Model 4650
Swept Spectrometer®

Fast IL, PDL and ORL Measurement Across Wavelength

The Model 4650 Swept Spectrometer® will characterize loss, polarization dependency and return loss quickly, accurately and repeatably—all at an affordable cost. dBm Optics' technology supports unprecedented optical repeatability, accuracy, and speed. A device can be characterized over a 100 nm span at 1 pm resolution with 1 pm wavelength accuracy and 0.015 dB insertion loss accuracy in less than 1 second.

Repeatable Loss Measurements

Loss measurements normally require a reference measurement—then a measurement of the loss. The Model 4650 eliminates the need for the reference measurement entirely by using a proprietary real-time reference. The Model 4650 is constantly monitoring the input power to the device and calculating the loss based on the power out of the device. In addition to speeding the measurement and eliminating the reference errors, the Model 4650 eliminates the effect of variation in the source power between the reference and the loss measurement. The result is the most accurate loss measurements available anywhere.

Fast, Accurate Polarization Dependency Measurements

The PDL meter function of the Model 4650 performs fast and accurate measurement of the polarization dependency of the device using either all-state or matrix method. The matrix method will characterize 100,000 points of PDL in about 1 second.

Simultaneous Return Loss Measurements

High dynamic range allows the Model 4650 to characterize return loss to levels approaching -70 dB. Return loss and polarization measurements are taken simultaneously.

PDBW and PDCW

The Model 4650 will measure both PDBW and PDCW, polarization dependency of the center wavelength and bandwidth of a filter, very quickly.

Summary

- IL and ORL simultaneously measured in less than 1 second over a 100 nm band
- IL, ORL and PDL simultaneously measured in less than 8.5 seconds over a 100 nm band
- > 65 dB dynamic range at full speed; > 100 dB total dynamic range
- Low PDL error and high repeatability
- Real-time referencing reduces test time and increases accuracy
- Built-in or external TLS or fixed wavelength sources
- Built-in or external polarization controller
- Large color display makes data visualization and analysis simple
- Communicate over GPIB or Ethernet
- Exchange data using a USB flash drive
- 1 or 2 channels
- System is upgradeable: Add polarization control, attenuation, shutter
- 4-year warranty

Fast, Accurate
IL, PDL, ORL vs. Wavelength

Model 4650: Swept Spectrometer®
Overview

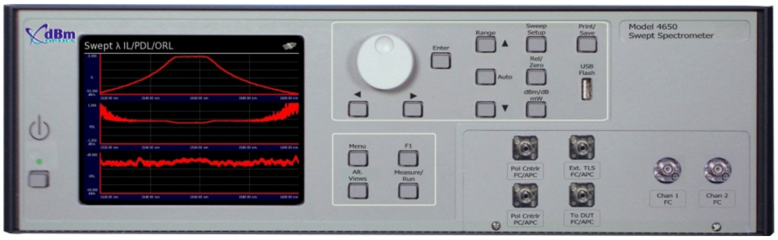
High speed GPIB makes the Model 4650 easy to integrate into any automated test rack

Data entry and instrument setup are easy with the built-in knob

USB flash drive allows simple data transfer

Measurements at any rate from 0.01 to 100,000 rps

High resolution 4"x6" display brings data to life



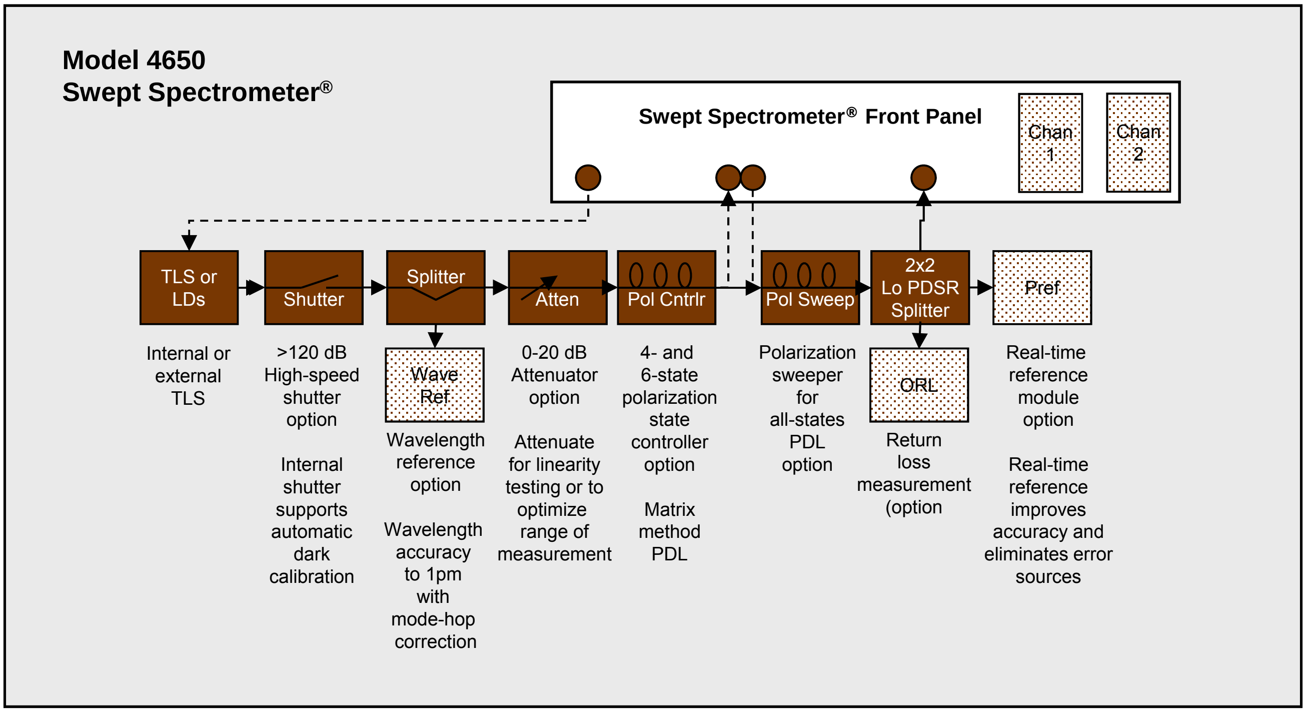
1 or 2 channels available (The dBm Optics CSA is an option if more than two channels are needed.)

Real-time power reference, wavelength Reference and ORL are all inside, no external connections necessary

Built-in Ethernet means the meter is accessible over a network, from a desktop, from home or another remote location via a VPN

Proprietary measurement technology yields 0.005 dB repeatability

Optical measurement from +10 dBm to -95 dBm (Contact dBm directly if higher power is required—up to +23 dBm is available)

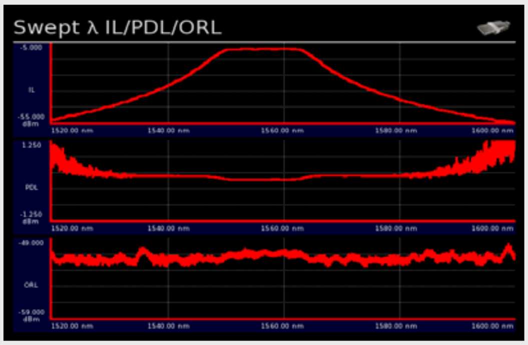


Model 4650: Swept Spectrometer®
A Wide Range of Applications

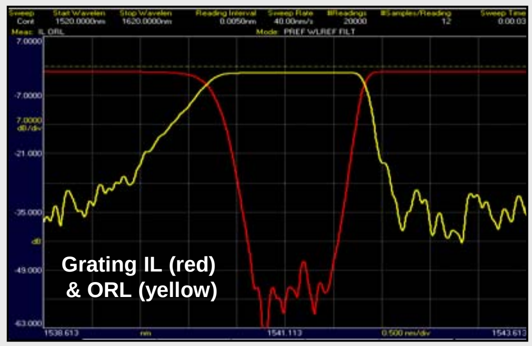
Device Loss Versus Wavelength

Characterize insertion loss, polarization dependent loss and optical return loss for wavelength-dependent devices. Devices include fiber Bragg gratings, WADMs, etalons, filters, splitters, triplexers and interleavers.

- Very fast characterization even with very deep (over 65 dB) wells.
- Low noise allows TLS signal to be split to many benches without loss of test performance.
- Built-in wavelength reference meter options provides < 1 pm or < 1.8 pm accuracy for high center wavelength accuracy.
- Complete characterization in less than one second over 100 nm and at 1 pm resolution.



View IL, PDL and ORL Simultaneously

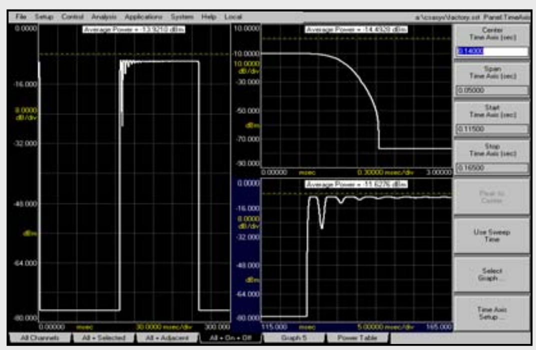


Fully Characterize Filters, Gratings, Etalons

Optical Switch Testing

Characterize optical transients (switch transition time, attenuator transition time, laser turn-on time or any other fast transient) to a resolution of 10's of microseconds.

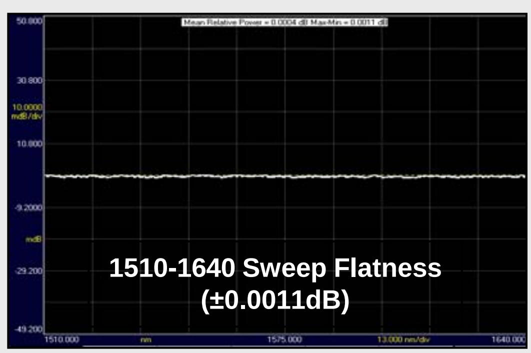
- Catch switch dynamics with 10 μs measurements—fully characterize switch transitions
- Wide dynamic range provides resolution to characterize very low cross-talk levels
- Handle over 1500 channels with one system
- Trigger the Model 4650 simultaneously with the switch to characterize total latency of the switch, including electronic delay


Capture Dynamic Signals

Broadband Device Characterization

The Model 4650 affords fast, inexpensive and accurate characterization of devices, including circulators, isolators, splitters, couplers and attenuators.

- Real-time reference means no reference sweeps
  - Faster
  - Less opportunity for operator error
  - Reduces measurement error dramatically
- Easy to use
- Fast—speeds test execution
- Automated measurements for PDL and ORL

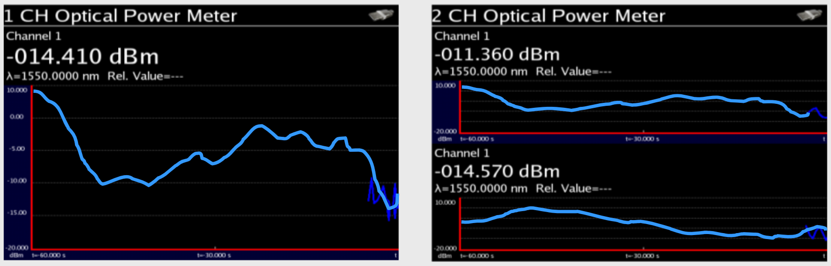


Highly Accurate
Low Insertion Loss Measurement

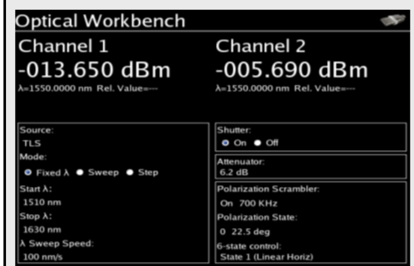
Model 4650: Swept Spectrometer®
A Front Panel that Makes Your Work Easier

Multiple Alternate Displays

View the data as a typical power meter numeric display, a graphical display, multi-channel graphical display or a tabular display. The Model 4650 Swept Spectrometer® offers a number of unique capabilities that will make a difference in the lab or on the production floor—at an affordable cost.

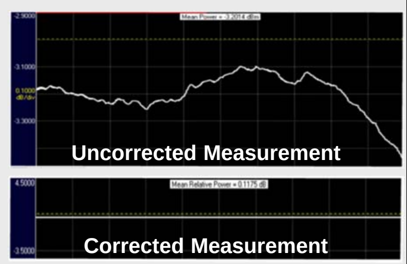


Single- and Dual-Channel Displays Make Data Visualization Simple



Comprehensive Control from a Single Display

Capture Max and Min Excursions



Automatic Referencing Eliminates Most Errors

Save Trace

Save the results of a measurement or set of measurements across wavelength and display or use that data automatically in subsequent measurements by using the save trace capability.

Max Hold and Min-Hold Traces

Turn these traces on and get a real-time graphic update of the envelope of a measurement at each wavelength. The maximum and minimum excursions of the measurement are displayed.

Passband Analysis Trace

Average the data in the passband of a wavelength-dependent device and plot that single value along with values in other passbands for an easy visual indication of a device's performance.

Automatic Real-time Reference Across Wavelength

The Model 4650 will automatically perform a reference power sweep and correct all future data with this reference.

Wavelength Accuracy Trace

Characterize the linearity of a tunable laser with these built-in functions.

Digital Filtering

Multiple digital filter types (including Hamming, Hanning, rectangle) can be used on each channel independently or together.

Model 4650: Swept Spectrometer®
The Technology Behind the Performance

Polarization Dependency

The same breakthrough integrating sphere technology that provides high repeatability also serve to drastically reduce the polarization dependency. On average, each photon bounces 220 times inside the miniature integrating sphere. This ensures that the polarization of the light reaching the detector is very well randomized. This yields a polarization dependency of measurement of < 0.0015 dB (1.5 mdB) typical and < 0.0035 dB (3.5 mdB) guaranteed.

Low-Level Detection

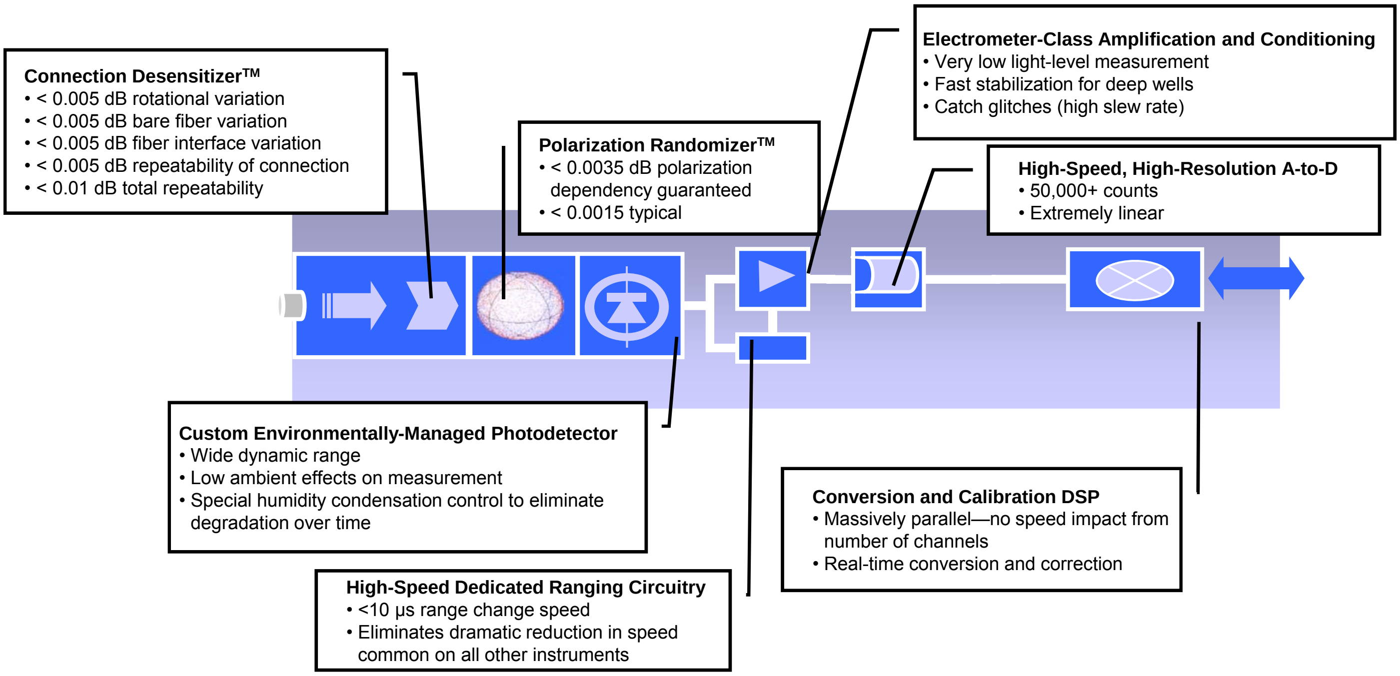
One of the core limits to making low-level measurements is the dark current of the internal photodetector. The precision power meter module (Option 202) use a special low dark current detector. Because dark current is sensitive to temperature, the photodiode is run at -20 °C. The world's authority on temperature control designed the temperature control circuitry and achieved stability of approximately 0.002 °C. This makes the dark current stable over time. The cooling itself is driven with high currents to allow the device to stabilize quickly and adapt to environmental changes without transient errors. To further enhance stability, the precision power meter module option has a dual-stage controller.

Low-Level Amplification With High Speed

Traditional current measurement techniques involve putting an equivalent resistance across the diode and measuring the voltage drop. The obstacle created using this technique is that high resistance is needed for low currents, and when high resistance is combined with the photodiode capacitance it creates slow measurement response. The Model 4650's measurement technology uses an electrometer approach which is more akin to charge counting. This allows measurements to be taken at much lower power (~200 fA or -95 dBm).

High Dynamic Range at Speed

The Model 4650 Swept Spectrometer® measures 100,000 readings per second, auto-ranges across three full ranges, spanning over 67 dB, at full speed. The alternative, using a logarithmic amplifier, substantially compromises low-level measurement accuracy and linearity. (Note: For applications requiring over 65 dB of dynamic range, ask a member of our Applications Team about built-in stitched measurements which expand the dynamic range at speeds to > 85 dB.)



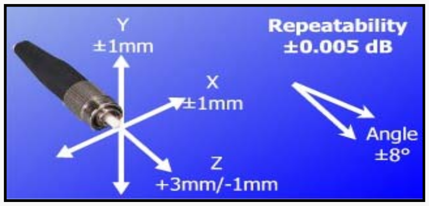
Model 4650: Swept Spectrometer®
The Technology Behind the Performance

Repeatably Capturing the Light

Unless all of the light from a source is captured consistently, a repeatable measurement will not be made. The action of simply connecting and disconnecting fiber connections to a typical power meter can create large power deltas. The proprietary Connection Desensitizer™ reduces this variation by a factor of 2-20 (with reductions of 4-8 typical). This technology is based on a patented miniature integrating sphere technology.

With any of the following changes, a less than ±0.005 dB variation in the measurement can be expected. This compares with typical values for other meters of ±0.05 to ±0.2 dB:

±1 mm X variation
±1 mm Y variation
+3 mm/– 1 mm Z variation
(typical with a bare fiber adapter)
±8° angular variation



Integrating sphere-like input eliminates most input variation

When using a bare fiber adapter to eliminate the need to connectorize in production, there is often a large variation when the bare fiber adapter is rotated in the chuck. The Connection Desensitizer™, combined with the low-stress, non-contact proprietary bare fiber adapter, reduces the rotational variation substantially.

OMM-502

OMM-501

Measurement repeatability with bare fiber adapters is <0.01 dB

The low connection sensitivity results in excellent performance with a bare fiber adapter. Many production teams perform temporary connectorization in production to accommodate in-process measurements. dBm Optics technology gives users the option of using a bare fiber adapter rather than taking the extra time to connectorize.

Long-Term Stability

An optical power meter measuring low power levels likely uses some form of a cooled detector. A potential problem with cooled detectors is that the window of a cooled detector is a miniature condensing surface. Atmospheric moisture condensates on the window. Although typical telecom bands are not affected by the absorption lines of H_2O, the contamination that comes with it is spectral in telecom bands. This contamination is one of the reasons optical power meters need to be recalibrated regularly. The dBm Optics precision power meter module (Option 202) virtually eliminates this problem by actively heating the photodiode enclosure (including the window). By holding the window 5 ^{o}C above ambient, any condensate, (and the contamination that comes along with it) is discouraged. The result is a stable measurement over time. Many of our customers use two-year calibration cycles (rather than one-year calibration cycles), resulting in decreased down time and increased dollar cost savings.

High-Speed Processing

Measurement speed without the ability to retrieve the data quickly can be a big limitation. Our precision power meter module (Option 202) has a 40 Mflop DSP. This allows real-time processing— including calibration, corrections, linearizations, referencing, and real-time user-defined math. By the time the measurement is complete, most of the processing is also complete. The high-speed main processor then formats the data for the display, for external communication over Ethernet, GPIB, or onto a USB flash memory stick.

Model 4650: Swept Spectrometer®
The Technology Behind the Performance

Real-Time Swept Wavelength Meter

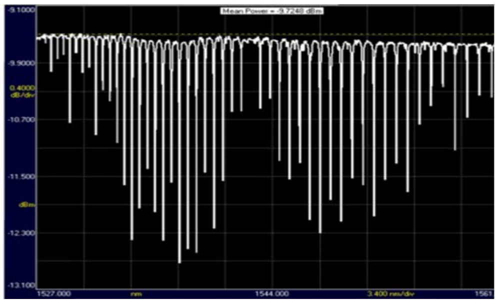
The dBm Model 4650 has an optional proprietary precision wavelength reference that assures absolute wavelength accuracy at full speed.

Model	Accuracy
410	< 1 pm (even with mode hops)
402	< 5 pm; < 1.8 pm (with occasional wavelength calibration)

Tunable Source Error	410 Correction	402 Correction
Initial wavelength offset	Yes, up to 200 pm	Yes, up to 200 pm
Sweep rate error	Yes	Yes
Sweep rate gross non-linearity	Yes, up to 200 pm total	Yes, up to 200 pm total
Sweep rate noise	Yes	Yes
Stiction	Yes	Yes
Mode hops	Yes, multiple	Partial

Absolute Reference on Every Sweep

Precision wavelength reference (Option 410) uses a proprietary multiple optical path technique combined with precise environmental control and dedicated digital signal processing to re-calibrate every measurement point to an absolute wavelength. This absolute wavelength is calibrated using real-time gas cell spectroscopy.

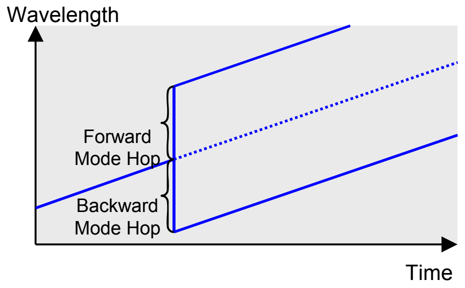


Absolute reference gas spectroscopy is at the core of the dBm Optics precision wavelength reference module option, augmented with several additional corrections.

Model 4650: Swept Spectrometer®
The Technology Behind the Performance

Mode-Hop Correction

The dBm Optics precision wavelength reference module (Option 410) has the patented capability to both detect *and* correct for mode hops in the tunable laser. Most tunable lasers mode hop outside the "mode-hop-free" tuning range. Even lasers that are specified not to mode hop often fail to meet this critical specification. Mode hops are generally 18-35 pm "instantaneous" jumps forward or backward in wavelength during a sweep. This is a direct error if not detected and corrected. dBm Optics precision wavelength meter corrects the entire wavelength table for these occurrences.



Mode hops occur in virtually every tunable laser. Option 410, precision wavelength reference, detects and corrects for mode hops.

Correction Over Wide Wavelength Range

dBm Optics has worked to develop a unique, comprehensive line of gas cell artifacts. Included in this range are multiple-gas cells. Our multiple-gas cells utilize isotopes that provide for non-overlapping absorption lines across wide wavelength ranges. They are designed to optimize the partial pressures to provide similar depth of line and line width appropriate for swept measurement applications. (See the gas cell specifications sheet for more information on single, double and triple cells, covering wavelength ranges from 800 to 1650 nm.)

Model 4650: Swept Spectrometer®
The Technology Behind the Performance

Real-Time Referencing

Real-time referencing reduces measurement time and improves accuracy and repeatability. The dBm Optics Model 4650 has the ability to correct for many of the key errors associated with measuring passive components automatically and in real time. These errors include the power flatness of the TLS, noise from the TLS, etalons in the optical path, fiber movement upstream from the DUT, vibration-induced noise, and insertion loss variation. To eliminate high frequency noise, the Model 4650 aligns the channel and reference readings to ±40 ns.

Automatic power reference makes measurements in lock-step with each channel, thereby eliminating TLS flatness errors while reducing the effective noise in each measurement.

The Model 4650's automatic real-time referencing not only increases speed and reduces noise, but makes it possible to measure broadband components to unheard-of flatness. The reference measurement is made within 40 ns of the power measurement, virtually eliminating even high-speed sources of noise.

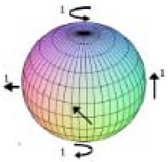
Real-time referencing eliminates many of the sources of noise and error in traditional systems

Making Real-Time Referencing Work

One of the major obstacles to real-time referencing is the polarization dependent split ratio (PDSR) of the splitter used for the reference signal. dBm Optics utilizes a proprietary technology, yielding extremely low PDSR.

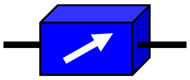
Amplitude Error Source	Real-time Reference Correction
Power line noise on TLS output	Yes
High-frequency digital noise from TLS processor	Yes
Polarization state wobble against polarizer for PDL	Yes
Wavelength dependence of TLS output power	Yes
IL variation of upstream polarization controller	Yes
IL variation of test interconnects	Yes
Vibration-induced IL variation	Yes
PDL of upstream components, such as switches, attenuators, etc.	Yes
Upstream connection variation	Yes
The last "To DUT" connection variation	No

Model 4650: Swept Spectrometer®
The Technology Behind the Performance



Polarization State Control

Option 953I, internal automatic matrix method PDL/IL measurement, provides 4 or 6 orthogonal states for use in polarization analysis. An Agilent 8169 polarization controller can also be used under direct control of the Swept Spectrometer®.

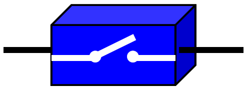


Attenuation

With the internal variable attenuator (Option 921), 0 to 20 dB of attenuation is added and controlled from either the front panel or remotely.

Output Shutter

The optical shutter/automatic dark calibration option (Option 310) enables fast stabilization power control of any tunable laser source (TLS). All TLS take some time to stabilize after turn-on, and Option 310 eliminates this stabilization time.



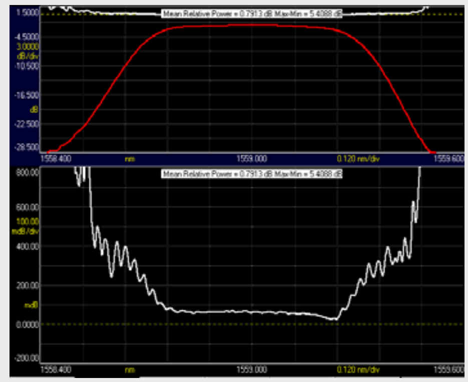
Photodiode Measurements

The Model 4650 Swept Spectrometer® performs photodiode measurements. Optical power and photodiode current can be measured simultaneously to characterize linked phenomena.

Model 4650: Swept Spectrometer®
Built-in PDL-Versus-Wavelength Measurement

Fast, Accurate, Inexpensive PDL Measurement

Today's optical components require better PDL performance than in the past. The Model 4650 will automatically characterize PDL using either the matrix method (which allows fast PDL-vs-wavelength measurement) or the all-states method (which is easy to set up and obtains accurate results). The Model 4650 automates these measurements, making it easy to get the results needed without a lot of setup and software. Polarization dependency of the power meter places a lower limit on the PDL error. The dBm Optics precision power meter module's (Option 222) 0.0015 dB dependency is the best available.



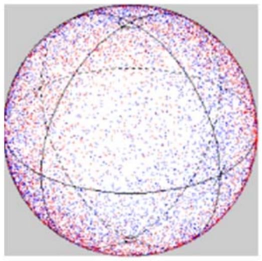
PDL measurement is fast, automatic and affordable

Fully Automatic PDL Measurement

To measure PDL, simply turn on the PDL trace for the measurement channel(s) being used. The Model 4650 will automatically perform the PDL measurement at the same time as it measures IL and ORL. No software to write and debug, no errors—just accurate, fast PDL measurement.

Select the Method

The Model 4650 supports: 4-state matrix PDL; 6-state matrix PDL; traditional all-states PDL; and swept all-states PDL. There are advantages of each method. See the chart below for a summary and the following sections for an explanation of each method.



Sphere coverage is key to all-states PDL

Traditional All-States Method

By sweeping a polarization controller in an attempt to get good coverage of the Poincaré sphere and taking measurements rapidly during this sweep, the maximum and minimum insertion loss points can be identified. This difference is the PDL.

The advantage of traditional all-states is its simplicity and familiarity. The downsides are the longer time of measurement for many wavelength points and the insertion loss variation during the polarization sweep.

Parameter	6-state Matrix	4-state Matrix	Traditional All-states	Swept All-states
Measurement time: 1 point	< 2 ms with internal controller; < 3 seconds with external controller	< 1.5 ms with internal controller; < 2.5 seconds with external controller	< 10 ms to 10 seconds	N/A
Measurement time: 5 pm spacing over 100 nm	< 12.8 seconds	< 8.3 seconds	3.4 minutes to 5 hours	40 seconds to 3 minutes
PDL accuracy	Same as 4-state; also corrects for test path birefringence	0.015 dB without PDL ref set; 0.004 dB with PDL Ref Set	0.002 dB; 0.015 dB typical	0.002 dB; 0.015 dB typical
Short-term repeatability	0.001 dB	0.001 dB	0.002 dB to 0.01 dB	0.002 dB to 0.01 dB
Wavelength range	1400-1640 nm	1400-1640 nm	1250-1640 nm	1250-1640 nm
Alternatives	956I	956I	--	--

Model 4650: Swept Spectrometer®
Built-in PDL-Versus-Wavelength Measurement

Matrix Method

The matrix method usually offers the best combination of speed and accuracy. The matrix method uses measurements at 4 or 6 orthogonal states to determine the polarization dependency of the device. One of the key advantages of matrix method is that each measurement is made at a deterministic polarization state (the all-states method's "random" sweeps are not deterministic). With older generation equipment, the matrix method was difficult to set up and susceptible to many error sources. This led many companies to avoid using the all-states method in production. Current generation equipment is much easier to use and avoids these potential pitfalls.

Simultaneous IL, PDL, ORL

With the matrix method, IL, PDL and ORL (along with PDCW and PDBW) can be measured simultaneously.

Drastic Improvement With Real-Time Referencing

PDL is a small, relative measurement that requires very stable measurement and referencing for accuracy. The dBm Model 4650 uses a unique real-time referencing process which eliminates the need to perform the separate reference and DUT measurements other systems require. The result is that the errors associated with connection and disconnection and the moving of fibers between steps are eliminated. This real-time referencing also reduces test time by the elimination of the separate referencing step.

Real-time referencing is accomplished by monitoring the input to the device simultaneously with measuring the output from the device. Any changes in the optical source power or other variations in the test path are automatically eliminated. For real-time referencing to work properly, each measurement must be made simultaneously to eliminate the effects of noise. The Model 4650 makes these measurements with less than 40 ns of latency.

Another requirement in achieving effective real-time referencing for PDL is to achieve very low PDSR (polarization dependent split ratio) for the monitor port. The Model 4650 uses a proprietary device with incredibly low PDSR.

Calibrating Out Test System Error

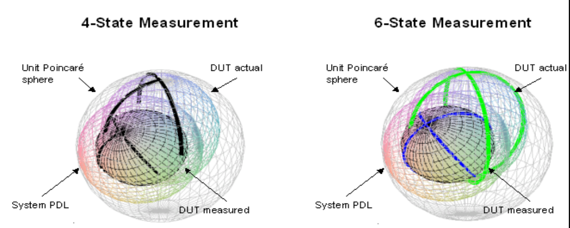
In those cases where ultimate accuracy is needed, matrix method measurements can be further enhanced by performing a "polarization reference set". The polarization reference set further corrects for errors in the system, permitting results below < 0.015 dB to < 0.004 dB.

Eliminate PDL Error

Most equipment takes matrix method PDL measurements. This increases error due to non-repeatability in wavelength of the measurements at each of the 4 or 6 states. The Model 4650 with the precision wavelength reference module (Option 410) measures the precise wavelength of each point, allowing the system to correct for the non-repeatability of the multiple sweeps. The result is exceptional accuracy, even on the edge of deep-well filters.

6-State Measurements

Although 4-state is the best-know matrix method measurement, the Model 4650 also supports 6-state measurement. This allows the measurement to reduce or eliminate the effects of parasitic birefringence in the optical path. The diagram below helps to illustrate. (For more information, refer to dBm Optics' 6-State PDL Measurement Application Note.)



6-State measurement corrects for parasitic birefringence

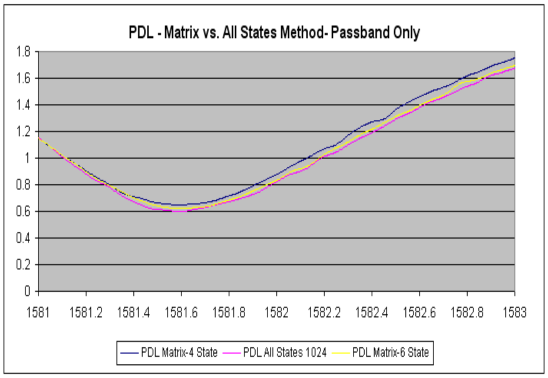
Alternative Implementations

The Model 4650 system can be configured with an Option 953I internal 4- and 6-state polarization controller. It can also be used with an external polarization controller. The Model 4650 automatically runs the external polarization controller over GPIB, making the measurement fully automatic. External polarization controllers have a wave plate angel error dependent on wavelength, and the Model 4650 automatically corrects for these errors. With the external controller, the Model 4650 will automatically perform the required polarizer alignment as well.

Model 4650: Swept Spectrometer®
PDL Accuracy and Determining Wavelength Dependence

Accuracy

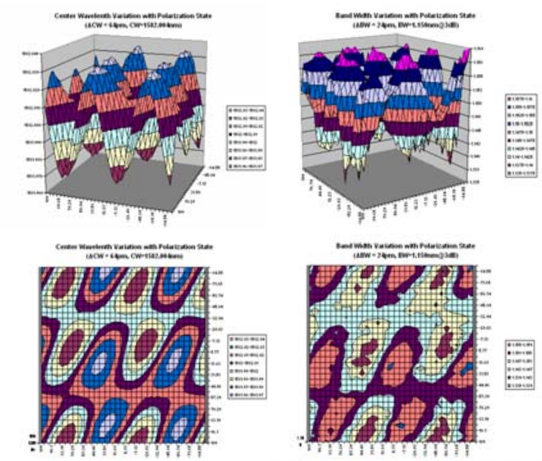
The chart (right) illustrates the high degree of consistency between all-states, 4-state and 6-state. In general, all-states will tend to understate PDL with very short measurement times (not enough time to adequately cover the sphere), and all-states will overstate PDL with longer measurement times (source variation and test lead IL variation are interpreted as PDL). Matrix 4-state will over state PDL by the amount of the effect of the parasitic PDL of the test setup. Matrix 6-state will generally have the lowest error of any of the methods. It is quite reasonable to achieve a few mdB of PDL accuracy on the factory floor with the matrix method.



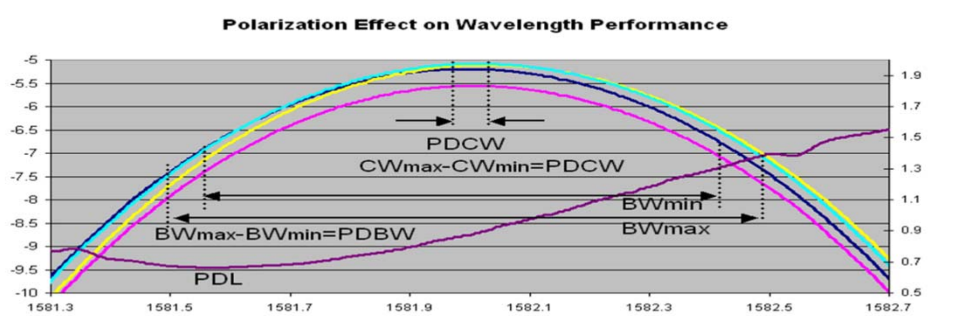
Correlation is excellent between the all states method and dBm's implementation of the matrix method

Determining the Effect of Polarization on the Wavelength Characteristics of a Filter

It is widely understood that polarization state can affect the insertion loss of a device. In addition, polarization state has an effect on the center wavelength and bandwidth of most devices. These effects are referred to as PDCW (polarization dependency of center wavelength) and PDBW (polarization dependency of bandwidth). One way of determining these values is to run separate sweeps, each with a different polarization state. Each sweep can be evaluated for its center wavelength and bandwidth, and these can be compared to determine the difference between max and min, which are the PDBW and PDCW. This method is generally referred to as the swept all-states method. The Model 4650 supports the swept all-states method for PDCW and PDBW. dBm Optics has developed a much simpler and faster method utilizing the 4- or 6-state matrix method. This methodology is proprietary and yields results that are identical to the swept all-states method to ±2 pm or better. The main advantage is that the test time is reduced from minutes or hours to *seconds.* The instrument can measure PDBW and PDCW simultaneously across 100 nm at 1 pm resolution in less than 12 seconds. For use by a design team, the Model 4650 can provide additional detail on the polarization characteristics of the device, including maps of the polarization dependent loss, PDCW and PDBW versus the actual polarization state. This can be critical in determining design changes to minimize these generally undesirable characteristics.



PDL, PDCW and PDBW mapping assists device designers improve performance

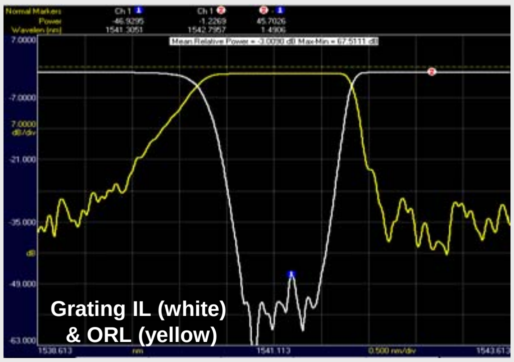


PDBW and PDCW are key measurements for DWDM and other applications

Model 4650: Swept Spectrometer®
Optical Return Loss Measurement

Fast, Accurate, Automatic ORL

Optical return loss (ORL) has become increasingly important as more components are typically in the optical path of a DWDM transmission system. Making good, reliable ORL measurement requires several factors, notably good low-power measurement, easy calibration, and built-in automation to eliminate test error sources.



ORL measurements are fast, automatic and affordable

Wide Dynamic Range Measurement

The internal optical return loss module (Option 940) ORL measurement option includes these key features—making it fast and easy to make accurate and repeatable ORL measurements. In addition, because of the integral implementation, the cost is much lower than with other solutions.

Fully Automated

Measuring ORL with other instruments can take time and expertise to set up. dBm Optics' measurement is completely automated. ORL measurements can be run simultaneously with IL and PDL measurements.

Integrate Fast Alignment with Accurate Optical Parametric Test

Verification and Alignment Combined

dBm Optics' instrumentation has the accuracy and broad capability to perform a full suite of tests with the speed and integration to drive an alignment system. By collapsing these two stages into one, handling, connecting and labor costs are reduced.

Easy Integration

The high-speed IL, ORL and PDL measurement capabilities of the Model 4650, combined with affordable cost, have made it the top choice for alignment systems. The feedback to the alignment stage can be either digital (through the GPIB, Ethernet or RS-232 ports) or analog (Option 222). Both measurements and overhead time are low, making this a very fast alignment meter.

High Speed

One way passives suppliers are cutting costs is by eliminating manufacturing steps. Once a device is aligned, the Model 4650 can run a full or partial optical parametric test, ensuring that the device is operational before packaging. This also eliminates one manufacturing step—further reducing costs. The high speed of the Model 4650 PDL measurement even allows using PDL as the alignment variable.

Fast "First Light" Alignment Step

The dBm Model 4650 has very high dynamic range even at high speed. This can make the "first light" step of alignment substantially faster regardless of the type of algorithm used: a traditional search algorithm or an advanced search algorithm based on relative light leakage at triple search points. (Contact a member of our Applications Team for more information.)

Model 4650: Swept Spectrometer® Internal Tunable Laser

Internal TLS

dBm Optics' line of internal tunable laser sources includes multiple wavelength ranges, low-noise and high-power versions. The low mass, small cavity tunables are amazingly resilient to shock and vibration. For more detail on the optical performance characteristics, see the brochure for the Model 4200 Tunable Laser Source, which utilizes the same optical engine as our built-in tunable laser sources.

Use An Existing External TLS

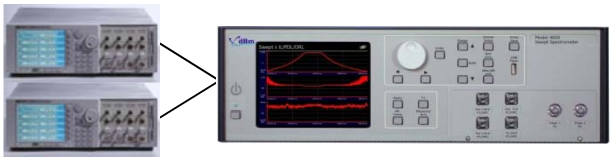
The Model 4650 Swept Spectrometer® will operate with all of the leading tunable laser sources. The external source can be run manually, or the Model 4650 will automatically control many different types of TLS's over the built-in secondary GPIB port (Option 940). Support includes both stepping and sweeping tunables. Because the Model 4650 handles measurements from 800 to 1700 nm, it will operate in conjunction with a wide range of tunable lasers, covering virtually every communications band in use.

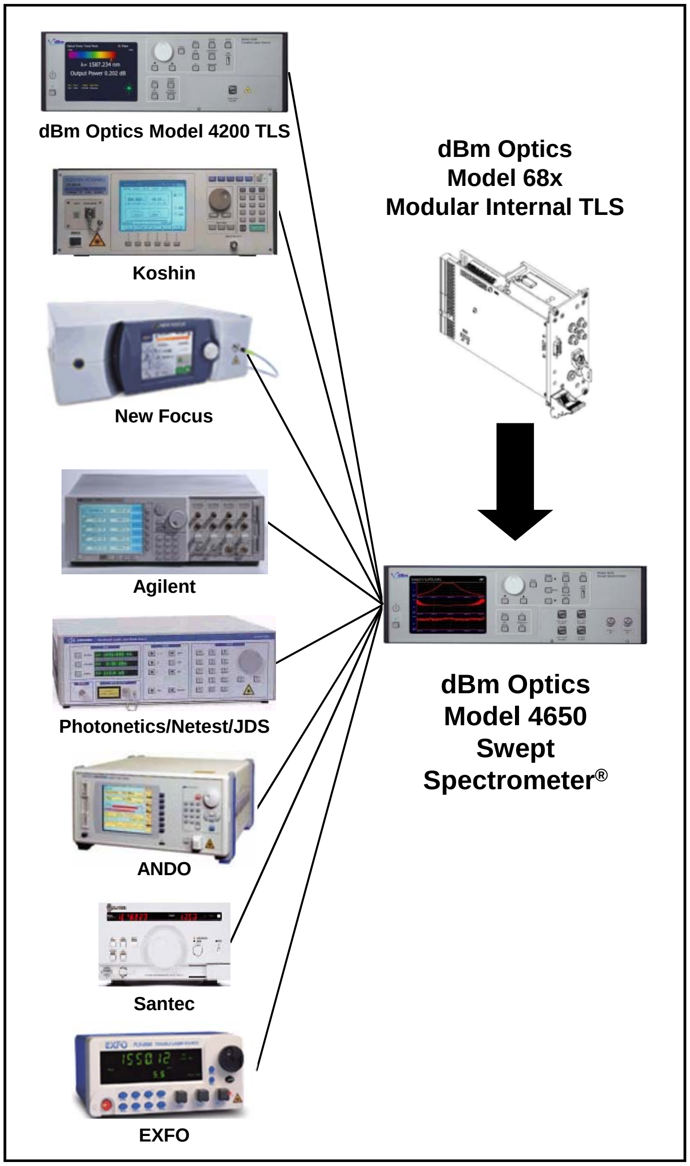
Wavelength and Power Correction

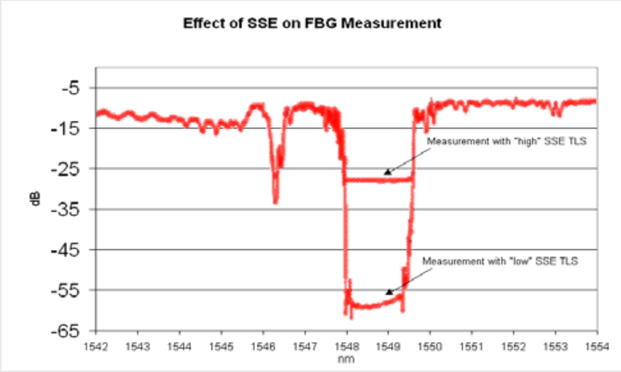
Regardless of the TLS type, the Model 4650 will automatically correct for many power and wavelength aberrations, yielding increased performance even from aging lasers. In addition to improving performance, this can save the high cost of TLS maintenance. (For more information, see our detailed descriptions of real-time referencing and wavelength referencing elsewhere in this data sheet.)

Multiple TLS Capable

The Model 4650 has the built-in capability of handling one or two tunable lasers in order to cover a wider wavelength band. The Model 4650 automatically controls the tunable lasers over a secondary GPIB port. The desired wavelength range is set, and the Model 4650 determines which TLS to employ, handles the setup (including wavelength overlaps) and combines the result into a single dataset across the total wavelength range desired.







When selecting a TLS, the STSE (Source Total Spontaneous Emission) can have a large impact when measuring deep-well devices.

Model 4650: Swept Spectrometer®
Options and Ordering Information

4650	1-2 channel Swept Spectrometer® mainframe
201	Power meter module, 800-1700 nm
202	Precision power meter module, 800-1700 nm
210	Remote power meter module, 800-1700 nm
222	Precision power meter module, 800-1700 nm, analog output
280	Photodiode measurement module
288	Photodiode measurement module, 8 channels
301	Real-time power reference measurement module
310	Optical shutter/automatic dark calibration
402Q	Precision wavelength reference module (extended range); 5 pm accuracy; 5 pm repeatability
402T	Precision wavelength reference module; 5 pm accuracy; 5 pm repeatability
410Q	Precision wavelength reference module (extended range); 1 pm accuracy; 1 pm repeatability
410T	Precision wavelength reference module; 1 pm accuracy; 1 pm repeatability
501	Bare fiber adapter, low stress, easy alignment
502	Bare fiber to FC adapter
681-HP	Internal tunable laser source, high power, 835-850 nm
684-LN	Internal tunable laser source, low noise, 1260-1340 nm
684-HP	Internal tunable laser source, high power, 1260-1340 nm
688-LN	Internal tunable laser source, low noise, 1510-1620 nm
688-HP	Internal tunable laser source, high power, 1520-1630 nm
692	Laser diode sources (1-5 sources). Specify 1-5 of the most common sources: 980 FBG; 1310 DFB; 1480 DFB; 1490 DFB; 1550 DFB; any wavelength from 1519-1630 nm DFB 980 FP; 1310 FP; 1490 FP; 1550 FP
705	Rack ears
740	Internal GPIB controller (required to automatically control external TLS or external polarization controller)
921	Internal variable attenuator, 0-20 dB, SM output
940	Internal optical return loss (ORL) module
953I-13	Internal automatic matrix method PDL/IL measurement (4- and 6-state polarization controller), 1310 nm version
953I-15	Internal automatic matrix method PDL/IL measurement (4- and 6-state polarization controller), 1550 nm version
956	Automated matrix method PDL/IL measurement (requires Option 740)
957I	Internal polarization scrambler
972-cc/ccc	Built-in source split with switches for 2 DUTs
973-cc/ccc	Built-in source split with switches for 3 DUTs
982	Built-in source split for 2 DUTs
983	Built-in source split for 3 DUTs

Model 4650: Swept Spectrometer®
Mainframe Specifications

Channels per mainframe	1 or 2 channels	
Input connection	Select from among the following at time of ordering:	
	1.5 UNIV	Universal 1.5 mm ferrule interface
	2.5 UNIV	Universal 2.5 mm ferrule interface
	BF	Bare fiber interface
	FC	FC connector interface
	LC	LC connector interface
	MU	MU connector interface
	SC	SC connector interface
	ST	ST connector interface
	SMA	SMA connector interface
Speed per channel	Variable measurement speed from 100K rps to 0.1 rps	
System transmit speed	Transmitting to host with Ethernet is 3 Mbytes/second (dedicated link). Transmitting to host with GPIB is 1.7 Mbytes/second into a PC.	
Multiple channel speed	100K rps per channel regardless of number of channels	
Trigger latency[1]	< 40 ns latency; < 40 ns jitter	
Display	4” x 6” graphical display; VGA (800 x 600); TFT LCD color	
Data storage	Memory for > 100K readings per channel on all channels real-time storage	
Triggering	Software synchronous trigger or two selectable external trigger inputs	
Interfaces	IEEE-488, 100-BaseT Ethernet standard	
Command set	IEEE-488.2 compliant (SCPI-like)	
Power	90-265 VAC; 175 VA max; 47-63 Hz. No switch or fuse change required.	
Ambient temperature	10 ºC to 35 ºC (50 ºF to 95 ºF). Contact factory for 0 ºC to 40 ºC (32 ºF to 104 ºF).	
Storage temperature	-40 ºC to +70 ºC (-40 ºF to 158 ºF).	
Humidity	< 95% non-condensing 0 ºC to 35 ºC	
Warm-up time	60 minutes to full specifications; useable immediately after turn on	
Recalibration period	1 year; certificate of calibration included	
Warranty period	Standard warranty is 4 years (Options 402, 410, 953I, and all switch modules carry a one-year warranty)	
Size	16.8” w x 16.4” d x 5.25” h (42.6 cm x 41 cm x 10.5 cm)	
Weight	15 lbs (6.8 kg)	
Mounting	Benchtop or rack mount	

[1] Trigger latency defined as total time from trigger edge to initiation of measurement

Power Meter Modules
Option 201, Option 202, Option 221, Option 222, Option 210, Option 301
Specifications *(Page 1 of 2)*

Sensitivity and Noise

Range	Fixed Range	Measurement		Measurement Resolution [1]		Precision Power Meter Module (Option 202, Option 222 [11]) Noise RMS [2]						Power Meter Module (Option 201, Option 221 [11]) Noise RMS [2]					
						5 secs [7]		100 ms [8]		10 µs (full speed) [9]		5 secs [7]		100 ms [8]		10 µs (full speed) [9]	
		W	dBm	W	dBm	±W	±dBm	±W	±dBm	±W	±dBm	±W	±dBm	±W	dBm	±W	±dBm
Fast 10 mW	10 mW	10 mW	10	200 nW	-37	50 nW	-43	100 nW	-41	400 nW	-34	100 nW	-41	200 nW	-37	800 nW	-31
	1 mW	1 mW	0	20 nW	-47	8 nW	-51	20 nW	-50	40 nW	-44	20 nW	-47	40 nW	-44	80 nW	-41
	100 µW	100 µW	-10	2 nW	-57	2 nW	-57	2 nW	-57	8 nW	-51	4 nW	-54	4 nW	-54	16 nW	-48
Fast 100 µW	100 µW	100 µW	-10	2 nW	-57	1 nW	-60	1 nW	-60	4 nW	-54	4 nW	-54	4 nW	-54	16 nW	-48
	10 µW	10 µW	-20	200 pW	-67	30 pW	-75	40 pW	-74	800 pW	-61	400 pW	-64	400 pW	-64	4 nW	-54
	1 µW	1 µW	-30	20 pW	-77	20 pW	-77	20 pW	-77	300 pW	-65	200 pW	-67	200 pW	-67	2 nW	-57
Fast 1 µW	1 µW	1 µW	-30	20 pW	-77	10 pW	-80	6 pW	-82	100 pW	-70	50 pW	-73	50 pW	-73	500 pW	-63
	100 nW	100 nW	-40	2 pW	-87	2 pW	-87	3 pW	-85	40 pW	-74	20 pW	-77	50 pW	-73	500 pW	-63
	10 nW	10 nW	-50	0.2 pW	-97	1 pW	-90	2 pW	-87	40 pW	-74	20 pW	-77	50 pW	-73	500 pW	-63
Fast 10 nW	10 nW	10 nW	-50	0.2 pW	-97	1 pW	-90	2 pW	-87	4 pW	-84	20 pW	-77	50 pW	-73	500 pW	-63
	1 nW	1 nW	-60	0.02 pW	-107	1 pW	-90	2 pW	-87	3 pW	-85	20 pW	-77	50 pW	-73	500 pW	-63
	100 pW	100 pW	-70	2 fW	-117	1 pW	-90	2 pW	-87	2 pW	-87	20 pW	-77	50 pW	-73	500 pW	-63
Fast 100 pW	100 pW	100 pW	-70	2 fW	-117	300 fW	-95	300 fW	-95	300 fW	-95	20 pW	-77	50 pW	- 73	500 pW	-63

Accuracy [1, 6]

Absolute uncertainty at reference conditions [4]:	2.5%
Absolute operational uncertainty [5]:	5%
Relative uncertainty:	<1% + noise (per table above)

Measurement Speed

Auto-Range Mode	Full Measurement Range	Reading Time with Averaging of: 1 Reading	2,000 Readings	500,000 Readings
Fast 10 mW - 2 nW	10 dBm to -57 dBm	10 µs	20 ms	5.00 s
Fast 100 µW - 20 pW	-10 dBm to -77 dBm	10 µs	20 ms	5.00 s
Fast 1 µW - 200 fW	-30 dBm to -97 dBm	10 µs	20 ms	5.00 s
Fast 10 nW - 2 fW	-50 dBm to -107 dBm	10 µs	20 ms	5.00 s
Fast 1 nW - 0.5 fW	-60 dBm to -117 dBm	10 µs	20 ms	5.00 s
Med 10 mW - 20 pW	10 dBm to -77 dBm	1 ms	21 ms	5.00 s
Med 10 mW - 200 fW	10 dBm to -97 dBm	10 ms	30 ms	5.01 s
Slow 10 mW - 2 fW	10 dBm to -107 dBm	1.5 s	1.52 s	6.52 s
Slow 10 mW - 0.5 fW	10 dBm to -117 dBm	5 s	5.02 s	10.02 s

Connections*

Model	Description
1.5 UNIV	Universal 1.5 mm ferrule interface
2.5 UNIV	Universal 2.5 mm ferrule interface
BF	Bare fiber interface
FC	FC connector interface
LC	LC connector interface
MU	MU connector interface
SC	SC connector interface
ST	ST connector interface
SMA	SMA connector interface

* Select when ordering. Additional connectors may be available. Input connection can be changed in the field.

(Continued)

Power Meter Modules
Option 201, Option 202, Option 221, Option 222, Option 210, Option 301
Specifications *(Page 2 of 2)*

Polarization Uncertainty of Measurement

< ±0.0015 dB typical; 0.0035 dB guaranteed for precision power meter module (Option 202, Option 301)
< ±0.0050 dB for power meter module (Option 201, Option 210, Option 221, Option 222)

Return Loss

> 55 dB

Remote Power Meter Module, 800-1700 nm (Option 210)

Input configurations: 3 mm free space; 1 mm free space; FC, SC, ST, UC Universal connector or BF (bare fiber)
Input orientation: End (axial) entry or side entry
Cable length: 1 meter standard; call factory for additional lengths

Precision Power Meter Module, 800-1700 nm (Option 221)

Analog output: 0-2V (4V max)
Output impedience: 600 ohms typical
Maximum input voltage: ±10V
Bandwidth: DC up to 7.5 kHz depending on range

Precision Power Meter Module, Analog Output*, 800-1700 nm (Option 222)

Analog output: 0-2V (4V max)
Output impedience: 600 ohms typical
Maximum input voltage: ±10V
Bandwidth: DC up to 7.5 kHz depending on range

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[1] From 1500 to 1620 nm. For 1400-1635, add 3 dBm; for 800 nm-1650 nm, add 10 dB noise and resolution specs (or multiply to W by 10). Assume automatic or manual dark calibration performed.

[2] Peak noise is typically 3 to 3.5 times the RMS figure. Noise figures are typical performance.

[3] Per "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results;" NIST Technical Note #1297

[4] Wavelength = 1310, 1520-1625 nm, $T_{(ambient)}$ = 23C ± 2C, 1.1 mm diameter beam, 30 µW

[5] Wavelength = 800-1650 nm, $T_{(ambient)}$ = 10 to 35C, Fiber with N.A. <0.3, -70 dBm to +3 dBm (total wavelength range 800 nm-1700 nm)

[6] Above 5 dBm, accuracy is typical

[7] Maximum variation ± for 4 measurements, filter on

[8] Maximum variation ± for 50 measurements, filter on

[9] Maximum variation ± for 10,000 measurements, filter on

[10] Includes the time to change range and take readings. All readings equally spaced.

[11] Measurement noise may be higher with analog output due to conducted noise from devices and cables connected to the analog output connection.

Photodiode Measurement Modules (Internal)
Option 280, Option 288
Specifications

(For use in measuring responsivity or current from external photodiode)

General Specifications

Measurement rate	100,000 readings per second (10 µs measurement time)
Measurement modes	Current measurement; voltage measurement
Photodiode bias supply voltage range	0 to 10V
Photodiode bias supply voltage resolution	5 mW resolution
Photodiode bias supply voltage noise	< 50 µV DC to 20 KHz
Display, absolute measurement	Displays 1 mV per mA measured from photodiode with no user calibration applied. Display in linear (mW) or log (dBm).
Display, relative measurement (Pref ON)	Displays the cal factor of mA per mW applied. Display in log (dB).
Math	Both dB and linear offset functions available standard
PD calibration factors	Selectable from front panel; GPIB, Ethernet, or RS-232
Triggering	Selectable through CSA mainframe. < 40 ns maximum trigger misalignment.
Maximum input	±40 V peak (no damage)
Channels	1 channel for Option 280; 8 channels for Option 288
Input connection	12-pin circular connector

Voltage Mode Specifications

Range	Resolution	Noise @ 10 µs[1]
10 V	200 µV	< 1 mV
1 V	200 µV	< 200 µV

[1] Peak-to-peak noise

PD Current Mode Specifications

Range	Resolution	Noise @ 100 ms [1]	Noise @ 10 µs[1]	Equiv Optical Power (direct)		Equiv Optical Power (10% tap)	
1A	20 µA	< 20 µA	< 80 µA	30 dBm	1W	40 dBm	10 W
100 mA	2 µA	< 2 µA	< 8 µA	20 dBm	100 mW	30 dBm	1 W
10 mA	200 nA	< 200 nA	< 800 nA	10 dBm	10 mW	20 dBm	100 mW
1 mA	20 nA	< 20 nA	< 80 nA	0 dBm	1 mW	10 dBm	10 mW
100 µA	2 nA	< 2 nA	< 8 nA	-10 dBm	100 µW	0 dBm	1 mW
10 µA	200 pA	<200 pA	< 800 pA	-20 dBm	10 µW	-10 dBm	100 µW
1 µA	20 pA	< 20 pA	< 80 pA	-30 dBm	1 µW	-20 dBm	10 µW
100 nA	2 pA	< 2 pA	< 40 pA	-40 dBm	100 nW	-30 dBm	1 µW
10 nA	200 fA	< 200 fA	< 4 pA	-50 dBm	10 nW	-40 dBm	100 nW

[1] Peak-to-peak noise

Response Time Specifications

Range	Response with 1 pF PD Capacitance
1A	~ 20 KHz
100 mA	~ 20 KHz
10 mA	~ 20 KHz
1 mA	~ 20 KHz
100 µA	~ 7.5 KHz
10 µA	~ 7.5 KHz
1 µA	~ 0.1 KHz
100 nA	~ 0.1 KHz
10 nA	~ 0.01 KHz

Wavelength Reference Module Options (Internal)
Options 410Q, 410T, 410THR, 402Q, 402T
Specifications

	410THR*	410Q	410T	402Q	402T
Description	Precision wavelength reference module (high resolution)	Precision wavelength reference module (extended range)	Precision wavelength reference module	Wavelength reference module (extended range)	Wavelength reference module
Absolute wavelength accuracy	< 0.6 pm typical; < 1 pm guaranteed under enhanced accuracy conditions*	< ±1 pm +1 pm per mode hop	< ±1 pm +1 pm per mode hop	< ±5 pm +1 pm per mode hop	< ±5 pm +1 pm per mode hop
Repeatability	< 0.08 pm at one standard deviation typical under enhanced accuracy conditions*	< ±1 pm	< ±1 pm	< ±5 pm	< ±5 pm
Wavelength range	1510-1648 nm full accuracy; wider wavelength range at reduced accuracy	1260-1640 nm	1510-1648 nm full accuracy; wider wavelength range at reduced accuracy	1260-1640 nm	1510-1648 nm full accuracy; wider wavelength range at reduced accuracy
Minimum sweep range	1 nm from: 1520-1532; 1536-1550; 1561-1573; 1575-1594; 1595-1608; 1610-1638; 5 nm for other wavelengths	1 nm from: 1520-1532; 1536-1550; 1561-1573; 1575-1594; 1595-1608; 1610-1638; 10 nm for other wavelengths	1 nm from: 1520-1532; 1536-1550; 1561-1573; 1575-1594; 1595-1608; 1610-1638; 5 nm for other wavelengths	1 nm from: 1520-1532; 1536-1550; 1561-1573; 1575-1594; 1595-1608; 1610-1638; 10 nm for other wavelengths	1 nm from: 1520-1532; 1536-1550; 1561-1573; 1575-1594; 1595-1608; 1610-1638; 5 nm for other wavelengths
Maximum wavelength error that can be corrected	The "Wavelength Offset Wizard" corrects beginning-of-sweep wavelength errors up to 5 nm. The error in any 5 nm span of the sweep may not exceed 200 pm.	The "Wavelength Offset Wizard" corrects beginning-of-sweep wavelength errors up to 5 nm. The error in any 10 nm span of the sweep may not exceed 200 pm.	The "Wavelength Offset Wizard" corrects beginning-of-sweep wavelength errors up to 5 nm. The error in any 5 nm span of the sweep may not exceed 200 pm.	The "Wavelength Offset Wizard" corrects beginning-of-sweep wavelength errors up to 5 nm. The error in any 10 nm span of the sweep may not exceed 200 pm.	The "Wavelength Offset Wizard" corrects beginning-of-sweep wavelength errors up to 5 nm. The error in any 5 nm span of the sweep may not exceed 200 pm.
Optical input power	+3 dB to -3 dB	> -15 dBm into "TLS IN" PORT typical			
Minimum sweep rate	20 nm/second for full specifications.				
Maximum sweep rate	100 nm/second guaranteed; 120 nm/second typical.				
Mode hop correction	Automatic: Finds, characterizes and corrects for single or up to 15 mode hops encountered during the sweep. Mode hops must be at least 1 nm apart and not be at the beginning 1nm of the sweep.				
Wavelength resolution	0.01 pm				
Wavelength correction	Each power/IL/ORL/PDL measurement point wavelength is automatically connected to the actual wavelength				
Wavelength sweep rate	Full specifications generally apply to TLS at its maximum sweep rate. At slower rates, some TLS become unstable and can even sweep backwards for short periods of time. TLS must sweep forward monotonically.				
Data available	Wavelength axis automatically corrected when wavelength correction is enabled. Data trace showing wavelength correction applied (TLS wavelength error) may be displayed.				

* The 410THR operates like the 410T in all respects except that accuracy and repeatability are enhanced with the 410THR. To obtain these enhanced results, the sweep should be configured as follows: 1) sweep rate 40 nm/second; 2) sweep start and sweep end in one of the following wavelength ranges: 1523 nm to 1530 nm, 1538 nm to 1550 nm, 1563 nm to 1571 nm, 1578 nm to 1588 nm, 1599 nm to 1605 nm, 1615 nm to 1623 nm; 3) analog filtering off 4) TLS models: Agilent model 81600B, New Focus model 6500, dBm Optics model 4200. Note: Accuracy is improved over the 410 outside these conditions, but performance may vary.

Tunable Laser Sources (Internal)
680 Series*
Specifications

	681	684		688	
	HP	LN	HP	LN	HP
Tuning range	835-850 nm	1265-1345 nm		1520-1630 nm	
Tuning range, mode-hop free	835-850 nm	1265-1345 nm		1510-1620 nm	1520-1630 nm
Output power	+6 dBm	0 dBm	+6 dBm	0 dBm	+8 dBm
Signal to source spontaneous emission ratio (SSE) [5,7]	> 40 dB	> 70 dB	> 40 dB	70 dB	>45 dB (1540-1630) > 40 dB
Signal to total source spontaneous emission ratio (STSE) [6,7]	> 15 dB	> 55 dB	> 15 dB	> 60 dB (1540-1625) > 55 dB	15 dB
Tuning speed	2 to 1000 nm/s (±1%)				
Wavelength resolution [2]	0.08 pm (10 MHz)				
Absolute wavelength accuracy [1]	< ±1 pm with precision wavelength reference (Option 410) < ±5 pm with wavelength reference (Option 402) < ±30 pm in fixed wavelength mode < ±1 nm in swept mode without wavelength reference				
Wavelength repeatability [2]	< ±1 pm with precision wavelength reference (Option 410) < ±5 pm with wavelength reference (Option 402) < ±30 pm in fixed wavelength mode < ±100 pm in swept mode without wavelength reference				
Wavelength resolution	0.1 pm				
Wavelength stability [3]	< ±2.5 pm				
Tuning linearity [1]	< ±1 pm in swept mode with precision wavelength reference (Option 410) < ±5 pm in swept mode with wavelength reference (Option 402) < ±80 nm in swept mode without wavelength reference				
Linewidth	< 50 MHz				
Side mode suppression (SMSR)	> 50 dBc typical				
Optical shutter	> 80 dB extinction available with integrated optical shutter/automatic dark calibration (Option 310)				
RIN	-140 dBc (0.1 GHz to 1.0 GHz); -150 dBc/Hz (1 GHz to 2.5 GHz) typical				
Connector	FC/APC standard; FC/APC-PM available				
Trigger output	+5 volt trigger at beginning of continuous sweep				
Remote interfaces	GPIB (IEEE 488); Ethernet; USB Flash Drive				
Power	90-240 VAC				
Environmental: Operating	+10 ºC to +32 ºC (+55 ºF to +90 ºF); < 80% RH non-condensing				
Environmental: Storage	-20 ºC to +70 ºC (-4 ºF to +158 ºF); < 80% RH non-condensing				
Size	16.8” width x 16.4” depth x 5.25” height (42.6 cm x 41 cm x 10.5 cm)				
Weight	6 lbs (2.7 kg)				
Shock/vibration	ISTB Procedure 2B; 100G non-operating				
Laser safety	Class 3B (FDA 21 CFR 1040.10); Class 3A (IEC 825-1; 1993)				

*** Most common for optical component test applications.**

NOTE: All specifications measured with one-hour warm up and constant temperature 23 ºC (±2 ºC).
CAUTION: Viewing the laser output with certain optical instruments (e.g., eye loupes, magnifiers, microscopes) within a distance of 100 mm may pose an eye hazard.

1 Using installed wavelength correction option if noted, see Option 402 for specifications or Option 410 for operating parameters
2 1 pm in step mode
3 In fixed wavelength mode
4 0.1 nm bandwidth; signal to max ASE; 1-3 nm from carrier
5 0.2 nm bandwidth; signal to max ASE; > 5 nm from carrier
6 Signal to total ASE > 0.5 nm from carrier
7 Measurement taken at maximum rated power

Miscellaneous Option Specifications and Descriptions

Note: Each model/unit has an Options and Ordering Information sheet. Refer to this sheet to determine option availability.

Option	Description	Specifications
310	Optical shutter/automatic dark calibration	"Off" blocking: > 100 dB
		Wavelength range: 700-1700 nm
501	Bare fiber adapter, low stress, easy alignment	N/A
502	Bare fiber to FC adapter	N/A
692	Laser diode source module. Select one laser diode. (Up to 5 total laser diode sources; order additional sources using 692X-wwww.)	N/A
692X	Additional laser diodes for 692-wwww. Includes switch. Select up to 4.	N/A
705	Rack ears (4000 Series)	N/A
740	Internal GPIB controller (required to automatically control external TLS or external polarization controller)	Allows control of external TLS or external polarization controller
940	Internal optical return loss (ORL) module	ORL measurement range dependent on test system configuration: > 55 dB under most conditions; > 70 dB with optimal configurations. (See Application Note 2004-014A.)
956	Automated matrix method PDL/IL measurement	Works in conjunction with customer's Agilent/HP 8169A polarization controller. Requires Option 740.
972	Built-in source split with switches for 2 DUTs	Additional PDL: +0.015 PDL
973	Built-in source split with switches for 3 DUTs	Additional PDL: +0.040 PDL
974	Built-in source switch for 2 external lasers	N/A
974-PM	Built-in PM source switch for 2 external lasers	N/A
975	Built-in source switch for 3 external lasers	N/A
976	Built-in source switch for 4 external lasers	N/A
982	Built-in source split for 2 DUTs	Additional PDL: +0.015 PDL
983	Built-in source split for 3 DUTs	Additional PDL: +0.040 PDL

* Contact the factory for extended specification, custom-designed, and OEM products or specials.
* Technical data subject to change.