Keysight 81491A/81492A Reference Transmitter Module

User Guide

KEYSIGHT TECHNOLOGIES

Notices

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Keysight Technologies Deutschland GmbH

Herrenberger Strasse 130,

71034 Böblingen, Germany

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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.

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4 Cleaning Information

5 Warranty Information

1 Getting Started

This chapter introduces the features of the Keysight 81491A and 81492A Reference Transmitter Modules.

Safety Considerations

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Keysight Technologies assumes no liability for the customer's failure to comply with these requirements.

Before operation, review the instrument and manual, including the red safety page, for safety markings and instructions. You must follow these to ensure safe operation and to maintain the instrument in safe condition.

CAUTION

The WARNING sign denotes a hazard. It calls attention to a procedure, practice or the like, which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

Safety Symbols

The apparatus will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect the apparatus against damage.

Hazardous laser radiation.

Initial Inspection

Inspect the shipping container for damage. If there is damage to the container or cushioning, keep them until you have checked the contents of the shipment for completeness and verified the instrument both mechanically and electrically.

The Performance Tests give procedures for checking the operation of the instrument. If the contents are incomplete, mechanical damage or defect is apparent, or if an instrument does not pass the operator's checks, notify the nearest Keysight Technologies Sales/Service Office.

WARNING To avoid hazardous electrical shock, do not perform electrical tests when there are signs of shipping damage to any portion of the outer enclosure (covers, panels, etc.).

WARNING You MUST return instruments with malfunctioning laser modules to a Keysight Technologies Service Center for repair and calibration.

Line Power Requirements

The Keysight 81491A/81492A Reference Transmitter Module operates when installed in the Keysight 8163A/B Lightwave Multimeter, Keysight 8164A/B Lightwave Measurement System, or Keysight 8166A/B Lightwave Multichannel System.

Firmware Requirements

The Keysight 81491A/81492A Reference Transmitter Module can only operate with more recent versions of the mainframe firmware.

To find the version of your firmware

1 Press *Config*.

2 Move to [About Mainframe], and press *Enter*.
The bottom line shows the firmware revision.

On a Keysight 8163A/B Lightwave Multimeter, you should have firmware V5.25 or greater.

On a Keysight 8164A/B Lightwave Measurement System, you should have firmware V5.25 or greater.

On a Keysight 8166A/B Lightwave Multichannel System, you should have firmware V5.25 or greater.

Operating Environment

The safety information in the Keysight 8163A/B Lightwave Multimeter, Keysight 8164A/B Lightwave Measurement System, & Keysight 8166A/B Lightwave Multichannel System User's Guide summarizes the operating

ranges for the Keysight 81491A/81492A Reference Transmitter Module. In order for these modules to meet specifications, the operating environment must be within the limits specified for the mainframe.

Storage and Shipment

The 81491A/81492A module can be stored or shipped at temperatures between -40 °C and +70 °C. Protect the module from temperature extremes that may cause condensation within it.

The *recommended* storage temperature range for 81491A-085 is +10°C to +40°C. If stored outside this range, the module must be conditioned at room temperature for at least 72 hours before use.

Environmental Information

Table 1 Compliance and Environmental Information

Safety Symbol	Description
	This product complies with 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 WEEE Directive Annex I, this product is classed as a "Monitoring and Control instrumentation" product. Do not dispose in domestic household waste. To return unwanted products, contact your local Keysight office, or see http://about.keysight.com/en/companyinfo/environment/takeback.shtml for more information.

Laser Safety Information

The laser sources specified by this user guide are classified according to IEC 60825-1 (2007)

The laser sources comply with 21 CFR 1040.10 except for deviations pursuant to Laser Notice No. 50, dated 2007-June-24.

Table 2 Reference Transmitter Module Safety Information

	Keysight 81491A-135 and 81492A-135	Keysight 81491A-085
Laser type	CW DFB Laser with built-in isolator	DFB-Laser 850nm MMF with built-in isolator
Wavelength range	1310 nm / 1550 nm	850nm
Max. CW output power*	<10 mW	<4 mW
Source OUT	<35 mW	na
Beam waist diameter	9 µm	50 µm
Numerical aperture	0.1	0.1
Laser Class according to IEC 60825-1 (2007)- International	1M	1M
Max. permissible CW output power **	52 mW / 163 mW	5.3 mW
* Max. CW output power means the highest possible optical CW power that the laser source can produce at its output. ** Max. permissible CW output power is the highest possible power that is permitted within the appropriate IEC laser class.		

Laser Safety Labels

A sheet of laser safety labels is included with the laser module as required. In order to meet the requirements of IEC 60825-1 we recommend that you stick the laser safety labels, in your language, onto a suitable location on the outside of the instrument where they are clearly visible to anyone using the instrument.

WARNING

Please pay attention to the following laser safety warnings:

- Under no circumstances look into the end of an optical cable attached to the optical output when the device is operational. The laser radiation can seriously damage your eyesight.
- Do not enable the laser when there is no fiber attached to the optical output connector.
- The laser is enabled by pressing the gray button close to the optical output connector on the front panel of the module. The laser is on when the green LED on the front panel of the instrument is lit.
- The use of the instruments with this product will increase the hazard to your eyes.
- The laser module has built-in safety circuitry which will disable the optical output in the case of a fault condition.
- Close all unused fiber connections.
- Refer servicing only to qualified and authorized personnel.

NOTE

Laser safety errors might sometimes appear erroneously on calibration of the reference transmitter's operating point in conjunction with the usage of an external tunable laser source (TLS). This does not affect the safety of the product.

As a workaround, repeat the operating point calibration and reduce the output power of the TLS as appropriate.

Getting Started with the Reference Transmitter Module

What is a Reference Transmitter Module?

A reference transmitter is an electrical-optical (E/O) converter, where the data input modulates the output of a (DFB) laser.

Keysight's Reference Transmitters are designed to offer excellent eye quality for NRZ and PAM4 signal and can serve as universal E/O converter. The 81491A supports speed up to 32 Gbaud and 81492A upto 56 Gbaud NRZ and 53 Gbaud PAM4. The single-mode (SM) flavors (81491A-135, 81492A-135) include internal lasers at 1310 nm and 1550 nm. The 81491A comes in Multimode (MM) flavor and includes an internal laser at 850 nm (MM). External optical input for usage with tunable laser sources is available on the SM options.

The separation of the signal source and the modulator is the only way to offer a zero-chirp modulation. This is essential for a clean and repeatable eye diagram when modulating with an appropriate clean external source to fulfill the requirements of the IEEE standard. Another advantage of this design, compared with directly modulated transmitters, is the wide extinction ratio range that can only be achieved by this architecture. Additionally, the reference transmitter has a linear transmission behavior. This means that when used with an electrical arbitrary waveform generator, Keysight Reference Transmitter Module can be used as an optical arbitrary waveform generator.

The Front Panel

Figure 1 Front Panel of the 81491A Reference Transmitter Module: option -135 (left) and -085 (right)

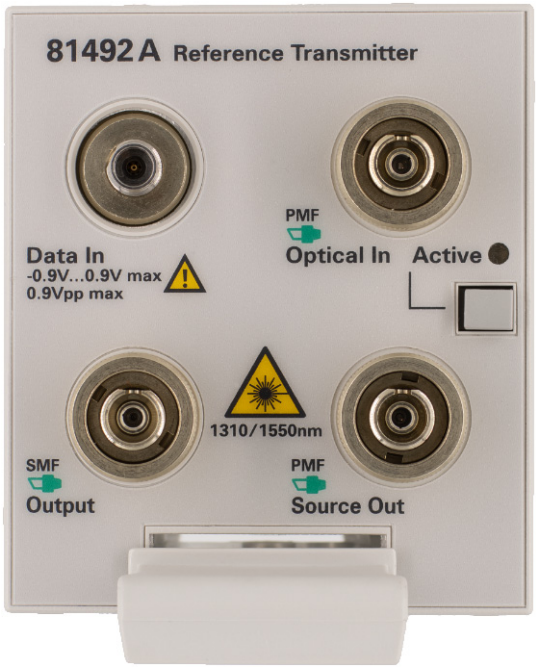


Figure 2 Front Panel of the 81492A-135 Reference Transmitter Module

To insert these modules into your mainframe see your mainframe's User's Guide.

Optical Connections

The output of the Keysight Reference Transmitter 81491A-135 and 81492A-135 (single mode) is equipped with an angled contact optical connector. The optical source output and optical input connectors are angled and should be connected using a polarization maintaining fiber (PMF).

The output of the Keysight Reference Transmitter 81491A-085 (multimode) is equipped with a multimode angled contact optical connector.

CAUTION **To avoid excess loss and reflection-induced interferences, use cables with same connectors only.**

Figure 3 Angled and Straight Contact Connector Symbols

Unlocking the Laser

You have to unlock the laser before you can switch it on.

You can unlock the laser when you first switch the mainframe by entering the password.

If you need to unlock the laser later, perform the following steps:

1 Press *Config*.
2 Move to [Unlock], and press *Enter*.
3 Enter the password, and press *Enter*.
4 Press *Close*.

NOTE The default password for the mainframe is “1234”.

Enabling and Disabling the Laser Output

Switch the laser on and off by pressing the Active button on the front panel of the module.

The State parameter and the Active LED indicate whether the module is emitting radiation.

If the laser is active, the State parameter is On and the Active LED on the front panel of the module is lit.

If the laser is inactive, the State parameter is Off and the green LED on the front panel of the module is unlit.

RF Data In

CAUTION Do not apply signals to the Data In that exceed -2V and +2V. Within this range, the signal voltage must be less than 2V peak-to-peak.

The RF input is a 1.85 mm female RF connector. It is AC coupled. For linear operation, the RF input signal should be less than or equal to 200mV for 81492A-135, 600 mV for option 81491A-135, and 300 mV for option 81491A-85. This is the linear regime of the E/O converter.

Values outside this range will overdrive the output signal

If you have applied a signal that overdrives the output

1 Reduce the level of the input.
2 Turn the laser off and back on again.

Accessories

The following diagram provides information on the available options and accessories for the most common applications.

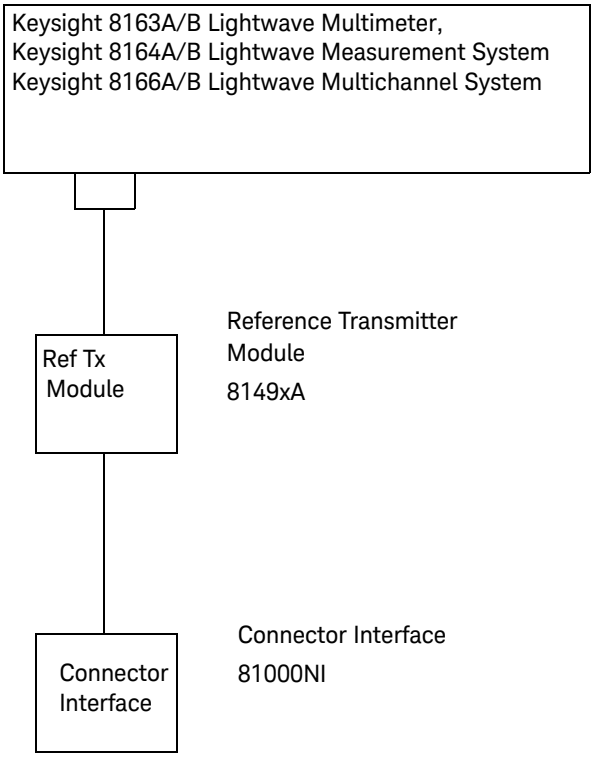


Figure 4 Available Options and Accessories

Operation

Setting the Wavelength

1 On your mainframe, move to the channel of the reference transmitter module.

2 Move to [λ], and press *Enter*.

3 Select the wavelength, and press *Enter*.

Setting the Optical Attenuation

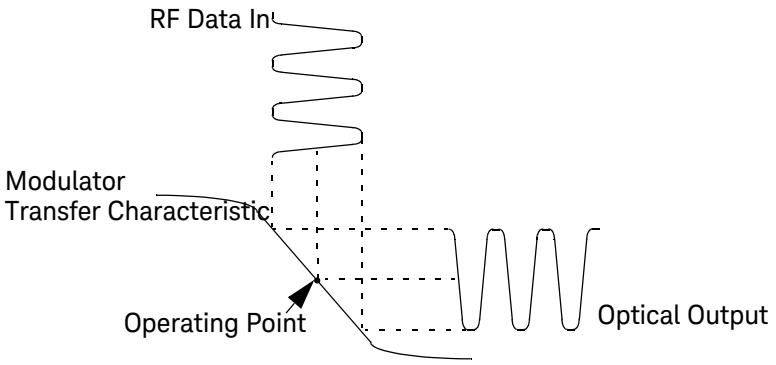
1 On your mainframe, move to the channel of the reference transmitter module.

2 Move to [Att] for the wavelength you are using, and press *Enter*.

3 Set the attenuation, and press *Enter*.

Calibrating and Setting the Operating Point

For the best possible results, the operating point for the reference transmitter should be as close as possible to the center of the modulator's transfer characteristic. This ensures you can make the best use of the linear part of the transfer characteristic.



When you turn the instrument on, a default value is used, and "Unc" or "Uncal" is shown on the display.

The reference transmitter also checks its temperature periodically. If the temperature differs too much from the temperature at which the last recalibration was performed, this is reflected in the modules status line in the user interface ("Uncal" for 8164A/B, "Unc" for 8163A/B and 8166A/B).

The instrument can set a first approximation to the best operating point.

1 Press *Tx Recal*.

To fine tune the operating point

2 Set up your equipment as displayed in Figure 5.

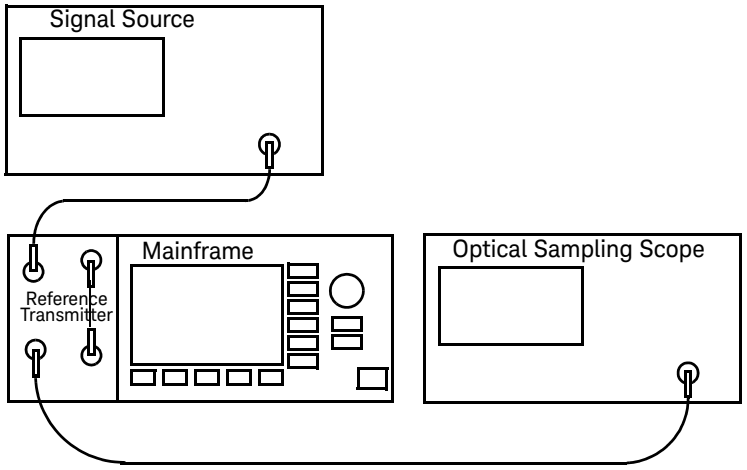


Figure 5 Operating Point Setup

3 On the signal source, set up a “best case” signal.

4 Turn on the laser of the reference transmitter.

5 Set up the optical sampling scope to show the “eye”.
The crossing point for the eye should be at 50% ± 1%.
If the crossing point is in this range, you do not need to adjust the operating point and you can start testing.
Otherwise continue with the following steps.

6 On your mainframe, move to the channel of the reference transmitter module.

7 For the wavelength you are using, move to [Oper pt.].

OR

1 Press *Menu*.

2 Move to [Oper Pt.] for the wavelength you are using, and press *Enter*.

8 Set the value for the offset, and press *Enter*.
You can adjust the operating point from -50 to 50.

9 Refresh the results on the optical sampling scope.
If the crossing point is in the range 50% ± 1% (see Figure 1), you do not need to adjust the operating point further and you can start testing.

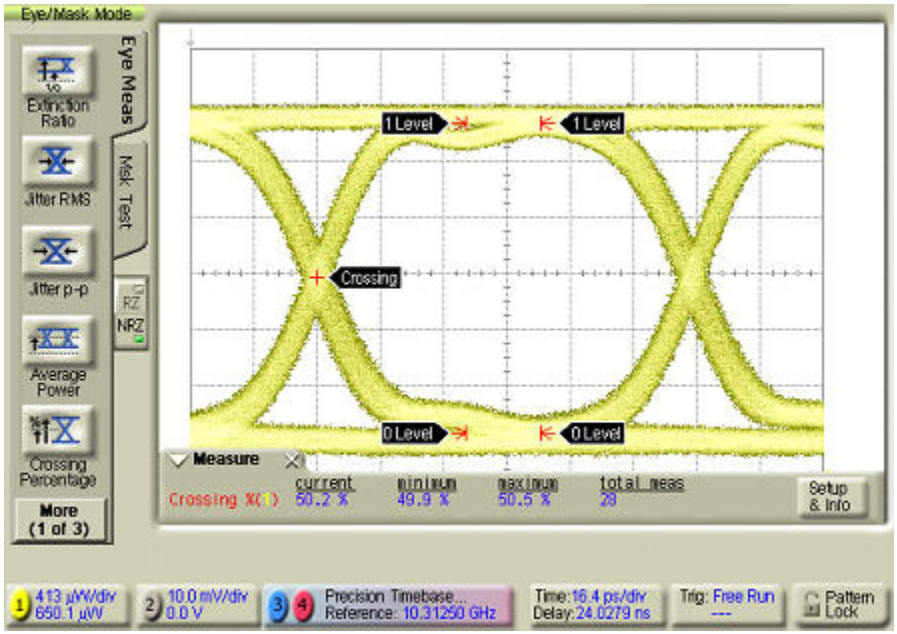


Figure 6 Modulator bias operating point optimized to eye crossing of 50% ± 1

If the operating point is not optimized (see Figure 7), return to step 8.

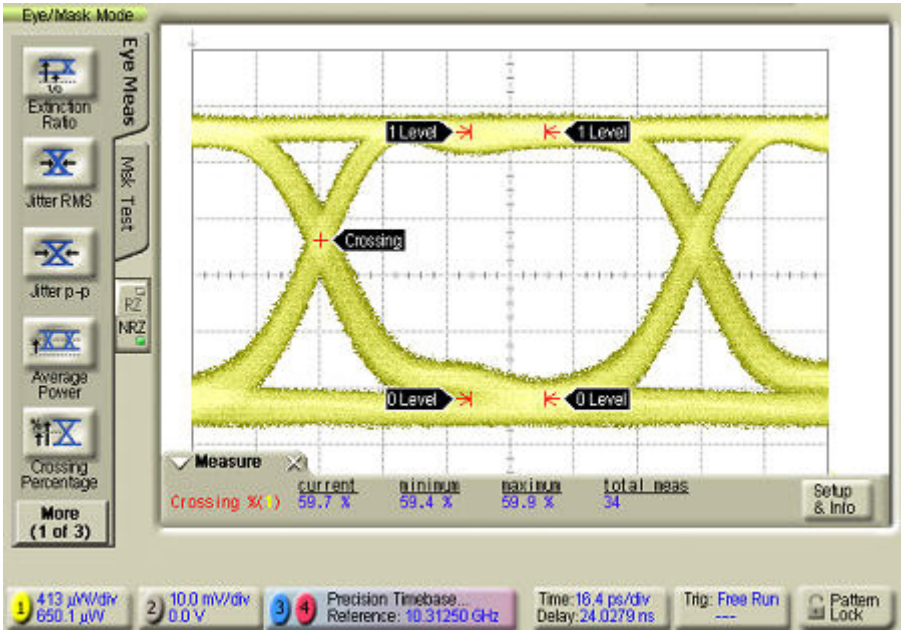


Figure 7 Modulator bias operating point not optimized.

2 Programming Information

This chapter introduces the programming commands associated with the Keysight 81491A and 81492A Reference Transmitter Modules.

SCPI Commands

NOTE The reference transmitter module occupies two slots. <*SlotNr*> always refers to the number of the left slot.

New Status Bit

A new status bit (bit 11, value 2048) indicates that the reference transmitter module needs to be calibrated.

This is set at boot time and also after temperature changes.

The module's status registers can be queried with ...

`:STATus<SlotNr>:QUEStionable[:EVENt]?`

`:STATus<SlotNr>:QUEStionable:CONDition?`

NOTE The condition register returns the actual state. That is, the bit is set when the module detects that it has to be recalibrated and cleared after a recalibration.

The bit in the event register is also set when the module detects that it has to be recalibrated. However the bit is not cleared by a recalibration but when the event register is read.

New Commands

Recalibration

command:	**:SOURce**<*SlotNr*>**:TRANsmitter:RECalibration**
syntax:	:SOURce<SlotNr>:TRANsmitter:RECalibration
description:	Recalibrates a reference transmitter module. The result can be queried using :SYSTem:ERRor?: It is either '+0,"No error"' or e.g. '-200,"Execution error (StatExecError)"' Recalibration takes about 6.8 seconds, so it also takes this time to get the reply to the :SYSTem:ERRor? query.
parameters:	none
response:	none
example:	:SOUR1:TRAN:REC

command:	**:SOURce**<*SlotNr*>**:TRANsmitter:RECalibration?**
syntax:	:SOURce<*SlotNr*>:TRANsmitter:RECalibration?
description:	Recalibrates a reference transmitter module. Recalibration takes about 6.8 seconds, so it also takes this time to get the reply to this query.
parameters:	none
response:	The result is returned as an unquoted string: "OK" or "ERROR - <error message>".
example:	:SOUR1:TRAN:REC? Æ OK<END>

Operating Point

command:	**:SOURce**<*SlotNr*>**:TRANsmitter:OPOint**<*laser (1,2)*>
syntax:	:SOURce<*SlotNr*>:TRANsmitter:OPOint<laser (1,2)> <data>
description:	Sets the operating point for one of the reference transmitter's two laser diodes (See "Calibrating and Setting the Operating Point" on page 17.). You can also set the minimum, maximum or default value.
parameters:	Operating point or MINimum | MAXimum | DEFault.
response:	none
example:	:sour1:tran:opo1 -17

command:	**:SOURce**<*SlotNr*>**:TRANsmitter:OPOint**<*laser (1,2)*>**?**
syntax:	:SOURce<*SlotNr*>:TRANsmitter:OPOint<laser (1,2)>?
description:	Get the operating point for one of the reference transmitter's two laser diodes (See "Calibrating and Setting the Operating Point" on page 17.). You can also query the minimum, maximum or default value.
parameters:	none | MINimum | MAXimum | DEFault.
response:	The operating point
example:	:sour1:tran:opo2 Æ -17<END>

Temperature Check

The reference transmitter checks its temperature periodically. If the temperature differs too much from the temperature at which the last recalibration was performed, it sets the "uncalibrated" status. This is reflected in the modules status line in the user interface ("Uncal" for 8164A/B, "Unc" for 8163A/B and 8166A/B) and also in the status register (See "New Commands" on page 23.)

command:	**:SOURce**<*SlotNr*>**:TRANsmitter:TCHeck?**
syntax:	:SOURce<*SlotNr*>:TRANsmitter:TCHeck?
description:	Get the temperature check status of the transmitter reference module.
parameters:	none
response:	A value ranging from 0.0 (recalibration necessary) to 1.0. Values near 1.0 indicate the current temperature is close to the temperature at the last recalibration. Values near 0.0 indicate the current temperature has drifted towards its maximum tolerance limit to trigger the UNCAL bit.
example:	:SOUR1:TRAN:TCH? Æ 1.0<END>

3 Specifications

Keysight 81491A and 81492A Reference Transmitter Modules are produced to the ISO 9001 international quality system standard as part of Keysight's commitment to continually increasing customer satisfaction through improved quality control.

Specifications describe the module's warranted performance. Supplementary performance characteristics describe the module's non-warranted typical performance.

Because of the modular nature of the instrument, these performance specifications apply to these modules rather than the mainframe unit.

Definition of Terms

Specification (guaranteed): describes a guaranteed product performance that is valid under the specified conditions. Specifications are based on a coverage factor[1] of 2 (unless otherwise stated), corresponding to a level of confidence of >95%.

Typical values (characteristics): a characteristic describing the product performance that is usually met but not guaranteed.

Generally, all specifications are valid at the stated operating and measurement conditions for temperature, temperature stability and settings, with uninterrupted line voltage.

Attenuation range (nominal) [optical out]

The range of attenuation factors selectable on the reference transmitter. Attenuation is the ratio between optical output power (in Watt) with attenuation factor set to 0 dB and the attenuated optical output power, expressed in dB.

$$\text{Attenuation [dB]} = 10\log\left\langle\frac{P_{att}[\text{W}]}{P_{0dB}[\text{W}]}\right\rangle$$

Conditions: As specified.

Average optical output power

The average output power from a fiber connected to the reference transmitter optical output.

Conditions: Using a fiber with high quality connectors in perfect condition. Other conditions as specified.

Electrical-optical conversion ratio

The optical output amplitude response of the reference transmitter to an electrical input voltage stimulus R calculated as the ratio of the ->*optical modulation amplitude* (in Watt) to the electrical input voltage amplitude (in V), expressed in W/V.

1 “Guide to the Expression of Uncertainty in Measurement” (“GUM”), BIPM, IEC, ISO et al. (1993)

NOTE

Electrical-optical conversion ratio expressed dBW/V is calculated as:

$$20\log_{10}\left\{\frac{R}{1\,\mathrm{W/V}}\right\}$$

Conditions: High quality connectors in perfect condition. Other conditions as specified.

Measurement: Using a suitable pattern generator and optical/electrical sampling scope with waveform and amplitude analysis software.

Electro-optical modulation bandwidth

The frequency range where the reference transmitter's ->*Electrical-optical conversion ratio* is above a specified limit.

Conditions: Response limit as specified. Other conditions as specified.

Input impedance nominal [RF in]

The nominal input impedance at the data input.

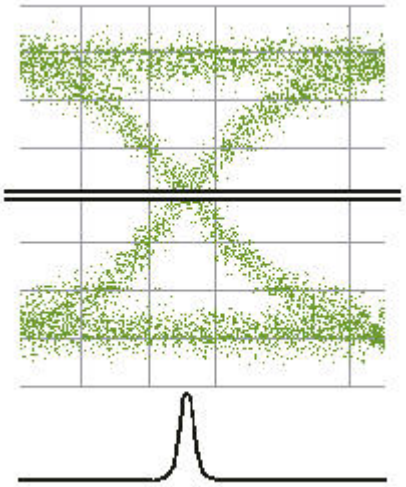
Input voltage range [RF in]

The voltage range where the reference transmitter has an increasing response on increasing input voltage.

Jitter (peak-peak) [optical out]

The variation of time intervals between successive falling or rising edges of the data output at constant frequency of the data input.

It is calculated as the peak to peak variation of the time interval between reference transmitter optical output edge 50% crossing point level and the input edge.



Conditions:
For option 81492A-135:

- Data rate: 53.125 Gbaud
- Pattern: NRZ PRBS11 (2^{11} - 1)
- Data Amp: 250 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (53.125 Gbaud, 39.8 GHz)

For option 81491A-135:

- Data rate: 28 Gbaud
- Pattern: NRZ PRBS11 (2^{11} - 1)
- Data Amp: 600 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (28.05 Gbaud, 21.0 GHz)

For option 81491A-085:

- Data rate: 26 Gbaud
- Pattern: NRZ PRBS11 (2^{11} - 1)
- Data Amp: 300 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (28.05 Gbaud, 21.0 GHz)

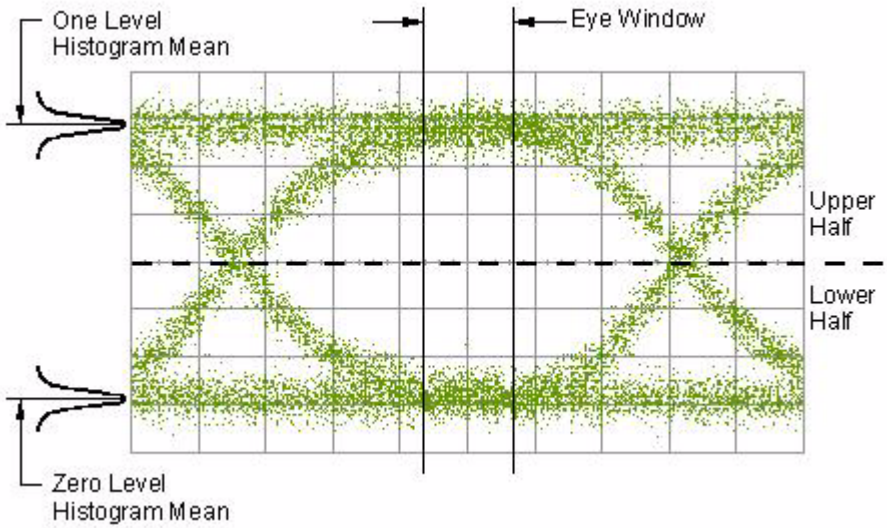
Measurement: Using a suitable pattern generator and optical/electrical sampling scope with pattern trigger capability and jitter analysis software. Measured with data pattern PRBS 2^{11}-1 and "pattern lock" (see Keysight 86100D DCA-X or DCA-M) enabled, 100 acquired waveforms and "BER" (see Keysight 86100D DCA-X or DCA-M) set to 10^{-3}.

Maximum extinction ratio [optical out]

The maximum ratio of the "one" level average optical power P_1 (in Watt) and the "zero" level average optical power P_0 (in Watt) of the reference transmitter data output, expressed in dB, calculated as

$$ER_{max}[\text{dB}] = 10\log_{10}\left(\frac{P_1}{P_0}\right)$$

Maximum over input voltage amplitude. The power levels P_0 and P_1 are determined within the eye window boundaries. The eye window boundaries mark the central 1% range of the bit period.



Conditions: Conditions as specified.

Measurement: Using a suitable pattern generator and optical/electrical sampling scope with waveform analysis software.

Maximum input voltage (RF in)

The maximum safe input voltage amplitude and range that does not cause permanent change of the reference transmitter's characteristics.

CAUTION **Applying a voltage beyond these limits may damage the reference transmitter.**

Operational data rate (RF in)

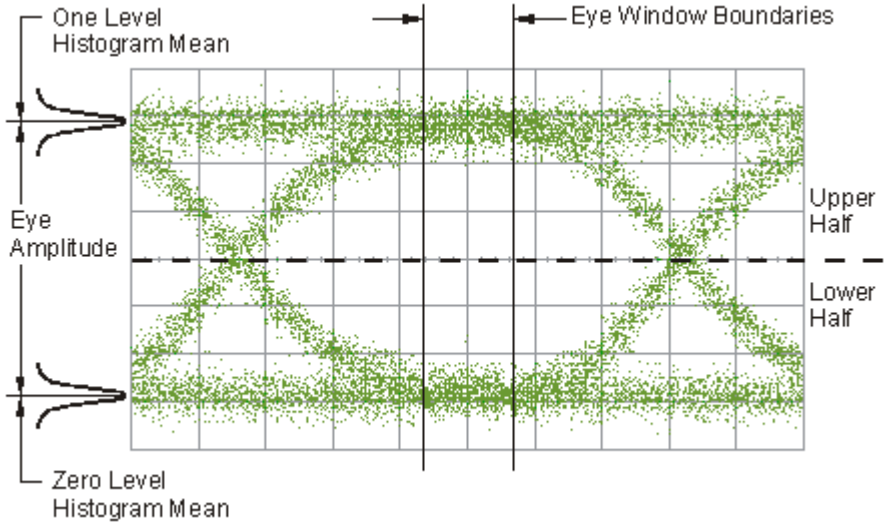
The non-return to zero (NRZ) or return to zero (RZ) data rate the reference transmitter is designed for.

Optical modulation amplitude (OMA)

The difference between the "one" level average optical power P_1 (in Watt) and the "zero" level average optical power P_0 (in Watt) of the reference transmitter data output, calculated as

$$OMA = P_1 - P_0$$

The power levels P_0 and P_1 are determined within the eye window boundaries. The eye window boundaries mark the central 20% range of the bit period.



Measurement: Using a suitable pattern generator and optical/electrical sampling scope with waveform and amplitude analysis software, using an optical modulation amplitude square-wave data pattern “0 0 0 0 1 1 1 1”.

Optical wavelength (optical out)

Center of wavelength of the signal at the reference transmitter optical output. Wavelength is defined as wavelength in vacuum.

Relative intensity noise (RIN)

In general, RIN specifies the ratio between the mean-square of the optical power fluctuation amplitude ΔPf,B within a specified bandwidth BW_N, and the square of the average optical power P_{avg}.

$$RIN = \frac{\langle \Delta P_B^2 \rangle}{P_{avg}^2 \cdot BW_N} \left[\frac{1}{Hz} \right]$$

RIN, if expressed as "dB/Hz", is calculated by:

$$RIN = 10\log\left(\frac{\langle \Delta P_B^2 \rangle \cdot 1Hz}{P_{avg}^2 \cdot BW_N}\right)$$

For the reference transmitter, $\langle \Delta P_B^2 \rangle$ is calculated from the optical random noise power of the one level $RN_{one(opt)}$ and of zero level $RN_{zero(opt)}$:

$$\langle \Delta P_B^2 \rangle = \left(\frac{RN_{one(opt)} + RN_{zero(opt)}}{2}\right)^2$$

and P_{avg} equals the ->*optical modulation amplitude (OMA)*, leading to:

$$RIN_{\mathrm{dB/Hz}} = 10\log\left(\frac{(RN_{one(opt)} + RN_{zero(opt)})^2 \cdot 1Hz}{4 \cdot OMA^2 \cdot BW_N}\right)$$

For the reference transmitter definition, BW_N relates to a 4th order Bessel-Thompson low pass filter, where BW_N equals 1.05 3/4 x bit rate.

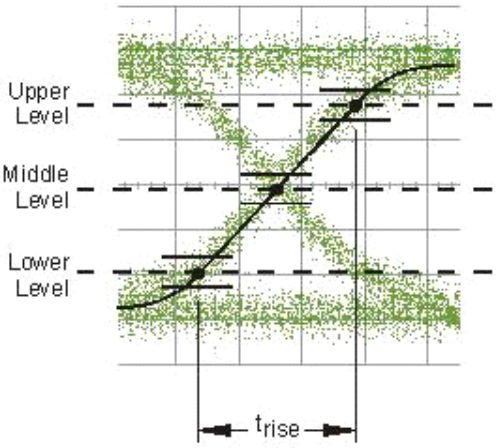
Conditions: Conditions as specified.

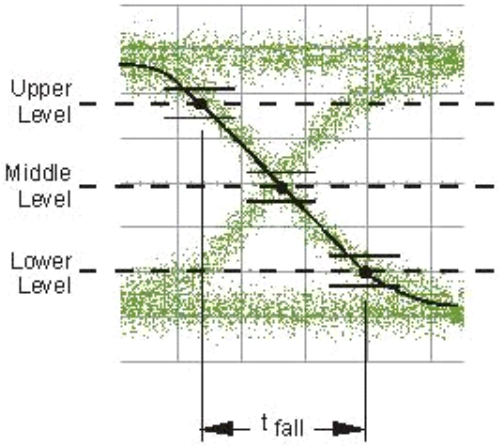
Measurement: Using a suitable pattern generator and optical/electrical sampling scope with waveform and amplitude analysis software. Attenuation set to 0 dB.

Rise and fall time [optical out]

Rise time is the average transition time of the data output response on an (instantaneous) upward edge at the data input. Fall time is defined correspondingly at the downward edge.

The transition time is the average time (over repetitions) between the data output crossing the 20% level (lower) and crossing the 80% level (upper). Levels 0% and 100% are the average power levels of the zero level and the one level (at the crossing point, i.e. where the signal crosses the middle level).





Conditions:
For option 81492A-135:

- Data rate: 53.125 Gbaud
- Pattern: NRZ Clock /16
- Data Amp: 250 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (53.125 Gbaud, 39.8 GHz)

For option 81491A-135:

- Data rate: 28 Gbaud
- Pattern: NRZ Clock /16
- Data Amp: 600 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (28.05 Gbaud, 21.0 GHz)

For option 81491A-085:

- Data rate: 26 Gbaud
- Pattern: NRZ Clock /16
- Data Amp: 300 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (28.05 Gbaud, 21.0 GHz)

Measurement: Using a suitable pattern generator and optical/electrical sampling scope with waveform analysis software.

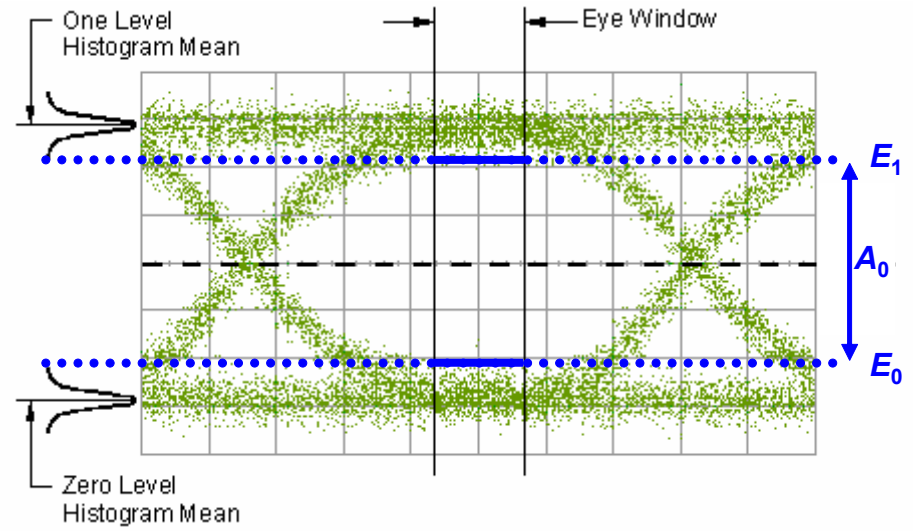
Vertical eye closure penalty [optical out]

The ratio VECP between ->*optical modulation amplitude* (OMA) and the amplitude of the vertical eye opening A_0 (in Watt), expressed in dB, calculated as

$$VECP(dB) = 10\log_{10}\left(\frac{OMA}{A_0}\right)$$

The vertical eye opening A_0 is the power difference between eye “one” level boundary E_1 and eye “zero” level boundary E_0.

E_1 is derived from a set of repeated data out values at “one” level within the eye window boundaries. The eye window boundaries mark the central 1% range of the bit period. The set contains 10^4 values.



From the set, the 5 smallest values are discarded. E_1 is the lowest remaining value.

E_0 is derived accordingly from values at “zero” level, discarding the 5 largest values and taking the highest remaining value.

Conditions:
For option 81492A-135:

- Data rate: 53.125 Gbaud
- Pattern: NRZ PRBS11 (2^11 - 1)

- Data Amp: 250 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (53.125 Gbaud, 39.8 GHz)

For option 81491A-135:

- Data rate: 28 Gbaud
- Pattern: NRZ PRBS11 (2^11 - 1)
- Data Amp: 600 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (28.05 Gbaud, 21.0 GHz)

For option 81491A-085:

- Data rate: 26 Gbaud
- Pattern: NRZ PRBS11 (2^11 - 1)
- Data Amp: 300 mV
- De-emphasis optimized with Eyewidth
- SIRC filter (28.05 Gbaud, 21.0 GHz)

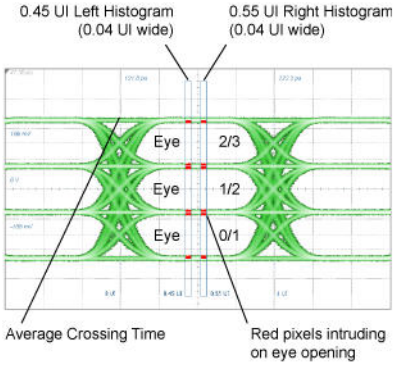
Measurement: Using a suitable pattern generator and optical/electrical sampling scope with waveform and amplitude analysis software.

Transmitter and Dispersion Eye Closure Quaternary TDECQ

The Transmitter and Dispersion Eye Closure Quaternary (TDECQ) is a measure of the optical transmitter's vertical eye closure as if observed at the end of a worst case fiber. It is defined as the ratio of the amount of noise a reference receiver could add to an ideal signal (with same OMA_{outer}) to the noise it could add to the transmitter under test after transmission over a worst case fiber in order to achieve the same BER. Expressed in decibels, the TDECQ is given by:

$$TDECQ = 10\log 10\left[\frac{OMAouter}{6} \times \frac{1}{Qt \bullet R}\right]$$

with Qt as Q-function consistent with target BER
(Qt = 3.414 for 2.4e-4 BER)
with R as RMS noise term of the receiver



Conditions:
For option 81492A-135:

- Data rate: 53.125 Gbaud
- Pattern: PAM4 SSPRQ
- Data Amp: 200 mV
- De-emphasis optimized with eye opening
- SIRC filter (53.125 Gbaud, 26.5625 GHz)

For option 81491A-135:

- Data rate: 26.5625 Gbaud
- Pattern: PAM4 SSPRQ
- Data Amp: 600 mV
- De-emphasis optimized with eye opening
- SIRC filter (26.5625 Gbaud, 13.8 GHz)

For option 81491A-085:

- Data rate: 26.5625 Gbaud
- Pattern: PAM4 SSPRQ
- Data Amp: 300 mV
- De-emphasis optimized with eye opening
- SIRC filter (26.5625 Gbaud, 13.8 GHz)

Measurement: Using a suitable pattern generator and optical/electrical sampling scope with waveform analysis software.

Reference Transmitter Module Preliminary Specifications

Optical Source Output			
Characteristic	**81491A -85**	**81491A -135**	**81492A-135**
Optical wavelength	λ_1: 850 nm +/- 10nm	λ_1: 1310 nm +/- 10nm λ_2: 1550 nm +/- 10nm	λ_1: 1310 nm +/- 10nm λ_2: 1550 nm +/- 10nm
Optical output power	NA	> +13 dBm typical	> +13 dBm typical
Attenuation range	6 dB	6 dB	6 dB
Output power stability over 15 min	NA	+/- 0.005 dB typical	+/- 0.005 dB typical
Optical interface type	no output	APC Panda PMF 9 / 125 µm	APC Panda PMF 9 / 125 µm

Optical Input			
Characteristic	**81491A -85**	**81491A -135**	**81492A -135**
Wavelength range	NA	1260 nm to 1360 nm 1480 nm to 1640 nm	1260 nm to 1360 nm 1480 nm to 1640 nm
Optical input power range	NA	+8 dBm to +16 dBm; +10 dBm (nominal)	+8 dBm to +16 dBm; +10 dBm (nominal)
Maximum safe input power	NA	+18 dBm	+18 dBm
Loss at quadrature bias point	NA	8 dB typical @ 1550nm 10 dB typical @ 1310nm	8 dB typical @ 1550nm 10 dB typical @ 1310nm

Data Output

Characteristic	81491A -85	81491A -135	81492A -135
Optical interface type	APC MMF 50 / 125µm	APC SMF 28 9 / 125 µm	APC SMF 28 9 / 125 µm
Electro-optical modulation bandwidth 3 dB	> 22 GHz typical	> 22 GHz typical	> 26 GHz typical, 1310 nm
Electro-optical modulation bandwidth 6 dB	> 35 GHz typical	> 35 GHz typical	> 40 GHz typical, 1310 nm
TDEC[1]	< 1.3 dB typical	< 1.2 dB typical, 1310 nm < 0.9 dB typical, 1550 nm	< 1.5 dB typical, 1310 nm
Extinction Ratio[1]	> 7 dB typical	> 8 dB typical, 1310 nm > 6 dB typical, 1550 nm	> 6.0 dB > 7.9 dB typical
Jitter (peak-peak)[1]	< 6.5 ps typical	< 6.5 ps typical	< 6.5 ps typical
Jitter (rms)[1]	< 400 fs typical	< 400 fs typical	< 400 fs typical
VECP for NRZ[1]	< 1.5 dB typical	< 1.5 dB typical, 1310 nm < 1.7 dB typical, 1550 nm	
Rise and Fall time (20% to 80%)[2]	< 16.5 ps typical	< 16.5 ps typical	< 12 ps typical < 9 ps typical with 59 GHz scope BW[4]
Outer ER (PAM4)[3]			>3.9 dB typical, 1310 nm >3.0 dB typical, 1550 nm
Outer OMA (PAM4)[3]	>2.5 dBm typical	>3 dBm typical, 1310 nm >4 dBm typical, 1550 nm	>2.0 mW typical, 1310 nm >2.9 mW typical, 1550 nm
TDECQ (PAM4)[3]	< 1.2 dB typical	< 1.2 dB typical	<2.4 dB typical, 1310 nm <2.1 dB typical, 1550 nm

For 81491A-85 and 81491A-135

Measurements performed with M8045A pattern generator with 300 or 600 mV output amplitude for options -085 and option -135, respectively. Optical waveforms captured and analyzed using an N1092A optical sampling scope.

1 - 26 Gbs NRZ, PRBS11

2 - measured at 26/28 Gbs NRZ, PRBS11. 14 ps characteristic rise/fall time at 32 Gbs

3 - 26.5625 Gbaud PAM4, SSPRQ, 6dB ER, 13.3 GHz Scope BW

For 81492A-135

Measurements performed with M8045A pattern generator. Optical waveforms captured and analyzed using an N1092A and 86116C optical sampling scope.

1 - M8045A settings: Signal rate 53.125 Gbaud, modulation type NRZ, output amplitude 250 mV, data pattern PRBS11,

N1092A settings: SIRC BW 39.84 GHz. De-emphasis optimized for eye width

2 - M8045A settings: Signal rate 56 Gbaud, modulation type NRZ, output amplitude 250 mV, data pattern Clock/16,

N1092A settings: SIRC BW 39.84 GHz. De-emphasis optimized for eye width

3 - M8045A settings: Signal rate 53.125 Gbaud, modulation type PAM4, output amplitude 200 mV, data pattern SSPRQ,

N1092A settings: SIRC BW 26.66 GHz. De-emphasis optimized with linear equalizer for eye opening

4 - M8045A settings: Signal rate 56 Gbaud, modulation type NRZ, output amplitude 250 mV, data pattern Clock/16,

86116C settings: SIRC BW 59.7 GHz. De-emphasis optimized for eye width

General specifications

Optical connector interface

- Keysight universal adapter APC SMF 28

RF connector interface

- 1.85 mm female

Module size (H x W x D)

- 75 mm x 64 mm x 335 mm (2.8” x 2.6” x 13.2”)

Module weight

1.0 kg (2.2 lbs)

Warmup time

60 minutes

Operating temperature

For option -135: +5 °C to +40 °C

For option -85: +15 °C to +35 °C

Storage temperature

-40 °C to +70 °C[1]

Humidity

5% to 95% relative humidity, non-condensing

816xA/B firmware revision

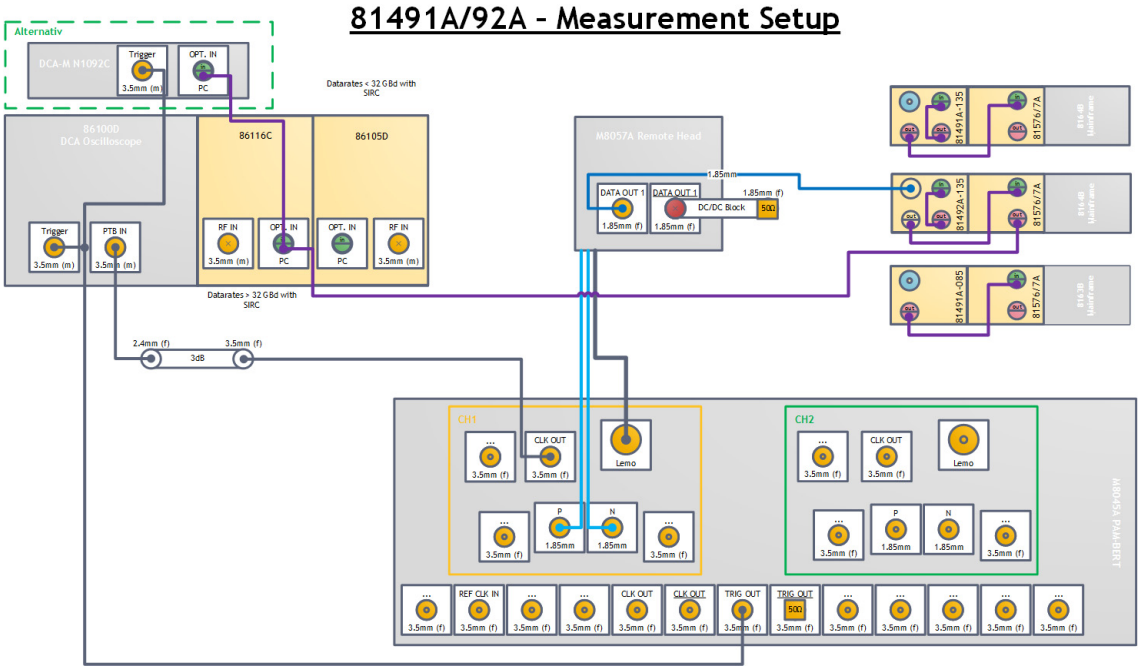
5.25 and higher

Recommended re-calibration period

2 years

1 The *recommended* storage temperature range for 81491A-085 is +10°C to +40°C. If stored outside this range, the module must be conditioned at room temperature for at least 72 hours before use.

81491A/81492A Measurement Setup



4 Cleaning Information

The following Cleaning Information contains some general safety precautions, which must be observed during all phases of cleaning. Consult your specific optical device manuals or guides for full information on safety matters.

Please try, whenever possible, to use physically contacting connectors, and dry connections. Clean the connectors, interfaces, and bushings carefully after use.

If you are unsure of the correct cleaning procedure for your optical device, we recommend that you first try cleaning a dummy or test device.

Keysight Technologies assume no liability for the customer's failure to comply with these requirements.

Cleaning Instructions for this Instrument

This Cleaning Information applies to a number of different types of Optical Equipment.

How to clean instruments with a physical contact interface on page 59 is particularly relevant to this module.

Safety Precautions

Please follow the following safety rules:

- Do not remove instrument covers when operating.
- Ensure that the instrument is switched off throughout the cleaning procedures.
- Use of controls or adjustments or performance of procedures other than those specified may result in hazardous radiation exposure.
- Make sure that you disable all sources when you are cleaning any optical interfaces.
- Under no circumstances look into the end of an optical device attached to optical outputs when the device is operational. The laser radiation is not visible to the human eye, but it can seriously damage your eyesight.
- To prevent electrical shock, disconnect the instrument from the mains before cleaning. Use a dry cloth, or one slightly dampened with water, to clean the external case parts. Do not attempt to clean internally.
- Do not install parts or perform any unauthorized modification to optical devices.
- Refer servicing only to qualified and authorized personnel.

Why is it important to clean optical devices?

In transmission links optical fiber cores are about 9 mm (0.00035") in diameter. Dust and other particles, however, can range from tenths to hundredths of microns in diameter. Their comparative size means that they can cover a part of the end of a fiber core, and as a result will reduce the performance of your system.

Furthermore, the power density may burn dust into the fiber and cause additional damage (for example, 0 dBm optical power in a single mode fiber causes a power density of approximately 16 million W/m^2). If this happens, measurements become inaccurate and non-repeatable.

Cleaning is, therefore, an essential yet difficult task. Unfortunately, when comparing most published cleaning recommendations, you will discover that they contain several inconsistencies. In this section, we want to suggest ways to help you clean your various optical devices, and thus significantly improve the accuracy and repeatability of your lightwave measurements.

What do I need for proper cleaning?

Some Standard Cleaning Equipment is necessary for cleaning your instrument. For certain cleaning procedures, you may also require certain Additional Cleaning Equipment.

Standard Cleaning Equipment

Before you can start your cleaning procedure you need the following standard equipment:

- Dust and shutter caps
- Isopropyl alcohol
- Cotton swabs
- Soft tissues
- Pipe cleaner
- Compressed air

Dust and shutter caps

All of Keysight Technologies' lightwave instruments are delivered with either laser shutter caps or dust caps on the lightwave adapter. Any cables come with covers to protect the cable ends from damage or contamination.

We suggest these protective coverings should be kept on the equipment at all times, except when your optical device is in use. Be careful when replacing dust caps after use. Do not press the bottom of the cap onto the fiber too hard, as any dust in the cap can scratch or pollute your fiber surface.

If you need further dust caps, please contact your nearest Keysight Technologies sales office.

Isopropyl alcohol

This solvent is usually available from any local pharmaceutical supplier or chemist's shop.

If you use isopropyl alcohol to clean your optical device, do not immediately dry the surface with compressed air (except when you are cleaning very sensitive optical devices). This is because the dust and the dirt is solved and will leave behind filmy deposits after the alcohol is evaporated. You should therefore first remove the alcohol and the dust with a soft tissue, and then use compressed air to blow away any remaining filaments.

If possible avoid using denatured alcohol containing additives. Instead, apply alcohol used for medical purposes.

Never drink this alcohol, as it may seriously damage your health.

Do not use any other solvents, as some may damage plastic materials and claddings. Acetone, for example, will dissolve the epoxy used with fiber optic connectors. To avoid damage, only use isopropyl alcohol.

Cotton swabs

We recommend that you use swabs such as Q-tips or other cotton swabs normally available from local distributors of medical and hygiene products (for example, a supermarket or a chemist's shop). You may be able to obtain various sizes of swab. If this is the case, select the smallest size for your smallest devices.

Ensure that you use natural cotton swabs. Foam swabs will often leave behind filmy deposits after cleaning.

Use care when cleaning, and avoid pressing too hard onto your optical device with the swab. Too much pressure may scratch the surface, and could cause your device to become misaligned. It is advisable to rub gently over the surface using only a small circular movement.

Swabs should be used straight out of the packet, and never used twice. This is because dust and dirt in the atmosphere, or from a first cleaning, may collect on your swab and scratch the surface of your optical device.

Soft tissues

These are available from most stores and distributors of medical and hygiene products such as supermarkets or chemists' shops.

We recommend that you do not use normal cotton tissues, but multi-layered soft tissues made from non-recycled cellulose. Cellulose tissues are very absorbent and softer. Consequently, they will not scratch the surface of your device over time.

Use care when cleaning, and avoid pressing on your optical device with the tissue. Pressing too hard may lead to scratches on the surface or misalignment of your device. Just rub gently over the surface using a small circular movement.

Use only clean, fresh soft tissues and never apply them twice. Any dust and dirt from the air which collects on your tissue, or which has gathered after initial cleaning, may scratch and pollute your optical device.

Pipe cleaner

Pipe cleaners can be purchased from tobacconists, and come in various shapes and sizes.The most suitable one to select for cleaning purposes has soft bristles, which will not produces scratches.

There are many different kinds of pipe cleaner available from tobacconists.

The best way to use a pipe cleaner is to push it in and out of the device opening (for example, when cleaning an interface). While you are cleaning, you should slowly rotate the pipe cleaner.

Only use pipe cleaners on connector interfaces or on feed through adapters. Do not use them on optical head adapters, as the center of a pipe cleaner is hard metal and can damage the bottom of the adapter.

Your pipe cleaner should be new when you use it. If it has collected any dust or dirt, this can scratch or contaminate your device.

The tip and center of the pipe cleaner are made of metal. Avoid accidentally pressing these metal parts against the inside of the device, as this can cause scratches.

Compressed air

Compressed air can be purchased from any laboratory supplier.

It is essential that your compressed air is free of dust, water and oil. Only use clean, dry air. If not, this can lead to filmy deposits or scratches on the surface of your connector. This will reduce the performance of your transmission system.

When spraying compressed air, hold the can upright. If the can is held at a slant, propellant could escape and dirty your optical device. First spray into the air, as the initial stream of compressed air could contain some condensation or propellant. Such condensation leaves behind a filmy deposit.

Please be friendly to your environment and use a CFC-free aerosol.

Additional Cleaning Equipment

Some Cleaning Procedures need the following equipment, which is not required to clean each instrument:

- Microscope with a magnification range about 50X up to 300X
- Ultrasonic bath
- Warm water and liquid soap
- Premoistened cleaning wipes

- Polymer film
- Infrared Sensor Card

Microscope with a magnification range about 50X up to 300X

A microscope can be found in most photography stores, or can be obtained through specialist mail order companies. Special fiber-scopes are available from suppliers of splicing equipment.

Ideally, the light source on your microscope should be very flexible. This will allow you to examine your device closely and from different angles.

A microscope helps you to estimate the type and degree of dirt on your device. You can use a microscope to choose an appropriate cleaning method, and then to examine the results. You can also use your microscope to judge whether your optical device (such as a connector) is severely scratched and is, therefore, causing inaccurate measurements.

Ultrasonic bath

Ultrasonic baths are also available from photography or laboratory suppliers or specialist mail order companies.

An ultrasonic bath will gently remove fat and other stubborn dirt from your optical devices. This helps increase the life span of the optical devices.

Only use isopropyl alcohol in your ultrasonic bath, as other solvents may cause damage.

Warm water and liquid soap

Only use water if you are sure that there is no other way of cleaning your optical device without causing corrosion or damage. Do not use hot water, as this may cause mechanical stress, which can damage your optical device.

Ensure that your liquid soap has no abrasive properties or perfume in it. You should also avoid normal washing up liquid, as it can cover your device in an iridescent film after it has been air dried.

Some lenses and mirrors also have a special coating, which may be sensitive to mechanical stress, or to fat and liquids. For this reason we recommend you do not touch them.

If you are not sure how sensitive your device is to cleaning, please contact the manufacturer or your sales distributor.

Premoistened cleaning wipes

Use pre-moistened cleaning wipes as described in each individual cleaning procedure. Cleaning wipes may be used in every instance where a moistened soft tissue or cotton swab is applied.

Polymer film

Polymer film is available from laboratory suppliers or specialist mail order companies.

Using polymer film is a gentle method of cleaning extremely sensitive devices, such as reference reflectors and mirrors.

Infrared Sensor Card

Infrared sensor cards are available from laboratory suppliers or specialist mail order companies.

With this card you are able to control the shape of laser light emitted. The invisible laser beam is projected onto the sensor card, then becomes visible to the normal eye as a round spot.

Take care never to look into the end of a fiber or any other optical component, when they are in use. This is because the laser can seriously damage your eyes.

Preserving Connectors

Listed below are some hints on how best to keep your connectors in the best possible condition.

Making Connections

Before you make any connection you must ensure that all cables and connectors are clean. If they are dirty, use the appropriate cleaning procedure.

When inserting the ferrule of a patchcord into a connector or an adapter, make sure that the fiber end does not touch the outside of the mating connector or adapter. Otherwise you will rub the fiber end against an unsuitable surface, producing scratches and dirt deposits on the surface of your fiber.

Dust Caps and Shutter Caps

Be careful when replacing dust caps after use. Do not press the bottom of the cap onto the fiber as any dust in the cap can scratch or dirty your fiber surface.

When you have finished cleaning, put the dust cap back on, or close the shutter cap if the equipment is not going to be used immediately.

Always keep the caps on the equipment when it is not in use.

All of Keysight Technologies' lightwave instruments and accessories are shipped with either laser shutter caps or dust caps. If you need additional or replacement dust caps, contact your nearest Keysight Technologies Sales/Service Office.

Immersion Oil and Other Index Matching Compounds

Wherever possible, do not use immersion oil or other index matching compounds with your device. They are liable to impair and dirty the surface of the device. In addition, the characteristics of your device can be changed and your measurement results affected.

Cleaning Instructions

Cleaning Instrument Housings

Use a dry and very soft cotton tissue to clean the instrument housing and the keypad. Do not open the instruments as there is a danger of electric shock, or electrostatic discharge. Opening the instrument can cause damage to sensitive components, and in addition your warranty will be voided.

Which Cleaning Procedure should I use?

Light dirt

If you just want to clean away light dirt, observe the following procedure for all devices:

- Use compressed air to blow away large particles.
- Clean the device with a dry cotton swab.
- Use compressed air to blow away any remaining filament left by the swab.

Heavy dirt

If the above procedure is not enough to clean your instrument, follow one of the procedures below. Please consult **Cleaning Instructions for this Instrument** on page 45 for the procedure relevant for this instrument.

If you are unsure of how sensitive your device is to cleaning, please contact the manufacturer or your sales distributor

How to clean connectors

Cleaning connectors is difficult as the core diameter of a single-mode fiber is only about 9 mm. This generally means you cannot see streaks or scratches on the surface. To be certain of the condition of the surface of your connector and to check it after cleaning, you need a microscope.

In the case of scratches, or of dust that has been burnt onto the surface of the connector, you may have no option but to polish the connector. This depends on the degree of dirtiness, or the depth of the scratches. This is a difficult procedure and should only be performed by a skilled person, and as a last resort as it wears out your connector.

WARNING Never look into the end of an optical cable that is connected to an active source.

To assess the projection of the emitted light beam you can use an infrared sensor card. Hold the card approximately 5 cm from the output of the connector. The invisible emitted light is projected onto the card and becomes visible as a small circular spot.

Preferred Procedure

Use the following procedure on most occasions.

1 Clean the connector by rubbing a new, dry cotton swab over the surface using a small circular movement.

2 Blow away any remaining lint with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the connector:

1 Moisten a new cotton swab with isopropyl alcohol.

2 Clean the connector by rubbing the cotton swab over the surface using a small circular movement.

3 Take a new, dry soft tissue and remove the alcohol, dissolved sediment and dust, by rubbing gently over the surface using a small circular movement.

4 Blow away any remaining lint with compressed air.

An Alternative Procedure

A better, more gentle, but more expensive cleaning procedure is to use an ultrasonic bath with isopropyl alcohol.

1 Hold the tip of the connector in the bath for at least three minutes.

2 Take a new, dry soft tissue and remove the alcohol, dissolved sediment and dust, by rubbing gently over the surface using a small circular movement.

3 Blow away any remaining lint with compressed air.

How to clean connector adapters

CAUTION Some adapters have an anti-reflection coating on the back to reduce back reflection. This coating is extremely sensitive to solvents and mechanical abrasion. Extra care is needed when cleaning these adapters.

Preferred Procedure

Use the following procedure on most occasions.

1 Clean the adapter by rubbing a new, dry cotton swab over the surface using a small circular movement.
2 Blow away any remaining lint with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the adapter:

1 Moisten a new cotton swab with isopropyl alcohol.
2 Clean the adapter by rubbing the cotton swab over the surface using a small circular movement.
3 Take a new, dry soft tissue and remove the alcohol, dissolved sediment and dust, by rubbing gently over the surface using a small circular movement.
4 Blow away any remaining lint with compressed air.

How to clean connector interfaces

CAUTION Be careful when using pipe cleaners, as the core and the bristles of the pipe cleaner are hard and can damage the interface.

Do not use pipe cleaners on optical head adapters, as the hard core of normal pipe cleaners can damage the bottom of an adapter.

Preferred Procedure

Use the following procedure on most occasions.

1 Clean the interface by pushing and pulling a new, dry pipe cleaner into the opening. Rotate the pipe cleaner slowly as you do this.
2 Then clean the interface by rubbing a new, dry cotton swab over the surface using a small circular movement.
3 Blow away any remaining lint with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the interface:

1 Moisten a new pipe cleaner with isopropyl alcohol.

2 Clean the interface by pushing and pulling the pipe cleaner into the opening. Rotate the pipe cleaner slowly as you do this.

3 Moisten a new cotton swab with isopropyl alcohol.

4 Clean the interface by rubbing the cotton swab over the surface using a small circular movement.

5 Using a new, dry pipe cleaner, and a new, dry cotton swab remove the alcohol, any dissolved sediment and dust.

6 Blow away any remaining lint with compressed air.

How to clean bare fiber adapters

Bare fiber adapters are difficult to clean. Protect from dust unless they are in use.

CAUTION

Never use any kind of solvent when cleaning a bare fiber adapter as solvents can:

- **Damage the foam inside some adapters.**
- **Deposit dissolved dirt in the groove, which can then dirty the surface of an inserted fiber.**

Preferred Procedure

Use the following procedure on most occasions.

1 Blow away any dust or dirt with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the adapter:

1 Clean the adapter by pushing and pulling a new, dry pipe cleaner into the opening. Rotate the pipe cleaner slowly as you do this.

CAUTION

Be careful when using pipe cleaners, as the core and the bristles of the pipe cleaner are hard and can damage the adapter.

2 Clean the adapter by rubbing a new, dry cotton swab over the surface using a small circular movement.

3 Blow away any remaining lint with compressed air.

How to clean lenses

Some lenses have special coatings that are sensitive to solvents, grease, liquid and mechanical abrasion. Take extra care when cleaning lenses with these coatings.

Lens assemblies consisting of several lenses are not normally sealed. Therefore, use as little alcohol as possible, as it can get between the lenses and in doing so can change the properties of projection.

Preferred Procedure

Use the following procedure on most occasions.

1 Clean the lens by rubbing a new, dry cotton swab over the surface using a small circular movement.

2 Blow away any remaining lint with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the lens:

1 Moisten a new cotton swab with isopropyl alcohol.

2 Clean the lens by rubbing the cotton swab over the surface using a small circular movement.

3 Using a new, dry cotton swab remove the alcohol, any dissolved sediment and dust.

4 Blow away any remaining lint with compressed air.

How to clean instruments with a fixed connector interface

CAUTION

Only use clean, dry compressed air. Make sure that the air is free of dust, water, and oil. If the air that you use is not clean and dry, this can lead to filmy deposits or scratches on the surface of your connector interface. This will degrade the performance of your transmission system.

Never try to open the instrument and clean the optical block by yourself, because it is easy to scratch optical components, and cause them to become misaligned.

You should only clean instruments with a fixed connector interface when it is absolutely necessary. This is because it is difficult to remove any used alcohol or filaments from the input of the optical block.

It is important, therefore, to keep dust caps on the equipment at all times, except when your optical device is in use.

If you do discover filaments or particles, the only way to clean a fixed connector interface and the input of the optical block is to use compressed air.

If there are fluids or fat in the connector, please refer the instrument to the skilled personnel of Keysight's service team.

How to clean instruments with an optical glass plate

Some instruments, for example, the optical heads from Keysight Technologies have an optical glass plate to protect the sensor. Clean this glass plate in the same way as optical lenses (See "How to clean lenses" on page 58.).

How to clean instruments with a physical contact interface

Remove any connector interfaces from the optical output of the instrument before you begin the cleaning procedure.

Cleaning interfaces is difficult as the core diameter of a single-mode fiber is only about 9 mm. This generally means you cannot see streaks or scratches on the surface. To be certain of the degree of pollution on the surface of your interface and to check whether it has been removed after cleaning, you need a microscope.

WARNING **Never look into an optical output because this can seriously damage your eyesight.**

To assess the projection of the emitted light beam you can use an infrared sensor card. Hold the card approximately 5 cm from the interface. The invisible emitted light is projected onto the card and becomes visible as a small circular spot.

Preferred Procedure

Use the following procedure on most occasions.

1 Clean the interface by rubbing a new, dry cotton swab over the surface using a small circular movement.

2 Blow away any remaining lint with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the interface:

1 Moisten a new cotton swab with isopropyl alcohol.

2 Clean the interface by rubbing the cotton swab over the surface using a small circular movement.

3 Take a new, dry soft tissue and remove the alcohol, dissolved sediment and dust, by rubbing gently over the surface using a small circular movement.

4 Blow away any remaining lint with compressed air.

How to clean instruments with a recessed lens interface

WARNING

For instruments with a deeply recessed lens interface (for example the Keysight 81633A and 81634A Power Sensors) do NOT follow this procedure. Alcohol and compressed air could damage your lens even further.

Keep your dust and shutter caps on when your instrument is not in use. This should prevent it from getting too dirty. If you must clean such instruments, please refer the instrument to the skilled personnel of Keysight's service team.

Preferred Procedure

Use the following procedure on most occasions.

1 Blow away any dust or dirt with compressed air.

If this is not sufficient, then

2 Clean the interface by rubbing a new, dry cotton swab over the surface using a small circular movement.

3 Blow away any remaining lint with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the interface, and using the preferred procedure is not sufficient. Using isopropyl alcohol should be your last choice for recessed lens interfaces because of the difficulty of cleaning out any dirt that is washed to the edge of the interface:

1 Moisten a new cotton swab with isopropyl alcohol.

2 Clean the interface by rubbing the cotton swab over the surface using a small circular movement.

3 Take a new, dry soft tissue and remove the alcohol, dissolved sediment and dust, by rubbing gently over the surface using a small circular movement.

4 Blow away any remaining lint with compressed air.

How to clean optical devices which are sensitive to mechanical stress and pressure

Some optical devices, such as the Keysight 81000BR Reference Reflector, which has a gold plated surface, are very sensitive to mechanical stress or pressure. Do not use cotton swabs, soft tissues or other mechanical cleaning tools, as these can scratch or destroy the surface.

Preferred Procedure

Use the following procedure on most occasions.

1 Blow away any dust or dirt with compressed air.

Procedure for Stubborn Dirt

To clean devices that are extremely sensitive to mechanical stress or pressure you can also use an optical clean polymer film. This procedure is time-consuming, but you avoid scratching or destroying the surface.

1 Put the film on the surface and wait at least 30 minutes to make sure that the film has had enough time to dry.

2 Remove the film and any dirt with special adhesive tapes.

Alternative Procedure

For these types of optical devices you can often use an ultrasonic bath with isopropyl alcohol. Only use the ultrasonic bath if you are sure that it won't cause any damage any part of the device.

1 Put the device into the bath for at least three minutes.

2 Blow away any remaining liquid with compressed air.

If there are any streaks or drying stains on the surface, repeat the cleaning procedure.

How to clean metal filters or attenuator gratings

This kind of device is extremely fragile. A misalignment of the grating leads to inaccurate measurements. Never touch the surface of the metal filter or attenuator grating. Be very careful when using or cleaning these devices. Do not use cotton swabs or soft tissues, as there is the danger that you cannot remove the lint and that the device will be destroyed by becoming mechanically distorted.

Preferred Procedure

Use the following procedure on most occasions.

1 Use compressed air at a distance and with low pressure to remove any dust or lint.

Procedure for Stubborn Dirt

Do not use an ultrasonic bath as this can damage your device.

Use this procedure when there is greasy dirt on the device:

1 Put the optical device into a bath of isopropyl alcohol, and wait at least 10 minutes.

2 Remove the fluid using compressed air at some distance and with low pressure. If there are any streaks or drying stains on the surface, repeat the whole cleaning procedure.

Additional Cleaning Information

The following cleaning procedures may be used with other optical equipment:

- How to clean bare fiber ends
- How to clean large area lenses and mirrors

How to clean bare fiber ends

Bare fiber ends are often used for splices or, together with other optical components, to create a parallel beam. The end of a fiber can often be scratched. You make a new cleave. To do this:

1 Strip off the cladding.

2 Take a new soft tissue and moisten it with isopropyl alcohol.

3 Carefully clean the bare fiber with this tissue.

4 Make your cleave and immediately insert the fiber into your bare fiber adapter in order to protect the surface from dirt.

How to clean large area lenses and mirrors

Some mirrors, as those from a monochromator, are very soft and sensitive. Therefore, never touch them and do not use cleaning tools such as compressed air or polymer film.

Some lenses have special coatings that are sensitive to solvents, grease, liquid and mechanical abrasion. Take extra care when cleaning lenses with these coatings.

Lens assemblies consisting of several lenses are not normally sealed. Therefore, use as little liquid as possible, as it can get between the lenses and in doing so can change the properties of projection.

Preferred Procedure

Use the following procedure on most occasions.

1 Blow away any dust or dirt with compressed air.

Procedure for Stubborn Dirt

Use this procedure when there is greasy dirt on the lens:

CAUTION **Only use water if you are sure that there is no other way of cleaning your optical device without causing corrosion or damage. Do not use hot water, as this may cause mechanical stress, which can damage your optical device.**

Ensure that your liquid soap has no abrasive properties or perfume in it. You should also avoid normal washing up liquid, as it can cover your device in an iridescent film after it has been air dried.

Some lenses and mirrors also have a special coating, which may be sensitive to mechanical stress, or to fat and liquids. For this reason we recommend you do not touch them.

If you are not sure how sensitive your device is to cleaning, please contact the manufacturer or your sales distributor.

1 Moisten the lens or the mirror with water.

2 Put a little liquid soap on the surface and gently spread the liquid over the whole area.

3 Wash off the emulsion with water, being careful to remove it all, as any remaining streaks can impair measurement accuracy.

4 Take a new, dry soft tissue and remove the water, by rubbing gently over the surface using a small circular movement.

5 Blow away remaining lint with compressed air.

Alternative Procedure A

To clean lenses that are extremely sensitive to mechanical stress or pressure you can also use an optical clean polymer film. This procedure is time-consuming, but you avoid scratching or destroying the surface.

1 Put the film on the surface and wait at least 30 minutes to make sure that the film has had enough time to dry.

2 Remove the film and any dirt with special adhesive tapes.

Alternative Procedure B

If your lens is sensitive to water then:

1 Moisten the lens or the mirror with isopropyl alcohol.

2 Take a new, dry soft tissue and remove the alcohol, dissolved sediment and dust, by rubbing gently over the surface using a small circular movement.

3 Blow away remaining lint with compressed air.

Other Cleaning Hints

Selecting the correct cleaning method is an important element in maintaining your equipment and saving you time and money. This Appendix highlights the main cleaning methods, but cannot address every individual circumstance.

This section contain some additional hints which we hope will help you further. For further information, please contact your local Keysight Technologies representative.

Making the connection

Before you make any connection you must ensure that all lightwave cables and connectors are clean. If not, then use the appropriate cleaning methods.

When you insert the ferrule of a patchcord into a connector or an adapter, ensure that the fiber end does not touch the outside of the mating connector or adapter. Otherwise, the fiber end will rub up against something which could scratch it and leave deposits.

Lens cleaning papers

Some special lens cleaning papers are not suitable for cleaning optical devices like connectors, interfaces, lenses, mirrors and so on. To be absolutely certain that a cleaning paper is applicable, please ask the salesperson or the manufacturer.

Immersion oil and other index matching compounds

Do not use immersion oil or other index matching compounds with optical sensors equipped with recessed lenses. They are liable to dirty the detector and impair its performance. They may also alter the property of depiction of your optical device, thus rendering your measurements inaccurate.

Cleaning the housing and the mainframe

When cleaning either the mainframe or the housing of your instrument, only use a dry and very soft cotton tissue on the surfaces and the numeric pad.

Never open the instruments as they can be damaged. Opening the instruments puts you in danger of receiving an electrical shock from your device, and renders your warranty void.

5 Warranty Information

All system warranties and support agreements are dependent upon the integrity of the Keysight Reference Transmitter Module. Any modification of the system software or hardware will terminate any obligation that Keysight Technologies may have to the purchaser. Please contact your local Keysight field engineer before embarking in any changes to the system.

Remove all doubt

Keysight offers a wide range of additional expert test and measurement services for your equipment, including initial startup assistance, onsite education and training, as well as design, system integration, and project management.

Our repair and calibration services will get your equipment back to you, performing like new, when promised. You will get full value out of your Keysight equipment throughout its lifetime. Your equipment will be serviced by Keysight-trained technicians using the latest factory calibration procedures, automated repair diagnostics and genuine parts. You will always have the utmost confidence in your measurements.

For more information on repair and calibration services, go to

www.keysight.com/find/removealldoubt

Keysight E-mail Updates

Get the latest information on the products and applications you select.

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Keysight Open

Keysight Open simplifies the process of connecting and programming test systems to help engineers design, validate and manufacture electronic products. Keysight offers open connectivity for a broad range of system ready instruments, open industry software, PC-standard I/O and global support, which are combined to more easily integrate test system development.

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