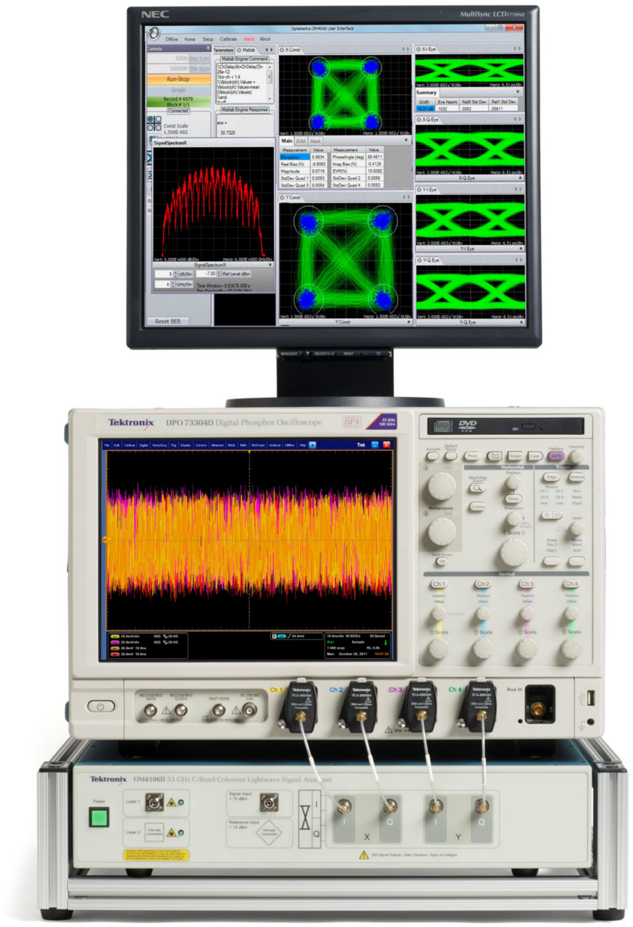
Coherent Lightwave Signal Analyzer

OM4000 Series Datasheet



OM4000 Series Coherent Lightwave Signal Analyzer and Tektronix DPO70000 Series Oscilloscope.

Features & Benefits

Unparalleled Flexibility

- Coherent Lightwave Signal Analyzer Architecture Compatible with both Real-time and Equivalent-time Oscilloscopes*1
- Complete Coherent Signal Analysis System for Polarization-multiplexed QPSK, Offset QPSK, QAM, Differential BPSK/QPSK, and Other Advanced Modulation Formats
- Displays Constellation Diagrams, Phase Eye Diagrams, Q-factor, Q-plot, Spectral Plots, Poincaré Sphere, Signal vs. Time, Laser Phase Characteristics, BER, with Additional Plots and Analyses Available through the MATLAB Interface
- Measures Polarization Mode Dispersion (PMD) of Arbitrary Order with Most Polarization Multiplexed Signals

Precise Optical Receiver

- Precise Coherent Receiver Hardware provides Minimal Variation over Temperature and Time for a High Degree of Accuracy and High-stability, Polarization-diverse, Optical Field Detection
- Highly Linear Photo Detection allows Operation at High Local Oscillator and Signal Power Levels to Eliminate Electrical Amplification
- An Integrated Pair of ECDL Tunable Lasers for Use as a Local Oscillator and Another for Self-test. Both Lasers have Industry-best Linewidth and Tuning Range for Any Wavelength within the Band
- Coherent Lightwave Signal Analyzer Software Tolerates >5 MHz Instantaneous Signal Laser Linewidth – Compatible with Standard Network Tunable Sources such as DBR and DFB Lasers
- No Laser Phase or Frequency Locking Required
- Smart Polarization Separation Follows Signal Polarization

User-defined Extensibility

- User Access to Internal Functions with a Direct MATLAB*2 Interface
- The OM4000 can be Controlled through Ethernet for Remote Access
- Superior User Interface offers Comprehensive Visualization for Ease-of-Use Combined with the Power of MATLAB
- Coherent Lightwave Signal Analyzer Software included with OM1106 and OM4000 Series Products

400G and 1Tb/s Superchannel Support

- Multi-carrier software option allows user-definable superchannel setup
- Superchannel configuration allows user to define number of channels, channel frequency, and channel modulation format
- Test automation acquires complete measurements at each channel
- Integtrated measurement results allow easy channel-to-channel comparisons

*1 Certain features may be available only when used with Tektronix oscilloscopes.

*2 MATLAB is a registered trademark of MathWorks.

Tektronix

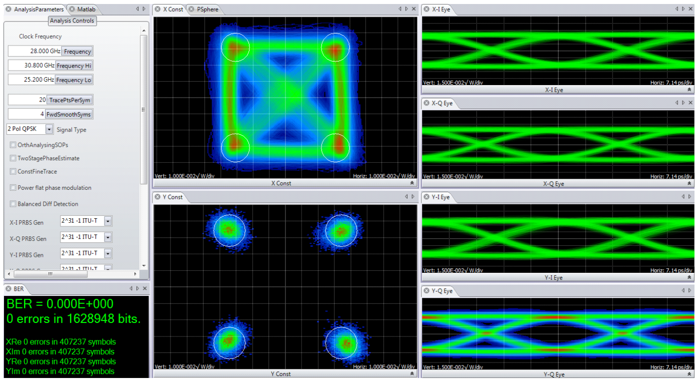


Figure 1 – OM4000 User Interface (OUI) showing color-grade graphics options. Symbols can also be colored to a key indicating prior state. Data shown is 112 Gb/s PM-QPSK.

Introduction

The OM4000 Coherent Lightwave Signal Analyzer (CLSA) is a 1550 nm (C- and L-band) fiber-optic test system for visualization and measurement of complex modulated signals, offering a complete solution to testing both coherent and direct-detected transmission systems. The CLSA consists of a polarization- and phase-diverse receiver and analysis software enabling simultaneous measurement of modulation formats important to advanced fiber communications, including polarization-multiplexed (PM-) QPSK. The CLSA software performs all calibration and processing functions to enable real-time burst-mode constellation diagram display, eye-diagram display, Poincaré sphere, and bit-error detection.

OM4000 Series Instrument Flexibility

The OM4000 is unique in the industry in that it works with both real-time and equivalent-time oscilloscopes. This unprecedented architecture allows the user to get the benefits of either acquisition format all with a single CLSA. For customers whose analysis requires a high sample rate, using the CLSA with a real-time oscilloscope, such as the DPO73304D, may be optimal. For customers whose analysis requires high vertical resolution – such as modulator characterization – an equivalent-time oscilloscope may be the most beneficial. Working with a Tektronix oscilloscope solution of sufficient bandwidth, bit rates exceeding 240 Gb/s can be analyzed.

OM4000 Series User Interface (OUI)

The common thread through the Coherent Lightwave Signal Analyzer product line is the OUI which governs the operation and display of data. This OUI can also be ordered separately without the OM4000 for analysis purposes with another coherent receiver system. The data-capture and analysis only version of the OUI software is called the OM1106. Color-grade, persistence, and color-key options are available to help you visualize the data. In Figure 1, the horizontal transitions are more rare than the vertical transitions due to the relative timing of the IQ data sequence (upper middle of Figure 1). The other polarization constellation is shown in

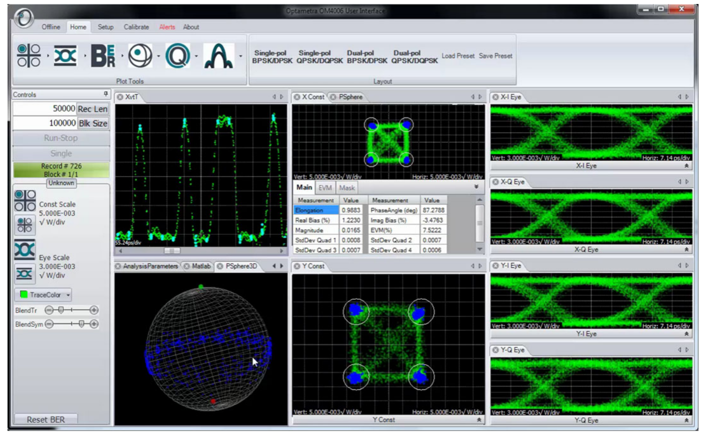


Figure 2 – OM4000 User Interface (OUI) showing display of select equivalent-time measurements.

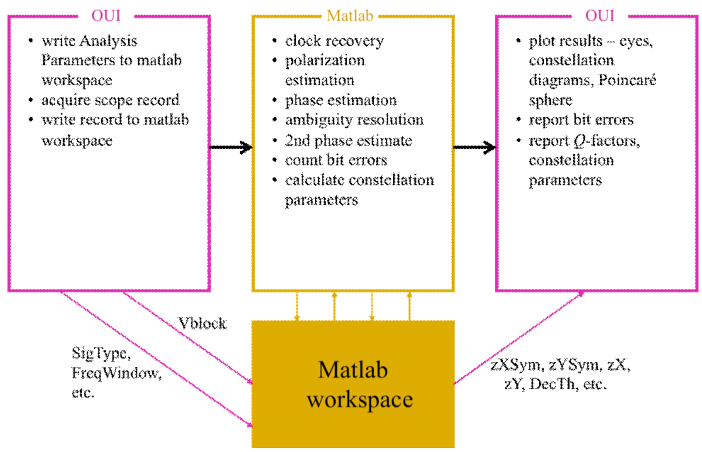


Figure 3 – Illustration of data flow under control of the OUI.

color grade with only the symbol points (lower middle). Color grade is also available for the eye diagram (bottom right).

Interaction between OM4000 Series User Interface (OUI) and MATLAB

The OUI takes information about the signal provided by the user together with acquisition data from the oscilloscope and passes them to the MATLAB workspace, shown in Figure 3. A series of MATLAB scripts are then called to process the data and produce the resulting field variables. The OUI then retrieves these variables and plots them. Automated tests can be accomplished by connecting to the OUI or by connecting directly to the MATLAB workspace. The user does not need any familiarity with MATLAB; the OUI can manage all MATLAB interactions. However, advanced users can access internal functions through the MATLAB interface. This can be used to create user-defined demodulators and algorithms, or for custom analysis visualization.

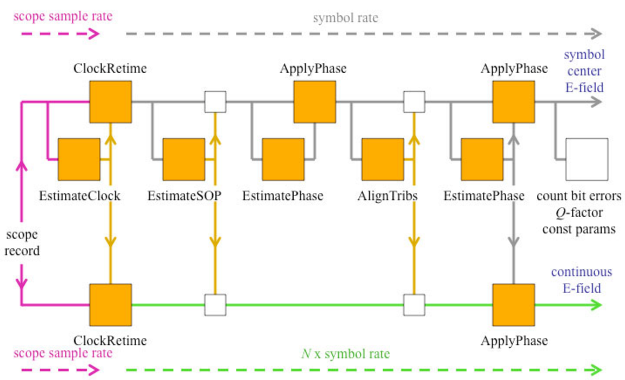


Figure 4 – Data flow through the “Core Processing” engine.

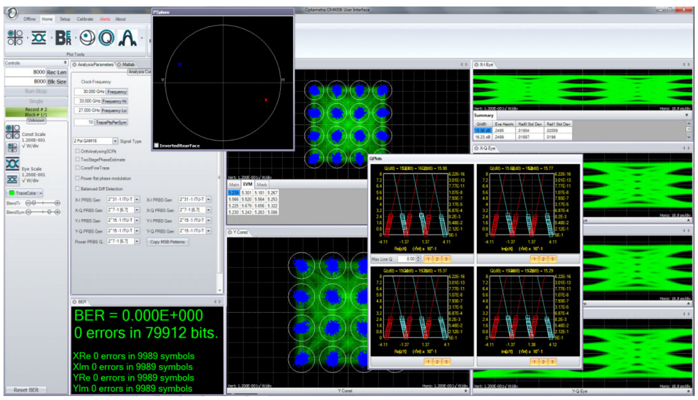


Figure 5 – QAM Measurements on the OM4000 User Interface (OUI).

Signal Processing Approach

For real-time sampled systems, the first step after data acquisition is to recover the clock and re-time the data at 1 sample per symbol at the symbol center for the polarization separation and following algorithms (shown as upper path in Figure 4). The data is also re-sampled at 10X the baud rate (user settable) to define the traces that interconnect the symbols in the eye diagram or constellation (shown as the lower path). The clock recovery approach depends on the chosen signal type. Laser phase is then recovered based on the symbol-center samples. Once the laser phase is recovered, the modulation portion of the field is available for alignment to the expected data for each tributary. At this point bit errors may be counted by looking for the difference between the actual and expected data after accounting for all possible ambiguities in data polarity. The polarity with the lowest BER is chosen. Once the actual data is known, a second phase estimate may be performed to remove errors that may result from a laser phase jump. Once the field variables are calculated, they are available for retrieval and display by the OUI. At each step the best algorithms are chosen for the specified data type, requiring no user intervention unless desired.

Measurements

Measurement	Value	Mean	Min	Max	StdDev	Count
Xconst Symbol Std. Dev.	0.0886√mW	0.0886√mW	0.0833√mW	0.0912√mW	0.00208√mW	19
Xconst Symbols Displayed	3942	4101	3905	4268	132	19
Xconst Mask Violations	6	6	6	7	0	19
Xconst EVM,Average	8.8 %	8.6 %	8.2 %	8.9 %	0.23 %	19
Xconst Magnitude	1.482√mW	1.439√mW	1.373√mW	1.505√mW	0.03873√mW	19
Xconst Phase Angle	94 deg	90 deg	85 deg	94 deg	3.2 deg	19
Xconst Bias, Imag	-0.12 %	-0.12 %	-0.13 %	-0.12 %	0.0029 %	19
Xconst Bias, Real	-0.011 %	-0.011 %	-0.012 %	-0.011 %	0.00028 %	19
Xconst IQ Imbalance	0.9946	0.9976	0.9534	1.046	0.02677	19
X-I Undershoot	0.79 %	0.75 %	0.72 %	0.79 %	0.023 %	19
X-I Overshoot	0.86 %	0.86 %	0.82 %	0.9 %	0.022 %	19
X-I Falltime	45 ps	47 ps	45 ps	49 ps	1.3 ps	19
X-I Risetime	49 ps	47 ps	45 ps	50 ps	1.5 ps	19
X-I Skew	0.027 ps	0.028 ps	0.027 ps	0.029 ps	0.00082 ps	19
X-I Crossing Point	50 %	50 %	48 %	52 %	1.4 %	19
X-I Rail 1 Std Dev	0.0873√mW	0.0904√mW	0.0863√mW	0.0949√mW	0.00244√mW	19
X-I Rail 0 Std Dev	0.0838√mW	0.0868√mW	0.0828√mW	0.0911√mW	0.00234√mW	19
X-I Eye Height	2.04√mW	2.02√mW	1.96√mW	2.11√mW	0.053√mW	19
X-I Q-Factor	21 dB	21 dB	20 dB	22 dB	0.61 dB	19
X-Q Undershoot	0.71 %	0.73 %	0.69 %	0.76 %	0.021 %	19
X-Q Overshoot	0.85 %	0.87 %	0.83 %	0.91 %	0.025 %	19
X-Q Falltime	47 ps	47 ps	45 ps	50 ps	1.3 ps	19
X-Q Risetime	47 ps	48 ps	45 ps	50 ps	1.3 ps	19
X-Q Skew	0.054 ps	0.056 ps	0.054 ps	0.059 ps	0.0014 ps	19
X-Q Crossing Point	49 %	50 %	48 %	53 %	1.3 %	19

Figure 6 – Annotated measurement table from OM4000 User Interface (OUI).

Get Up and Running Fast with the Easy-to-Use OUI

The user interface for the Coherent Lightwave Signal Analyzer is called the OUI. The OUI allows you to easily configure and display your measurements and also provides a means of software control for 3rd-party applications using WCF or .NET communication. It can also be controlled from MATLAB or LabVIEW. A QAM measurement setup is shown in Figure 5. The plots can be moved, docked, or resized. You can close or create plots to display just the information you need.

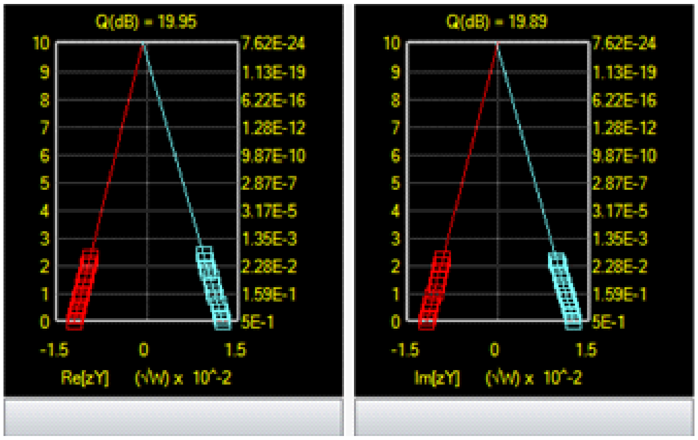
In addition to the numerical measurements provided on the plots, the measurements are also summarized on the Measurements window where statistics are also displayed. An example of some of these measurements is shown in Figure 6.

Make Adjustments Faster

The OUI is designed to collect data from the oscilloscope and move it into the MATLAB workspace with extreme speed to provide the maximum data refresh rate. The data is then processed in MATLAB and the resulting variables are extracted for display.

Take Control with Tight MATLAB Integration

Since 100% of the data processing is done in MATLAB, it is easy for test engineers to probe into the processing to understand each step along the way. R&D labs can also take advantage of the tight MATLAB integration by writing their own MATLAB algorithms for new techniques under development.



Q-plot.

Use the Optimum Algorithm

Don't worry about what algorithm to use. When you select a signal type in our OUI, for example, PM-QPSK, the optimal algorithm is applied to the data for that signal type. Each signal type has a specially designed signal processing approach that is best for the application. This means that you can get results right away.

Don't Get Stymied by Laser Phase Noise

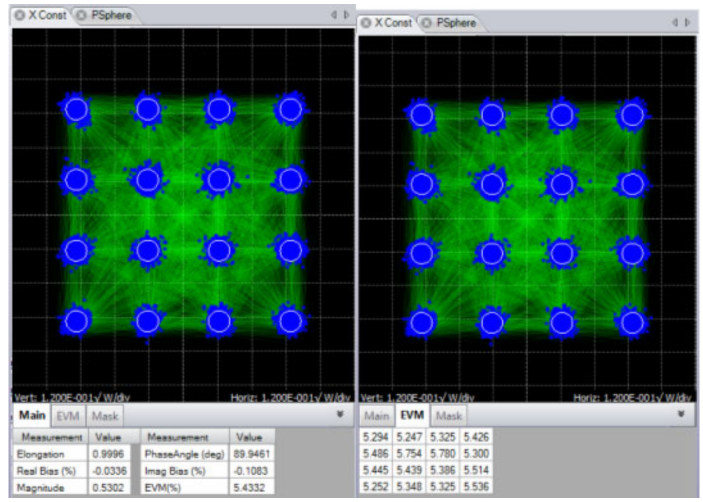
Signal processing algorithms designed for electrical wireless signals don't always work well with the much noisier sources used for complex optical modulation signals. Our robust signal processing methods tolerate enough phase noise to even make it possible to test signals which would traditionally be measured by differential or direct detection such as DQPSK.

Find the Right BER

Our Q-plots are a great way to get a handle on your data signal quality. Numerous BER measurements vs. decision threshold are made on the signal after each data acquisition. Plotting BER vs. decision threshold shows the noise properties of the signal. Gaussian noise will produce a straight line on the Q-plot. The optimum decision threshold and extrapolated BER are also calculated. This gives you two BER values: the actual counted errors divided by the number of bits counted, as well as the extrapolated BER for use when the BER is too low to measure quickly.

Constellation Diagrams

Once the laser phase and frequency fluctuations are removed, the resulting electric field can be plotted in the complex plane. When only the values at the symbol centers are plotted, this is called a Constellation Diagram. When continuous traces are also shown in the complex plane, this is often called a Phase Diagram. Since the continuous traces can be turned on or off, we refer to both as the Constellation Diagram. The scatter of the symbol points indicates how close the modulation is to ideal. The symbol points spread out due to additive noise, transmitter eye closure, or fiber impairments. The scatter can be measured by symbol standard deviation, error vector magnitude, or mask violations.

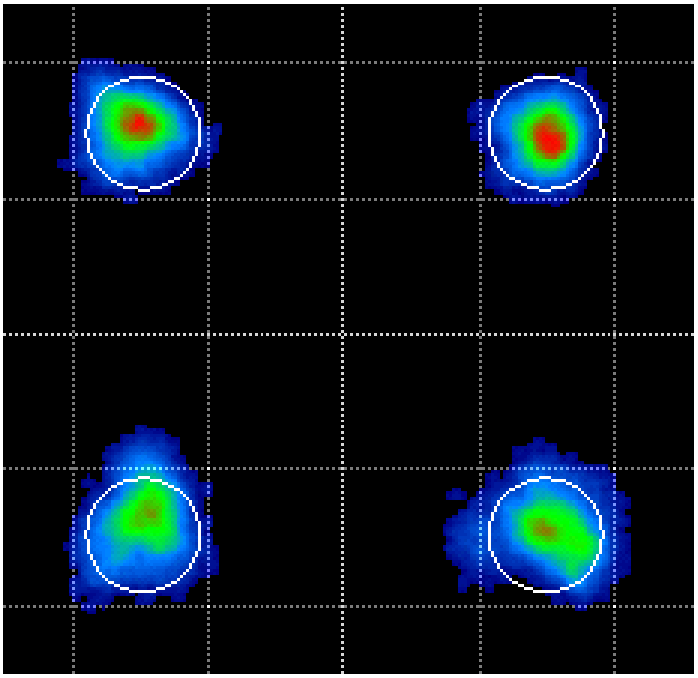


Constellation Diagram.

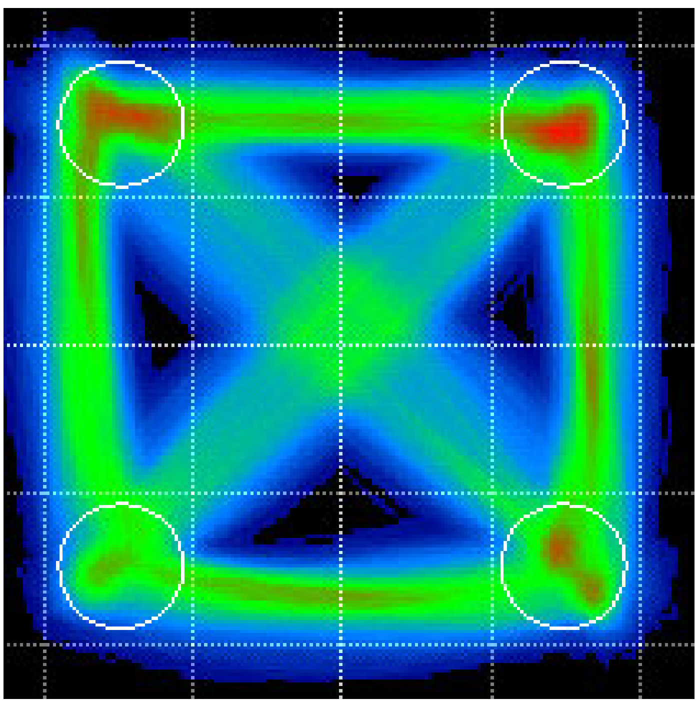
Measurements made on constellation diagrams are available on the "fly-out" panel associated with each graphic window. The measurements available for constellations are described below.

Constellation Measurements

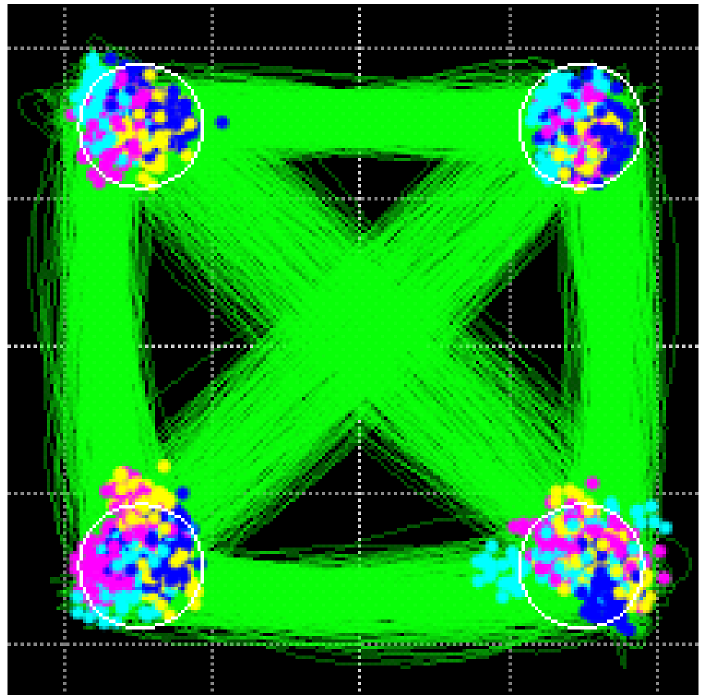
Measurement	Description
Elongation	The ratio of the Q modulation amplitude to the I modulation amplitude is a measure of how well balanced the modulation is for the I and Q branches of a particular polarization's signal
Real Bias	Expressed as a percent, this says how much the constellation is shifted left or right. Real (In-phase) bias other than zero is usually a sign that the In-phase Tributary of the transmitter modulator is not being driven symmetrically at eye center
Imag Bias	Expressed as a percent, this says how much the constellation is shifted up or down. Imaginary (Quadrature) bias other than zero is usually a sign that the Quadrature Tributary of the transmitter modulator is not being driven symmetrically at eye center
Magnitude	The mean value of the magnitude of all symbols with units given on the plot. This can be used to find the relative sizes of the two Polarization Signals
Phase Angle	The transmitter I-Q phase bias. It should normally be 90 degrees
StdDev by Quadrant	The standard deviation of symbol point distance from the mean symbol in units given on the plot. This is displayed for BPSK and QPSK
EVM (%)	The RMS distance of each symbol point from the ideal symbol point divided by the magnitude of the ideal symbol expressed as a percent
EVM Tab	The separate EVM tab shown in the right figure provides the EVM% by constellation group. The numbers are arranged to correspond to the symbol arrangement. This is ideal for setting Transmitter modulator bias. For example, if the left side groups have higher EVM than the right side, this usually means that the In-phase Transmitter modulator bias needs to be adjusted to drive the negative rail harder
Mask Tab	The separate Mask tab shown in the right figure provides the number of mask violations by constellation group. The numbers are arranged to correspond to the symbol arrangement. The mask threshold is set in the Engine window and can be used for pass/fail transmitter testing



Color Grade Constellation.



Color Grade with fine traces.

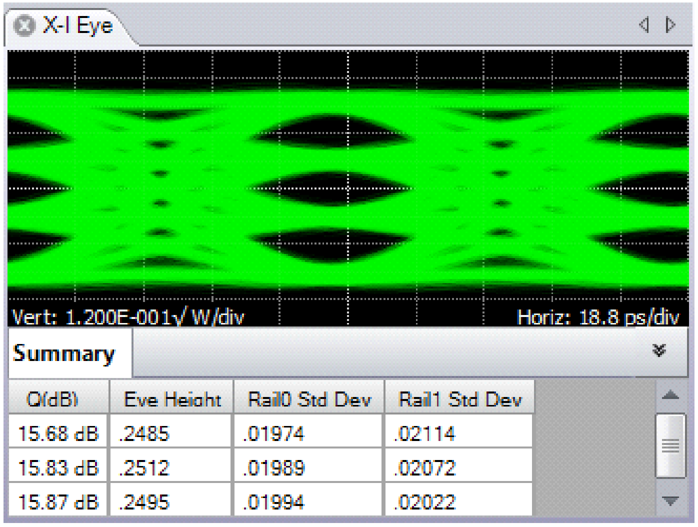


Color Key Constellation – If the prior symbol was in Quadrant 1 (upper right) then the current symbol is colored Yellow. If the prior symbol was in Quadrant 2 (upper left) then the current symbol is colored Magenta. If the prior symbol was in Quadrant 3 (lower left) then the current symbol is colored Light Blue (Cyan). If the prior symbol was in Quadrant 4 (lower right) then the current symbol is colored Solid Blue.

Color Features

The Color Grade feature provides an infinite persistence plot where the frequency of occurrence of a point on the plot is indicated by its color. This mode helps reveal patterns not readily apparent in monochrome. Note that the lower constellation groups of the example below have higher EVM than the top groups. In most cases this indicates that the quadrature modulator bias was too far toward the positive rail. This is not evident from the crossing points which are approximately correct. In this case an improperly biased modulator is concealing an improperly biased driver amp.

Color Key Constellation Points is a special feature that works when not in Color Grade. In this case the symbol color is determined by the value of the previous symbol. This helps reveal pattern dependence. Here it shows that pattern dependence is to blame for the poor EVM on the other groups. The modulator nonlinearity would normally mask this type of pattern dependence due to RF cable loss, but here the improper modulator bias is allowing that to be transferred to the optical signal.



Field Eye Diagram.

Eye Diagrams

Eye diagram plots can be selected for appropriate modulation formats. Supported eye formats include Field Eye, which is simply the real part of the phase trace in the complex plane, Power Eye which simulates the eye displayed with a Tektronix oscilloscope optical input, and Diff-Eye, which simulates the eye generated by using a 1-bit delay-line interferometer. As with the Constellation Plot you can right-click to choose color options as well. The Field Eye diagram provides the following measurements:

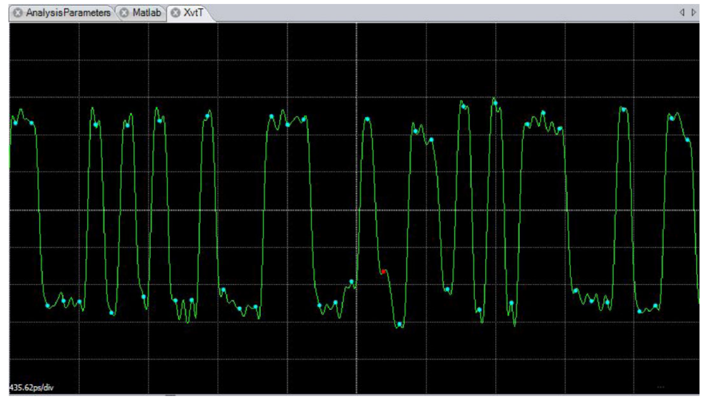
Field Eye Measurements

Measurement	Description
Q (dB)	Computed from 20 × Log10 of the linear decision threshold Q-factor of the eye
Eye Height	The distance from the mean 1-level to the mean 0-level (units of plot)
Rail0 Std Dev	The standard deviation of the 0-level as determined from the decision threshold Q-factor measurement
Rail1 Std Dev	The standard deviation of the 1-level as determined from the decision threshold Q-factor measurement

In the case of multilevel signals, the above measurements will be listed in the order of the corresponding eye openings in the plot. The top row values correspond to the top-most eye opening.

The above functions involving Q-factor use the decision threshold method described in the paper by Bergano*4. When the number of bit errors in the measurement interval is small, as is often the case, the Q-factor derived from the bit error rate may not be an accurate measure of the signal quality. However, the decision threshold Q-factor is accurate because it is based on all the signal values, not just those that cross a defined boundary.

*4 N.S. Bergano, F.W. Kerfoot, C.R. Davidson, "Margin measurements in optical amplifier systems," IEEE Phot. Tech. Lett., 5, no. 3, pp. 304-306 (1993).



Errored symbol in Measurement vs. Time plot.

Additional Measurements Available for Non-offset Formats

Measurement	Description
Overshoot	The fractional overshoot of the signal. One value is reported for the tributary, and for a multilevel (QAM) signal it is the average of all the overshoots
Undershoot	The fractional undershoot of the signal (overshoot of the negative-going transition)
Risetime	The 10-90% rise time of the signal. One value is reported for the tributary, and for a multilevel (QAM) signal it is the average of all the rise times
Falltime	The 90-10% fall time of the signal
Skew	The time relative to the center of the power eye of the midpoint between the crossing points for a particular tributary
Crossing Point	The fractional vertical position at the crossing of the rising and falling edges

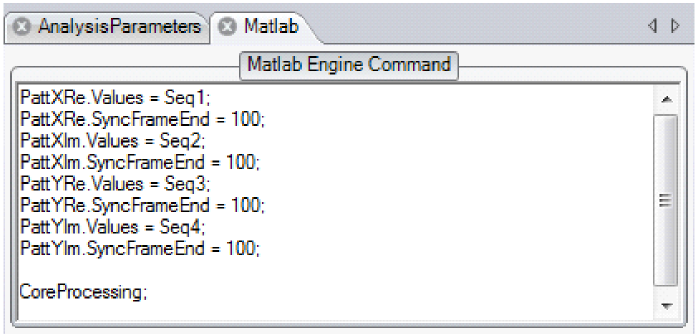
Measurements vs. Time

In addition to the eye diagram, it is often important to view signals versus time. For example, it is instructive to see what the field values were doing in the vicinity of a bit error. All of the plots which display symbol-center values will indicate if that symbol is errored by coloring the point red (assuming that the data is synchronized to the indicated pattern). The Measurement vs. Time plot is particularly useful in this way as it helps to distinguish errors due to noise, pattern dependence, or pattern errors.

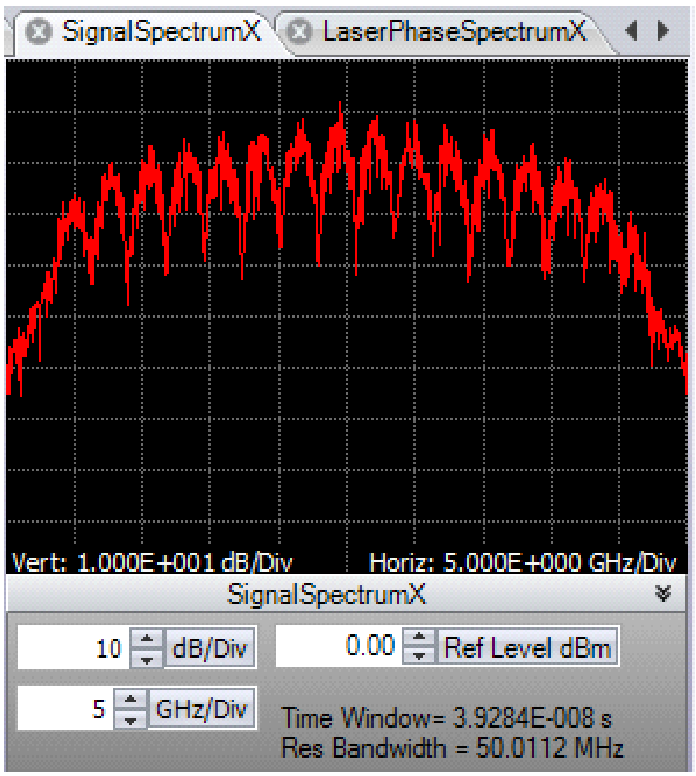
3D Visualization Tools

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.



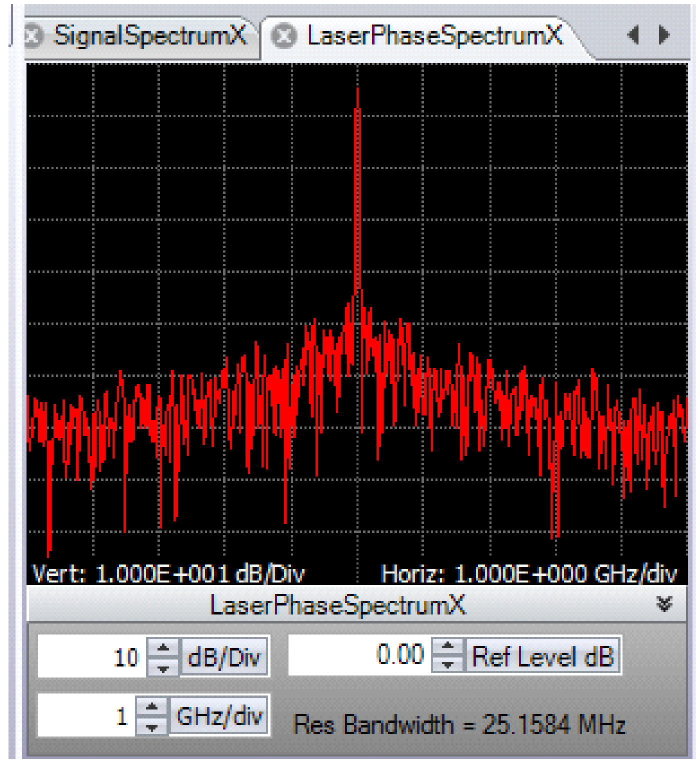
MATLAB window.



Signal Spectrum window.

Analysis Controls

The Analysis Controls window allows you to set parameters relevant to the system and its measurements.



Laser Phase Spectrum window.

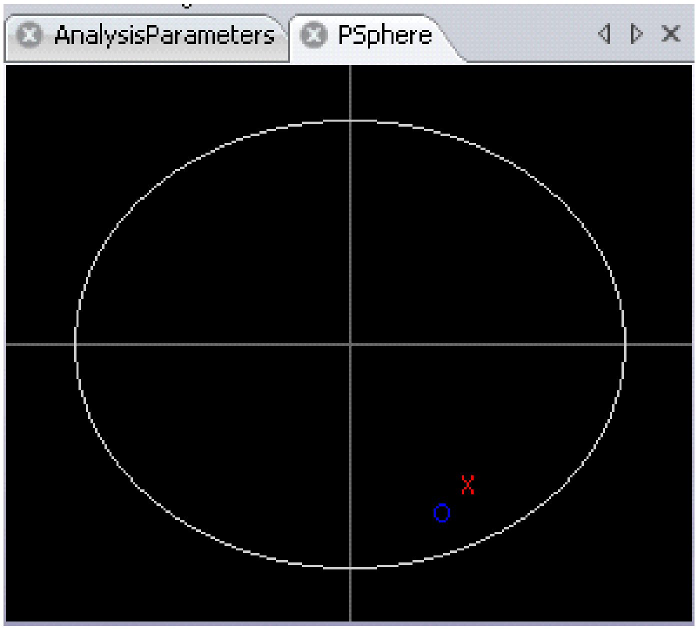
Analysis Parameters

Parameter	Description
Frequency	Clock recovery is performed in software, so only a frequency range of expected clock frequencies is required
Signal Type	The signal type (such as PM-QPSK) determines what algorithms will be used to process the data
Data Patterns	Specifying the known PRBS or user pattern by physical tributary permits error counting, constellation orientation, and two-stage phase estimation

User patterns may be assigned in the MATLAB window shown here. The data pattern can be input into MATLAB or found directly through measurement of a high SNR signal.

Signal Spectra

An FFT of the corrected electric field vs. time can reveal much about the data signal. Asymmetric or shifted spectra can indicate excessive laser frequency error. Periodicity in the spectrum shows correlation between data tributaries. The FFT of the laser phase vs. time data can be used to measure laser phase noise.

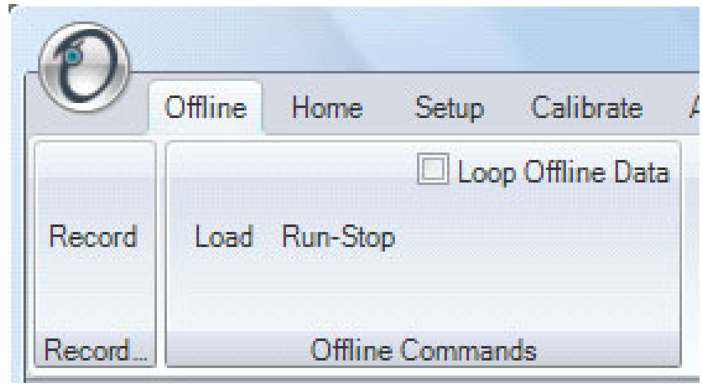


Poincaré Sphere window.

Poincaré Sphere

Polarization data signals typically start out well aligned to the PM-fiber axes. However, once in standard single mode fiber, the polarization states will start to drift. However, it is still possible to measure the polarization states and determine the polarization extinction ratio. The software locks onto each polarization signal. The polarization states of the two signals are displayed on a circular plot representing one face of the Poincaré sphere. States on the back side are indicated by coloring the marker blue. The degree of orthogonality can be visualized by inverting the rear face so that orthogonal signals always appear in the same location with different color. So, Blue means back side (negative value for that component of the Stokes vector), X means X-tributary, O means Y-tributary, and the Stokes vector is plotted so that left, down, blue are all negative on the sphere.

InvertedRearFace – Checking this box inverts the rear face of the Poincaré sphere display so that two orthogonal polarizations will always be on top of each other.



Workspace Record and Playback.

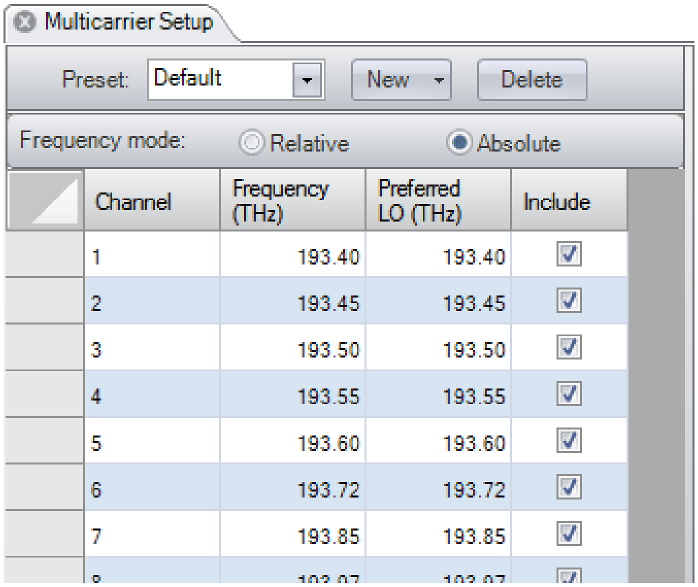
Impairment Measurement and Compensation

When studying transmission implementations, it is important to be able to compensate for the impairments created by long fiber runs or optical components. Chromatic Dispersion (CD), and Polarization Mode Dispersion (PMD) are two important linear impairments that can be measured or corrected by the OM4000 software. PMD measurement is based on comparison of the received signal to the back-to-back transmitter signal or to an ideal signal. This produces a direct measure of the PMD instead of estimating based on adaptive filter behavior. The user can specify the number of PMD orders to calculate. Accuracy for 1st-order PMD is ~1 ps at 10 Gbaud. There is no intrinsic limit to the CD compensation algorithm. It has been used successfully to compensate for many thousands of ps/nm.

Recording and Playback

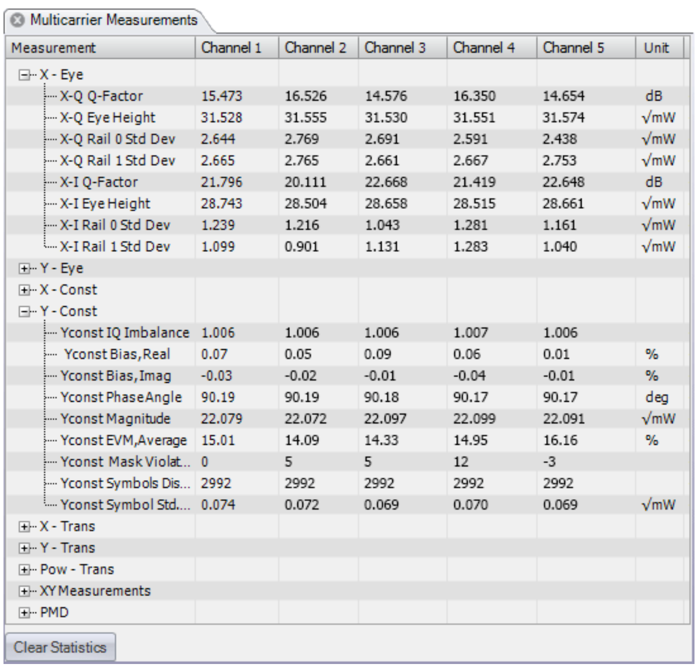
You can record the workspace as a sequence of .MAT files using the Record button in the Offline ribbon. These will be recorded in a default directory, usually the MATLAB working directory, unless previously changed.

You can play back the workspace from a sequence of .MAT files by first using the Load button in the Offline Commands section of the Home ribbon. Load a sequence by marking the files you want to load using the Ctrl key and marking the filenames with the mouse. You can also load a contiguous series using the Shift key and marking the first and last filenames in the series with the mouse. Use the Run button in the Offline Commands section of the Home ribbon to cycle through the .MAT files you recorded. All filtering and processing you have implemented is done on the recorded files as they are replayed.



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	[illegible]	[illegible]	☑

Multi-carrier setup.

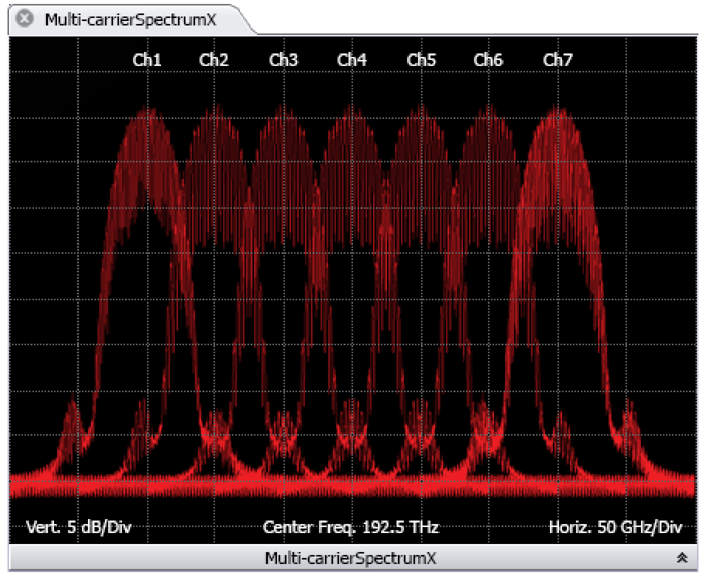


Measurement	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Unit
X - Eye						
X-Q Q-Factor	15.473	16.526	14.576	16.350	14.654	dB
X-Q Eye Height	31.528	31.555	31.530	31.551	31.574	√mW
X-Q Rail 0 Std Dev	2.644	2.769	2.691	2.591	2.438	√mW
X-Q Rail 1 Std Dev	2.665	2.765	2.661	2.667	2.753	√mW
X-I Q-Factor	21.796	20.111	22.668	21.419	22.648	dB
X-I Eye Height	28.743	28.504	28.658	28.515	28.661	√mW
X-I Rail 0 Std Dev	1.239	1.216	1.043	1.281	1.161	√mW
X-I Rail 1 Std Dev	1.099	0.901	1.131	1.283	1.040	√mW
Y - Eye						
X - Const						
Y - Const						
Yconst IQ Imbalance	1.006	1.006	1.006	1.007	1.006	
Yconst Bias,Real	0.07	0.05	0.09	0.06	0.01	%
Yconst Bias,Imag	-0.03	-0.02	-0.01	-0.04	-0.01	%
Yconst PhaseAngle	90.19	90.19	90.18	90.17	90.17	deg
Yconst Magnitude	22.079	22.072	22.097	22.099	22.091	√mW
Yconst EVM,Average	15.01	14.09	14.33	14.95	16.16	%
Yconst Mask Violat...	0	5	5	12	-3	
Yconst Symbols Dis...	2992	2992	2992	2992	2992	
Yconst Symbol Std....	0.074	0.072	0.069	0.070	0.069	√mW
X - Trans						
Y - Trans						
Pow - Trans						
XY Measurements						
PMD						

Multi-carrier measurements.

Multi-carrier Superchannel Support

Even as 100G coherent optical systems are being deployed, architectures for 400G and beyond are being proposed and developed. One architecture gaining prominence is the "superchannel." The configurations of superchannels vary considerably. Some proposals call for 400G to be achieved by 2 carriers of DP-16QAM. Other proposals are for 500 Gb/s consisting of 10 or more carriers of DP-QPSK. Some of these carriers are arranged on a standard ITU carrier grid, while others support 12.5 GHz "grid-less" layouts. Clearly, flexible test tools are needed for such next-generation systems. Option MCS to the OM4106D and OM1106 offers the complete flexibility to carrier out such tests.



Superchannel spectrum.

User-Definable Superchannels

For manufacturers getting a jump on superchannels, or researchers investigating alternatives, user-definable superchannel configurations are a must. Option MCS allows the user to set up as many carriers within the superchannel definition as necessary. Each carrier can have an arbitrary center frequency; no carrier grid spacing is imposed. The carrier center frequencies can be set as absolute values (in THz) or as relative values (in GHz). Typically, the OUI will re-tune the OM4106D local oscillator for each carrier. However, in cases where multiple carriers may fit within the scope bandwidth, multiple carriers can be demodulated in software from a common local oscillator frequency. The user is given the flexibility to specify the preferred local oscillator frequency for each carrier.

Automated Measurements

Once the superchannel has been configured, the system is capable of taking measurements at each channel without further intervention by the user. The OUI automatically tunes the OM4106D local oscillator, takes measurements at that channel, re-tunes to the next channel, and so forth until measurements of the entire superchannel have been taken. Results of each channel are displayed in real-time and persist after all measurements are made for easy comparison.

Integrated Measurement Results

All of the same measurement results that are made for single channels are also available for individual channels in a superchannel configuration. Additionally, multi-carrier measurement results are available side-by-side for comparison between channels. Visualizations such as eye diagrams, constellation diagrams, and optical spectrum plots can be viewed a single channel at a time, or with all channels superimposed for fast comparison. For separating channels in a multi-carrier group, several different filters can be applied, including raised cosine, Bessel, Butterworth, Nyquist, and user-defined filters. These filters can be any order or roll-off factor and track the signal frequency.

Characteristics

Values stated in the following tables are typical unless stated otherwise (some values are oscilloscope limited).

Coherent Lightwave Signal Analyzer

Characteristic	Description
Maximum Detectable Baud Rate (at Q of 9.5 dB)	60 Gbaud with Tektronix DPO73304D (2-Ch) 46 Gbaud with Tektronix DPO73304D (4-Ch) 40 Gbaud with Tektronix DPO72004
Maximum Detectable Bit Rate for PM-QPSK (at Q of 9.5 dB)	240 Gb/s with Tektronix DPO73304D (×2) 180 Gb/s with Tektronix DPO73304D (×1) 160 Gb/s with Tektronix DPO72004
Sample Rate	100 GS/s with Tektronix DPO73304D 50 GS/s with Tektronix DPO72004
Optical Field Uncertainty (RMS)	2%
O/E Gain Imbalance Between I and Q	0.1 dB
Available Modulation Formats	OOK, 3-state OOK, (PM) BPSK, (PM) QPSK, (PM) 8, 16, 32, 64-QAM, (PM) Offset QPSK, (PM) 8-PSK Any PRBS or user-supplied pattern Contact factory for new modulation formats
Control	Built-in Ethernet interface

OM4000 Series Coherent Receiver

Characteristic	Description
Optical Input	C-band: 1530 to 1570 nm L-band: 1570 to 1610 nm (Optional) C- and L-band: 1530 to 1610 nm (Optional)
Maximum Input Power	+15 dBm
Maximum Input Power Damage Level	+20 dBm
Polarization Extinction Ratio	>35 dB
Optical Local Oscillator Output	
Optical CW Output Power	+14.5 dBm C-band: 1527.6 to 1565.5 nm L-band: 1570.01 to 1608.76 nm (Optional)
External Local Oscillator Input	
Optical Input Wavelength Range	C-band: 1530 to 1570 nm L-band: 1570 to 1610 nm (Optional)
Suggested External Local Oscillator Input Power Range	+7 to +15 dBm
Maximum Input Peak Power (Damage level)	+20 dBm
Instantaneous Linewidth	<5 MHz
Additional Items	
Electrical Bandwidth	OM4106D: 33 GHz OM4106B: 32 GHz OM4006D: 23 GHz
Optical Phase Angle of IQ Mixer After Correction	90° ±1°
Skew After Correction	±1 ps

Local Oscillator

Characteristic	Description
Wavelength Range	C-band: 1527.6 to 1565.5 nm L-band: 1570.01 to 1608.76 nm
Minimum Wavelength Step	10 GHz
Minimum Frequency Step	100 MHz
Absolute Wavelength Accuracy	10 pm
Linewidth (Short term)	100 kHz
Sidemode Suppression Ratio	55 dB

High-resolution Spectrometer

Characteristic	Description
Maximum Frequency Span	LO frequency ± scope bandwidth
LO Wavelength Range	C-band: 1527.6 to 1565.5 nm L-band: 1570.01 to 1608.76 nm
Number of FFT Points	500k
Minimum RBW	1/max scope time window
Frequency Accuracy	10 pm

OM1106 Coherent Lightwave Signal Analyzer Software

A stand-alone software-only tool that can perform all the data acquisition, analyses, filtering, and display of the OM4000 system using the customer's polarization-diverse coherent receiver.

OM2210 Coherent Receiver Calibration Source

See Tektronix OM2210 data sheet for more detail. The OM2210 can be used to maintain calibration of the OM4000 Series hardware or to characterize 3rd-party receivers.

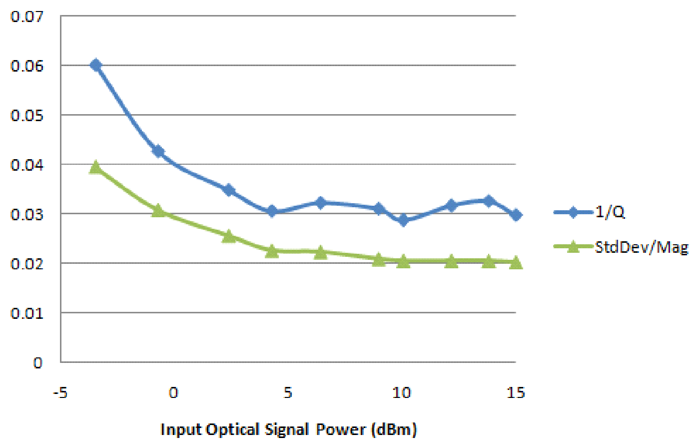


Figure 7 – Constellation diagram accuracy including intradyne and demodulation error can be measured by the RMS error of the constellation points divided by the magnitude of the electric field for each polarization signal. The following data has been measured on a 2.5 Gbaud NRZ 1-pol QPSK transmitter using a Tektronix MSO72004 digitizer.

Measurement Display and Analysis Tools (OM1106 and OM4000 Series)

Characteristic	Description	Real-time Supported Feature	Equivalent-time Supported Feature
Constellation Diagram	Constellation diagram accuracy including intradyne and demodulation error can be measured by the RMS error of the constellation points divided by the magnitude of the electric field for each polarization signal; See Figure 7	X	X
Constellation Elongation	Ratio of constellation height to width	X	X
Constellation Phase Angle	Measure of transmitter IQ phase angle	X	X
Constellation I and Q Bias	Measure of average symbol position relative to the origin	X	X
Constellation Mask	User-settable allowed EVM level. Symbols violating the mask are counted	X	X
Eye Decision Threshold Q-factor	The actual Q achieved will depend on the quality of the data signal, the signal amplitude, and the oscilloscope used for digitalization. Using the Tektronix DPO73304D oscilloscope (4-Ch), a Q-factor of 20 dB is achievable at 40 Gbaud	X	X
Decision Threshold Q-plot	Displays BER vs. decision threshold for each eye opening. The Q value at optimum decision threshold is the Q-factor	X	X
Phase Diagram Signal Spectrum and Laser Spectrum	Display of signal electric field vs. time in the complex plane FFT of power signal or laser phase noise	X	X
MATLAB Window	Commands may be entered that execute each time signals are acquired and processed	X	X
Measurements vs. Time	Optical field, symbol-center values, errors, and averaged waveforms are displayed vs. time in the OUI; any parameter can be plotted vs. time using the appropriate MATLAB expression	X	X
3D Measurements	3D Eye (complex field values vs. time), and 3D Poincaré Sphere for symbol and tributary polarization display	X	X
Differential Eye Diagram Display	Balanced or single-ended balanced detection is emulated and displayed in the Differential Eye Diagram	X	
Frequency Offset	Frequency offset between signal and reference lasers is displayed in Measurement panel	X	X
Poincarè Sphere	Polarizations of the Pol-muxed signal tributaries are tracked and displayed on the Poincarè Sphere. PER is measured	X	
Signal Quality	EVM, Q-factor, and mask violations	X	X
Tributary Skew	A time offset for each tributary is reported in the Measurement panel	X	X
CD Compensation	No intrinsic limit for offline processing – FFT-based filter to remove CD in frequency domain based on a given dispersion value	X	
PMD Measurement	PMD values are displayed in the Measurement panel for Polarization-multiplexed formats with a user-specified number of PMD orders	X	
Oscilloscope and/or Cable Delay Compensation	Cable, oscilloscope, and receiver skew is corrected through interpolation in the OUI. Additional cable adjustment is available using the oscilloscope UI	±0.5 ns	
Oscilloscope Skew Adjustment	Equivalent-time oscilloscope skew is adjusted using the "Delay" feature in the supported sampling head plug-ins		±100%
Calibration Routines	Receiver Skew, DC Offset, and Path Gain Mismatch Hybrid angle and state of polarization are factory calibrated	X	X
Data Export Formats	MATLAB (other formats available through MATLAB or ATE interface); PNG	X	X
Raw Data Replay with Different Parameter Setting	Movie mode and reprocessing	X	X
Bit Error Ratio Measurements	Number of counted bits/symbols	X	X
	Number or errors detected	X	X
	Bit error ratio	X	X
	Differential-detection errors	X	
	Save acquisition on detected error	X	X
Offline Processing	Run software on a separate PC or on the oscilloscope	X	X

Physical Characteristics

Dimension	mm	in.
Height	89	3.5
Width	432	17.0
Depth	298.5	11.75
Weight	**kg**	**lb.**
Net	11.8	26
Shipping	15.9	35

Environmental Characteristics – Scope Not Included (OM4106B)

Characteristic	Description
Temperature	
Operating	+10 +35 °C
Storage	–20 to +70 °C, noncondensing humidity
Humidity	15% to 80% relative humidity, noncondensing
Power Requirements	100/115/230 V AC, ~50 to 60 Hz, 1 power cable, max. 100 VA

Calibration and Warranty

Characteristic	Description
Calibration Interval	1 year

CAUTION

This device is a Class 1M laser product for use only under the recommended operating conditions and ratings specified in the data sheet. Use of controls or adjustments or performance of procedures other than those specified in the data sheet may result in hazardous radiation exposure.

Invisible laser radiation – Do not view the laser output from this device directly with optical instruments.

This device complies with 21CFR1040.10 except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.

INVISIBLE LASER RADIATION; DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS. CLASS 1M LASER PRODUCT
EMISSION DE RAYONS LASER INVISIBLES DE CLASSE 1M. NE PAS OBSERVER A L'AIDE D'INSTRUMENTS OPTIQUES

Ordering Information

Models

Model	Option	Description	Receiver Bandwidth	C-band Lasers Included	L-band Lasers Included	Wavelength Band	Oscilloscope Connectivity
OM4006D	CC	23 GHz C-band Coherent Lightwave Signal Analyzer	23 GHz	2	0	1530 to 1570 nm	IVI / Visa
OM4006D	LL	23 GHz L-band Coherent Lightwave Signal Analyzer	23 GHz	0	2	1570 to 1610 nm	IVI / Visa
OM4006D	CL	23 GHz C- and L-band Coherent Lightwave Signal Analyzer	23 GHz	1	1	1530 to 1610 nm	IVI / Visa
OM4106D	CC	33 GHz C-band Coherent Lightwave Signal Analyzer	33 GHz	2	0	1530 to 1570 nm	DataStore
OM4106D	LL	33 GHz L-band Coherent Lightwave Signal Analyzer	33 GHz	0	2	1570 to 1610 nm	DataStore
OM4106D	CL	33 GHz C- and L-band Coherent Lightwave Signal Analyzer	33 GHz	1	1	1530 to 1610 nm	DataStore

Note: DataStore interface is only applicable to Tektronix 70000 Series oscilloscopes.

Configuration Recommendations

	Receiver Model	Receiver Options	Receiver Bandwidth	Recommended Scope Model	Scope Bandwidth
Real-time Systems	OM4006D	Recommended: Opt. CC, Opt. QAM, Opt. TSI, OMRACK	23 GHz	DPO/DSA72504C	25 GHz
	OM4106D	Recommended: Opt. CC, Opt. QAM, Opt. TSI, OMRACK	33 GHz	DPO/DSA73304D	33 GHz
Equivalent-time Systems	OM4006D	Recommended: Opt. CC, Opt. QAM, Opt. TSI, OMRACK Required: Opt. EXT	23 GHz	DSA8300 with Opt. ADVTRIG and 2 each 80E07	30 GHz
	OM4106D	Recommended: Opt. CC, Opt. QAM, Opt. TSI, OMRACK Required: Opt. EXT	33 GHz	DSA8300 with Opt. ADVTRIG and 2 each 80E09	60 GHz

User Manual Options

Option	Description
Opt. L0	English manual

Power Plug Options

Option	Description
Opt. A0	US plug, 115 V, 60 Hz
Opt. A1	Universal Euro plug, 220 V, 50 Hz
Opt. A2	UK plug, 240 V, 50 Hz
Opt. A3	Australian plug, 240 V, 50 Hz
Opt. A5	Swiss plug, 220 V, 50 Hz
Opt. A6	Japanese plug, 100 V, 110/120 V, 60 Hz
Opt. A10	China plug, 50 Hz
Opt. A11	India plug, 50 Hz
Opt. A12	Brazilian plug, 60 Hz

Service Options

Option	Description
Opt. C3	Calibration Service 3 Years
Opt. C5	Calibration Service 5 Years
Opt. D1	Calibration Data Report
Opt. D3	Calibration Data Report 3 Years (with Opt. C3)
Opt. D5	Calibration Data Report 5 Years (with Opt. C5)
Opt. R3	Repair Service 3 Years
Opt. R5	Repair Service 5 Years

Software Options

Option	Description
QAM	Adds QAM and other software demodulators
MCS	Adds multi-carrier superchannel support

OM2210 Coherent Receiver Calibration Source Configuration Recommendations

When Used with OM4006D or OM4106D Receiver Model Option:	Recommended OM2210 Coherent Receiver Calibration Source
Opt. CC – 2 C-band lasers	OM2210 Opt. NL – To be able to fully calibrate the receiver with Opt. CC OM2210 Opt. CC – To be able to fully calibrate the receiver with Opt. CC or a 3rd-party C-band receiver
Opt. LL – 2 L-band lasers	OM2210 Opt. NL – To be able to fully calibrate the receiver with Opt. LL OM2210 Opt. LL – To be able to fully calibrate the receiver with Opt. LL or a 3rd-party C-band receiver
Opt. CL – 1 each C-band and L-band lasers	OM2210 Opt. CL – To be able to fully calibrate the receiver with Opt. CL
Opt. NL – No lasers	Both of the following instruments are required: OM2210 Opt. CL – To be able to fully calibrate the receiver with Opt. CL OM2012 Opt. CL – Provides lasers sources required for calibration of receiver

Instrument Models and Options

Order	Description
OM1106	**OUI Signal Analysis Software only**
OM1106 QAM	Adds QAM and other software demodulators
OM1106 SWS0	1-year OM1106 software maintenance agreement from date of purchase (included at no charge)
OM1106 SWS2	2-year OM1106 software maintenance agreement from date of purchase
OM1106 SWS3	3-year OM1106 software maintenance agreement from date of purchase
OM4006D	
OM4006D	23 GHz Coherent Lightwave Signal Analyzer (requires choice of lasers)
OM4006D CC	C-band lasers (receiver tested over C-band)
OM4006D LL	L-band lasers (receiver tested over L-band)
OM4006D CL	Coupled C- and L-band lasers (receiver calibrated over C- and L-band)
OM4006D NL	No lasers (receiver calibrated over C- and L-band)
OM4006D EXT	Adds external connections for reference laser. Required for ET
OM4006D QAM	Adds QAM and other software demodulators
OM4006D SWS0	1-year Signal Analyzer software maintenance agreement from date of purchase (included at no charge)
OM4006D SWS2	2-year Signal Analyzer software maintenance agreement from date of purchase
OM4006D SWS3	3-year Signal Analyzer software maintenance agreement from date of purchase
OM4106D	
OM4106D	33 GHz Coherent Lightwave Signal Analyzer (requires choice of lasers)
OM4106D CC	C-band lasers (receiver tested over C-band)
OM4106D LL	L-band lasers (receiver tested over L-band)
OM4106D CL	Coupled C- and L-band lasers (receiver calibrated over C- and L-band)
OM4106D NL	No lasers (receiver calibrated over C- and L-band)
OM4106D EXT	Adds external connections for reference laser
OM4106D QAM	Adds QAM and other software demodulators
OM4106D MCS	Adds multi-carrier superchannel support
OM4106D SWS0	1-year Signal Analyzer software maintenance agreement from date of purchase (included at no charge)
OM4106D SWS2	2-year Signal Analyzer software maintenance agreement from date of purchase
OM4106D SWS3	3-year Signal Analyzer software maintenance agreement from date of purchase
General	
OMCABLE	Replacement OM cable kit
OMDONGLE	Replacement OM license dongle (requires software license key number)
OMRACK	Tabletop mounting rack for OM4000 Series
OMTRAIN	On-site training and/or installation for OMxxxx products
OMADDLSW	Additional set of Coherent Lightwave Signal Analyzer Software (requires OM4106 instrument serial number)
OMSWS1	1-year Signal Analyzer software maintenance agreement from date of purchase
OMSWS2	2-year Signal Analyzer software maintenance agreement from date of purchase
OMSWS3	3-year Signal Analyzer software maintenance agreement from date of purchase
DPOACQSYNC	Multi-scope synchronization kit

Order	Description
OMINSTALL AMR	On-site OM-series install for the Americas
OMINSTALL JPN	On-site OM-series install for Japan
OMINSTALL EMEA	On-site OM-series install for Europe, Middle East, and Africa
OMINSTALL APAC	On-site OM-series install for Asia Pacific

Upgrade Options

Order	Description
OM1106	
OM11UP QAM	Adds QAM and other software demodulators
OM11UP MCS	Adds multi-carrier superchannel support
OM4006D	
OM40UP QAM	Adds QAM and other software demodulators
OM40UP CC	Replaces OM4006 lasers with 2 C-band lasers
OM40UP LL	Replaces OM4006 lasers with 2 L-band lasers
OM40UP CL	Replaces OM4006 lasers with 1 C-band laser and 1 L-band laser
OM40UP EXT	Adds external connections for reference laser
OM40UP TSI	Adds integration with Tektronix oscilloscope Contact sales for integration with other oscilloscopes
OM40UP 4006D	Upgrades OM4006 (any model) to OM4006D
OM40UP 4106B	Upgrades OM4006 (any model) to OM4106B
OM40UP 4106D	Upgrades OM4006 (any model) to OM4106D
OM4106D	
OM41DUP QAM	Adds QAM and other software demodulators
OM41DUP MCS	Adds multi-carrier superchannel support
OM41DUP CC	Replaces OM4006 lasers with 2 C-band lasers
OM41DUP LL	Replaces OM4006 lasers with 2 L-band lasers
OM41DUP CL	Replaces OM4006 lasers with 1 C-band laser and 1 L-band laser
OM41DUP EXT	Adds external connections for reference laser
OM41DUP TSI	Adds integration with Tektronix oscilloscope

Additional Requirements for CLSA Software

Supported platforms for the OM4000 Software:
- Computer with nVidia graphics card running US Windows 7 64-bit and Matlab 2011b (64-bit)
- Computer with nVidia graphics card running US Windows XP 32-bit and Matlab 2009a (32-bit)

The following platforms are supported by may not be able to utilize certain advanced graphics features such as color grade and 3D:
- Tektronix 70000 Series Oscilloscopes running Windows 7 64-bit and Matlab 2011b (64-bit)
- Computer with non-nVidia graphics running US Windows 7 64-bit and Matlab 2011b (64-bit)
- Computer with non-nVidia graphics running US Windows XP 32-bit and Matlab 2009a (32-bit)

Please check with Tektronix when ordering for the most up-to-date detailed requirements including support for the latest releases of MATLAB software.

Please contact Tektronix for a price quote or to arrange a demonstration. All product descriptions and specifications are subject to change without notice.

CE

Tektronix is registered to ISO 9001 and ISO 14001 by SRI Quality System Registrar.

Contact Tektronix:

ASEAN / Australasia (65) 6356 3900
Austria 00800 2255 4835*
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium 00800 2255 4835*
Brazil +55 (11) 3759 7627
Canada 1 800 833 9200
Central East Europe and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France 00800 2255 4835*
Germany 00800 2255 4835*
Hong Kong 400 820 5835
India 000 800 650 1835
Italy 00800 2255 4835*
Japan 81 (3) 6714 3010
Luxembourg +41 52 675 3777
Mexico, Central/South America & Caribbean 52 (55) 56 04 50 90
Middle East, Asia, and North Africa +41 52 675 3777
The Netherlands 00800 2255 4835*
Norway 800 16098
People's Republic of China 400 820 5835
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 001 800 8255 2835
Russia & CIS +7 (495) 7484900
South Africa +41 52 675 3777
Spain 00800 2255 4835*
Sweden 00800 2255 4835*
Switzerland 00800 2255 4835*
Taiwan 886 (2) 2722 9622
United Kingdom & Ireland 00800 2255 4835*
USA 1 800 833 9200

* European toll-free number. If not accessible, call: +41 52 675 3777

Updated 10 February 2011

For Further Information. Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

05 Mar 2013 52W-27474-5