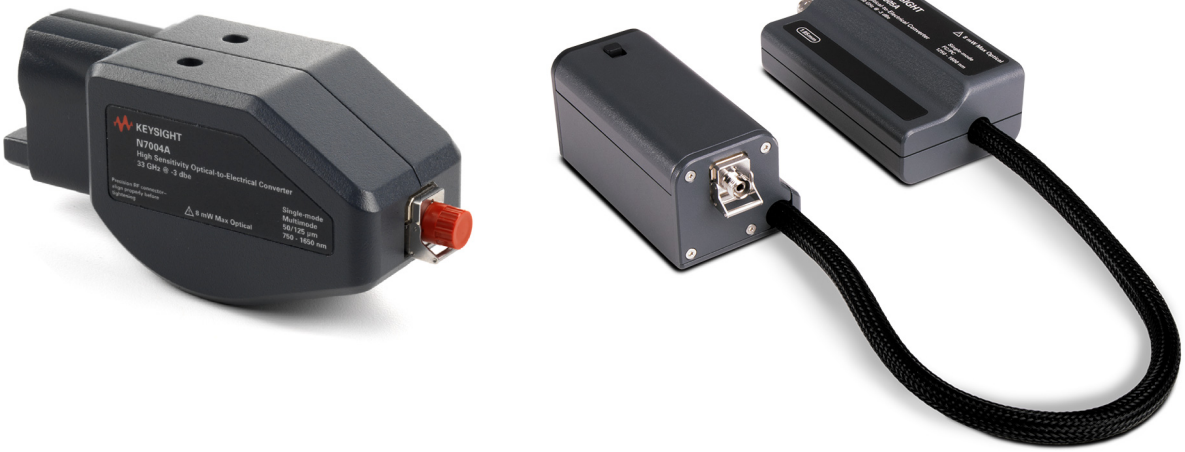
Keysight N7004A /N7005A Optical-to-Electrical Converters

User's Guide



KEYSIGHT TECHNOLOGIES

Notices

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Safety Notices

CAUTION

A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Contents

1 Overview

This chapter introduces the N7004A and N7005A O/E converters and lists their features, usage, characteristics, and specifications.

Introduction

The following two optical-to-electrical converters are described in this guide.

- N7004A 33 GHz optical-to-electrical converter
- N7005A 60 GHz optical-to-electrical converter

These optical-to-electrical converters directly convert optical signals into electrical signals for convenient analysis on a compatible Infiniium real-time oscilloscope.

N7004A and N7005A have a high-sensitivity photodetector module with an FC/PC input connector to receive optical telecom or datacom signals from an optical source/transmitter through a fiber optic patch cable. The N7004A supports transmission through a single-mode as well as a multimode fiber. The N7005A supports transmission through a single-mode fiber.

The O/E output connector of N7004A / 5A connects to the oscilloscope's channel to provide its electrical output to the oscilloscope for analysis.

NOTE

The N7004A O/E Converter is designed for use with oscilloscopes that have AutoProbe II interface channel inputs.
The N7005A O/E Converter is designed for use with oscilloscopes that have AutoProbe III interface channel inputs.

The AutoProbe interface provides power to the N7004A /5A as well as ensures the auto-configuration of probe type and attenuation settings when you connect the N7004A /5A to the oscilloscope.

N7004A Components

Figure 1 N7004A Optical-to-Electrical Converter - Components

N7005A Components

Figure 2 N7005A Optical-to-Electrical Converter - Components

Usage

The following are the broad usage scenarios of N7004A / 5A with an Infiniium real-time oscilloscope as an optical measurement solution.

- To view the raw (unfiltered) response of the optical source/transmitter under test.
- To make industry-standard optical measurements on the optical source/transmitter under test. The N7004A and N7005A support 4th Order Bessel Thomson filter to help you accomplish this.
- To perform system-level troubleshooting and characterization for the optical source(s) used in your optical system.
- To test system boards with an embedded optical transceiver in scenarios where there is no clock signal. The N7004A / 5A and real-time oscilloscope setup does not require an external clock source to trigger the oscilloscope for capturing data.
- To view and troubleshoot a one-time, transient single-shot event.
- To make optical PAM4 measurements including Transmitter Dispersion and Eye Closure Quaternary (TDECQ), Outer Extinction Ratio (ER), Outer Optical Modulation Amplitude (OMA), and Average Optical Power using N7005A. The high bandwidth supported by N7005A is specifically suited to cover 56 Gbaud optical PAM4 measurements.

Features

Refer to page 15 for the complete set of specifications and characteristics for N7004A / 5A.

N7004A	N7005A
Allows you to view optical streams at speeds up to 28 Gbps.	Allows you to view optical streams at speeds up to 56 Gbaud PAM4. Allows you to make the TDECQ optical measurement using the FlexRT software GUI which can be launched from the Infiniium GUI **(see** page 37**)**
Supports DC to 33 GHz of electrical bandwidth.	Supports DC to 60 GHz of electrical bandwidth.
Supports single-mode as well as multimode fibers. *(See* page 15 *for supported wavelength ranges and conversion gain.)*	Supports single-mode fiber. *(See* page 15 *for supported wavelength ranges and conversion gain.)*
Designed for use with oscilloscopes that have AutoProbe II interface channel inputs.	Designed for use with oscilloscopes that have AutoProbe III interface channel inputs.
Supports the following filter types: - Brickwall filter - 4th Order Bessel Thomson filter - Butterworth filter (*available only on UXR-series oscilloscopes*)	
Built-in unique s-parameter correction filters to ensure a flat frequency response thereby yielding more accurate measurements. The system response is automatically corrected on connecting the N7004A/5A to the oscilloscope.	
Allows you to improve the accuracy of the extinction ratio measurement by providing the option of Dark Calibration which is performed by covering the optical input of the N7004A / 5A. The optical power reading thus obtained from dark calibration is subtracted from the optical measurements to achieve accuracy in measurements.	
Use either front panel controls on the oscilloscope or remote programs to set up, configure, and make measurements using the N7004A / 5A.	
Supports built-in trigger source. You need not configure a trigger setup explicitly for making optical measurements using the N7004A / 5A.	
Allows you to make critical optical signals measurements in real time with an Infiniium real-time oscilloscope. In the Infiniium software GUI, you get: - a suite of optical measurements (see page 40) with data presented in watts. - features for eye-mask testing and measuring eye diagram parameters including extinction ratio. - features for loading masks with margin or drawing your own mask or create an automask.	
Provides a built-in software reference receiver filter. The reference receiver measurement is made with a 4th Order Bessel Thomson filter set to 75% of the data rate. This reduces the effects of the transmitter's high frequency overshoot and noise.	

Compatible Oscilloscopes

For N7004A

N7004A Compatible Oscilloscopes	Adapter Required	Oscilloscope Software
- V-Series - Z-Series - 90000 Q-Series - 90000 X-Series	None	Infiniium baseline software version 5.70 or higher
UXR-Series (13-33 GHz)	None	Infiniium baseline software version 10.25.00702 or higher
UXR-Series (40 GHz or higher)	N2852A AutoProbe II to AutoProbe III Interface adapter)	Infiniium baseline software version 10.25.00702 or higher

NOTE The N2852A AutoProbe II to AutoProbe III Interface adapter allows you to connect the N7004A (with the AutoProbe II interface) to a Keysight UXR-Series 40 GHz or higher Infiniium oscilloscope (with the AutoProbe III interface).

To know more about the N2852A adapter, visit http://www.keysight.com/find/N2852A and then download the adapter's user guide available in the Document Library tab.

CAUTION Care should be taken while handling the N2852A adapter's RF cable. Avoid bending this cable backwards or kinking the cable to ensure measurements accuracy.

For N7005A

N7005A Compatible Oscilloscopes	Adapter Required	Oscilloscope Software

UXR-series (40 GHz or higher) with 1.85 mm AutoProbe III Interface	1.85 mm F - F adapter available with the UXR oscilloscope (p/n - 85058-60114)	**For optical measurements and Infiniium based dark calibration**
		▪ Infiniium baseline software version 10.25.00702 or higher
		For TDECQ measurement features (see page 37)
		▪ Infiniium baseline software version 10.25 Patch 6 or higher
		▪ FlexRT software
		  ▪ N1010A FlexDCA oscilloscope software version A.06.70 or higher
		  ▪ N1010200A Manufacturing license to make the TDECQ measurement
		  ▪ N1010100A RND license if you want to run the FlexRT application from a remote PC connected to the real-time oscilloscope. This license also allows you to make the TDECQ measurement.

UXR-series (40 GHz or higher) with 1 mm AutoProbe III Interface	1 mm Ruggedized F - 1.85 mm F adapter available as an optional UXR oscilloscope accessory. (p/n - Y1901B)	

Is Your Oscilloscope Software Up-to-Date?

Keysight periodically releases software updates to support your probe, fix known defects, and incorporate product enhancements. To download the latest firmware, go to www.keysight.com and search for your oscilloscope's series. Then click on the "Drivers, Firmware & Software" tab.

Oscilloscope Bandwidth Requirements

You can use the following calculations to determine the real-time oscilloscope bandwidth needed when using the N7004A or N7005A.

For NRZ (PAM2) Signals

Oscilloscope bandwidth requirement >= Optical data rate (Gbps) * 0.75 * 3/2

For example, if the optical data rate is 10 Gbps, then the oscilloscope bandwidth requirement is:
10 Gbps * 0.75 * 3/2 which is equal to 11.25 GHz.

Based on the above calculations, the following table provides the recommended bandwidth of the compatible Infiniium oscilloscopes for NRZ (PAM2) signals measurements.

Optical Data Rates	Reference Receiver Bessel Thomson Bandwidth *(0.75 * optical data rate)*	Oscilloscope Bandwidth Requirement *(3/2 * Reference Receiver Bandwidth)*	Recommended Oscilloscope Bandwidth
28 Gbps	21 GHz	>31.5 GHz	**For N7004A** V-series 33 GHz Z-series 33 GHz UXR-series 33 GHz **For N7005A** UXR-series 40 GHz

For PAM4 Signals *(applicable to N7005A only)*

Oscilloscope bandwidth requirement >= Optical symbol rates in Gbaud * 0.5 * 3/2

For example, if the optical data rate is 56 Gbps (28 Gbaud) then the oscilloscope bandwidth requirement is:
28 Gbaud * 0.5 * 3/2 which is equal to 21 GHz.

Based on the above calculations, the following table provides the recommended bandwidth of the compatible Infiniium oscilloscope for PAM4 signals measurements.

Optical Data Rates	Optical Symbol Rates	Reference Receiver Bessel Thomson Bandwidth *(0.75 * optical data rate)*	Oscilloscope Bandwidth Requirement *(3/2 * Reference Receiver Bandwidth)*	Recommended Oscilloscope Bandwidth
56 Gbps	28 Gbaud	14 GHz	>21 GHz	**For N7005A** UXR-series 40 GHz
112 Gbps	56 Gbaud	28 GHz	>42 GHz	**For N7005A** UXR-series 70 GHz

N7004A and N7005A Specifications and Characteristics

Environmental Specifications

Characteristic	N7004A	N7005A
Use	For indoor use only	
Temperature	Operating +10 °C to +40 °C (50 °F to +104 °F) Non-operating -40 °C to +70 °C (-40 °F to +158 °F)	Operating +10 °C to +55 °C (50 °F to +131 °F) Non-operating -40 °C to +70 °C (-40 °F to +158 °F)
Altitude	Up to 4,600 meters (15,000 ft)	Up to 4,600 meters (15,000 ft)
Maximum relative humidity	80% for temperatures up to 31 °C decreasing linearly to 50% relative humidity at 40 °C	80% for temperatures up to 31 °C decreasing linearly to 50% relative humidity at 40 °C
Weight	350 g (0.77 lbs)	410 g (0.9 lbs)
Dimensions	Refer to the topic "N7004A Dimensions" on page 16.	Refer to the topic "N7005A Dimensions" on page 17.

Bandwidth Performance Specification

Specification	N7004A	N7005A
Bandwidth, warranted (electrical, –3 dB)	32 GHz (with Brickwall filter) 21.3 GHz (with 4th order Bessel Thomson filter)	60 GHz (with Brickwall filter) 46.6 GHz (with 4th order Bessel Thomson filter)
Specifications are the performance standards against which the product is tested. It represents warranted performance of a calibrated instrument.		

Optical and Electrical Characteristics

Characteristic	N7004A	N7005A
Bandwidth, typical (electrical, –3 dBe)	33 GHz (with Brickwall filter) 22 GHz (with 4th order Bessel Thomson filter)	60 GHz (with Brickwall filter) 46.6 GHz (with 4th order Bessel Thomson filter)
Rise time (10 to 90%), typical	13.3 psec (with Brickwall filter) 17.7 psec (with 4th order Bessel Thomson filter)	7.3 psec (with Brickwall filter) 8.4 psec (with 4th order Bessel Thomson filter)
Rise time (20 to 80%), typical	9.4 psec (with Brickwall filter) 12.3 psec (with 4th order Bessel Thomson filter)	5.2 psec (with Brickwall filter) 5.8 psec (with 4th order Bessel Thomson filter)
Optical output coupling	DC	
Wavelength range	750 to 1650 nm (including factory-calibrated 850, 1310 nm, and 1550 nm)	1250 nm to 1600 nm (including factory-calibrated 1310 nm and 1550 nm)
RMS noise (uW)	See the noise characteristics table in the data sheet	
Conversion gain (V/W)	850 nm multimode: 68 (min), 75 (typical) 1310 nm multimode/single-mode: 105 (min), 110 (typical) 1550 nm single-mode: 105 (min), 110 (typical)	1310 nm single-mode: 85 (min), 93 (typical) 1550 nm single-mode: 72 (min), 85 (typical)
Maximum linear input power	4 mW	
Maximum non-destructive input power	8 mW	

Characteristic	N7004A	N7005A
Input return loss (dB)	850 nm multimode: –17 (typical), –15 (max) (fully filled fiber) 1310 nm single-mode: –18.5 (typical), –16 (max) 1550 nm single-mode: –14 (typical)	1310 nm single-mode: -25 (max) 1550 nm single-mode: -25 (max)
Connector type	FC/PC to 50/125 µm fiber Compatible with single-mode or multimode fibers	FC/PC to 9/125 µm fiber Compatible with single-mode fiber
Oscilloscope Interface	AutoProbe II	AutoProbe III

N7004A Dimensions

The N7004A dimensions shown below are in Inches.

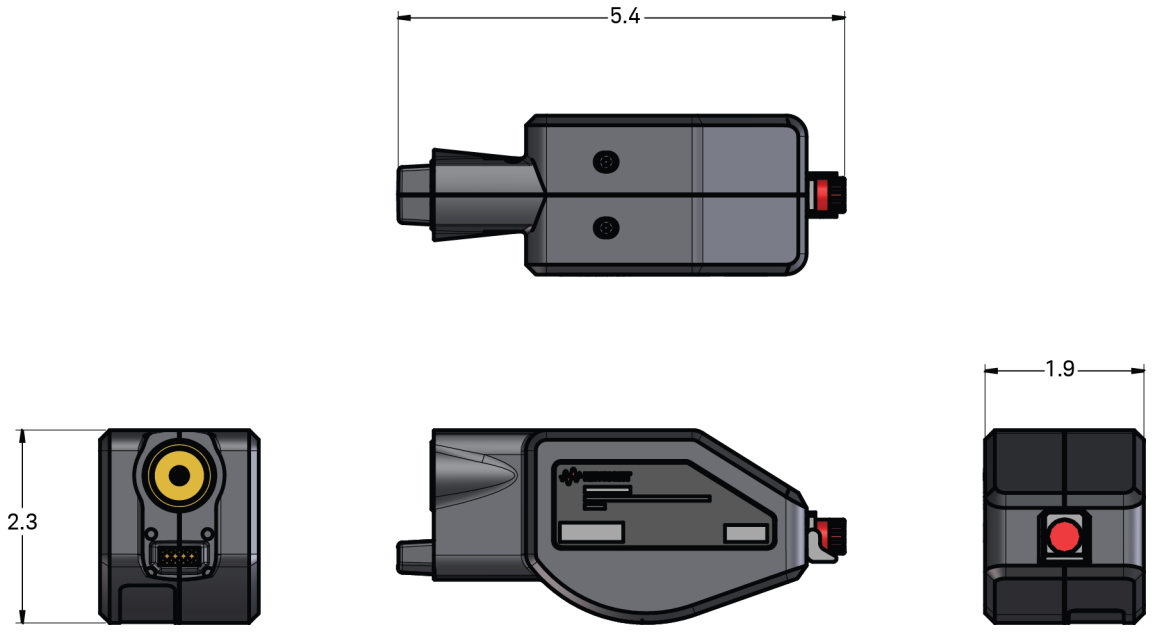


Figure 3 N7004A Dimensions

N7005A Dimensions

The N7005A dimensions shown below are in Inches [mm].

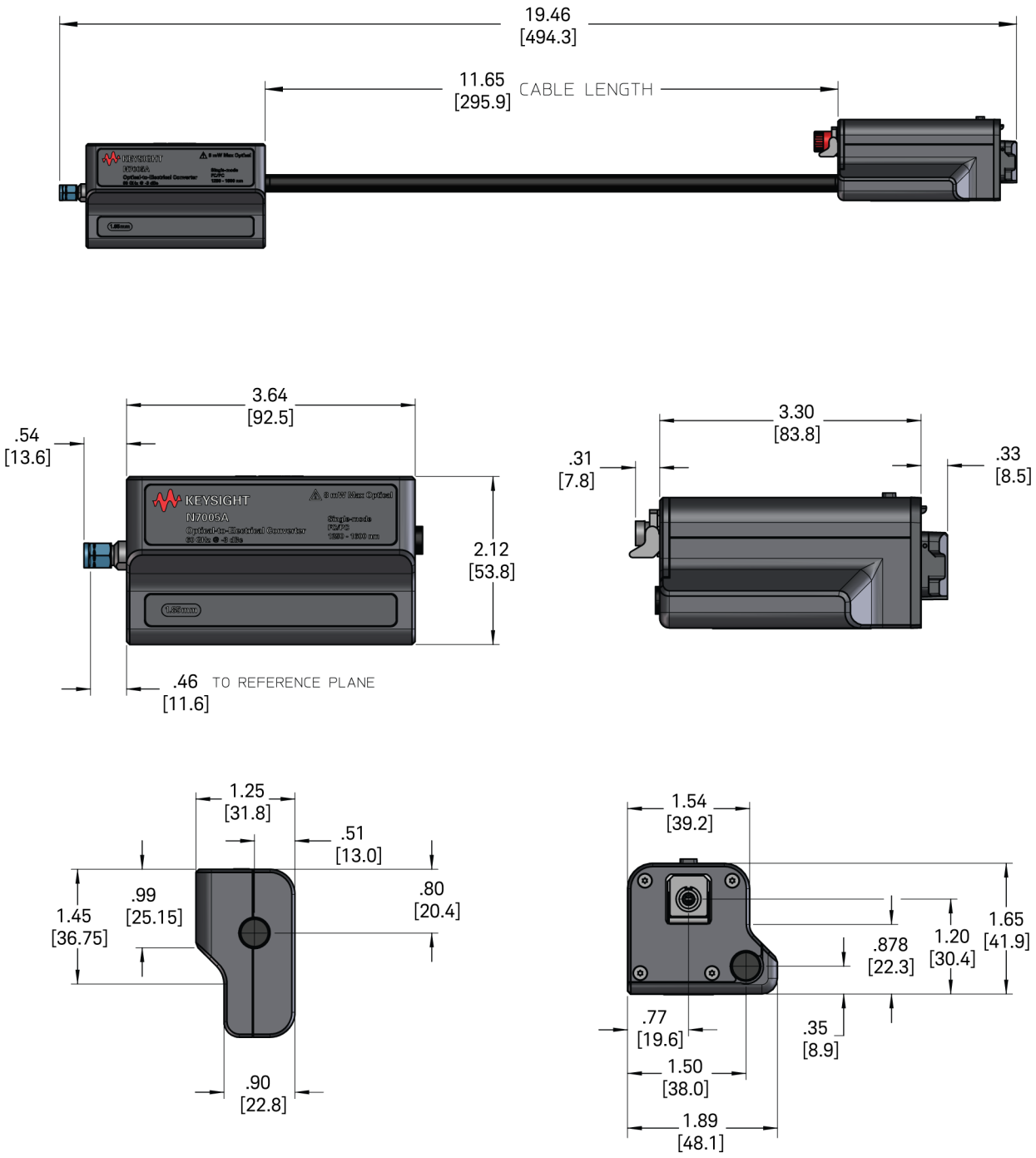


Figure 4 N7005A Dimensions

2 Setting up the N7004A and N7005A O/E Converters

Step 1 - Clean the Fiber-Optic Connectors

Fiber-optic connectors are very sensitive, easy to damage, and expensive to replace. These connectors can be easily damaged when connected to dirty or damaged cables and accessories. Therefore, you must clean the fiber ends of the N7004A / 5A fiber-optic connector and the mating fiber-optic cable or patch cable before each and every time a connection is made.

CAUTION

Damage to the fiber-optic connectors can:

- Degrade measurement accuracy and repeatability.
- Cause expensive damage to instruments.

Repair of the N7004A / 5A connector damaged due to lack of cleaning, improper use, or improper cleaning procedures is NOT covered under warranty.

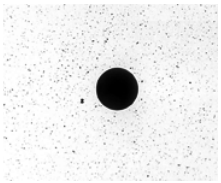
NOTE

Keep fiber-optic connectors covered when not in use. The N7004A / 5A shipment includes protective plastic caps for covering its fiber-optic connector.

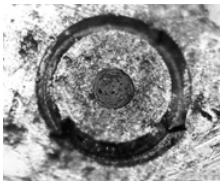
To visually inspect the fiber-ends

The visual inspection of the fiber-ends can help you identify any damage to the ferrule or end of the fiber, any stray particles, or finger oil that can have a significant effect on connector performance.

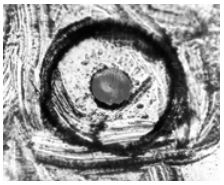
The following picture shows the end of a clean, problem-free fiber-optic connector. The dark center circle is the fiber's 125 mm core and cladding which carries the light. The surrounding area is the ferrule.



The following picture shows a fiber end that is dirty from neglect or improper cleaning. Loose particles or oils are smeared and ground into the end of the fiber causing light scattering and poor reflection. Not only is the precision polish lost, but this action can also grind off the glass face and destroy the connector.



The following picture shows physical damage to the glass fiber end caused by either repeated connections made without removing loose particles from the fiber end or by using improper cleaning tools. This damage can be severe enough to transfer the damage from the connector end to a good connector that comes in contact with it.

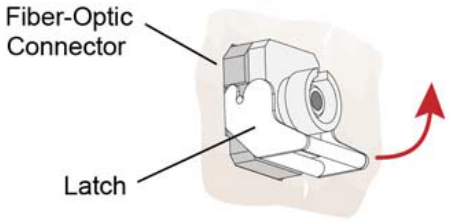


Use a microscope (100X to 200X magnification) to inspect the entire end face for contamination, raised metal, dents in the metal, and any other imperfections. Visible imperfections not touching the fiber core may not affect performance, unless the imperfections keep the fibers from contacting.

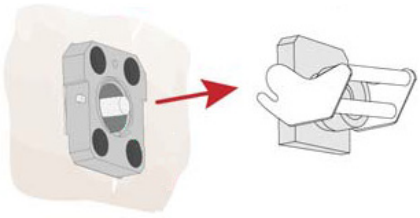
WARNING **Always remove both ends of fiber-optic cables from any instrument, system, or device before visually inspecting the fiber-ends. Disable all optical sources before disconnecting fiber-optic cables. Failure to do so may result in permanent injury to your eyes.**

To clean the fiber-end of the N7004A / 5A fiber-optic connector

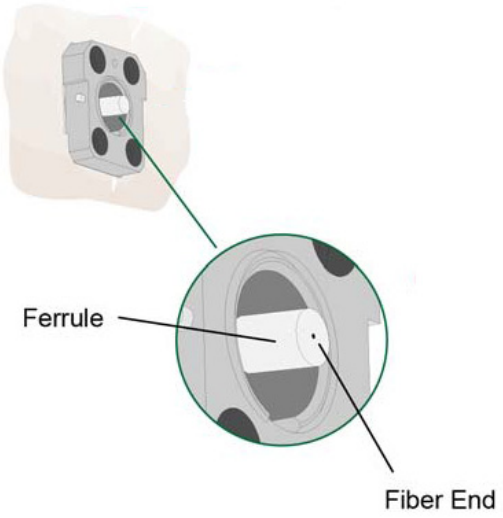
1 Lift the latch of the fiber-optic connector.



2 Carefully pull off the receptacle without touching the ferrule or fiber end. This will expose the fiber-end for cleaning.



3 Clean the fiber-optic end using a professional fiber-optic cleaning product. A variety of products are available and are easily located via an Internet search on "fiber optic cleaning products". You can purchase tools designed specifically for the type of fiber-optic cable that you are using. You can also use a cloth or a swab with alcohol to clean.



CAUTION Never use metal or sharp objects to clean a connector and never scrape the connector.

To clean the fiber-end of the mating patch cable

1 Use a clean wipe each time you need to clean the mating cable. Wipes that are available in a dispenser are recommended for cleaning.

WARNING If flammable cleaning materials are used, the material shall not be stored, or left open in the area of the equipment. Adequate ventilation shall be assured to prevent the combustion of fumes, or vapors. Ensure that the disposal of cleaning materials is done in a manner consistent with local regulations.

WARNING Cleaning connectors with alcohol shall only be done with the instruments power cord removed, and in a well-ventilated area. Allow all residual alcohol moisture to evaporate and the fumes to dissipate prior to energizing the instrument.

CAUTION Do not use any type of foam swab to clean optical fiber ends. Foam swabs can leave filmy deposits on fiber ends that can degrade performance.

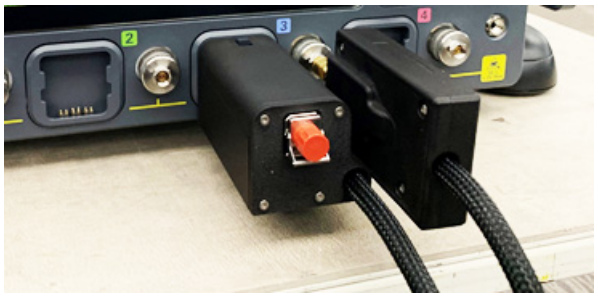
CAUTION Do not scrub during this initial cleaning because grit can be caught in the swab and become a gouging element.

CAUTION Do not shake, tip, or invert compressed air canisters, because this releases particles in the can into the air. Refer to instructions provided on the compressed air canister.

CAUTION Keysight Technologies strongly recommends that index matching compounds not be applied to their instruments and accessories. Some compounds, such as gels, may be difficult to remove and can contain damaging particulates. If you think the use of such compounds is necessary, refer to the compound manufacturer for information on application and cleaning procedures.

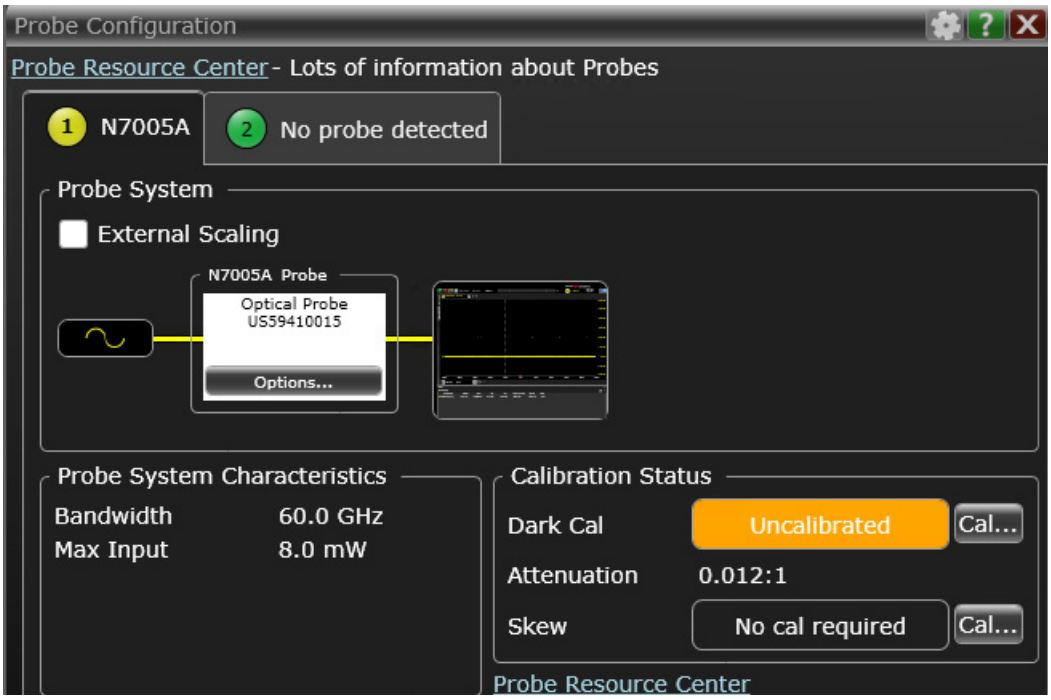
Step 2 - Connect the N7004A / 5A Output to a Compatible Keysight Oscilloscope

CAUTION When using N7005A, ensure that it is not connected to the optical signal until both its modules (AutoProbe III interface module and O/E module) are connected to the oscilloscope.



On connecting,

- The oscilloscope automatically recognizes the N7004A / 5A.
- The s-parameters are automatically read to adjust the system response and the N7004A / 5A is displayed in the Infiniium software GUI for setup and configuration.
- The vertical unit is changed to **Watts** in the Infiniium software GUI.



Step 3 - Connect a Fiber-optic Cable to the N7004A / 5A Optical Input Connector

WARNING Ensure that all connections to N7004A / 5A are secure prior to enabling any laser source.

Fiber-optic Cable Selection

- With N7004A, you can use a 9/125 µm single-mode or a 50/125 µm multimode fiber-optic cable that has an FC/PC connector. With N7005A, you can use a 9/125 µm single-mode fiber-optic cable that has an FC/PC connector.
- If your fiber has a connector other than FC/PC, then you can use a LC-to-FC or SC-to-FC patch cord to establish connectivity with the N7004A / 5A.
- If your fiber has a FC/APC connector, use a fiber patch cord with FC/UPC to connect to the O/E side of N7005A and FC/APC to connect to the target.
- Ensure that you use a fiber patch cord with ceramic fiber-optic ferrule.

Guidelines for Making the Connection

When inserting a fiber-optic cable into a connector:

- Gently insert the fiber-optic cable in as straight a line as possible. Tipping and inserting at an angle can scrape material off the inside of the connector or even break the inside sleeve of connectors made with ceramic material.
- Ensure that the fiber end does not touch the outside of the mating connector or adapter.
- Avoid over tightening connections. Unlike common electrical connections, tighter is not better. The purpose of the connector is to bring two fiber ends together. Once they touch, tightening only causes a greater force to be applied to the delicate fibers.

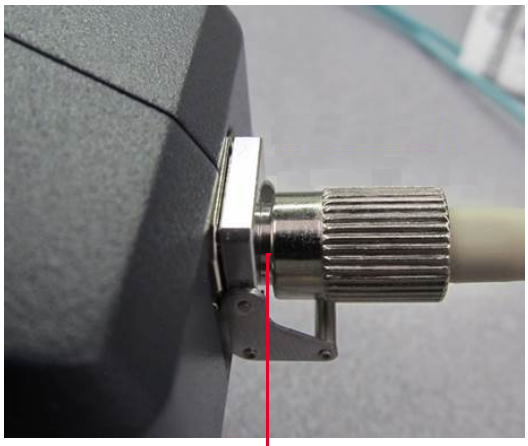
  With connectors that have a convex fiber end, the end can be pushed off-axis resulting in misalignment and excessive return loss. Many measurements are actually improved by backing off the connector pressure. Also, if a piece of grit does happen to get by the cleaning procedure, the tighter connection is more likely to damage the glass. Tighten the connectors just until the two fibers touch.
- Use fusion splices on the more permanent critical nodes. Choose the best connector possible. Replace connecting cables regularly. Frequently measure the return loss of the connector to check for degradation, and clean every connector, every time.

CAUTION **To avoid damage to the fiber-optic connector, use proper cleaning techniques. Refer to "Step 1 - Clean the Fiber-Optic Connectors" on page 20.**

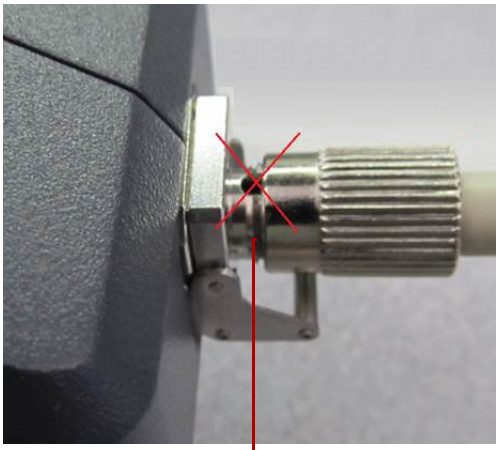
Aligning the Keying Features while Making the Connection

While securing the connection between the N7004A / 5A and fiber-optic cable, ensure that the keying features of both the N7004A/5A FC/PC Input connector and fiber-optic cable's connector are aligned properly before you start finger-tightening the connection. Misaligned keys can adversely affect the optical signal transmission.

The following are the examples of finger-tightened connections, one with the keying features properly aligned and the other with the keying features misaligned.



Correct way of connecting - Keying features are proper aligned



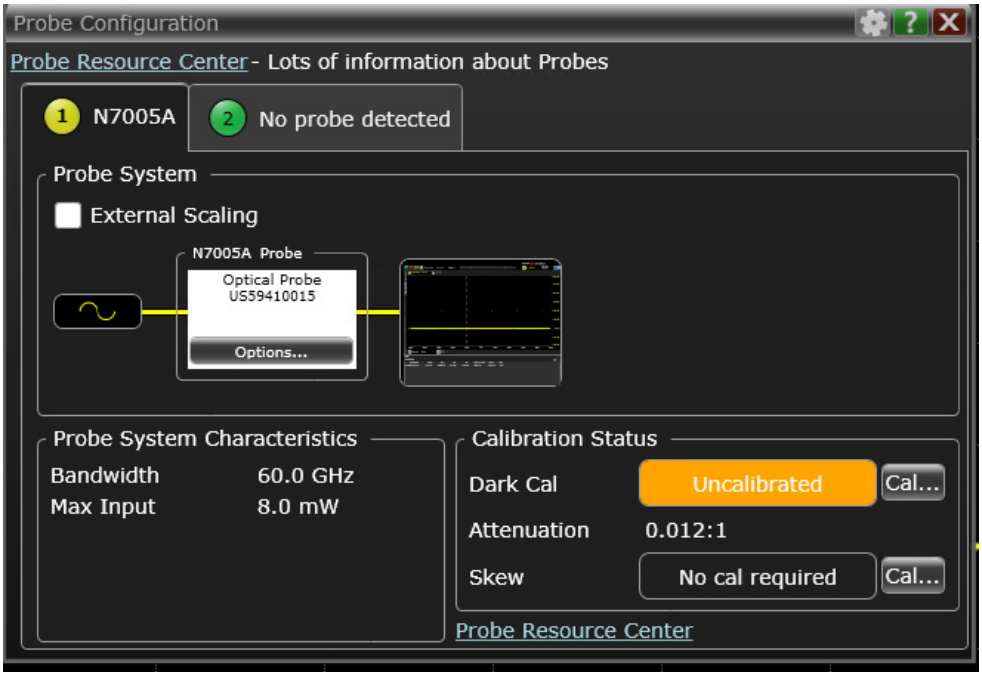
Incorrect way of connecting - Keying features are misaligned

CAUTION The input circuitry of the N7004A / 5A can be damaged when total input power levels exceed 8 mW. To prevent damage, this specified level must not be exceeded.

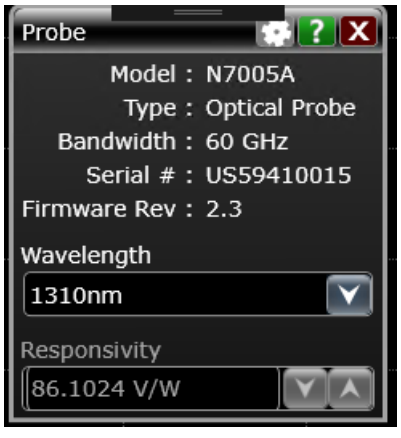
Step 4 - Configure the N7004A / 5A Setup on the Infiniium Software

Selecting the Wavelength

1 In the Infiniium software GUI, choose **Setup** > **Probe Configuration...** to open the **Probe Configuration** dialog box. Notice that the N7004A / 5A is recognized and displayed as connected to the scope's channel.



2 Click **Options...** displayed under N7004A / 5A to set the wavelength for N7004A / 5A.



3 Select the required wavelength. N7004A and N7005A support the following wavelengths:

N7004A Supported Wavelengths

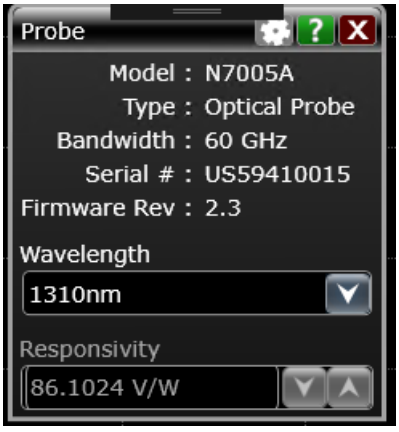
Predefined (Factory-calibrated) Wavelengths	User-defined Wavelengths
850 nm	Wavelength should be in the range of 750 to 1650 nm.
1310 nm	
1550 nm	

N7005A Supported Wavelengths

Predefined (Factory-calibrated) Wavelengths	User-defined Wavelengths
1310 nm	Wavelength should be in the range of 1250 to 1600 nm.
1550 nm	

Adjusting Conversion Gain for a User-defined Wavelength

If you select a predefined wavelength, the N7004A / 5A's predefined responsivity value for this wavelength is displayed in the **Responsivity** field. Based on the selected predefined wavelength, the N7004A / 5A's conversion gain is therefore automatically adjusted to provide an accurate measurement of the signal's average optical power.



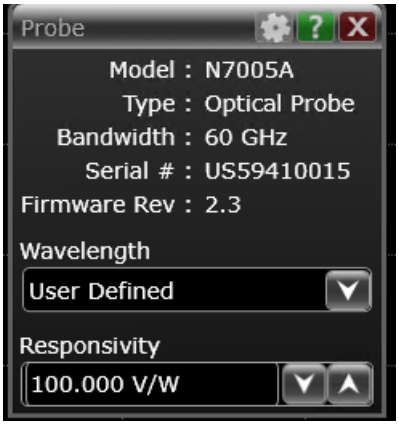
Responsivity Vs. Wavelength for N7004A

Wavelength	Responsivity (Conversion Gain)	
	Minimum	Typical
850 nm	Multimode: 68 V/W	Multimode: 75 V/W
1310 nm	Multimode/Single Mode: 105 V/W	Multimode/Single Mode: 110 V/W
1550 nm	Single Mode: 105 V/W	Single Mode: 110 V/W
User-defined	To be manually adjusted	

Responsivity Vs. Wavelength for N7005A

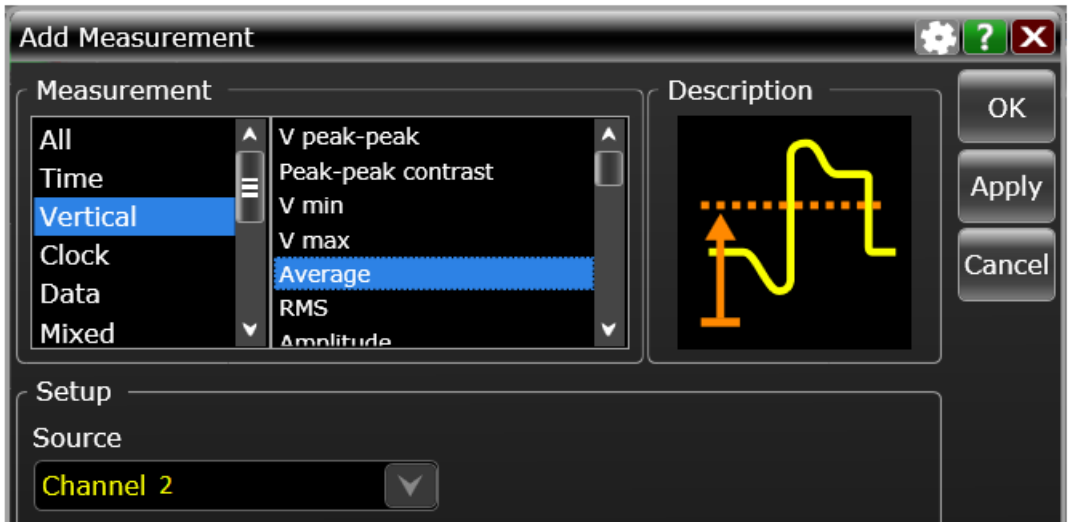
Wavelength	Responsivity (Conversion Gain)	
	Minimum	Typical
1310 nm	Single Mode: 85 V/W	Single Mode: 93 V/W
1550 nm	Single Mode: 72 V/W	Single Mode: 85 V/W
User-defined	To be manually adjusted	

If you select the **User Defined** wavelength option, then you need to manually specify and adjust the Responsivity value in the **Responsivity** field to adjust the N7004A / 5A's conversion gain for this user-defined wavelength.



To determine the responsivity value for a user-defined wavelength

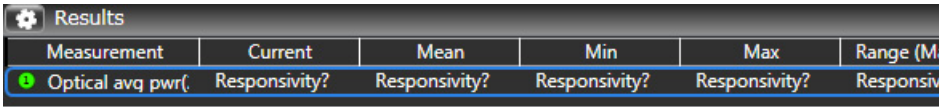
1 Measure the optical signal using an optical power meter.
2 Transmit this signal to the N7004A / 5A. This may be an active signal or just a DC optical level.
3 Set up the **Vaverage** measurement for the waveform on the Infiniium software GUI. This measurement is available under the **Vertical Measurements** group.



4 For the user-defined wavelength, the **Responsivity** field is enabled to allow you to adjust the responsivity value. Adjust the **Responsivity** value in this field until the **Vaverage** measurement agrees with the power level determined by the optical power meter in step1.

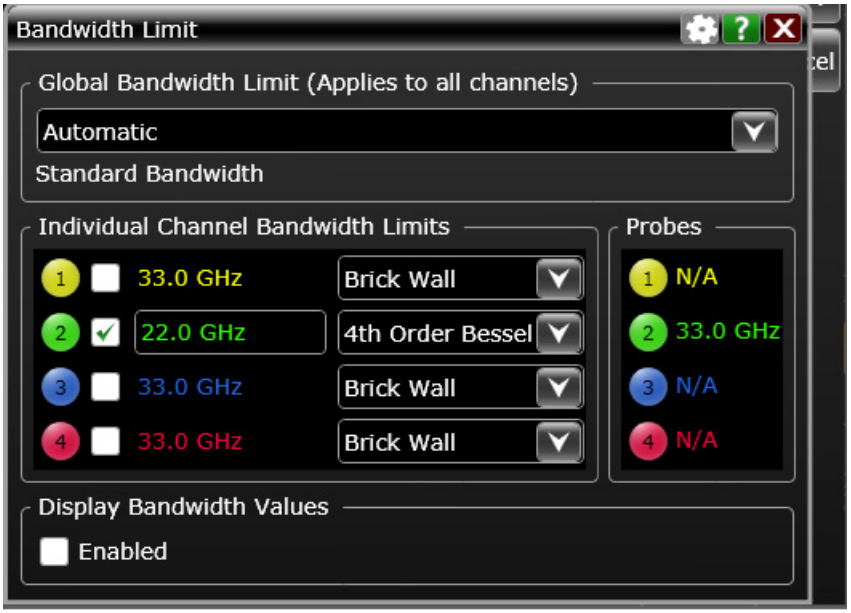
NOTE

On selecting the **User-defined** wavelength option, the **Optical Average Power** measurement displays the value "**Responsivity?**" instead of the average optical power value. This is because this measurement is calibrated based on the selected wavelength and in case of a user-defined wavelength, there is no calibration factor available for this measurement.



Configuring the Bandwidth Limits for the Oscilloscope and its Channel

Set the bandwidth limit for the oscilloscope and the individual channel to which you have connected the N7004A / 5A using the **Bandwidth Limit** dialog box. You may want to reduce bandwidth settings for improved noise performance. For details on how to set bandwidth limits on the oscilloscope, click the icon in the Bandwidth Limit dialog box.



Individual Channel Bandwidth Limit Filters

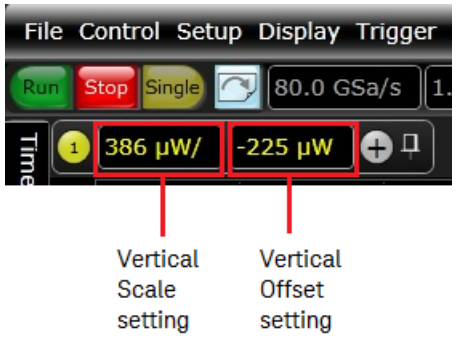
When setting the bandwidth limits, you can select one of the following two bandwidth limit filters for the channel to which the N7004A / 5A is connected.

Brickwall	4th Order Bessel Thomson (BT4)
Suitable when you want to characterize the raw response of the optical transmitter under test.	Suitable when you want to do reference receiver testing of industry-standard optical measurements on the optical transmitter under test. This filter limits the bandwidth to optimize the signal-to-noise ratio but does not lower it down to the extent of causing inter-symbol interference. This allows the waveform to be displayed similar to what a receiver would see.
The maximum bandwidth limit that you can specify can be the same as the N7004A / 5A's bandwidth limit, that is, 33 GHz and 60 GHz respectively.	**For NRZ signals:** The maximum bandwidth limit that you can specify is about 2/3 of the maximum bandwidth you could specify with the Brickwall filter. For a 33 GHz oscilloscope with the Bessel Thomson filter on, this yields a 22 GHz BT4, which covers 28 Gbps x 0.75 = 21 GHz. **For PAM4 signals:** The BT4 electrical bandwidth of a PAM4 signal is set to a frequency corresponding to 50% of the symbol rate. For example, to set a BT4 filter for 56 Gbaud PAM4 measurement, you will need to set the filter frequency to 28 GHz BT4.
While setting up the bandwidth limits, refer to the topic "Oscilloscope Bandwidth Requirements" on page 14 to know how much oscilloscope bandwidth is needed based on your optical data rates / optical symbol rates requirements.	

Adjusting the Vertical Settings for the Oscilloscope Channel

Adjust the vertical scale (Watts per division) and offset settings for the oscilloscope channel to which you connected the N7004A / 5A. For the extinction ratio measurement, this step is critical as the vertical settings affect the magnitude of the dark level offset which can affect the accuracy of this measurement.

You can adjust the vertical settings using the options displayed in the Infiniium software GUI or using the vertical scale and offset knobs of the oscilloscope.



NOTE

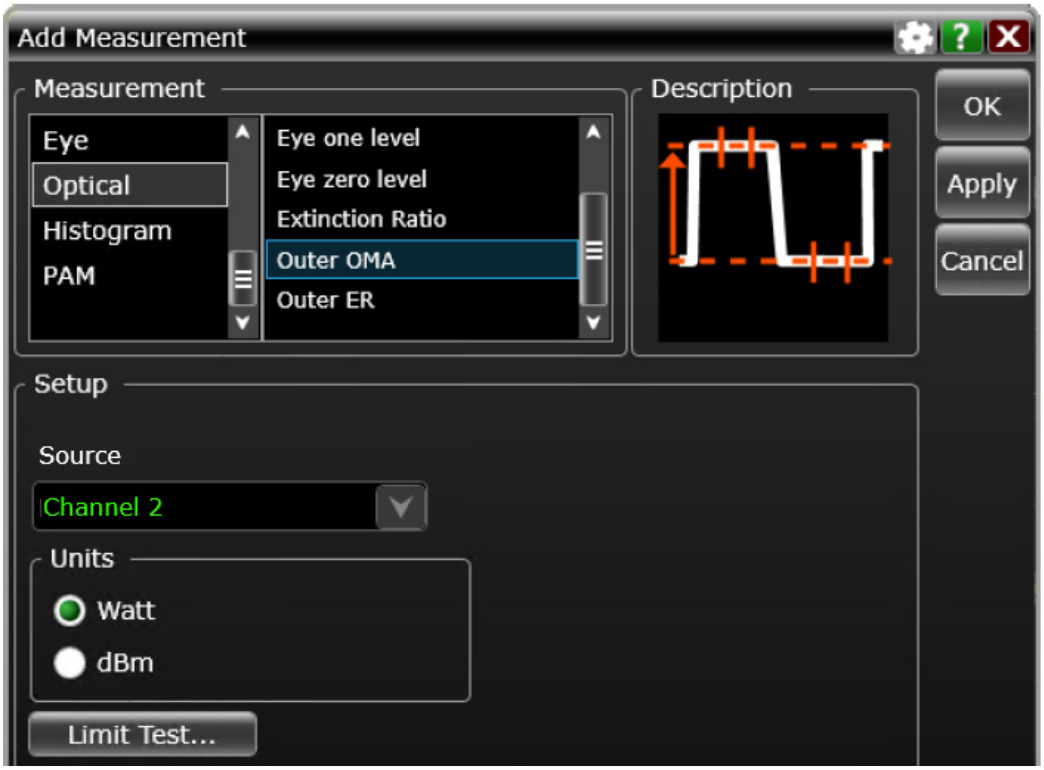
The Vertical scale of an oscilloscope channel is displayed in Watts when you connect the N7004A / 5A O/E Converter to the channel.

Adjust the vertical scale and offset levels in such a way that the output levels are completely on the screen and the eye diagram uses the full display.

Adding and Configuring Optical Measurements

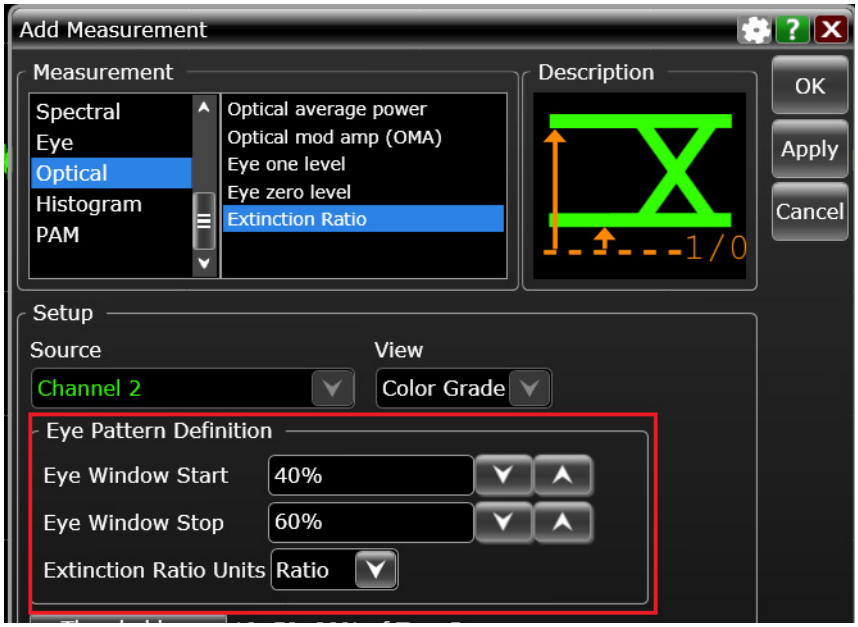
1 Click **Measure** > **Add Measurement** to access the **Add Measurement** dialog box.

2 Select and add the required optical measurements from the set of measurements displayed under the **Optical** group in the Add Measurement dialog box.



NOTE

For measurements such as the Extinction ratio and Outer ER, you may want to define settings such as eye pattern settings used to make eye waveform measurements. You can do this while adding the measurement using the Add Measurement dialog box. Refer to the *Optical Measurements* help topics in the online help of your Infiniium oscilloscope to get a detailed description of each of the optical measurements.



Step 5 - Perform Dark Calibration on the Infiniium GUI

After you have configured the N7004A / 5A settings and the optical measurement setup on the Infiniium software, you can perform dark calibration.

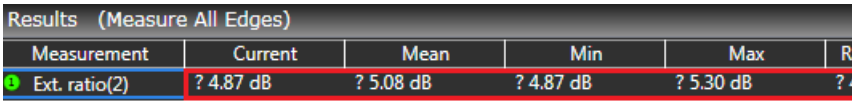
What is Dark Calibration

Dark calibration is the process of factoring out the power transmitted by the N7004A / 5A when there is no light being transmitted.
In this calibration, the oscilloscope identifies the offset (dark level) signals internally generated by N7004A / 5A when no light is present at the input channel. These internal offset signals are then removed by the oscilloscope from the extinction ratio calculations to ensure accurate measurement results.

NOTE

When the Extinction Ratio or Outer ER measurement is performed, the oscilloscope mathematically removes the offset error measured by dark calibration from the extinction ratio calculation. Therefore, if you plan to make the Extinction Ratio or Outer ER measurement, it is highly recommended that you perform dark calibration to maximize the accuracy in these measurement's results.

A "?" is displayed with the Extinction Ratio and Outer ER measurements results if dark calibration is not valid.



When to Perform Dark Calibration

Dark calibration is only valid for a given vertical scale, offset, and sample rate of the oscilloscope. A change in any of these invalidates the calibration and you have to perform dark calibration again. Therefore, you must perform dark calibration as the last step just before making optical measurements when you have set the vertical scale and offset at which you want to make your measurements.

NOTE

You need to perform dark calibration again when:

- vertical scale or offset is changed.
- sample rate is changed.
- ±1 °C temperature change from the calibration temperature.
- wavelength or responsivity is changed.
- power is recycled.

Before your Perform Dark Calibration

For dark calibration accuracy, ensure that:

- both ends of the fiber-optic cable are connected.
- the laser source connected to N7004A / 5A is turned off.

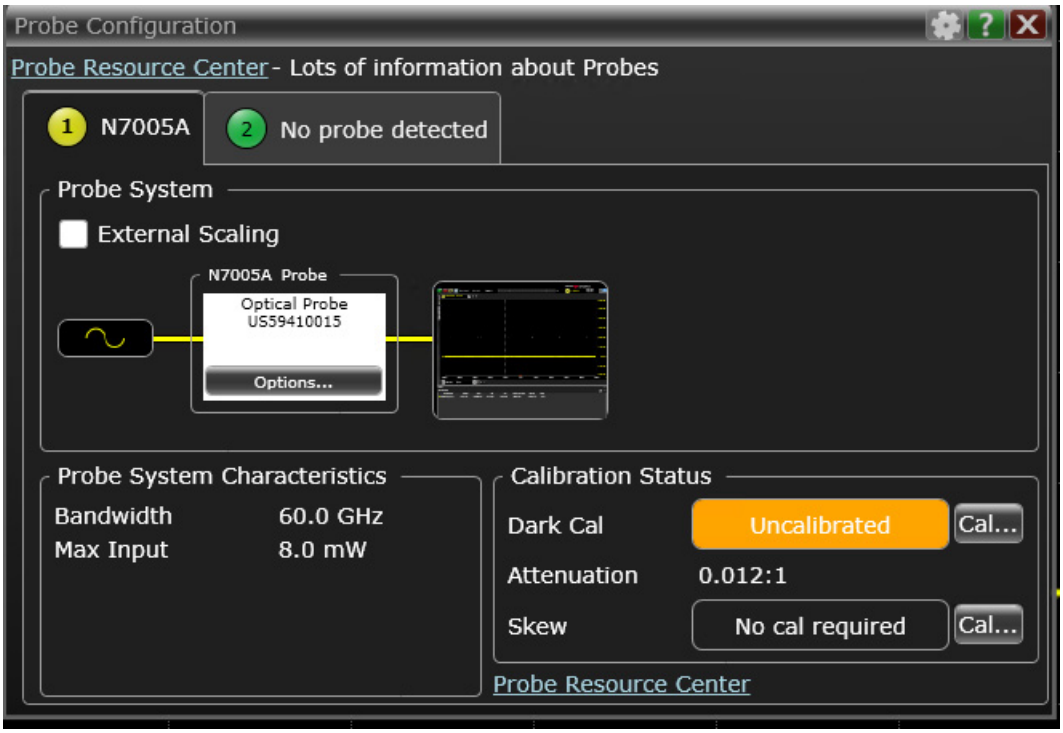
NOTE It is recommended to cover any open optical inputs with a cap to avoid stray light that could impact calibration accuracy.

Steps to Perform Dark Calibration

1 Allow the N7004A / 5A to warm up for15 minutes before starting the calibration.

2 Choose **Setup** > **Probe Configuration..**.

The **Probe Configuration...** dialog box is displayed.

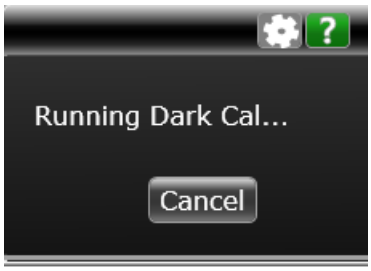


3 In the **Calibration Status** section, the **Dark Cal** status is currently displayed as **Uncalibrated**. Click the **Cal...** button.

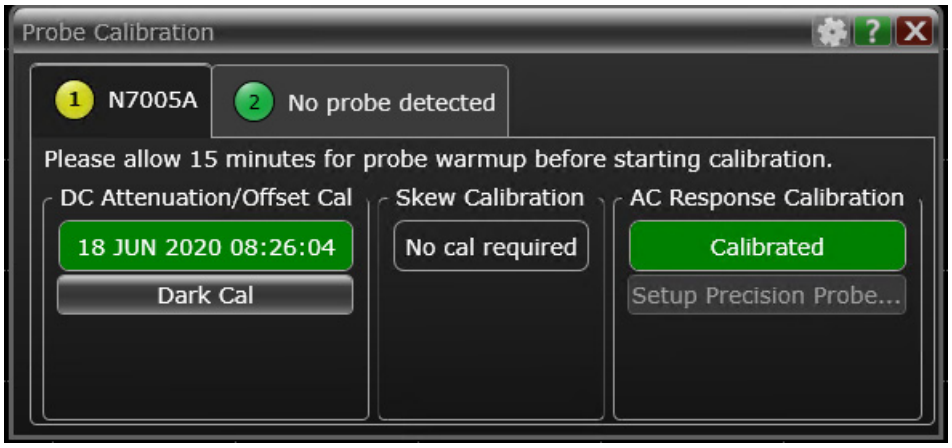
The **Probe Calibration** dialog box is displayed.

4 Click the **Dark Cal** button to begin dark calibration.

5 Ensure that the laser source connected to N7004A / 5A is turned off and then click OK on the following warning message.



If the dark calibration competes successfully, the date and time of its completion is shown on screen. If it fails, the status is displayed as Uncalibrated.

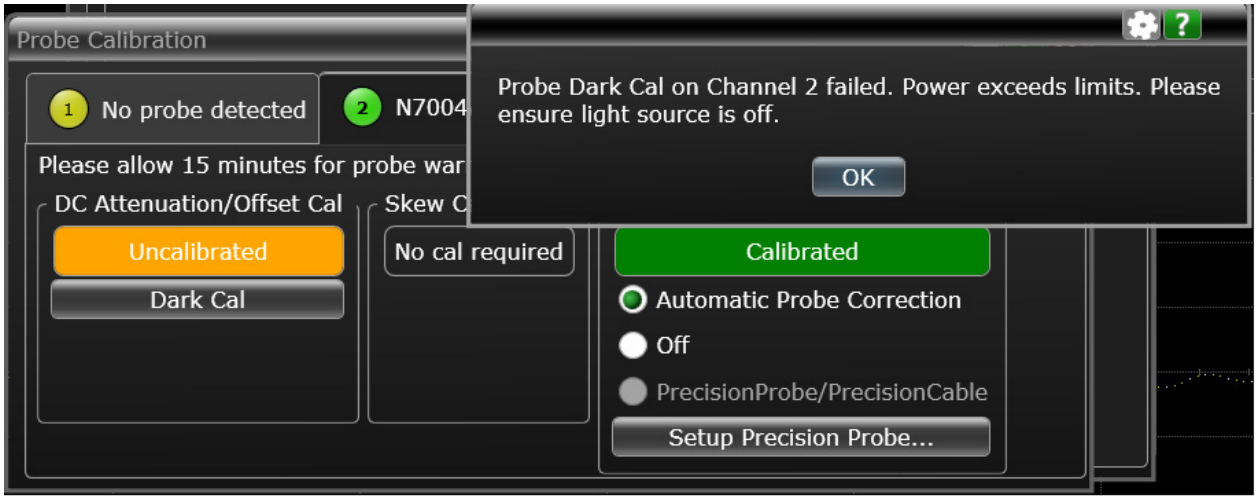


The setup is now complete to start making the measurements.

Reasons for the Failure of Dark Calibration

- The N7004A / 5A optical input is not covered properly to block light completely or the optical source is not turned off.

- The dark level (signal with the light source off) is not on the Infiniium screen. This signal must be completely on the screen to be correctly measured during dark calibration.
- The dark level (signal with the light source off) is less than 20mV converted to Watts by the responsivity. The dark calibration should be performed after the signal has been scaled correctly. It is recommended to set the vertical sensitivity of the oscilloscope so that the signal you try to capture takes about 5-6 divisions high.
- The dark calibration is canceled by the user.



Configuring Software for the TDECQ Measurement – An Overview

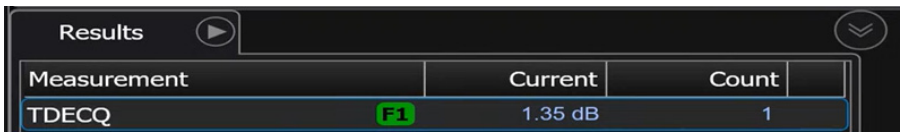
This topic provides an overview of the software configuration steps that you need to perform on the Infiniium GUI and FlexRT GUI to make the TDECQ measurement using the N7005A. The Infiniium GUI based steps are described in detail in the previous topics of this chapter. For details on the steps that you need to perform on the FlexRT GUI for TDECQ, refer to the online help integrated with the FlexRT GUI.

Software Requirements for the TDECQ Measurement
• Infiniium baseline software version 10.25 patch 6 or higher
• FlexRT application (N1010A FlexDCA oscilloscope software version A.06.70 or higher) You can install and run FlexRT either directly on the real-time oscilloscope or from a remote PC connected to the real-time oscilloscope.
• N1010200A Manufacturing license to make the TDECQ measurement
• N1010100A RND license if you want to run the FlexRT application from a remote PC connected to the real-time oscilloscope. This license also allows you to make the TDECQ measurement.

NOTE

N1010A FlexDCA is the software for Keysight's DCA family of sampling oscilloscopes. The A.06.70 or higher version of this software identifies and supports an Infiniium UXR-series real-time oscilloscope as an extended module and provides the FlexRT real-time oscilloscope application. Using this application, you can make the TDECQ measurement on an optical PAM4 signal acquired using the N7005A probe and UXR-series real-time oscilloscope.

Software Component to be Used	Step	
Infiniium GUI	1	Perform steps 1 to 4 described in the previous topics of this chapter. Do not perform dark calibration using Infiniium GUI because for TDECQ measurement, you need to perform the dark calibration on the FlexRT GUI.
Infiniium GUI	2	Launch the FlexRT GUI on the UXR real-time oscilloscope or from a remote PC connected to the oscilloscope using: • Either **Analyze** > **Launch FlexRT** from the Infiniium GUI menubar. • Or by double-clicking the FlexDCA software's desktop shortcut.
FlexRT GUI	3	If you are running FlexRT from a remote PC, click **Setup** > **Infiniium Connection Setup** to connect FlexRT to the UXR real-time oscilloscope. If you are running FlexRT on the UXR oscilloscope, a connection is automatically established between the oscilloscope and FlexRT on launching the FlexRT GUI. Once a connection is established, a default setup and an auto-trigger in Infiniium are used.

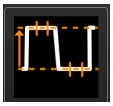
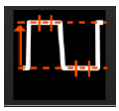
Software Component to be Used	Step	
FlexRT GUI	4	To quickly configure FlexRT settings including TDECQ Reference Equalizer Setup, load the FlexDCA instrument demo setup file available for N7005A by clicking **File** > **Open Instrument Setup**. You can either retain the default settings in this setup file or change as per your requirements. Alternatively, you can manually configure the Timebase, Acquisition, Clock Recovery, and TDECQ Equalizer setup using the **Infiniium Scope Setup** and **TDECQ Reference Equalizer Setup** dialog boxes.
FlexRT GUI	5	Verify the channel settings such as reference filter and wavelength configured for your optical channel on FlexRT using **Setup > Module > UXR040X: Channels...**. If needed, you can change these settings.
FlexRT GUI	6	For TDECQ measurement using FlexRT, you should NOT perform dark calibration in Infiniium GUI. You need to use the dark calibration available in the FlexRT GUI because it measures the intrinsic noise as well, which is required for a valid TDECQ measurement. Additionally, it also calibrates at multiple scales/offsets. Therefore, it remains valid when the scale/offset changes. If the dark calibration has not been performed or is not current, the Status of the TDECQ measurement is displayed as **?**.  To correct the TDECQ measurement status: *a* Disconnect or disable optical signal to the N7005A. *b* Turn off the TDECQ equalizer on FlexRT. *c* Perform an autoscale using the **Auto Scale** button to adjust the vertical scale and offset so that the displayed signal uses the full display. *d* Perform dark calibration on the optical channel by clicking **Tools** > **Calibration** in FlexRT GUI. It will determine the dark level and the intrinsic noise in the current configuration. A configuration change such as sample rate or filter rate change causes dark cal to go invalid. *e* Turn on the optical signal and TDECQ equalizer.
FlexRT GUI	7	View the TDECQ measurement results in the Results table. 

3 Making Optical Measurements

This chapter provides information on the optical measurements that you can make using the N7004A / 5A on an Infiniium real-time oscilloscope.

Optical Measurements Supported

You can make the following optical measurements with N7004A or N7005A using the appropriate software as listed in the table below.

Optical Measurement		Description	O/E Converter to be Used	Software to be Used
For NRZ/PAM2 Signals				
Optical Average Power		Optical power is a measure of the true average component of an optical signal. it differs from other measurements because it does not rely on the waveform display to determine the measurement result. The analog-to-digital converter in the N7004A allows the generation of this result independent of the waveform displayed on the screen.	N7004A or N7005A	Infiniium software GUI
Optical Modulation Amplitude (OMA)		Optical Modulation Amplitude (OMA) is the measure of the difference between the optical power of an NRZ (non-return-to-zero) one pulse and the optical power of an NRZ zero pulse.	N7004A or N7005A	Infiniium software GUI
Eye One Level		Eye one level is a measure of the mean value of the logical 1 of an eye diagram.	N7004A or N7005A	Infiniium software GUI
Eye Zero Level		Eye zero level is a measure of the mean value of the logical 0 of an eye diagram.	N7004A or N7005A	Infiniium software GUI
Extinction Ratio		Extinction Ratio is the ratio of the one level and the zero level of an eye diagram of an optical signal.	N7004A or N7005A	Infiniium software GUI
For PAM4 Signals				
Outer Optical Modulation Amplitude (OMA)		Outer OMA is the measure of the difference between the optical power of a PAM4 signal's level 3 and level 0 symbols.	N7005A	Infiniium software GUI

Optical Measurement		Description	O/E Converter to be Used	Software to be Used
Outer Extinction Ratio (ER)		Outer ER is the ratio of a PAM4 optical signal eye diagram's level 3 and level 0 symbols.	N7005A	Infiniium software GUI
Transmitter Dispersion and Eye Closure Quaternary (TDECQ)		TDECQ is the indicator of your optical transmitter's performance relative to an ideal transmitter. It compares the Symbol Error Ratio (SER) performance of your transmitter to a virtual ideal transmitter. TDECQ measures the increase of optical power required for the measured optical transmitter to achieve the same eye opening as the ideal optical transmitter. The lower the TDECQ measurement, the higher the quality of the measured transmitter.	N7005A	FlexRT software GUI (see page 37) and Infiniium software GUI

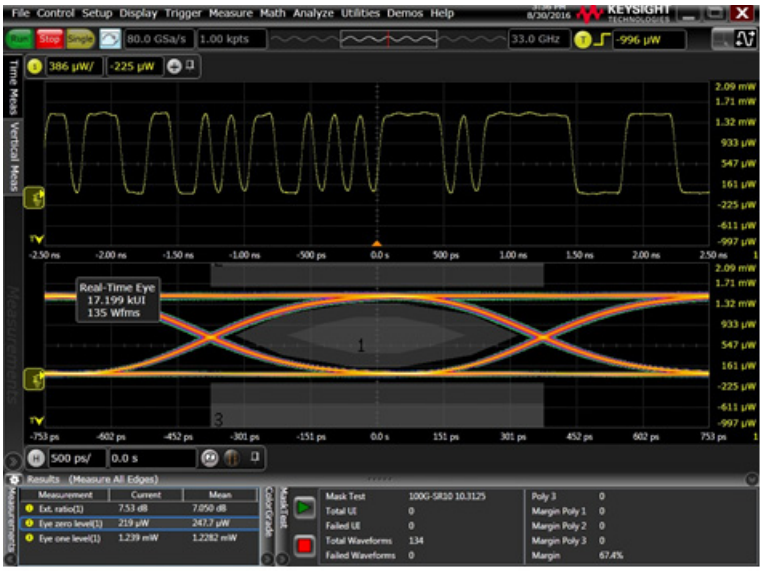
- Refer to the **Optical Measurements** help topics in the online help of your Infiniium real-time oscilloscope to get a detailed description of each of these measurements.
- Refer to the online help integrated with the FlexRT software to get a detailed description of the TDECQ measurement.

N7004A Optical Measurement Results

The following screens display sample optical data and optical measurements results as displayed on an Infiniium oscilloscope connected to N7004A.

Examples of Optical Data Acquired with N7004A for Different Optical Data Rates

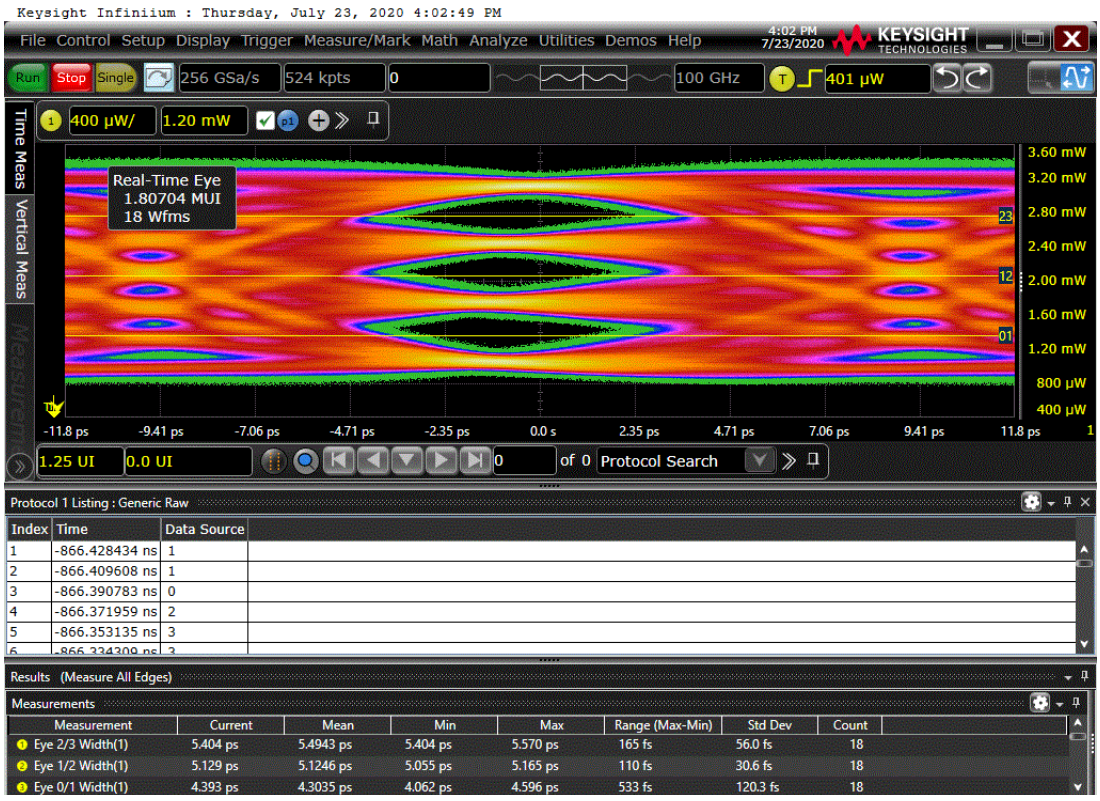
For 10 Gbps data rate



For 25 Gbps data rate

N7005A Optical Measurement Results

The following screen displays sample optical data and optical measurements results for a 53.125 Gbaud PAM4 signal acquired using N7005A with a UXR-series 70 GHz oscilloscope. (Note: For this sample screen, FFE equalization is enabled on the oscilloscope.)



Performing Eye Mask Testing

When using the N7004A / 5A, you can use the mask testing feature of the Infiniium oscilloscope to verify whether or not a displayed eye diagram complies with industry-standard definitions for optical waveforms. A mask (template) defines the shaded mask regions in the display. A waveform must remain outside these mask regions to meet the requirements of a standard. A data point from a waveform that illuminates a pixel in the mask region causes a mask test failure.

Types of Masks Supported with N7004A / 5A

You can:

- either load standard masks (for Keysight DCA oscilloscopes). These are provided with the Infiniium software for optical waveforms. These masks have the **.mskx** extension and are available at the following location:

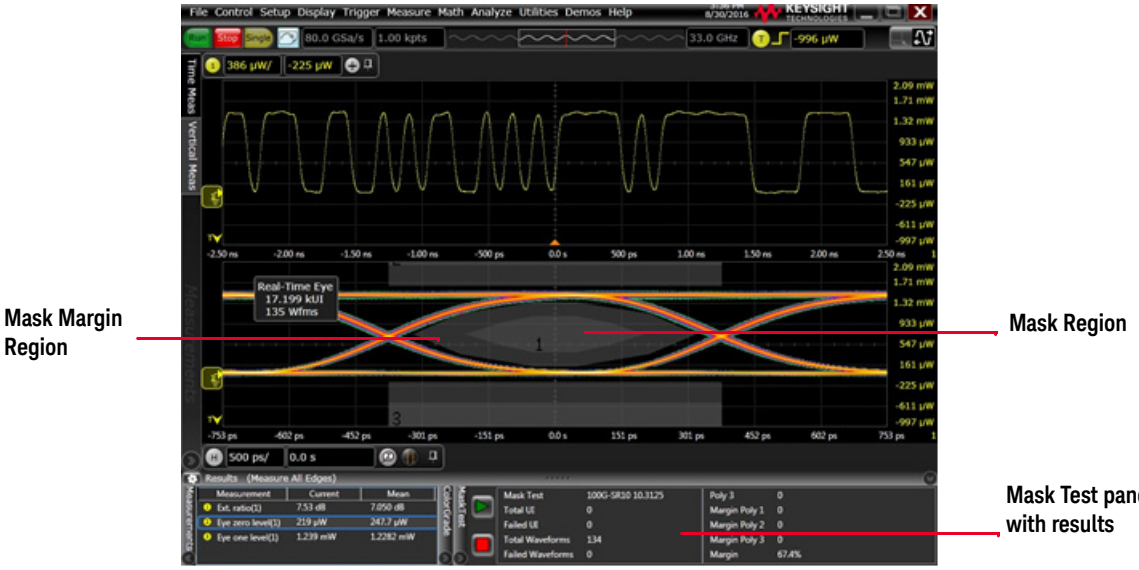
  C:\Users\Public\Documents\Infiniium\Masks

- or create your own masks and load these in the Infiniium software.
- or use the Automask or the Draw Mask feature of the oscilloscope.

Mask Margins

You can also enable mask test margins to ensure that mask testing is performed using the defined margins.

The following screen displays optical data with a standard mask applied. Mask regions are shown in lighter shade of gray and mask margins are shown in darker shade of gray.



You use the **Mask Test** dialog box to enable and load a mask and the **Mask Test Margins** dialog box to enable and specify margins for the mask.

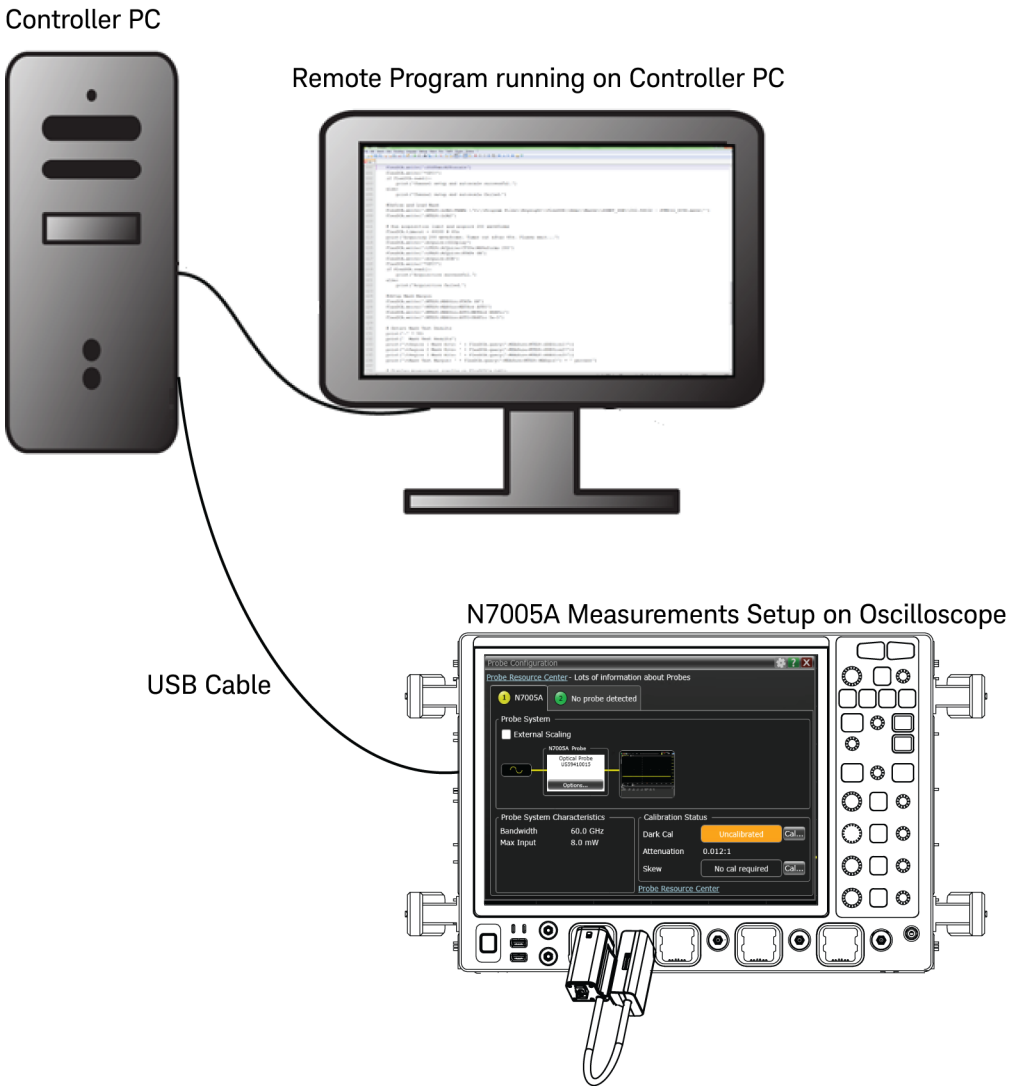
To know in detail how you can implement mask testing and mask margins on your Infiniium oscilloscope, refer to the ***Mask Testing*** help topics in the Infiniium online help. You can also click the  icon displayed in these dialog boxes.

4 Remotely Controlling the N7004A / 5A Measurement Setup

You can use the Remote Programming SCPI commands described in this chapter to remotely control the oscilloscope from a controller PC for:

- configuring the N7004A / 5A setup such as channel's bandwidth limit filter response.
- adding optical measurements and querying for these measurements' results.
- configuring eye mask testing.

Sample Remote Control Setup of N7004A / N7005A



NOTE

Before you can start remotely controlling the N7004A / 5A setup using SCPI commands, ensure that you have:

- installed the Keysight IO Libraries Suite software on the controller PC.
- connected the oscilloscope to the controller PC using USB, LAN, or GPIB.
- verified the oscilloscope connection.

To get detailed information on the above-mentioned points or on basic program communications, interface, syntax, data types, and status reporting, refer to your oscilloscope's *Programmer's Guide*.

SCPI Commands for Controlling the N7004A / N7005A Setup

This topic includes only those SCPI commands that are unique to the N7004A / N7005A usage scenarios. The complete list of SCPI commands for remotely controlling you oscilloscope is available in your oscilloscope's *Programmer's Guide*.

:MEASure:OPOWer

Command Syntax

```
:MEASure:OPOWer [<source>][,{WATT | DBM}]
```

where:

- **<source>** can be {CHANnel<N> | DIFF<D> | COMMonmode<C> | FUNCtion<F> | WMEMory<R> |CLOCk | MTRend | MSPectrum | EQUalized}
- **{WATT | DBM}** - Specifies the measurement units in Watts or dBm.

Description

The **`:MEASure:OPOWer`** command installs an Optical Average Power measurement into the user interface's measurement Results pane.

Optical average power is a measure of the true average component of an optical signal. If markers are tracking this measurement, the marker is placed on the optical power Watts. This measurement is commonly used when identifying the fundamental parameters of a lightwave transmitter. However, it differs from other measurements because it does not rely on the waveform display to determine the measurement. The analog-to-digital converter is in the probe itself, independent of the waveform displayed on the screen. You can measure the optical power of an eye diagram.

Query Syntax

```
:MEASure:OPOWer? [<source>][,{WATT | DBM}]
```

The query returns the measured Optical Average Power.

Query Response Format

```
[:MEASure:OPOWer] <value>[,<result_state>]<NL>
```

where:

- <value> is the measured Optical Average Power value.
- <result_state> - If SENDvalid is ON, the result state is returned with the measurement result. See the :MEASure:RESults table in your oscilloscope's programmer's guide for a list of the result states.

:MEASure:CGRade:OLEVel

Command Syntax

```
:MEASure:CGRade:OLEVel [<source>]
```

where:

- <source> can be {CHANnel<N> | DIFF<D> | COMMonmode<C> | FUNCtion<F> | WMEMory<R> |CLOCk | MTRend | MSPectrum | EQUalized}
- If <source> is omitted, the Q-factor will be performed on the first waveform that has color grade enabled.

Description

The **`:MEASure:CGRade:OLEVel`** command installs an Eye One Level measurement into the user interface's measurement Results pane. Eye one level is a measure of the mean value of the logical 1 of an eye diagram.

Before using this command or query, you must use the **`:DISPlay:CGRade`** command to enable the color grade persistence feature. Also, there must be a full eye diagram on screen before a valid measurement can be made.

Query Syntax

```
:MEASure:CGRade:OLEVel? [<source>]
```

The query returns the measured Eye One Level.

Query Response Format

```
[:MEASure:CGRade:OLEVel] <value>[,<result_state>]<NL>
```

where:

- <value> is the measured Eye One Level value.
- <result_state> - If SENDvalid is ON, the result state is returned with the measurement result. See the :MEASure:RESults table in your oscilloscope's programmer's guide for a list of the result states.

:MEASure:CGRade:ZLEVel

Command Syntax

```
:MEASure:CGRade:ZLEVel [<source>]
```

where:

- <source> can be {CHANnel<N> | DIFF<D> | COMMonmode<C> | FUNCtion<F> | WMEMory<R> |CLOCk | MTRend | MSPectrum | EQUalized}
- If <source> is omitted, the Q-factor will be performed on the first waveform that has color grade enabled.

Description

The **`:MEASure:CGRade:ZLEVel`** command installs an Eye Zero Level measurement into the user interface's measurement Results pane. Eye zero level is a measure of the mean value of the logical 0 of an eye diagram. Before using this command or query, you must use the **`:DISPlay:CGRade`** command to enable the color grade persistence feature. Also, there must be a full eye diagram on screen before a valid measurement can be made.

Query Syntax

```
:MEASure:CGRade:ZLEVel? [<source>]
```

The query returns the measured Eye Zero Level.

Query Response Format

```
[:MEASure:CGRade:ZLEVel] <value>[,<result_state>]<NL>
```

where:

- <value> is the measured Eye Zero Level value.
- <result_state> - If SENDvalid is ON, the result state is returned with the measurement result. See the :MEASure:RESults table in your oscilloscope's programmer's guide for a list of the result states.

:MEASure:OMAMplitude

Command Syntax

`:MEASure:OMAMplitude [<source>][,{WATT | DBM}]`

where:

- <source> can be {CHANnel<N> | DIFF<D> | COMMonmode<C> | FUNCtion<F> | WMEMory<R> |CLOCk | MTRend | MSPectrum | EQUalized}
- {WATT | DBM} Specifies the measurement units in Watts or dBm.

Description

The **`:MEASure:OMAMplitude`** command installs an Optical Modulation Amplitude (OMA) measurement into the user interface's measurement Results pane. Optical Modulation Amplitude (OMA) is the measure of the difference between the optical power of an NRZ (non-return-to-zero) one pulse and the optical power of an NRZ zero pulse. It requires an NRZ pattern and is designed to be used with a square wave made of consecutive zeros followed by consecutive ones. Be sure to check any relevant standard for one and zero run requirements. All instances are measured if Measure All Edges is selected. Otherwise, the edges closest to the timebase reference are measured.

Query Syntax

`:MEASure:OMAMplitude? [<source>][,{WATT | DBM}]`

The query returns the measured Optical Modulation Amplitude (OMA).

Query Response Format

`[:MEASure:OMAMplitude] <value>[,<result_state>]<NL>`

where:

- <value> is the measured Optical Modulation Amplitude (OMA) value.
- <result_state> - If SENDvalid is ON, the result state is returned with the measurement result. See the :MEASure:RESults table in your oscilloscope's programmer's guide for a list of the result states.

:MEASure:ERATio

Command Syntax

`:MEASure:ERATio [<source>[,{RATio | DB | PERCent}]]`

where:

- <source> can be {CHANnel<N> | DIFF<D> | COMMonmode<C> | FUNCtion<F> | WMEMory<R> |CLOCk | MTRend | MSPectrum | EQUalized}
- {RATio | DB | PERCent} Specifies the measurement units in Ratio, Decibel, or Percentage.

Description

The **`:MEASure:ERATio`** command installs an Extinction Ratio measurement into the user interface's measurement Results pane. Extinction Ratio is the ratio of the one level and the zero level of an eye diagram of an optical signal.

Query Syntax

`:MEASure:ERATio? [<source>[,{RATio | DB | PERCent}]]`

The query returns the measured extinction ratio.

Query Response Format

`[:MEASure:ERATio] <value>[,<result_state>]<NL>`

where:

- <value> is the measured extinction ratio value.
- <result_state> - If SENDvalid is ON, the result state is returned with the measurement result. See the :MEASure:RESults table in your oscilloscope's programmer's guide for a list of the result states.

NOTE

The `:MEASure:ERATio` query returns a '?' on the extinction ratio measurement if:

- The dark calibration has not been performed at all.

- The vertical sensitivity, offset, or sample rate of the oscilloscope has changed since the dark calibration was run.

- The N7004A /5A's temperature has changed by > 2 ^{0}C.

5 Performance Verification

This chapter describes how to verify the bandwidth performance of the N7004A / 5A against the bandwidth specification (as listed on page 15).

For N7004A

Test Strategy

The basic method for verifying the bandwidth of the N7004A is to use a femtosecond pulse laser. These types of laser sources output a very fast impulse that is much faster than the impulse response of the N7004A thus allowing measurement of the N7004A bandwidth without de-embedding the laser impulse response. Verification of the laser source is not considered in this testing but can be typically verified with an optical sampling scope or other optical methods.

NOTE

The performance verification testing is also performed at the Keysight Technologies as part of the return-to-factory recertification to warrant performance.

You can either test the N7004A bandwidth performance using the recommended test equipment and by following the procedure documented in this chapter. Or you may want to send your N7004A to the Keysight Technologies to get the bandwidth performance verification done by specialized Keysight staff.

Test Interval

The Keysight return-to-factory recertification interval to warrant performance of N7004A is 1 year. However, you can also test the N7004A bandwidth performance as and when required using the recommended test equipment and by following the procedure documented in this chapter.

Test Equipment

A list of the recommended test equipment is provided. The instructions in this chapter are written with the presumption that you are using these recommended test equipment. You can substitute these equipment with equivalent equipment that satisfy the specifications given. However, results with substituted equipment may or may not yield identical results.

Test Equipment	Model #
Calmar femtosecond pulse laser (Qty 1) This laser source has two outputs; ▪ a 1560 nm port for testing longer wavelengths (i.e. 1310 and 1550nm) ▪ a 780 nm port for testing shorter wavelengths (i.e. 760 and 850nm)	FPL-02RFFAGT12
Keysight Lightwave Multimeter 2 slot mainframe (or other Keysight mainframe with more slots) (Qty 1)	8163B
Keysight single-mode optical attenuator module for use in mainframe (Qty 1)	81570A
Keysight multimode optical attenuator module for use in mainframe (Qty 1)	81578A
L-Com 1m single-mode FC/FC patch cables (or equivalent) (Qty 2)	SFOFC-01
L-Com dual multimode FC/FC patch cable (or equivalent) which can be separated into two single cables for use in this procedure (Qty 1)	FODFC50-01
Infiniium oscilloscope	33 GHz Infiniium oscilloscope

Test Procedure

CAUTION

The Calmar pulse laser used in this procedure outputs a large impulse that could damage the input of the N7004A. As described in the procedure below, set the optical attenuators to the maximum attenuation before enabling the optical attenuators and then lower the attenuation until a 1.5 to 2 mW signal is seen on the oscilloscope's screen.

CAUTION

Before making the connections between the fiber-optic connectors using a single-mode or a multimode patch cable, you must clean the fiber ends of these connectors and the mating fiber-optic cable. To get details on the cleaning procedure, refer to the topic, "Step 1 - Clean the Fiber-Optic Connectors" on page 20

1 Install 81570A SM attenuator and 81578A MM attenuator in 8163B frame.
2 Turn on Calmar laser (but not the keyed "Pump Laser"), Infiniium oscilloscope, and 8163B frame.
3 Connect N7004A to be tested to channel 1 of the oscilloscope.
4 Let all equipment warm up for 45 minutes.
5 Set both attenuators for the maximum attenuation of 60db.
6 While observing cleaning procedures, connect optical output A (760nm) to the input of the MM 81578A using the multimode patch cable.
7 While observing cleaning procedures, connect optical output B (1560nm) to the input of the MM 81570A using the single mode patch cable
8 Perform a default setup on the oscilloscope.
9 While observing cleaning procedures, connect the output of the 81578A to the N7004A using a multimode patch cable.
10 Under **Setup Probe Configuration**, select **Options** for the N7004A on channel 1 and select **850 nm**.
11 Enable the 81578A attenuator by pressing the button on the front of the module. This allows the laser light through the attenuator.
12 Turn on the keyed Pump Laser on the Calmar laser and adjust the Pump Current to maximum.
13 Set up the oscilloscope as follows:
   - Trigger on channel 1, level **500 uW**
   - Timebase to **200 pS/div**
   - Channel 1 to **500 uW/div**
   - In Setup Acquisition, set for average mode with **1024** averages
14 Begin lowering the attenuation on the 81578A until an impulse is seen. Lower it until the amplitude of the impulse is **1.5 to 2 mW**.

NOTE

The Calmar laser may produce a "double" (multiple) pulse when the pump laser is set to maximum. If it does, then lower the pump laser setting until the "double" pulse stops.

Single pulse outputs are stable with pulses evenly spaced in time. Multiple pulse outputs have arbitrary time delays between adjacent pulses. For details on single and multiple pulse, refer to the Calmar user manual.

15 Change the timebase to **2 nS/div**.

16 Invoke a frequency response (FFT) on channel 1 using **Math/New FFT/Channel1** from the pull down menu.

17 Set the FFT scale to **3 db/div** and adjust the FFT offset to get the left hand side of the FFT waveform (0 to 4 GHz) at center screen. To do this, grab the FFT waveform with the left mouse button and move it to center screen. See Figure 5.

Figure 5 Upper trace: N7004A impulse response. Lower trace: FFT of impulse showing bandwidth

Verify that the FFT is not down more than 3 db at 32 GHz. For instance, in the sample screen above, the response is still at 0db at 32 GHz.

18 Disable the 81578A attenuator.

19 While observing cleaning procedures, connect the output of the 81570A to the N7004A using a single mode patch cable.

20 Under **Setup Probe Configuration**, select **Options** for the N7004A on channel 1 and select **1550 nm**.

21 Enable the 81570A attenuator by pressing the button on the front of the module. This allows the laser light through the attenuator.

22 Begin lowering the attenuation on the 81570A until an impulse is seen. Lower it until the amplitude of the impulse is 1.5 to 2 mW,

NOTE

The Calmar laser may produce a "double" (multiple) pulse when the pump laser is set to maximum. If it does, then lower the pump laser setting until the "double" pulse stops.

Single pulse outputs are stable with pulses evenly spaced in time. Multiple pulse outputs have arbitrary time delays between adjacent pulses. For details on single and multiple pulse, refer to the Calmar user manual.

23 If needed, center the FFT waveform as done earlier in this procedure.
Verify that the frequency response (FFT) is not down more than 3 db at 32 GHz.

24 Disable the 81570A attenuator.
This completes the bandwidth performance verification testing for N7004A.

For N7005A

Test Strategy

The basic method for verifying the bandwidth of the N7005A is to use a femtosecond pulse laser. These types of laser sources output a very fast impulse that is much faster than the impulse response of the N7005A thus allowing measurement of the N7005A bandwidth without de-embedding the laser impulse response. Verification of the laser source is not considered in this testing but can be typically verified with an optical sampling scope or other optical methods.

NOTE

The performance verification testing is also performed at the Keysight Technologies as part of the return-to-factory recertification to warrant performance.

You can either test the N7005A bandwidth performance using the recommended test equipment and by following the procedure documented in this chapter. Or you may want to send your N7005A to the Keysight Technologies to get the bandwidth performance verification done by specialized Keysight staff.

Test Interval

The Keysight return-to-factory recertification interval to warrant performance of N7005A is 1 year. However, you can also test the N7005A bandwidth performance as and when required using the recommended test equipment and by following the procedure documented in this chapter.

Test Equipment

A list of the recommended test equipment is provided. The instructions in this chapter are written with the presumption that you are using these recommended test equipment. You can substitute these equipment with equivalent equipment that satisfy the specifications given. However, results with substituted equipment may or may not yield identical results.

Test Equipment	Model #
Calmar femtosecond pulse laser with the following output: ▪ a 1560 nm port for testing longer wavelengths (1310 and 1550 nm) (Qty 1)	FPL-02RFFAGT12
Keysight Lightwave Multimeter 2 slot mainframe (or other Keysight mainframe with more slots) (Qty 1)	8163B
Keysight single-mode optical attenuator module for use in mainframe (Qty 1)	81570A
L-Com 1 m single-mode FC/FC patch cables (or equivalent) (Qty 2)	SFOFC-01
Infiniium oscilloscope	Keysight 70 GHz UXR oscilloscope with 1.85 mm M inputs + N5520B 1.85 mm F-1.85 mm F adapter Or Keysight >70 GHz UXR oscilloscope with 1 mm M ruggedized inputs + Y1901B 1 mm F ruggedized to 1.85 mm F adapter

Test Procedure

CAUTION The Calmar pulse laser used in this procedure outputs a large impulse that could damage the input of the N7005A. As described in the procedure below, set the optical attenuators to the maximum attenuation before enabling the optical attenuators and then lower the attenuation until a 1.5 to 2 mW signal is seen on the oscilloscope's screen.

CAUTION Before making the connections between the fiber-optic connectors using a single-mode patch cable, you must clean the fiber ends of these connectors and the mating fiber-optic cable. To get details on the cleaning procedure, refer to the topic, "Step 1 - Clean the Fiber-Optic Connectors" on page 20

1 Install 81570A SM attenuator in 8163B frame.
2 Turn on Calmar laser (but not the keyed "Pump Laser"), ≥70 GHz Infiniium UXR Infiniium oscilloscope, and 8163B frame.
3 Connect N7005A to be tested to channel 1 of the oscilloscope.
4 Let all equipment warm up for 45 minutes.
5 Set the attenuator for the maximum attenuation of 60 db.
6 While observing cleaning procedures, connect optical output B (1560 nm) to the input of the MM 81570A using the single mode patch cable.
7 Perform a default setup on the oscilloscope.
8 While observing cleaning procedures, connect the output of the 81570A to the N7005A using a single-mode patch cable.
9 Under **Setup Probe Configuration**, select **Options** for the N7005A on channel 1 and select **1550 nm**.
10 Enable the 81570A attenuator by pressing the button on the front of the module. This allows the laser light through the attenuator.
11 Turn on the keyed Pump Laser on the Calmar laser and adjust the Pump Current to maximum.
12 Set up the oscilloscope as follows:
   - Trigger on channel 1, level **500 uW**
   - Timebase to **200 pS/div**
   - Channel 1 to **500 uW/div**
   - In Setup Acquisition, set for average mode with **4096** averages
13 Begin lowering the attenuation on the 81570A until an impulse is seen. Lower it until the amplitude of the impulse is **1.5 to 2 mW**.

NOTE The Calmar laser may produce a "double" (multiple) pulse when the pump laser is set to maximum. If it does, then lower the pump laser setting until the "double" pulse stops.

Single pulse outputs are stable with pulses evenly spaced in time. Multiple pulse outputs have arbitrary time delays between adjacent pulses. For details on single and multiple pulse, refer to the Calmar user manual.

14 Set the oscilloscope to:
   - Timebase: **10 nS/div**
   - Manual memory depth: **16384**
   - Sample rate locked at **256 GSa/s**

15 Invoke a frequency response (FFT) on channel 1 using **Math/New FFT/Channel1** from the pull-down menu and set the window to rectangular. Set stop frequency to **100 GHz**.

16 Set the FFT scale to **3 db/div** and adjust the FFT offset to get the left-hand side of the FFT waveform (0 to 8 GHz) at center screen. To do this, grab the FFT waveform with the left mouse button and move it to center screen. See Figure 5.

Figure 6 Upper trace: N7005A impulse response. Lower trace: FFT of impulse showing bandwidth

Verify that the FFT is not down more than **3 db** at **60 GHz**.

This completes the bandwidth performance verification testing for N7005A.

6 Calibration Strategy

You need to perform dark calibration (see page 33) on N7004A / 5A whenever you change the vertical scale or offset of the oscilloscope.

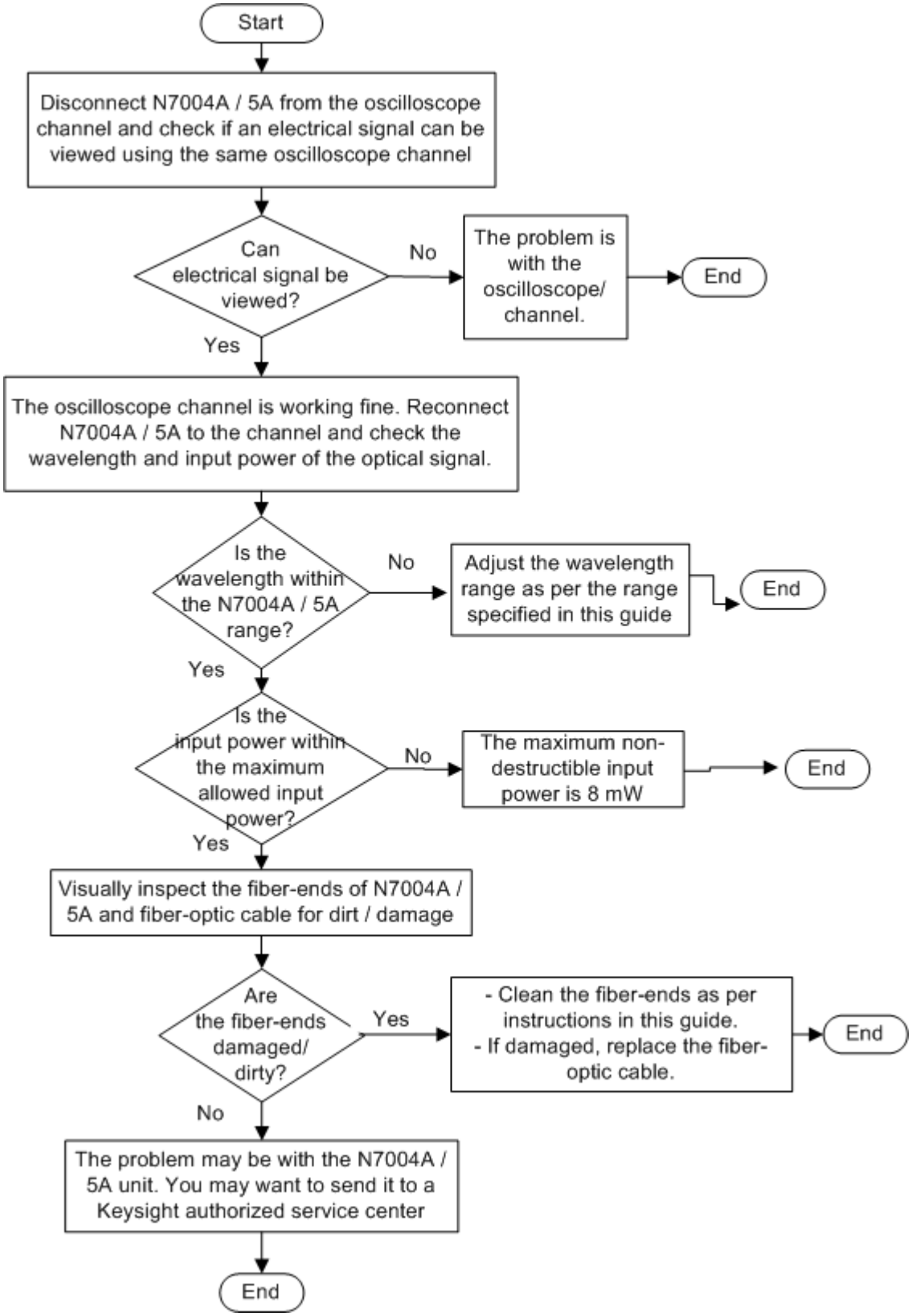
In addition to performing dark calibration, Keysight recommends that you also get the factory calibration done once in a year by sending the N7004A / 5A to the Keysight Technologies. Factory calibration also includes bandwidth performance verification testing (see page 55) for N7004A / 5A.

7 Troubleshooting

This chapter covers some common troubleshooting scenarios that you may find useful while using N7004A / N7005A.
If the problem persists, contact Keysight Technologies. To locate a sales or a service office near you, go to www.keysight.com/find/contactus.
The service strategy for the N7004A / 5A is to send it to Keysight Technologies for all service work. Keysight requires that the N7004A / 5A unit be repaired only at qualified repair facilities such as the Keysight Repair Centers.

Problem	Possible Cause(s)	Solution
Unable to make optical measurements using N7004A / 5A.	Multiple (as indicated in the flowchart provided in "Troubleshooting Flowchart section.)	Start at the top of the flowchart provided in "Troubleshooting Flowchart section. The flowchart directs you to the relevant steps.
The dark calibration failed.	Refer to the topic "Reasons for the Failure of Dark Calibration" on page 35.	
Problem in optical signal transmission	Low transmitted power	Check alignment of the optical cable into N7004A / 5A. Ensure that the keying features of both the N7004A / 5A FC/PC Input connector and fiber-optic cable's connector are aligned properly before you start finger-tightening the connection. Refer to the topic "Aligning the Keying Features while Making the Connection" on page 25.
Extinction ratio is out of range (that is, lower than expectations)	The optic connector of N7004A / 5A or optic cable is dirty and requires cleaning.	Clean the fiber-ends of both N7004A / 5A as well as optic cable's connectors as per instructions given in "Step 1 - Clean the Fiber-Optic Connectors" on page 20.
The Optical Average Power measurement displays the value "Responsivity?"	You have selected the User Defined wavelength option for N7004A / 5A.	Manually specify and adjust the Responsivity value for N7004A / 5A. Refer to the topic "Adjusting Conversion Gain for a User-defined Wavelength" on page 28.
Erratic optical measurements are displayed.	The optic connector of N7004A / 5A or optic cable is dirty and requires cleaning.	Clean the fiber-ends of both N7004A / 5A as well as optic cable's connectors as per instructions given in "Step 1 - Clean the Fiber-Optic Connectors" on page 20.

Troubleshooting Flowchart



8 Returning the N7004A / 5A for Repair or Service

If the N7004A / 5A is found to be defective, we recommend sending it to a Keysight authorized service center for all repair and calibration needs.

Perform the following steps before shipping the N7004A / 5A back to Keysight Technologies for repair / service.

1 Contact your nearest Keysight sales office for any additional details.

2 Write the following information on a tag and attach it to the malfunctioning equipment.
   - Name and address of owner
   - Product model number (N7004A)
   - Product Serial Number (for example, MYXXXXXXXX)
   - Description of failure or service required

3 Protect the N7004A / 5A by wrapping in plastic or heavy paper. Use original packaging or comparable.

4 Pack the N7004A / 5A in the original carrying case or if not available, use bubble wrap or packing peanuts.

5 Place securely in sealed shipping container and mark container as "FRAGILE".

If any correspondence is required, refer to the product by serial number and model number.

Contacting Keysight Technologies

For technical assistance, contact your local Keysight Call Center.

- In the Americas, call 1 (800) 829-4444
- In other regions, visit http://www.keysight.com/find/assist

Before returning an instrument for service, you must first call the Call Center.

9 Safety and Regulatory Information

This product has been designed and tested in accordance with accepted industry standards, and has been supplied in a safe condition. The documentation contains information and warnings that must be followed by the user to ensure safe operation and to maintain the product in a safe condition.

Only Keysight approved accessories shall be used.

WARNING If this product is not used as specified, the protection provided by the equipment could be impaired.

WARNING Do not attempt internal service or adjustment. Service should be carried out by a Keysight Technologies authorized service personnel. For any service needs, contact Keysight Technologies.

WARNING Indoor Use Only. Do not operate in wet / damp environments. Keep product surfaces dry and clean.

Do not operate in an explosive environment.

CAUTION The input circuitry of the N7004A / 5A can be damaged when total input power levels exceed 8 mW. To prevent damage, this specified level must not be exceeded.

CAUTION Damage to the fiber-optic connectors can degrade measurement accuracy and repeatability and can cause expensive damage to instruments.
To avoid damage to the N7004A / 5A's fiber-optic connector, ensure that you follow the cleaning techniques and the warnings and cautions included in the topic "Step 1 - Clean the Fiber-Optic Connectors" on page 20.

Instrument Markings

Marking	Description
	The instruction documentation symbol. The product is marked with this symbol when it is necessary for the user to refer to the instructions in the documentation to protect against damage to the product or personal injury.
	This symbol indicates the Environmental Protection Use Period (EPUP) for the product's toxic substances for the China RoHS requirements.
	This product complies with the WEEE Directive (2002/96/EC) marking requirements. The affixed label indicates that you must not discard this electrical/electronic product in domestic household waste. Product Category: With reference to the equipment types in the WEEE Directive Annex I, this product is classed as a "Monitoring and Control instrumentation" product. Do not dispose in domestic household. To return unwanted products, contact your local Keysight office, or refer to www.keysight.comfor more information.

Cleaning the N7004A / 5A

To clean the outer enclosures of N7004A / 5A:

1 Disconnect the N7004A / 5A from the oscilloscope and signal source.

2 Wipe it with a soft cloth dampened with a mild soap and water solution. Do not use too much liquid or any chemicals.

3 Make sure the N7004A / 5A is completely dry before reconnecting it to the oscilloscope.

Ensure that you follow the cleaning instructions provided for the fiber-optic connectors as these are very sensitive, easy to damage, and expensive to replace. Refer to the topic “Step 1 - Clean the Fiber-Optic Connectors" on page 20.

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