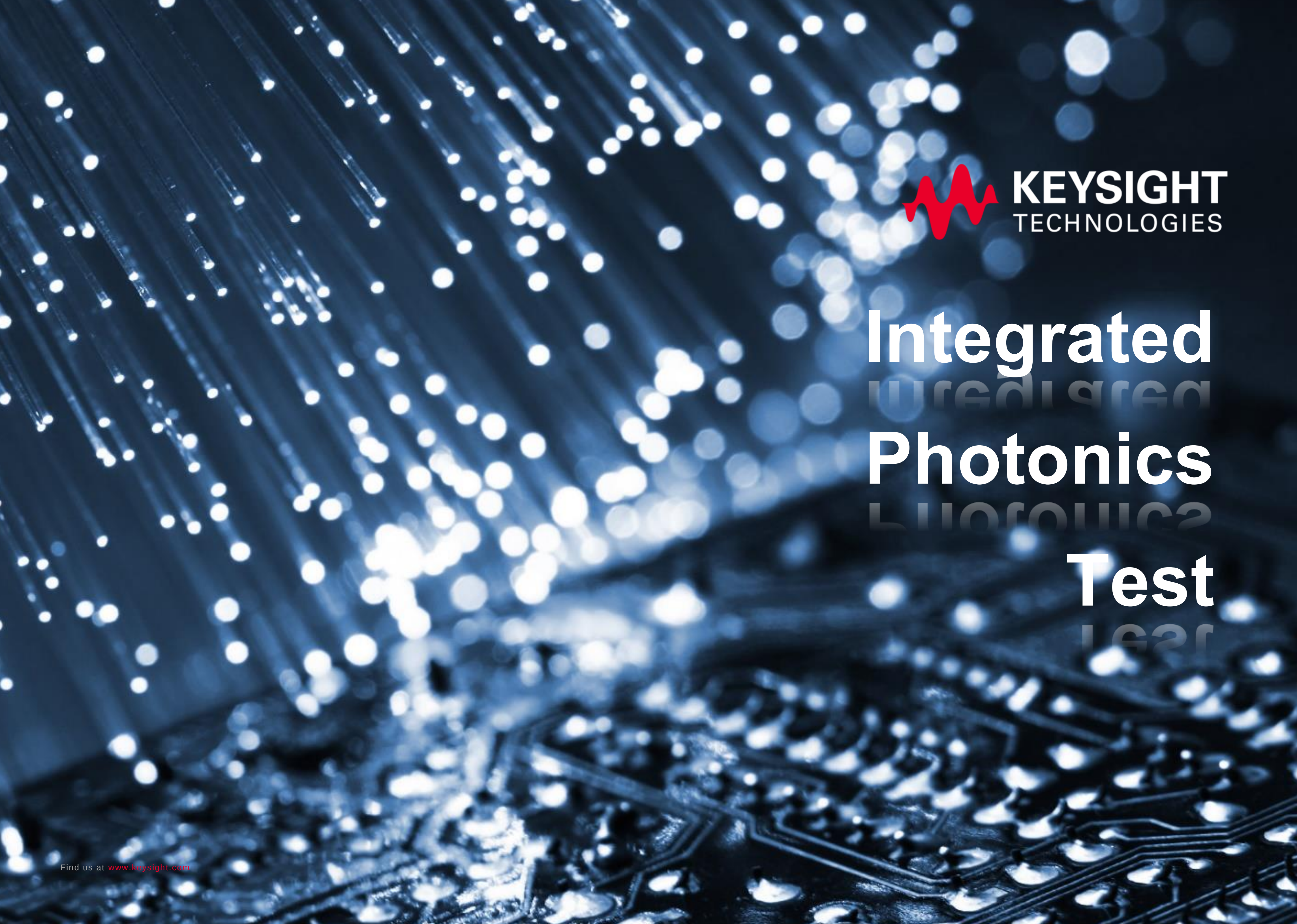

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Integrated Photonics Test

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Integrated Photonics Test

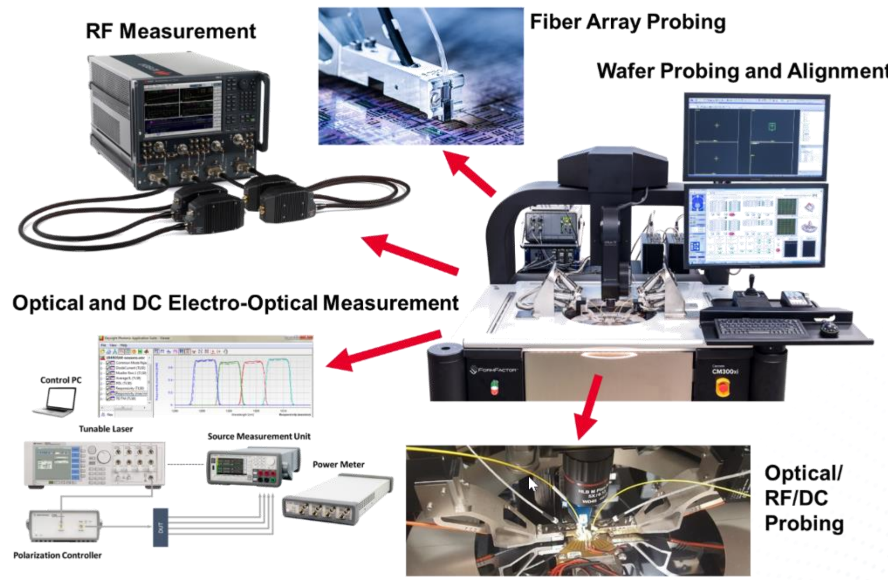
Silicon Photonics - Efficient Wafer Level Test

Integrated Photonics, often called Silicon Photonics, promises additional benefits for industrial segments such as Intra Data Center communication and Data Center Interconnects (DCI), Telecom, 5G and Automotive connectivity, High Performance Computing, LIDAR, Sensing and Medical.

Notably, optical components for the datacenter infrastructure design margins and low energy consumption targets are getting under pressure with higher data rates. This adds various forms of device integration.

- Integrated photonics technologies emerge to integrate various optical components, to scale parallel optical channels.
- Photonic Integrated Circuit (PIC) technology is a foundation to integrate and co-package electrical silicon devices with optical components.
- Chip makers move to selling dies (instead of packaged devices) that are further integrated into multi-die designs.
- Opportunities arise to qualify known-good dies.
- In the long-term, device integration can lead to a lack of access to devices for test purposes. New ways of testing multi-die and integrated devices need to be developed.

Keysight's program addresses R&D and Manufacturing of Integrated Photonics technologies by supporting you along your product lifecycle workflows with our solutions, solution elements and services for design, test and analytics.



Integrated Photonics Test Solution Combining Measurement

Keysight provides test solutions for silicon photonics wafer test:

- with wavelength and polarization dependent measurements with 81606A tunable laser source, N7786B polarization synthesizer, N7745A multiport power meter, and B2902A source measurement unit with N7700A application software
- RF tests with Keysight N4373E Lightwave Component Analyzer
- Wafer probing with FormFactor CM300xi probe station

Keysight's Photonic Test Solution integrated with PathWave Test driver plugins for instrument and wafer probe control enables

- Optical to optical and optical to electrical device test
- RF O/E and E/O measurements up to 67 GHz and beyond
- Software plugin with Keysight PathWave Tests for integration on T&M engines
- Automated probe station with FormFactor CM300xi
- Integrated & automated test flow

Enjoy this brochure with test solutions for integrated photonics testing and characterization accompanied with a comprehensive set of application briefs.

Dr.-Ing Joachim Peerlings
Vice President and General Manager
Network & Data Center Solutions

PATHWAVE

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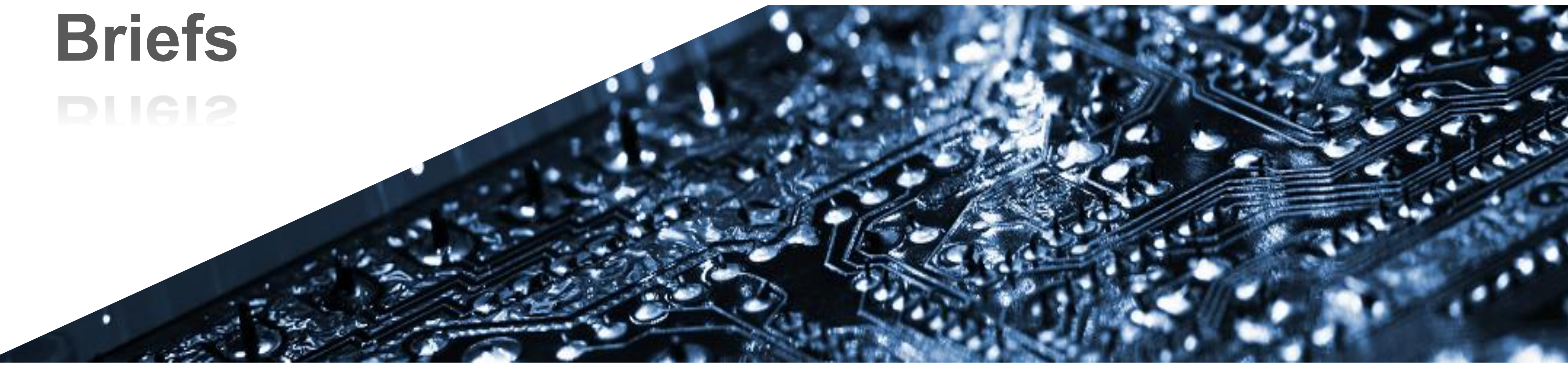
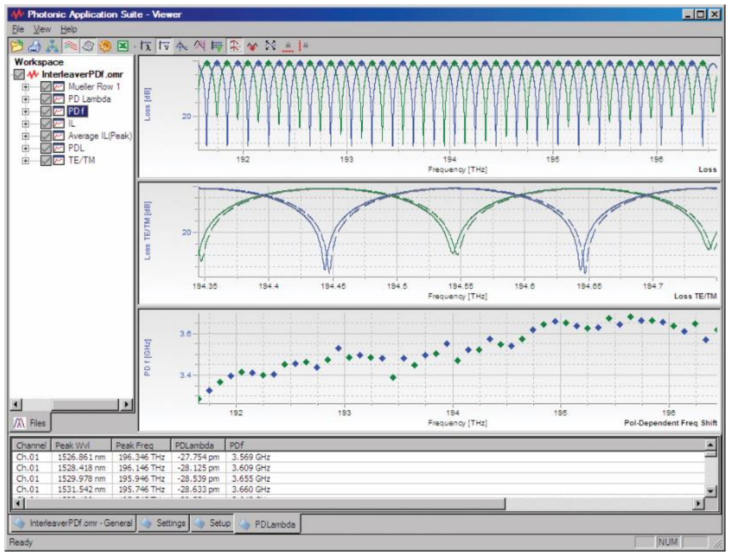


Swept-Wavelength Optical Measurement Solutions

Tunable laser instruments are used for spectral measurements of optical components and materials. The wavelength dependence is rapidly determined with selectable and very high wavelength resolution. The measurement systems can be flexibly configured to match the requirements of the application. Here we suggest some examples.



Insertion loss measurement (IL)

Combining one or more optical power meters with the tunable laser source (TLS) permits measurement of optical power vs. wavelength. Often this is used to find the ratio of power at the input of a component to the output power, commonly called insertion loss and expressed in dB. While the TLS tunes the wavelength over the chosen range, the power meters periodically sample the power for the desired number of measurement points. These samples are synchronized with the TLS sweep by a trigger signal for accurate association with the corresponding wavelength. Use of multiple power meters allows simultaneous measurement of outputs from multiport components like multiplexers, splitters and wavelength switches. Reflection spectra (return loss) can also be measured, by adding the 81610A return loss module.

A setup can combine the 81606A, 81607A or 81608A TLS with power meters from the 816x-series modules or the N774x-series multiport power meters and the free N7700 IL software. Faster sweep speeds, sampling rate and scan repetition are achieved using the N7700 FSIL software option.

Performance considerations

High wavelength accuracy and repeatability, particularly during fast wavelength scans, is assured with the built-in wavelength monitoring in these laser sources. These “lambda-logging” data are synchronized with the measurement triggers to the power meters. For highest absolute and relative wavelength accuracy the monitor is calibrated with a built-in gas cell reference and uses fast sampling to support the high sweep speeds. InGaAs power detectors are best for such measurements due to the small variation in responsivity over the single-mode fiber wavelength range (1260 to 1630 nm), the high sensitivity and dynamic range. The N7744A and N7745A power meters are especially well adapted to these swept-wavelength measurements with fast sampling rates and high signal bandwidth that allow high-resolution measurements at high sweep speeds without distortion of the measurement trace.

Fast data transfer supports high throughput, especially at high port counts. When measuring weaker signals, like for channels with crosstalk better than -60 dB or when the laser power is split to multiple devices, the N7747A or N7748A power meters can be used. The cooled detectors and low-noise amplifiers provide the highest sensitivity.

When insertion loss is low at some wavelengths and very high at others (high dynamic), like in DWDM components, it is very important that the broadband spontaneous emission from the TLS is very low. This avoids detecting light transmitted by the passband of the component when the TLS wavelength is outside this band, especially for measuring components with more than 40-50 dB dynamic. The 8160xA TLS provides light with practically no source spontaneous emission (SSE), even very close to the laser line. The dynamic range of the power meters is then important too. Keysight power meters use linear transimpedance amplification of the detector photocurrent for stability and accuracy, even at low power and high sampling speed. For fast measurements of dynamic up to about 55 dB, the N7744A and N7745A can do this with a fixed power range during a single wavelength sweep of the laser. Even more range is achieved by measuring with multiple power ranges and "stitching" the traces to capture both the strongest and weakest signal, especially when using the high sensitivity N7747A or N7748A. The N7700 FSIL and IL engines, as well as the 816x Plug&Play driver provide such stitching automatically.

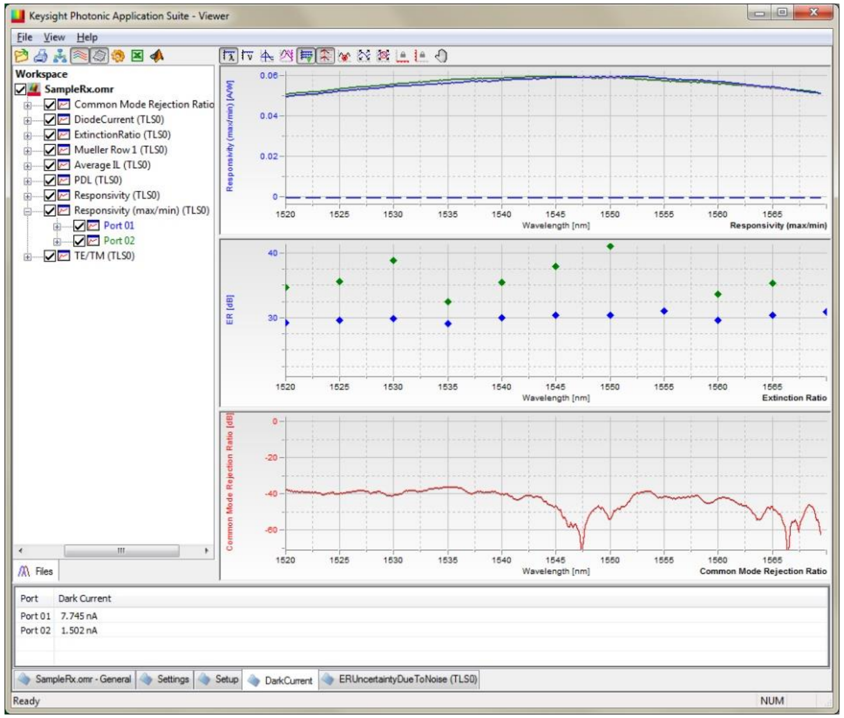
Polarization dependent loss (PDL)

Optical signals are generally polarized and the variation in insertion loss with polarization must be determined for network components. Measurement involves determining the maximum and minimum IL vs. polarization for all desired wavelengths, and all combinations of linear and circular polarization. Fortunately, this can be done by measuring swept-wavelength IL at a set of four (or optionally six) polarizations, from which any other IL can be calculated. This is known as the Mueller Matrix method. The setup includes a polarization controller after the TLS, that sets the polarization of the light into the device under test. The 8169A polarization controller has been used for this by sequentially setting each polarization for separate TLS sweeps. However, now the N7786B can rapidly switch polarization while monitoring the SOP and power, so PDL can be measured in a single wavelength sweep. This innovative method provides more stable PDL measurements in common working environments because the samples required for the PDL calculation at each point are collected in less than 1 ms, rather than in the several seconds usually used for repeating 4 sweeps.

From the resulting Mueller Matrix data, calculations are provided by the N7700 software, such as resolution of the IL spectra for the principal axes of the device, labeled TE and TM for planar devices like chips and wafers, and determination of polarization dependent wavelength are provided in the N7700A IL/PDL engine software.

Further details can be found in the brochure for the "*N7700A* Photonic Application Suite", 5990-3751EN and "Programming Keysight Technologies Continuous-Sweep Tunable Lasers", 5992-1125EN.

Wavelength and Polarization Characterization of Optical-to-Electrical Components

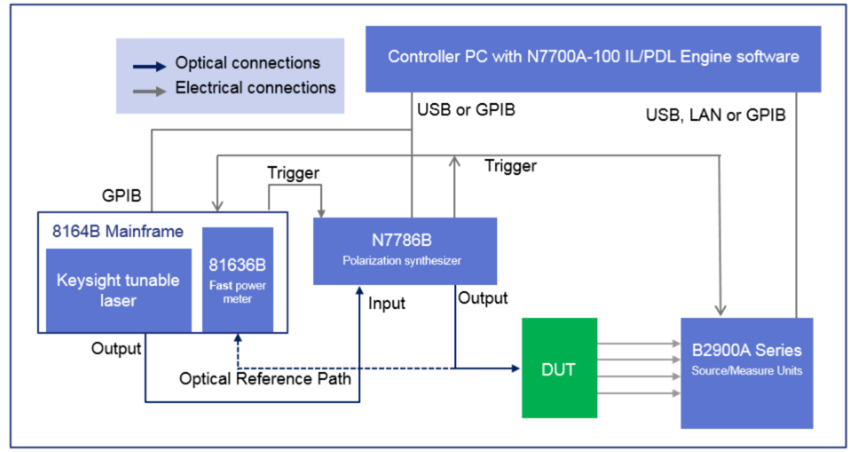


There is an increasing number of fiberoptic components that integrate photodiodes with passive optical functionality and with electronic circuits. Important examples are:

- Integrated coherent receivers (ICR)
- CWDM ROSA components
- Optical channel monitors

These all have optical input ports and electrical or RF output ports. The photodiodes produce photocurrent from the optical signal after it has passed the passive sections, such as polarizer, splitter, or interferometer.

Thus, the responsivity of the photodiodes to the input signal, measured in mA/mW in dependence of wavelength and polarization, is a fundamental performance measure of the component. Measurement of such devices can be made in the same way as mentioned on Page 19 for PDL, by replacing the optical power meter with an instrument for logging photocurrent. The N7700A-100 IL/PDL software supports this setup.



Setup example for measuring optoelectrical devices with the B2900A

From the swept-wavelength measurement of the input optical power and the output diode current, the spectra are calculated as the average responsivity vs. state of polarization.

The maximum and minimum responsivity vs. SOP are also determined, which is especially useful for polarizing components like ICR for polarization-multiplexed signals. The polarization dependence is also displayed in dB and the TE/TM traces are also calculated, as for optical-optical measurements. For balanced-detection components, the common-mode rejection ratio (CMRR) of detector pairs is also determined. The N7700A-100 software also has added functionality for measuring high PER with an additional measurement step that rapidly scans a large number of SOP at a set of fixed wavelength points. The user can choose the number of points to balance measurement time vs. resolution. Good accuracy to well beyond 20dB can be obtained.

For devices like ICR, where the photocurrent is converted to an RF output signal, the “CW” photocurrent can typically be accessed from the pins for applying bias voltage. For higher flexibility in the polarity and isolation of the biasing, the B2900A-series source measure units can also be used for detection, as shown here.

B2900A-series source measure unit

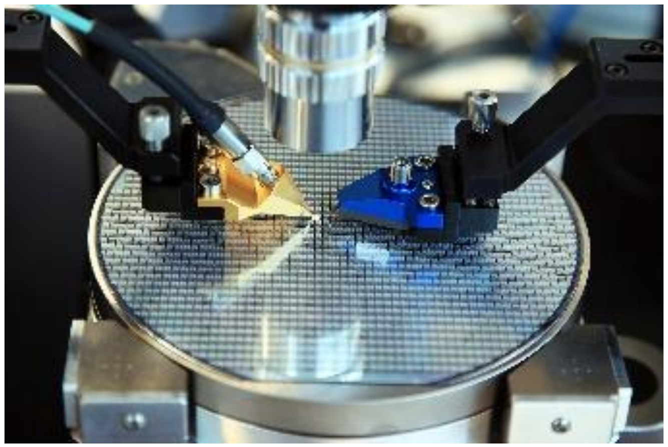
Support for these instruments is added to the N7700A-100 IL/PDL engine.

Further details can be found in the brochure for the *N7700A Photonic Application Suite,* 5990-3751EN and “*Wavelength and polarization dependence of 100G-LR4 components”.*
5992-1588EN.

Wafer and Chip-Level Optical Test: Solving Polarization Alignment

Semiconductor technology for photonic integrated circuits

Photonic integrated circuit (PIC) and silicon photonics technologies are being used to manufacture devices for optical communications at higher volumes with lower costs, energy consumption, and size. This is now especially driven by the rapidly increasing needs of data centers. These technologies also offer the means to realize new functionality with high-level integration of electronics and optics.



Appropriate test and measurement at an early stage, like wafer-level test, is valuable to avoid the high cost of processing and packaging devices that would fail final test and for controlling the wafer production process. Optical parametric testing generally includes the dependence on wavelength and on the alignment of optical polarization with the waveguide structures. For transponder devices like photodetectors and modulators, the RF-frequency dependence is also important for characterizing the bandwidth of the devices.

The challenge of polarization alignment

Adding optical measurements to wafer-level test requires optical probes to couple light to or from the wafer. Optical fiber cable is the usual way to connect to the instruments. Then an adapting structure is needed to provide matched coupling between the probe fiber and the wafer waveguides. For example, coupling into the surface of a wafer to waveguides running parallel to the wafer surface is achieved with coupler grating structures that can match the beam profiles and provide the refraction needed to change the direction of the light. Tapered waveguides can be used for edge-coupling into chips after dicing the wafer. For packaging, the chips can be attached to an interposer, generally a passive planar structure that provides accessible connections to the smaller chip.

In all of these cases, it is common for the coupling efficiency to depend strongly on the alignment of the optical polarization, due to the properties of both the waveguides and especially of the coupling gratings. This makes it important to either assure that the light is aligned with the correct axis of the waveguide or to measure the dependence of the device parameters on polarization. For typical planar waveguides with rectangular cross-section, the polarization modes associated with the axes are commonly labeled transverse electric (TE) for electric field of the optical wave along the wider dimension usually parallel to the wafer surface and transverse magnetic (TM) when the magnetic field is parallel to the wide dimension.

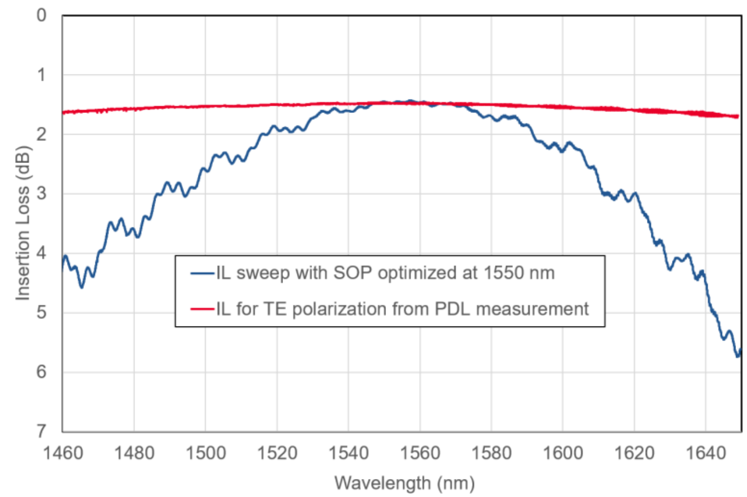
One way to assure alignment is using polarization-maintaining fiber (PMF), which has structure to define optical axes so that when the input light is exactly aligned with either axis the output light will also be aligned with that axis. This can be used if the laser source provides the output aligned in PMF and the alignment of the probe fiber axis with the wafer axis can be assured. It can be a good approach but is limited in flexibility. Such probes can only be easily used for measuring with that one state of polarization but not for determining polarization dependence.

Another approach uses SMF probes with a polarization controller before the probe to align the polarization. Unfortunately, the polarization at the output of the polarization controller and the SMF probe generally varies with the wavelength of the light. So if the device parameter (like attenuation or responsivity) should be determined over a wide wavelength range it is usually necessary to repeat the optimization step at several wavelengths over the desired range.

This prevents getting good measurements of a particular axis by simply scanning the wavelength of the tunable laser while sampling the DUT output. Typical results show an optimum signal at the wavelength used for alignment and (falsely) degraded performance as the wavelength is increasingly far from this point. An example of this is shown (blue curve) for a measurement of a polarization filter. The severity of degradation depends on the wavelength dependence and on the amount of birefringence in the polarization controller, fibers and other instruments in the optical path. Breaking the sweep into shorter separately optimized segments to avoid this requires much longer test duration.

Single-sweep measurement with matrix analysis

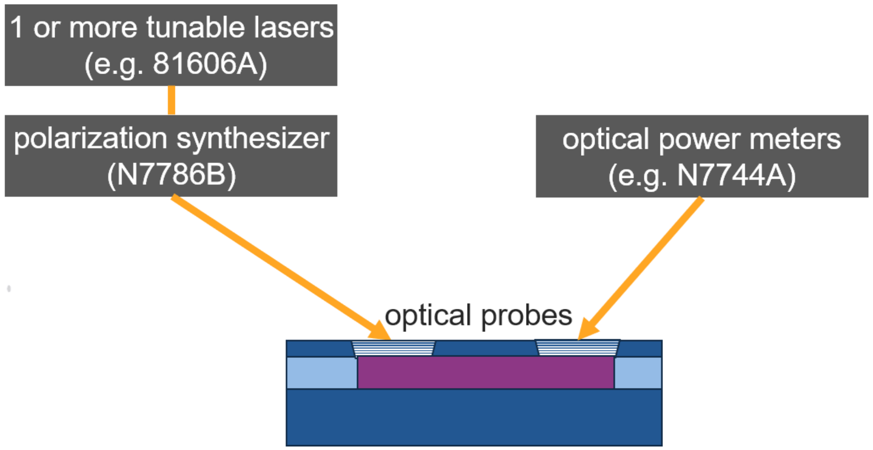
An improved approach, especially for obtaining wavelength-dependent data, is provided by the tunable-laser based systems controlled by the N7700A IL/PDL software. This approach measures the complete polarization dependence with a single wavelength scan. The results can be used to provide the response (insertion loss or responsivity) averaged over all possible polarization states, the dependence on polarization, and the response for the preferred polarization state, without needing to first optimize the polarization and especially without needing to maintain the optimization vs. wavelength. Such a result is shown as the red curve in the figure below.



Insertion loss measurements of a polarizer; blue: using the polarization controller to align the polarization at 1550 nm, red: using the matrix measurement to calculate the IL at the aligned polarization

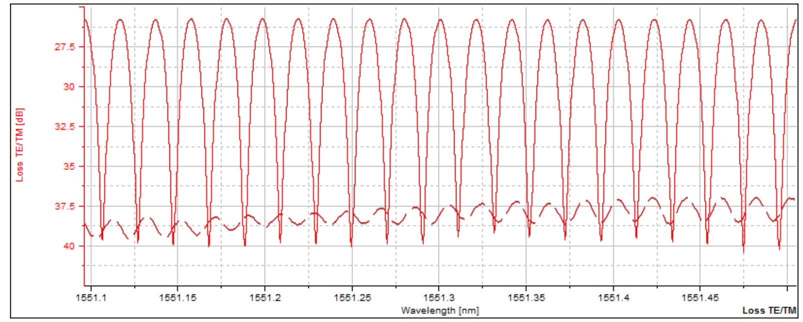
The measurement itself uses the fast-switching N7786B polarization synthesizer to repeatedly step through a set of 6 states of polarization (SOP) while the laser scans the wavelength continuously at a fixed sweep speed. The setup can thus measure the output signal for each 6-SOP sequence in just 300 µs. This makes the measurement very insensitive to vibrations and drift.

After the sweep, the measured wavelengths, SOPs, and output signal levels, all logged in real time by the respective instrument, are used to determine the Mueller matrix elements needed to calculate the polarization dependence of the signal power through the DUT. The software also provides the IL spectra corresponding to the optical axes of the DUT, presenting these as the TE and TM pair.



Basic instrumentation for the single-sweep matrix measurement with the N7700A IL/PDL software. For details, see www.keysight.com/find/n7700

So, with this approach, the wavelength-dependent measurement can be made as soon as the probes have been positioned, without first needing to align the polarization and without working around its drift with wavelength. That both saves time and improves measurement quality. Another example of the TE/TM result directly from a measurement is shown in Fig. 4, with a DUT where the TE and TM spectra cross (many times!).



Insertion loss spectra for the TE and TM polarization modes of a photonic integrated circuit, determined from the single-sweep matrix measurement

Static mode

It can still be necessary to provide an optical input signal and align the SOP with the DUT for other operations, including probe positioning, adjusting settings to the DUT, and measuring the dependence of the DUT to other variables such as modulation frequency, temperature or applied voltages. These operations are supported by the ‘Static Mode’ functionality of the N7700A IL/PDL engine.

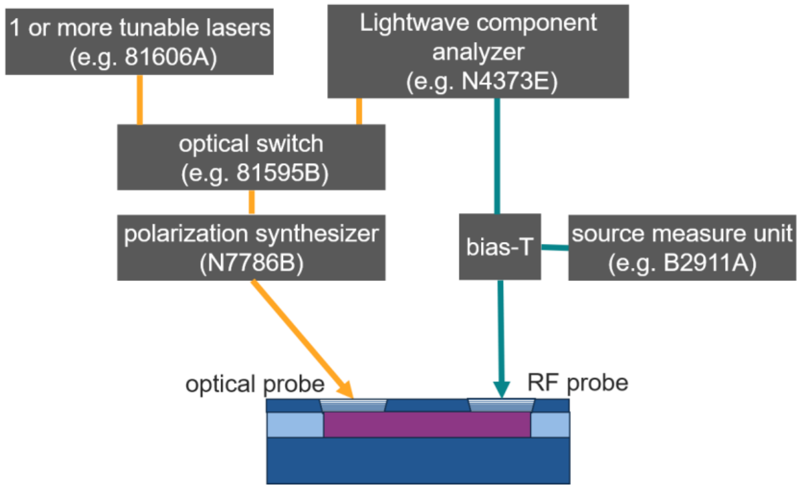
The ‘Static Mode’ provides functions from the IL/PDL engine server to set the polarization synthesizer to output a chosen SOP with a chosen laser wavelength and power. This can be done from the client GUI or from an automation program. With these settings, the desired operations can then be performed using the optical power meters or other instruments. When that is finished, the IL/PDL software can again be used to change to a different static setting or to make swept-wavelength spectral measurements. Especially powerful, the Static Mode can determine and set the SOP based on the matrix analysis of a previous swept-wavelength IL/PDL measurement, either directly after that measurement or based on a saved measurement file.

As a use case example, the following steps could be used.

1. An initial positioning of the probes is made, sufficient to couple light into the DUT and receive the output signal.
2. With this, the single-sweep IL/PDL measurement is made over the chosen wavelength range.
3. From the result, a wavelength where the signal transmission is reasonably high, like in a passband, can be chosen. On the Static Mode tab, this wavelength can be entered and the Mode setting “Last measurement (max/min)” chosen to use the polarization setting for the maximum (or minimum) signal level at this wavelength from the chosen detector port. Pressing “Set Static” then adjusts the laser and polarization controller to these settings.
4. The probe positions can be further optimized, using only signal polarization in the desired waveguide axis.
5. When finished, the IL/PDL engine can again be used in Swept Measurement mode with the optimized connections.

While still in Static Mode, the stabilizer function of the N7786B continues to regulate the output SOP, so that it can be kept constant if the SOP input to the N7786B changes. That can be useful in a case like illustrated below.

Here an optical switch is used to select either the tunable laser or the N4373E Lightwave Component Analyzer (LCA) as optical source to the N7786B. The LCA is used to measure the RF frequency dependence of device responsivity, especially for optical-to-electrical and electrical-to-optical transponders. In the former case, a modulated optical signal is applied to the DUT.



Example setup using the matrix measurement to set and stabilize the polarization, also for applying the modulated optical signal from the LCA.

The wavelength dependent CW responsivity of such a device can be measured with the swept-wavelength measurement, also resolving the spectra for TE and TM polarization. In this case the electrical photocurrent output is measured with a source/measure unit in place of the optical power meter. Then the Static Mode can be used to align the N7786B output SOP for the wavelength to be used by the LCA transmitter. The LCA software also includes functionality to de-embed the attenuation and delay from the additional elements in the optical path as well as the RF probes. For further details see the application note.
http://literature.cdn.keysight.com/litweb/pdf/5992-3258EN.pdf

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Calibrating Optical Paths in Spectral Test Stations

IL De-embedding

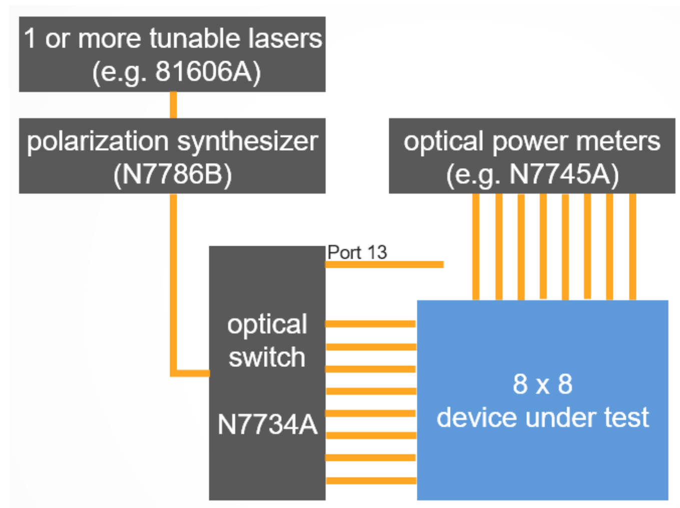
The Keysight N7700A IL/PDL software engine, widely used for parametric measurements of optical-to-optical and optical-to-electrical devices, also has functionality to simplify system calibration in test solutions with multiple optical paths, to support use of optical switches, splitters and especially optical probes for measuring wafers and chips.

This functionality, labeled “IL De-embedding”, provides for measuring the wavelength-dependent insertion loss (IL) for the various path segments relative to a common reference, usually during the initial installation or later modification of the test station. The resulting data, or equivalent calibration data obtained in another way, are then saved and can be applied to the corresponding device port measurements. These test station calibration data can retain validity over long duration when the corresponding paths are stable, as when using switches with high repeatability and when avoiding changes of fiber connections.

Optical switching example for an MxN device

Optical switch instruments can provide extremely repeatable selection among multiple optical paths. In an automated test station, this provides rapid path configuration and avoids the delay and insertion loss uncertainty associated with changing physical-contact fiber connections. However, there is usually some difference in IL among the switched paths, both due to possible internal details of the switch and to nearly unavoidable variations in the optical connections between patchcords and the instrument. For best measurement accuracy, instead of frequently repeated reference measurements at each port, it is valuable to calibrate the stable port-to-port differences when the switch is installed, so that later reference measurements made with one path can be correctly applied to the other paths as well. The same approach can also be used when a fiber splitter is used to provide multiple paths.

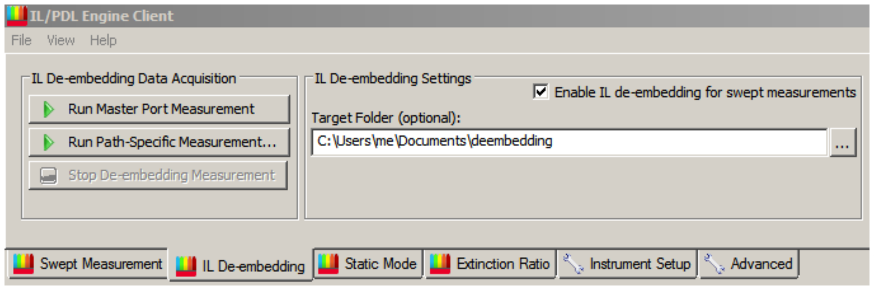
In this example, we consider the use of a switch to extend the basic N7700A IL/PDL setup for measurement of a device with multiple inputs. The basic setup uses a tunable laser and polarization synthesizer to apply an optical signal with variable wavelength and polarization to the device input and uses synchronized optical power meters to measure the signal of each device output port. The additional switch permits selectively addressing any of the device input ports. As a concrete example, we assume an 8x8 device under test (DUT), with the 8 outputs connected to the 8 ports of the N7745A power meter and with an N7734A 1x13 switch connecting to the 8 input ports, as shown in the below figure. Other configurations can be handled in a similar way



Example setup for measuring an 8x8 optical device

Switch calibration

The path-specific de-embedding data are determined relative to a chosen "Master Port" measurement. The path for this measurement should ideally be easy to use for future reference measurements. In our example, the 1x13 switch has several output ports free, so we could choose to use Port 13, and connect a fiber cord for these measurements that is then temporarily connected to one of the power meters, e.g. Port 1 of the N7745A as the Master Port. The switch itself should be switched to Port 13.



IL De-embedding tab of IL/PDL Engine Client

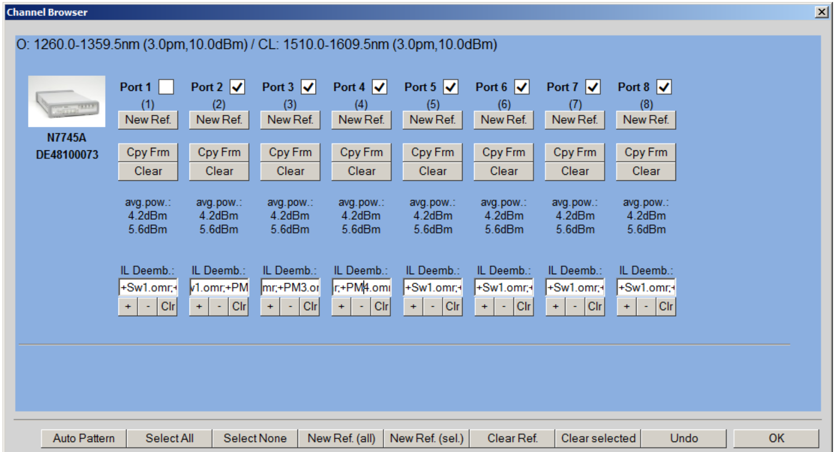
From the IL De-embedding tab in the IL/PDL software client, the button for "Master Port Measurement" can now be pressed. This will start a measurement sweep over the full range of the tunable laser or lasers and the polarization-averaged data will be taken from the power meter port that gets the signal. Once the measurement is finished, the software is ready to proceed with a series of measurements for specific paths.

After making the appropriate connections, press the button for "Path-Specific Measurement" and choose a convenient name for the file, like e.g. "Sw1". The measurement sweep will be run in the same way as for the Master Port. The result in the file Sw1.omr will represent the polarization-averaged attenuation difference in dB, relative to the Master Port path. The process should then be repeated for each of the switch output ports, each time connecting the cord on that port to the power meter at Port 1 and switching to that port. The resulting data should have long-term validity for the station under stable conditions, when the connectors are not changed.

Using the IL de-embedding data

The N7700A software measures the wavelength dependent IL and PDL by comparing the signal output from the device with the previously measured signal to be input to the device. This previous step is referred to as the reference measurement. For best accuracy, the device measurement is made with the same sweep settings (wavelength range, sample spacing, polarization states) as the reference. Therefore, the reference measurement is usually replaced periodically to reestablish optimized polarization state settings that can evolve with system and environment temperature, fiber movement, etc., as well as for selection of other sweep parameters. In our case, the reference measurements should be made with the reference cord from Port 13 connected to Port 1 of the power meter, as with the Master Port measurement.

By using the IL de-embedding data, the reference data can be normalized for application to other optical paths, without needing to make the reference measurement at those ports each time. The software also applies appropriate interpolation, so that the same de-embedding data can be used for measurements with different wavelength ranges and sample spacing (step).



Channel Browser used for configuring the reference measurement and the IL de-embedding

In the Channel Browser, the reference measurement can be applied to all desired ports. The switch de-embedding is used to calibrate the path to the input of the DUT, so all output ports need to use the same switch data. For measurements to the first input port of the DUT, the file Sw1.omr should be used. When the measurement signal should be switched to the second input port, the de-embedding settings should be changed to use the file Sw2.omr. This will usually be done with automation commands together with the command to set the switch.

Detector path calibration

The same procedure as used above for calibrating the switch paths into the DUT can be used to calibrate the paths from the DUT to the individual power meters. This is particularly useful if the path includes additional components like switches, couplers, or intermediate connectors. But this can also be used to correct for the usually small differences in power readings among the power meters, which can be estimated from the specifications for absolute power uncertainty and in the case of the N7744A and N7745A from the narrower relative port-to-port uncertainty. Calibrating these differences improves the accuracy of measurements on one power meter based against the reference measurement on another power meter, as was described above.

In our example, the measurements for the detector path calibration files can be made as part of the same procedure used to calibrate the switch. The resulting files can then be added to the corresponding ports in the Channel Browser. So at Port 1 the IL Deemb field could use "+Sw1", at Port 2 "+Sw1;+PM2", at Port 3 "+Sw1;+PM3" and so forth on the remaining ports. Note that this concatenation of files for de-embedding can also be used with the '-' polarity, in which case the IL data in dB is applied with reversed sign. This is appropriate for example when the file characterizes a component that is present in the reference path, but not in the DUT measurement path.

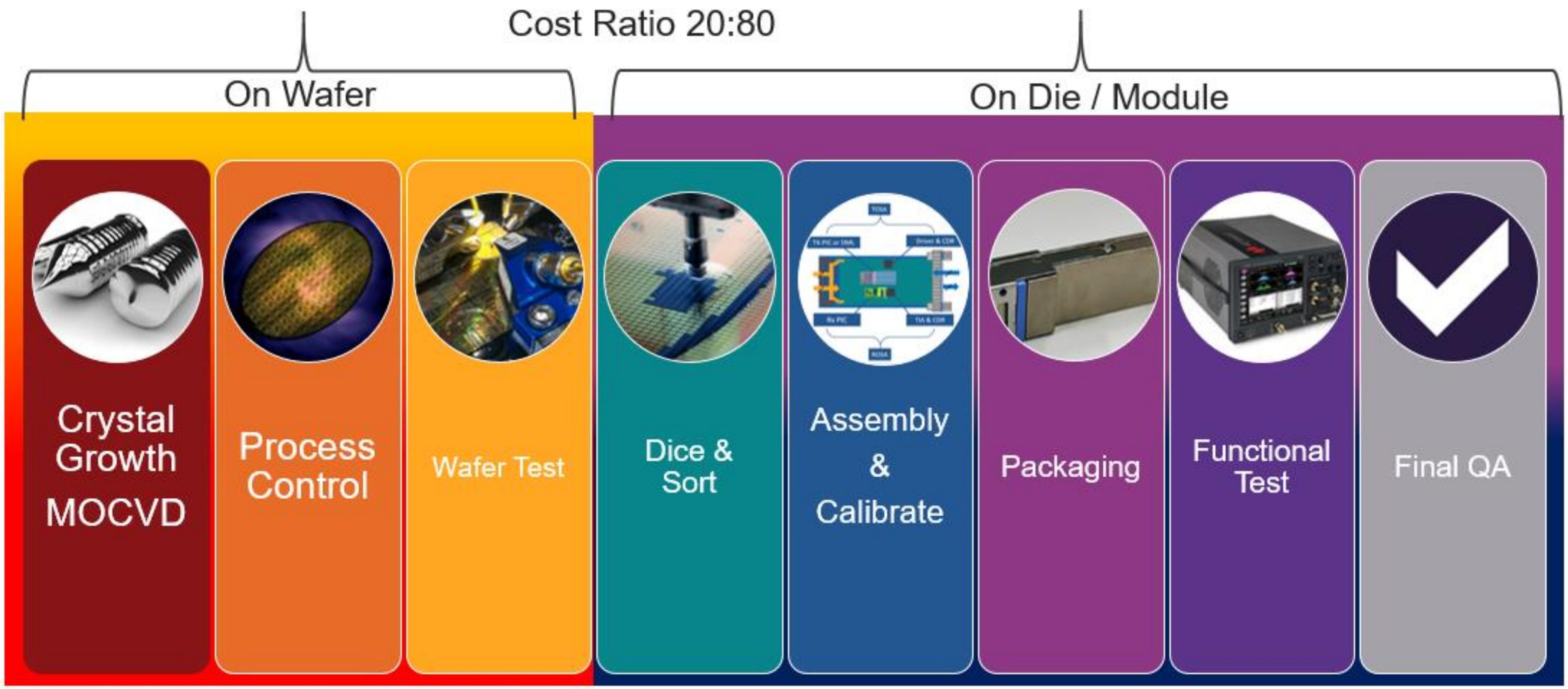
Application to wafer probing

The IL de-embedding functionality is likely to be helpful for parametric testing with automated wafer probing, where manual steps for referencing and reconfiguration need to be avoided when possible. Some additional flexibility is helpful for this case.

It is not necessary to generate the de-embedding calibration data using the function in the IL/PDL software. If the signal attenuation or insertion loss of a component is known or can be otherwise measured, then that data can also be loaded from a csv text file.

For full details, please refer to the application note:
http://literature.cdn.keysight.com/litweb/pdf/5992-3393EN.pdf.

Transceiver Manufacturing Test Automation



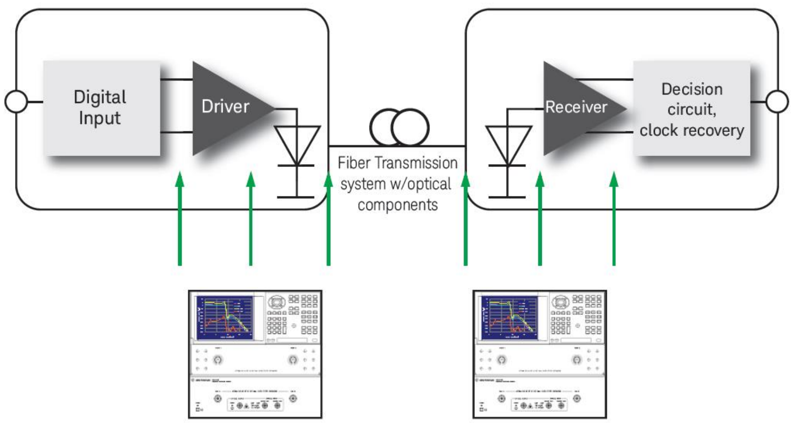
While for electronic parts 80% of the manufacturing cost is on the silicon chip and remaining 20% on the packaging, whereas, photonic modules; 80% of the cost is in the chip packaging and module assembly, with a remaining 20% on the silicon-photonics chip manufacturing.

The „Key" to reducing costs is in using ONLY known good dies for packaging.

Substrates for Silicon Photonics transceivers are 300mm Silicon-on-Insulator wafers. Selective growth of Ge for active devices and doping (detectors, modulators, PN junctions) realized by MOCVD (Metalorganic Chemical Vapor Deposition)	Partial etching is used for passive device patterning. The large variety of sizes and shapes in the photonic devices, from long isolated narrow waveguides to bends and gratings of varying pitches and fill factors, require careful and extensive physical characterization to understand process windows and device variability. Optical and electrical test structures help monitor process quality.	Comprehensive testing for basic device performance already at wafer level is key to shorten cycle time in design verification and good-known-die identification for high yield of finished good.	Known good dies, both from Silicon Photonics wafers, InP wafers for lasers and CMOS electronics are picked and binned for various performance grades and later hybrid integration.	Hybrid integration of passive and active photonics and electronics use a flip-chip style approach: the passive photonic dies are used as a kind of substrate on which InP laser diode or optical amplifier and electronic-only dies are attached via the use of tiny metal pillars or micro bumps. First calibration of basic operation parameter like bias points performed.	Key packaging steps include wire bonding to PCB and module connector and fiber coupling to subassemblies and mounting into housings	Functional and final performance testing of module include testing according to customer specifications or standards (e.g. transmitter eye mask, TDECQ, wavelength or receiver sensitivity) *See also N1000A DCA-X Wide Bandwidth Oscilloscope Mainframe and Modules	Final QA includes serialization, labeling, visual inspection and final packaging for shipment

Lightwave Component Analysis

In digital photonic transmission systems, the performance is ultimately determined by Bit Error Ratio Test (BERT). As this parameter describes the performance of the whole system, it is necessary to design and qualify subcomponents like modulators, PIN detectors and PIN-TIAs, which are analog by nature, with different parameters that reflect their individual performance.



These components significantly influence the overall performance dependent of modulation frequency system with the following parameters:

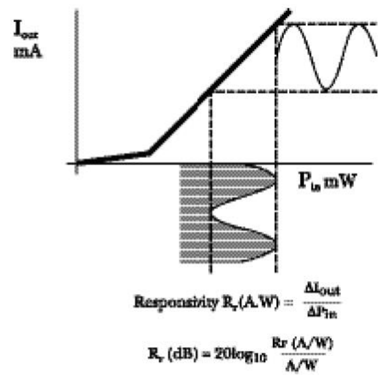
- 3 dB bandwidth of the electro- optical transmission
- Relative frequency response, quantifying how the signal is transformed between optical and electrical connection
- Absolute frequency response, relating the conversion efficiency of signals from the input to the output
- Electrical reflection at the RF port
- Group delay of the opto-electronic component to qualify the distortion caused by frequency dependent delay

In many cases it is necessary to qualify the lab prototype of a receiver or transmitter for manufacturing. In this case the device under test needs to be characterized under various environmental and operating conditions. With the SCPI or .NET based remote control this task can be automated to verify the optimal working conditions of the device. In the following manufacturing process each device can be characterized using this automated control of the LCA via LAN.

O/E characterization

The measurement of an electro-optical receiver device consists of the ratio of output electrical modulation current to input optical modulation power. Responsivity for OE devices described how a change in optical power produces a change in electrical current. Graphically this is shown in the figure below.

The LCA measures the input optical modulation power and output modulation current and displays the ratio of the two in Amps/Watt.



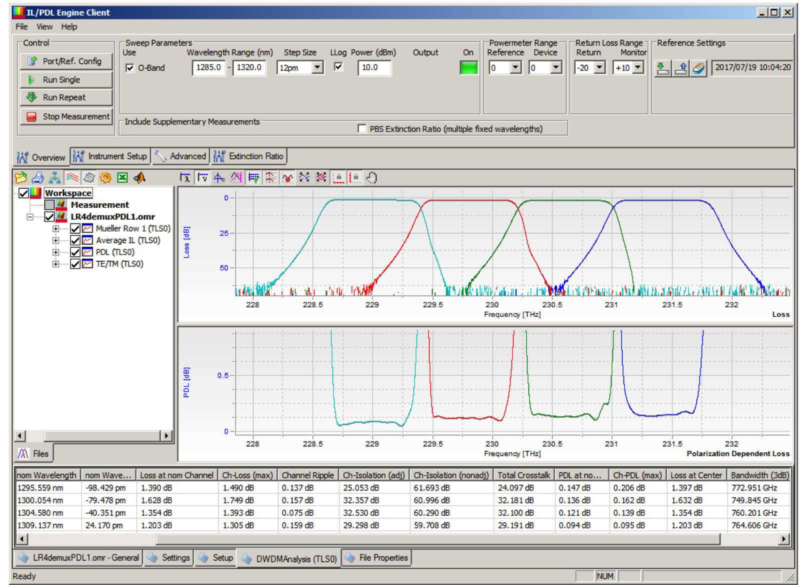
The N7700 Photonic Application Suite

The N7700 Photonic Application Suite is a collection of advanced and basic software tools for making optical measurements, controlling fiberoptic instruments, and analyzing measurement results.
Key elements

- N7700A Package Manager: Select, install and maintain N7700 software packages
- Main Package: Analyze results in a powerful Viewer, save and export to common file formats and tools
- IL Engine: Measure IL vs. wavelength with a tunable laser and power meters
- Fast Spectral Loss Engine: Calibrate and adjust devices with the fast-spectral loss engine at repetition rates up to 10x faster than the IL engine
- IL/PDL Engine: Measure IL and PDL vs. wavelength with the advanced single-sweep matrix method; including responsivity for receiver devices with integrated photodiodes, polarization extinction ratio and return loss
- Polarization Navigator: Use N778x instruments for polarization analysis and control, including PMD measurements
- Drivers, firmware, documents, N77xx Viewer: Keep equipment and guides up to date
- COM automation interface: This allows easy integration of the test station into the production work flow. Programming examples are included in the installation.

New features in the IL/PDL Engine:

- Static mode for setting optimum polarization and wavelength for steps like wafer probe alignment and device calibration.
- IL de-embedding to correct for switches, probes, etc. in setup



The freely-distributed main package of the N7700A Photonic Application Suite provides a powerful File Viewer program that allows viewing and analyzing measurement data. It has been designed for sharing measurement results throughout entire development teams or manufacturing groups using the .omr data files produced by the measurement software

Display and overlay of traces from multiple channels and files:

- Scale switching between wavelength and frequency
- Display of tabular analysis
- Smoothing, markers and zooming
- File loading, saving and data export
- Direct launching of Excel and Matlab with data

Insertion loss

The Insertion Loss measurement package performs very accurate swept- wavelength insertion loss measurements using one of Keysight's tunable laser sources along with optical power meters. No license required.

IL/PDL measurement

The IL/PDL measurement package makes rapid and very accurate measurements of spectral insertion loss and polarization dependent loss (PDL) characteristics of multiport optical components. The single-sweep Mueller Matrix method provides speed and immunity from vibrations and noise. Measurements including multiple lasers for wider wavelength coverage and return loss module are also supported, as well as use of source/measure units for detecting photocurrent from devices with integrated detectors.

In addition to the measured IL and PDL traces, the Mueller Matrix data can be exported and analyzed to provide the polarization resolved IL traces for the device axes (TE/TM). Measurement of optical-to-electrical devices like receiver assemblies is also supported.

The matrix analysis for calculating the IL traces aligned with TE or TM is especially valuable for fast characterization on wafers or chips (integrated photonics), often eliminating the need to directly align and stabilize the polarization launched into the device. The new Static Mode further allows optimizing the polarization for alignment and calibration steps.

License available for purchase as **N7700A-100.**

Filter analysis

The Filter Analysis package provides extended post-processing of measurements from the IL/PDL and IL measurement packages for analysis of narrow-band components like filters and multiplexers. Analysis parameters include peak and center wavelength, wavelength offset from ITU grid, IL at ITU wavelength and center wavelength, bandwidth and channel isolation from adjacent and non-adjacent channels. From the TE & TM traces of the IL/PDL engine, the polarization dependent frequency shift (PDf or PDλ) of channels in filters, interleavers or phase demodulators can also be determined. A convenient peak search function is also included.

License available for purchase as **N7700A-101**.

Fast spectral loss measurement

This package measures insertion loss and power spectra at enhanced repetition rate and is a valuable tool for tuning and calibrating devices with near real-time feedback. Especially powerful in combination with the 81606A and 81608A tunable lasers using bidirectional sweeps, repetition rates of 1 to 3 scans per second can be attained, depending on the sweep range. His package also provides stitching of scans with multiple power ranges for highest dynamic range. License available for purchase as **N7700A-102**.

Polarization navigator

The Polarization Navigator package provides all the tools needed for your work with N778x polarization analysis and control instruments.

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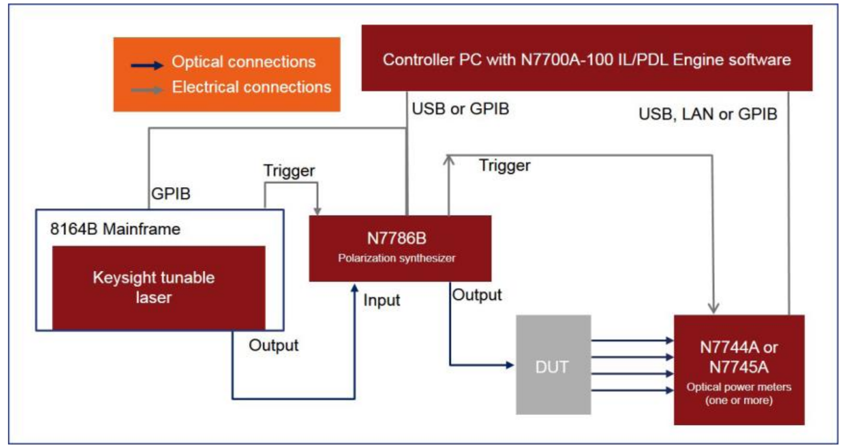
Wavelength and Polarization Dependence of CWDM and LR4 Components

Datacenter interconnection networks, like telecom networks, increase the capacity of fiberoptic links by multiplexing wavelength channels over the same fiber. Compared to telecom, where many channels are closely packed over a relatively narrow wavelength range that can be easily amplified (dense wavelength division multiplexing or DWDM), the cost of transmitters for shorter links can be reduced by relaxing the wavelength stability tolerance, using wider-spaced channels: course wavelength division multiplexing with 20 nm spacing (CWDM) or the LAN-WDM spacing used for LR4 with four wavelength channels in single mode fiber, centered at: 231.4 THz (1295.56 nm), 230.6 THz (1300.05 nm), 229.8 THz (1304.58 nm), 229.0 THz (1309.14 nm).

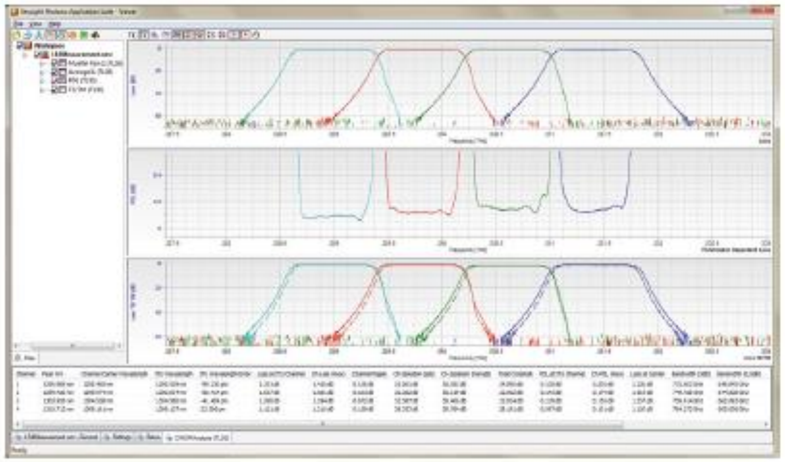
Spectral measurements for passive components

The spectral response of components used in WDM links is a key factor in determining link performance at the physical level. The insertion loss (IL) of passive components influences the signal power budget. The wavelength selectivity of filters used for multiplexing and especially demultiplexing, characterized from traces of IL vs. wavelength with parameters like ripple or flatness in the passband and isolation of wavelength outside the passband, is important for signal stability and avoiding crosstalk. Reflections, parametrized as return loss (RL), can also degrade link performance and should be controlled. Low dependence of these response parameters on the polarization of the optical signal is also needed to avoid fluctuations in power, because the polarization state can change randomly along fiber links. So passive WDM components are typically tested and verified by measuring IL, PDL and often RL across the applicable wavelength range. Using a tunable laser source at the common side of a multiplexer, for example, allows all four lane ports to be measured simultaneously with synchronized power meters. A block diagram for such measurements is shown below, implemented using the N7700A-100 application software package. Details for the instrumentation are given further below.



Block diagram for swept-wavelength IL & PDL measurements

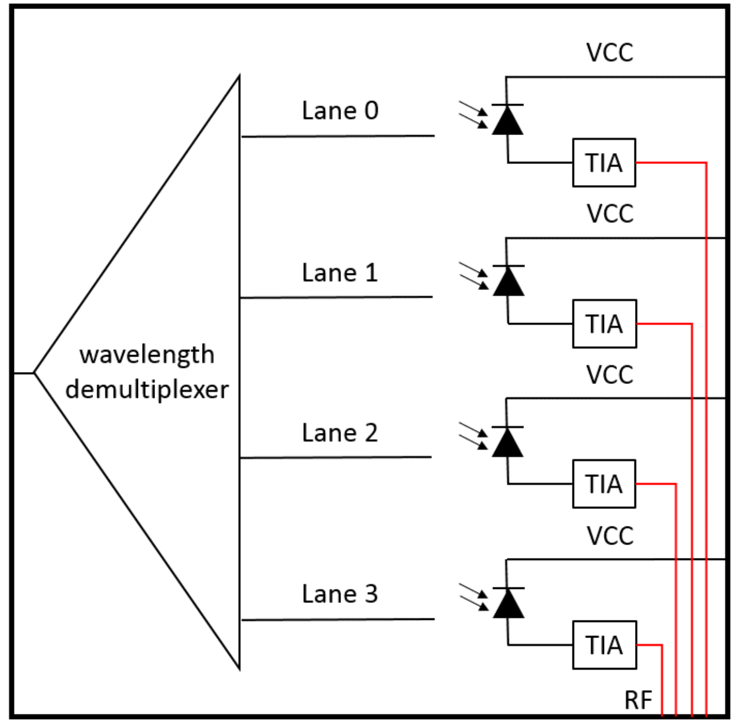
In the measurement results diagram, the insertion loss spectrum for each output port is shown, averaged over all states of polarization. That would be the IL of unpolarized input signal. Spectra of the polarization dependent loss are also determined. This can also be shown as two IL spectra for each port corresponding to the IL for the input polarization states for maximum and minimum transmission. For planar devices like wafer chips, this usually corresponds to polarization parallel or perpendicular to the chip surface (TE or TM). The N7700A software also provides for calculation of key analysis parameters for the LR4 passbands, like wavelength offset, bandwidth, isolation, ripple and maximum in-channel IL and PDL.



Measurement result for a 4-port multiplexer, including data analysis

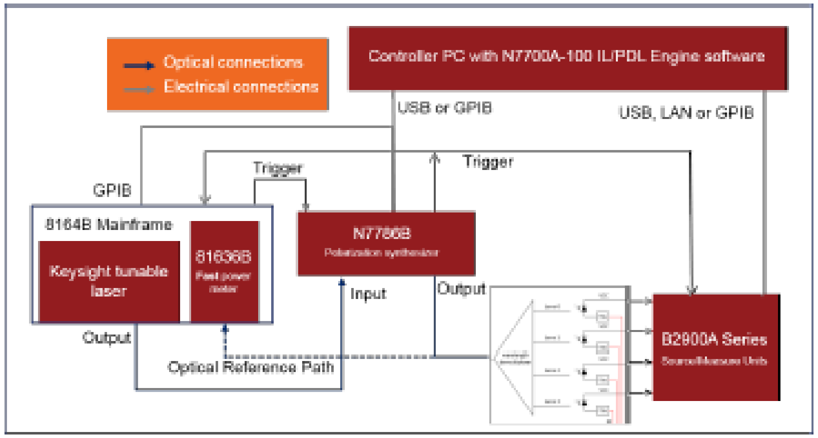
Spectral measurements for components with integrated detectors

Another class of components requiring similar measurements is increasingly important. The optical detectors used in receivers are also characterized with respect to relevant wavelength and polarization dependence, but the response usually doesn't have strong variation. However, when the detectors are integrated with filters or other passive components, this assembly needs to be characterized in a similar way as for the individual components. An important example is the CWDM or LR4 receiver optical subassembly (ROSA), which can include the demultiplexer optics, photodiodes for detecting each signal lane, and often some electronics for transimpedance amplification for the RF signal carried on the detected photocurrent. Such a structure is shown schematically in the figure below.



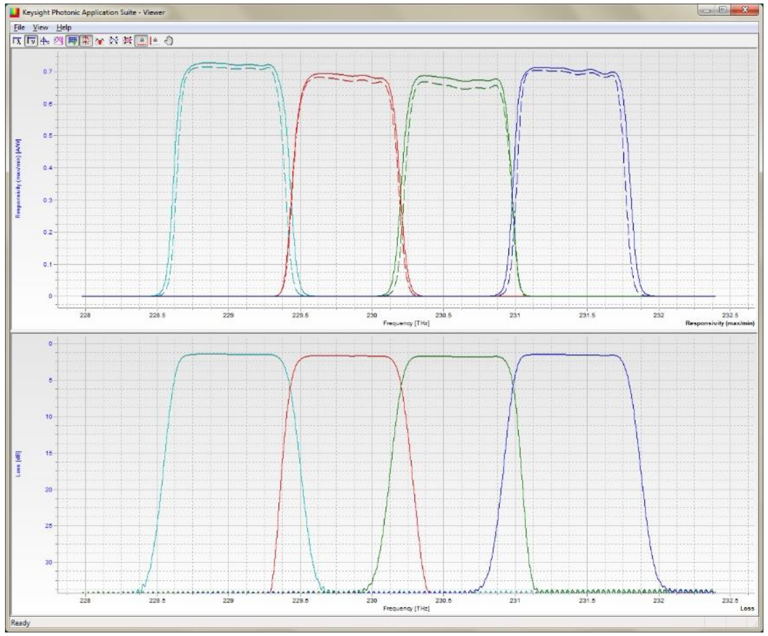
Schematic diagram of an LR4-ROSA device

The electrical contacts on the ROSA that are used for providing bias voltage to the photodiode detectors can also be used to access the photocurrent while an input optical signal is varied in wavelength and polarization to measure responsivity response parameters. Such a solution is shown in the diagram below.



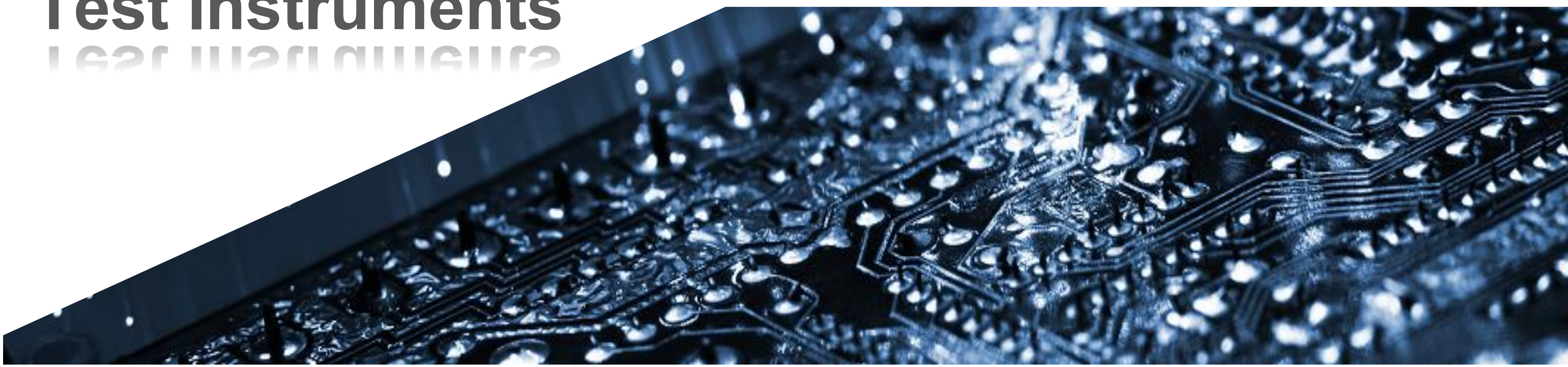
Block diagram for measurements of wavelength and polarization dependent responsivity

This measurement uses source/measure units to apply bias voltage and measure the photocurrent from the integrated detectors of the DUT. The results are then interpreted as responsivity in units of mA current per mW optical input power. So, the absolute input optical power is measured with an optical power meter and then applied to the DUT. Again, both the polarization-averaged response as well as the minimum and maximum responsivity vs. polarization are determined by the software. An example is shown here.



Sample measurement of an LR4-ROSA device

Optical DC Parametric Test Instruments



81602A, 81606A, 81607A, 81608A, 81609A Tunable Laser Modules

- Complete wavelength coverage from 1240 to 1650 nm
- High power with low SSE for high dynamic range
- Fast two-way sweeps to reduce test times
- Built-in wavelength meter for optimum tuning precision
- Specified performance in the continuous sweep mode

Single-Box Test solution for swept wavelength characterization

Keysight 8160XX family of tunable laser sources

The Keysight 8160xx tunable laser modules fit into the bottom slot of the Keysight 8164B Lightwave Measurement System mainframe.

The Keysight 81606A top-line tunable laser source

The 81606A Option 216 Tunable Laser Source is the flagship model, featuring the widest tuning range of 200 nm, and an outstanding dynamic wavelength accuracy and repeatability. The excellent low-SSE performance of better than 80 dB/nm signal-to-source spontaneous emission ratio (signal-to-SSE ratio) and the high signal power permit measurements of wavelength isolation to 100 dB, most often limited by power meter sensitivity.

The Keysight 81607A, 81608A value line tunable laser

The 81607A value line tunable laser source complements the top line 81606A model at a moderately reduced output power. With a typical wavelength repeatability of ±1 pm even during two way sweeps with up to 200 nm/s, it is ideal for high-throughput test and automated adjustment of passive optical components. The 81608A, another member of the value line tunable laser sources, offers a peak output power of more than +12 dBm, at least 75 dB/nm above its spontaneous emission level. The 81608A features a typical wavelength repeatability of ±1.5 pm at two-way sweeps up to 200 nm/s. The laser’s balance of features, performance and price makes it suitable for both coherent transmission experiments and cost-effective manufacturing-floor component testing.

The Keysight 81609A basic line step-tunable laser

The 81609A basic line module can step within 300 milliseconds to discrete wavelengths with a resolution of 0.1 pm and a typical wavelength repeatability of ±3 pm, making it ideal for cost-effective testing of broadband optical devices. Like the other modules in the family, it delivers more than +12 dBm peak output power with low spontaneous emission levels. At ±0.01 dB power stability over an hour, it can also serve as a static local oscillator with a wide tuning range for receiver testing or transmission experiments.

Improved O-band models for silicon photonics applications

The 8160xA option 113 covers the wavelength range from 1240 nm to 1380 nm for an important set of applications. Equipped with PMF output fiber, these are a good match for testing and developing components with silicon photonics technology.

Verifying the spectral responsivity and the sensitivity of receiver optical subassemblies (ROSA) for 100G Ethernet benefit from more than +10 dBm output power - enough to allow for external modulation in BER testing. Combined with very low SSE levels, Option 113 is ideal for testing wavelength filters for LR4 components.

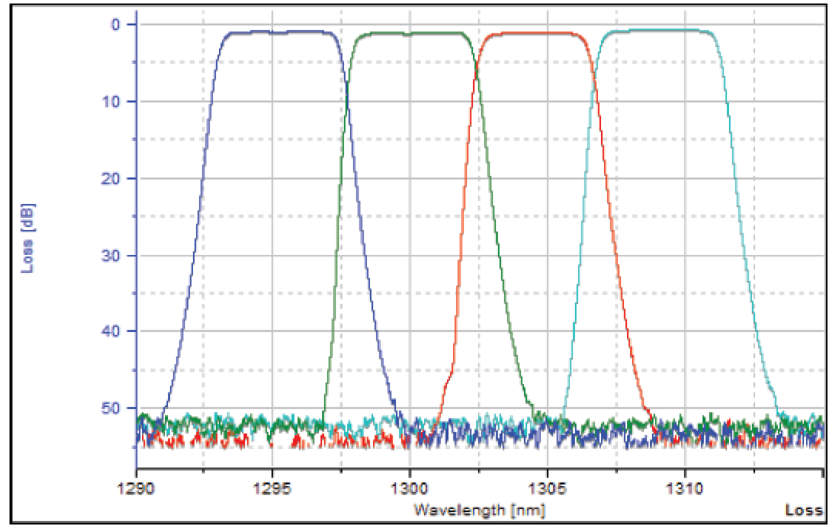
The Keysight 81602A: an O-band tunable laser source exceeding 63 mW output power

The 81602A Tunable Laser Source reaches an optical power level of over +18 dBm. The high output power helps compensate for the coupling loss of optical surface probes or the insertion loss of external modulators during the verification of integrated photonic designs. This allows testing photonic devices at relevant signal levels and wavelengths. With a tuning range of 1250 nm to 1370 nm, the laser addresses the latest Silicon Photonics research.

The extra high-power tunable laser model extends power budget limits in test setups and speeds fiber or probe alignment by getting first light faster: +18 dBm output power help overcome the limitations of probe coupling efficiency, particularly where surface probes need to operate over a broad wavelength range.

Characterize filters

A critical aspect of measuring filters to demultiplex wavelengths is the spectral isolation which determines the crosstalk between signals at different wavelengths. The insertion loss should be low for desired wavelengths and high for wavelengths that should be rejected and routed elsewhere.

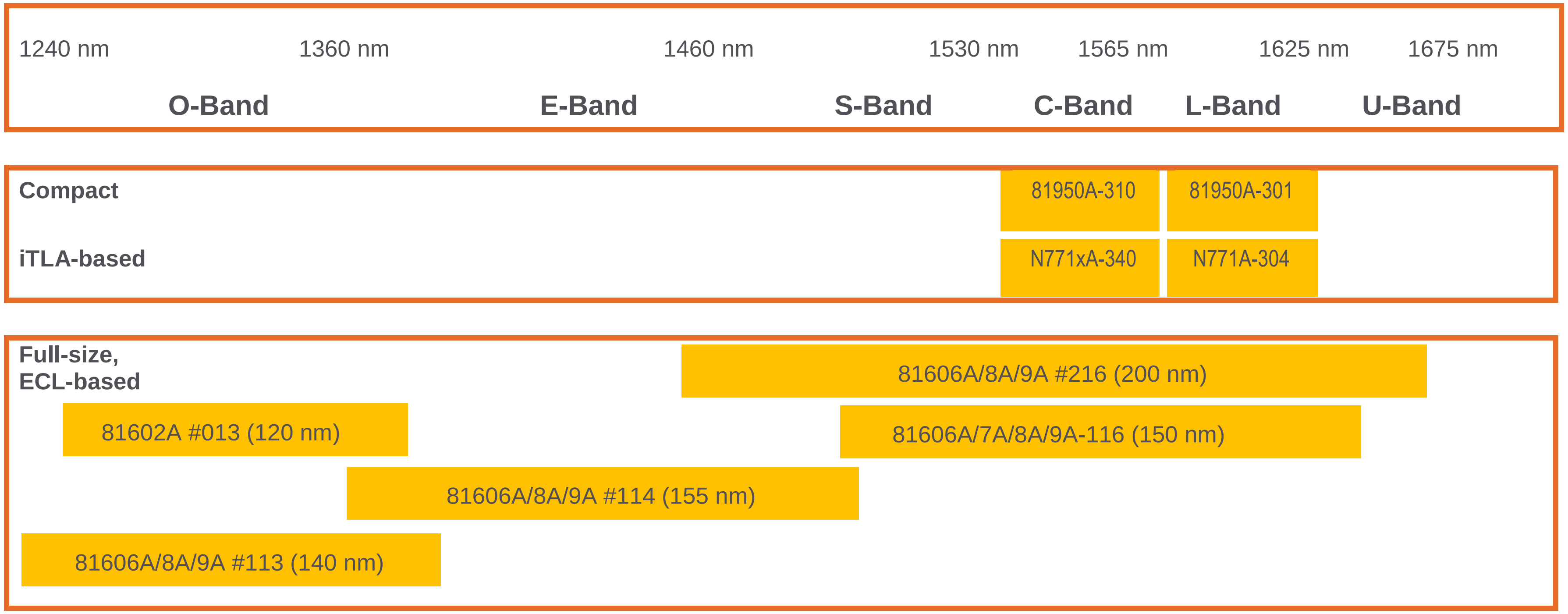


An aspect of lasers that cover wide wavelength ranges is the broadband spectrum of the optical emitter medium. In a laser cavity, most of the emitted power is stimulated at the tuned wavelength, but a natural proportion of broadband source spontaneous emission (SSE) is also produced. Since some of this light will be in the passband wavelengths of a filter, even when the laser line is blocked, a power meter will receive some background light after the filter. This effect is stronger when the passband is wider, like for CWDM filters. This limits the dynamic range for measuring the isolation.

Low-SSE optical output port

The 81606A features a single optical output with more than +12 dBm output power. It combines the highest power level with the lowest SSE level in the 8160xx product family, 80 dB/nm below the signal. The 81607A comes with +8 dBm peak output power, 81608A and 81609A with more than +12 dBm, 75 dB/nm above their spontaneous emission level. For all 8160xA modules, the output power can be reduced to 0 dBm by the user.

Keysight tunable laser module selection table



Realize the cost efficiency and performance benefits in WDM component tests

The testing of optical filters is based on a generic principle, namely the stimulus-response test. The state-of-the-art approach is a wavelength-resolved stimulus-response measurement utilizing a tunable laser source that is capable of fast and precise sweeps across the entire wavelength range, and optical power meters.

For DWDM components, high wavelength accuracy and dynamic range are critical. For CWDM and PON components, a wide wavelength range, dynamic range and tight costing are key targets. If the investment in the test solution can be shared among many different types of filters, the contribution to each individual filter is minimized. In this way, cost targets for CWDM and PON components can be met without sacrificing accuracy. Investing in the Keysight 8160xx Family of Tunable Laser sources can realize both the cost efficiency and performance benefits required.

Compact Tunable Laser Sources in Two Formats

The 81950A, N7711A and N7714A tunable laser sources are step-tunable within the C-band (1527.60 to 1570.01 nm) or L-band (1570.01 to 1611.76 nm). Their output power of up to +15 dBm and a linewidth under 100 kHz are ideal to emulate state-of-the-art DWDM transmitters. Stimulated Brillouin scattering (SBS) can be suppressed with a modulation function.

These lasers do not perform continuously swept wavelength scans. In channel setting mode, the source wavelength, (or frequency, respectively) is determined by the chosen channel index, zero frequency and grid spacing; ITU-T standard grids are possible as well as custom grids. In wavelength setting mode the laser operates gridless and is tunable to any wavelength point within its range. Each laser channel operates independently and can be fine-tuned by ±6 GHz with output power active.

81950A tunable laser source module

The Keysight Technologies 81950A compact tunable laser source is a module that can be used with the 8163B and 8164B platforms. In this mode, code compatibility with existing test setups based on Keysight's range of tunable lasers is a great asset.

N7711A, N7714A Tunable laser sources

- Compact instrument format with one or four ports per unit on one-half rack-unit width and one-unit height
- Flexible configuration of four-port model between C- and L-band channels (N7714A)
- Adjustable to any wavelength grid (ITU-T 100 GHz, 50 GHz, 25 GHz, and arbitrary grids), or use gridless wavelength setting
- Narrow linewidth less than 100 kHz and offset-grid tuning greater than ± 6 GHz ideally suited for coherent mixing applications and new complex modulation formats
- Up to +15 dBm output power, with 8 dB power adjustment range
- Polarization maintaining fiber output

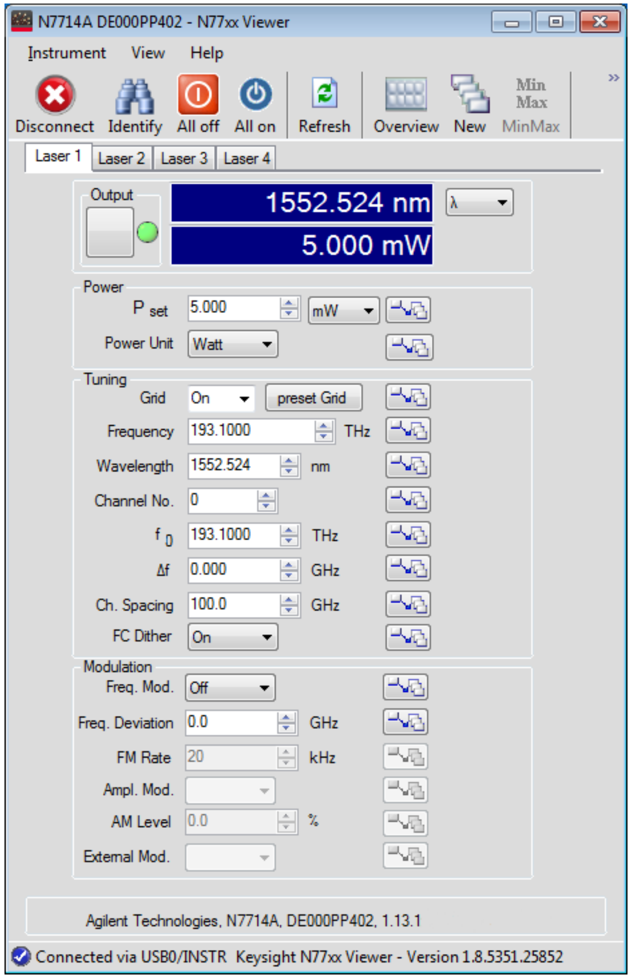
The Keysight N7711A and N7714A tunable lasers are single port and four-port sources, available with C-band or L-band wavelength coverage. The narrow linewidth and offset grid fine-tuning capability of the N7711A and N7714A make them ideal sources for realistic loading of the latest transmission systems.

N7711A one-port Tunable Laser Source

N7714A four-port Tunable Laser Source

The N77-viewer: an easy-to-use graphical user interface

The N77's Window's based graphical user interface offers flexible and complete control of the N7711A and N7714A instruments. N7711A and N7714A Tunable Laser Source



Specifications: 81950A, N7711A, N7714A	
Wavelength range	1527.60 - 1570.01 nm (196.25 -190.95 THz) Options 310, 322, 340 1570.01 to 1611.76 nm (190.95 to 186.00 THz) Options 301, 322, 304
Wavelength resolution	100 MHz, 0.8 pm at 1550 nm
Tuning time	typ. < 30 s (incl. power stabilization)
Fine tuning range / resolution	typ. ±6 GHz / typ. 1 MHz
Absolute wavelength accuracy	±22 pm (±2.5 GHz)
Relative wavelength accuracy	±12 pm (±1.5 GHz)
Wavelength repeatability	Typ. ±2.5 pm (±0.3 GHz) (2)
Wavelength stability	Typ. ≤ ±2.5 pm (±0.3 GHz) over 24 hours (2)
Linewidth, (SBS suppression off)	Typ. < 100 kHz
Maximum output power	≥ +13.5 dBm (typ. ≥ +15 dBm) Option 310 ≥ +11.5 dBm (typical ≥ +13 dBm) Option 301
Power stability	Typ. ±0.03 dB over 24 hours (2)
Power flatness	Typ. ±0.2 dB (full wavelength range)
Power attenuation range	8 dB
Power setting resolution	0.1 dB
Power repeatability	Typ. ±0.08 dB (2)
Residual power (shutter closed)	≤ -45 dBm
Side-mode suppression ratio	Typ. 50 dB
Signal to source spontaneous emission ratio	Typ. 50 dB/1 nm (1) Typ, 60 dB/0.1 nm (1)
Relative intensity noise (RIN)	Typ. –145 dB/Hz (10 MHz to 40 GHz) (1)
SBS suppression modulation	FM p-p modulation range: Typ. 0 GHz to 1 GHz Dither frequency: 20.8 kHz
Dimensions (H x W x D)	75 mm x 32 mm x 335 mm

1. At maximum output power as specified per wavelength range.
2. At constant temperature ± 0.5 K.

81606A Tunable Laser Source

The new 81606A is the top of our tunable laser family, with a new level of performance for rapid wavelength dependent measurements.

- More than10 mW signal power with even lower spontaneous emission background
- Better wavelength accuracy, repeatability and resolution at all sweep speeds
- Faster maximum sweep speed and shorter acceleration zones at sweep endpoints
- Bidirectional measurement sweeps

For results in practice, this brings:

- The widest dynamic range for measuring the spectral transmission of wavelength-selective components, especially combined with Keysight optical power meters and software
- Extreme accuracy and repeatability on both wavelength and power scales for confidence in spectral test tolerance limits
- The ability to repeat such measurements at a high rate, even over a wide wavelength range, for real-time feedback in adjustment and calibration procedures

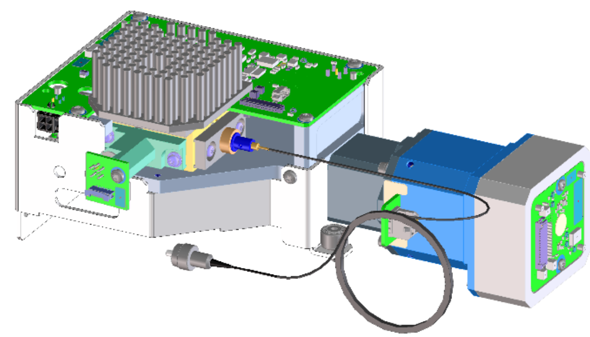
Key performance features

- Wavelength: 1450-1650 or 1490-1640nm
- Sweep speeds: up to 200nm/s
- Typ.max.power: >12 dBm peak
- Typ. Signal to SSE ration: > 80dB/nm
- Typ. λ accuracy: ±2 pm static, ±3 pm sweeping

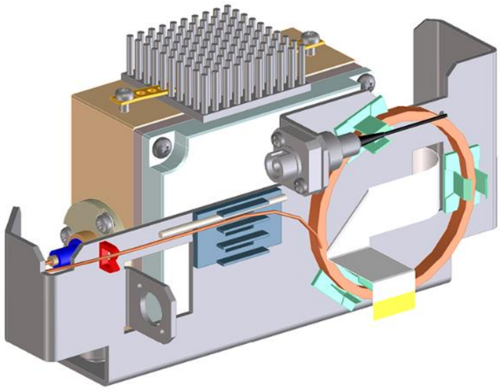
A new cavity design makes it possible

The 81606A is built around a new cavity design for improved spectral purity: lower SSE, lower SMSR at higher output power.

The drive unit has been redesigned for better acceleration and sweep linearity which makes it the ideal actor for the laser's closed-loop tuning control.



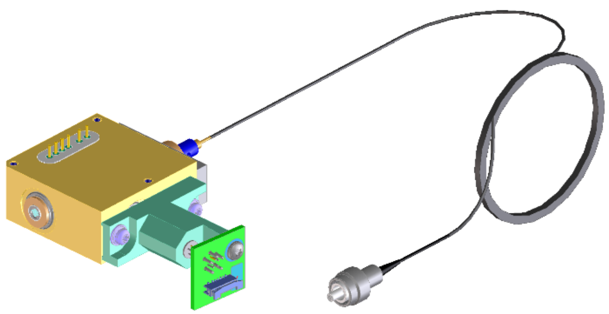
The multi-axis dynamic control during sweeps and the resulting wavelength accuracy, and power and mode stability are supported by a new high-bandwidth wavelength monitor including a gas-cell reference. The mechanical drive is also further developed for high speed sweep control, fast acceleration and qualified for long life.



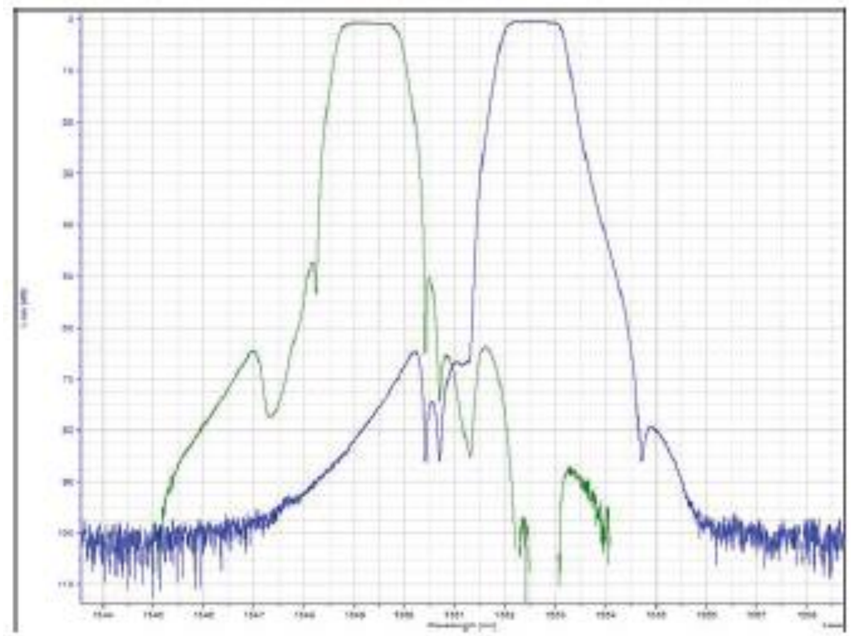
The novel wavelength reference unit

A new laser module design

The redesigned laser module contains a news, higher-output gain chip and a novel beam splitter for lower SSE. A monitor provides additional feedback for the active tuning control loop.



15 dB more dynamic range

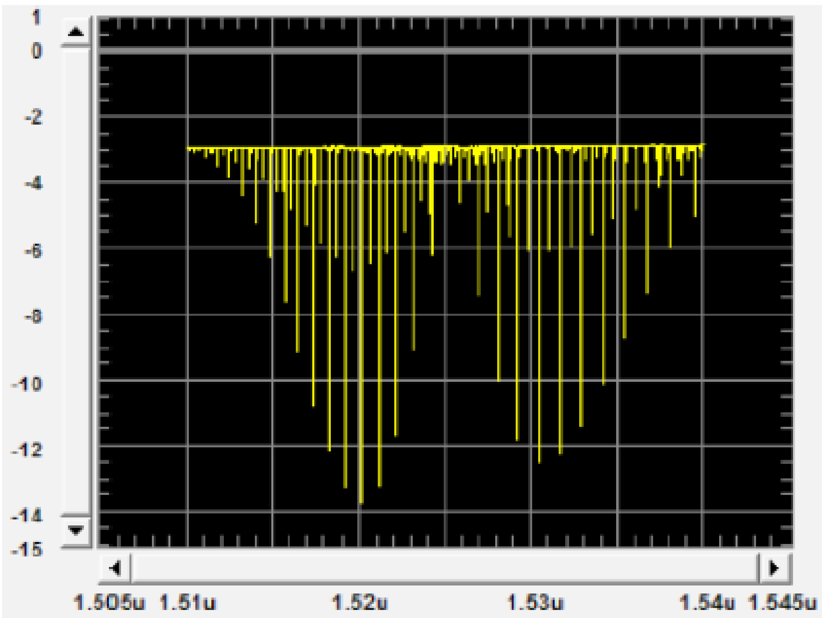


2 channels of a DWDM demultiplexer measured with the N7747A high-sensitivity power meter at 50 nm/s: lower SSE and high-sensitivity linear detectors uncover filter details to 100 dB dynamic range. The lower total SSE benefits notch filter and interleave measurements, showing depths beyond 70 dB.

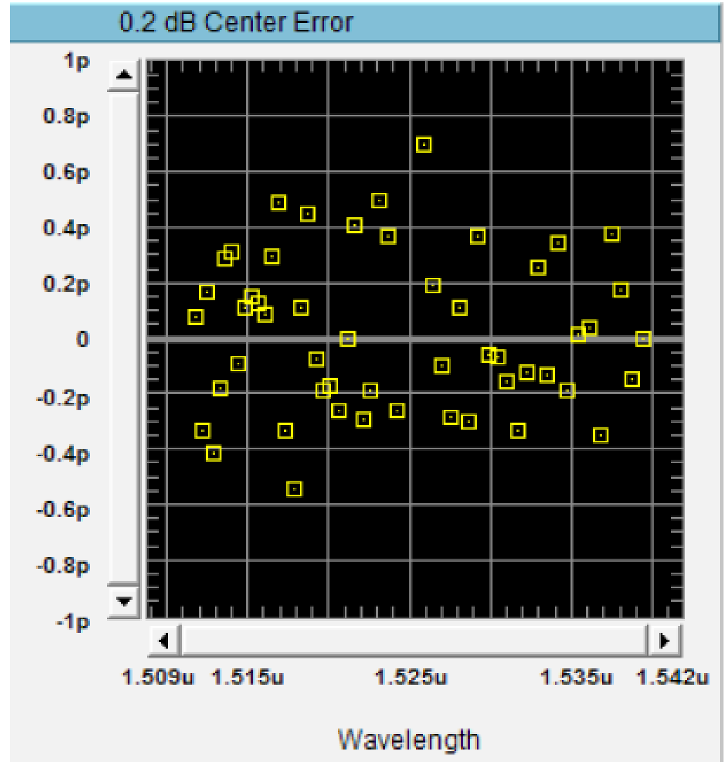
Our innovation technology is supported by the mature experience and continuous research in our calibration and test procedures, which allow a statistically solid and traceable basis for confidence in our published specifications.

Keysight 81606A – designed for best accuracy

While static wavelength accuracy can be verified with a wavelength meter, that isn't enough to confirm the dynamic accuracy during a sweep. As an illustration of the dynamic accuracy achieved by the laser with its internal reference unit, these figures show the offset of spectral lines, when measured at full 200 nm/s speed with 0.5pm resolution.



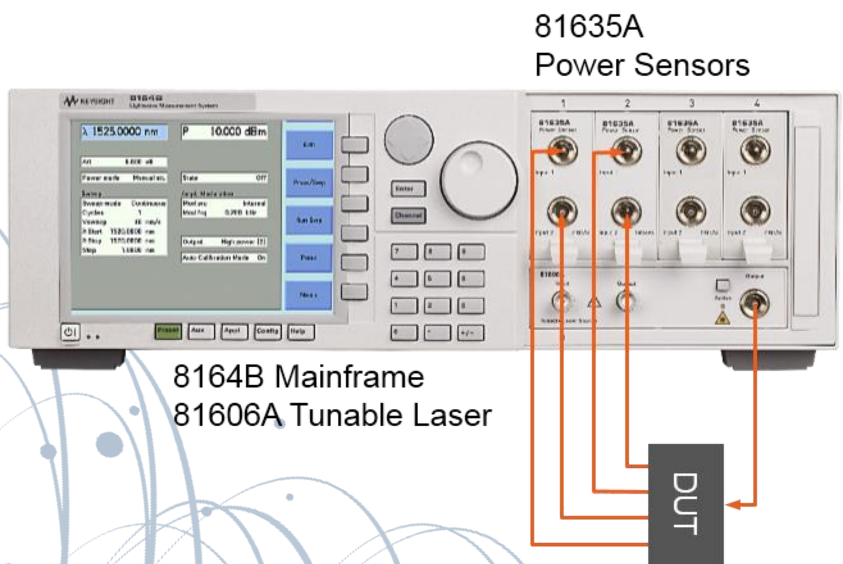
Absorption lines of C2H2 gas cell



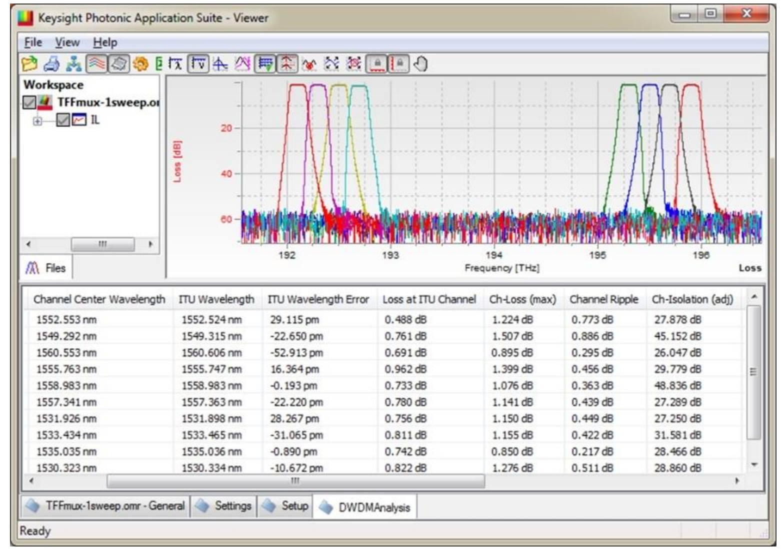
Less than +1 pm deviation of the measured center wavelengths from the known values (according to NIST SRM 2517a) acquired at 200 nm/s sweep

Spectral loss testing on up to 8 channels in a single box

The 81606A Tunable Laser Source module in an 8164B Lightwave Measurement System mainframe, plus up to four dual power sensor modules, is sufficient for 8-channel devices, such as a CWDM multiplexer.



The N7700A photonic application suite helps getting to results fast.



Protect your investment

As a successor to the industry-standard 81600B, which we expect to continue in service for many years, the 81606A has also been designed to maximize compatibility with existing test stands and software.

- The modular 81606A uses the same 8164B mainframe slot and works with the same firmware version and the same front panel controls
- The N7700A application software engines can be updated online to versions that use both models and add the new 81606A functionality
- The 816x VXI Plug&Play driver, widely used in customized software, can be updated to recognize the new model and operate in the same way, while providing enhanced spectral performance
- The SCPI command set remains the same and has a few extensions for the additional functionality.

N7744A and N7745A Optical Multiport Power Meter

- Patented quick-release 4-port optical connector interface for FC, SC, LC, MU and bare-fiber
- Storage of up to 1 million power values per channel for high speed measurement data acquisition and transfer
- Short minimum averaging time of 1 µs for high time resolution and transient power measurements
- LAN, USB and GPIB programming interfaces
- High dynamic range with high bandwidth for accurate high-speed spectra
- Code compatibility to the 816x Lightwave Measurement System

Keysight N7745A Multiport Power Meter with Quad-Adapter Connector Interfaces N7740ZI, N7740KI, N7740BI, N7740FI (left to right)

Up to eight power meter channels in a small package

The N7744A and N7745A optical power meters with four or eight power-sensors are high-performance instruments to increase throughput and operational efficiency in manufacturing and development measurements.

Designed for optical multiport applications

Designed for characterizing optical multiport components, these optical power meters offer industry-leading device connectivity, high-speed data acquisition and transfer. They support fast wavelength-dependent measurements, e.g. for: CWDM and DWDM multiplexers, wavelength selective switches (WSS), as well as compact setups for simultaneous testing of multiple single-port devices. N7700A software can be used to integrate them with tunable lasers for fast IL and PDL measurements.

Continuous data logging

Each channel can log up to 1 M samples with an additional 1 M buffer to allow data upload during measurements. Sampling can be set between 1 us and 10 s. The buffer provides uninterrupted transient power measurement and monitoring.

A reliable four-port optical connection with the one-click quad-adapter

The unprecedented N7740xI fiber connectivity concept uses a quadruple adapter with a snap-on quick-locking mechanism. The device to be tested can be connected to the quad-adapters at an ergonomic working location, even while the instrument is measuring another device. Then the quad-adapters can be quickly attached, to provide repeatable high-precision connections. Use of the quad-adapters simplifies aligning connector keys, especially for rack-mounted instruments and makes it easier to connect ports in the desired order, helping to avoid errors and connector damage..

Abbreviated specifications (1)	Keysight N7744A, N7745A		
Sensor element	InGaAs		
Wavelength range	1250 to 1650 nm		
Specification wavelength range	1250 to 1625 nm		
Power range	-80 to +10dBm		
Maximum safe power	+16 dBm		
Data logging capability	2 buffers per port, each with 1 million measurement points		
Averaging time	1 µs to 10 s		
Applicable fiber type	Standard SM and MM ≤ 62.5 µm core size, NA ≤ 0.24		
Uncertainty at reference conditions	±2.5%		
Total uncertainty	±4.5%		
Relative port to port uncertainty	typ. ± 0.05 dB		
Linearity at (23+5°C) over operating temperature	±0.02 dB ± 3 pW ±0.04 dB ± 5 pW		
Polarization dependent responsivity	< ±0.015 dB (1520 to 1580 nm) Typ. < ±0.01 dB (1250 to 1580 nm)		
Noise peak-to-peak (dark)	< 7 pW (1 s averaging time, 300 s observation time)		
Dynamic range (logging mode)	1 µs averaging time	25 µs averaging time	1 ms averaging time
Power range setting			
-30 dBm	> 43 dB	> 49 dB	> 57 dB
-20 dBm	> 43 dB	> 54 dB	> 62 dB
-10 dBm	> 46 dB	> 57 dB	> 64 dB
0 dBm	> 46 dB	> 57 dB	> 63 dB
+10 dBm	> 43 dB	> 54 dB	> 60 dB
Return loss	> 50 dB (1520 to 1580 nm) typ. > 57 dB (1280 to 1580 nm)		
Operating temperature	+5 to +40 °C		
Operating humidity	15% to 95%, non-condensing		
Storage conditions	–40 °C to +70 °C		
Warm-up time	20 min.		
Dimensions (H x W x D)	372 mm x 212 mm x 43 mm		

1. Abbreviated specifications: for full details, please refer to the product data sheet at http://www.keysight.com/find/mppm

B2901A/02A/11A/12A Precision Source/Measure Unit (SMU)

The Keysight B2900A Series of Precision Source/Measure Units are compact and cost-effective bench-top Source/Measure Units (SMUs) with the capability to output and measure both voltage and current. An SMU combines the capabilities of a current source, a voltage source, current meter and a voltage meter along with the capability to switch easily between these various functions into a single instrument.

Best-in-class performance

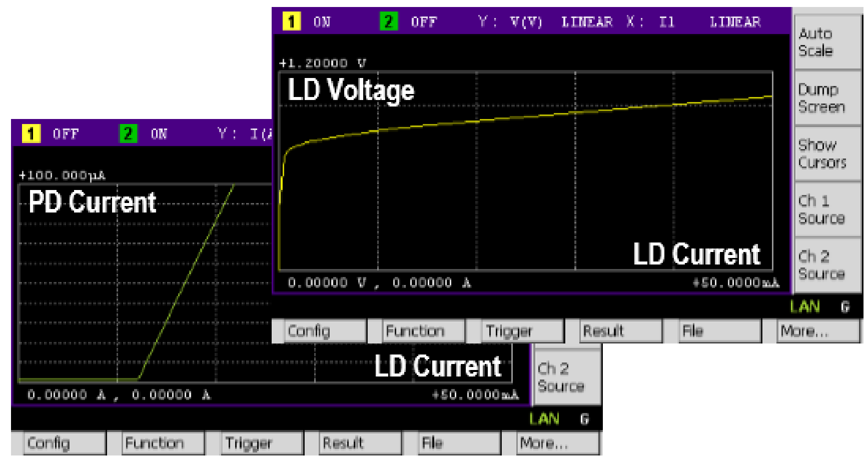
The Keysight B2900A series of SMUs provide best-in-class performance at a lower price than ever before. They have broad voltage (210 V) and current (3 A DC and 10.5 A pulsed) sourcing capability, excellent precision (minimum 10 fA/100 nV sourcing and measuring resolution) and high measurement throughput. In addition, the Keysight B2900A series possess a superior graphical user interface with various viewing modes that dramatically improve test productivity, debug and characterization. The versatile integrated source and measurement capabilities of the Keysight B2900 series SMUs make them an ideal choice for testing semiconductors, active/passive components and a variety of other devices and materials.

Four models

The Keysight B2900A series consists of four models, the B2901A, B2902A, B2911A and B2912A, differentiated through their available features (number of digits displayed, measurement resolution, minimum timing interval, supported viewing modes, etc.) and by the number of SMU channels (one or two) they contain. This makes it easy to select the exact price/performance point to meet your testing needs.

Broad application range

The B2900 series has a broad application range that spans from R&D and education uses to industrial development, test and manufacturing. Moreover, they work equally well as either standalone or system components.



Key features & specifications

Measurement capabilities

- Supports one-channel (B2901A and B2911A) and two channel (B2902A and B2912A) configurations
- Minimum source resolution: 10 fA/100 nV, minimum measurement resolution: 10 fA/100 nV (B2911A and B2912A)
- Minimum source resolution: 1 pA /1 μV, minimum measurement resolution: 100 fA/100 nV (B2901A and B2902A)
- Maximum output: 210 V, 3 A DC/10.5 A pulse
- Digitizing capabilities from 10 μs (B2911A and B2912A) and 20 μs (B2901A and B2902A) interval

General features

- Integrated 4-quadrant source and measurement capabilities
- The 4.3'' color display supports both graphical and numerical view modes
- Free application software to facilitate PC-based instrument control
- High throughput and SCPI command supporting conventional SMU command set

N7784B, N7785B, N7786B Polarization Controllers

N7784B

N7785B

N7786B

These 3 instruments are all based on high-speed solid-state optics to rapidly switch the polarization of an incoming signal. They are used with polarized input signals form lasers and can adjust, scan or align the output state of polarization. The instruments are controlled from an external PC and convenient graphical user interface control is provided with the included polarization Navigator software, distributed with the N7700A Photonic Application Suite. Automated control is provided by the GPIB and USB interfaces.

N7785A synchronous scrambler

The N7785B synchronous scrambler provides fast SOP switching in response to internal or external triggering. This supports optical network simulations that often require switching of the signal SOP within a few microseconds, such as in recirculating loop tests. The SOP is switched rapidly, and then held for a predefined time until it again switches to a new SOP. The output SOP is controlled but not determined by the N7785B and will be changed if the input SOP changes. The output SOP can be adjusted to a desired external condition, such as maximizing the signal through a polarizer and the settings are repeatable. Application routines in the Polarization Navigator software can be used for random and continuous scanning (where the state of polarization moves smoothly about the Poincaré sphere, similar to a flipper-style scrambler) over a wide range of speeds as for fast SOP-change tolerance testing of coherent receivers.

N7784B polarization controller

The N7784B polarization controller provides alignment and fast stabilization of SOP with respect to an external condition by adding an analog feedback and polarizer path to the basic N7785B configuration. For alignment into PMF, the input signal is first routed through the fast.

switching controller with single-mode fiber (SMF) and can be routed into a built-in polarizing beam splitter with one output monitored by a photodetector. The other output is coupled to the front panel output with PMF. The signal from the photodetector is used to actively align and stabilize the input signal into the PMF output that could then be connected to a modulator or other polarization dependent device. Similarly, the signal can be used directly from the intermediate output and a user-configured setup can provide the feedback for optimizing the desired SOP from the instrument. Stabilization can be used without PC control.

N7786B polarization synthesizer

The N7786B polarization synthesizer includes internal SOP monitoring and feedback to deterministically set and hold any chosen states or sequences of polarization. This allows generation of sequences with chosen relative SOP orientation. This is often used for component analysis based on Mueller Matrix analysis. The fast switching supports the unique single-sweep spectral PDL measurements with the N7700A software, which eliminates sensitivity to environmental instability and minimizes measurement time. Analysis of these results into transmission spectra of the primary device axes (like TE and TM) is also achieved in this way. The real-time monitoring and logging of output SOP permits accurate calculation including the wavelength dependence of the SOP. The real-time monitoring and feedback also are used in this instrument to provide stabilized SOP, even with fluctuation and drift of the input SOP.

The output SOP can be defined in following ways:

- Set-and-forget: When the front panel button is pushed, the current SOP is stored and maintained, even if polarization changes occur at the instrument input
- Defined Stokes: The target output SOP can be defined by the user using the Stokes parameters

The Polarization Navigator also has a convenient button to quickly change from a manually adjusted SOP to the corresponding orthogonal state, as can be used to check extinction ratio.

Quick comparison guide

- N7785B: rapidly switches SOP in reproducible patterns that can be synchronized with external triggers. This can be used to scramble polarization or sample many SOP. Based on measurements at each SOP, the controller can be set programmatically to the optimum SOP for the measurement.
- N7784B: all functions of the N7785B plus the capability for real-time alignment of the SOP based on an external feedback signal (analog voltage). This can be used to achieve and maintain optimum polarization alignment at the input of a polarizing component that can provide a feedback signal. In addition, a built-in polarizing beam-splitter provides the ability to align an input signal into polarization maintaining fiber (PMF output).
- N7786B: all functions of the N7786B plus real-time monitoring and feedback with an internal polarimeter that taps the output signal. This is used to set chosen SOP and especially sequences of SOP with definite relation to another. This is used with the N7700 software to make matrix measurements of component polarization dependence. Real time SOP measurement and logging is provided

Specifications (1) N7784B Polarization Controller	
Wavelength	
Operating wavelength range I Wavelength range in stabilizer mode (2)	1260 to 1640 nm I 1520 to 1580 nm
Polarization control and stabilization	
SOP switching time (open-loop)	< 10 µs
PER at PMF output (typical)	> 23 dB
Stabilizer response time (3) (typ.)	2 ms
Optical power	
Insertion loss port I –> port II (4)	Insertion loss port III –> port IV (5)	< 3.5 dB (< 3.0 dB, typ.)	< 1.8 dB (< 1.4 dB, typ.)
PDL port I –> port II (typ.)	< 0.2 dB (C/L-band), < 0.5 dB (O-band)
Maximum safe input power	Port I: 20 dBm, Port III: 3 dBm
Input power range in stabilizer mode	Port III: –30 to 0 dBm

1. Ambient temperature change max. ± 0.5 °C since normalization. Specification valid on day of calibration;
2. Outside the stabilizer wavelength range, the PER at PMF Output may be degraded;
3. Input power at Port III > –30 dBm, response to an immediate step of 180° on the Poincaré sphere;
4. For SOP scrambling/switching, only ports I/II are used;
5. Valid for optimum input polarization at PBS input (Port III). Add insertion loss of port I/II and III/IV to obtain total insertion loss for SOP stabilizing mode

1. Ambient temperature change max. ± 0.5 °C since normalization. Specification valid on day of a calibration

Specifications (1) N7785B Synchronous Scrambler	
Wavelength	
Operating wavelength range	1260 to 1640 nm
Polarization control	
SOP switching time	< 10 µs
Optical power	
Insertion loss	< 3.5 dB (< 3.0 dB, typ.)
PDL (typ.)	< 0.2 dB (C/L-band), < 0.5 dB (O-band)
Maximum safe input power	20 dBm

1. Ambient temperature change max. ± 0.5 °C since normalization. Specification valid on day of calibration

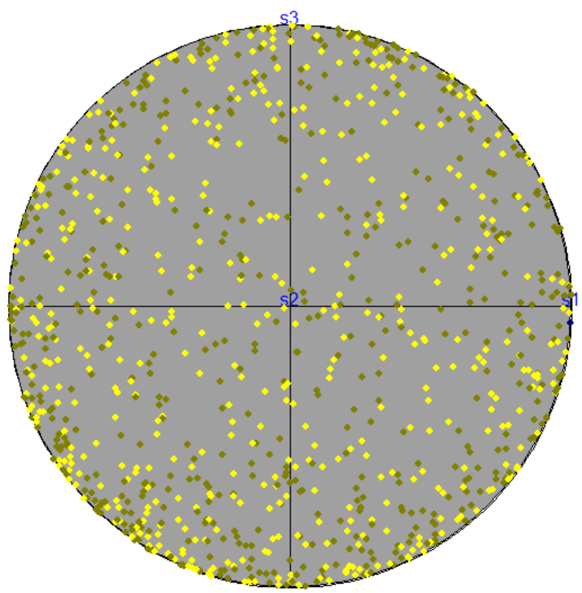
Specifications (1) N7786B Polarization Synthesizer	
Wavelength	
Specification wavelength range	1270 to 1375 nm, 1460 to 1620 nm (Opt 400, O/C/L-band) 1460 to 1620 nm (Opt 500, C/L-band)
Operating wavelength range (2)	1260 to 1640 nm
Polarization control and stabilization	
SOP switching time (non deterministic)	< 10 µs
SOP cycling time (3)	< 25 µs
Remaining SOP error after deterministic SOP setting (typ.) (4)	< 3° / < 6.5° at input SOP movement rate of 1.2 rad/s / 40 rad/s
Polarization analysis	
SOP uncertainty (5,6)	1.5° on the Poincaré sphere
DOP uncertainty (5)	± 2.0%
DOP uncertainty after user calibration (typ.) (5,7)	± 0.5%
Optical power measurement	
Relative power uncertainty (5)	C/L-Band: ± 0.14 dB (± 0.12 dB typ.), O-band: ± 0.16 dB (± 0.14 dB typ.)
Input power range	-38 to +19 dBm
Optical power	
Insertion loss	< 4.0 dB (< 3.5 dB typ.)
PDL (typ.)	< 0.2 dB (C/L-band), < 0.5 dB (O-band)
Maximum safe input power	20 dBm

1. Ambient temperature change max. ± 0.5 °C since normalization. Specification valid on day of calibration.
2. SOP/DOP measurements are possible outside the specification wavelength range if the user performs a manual calibration.
3. The instrument adaptively finds the polarization controller settings to let the SOP cycle through user-defined polarization states (closed loop operation). After having found these settings, the SOP can cycle through the polarization states in open loop operation.
4. This value is defined to be 5 times the standard deviation of the angular SOP error on the Poincaré sphere. Valid if controller is turned on. Power at instrument input > –10 dBm.
5. Input power > –20 dBm.
6. DOP > 95%.
7. User calibration requires a source with a 100% DOP

All-states Method for PDL and PER

All-states method for PDL and PER

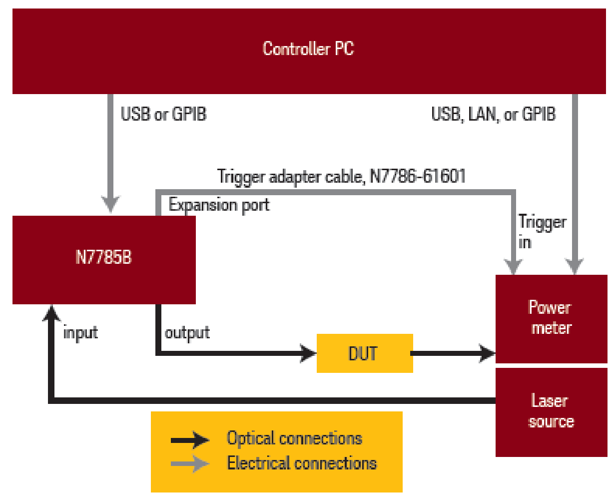
The all-states PDL method for measuring polarization dependent loss by scanning the polarization of light input to the DUT over a large sampling of all possible states is a good way to measure components with little wavelength dependence, so that the wavelength can be fixed during the scanning. Fiberoptic couplers, splitters and isolators are typical components to test this way. Tests of polarization beam splitters and other devices designed for high PER also benefit from this method, because it samples the states with high polarization extinction.



Random sampling of SOP represented on the Poincare sphere

Conventionally, this method has been realized by monitoring output optical power while scanning the input polarization, so that the accuracy is limited by the polarization dependence of the instrumentation, particularly the polarization controller. This was generally addressed by using mechanical movement of fiber loops, which can give very low polarization dependence of the power level but has limited speed.

Faster accurate measurements now use the Keysight N7785B synchronous scrambler, which can be programmed for repeatable stepping through a sequence of polarization states at high speed while producing synchronization triggers. This can be used to shorten total measurement time, allow optimized detector averaging times, and normalize the results to remove the polarization dependence of the setup from the results.



A typical setup for synchronized all-states measurement

For measuring PDL values up to 1 dB, about 100 samples are sufficient for the minimum/maximum ratio to come within 10% of the full PDL value. So, a good measurement is achieved in less than 50 ms using 100 µs averaging time. For measuring PDL values significantly below 0.1dB, the noise is a limitation and longer averaging time is needed. Using 10 ms averaging time with a stable setup has been seen to give repeatability corresponding to less than 0.005 dB over times of 10 minutes or more. The 10 ms averaging time also supports use of the coherence control function of the laser sources, if needed to avoid interference effects due to reflections in the setup. Again, for these values, good measurements are obtained with sequence lengths of about 100.

The range of high extinction ratio measurements amounts to how well the lowest transmission value is determined. When using a random pattern of SOP, this is improved by using many samples and having minimum SOP variation during the averaging time of the sample. This latter condition is an advantage of the polarization switching vs. continuous scanning. To assure measurements above 30 dB PER, a minimum of 20 k samples is recommended. For example, using 100 µs averaging time, the 20 k sequence requires 8 s.

For further details, refer to 5990-9973EN, "*All-States Measurement Method for PDL and PER with a Synchronous Polarization Scrambler - Application Note".*

N7781B Polarization Analyzer

The Keysight N7781B is a compact high-speed polarization analyzer which provides comprehensive capabilities for analyzing polarization properties of optical signals. This includes representation of the State of Polarization (SOP) on the Poincaré Sphere (Stokes Parameter). The on-board algorithms together with the on-board calibration data ensure highly accurate operation across a broad wavelength range.

Due to its real time measurement capability (1 MSamples/s) the instrument is well suited for analyzing disturbed and fluctuating signals as well as for control applications requiring real time feedback of polarization information.

Analog data output ports are provided for example for support of control loops in automated manufacturing test systems.

Powerful user Interface and remote programming capabilities are provided by Polarization Navigator software package of the N7700A Photonic Application suite.

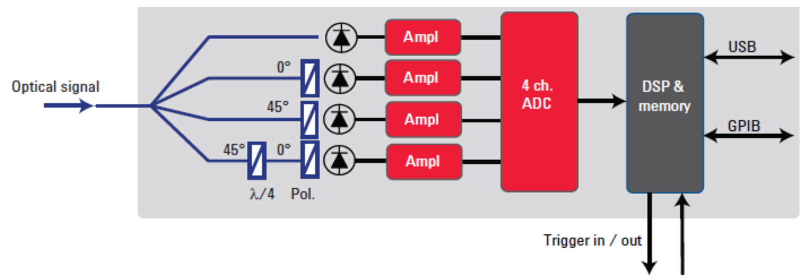
Key features:

- Measurement of Stokes Parameter (SOP)
- Measurement of degree of polarization (DOP)
- High-speed operation (1 MSamples/s)
- Analog output port for DOP/SOP data

Monitoring/measurement application of

- State of Polarization (SOP), Stokes Parameters
- Degree of Polarization (DOP)
- High-speed analysis of SOP/DOP of recirculating signal

Instrument setup: Polarization analyzer setup



The instrument setup of the N7781B polarization analyzer is shown in the figure above. It consists of a unique polarimeter optical blocks and a high-speed sampling subsystem. The measurement principle is based on splitting the light into four sub beams that are filtered through different polarizers. The resulting four power levels are evaluated using on-board calibration data to obtain an accurate SOP- and DOP-measurement.

N7781B Polarization Analyzer (1)	
Wavelength	
Specification wavelength range	1270 to 1375 nm (Opt 300, O-band) 1270 to 1375 nm, 1460 to 1620 nm (Opt 400, O/C/L-band) 1460 to 1620 nm (Opt 500, C/L-band)
Operating wavelength range (2)	1260 to 1640 nm
Polarization analysis	
SOP uncertainty (3,4) (typ.)	1.5° on the Poincaré sphere
DOP uncertainty (3); After use calibration (3,5) (typ.)	± 2.0%; ± 0.5% typ. after user calibration
Maximum sampling rate	Up to 1 MHz
Optical power measurement	
Relative power uncertainty (3)	C/L-band: ± 0.03 dB (± 0.02 dB typ.), O-band: ± 0.07 dB (± 0.04 dB typ.)
Input power range	-50 to +7 dBm
Maximum safe optical input power	+12 dBm

1. Ambient temperature change max. ± 0.5°C since normalization. Specification valid on day of calibration.
2. SOP/DOP measurements are possible outside the specification wavelength range if a manual user calibration is performed.
3. Input power > –30 dBm
4. DOP > 95%
5. User calibration requires a source with DOP = 100%. User calibration is valid for a fixed wavelength.

N7782B PER Analyzer and N7783B Thermal Cycling Unit

Keysight's N7782B PER analyzer has been designed for high speed and highly accurate testing of the polarization extinction ratio (PER) in PM fibers. The polarimetric measurement principle guarantees reliable measurements of PER values up to 50 dB.

Key benefits

- Accurate PER-measurement up to 50 dB
- Real-time display of PER
- Easy-to-use: reliable results independent of operator skill set
- Swept-wavelength and heating/stretching method available
- Measurement of the PER versus wavelength
- Fast/slow axis detection
- Instruments available for 1260 up to 1640 nm
- Internal fixed wavelength sources at 1310 nm and 1550 nm available

The real time measurement capability in combination with automation interfaces makes this unit ideally suited for integration in manufacturing systems, for example pig-tailing stations for laser diodes and planar waveguide components. Analog interfaces are provided for integration of the system in control-loop applications.

Applications

- **Laser diode PMF pig-tailing:** Alignment of the PM fiber during the pig-tailing process is supported by real-time display of the PER and the optical power.
- **PMF splicing:** To support alignment during the splicing process of PM fibers. the Keysight N7782B provides real time display of the optical power and of the angular misalignment of the two fibers.
- **PM component characterization:** Measurement of the PER on PM components like fiber polarizers, PMF couplers, PMF splitters, etc.
- **PM splice characterization:** The angular misalignment of a PM splice can be measured in a non-destructive way. Even multiple splices in a chain can be characterized independently.

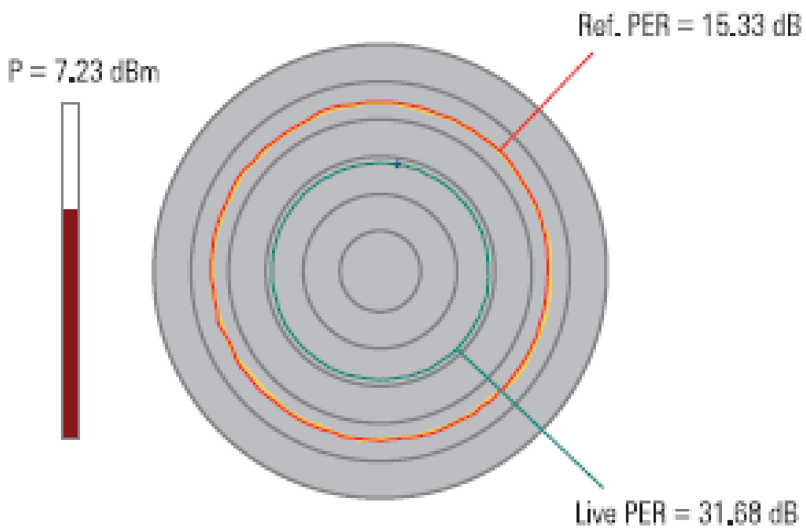
N7782B and N7783B application examples

Wavelength scanning method

Used together with a Keysight tunable laser source the N7782B supports measuring the PER as a function of wavelength.

The heating/stretching method

The heating/stretching method provides accurate measurements of the PER at a single wavelength. This method is particularly well suited to measure the alignment of PMF to laser components. An optional internal laser source allows stand-alone operation of the system for applications like PMF splicing..



This screenshot from the Polarization Navigator software shows how a (yellow/red) circle is measured while cycling the temperature to determine the PER. The center of this circle is then used as a reference for perfect alignment and the offset from this point is used to determine "Live PER" during adjustments

Keysight's thermal cycling unit N7783B is fully controlled by the Keysight N7782B PER analyzer and allows accurate and repeatable cycling of the temperature of the fiber under test. The PER measurement system consisting of the Keysight N7782B and the Keysight N7783B shows excellent accuracy and repeatability. Ease of use and automation interfaces, such as analog output ports for active alignment, make it particularly useful for production environments.

N7783B thermal cycling unit

For characterizing an optical connection between two polarization maintaining fibers (PMFs), such as an optical splice, two thermal cycling units can be used, one before and one after the splice. This eliminates the need to make align the input polarization of the light source, because the alignment is evaluated from the change in PER at the splice. This is done by first cycling the temperature before the splice and then comparing this with a measurement while cycling the temperature of the fiber after the splice.

Specifications (1) N7782B PER Analyzer		
Wavelength		
Specification wavelength range	1270 to 1375 nm, (Opt. 300, O-band)	
	1270 to 1375 nm, 1460 to 1620 nm (Opt.400, O/C/L-band)	
	1460 to 1620 nm (Opt.500, C/L-band)	
Operating wavelength range (2)	1260 to 1460 nm (Opt.300/400/500)	
PER analysis		
PER range (3, 4)	0 to 50 dB	
PER uncertainty, single-TCU method (typ.) (3,4)	PER = 0 to 30 dB	0.30 dB
	PER = 30 to 50 dB	0.60 dB
Splice uncertainty, dual-TCU method (typ.) (3,4)	± (0.1 ° + 4 % x angle)	
Optical power		
Input power range	–50 to +7 dBm (Opt 300/400/500)	
Relative power uncertainty (3)	C/L-band: ± 0,03 dB (±0.02 dB, typ.) O-band: ± 0.07 dB (± 0.04 dB, typ.)	
Internal Laser Source Options		
Internal Laser Source Wavelength	Opt. 401 (O-band):	1290 to 1360 nm, 1310 nm typ.
	Opt. 501,401 (C-band):	1510 to 1580 nm, 1550 nm typ.
Internal Laser Source Output power (5) (typ.)	Opt. 401 (O-band):	-12 dBm
	Opt. 501, 401 (C-band):	-10 dBm

1. Ambient temperature change max. ± 0.5°C since normalization. Specification valid on day of calibration.
2. PER measurements are possible outside the specification wavelength range if the user performs a manual calibration. Note that a fully polarized light source is needed for calibration.
3. Input power > –30 dBm
4. Narrow-band light source with DOP > 95% needed.
5. At room temperature.

N7783B Thermal Cycling Unit Characteristics	
Fiber jacket diameter	Up to 3 mm
Ambient temperature range	20 to 30°C
Minimum peak-to-peak temperature tuning range	50 K
Power	100 to 240 VAC, <36W
Dimension (H x W x D)	64 mm x 160 mm x 61 mm

N7788B Optical Component Analyzer

N7788B optical component analyzer

General information

The N7788B combines a fast-switchable polarization controller with a polarimeter to enable full polarization-dependent analysis of passive optical performance. Measuring the polarization state of the signal from a device under test in dependence of the input polarization provides the data needed for the standardized Jones-Matrix-Eigenanalysis (JME) method to determine Polarization Mode Dispersion (PMD), differential group delay (DGD) and polarization dependent loss (PDL).of optical devices. The unique single-scan implementation, enabled by the fast-synchronized SOP switching, dramatically reduces the impact of vibration and temperature drift during measurements.

The N7788B is used together with a Keysight continuous-sweep tunable laser to make wavelength-dependent measurements, controlled by the Polarization Navigator package of the N7700A Photonic Application Suite. The software has a COM automation interface.

The swept PMD/PDL/IL application provides:

- DGD/ PMD / PDL / 2nd-order PMD
- power / insertion loss averaged over polarization
- Insertion loss for signal aligned with device TE and TM axes
- Principal states of polarization (PSPs)
- Jones and Mueller matrices

High measurement speed:

- Complete measurement across C/L-band in less than 10 seconds (no need to wait for many averages)
- Robustness against fiber movement/vibration and drift
- No limitation on optical path length of component
- An internally-switched reference path guarantees reliable and accurate measurements

Applications

- Fiber characterization: SMF, PMF, DCF
- Passive component testing: WSS, filters, isolators, circulators, VOA
- optical amplifier testing: EDFAs, SOAs
- Link test: In-Channel measurements across amplifiers

Real-time power readout:

High throughput measurement of non-connectorized components is supported by providing a real time power readout which simplifies fiber coupling of the new device.

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Specifications (1) N7788B Optical Component Analyzer	
Wavelength	
Specification wavelength range	1270 to 1375 nm (Opt 300, O-band) 1270 to 1375 nm, 1460 to 1620 nm (Opt 400, O/C/L-band) 1460 to 1620 nm (Opt 500, C/L-band)
Operating wavelength range (2)	1260 to 1640 nm
Dispersion	
DGD uncertainty (3)	Resolution 2.0 nm: ± (30 fs + 3.0% × DGD) Resolution 0.1 nm: ± (30 fs + 3.0% × DGD)
DGD measurement range (3)	0 to 1000 ps
PMD uncertainty (4)	± (30 fs + 2.0% × PMD)
PMD repeatability (typ.)	± 3 fs
PMD measurement range (4)	0 to 300 ps
Loss	
PDL uncertainty (5)	C/L-band: ± (0.05 dB + 4% × PDL)) O-band: ± (0.10 dB + 4% × PDL)
PDL repeatability (typ.)	± 0.005 dB
Insertion loss uncertainty (typ.) (3)	C/L-band: ± 0.03 dB O-band: ± 0.07 dB
Insertion loss dynamic range (typ.) (3)	> 41 dB (for TLS power levels higher than –6 dBm, increase value accordingly
Polarization analysis	
See N7781B specifications	
Optical power measurement	
See N7781B specifications	
Polarization control	
See N7785B specifications	

1. Ambient temperature change max. ± 0.5°C since normalization. Valid for 81600B tunable laser source family. Tunable laser power set to –6 dBm. Sweep over specification wavelength range. Specification does not include instability in test device. Specified loss ranges include loss of test device and any additional switches or connections in the optical path. Specification valid on day of calibration.
2. SOP/DOP measurements are only possible outside the specification wavelength range if the user performs a manual calibration.
3. DUT properties: Insertion Loss < 30 dB, PDL < 1 dB, DGD < 150 ps. Specification is typical for DGD > 150 ps.
4. DUT properties: Insertion Loss < 41 dB, PDL < 3 dB, PMD < 50 ps. Applies for highly mode-coupled devices such as single mode fibers. Specification applies for PMD being the averaged DGD over a wavelength span of 100 nm. Specification is typical for PMD > 50 ps.
5. DUT properties: Insertion Loss < 25 dB, PDL < 6 dB. Note: DUT connectors are considered being part of the DUT. Thus, angled connectors will add to the device PDL

LIV Test of Laser Diode Using the B2900A Series of SMUs

Determine the operating characteristics of a laser diode

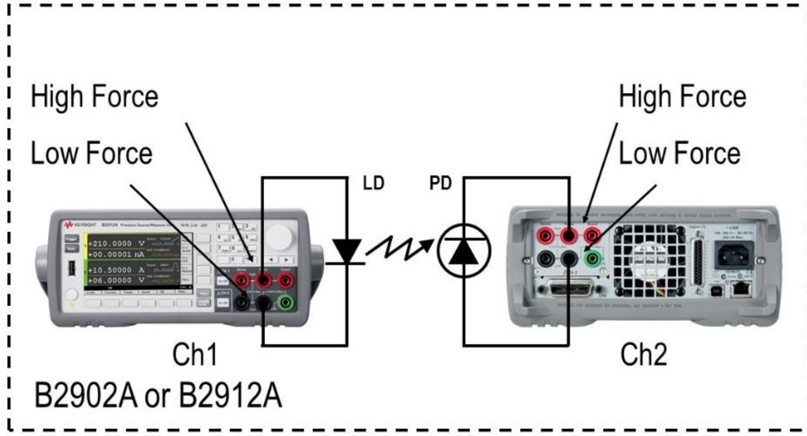
The light-current-voltage (LIV) sweep test is a fundamental measurement to determine the operating characteristics of a laser diode (LD). In the LIV test, current applied to the laser diode is swept and the intensity of the resulting emitted light is measured using a photo detector (PD).

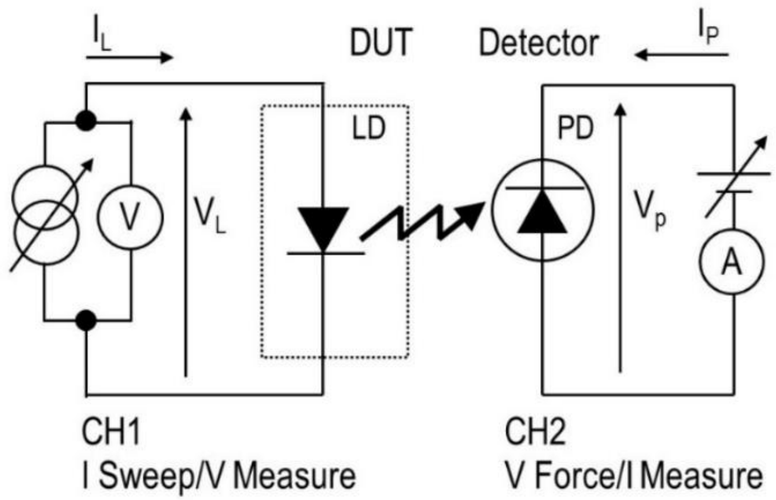
The Keysight Technologies, Inc. B2901/02/11/12A Precision Source/Measure Unit is a compact and cost-effective bench-top Source/Measure Unit (SMU) with the capability to output and
measure both voltage and current. It covers currents from
10 fA to 3 A (DC)/10.5 A (pulse) and voltages from
100 nV to 210 V, which enables you to make a wide range of current versus voltage (IV) measurements more accurately and quickly than ever before.

Get support from multiple free software control options

In addition, the B2900A Series of SMUs comes with an intuitive graphical user interface (GUI) and multiple free software control options that make it easy for you to begin making productive measurements immediately, allowing you to choose the solution that best fits your particular application. These features make the B2900A Series of SMUs the best solution for LIV testing of laser diodes.

The B2902A and B2912A have two SMU channels, and each channel possesses accurate IV measurement capabilities as well as the ability to supply either constant or swept voltage/current. The B2902A and B2912A excellent choices for laser diode LIV testing.





As shown in above using the B2902A or B2912A, you can easily measure the LIV characteristics of laser diodes, including tests such as a laser forward voltage, threshold voltage and slope efficiency..

B2900A Series of SMUs comes with a Range of free Software Options

In addition to its powerful and easy-to-use GUI, if you prefer PC-based instrument control, then the B2900A Series of SMUs comes with a range of free software control options to facilitate program development, allowing you to choose the solution that best fits your particular application.

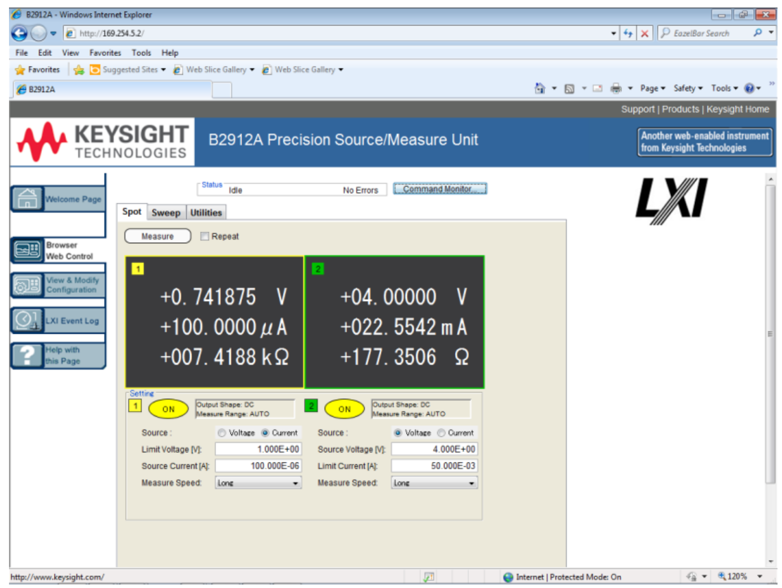
BenchVue

The Keysight BenchVue software for the PC reinvents your bench testing by making it simple to connect and record results with your instruments without the need for programming. You can quickly and easily obtain results by viewing, logging and exporting measurement data and screen images with just a few mouse clicks. BenchVue provides a wide array of capabilities, depending on the chosen instrument application. These capabilities will vary according to the functionality of the instrument types and models, including the B2900A Series of SMUs, that are connected to the PC that is running the BenchVue software.

See http://www.keysight.com/find/benchvue for more details.

Graphical web interface

The Keysight B2900A Graphical Web Interface provides functionality to allow access to the B2900A Series of SMUs over a LAN connection. The B2900A Series of SMUs is fully compliant with the LXI class C specification and contains a web server that provides a webpage with an interface to support the basic measurement functions of the B2900A. You can quickly and easily make measurements using a standard web browser by simply connecting the B2900A Series of SMUs to a PC using a LAN cable.



86120D and 86122C Multi-Wavelength Meters

- New 86120D replaces 86120B and 86120C, providing faster measurements and better accuracy form 700-1650 nm
- Characterize WDM spectra during R&D and manufacturing
- Wavelength accuracy < ±0.3 pm with 0.5 s update rate
- Simultaneously measure wavelengths and powers of up to 1000 channels
- Automatic optical signal-to-noise ration measurements
- Automated measurement routines and data logging

As the demand for access to more information increases, the need for greater capacity on transmission systems drives component manufacturers and network equipment manufacturers to push their capabilities to new limits. The use of tunable transmitters and ROADMs in networks makes accurate and fast measurements of wavelength more critical than ever. With Keysight multi-wavelength meters, you will be able to address these demands with confidence.

The Performance You Need – When You Need it

The Keysight family of multi-wavelength meters is just that – a family. Each model uses compatible SCPI remote commands. You pay for only the performance you need, when you need it. If your requirements become more demanding in the future, you can substitute another Keysight multi-wavelength meter, avoiding unnecessary cost and time developing new code for your test system. With the 86122C, you can upgrade to a unit with the best performance available. Keysight multi-wavelength meters allow you to optimize test costs while protecting your investments.

Simultaneously measure up to 1000 wavelengths and powers

The Keysight 86120D and 86122C multi-wavelength meters, like other, Michelson interferometer-based wavelength meters, allow you to measure the average wavelength of the input signal. In addition, the Keysight multi-wavelength meters – with advanced digital processing – accurately and easily differentiate and measure up to 1000 discrete wavelengths. Keysight multi-wavelength meters simultaneously measure the individual powers of discrete wavelengths, offering the following measurement capabilities:

- 1 to 1000 wavelengths and powers
- Average wavelength and total power
- Up to ± 0.2 ppm wavelength accuracy
- Up to 5 GHz wavelength resolution
- Calibrated for evaluation in air or vacuum
- Wavelength units in nm, THz, or wave number (cm-1)
- Amplitude units in dBm, mW, or µW
- Rugged design to withstand strong shocks and vibrations

WDM transmission systems

Combining measurement performance with reliability, the Keysight multi-wavelength meters allow easy and accurate verification of optical carrier performance in transmission systems by measuring wavelength, power and optical signal-to noise ratios during design and manufacturing test. The 86122C multi-wavelength meter is optimized for measuring ultra-dense channel spacing with an absolute wavelength accuracy of up to ± 0.2 ppm (± 0.3 pm referenced to 1550 nm). With a resolution of < 5 GHz, it is an ideal solution for the design and manufacturing of next-generation optical networks.

Features and advanced measurement applications:

- Relative Wavelength and Amplitude Measurements
- Built-in Data Logging
- Drift: Current and Min/Max values
- Optical Signal-To-Noise Ratio
- Fabry-Perot Laser Characterization
- Broadband signal mode

Instrument drivers

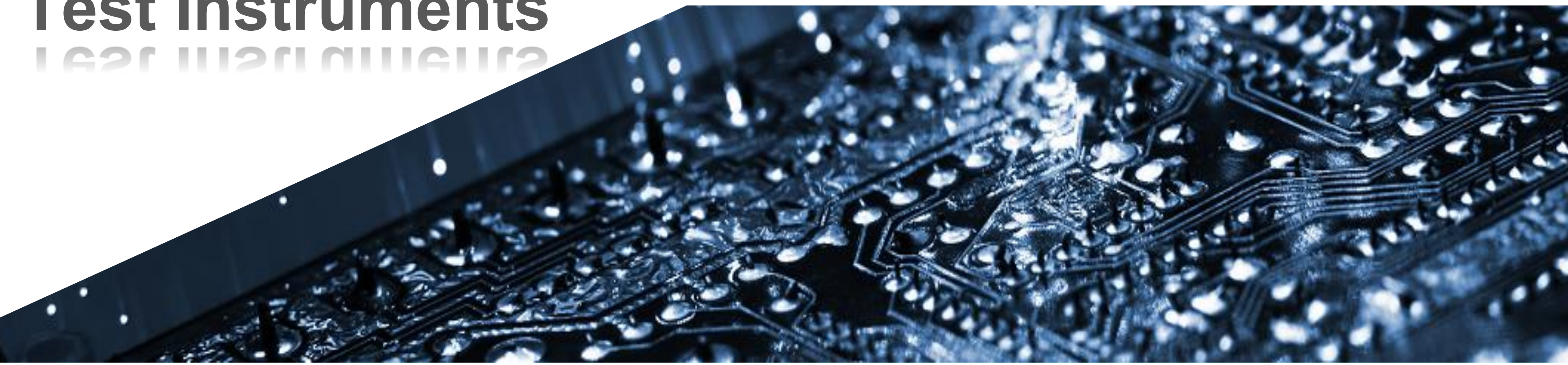
Instrument drivers compatible with LabView, Visual Basic, C++, and LabWindows are available for the Keysight 86120D and 86122C multi-wavelength meters. These drivers enable remote program development by offering building blocks that allow you to customize your measurements

		86120D	86122C
Maximum number of laser lines input		1000	
Wavelength	Range	700 to 1650 nm (182 to 428 THz)	1270 to 1650 nm (182 to 236 THz)
	Operating range	700 to 1700 nm (176 to 428 THz)	
	Absolute accuracy	± 1.5 ppm, typ. 1 ppm (within 15°C to 35°C) (± 2.3 pm at 1550 nm, ± 2.1 pm at 1310 nm) for laser lines separated by ≥ 20 GHz	± 0.2 ppm (± 0.3 pm at 1550 nm and 1310 nm); for laser lines separated by ≥ 10 GHz
	Differential accuracy [1]	± 0.4 ppm	± 0.15 ppm
	Minimum resolvable separation (equal power lines input)	15 GHz (0.12 nm at 1550 nm, 0.09 nm at 1310 nm)	5 GHz (0.04 nm at 1550 nm; 0.03 nm at 1310 nm)
	Display resolution	0.0001 nm	
	Units	nm (vacuum or standard air) cm-1, THz	nm (vacuum or standard air) cm-1, THz
Power	Calibration accuracy	± 0.6 dB (at ± 30 nm from 780, 1 1310, and 1550 nm)	± 0.5 dB (at ± 30 nm from 1310 and 1550 nm)

		86120D	86122C
	Flatness [1] 30 nm from any wavelength	± 0.2 dB, 1200 to 1600 nm ± 0.5 dB, 700 to 1650 nm	0.2 dB, 1270 to 1600 nm ± 0.5 dB, 1270 to 1650 nm
	Linearity, lines above -30 dBm	± 0.3 dB, 1200 to 1600 nm	± 0.3 dB, 1270 to 1600 nm
	Polarization dependence	± 0.6 dB, 1200 to 1600 nm ± 1.5 dB 1, 700 to 1650 nm	0.6dB, 1270 to 1600 nm ± 1.0 dB 1, 1600 to 1650 nm
	Units	dBm, mW, µW	dBm, mW, µW
Sensitivity [1]	Single line input	–20 dBm, 700 to 900 nm –25 dBm 1, 800 to 1200 nm –40 dBm, 1200 to 1600 nm –30 dBm, 1600 to 1650 nm	-32 dBm, 1270 to 1600 nm –22 dBm, 1600 to 1650 nm
	Multiple lines input [1]	30 dB below total input power, but not less than single line	
Selectivity		25 dB spacing ≥ 100 GHz 10 dB spacing ≥ 25 GHz	25 dB spacing ≥ 90 GHz 10 dB spacing ≥ 10 GHz
Measurement cycle time		0.6 s	0.5 s (86122C-100) 0.3 s (86122C-110)
Input power	Maximum displayed level	+10 dBm (sum of all lines input)	
	Maximum safe input level	+18 dBm (sum of all lines input)	
Built-in automatic measurement applications			
	Signal-to- noise ration, 100 Averages, at 1550 nm, 0.1 nm noise Bandwidth, lines above -25 dBm [1]	> 35 dB, channel spacing ≥ 200 GHz	> 35 dB, channel spacing ≥ 100 GHz 27 dB, channel spacing ≥ 50 GHz
	Drift	Maximum, Minimum, total drift (max-min) wavelengths and powers over-time	
	Fabry-Perot characterization [1]	Mean wavelength, peak wavelength, mode spacing full-width half maximum, peak amplitude, total power, sigma	
Reliability	Warranty	3 years standard warranty	5 years standard warranty
	Recommended re-calibration period	2 years	2 years
Laser Classification		FDA Laser Class I according to 21 CFR 1040.10; IEC Laser Class 1 according to IEC 60825-1/2007	
Dimensions		138 mm x 425 mm x 520 mm (5.4 in x 16.7 in x 20.5 in)	
Weight		14.5 kg (32 lb)	

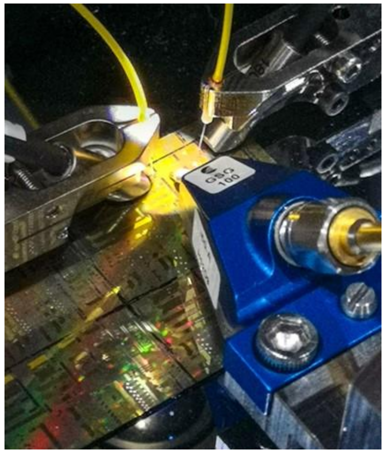
1. Supplementary performance characteristics provide information about non-warranted instrument performance in the form of nominal values.
2. For lines separated by less than the specified amount, wavelength accuracy is reduced.

Optical RF Parametric Test Instruments



On-Wafer Testing Opto-Electronic Components

Using the lightwave component analyzers



A typical on-wafer measurement of an opto-electronic transmitter component uses an RF wafer probe for the electronic stimulus and optical probe for picking up the optical response. For receive components the device under test is stimulated via the optical probe and the RF response is picked up by the RF wafer probe.

For calibrated opto-electronic S-Parameter measurements on opto-electronic components like lasers, modulators, detectors, receivers, and PIN-TIAs the Lightwave Component Analyzer requires an RF calibration of the measurement setup and test fixture, up to the electrical RF interfaces of the device under test prior to the LCA measurement.

The LCA normally requires an electronic calibration up to the coaxial DUT interface. Mechanical or electronic calibration kits are available for the coaxial interface calibration. The LCA allows for extension of the coaxial calibration plane to the tip of the wafer probe via the “RF path de-embedding” feature (see Figure 1). For the RF path de-embedding the RF wafer probe is considered as an RF adapter. The adapter characteristics can easily be determined by the adapter characterization provided with the NWA firmware.

The steps described in this application brief refer mainly to LCAs based on the PNA Series Network Analyzers. However, the principles apply for the ENA Series based Network Analyzers as well.

The PNA performs 2- and 4-port calibrations using either SmartCal (Guided calibration) or an Electronic Calibration (ECal) module. With Guided calibration, the process chooses the standards to apply from the calibration kit based on how they were defined. For on-wafer calibration, only SmartCal is applicable.

The on-wafer LCA measurement requires the following preparatory steps:

Step 1. Create a new calibration kit for probing.

Step 2. Perform an electronic calibration of the coaxial RF interfaces of the LCA

Step 3. Connect RF cable to wafer probe

Step 4. Characterization of the wafer probe

Step 4a. Perform a 1-port SOL (Short-Open-Load) calibration of the wafer probe

Step 4b. Return to the coaxial 2-port calibration before proceeding to Step 4c

Step 4c. Run adapter characterization on PNA to determine adapter file for wafer probe

Step 5. Start and configure LCA including specifying wafer probe adapter file

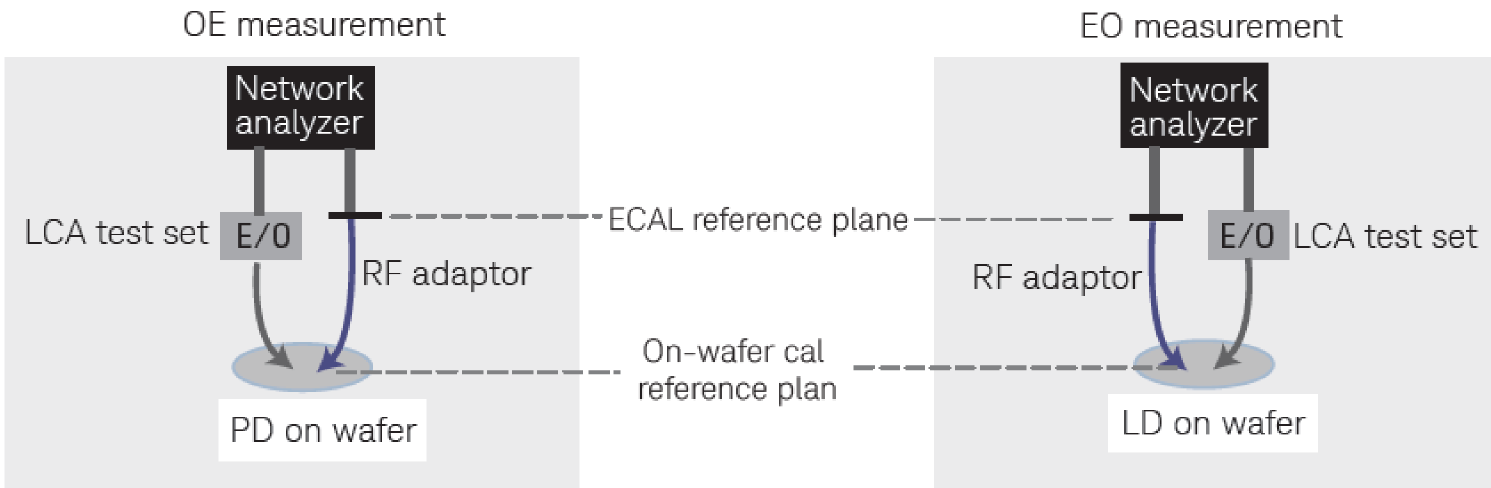


Figure 1. LCA configurations for On-Wafer measurements

Measurement example:
The following measurements performed on wafer e.g. at an early stage in the device processing, demonstrate the importance of precisely expanding the electronic and optical calibration reference planes to the DUT interfaces, and to fully reference out the device fixture and cables. By applying the steps and procedures described before using electronic calibration kits and the on-wafer calibration standards, the setup has been electronically calibrated with reference to the coaxial interfaces closest to the DUT and this calibration plane has been extended to the DUT connection plane e.g. beyond the wafer probe. Figure 2 and Figure 3 compare the on-wafer S-Parameter and Group Delay measurements of an unmatched broadband detector with and without proper de-embedding of the wafer probe. Both GD curves are offset by the delay of the probe. The “erroneous” group delay ripple, which is an important parameter impacting system performance of the DUT, is effectively removed by the proper de-embedding of the ripple contributing wafer probe.

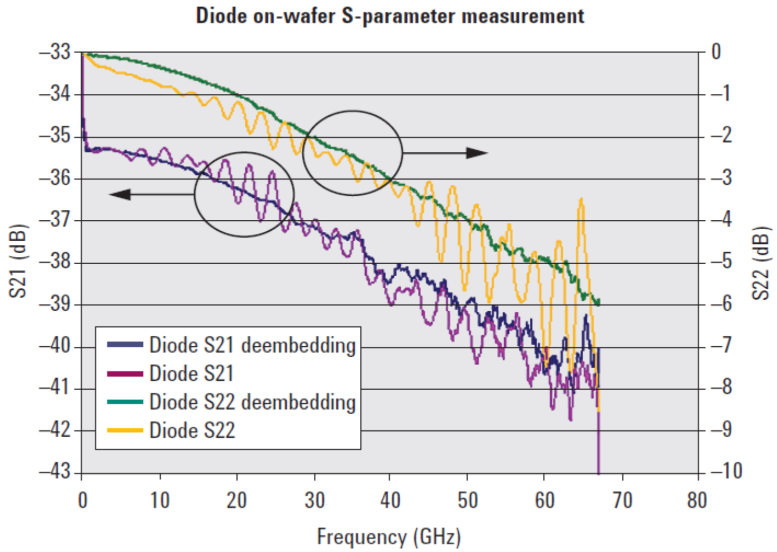


Figure 2: On-wafer OE S-Parameters of Detector

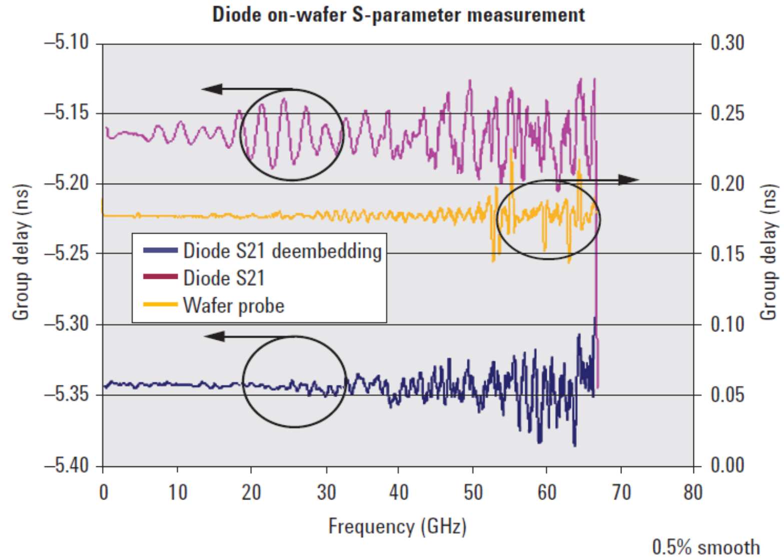


Figure 3: On-wafer Group Delay of Detector

Gain Compression Measurement with Lightwave Component Analyzer

Introduction

This application brief is intended to provide an overview on gain compression measurement using the N437xD/E Lightwave Component Analyzer. Detailed procedure is described in application note 5992-3401EN.

Gain compression measurements on active electro-optic components with a Lightwave Component Analyzer uses the gain compression measurement class of a PNA/ENA enabled through S93086A or S96086A Gain-Compression Measurement Application (GCA) license installed on the PNA or ENA Network Analyzer and an RF power meter. GCA provides fast and accurate input power, output power, electro-optic conversion gain, and phase at the compression point of an amplified transmitter or PIN-TIA receiver, over a specified frequency and power range, with a simple setup. GCA eliminates the problems of lengthy test times and inconvenient setups by providing SMART Sweep that is easy-to-use, fast and accurate. GCA also includes a guided calibration that corrects for absolute power levels, frequency response, and mismatch errors.

Key steps include performing calibration and setting up the LCA de-embedding in the gain compression measurement channel. Since a vector network analyzer always measures electrical RF signals, like in standard OE or EO measurements, LCA de-embedding is required for correct gain compression measurement. For example for a transmitter device under test (DUT) EO measurement it is required to de-embed the LCA receiver used for the conversion of the optical RF signal to an electrical RF signal. The LCA FW automatically generates the appropriate S-parameters for the LCA receiver.

The principles are also applicable to balanced measurements.

LCA measurement and gain compression application (GCA) run in parallel on separate measurement channels on the Network Analyzer.

The gain compression LCA measurement requires the following preparatory steps:

Step 1 Configuring and Setting up LCA measurement on measurement channel 1 including electronic RF calibration

Step 2 Configuring and setting up Gain Compression measurement on measurement channel 2 including Gain Compression Calibration

Step 3 Configuring LCA de-embedding via fixturing on measurement channel 2

Step 4 Defining measurement traces for GCA

Step 5 Perform continuous LCA measurements (in channel 1) and GCA measurements (in channel 2) in parallel

Measurement example

The following example shows gain compression measurement on an optical transmitter consisting of a LiNbO3 Modulator driven by a high gain high output voltage driver amplifier.

Figure 1 shows a screen shot of the measurement with gain compression measurement traces.

The upper window shows the standard LCA EO measurement in measurement channel 1 with forward conversion gain (S41) and the return loss of the electrical input.

The lower wind shows the Electro-Optic Gain Compression measurement in channel 2 with the selected traces linear conversion (S41), compressed conversion gain (CompGain41), Gain difference (DeltaGain41) and most importantly the input power (dBm) for 1dB compression of conversion gain (CompIn41).

Figure 1: Screen with LCA measurement (upper window) and Gain Compression Measurement (lower window)

Figures 2a and b show the sweep results for a 2D power and frequency sweep from -25dBm to +5dBm RF input power for various frequencies in the range of 10MHz to 50GHz:

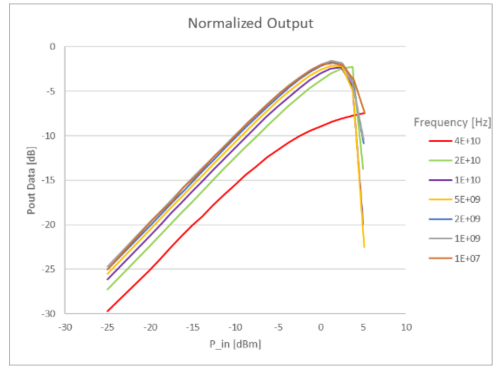


Figure 2a: Normalized* optical modulation output vs. electrical RF input power for various frequencies

*The optical output signal strength has been normalized with linear conversion gain at -25dBm RF input power and 10MHz modulation frequency.

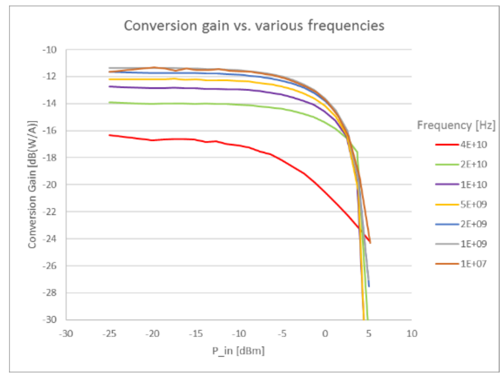


Figure 2b: Conversion Gain vs. electrical RF input power for various frequencies.

Further details on Gain Compression Measurements with PNA can be found in the application note “Gain Compression Application for Amplifier Test”.

N4373E Lightwave Component Analyzer

The N4373E offers the latest N5227B series network analyzers with 2-port or 4-port configuration. This LCA is the ideal measurement solution for test of electro-optical components up to 67 GHz. It is the ideal test instrument for electro-optical components for 64 Gbaud PAM-4 and coherent transmission, as well as Radio over Fiber (RoF) and aerospace and defense electro-optical test applications.

The N4373E is traceable to international standards and provides guaranteed specifications for electro-optical responsively S-parameter measurements in a turn-key solution. In combination with N4694A electronic calibration kit you get fastest setup of your test, so you can focus on developing your components.

Fast and easy measurement setup increases productivity as time-

consuming electrical calibration steps are automated and optical calibration by the operator is no longer necessary.

Features

- Built-in average power meter for fast transmitter power test
- SCPI remote control
- External tunable laser input for 1260 - 1640nm receiver test.
- User selectable optical transmitter output power helps to adapt to target test conditions

Absolute frequency response accuracy

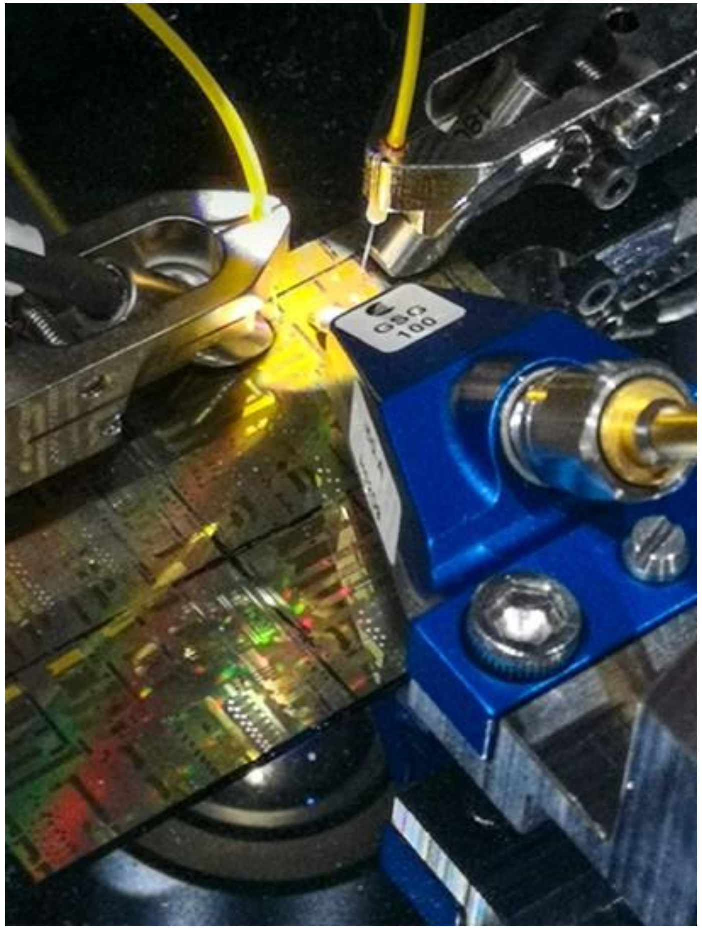
- < 0.9 dBe at 50 GHz (typ.)
- < 1.3 dBe at 67 GHz (typ.)

Relative frequency response accuracy

- < 0.5 dBe at 50 GHz (typ.)
- < 1.3 dBe at 67 GHz (typ.)

Noise floor 26.5 GHz

- < –59 dB (W/A) at 67 GHz for E/O measurements
- < –55 dB (A/W) at 67 GHz for O/E measurements



Silicon Photonics wafer probing

Benefits

Design assurance with fast, accurate and complete measurements

- Quick time-to-market with fast test turnaround
- Protected investment with flexibility to add and change options and wavelength range
- Efficient use of measurement time with intuitive and powerful user interface and measurements at the touch-of-a-button
- Confident and easy analysis with built-in smoothing and fitting tools
- High uptime with worldwide service and support. Easy data transfer with LAN and USB connectivity
- Optimized use of time with programmable automation

Special option available on request

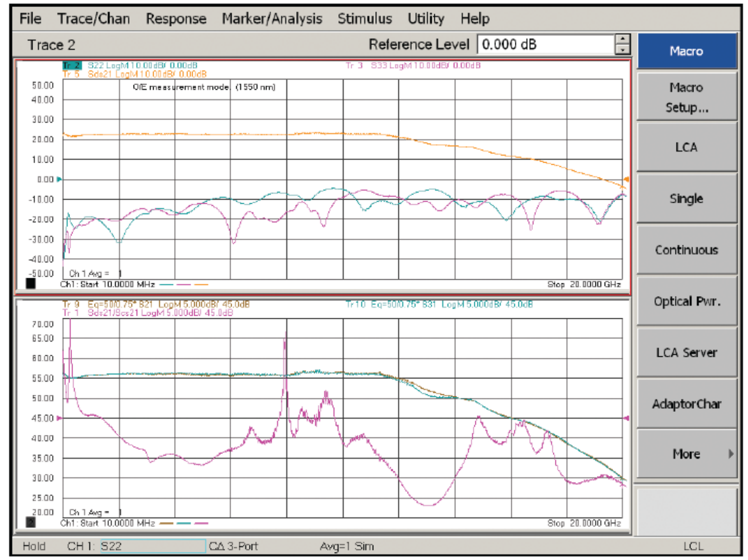
- Multimode fiber component S-parameter test up to 55 GHz @ 850nm. Other wavelengths upon request.
- Integration of PNA-X network analyzers 55 GHz @ 850nm.

N4375E Lightwave Component Analyzer

Keysight's N4375E lightwave component analyzer (LCA) is the successor of the industry standard 8703A/B LCA. Its target application is the test of electro-optical components for 10 GbE, Fibre Channel FCx8, FCx10 and FCx16.

With a completely new design of the optical test set and a new RF-switched architecture, together with the latest PNA family of network analyzers, the N4375E guarantees excellent electrooptical measurement performance. In addition a unique new calibration concept significantly reduces time from powering up the LCA until the first calibrated measurement can be made. This increases productivity in R&D and on the manufacturing floor.

The fully integrated "turnkey" solution reduces time to market, compared to the time-consuming development of a self-made setup. By optimizing the electrical and optical design of the N4375E for lowest noise and ripple, the accuracy has been improved by more than a factor of 3 and is now independent of the electrical return loss of the device under test. It is the excellent accuracy that improves the yield from tests performed with the N4375E, by narrowing margins needed to pass the tested devices. NIST traceability ensures worldwide comparability of test results.



Key benefits

- High absolute and relative accuracy measurements improve the yield of development and production processes
- High confidence and fast time-to-market with a NIST traceable turnkey solution
- Significantly increased productivity using the fast and easy measurement setup with a unique new calibration process leads to lower cost of test.

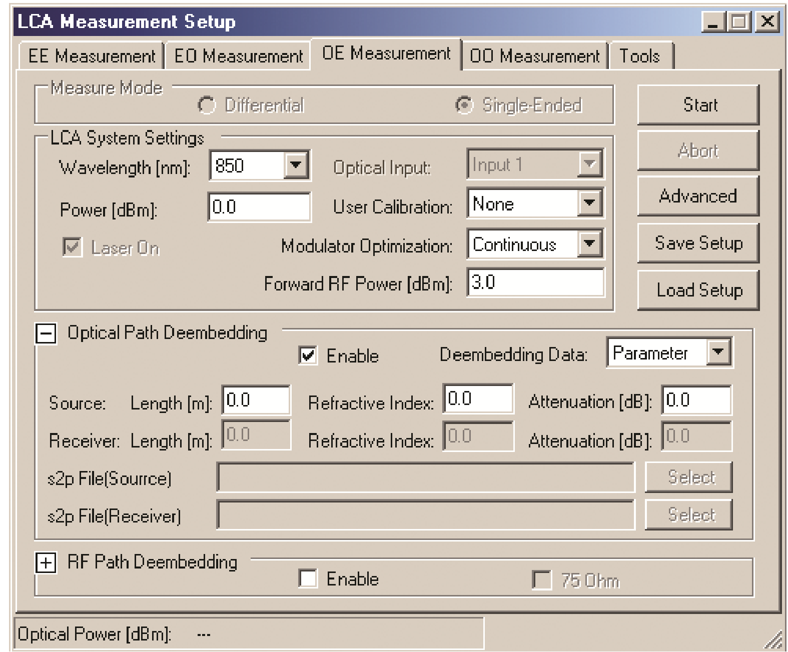
- New switched architecture of optical test set for long term reliability and stability of test results
- Identical LCA software and remote control across the N437xx family simplifies integration

N4375E (LCA) System performance extract (typical data @1550 nm)		100 kHz to 0.7 GHz	100 kHz to 0.7 GHz	0.7 GHz to 4.5 GHz
Relative frequency response uncertainty	E/O	± 0.7 dBe	± 0.5 dBe	± 0.5 dBe
	O/E	± 0.7 dBe	± 0.5 dBe	± 0.5 dBe
Absolute frequency response uncertainty	E/O	± 1.7 dBe	± 1.5 dBe	± 1.5 dBe
	O/E	± 1.7 dBe	± 1.5 dBe	± 1.5 dBe
Frequency response repeatability	E/O, O/E	± 0.02 dBe	± 0.02 dBe	± 0.05 dBe
Noise floor	E/O	–60 dB (W/A)	–86 dB (W/A)	–86 dB (W/A)
	O/E	–49 dB (A/W)	–72 dB (A/W)	–74 dB (A/W)
Phase uncertainty (typ.)	E/O	-	± 2.0°	± 2.0°
	O/E	-	± 2.0°	± 2.0°
Group dlay uncertainty	E/O	Derived from phase uncertainty, see section		
	O/E	“Group delay uncertainty”.		
		Example: ± 2.0° –> ± 8 ps (1 GHz aperture)		

N4376E Lightwave Component Analyzer

Keysight's N4376E multimode lightwave component analyzer (LCA) operates at 850 nm to characterize short wavelength 10 GbE, Fibre Channel FCx8, FCx10 and FCx16 electro- optical components, with up to 20 or 26.5 GHz modulation range. The N4376E also supports the test of transmitter and receivers for ultra fast optical computer or server backplanes and optical chip-to-chip connections in high speed computers and server applications. With a completely new design of the optical test set and a new RF-switched architecture, together with the latest PNA family of network analyzers, the N4376E guarantees excellent electro-optical measurement performance. In addition, a unique new calibration concept significantly reduces time from powering up the LCA until the first calibrated measurement can be made.

This increases productivity in R&D and on the manufacturing floor. Multimode measurements are typical much more critical regarding repeatability and stability than single-mode measurements. A well-defined and stable launch condition increases measurement repeatability. The N4376E has typical multimode launch conditions as defined by the IEEE 802.3ae standard, resulting in application realistic and repeatable test results.



Key benefits

- Traceable multimode S21 test at 850 nm wavelength
- IEEE 802.2ae launch power distribution leads to test results comparable to the final application
- Fast and easy measurement setup and calibration for all standard tests
- High confidence and a fast-time-to-market with a traceable turn-key solution
- Significantly increased productivity using the fast and east measurement setup with and unique new calibration process leads to lower cost of test
- Test right at target launch condition eliminates test uncertainty
- Identical LCA software and remote control across the N437xB/C/E family simplifies integration
- LC or SC straight connectors
- Built-in optical power meter for fast transmitter power verification
- Powerful remote control with state-of-the-art programming interface based on Microsoft NET or COM
- Identical LCA software and remote control across the N437xx family simplifies integration

N4376E System performance extract (typical data @ 850 nm)		0.05 GHz to 0.2 GHz	0.2 GHz to 10 GHz	10 GHz to 26.5 GHz
Relative frequency response uncertainty	E/O	± 1.3 dBe	± 1.3 dBe	± 1.6 dBe
	O/E	± 1.3 dBe	± 1.3 dBe	± 1.6 dBe
Absolute frequency response uncertainty	E/O	± 2.0 dBe	± 2.0 dBe	± 2.0 dBe
	O/E	± 1.7 dBe	± 2.0 dBe	± 2.0 dBe
Frequency response repeatability	/O, O/E	± 2.0 dBe	± 0.1 dBe	± 0.1 dBe
Noise floor	E/O	-50 dB (W/A)	-70 dB (W/A)	-70 dB (W/A)
	O/E	-40 dB (A/W)	-60 dB (A/W)	-60 dB (A/W)

LCA Plug-In for TAP

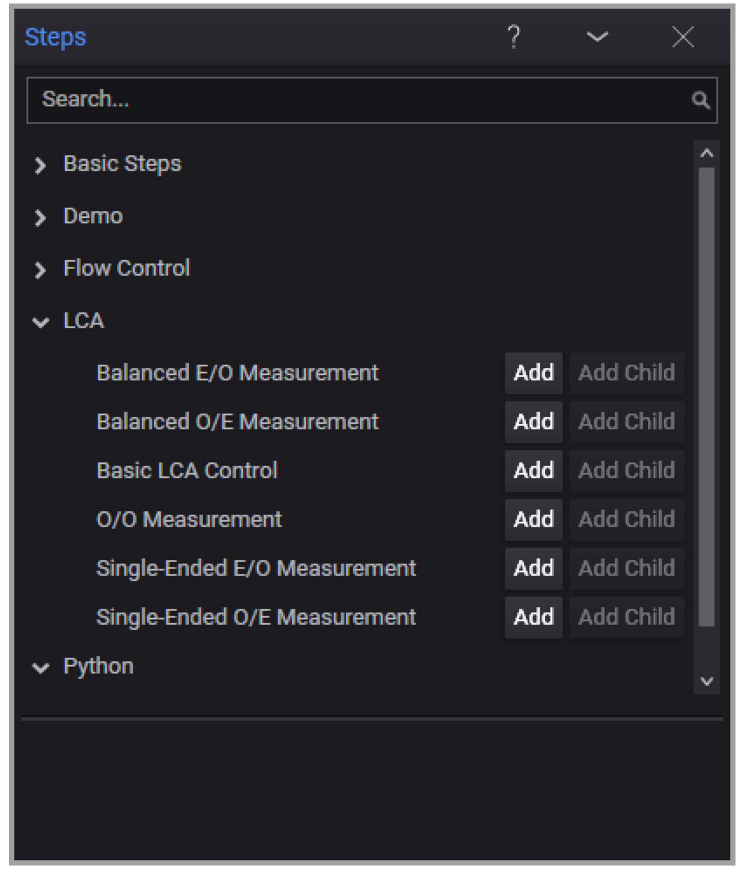
The Keysight Test Automation on PathWave (TAP) software provides powerful, flexible and extensible test sequence and test plan creation with additional capabilities that optimize your test software development and overall performance. Keysight TAP is a modern Microsoft .NET-based application that can be used stand-alone or in combination with higher-level test executive software environments. Leveraging C# and the power of Microsoft Visual Studio, TAP is not just another programming language. It's a platform upon which you can build your test solutions, maximizing your team's productivity by using your existing software development tools and infrastructure. http://www.keysight.com/find/pathwavetest

N4370P01A LCA plug-in for TAP

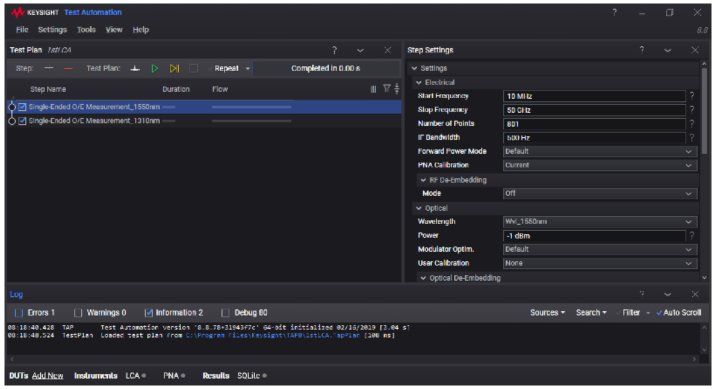
The N4370P01A LCA plugin simplifies automation by providing easy-to-use measurement steps for the integrated LCA that handle the details for configuring the instrumentation and LCA software. The flexibility of configuring workflow with sequences of steps and coordination with other instruments and resources using TAP is a powerful contribution to enhancing efficiency in test development and throughput. The plugin also provides a template for the display of commonly required results from the LCA.

Using the LCA plugin

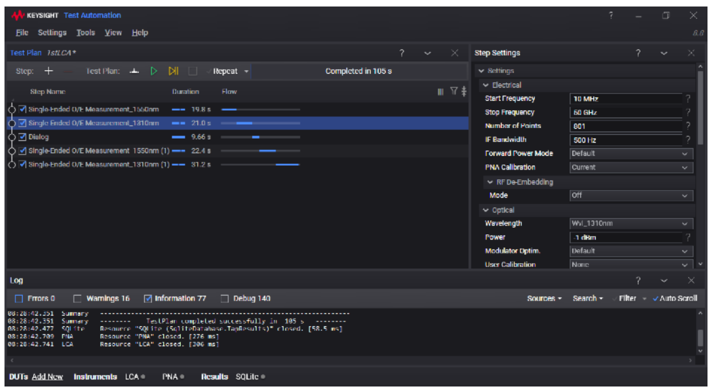
The plugin provides a set of measurement steps that can be added to an automated test plan in TAP. The desired function can be chosen from the Step panel.



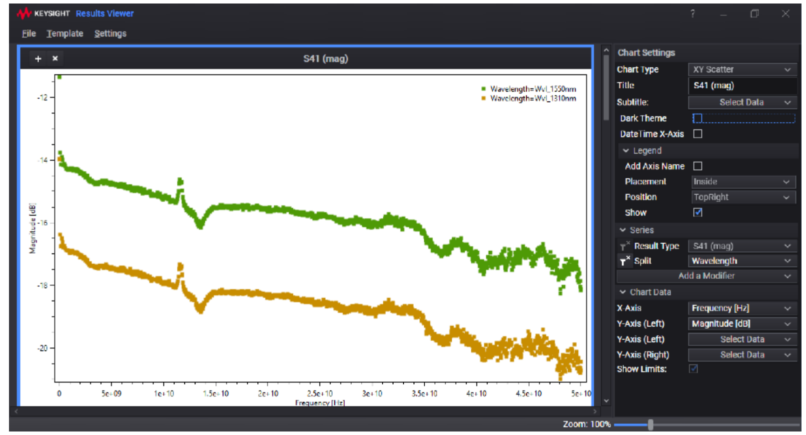
The step can then be configured in TAP with the necessary details for the desired measurement. Besides the desired frequency range and other sweep parameters, the settings support selection of the files for PNA calibration and both RF and optical path de-embedding.



Once a test plan has been set up, it can be run from the Test Automation software. A log of the process is recorded, and flow timing is also displayed.



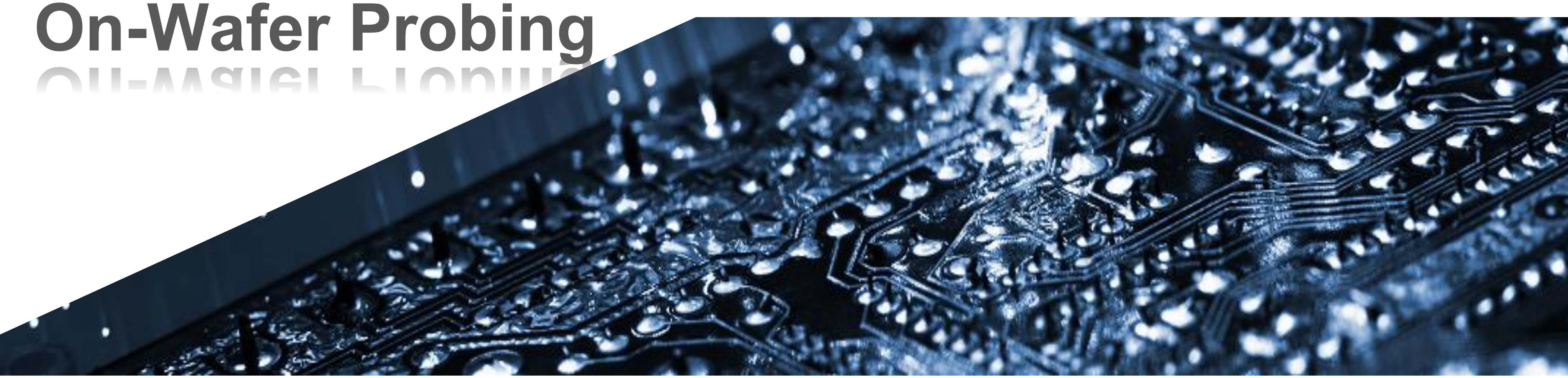
The default configuration of the TAP Results Viewer can present the measurement spectra as several configurable graphs, like this:



Available steps

Step Name	Description
Balanced E/O Measurement	For balanced RF input from and optical output to LCA
Balanced O/E Measurement	For optical input from and balanced RF output to LCA
Basic LCA Control	For controlling LCA settings
O/O Measurement	For optical input from and optical output to LCA
Single-Ended E/O Measurement	For single RF input from and optical output to LCA
Single-Ended O/E Measurement	For optical input from and single RF output to LCA

Optical and Electrical On-Wafer Probing



FormFactor and Keysight will work together to provide you a complete wafer-test solution

FormFactor's Cascade Autonomous Silicon Photonics Measurement Assistant

FormFactor understands a test engineers' goal is to make measurements. An integrated, verified solution will prevent engineers from spending valuable time on long development projects. Keysight and FormFactor have developed all the tools, fixtures and calibration techniques to enable you to measure your photonic devices in days instead of months or years. From the Photonics Integration Kit to the Calibration Kit, you will get production-proven, optimized optical measurements right after installation.

FormFactor's Cascade CM300xi-SiPh 300 mm Semi-/ Fully-automated Probe System

- Automated Calibrations and Alignments ensure precision measurements and coupled power repeatability
- FFI SiPh-Tools software integrates machine vision to facilitate minimal time to first measurement
- Reconfigurable fiber arm enables easy setup flexibility between single fibers and arrays
- Precision Z displacement technology ensures accurate fiber placement
- Verified system performance to specified criteria

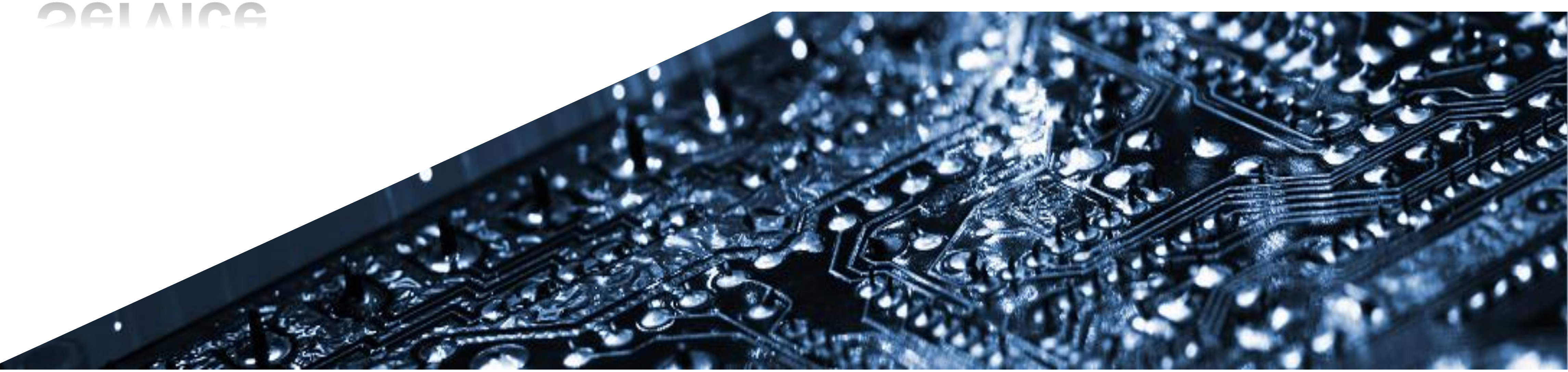
SiPh-Tools is a powerful software package that includes a vast tool set for enabling and facilitating optical probing.

By integrating probe station vision capability with optical positioning and even test equipment, SiPh-Tools automates manual tasks.

From training measurement positions to performing optical scans during die-to-die stepping, SiPh-Tools provides the functionality needed to quickly gather data from your devices.

In addition, SiPh-Tools has a wide range of tools for capturing, logging and interpreting the data you collect.

Service



KeysightCare – SUPPORT. ELEVATED.

The days of simple design are gone. You are pushing new limits. Your designs are redefining “state of the art.” Tools for designing and testing the future are evolving with you, but customer support has not. Until now.

Accelerate your development

When the pressure is on, costly delays come from waiting on tools, answers, or help. That’s why we created KeysightCare. It is ensured action, when you need it. KeysightCare transforms service and support to help your team deliver better results, consistently. It’s a bold promise, and we back it up.

Whether you are dealing with a test equipment question, calibration, or repair, response time counts. KeysightCare provides complete customer care, far beyond basic warranty, including:

- Providing committed response times for repair requests
- Tracking equipment configuration to keep your test assets current
- Ensuring proactive software updates, enhancements, and fixes
- Offering a choice of service tiers to fit your business needs: Assured, Enhanced, or Performance

Assured - Fast, committed support

- 14-day instrument repair
- Firmware and software updates
- 8 business hour technical response
- Support knowledge base
- Self-service web portal

Enhanced - Priority support for faster issue resolution

- 10-day instrument repair
- Firmware and software updates
- 4 business hour technical response
- Support knowledge base
- Self-service web portal
- 5-day expedited calibration
- Customer success manager

Performance - Proactive, enterprise support

- 7-day instrument repair
- Firmware and software updates
- 2 business hour technical response
- Support knowledge base
- Self-service web portal
- 3-day expedited calibration
- Customer success manager
- 24x5 emergency response
- Onsite post-sales technical support

Additional Literature

Publication Number	Title	Link to Document
5992-3393EN	Calibrating Optical Paths in spectral Test Stations Using the N7700A IL/PDL Software Engine	https://literature.cdn.keysight.com/litweb/pdf/5992-3393EN.pdf
5990-3751EN	N7700A Photonic Application Suite	http://literature.cdn.keysight.com/litweb/pdf/5990-3751EN.pdf
5992-1125EN	Programming Keysight Technologies Continuous-Sweep Tunable Lasers	http://literature.cdn.keysight.com/litweb/pdf/5992-1125EN.pdf
5992-1588EN	Wavelength and polarization dependence of 100G-LR4 components	https://literature.cdn.keysight.com/litweb/pdf/5992-1588EN.pdf
5992-3258EN	Wafer and Chip-Level Optical Test	https://literature.cdn.keysight.com/litweb/pdf/5992-3258EN.pdf
5990-9973EN	All-States measurement method for PDL and PER with a synchronous polarization scrambler	http://literature.cdn.keysight.com/litweb/pdf/5990-9973EN.pdf
5992-3401EN	Gain Compression Measurement with Lightwave Component Analyzer	http://literature.cdn.keysight.com/litweb/pdf/5992-3401EN.pdf
5992-3094EN	On-Wafer Testing of Opto-Electronic Components	https://literature.cdn.keysight.com/litweb/pdf/5992-3094EN.pdf

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