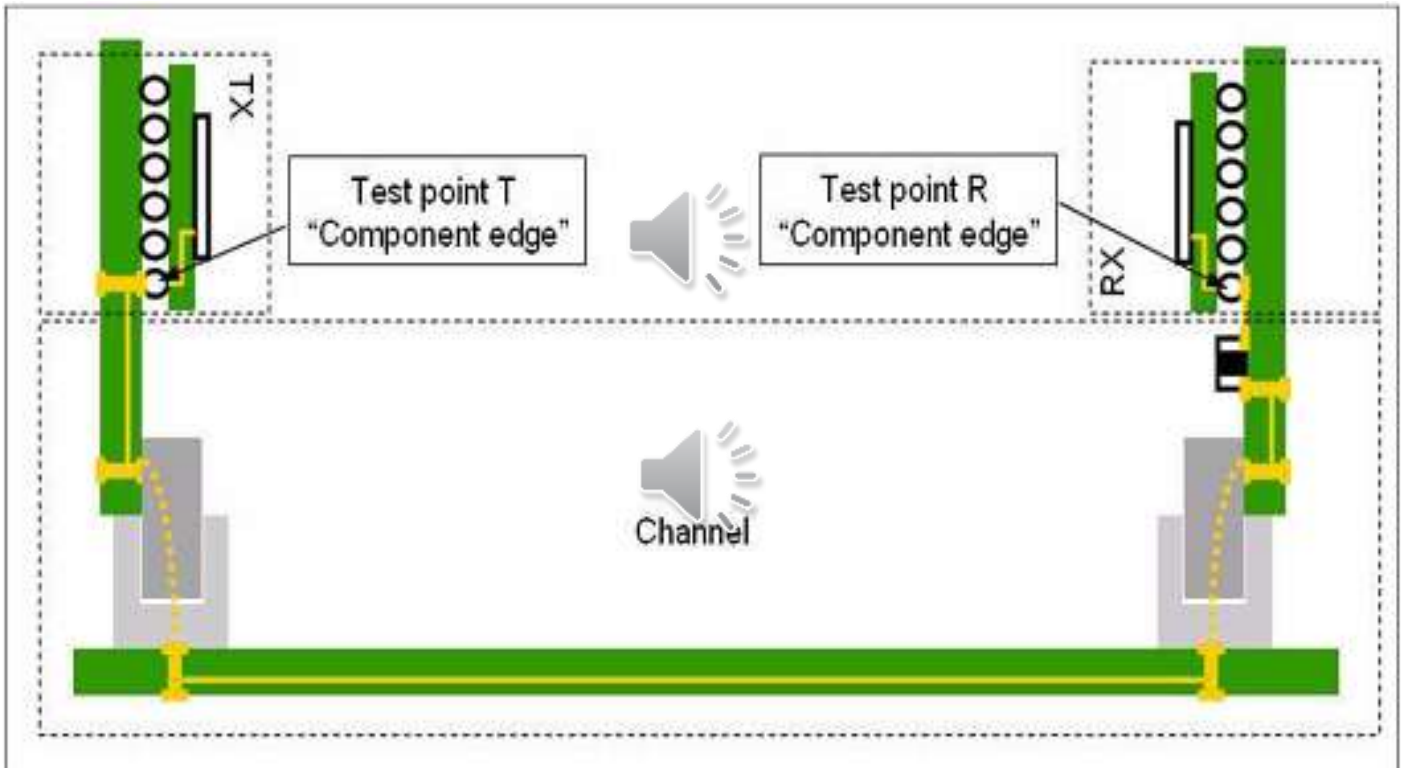
CEI-25G-LR Technology Evolution

OIF-CEI-VSR - Optical Internetworking Forum - Common Electrical Interface -25G-LR (CEI-25G-LR)



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CEI-28G-VSR Technology Evolution

- CEI-28G-VSR - This clause details the requirements for the CEI-28G-VSR very short reach high speed chip-module electrical I/O of nominal baud rates of 19.60 Gsym/s to 28.05 Gsym/s.
- The industry is transitioning from 10x10G to a more efficient 4x25 electrical interconnect.
- The first standard body in the move to 25 Gb/s signaling is the OIF CEI, with the VSR, SR, and LR (very short reach, short reach, long reach) standards
- Under development is the Ethernet's 802.3bm 100GBASE-KR4 backplane standard, as well as the Ethernet interconnect standard, 802.bj CAUI4.
- The electrical I/O is based on high speed, low voltage logic, and connections are point-to-point balanced differential pairs.

CEI-VSR Test Challenges – Bandwidth Requirements

- "K" Vs 2.4mm Connector
  - 2.4mm connector upto 50 GHz bandwidth
  - Longer interconnect, e.g. cables are very harmful to signal integrity
- Scope BW Requirements
  - For characterization of important components e.g. silicon, Tektronix recommends a higher bandwidth interconnect, e.g. 50 GHz.
  - Using a connector/cable system interconnect with just 40 GHz of BW might be interpreted as allowable by standards; however it is marginal.
- Extra challenges abound when transferring these signals on printed circuit boards, even for short distances. The Implementation Agreement for Optical Internetworking Forum Common Electrical Interface (OIF CEI) 3.0 specifies the tests and limits for these devices
- The parameters can take a full day when characterized manually, and the recalculation of factors and CTLE values adds to the time the designer spends on testing.

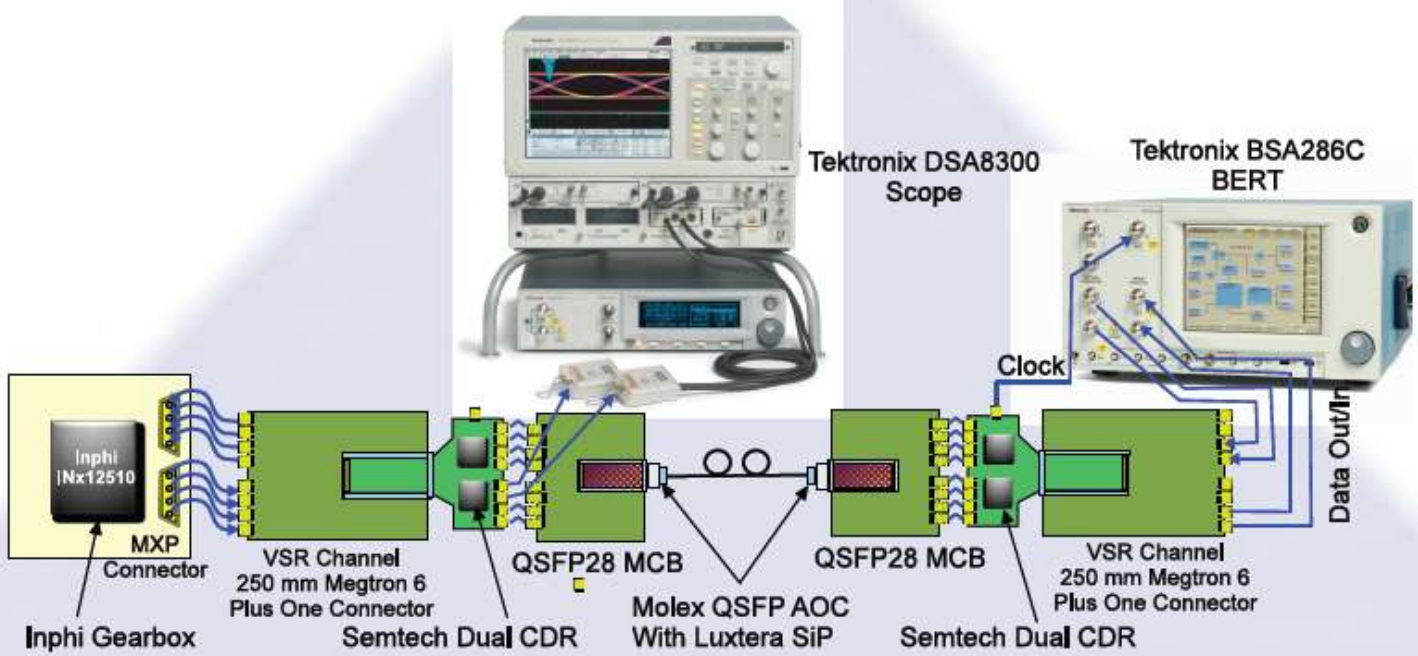
CEI-VSR Test Challenges – De-embedding

- 25+ Gb/s standards, exhibit two main applications where de-embedding can be considered:
  - De-embedding of the fixture – e.g. the test board
  - De-embedding of the interconnect between the oscilloscope and the fixture
- Sampling oscilloscopes offer higher resolution, and de-embedding is more practical. De-embedding turns loss into noise, thus minimizing the amount of de-embedding is also important.
- In case of de-embedding, it is critical to acquire high quality network description (S-parameters) of the signal under test.
- Focus needs to be on effort to minimizing the length and loss of the interconnect, its quality and repeatability. Only after this has been accomplished, applying de-embedding helps generate realistic results.

CEI-VSR Test Challenges – Clock Recovery

- Typically the DUT's – the Serial Data transmission devices themselves - operate with the clock recovery circuit (CR) in the receiver (RX). The measurement device (e.g. oscilloscope) therefore also need CR.
- T&M CR: Internal or External?
  The advantage of an external clock recovery include higher flexibility (e.g. the same CRU can be used with an oscilloscope or with a BERT), and higher functionality – such as access to the analog PLL control voltage for troubleshooting of clock problems.
- In case of real time oscilloscope the clock recovery can be implemented in software.
- The clock recovery is required by standards and emulates the behavior of the physical receiver.
- CR may not be necessary in cases of simple tests of devices that do not include a re-timer.

OIF CEI-28G-VSR Topology and test overview



An overview of OIF's typical 28G CFP2 Host, Channel and CFP2 Module Endpoint. The OIF 28G-VSR spec is the fundamental building block for 100GE, OTN, 32GFC and IB EDR.

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DUT Interconnect conclusion…

“Remote Head Manifesto”:

- At 25 Gb/s, 60 cm (ca. 2’) of best cable nearly doubles the rise-time
- De-embedding probably already used to remove the PCB; also very sensitive to connector repeatability

➔Use the remote head !

and

➔Use 2.4 mm or 1.85 mm connectors (check the rise-times)

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Option CEI-VSR - Compliance and Debug Solution

- Automated Tests
  - One-button selection of critical H2M & M2H Tests reduces testing time
- Integrated Debugging
  - Popular 80SJNB-based interface enables deeper debug of timing root cause analysis without moving to a different instrument/measurement setup
  - CTLE Filters
  - Option CEI-VSR determining the optimal value of CTLE peaking, which is required by the CEI 28G Very Short Reach for the Host-to-Module interface. The best CTLE filter is chosen from the given set of filters and used for performing the measurement.
- J2 & J9 Measurements
  - Rely on off-the-shelf products to perform this complex measurement rather than developing custom lab setup reducing testing time and complexity
- Documentation/Reporting
- Signal Validation

Option CEI-VSR – Automation Part

- Operates on Tektronix DSA8300 Series Oscilloscopes
- Automate setup & quickly generate reports
- Meets Compliance needs of CEI-28G-VSR
- PRBS9 for all measurements and 8180 support in addition for Transition time measurement.
- VEC – Vertical Eye Closure as Informative Test under H2M

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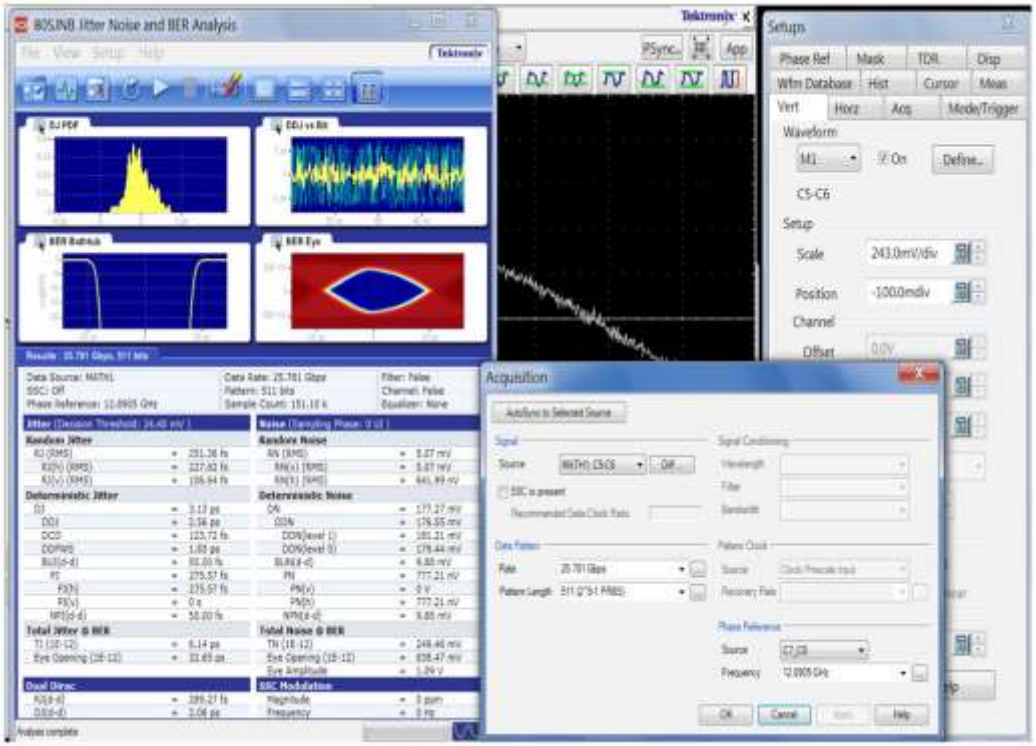
Tektronix CEI-VSR – Debug Part



- Performs advanced jitter and noise analysis (RJ, DDJ, PJ, DCD, TJ@BER, and RN, DDN(high) and
- DDN(low), TN@BER, vertical and horizontal eye opening at BER
- Acquires complete pattern waveform at 100 Samples/UI

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Rx/Tx testing for Industrial HSSD at 100G
Key Value Propositions

- BSA286C:
  - Support for rates through 29G offer 3% margin over standard base spec's.
  - <300pSec RMS Rj allows following the J2 and J9 jitter intercepts with margin.

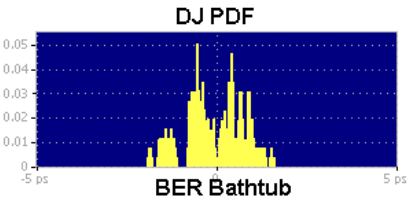
Key Comms Rates	100GBase-XR4	100GBase-XR4 (FEC)	32G Fibre-Channel	CEI
Rate	25.7813	27.7390	28.0500	28.0500
I UI (period)	38.7879	36.0500	35.6500	35.6500
Allocated Rj (UI)	0.13	0.13	0.14	0.13
Rj in Psec RMS	0.3602	0.3348	0.3565	0.3310

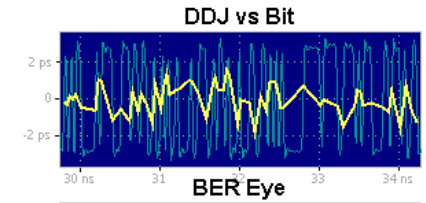
- DSA8300: ~100fSec Jitter measurements.

Data Source: CH1	Data Rate: 28 Gbps	Filter: False
SSC: Off	Pattern: 127 bits	Channel: False
Phase Reference: 7 GHz	Sample Count: 52.70 k	Equalizer: None

Jitter (Decision Threshold: -7.73 mV)		Noise (Sampling Phase: 0 UI)	
Random Jitter		**Random Noise**	
RJ (RMS)	= 199.01 fs	RN (RMS)	= 4.98 mV
RJ(h) (RMS)	= 160.06 fs	RN(v) (RMS)	= 4.98 mV
RJ(v) (RMS)	= 118.26 fs	RN(h) (RMS)	= 108.30 uV
Deterministic Jitter		**Deterministic Noise**	
DJ	= 3.59 ps	DN	= 161.33 mV
DDJ	= 3.17 ps	DDN	= 155.62 mV
DCD	= 198.77 fs	DDN(level 1)	= 144.05 mV
DDPWS	= 1.13 ps	DDN(level 0)	= 171.04 mV
PJ	= 144.94 fs	PN	= 4.53 mV
PJ(h)	= 97.27 fs	PN(v)	= 4.53 mV
PJ(v)	= 107.46 fs	PN(h)	= 65.82 uV

Total Jitter @ BER		Total Noise @ BER	
TJ (1E-12)	= 5.92 ps	TN (1E-12)	= 220.38 mV
Eye Opening (1E-12)	= 29.79 ps	Eye Opening (1E-12)	= 684.89 mV
		Eye Amplitude	= 905.27 mV
Dual Dirac		**SSC Modulation**	
RJ(d-d)	= 223.73 fs	Magnitude	= 0 ppm
DJ(d-d)	= 2.77 ps	Frequency	= 0 Hz





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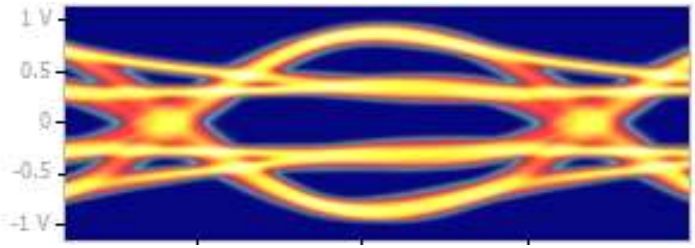
Tektronix LE320/LE160
32 & 16Gbps Linear Equalizer Product Introduction

- Compact two channel 32Gbps 9 Fixed Tap linear equalizer design in a “remote module” configuration
- +/-20dB tap controls offer flexible pre-emphais or channel de-embed capabilities.
- User (and PI) configurable filter properties allows flexible parametric equalization
- Electronically switchable frequency dependent filter capability permits DDJ tolerance testing and testing against known reference channel models
- Front-end signal path (CTLE) for Sampling or BERT Instruments



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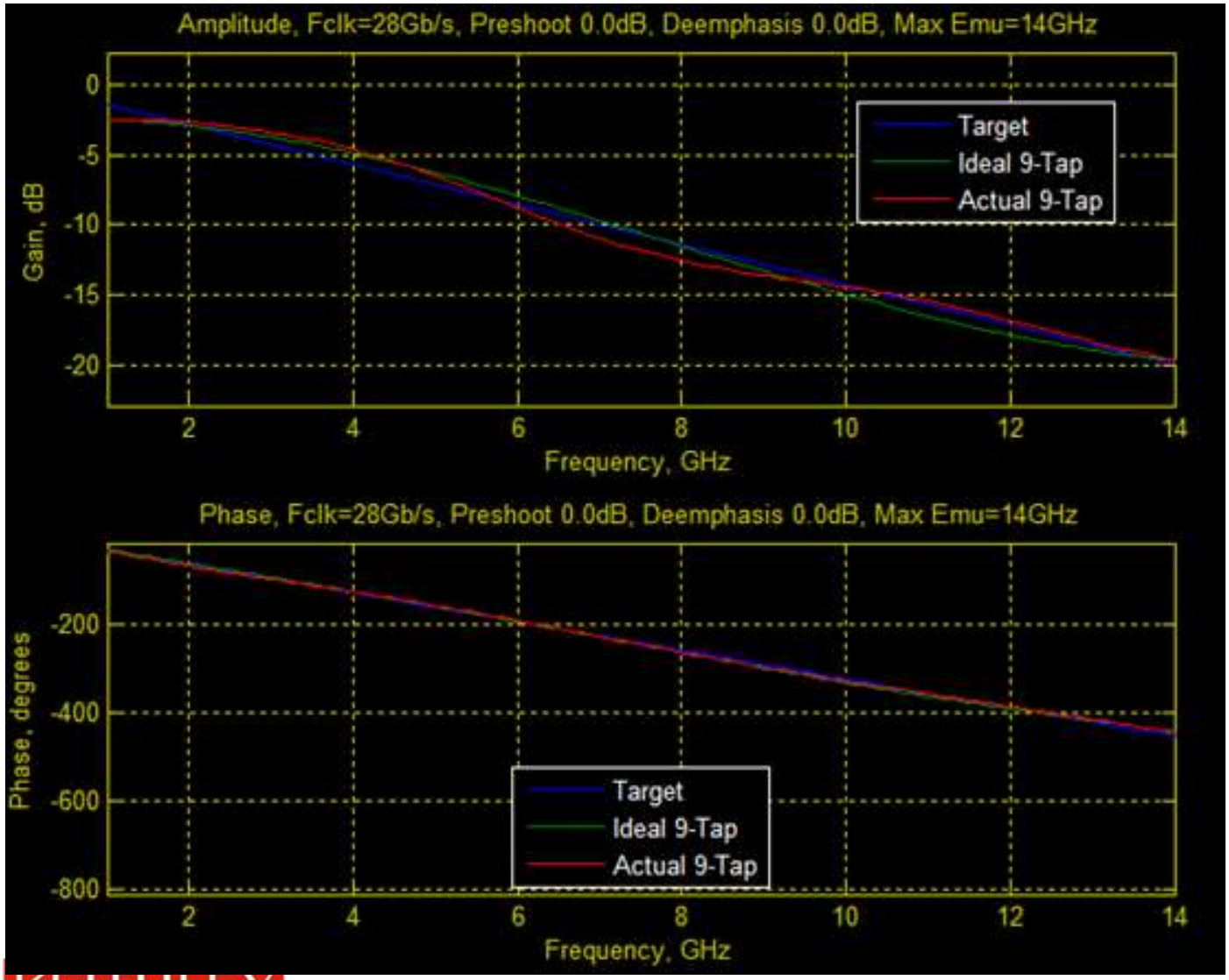
LE320 9 Tap model of a CEI reference channel.



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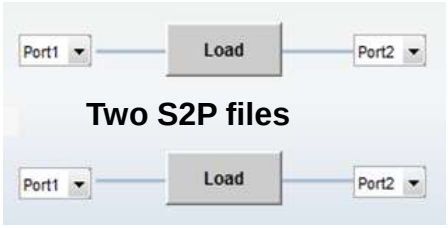
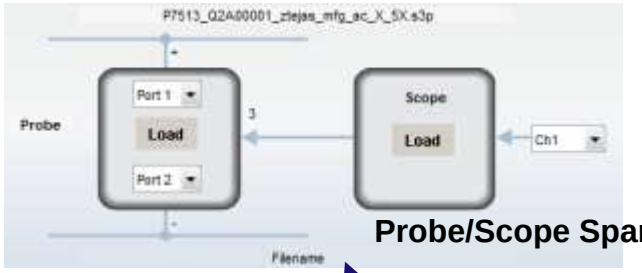
Configuration Options for De-Embed and Embed Blocks

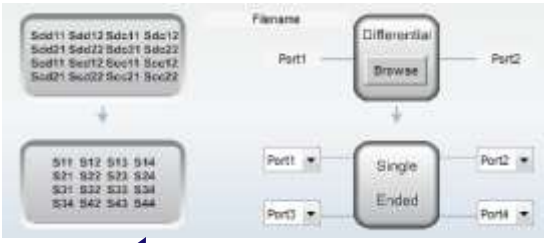


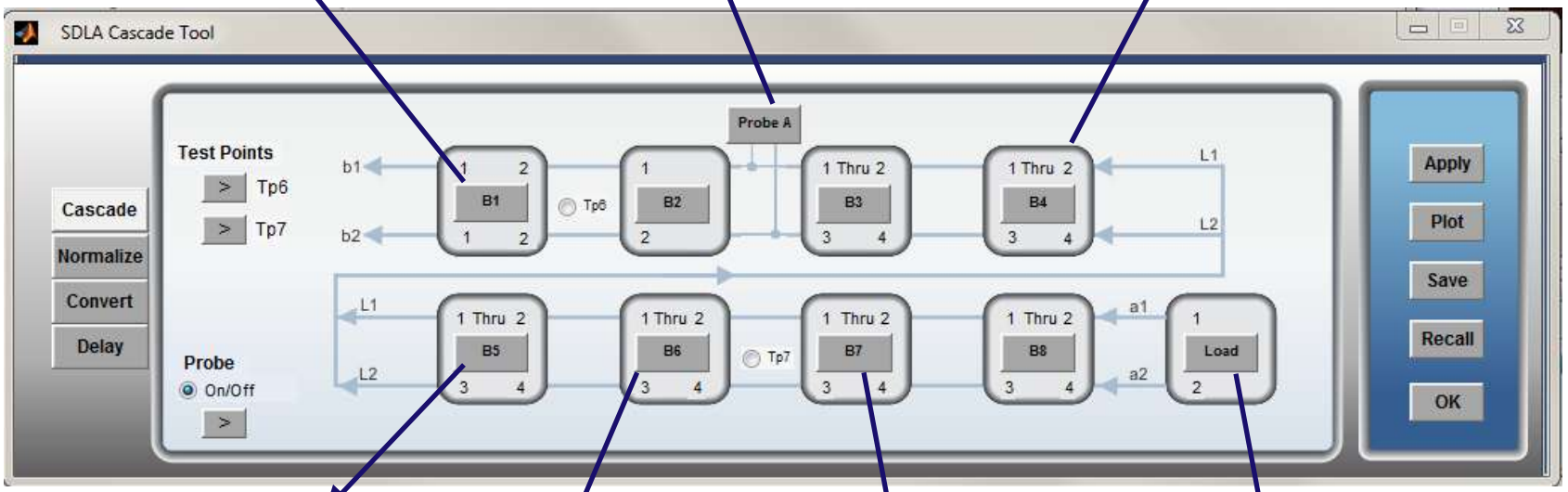
Or Two Transfer function files
Or Two FIR files

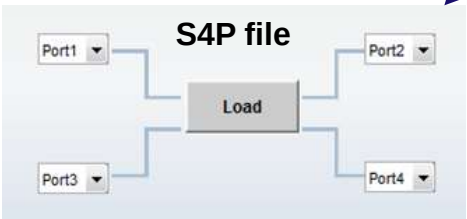


Probe/Scope Spars

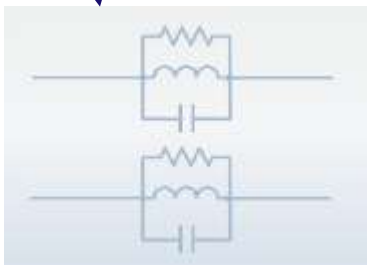
Mixed mode to single ended



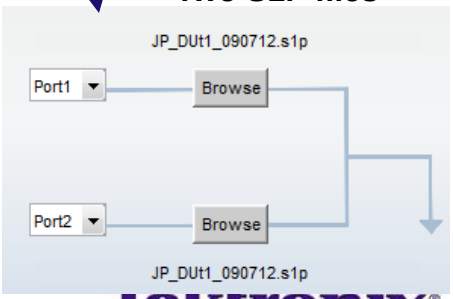




RLC Models



Two S1P files



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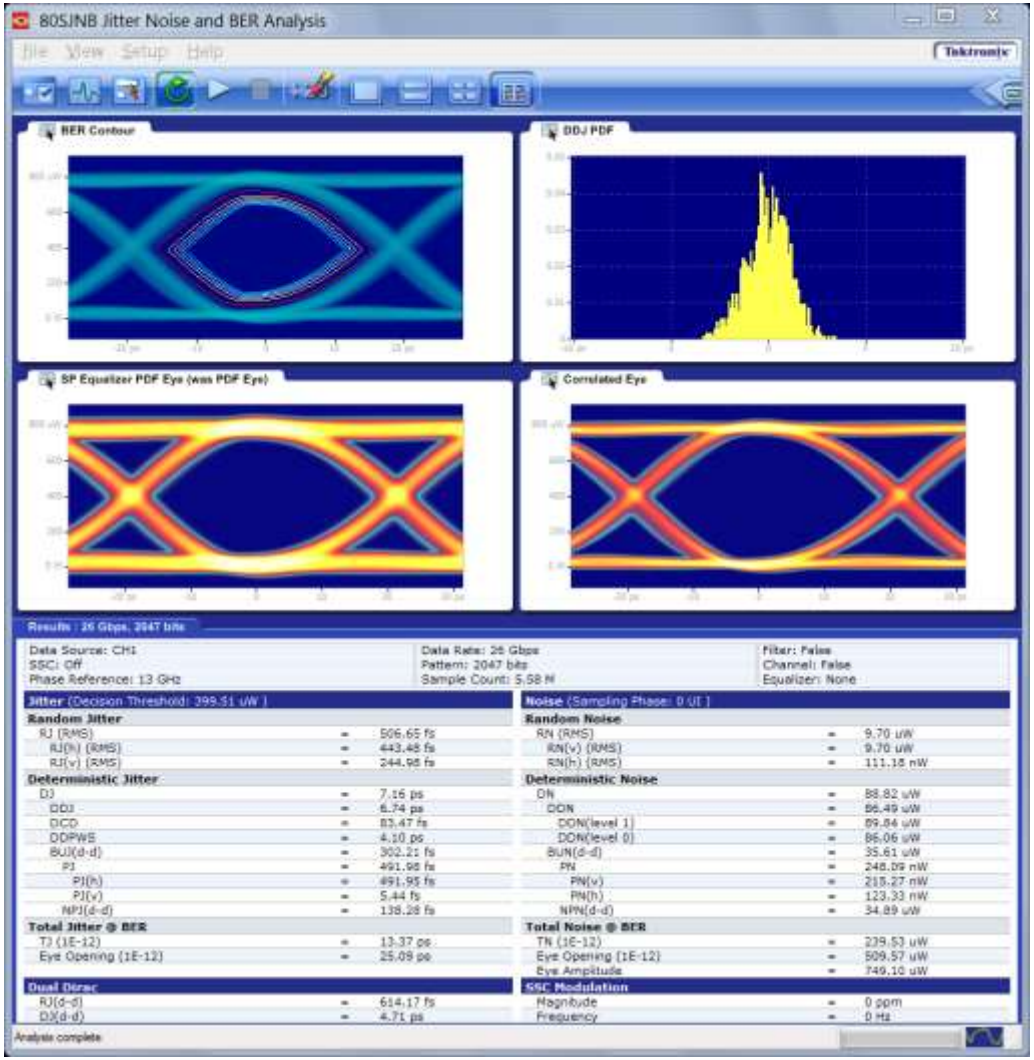
Jitter & Noise Analysis of 26G Optical Signals with 80SJNB

Detailed signal insight with 80SJNB Analysis Tool (available as SW option with DSA8300)

Complete Jitter and Noise decomposition of optical waveforms, including
- ✓Bounded Uncorrelated Jitter
- ✓Crosstalk Noise
- ✓J2, J9 Jitter per IEEE 802.3ba

Perform serial data link analysis with built-in signal processing capabilities.



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40GBASE_KR install base reuse

- 2 PHY to be defined
  - PAM
    - For re-use of 40GBASE_KR install base
    - Lower bandwidth
    - more bit per baud
  - NRZ
    - Higher efficiency
    - Improved channel characteristics

PatternPro Advanced BERT Solutions

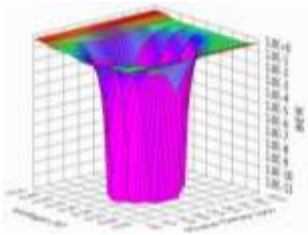
Multi-channel Multi-level Instruments

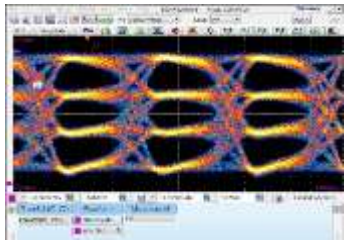
Highest Performance Analog Inputs and Outputs

100G & 400G Applications

Analysis and Control Software

JTOL J2/J9
Bathtub
Contour Analysis





Accessory Modules Components and Cables

Combiner Kits
Amplifier Modules
Equalized Cables

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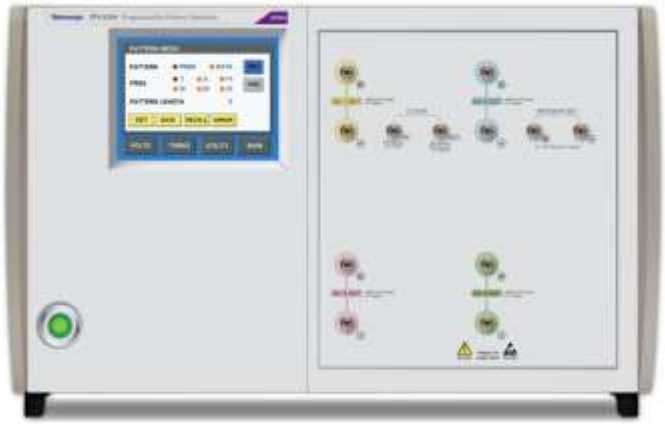
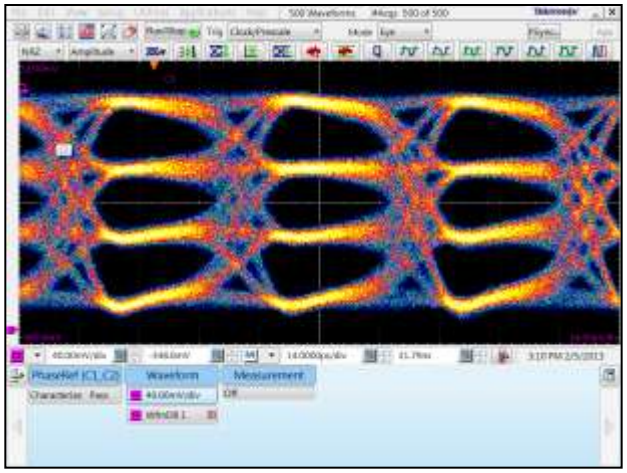
PPG & PED Product overview

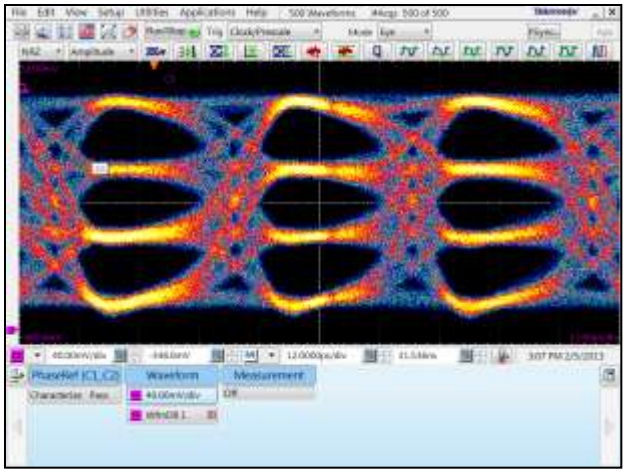
- **Model PPG1600/3000/3200/4000 up to 40Gbps,** 1, 2, and 4-channel pattern generators
- **PED 320x and 400x** 32G and 40G error detectors
- Multi-channel versions feature aligned data across channels
- Fast rise/fall times (as low as 9ps depending upon model)



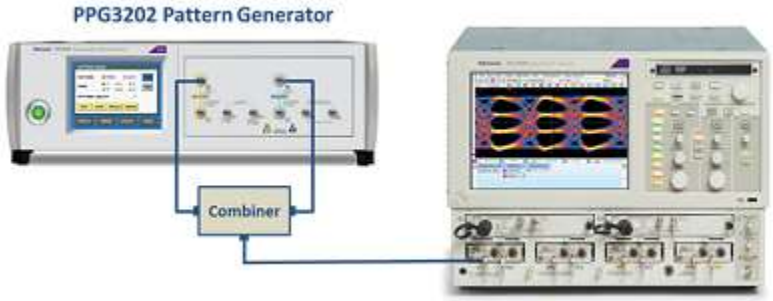
PAM4 on PPG3202

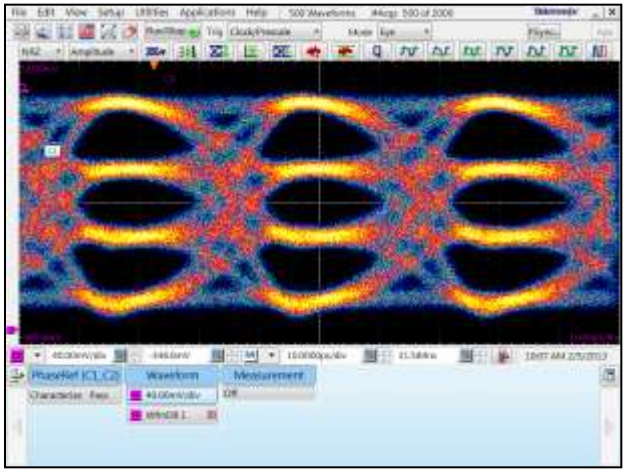


25 Gb/s



28 Gb/s





32 Gb/s

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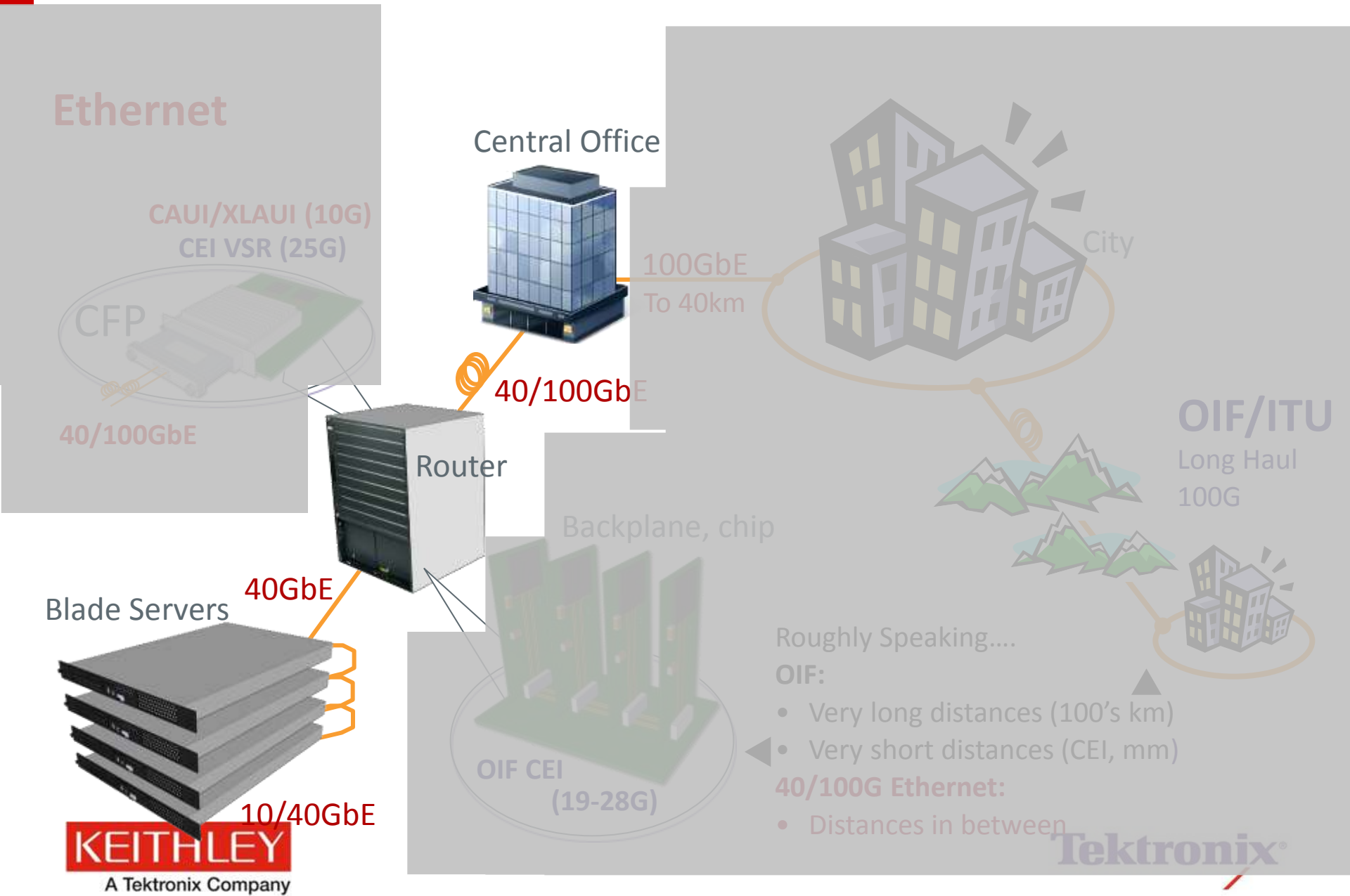
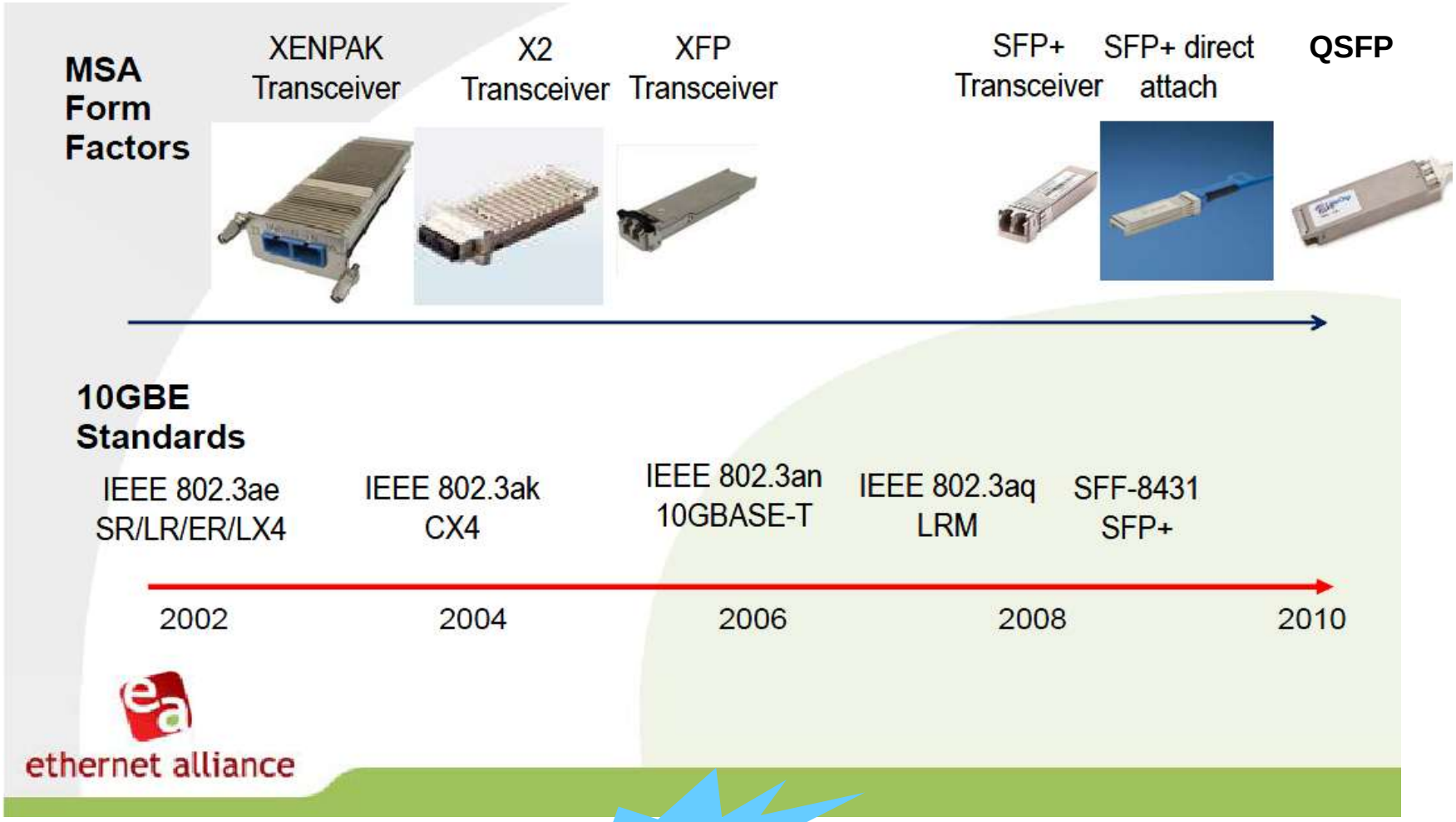
High Speed Networks & Standards



10Gigabit Ethernet Interface Evolution



Source : Ethernet Alliance

Next Big Thing
SFF-8431
SFP+, QSFP+

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40GBASE-CR4 technology overview

The clause 85 of IEEE 802.3 specification details out 40GBASE-CR4 PMD. The 40GBASE-CR4 is a low-swing AC coupled differential interface. AC coupling at the receiver allows for interoperability between components operating from different supply voltages. Low-swing differential signaling provides noise immunity and improved electromagnetic interference (EMI).

The 40GBASE-CR4 signal paths are point-to-point connections. For 40GBASE-CR4, there are four differential paths in each direction for a total of eight pairs, or sixteen connections. 40GBASE-CR4 is a 40 Gigabit Ethernet technology. It uses 4 lanes to achieve the required data rate(4 *10.3125 Gbps). The channel between transmitter and receiver is four lanes of shielded balanced copper cabling. Length of the signal path in 40GBASE-CR4 can range from 0.5 m to 7 m.

SFF-8431 SFP+/SFF-8635 QSFP+ Technology overview

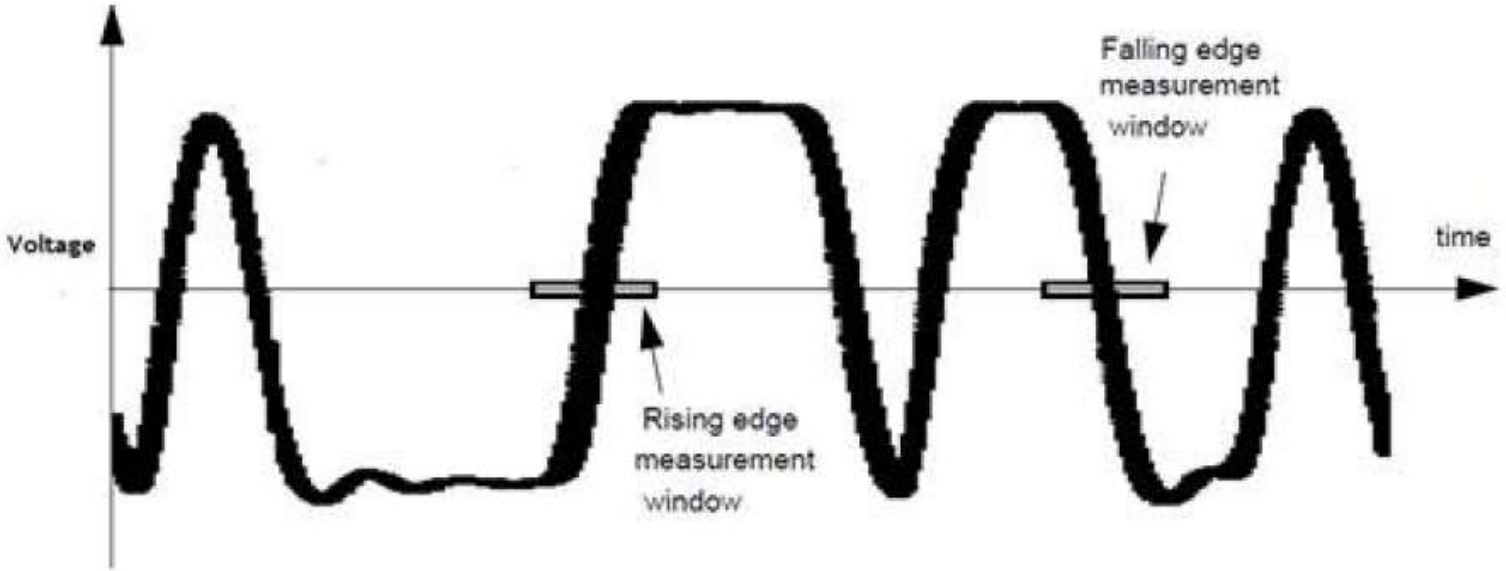
- SFP+ is a next-generation hot-pluggable, small footprint, serial-to-serial multi-rate optical transceiver for 8.5GbE to 11.1GbE Datacom and Storage Area Networks (SAN) applications.
- SFF-8635 QSFP+ 10 Gb/s 4X Pluggable Transceiver Solution (QSFP10)
- SFP+ technology moved the clock and data recovery units out of the module and onto the line card – Reducing size drastically
- As a result, the modules are smaller, consume less power, allow increased port density, and are less expensive compared to XFP.
- High density capable Up to 48 ports in a rack
- Low power per port - Host Port power < 1 W and Low Latency

SFP-TX Host Transmitter Measurements

SL No.	Measuremnts	Signal Type Recommended	Limit			
			Min	Target	Max	Units
Host Transmitter output electrical Specifications:						
1	Single Ended Output Voltage Range	PRBS31	-0.3		4	V
2	Output AC Common Mode voltage (RMS)	PRBS31			15	mV(RMS)
Host Transmitter Jitter and Eye Mask specifications						
3	Crosstalk source rise/fall time (20%-80%) (Tr, Tf)	8180		34		ps
4	Crosstalk source amplitude (p-p differential)	8180		1000		mV
5	Signal rise/fall time (20%-80%) (Tr, Tf)	8180	34			ps
6	Total Jitter (p-p) (Tj)	PRBS31			0.28	UI(p-p)
7	Data Dependent Jitter (p-p) (DDJ)	PRBS9			0.1	UI(p-p)
8	Data Dependent Pulse Width Shrinkage (p-p) (DDPWS)	PRBS9			0.055	UI(p-p)
9	Uncorrelated Jitter (RMS) (UJ)	PRBS9			0.023	UI(p-p)
10	Transmitter Qsq	8180	50			
11	Eye mask hit ratio(Mask hit ratio of 5×10-5)	PRBS31	X1=0.12UI, X2=0.33UI, Y1=95mV, Y2=350mV			
Host Transmitter output specifications for Cu (SFP+ host supporting direct						
12	Voltage Modulation Amplitude (p-p)	8180	300			mV
13	Transmitter Qsq Output AC Common Mode voltage	8180	63.1			
14	Output AC Common Mode Voltage	PRBS31			12	mV(RMS)
15	Host Output TWDPc	PRBS9			10.7	dBe

Uncorrelated Jitter - UJ

- Uncorrelated Jitter is the deviation/TIE of each rising and falling edge on the input signal from its ideal location
- Rising and falling edges are obtained from patterns with longest runs of 1s and 0s in order to maintain uniformity on the edges. if deviations are measured on all edges then deviations will be inconsistent and hence resulting in errors
- Then standard deviation of computed TIE of rising and falling edges.



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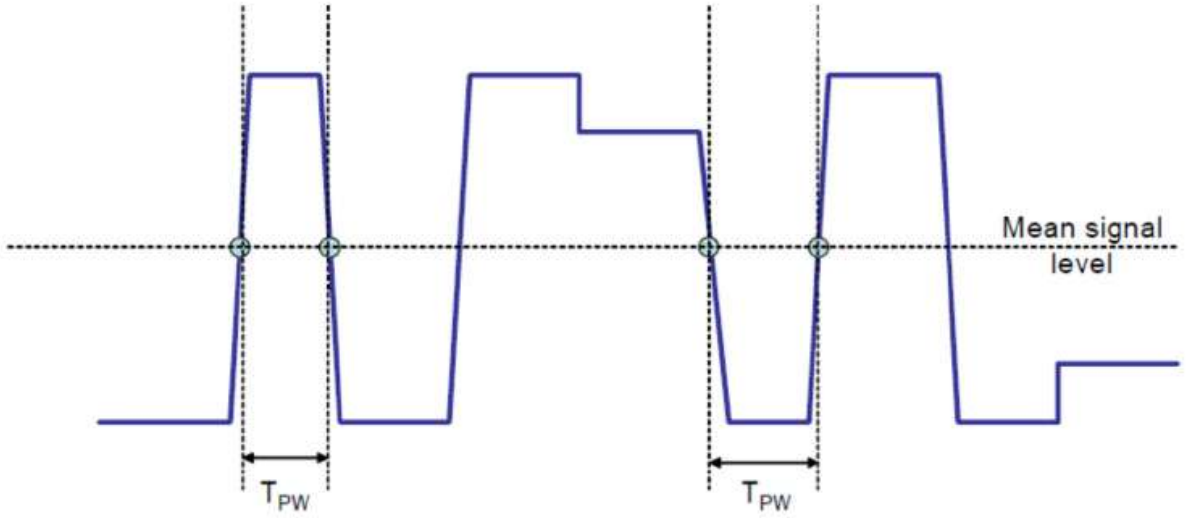
Data Dependent Pulse Width Shrinkage

- Data Dependent Pulse Width Shrinkage (DDPWS) is the Difference between Unit interval and Minimum pulse width.
  - If the waveform contains PRBS7, 9, 11, then it is the average of all minimum pulse width for each pattern it contains.
  - If the waveform is PRBS15, 20, 23 and 31, then it is the minimum pulse width across entire waveform.

- DDPWS is computed as follows:
  - DDPWS = Unit Interval – Minimum Pulse Width

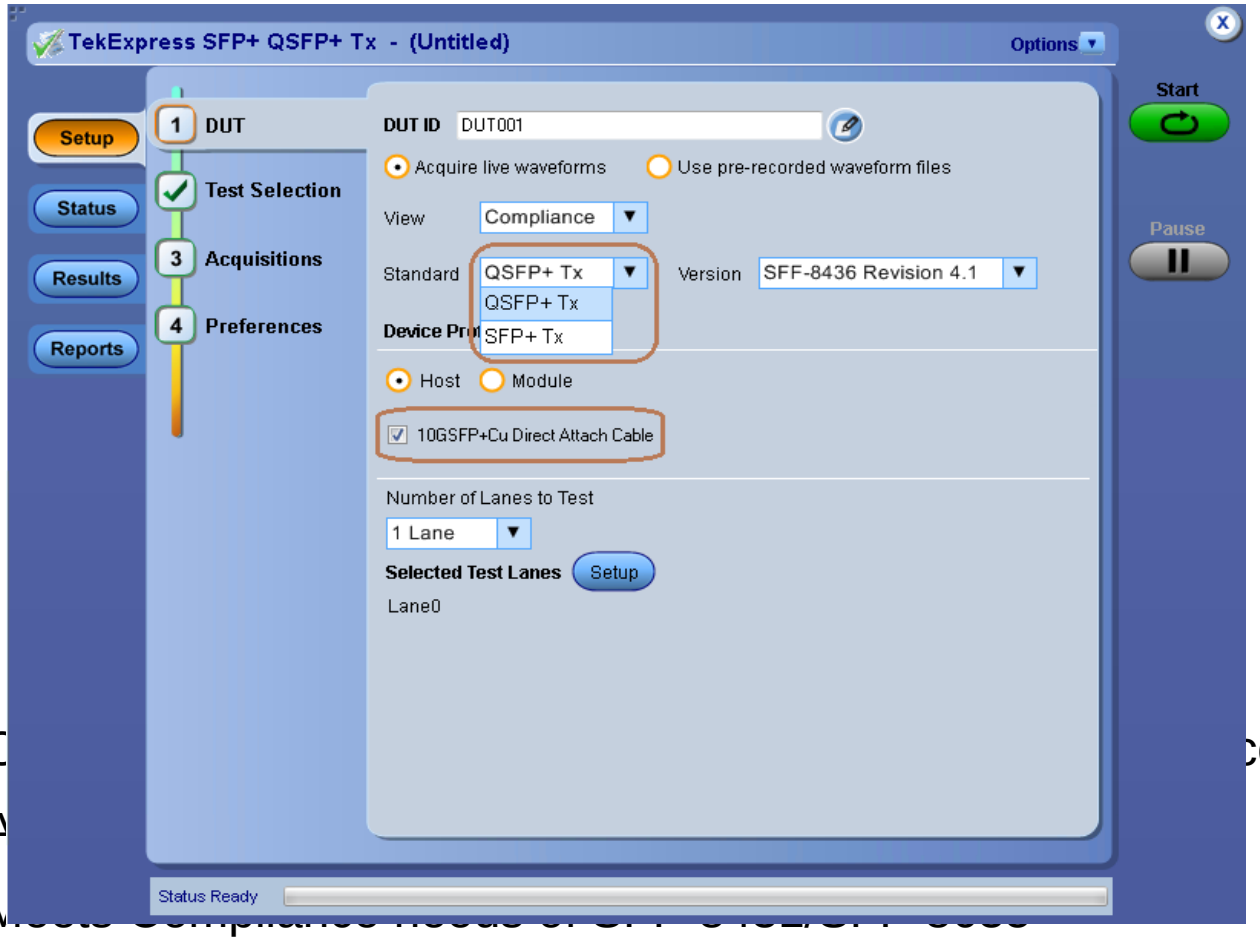


TWDPc Measurement Definitions

- TWDPc
  - **T**ransmitter **W**aveform **D**ispersion **P**enalty for **C**opper
  - *Defined as a measure of the deterministic dispersion penalty due to a particular transmitter with reference to the emulated multi-mode fibers and a well-characterized receiver.*
  - The fiber optics concept has been extended to quantify channel performance of high speed copper links “10GSFP+Cu”
  - Critical for performance
  - Requires a special algorithm
  - ClariPhy has IP rights for this algorithm

- Test Specification Requirements for TWDPc
  - 7 measurement samples per unit interval
  - Causes worst-case 0.24 dB TWDPc over 30 measurements

Tek SFP-TX – Automation Part



- C copes
- A
- M
- User defined mode supports PRBS7, PRBS11, PRBS15,PRBS20 & PRBS23 in addition to patterns supported in Compliance mode including PRBS9, PRBS31 and 8180.

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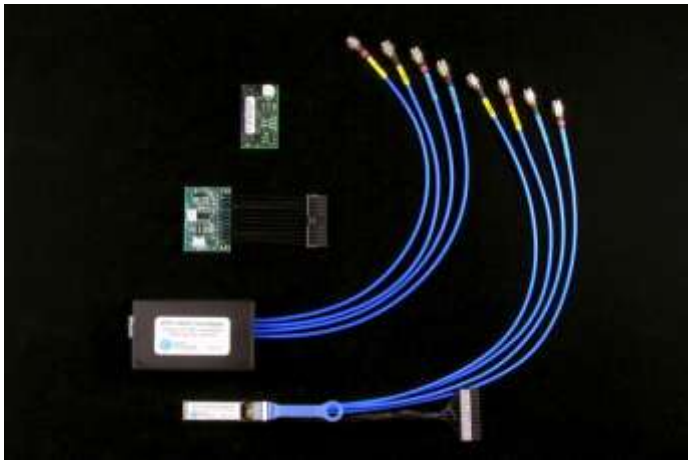
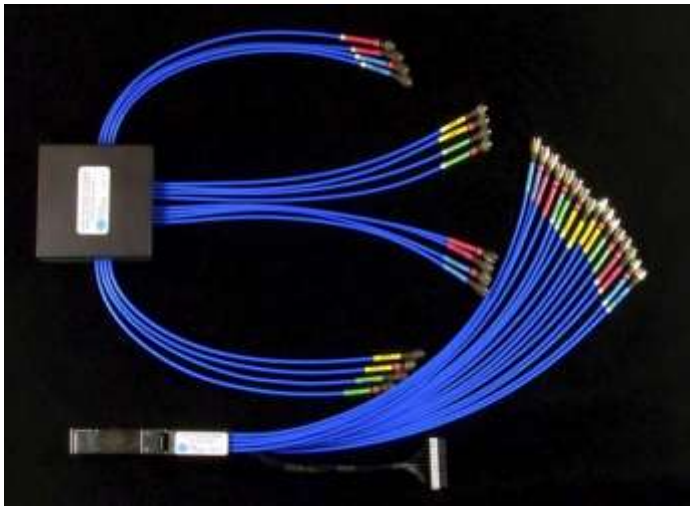
QSFP+ SFP+ Fixture

Transmitter Test Recommended Accessories – Probes & Fixtures	
Probing	
SMA Cables	Matched-pair SMA cables (TCA-SMA connector)
Fixturing	
TF-SFP-TPA-HCB-P	SFP+ Host Compliance Board Plug
TF-SFP-TPA-MCB-R	SFP+ Module Compliance Board Receptacle
TF-SFP-TPA-PR	SFP+ Host Compliance Board Plug and Module Compliance Board Receptacle
TF-SFP-TPA-HCB-PK	SFP+ Host Compliance Board Plug Kit with DC Blocks
TF-SFP-TPA-MCB-RK	SFP+ Module Compliance Board Receptacle Kit with DC Blocks and Termination
TF-SFP-TPA-PRK	SFP+ Host Module Compliance Board and Module Compliance Board with DC Blocks and Termination
TF-QSFP-TPA-HCB-P	QSFP+ Host Compliance Board Plug
TF-QSFP-TPA-MCB-R	QSFP+ Module Compliance Board Receptacle
TF-QSFP-TPA-PR	QSFP+ Host Compliance Board Plug and Module Compliance Board Receptacle
TF-DC-BLOCK-KIT	DC Block Kit (Quantity 4)





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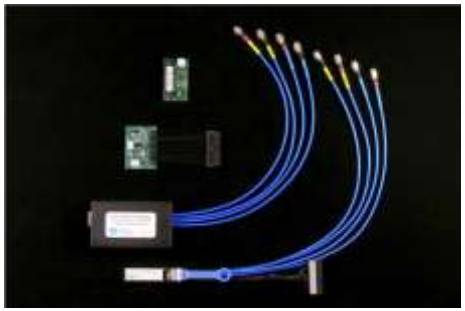
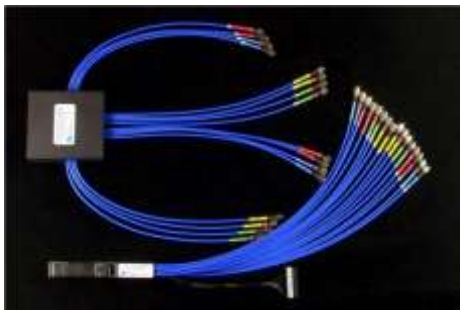
40G-CR4 Compliance and Debug Solution

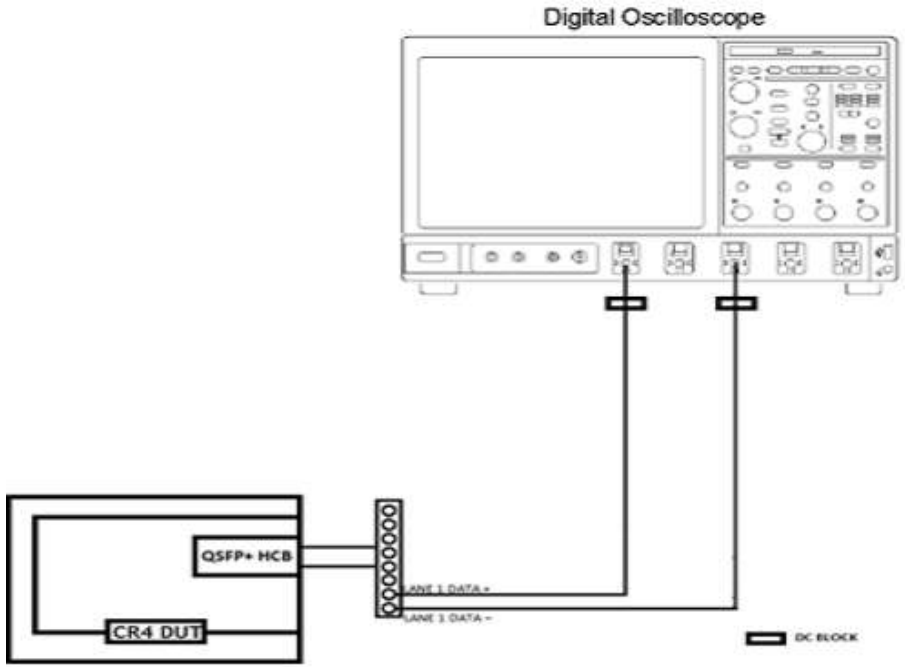
Recommended Equipment			
Oscilloscope Required	Software Required	Accesscories	Test Fixture
DPO/DSA/MSO71604C DPO/DSA/MSO72004C DPO/DSA72504D DPO/DSA73304D	40G-CR4 & DJA*1	TF-DC-BLOCK-K	TF-QSFP-TPA-HCB-P QSFP+ Host Compliance Board Plug
*1 - Prerequisite for 40G-CR4			



SFP+ HCB & MCB



QSFP+ HCB & MCB



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16 GFC Single/Multi-mode Solution

80C14 Optical Module

Performance Specifications	
Single and multi-mode	9, 50, 62.5μm core
Supported wavelengths	700 – 1650 nm
Maximum Optical Bandwidth	14 GHz
Optical Reference Receivers	**All 10 Gb/s standards + 8 and 16 GFC**
Sensitivity	**-12 dBm at 850nm (-15 dBm at 1310 nm)**
Buffered electrical data pick-off to support external clock recovery instrument	Recommended Tektronix CR175A or CR286A

Standards Supported

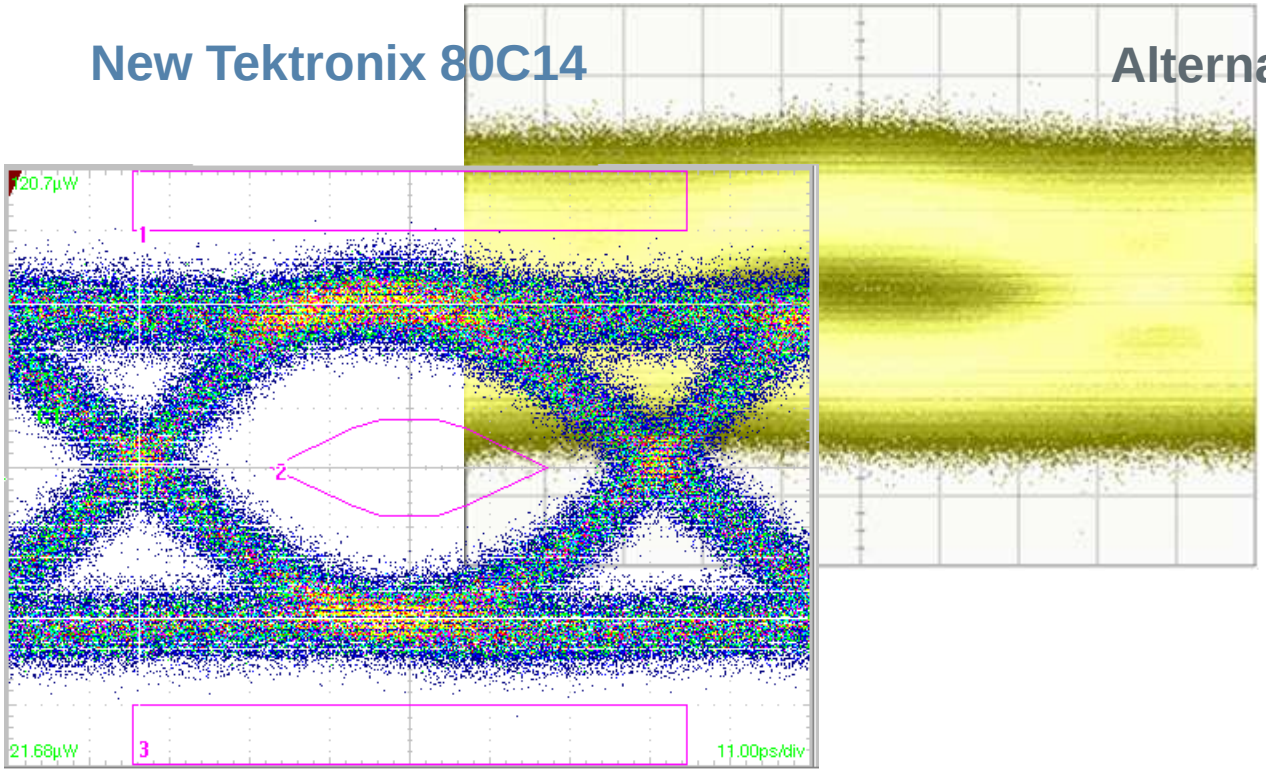
Standard	Data Rate
8 GFC (old)	8.500 Gb/s
OC192/STM64	9.953 Gb/s
10GBase-W	9.953 Gb/s
10GBase-R	10.31 Gb/s
40GBase-LR4	9.953 Gb/s
10G EPON	9.953 Gb/s
100GBase-SR10	10.31 Gb/s
10GFC	10.51 Gb/s
G.975 FEC	10.66 Gb/s
G.709 FEC	10.71 Gb/s
10GBE FEC	11.10 Gb/s
10 GFC FEC	11.317Gb/s
12.5 Gb/s FEC	12.50 Gb/s
16 GFC	14.025 Gb/s
Infiniband FDR	14.063 Gb/s

80C14 Optical Module
Unmatched Sensitivity for 16G Fibre Channel

16GFC SW transceiver: -11dBm, 850nm,14.025Gb/s, 50um MMF

New Tektronix 80C14

Alternative Solution



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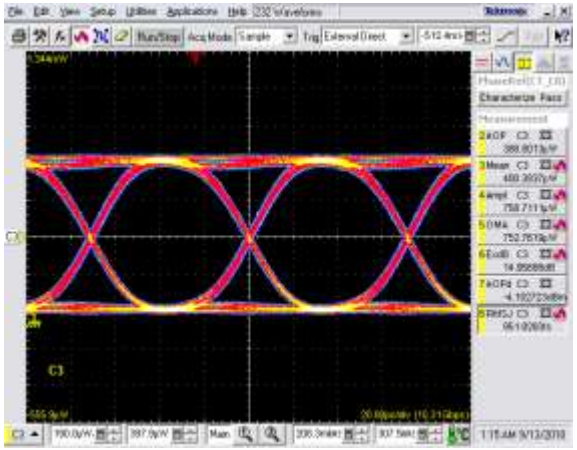
155 Mb/s to100 Gb/s Optical Compliance Testing

DSA8300 ALL-IN-ONE Solution

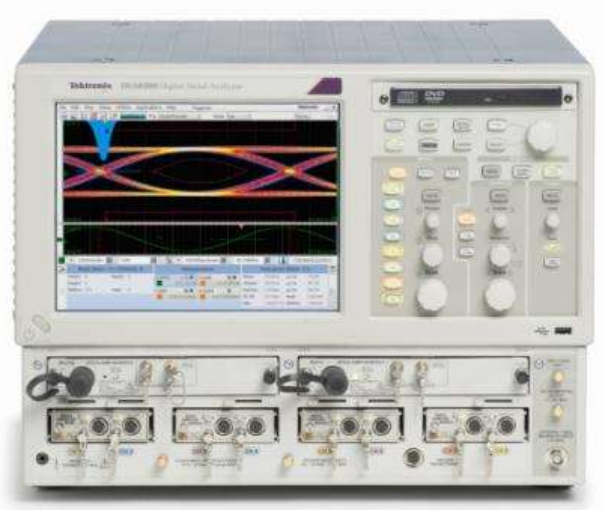
Tektronix DSA8300 All-In-One System

+ 80C12B Optical Module (155 Mb/s to 11.3 Gb/s)
+ 80C10C-F1 Optical Module (25.7 Gb/s to 44.5 Gb/s)
+ 80C15 Optical Module (MM,25.78Gb/s to 28.05Gb/s)
+ 2 slots available to acquire 4 electrical signals



The Only ALL-IN-ONE Solution with:

- All major ORRs from 155 Mb/s thru 44.5Gb/s
- Highest repeatability & best sensitivity
- SMF and MMF support to 12G
- Up to 3x throughput advantage vs. alternative
- 425 fs $_{RMS}$ native jitter
- 100 fs $_{RMS}$ jitter when equipped with 82A04B
- Integrated clock recovery trigger pickoff
- Clock recovery available via Tektronix CR286 (to 28.6 Gb/s), or third party (to 44.5 Gb/s)



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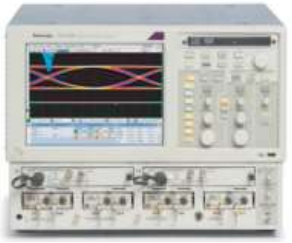
Tektronix Performance Solutions
By Application and Customer End Product

End Product	Interface PHY	Transmission Test	Receiver Test
SerDes	Electrical	DSA8300 w/80E10B & 82A04B (Golden Eye) MSO70000DX (Debug)	BSA286C PSPL PatternPro *(full line of Picosecond Products, OEM+new)*
Transceiver/Cable	Electrical	DSA8300 w/80E10B (Compliance & TDR) MSO70000DX (Debug)	BSA286C PSPL PatternPro
Transceiver/Cable	Optical	DSA8300 w/80C10C, 80C14 (NRZ-Serial) OM4000 w/DPO73304DX (Modulation Check)	BSA286C (NRZ-Serial Signaling) PSPL PatternPro AWG70000 or PPG320X w/OM5510 (QPSK, PAM-based Modulation)
Line Card/System	Electrical	DSA8300 w/80E10B (Compliance & TDR) MSO70000DX (Debug)	BSA286C PSPL PatternPro
Line Card/System	Optical	DSA8300 w/80C10C, 80C14 (NRZ-Serial) OM4000 w/DPO73304DX (Modulation)	BSA286C (NRZ-Serial) PSPL PatternPro AWG70000 or PPG320X w/OM5510 (QPSK, PAM-based Modulation)

Tektronix 100G Comprehensive Testing Solutions

- **DSA8300 Sampling Oscilloscope**
  - **>70GHz Bandwidth**
  - **<100 fsec jitter noise**
  - **Pass/Fail at high throughput**
  - **BUJ-Based Jitter Analysis**



- **BSA286C Bit Error Rate Tester**
  - **28.6 Gb/sec Data Rate**
  - **Low intrinsic jitter**
  - **Stressed, calibrated PRBS31 patterns**
  - **Error location & Jitter Analysis**

- **PatternPro BERT Instruments**
  - **32 Gb/sec Data Rate**
  - **Up to 4 synchronized channels (PG + ED)**
  - **Low intrinsic jitter**
  - **Stressed, calibrated PRBS31 patterns**

- **OM4000 Coherent Lightwave Analyzer**
  - **DP-QPSK Analysis**
  - **Constellation Mapping to BER**
  - **Works with RT or ET Scopes**

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Thanks !

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