

N4372E

Lightwave Component Analyzer

Opto-electronic S-parameter measurements up to 110 GHz

Industry-First 110 GHz Turn-Key Test System for Optical RX and TX

Based on the N5290A and N5291A 900 Hz to 110/120GHz PNA Millimeter-Wave Systems, the new N4372E Lightwave Component Analyzer offers unprecedented bandwidth for both, optical receiver testing and optical transmitter testing.

Traceable S21 Measurement Across the Entire CWDM Wavelength Window

TX/RX manufacturers are approaching higher baud rates in RZ/NRZ and PAM formats, which pushes the envelope on high-bandwidth S-parameter testing. Up to now, the industry had only access to testing optical transmitters to 110 GHz bandwidth. The new N4372E not only offers opto-electronic tests up to 110 GHz in an extended wavelength range down to 1260 nm but addresses also RX test up to 110 GHz in the full 1260 nm to 1620 nm range, thanks to a transmitter that is calibrated traceable to NIST.

Setup for measurement of a photonic device



Figure 1. N4372E system setup

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Target Test Devices

Transmitters and receivers are typically tested for their frequency response and electrical return loss over a range of bias voltages, optical input power levels, operating currents and ambient temperatures. The LCA's built-in optical power meter allows to check and control the user-selectable operating power, but also gives an indication of a bent fiber or a bad connection. The LCA optical transmitter's input port is normally connected to the built-in laser source of the LCA controller. With an auxiliary tunable laser, the verification of S-parameters over wavelength is enabled. With the LCA's fast update of the electro-optic transfer function measurement, operating parameters can be quickly adjusted to determine the optimum operating point of such devices.

Transmitters (E/O)

Mach-Zehnder modulators (MZM), electro-absorption modulators (EAM), directly modulated lasers and transmitter optical subassemblies (TOSA) represent the most common optical transmitters. Dual-drive optical modulators can be characterized with 4-port PNA versions of the LCA, using three RF extender heads.

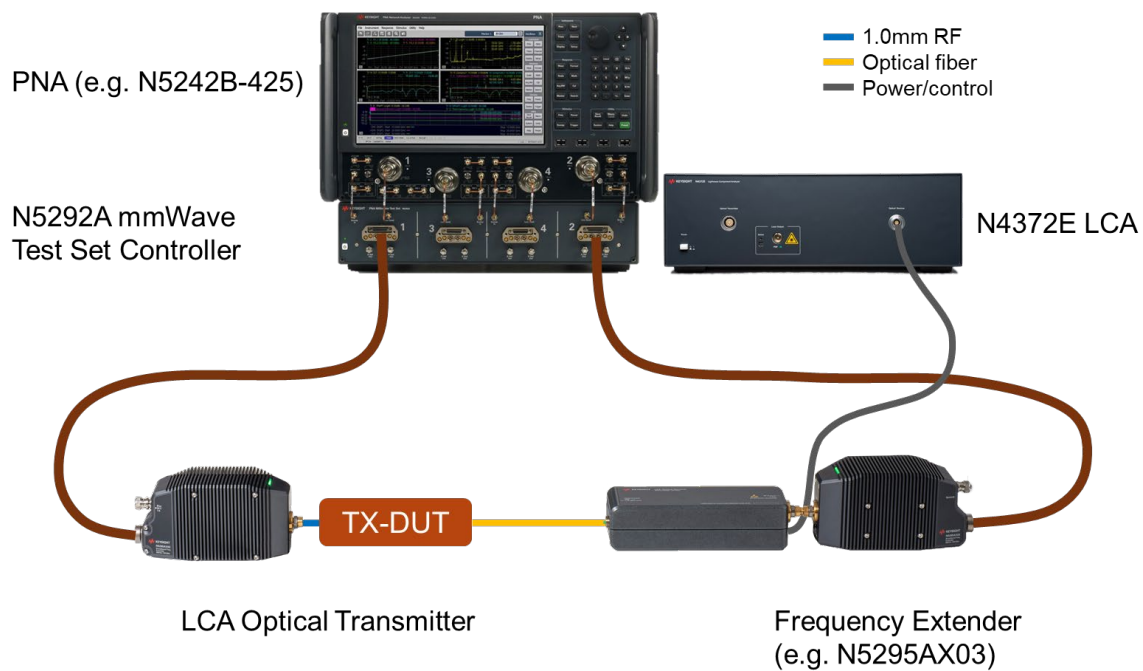


Figure 2. Optical transmitter test configuration

Receivers (O/E)

PIN photodiodes, avalanche photodiodes (APD), receiver optical subassemblies (ROSA) and integrated PIN-TIA receivers are examples of optical receivers. 4-port PNA versions of the LCA can characterize PIN-TIA combinations with differential output for differential gain, common-mode rejection and gain imbalance, using three RF extender heads.

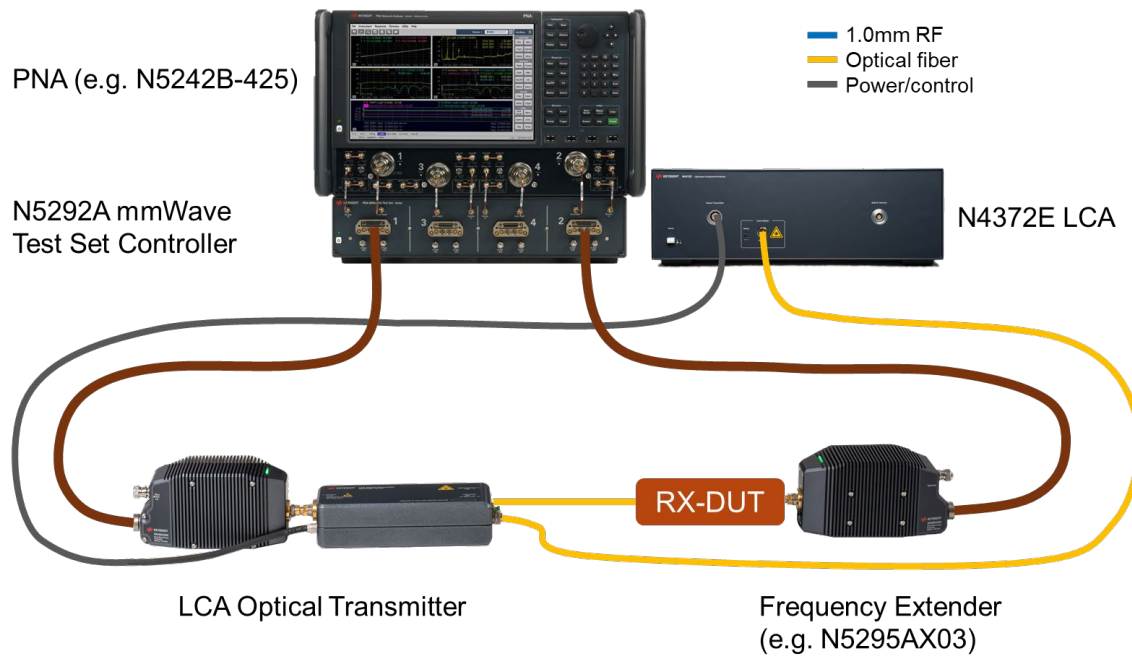


Figure 3. Photodiode test configuration

Optical devices (O/O)

Transmission systems are typically tested for bandwidth and group delay. Passive optical components can be tested for insertion loss, bandwidth limitations caused by dispersion effects, and for 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.

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.

Guaranteed specifications only apply with the pre-defined configurations for the N5290A and N5291A 900 Hz to 110/120 GHz PNA Millimeter-Wave Systems. Please refer to the configuration guide for the Millimeter Wave Network Analyzers N5290A/N5291A (document [5992-2179EN](#)) for a complete list of viable configurations.

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.

Explanation in Terms

Device under test (DUT) response

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.

Measurement Capabilities

Responsivity (S21, amplitude and phase)

- Absolute frequency response, the conversion efficiency of a transmitter, or the responsivity and gain of a receiver
- Relative frequency response, the filter shape of the electro-optical conversion or of the gain of an amplifier
- 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, S22, amplitude and phase)

- Electrical reflectivity at the RF port
- Impedance match

Balanced measurements (requires min. 3 extender heads)

- Differential gain, gain imbalance
- Differential frequency response
- Common-mode rejection
- Common-mode transfer function

Optical Receiver Test Specifications (N4372E-310, N4372E-311)

Measurement conditions

- Network analyzer set to 0 dBm electrical output power
- PNA path configuration for port to which LCA Optical Transmitter is connected to set to “Low Bnd Hi Pwr”
- Number of averages: 1
- After full two-port electrical calibration using a mechanical calibration kit, Keysight 85059B, at constant temperature (± 1 K) with network analyzer set to -15 dBm electrical output power
- Modulation-bias optimization set to “continuous”
- Measurement frequency grid equals electrical calibration grid
- DUT signal delay $\leq 0.1/IF-BW$
- Specified temperature range: $+20$ °C to $+26$ °C, with < 1 K deviation from temperature at PNA mechanical calibration
- After warm-up time of 90 minutes after LCA software has been started
- Using high quality electrical and optical connectors in very good condition
- All specifications are typical when using external laser sources

The optical test set always has angled connectors. Depending on the selected Option (-021 straight, -022 angled) 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.

System specifications	Receiver testing (N4372E-310, N4372E-311)
Calibrated frequency range	10 MHz to 100 GHz (Options 010, E10) 10 MHz to 110 GHz (Options 011, E11)
Internal laser wavelength	1310 nm \pm 20 nm (Options 100, 102) 1550 nm \pm 20 nm (Options 101, 102)
Operating wavelength range	1260 nm to 1620 nm ¹

1. External laser source required. Excluding water absorption wavelengths.

Specifications for testing optical receivers at 1310 nm (O/E measurement mode)

IF bandwidth settings:

- 300 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 10 MHz raster (if not stated otherwise) for relative frequency response uncertainty
- 10 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 100 MHz raster (if not stated otherwise) for minimum measurable frequency response

System specifications	DUT response	10 MHz to 200 MHz	> 200 MHz to 1 GHz	> 1 GHz to 26.5 GHz	> 26.5 GHz to 64 GHz	≤ 100 GHz (Options 010, E10) ≤ 110 GHz (Options 011, E11)
Relative frequency response uncertainty ¹	≥ -27 dB (A/W)	-	≤ ± 0.9 dBe	≤ ± 0.9 dBe	≤ ± 1.2 dBe	≤ ± 2.8 dBe (010, E10, 011)
(typical)		≤ ± 1.2 dBe	≤ ± 0.7 dBe	≤ ± 0.7 dBe	≤ ± 1.0 dBe	≤ ± 2.0 dBe (010, E10, 011) ≤ ± 2.8 dBe (E11)
Absolute frequency response uncertainty (typical) ¹	≥ -27 dB (A/W)	≤ ± 2.8 dBe	≤ ± 2.1 dBe	≤ ± 2.1 dBe	≤ ± 2.4 dBe	≤ ± 4.2 dBe
Frequency response repeatability (typical) ¹	≥ -27 dB (A/W)	≤ ± 0.7 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.3 dBe	≤ ± 1.4 dBe
Minimum measurable freq. response (noise floor) ^{2,4}	-	-	-79 dB (A/W)	-90 dB (A/W)	-79 dB (A/W)	-67 dB (A/W)
(typical)		-62 dB (A/W)	-84 dB (A/W)	-93 dB (A/W)	-82 dB (A/W)	-71 dB (A/W)
Phase uncertainty (typical) ^{1,2,3}	≥ -27 dB (A/W)	≤ ± 3.4°	≤ ± 1.8°	≤ ± 4.0°	≤ ± 4.0°	≤ ± 12.5°
Group delay uncertainty	-	Derived from phase uncertainty, see section “Group delay uncertainty”. Example: ± 2.0° → ± 8 ps (1 GHz aperture)				

1. For maximum available average output power from LCA Optical Transmitter.
2. Average value over frequency range
3. Except phase wrap aliasing (Example: A DUT group delay of 5 ns (1 m cable length) requires a frequency step size of ≤ 0.2 GHz to avoid phase wraps). Excluding a constant group delay offset of < ± 0.3 ns typical. (Cable length uncertainty < ± 0.06 m). A constant group delay offset leads to a phase offset $\Delta\Phi = 360 \times \Delta\text{GD} \times f_{\text{mod}}$ (in deg).
4. 6 dB higher noise floor for Options N4372E-E10, N4372E-E11.

Specifications for testing optical receivers at 1550 nm (O/E measurement mode)

IF bandwidth settings:

- 300 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 10 MHz raster (if not stated otherwise) for relative frequency response uncertainty
- 10 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 100 MHz raster (if not stated otherwise) for minimum measurable frequency response

System specifications	DUT response	10 MHz to 200 MHz	> 200 MHz to 1 GHz	> 1 GHz to 26.5 GHz	> 26.5 GHz to 64 GHz	≤ 100 GHz (Options 010, E10) ≤ 110 GHz (Options 011, E11)
Relative frequency response uncertainty ¹	≥ -27 dB (A/W)	-	≤ ± 0.8 dBe	≤ ± 0.9 dBe	≤ ± 1.3 dBe	≤ ± 2.5 dBe (010, E10, 011)
(typical)		≤ ± 0.8 dBe	≤ ± 0.7 dBe	≤ ± 0.7 dBe	≤ ± 1.0 dBe	≤ ± 1.8 dBe (010, E10, 011) ≤ ± 2.5 dBe (E11)
Absolute frequency response uncertainty (typical) ¹	≥ -27 dB (A/W)	≤ ± 2.3 dBe	≤ ± 2.4 dBe	≤ ± 2.4 dBe	≤ ± 2.5 dBe	≤ ± 3.7 dBe
Frequency response repeatability (typical) ¹	≥ -27 dB (A/W)	≤ ± 0.5 dBe	≤ ± 0.2 dBe	≤ ± 0.2 dBe	≤ ± 0.2 dBe	≤ ± 1.1 dBe
Minimum measurable freq. response (noise floor) ²	-	-	-80 dB (A/W)	-93 dB (A/W)	-82 dB (A/W)	-70 dB (A/W)
(typical)		-63 dB (A/W)	-85 dB (A/W)	-95 dB (A/W)	-85 dB (A/W)	-74 dB (A/W)
Phase uncertainty (typical) ^{1, 2, 3}	≥ -27 dB (A/W)	≤ ± 8.0°	≤ ± 1.2°	≤ ± 4.0°	≤ ± 4.0°	≤ ± 12.0°
Group delay uncertainty	-	Derived from phase uncertainty, see section “Group delay uncertainty”. Example: ± 2.0° → ± 8 ps (1 GHz aperture)				

1. For maximum available average output power from LCA Optical Transmitter.

2. Average value over frequency range

3. Except phase wrap aliasing (Example: A DUT group delay of 5 ns (1 m cable length) requires a frequency step size of ≤ 0.2 GHz to avoid phase wraps). Excluding a constant group delay offset of < ± 0.3 ns typical. (Cable length uncertainty < ± 0.06 m). A constant group delay offset leads to a phase offset $\Delta\Phi = 360 \times \Delta\text{GD} \times f_{\text{mod}}$ (in deg).

Optical Transmitter Test Specifications (N4372E-301, N4372E-311)

Measurement conditions

- Network analyzer set to 0 dBm electrical output power
- PNA path configuration for port to which LCA Optical Transmitter is connected to set to “Low Bnd Hi Pwr”
- Number of averages: 1
- After full two-port electrical calibration using a mechanical calibration kit, Keysight 85059B, at constant temperature (± 1 K) with network analyzer set to -15 dBm electrical output power
- Modulation-bias optimization set to “continuous”
- Measurement frequency grid equals electrical calibration grid
- DUT signal delay $\leq 0.1/IF-BW$
- Specified temperature range: $+20$ °C to $+26$ °C, with < 1 K deviation from temperature at PNA mechanical calibration
- After warm-up time of 90 minutes after LCA software has been started
- Using high quality electrical and optical connectors in very good condition

The optical test set always has angled connectors. Depending on the selected Option (-021 straight, -022 angled) 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.

System specifications	Transmitter testing (N4372E-301, N4372E-311)
Calibrated frequency range	10 MHz to 100 GHz (Options 010, E10) 10 MHz to 110 GHz (Options 011, E11)
Operating wavelength range	1260 nm to 1620 nm ¹
Maximum optical input power	+14 dBm

1. Excluding water absorption wavelengths

Specifications for testing optical transmitters at 1310 nm (E/O measurement mode)

IF bandwidth settings:

- 300 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 10 MHz raster (if not stated otherwise) for relative frequency response uncertainty
- 10 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 100 MHz raster (if not stated otherwise) for minimum measurable frequency response

System specifications	DUT response	10 MHz to 200 MHz	> 200 MHz to 1 GHz	> 1 GHz to 26.5 GHz	> 26.5 GHz to 64 GHz	≤ 100 GHz (Options 010, E10) ≤ 110 GHz (Options 011, E11)
Relative frequency response uncertainty	≥ -31 dB (W/A)	-	≤ ± 0.8 dBe	≤ ± 0.9 dBe	≤ ± 1.3 dBe	≤ ± 2.5 dBe (010, E10, 011, 301)
(typical)		≤ ± 1.0 dBe	≤ ± 0.7 dBe	≤ ± 0.7 dBe	≤ ± 1.0 dBe	≤ ± 1.6 dBe (010, E10, 011, 301) ≤ ± 2.5 dBe (E11)
Absolute frequency response uncertainty (typical) ¹	≥ -31 dB (W/A)	≤ ± 3.5 dBe	≤ ± 2.9 dBe	≤ ± 2.9 dBe	≤ ± 3.1 dBe	≤ ± 4.6 dBe
Frequency response repeatability (typical)	≥ -31 dB (W/A)	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.4 dBe
Minimum measurable freq. response (noise floor) ¹	-	-	-86 dB (W/A)	-102 dB (W/A)	-93 dB (W/A)	-88 dB (W/A)
(typical)		-75 dB (W/A)	-91 dB (W/A)	-104 dB (W/A)	-96 dB (W/A)	-92 dB (W/A)
Phase uncertainty (typical) ²	≥ -31 dB (W/A)	≤ ± 4.2°	≤ ± 1.5°	≤ ± 1.5°	≤ ± 2.8°	≤ ± 9.5°
Group delay uncertainty	-	Derived from phase uncertainty, see section “Group delay uncertainty”. Example: ± 2.0° → ± 8 ps (1 GHz aperture)				

1. Average value over frequency range

2. Except phase wrap aliasing (Example: A DUT group delay of 5 ns (1 m cable length) requires a frequency step size of ≤ 0.2 GHz to avoid phase wraps). Excluding a constant group delay offset of < ± 0.3 ns typical. (Cable length uncertainty < ± 0.06 m). A constant group delay offset leads to a phase offset $\Delta\Phi = 360 \times \Delta\text{GD} \times f_{\text{mod}}$ (in deg).

Specifications for testing optical transmitters at 1550 nm (E/O measurement mode)

IF bandwidth settings:

- 300 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 10 MHz raster (if not stated otherwise) for relative frequency response uncertainty
- 10 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 100 MHz raster (if not stated otherwise) for minimum measurable frequency response

System specifications	DUT response	10 MHz to 200 MHz	> 200 MHz to 1 GHz	> 1 GHz to 26.5 GHz	> 26.5 GHz to 64 GHz	≤ 100 GHz (Option 010, E10) ≤ 110 GHz (Option 011, E11)
Relative frequency response uncertainty	≥ -28 dB (W/A)	-	≤ ± 0.7 dBe	≤ ± 0.9 dBe	≤ ± 1.2 dBe	≤ ± 2.8 dBe (010, E10, 011, 301)
(typical)		≤ ± 0.7 dBe	≤ ± 0.7 dBe	≤ ± 0.7 dBe	≤ ± 1.0 dBe	≤ ± 1.8 dBe (010, E10, 011, 301) ≤ ± 2.8 dBe (E11)
Absolute frequency response uncertainty (typical) ¹	≥ -28 dB (W/A)	≤ ± 2.1 dBe	≤ ± 2.0 dBe	≤ ± 2.0 dBe	≤ ± 2.1 dBe	≤ ± 2.6 dBe
Frequency response repeatability (typical)	≥ -28 dB (W/A)	≤ ± 0.2 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.2 dBe
Minimum measurable freq. response (noise floor) ¹	-	-	-85 dB (W/A)	-102 dB (W/A)	-94 dB (W/A)	-88 dB (W/A)
(typical)		-72 dB (W/A)	-92 dB (W/A)	-104 dB (W/A)	-97 dB (W/A)	-91 dB (W/A)
Phase uncertainty (typical) ²	≥ -28 dB (W/A)	≤ ± 4.6°	≤ ± 1.4°	≤ ± 1.6°	≤ ± 2.5°	≤ ± 5.5°
Group delay uncertainty	-	Derived from phase uncertainty, see section “Group delay uncertainty”. Example: ± 2.0° → ± 8 ps (1 GHz aperture)				

1. For +4 dBm average output power from LCA Optical Transmitter output.

2. Except phase wrap aliasing (Example: A DUT group delay of 5 ns (1 m cable length) requires a frequency step size of ≤ 0.2 GHz to avoid phase wraps). Excluding a constant group delay offset of < ± 0.3 ns typical. (Cable length uncertainty < ± 0.06 m). A constant group delay offset leads to a phase offset $\Delta\Phi = 360 \times \Delta GD \times f_{mod}$ (in deg).

Optical-Only Device Test Specifications (N4372E-311)

Measurement conditions

- Network analyzer set to 0 dBm electrical output power
- PNA path configuration for port to which LCA Optical Transmitter is connected to set to “Low Bnd Hi Pwr”
- Number of averages: 1
- After full two-port electrical calibration using a mechanical calibration kit, Keysight 85059B, at constant temperature (± 1 K) with network analyzer set to -15 dBm electrical output power
- Modulation-bias optimization set to “continuous”
- Measurement frequency grid equals electrical calibration grid
- DUT signal delay $\leq 0.1/IF-BW$
- Specified temperature range: $+20$ °C to $+26$ °C, with < 1 K deviation from temperature at PNA mechanical calibration
- After warm-up time of 90 minutes after LCA software has been started
- Using high quality electrical and optical connectors in very good condition
- All specifications are typical when using external laser sources

The optical test set always has angled connectors. Depending on the selected Option (-021 straight, -022 angled) 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.

System specifications	Optical-only device testing (N4372E-311)
Calibrated frequency range	10 MHz to 100 GHz (Options 010, E10) 10 MHz to 110 GHz (Options 011, E11)
Operating wavelength range	1260 nm to 1620 nm ¹
Internal laser wavelength	1310 nm \pm 20 nm (Options 100, 102) 1550 nm \pm 20 nm (Options 101, 102)
Maximum optical input power	+14 dBm

1. Excluding water absorption wavelengths

Specifications for testing optical transmitters at 1310 nm (O/O measurement mode)

IF bandwidth settings:

- 300 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 10 MHz raster (if not stated otherwise) for relative frequency response uncertainty
- 10 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 100 MHz raster (if not stated otherwise) for minimum measurable frequency response

System specifications	DUT response	10 MHz to 200 MHz	> 200 MHz to 1 GHz	> 1 GHz to 26.5 GHz	> 26.5 GHz to 64 GHz	≤ 100 GHz (Options 010, E10) ≤ 110 GHz (Options 011, E11)
Relative frequency response uncertainty ¹	≥ -3 dBe	-	≤ ± 0.2 dBe	≤ ± 0.2 dBe	≤ ± 0.3 dBe	≤ ± 0.9 dBe (010, E10, 011)
(typical)		≤ ± 0.3 dBe	-	-	≤ ± 0.2 dBe	≤ ± 0.6 dBe (010, E10, 011) ≤ ± 0.9 dBe (E11)
Absolute frequency response uncertainty (typical) ¹	≥ -3 dBe	≤ ± 0.9 dBe	≤ ± 0.8 dBe	≤ ± 0.8 dBe	≤ ± 0.8 dBe	≤ ± 1.1 dBe
Frequency response repeatability (typical) ¹	≥ -3 dBe	≤ ± 0.2 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.3 dBe
Minimum measurable freq. response (noise floor) ^{2,4}	-	-	-71 dB (W/A)	-76 dB (W/A)	-63 dB (W/A)	-52 dB (W/A)
(typical)		-52 dB (W/A)	-74 dB (W/A)	-79 dB (W/A)	-66 dB (W/A)	-55 dB (W/A)
Phase uncertainty (typical) ^{1,2,3}	≥ -3 dBe	≤ ± 2.2°	≤ ± 0.2°	≤ ± 0.2°	≤ ± 0.7°	≤ ± 3.6°
Group delay uncertainty	-	Derived from phase uncertainty, see section “Group delay uncertainty”. Example: ± 2.0° → ± 8 ps (1 GHz aperture)				

1. For maximum available average output power from LCA Optical Transmitter output.
2. Average value over frequency range
3. Except phase wrap aliasing (Example: A DUT group delay of 5 ns (1 m cable length) requires a frequency step size of ≤ 0.2 GHz to avoid phase wraps). Excluding a constant group delay offset of < ± 0.3 ns typical. (Cable length uncertainty < ± 0.06 m). A constant group delay offset leads to a phase offset $\Delta\Phi = 360 \times \Delta\text{GD} \times \text{fmod}$ (in deg).
4. 6 dB higher noise floor for Options N4372E-E10, N4372E-E11.

Specifications for testing optical transmitters at 1550 nm (O/O measurement mode)

IF bandwidth settings:

- 300 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 10 MHz raster (if not stated otherwise) for relative frequency response uncertainty
- 10 Hz IFBW (“Reduce IF bandwidth at low frequency” enabled) with measurement points on a 100 MHz raster (if not stated otherwise) for minimum measurable frequency response

System specifications	DUT response	10 MHz to 200 MHz	> 200 MHz to 1 GHz	> 1 GHz to 26.5 GHz	> 26.5 GHz to 64 GHz	≤ 100 GHz (Options 010, E10) ≤ 110 GHz (Options 011, E11)
Relative frequency response uncertainty ¹	≥ -3 dBe	-	≤ ± 0.2 dBe	≤ ± 0.2 dBe	≤ ± 0.3 dBe	≤ ± 0.6 dBe (010, E10, 011)
(typical)		≤ ± 0.2 dBe	-	-	≤ ± 0.2 dBe	≤ ± 0.5 dBe (010, E10, 011) ≤ ± 0.6 dBe (E11)
Absolute frequency response uncertainty (typical) ¹	≥ -3 dBe	≤ ± 0.9 dBe	≤ ± 0.8 dBe	≤ ± 0.8 dBe	≤ ± 0.8 dBe	≤ ± 1.0 dBe
Frequency response repeatability (typical) ¹	≥ -3 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.1 dBe	≤ ± 0.3 dBe
Minimum measurable freq. response (noise floor) ²	-	-	-72 dBe	-80 dBe	-67 dBe	-55 dBe
(typical)		-54 dBe	-74 dBe	-81 dBe	-69 dBe	-59 dBe
Phase uncertainty (typical) ^{1, 2, 3}	≥ -3 dBe	≤ ± 0.9°	≤ ± 0.2°	≤ ± 0.2°	≤ ± 0.5°	≤ ± 2.8°
Group delay uncertainty	-	Derived from phase uncertainty, see section “Group delay uncertainty”. Example: ± 2.0° → ± 8 ps (1 GHz aperture)				

1. For maximum available average output power from LCA Optical Transmitter output.

2. Average value over frequency range

3. Except phase wrap aliasing (Example: A DUT group delay of 5 ns (1 m cable length) requires a frequency step size of ≤ 0.2 GHz to avoid phase wraps). Excluding a constant group delay offset of < ± 0.3 ns typical. (Cable length uncertainty < ± 0.06 m). A constant group delay offset leads to a phase offset $\Delta\Phi = 360 \times \Delta\text{GD} \times f_{\text{mod}}$ (in deg).

Specifications for electrical-electrical measurements (E/E measurement mode)

All specifications of the N5290A, N5291A PNA MM-Wave System apply, depending on selected options. Please see the corresponding PNA MM-Wave System data sheet and User's Guide.

Group delay

Group delay is computed by measuring the phase change within a specified aperture (for aperture see below):

$$GD [s] = \frac{\text{Phase change } [\pm deg]}{\text{Aperture [Hz]} * 360} \quad (\text{Equation 1})$$

Group delay uncertainty

Is calculated from the specified phase uncertainty and from the aperture (for aperture see below):

$$GD [\pm s] = \frac{\text{Phase uncertainty } [\pm deg]}{\text{Aperture [Hz]} * 360} * \sqrt{2} \quad (\text{Equation 2})$$

For more details see the specifications of the N5290A, N5291A PNA MM-Wave System.

Aperture

Determined by the frequency span and the number of points per sweep:

$$\text{Aperture} = \frac{\text{frequency span}}{\text{number of points} - 1} \quad (\text{Equation 3})$$

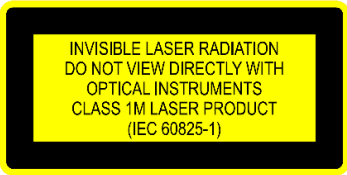
Group delay range

The maximum group delay is limited to measuring no more than ± 180 degrees of phase change within the selected aperture (see Equation 1).

General Specifications

LCA controller

LCA controller	Laser output
Wavelengths	1310 nm \pm 20 nm (Options 100, 102) 1550 nm \pm 20 nm (Options 101, 102)
Output power	+14 dBm
Fiber type	Panda polarization maintaining fiber (PMF). Electrical field is oriented in slow axis, in line with the connector key.
Laser safety Information	All laser sources listed above are classified as Class 1M according to IEC 60825-1 (2014). All laser sources comply with 21 CFR 1040.10 except for deviations pursuant to Laser Notice No. 50, dated 2007-06-24.



LCA optical transmitter

LCA optical transmitter	Laser input ¹
Wavelength range	1260 nm to 1620 nm, excluding water absorption wavelengths
Maximum optical input power	+17 dBm
Insertion loss, characteristic	11 dB at 1310 nm (Options E10, E11) 8 dB at 1310 nm (Options 010, 011) 6 dB at 1550 nm
Fiber type	Panda Polarization Maintaining Fiber (PMF). Electrical field is oriented in slow axis, in line with the connector key.
	Optical output
Average output power range of optical transmitter with internal laser (typical)	-5 dBm to +1 dBm at 1310 nm (Options E10, E11) -2 dBm to +4 dBm at 1310 nm (Options 010, 011) -1 dBm to +5 dBm at 1550 nm
Fiber type	Panda Polarization Maintaining Fiber (PMF). Electrical field is oriented in slow axis, in line with the connector key.
	Electrical input
RF connector	1 mm, male, rugged
Maximum RF input power	+21 dBm RF, 8 V DC

1. Required source characteristics: SMSR > 35 dB, line width < 10 MHz, power stability < 0.1 dB pp, PER > 20 dB, unmodulated, Panda polarization maintaining fiber

LCA optical receiver

LCA optical receiver	Optical input
Wavelength range	1260 nm to 1620 nm, excluding water absorption wavelengths
Maximum linear average input power (typical)	+1 dBm at 1310 nm (Options E10, E11) +4 dBm at 1310 nm (Options 010, 011) +5 dBm at 1550 nm
Average power measurement range (typical)	-25 dBm to +5 dBm
Maximum safe optical input power	+14 dBm
Absolute average power measurement uncertainty (typical)	$\leq \pm 0.5$ dB
Fiber type	Single mode
	Electrical output
RF connector	1 mm, male, rugged
Maximum input level	No RF signal, 8 V DC

Environmental conditions

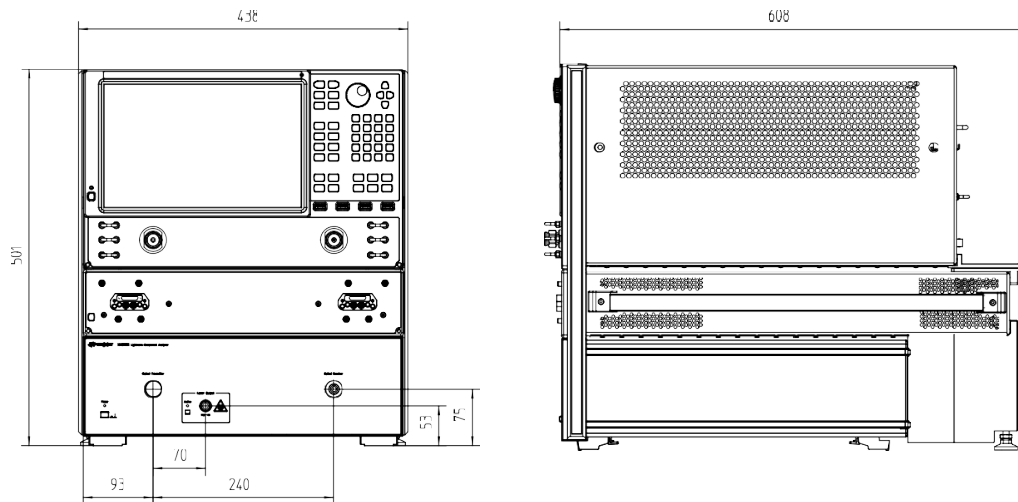
Environmental conditions	LCA controller, LCA optical transmitter, LCA optical receiver
Storage temperature	-40 °C to +65 °C
Operating temperature	+10 °C to +35 °C
Specified temperature range	+20 °C to +26 °C
Relative humidity	15% to 80%, non-condensing
Maximum operating altitude	2000 m (6600 ft)

General Characteristics

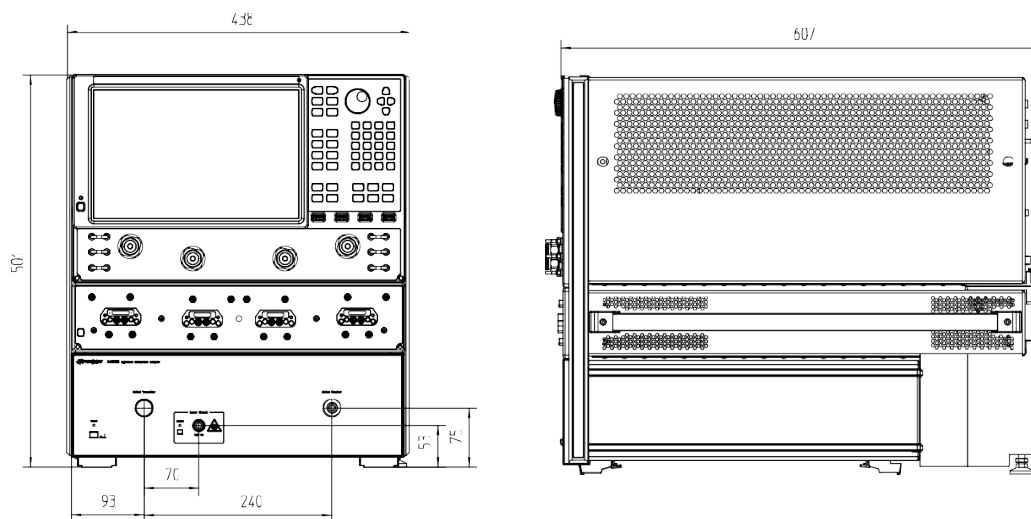
Net weight	LCA test set controller 8 kg (18 lbs) LCA optical receiver 1 kg (2 lbs) LCA optical transmitter 1 kg (2 lbs)
Power requirements	Max. 400 VA AC 100 V to 240 V $\pm 10\%$, 50 Hz to 60 Hz (LCA test set controller)

For weight, dimensions, space requirements and power requirements of the broadband network analyzer, please refer to the manual of the Keysight Technologies N5290/1A PNA Series 2-Port and 4-Port Microwave Network Analyzer System (900 Hz - 110 GHz / 900 Hz - 120 GHz) at <https://www.keysight.com/us/en/assets/9018-04581/installation-guides/9018-04581.pdf>

Mechanical outline drawings, 2-port mmWave system (dimensions in mm)



Mechanical outline drawings, 4-port mmWave system (dimensions in mm)



Ordering Information

Option	Test set configurations; must choose one
N4372E-301	LCA for testing transmitters (E/O measurements)
N4372E-310	LCA for testing receivers (O/E measurements)
N4372E-311	LCA for testing transmitters and receivers (O/E, E/O, O/O measurements)
Option	Receiver test wavelength options, available with N4372E-310, -311; must choose one
N4372E-100	Test Set with 1310 nm source
N4372E-101	Test Set with 1550 nm source
N4372E-102	Test Set with 1310 nm and 1550 nm source
Option	Receiver test bandwidth options, available with N4372E-310, -311; must choose one
N4372E-E10	Operating frequency range for testing receivers up to 100 GHz
N4372E-E11	Operating frequency range for testing receivers up to 110 GHz
N4372E-010	Operating frequency range for testing receivers up to 100 GHz, available with N4372E-101
N4372E-011	Operating frequency range for testing receivers up to 110 GHz, available with N4372E-101
Option	Connector options; must choose one
N4372E-021	Straight FC/PC
N4372E-022	Angled FC/APC
Option	2-Port PNA/ PNA-X configurations
N4372E-221	PNA, 2-port, 26.5 GHz (N5222B-201, -020) with config. test set, IF inputs
N4372E-222	PNA, 2-port, 26.5 GHz (N5222B-205, -020) with config. test set, IF inputs, LFE
N4372E-223	PNA, 2-port, 26.5 GHz (N5222B-219, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-224	PNA-X, 2-port, 26.5 GHz (N5242B-201, -020) with config. test set, IF inputs
N4372E-225	PNA-X, 2-port, 26.5 GHz (N5242B-205, -020) with config. test set, IF inputs, LFE
N4372E-226	PNA-X, 2-port, 26.5 GHz (N5242B-219, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-229	Integration of customer's 26.5 GHz, 2 Port PNA(-X) B with at least Option -020, -201
N4372E-271	PNA, 2-port, 67 GHz (N5227B-201, -020) with config. test set, IF inputs
N4372E-272	PNA, 2-port, 67 GHz (N5227B-205, -020) with config. test set, IF inputs, LFE
N4372E-273	PNA, 2-port, 67 GHz (N5227B-219, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-274	PNA-X, 2-port, 67 GHz (N5247B-201, -020) with config. test set, IF inputs
N4372E-275	PNA-X, 2-port, 67 GHz (N5247B-219, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-279	Integration of customer's 67 GHz, 2-port PNA(-X) B with at least Option -020, -201
N4372E-299	Integration of customer's 110/120 GHz, 2-port PNA(-X) B system
Option	Millimeter-wave test set controller for 2-port PNA/ PNA-X (required)
N4372E-TC2	Test set controller, 2-port (N5292A-200)
Option	Interconnect kits for 2-Port PNA/PNA-X
N4372E-IK1	Interconnect kit for 2-port PNA(-X) with 3.5 mm ports (N5292A-222)
N4372E-IK2	Interconnect kit for 2-port PNA(-X) with 2.4 mm or 1.85 mm ports (N5292A-224)

Option	4-port PNA/ PNA-X configurations
N4372E-421	PNA, 4-port, 26.5 GHz (N5222B-401, -020) with config. test set, IF inputs
N4372E-422	PNA, 4-port, 26.5 GHz (N5222B-405, -020) with config. test set, IF inputs, LFE
N4372E-423	PNA, 4-port, 26.5 GHz (N5222B-419, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-424	PNA-X, 4-port, 26.5 GHz (N5242B-401, -020) with config. test set, IF inputs
N4372E-425	PNA-X, 4-port, 26.5 GHz (N5242B-419, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-426	PNA-X, 4-port, 26.5 GHz (N5242B-425, -020) with config. test set, IF inputs, LFE, attenuators
N4372E-429	Integration of customer's 26.5 GHz, 4-port PNA(-X) B with at least Option -020, -401
N4372E-471	PNA, 4-port, 67 GHz (N5227B-401, -020) with config. test set, IF inputs
N4372E-472	PNA, 4-port, 67 GHz (N5227B-405, -020) with config. test set, IF inputs, LFE
N4372E-473	PNA, 4-port, 67 GHz (N5227B-419, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-474	PNA-X, 4-port, 67 GHz (N5247B-401, -020) with config. test set, IF inputs
N4372E-475	PNA-X, 4-port, 67 GHz (N5247B-419, -020) with config. test set, IF inputs, bias-tee, attenuators
N4372E-476	PNA-X, 4-port, 67 GHz (N5247B-425, -020) with config. test set, IF inputs, LFE, attenuators
N4372E-479	Integration of customer's 67 GHz, 4-port PNA(-X) B with at least Option -020, -401
N4372E-499	Integration of customer's 110/120 GHz, 4-port PNA(-X) B system
Option	Millimeter-wave test set controller for 4-port PNA/ PNA-X (required)
N4372E-TC4	Test set controller, 4-port (N5292A-400)
Option	Interconnect kits for 4-port PNA/ PNA-X
N4372E-IK3	Interconnect kit for 4-port PNA(-X) with 3.5 mm ports (N5292A-442)
N4372E-IK4	Interconnect kit for 4-port PNA(-X) with 2.4 mm or 1.85 mm ports (N5292A-444)
Option	Frequency extender heads (2 required for single-ended devices, min. 3 for balanced devices)
N4372E-FE1	Frequency extender 110 GHz, 1.2 m cable (N5293AX01)
N4372E-FE2	Frequency extender 110 GHz, 1.2 m cable, LFE, bias-tee (N5293AX03)
N4372E-FE3	Frequency extender 120 GHz, 1.2 m cable (N5295AX01)
N4372E-FE4	Frequency extender 120 GHz, 1.2 m cable, LFE, bias-tee (N5295AX03)
Option	Recommended calibration kits and accessories
N4372E-801	Calibration kit, 1 mm, DC to 120 GHz (85059B)
N4372E-802	USB thermocouple power sensor, DC to 120 GHz (U8489A)
N4372E-803	Verification kit, 1 mm (85059V)

Product Upgrade Ordering Information

Option	LCA optical head upgrade; must choose one
N4372EU-301	Upgrade from LCA for testing TX (N4372E-301) to LCA for testing TX and RX (N4372E-311)
Option	Receiver test wavelength options, available with N4372EU-301; must choose one
N4372EU-100	Test Set with 1310 nm Source
N4372EU-101	Test Set with 1550 nm Source
N4372EU-102	Test Set with 1310 nm and 1550 nm source
Option	Receiver test bandwidth options, available with N4372EU-301; must choose one
N4372EU-E10	Operating frequency range for testing receivers up to 100 GHz
N4372EU-E11	Operating frequency range for testing receivers up to 110 GHz
N4372EU-010	Operating frequency range for testing receivers up to 100 GHz, available with N4372EU-101
N4372EU-011	Operating frequency range for testing receivers up to 110 GHz, available with N4372EU-101
Option	LCA optical head upgrade for N4372E-310 (RX testing)
N4372EU-310	Upgrade from LCA for testing RX (N4372E-310) to LCA for testing TX and RX (N4372E-311)
N4372EU-103	Add 1310 nm laser source, available with N4372EU-310
N4372EU-104	Add 1550 nm laser source, available with N4372EU-310
Option	Connector options; must choose one
N4372EU-021	Straight FC/PC
N4372EU-022	Angled FC/APC

Lightwave Component Analyzers Online Information

www.keysight.com/find/lca

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