Polarization-dependent loss measurements using modular test system configurations
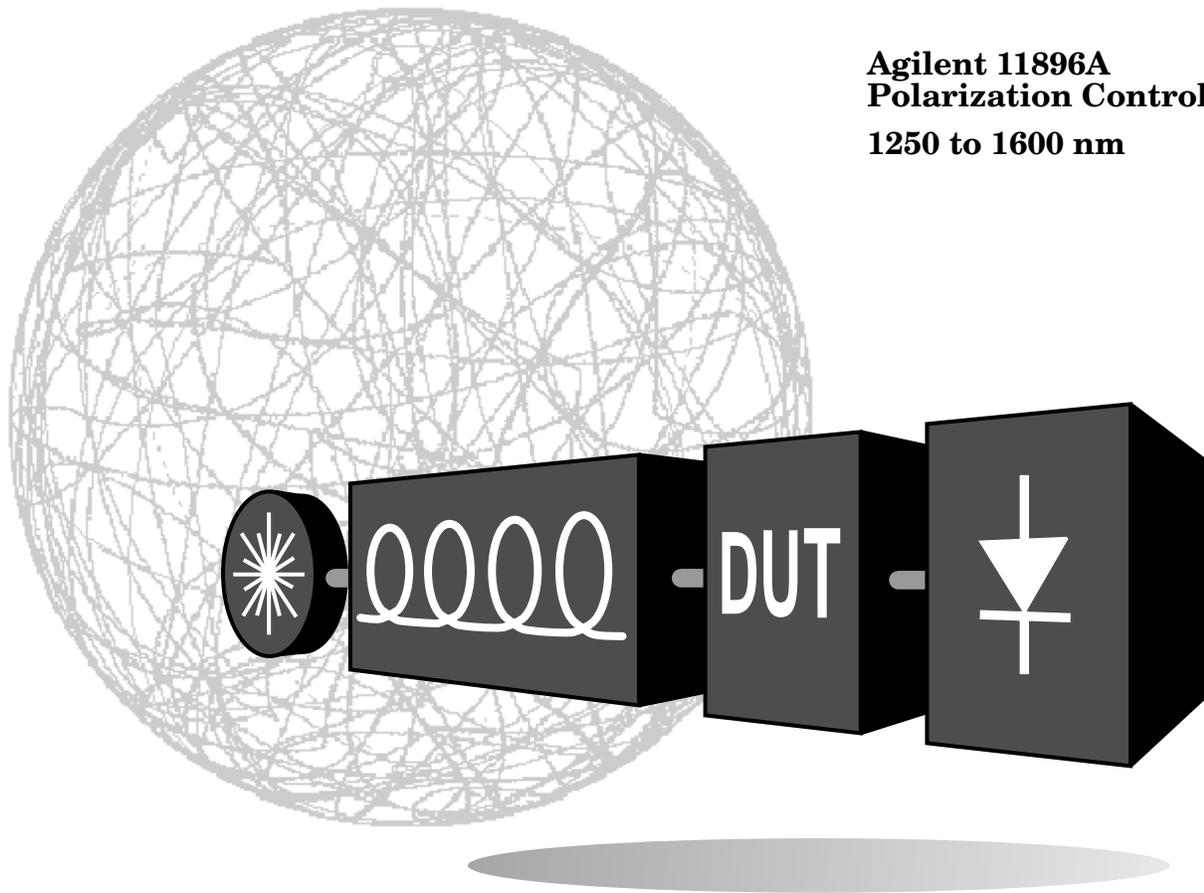
Product Note 11896-2

Agilent 11896A
Polarization Controller

1250 to 1600 nm

Contents

Introduction

Polarization-dependent loss (PDL) is a major concern for scientists and engineers because analog and digital signals are adversely affected by too much or too little PDL. The PDL of optical components and systems can be accurately measured using the measurement methods described in this product note. The Agilent 11896A Polarization Controller is an important part of these measurement methods.

This product note discusses the concept of PDL and gives examples of typical values that are expected for common light-wave components.

Four PDL measurement methods are presented:

• Agilent 8153A/11896A Power Meter Method

• Agilent 8509/11896A Power Max/Min Method

• Agilent 71451B/11896A Swept-Wavelength Method

• Agilent 83438A/71452B/ 11896A Swept-Wavelength Method for WDM Components

Each measurement method presentation is organized in order of: measurement overview, example data, measurement setup, measurement procedure and uncertainty analysis.

Achieving the best measurement results depend on selecting the proper measurement method for the application.

Various Agilent instruments are described in this product note. Refer to the appropriate users manuals for complete operation and performance information.

Description of polarization-dependent loss

Polarization-dependent loss (PDL) for a component or system is the maximum, peak-to-peak insertion loss (or gain) variation caused by a component when stimulated by all possible polarization states (see Figure 1). It is specified in dB units. Polarization-dependent loss may also be referred to as polarization sensitivity, polarization-dependent gain (PDG) or extinction ratio (for optical polarizers).

Some components are designed for maximum PDL. A linear optical polarizer, for example, must have high PDL in order to convert unpolarized light into linearly polarized light. Only one orientation of linearly polarized light passes through the polarizer unattenuated. Misaligned orientations of polarized light are attenuated by the polarizer's PDL.

In other situations, any amount of PDL is a liability. Long-haul telecommunication systems, for example, are more cost effective as transmission distances between amplification stages become longer. Transmission-distance calculations are partly based on guaranteed power levels. Large variations in system power occur as the PDL of individual system components randomly combine. This makes power-budget calculations more difficult, expands design margins and reduces guaranteed performance.

Typical PDL values

Almost all optical components have some amount of PDL. PDL values range from less than 0.05 dB for optical connectors and cables to greater than 30 dB for optical polarizers (see Table 1).

Table 1.
Typical PDL for Common Lightwave Components

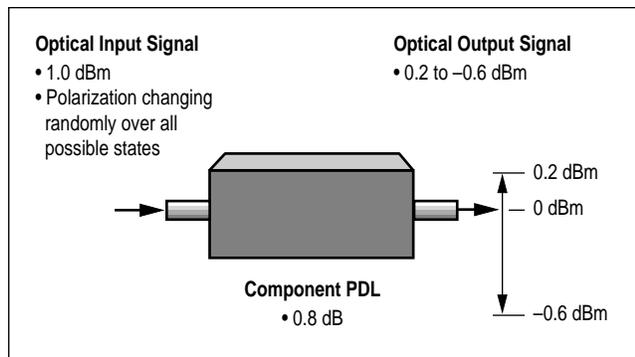| Component Description	Typical PDL
Single-mode fiber:	
1.0 meter length	<0.02 dB
10 Km length	<0.05 dB
Optical connector:	
Straight	<0.05 dB
Angled	<0.1 dB
Open beam launch	<0.3 dB
Isolator	<0.3 dB
Coupler	<0.1 dB
Polarizer	>30 dB
Erbium doped fiber amplifier	<0.4 dB

Figure 1. Polarization-dependent loss causes power variations.

Agilent 11896A polarization controller description

The Agilent 11896A adjusts polarization and not power and is an important part of a PDL test system. Its optical fiber loop design, shown in Figure 2, provides all states of polarization (see Figure 3) with extremely small optical insertion-loss variations (0.004 dB) over a 1250 to 1600 nm spectral range. This performance combination maximizes measurement accuracy for power sensitive PDL measurements (see Figure 4).

The Agilent 11896A adjusts the polarization of a transmitted signal as it passes through the internal four-fiber-loop assembly. Each loop's dimensions are optimized to approach a quarter-wave retarder response over the controller's specified wavelength range. Complete and continuous polarization adjustability is achieved by independently rotating each loop over a 180° angular range. This range is divided into 1000 equal steps (front panel reading 000 to 999), providing adjustment resolution of 0.18°. Adjustments are made manually, using front panel knobs, or automatically, using remote GPIB commands or built-in autoscanning control and Save/Recall registers.
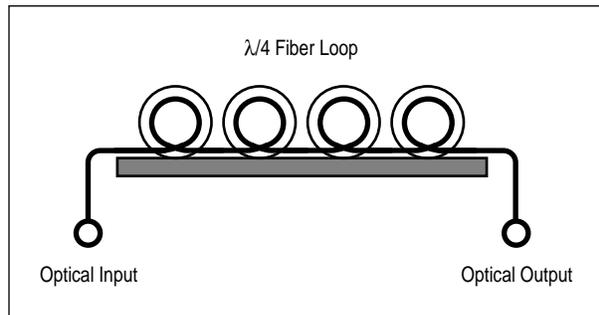

λ/4 Fiber Loop

Optical Input

Optical Output
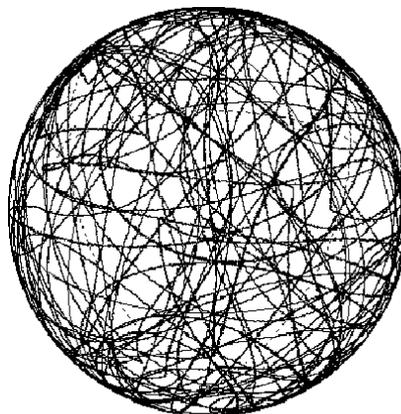
Figure 2. Agilent 11896A block diagram

Figure 3. The Agilent 11896A produces all states of polarization and covers the entire Poincare sphere in a pseudo-random manner.

Lightwave Source

Agilent 11896A Polarization Controller
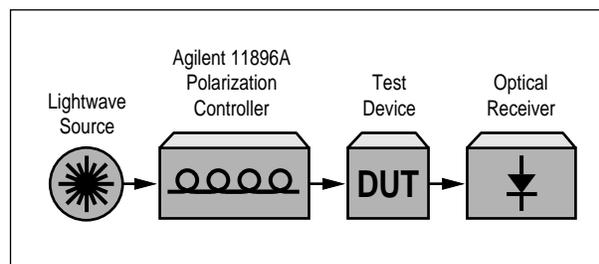
Test Device

DUT

Optical Receiver

Figure 4. Conceptual diagram of Agilent 11896A applications in a polarization-dependent loss measurement system

Select the proper PDL measurement method

Table 2 shows the typical PDL measurement capabilities of each method compared to possible performance requirements. The power and PDL ranges shown in this table will be referred to throughout this document. Use this table to decide which measurement method is most appropriate for a specific application.

**Table 2.
PDL measurement method performance comparison**

Among the three methods offered, the Power Meter Method offers the highest single-wavelength PDL measurement accuracy. This method is well suited for general-purpose applications.

The Power Max./Min. Method provides single-wavelength PDL data plus polarization state information about which relative states of polarization create maximum and minimum power points. These power points can be recreated and device performance adjusted using the assistance of a Poincare sphere display and Stokes parameter data.

The Swept-Wavelength Method delivers high-speed measurements of PDL across a specified wavelength span. This method is ideal for wavelength-division-multiplexing applications where single-wavelength PDL information is not sufficient.

Note that the PDL Measurement Ranges shown in Table 2 relate to the Measurement Accuracy. PDL values greater than the ranges shown can be measured however measurement accuracy may decrease and measurement time (also known as scan time) will increase.

	Measurement Method			
				Swept-Wavelength Method
	Power Meter Method	Power Max/Min Method	Swept-Wavelength Method	for WDM Components
Performance Requirement	Agilent 8153A/11896A	Agilent 8509/11896A	Agilent 71451B Option 002/003	Agilent 71452B/11896A
Measurement Accuracy				
Worst-Case Value	<±0.011 dB	<±0.1 dB	<±0.1 dB	<±0.1 dB
RSS Value	<±0.007 dB	<±0.06 dB	<±0.05 dB	<±0.06 dB
(Typical repeatability)	(±0.001 dB)	(<±0.01 dB)	(±0.01 dB)	(±0.01 dB)
PDL Measurement Range				
(based on accuracy)	0 to 3.0 dB	0 to 30.0 dB	0 to 5.0 dB	0 to 2 dB
Wavelength Range	1250 to 1600 nm	1250 to 1600 nm	1250 to 1600 nm	1525 to 1565 nm
DUT Output Power Range	+3 to −50 dBm	+10 to −55 dBm	0 to −65 dBm/nm	−10 to −70 dBm/nm
Approximate Test Time	10 sec.	10 sec. to 1.5 min.	5 min.	1 to 5 min.
Automatically-Swept Wavelength	No	No	Yes	Yes
Polarization Information	No	Yes	No	No

Polarization-dependent loss measurements

Agilent 8153A/11896A power meter PDL test system

The Agilent 8153A/11896A power meter-based PDL test system provides high-accuracy, single-wavelength, PDL data. During this measurement, the Agilent 8153A Lightwave Multimeter monitors output power variations and displays the PDL values (see Figures 5). The polarization state of the test signal is continually and automatically adjusted using the Agilent 11896A Polarization Controller shown in Figure 6.

Measurement procedure

This 11-step procedure enables single-wavelength PDL measurements to be performed on an Agilent 8153A/11896A power meter-based PDL measurement system.

The Agilent 8153A Lightwave Multimeter should be equipped with the MinMax automatic measurement feature before beginning this procedure. Contact an Agilent representative to upgrade an Agilent 8153A Lightwave Multimeter with this feature if "MinMax" does not appear in step #4 below.

Agilent 8153A settings (1/2):
1. Press **Chan** to activate the power sensor channel. Channel B is assumed.

2. Press **Param** several times until the measurement averaging time T appears in the lower-right side of the display. Enter a 20 ms averaging time by using the Modify up-and-down keys.
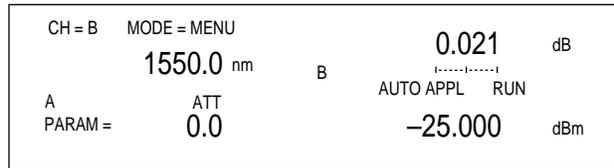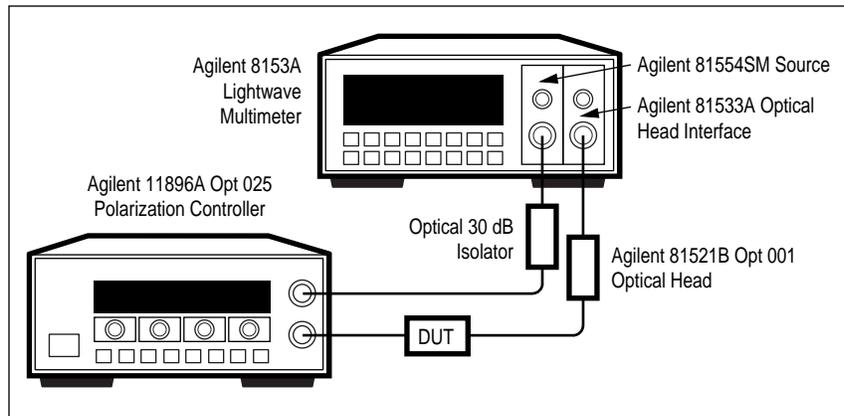
Figure 6. Setup for PDL measurements using the Agilent 8153A/11896A power meter based PDL measurement system

3. Press **Mode.**

4. Press **Record** (under the Applications section of the front panel) several times until MinMax-C appears. If the "C" in MinMax-C does not appear press Edit and then the Modify up-and-down keys until CONT appears. Press **Edit** again to return to the main menu. (Contact an Agilent representative for an Agilent 8153A firmware upgrade if "MinMax" does not appear).

5. Press **Exec.**

Agilent 11896A settings (1/1):
6. Press **SCANRATE.**

7. Use the far right knob to select **SCAN RATE: 5** and press **ENTER.** Refer to the Uncertainty Analysis of this measurement for information about scan rate selection.

8. Press **AUTOSCAN.**

9. When 0:10 (10 seconds) appears in the scan time indicator, press **Manual.** This stops the polarization scan. 10 seconds is the recommended polarization scan time (also referred to as measurement time) for PDL values of <3.0 dB. Refer to the Uncertainty Analysis section of this measurement for a discussion of recommended scan times for PDL values greater than 3.0 dB.

Agilent 8153A settings (2/2):
10. The measurement is complete. PDL data is displayed in the upper right-hand corner of the Agilent 8153A display (see Figure 5).

11. To begin the next measurement, connect a DUT as shown in Figure 6, press **Exec** two times and return to step #8.

Uncertainty analysis

PDL measurement uncertainty for the Agilent 8153A/11896A PDL measurement system is the sum of the measurement system's inherent uncertainty (values shown in Table 3) and the uncertainty created by the measurement's finite scan time relative to the PDL of the test device (see Table 4). Below is an explanation of these terms and an uncertainty calculation.

It is assumed that the DUT output power range is between +3.0 to –50 dBm and the PDL value is <3.0 dB, as shown in Table 2. Actual system performance will vary depending upon the individual performance of the specific equipment in the system. Refer to the Appendix for additional ways to ensure maximum PDL measurement accuracy from a given PDL measurement system.

Inherent PDL measurement system uncertainty contribution:
Individual elements in a PDL measurement system randomly combine to create a system uncertainty contribution value as shown in Table 3.

PDL measurement time and scan rate relationships for uncertainty contribution:
Various PDL measurement conditions may require different power measurement averaging times in order for the Agilent 8153A Lightwave Multimeter to achieve optimum performance. Table 4 shows the relationships between the averaging time, the Agilent 11896A Polarization Controller scan rate and the overall polarization scan time.

All scan time recommendations are based on a DUT PDL of ≤1.0 dB and a 5% scan time uncertainty contribution. The percent-PDL uncertainty equations shown in Table 4 are provided for estimating scan time (also known as measurement time) uncertainty contributions for a given scan time. Figure 7 shows how percent-PDL uncertainty decreases with increased scan time.

Table 3. Agilent 8153A/11896A PDL Measurement System uncertainty contribution calculation

Element Description	Value
Source drift (10 sec. test time)	<0.001 dB
Agilent 11896A loss variation	<0.004 dB
Effective power sensor PDL	<0.005 dB
Power sensor linearity	<0.001 dB
Connector pair PDL	<0.02 dB

Measurement System Uncertainty Contribution

Worst case	
Fusion spliced	0.011 dB
Connectors	0.031 dB
RSS case	
Fusion spliced	0.007 dB
Connectors	0.021 dB

Table 4. Relationships between Agilent 8153A Power Meter averaging time (T), Agilent 11896A scan rate and polarization scan time

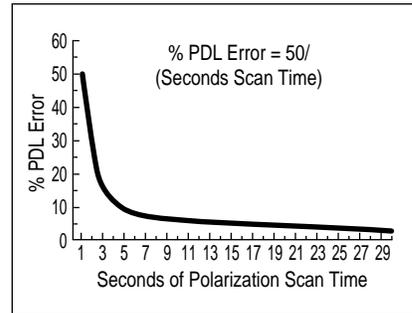| Optical Power Meter Averaging Time (T)	Scan Rate	Scan Time	% PDL Uncertainty versus Scan Time (ST in sec.)
20 msec	5	10 sec	(50/ST)%
50 msec	4	25 sec	(125/ST)%
100 msec	3	50 sec	(250/ST)%
200 msec	2	100 sec	(500/ST)%

Figure 7. Typical Agilent 8153A/11896A PDL polarization scan time uncertainty contribution (for power measurement averaging time T=20 msec only)

Example of uncertainty calculation:
Below is an example for calculating the worst-case uncertainty for an Agilent 8153A/11896A PDL measurement of 0.3 dB. Values shown are derived from information in Tables 3 and 4.

Table 5. Uncertainty contribution for an Agilent 8153A/11896A PDL Measurement System

Measurement Conditions

DUT's measured PDL value	0.3 dB
Power measurement averaging time (T)	20 msec
Scan time (ST)	10 sec

Uncertainty Contributions

System uncertainty:	
Worst case	0.011 dB
RSS case	0.007 dB
Scan time uncertainty (=PDL value x 5%)	0.015 dB

Measurement Uncertainty

Worst case	0.026 dB
RSS case	0.022 dB

Agilent 8509/11896A power max./min. PDL test system

The Agilent 8509/11896A Power Max./Min. PDL test system is a semi-automatic, single-wavelength PDL measurement system. It provides a PDL value and absolute maximum and minimum power values and polarization information (see Figure 8).

The Power Max./Min. PDL measurement method is similar to the Agilent 8153A/11896A power meter method discussed in this document. During this measurement, the Agilent 8509A or 8509B Polarization Analyzer monitors the average output power and state of polarization. PDL Markers are automatically placed on the Poincare sphere (see Figure 8) to indicate the points at which optical power maximum and minimum occur. The respective Stokes parameters for the Max. and Min. points are also shown in Figure 8. The polarization state of the test signal is automatically adjusted using the Agilent 11896A Polarization Controller shown in Figure 9.

PDL Markers and Max./Min. Stokes parameters help the user reproduce the Max. and Min. power polarization states if further analysis or DUT adjustment is required.
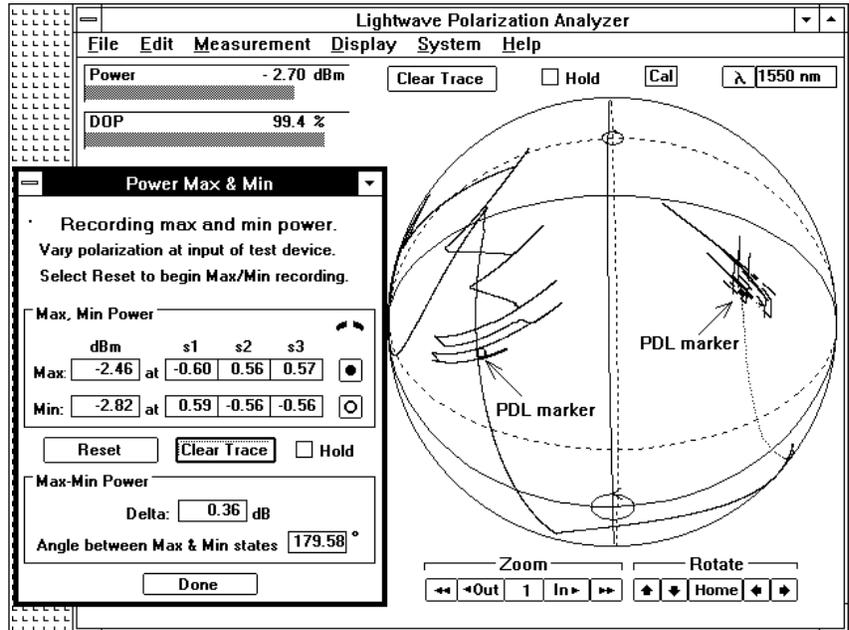

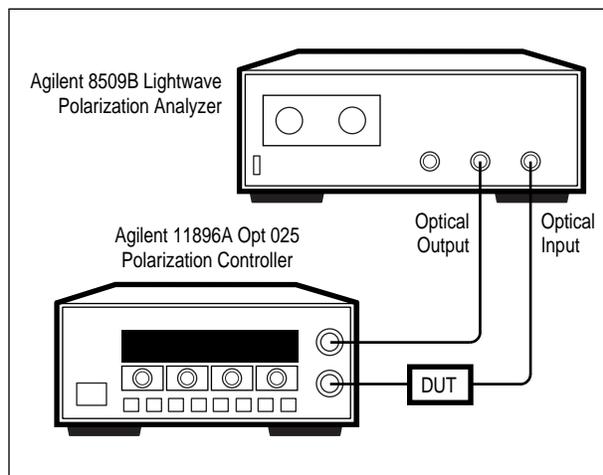**Figure 8. Typical display for Agilent 8509/11896A Power Max./Min. PDL Measurement System**

Figure 9. Setup for PDL measurements using the Agilent 8509/11896A Power Max./Min. PDL measurement system

Measurement procedure

This eight-step procedure enables single-wavelength PDL and polarization measurements to be made on the Agilent 8509/11896A Power Max./Min. PDL test system. It is assumed that the Agilent 8509 optical source settings have already been completed.

Agilent 8509 settings (1/2):
1. Use the computer mouse to select **Measurement, PDL: Power Max – Min.**

2. Select **Reset.**

Agilent 11896A settings (1/1):
3. Press **SCANRATE.**

4. Use the far right knob to select **SCAN RATE: 5** and press **ENTER.** This scan rate is slow enough for the measurement rate of the Agilent 8509 yet fast enough to perform an accurate measurement in a short amount of time.

5. Press **AUTOSCAN.**

6. When 0:10 (10 seconds) appears in the scan time indicator, press **Manual.** This stops the polarization scan. 10 seconds is the recommended polarization scan time (also referred to as measurement time) for PDL values of <3.0 dB. PDL values greater than 3.0 dB will require more polarization scan time. As a general rule, let the polarization scan continue until the value of the "Angle between Max & Min states", shown in Figure 8, is between 150 to 180 degrees. This is the angle between the Max. and Min. PDL markers on the Agilent 8509 Poincare sphere display.

Agilent 8509 settings (1/2):
7. The measurement is complete. PDL data is shown in the "Max-Min Power" data box (see Figure 8).

8. Begin another measurement by selecting **Reset** and returning to step #5.

Uncertainty analysis

Measurement uncertainty for the Agilent 8509/11896A Power Max./Min. PDL test system is shown in Table 6.

Table 6. Agilent 8509/11896A Power Max./Min. PDL Test System uncertainty calculation

Element Description	Value
Internal source drift	<0.01 dB (typical)
Agilent 11896A loss variation	<0.004 dB
Power sensor PDL	0.02 dB
Power linearity	0.05 dB
Connector pair PDL	<0.02 dB
Measurement Uncertainty	
Worst case	0.104 dB
RSS case	0.058 dB

It is assumed that the PDL of the DUT is less than 3.0 dB and the Agilent 8509 optical input power is between +10 to –55 dBm at all times during the measurement, as shown in Table 2.

Refer to the Appendix for additional ways to ensure maximum possible PDL measurement accuracy from a given PDL measurement system.

Agilent 71451B/11896A swept-wavelength PDL test system

The Agilent 71451B/11896A Swept-Wavelength PDL Test System provides a high-speed method for measuring PDL across a 1250 to 1600 nm wavelength range. Measurement data examples are shown in Figures 10 and 11.

This measurement uses the Agilent 71451B Optical Spectrum Analyzer to monitor changes in DUT insertion loss versus wavelength. Automatically swept wavelength coverage is provided by the built-in, white-light source and monochromator of the Agilent 71451B Option 002 (see Figure 12). The test signal's polarization state is automatically adjusted using the Agilent 11896A Polarization Controller (included as part of the Agilent 71451B Option 003). PDL calculations are done automatically using the built-in down loadable program provided on a memory card (included as part of the Agilent 71451B Option 003).

Measurement procedure

This 14-step procedure enables PDL measurements to be performed over a specified wavelength span. It is assumed that Agilent 71451B Optical Spectrum Analyzer has already been configured and the PDL down-loadable program card (included with the Agilent 71451B Option 003) has already been installed according to the instructions included with the Option 003 documentation.

Agilent 71451B settings (1/2):
1. Activate the swept polarization-dependent loss measurement personality by pressing
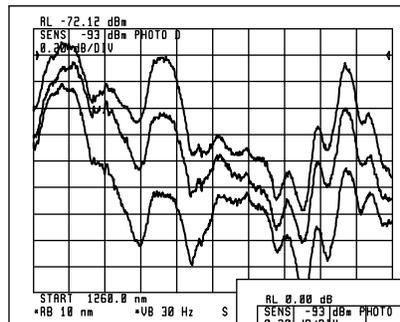

Figure 10. Agilent 71451B Option 002/003 automatically traces maximum and minimum power points measured during a swept PDL measurement.
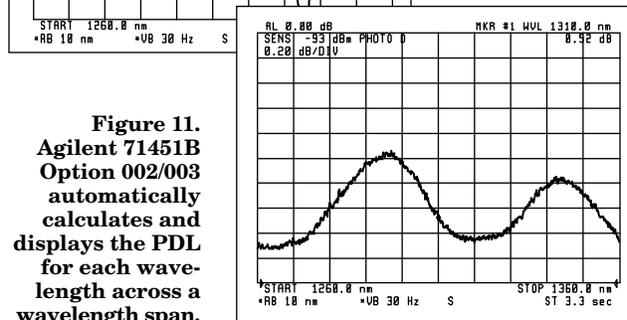

Figure 11. Agilent 71451B Option 002/003 automatically calculates and displays the PDL for each wavelength across a wavelength span.

USER and then **PDL.**

2. Press **Detectr Internal Ext** so that Ext is underlined indicating that an external photodetector is being used.

3. Press **Source On Off** so that On is underlined indicating an On condition.

4. Set the start and stop wavelengths for the measurement using the **Start** and **Stop** keys on the keypad.

5. Press the **RES BW AutoMan** softkey and set the resolution bandwidth to 10 nm. This resolution bandwidth setting is for the greatest measurement range and signal-to-noise performance. Narrower bandwidths can be used if greater wavelength resolution is required.

6. Wait for at least one sweep of the entire wavelength span to be completed and press **AUTO SCALE.**

7. If the noise level of the measurement is not acceptable it can be adjusted by using the video bandwidth filter. Note that a reduction in the video bandwidth reduces the noise floor and automatically increases the measurement sweep time. Press **VID BW AutoMan** and use the up/down arrows to adjust as needed.

8. Begin the PDL measurement by pressing **INIT PDL.** This activates the maximum and minimum hold function which generates a set of traces from the maximum and minimum power points encountered at each wavelength during the measurement.

Agilent 11896A settings (1/1):
9. Press **SCANRATE.**

10. Use the far right knob to select **SCAN RATE: 1** and press **ENTER.** Refer to the Uncertainty Analysis for this measurement for further information about scan rate selection.

11. Press **AUTOSCAN.**

12. When 05:00 (5 minutes) appears in the scan time indicator, press **Manual.** This stops the polarization scan. Refer to the Uncertainty Analysis for this measurement for further information about a 5 minute scan time recommendation.
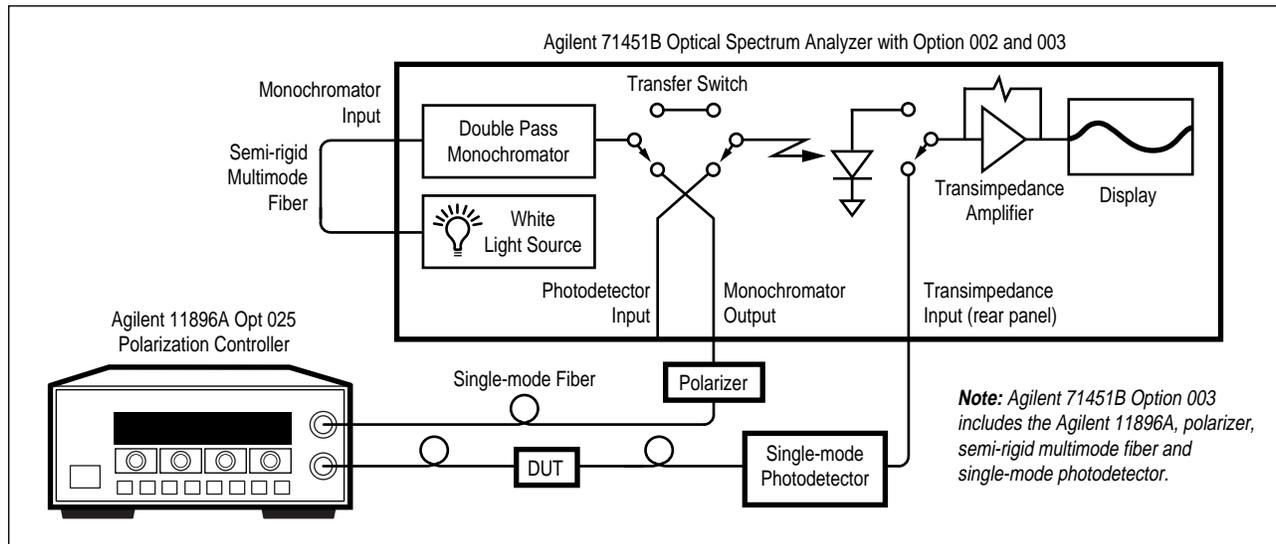
Figure 12. Setup for swept-wavelength PDL measurements using the Agilent 71451B Option 002/003 and the Agilent 11896A

Agilent 71451B settings (2/2):
13. PDL across the measured wavelength range is automatically calculated and graphically displayed by pressing **CALC+ DISPLAY.** Press **AUTO SCALE** and marker functions as needed to optimize the view of the measurement trace.

14. To test additional devices, connect a new test device as shown in Figure 12 and return to step #8.

Uncertainty analysis

PDL measurement uncertainty for the Agilent 71451B/11896A Swept-Wavelength PDL Test System is based upon the inherent uncertainty of the measurement system (values shown in Table 7).

It is assumed that the Agilent 71451B Option 002 white light source is used and the PDL value is between 0 to 5 dB, as shown in Table 2. The Agilent 11896A Polarization Controller scan time should be long enough to allow the maximum and minimum traces (shown in Figure 10) to stabilize. Actual system performance will vary depending upon the individual performance of the specific equipment in the system.

Refer to the Appendix for additional ways to ensure maximum possible PDL measurement accuracy from a given PDL measurement system.

Table 7. Agilent 71451B Option 002/003 and Agilent 11896A Swept-Wavelength PDL Measurement System uncertainty calculation

Element Description	Value
White light source drift	<0.01 dB (typical)
Agilent 11896A loss variation	<0.004 dB
OSA Detector PDL	<0.04 dB (typical)
Scale fidelity	<0.02 dB (typical)
Signal digitization	<0.01 dB
Connector pair PDL	<0.02 dB (typical)
Measurement Uncertainty	
Worst case	0.104 dB
RSS case	0.051 dB

Additional information about swept-wavelength Agilent 71451B settings and polarization scan rate

Typical Agilent 71451B Option 002 (white light source option)/003 (swept PDL measurement kit with Agilent 11896A included) settings are shown below. The PDL down loadable program (included with Option 003) automatically sets values to within these typical ranges.

Wavelength range	1250 to 1600 nm
Measurement wavelength span	100 to 350 nm
Reference level	≤50 dBm
Resolution bandwidth	10 nm
Video bandwidth	30 to 300 Hz

Under these conditions and an Agilent 11896A Polarization Controller scan rate of 1, the Agilent 71451B is able to make an entire sweep at approximately the same polarization state. Over a five minute period, a sufficiently large sampling of random polarization states can be measured in order to accurately measure PDL over a specified wavelength range.

Agilent 83438A/71452B/ 11896A swept-wavelength measurement of DWDM components

The Agilent 83438A #009/71452B/ 11896A setup as shown in Figure 13 characterizes components for dense wavelength-division multiplexing (DWDM) applications fast and accurately versus wavelength. Under remote control, it can measure insertion loss, crosstalk and PDL automatically. Other characteristics can be calculated too, such as the polarization dependence of the center wavelength or bandwidth of a filter.
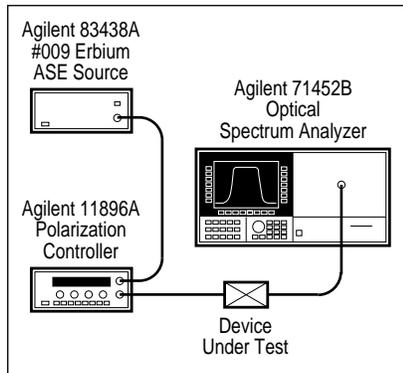

Figure 13.

The Erbium ASE Source Agilent 83438A with option 009 provides polarized light in the range 1525 to 1565 nm. Its polarization state is automatically randomized using the Agilent 11896A Polarization Controller. If the Agilent 11896A runs fast and the Agilent 71452B Optical Spectrum Analyzer averages 100 or more sweeps, then the resulting trace represents the loss versus wavelength of unpolarized light.

However, if the Agilent 11896A runs slowly and the Agilent 71452B Optical Spectrum Analyzer sweeps quickly, then trace A of the OSA can capture the maxima and trace B the minima of each sweep. The difference between trace A and trace B shows the polarization dependent loss versus wavelength. For low PDL values (<1 dB), the average of the two traces is approximately the insertion loss for unpolarized light.

Measurement procedure

This procedure enables PDL measurements to be performed over a specified wavelength span which is equal to or less than the width of the source used in the test system. The best setting for the Agilent 11896A depends on the OSA. The following explains the procedure and the relationship between the Agilent 11896A and the OSA for the best measurement results.

Agilent 11896A settings:

In this setup, the Agilent 11896A AUTO SCAN mode is used. However, what scan rate is the best? To minimize the overall measurement time, the scan rate should not be too slow. To measure the PDL at one state of polarization, that state should stay long enough for the OSA to complete a sweep; therefore the OSA sweep speed should be appropriately fast.

Table 8 lists the relationship between displayed scan rate and the time Tc required for one great circle on the Poincaré sphere. The Agilent 11896A randomizes the SOP. Therefore, the time Tc is only a statistical measure.

The actual time may be longer or shorter. The SOP rarely moves exactly along a great circle. Rather it rather moves in a figure "8" as well as other figures along the whole surface of the Poincaré sphere.

Agilent recommends that Tc be about ten to forty times larger than the sweep time of the OSA. In this case the state of polarization changes little during a single OSA sweep. The total measurement time should exceed twenty to fifty times Tc, so that the Agilent 11896A exposes the DUT to all SOPs during hundreds of OSA sweeps.

In the example below, the OSA sweeps in 110 ms. From Table 8 we selected the scan rate 3 (Tc = 3 sec is greater than 20 * 110 ms) and let the measurement run for two minutes (40 * Tc).

Table 8. Typical Agilent 11896A times to statistically complete one great circle on the Poincaré sphere

Displayed Scan Rate	Statistical Time For a Great Circle Tc (seconds)
1	12
2	6
3	3
4	1.2
5	0.6
6	0.3
7	0.25
8	0.2

Agilent 71452B settings:

Set wavelength and amplitude settings to match the device under test. In the example shown here, START is 1542 nm, STOP is 1562 nm, and resolution bandwidth (RES BW) is 0.2 nm. Our DUT has approximately 7 dB insertion loss.

1. Connect the DUT as shown in Figure 13. Activate the light source and let the Agilent 11896A scan.

2. AUTO ALIGN the OSA, then set its wavelength range and resolution as desired.

3. Select an appropriate vertical scale: press **PEAK SEARCH**, then **TO REF LEVEL**, then **Ampt**, **LOG dB/DIV** and enter 1 dB.

4. Set **SENS**itivity to –60 dBm. If necessary, increase the sensitivity. Watch the sweep time (ST).

5. Set the **SCAN RATE** of the Agilent 11896A Polarization Controller as discussed above (e.g., scan rate 3).

6. Press **Traces**, **CLEAR WRT A**. Wait until at least one sweep has been completed, then press **MAX HOLD A**.

7. Activate **trace B** and **CLEAR WRT B**. Wait until at least one sweep has been completed, then press **MIN HOLD B**. Then activate trace C.

8. Adjust the vertical scale (e.g., **Ampt**, **LOG dB/DIV**, 0.2 dB)

9. Wait a sufficient time (2 minutes in this example), then stop the sweep (**BW**, **Swp**, **SINGLE SWEEP**).

Calculate the PDL: press **Traces**, **MORE**, **trace logmath**, **A <- A-B**. Trace A now contains the peak-to-peak PDL, but it may be out of the display. Press **Ampt**, **REV LVL** 0 dB, then **MORE**, **REF LVL POSN** 0 <enter>. This sequence causes the OSA to display 0 dB PDL at the bottom of the screen. Use **Ampt**, **LOG dB/DIV** to adjust the scale.
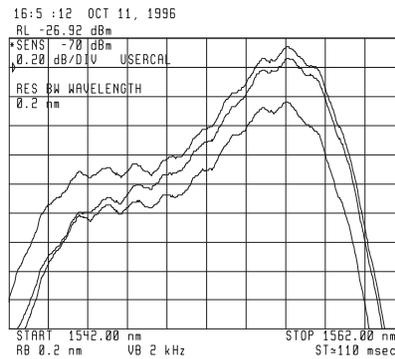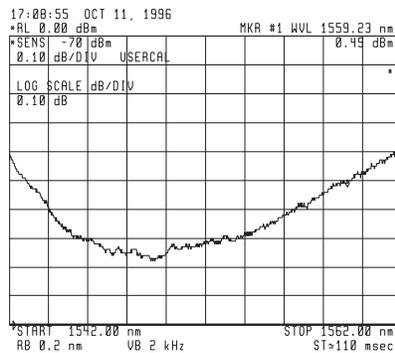

Figure 14. Raw measurement data

Figure 15. PDL of a material probe

Uncertainty analysis

The uncertainty of the measurement result depends on the DUT. Many components and materials have less than 2 dB PDL. The following analysis considers two examples. One has 2 dB PDL and the other 0.2 dB (see Table 9). The measurement uncertainty for such devices is ±0.12 and ±0.06 dB, respectively.

The degree of polarization of the Agilent 83438A with option 009 is 95% to 99%. For devices with high PDL (>2 dB), the amount of un-polarized light contributes most to measurement errors. In the range 2 to 10 dB PDL, the error is up to 10% of the PDL measured. Above 10 dB it increases even more; therefore Agilent does not recommend this setup any more.

Table 9. Agilent 83438A Option 009, 71452B and 11896A measurement setup uncertainty calculation

PDL of DUT	2.0 dB	0.2 dB
Agilent 83438A Source drift	<0.04 dB	<0.04 dB
Agilent 83438A #009 Polarization	<0.21 dB	<0.02 dB
Agilent 11896A Loss variation	<0.004 dB	<0.004 dB
Agilent 71452B OSA		
PDL (peak-peak)	<0.1 dB	<0.1 dB
Scale fidelity	<0.05 dB	0.02 dB
Signal digitization	<0.01 dB	0.01 dB
Connector pair PDL	<0.02 dB	0.02 dB
Measurement Uncertainty		
Worst case	0.43 dB	0.21 dB
RSS case	0.24 dB (±0.12 dB)	0.12 dB (±0.06 dB)

It is possible to further reduce the measurement uncertainty for devices with very low PDL. However, it requires a second Agilent 11896A and sophisticated software running on a remote computer[1] to get up to ±0.025 dB accuracy. The necessary setup and the procedures are very complex and therefore not discussed in this document.

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[1] In order to improve the measurement accuracy, it is important to know the specifications of the device under test. Then Agilent can adapt the algorithms used on the remote computer. For details, contact Agilent and ask for customizing a lightwave measurement system.

Appendix:
General techniques for improving PDL measurement accuracy

Measurement accuracy can be maximized for a given PDL measurement system by taking the following precautions.

1. Minimize the optical insertion loss variations of the polarization controller by using the Agilent 11896A Polarization Controller with Option 025 which provides fiber pigtail interfaces that can be cut and spliced to the test system and to the DUT for minimal reflections.

2. Maintain constant source output power for each wavelength being measured.

3. Use an optical source which approaches 100% degree of polarization (DOP). Unpolarized light will not be attenuated by the PDL of a test device; therefore, the lower the DOP is, the more unpolarized light is available to adversely affect measurement accuracy.

4. Be sure that the DUT's maximum polarization mode dispersion (PMD, also known as differential group delay) is less than one-half of the coherent length of the test signal. PMD values greater than this can depolarize (cause DOP degradation) the test signal and cause PDL measurement errors. PMD measurements can be performed with the Agilent 8509 Lightwave Polarization Analyzer.

5. Be sure the test device and test equipment are thermally stable before beginning a measurement. One-hour warm-up is usually sufficient time for most equipment and components to thermally stabilize.

6. Ensure that the test device and test system's optical fibers do not move during a measurement. The polarization transfer function of a fiber changes with movement because the stress induced birefringence, which affect polarization transfer function, changes with movement. It requires one minute or more for fiber stress patterns to relax and stabilize after a fiber is moved.

7. Connector pairs cause reflections and PDL within the connector interface. Minimize optical reflections and etalons by using proper connector care and fusion spliced connections when possible. For this reason the Agilent 11896A Option 025 is recommended.

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