2014年泰克测试测量技术研讨会-厦门

10M-100G的通信标准全面方案

泰克科技（中国）有限公司 王宏军

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Agenda

- 电信号通信测试方案

  10M/100M/1000M/10G以太网，10G KR SFP+

- 光信号通信测试方案

  40G/100G光通信方案

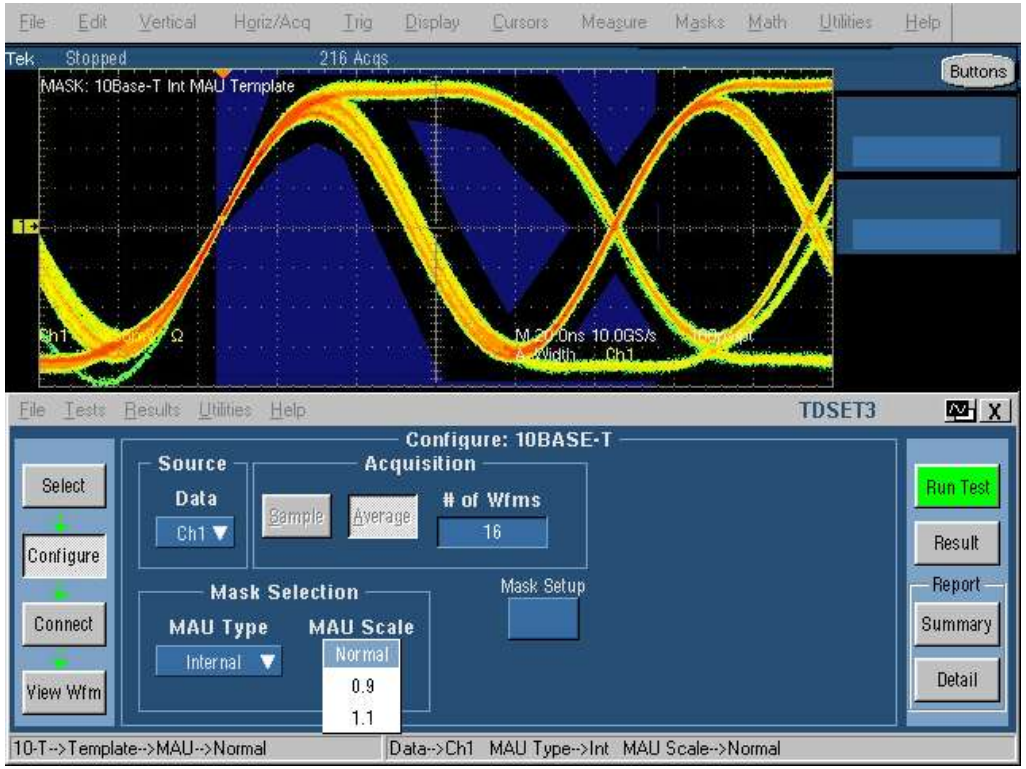
- **100G/400G相干光传输方案**

10M、100M、1000M以太电接口的测试

- 模板测试：脉冲模板、眼图模板
- 幅度：差分输出电压、对称度
- 时域：上升/下降时间、对称度、占空比失真
- 抖动：测试设定不同
- 回波损耗测试

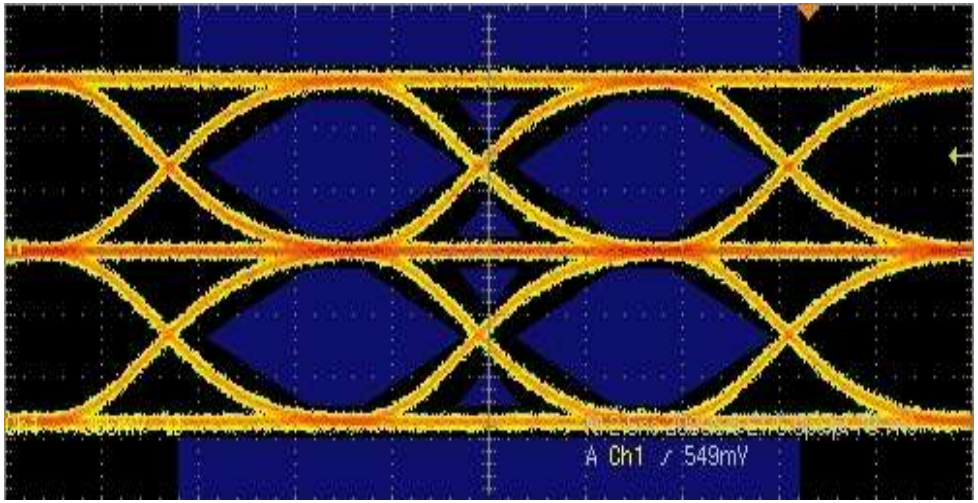
10Base-T以太网接口测试项目

- 核心测试
  - 差分输出电压模板以及电压的测试
  - 连接（link test）脉冲模板测试
  - 空闲（idle)信号模板测试
  - 输出抖动测试（8BT, 8.5BT）
  - 谐波成分
  - MDI回波损耗（发送和接收）
  - 共模电压



100Base-TX以太网接口测试项目

- 核心测试
  - 模板
  - 幅度域
    - 峰值幅度
    - 过冲
    - 幅度对称
  - 时域
    - 上升时间和下降时间
    - 上升/下降对称
  - 抖动
  - 占空比失真
  - MDI回波损耗
    - 发送，接收



1000Base-T以太网接口测试项目

- 核心测试
  - 模板
  - 峰值电压
  - 电平精度
  - 衰落
  - 失真
  - MDI回波损耗
  - MDI共模电压
  - 抖动

测试模式 1

测试模式4

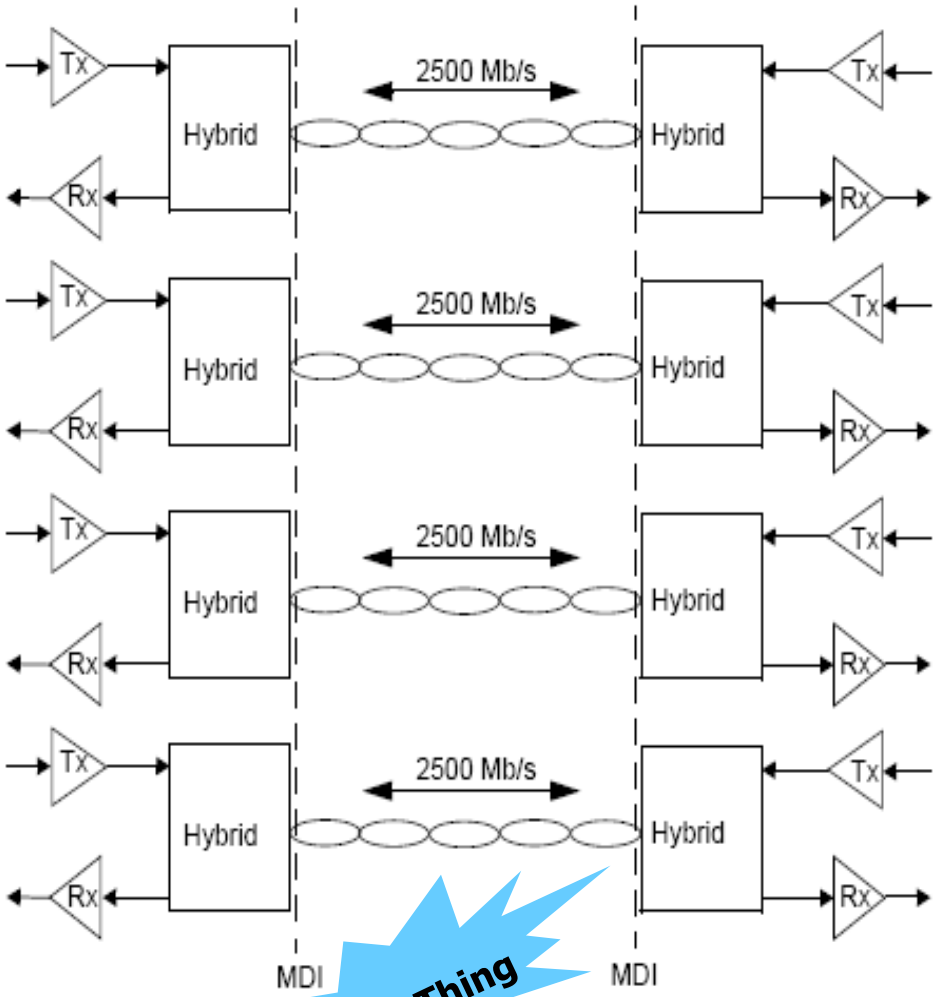
- 其它测试
  - 共模抑制
  - 误码率
  - 阻抗均衡
  - 串扰噪声抑制

1000Base-T以太网接口测试：DUT设置

- 1000Base-T接口有4种IEEE组织规定的测试模式：
  - 测试模式1：脉冲模板测试、电压衰落测试、峰值电压测试
  - 测试模式2：主模式抖动
  - 测试模式3：从模式抖动
  - 测试模式4：波形失真测试、回波损耗测试、共模输出电压测试

10GBASE-T - Overview

- 10GBASE-T provides 10 gigabit/second connections over unshielded or shielded twisted pair cables, over distances up to 100 m. 2.5Gbps per lane (A, B, C & D)
- Baseband 16-level PAM signaling with a modulation rate of 800 Msymbols per second is used on each of the wire pairs.
- Supports full duplex operation only
- Compatibility of Auto Negotiation enabled to also operate 10/100/1000 BASE-T
- Supports a BER of less than or equal to 10E-12 on all supported distances and Classes
- Provides a cost advantage over fiber



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XGbT – 10GBASE-T 发送端测试

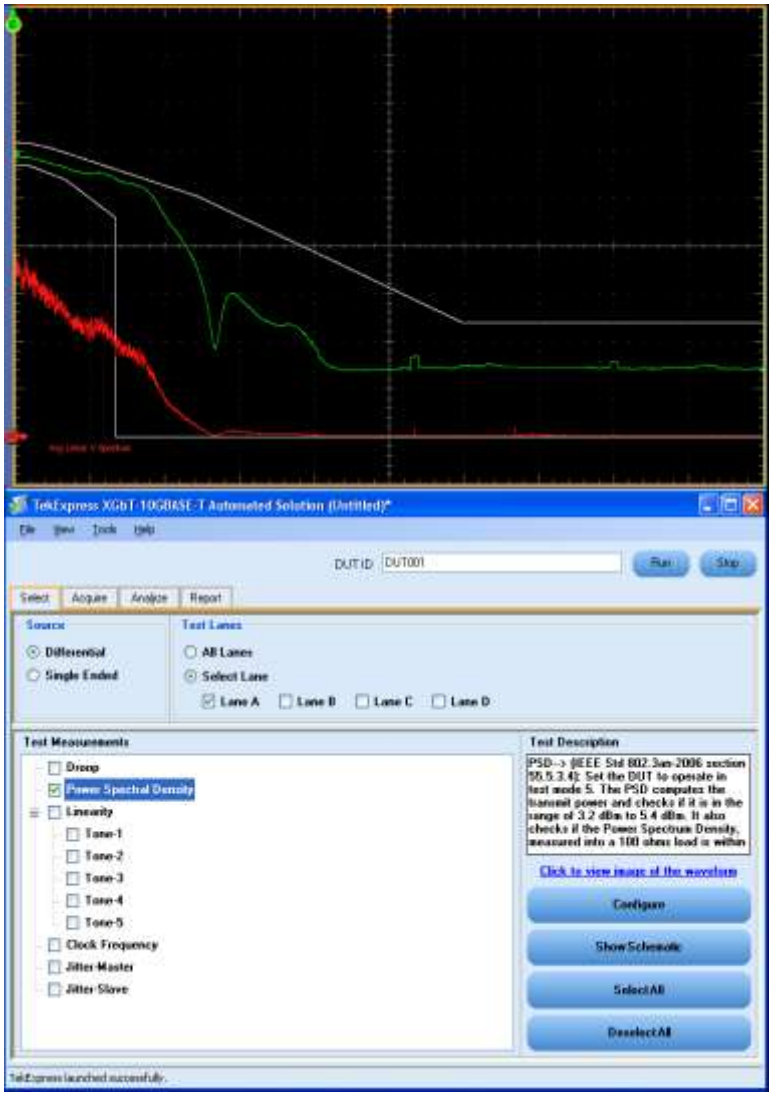
	Measurement	Test Mode	XGbT Features / Notes	Does XGbT cover this measurement?
1	Maximum output droop	Sub clause 55.5.3.1, Test Mode 6	Flexibility to test beyond compliance – XGbT provides the flexibility to perform testing beyond what is specified in IEEE standard 802.3an-2006. It helps users to analyze their PHY in addition to compliance tests.	Yes
2	Transmitter timing jitter – Master	Sub clause 55.5.3.3, Test Mode 2	Measure Jitter down to just few picoseconds. Software Filters are designed and applied on the acquired data automatically while performing measurements.	Yes
3	Transmit clock frequency	Sub clause 55.5.3.5,Test Mode 2	Exact value PPM for measured clock frequency is provided	Yes
4.	Transmitter timing jitter – Slave	Sub clause 55.5.3.3, Test Mode 1 ans Mode 3	Measure Jitter down to just few picoseconds. Software filters are designed and applied on the acquired data automatically while performing measurements.	Yes
5	Transmitter linearity	Sub clause 55.5.3.2, Test Mode 4. Tones 1-5	Spectral Features of the scope are used to perform the measurement, a methodology that is unique to Tektronix and approved by UNH-IOL	Yes
6	Transmitter power spectral density (PSD) and power level	Sub clause 55.5.3.4, Test Mode 5	Spectral Features of the scope are used to perform the measurement, a methodology that is unique to Tektronix and approved by UNH-IOL	Yes
7.	Return Loss	Sub clause 55.8.2.1, Test Mode 5	Return Loss is not part of XGbT solution for now, however it will finally be released in next version. For time gap arrangement please request product line for Return Loss utility	Yes**

Transmitter Power Spectral Density (PSD) and Power Level
发送端功率谱密度及功率值

- **目的**：确保发送端功率谱密度和功率值满足规范要求。
- 功率值应在3.2dBm~5.2dBm范围内

  功率谱密度曲线应介于规范要求的上下限曲线之间。
- 需进入Test Mode 5
- IEEE 标准 802.3an-2006, 55.5.3.4条目。
- Test Mode 5：

  正常操作模式



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TF-XGbT Test Fixture

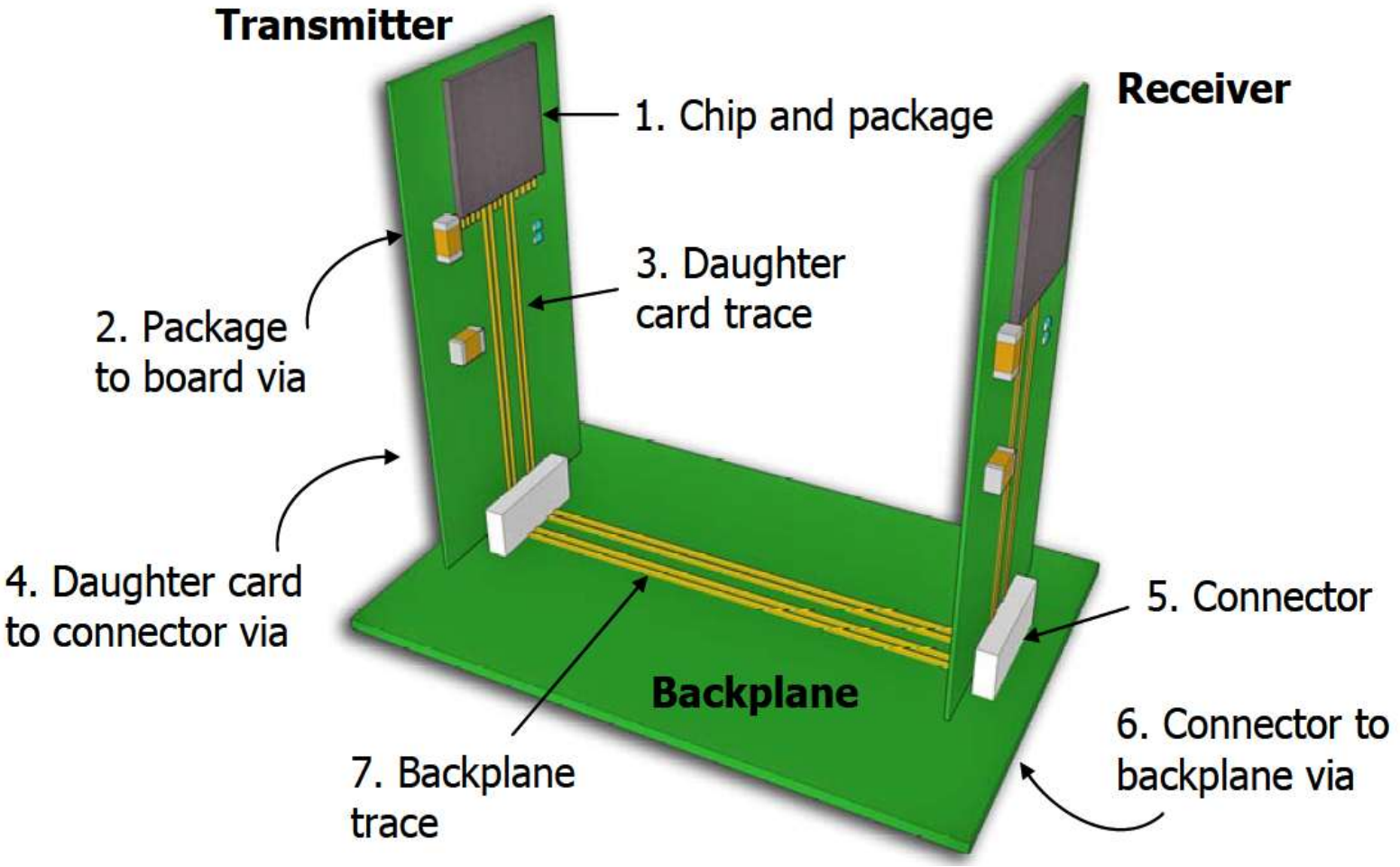
- The XGbT test fixture provides easy access to the 10GBASE-T Electrical signals to perform conformance testing and device characterization as described in of IEEE 802.3an-2006 sub-clause 55.5.3 & 55.8.2.1. This fixture is used with the Tektronix's XGbT- 10GBASE-T Automation Solution to provide fast and accurate design debugging and validation. XGbT fixture covers all seven measurements including Jitter Slave and MDI Return Loss

Fig 1: XGbT Test Fixture main board

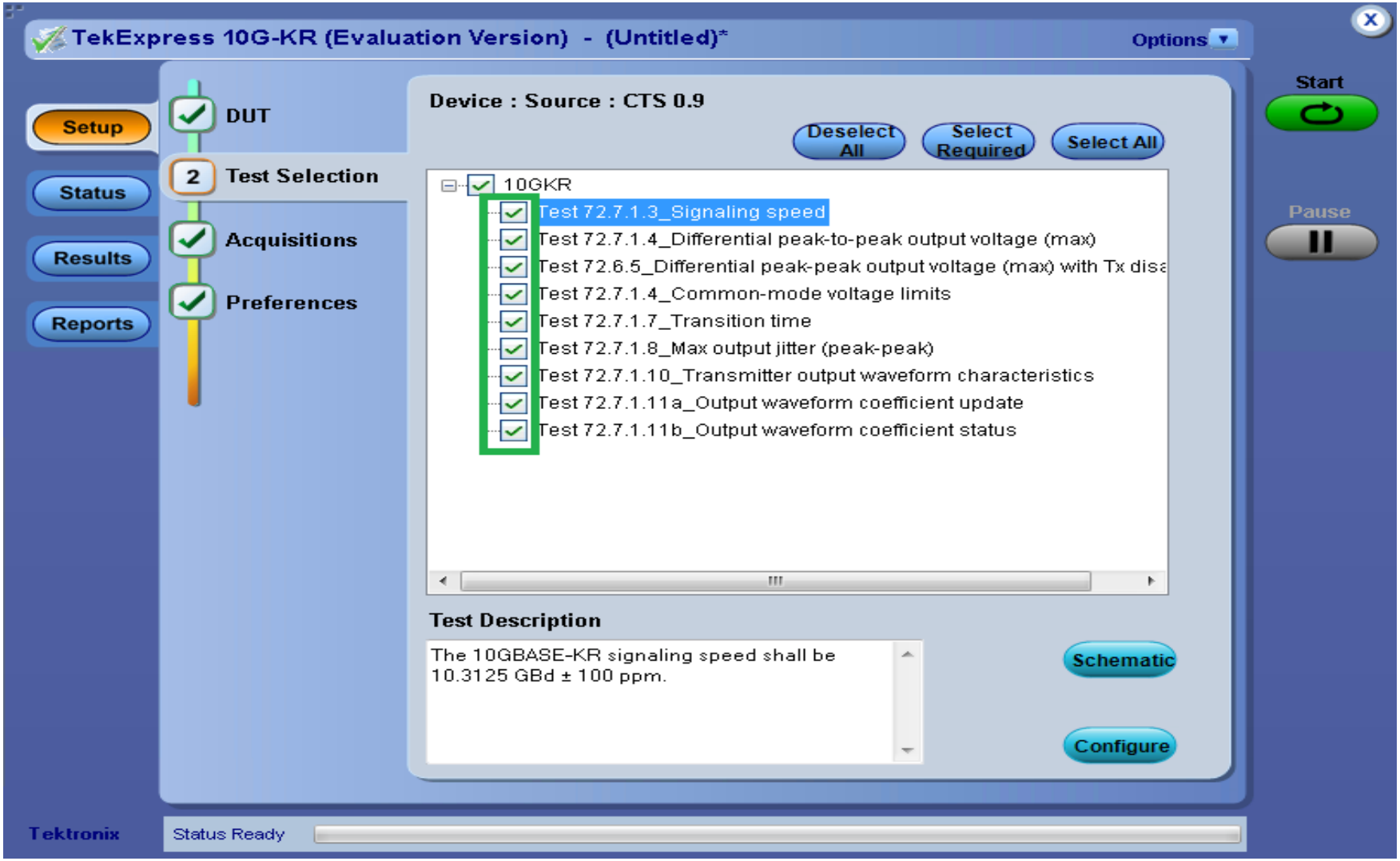
Fig 2: Calibration Board

Figure 3: RJ45 Shielded Patch cord

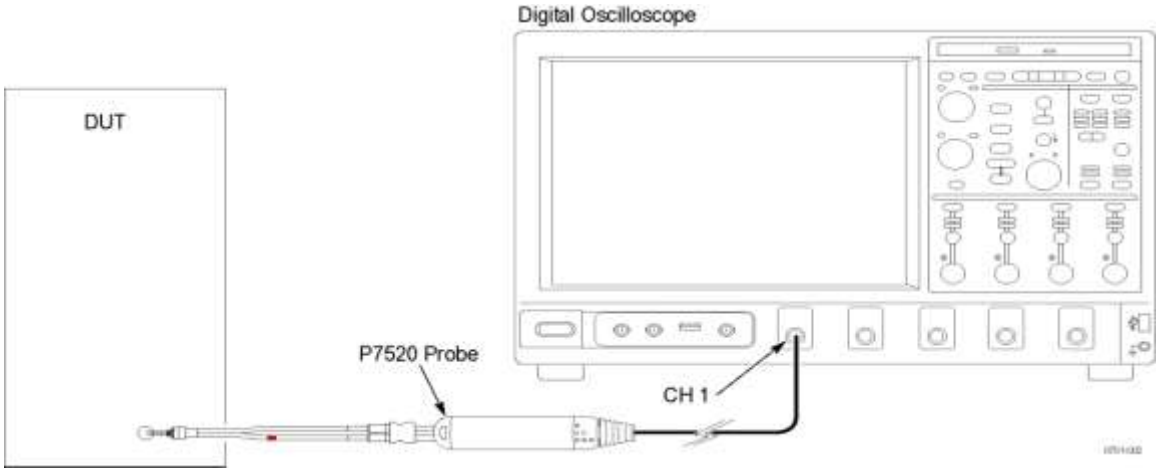
10G-KR Typical Backplane Ethernet

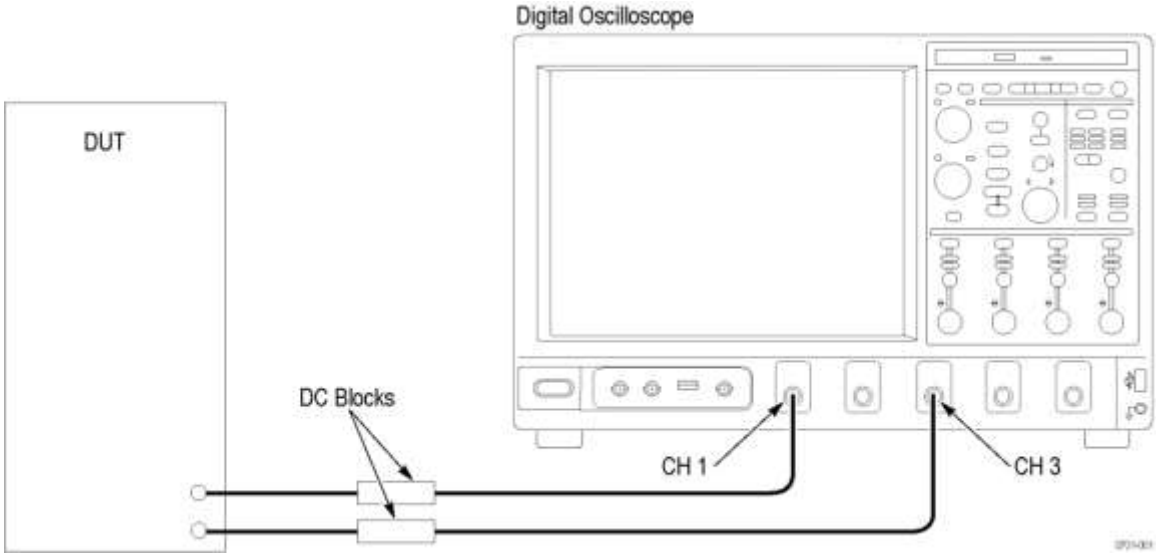


10G-KR自动化测试软件



Testing connection for 10G-KR





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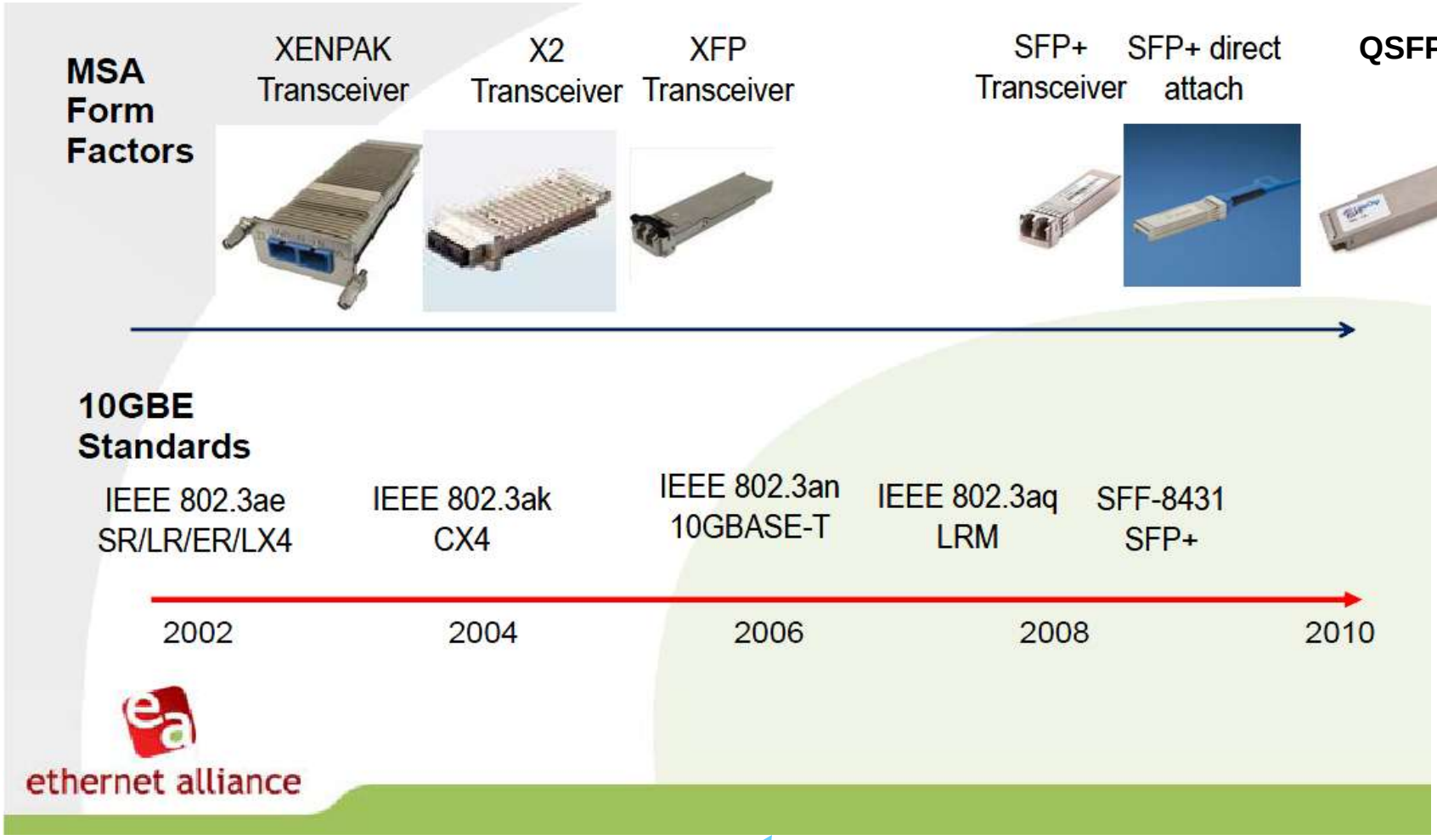
10Gigabit Ethernet Interface Evolution

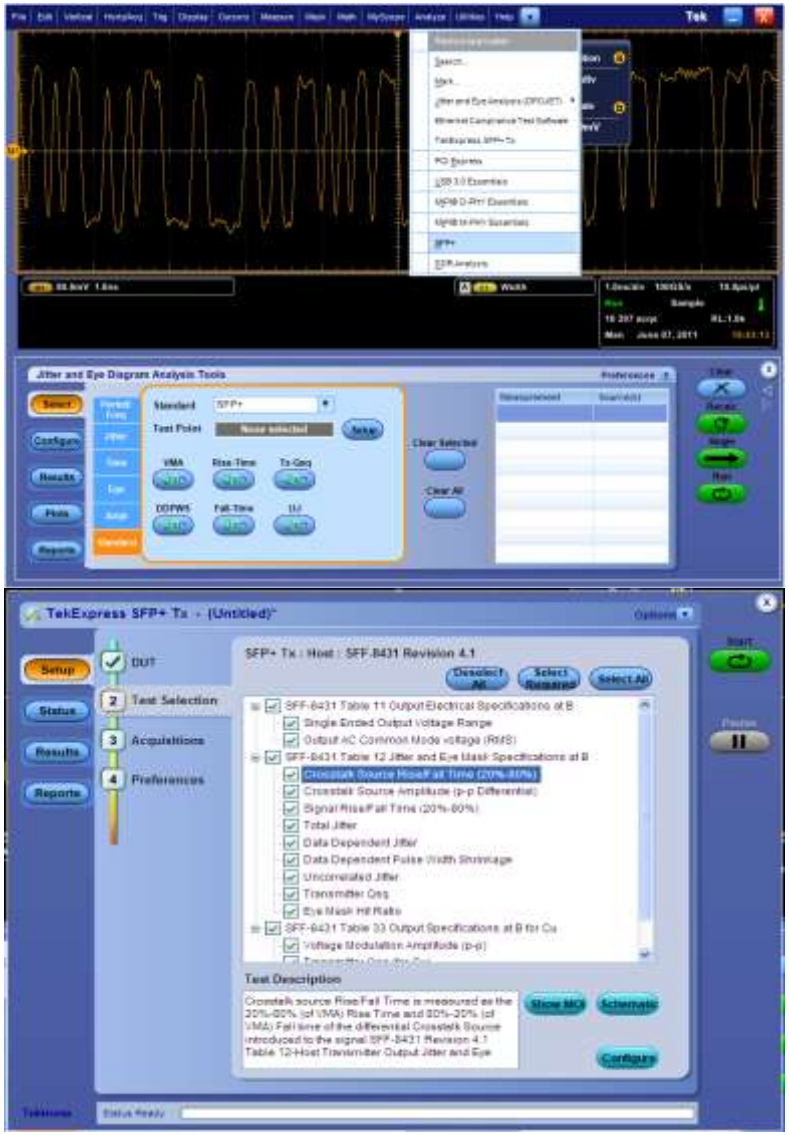


Source : Ethernet Alliance

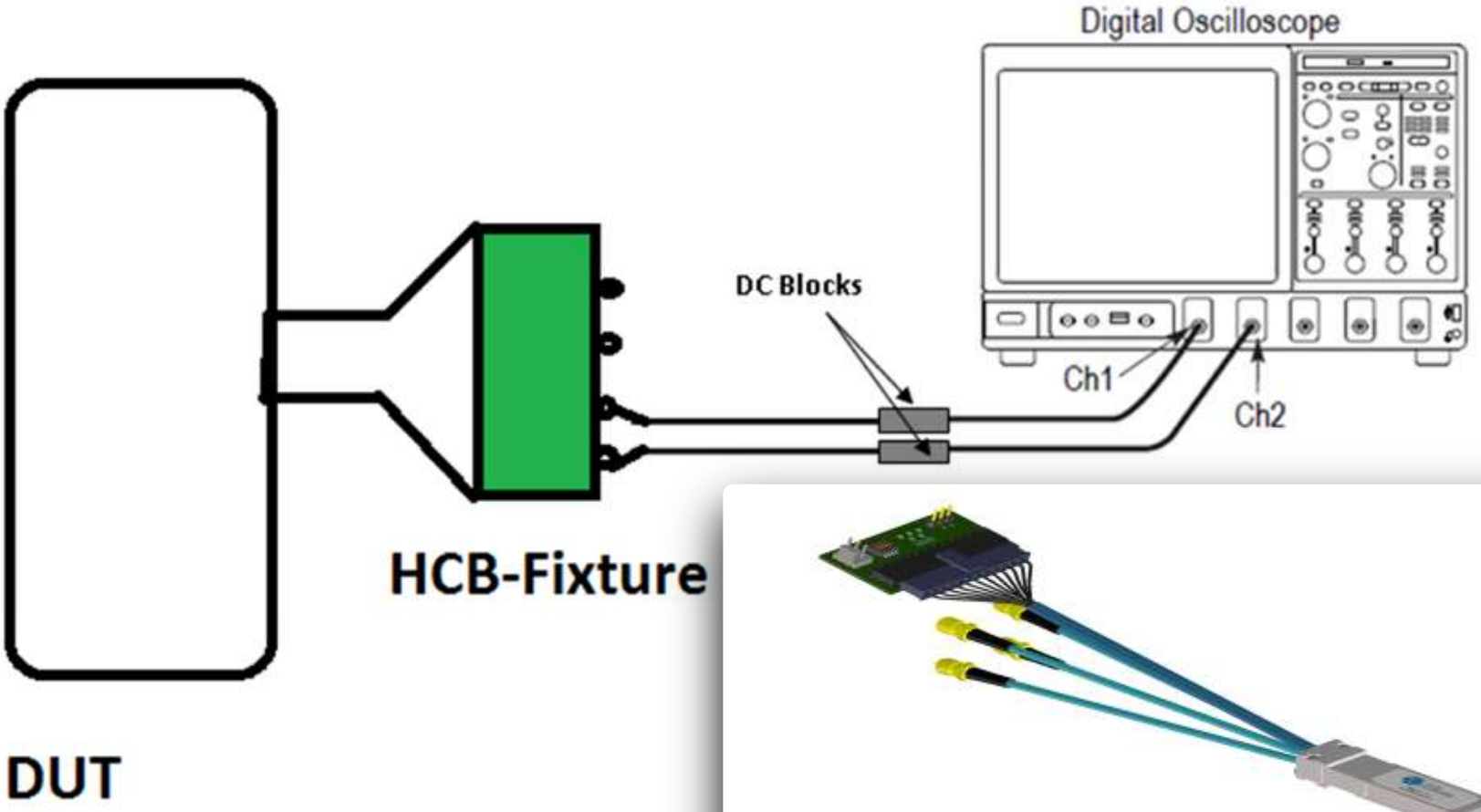
Next Big Thing
SFF-8431
SFP+

Tektronix SFP-TX – Automation & DPOJET Option

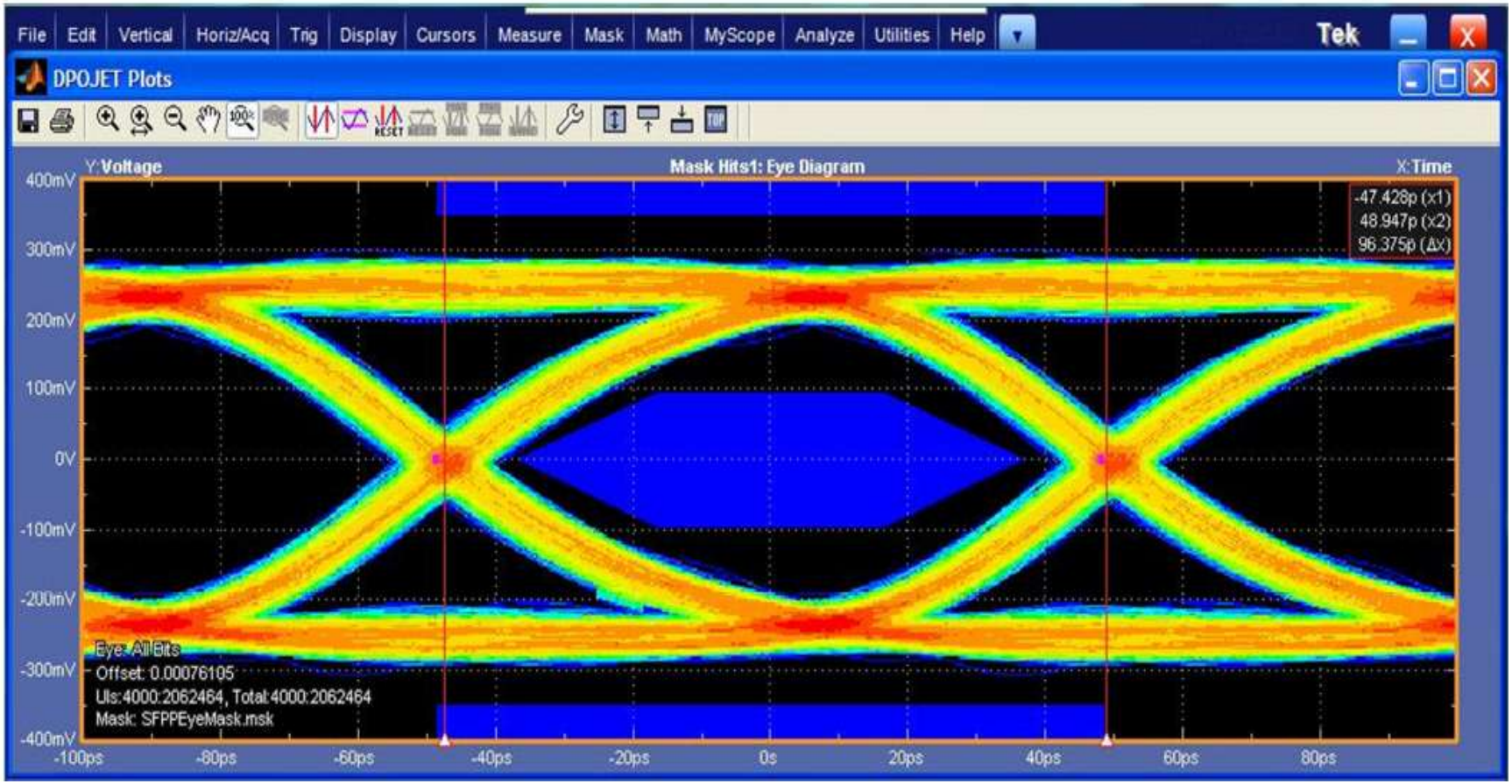
SL No.	Measuremnts	Signal Type Recommended	Limit Min	Target	Max	Units
Host Transmitter output electrical Specifications:						
1	Single Ended Output Voltage Range	PRBS31	-0.3		4	V
2	Output AC Common Mode voltage (RMS)	PRBS31			15	mV(RMS)
Host Transmitter Jitter and Eye Mask specifications						
3	Crosstalk 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



SFP test connection



SFP Eye Mask hit ratio :less than 5E10-5



光通信测试方案

- Telecom (125 Mb/s to 44.50 Gb/s)
- Datacom (gigabit Ethernet, 10 GbE, 40 GbE, 100 GbE, Fibre Channel to 16 GFC, and InfiniBand) solution

Introducing the DSA8300 Digital Serial Analyzer
More Performance and Versatility

- Industry's best native jitter noise floor, 425 fs $_{RMS}$ *typical* on up to 8 simultaneously acquired channels
- ≤100 fs $_{RMS}$ jitter noise floor, when equipped with the 82A04B on up to 6 simultaneously acquired channels
- 16,000 point native record length
- 16 bits of vertical resolution
- Optional fully integrated pattern synchronization
- 4X Pattern Sync throughput improvement
- **Clock Pre-scalar maximum input frequency 20 GHz *typical***
- **3 GHz Intel Core 2™ Duo CPU**
- **New user interface look and feel leveraging MS Windows 7 Ultimate Operating System**
- **XVGA (1024 X 768) 10.4 inch display**

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DSA8300 Digital Serial Analyzer
DSA8300 Optical Module Portfolio

Single and Multi-mode, Broad Wavelength (750 - 1650 nm) Modules	
80C07B	Supports standard rates to 2.7 Gb/s, high sensitivity, optional integrated clock recovery
80C08D	Supports all of the 8/10 Gb/s applications, high sensitivity, optional integrated clock recovery, optional Integrated CR
80C12B	Supports standard rates from 155 Mb/s – 11.3 Gb/s, high sensitivity - data pick-off for external CRU e.g. CR125A
80C14	Supports rates from 8.5 Gb/s – 14.063 Gb/s, high sensitivity – data pick-off for external CRU e.g. CR175A
80C15 New	Supports standard rates from 25.73 Gb/s – 28.05 Gb/s (maximum optical bandwidth > 32 GHz)
Single-mode, Long Wavelength (1100 - 1650nm) Modules	
80C11B	Optical bandwidth to 30GHz, supports 10Gbit/s up to14G+ standards, optional Integrated CR
80C10C	Optical bandwidth to 80GHz, supports all 40 and 100 Gb/s (4 x 25 Gb/s) standards, optional CR trigger pickoff for e.g. CR286A CRU, optional high sensitivity photo-receiver for use with external equipment (e.g. for optical BER testing with BERTScope)

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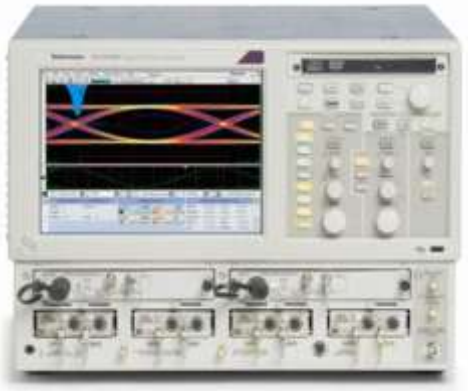
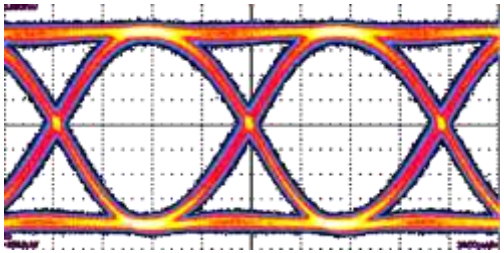
Tektronix 80C15 Optical Sampling Module Highlights

NEW

80C15

- Single-Channel Optical Plug-in Module for DSA8300
- Unfiltered Optical Bandwidth >32 GHz
- 62.5/125 µm Multi-Mode Fiber Input
- Short- and Long-Wavelength Support 780-1650 nm
- 200 kS/s Acquisition Rate
- Jitter Floor <150 fs_{RMS} (with 82A04B)
- Reference Receiver Filters:
  - ✓ 32G FibreChannel (28.05 Gb/s)
  - ✓ OTU4 (27.95 Gb/s)
  - ✓ 100Gbase-LR4/ER4/SR4 (25.78 Gb/s)
  - ✓ 26G EDR Infiniband (25.78 Gb/s)





26 Gb/s

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Industry-Leading Optical Portfolio

The 80C15 covers the space between current 80C14 and 80C10C modules

Feature / Specification	80C14	80C15 NEW	80C10C
Input Fiber Type	SMF + MMF 9, 50, 62.5 µm	**SMF + MMF** **9, 50, 62.5 µm**	SMF 9 µm
Wavelength Range	700-1650nm	**780nm-1650nm**	1290-1620nm
Unfiltered Optical Bandwidth	14 GHz	**32+ GHz**	80+ GHz
Unfiltered Risetime, typ	31 ps	**14 ps**	6 ps
Filter Rates	8.5 – 14.06 Gb/s	**25.78 – 28.05 Gb/s**	25.78 – 44.5 Gb/s
26Gb/s Mask Test Sensitivity AOP @ 1310nm	-16.5 dBm	***-9 dBm***	-7.5 dBm

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80C15 Optical Module
100G Single/Multi-mode Solution

New

80C15 Optical Module

Performance Specifications	
Single and multi-mode	9, 50, 62.5μm core
Supported wavelengths	700 – 1650 nm
Maximum Optical Bandwidth	>32 GHz
Optical Reference Receivers	25.78 Gb/s – 28.05 Gb/s
Sensitivity	-9 dBm (at 1310 nm)

Standards Supported

Standard	Data Rate
26G EDR Infiniband	25.78 Gb/s
100Gbase-LR4/ER4/SR4	4×25.78 Gb/s
OTU-4	4×27.95 Gb/s
32G Fibre Channel	28.05 Gb/s

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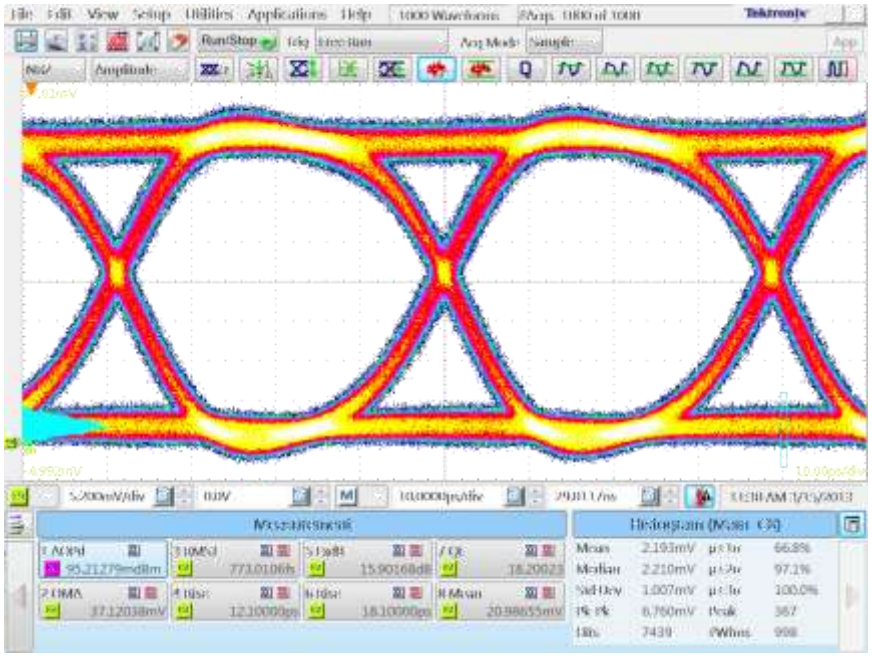
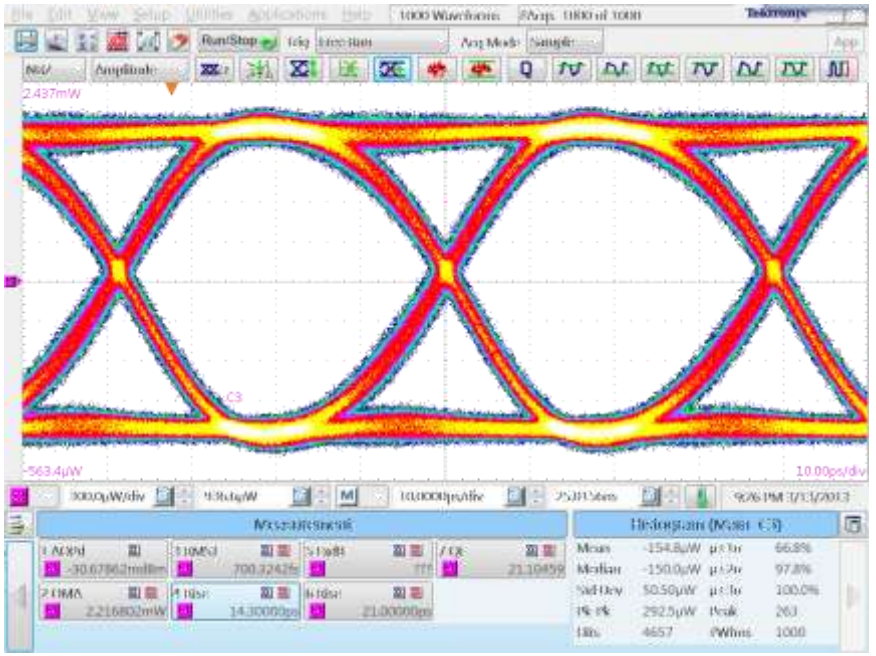
Unfiltered and Filtered 26Gb/s Eye Comparison

Unfiltered 30+GHz bandwidth



100GBase-R4 filter turned on



Signal source : 1550nm MZM Tx at 0dBm, 25.78125 Gb/s, PRBS31

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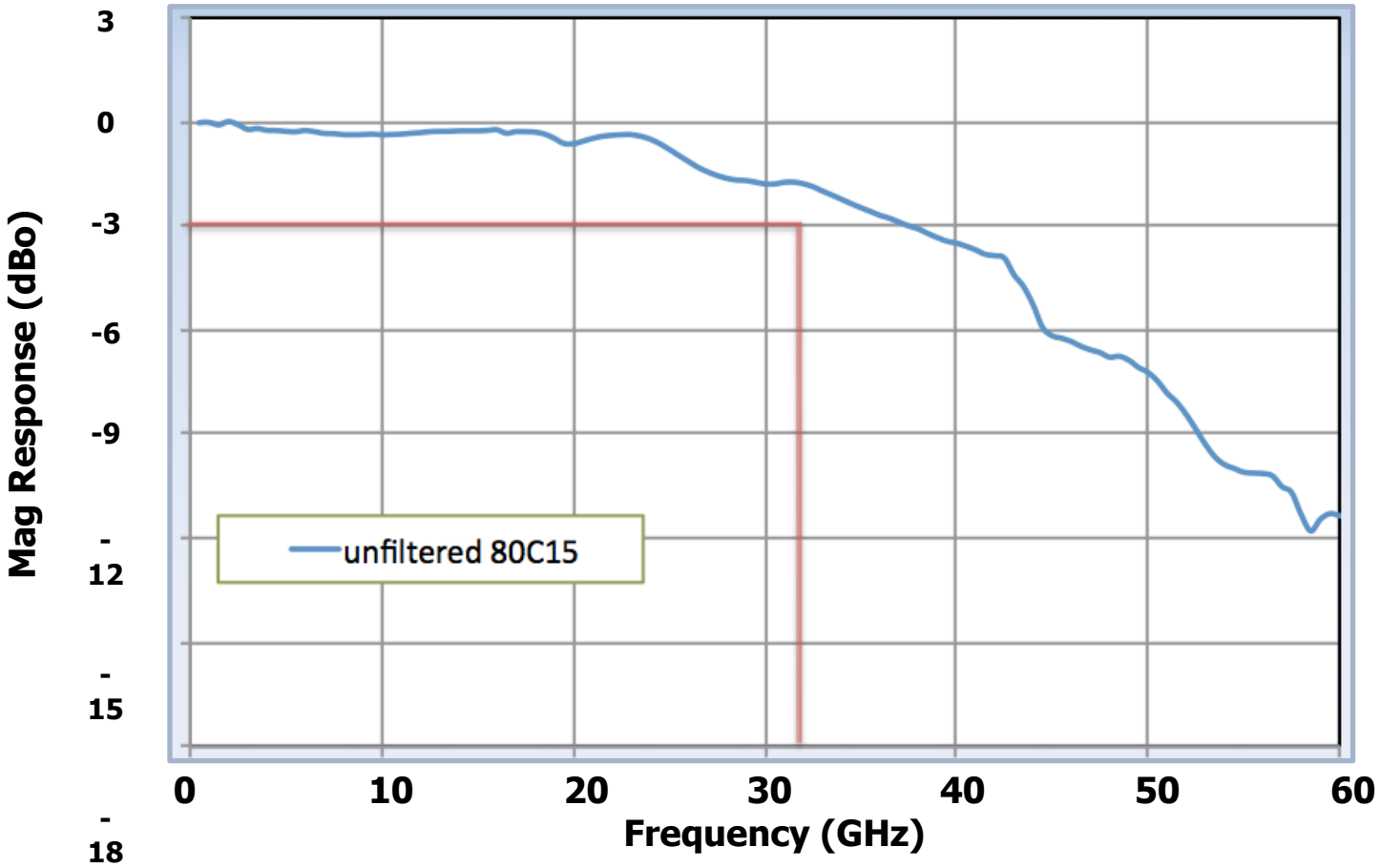
Unfiltered Optical Bandwidth >32GHz



Actual Measured Optical Bandwidth: 37 GHz

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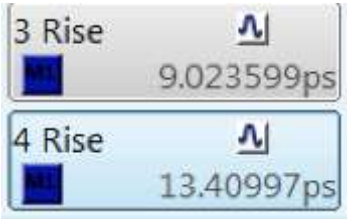
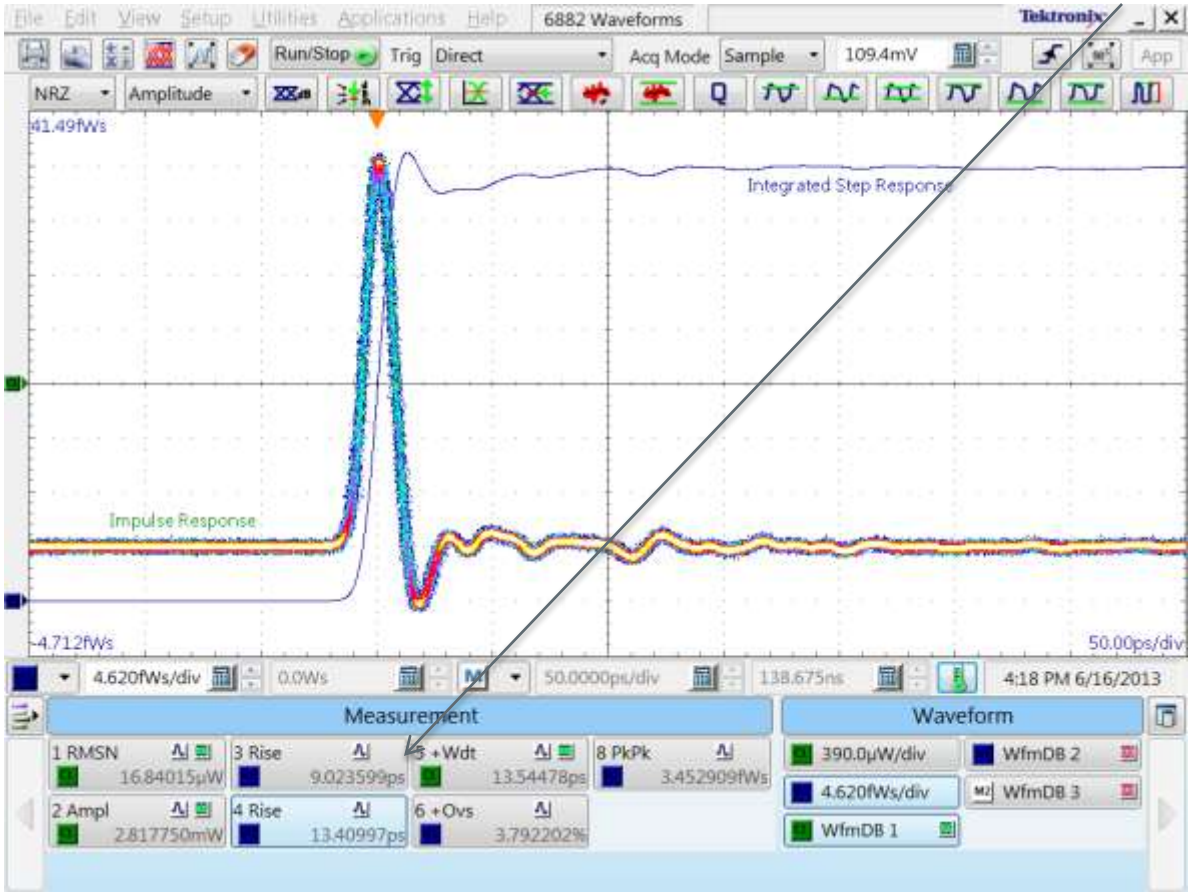
80C15 Unfiltered Transient Response

Measured Step Rise Time: 9.0 ps (20-80%)

13.4 ps (10-90%)





Impulse source: MLL width FWHM<1ps at 1550nm

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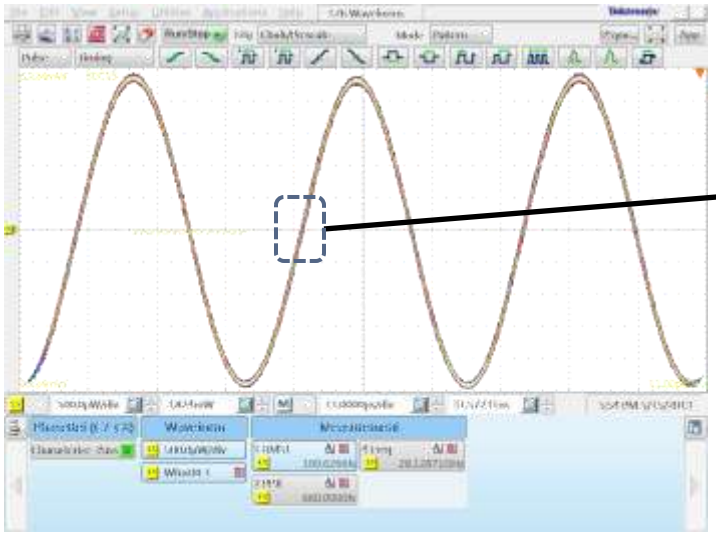
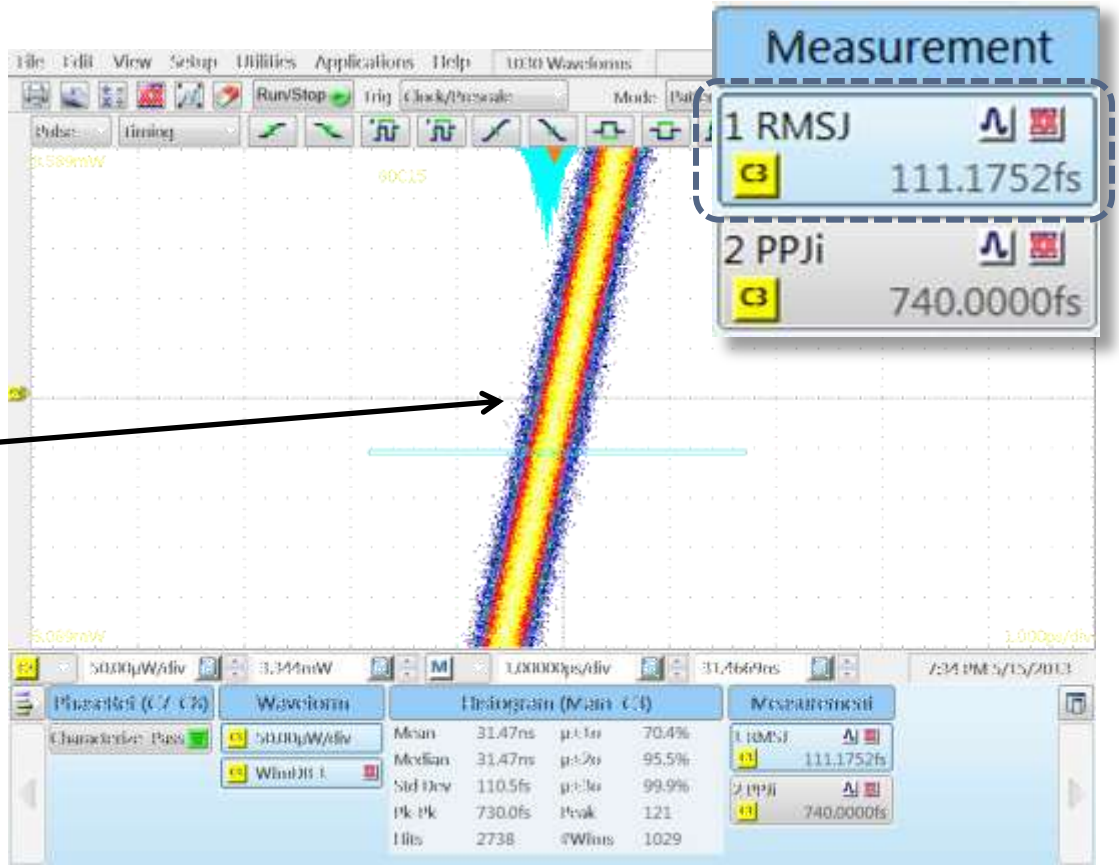
80C15 Optical Jitter Floor < 150 fs

New 82A04B PhaseReference module enables ultra-low jitter measurements of optical waveforms with a measured floor of ~110 fs $_{RMS}$



28GHz optical CLOCK waveform



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80C14 Optical Module
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

80C12B Optical Module
Tributary and 10G Rate, Single/Multi-mode Solution

80C12B

- **Performance Specifications**
  - Single and multi-mode (9, 50, 62.5μm core)
  - Supported wavelengths (700 – 1650 nm)
  - Maximum optical bandwidth – 12 GHz
  - Optical Reference Receivers – All 125 Mb/s through 11.3 Gb/s standards
  - Buffered electrical data pick-off to support external clock recovery
  - Recommended clock recovery, Tektronix CR175A or CR125A
- **80C12B Module with available ER-Calibrated for accurate repeatable ER measurements**
  - Accuracy: ±1.2% (–0.76 dB /+0.92 dB at 12dB)
  - Repeatability: ±0.6% (–0.39 dB / +0.42 dB at 12 dB)

Three configuration strategies available:

1. **Any 4 Trib. rate filters, options F0 through F12**
2. **All 10 G rates only (8.5 Gb/s to 11.3 Gb/s filters only), Opt. 10G only**
3. **Select any 3 Trib rate filters, plus 10GP (10G rates)**

Filter Opt.	Rate(s) Supported
F0	Unfiltered 12 GHz bandwidth and 8.500 ORR filter
F1	155.52 Mb/s Optical Reference Receiver (ORR) Filter
F2	622 Mb/s ORR Filter
F3	1.0625 Gb/s ORR Filter
F4	1.250 Gb/s ORR Filter
F5	2.125 Gb/s ORR Filter
F6	2.488, 2.500 Gb/s ORR Filter
F7	2.666 Gb/s ORR Filter
F8	3.125, 3.188 Gb/s ORR Filters
F9	4.250 Gb/s ORR Filter
F10	5.000 Gb/s ORR Filter
F11	6.144 Gb/s ORR Filter
F12	7.373 Gb/s ORR Filter
10G	8.500, 9.95, 10.31, 10.51, 10.66, 10.71, 11.1, 11.3 Gb/s ORR Filters plus Unfiltered full bandwidth path (typically 12 GHz)
10GP	8.500, 9.95, 10.31, 10.51, 10.66, 10.71, 11.1, 11.3 Gb/s ORR Filters plus Unfiltered full bandwidth path (typically 12 GHz) – specify 3 additional filter options (F1-F12) to be included.

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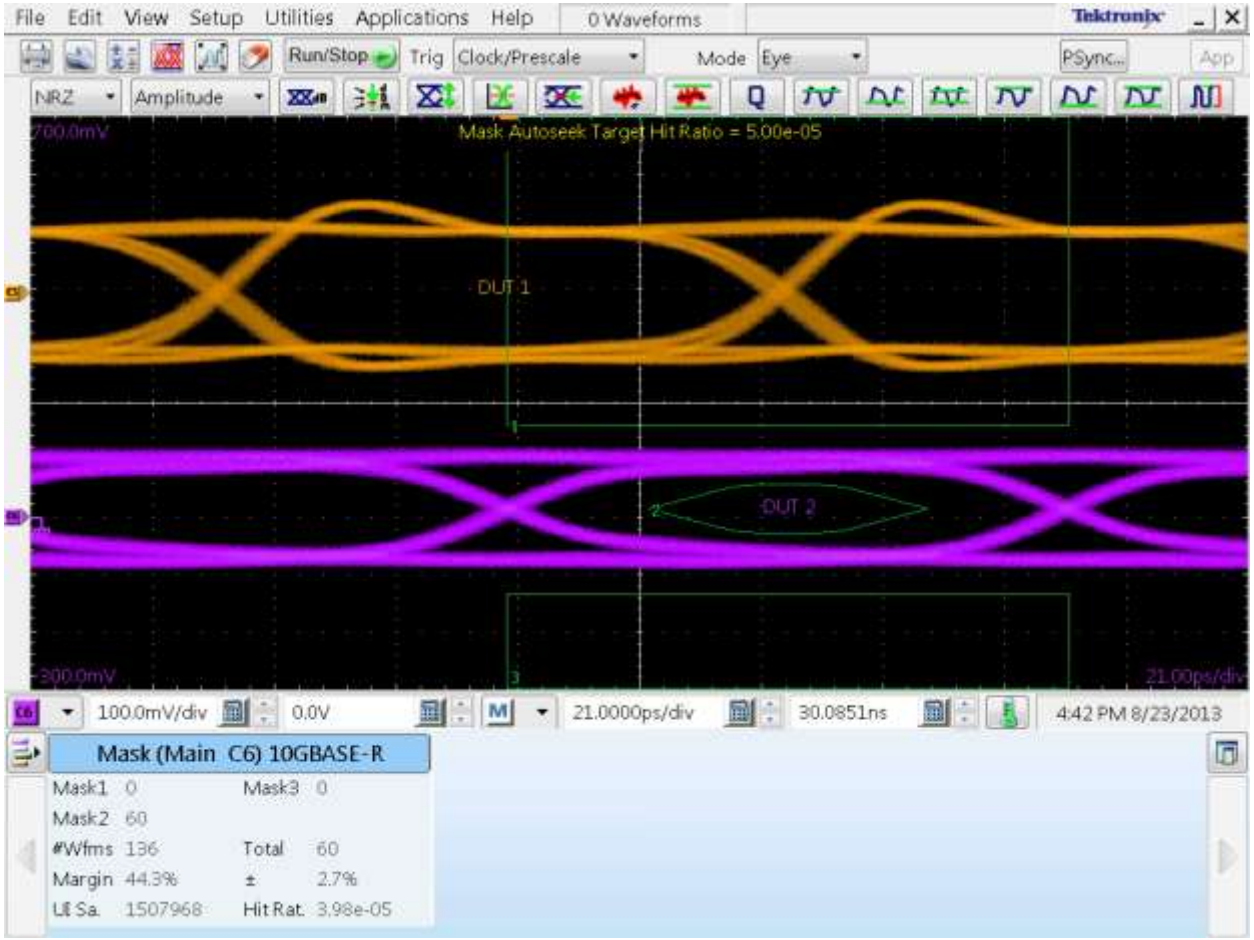
Automated Mask Compliance Testing and Measurements

Multiple signals acquired simultaneously and mask testing done on each signal sequentially improves test throughput and compliance accuracy.

Automated mask margin testing and mask hit ratio measurement simplifies compliance testing



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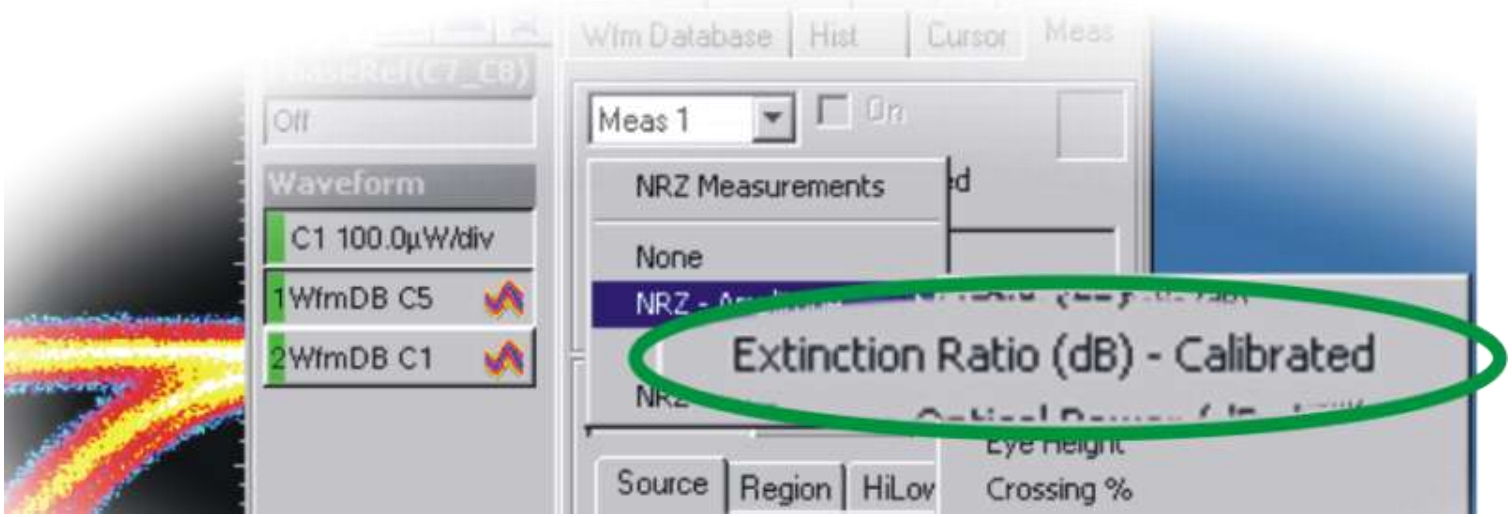
Accurate, Repeatable ER Measurements with “ER Calibrated”

- New calibration factor for the 2nd order errors
- Established in the factory calibration process and saved in the module
- Accessible as a new “ER Calibrated” measurement (while old measurement remains available)
- Calibration is provided on a reference ER source
- Both Absolute accuracy and repeatability are provided



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ER Calibrated
Measurement Confidence and Improved Yields

- ER Calibrated: Guaranteed Absolute Accuracy:
  - +/- 1.2 % (-0.49dB /+0. 56dB @ 10 dB)
- ER Calibrated: Typical Repeatability:
  - +/- 0.6 % (-0.25dB / +0.27dB @ 10 dB)
- Removal of 2nd order effects improves the repeatability and absolute accuracy of ER result for the industry
- The result is guaranteed against Tektronix calibration reference source and against Tektronix verification signal

- **For manufacturing this means:**
  - **Better yield, or longer reach, or better margins**
- **For component and module manufacturers and module users this means**
  - **Clarity on quality and compliance**
- **As the usage of the ER Calibrated grows, you can increase your competitiveness with DSA8300 "ER Calibrated"**

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DSA8300 ER Calibrated
Order New or Upgrade Your Existing Modules

- ER Calibrated is available on new DSA8300/8200 Optical Modules as Option 01 for:
  - 80C12B
  - 80C08D
  - 80C11B
  - 80C02

- ER Calibrated can be added to your existing 8000 Series Optical Modules by ordering 80CUP, Opt. 01 for the same modules.
  - Requires 8000 Series mainframe running Windows® XP or Windows® 7 operating systems

Optical Summary

Support for all major rates from 155 Mb/s to 44.5 Gb/s

- SMF and MMF support from 155 Mb/s to 28.05 Gb/s in a single mainframe simultaneously
- Optical bandwidth to 80+GHz
- Ultra-low jitter
  - Optical: ≤150 fs $_{RMS}$ jitter noise floor
  - Electrical: ≤100 fs $_{RMS}$ jitter noise
  - Integrated & Calibrated Clock Recovery
  - Tektronix CR286A up to 28.6 Gb/s
  - Third party CRU to 44.5 Gb/s
- Versatile six slot modular architecture
  - Supports optical / electrical / TDR / frequency domain analysis applications in a single instrument

Support for all major rates from 155 Mb/s to 44.5 Gb/s

Standard	Line Rate	80C12B	80C14	80C15	80C10C Opt F1
Fiber Type Supported		SM & MM	SM & MM	SM & MM	SMF
OC-3/STM-1	155 Mb/s	✓			
OC-12/STM-4	622 Mb/s	✓			
FC1063	1.0625 Gb/s	✓			
ENET1250	1.250 Gb/s	✓			
FC2125	2.125 Gb/s	✓			
OC48//STM48, GBE, INF2500	2.488 Gb/s 2.500 Gb/s	✓			
FEC2.666	2.666 Gb/s	✓			
!0GBASE-X4, FC3188	3.125 Gb/s 3.188 Gb/s	✓			
FC4250	4.250 Gb/s	✓			
INF5000	5.000 Gb/s	✓			
OBSAI6144	6.144 Gb/s	✓			
CPRI7373	7.373 Gb/s	✓			
FC8500*8, OC-192/STM-64, 8GFC, 10GBASE-W, 10GBASE-R, 40GBASE-R4, 100GBASE-R10, 10GFC, FEC10.66, FEC10.71, FEC11.10, FC11317	8.500, 9.95,10.31, 10.51,10.66,10.71,11.1, 11.3 Gb/s ORR	✓	✓		
12.5 Gb/s FEC	12.5 Gb/s		✓		
16 GFC	14.025 Gb/s		✓		
Infiniband FDR	14.063 Gb/s		✓		
100GBase-LR4, 100GBase-ER4 Infiniband EDR (LW)	4 x 25.781 Gb/s				✓
26G EDR Infiniband 100Gbase-LR4/ER/SR4	25.781 Gb/s			✓	
SONET/SDH OTU4	4 x 27.95 Gb/s			✓	✓
32G FibreChannel	28.05 Gb/s			✓	
40GBase-FR	41.25 Gb/s				✓
OC-768 / STM-256, VSR-2000	39.813 Gb/s				✓
OTU3 (OC-768 + G.709 FEC), VSR-2000 , 4x10G LAN-PHY (OTU3)	43.018 Gb/s 44.50 Gb/s				✓

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DSA8300 Digital Serial Analyzer

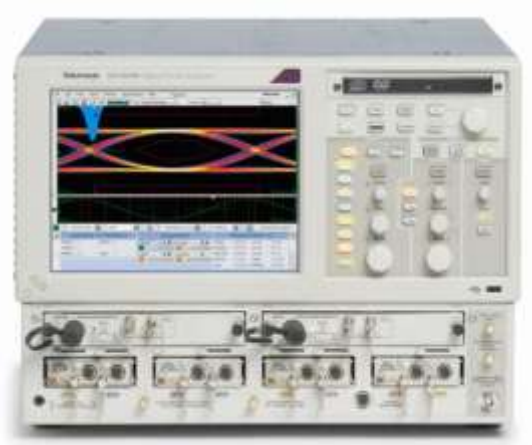
Key specifications and ordering information

Electrical Modules	Channels	Bandwidth	TDR System Incident Rise Time (10-90%)	TDR System Reflected Rise Time (10-90%)	Remote Sampler
80E01	1	50 GHz	-	-	-
80E03 / 04	2	20 GHz	23 ps (80E04)	28 ps (80E04)	With 80N01 extender cable
80E07B / 8B	2	20/30 GHz	18 ps (80E08B)	20 ps(80E08B)	Yes
80E09B	2	30/40/60 GHz	-	-	Yes
80E10B	2	30/40/50 GHz	12 ps	15 ps	Yes
80E11 / 11X1	2/1	40/60/70 GHz	-	-	With 80N01 extender cable

Optical Modules	Channels	Bandwidth	Clock Recovery (Min/Max)	Filter Rates Supported (Min/Max)
80C07B	1	2.5 GHz	155 Mb/s - 2.666 Gb/s	155 Mb/s - 2.5 Gb/s
80C08D	1	10 GHz	9.8 Gb/s - 12.6 Gb/s	9.953 Gb/s - 11.3 Gb/s
80C10C	1	80+ GHz	Provided by Opt CRTP and CR286A	25.8 Gb/s - 43.018 Gb/s
80C11B	1	30 GHz	9.8 Gb/s - 12.6 Gb/s	9.953 Gb/s - 11.3 Gb/s
80C12B	1	12 GHz	Provided by CR125A	155 Mb/s - 11.4 Gb/s
80C14	1	14 GHz	Provided by CR175A or CR286A	8.500 Gb/s - 14.025 Gb/s
80C15	1	32 GHz	NA	25.78 Gb/s - 28.05 Gb/s

Key Analysis Software	
80SSPAR	IConnect S-Parameters and Z-Line Software
80SICMX	IConnect and MeasureXtractor Signal Integrity TDR and S-Parameter Software
80SICON	IConnect Signal Integrity TDR and S-Parameter Software
80SJNB	Essential & Advanced Jitter, Noise and BER Analysis Software
80SJARB	Basic Jitter Analysis Software

Recommended Probes and Accessories	
A wide variety of accessories are available for the DSA8300, including:	
80A02	DSA8300 EOS/ESD Protection Module
80A03	TekConnect Probe Interface
82A04B	Phase Reference Module
P8018	20 GHz Single-Ended TDR Probe
P80318	18 GHz 100 Ω Differential Impedance TDR Hand Probe
CR125A CR175A CR286A	12.5, 17.5 and 28.6 GB/sec Clock Recovery Instruments



DSA8300 / Option	Description
DSA8300	Digital Signal Analyzer mainframe
Opt. ADTRIG	Add Advanced Trigger (required for JNB or JNB01)
Opt. JNB	Add 80SJNB Essentials
Opt. JNB01	Add 80SJNB Advanced
Opt JARB	Add 80SJARB (included in JNB & JNB01)
Opt. ICMX	Add IConnect with Measurement Extractor
Opt. ICON	Add IConnect Signal Integrity Software
Opt. SPAR	Add IConnect S-parameter and Z-line

Recommended Service Options:	
Opt. R5	5 year repair service plan
Opt. C5	5 year calibration service plan
Opt G3/G5	3 or 5 year Gold Care service plan

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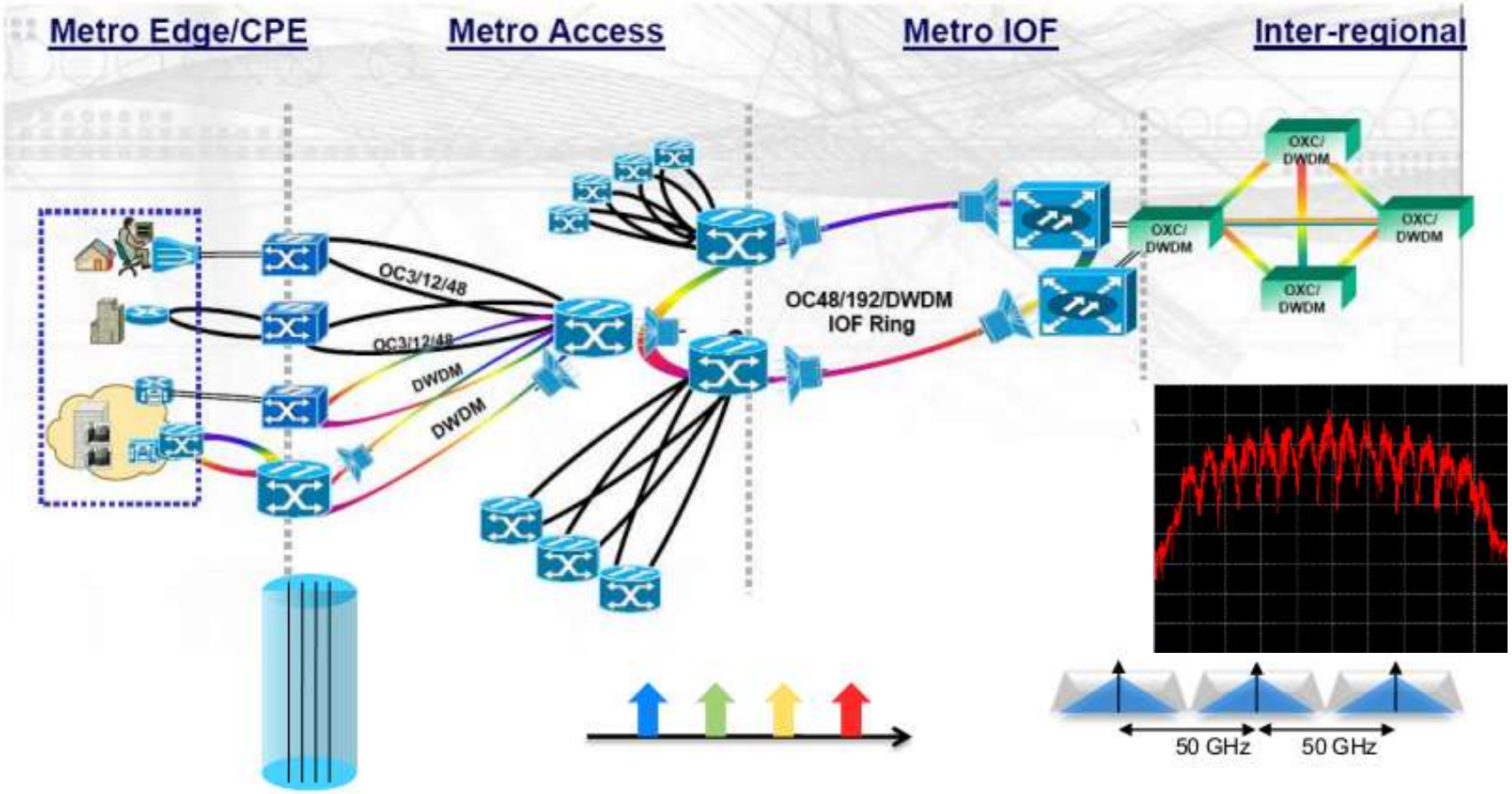
Outline

- Coherent Optical Solution
- Intradyne Coherent Receiver(ICR) test
- Multi-carrier Support for 400G/1T (NEW!)
- Summary/Conclusion

Some feasible ways to implement 100G



4 fiber/1 wave
4 x 25G
NRZ

1 fiber/4 wave
4 x 25G
NRZ

1 fiber/1 wave
Amplitude/phase
modulation

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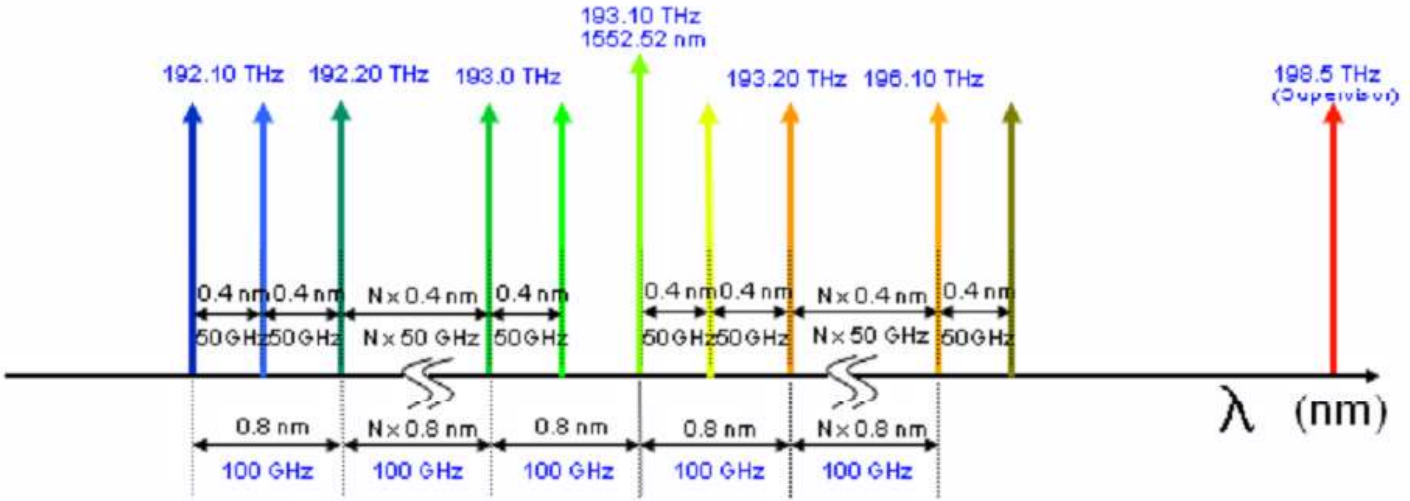
Why Coherent Modulation

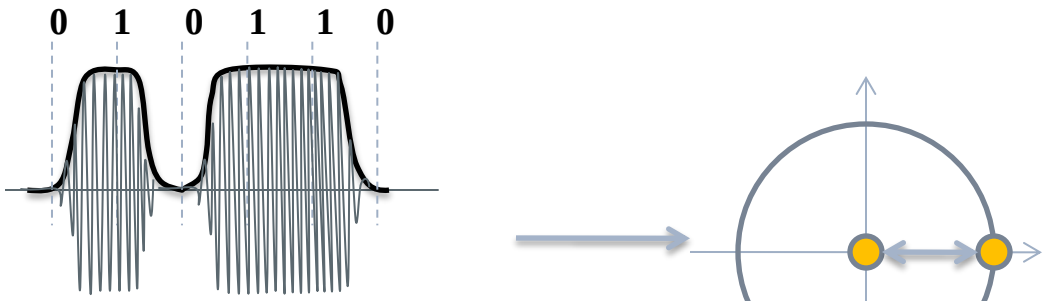


- Limited Bandwidth on ITU grid
  - 50GHz carrier spacing for installed DWDM equip
  - 100Gb/s pushes spectrum of information to this limit
- Dispersion(CD&PMD) limits transmission distance for high direct modulation rate
- Coherent modulation enables more efficient bandwidth utilization
- Coherent detection captures the full electric field of the optical signal allowing for more effective dispersion compensation

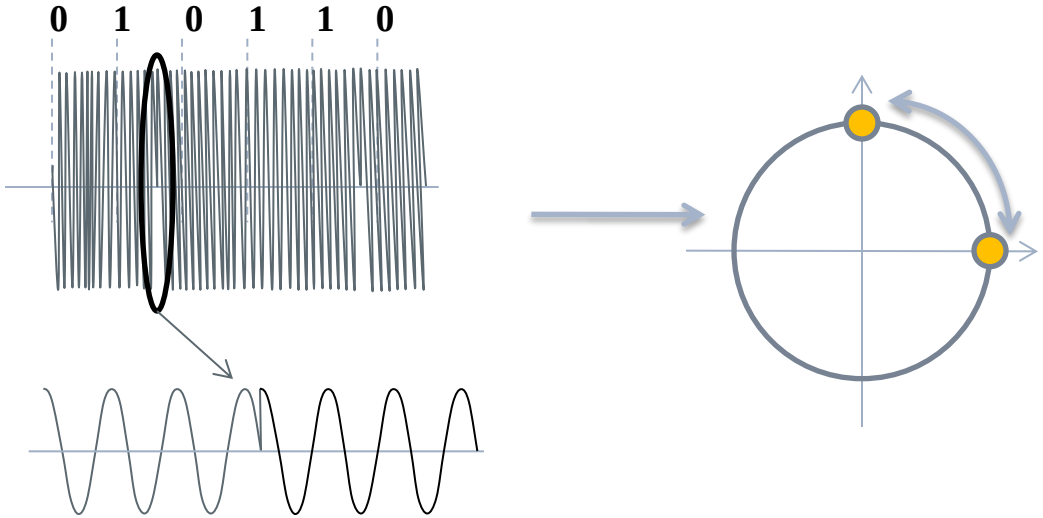
Compelling advantage for coherent

- Higher bit rates per wavelength have best economics
- Bandwidth and link quality set by infrastructure
- Complex modulation allows more bits per hertz
- Coherent detection
  - Enables software-based impairment compensation
  - Provides highest bits/hertz
  - Enables huge selection of modulation formats
  - Huge success in longhaul may lead to other applications

Optical Modulation Methods

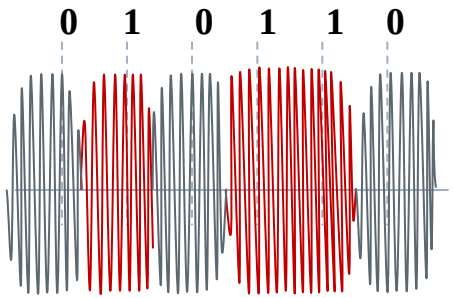


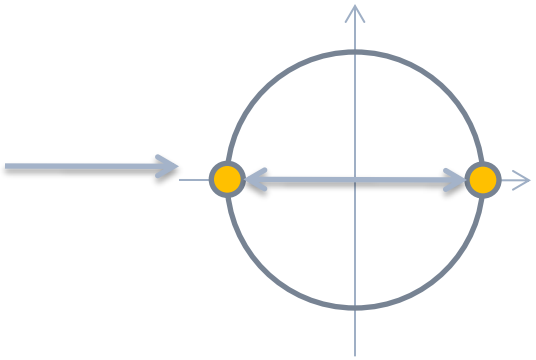
Pure AM (OOK)



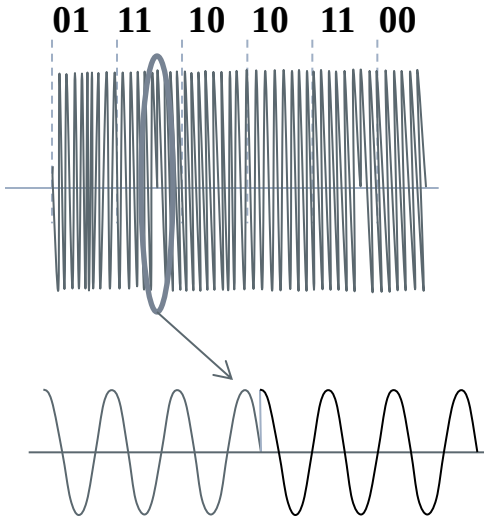
Pure PSK

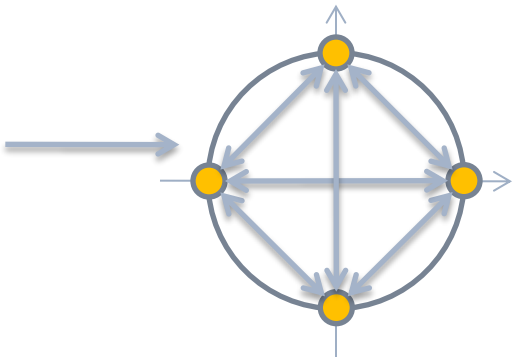
Optical Modulation Methods continued





Typical BPSK

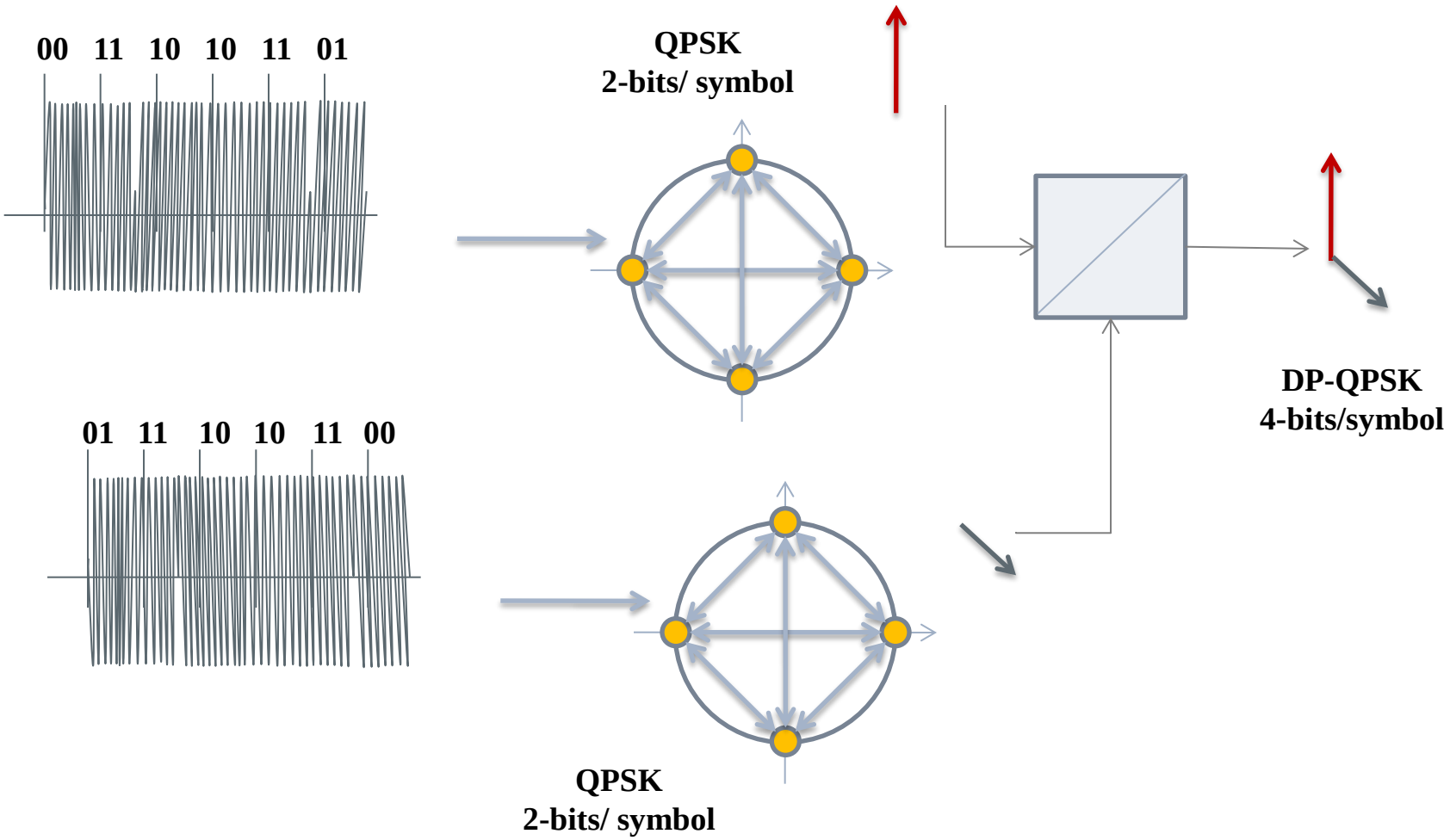




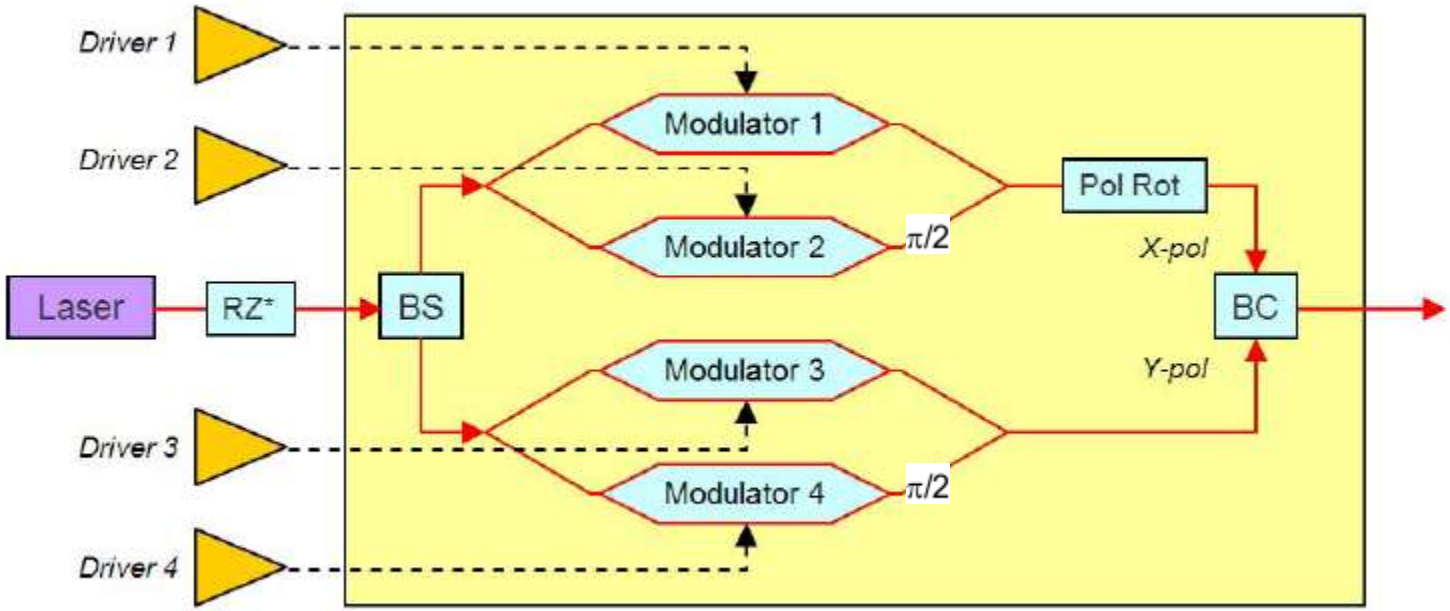
Typical QPSK

2-bits/ symbol

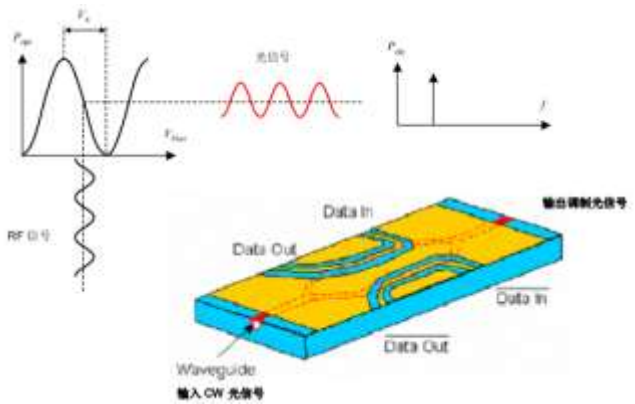
Optical Modulation Methods continued



Polarization Multiplexed QPSK Integrated Transmitter

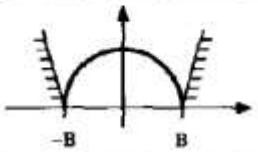
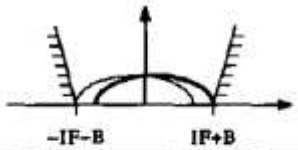
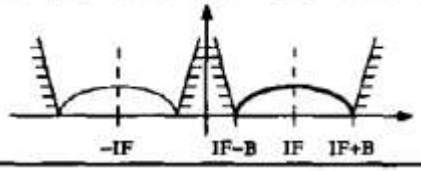


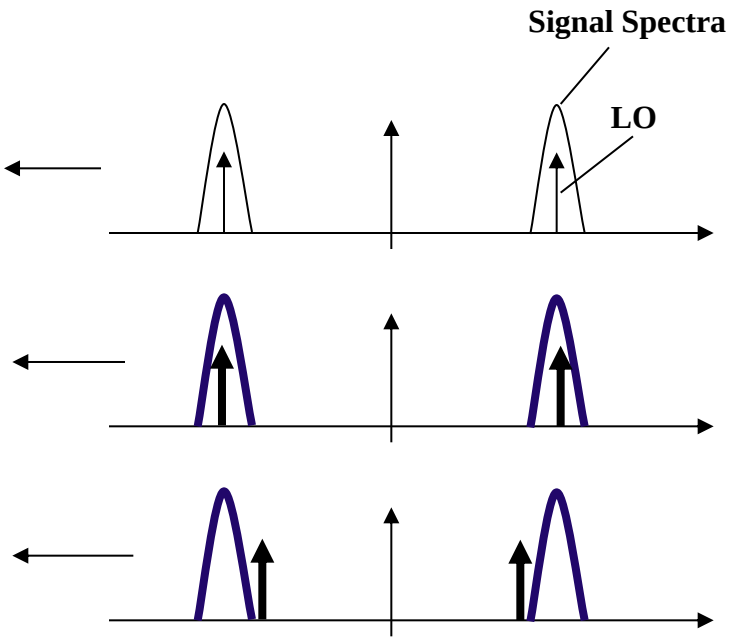
* Optional RZ Carver



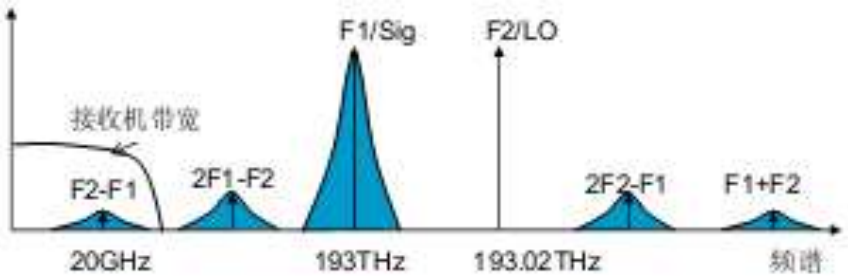
Intradyne + DSP Make It Work

TABLE I
COHERENT OPTICAL TRANSMISSION SYSTEMS (IF = INTERMEDIATE FREQUENCY; B = BANDWIDTH OF BASEBAND SIGNAL)

system	IF spectrum	IF
homodyne		IF = 0 Optical PLL
intradyne		IF < B
heterodyne		IF > B



Without PLL, frequency and phase error must be corrected in DSP



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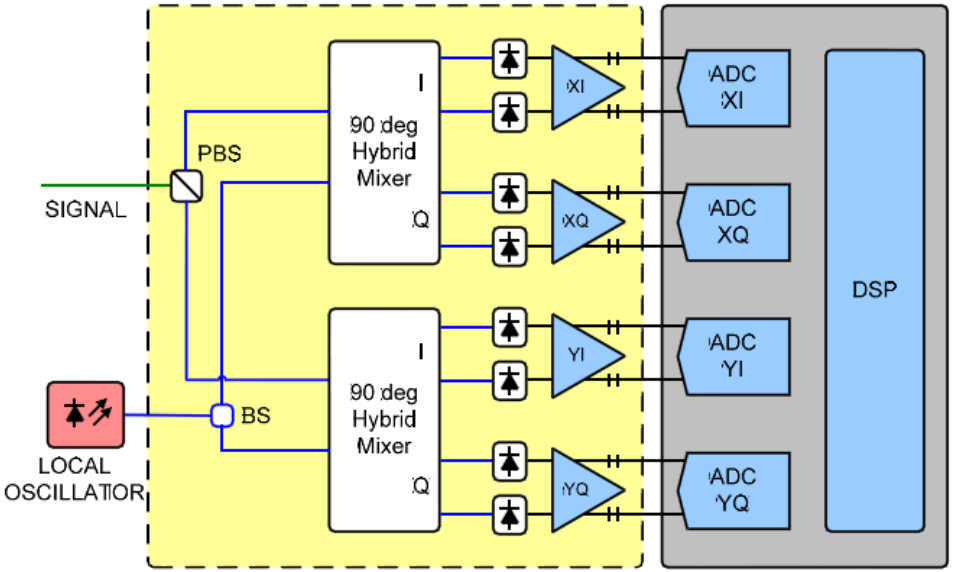
Integrated Dual Polarization Intradyne Coherent Receivers (ICR)

Replace input signals with reference signals



Replace ADC with real-time oscilloscope

New OIF Agreement IA OIF2009.033.06

Test overall:

- **Path gains**
- **Cross talk**
- **Phase angles**

At any frequency or wavelength

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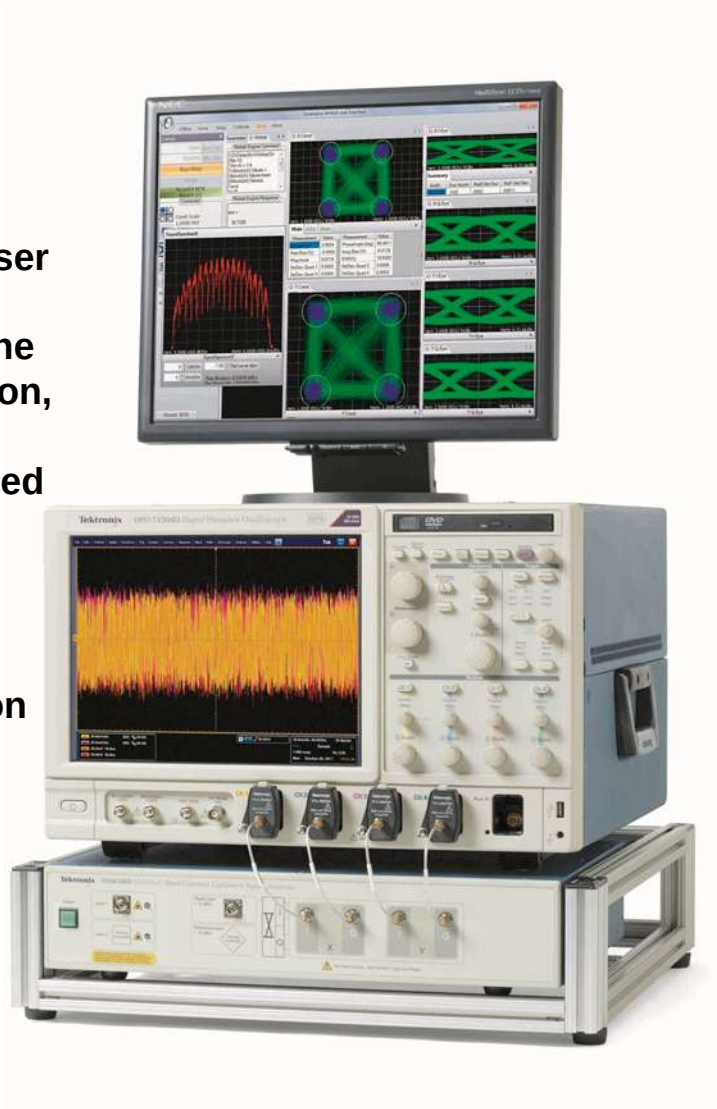
OM4106D 33 GHz Coherent Lightwave Signal Analyzer for >100Gb/s Analysis

Complete and open solutions to complex measurement challenges in long-haul fiber-optic communications

- **Advanced dual-polarization in-phase and quadrature receiver with integrated signal and reference tunable laser sources**
- **Open-architecture MATLAB-based computational engine offers powerful phase-recovery analyses with polarization, bit-error rates, and record/playback**
- **Intuitive graphical user interface controls frequently-used instrument functions:**
  - **Laser control**
  - **Modulation schemes**
  - **PRBS or user-generated data**
- **Accessories available to easily verify optical calibration**



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Tektronix OM4000 series ICR compliance with OIF

- Only the T&M vendor in OIF member list
- First instrumentation ICR in the world

OIF OPTICAL INTERNETWORKING FORUM

IA # OIF-DPC-RX-01.1
IA for Integrated Intradyne Coherent Receivers

NEC	Tektronix
NeoPhotonics	Telcordia Technologies
Nokia Siemens Networks	Tellabs
NTT Corporation	TeraXion
Oclaro	Texas Instruments Iain Robertson
Opnext	Time Warner Cable
Picometrix	TriQuint Semiconductor
PMC Sierra	u2t Photonics AG
QLogic Corporation	Verizon
Semtech	Vitesse Semiconductor
SHF Communication Technologies	Xilinx
Sumitomo Electric Industries	Xtera Communications
Sumitomo Osaka Cement	Yamaichi Electronics Ltd.
TE Connectivity	ZTE Corporation

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Measurement Algorithm for modulation quality

- Industrial standard open algorithm
- Compliance with IEC specification

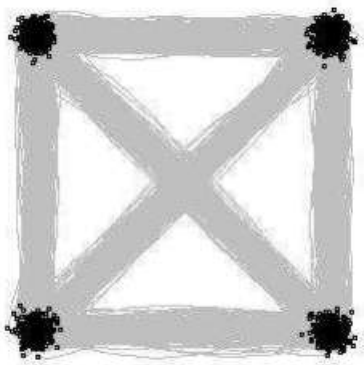

Figure 2 – IQ diagram for the same QPSK coding

$$\mathrm{EVM}_{\mathrm{rms}} = \sqrt{\frac{1}{N}\sum_{n=1}^{N}\mathrm{EVM}(n)^2}$$

IEC

86C/1071/DTR

DRAFT TECHNICAL REPORT

Project number	**IEC 61282-10/TR/Ed1**
IEC/TC or SC: **SC86C**	Secretariat: **USA**
Distributed on: **2012-06-01**	Voting terminates on: **2012-08-03**
Also of interest to the following committees	Supersedes document: N/A
Functions concerned	
☐ Safety ☐ EMC ☐ Environment ☒ Quality assurance	

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Title

IEC 61282-10/TR/Ed1: Fibre optic communication system design guides – Part 10: Characterization of the quality of optical vector-modulated signals with the error vector magnitude

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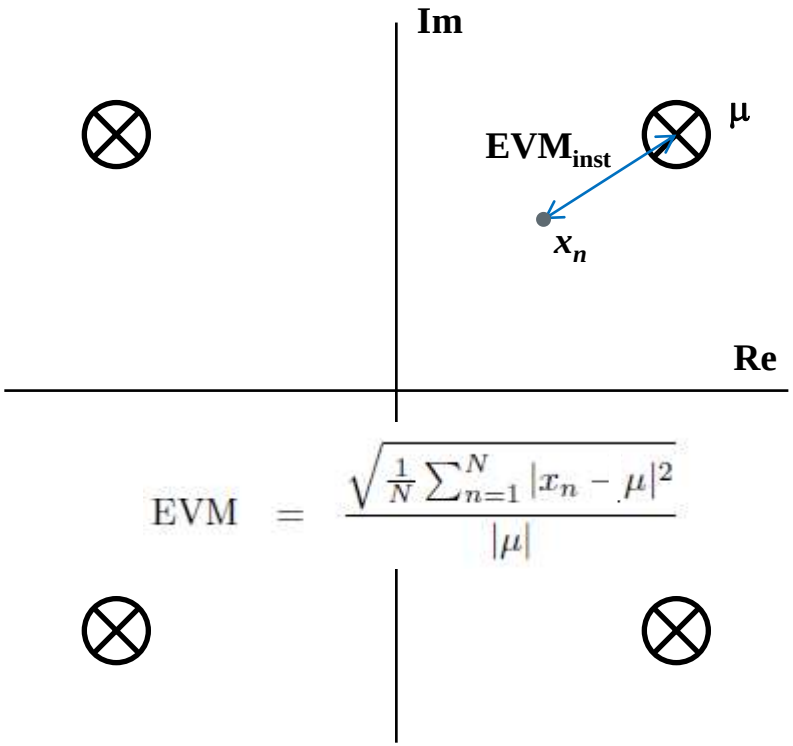
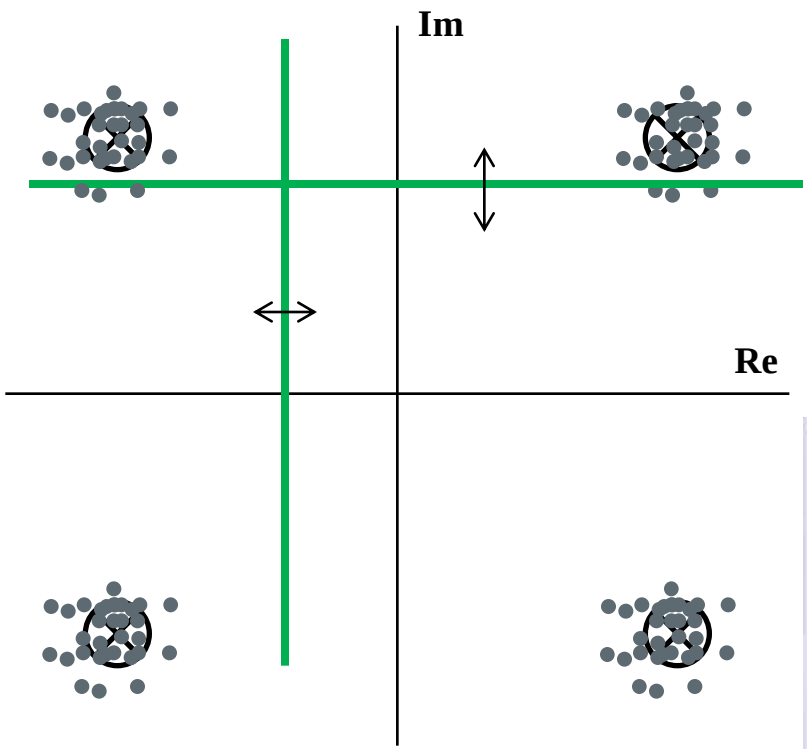
Measuring TX Constellation Imperfections: EVM

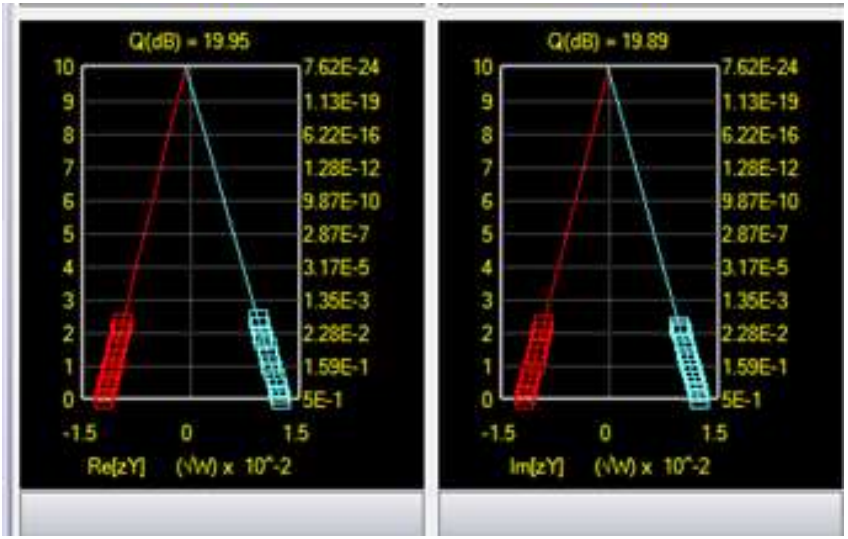


- Distance of a symbol point from the ideal location.
  - Instantaneous or rms value
  - Normalized to ideal symbol magnitude
- QAM EVM often normalized to largest symbol magnitude

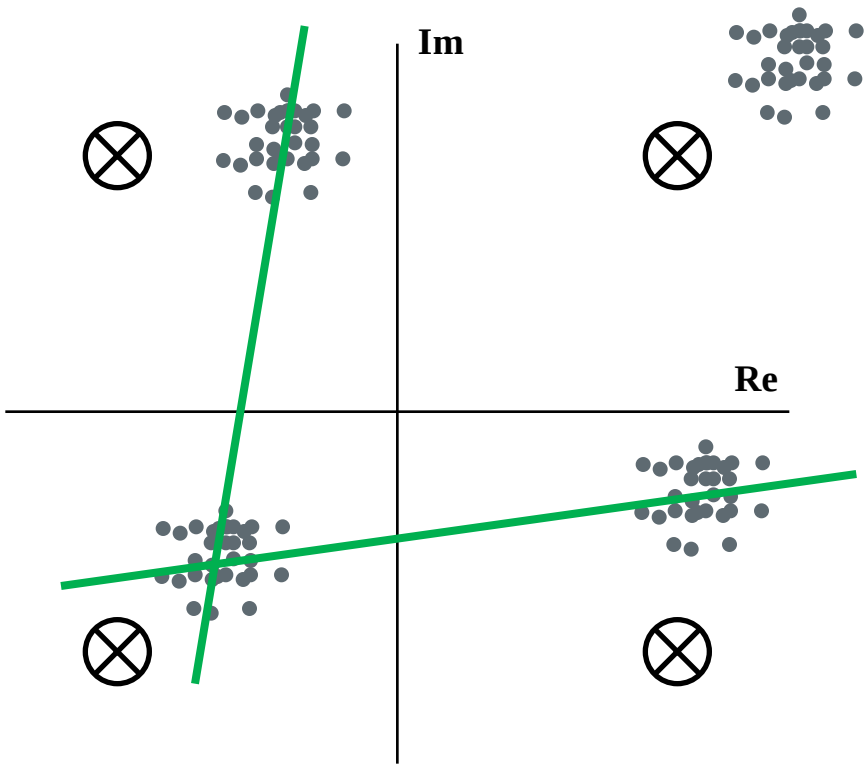
Exclusive:
Measuring TX Constellation Imperfections: Q-factor

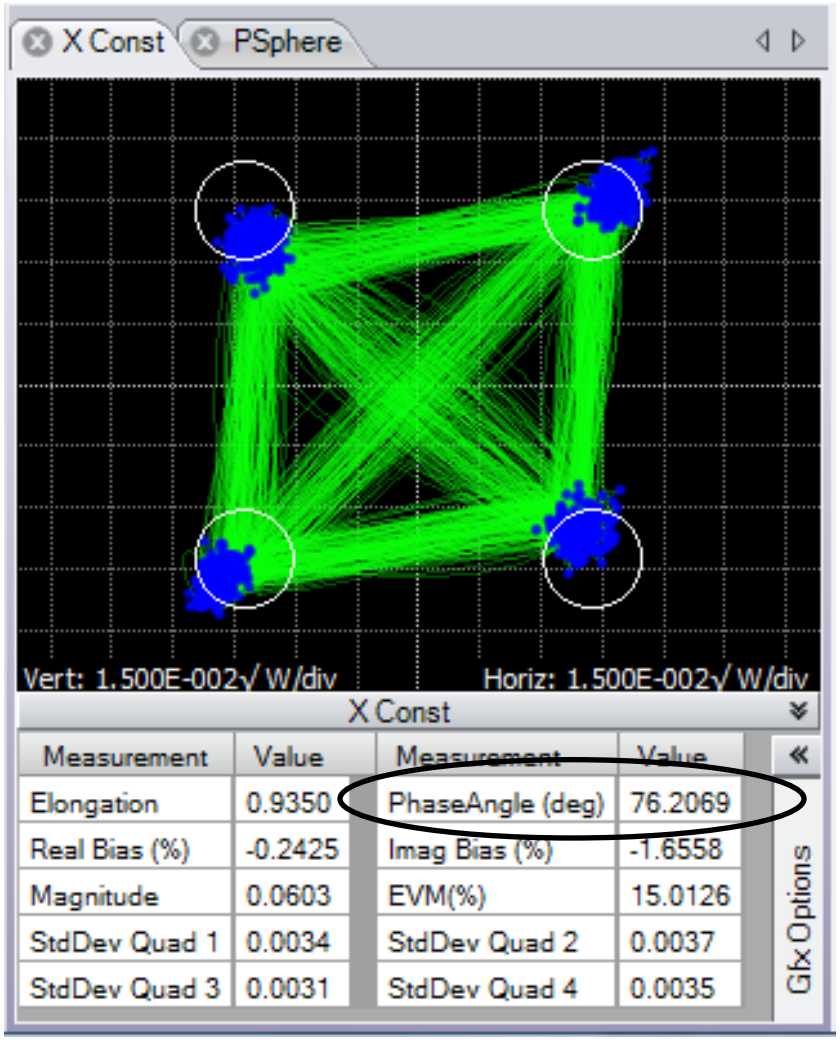


- Counts errors as decision threshold is moved.
- Errors fitted to error function in “Q-space”
- → Plot, max-Q and optimum decision threshold

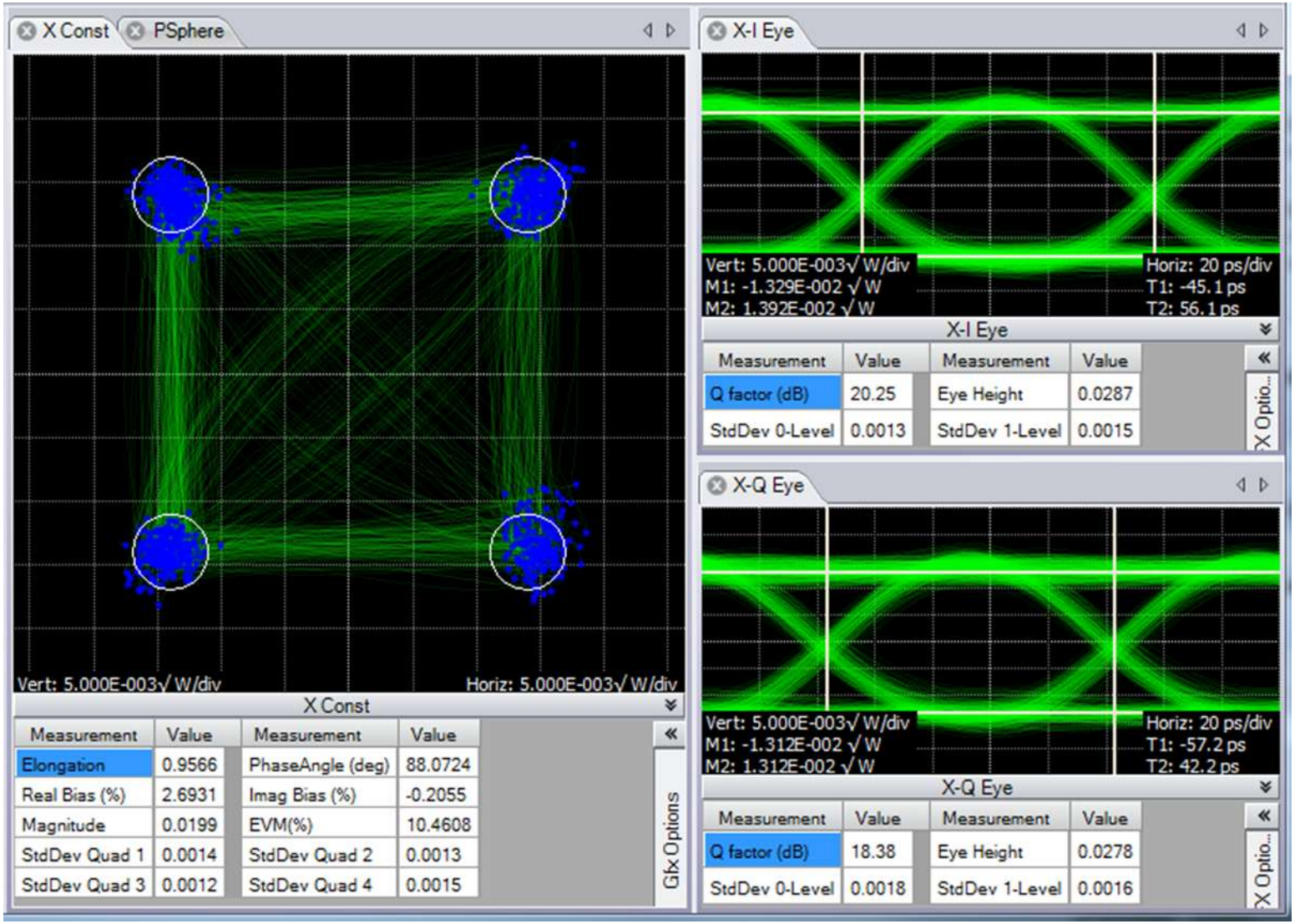


Measuring TX Constellation Imperfections: Phase Angle





Exclusive:
Example: Adjusting Tributary Timing Skew



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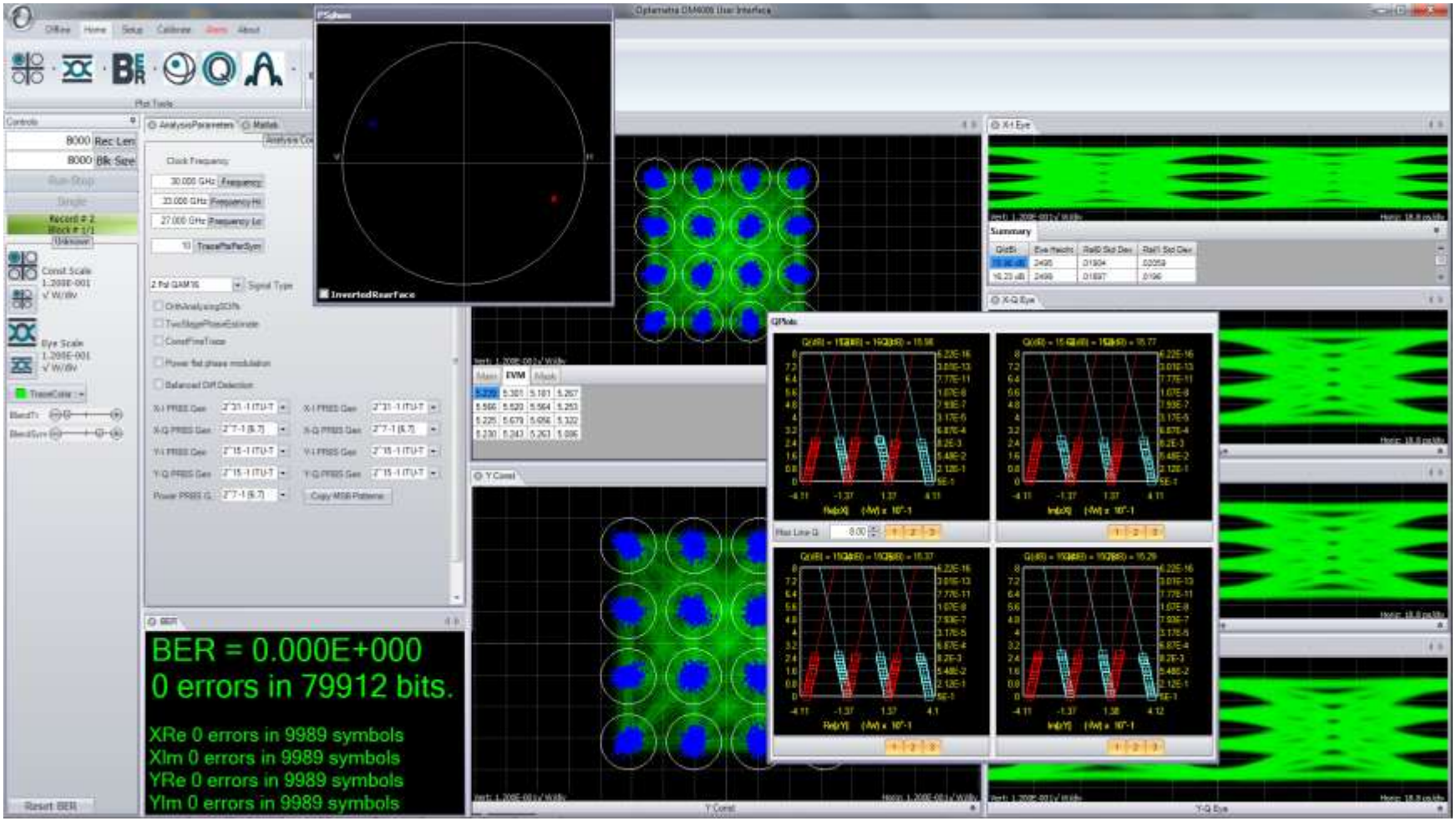
Measurements Available for QAM Signals



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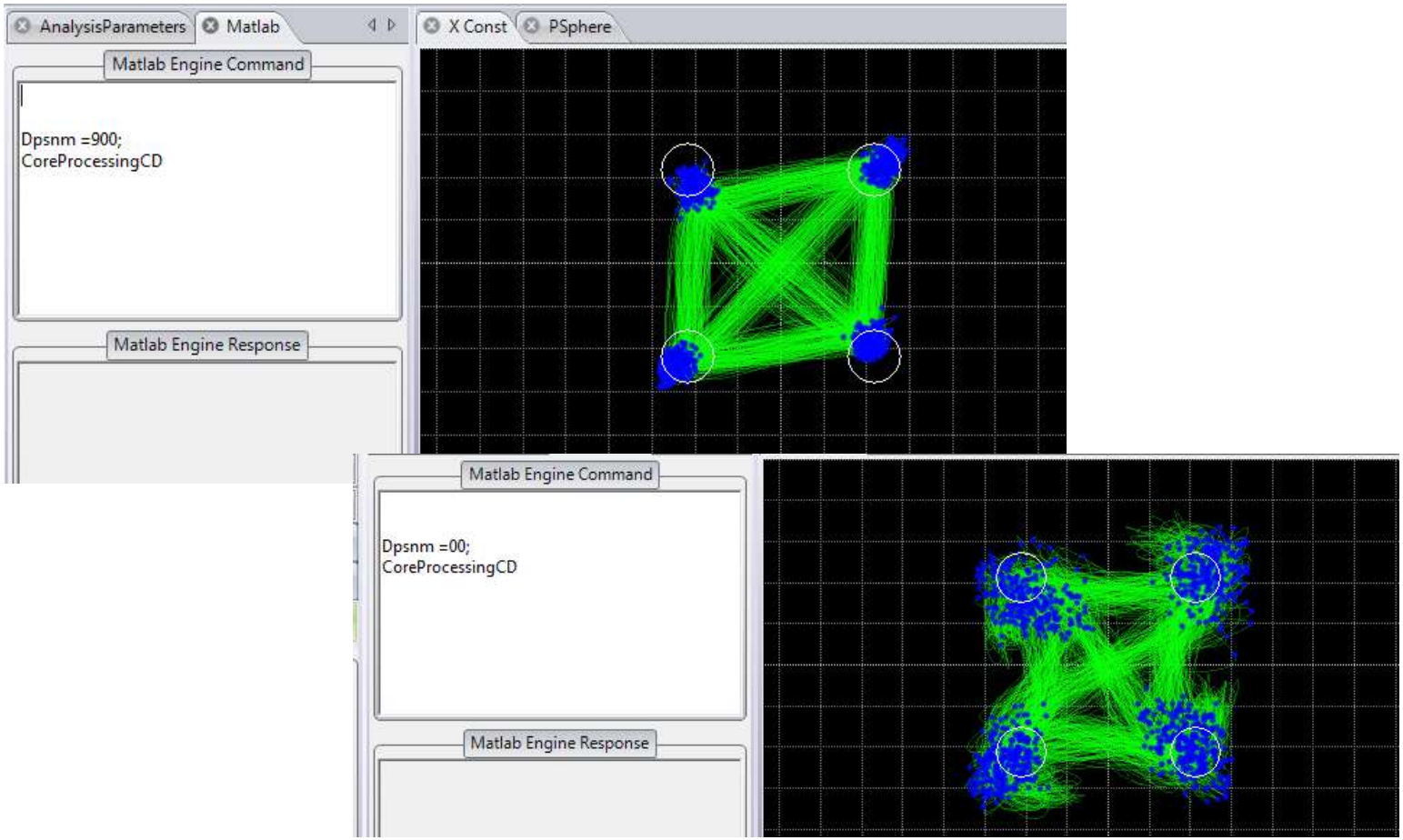
One DC Module Being Compensated. CD = 900 ps/nm



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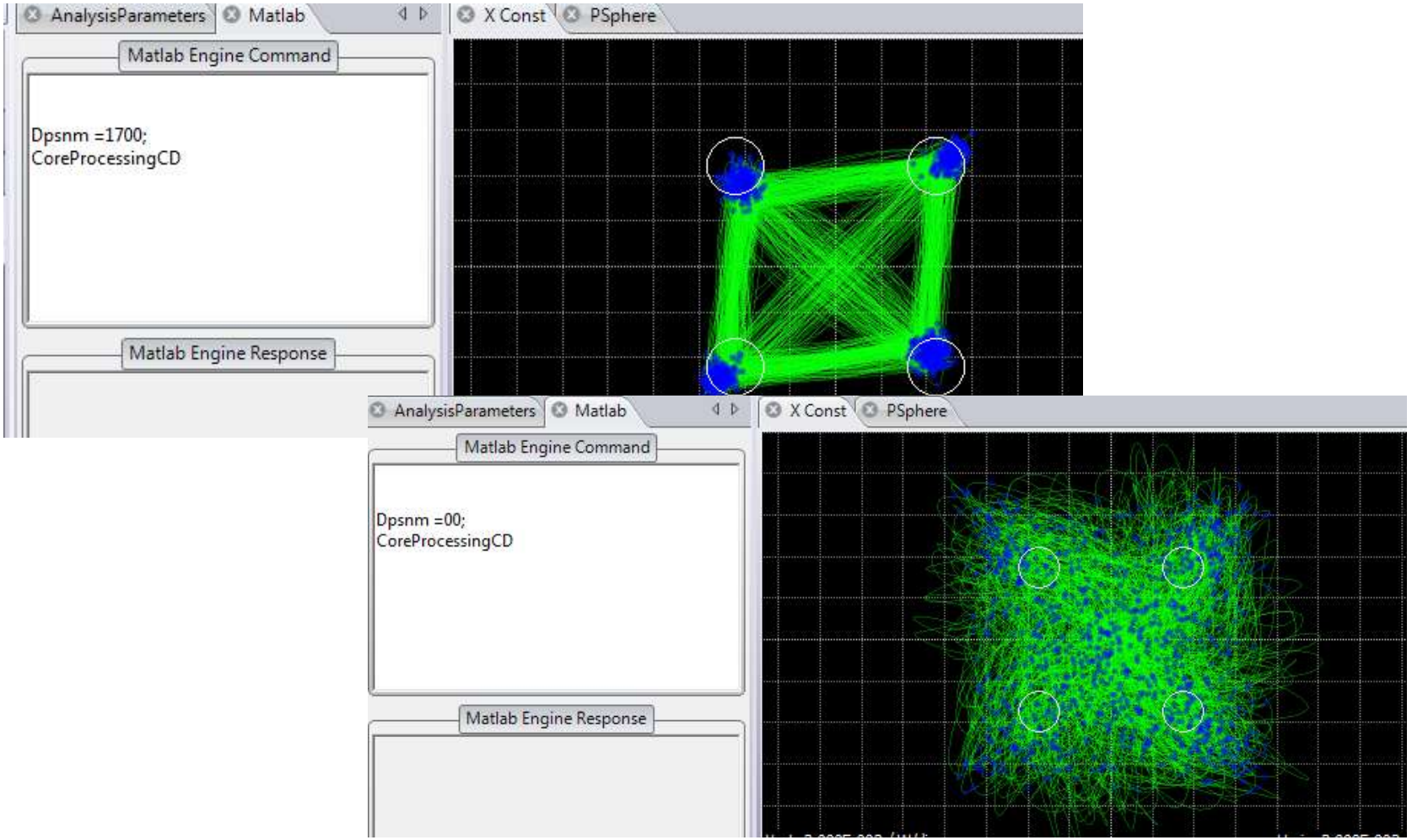
2 CD Modules CD = 1700 ps/nm



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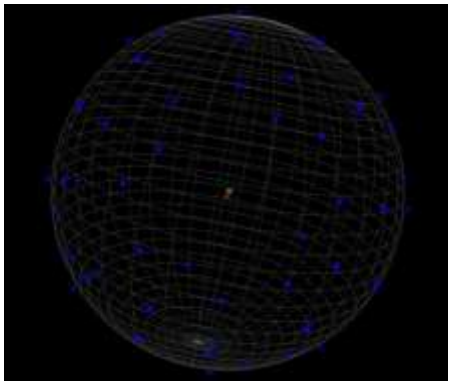
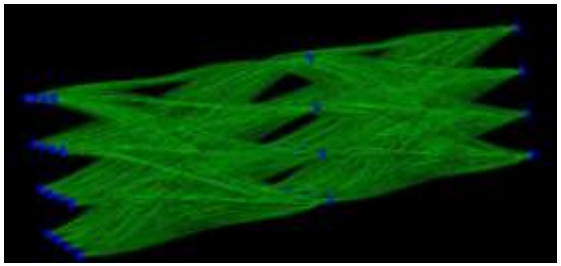
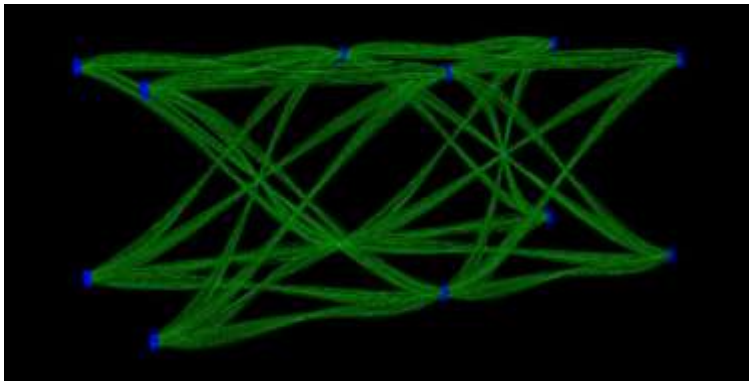
3D Visualization Tools

NEW

Complex-modulation signals are inherently 3D since in-phase and quadrature components are being changed vs. time. The 3D Eye Diagram provides a helpful combination of the Constellation and Eye diagrams into a single 3D diagram. This helps to visualize how the complex quantity is changing through the bit period. The diagram can be rotated and scaled. Also available in 3D is the Poincaré Sphere. The 3D view is helpful when viewing the polarization state of every symbol. The symbols tend to form clusters on the Poincaré Sphere which can be revealing to expert users. The non-normalized Stokes Vectors can also be plotted in this view.







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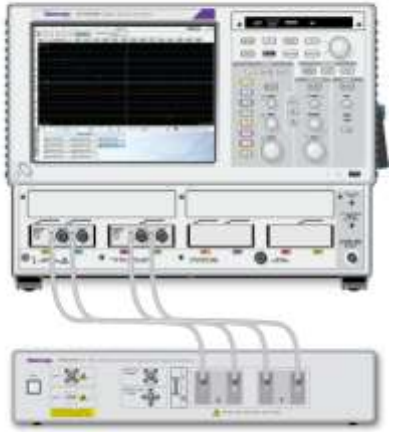
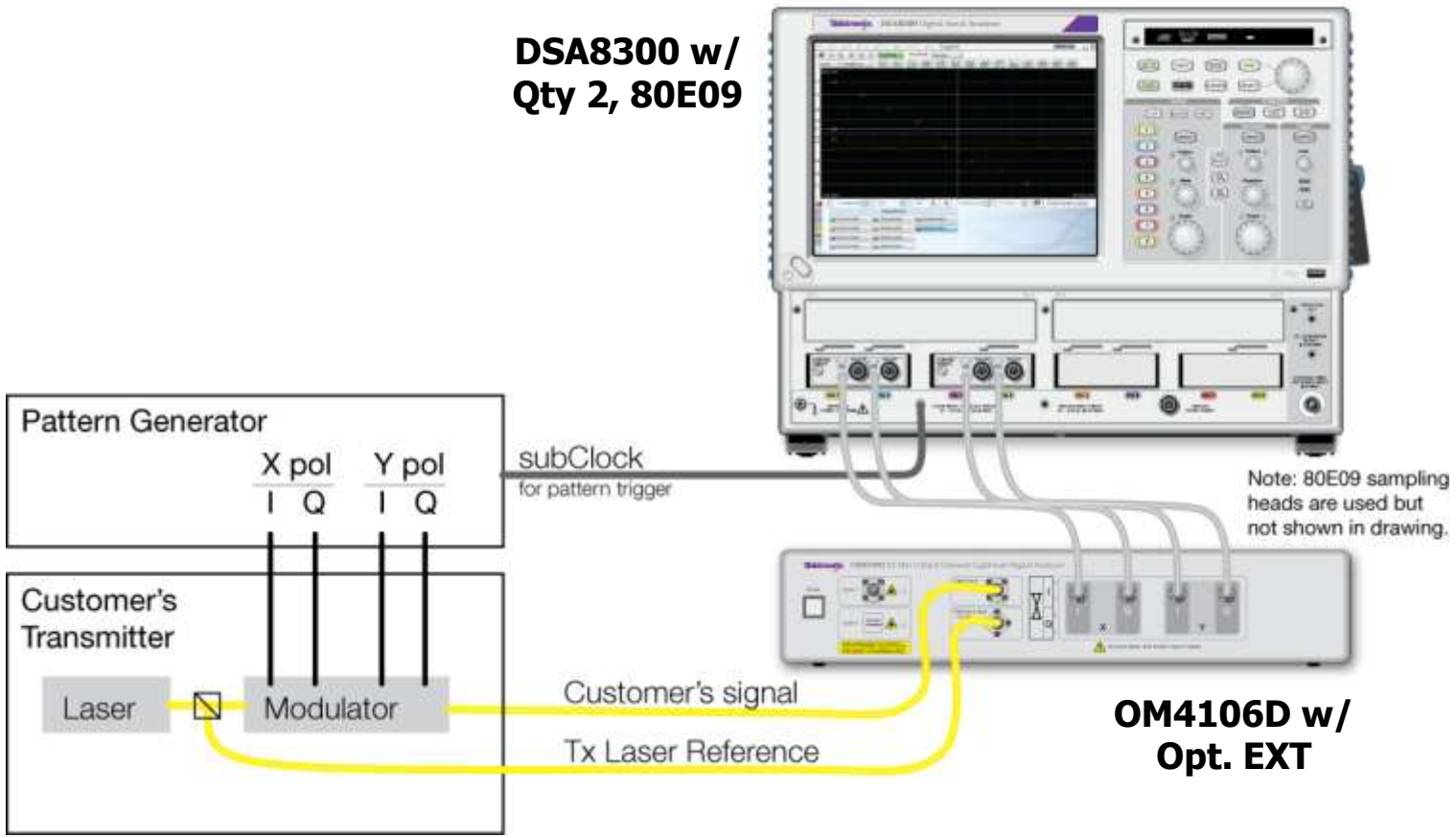
OM4106D support for the DSA8300 Sampling Scope



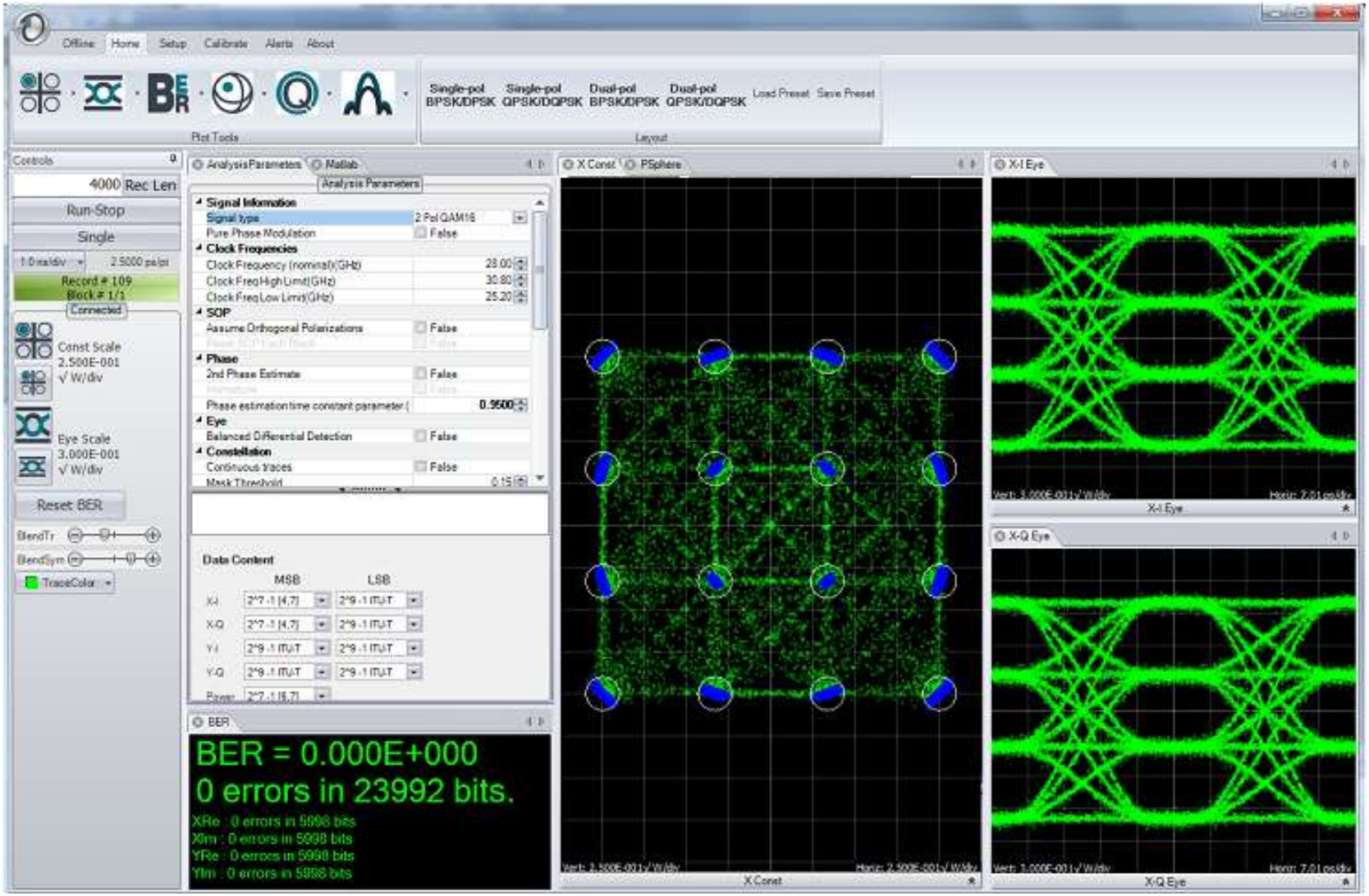
- The OM4106D and the OM1106 software have been modified to support the DSA8300 sampling scope, an equivalent-time based acquisition system.
- Any existing OM4106D is capable of supporting both DSA/DPO70k real-time scopes and the DSA8300 sampling scopes with a software upgrade.
- Using the sampling scope for acquisition provides greater vertical resolution at a lower total system price compared to real-time solutions.
  - 16 bits vertical resolution and 450uV rms noise floor at 60 GHz provide added dynamic range and accuracy.
  - Up to 60 GHz sampler bandwidth on four channels provides future-proof capability for next-gen baud rates.
  - Timing jitter as low as 450fs RMS lets you see signal jitter. (as low as 100fs when using the 82A04B Phase Reference Module)

Example Equivalent Time Scope Configuration

Note: Ethernet connections not shown. All instruments assumed to be connected to same network.



PM-16QAM @ 28G Baud Rate via Sampling



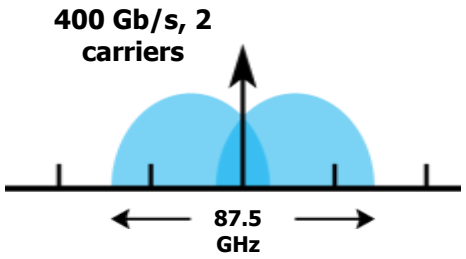
Customer Challenges for 400G

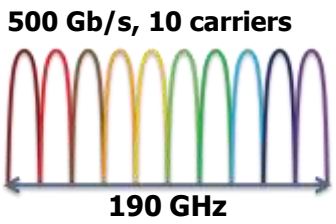
- Even as 100G coherent optical systems are being deployed, architecture for 400G systems and beyond are in development
- Current proposals vary considerably from the number of carriers, to the carrier spacing, to the modulation format used
- The test and measurement system must have the flexibility to support any combination of system parameters

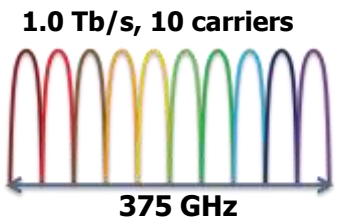
Example Industry Approaches to 400G and Beyond

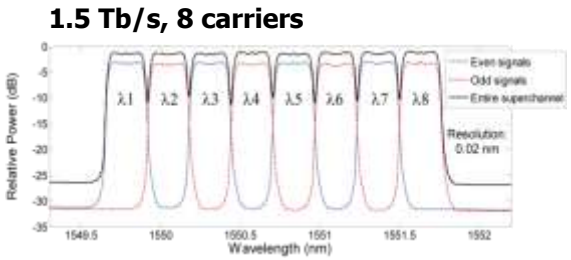
- **No industry consensus on how to build superchannels**
- **Vendors differ on characteristics as basic as carrier count and carrier spacing to what modulation format should be used**

system rate	# of carriers	modulation format
400 Gb/s[1]	2	DP-16QAM
500 Gb/s[2]	5	DP-QPSK
500 Gb/s[3]	10	DP-QPSK
1.0 Tb/s[4]	10	DP-QPSK
1.5 Tb/s[5]	8	DP-16QAM







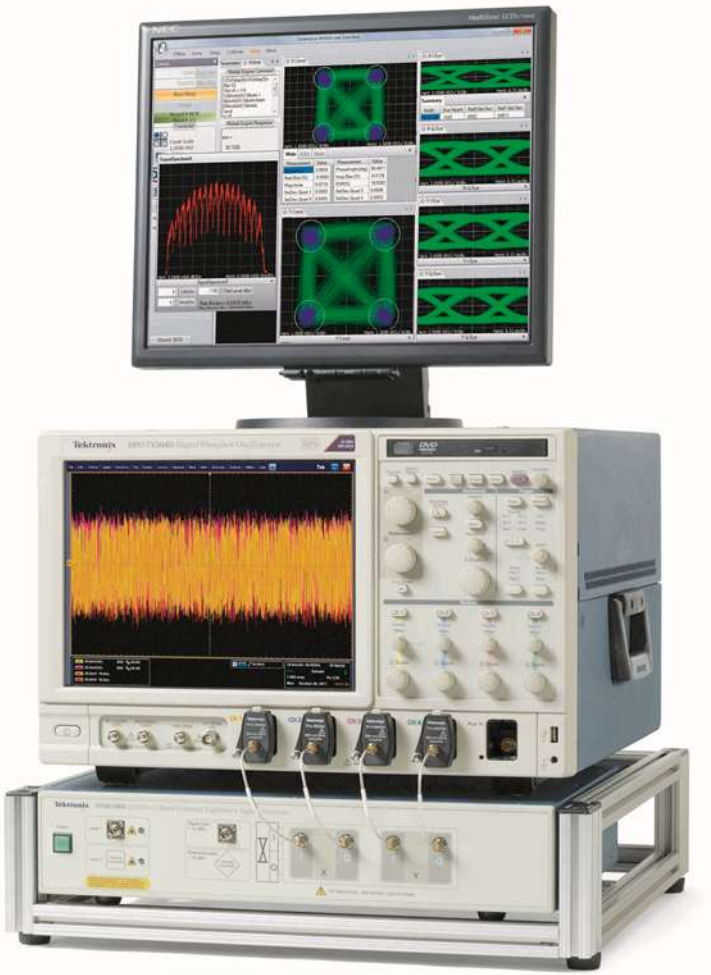


Sources: [1]*Beyond 100G, Fujitsu Network Communications, Inc.*
[2]*Dawn of the Terabit Age, Infinera Corporation*
[3]*Coherent Super-Channel Technologies, OSA Webinar, Infinera Corporation*
[4]*Super-Channels: DWDM Transmission at100Gb/s and Beyond, Infinera Corporation*
[5]*1.5-Tb/s Guard-Banded Superchannel Transmission over 56 × 100-km (5600-km) ULAF Using 30-Gbaud Pilot-Free OFDM-16QAM Signals with 5.75-b/s/Hz Net Spectral Efficiency, Alcatel-Lucent, Bell Labs*

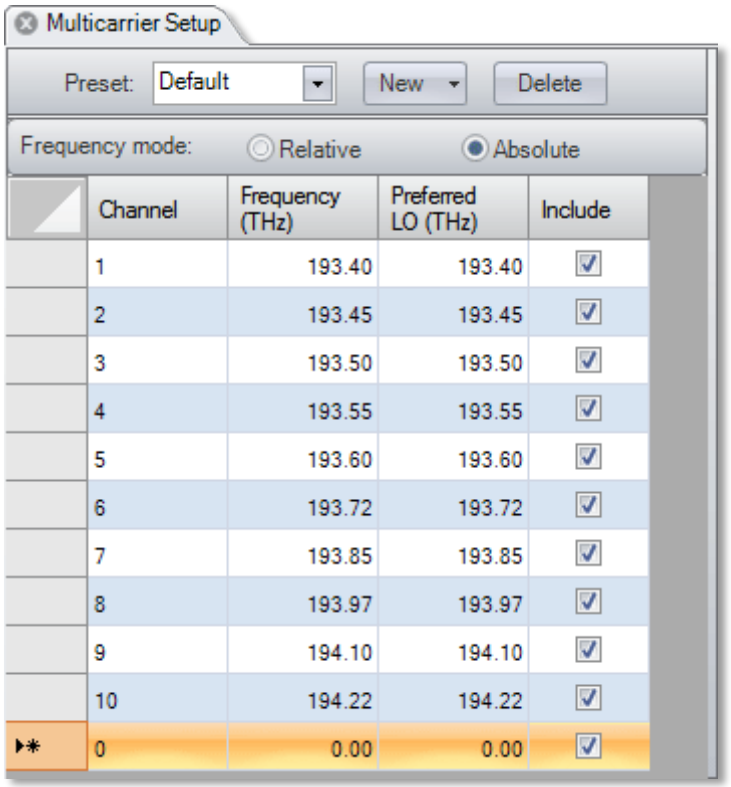
Tektronix Introduces Multi-Carrier Superchannel Support

Option MCS on the OM-Series Coherent Lightwave Signal Analyzers

- ***Industry's first*** automated test support for **400G** multi-carrier superchannel coherent optical systems
- Tightly integrated with Tektronix **DPO70000D** Series 33 GHz oscilloscopes and **DSA8300** Series 70 GHz sampling oscilloscopes
- Addresses customers' challenges for testing multi-carrier superchannel systems by offering:
  - ***Unlimited*** user-definable superchannel definition
  - ***Unique*** test automation to efficiently take measurements at each carrier
  - ***Reduced*** test times
  - ***Integrated*** multi-carrier measurement results enabling streamlined channel-to-channel comparisons and visualizations



Super-Channel Definition



	Channel	Frequency (THz)	Preferred LO (THz)	Include
	1	193.40	193.40	☑
	2	193.45	193.45	☑
	3	193.50	193.50	☑
	4	193.55	193.55	☑
	5	193.60	193.60	☑
	6	193.72	193.72	☑
	7	193.85	193.85	☑
	8	193.97	193.97	☑
	9	194.10	194.10	☑
	10	194.22	194.22	☑
▸*	0	0.00	0.00	☑

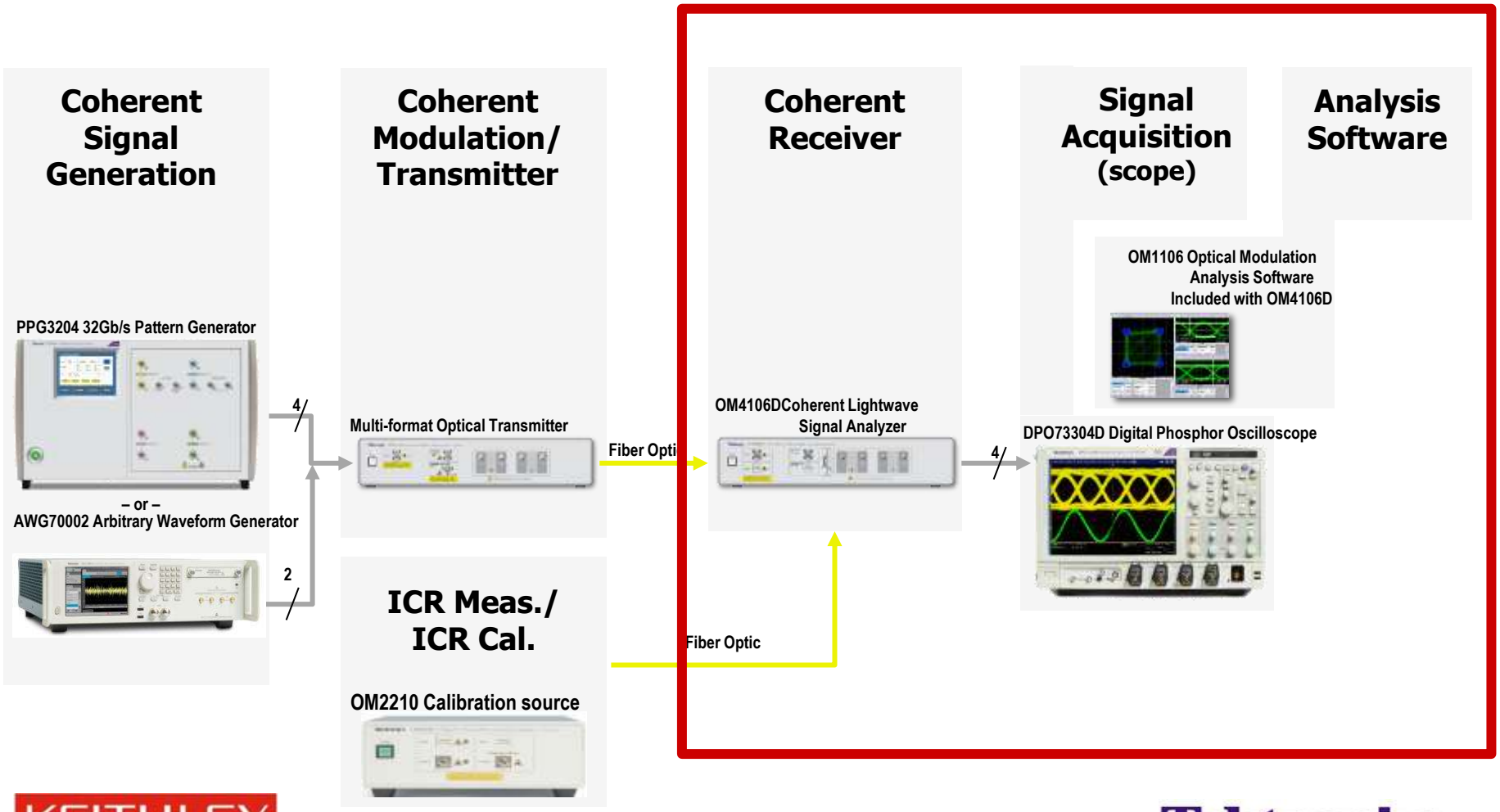
- Any number of carriers can be defined
- Carrier center frequencies can be specified as either absolute values (THz) or as relative values (GHz)
- No carrier fixed grid is imposed -- the carrier width can vary from carrier to carrier
- Modulation format can be set individually for each carrier

Optametra/Tektronix 技术创新

- 专为相关光接收机定制、优化的算法
- 支持专利的基于判决电平Q因子算法，支持QPSK和高阶QAM（QAM1024）星座图测试
- 先进的解偏振、相位恢复算法，提供业内灵敏度最高的接收性能
- 直接集成Matlab界面
  - 可以对任何变量进行快速计算
  - 客户可定制化的算法
  - 实时客户自定义变量结果
- 内置双激光本振源，可以进行快速的校准、验证
- Optametra用户软件
  - 易用使用
  - 可定制化
- 测试数据和状态信息可以远程通过WCF进行控制和收集
- OM2210校准光源直接测量用户接收机性能
- 支持客户接收机数据分析、处理
- 配合业内性能最优Tektronix四通道示波器系统

Coherent Optical System

Tektronix offers complete end-to-end testing of coherent modulation formats.



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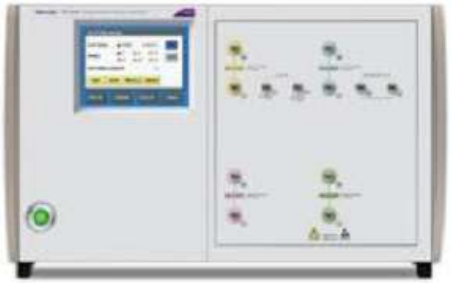
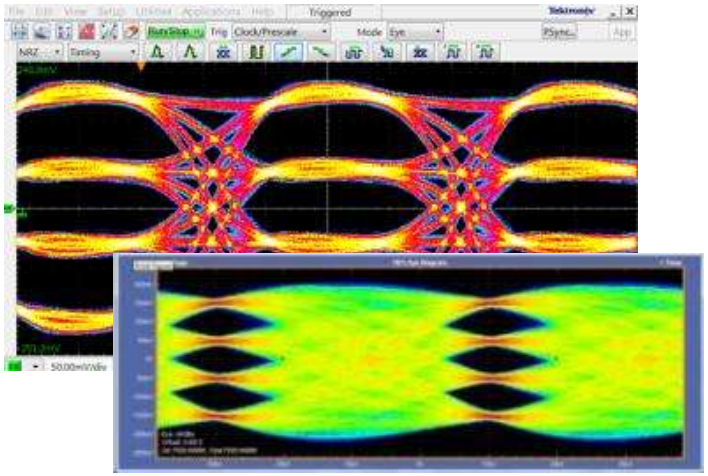
Signal Generation solution for Optical



- QPSK
  - BSA: 1 channel 28.6G, super stress, super low jitter
  - PPG: 4 channel 32G, super performance, super flexible

- QAM/OFDM
  - AWG70001: 50GS/s sample
  - AWG70002: 25GS/s sample rate



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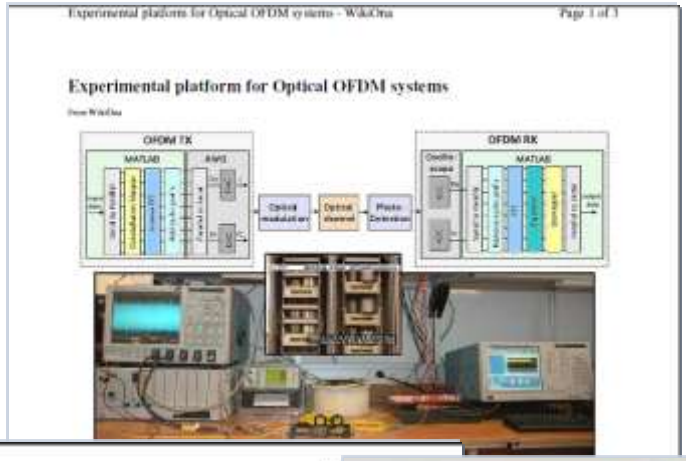
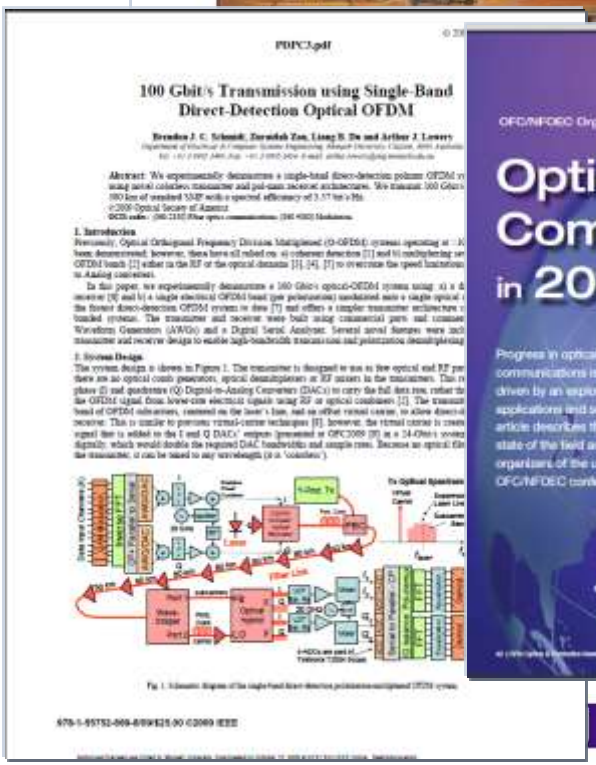
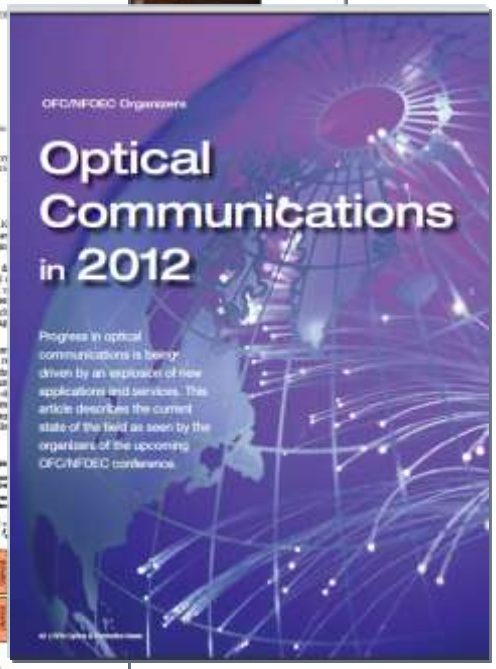
What's more from Tektronix? Optical-OFDM

- Proven signal generation solution in optical research
- AWG7000 key tool in over 30 research papers
  - 100Gb/s, OFDM,..
- Leading industry and university players, worldwide, rely on the AWG7000







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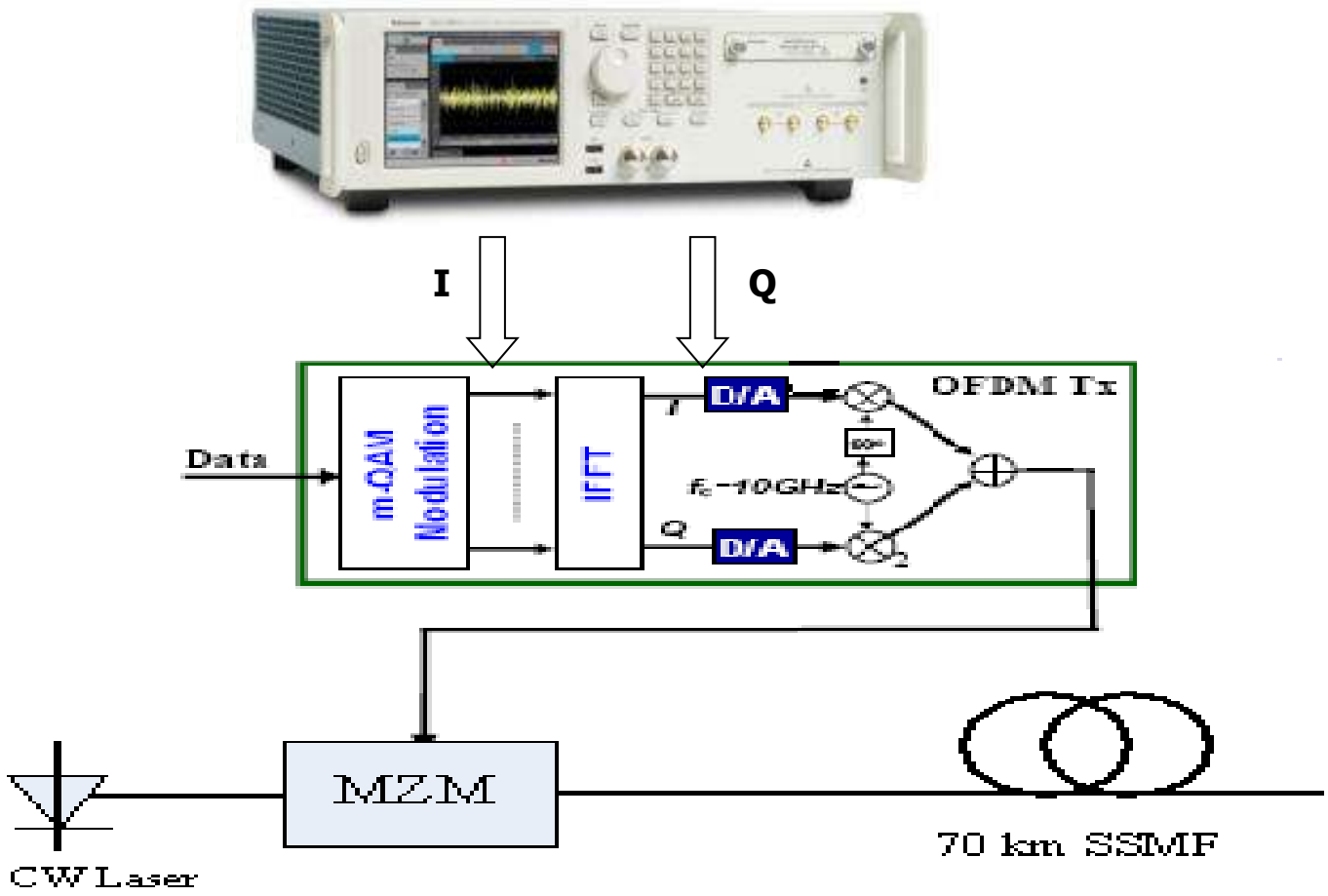
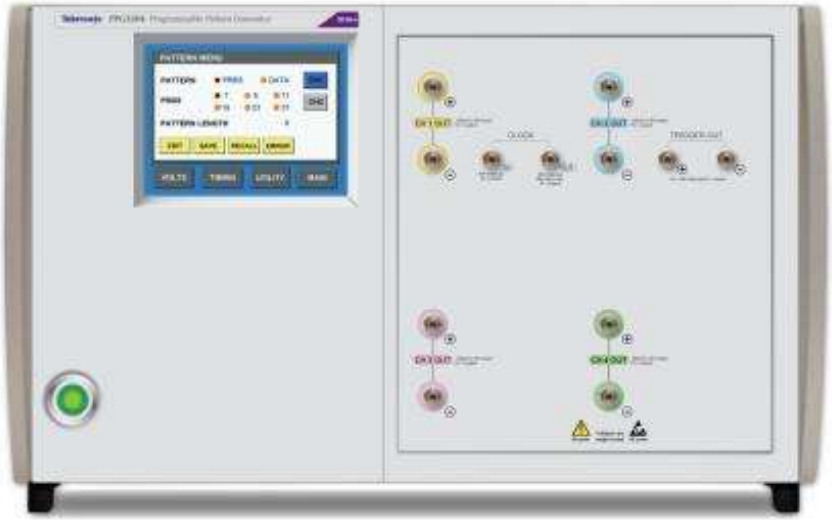
Optical OFDM Generation



High Speed and Multi-channel BERTs



Co-develop with PicoSecond Pulse Lab™, provide most high performance parallel PG and ED and comprehensive solution than any vendors !

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The Lineup

These products will complement the BERTScope product family for:

- **Multi-channel** BERT requirements
- Applications **beyond 28.6** Gb/s

Product	Description
PPG3001	30Gb/s Programmable Pattern Generator, 1-channel
PPG3002	30Gb/s Programmable Pattern Generator, 2-channel
PPG3004	30Gb/s Programmable Pattern Generator, 4-channel
PPG3201	32Gb/s Programmable Pattern Generator, 1-channel
PPG3202	32Gb/s Programmable Pattern Generator, 2-channel
PPG3204	32Gb/s Programmable Pattern Generator, 4-channel
PED3201	32Gb/s Programmable Error Detector, 1-channel
PED3202	32Gb/s Programmable Error Detector, 2-channel

A Full Range of BERT Testers from Tektronix
Summary

Application/Usage	BERTScope	PPG/PED
Single Channel BERT <28.6Gb/s >28.6Gb/s	X	 X
Multi-channel BERT/PG/ED		X
Built-in Analysis	X	
Integrated Compliance Testing	X	
Separate PG or ED		X

BERTScope Series

BSA286C
28.6Gb/s. 1-channel
Bit Error Rate Tester

PPG/PED3000 Series

PED3202
32 Gb/s, 2-channel
Error Detector

PPG3204
32 Gb/s, 4-channel
Pattern Generator

BA1600
1.6Gb/s. 1-channel
Bit Error Rate Tester

PPG3002
30 Gb/s, 2-channel
Pattern Generator

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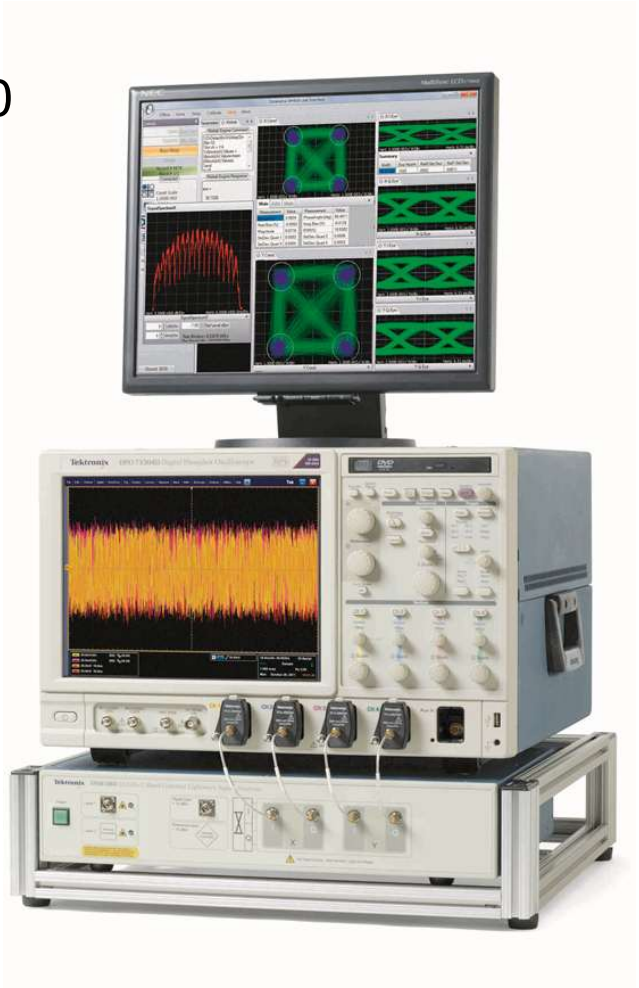
Conclusions

- OM4000 Series Analyzer and DPO70000 Series Oscilloscope
  - Oscilloscope best matched to application
  - Best coherent signal analysis algorithms (“designed for optical”)
  - Preferred user interface
  - Open architecture DSP based in Matlab



Thank You For Attending!

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