

N4376E 26.5 GHz Multimode Fiber Lightwave Component Analyzer for 10G/40G/100G Electro-Optical Test

General Information

The performance of digital, photonic transmission is ultimately described by the Bit Error Ratio (BER), but it is the analog nature of electro-optical subcomponents like modulators, PIN-TIA receivers and detectors that determines the performance of the entire transmission system.

Only a careful design of these electro-optical components over a wide modulation signal bandwidth guarantees successful operation in the transmission system.

Keysight's N4376E Lightwave Component Analyzer (LCA) is the ideal choice to characterize such electro-optical components for 10 Gbit/s, 40 Gbit/s and 100 Gbit/s transmission systems. Using the advanced measurement capabilities of the new N52xxB series PNA Microwave Network Analyzers, all relevant S-parameter related characteristics of the device under test can be qualified from 10 MHz to 26.5 GHz.



Productivity and Operator Guidance

The N4376E LCA has been designed with high productivity in mind: As an integrated, turn-key solution, it speeds up time-to-market when implementing the testing strategy for a new device. Compared to home-grown measurement solutions that leave the responsibility for accuracy and traceability to the user, high confidence in measurement results is maintained through self-test routines, which take uncertainty out of the calibration and measurement procedures.

An easy-to-perform, highly automated user calibration routine based on the e-Cal module, reduces the number of manual operator tasks, therefore shortening the measurement preparation time. Built-in RF switches, and the guidance provided by the instrument during user calibration and measurement setup minimize the number of re-connections and reduce operator-induced uncertainties.

Accuracy and Traceability

The N4376E LCA is built from carefully selected opto-electronic and electronic components. Temperature-stabilized transmitter and receiver components ensure measurements are reproducible over days without user re-calibration.

Because measurements at high absolute and relative accuracy improve both, development results, and production yield, every LCA undergoes an extended factory calibration across multiple optical power levels to minimize noise and ripple in the measurement traces.

Factory calibration against reference standards traceable to national standards ensures that test results can be compared among test locations worldwide. For balanced measurements, traceability is ensured up to frequencies as high as 26.5 GHz.

Software and Remote Control

Software and remote control are identical across the N437xB/C/D and N437xE generations of LCAs. They also share a common user interface, just like the recent PNA generations, to reduce operator training needs.

Remote control via LAN using .NET or COM interfaces, or through the industry-standard, easy-to-use SCPI interface simplifies the LCA's integration into an automated test environment. This is particularly helpful when an opto-electronic component's frequency response needs to be qualified over a wide range of parameters – a cumbersome and error-prone process if done manually.

The Network Analyzer

The N4376E is based on the new 2- and 4-port N5222B PNA microwave network analyzer with an identical and well-known user interface across all Keysight network analyzers. Versions with configurable test set and bias-T integrated in the network analyzer are available. The High RF output power ensures an optical modulation index (OMI) above 50%. This offers the freedom to change between small signal analysis and large signal analysis of a device under test. True mode balanced measurements are possible with 4-port, dual source network analyzers

Target Test Devices

Transmitters and receivers are typically tested for their frequency response over a range of bias voltages, optical input power levels, operating currents and ambient temperatures. The LCA's built-in optical power meter allows checking and controlling the user-selectable operating power, but also gives an indication of a bent fiber or a bad connection. The optional, auxiliary PMF input (option 050) enables the measurement of optically filtered/ demultiplexed O/E devices at specific wavelengths as proposed by the IEEE 802.3 standards and MSAs, or the verification of S-parameters over wavelength using an external tunable laser. With the LCA's high update rate, parameters can be adjusted to determine the optimum operating point of such devices.

Transmitters (E/O)

Mach-Zehnder modulators (MZM), electro-absorption modulators (EAM), directly modulated lasers, driver amplifier – modulator hybrids and transmitter optical subassemblies (TOSA) are among the most common optical transmitter components that can be characterized using the LCA. Dual-drive optical modulators and transmitters with differential electrical inputs can also be characterized using 4-port PNA versions of the LCA.

Receivers (O/E)

PIN photodiodes, avalanche photodiodes (APD), receiver optical subassemblies (ROSA) and integrated PIN-TIA receivers are examples of optical receiver components typically tested with an LCA. Moreover, 4-port PNA versions of the LCA can characterize PIN-TIA combinations with differential output for common-mode rejection and gain imbalance.

Optical Devices (O/O)

Transmission systems are typically tested for bandwidth and group delay using an LCA. Passive optical components and multimode fiber can be tested for insertion loss, bandwidth limitations, and optical group delay.

Electronic Devices (E/E)

Measurements of amplifiers, filters and transmission lines focus on transmission bandwidth, insertion loss or gain, impedance match and group delay. Such purely electronic measurements are possible with the network analyzer that is part of the LCA

Measurement Capabilities

| | |
|--|---|
| Responsivity (S21, amplitude and phase) | Absolute frequency response, such as the conversion efficiency of a transmitter, or the responsivity and gain of a receiver |
| | Relative frequency response, such as filter shapes or amplifier gain |
| | 3-dB bandwidth of the electro-optical or electrical transfer function |
| | Group Delay vs. frequency of the transfer function |
| | Optical Insertion Loss (IL) |
| Reflectivity (S11 or S22, amplitude and phase) | Electrical reflectivity at the RF port |
| | Impedance match |
| Balanced measurements (requires 4-port PNA) | Differential gain, gain imbalance |
| | Common-mode rejection, common-mode transfer function |

IEEE802.3ae Multimode Launch Condition

The repeatability and stability of measurements with multimode fiber are much more critical than measurements with single mode fiber. To minimize these effects, it is necessary to apply well defined and stable mode filling of the transmitter fiber. The N4376E offers typical multimode launch conditions or power-distribution in the transmitter fiber as defined by the IEEE 802.3ae standard, leading to repeatable test results that provide a realistic view of the application performance.

Key Specifications

Operating frequency range

10 MHz to 26.5 GHz

Relative frequency response uncertainty

± 1.5 dB @ 20 GHz

± 1.0 dB @ 20 GHz (typical)

Absolute frequency response uncertainty

± 1.8 dB @ 20 GHz (typical) for O/E measurements

± 2.0 dB @ 20 GHz (typical) for E/O measurements

Noise floor

-68 dB (A/W) @ 20 GHz for O/E measurements

-69 dB (W/A) @ 20 GHz for E/O measurements

Transmitter wavelength

850 nm ± 10 nm

Supported connector types

LC or SC straight

Built-in optical power meter

For fast transmitter power verification and indication of breaks, bends and bad connections

Powerful remote control

Programming interface based on Microsoft .NET or COM and SCPI

Definitions

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

Specifications (guaranteed)

Describes warranted product performance that is valid under the specified conditions. Specifications include guard bands to account for the expected statistical performance distribution, measurement uncertainties, changes in performance due to environmental changes and aging of components.

Typical values (characteristics)

Describe the product performance that is usually met but not guaranteed. Typical values are based on data from a representative set of instruments.

General characteristics

Give additional information for using the instrument. These are general descriptive terms that do not imply a level of performance.

LCA Inputs and Outputs



Explanation of Terms

Responsivity

For electro-optical devices (e.g. modulators) this describes the ratio of the optical modulated output signal power to the RF amplitude at the device input.

For opto-electrical devices (e.g. photodiodes) this describes the ratio of the RF amplitude at the device output to the modulated optical signal input power.

Relative frequency response uncertainty

Describes the maximum deviation of the shape of a measured trace from the (unknown) real trace. This specification has strong influence on the accuracy of the 3-dB cut-off frequency determined for the device under test.

Absolute frequency response uncertainty

Describes the maximum difference between any amplitude point of the measured trace and the (unknown) real value. This specification is useful to determine the absolute responsivity of the device versus modulation frequency.

Frequency response repeatability

Describes the deviation of repeated measurement without changing any parameter or connection relative to the average of this measurements.

Minimum measurable frequency response

Describes the average measured responsivity when no modulation signal is present at the device under test. This represents the noise floor of the measurement system.

Keysight N4376E Specifications

Measurement conditions

- Modulation frequency range from 10 MHz to 26.5 GHz
- Forward RF power: +3 dBm
- Reverse RF power: -5 dBm
- Number of averages: 1
- 100 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with modulation frequency step size 10 MHz and measurement points on a 10 MHz raster (if not stated otherwise)
- Network analyzer set to “stepped sweep – sweep moves in discrete steps”
- Network analyzer configured in normal coupler configuration (“CPLR ARM” to “RCVB B in”, “SOURCE OUT” to “CPLR THRU”) on network analyzer port connected to LCA receiver
- After full two-port electrical calibration using an Electronic Calibration Module, Keysight N4691D, at constant temperature (± 1 °C) with network analyzer set to -10 dBm electrical output power
- Modulation-bias optimization set to “Continuous”
- Measurement frequency grid equals electrical calibration grid
- Tested from PNA Port 1 to Port 2, respectively from PNA Port 1 to Port 4 for 4-port PNA
- DUT signal delay $\leq 0.1/IF-BW$
- Specified temperature range: +20 °C to +26 °C
- After warm-up time of 90 minutes
- Using high quality electrical and optical connectors in perfect condition
- 50 μm FC/APC to FC/PC patchcord at the input and output
- Test performed using an optical reference source with return loss better than 45 dB, spectral width FWHM < 10 MHz and InGaAs detector
- Launched power distribution according to IEEE 802.3ae - 2002, see figure 1

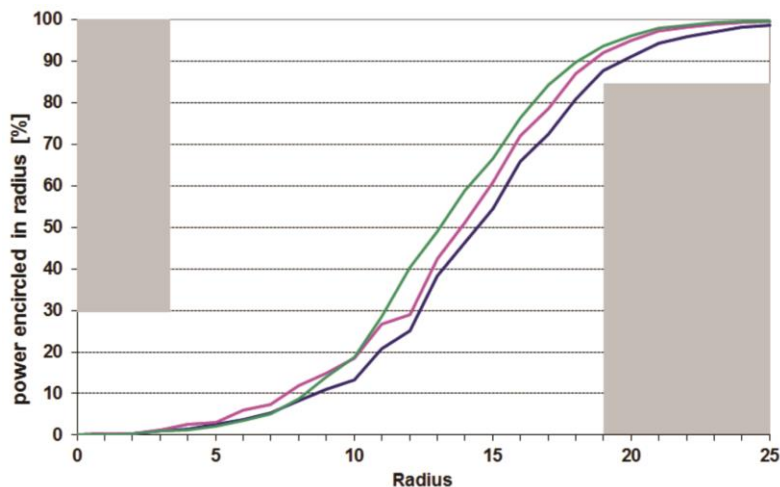


Figure 1: IEEE 802.3ae launch conditions measured with 3 samples

The optical test set always has angled connectors. Depending on the selected option (023, 024, 025, 026) the appropriate jumper cable will be delivered. This jumper cable must always be used to connect the device under test to the optical test set to protect the test set's connectors and is required for performance tests.

Transmitter and Receiver Specifications

| Optical Test Set | | |
|--|----------------|---|
| Operation frequency range | | 10 MHz to 26.5 GHz |
| Connector type | Optical input | 62.5 μ m MMF angled with Keysight universal connector interface |
| | Optical output | 50 μ m MMF angled with Keysight universal connector interface |
| | RF | 3.5 mm male |
| LCA optical input | | |
| Operating input wavelength range | | 750 nm to 1650 nm ³ |
| Maximum linear average input power ¹ | Optical input | -1 dBm |
| Maximum safe average input power | Optical input | +3 dBm |
| Optical return loss (typical) ¹ | | > 14 dBo |
| Average power measurement range ¹ | Optical input | -25 dBm to -1 dBm |
| Average power measurement uncertainty (typical) ¹ | | \pm 0.7 dBo |
| LCA optical output (Internal source) | | |
| Optical modulation index (OMI) at 10 GHz (typical) | | > 25% @ +3 dBm RF power |
| | | > 31% @ +5 dBm RF power |
| Output wavelength | | (850 \pm 10) nm |
| Launched power distribution (typical) | | according to IEEE 802.3ae - 2002 |
| Average output power range | | -5 dBm to -1 dBm |
| Average output power uncertainty (typical) ² | | \pm 0.7 dBo |
| Average output power stability, 15 minutes (typical) | | \pm 0.5 dBo |
| LCA RF test port input | | |
| Maximum safe input level at port A or B | | +15 dBm RF, 7V DC |

¹ Wavelength within range as specified for LCA optical output.

² After modulator optimization.

³ Excluding water absorption wavelengths.

Specifications for Electrical to Optical Measurements at 850 nm (E/O Mode)

N4376E with network analyzer: N5222B option 200, 201, 219, 400, 401, or 419.

Specifications are valid under the stated measurement conditions.

- For wavelength: (850 ± 10) nm.

| System performance | DUT response | 0.05 GHz to 0.2 GHz | 0.2 GHz to 10 GHz | 10 GHz to 20 GHz | 20 GHz to 26.5 GHz |
|---|---------------------------------|-----------------------|--|--|-------------------------|
| | ≥ -26 dB(W/A) ¹ | ± 1.0 dBe typical | ± 1.3 dBe (± 0.9 dBe, typical) | ± 1.5 dBe (± 1.0 dBe, typical) | ± 1.0 dBe, typical |
| Relative frequency response uncertainty | ≥ -36 dB(W/A) (typical) | ± 1.0 dBe | ± 0.9 dBe | ± 1.0 dBe | ± 1.2 dBe |
| | ≥ -46 dB(W/A) (typical) | ± 1.1 dBe | ± 0.9 dBe | ± 1.3 dBe | ± 2.0 dBe |
| Absolute frequency response uncertainty | ≥ -26 dB(W/A) ¹ | ± 2.1 dBe typical | ± 2.0 dBe | ± 2.0 dBe | ± 2.4 dBe, typical |
| Frequency response repeatability (typical) | ≥ -26 dB(W/A) ¹ | ± 0.1 dBe | ± 0.1 dBe | ± 0.1 dBe | ± 0.1 dBe, typical |
| | ≥ -36 dB(W/A) | ± 0.15 dBe | ± 0.1 dBe | ± 0.15 dBe | ± 0.25 dBe, typical |
| Min. measurable freq. response (noise floor) 2, 3, 4 | - | -65 dB(W/A) | -82 dB(W/A) | -69 dB(W/A) | -69 dB(W/A), typical |

¹ For DUT optical peak output power ≤ 0 dBm.

² IFBW = 10 Hz.

³ Average value over frequency range.

Specifications for Optical to Electrical Measurements at 850 nm (O/E Mode)

N4376E with network analyzer: N5222B option 200, 201, 219, 400, 401, or 419.

Specifications are valid under the stated measurement conditions.

- For wavelength: (850 ± 10) nm

| System performance | DUT response | 0.05 GHz to 0.2 GHz | 0.2 GHz to 10 GHz | 10 GHz to 20 GHz | 20 GHz to 26.5 GHz |
|---|---------------------------------|------------------------|--|--|-------------------------|
| | ≥ -21 dB(A/W) ¹ | ± 1.0 dBe, typical | ± 1.3 dBe (± 0.9 dBe, typical) | ± 1.5 dBe (± 1.0 dBe, typical) | ± 1.0 dBe, typical |
| Relative frequency response uncertainty ² | ≥ -31 dB(A/W) (typical) | ± 1.0 dBe | ± 0.9 dBe | ± 1.1 dBe | ± 1.2 dBe |
| | ≥ -46 dB(A/W) (typical) | ± 1.2 dBe | ± 0.9 dBe | ± 1.5 dBe | ± 1.2 dBe |
| Absolute frequency response uncertainty ² | ≥ -21 dB(A/W) ¹ | ± 1.9 dBe | ± 1.7 dBe | ± 1.8 dBe | ± 2.0 dBe, typical |
| | ≥ -21 dB(A/W) ¹ | ± 0.25 dBe | ± 0.1 dBe | ± 0.2 dBe | ± 0.25 dBe, typical |
| Frequency response repeatability (typical) ² | ≥ -31 dB(A/W) | ± 0.3 dBe | ± 0.1 dBe | ± 0.25 dBe | ± 0.5 dBe, typical |
| | | | | | |
| Min. measurable freq. response (noise floor) ^{2, 3, 4} | - | -58 dB(A/W) | -77 dB(A/W) | -68 dB(A/W) | -68 dB(A/W), typical |

¹ DUT response max. +10 dB (A/W).

² For +4 dBm average output power from LCA optical output.

³ IFBW = 10 Hz.

⁴ Average value over frequency range.

Specifications for Optical to Optical Measurements at 850 nm (O/O Mode)

N4373E with network analyzer: N5222B option 200, 201, 219, 400, 401, or 419.

Specifications are valid under the stated measurement conditions.

- For wavelength: (850 ± 10) nm

| System performance | DUT response | 0.05 GHz to 0.2 GHz | 0.2 GHz to 10 GHz | 10 GHz to 20 GHz | 20 GHz to 26.5 GHz |
|---|---|--|-----------------------------------|------------------------------------|---|
| Relative frequency response uncertainty | ≥ -10 dBe ^{1,2} (≥ -5 dBo) | ± 0.5 dBe (± 0.25 dBo, typ.) | ± 0.4 dBe (± 0.2 dBo) | ± 0.5 dBe (± 0.25 dBo) | ± 0.5 dBe, typical (± 0.25 dBo, typ.) |
| Absolute frequency response uncertainty (typical) | ≥ -10 dBe ^{1,2} (≥ -5 dBo) | ± 1.1 dBe (± 0.55 dBo) | ± 1.0 dBe (± 0.5 dBo) | ± 1.0 dBe (± 0.5 dBo) | ± 1.0 dBe (± 0.5 dBo) |
| Frequency response repeatability (typical) | ≥ -10 dBe ^{1,2} (≥ -5 dBo) | ± 0.15 dBe | ± 0.1 dBe | ± 0.15 dBe | ± 0.15 dBe |
| Min. measurable freq. response (noise floor) ^{2,3,4} | - | -53 dBe (-26.5 dBo) | -70 dBe (-35 dBo) | -44 dBe (-22 dBo) | -44 dBe, typical (-22 dBo, typical) |

¹ For DUT response max. 0 dB

² For -1 dBm average output power from LCA optical output.

³ IFBW = 10 Hz.

⁴ Average value over frequency range.


Specifications for Electrical-Electrical Measurements (E/E Mode)

All specifications of the N5222B option 200, 201, 219, 400, 401, or 419 Network Analyzer apply depending on selected LCA option x2z. Please see the corresponding Network Analyzer data sheet (pub no. [N5221-90003](#)) and User's Guide.

| Optical Test Set | |
|-------------------------------------|---------------------|
| Electrical loss of optical test set | < 2.0 dBe (typical) |

General Characteristics

| Weight | Net | Packaged |
|--|---|-------------------|
| 2 port LCA | 35.5 kg (78.3 lbs) | 52 kg (114.6 lbs) |
| 4 port LCA | 45.2 kg (99.6 lbs) | 60 kg (132.3 lbs) |
| Assembled Dimensions (H x W x D) | | |
| 413 mm x 438 mm x 538 mm (16.3 in x 17.3 in x 21.2 in) | | |
| Power Requirements | | |
| N5222B | 100 to 240 V~, 50 to 60 Hz, max. 450 VA | |
| Optical test set | 100 to 240 V~, 50 to 60 Hz, max. 40 VA | |
| Shipping Content | | |
| N5222B NA according to ordered option | | |
| 2x N4373-61604 0.5 m (m) to (f) high performance RF cable (4-port network analyzer) or 1x N4373-61604 0.5 m (m) to (f) high performance RF cable (2-port network analyzer) | | |
| 1x N4376E optical test set | | |
| 1x N4373-61627 f 3.5 mm to f 3.5 mm RF short cut cable | | |
| 2x 81000NI optical adaptor | | |
| 2x LC 50 µm to FC/APC 0.5 m patch cord, feedthrough (option 023), or 2x LC 62.5 µm to FC/APC 0.5 m patch cord, feedthrough (option 024), or 2x SC 50 µm to FC/APC 0.5 m patch cord, feedthrough (option 025), or 2x SC 62.5 µm to FC/APC 0.5 m patch cord, feedthrough (option 026) | | |
| 1x 8121-1242 USB cable | | |
| 1x 0960-3245 keyboard | | |
| 1x 0960-3248 mouse | | |
| 1x 5692-0476 calibration certificate | | |
| 1x 5692-5955 test data sheet | | |
| 1x 4376E-90A01 Getting Started Guide | | |
| 1x 4373B-90CD1 LCA support CD | | |
| 2x local power cord | | |
| 1x 9320-6654 RoHS addendum for photonic T&M products, 1x 9320-6677 RoHS addendum for photonic T&M accessories | | |

| | |
|--|--|
| Connectivity | |
| LCA electrical input | LCA electrical output |
| 3.5 mm (m) | 3.5 mm (m) |
| LCA optical input | LCA optical output |
| 62.5 µm MMF, angled ¹ , with Keysight universal adapter | 50 µm MMF, angled ¹ , with Keysight universal adapter |
| Storage Temperature Range | |
| -40 °C to +70 °C | |
| Operating Temperature Range | |
| +5 °C to +32 °C | |
| Humidity | |
| 15% to 80% relative humidity, non-condensing | |
| Altitude (Operating) | |
| 0 ... 2000 m | |
| Recommended Recalibration Period | |
| 1 year | |
| Laser Safety Information | |
| <p>All laser sources listed above are classified as Class 1M according to IEC 60825-1/2007.</p> <p>All laser sources comply with 21 CFR 1040.10 except for deviations pursuant to Laser Notice No. 50, dated 2007-06-24.</p> | |
|  | |

¹ The optical test set always has angled connectors. For input and output, a 50 µm or 62.5 µm angled to straight LC or SC patchcord must be selected. The connection to the DUT is always either LC or SC straight. The jumper cable must always be used in front to the optical test set to protect the connectors at the optical test set.

Ordering Information

The N4376E consists of an optical test set and an electrical network analyzer which are mechanically connected. To protect your network analyzer investment, Keysight offers the integration of an already owned PNA/PNA-X with the optical test set as listed below.

All systems come with Keysight's standard warranty.

| LCA N4376E Family Options | |
|---------------------------------|---|
| Wavelength options | Description |
| N4376E-103 | 850 nm source optical test set |
| Network analyzer options | Description |
| N4376E-220 | 26.5 GHz, 2 ports, single source PNA (N5222B-200) and RF-cables |
| N4376E-221 | 26.5 GHz, 2 ports, single source PNA (N5222B-201) with configurable test set and RF-cables |
| N4376E-222 | 26.5 GHz, 2 ports, single source PNA (N5222B-219) with configurable test set, extended power range, bias-tees and RF-cables |
| N4376E-420 | 26.5 GHz, 4 ports, dual source PNA (N5222B-400) and RF-cables |
| N4376E-421 | 26.5 GHz, 4 ports, dual source PNA (N5222B-401) with configurable test set and RF-cables |
| N4376E-422 | 26.5 GHz, 4 ports, dual source PNA (N5222B-419) with configurable test set, extended power range, bias-tees and RF-cables |
| N4376E-229 | Integration of customer's 26.5 GHz, 2 port PNA (N5222A/B or N5242A/B) with any configuration and RF-cables ¹ |
| N4376E-249 | Integration of customer's 26.5 GHz, 4 port PNA (N5222A/B or N5242A/B) with any configuration and RF-cables ¹ |
| Software options | Description |
| | Refer to the network analyzer configuration guide, pub no. 5992-1465EN , for information about other software options |
| Connector options | Description |
| N4376E-023 | LC 50 μm connector interface (external 0.75 m patch cord) |
| N4376E-024 | LC 62.5 μm connector interface (external 0.75 m patch cord) |
| N4376E-025 | SC 50 μm connector interface (external 0.75 m patch cord) |
| N4376E-026 | SC 62.5 μm connector interface (external 0.75 m patch cord) |

¹ Guaranteed specifications apply only for the above-mentioned network analyzer options.

| Recommended Accessories | |
|--|---|
| Rack mount kit for network analyzer | Description |
| 1CM042A | Rack mount flange kit - 265.9 mm height for installation without handles |
| E3663AC | Basic rail kit (for system II instruments) |
| Rack mount kit for LCA test set | Description |
| 34192A | Rack mount flange kit - 132.6 mm height for installation without handles |
| E3663AC | Basic rail kit (for system II instruments) |
| Electrical calibration module | Description |
| N4691D | Electronic Calibration Module, 26.5 GHz, 3.5 mm, 2 port (option 003, F0F or M0F with 00A recommended) |

Optical Instruments Online Information

Optical test instruments

www.keysight.com/find/oct

Lightwave component analyzers

www.keysight.com/find/lca

Polarization solutions

www.keysight.com/find/pol

Electro-optical converters

www.keysight.com/find/ref

Optical test instruments accessories

www.keysight.com/comms/oct-accessories

Keysight photonic discussion forum

www.keysight.com/find/photonic_forum

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www.keysight.com/find/contactus

