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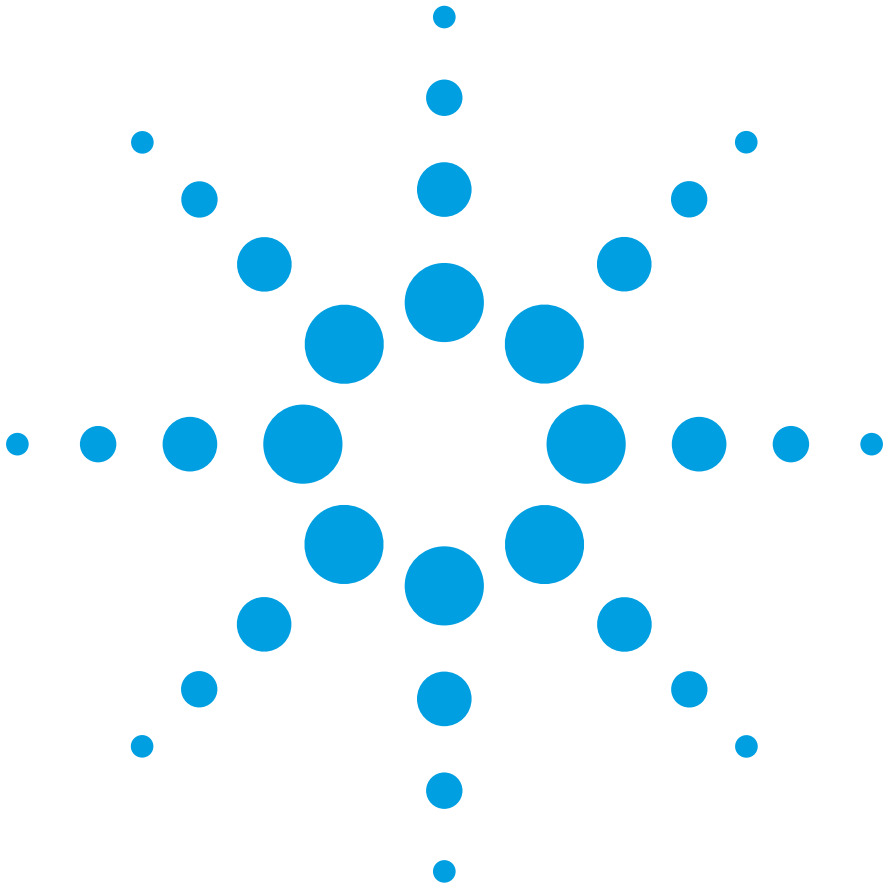
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Agilent 8509A/B Lightwave Polarization Analyzer

User's Guide



Agilent Technologies

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The instruction manual symbol. The product is marked with this warning symbol when it is necessary for the user to refer to the instructions in the manual.


The laser radiation symbol. This warning symbol is marked on products which have a laser output.


The AC symbol is used to indicate the required nature of the line module input power.


| The ON symbols are used to mark the positions of the instrument power line switch.


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ISM1-A This text denotes the instrument is an Industrial Scientific and Medical Group 1 Class A product.

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General Safety Considerations

WARNING **This is a Safety Class 1 Product (provided with a protective earthing ground incorporated in the power cord). The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. Any interruption of the protective conductor inside or outside of the product is likely to make the product dangerous. Intentional interruption is prohibited.**

WARNING **No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock, do not remove covers.**

CAUTION Before switching o this instrument, make sure that the line voltage selector switch is set to the voltage of the power supply and the correct fuse is installed.

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This documentation supports a product that previously shipped under the Hewlett-Packard company brand name. The brand name has now been changed to Agilent Technologies. The two products are functionally identical, only our name has changed. The document still includes references to Hewlett-Packard products, some of which have been transitioned to Agilent Technologies.

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1

Getting Started

This chapter contains the following sections.

- Description of the Instrument
- Installation
- About This Manual Set
- The Main Menu
- The Data Displays (Power, DOP, Ellipse and Poincare Sphere)
- The Marker Functions
- Zoom and Rotate
- (Clear Trace) and Hold
- (λ) and Cal

Description of the Instrument

The HP 8509A/B Lightwave Polarization Analyzer offers high-speed, calibrated polarization measurements of optical signals and components.

Installation

The lightwave polarization analyzer is preconfigured at the factory. All that is required to install the system is to unpack the pieces, correctly connect them, and turn them on. Refer to the "Installation" chapter of the *HP 8509A/B Installation and Quick Start Guide* for complete instructions. The "Installation" chapter also provides instructions for unpacking the system and returning the system to the factory for service.

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About This Manual Set

The HP 8509A/B manual set is made up of three documents.

HP 8509A/B Lightwave Polarization Installation Quick Reference Card	contains an installation procedure.
Installation and Quick Start Guide	contains an installation procedure, and an operation verification procedure to ensure that your analyzer is operating properly.
User's/Reference Guide (this manual)	this is the main manual for the lightwave polarization analyzer. This manual is described in detail later in this chapter.

This guide uses the following conventions:

Button	This represents a button that can be selected on the computer screen to perform an action.
`Menu Item`	This indicates a menu item that can be selected on the computer screen.

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HP 8509A/B User's/Reference Guide Table of Contents (this manual)

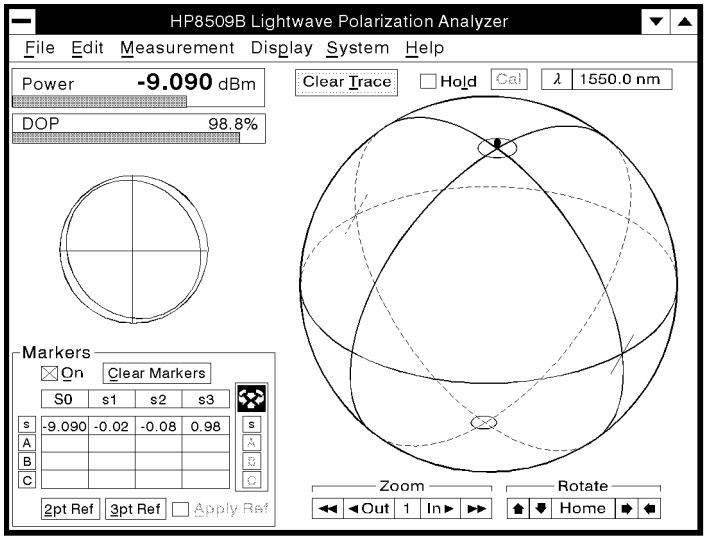
This manual contains the following chapters.

1.	**Getting Started**	describes the HP 8509A/B manual set, and provides a description of the Main Menu screen of the software.
2.	**Making Measurements**	provides step-by-step instructions for making the following measurements. ■ Polarization Mode Dispersion: Jones Matrix Eigenanalysis Method (PMD JME) ■ Polarization Mode Dispersion: Wavelength-Scanning Method (PMD WS) ■ Polarization Dependent Loss: Jones Matrix (PDL JM) ■ Polarization Dependent Loss: Power Max-Min Method ■ Jones Matrix ■ Polarization Maintaining Fiber Alignment ■ Polarization Reference Frame ■ State of Polarization ■ Degree of Polarization
3.	**Accuracy Enhancement and Troubleshooting**	provides procedures for improving the accuracy of measurements and solving measurement problems.
4.	**Printing, Saving, and Recalling Measurement Results and Instrument Configurations**	provides information about the items in the File menu.
5.	**The Display Menu**	provides a description of the items in the Display menu.
6.	**The System Menu**	provides a description of the items in the System menu.
7.	**User Interface Reference**	shows each control and display, the path to reach it, and a description of what it does.
8.	**Lightwave Connector Care**	provides information on caring for the analyzer's connectors.
9.	**Safety and Regulatory Information**	provides licensing, safety, regulatory, cleaning, and environmental information.
10.	**Programming**	provides guidance for programming problems.
11.	**Specifications and Characteristics**	provides performance specifications and characteristics of the lightwave polarization analyzer.
	Glossary	provides an alphabetized list of terms and their definitions.
	Index	provides an alphabetized list of terms with page number references. This is a subject index.
	Appendix	provides specialized background information.

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The Main Menu

This chapter describes the functions that are available from the basic measurement screen. Subsequent chapters describe functions that are accessed through the main menu shown in this screen.



pq716b_c

Figure 1-1. The HP 8509 Basic Measurement Screen

The main menu selections are:

File	Most of the menu items under this selection are explained in the "Printing, Saving, and Recalling Measurement Results and Instrument Configurations" chapter of this manual.
Edit	This selection allows you to copy the display or a measurement window to the Clipboard.
Measurement	The measurement selections are discussed in the "Measurement Applications" chapter of this manual.
Display	The items in the Display menu are discussed in "The Display Menu" chapter of this manual.
System	The system functions are described in the "The System Menu" chapter of this manual.
Help	The online help function is not available at this time.

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The Data Displays (Power, DOP, Ellipse and Poincare Sphere)

Refer to Figure 1-1 for the location of the displays on the basic measurement screen.

Power Display

The power of the optical signal under test is displayed as both a horizontal bar, and a digital readout. When the receiver zeroing routine is being performed, a green "zero" message appears in the power display. Red "Overrange" and "Underrange" messages appear here also.

DOP Display

The Degree of Polarization (DOP) is displayed as both a horizontal bar and a digital readout. For the most reliable and accurate measurements, use polarized light that approaches 100% DOP.

Poincare Sphere

The HP 8509 Poincare sphere is a three-dimensional graphing system showing all possible states of polarization. A dot or trace on the sphere represents the *polarized portion* of the lightwave signals as measured inside the instrument's receiver. The reference frame feature allows the Poincare sphere to display a signal's state of polarization relative to a user-defined reference frame.

ADDITIONAL INFORMATION
Since the Poincare sphere is a three-dimensional representation, it is helpful to know that the graticules (equator and longitude lines) are solid lines on the front of the sphere, and broken lines on the back of the sphere. Data on the front of the sphere is shown in red, and data on the back of the sphere is shown in blue.

Polarization Ellipse

The polarization ellipse provides a two-dimensional visual representation of the state of polarization of an optical signal and corresponds with points on the Poincare sphere.

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The Marker Functions

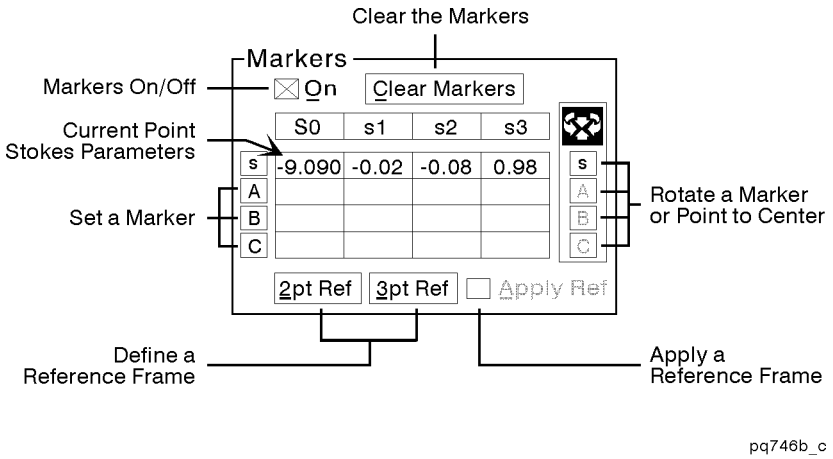


Figure 1-2. The Marker Window

The marker window, in the lower left corner of the HP 8509 display, always displays the Stokes parameters, comprised of the average optical power (S0), in dBm, and the normalized Stokes parameters (s1, s2 and s3). Stokes parameters for the current data point are on the top line (s) of the marker table.

When marker A, B, or C is set, the respective parameters will also be displayed adjacent to the respective marker button (A, B, or C). (For information on Stokes parameters, refer to the "Making Measurements" chapter of this manual.)

The following marker functions are discussed in this section.

- Setting a marker
- Turning the markers on and off
- Clearing the markers
- Centering the sphere on a marker or current point
- Two- and three-point polarization reference frames

Setting a Marker

There are two ways to set markers on the Poincare sphere:

- set a marker at the current data point, *or*
- set a marker at a user-specified point on the sphere (regardless of where the current data point is)

In both of these cases, when a marker is set, the Stokes parameters for the particular marker (A, B, or C) always appears in the table in the Markers window. However, for the marker to appear on the Poincare sphere, the Markers must be turned "on."

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Setting a Marker at the Current Data Point

1. Select (A), (B) or (C) (on the left side of the Marker window) to set a marker on the Poincare sphere at the current data point. (See Figure 1-3.)

   Once a marker has been set, the Stokes parameters for the marker point will be displayed in the marker table.

ADDITIONAL INFORMATION
Once a marker has been set, it is fixed on the sphere and cannot be adjusted to move along a trace.

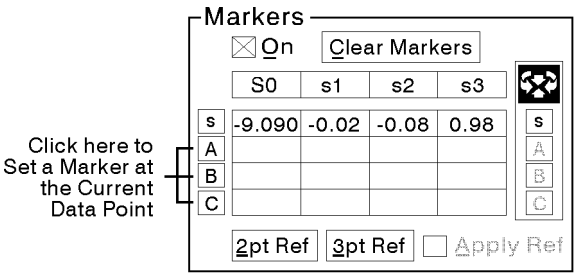


Figure 1-3. Setting a Marker

Setting a Marker at a User-Specified Point

1. Move the mouse pointer to the point on the front face of the sphere where you want to place a marker.
2. Double-click the left button on the mouse.
   The Set Marker window appears below the Poincare sphere (see Figure 1-4).
3. Use the mouse to select A, B, or C to set a marker at the place on the sphere where you double-clicked the mouse.
4. Notice that the Stokes parameters for that point appear in the marker table in the marker window.
5. If you have decided not to set a marker and wish to close the Set marker window, select None.

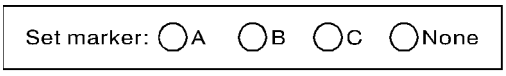


Figure 1-4. Close Set Marker Window

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Turning the Markers On and Off

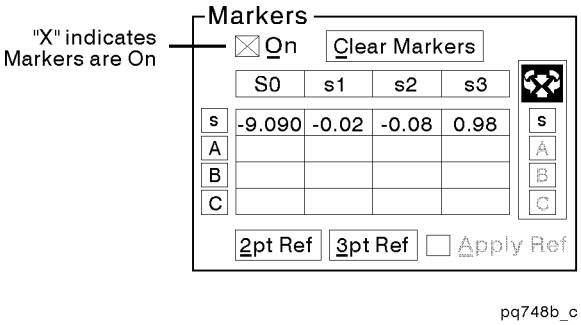


Figure 1-5. Turn Markers On/Off

When the markers are turned on, there is an "X" in the Markers On box (see Figure 1-5).

When the markers are turned on and you set a marker, the Stokes parameters appear in the marker table, and the marker appears on the Poincare sphere.

When the markers are turned off, the Stokes parameters still appear in the marker table, but the marker will *not* appear on the Poincare sphere.

Clearing the Markers

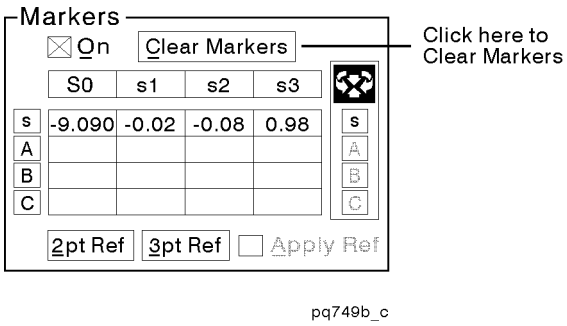


Figure 1-6. Clear Markers

Select Clear Markers to remove the markers from the sphere and clear the Stokes data in the marker table associated with markers A, B, and C.

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Centering the Sphere on a Marker or Current Point

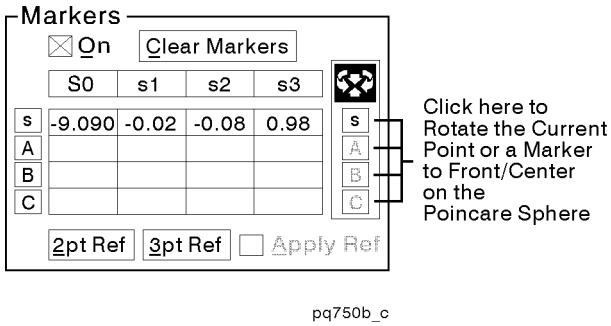


Figure 1-7. Center Sphere on Marker

The buttons along the right side of the marker box correspond to the current data point and the three markers. These buttons can be used to rotate the sphere so that the selected point or marker is front and center.

Two- or Three-Point Polarization Reference

For information on setting a two- or three-point polarization reference frame, refer to the "Making Measurements" chapter of this manual.

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Zoom and Rotate

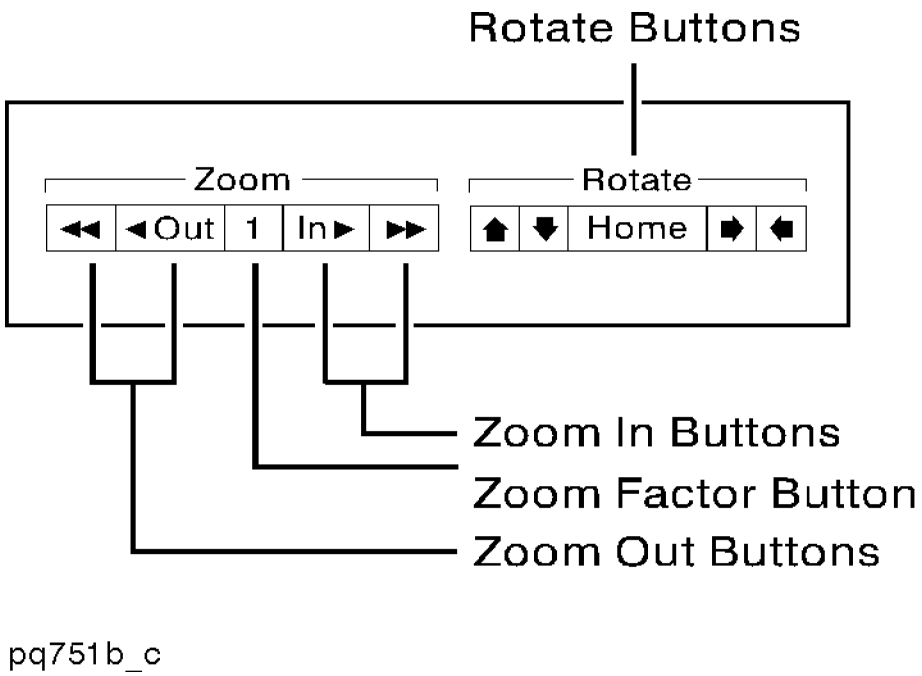


Figure 1-8. Marker Zoom and Rotate

Zoom

To Zoom In

To zoom in on data on the Poincare sphere, select either In ▶ or ▶▶. Use In ▶ to advance the zoom factor in increments of one. Use ▶▶ to advance the zoom factor more rapidly.

To Zoom Out

To zoom out, select either ◀Out or ◀◀. Use ◀Out to decrease the zoom factor in increments of one. Use ◀◀ to decrease the zoom factor more rapidly.

The Zoom Factor Function

You can use the zoom factor function in two ways:

Select this function in a zoomed condition to immediately bring the zoom factor back to 1 without having to use the "Out" buttons.

Select this function when the factor is 1 to set the zoom factor to the most recently visited zoom factor.

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Rotate

To Rotate the Sphere

To rotate the sphere, select any of the four arrows in the Rotate area (see Figure 1-8). The sphere will rotate in the direction of the selected arrow.

The Home Button

To bring the sphere back to the default orientation, select Home.

CAUTION Any time you rotate the sphere, the trace is cleared. The only exception to this is when you are viewing a recalled data trace or a timed measurement. (See the "Printing, Saving and Recalling Measurement Results and Instrument Configurations" chapter in this manual.) In these cases, the recalled trace will not be cleared as the sphere is rotated.

Clear Trace and Hold

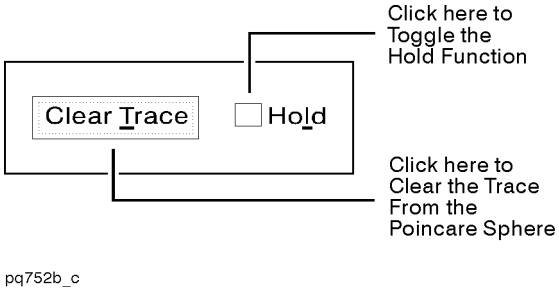


Figure 1-9. Clear Trace and Hold

Clear Trace

Select Clear Trace to clear the Poincare sphere of previously displayed data points. The HP 8509 will immediately resume data display unless the Hold function has been activated.

Hold

When Hold is activated, the HP 8509 does not update the Poincare sphere display, the power display, the DOP display, the polarization ellipse, or the Stokes parameters (in the Marker window). When the Hold function is activated, there is an "X" in the Hold box. Hold is toggled on and off by selecting Hold (see Figure 1-9). Putting the instrument on **HOLD** dramatically speeds up graphics and computational activity in the computer. Put the HP 8509 in **HOLD** when running other software programs.

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λ and Cal

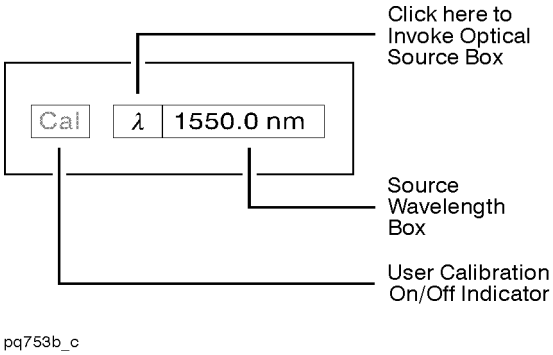


Figure 1-10. λ and Cal

λ

Select λ to show the Optical Source window. Refer to "The System Menu" chapter of this document for more information on the Optical Source window.

Source Wavelength

The source wavelength is displayed next to the λ function.

Cal

The Cal function indicates whether or not a user-performed calibration has been applied. If a wavelength calibration has been applied, the word "Cal" appears in bold (black) lettering. If a calibration has not been applied, the word "Cal" appears in gray lettering. Refer to "The System Menu" chapter of this document for instructions on performing a wavelength specific calibration.

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2

Making Measurements

This chapter contains information on the following measurements.

1. Jones Matrix Eigenanalysis Method, PMD Measurement
2. Wavelength-Scanning Method, PMD Measurement
3. Jones Matrix Method, PDL Measurement
4. Power Max-Min Method, PDL Measurement
5. Jones Matrix Measurement
6. Polarization Maintaining Fiber Launch
7. Polarization Reference Frame Measurement
8. State of Polarization Measurements

Conventions

The measurements in this chapter tend to follow this outline;

- Description of the measurement and an example data display
- Performing a basic measurement
  - Setting up the System
  - Source Preparation
  - Making the Measurement
- Manipulating the Measurement Results
- Specialized Measurements
- Measurement Specific Concept Information

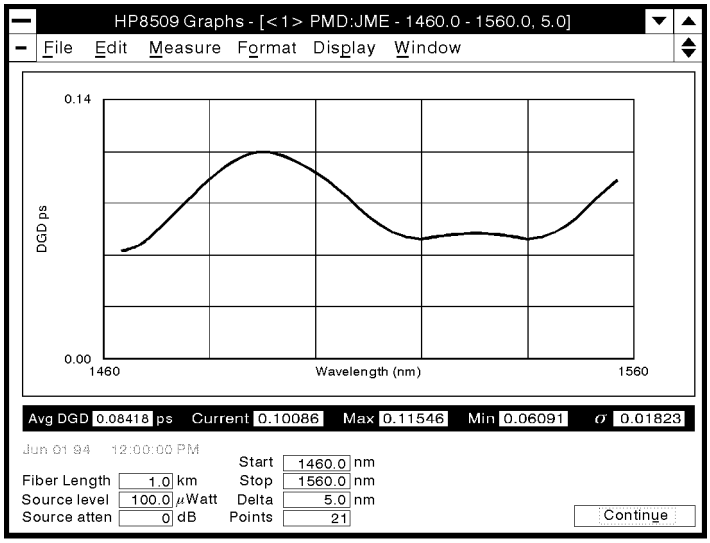
Button	This represents a button that can be selected on the computer screen to perform an action.
`Menu Item`	This indicates a menu item that can be selected on the computer screen.

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PMD Measurement: Jones Matrix Eigenanalysis Method

Polarization mode dispersion (PMD) is a fundamental physical property of optical fiber and components in which a lightwave is split into two waves of slightly different speed on the basis of polarization state. At a given wavelength, these two polarization modes experience a difference in propagation time known as "differential group delay" (DGD). The DGD of long optical fibers varies with wavelength. The "PMD" of a test device also refers to the average value of the differential group delay. PMD is fundamentally expressed in units of time, typically picoseconds (1 ps = 10^{-12} s). In the case of long fibers, it may be normalized to the square root of fiber length with the units of picoseconds per root kilometer.

This section explains how to measure the PMD of a test device using the Jones matrix eigenanalysis (JME) method, available in the HP 8509B. A typical measurement result, showing the differential group delay as a function of wavelength, is shown in the following figure.



pq779b_c

Figure 2-1. Example of data display for a PMD:JME measurement

Typical applications of the JME method include measurement of EDFA's, couplers, isolators, fibers, and optical connectors. Cables and systems consisting of any number of amplifiers and fiber spans can also be tested. Consider the following aspects of the JME method when deciding which PMD measurement method to use:

- Differential group delay (DGD) is measured as a function of wavelength.
- Measurement of low PMD components can be accomplished with a narrow wavelength range.
- The measurement is independent of pigtail position and polarization launch condition.
- Optical fiber DGD data can be shown in a histogram and compared with the expected distribution to assess the statistical confidence of the measurement.

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Basic Measurement

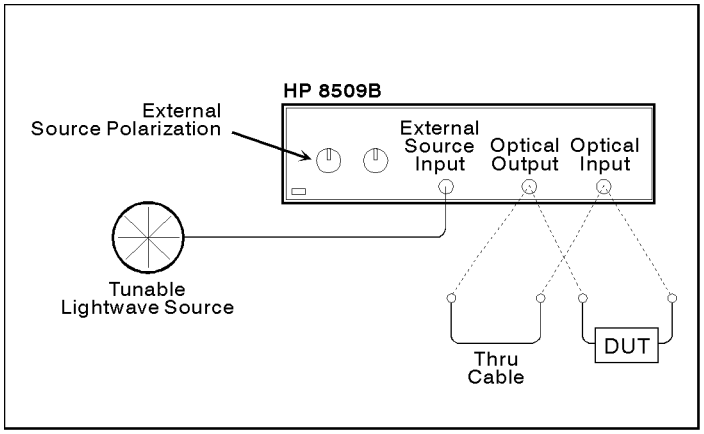
The following measurement procedure illustrates the simplest and most straightforward path in using the HP 8509B Lightwave Polarization Analyzer to make a PMD:JME measurement. Other specialized measurement applications and techniques are included later on in this section.

Setting up the System

Connect your measurement system as outlined in the following illustration. Install the thru cable for the one-time adjustment of external source polarization.

ACCURACY ENHANCEMENT NOTE

The fiber cable leading from the external source to the HP 8509B EXTERNAL SOURCE INPUT must be taped down to prevent any movement after source polarization has been adjusted. Movement of this source cable may jeopardize PMD measurement accuracy.



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Figure 2-2. Measurement Setup

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External Source Preparation

Before performing the PMD:JME measurement, external source polarization must be adjusted via the two knobs on the front panel of the HP 8509B. The following procedure will guide you through the process.

ADDITIONAL INFORMATION

The 8509B uses an internal three-state, switchable polarizer to condition the light before it is applied to the device under test. Adjustment of external source polarization via the front panel knobs is done to provide a roughly circular state of polarization within the polarizer assembly, so that all three polarizers will pass high levels of optical power. This adjustment typically need not be repeated unless the front panel knobs or the fiber connecting the tunable optical source and the HP 8509B have moved. However, it is recommended that the adjustment be performed once a week or once at the beginning of a long series of tests.

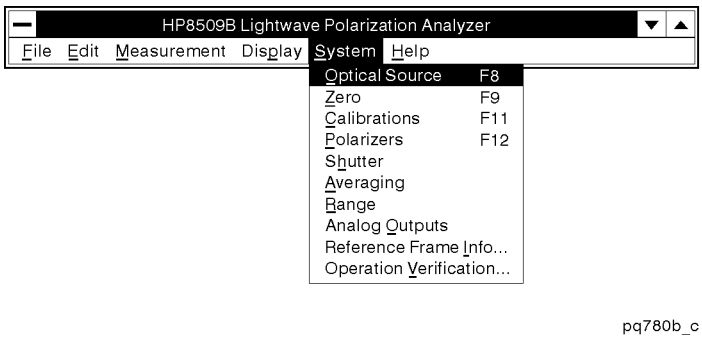


Figure 2-3. System Menu

To set up the optical source, select `System` from the main menu, and then select `Optical Source`. You may also set up the optical source by selecting the λ button in the upper right hand corner of the main window.

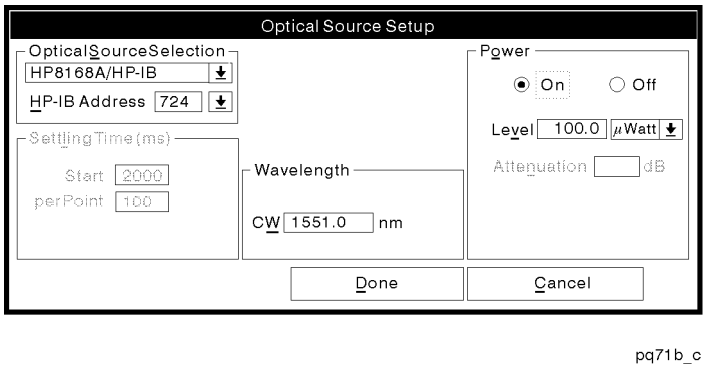


Figure 2-4. Optical Source Setup

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Select the external, tunable laser source and set the wavelength to the approximate center of the widest range you expect to use in your JME PMD measurements. Use the default power level or set as desired. If the screen on your computer looks similar to the previous illustration, select Done.

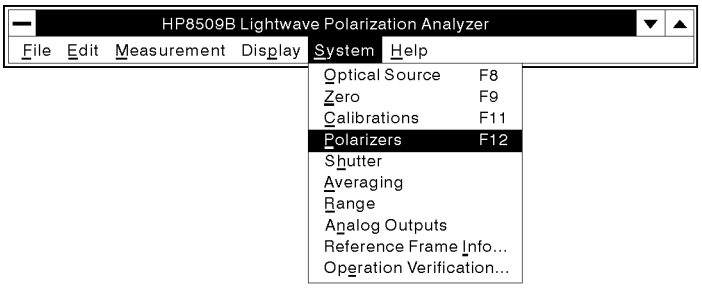


Figure 2-5. Polarizer Selection

Select `System` from the main menu, and then select `Polarizers`

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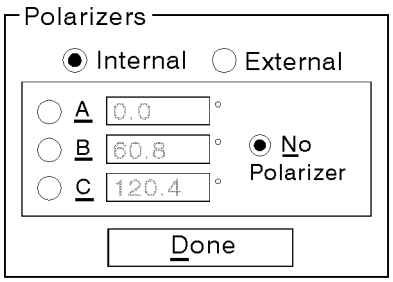


Figure 2-6. Polarizer Setup

Set the polarizers to Internal and select No Polarizer. If the screen on your computer looks like the previous illustration, select Done.

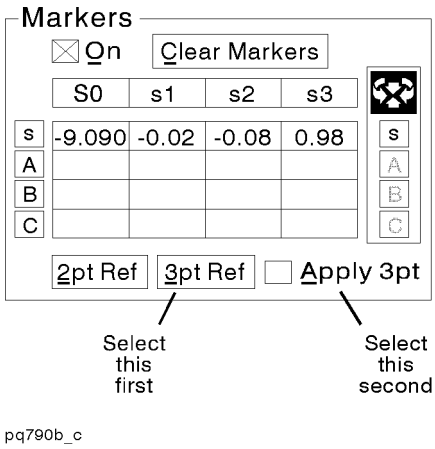


Figure 2-7. 3pt Reference Applied

Select `3pt Ref` from the Markers Area on the Main Screen, wait 5 seconds, and then select `Apply 3pt`.

ADDITIONAL INFORMATION

Creating and applying a 3pt reference frame allows measurement of polarization state within a physical frame of reference. In this case, the reference frame is located inside the internal polarizer assembly.

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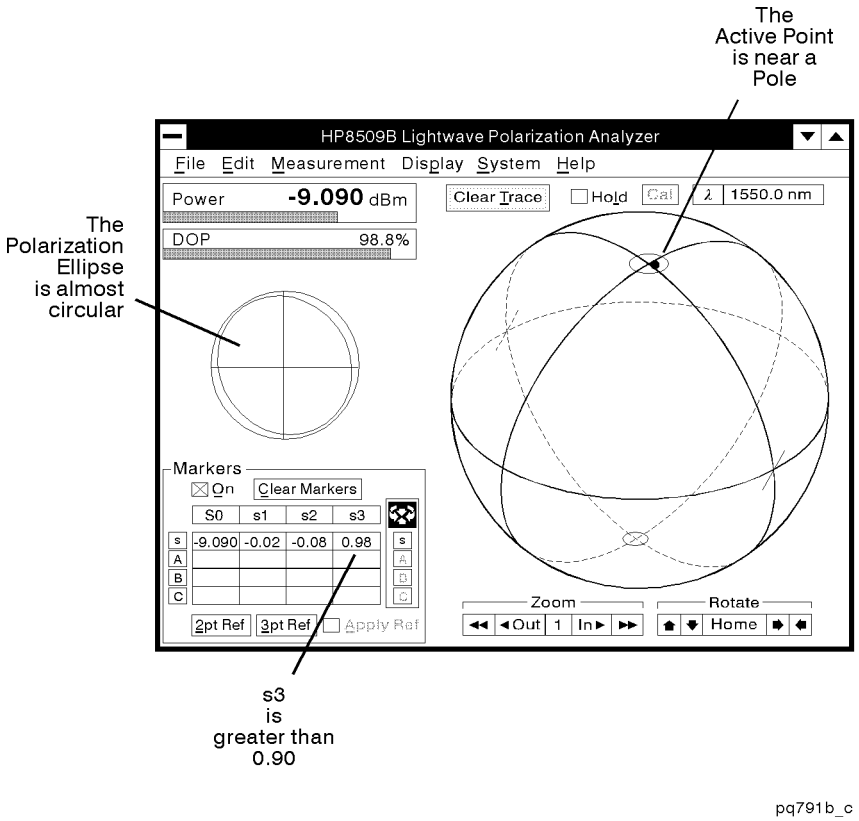


Figure 2-8. Circular Polarization

Adjust the External Source Polarization knobs on the front panel of the HP 8509B until the active point on the Poincare sphere approaches a pole, and the absolute value of the s3 marker is greater than 0.90. The active point is easier to see by marking the current point (select `Display` and then `Mark Current Point`). Also notice that the polarization ellipse will become more circular as s3 approaches 0.90. Un-apply the 3pt reference (reselect `Apply 3pt`) before going on to do the JME PMD measurements. Do not move the cable or the external source polarization knobs.

FOR MORE INFORMATION

More information on State of Polarization (SOP) and Degree of Polarization (DOP) may be found in the glossary and in this chapter.

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Making the Measurement

At this point your measurement system is ready to make your first measurement. For our purposes we are going to measure a 10 kilometer spool of optical fiber. Remove the fiber cable connecting the optical output to the optical input on the HP 8509B. Connect your test device between the optical output and the optical input.

ACCURACY ENHANCEMENT NOTE

The fiber path leading from the optical output of the HP 8509to the DUT and from the DUT to the optical input of the HP 8509 must not move during the measurement process. Unsupported fiber, particularly unjacketed fiber, should be taped down or placed against stationary objects. Movement of the fiber may jeopardize PMD measurement accuracy.

CAUTION Observe proper connection techniques. Refer to the "Lightwave Connector Care" chapter in this manual.

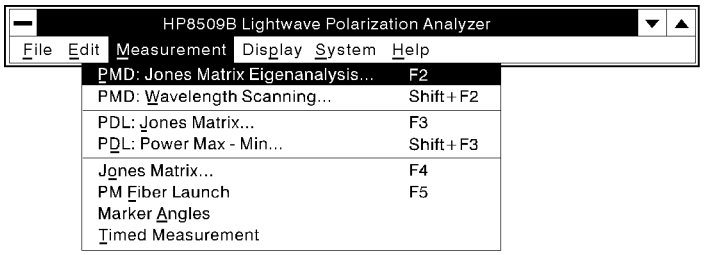
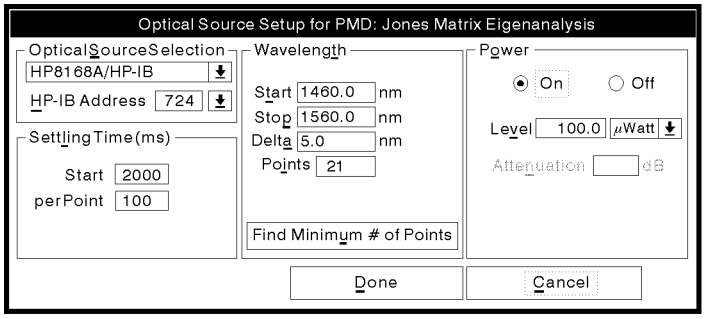


Figure 2-9. JME Measurement Selection

Select `Measurement` from the main menu, and then select `PMD:Jones Matrix Eigenanalysis... F2`

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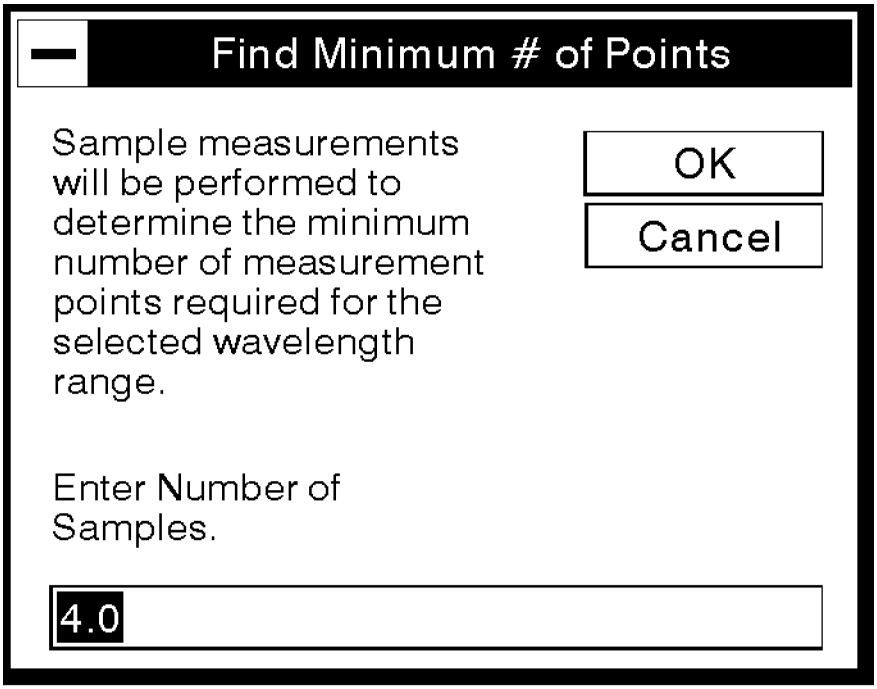
Figure 2-10. JME Source Setup

Verify that the source and start and stop wavelengths are correct for your measurement, and that the optical power is turned on. If the screen on your computer looks like the previous illustration, select `Find Minimum # of Points`.

ADDITIONAL INFORMATION

- The Jones matrix eigenanalysis method computes differential group delay (DGD) from pairs of optical measurements, so the number of DGD values obtained in a completed measurement is actually one less than the number of measurement wavelength points.
- If you wish the source to remain leveled during the measurement, enter into the power level display of the optical source setup window, a value no greater than the minimum power shown in the lasers display of available laser power.

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Figure 2-11. Segment Selection

The window is called Find Minimum # of Points. Sample measurements will be performed to identify the maximum DGD of the DUT. The number of points will be set to accommodate this value. Sample measurements are evenly spaced across the wavelength range. For this measurement, use the default setting by selecting OK.

FOR MORE INFORMATION

More information on selecting the appropriate number of points may be found in the "Concepts" section later on in this chapter (Choosing Delta Wavelength and Fiber PMD Statistics/Enlarging the Sample Size).

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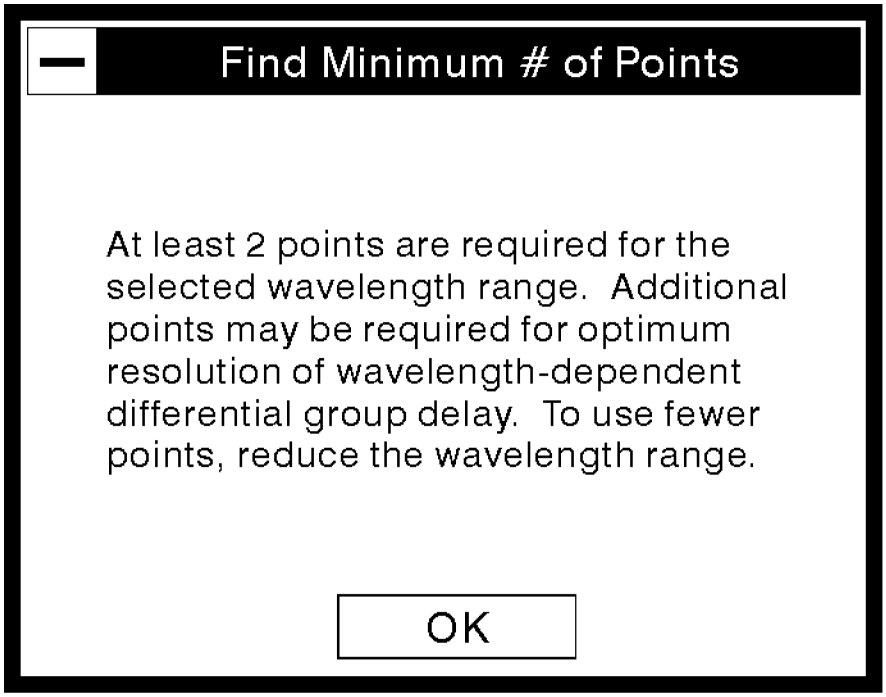


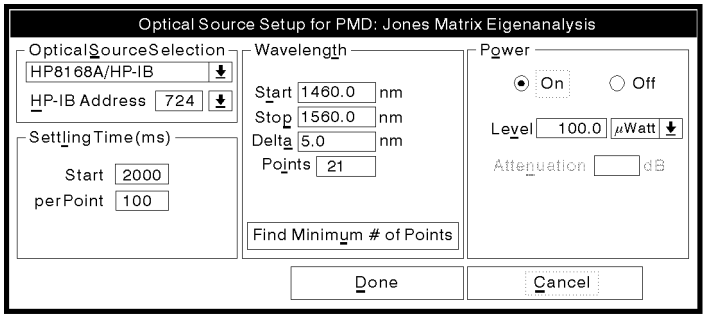
Figure 2-12. Find Minimum # of Points

When the automatic routine is finished, you will be advised what minimum number of measurement points is required for your wavelength range. The minimum number of points is automatically entered in the optical source setup window when this message box is closed. Select OK to continue with the measurement.

ACCURACY ENHANCEMENT NOTE

When measuring components, polarization maintaining fiber, or short lengths of single mode fiber, use the indicated minimum number of points. When measuring long fiber, or any device that is expected to exhibit wavelength dependent PMD, increase the number of points to measure the wavelength dependent behavior of the device.

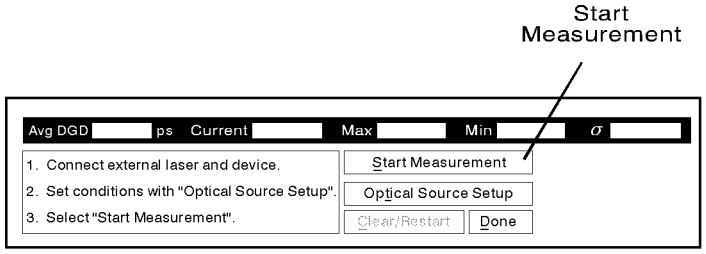
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Figure 2-13. Optical Source Setup for PMD: Jones Matrix Eigenanalysis

Select Done on this window.

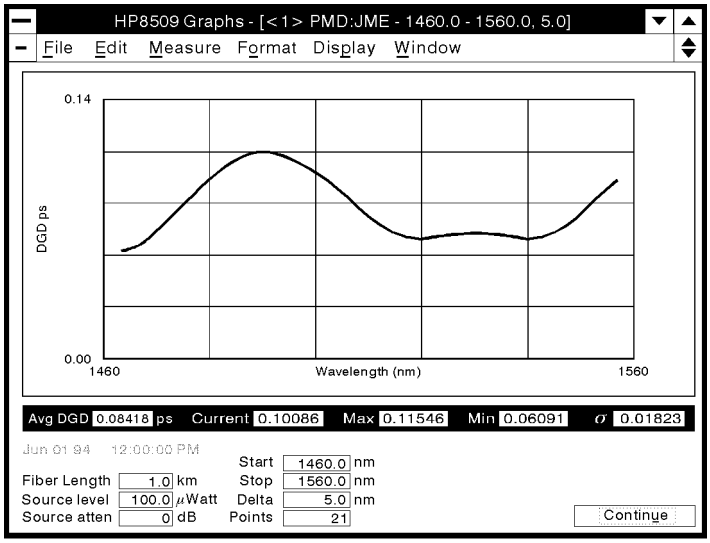


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Figure 2-14. PMD: JME Measurement Start

Select Start Measurement from the HP 8509B Graphs screen.
The JME graph is derived from a series of optical measurements performed across the selected wavelength range. As the measurement progresses, the **Measurement Summary** display bar directly below the graph lists the PMD results obtained, up to the current wavelength. The axes of the PMD graph are annotated as differential group delay in picoseconds and wavelength in nanometers.

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Figure 2-15. Measurement Results

Your measurement is complete. The screen on your computer should look similar to the previous illustration.

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Manipulating the Measurement Results

When your measurement is complete, you may;

- Review the results in the **Measurement Summary** bar.
- Review the measurement setup conditions in the **Measurement Annotation** area.
- Examine the differential group delay at a particular wavelength, by using the cursor bar.
- Display, edit, and print the data in tabular form.
- Print the graph with or without measurement annotation and data listing.
- Save your measurement and annotation information to a database for future use, or to reload the measurement back into the HP 8509A/B.
- Save your measurement data as a text file for use with spreadsheets.
- Perform other PMD measurements without leaving the **Graphs** window.
- Display all of your measurements in one window, using windows tile or cascade modes.

The Measurement Summary Bar

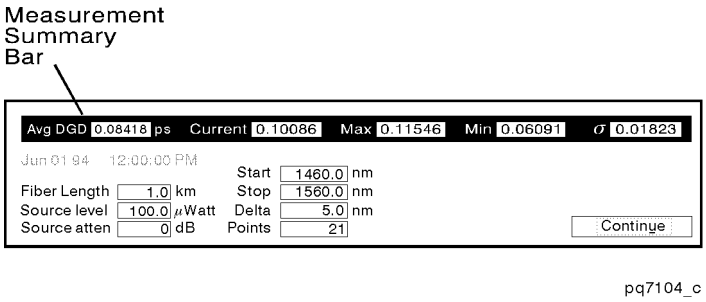


Figure 2-16. The Measurement Summary

The **Measurement Summary Bar** displays the PMD results obtained up to the current wavelength.

All of the displays have the same units, which are user selectable but default to picoseconds. The bar displays the average, current, maximum, minimum, and standard deviation (σ) of the differential group delay, up to the current wavelength.

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The Measurement Annotation Area

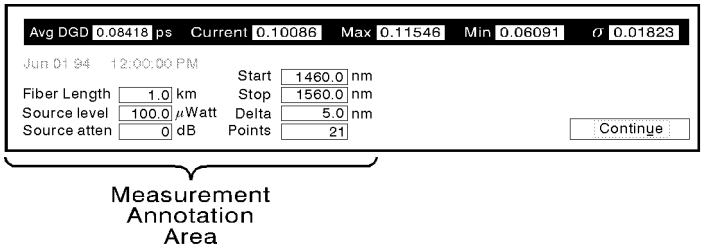


Figure 2-17. The Measurement Annotation Area

When the measurement ends, the control panel at the bottom of the Graphs window is replaced by **Measurement Annotation**. This area lists the date and time of the start of the measurement, the fiber length in kilometers, the tunable laser power and attenuator settings, the start and stop wavelengths and the wavelength interval or delta. It also lists the number of points, that is, the number of wavelengths at which optical measurements were taken. The measurement annotation area can be toggled on and off by selecting `Display` from the main window menu, and then `Annotation`.

ADDITIONAL INFORMATION

The Jones matrix eigenanalysis method computes differential group delay (DGD) from adjacent pairs of optical measurements, so the number of DGD values obtained in a completed measurement is actually one less than the number of measurement wavelengths.

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Using The Cursor

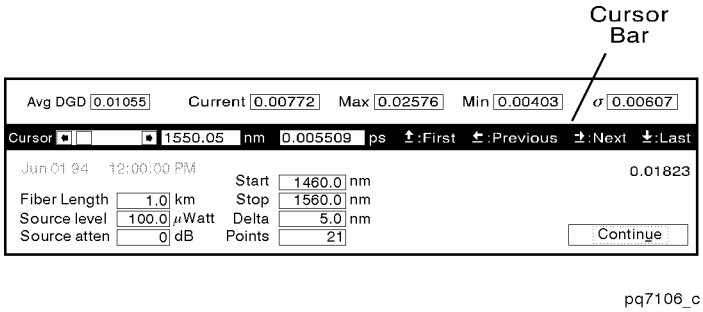


Figure 2-18. The Cursor Bar

Maximize the PMD:JME window within the HP 8509B graphs window. Activate the **Cursor Bar** by selecting `Display` and then `Cursor` from the Graphs window menu. The cursor bar appears between the **Measurement Summary Bar** and the **Measurement Annotation** area. The cursor display shows the DGD value for a selected wavelength. The wavelength is selected by the slider control, arrow keys (The keyboard is activated by pressing the Alt and then the arrow keys), or by editing the wavelength display.

Changing The Measurement Format

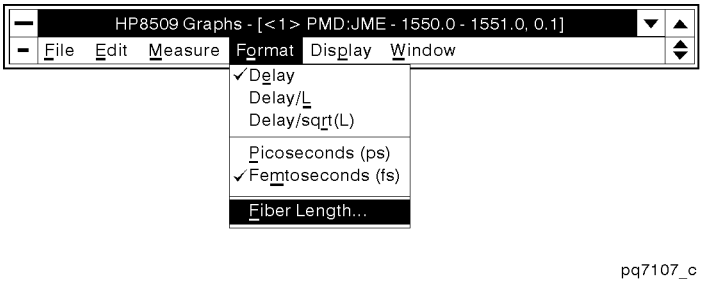


Figure 2-19. Changing the Measurement Format

Select `Format` from the Main Graphs window menu to access the measurement formatting functions. The measurement graph may be formatted in either picoseconds or femtoseconds. It can also be expressed per kilometer or per root kilometer of fiber length. Choose `Fiber Length...` from the `Format` menu to enter the length of the fiber you have just measured.

ADDITIONAL INFORMATION

If the fiber is long enough to exhibit strong polarization mode coupling, you may wish to express the result in units of time per root length using `Format Delay/sqrt(L)`. The new units are listed, and all values are updated, on the Y-axis and in the measurement summary bar.

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Changing The Graph's Y-Scale

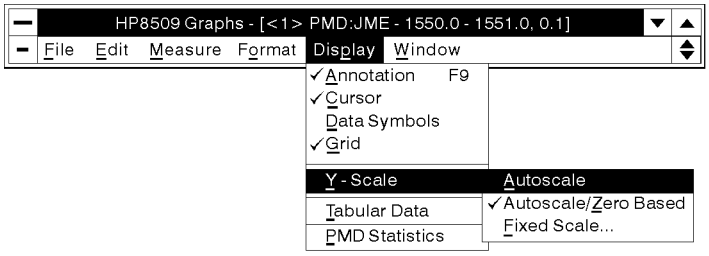


Figure 2-20. Changing the Graph's Y-Scale

To change the vertical axis on the measurement graph, select `Display` and then `Y-Scale` from the Graphs main window menu. The submenu provides three selections. The default selection, `Autoscale/Zero Based`, autoscales the maximum Y-axis value but uses zero as the minimum value. The `Autoscale` selection optimizes both the minimum and maximum Y-axis values to expand the measurement curve to fill the graph area. The `Fixed Scale ...` selection allows specification of the maximum Y-axis value and uses zero as the minimum value.

Displaying and Printing Data in Tabular Format

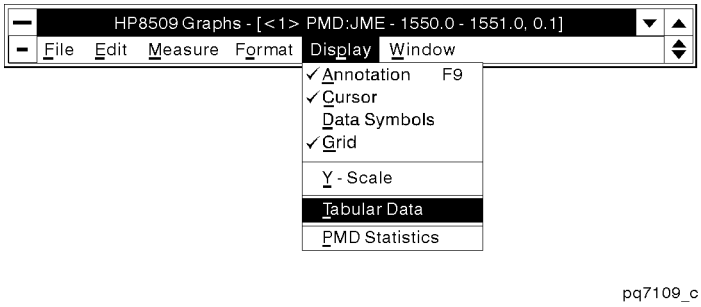


Figure 2-21. Displaying Data in Tabular Format

Display the tabular measurement data by selecting `Display` and then `Tabular Data` from the Graphs main window menu. A text box fills the Graphs window, overlaying the measurement graph. The text box lists information from the measurement annotation area, the values in the measurement summary, and a list of wavelengths at which optical measurements were performed along with the DGD values derived from each pair. The Start Measurement button is disabled when the text box is open.

ADDITIONAL INFORMATION

You can add your own notes to the text. All of the standard keyboard and mouse editing features are available. Use the mouse to place a text insertion point anywhere in the document, and then type the desired text. Text may be selected using the drag features of the mouse. Selected text may

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be deleted or copied to the clipboard for use in a report or a spreadsheet by pushing the Copy to clipboard button.
The tabular data text box is limited to 60,000 characters.

All or a portion of the text box information may be printed. Printing uses the default printer selected in the windows control panel. To print all of the text box information just press the Print tabular data button at the top of the text box. To print a portion of the text box information, hi-light the desired text with the mouse before pressing the Print tabular data button. To return to the graphic display, press the Return to graph button or re-select `Tabular Data` under the `Display` menu.

Displaying Data in a Statistical Format

Data from PMD:JME measurements can be displayed in statistical format using the PMD Statistics feature. See the Concepts section for a discussion of its application (Fiber PMD Statistics).

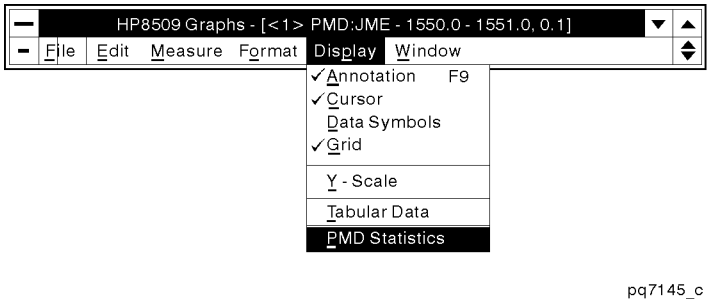
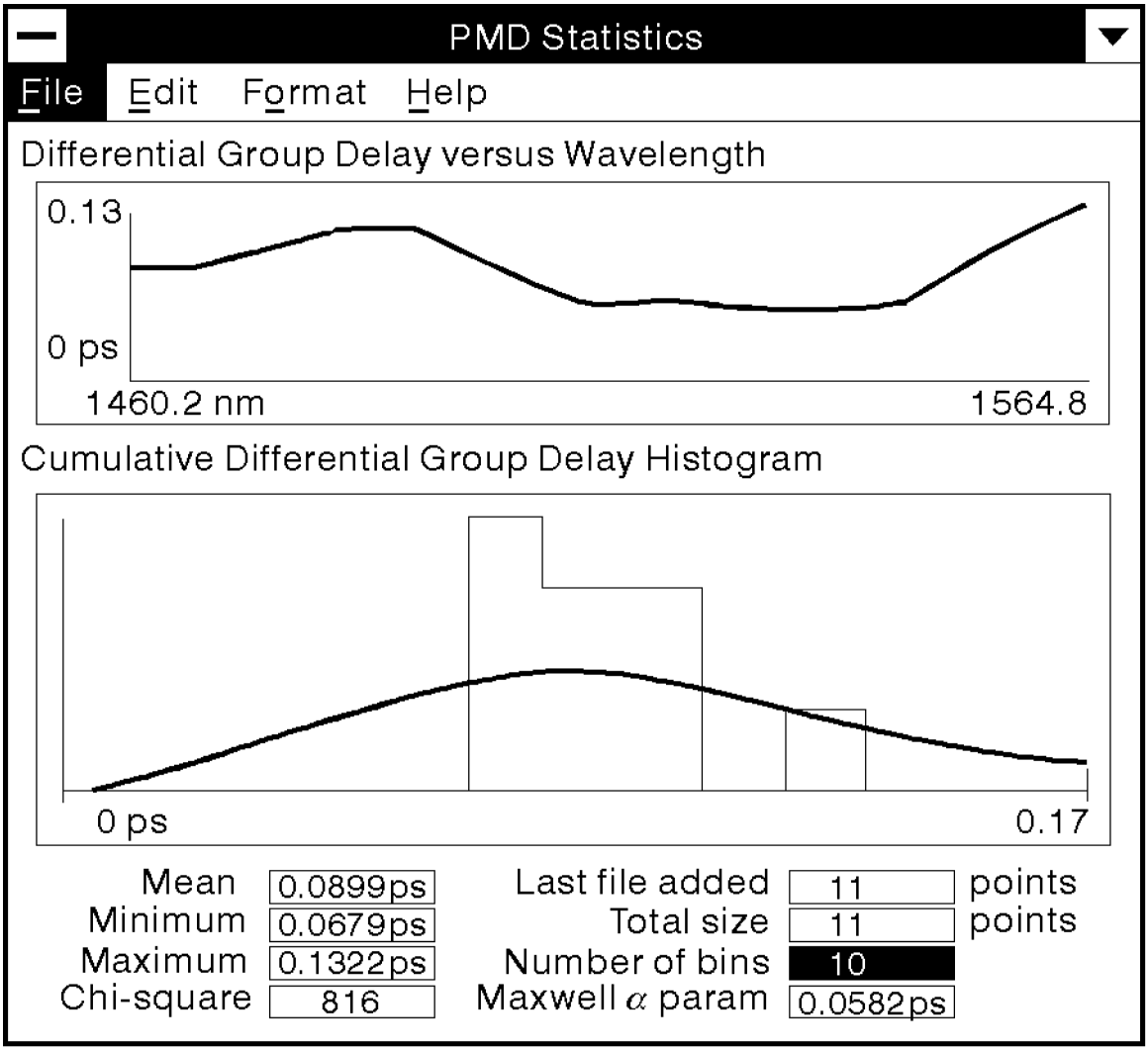


Figure 2-22. Displaying Data in a Statistical Format

After making your PMD:JME measurement, and while still in the PMD:JME measurement window, you may display the results in a statistical format by first selecting `Display` and then `PMD Statistics`. A PMD Statistics window will open.

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pq7148_c

Figure 2-23. Displaying Data in a Statistical Format

The previous illustration is an example of the PMD statistics window. A Maxwell curve is automatically fitted to the histogram.

Single or multiple PMD:JME measurements can be displayed in the PMD Statistics window. Use any combination of `Add from Selected JME Window F2`, `Add from Database...F3`, and `Add from Text File...F4` to import data.

ADDITIONAL INFORMATION

The PMD Statistics function can be selected in two ways; from the PMD:JME measurement window, or by double clicking on the PMD Statistics

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icon in the HP 8509 Program Group in the Program Manager. The PMD Statistics function is actually provided by a separate software application.

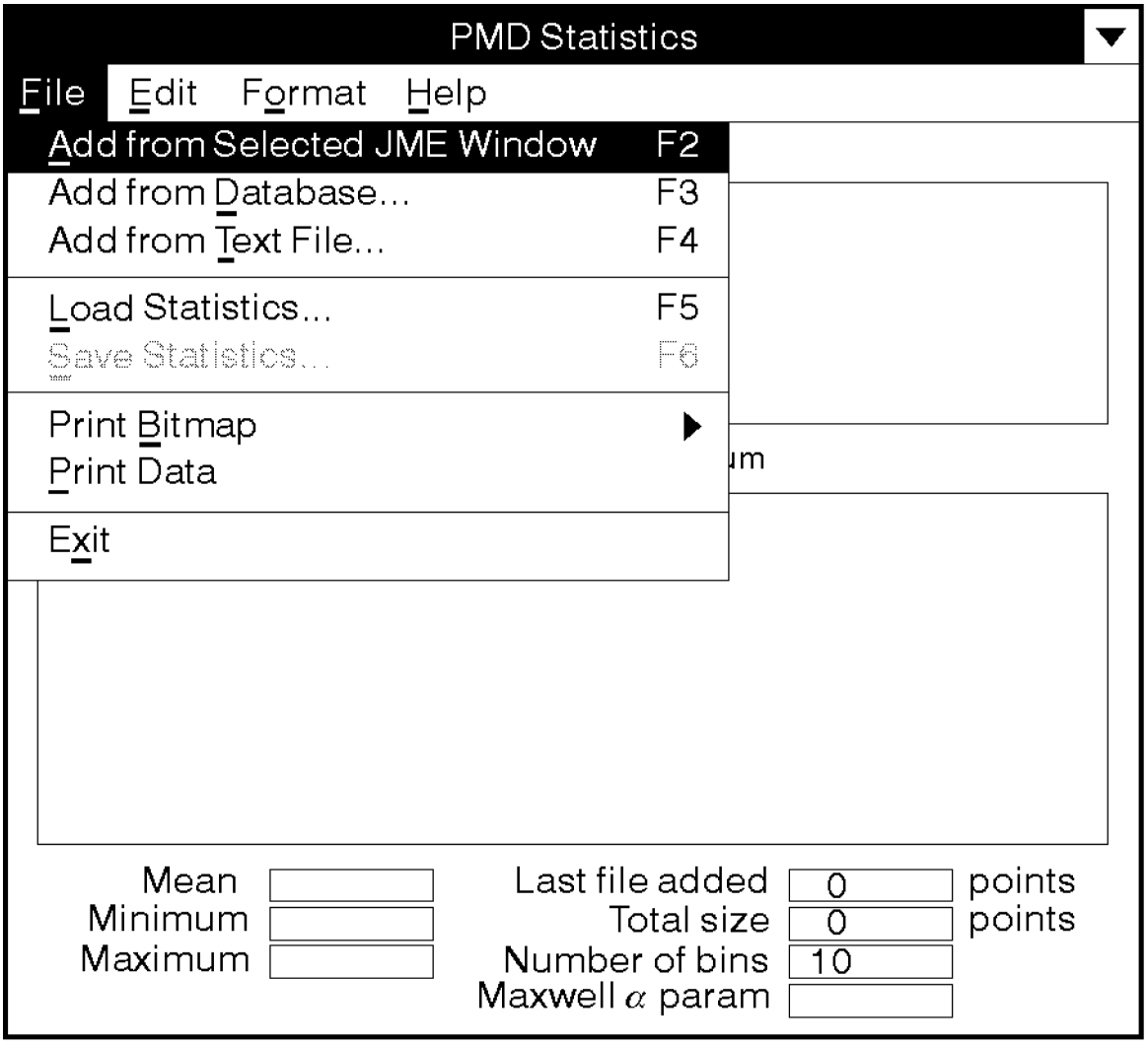


Figure 2-24. PMD Statistics File Menu

The File menu

Selecting `File` from the main PMD Statistics window, will drop down a menu structure. The following is a brief description of the elements of the File menu.

`Add from Selected JME Window F2`. The data from the current JME window will be shown in the Differential Group Delay versus the Wavelength graph. The individual measurement points of this graph are used to build the Cumulative Differential Group Delay Histogram and to derive the other statistics listed in the PMD Statistics window.

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`Add from Database...F3.` Selecting this menu item will cause the PMD Statistics Database Interface window to open. You can then load the measurement results from a previously stored measurement into the PMD Statistics window.

`Add from Text File...F4.` Selecting this menu item will cause a window titled "Load: Text File" to open. You can then impose a previously stored text file to import into the PMD Statistics window.

`Load Statistics...F5.` Selecting this menu item clears the PMD Statistics displays and opens a window titled "Load: Text File". You can then load previously stored PMD statistics data into the PMD Statistics window.

`Save Statistics...F6.` Selecting this menu item opens a window titled "Save: Text File". You can then save the current statistical data in a text file for future retrieval to the PMD Statistics window or analysis with a spreadsheet. All measurement points are saved, including points beyond the displayed wavelength range.

`Print Bitmap.` Selecting this menu, will give you three choices. To print the DGD versus Wavelength graph, the Histogram or the entire window.

`Print Data.` Selecting this menu will print the data. Printing uses the default printer selected in the windows control panel.

`Exit.` Selecting this menu will quit the PMD Statistics window

The Edit menu

Selecting `Edit` from the main PMD Statistics window, will drop down a menu structure. The following is a brief description of the elements of that Edit menu.

`Undo Last Add  Alt+Bksp`. Selecting this menu item removes the most recently added measurement from the statistics displays and from the statistical data set. This allows you to examine the DGD versus Wavelength data before committing it to the statistical data set.

`Clear All Data`. Selecting this menu item removes all displayed data and purges the statistical data set.

`Copy Bitmap to Clipboard`. This menu item provides three selections, copying to the clipboard your choice of DGD versus Wavelength, the Histogram or the entire PMD Statistics window.

The Format Menu

Selecting `Format` from the main PMD Statistics window, will drop down a menu structure. The following is a brief description of the elements of that Format menu.

`Wavelength Range`. This menu item provides two ways to select the wavelength range to be used in the DGD vs Wavelength graph. Only data points displayed in this graph are included in the histogram. `Autorange` adjusts the wavelength limits to include the lowest and highest

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wavelengths of the added or loaded JME PMD data. The `Fixed Range...` selection opens a dialog box with which you can set the minimum and maximum displayed wavelengths.

`Histogram X-Axis`. This menu item provides two ways to select the range of DGD values to be displayed in the histogram. When `Autoscale` is selected, the X-axis range automatically adjusts to include all DGD values in the statistical data set. When `Fixed Scale...` is selected, a dialog box enables you to set the maximum value of DGD to be displayed. The minimum value is always zero.

The Help menu

The Help menu only provides information about the software revision of the PMD Statistics software, which is a separate application.

The Annotation Area

At the bottom of the PMD Statistics window are a group of numeric displays, which are described below.

Mean. This display shows the mean, or average, value of the data points which are displayed in the DGD vs Wavelength graph. The mean is not affected by selection of the X-axis scale of the histogram.

Minimum, Maximum . These displays show the minimum and maximum values of DGD of the data points which are displayed in the DGD vs Wavelength graph. These values are not affected by selection of the X-axis scale of the histogram.

Last file added . This display shows the number of DGD measurement data points which were added with the last add operation. The number indicates the size of the original measurement data set, and is not affected by the choice of X-axis limits of either of the graphical displays.

Total size. This display shows the cumulative size of the statistical data set when the DGD versus Wavelength graph is in the Wavelength Range / Auto Range mode.

Subset size. This display replaces the Total size display when the DGD versus Wavelength graph is placed in the Fixed Range mode. This parameter indicates the number of DGD measurement data points that fall within the displayed wavelength range.

Number of bins. This is an editable display which shows the number of categories or buckets into which the DGD range is divided for construction of the DGD Histogram.

Maxwell alpha parameter. This display shows the value of the single parameter which specifies the Maxwell curve that is automatically fitted to the DGD histogram.

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Printing the PMD:JME Graph

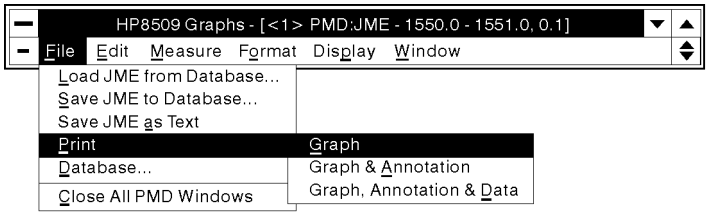


Figure 2-25. Printing the PMD:JME Graph

Select `File` and then `Print` from the Graphs main window.

- Selecting `Graph` will print only the graph.
- Selecting `Graph & Annotation` will print the graph and the annotation information discussed in "The Measurement Annotation Area."
- Selecting `Graph, Annotation, & Data` will print the graph, annotation information and list the measurement wavelengths and the corresponding data points.

Saving your Measurement as Text

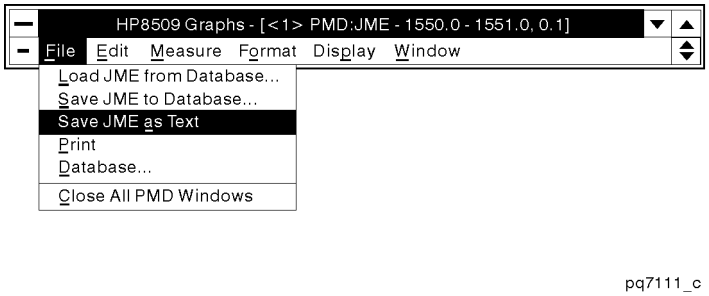


Figure 2-26. Save as Text

Select `File` and then `Save JME as Text` from the Graphs main window. A standard window **Save** screen will be displayed. At this point you can select a file name and a directory in which the data will be stored. Columns of wavelengths and measurement data points will be saved as text for later use in a spreadsheet. Data saved as text cannot be recalled for future display by the analyzer.

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Saving in Database Format

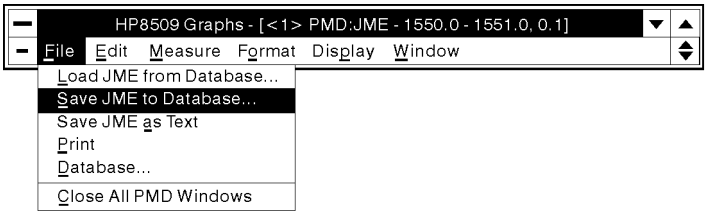


Figure 2-27. Saving in Database Format

Select `File` and then `Save JME to Database...` from the Graphs main window to save the entire measurement and annotation for future analysis using a database program or to reload the measurement and certain setup parameters back into the analyzer. A default title for the measurement is provided. The title is made up of the measurement type and the date and time. It is a unique name, but you may wish to edit it for your own purposes. You may also enter a serial number and date code for the device under test.

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Specialized Measurement Methods

Performing a Cascade Measurement

Cascading is a measurement procedure that mathematically increases the accuracy of polarization mode dispersion (PMD) measurements of devices and components that can't be directly connected to the HP 8509B Optical Output without using additional optical interfacing. PMD cascading techniques are used in bulk optical applications to separate the PMD response of the test device from the cloaking effects of the combined PMD response of the fixtures and adapters between the HP 8509B Optical Output and the input to the test device. Fiber optical applications benefit as well because the response of optical source interfacing isolators, connectors and cables of the test system (represented by DCO in the figure shown below) can be mathematically removed from the total PMD response, leaving behind the response of the targeted test device (DUT in the figure shown below). This technique is most effective when the PMD response of the test device (DUT) and the undesired PMD of the optical source interfacing (DCC) are approximately the same and individually greater than 100 fs.

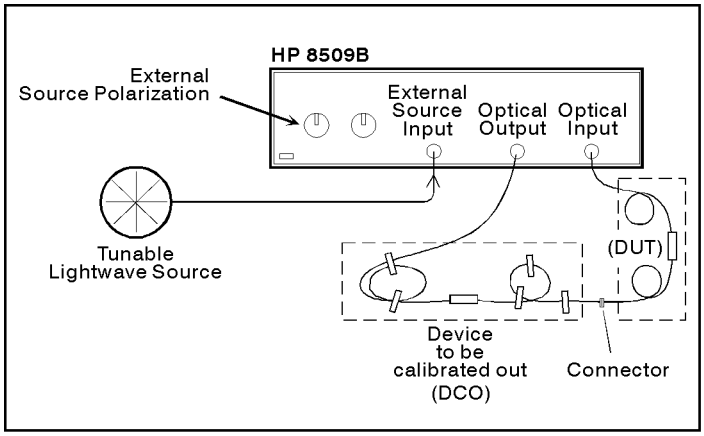
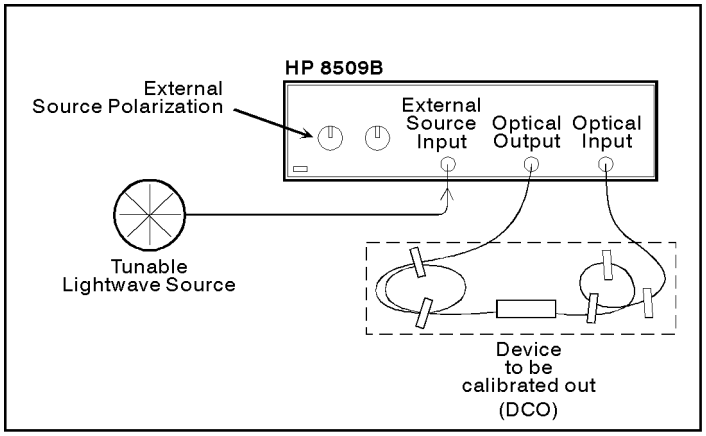


Figure 2-28.

Setting up the System

Attach the device to be calibrated out (DCO), between the Optical Output and the Optical Input of the HP 8509B, as outlined in the following illustration. Tape down the pigtails so that only the final portion of the output pigtail of the DCO will be allowed to move when the final test device (DUT) is inserted. Movement of the DCO, or movement of its input pigtail, between the calibration and measurement, causes measurement error.

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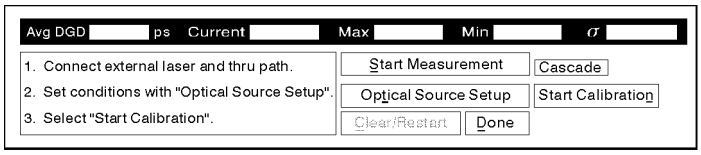


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Figure 2-29. Measurement Setup

Making the Measurement

1. Prepare the external source to provide a circular state of polarization by following the procedure described in the External Source Preparation portion of this JME PMD section.
2. Select `Measurement` from the main window menu selections, and then `PMD: Jones Matrix Eigenanalysis... F2`.
3. Set up the optical source for the desired wavelength range and the number of points, then select Done.
4. Select `Measurement` from the graphs main window menu selections, and then `Cascaded Device`.

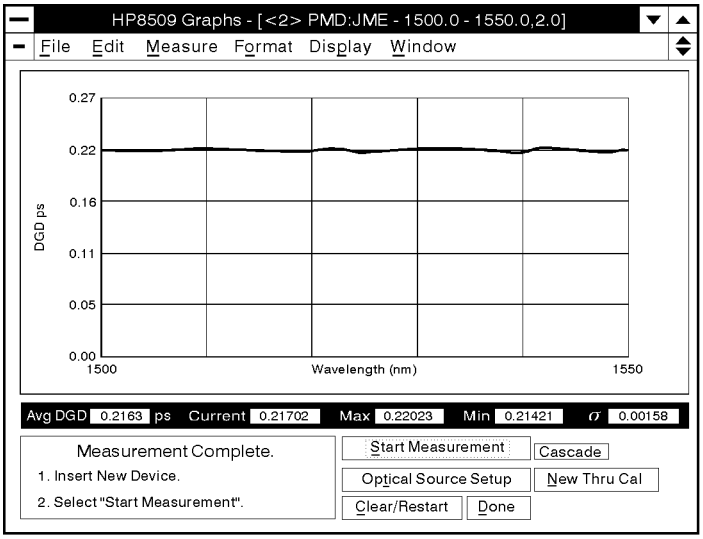


pq7156_c

Figure 2-30. Measurement Start

5. Note that the measurement control area at the bottom of the graphs window, a yellow `Cascade` banner appears. Select Start Calibration or New Thru Cal, whichever appears at the bottom right portion of the graph window.

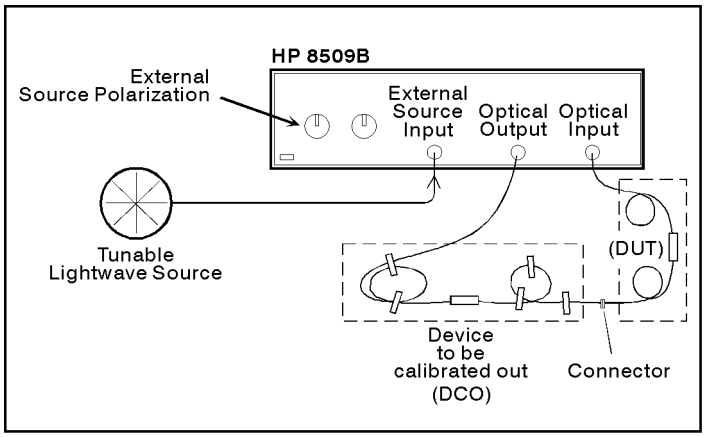
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pq7157_c

Figure 2-31. Thru Calibration

6. The resulting measurement characterizes PMD effects of the DCO. When the thru calibration is complete, select Continue. The calibration may be redone by selecting New Thru Cal. Perform this only if the fiber or the DCO has moved during the calibration.

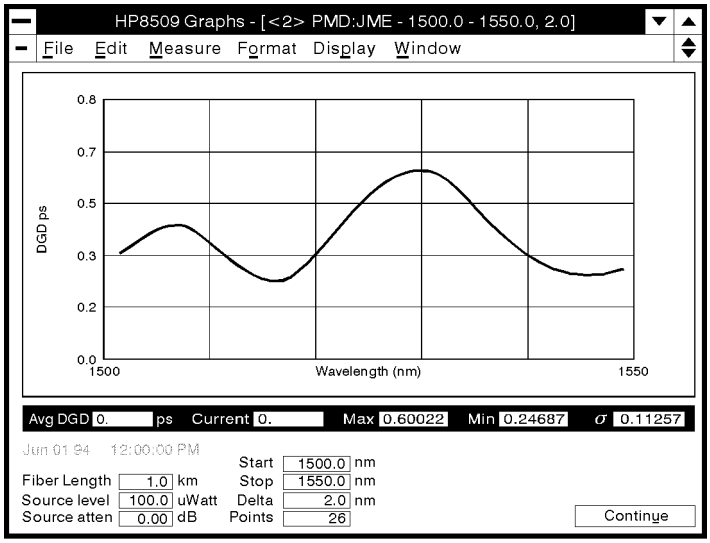


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Figure 2-32. The Measurement

7. Remove the output pigtail of the DCO from the optical input of the HP 8509B, taking care to move only the output pigtail and not the DCO or its input pigtail. Connect the device to be measured (DUT) between the output pigtail of the DCO and the Optical Input of the polarization analyzer.
8. Select Start Measurement. When the measurement is complete, the PMD effects of the first DCO are removed and the displayed DGD represents the newly inserted device. Refer to the following figure.

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pq7158_c

Figure 2-33. The Results

CAUTION In general, the PMD values of cascaded devices do not simply add. Single Device measurements of two devices cannot be added to produce the expected DGD of the same devices in cascade.

ADDITIONAL INFORMATION

The effectiveness of this method can be verified in two ways.

1. Perform a cascade thru calibration on a device and then measure the same device without moving any fibers. The result should be a very small value of DGD, typically under 0.010ps, indicating that the device itself has been removed from the measurement path. The device must be stable in temperature for this verification to be meaningful.
2. Measure the DGD of a device (DUT) in the Single Device mode (without a cascade thru calibration). Then perform a cascaded PMD measurement using this same device (DUT) connected to a second device (DOC) that has been cascaded out. The PMD measurement result should be very close to the measurement obtained in the Single Device mode. Again, temperature stability is important.

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Using a Voltage-Tuned Source

The JME PMD measurement may be performed using a voltage tuned optical source. Operation is automatic once the measurement is started. To perform a measurement with a voltage-tuned source, open a JME PMD window and select Optical Source Setup. Use Optical Source Selection to choose the voltage-tuned mode. You will see a change in the information displayed in the Wavelength area of the window. Enter the wavelength parameters and number of points as you would for an HP-IB source. Enter the tuning voltages corresponding to the start and stop wavelengths. This "calibrates" your wavelength tuning and requires knowledge of the source tuning characteristic. The tuning voltage is programmed in linear fashion between the entered limits. Set the settling times as required for your source, or use the default values. Connect the tuning voltage from BNC connector "A" on the rear panel of the 8509 to the voltage-tuned laser. Close the Optical Source Setup form and start the measurement.

Using a Manually-Tuned source

The JME PMD measurement may be performed using a manually tuned optical source. This feature enables you to use tunable single line laser sources that lack hardware tuning interfaces. To perform a measurement with a manual source, open a JME PMD window and select Optical Source Setup. Use Optical Source Selection to choose the manually tuned mode. The settling time parameters are no longer relevant and are grayed out. Enter the wavelength parameters and number of points as you would for an HP-IB source. Close the Optical Source Setup form and start the measurement. The instruction window will prompt you to adjust the wavelength of the source and take the next point. Repeat this until the measurement is complete.

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PMD:JME Concepts

Polarization Mode Dispersion

Polarization modes

PMD is a fundamental property of optical fiber and components by which any lightwave signal is split into two polarization modes that travel at different speeds. In effect, single mode fiber is bimodal with respect to polarization. The difference in propagation time between the two polarization modes is called differential group delay.

General effects

Because of PMD, lightwave pulses launched partly into each of the polarization modes broaden as they propagate, degrading the distinction between pulses. In addition, light from a spectrally wide source may become partly depolarized under the influence of large values of differential group delay. Finally, transmitter laser frequency chirp in combination with PMD in a transmission path can cause a transmitted signal to vary in polarization state as a function of time and signal intensity. If polarization-dependent loss is present in the system, the polarization variation is converted to amplitude variation. This effect causes composite second-order distortion in cable-television systems.

Mode coupling

Mode-coupling is the term given to the coupling of optical energy between polarization modes along the transmission path. Two-port optical devices (including optical fiber) fall into two categories according to the degree of mode coupling. Non-mode-coupled devices include most components, hi-bi (polarization maintaining) fiber and short lengths of ordinary single-mode fiber. For these devices, energy launched into each polarization mode remains in that mode as it propagates. The differential group delay of non-mode-coupled devices is generally independent of wavelength. The other extreme, strong mode coupling, is exhibited by long lengths of single-mode fiber. For long fibers, energy couples between modes due to physical variations internal to the fiber and optical effects induced by the fiber's environment. The differential group delay of highly mode-coupled devices is a strong function of wavelength. An intermediate degree of mode coupling, typical of short to medium lengths of optical fiber, results in differential group delay which is a relatively weak function of wavelength.

PMD units

Differential group delay is expressed in units of time, generally either picoseconds (1 ps = 10^{-12} s) or femtosecond (1 fs = 10^{-15} s). Short-fiber PMD may be expressed in terms of time per meter or kilometer. Due to the effects of mode-coupling, long-fiber differential group delay increases as the square root of fiber length. Therefore, long-fiber differential group delay is often expressed in terms of time per square root of fiber length (in kilometers).

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Fiber PMD statistics

The "PMD" of a component or fiber is simply the average differential group delay. For non-mode-coupled devices, this may be obtained from a single pair of Jones matrix measurements separated by a known wavelength interval, although in practice an average of several intervals is used. For highly mode-coupled devices, the measurement is repeated at a many wavelength intervals across a large wavelength range. The average differential group delay is simply the average of these individual values.

Fitting the Maxwell curve to the distribution

To determine whether the wavelength dependence of a fiber has been sufficiently sampled in a particular measurement, a histogram of the individual differential group delay values may be compared to a best-fit Maxwell probability distribution function. The Maxwell curve represents the expected shape for long fibers. If the data closely resembles the Maxwell curve, the average differential group delay taken from the measurement can be considered statistically accurate.

The HP 8509B software provides a statistical display of Jones matrix eigenanalysis measurement results for this purpose. It uses the chi-squared method to generate the best-fit Maxwell curve.

Once the Maxwell curve fit has been performed, the quality of the fit to the data must be determined. This may be done qualitatively, by visually assessing the fit, or by use of the quality of fit parameter displayed in the statistics window.

Enlarging the sample size

If the quality of fit is poor, more data is required to fully represent the fiber. This is most easily accomplished by expanding the wavelength range of the measurement. Generally, long-fiber PMD measurements should be taken over as wide a wavelength range as possible, with wavelength interval small enough to capture the features of the curve of differential group delay versus wavelength. However, for some fibers even the full wavelength range may not be sufficient to produce a distribution of Maxwellian shape. In such cases, the sample size can be increased by repeating the measurement at different temperatures, based on the fact that the mode-coupling characteristics of the fiber are strong functions of temperature. All of the resulting data is combined in a single histogram for analysis. If the fiber temperature is changing naturally, due to changes in the ambient temperature, the measurement may be repeated versus time to enlarge the sample size. If the fiber is in cable form, temperature change may be induced by passing a current through the metal members of the cable. The sample size for spooled fiber can also be enlarged by rearranging the turns of fiber on the spool. For example, a spool of loosely coiled fiber can be turned end over end between measurements.

Source spectral characteristics

The Jones matrix eigenanalysis method of PMD measurement involves measuring the output state of polarization of the device under test with various linear polarizers inserted in the path between optical source and the device. This requires that the output of the test device always be at least partially polarized. The output will depolarize if the coherence time of the source approaches the differential group delay of the test device. Single-line lasers of narrow spectral width, such as the HP 8168A Tunable Laser Source, are recommended for the Jones matrix eigenanalysis PMD measurement method.

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Should I use the reference frame?

The reference frame feature removes birefringence (2-point method) or birefringence and polarization dependent loss (3-point method) from the test path between the automatic polarizer and the polarization receiver. The reference frame is appropriate only to the wavelength at which it is set up. Since PMD measurements are preformed across a wavelength range, the reference frame feature should not be used.

Cascade measurements

What is a cascade measurement?

A cascade measurement measures the DGD of a single test device while that test device is connected in series with other elements that demonstrate DGD. The measurement is a two step process involving PMD:JME measurements of a through path with and without the test device installed. This allows the HP 8509B to mathematically remove the differential group delay of the path between the polarizer and the test device.

Typical applications

The cascade method is not used in ordinary PMD measurements in which the device under test is connected by pigtails to the front panel of the instrument, as it is not capable of removing the very small amount of differential group delay of the pigtails. However, it may be used in cases where an optical device with significant PMD, such as an isolator, is placed between the instrument and the input of the device under test.

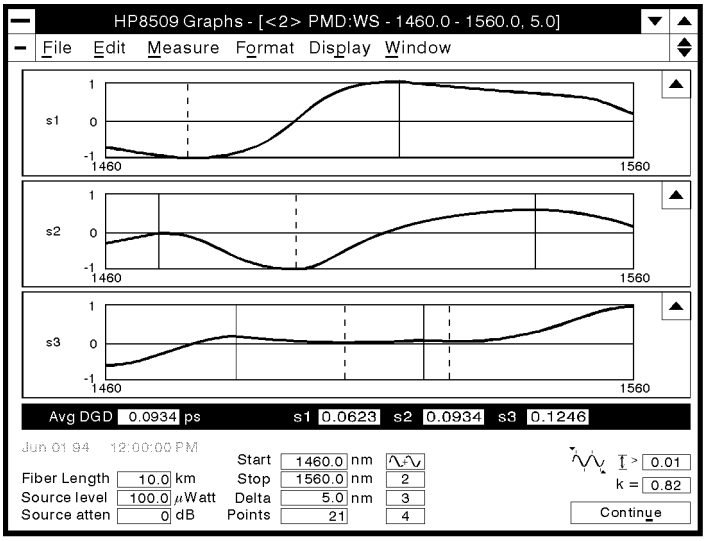
The cascade measurement may also be used to test individual sections of a telecommunications system model or test bed. Such systems consist of many sections, each of which is made up of one or more amplifier/fiber pairs. Such systems may provide measurement taps between sections. The PMD of individual sections may be measured using these taps, without disturbing the through path connections. The output pigtail of the polarization analyzer is connected to the input of the system and left there throughout the measurement. A cascade reference measurement is taken with the optical input of the polarization analyzer connected to the tap just prior to the section of interest. Then the section of interest is added and the second step of the measurement is performed. The resulting measurement characterizes only the selected section. If the goal of the PMD measurement is to relate the PMD of individual sections to the PMD of the whole system, the cascade measurement may be repeated on each of the sections to characterize the sections. At each stage, the composite PMD of all preceding sections is given by the cascade reference measurement. With individual and composite PMD values, one may compare the addition of PMD with the expected root-sum-of-squares expected value.

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PMD Measurement: Wavelength-Scanning Method

Polarization mode dispersion (PMD) is a fundamental physical property of optical fiber and components in which a lightwave is split into two waves of slightly different speed on the basis of polarization state. The two polarization modes experience a difference in propagation time known as "differential group delay" (DGD). The DGD of long optical fibers varies with wavelength. The "PMD" of a test device also refers to the average value of the differential group delay. PMD is fundamentally expressed in units of time, typically picoseconds (1 ps = 10^{-12} s), although in the case of long fibers it may be normalized to the square root of fiber length with the units of picoseconds per root kilometer.

This section explains how to measure the PMD of a test device using the wavelength-scanning (WS) method. A typical measurement result is shown in the following figure.



pq777b_c

Figure 2-34. Example of data display for a wavelength-scanning PMD measurement

Typical applications of the wavelength-scanning method include measurement of medium to long optical fibers and cables. It can also be applied to the measurement of some components, and may be used to characterize amplified systems in which the level of PMD is large enough to produce a useable number of peaks and valleys in the response within the system passband. Consider the following aspects of the wavelength-scanning method when deciding which PMD measurement method to use:

- Measurement speed is slightly faster than the JME method.
- The method can be performed with the HP 8509A or B.
- The method provides more optical power to the DUT than the JME method does.
- A single PMD value, or average differential group delay, is produced from measurement across a wavelength span.
- Broad wavelength ranges are required for measurement of low PMD values.
- The measurement is influenced by pigtail position and polarization launch condition, particularly for low values of PMD.

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Basic Measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the HP 8509A/B Lightwave Polarization Analyzer operating system software to make a wavelength-scanning PMD measurement.

Setting up the System

Connect your measurement system as outlined in the following illustration.

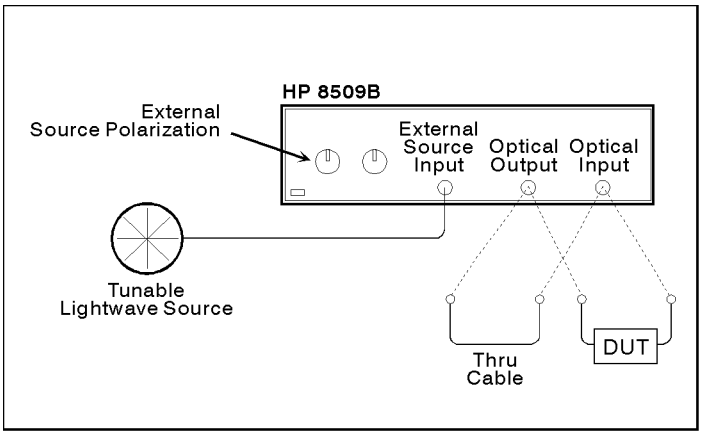


Figure 2-35. Wavelength-Scanning System Setup

If the source signal is applied to the External Source Input of the HP 8509B, External Source Polarization should be adjusted for circular polarization as described in External Source Preparation in this chapter.

Connecting the tunable laser directly to the DUT extends the amplitude range of the measurement to allow measurement of higher loss devices. If the source is not polarized, an external polarizer must be used.

Making the Measurement

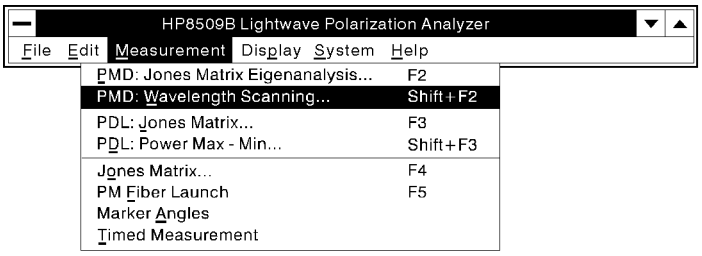
At this point your measurement system is ready to make your first measurement. For our purposes we are going to measure a ten kilometer length of fiber. Connect your test device between the optical output of the laser source and the optical input of the analyzer.

ACCURACY ENHANCEMENT NOTE

The fiber path leading from the tunable laser source to the DUT and from the DUT to the 8509 optical input must not move during the measurement process. Unsupported fiber, particularly unjacketed fiber, should be taped down or placed against stationary objects. Movement of the fiber may jeopardize PMD measurement accuracy.

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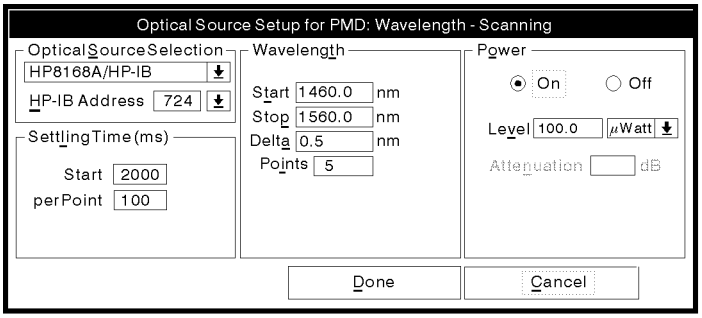
CAUTION Observe proper connection techniques. Refer to the "Lightwave Connector Care" chapter in this manual.



pq793b_c

Figure 2-36. Wavelength-Scanning Measurement Selection

Select `Measurement` from the main menu, and then select `PMD:Wavelength Scanning... Shift+F2`



pq7113_c

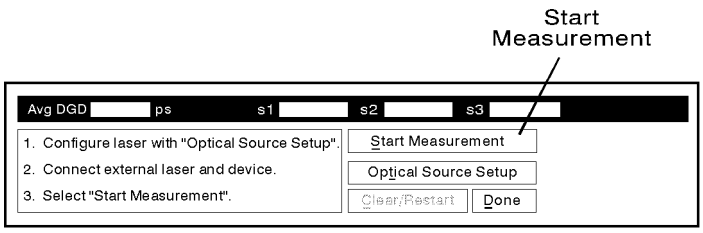
Figure 2-37. Optical Source Setup for PMD:Wavelength Scanning

Verify that the source and wavelength are correct for your measurement, and that the power is on. If the screen on your computer looks like the previous illustration, select Done.

ADDITIONAL INFORMATION

- A broader measurement wavelength range produces a more accurate measurement.
- If you wish to maintain leveled power during the measurement, enter into the power level display of the optical source setup window, a value no greater than the minimum power shown in the lasers display of available laser power.
- Single-mode fiber lengths in the range of 10 km or low PMD fibers, generally, may be adequately measured by using a wavelength delta of 1 nm.
- Single-mode fibers that are much longer than 10 km or have high PMD fibers, are best measured with wavelength deltas of 0.25 nm

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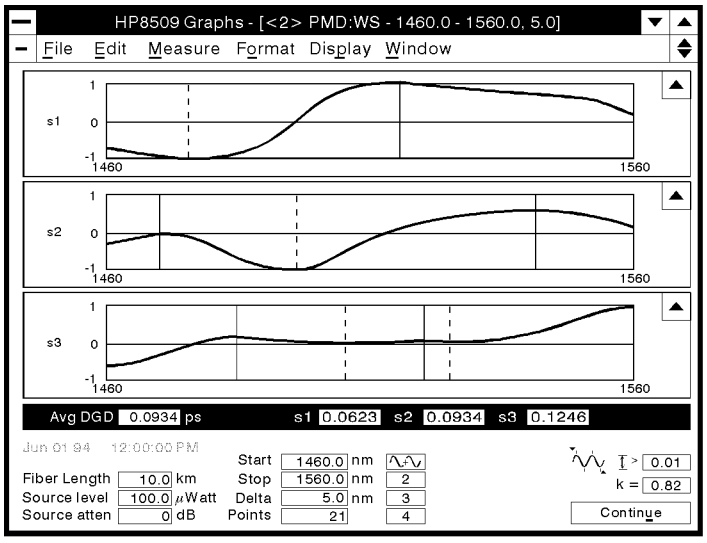
pq7114_c

Figure 2-38. PMD: WS Measurement Start

Select Start Measurement from the HP 8509A/B Graphs screen.
The WS graphs are derived from a series of optical measurements performed across the selected wavelength range. As the measurement progresses, the **Measurement Summary** display bar directly below the graph lists the PMD results obtained, up to the current wavelength.

ACCURACY ENHANCEMENT NOTE

If your wavelength range was not sufficient to provide at least two peaks in one or more of the measurement curves, you will get the message "One or more of the wavelength scanning traces has an insufficient number of peaks." If you choose OK and continue with the measurement, the measurement will ignore these curves and derive PMD from the curves which **do** show at least two peaks.



pq777b_c

Figure 2-39. Measurement Results

Your measurement is complete. The screen on your computer should look similar to the previous illustration.

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The three graphs have fixed Y-axes of +1 to −1 and show the measured values of the normalized Stokes parameters s1, s2, and s3.

PMD is determined from analysis of these graphs.

Manipulating the Measurement Results

When your measurement is complete, you may;

- Select one of the measurement curves to enlarge vertically.
- Review the results in the **Measurement Summary** bar.
- Review the measurement setup conditions in the **Measurement Annotation** area.
- Examine a curve at a particular wavelength, by using the cursor bar.
- Display, edit, and print the data in tabular form.
- Print the graph with or without measurement annotation and data listing.
- Save your measurement and annotation information to a database for future use or to reload the measurement back into the HP 8509A/B.
- Perform other measurements without leaving the **Graphs** window.
- Display all of your measurements in one window, using either tile or cascade mode.

The Measurement Summary Bar

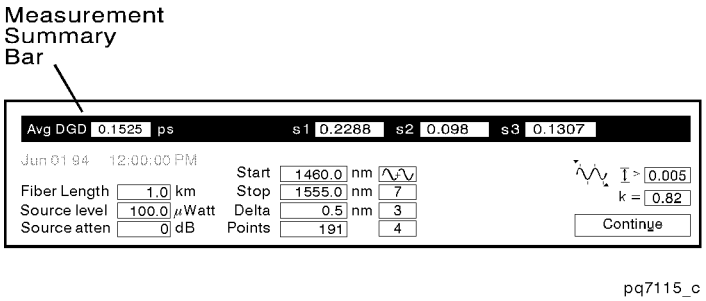


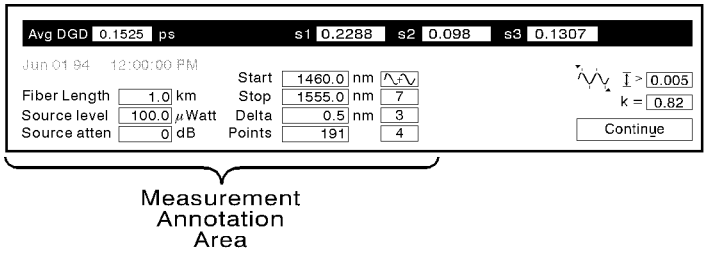
Figure 2-40. The Measurement Summary

The **Measurement Summary Bar** displays the PMD results obtained up to the current wavelength.

All of the displays have the same units, which are user selectable but default to picoseconds. The bar displays the PMD derived from each of the measured Stokes parameters, as well as their average.

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The Measurement Annotation Area

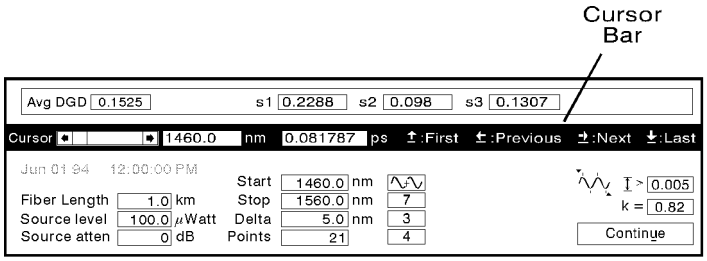


pq7116_c

Figure 2-41. The Measurement Annotation Area

When the measurement ends, the control panel at the bottom of the Graphs window is replaced by the **Measurement Annotation Area**. This area lists the date and time of the start of the measurement, the fiber length in kilometers, the tunable laser power and attenuator settings, the start and stop wavelengths and the step wavelength. It also lists the number of points, that is, the number of wavelengths at which optical measurements were taken. A table lists the number of peaks identified in each of the curves. At the right hand edge of the annotation area is an icon which indicates the type of analysis performed on the traces and the minimum feature size. The value of the mode coupling factor k is also shown. These topics are discussed in detail in the Concepts section under the title Analysis Mode and Minimum Feature Size. The measurement annotation area can be toggled on and off by selecting `Display` from the main window menu, and then `Annotation`.

Using The Cursor



pq7117_c

Figure 2-42. The Cursor Bar

Use the arrow button in one of the graphs to expand the graph. Activate the **Cursor Bar** by selecting `Display` and then `Cursor Bar` from the Graphs window menu. The cursor bar appears between the **Measurement Summary Bar** and the **Measurement Annotation** area. The cursor display shows the normalized stokes parameters for a selected wavelength. The wavelength is selected by the slider control, arrow keys, or by editing the wavelength display.

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Changing The Measurement Format

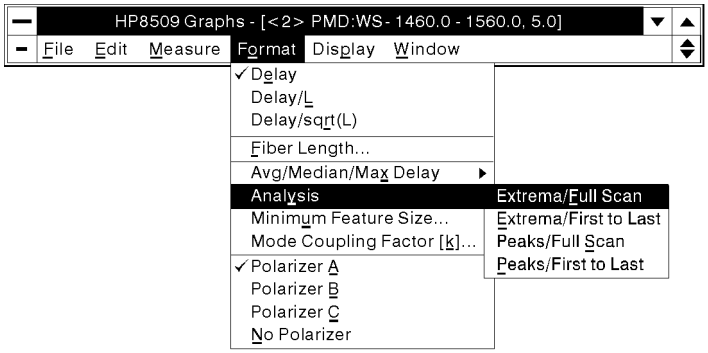


Figure 2-43. Changing the Measurement Format

Select `Format` from the Graphs window menu to access the measurement formatting functions. For a discussion of PMD units, see the section by that title in PMD:WS Concepts.

- `Delay` Causes the PMD values in the **Measurement Summary Bar**, to be displayed in picoseconds.
- `Delay/L` Causes the PMD values in the **Measurement Summary Bar**, to be displayed in picoseconds per kilometer of fiber length.
- `Delay/sqrt(L)` Causes the PMD values in the **Measurement Summary Bar**, to be displayed in picoseconds per root kilometer of fiber length.
- `Fiber Length...` This menu selection lets you enter the length of the fiber you have just measured.
- `Avg/Median/Max Delay` The PMD value displayed in the left most position of the **Measurement Summary Bar**, may be chosen as the average, median, or maximum value of PMD derived from the three graphs s1, s2, and s3.
- `Analysis` This menu item allows selection of the method by which the wavelength-scanning response curves are analyzed. The instrument can be set to count peaks or extrema (peaks plus valleys), and to use the endpoints of the wavelength range or the wavelengths of the first and last feature (peak or peak/valley as appropriate). For a detailed discussion of the Analysis modes, see the PMD:WS Concepts section with that title.
  - `Extrema/Full Scan` Causes the HP 8509A/B to count both peaks and valleys and to use the endpoints of the wavelength scan in the wavelength-scanning formula.
  - `Extrema/First to Last` Causes the HP 8509A/B to count both peaks and valleys and to use the wavelengths of the first and last feature (peak or valley) in the wavelength-scanning formula.
  - `Peaks/Full Scan` Causes the HP 8509A/B to count only peaks and to use the endpoints of the wavelength scan in the wavelength-scanning formula.
  - `Peaks/First to Last` Causes the HP 8509A/B to count only peaks and to use the wavelengths of the first and last (peak) in the wavelength-scanning formula.

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- `Minimum Feature Size..` The value entered here is the amplitude change, in linear units, required between a feature and both of its nearest neighbors in order to be recognized as a feature (peak or valley). For more details, see the PMD:WS Concepts section of the same title.
- `Mode Coupling Factor (k)...` The mode coupling factor must be set according to the type of test device. See the PMD:WS Concepts section of the same title for details
- `Polarizer A`,`Polarizer B`,`Polarizer C`,`No Polarizer` These selections control the use of the internal polarizer and are available only in the HP 8509B. See the PMD:WS Concepts section titled Polarizers for details.

Select the appropriate units for the measurement results. If the fiber is long enough to exhibit strong polarization mode coupling, you may wish to express the result in units of time per root length (`Format` `Delay/sqrt(L)`). The new units are listed, and all values are updated, on the Y-axis of the graph, and in the measurement summary bar.

Displaying and Printing Data in Tabular Format

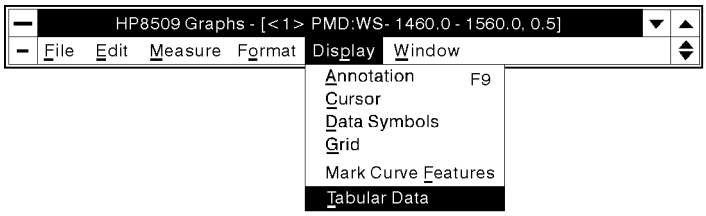


Figure 2-44. Displaying Data in Tabular Format

Display the tabular measurement data by selecting `Display` and then `Tabular Data` from the Graphs main window menu. A text box fills the Graphs window, overlaying the measurement graph. The text box lists information from the measurement annotation area, the values in the measurement summary, and a list of wavelengths at which optical measurements were performed along with the DGD values derived from each pair.

ADDITIONAL INFORMATION

You can add your own notes to the text. All of the standard keyboard and mouse editing features are available. Use the mouse to place a text insertion point anywhere in the document, and then type the desired text. Text may be selected using the drag features of the mouse. Selected text may be deleted or copied to the clipboard by pushing the Copy to clipboard button.

The tabular data text box is limited to 60,000 characters.

All or a portion of the text box information may be printed. Printing uses the default printer selected in the Windows Control Panel. To print all of the text box information just press Print tabular data on the Graphs window area. To print a portion of the text box information, select the desired text with the mouse before pressing Print tabular data. To return to the

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graphic display, select Return to Graph at the top of the window or re-select Tabular Data under the Display menu.

Printing your Graph

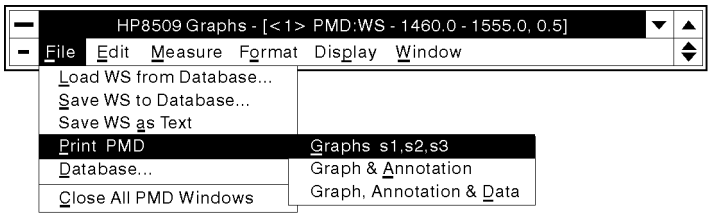


Figure 2-45. Printing your Graph

Select File and then Print PMD from the Graphs main window.

- Selecting Graphs S1, S2, S3 will print only the graph.
- Selecting Graph & Annotation will print the graph and the annotation information discussed in "The Measurement Annotation Area."
- Selecting Graph, Annotation, & Data will print the graph, annotation information and list the measurement wavelengths and the corresponding data points.

Saving your Measurement as Text

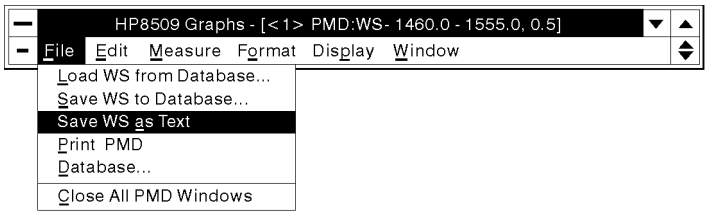


Figure 2-46. Save as Text

Select File and then Save WS as Text from the Graphs main window. A standard window **Save** screen will be displayed. At this point you can select a file name and a directory for the data to be stored. Columns of wavelengths and measurement data points will be saved as text for later use in a spreadsheet.

The data saved as text cannot be recalled for future display by the instrument.

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Saving in Database Format

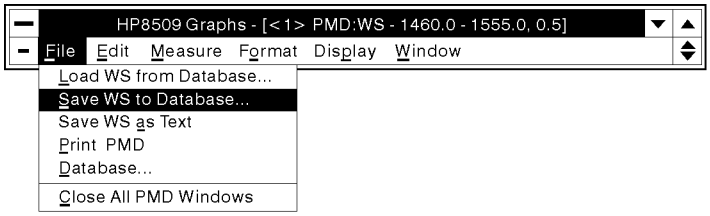


Figure 2-47. Saving in Database Format

Select `File` and then `Save WS to Database...` from the Graphs main window to save the entire measurement and annotation for future analysis using a database program or to reload the measurement and certain setup parameters into the analyzer. A default title for the measurement is provided. The title is made up of the measurement type and the date and time. It is a unique name, but you may wish to edit it for your own purposes.

PMD:WS Concepts

Polarization Mode Dispersion

Polarization modes

PMD is a fundamental property of optical fiber and components by which any lightwave signal is split into two polarization modes that travel at different speeds. In effect, single mode fiber is bimodal with respect to polarization. The difference in propagation time between the two polarization modes is called differential group delay.

General effects

Because of PMD, lightwave pulses launched partly into each of the polarization modes broaden as they propagate, degrading the distinction between pulses. In addition, light from a spectrally wide source may become partly depolarized under the influence of large values of differential group delay. Finally, transmitter laser frequency chirp in combination with PMD in a transmission path can cause a transmitted signal to vary in polarization state as a function of time and signal intensity. If polarization dependent loss is present in the system, the polarization variation is converted to amplitude variation. This effect causes composite second-order distortion in cable-television systems.

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Mode coupling

Mode-coupling is the term given to the coupling of optical energy between polarization modes along the transmission path. Two-port optical devices (including optical fiber) fall into two categories according to the degree of mode coupling. Non-mode-coupled devices include most components, hi-bi (polarization maintaining) fiber and short lengths of ordinary single-mode fiber. For these devices, energy launched into each polarization mode remains in that mode as it propagates. The differential group delay of non-mode-coupled devices is generally independent of wavelength. The other extreme, strong mode coupling, is exhibited by long lengths of single mode fiber. For long fibers, energy couples between modes due to physical variations internal to the fiber and optical effects induced by the fiber's environment. The differential group delay of highly mode-coupled devices is a strong function of wavelength. An intermediate degree of mode coupling, typical of short to medium lengths of optical fiber, results in differential group delay which is a relatively weak function of wavelength.

PMD units

Differential group delay is expressed in units of time, generally either picoseconds (1 ps = 10^{-12} s) or femtosecond (1 fs = 10^{-15} s). Short-fiber PMD may be expressed in terms of time per meter or kilometer. Due to the effects of mode-coupling, long-fiber differential group delay increases as the square root of fiber length. Therefore, long-fiber differential group delay is often expressed in terms of time per square root of fiber length (in kilometers).

Optimizing the setup for fiber or component test

Wavelength tuning range

The wavelength-scanning PMD measurement is based upon the detection of changes in output polarization as a function of wavelength. These changes are manifested as peaks and valleys in the normalized Stokes parameter responses s1, s2 and s3. Single-mode fiber measurements are more accurate if the number of peaks is large; wavelength range should be chosen to produce ten or more peaks. However, because the 8509's implementation of wavelength-scanning method analyzes three polarization axes or components, accuracy is enhanced and useful measurements may be obtained from wavelength-scanning responses having fewer peaks.

When measuring components and polarization maintaining fiber, the wavelength-scanning responses are sinusoidal. In such cases, a good measurement can be derived from a single pair of peaks or extrema, although accuracy is somewhat improved for larger numbers of features.

The wavelength spacing of peaks is predictable for non-mode coupled devices (most components). At 1550 nm, the product of the DGD of the test device (in ps) and the wavelength interval between adjacent peaks (in nm) is approximately 7.4 ps nm. A device with DGD of 1.0 ps produces a peak every 7.4 nm.

Analysis mode

The analysis mode is represented at the right hand edge of the annotation area of the Graphs window by an icon showing a sine wave with two types of marks, or tics. The two bold triangular marks indicate whether the analysis is using the full scan or first and last feature wavelengths in the wavelength-scanning formula. The smaller, vertical marks indicate whether the analysis is counting peaks or peaks and valleys.

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PMD Measurement: Wavelength-Scanning Method

Depending upon the analysis mode selected, the wavelength-scanning algorithm counts peaks or extrema (peaks and valleys). When the number of peaks occurring in the selected wavelength range is small, accuracy is improved by choosing one of the extrema-based analysis modes; extrema full scan or extrema first to last.

When measuring single mode fiber, analysis should be applied to the full wavelength scan. When measuring components and polarization maintaining fiber, cases in which the wavelength-scanning responses are sinusoidal, analysis should be started and ended on the first and last peak (or extrema). This avoids error caused by the arbitrary relationship of the endpoints of the wavelength scan and the first and last peaks (or extrema) of the wavelength-scanning response.

In summary, use the analysis modes as follows;

Single-mode fiber	peaks or extrema/full scan
Components, PMF	peaks or extrema/first to last

Always analyze extrema if the number of peaks is small.

Minimum feature size

Once a wavelength-scanning response has been measured, it must be analyzed to identify and count the peaks or peaks and valleys (extrema). The “minimum feature size” parameter specifies the magnitude change which differentiates a peak from an adjacent valley. The default minimum feature size is .05, a dimensionless number. The value is user selectable. It may be increased in size in situations where fiber movement is causing the detection of false peaks and valleys.

Statistical characterization of fiber PMD

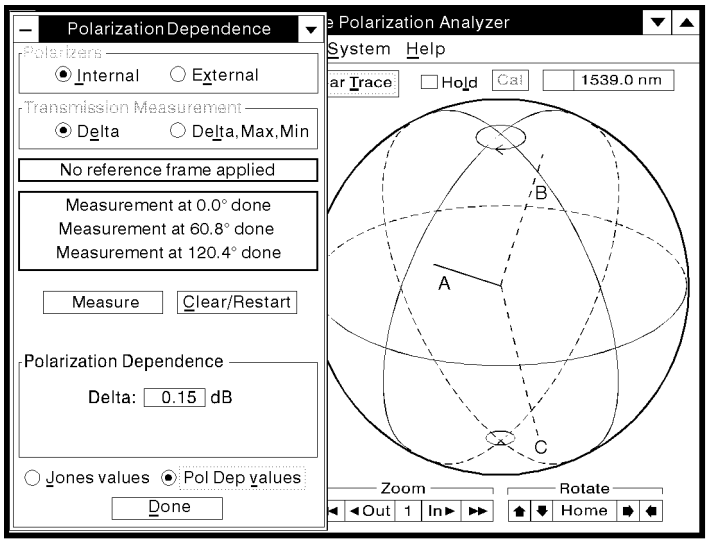
The wavelength-scanning method is less commonly used for accumulation of fiber PMD statistics than its counterpart, the Jones matrix eigenanalysis method. However, statistics may be gathered from a series of wavelength-scanning measurements performed at different temperatures or other physical configurations of the fiber. Each wavelength-scanning measurement contributes a single point to the distribution, unlike the Jones matrix eigenanalysis method in which each wavelength interval produces a point.

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PDL Measurement: Jones Matrix Method

Polarization dependent loss (PDL) describes the insertion loss variation, gain variation or coupling variation of an optical component, given all possible input signal polarization states. It is found in all lightwave components to some degree. PDL can be desirable (in a linear polarizer) or undesirable (in a telecommunication system or cable TV system) depending on the application.

This measurement section explains how to measure the polarization dependent loss or gain of a test device using the Jones matrix (PDL:JM) method. This method measures the absolute or relative PDL of a lightwave component and displays the results as shown in the following figure.



pq774b_c

Figure 2-48. Example of a Jones matrix PDL measurement data display

Typical test devices for this method include EDFAs, couplers, isolators, optical connectors and long fiber cables. Consider the following aspects of this method when deciding whether to use PDL:JM or the PDL: Power Max-Min method.

- Measurements are typically completed in two to three seconds.
- Measurement uncertainty is typically ±0.1 dB.
- Measurement range is 3.0 dB.
- Operation is completely automatic.

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Basic Measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the HP 8509B Lightwave Polarization Analyzer operating system software to make a PDL: Jones Matrix measurement.

Setting up the System

Connect your measurement system as outlined in the following illustration. Begin by connecting the thru cable as shown in the following figure.

ACCURACY ENHANCEMENT NOTE

The fiber cable leading from the external source to the HP 8509A/B EXTERNAL SOURCE INPUT must be taped down to prevent any movement after source polarization has been adjusted. Movement of this source cable may jeopardize measurement accuracy.

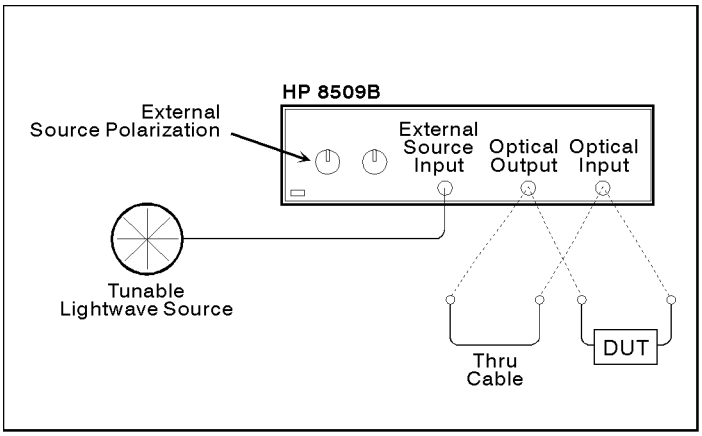


Figure 2-49. Measurement Setup

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External Source Preparation

Before performing the measurement, you must select an optical source. The following procedure will guide you through the process.

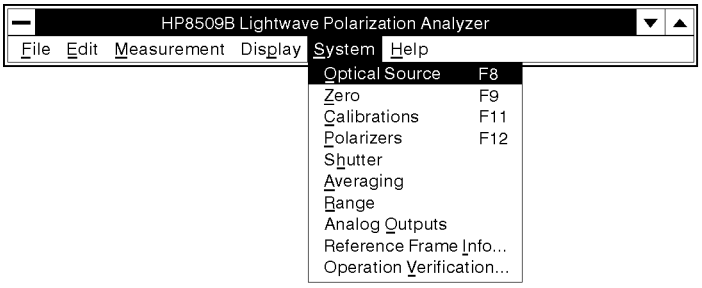


Figure 2-50. System Menu

Select `System` from the main menu, and then select `Optical Source`.

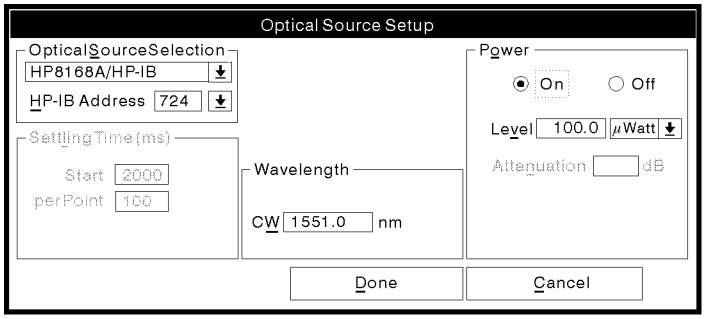


Figure 2-51. Optical Source Setup

Select the external laser source and set the CW wavelength for your measurement. Use the default power level or set as desired. If the screen on your computer looks similar to the previous illustration, select Done.

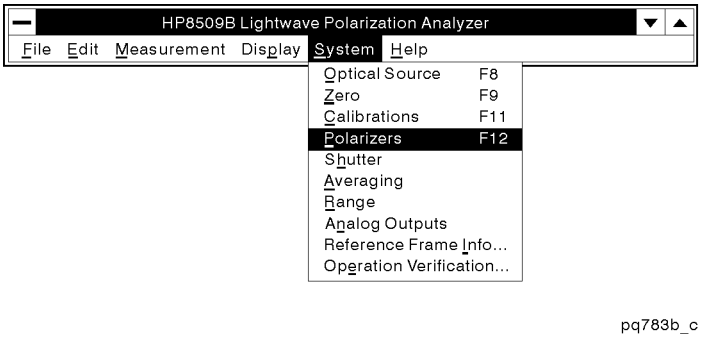


Figure 2-52. Polarizer Selection

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Select `System` from the main menu, and then select `Polarizers`

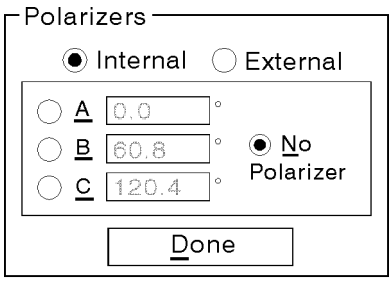


Figure 2-53. Polarizer Setup

Set the polarizers to (Internal) and select (No Polarizer). If the screen on your computer looks like the previous illustration, select (Done).

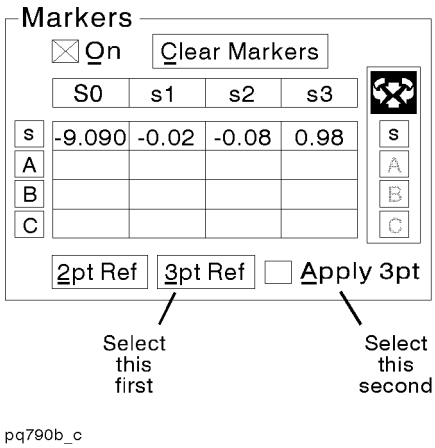


Figure 2-54. 3pt Reference Applied

Select `3pt Ref` from the Markers Area on the Main Screen, wait 5 seconds, and then select `Apply 3pt`.

ADDITIONAL INFORMATION

Creating and applying a 3pt reference frame allows measurement of polarization state within a physical frame of reference. In this case, the reference frame is located inside the internal polarizer assembly.

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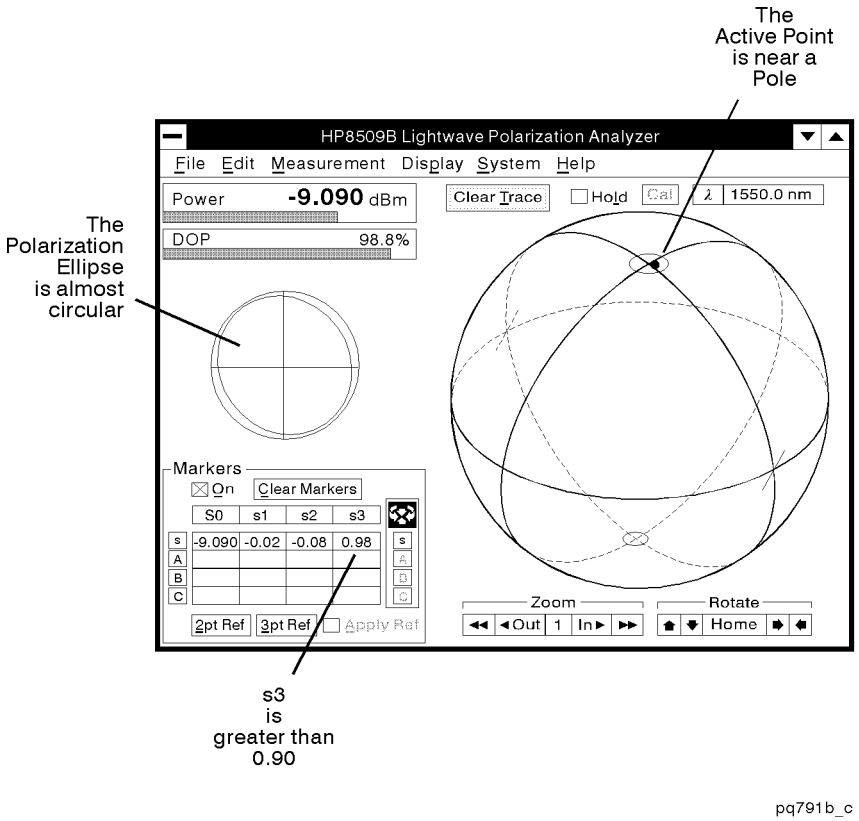


Figure 2-55. Circular Polarization

Adjust the External Source Polarization knobs on the front panel of the HP 8509B until the active point on the Poincare sphere approaches a pole, and the absolute value of the s3 marker is greater than 0.90. The active point is easier to see by marking the current point (select `Display` and then `Mark Current Point`. Also notice that the polarization ellipse will become more circular as s3 approaches 0.90. Then un-apply the 3pt reference before going on to do the JME PMD measurements. Do not move the cable or the external source polarization knobs.

FOR MORE INFORMATION

More information on State of Polarization (SOP) and Degree of Polarization (DOP) may be found in the glossary.

Making the Measurement

At this point your measurement system is ready to make your first measurement. For our purposes we are going to measure a optical isolator. Remove the fiber thru cable connecting the optical output to the optical input on the HP 8509B. Connect your test device between the optical output and the optical input.

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ACCURACY ENHANCEMENT NOTE

Accuracy is affected by the PDL of the optical connectors, the physical stability of the fibers during the test procedure, the DOP of the source, and the test signal power level. Accuracy is also degraded when the DUT depolarizes the test signal. This can occur when the differential group delay (between Ex and Ey), caused by the DUT, is greater than the coherence time (=1/(line width of the source in Hz)) of the test signal.

CAUTION Observe proper connection techniques. Refer to the "Lightwave Connector Care" chapter in this manual.

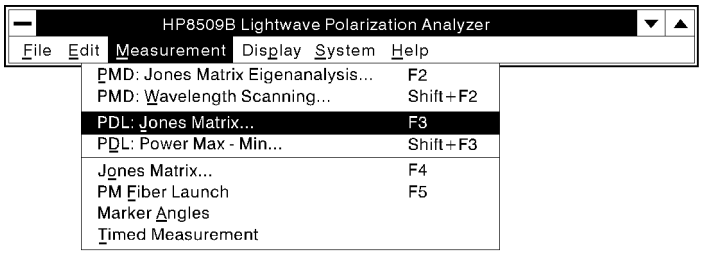


Figure 2-56. Jones Matrix Measurement Selection

Select `Measurement` from the main menu, and then select `PDL:Jones Matrix ... F3`

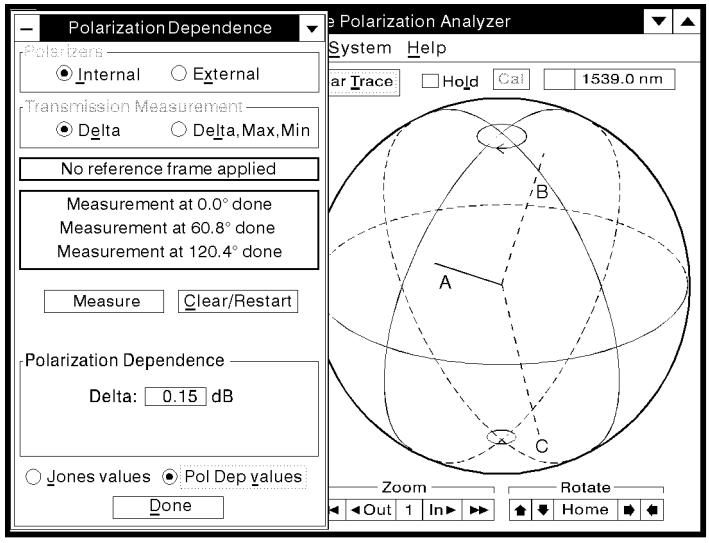
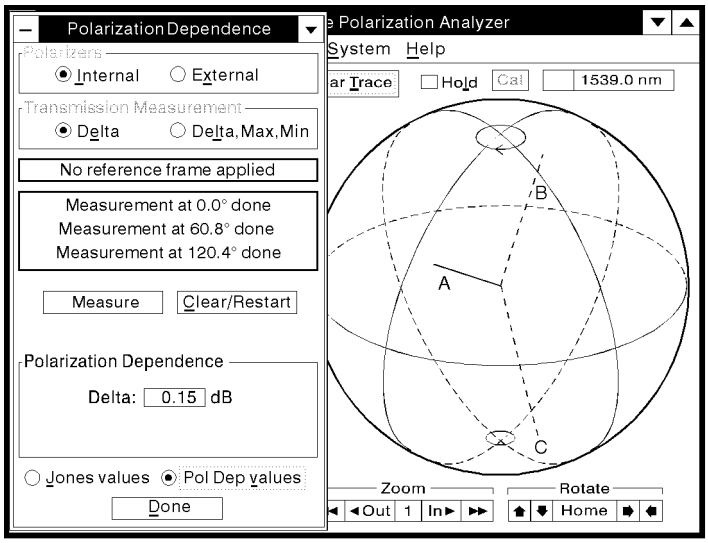


Figure 2-57. Jones Matrix Measurement Window

- Select Internal Polarizers and Delta Transmission Measurement.
- Connect the device you wish to measure.

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- Press the Measure button with your mouse pointer. The results of the measurement will appear in the Polarization Dependence data window.



pq774b_c

Figure 2-58. Measurement Results

Your measurement is complete. The screen on your computer should look similar to the previous illustration.

Saving the Measurement Results

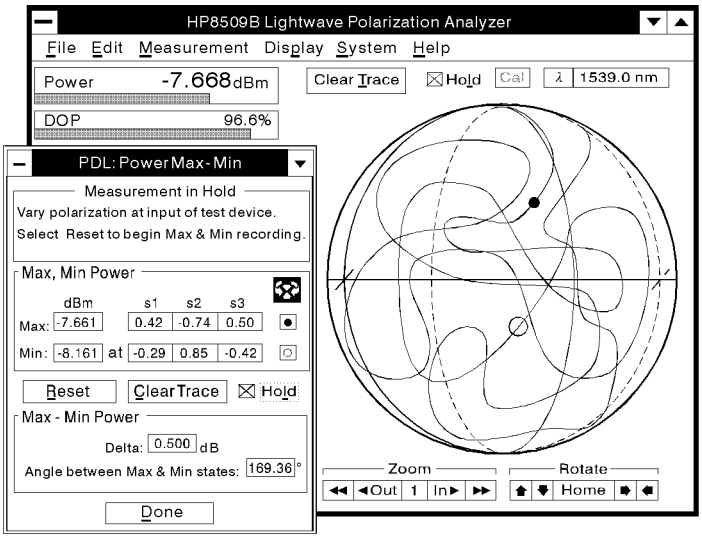
When your measurement is complete, you may save your results for future use by selecting `File` from the main window menu, then `Save`, and then `Jones Matrix & PDL: Jones Matrix...`. Also see chapter 4 in this manual.

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PDL Measurement: Power Max-Min Method

Polarization dependent loss (PDL) describes the insertion loss variation, gain variation or coupling variation of an optical component, given all possible input signal polarization states. It is found in all lightwave components to some degree. It can be desirable (in a linear polarizer) or undesirable (in a telecommunication or cable TV system) depending upon the application.

This measurement section explains how to measure the polarization dependent loss, or gain, of a test device using the power max-min method (PDL:PMM). A data display example is shown in the following figure.



pq775b_c

Figure 2-59. Example of a PDL measurement data display

Typical test devices for this method include linear polarizers, EDFAs, couplers, isolators, optical connectors and medium to long fiber cables. Consider the following aspects of PMM PDL when deciding whether to use this method or the Jones matrix PDL method.

- Measurements are typically completed in 10 seconds to three minutes.
- Measurement uncertainty is typically ±0.06 dB.
- Measurement range is 30.0 dB.
- Operation is completely automatic, when an automatic polarization controller is used.

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Basic Measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the HP 8509A/B Lightwave Polarization Analyzer operating system software to make a PDL: Power Max-Min measurement.

Setting up the System

Connect your measurement system as outlined in the following illustration. The HP 11896A Polarization Controller is recommended for this application.

ACCURACY ENHANCEMENT NOTE

Avoid fiber movement to eliminate errors due to bending loss.

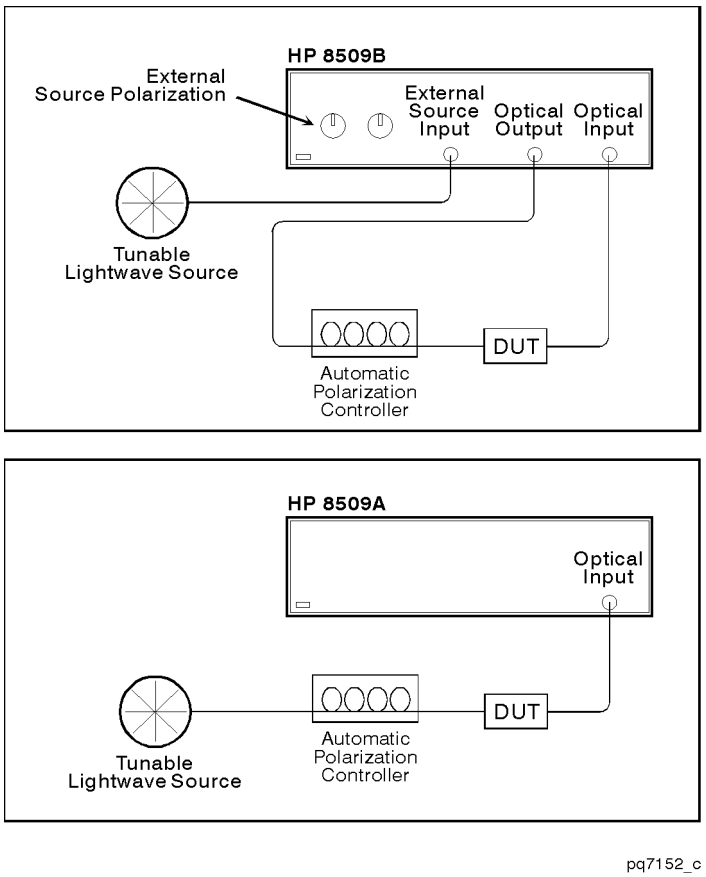


Figure 2-60. Measurement Setup

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External Source Preparation

Before performing the measurement, you must select an optical source. The following procedure will guide you through the process.

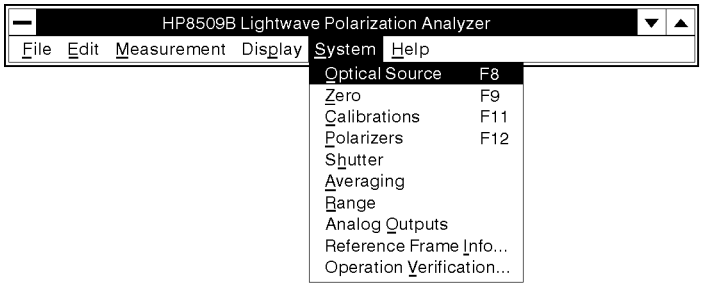


Figure 2-61. System Menu

Select `System` from the main menu, and then select `Optical Source`.

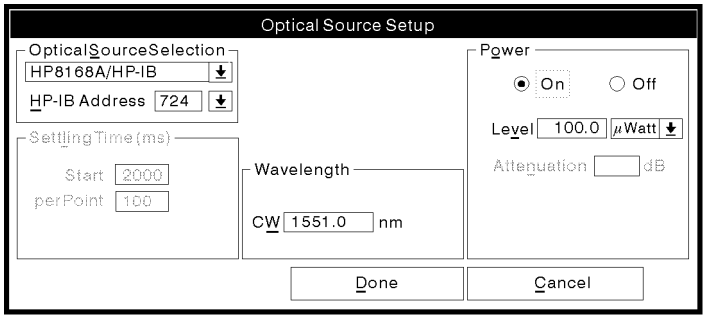


Figure 2-62. Optical Source Setup

Select the external laser source and set the wavelength. Use the default power level or set as desired. If the screen on your computer looks similar to the previous illustration, select Done.

Making the Measurement

At this point your measurement system is ready to make your first measurement. For our purposes we are going to measure an optical isolator. Connect your test device between the polarization controller and the optical input.

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ACCURACY ENHANCEMENT NOTE

Accuracy is affected by the PDL of the optical connectors, the physical stability of the fibers during the test procedure, the DOP of the source, and the test signal power level. Accuracy is also degraded when the DUT depolarizes the test signal. This can occur when the differential group delay (between Ex and Ey), caused by the DUT, is greater than the coherence time (=1/(line width of the source in Hz)) of the test signal.

CAUTION Observe proper connection techniques. Refer to the "Lightwave Connector Care" chapter in this manual.

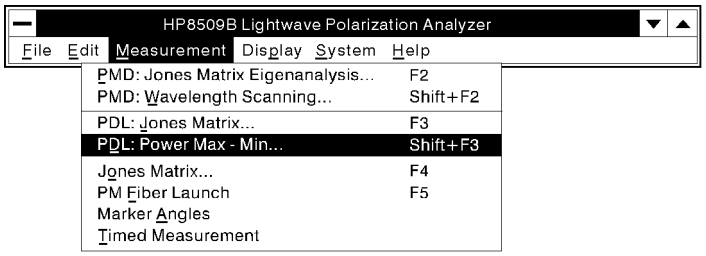
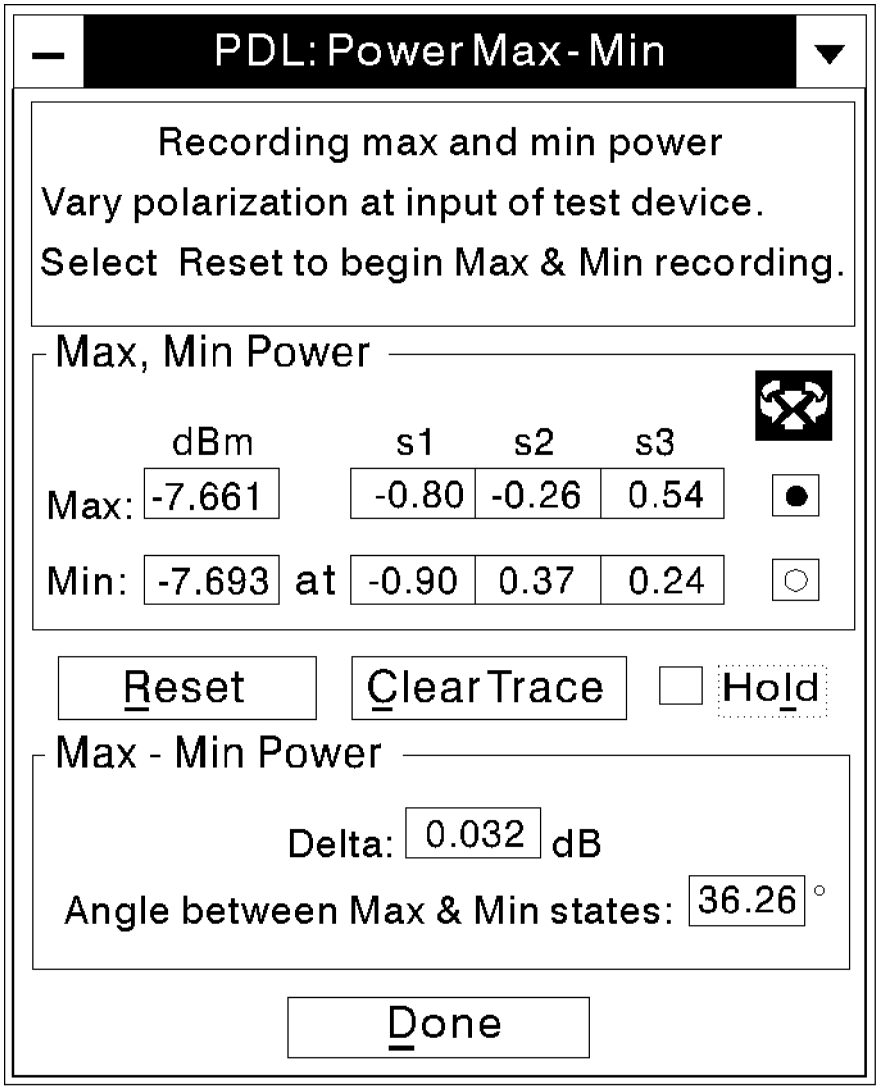


Figure 2-63. PDL Measurement Selection

Connect the device you wish to measure then select `Measurement` from the main menu, and then select `PDL:Power Max-Min ... Shift+F3`

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pq7151_c

Figure 2-64. PDL:Power Max-Min Measurement Window

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- Select the Reset button with your mouse pointer.
- Vary the polarization at the input of your device under test, preferably using an automatic (like the HP 11896A polarization controller, versus a manual controller) polarization controller. Continue adjustment until the Poincare sphere has been fully explored or the value of Delta has stabilized.

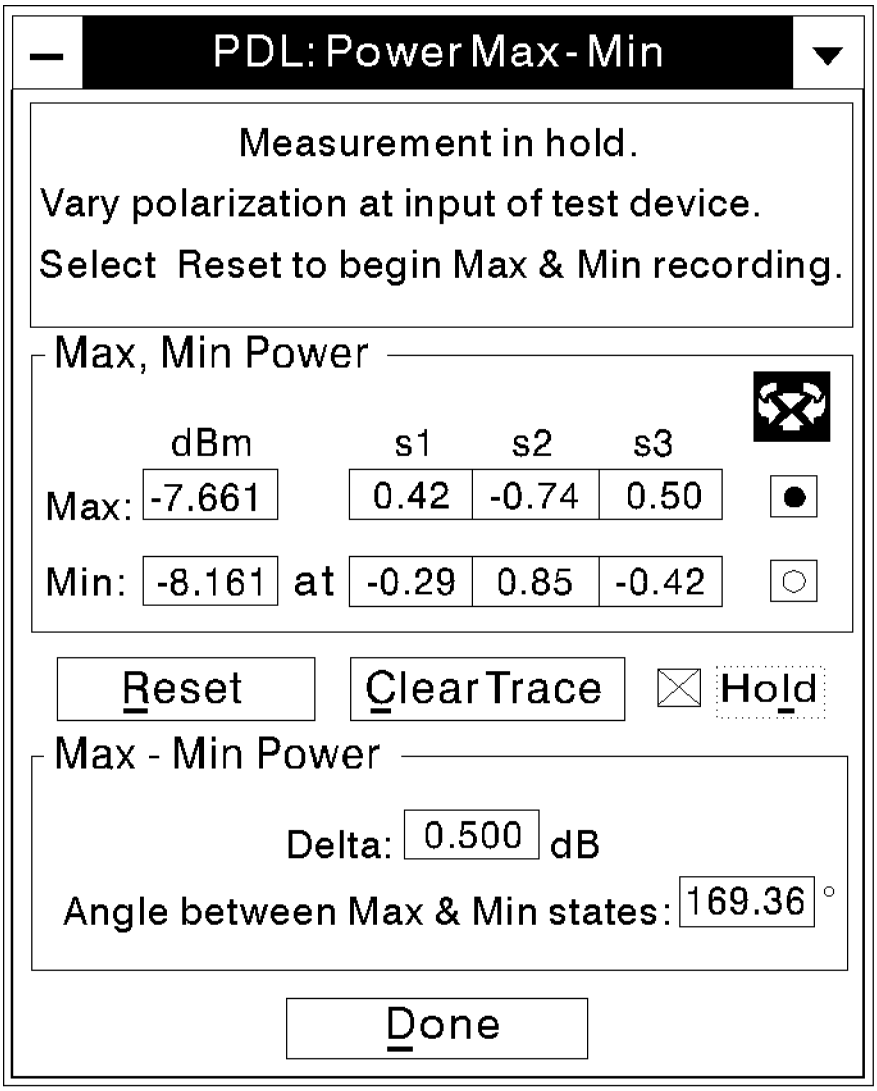


Figure 2-65. Measurement Results

Your measurement is complete. The screen on your computer should look similar to the previous illustration.

If an automatic polarization controller is used, the scanning speed of the polarization controller and the display averaging factor of the HP 8509A/B should be adjusted so that the HP 8509A/B can follow the polarization state changes.

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For the HP11896A polarization controller, automatic polarization scan rates of #4 to #5 are recommended depending on the PDL of the test device.

Saving the Measurement Results

Saving data capability is not available for this measurement.

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Jones Matrix Measurement

A Jones matrix is a complex two-by-two matrix that is measured by the analyzer and mathematically describes the polarization transfer function of an optical component at a specific optical wavelength. The Jones matrix of a lightwave component or device can be used to predict the SOP of an optical output signal given a specific SOP input signal. It is also used by the analyzer to calculate PDL and PMD and a polarization reference frame.

This measurement section explains how to measure the Jones matrix of a test device. A sample data display is shown in the following figure.

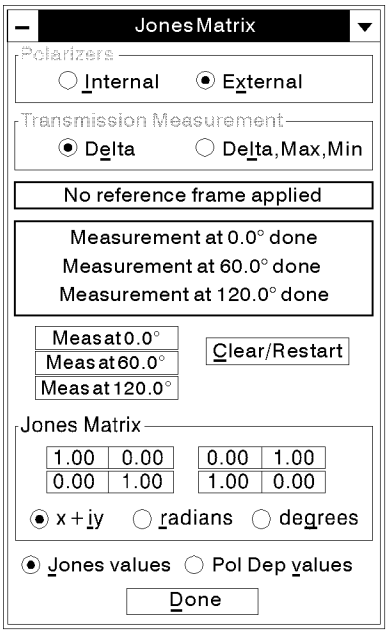


Figure 2-66. Example of data display for a Jones matrix measurement

Basic Measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the HP 8509A/B Lightwave Polarization Analyzer operating system software to make a Jones Matrix measurement.

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Setting up the System

Connect your measurement system as outlined in the following illustration. The HP 11896A polarization controller is recommended as the polarization adjuster for this application.

ACCURACY ENHANCEMENT NOTE

All fiber cables must be taped down to prevent any movement. Movement of cables may jeopardize measurement accuracy.

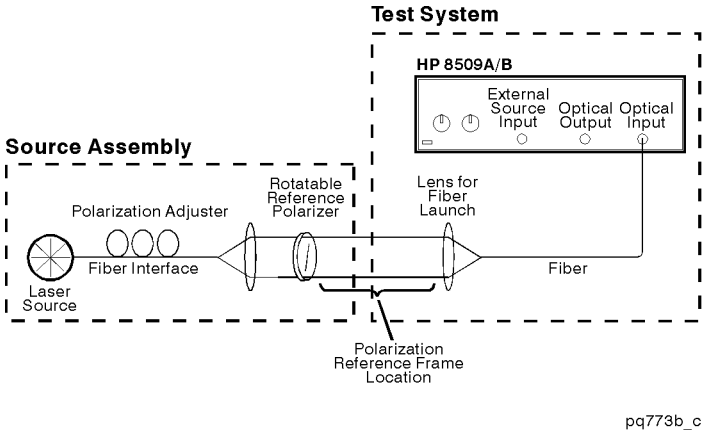


Figure 2-67. Measurement Setup

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External Source Preparation

Before performing the measurement, you must select an optical source. The following procedure will guide you through the process.

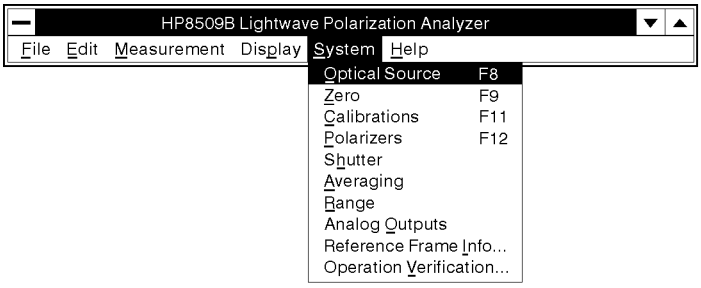


Figure 2-68. System Menu

Select `System` from the main menu, and then select `Optical Source`.

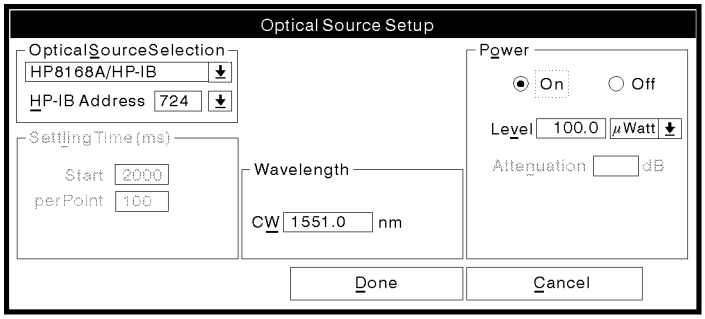


Figure 2-69. Optical Source Setup

Select the external laser source and set the CW wavelength for your measurement. Use the default power level or set as desired. If the screen on your computer looks similar to the previous illustration, select Done.

Next, set the HP8509B to use external polarizers. In the main window, select the System menu and Polarizers. When the Polarizers controls appear, select External with the mouse and select Done.

The next step is to adjust the source polarization so that approximately circularly polarized light is applied to the polarizers. To do this we create a temporary polarization reference frame.

Set the external reference polarizer to a starting angle, say 0 degrees, and select marker A on the main window.

Set the polarizer approximately 60 degrees from the original position and select marker B. Carefully remove the rotatable reference polarizer.

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Select [2pt Ref] and [Apply 2pt] with the mouse. Adjust the source assembly polarization adjuster until the active point on the Poincare sphere approaches a pole and the absolute value of the s3 marker is greater than 0.90. The active point is easier to see by marking the current point (select Display and then Mark Current Point).

Un-apply the 2-pt reference before proceeding. Replace the reference polarizer in the light beam.

FOR MORE INFORMATION

More information on State of Polarization (SOP) and Degree of Polarization (DOP) may be found in the glossary.

Measurement Procedure

At this point your measurement system is ready to make your first measurement. For our purposes we are going to measure a quarter-wave retarder oriented 45° to horizontal.

The measurement has two parts:

1. A polarization reference frame is established in the open beam by mathematically removing the birefringence and residual PDL of the path from the reference polarizer to the polarization receiver inside the HP8509A/B.
2. The test device is inserted in the open beam, Jones Matrix measurement window is opened and the device is measured at the same three reference polarizer angles used to create the reference frame.

Establish the Polarization Reference Frame

The Jones matrix of the test device is measured and expressed within the context of the angular relationship of the test device to the first, or horizontal, reference polarizer position. In some applications, it may be able to align a particular axis of the test device with this polarizer orientation.

1. Place the reference polarizer in the open beam, allowing enough space following the polarizer to insert the test device.
2. Rotate the polarizer to the position you wish to define as horizontal. Select marker A.

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ACCURACY ENHANCEMENT NOTE

From this point on, the fiber path and optics between the reference polarizer and the HP 8509A/B must not move. Movement will degrade measurement accuracy.

3. Rotate the reference polarizer by 60 degrees. Select marker B.
4. Rotate the reference polarizer another 60 degrees, for a total of 120 degrees from the initial orientation. Select marker C.
5. From the Markers area, select 3pt Ref and then Apply 3pt.

CAUTION Observe proper connection techniques. Refer to the "Lightwave Connector Care" chapter in this manual.

Making the Measurement

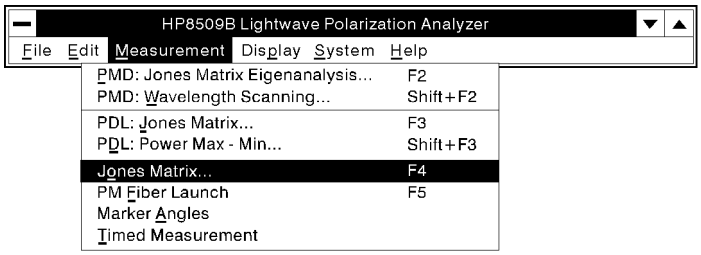


Figure 2-70. Jones Matrix Measurement Selection

Select `Measurement` from the main menu, and then select `Jones Matrix ... F4`

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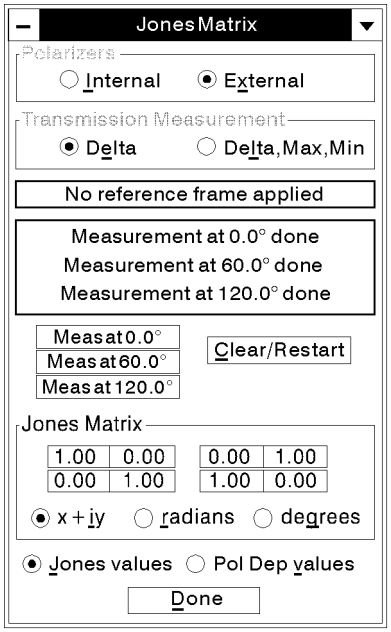
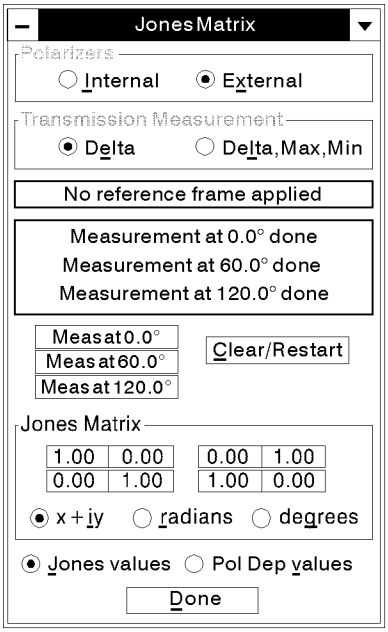


Figure 2-71. Jones Matrix Measurement Window

- Select External Polarizers and Delta Transmission Measurement.
- Insert the test device into the polarization reference frame location with the desired angular orientation relative to the first reference polarizer setting.
- Set the external polarizer angle to 0 degrees and then select **Meas at 0.0** from the Jones Matrix window.
- Set the external polarizer angle to 60 degrees and then select **Meas at 60.0** from the Jones Matrix window.
- Set the external polarizer angle to 120 degrees and then select **Meas at 120.0** from the Jones Matrix window.

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pq776b_c

Figure 2-72. Measurement Results

Your measurement is complete. The screen on your computer should look similar to the previous illustration. Notice that the Jones matrix measurement data can be shown in three formats: x+jy and magnitude and phase in radians and degrees. Polarization dependent values can be viewed by selecting **Pol Dep values** from the Jones Matrix window.

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Concepts

The Relative Jones Matrix

The HP8509A/B determines the Jones matrix to within a complex constant which relates to the absolute delay of the signal through the device under test. In other words, the Jones matrix only describes the differences between input and output light, not the time delay.

When the Jones matrix is measured in the fashion described in the basic measurement example above, the results are normalized before they are displayed. In general, the four elements of the matrix are normalized to the value in the lower right hand corner. Both amplitude and angle are normalized. Therefore, the lower right element may be displayed as 1 + j0 in the case of real and imaginary format, or 1.0 at an angle of 0.0 in the case of polar format. If the amplitude of the lower right element is very small and therefore vulnerable to noise, the instrument normalizes to one of the other elements of the matrix. This will be apparent from inspection of the results.

Jones matrix measurements should not be performed using the Delta, Max, Min mode as selected in the Jones Matrix window. This mode does not use a reference frame and the values of the Jones matrix returned from this measurement mode are influenced by birefringence and PDL in the path between reference polarizer and the HP8509A/B.

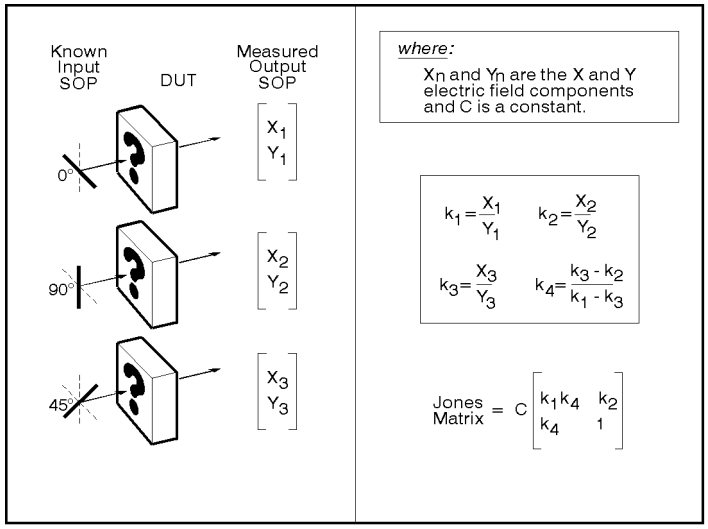
The sign of s3

Different reference texts use different conventions for the sign of normalized Stokes parameter s3. The convention used in the HP8509A/B is shown in the appendix to this manual.

Description of the Jones Matrix Measurement Algorithm

The HP 8509B automatically calculates the Jones matrix of a component using three different, known, linear states of polarization (typically at 0, 60 and 120 degrees). These are created using either the internal polarizer plates of the HP 8509B or an external, rotatable, linear polarizer as shown in the following figure. Each state of polarization individually stimulates the DUT while the output polarization is measured and recorded. It has been shown by R.C. Jones that this polarization information is sufficient for the HP 8509 to calculate a Jones matrix. The simple case where the known polarized inputs are 0, 45, and 90 degrees in shown in the following figure.

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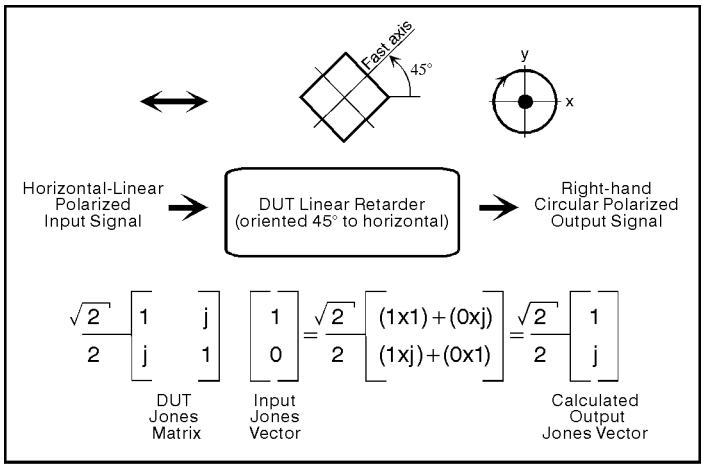


pq770b_c

Figure 2-73. Comparing the output Jones Vectors to 3 known input Jones Vectors

Application of the Jones Matrix

A Jones matrix for a specific device can be used to project the output state of polarization given that the Jones vector of the input signal is known. For example, Jones matrix calculations predict that a quarter- wave retarder, oriented 45 degrees to horizontal, will create a right-hand circular, polarized output when excited by a horizontal-linear, polarized lightwave signal.



pq759b_c

Figure 2-74. Jones Matrix Application

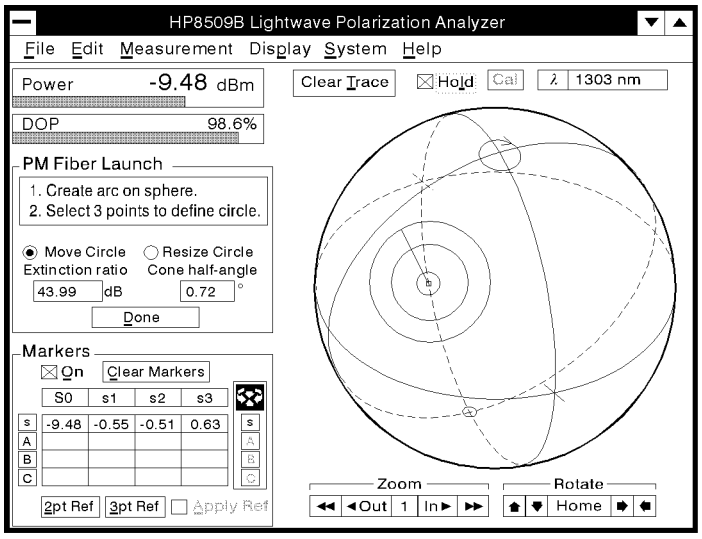
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Timed Measurements

Timed measurement documentation is in an online document. Select the Read Me icon in the Windows Program Group for more information about timed measurements.

Polarization Maintaining Fiber Launch

This measurement section explains how to align an input signal relative to a principal polarization state of a PMF cable. An HP 8509A/B Poincare sphere PMF alignment method is used, and 0 to 60 dB extinction ratios may be achieved depending on the polarization maintaining fiber. A sample data display is shown in the following figure.



pq763b_c

Figure 2-75. Example of a Polarization Maintaining Fiber Alignment data display

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Basic Measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the HP 8509A/B Lightwave Polarization Analyzer operating system software to make a PM Fiber Launch measurement.

Setting up the System

Connect your measurement system as outlined in the following illustration.

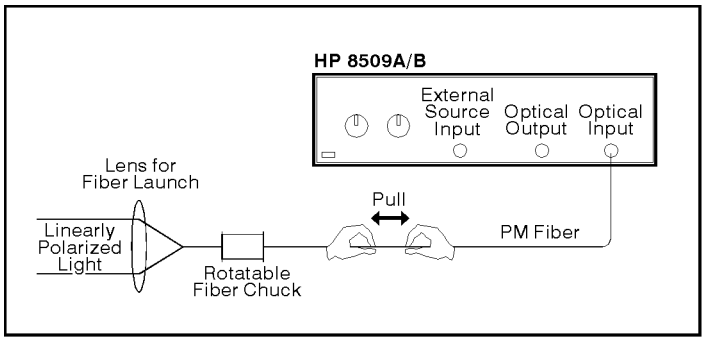
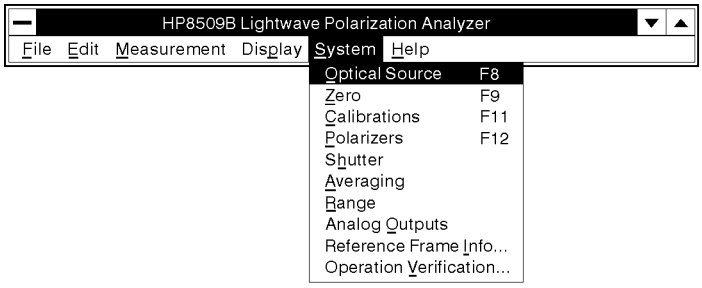


Figure 2-76. Measurement Setup

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External Source Preparation

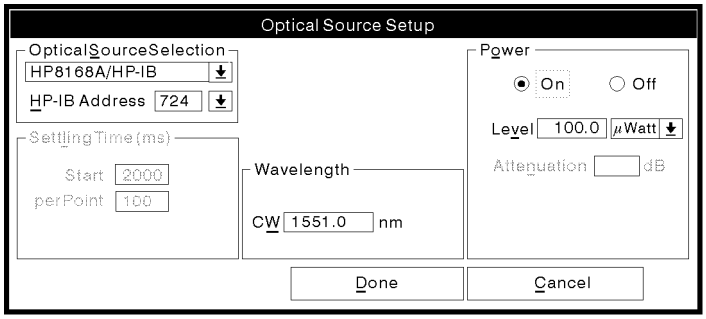
Before performing the measurement, you must select an optical source. The following procedure will guide you through the process.



pq780b_c

Figure 2-77. System Menu

Select `System` from the main menu, and then select `Optical Source`.



pq71b_c

Figure 2-78. Optical Source Setup

Select the external laser source and set the CW wavelength for your

measurement. Use the default power level or set as desired. If the screen on your computer looks similar to the previous illustration, select Done.

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Making the Measurement

At this point you are ready to make your first PMF alignment. For our purposes we are going to align a short length of fiber optic cable.

ADDITIONAL INFORMATION

The PMF alignment, or launch, method is based on the fact that if the launch into the PMF cable is misaligned then optical power is being sent into the orthogonal fast and slow axes of the PMF cable. The relative velocity or phase relationships between these two paths can be changed by slightly pulling or heating the fiber. This changes the cables output polarization and traces an arc on the Poincare sphere. The analyzer calculates the PMF cable launch extinction ratio by using a circle that you fit into an arc. The location of the arc and circle on the Poincare sphere are not important, since only the length of the radius of the circle, is used to calculate the extinction ratio of the launch. As the alignment is adjusted, the axis of the PMF cable will approach the linearly polarized input signal. Most of the optical power will be launched into one axis of the fiber and the arc on the Poincare sphere will approach a center point. The ideal alignment is at the center point of the arc.

CAUTION Observe proper connection techniques. Refer to the "Lightwave Connector Care" chapter in this manual.

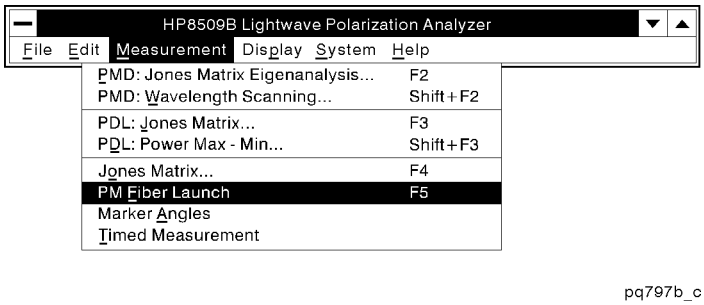
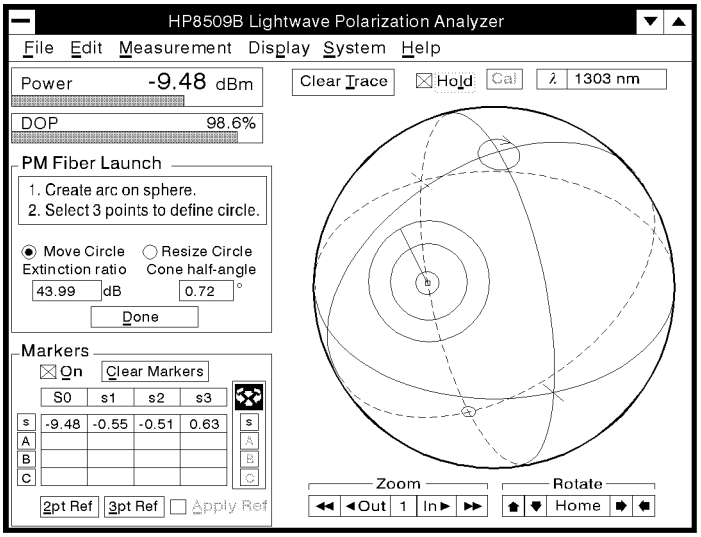


Figure 2-79. PM Fiber Launch Measurement Selection

Select `Measurement` from the main menu, and then select `PM Fiber Launch  F3`

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pq763b_c

Figure 2-80. PM Fiber Launch Alignment Window

- Slightly stress the PMF cable by pulling or heating it until an arc appears on the Poincare sphere. Be sure that the arc is on the front of the sphere, as indicated by a red line. If the arc is on the back side of the sphere use the **Rotate** function on the lower right side of the main window.
- Place three points along this arc by using the mouse pointer and then clicking the left mouse button.
- Select the Center button to center the display.
- Rotate the fiber chuck until the active point on the Poincare sphere approaches the center of the circle.
- Use the Poincare display **Zoom** and PM Fiber Launch **Center** functions to optimize the view of the arc.
- Slightly stress the PMF cable by pulling or heating it until an arc appears again.
- Select the New Circle button, place three points on the arc using the mouse pointer.
- Continue the previous steps until the value in the dB extinction ratio window is maximized.
- Select the Done button to finish this procedure.
- To align another PMF cable, connect it to the analyzer and repeat the previous procedure.

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Concepts

Explanation of Polarization Maintaining Fiber Launch

Mathematics The dB extinction ratio of the PMF launch is calculated according to the radius R drawn on the Poincare sphere as shown in the following figure.

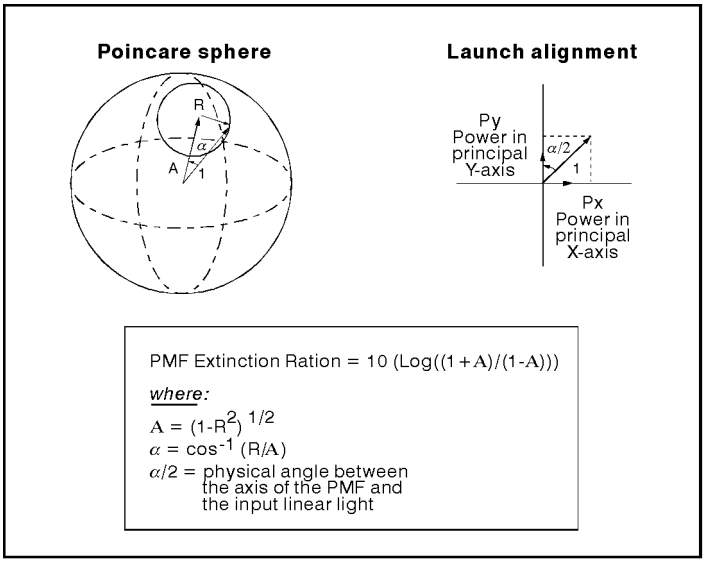
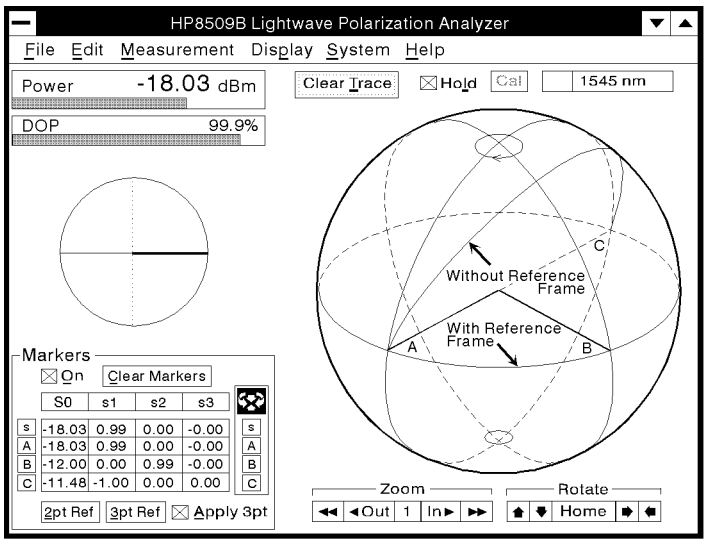


Figure 2-81. How PMF cable launch extension ratio is calculated

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Polarization Reference Frame

A polarization reference frame can increase the accuracy of polarization measurements by isolating the test device response and minimizing the effect of the test system, including the optical cables used to connect the test system to the test device. This is valuable for measurements where the response of the test device would otherwise be hidden by the response of the test system, as illustrated in the following figure. The following figure illustrates the response of a linear polarizer being rotated from 0 degrees to 90 degrees. The expected response, "Calibrated Test," trace along the equator of the Poincare sphere is only achieved when the measurement is done in a polarization reference frame. The analyzer automatically creates a polarization reference frame using open-beam polarization standards and Jones calculus. You can define the location of a polarization reference frame by following the instructions discussed in this measurement section.



pq772b_c

Figure 2-82.
Example of the results that can be achieved with and without a polarization reference frame

Basic Measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the HP 8509A/B Lightwave Polarization Analyzer operating system software to create a 3pt polarization reference frame, using an external polarizer.

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Setting up the System

Connect your measurement system as outlined in the following illustration.

ACCURACY ENHANCEMENT NOTE

The fiber leading from the second lens to the HP 8509A/B optical input must be taped down to prevent movement during or following the creation of the reference frame.

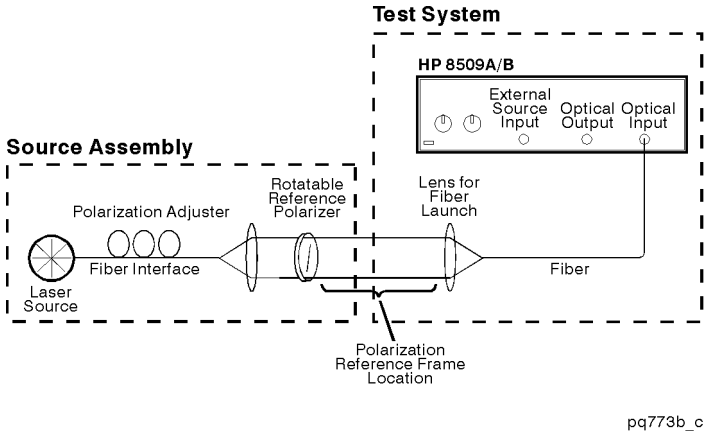


Figure 2-83. Measurement Setup

External Source Preparation

Before performing the measurement, you must select an optical source. The following procedure will guide you through the process.

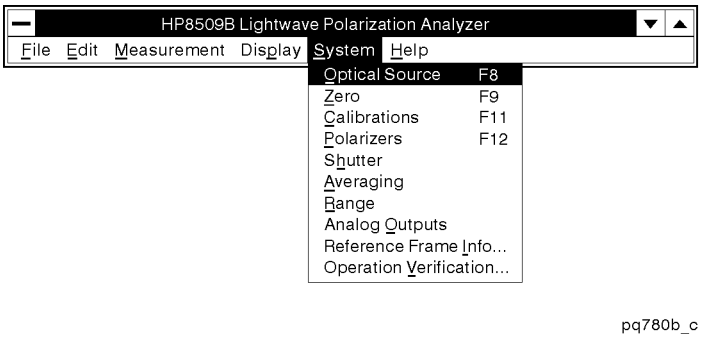


Figure 2-84. System Menu

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Select System from the main menu, and then select Optical Source.

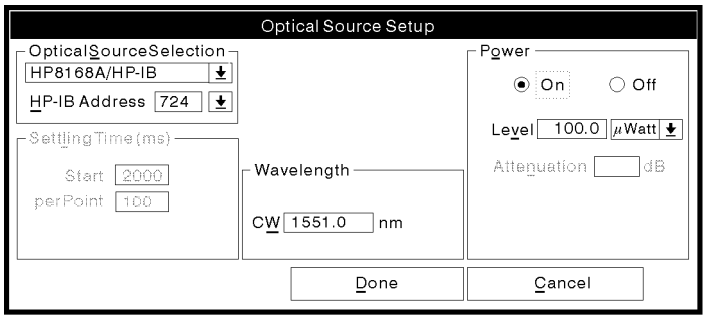


Figure 2-85. Optical Source Setup

Select the external laser source and set the wavelength to the desired value. Use the default power level or set as desired. If the screen on your computer looks similar to the previous illustration, select Done.

Choosing the Polarizers

To set a reference frame in an open beam environment you must select the external polarizers option on the analyzer. You may choose the external polarizers by first selecting System, with your mouse pointer, from the main window menu, and then Polarizers. When the Polarizers window appears, select External with the mouse pointer, then select Done.

Setting the Reference Frame

The next step in this procedure is to establish a reference for the analyzer to use in computing the reference frame. To do this you will rotate the reference polarizer and then set a marker, using the Markers on the Main measurement window. Polarizer angles must be set precisely to the angles listed in the Polarizer section of the System menu.

- Set the external polarizer to horizontal linear polarization, and select the **A** Marker.
- Rotate the external polarizer 60 degrees from original position and select the **B** Marker.
- Rotate the external polarizer an additional 60 degrees, to a position 120 ° from the original. Select the **C** Marker.
- Select 3pt Ref with your mouse pointer.

ADDITIONAL INFORMATION

The 3pt Ref Polarization Reference Frame (PRF) minimizes the uncertainty effects of the birefringence and PDL of the test system. A 2pt Ref minimizes only the uncertainty effects of the test system's birefringence.

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Checking Reference Frame Quality

To check the quality of the reference frame, select `System` and then `Reference Frame Info...`. If the quality is poor then you must repeat the previous steps, starting at Choosing the Polarizers. If the quality is good, select [OK] to continue, then select [Apply 3pt] with your mouse pointer from the Markers window.

Setting a Circular State of Polarization

This procedure works best when the source supplies a circular SOP. With a circular SOP input signal there is no chance for a low-power (−45 dBm) reference point caused by the rotatable polarizer being placed orthogonal to a linear SOP input signal. To set a circular SOP, perform the following steps.

- Remove the Rotatable Reference Polarizer.
- Use the mouse pointer to select the [Clear Trace] button.
- Adjust the polarization adjuster until the active data point approaches a pole on the Poincare sphere and s3 is greater than 0.9.
- Reinsert the Rotatable Reference Polarizer into the test setup and repeat the Reference frame procedure once more.

Using the Reference Frame

At this point a polarization reference has been established. The reference polarizer and any part of the source assembly may be moved or replaced without affecting the Polarization Reference Frame. The HP 8509A/B measures within the polarization reference frame. No part of the signal path after the reference polarizer can be moved without invalidating the Polarization Reference Frame.

ACCURACY ENHANCEMENT NOTE

A polarization reference frame can be used with external reference polarizers to improve PDL and Jones matrix measurement accuracy. The polarization reference frame, however, is ignored and has no effect on HP 8509B PMD measurements.

CAUTION Observe proper Laser Safety. Refer to the “Safety and Regulatory Information” chapter in this manual.
Observe proper connection techniques. Refer to the “Lightwave Connector Care” chapter in this manual.

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Additional Measurement Applications

2pt and 3pt Polarization Reference Frames

The 3pt frame of reference mathematically removes birefringence and polarization dependent loss from the path between the reference polarizer and the polarization analyzer receiver. This method requires that the reference polarizer be set precisely to the angles listed in the polarizers display, found by selecting the Polarizers from the System menu in the main window.

The 2pt frame of reference mathematically removes only birefringence from the path between the reference polarizer and the polarization analyzer receiver. This method requires only two orientations of the polarizer. The angle between the two reference orientations is not critical, but an angle of 45-60 degrees is suggested.

Following creation and application of a reference frame, rotation of the reference polarizer should cause the point on the Poincare sphere to move along the equator.

Measurement of the Retardance of an Optical Device

Retardance measurements make use of the polarization reference frame feature. For details, see the Jones matrix measurement section of this chapter.

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Measurement of Output Polarization of an Optical Integrated Circuit

Measurement of the output state of polarization of an optical IC may be achieved by creating a polarization reference frame at the end of a fiber which is in turn butt coupled to the IC. This removes the effects of birefringence and polarization dependent loss in the path between fiber tip and the HP8509A/B. Creation of the reference frame requires a setup procedure in which light is coupled through a rotatable reference polarizer into the fiber tip. Alternatively, polarized light at three angles can be provided from a single mode of a polarization maintaining fiber, by rotating the fiber to the necessary angles with a fiber chuck, or holder. (This PMF can also be used to stimulate the input of the optical IC). See the Polarization Maintaining Fiber Launch section for details on launching light into a single polarization mode of PMF.

Measuring Polarization State at a Connector Surface

A polarization reference frame can be established at a connector interface. The required two or three reference polarization states are provided from a polarization maintaining fiber in which all of the light is confined to a single mode (high extinction ratio). For accurate results, some fixturing is required. One of the connectors must be keyless to allow the pair to rotate relative to one another. A graduated dial is required to measure rotational angle. The scale may be indexed to the excited axis of the PMF. See the Polarization Maintaining Fiber Launch section for details on launching light into a single polarization mode of PMF.

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Concepts

Explanation of Polarization Reference Frame Mathematics

The HP 8509A/B produces a polarization reference frame using Jones Matrix calculus. The HP 8509A/B measures the Jones Matrix of the test system (Figure 2-83). The inverse of this Jones Matrix is applied to any incoming SOP data in an attempt to remove the birefringence and PDL effects of the test system.

Refer to the Jones matrix concept section of this manual for further information about the Jones Matrix.

Transmission Ratio (3pt Reference Frame)

The quality of a 2pt or 3pt reference frame is checked by selecting Reference Frame Info ... from the System menu of the main screen. For the 3pt reference frame, the resulting dialog box provides both a qualitative description (good.... very poor) and a parameter called the transmission ratio. Transmission ratio is a measure of the equivalent PDL of the path between the reference polarizer and the HP8509A/B polarization receiver, expressed in linear terms. The equivalent PDL is found by multiplying the log to base ten of the displayed number by ten. An excellent reference frame shows a transmission ratio of 1.0, equivalent to a PDL of 0 dB.

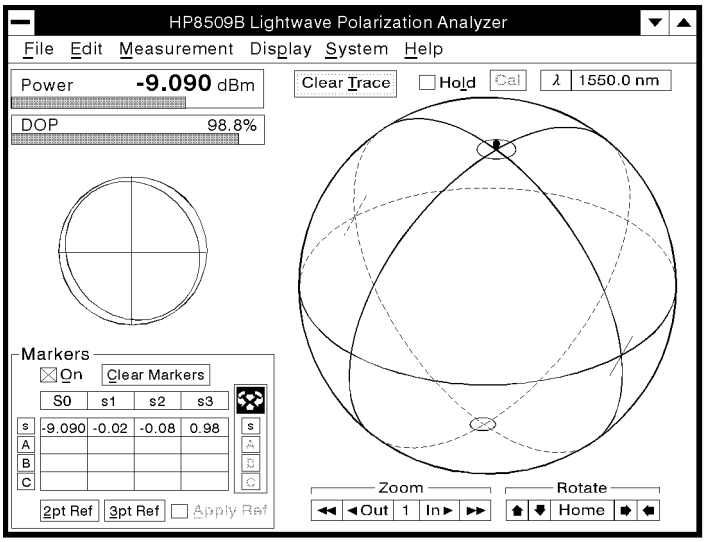
The equivalent PDL specified by the transmission ratio does not necessarily describe real PDL in the measurement both between reference polarizer and HP8509A/B. The quality of the reference frame can be degraded by not only weak or strong polarizing elements, but also by low signal level, incorrect setting of the reference polarizer angles or movement of fibers between polarizer rotations.

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State of Polarization Measurements

The state of polarization of a lightwave signal is described by the parameters of total optical power, degree of polarization and a description of the polarized portion of the light within a polarization reference frame. All of these parameters are measured by the HP 8509A/B and are discussed in this section. A typical measurement window is shown in the following figure.

Unless a polarization reference frame is specifically created by the user (see Polarization Reference Frame), the HP 8509A/B uses the reference frame of the polarimeter receiver inside the instrument.



pq716b_c

Figure 2-86. Example of a SOP measurement data display

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Basic Measurement

The following measurement procedure illustrates how to use the HP 8509A/B Lightwave Polarization Analyzer operating system software to measure the polarization parameters of a signal.

Setting up the System

Connect your measurement system as outlined in the following illustration.

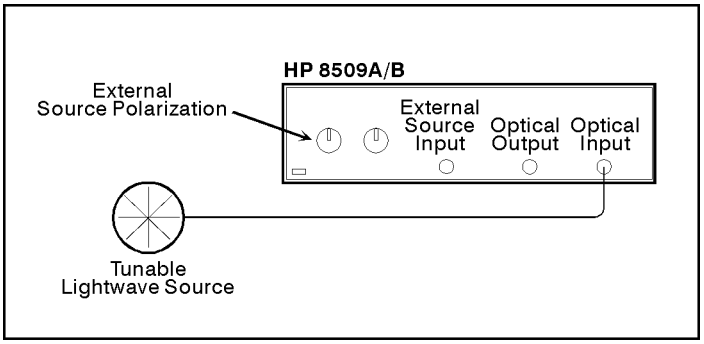
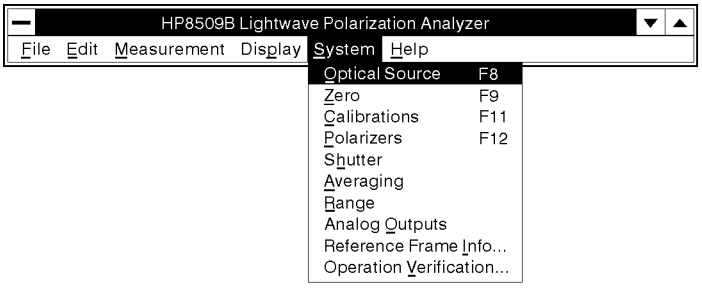


Figure 2-87. Measurement Setup

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External Source Preparation

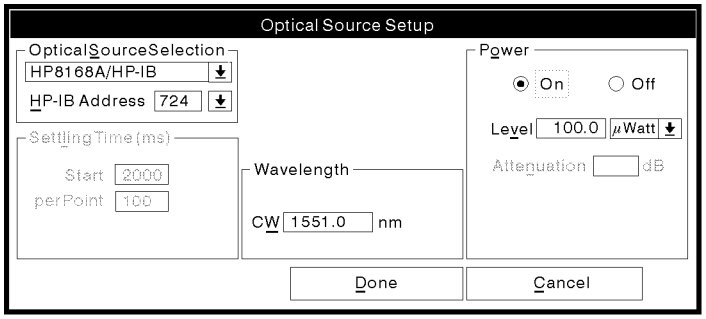
Before performing the measurement, you must select an optical source. The following procedure will guide you through the process.



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Figure 2-88. System Menu

Select `System` from the Main menu, and then select `Optical Source`.



pq71b_c

Figure 2-89. Optical Source Setup

Select the external laser source and set the desired wavelength.

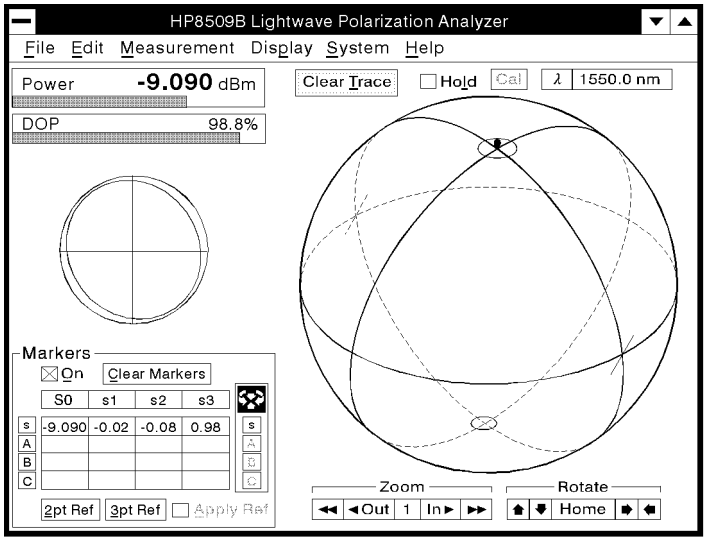
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Making the Measurement

At this point your measurement system is ready to make your first measurement. For our purposes we are going to measure the 1550 nm signal from a tunable laser source.

CAUTION Observe proper connection techniques. Refer to the "Lightwave Connector Care" chapter in this manual.

Measurement Results



pq716b_c

Figure 2-90. SOP and DOP Measurement Example

Signal polarization parameters are presented on the basic HP 8509A/B measurement screen shown in the previous figure. Your measurement is complete. The screen on your computer should look similar to the previous illustration.

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Specialized Measurement Techniques

Measuring effective degree of polarization

The degree of polarization (DOP) of a lightwave signal is defined as the ratio of the power of the polarized component of the signal to the total power. The HP8509 calculates DOP from the square root of the sum of the squares of the normalized Stokes parameters, which in turn are calculated from the ratios of the measured Stokes parameters to the total power. The HP8509 can be used to measure the effective DOP of a polarization modulated signal by taking advantage of the display averaging feature. When display averaging is used, every normalized Stokes parameter produced by the measurement system represents the average of the most recent N measurement samples, where N is the number of display averages selected by the user. Because DOP is calculated from these averaged normalized Stokes parameters, the DOP value represents the average of the most recent N measurement samples.

As an example, suppose that a fully polarized signal is polarization modulated to random points on the Poincare sphere. If the number of states produced within the averaging time is statistically large, the average measured DOP for this signal will be nominally zero percent. In another example, the state of polarization may be modulated to follow a great circle on the Poincare sphere. If the polarization states on this circle are occupied with equal frequency and a statistically large number of states is created during the averaging interval, the average measured DOP will again be nominally zero percent.

When measuring the effective DOP of polarization modulated light, the modulation rate should be kept below 1 MHz to avoid spurious coupling and rectification of the demodulated electrical signal within the analog circuitry of the polarization receiver. The number of display averages should be large enough to provide a statistically significant average. For best accuracy, the instrument should be fully warmed up and zeroed following warmup. Performing a wavelength calibration may improve accuracy.

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Concepts

Degree of Polarization

The DOP of the lightwave signal used in measuring your fiber optic cable is displayed as a percentage in the upper left hand corner of the main window display. As a review: the DOP is a measure of what percentage of the total average lightwave signal power is polarized.

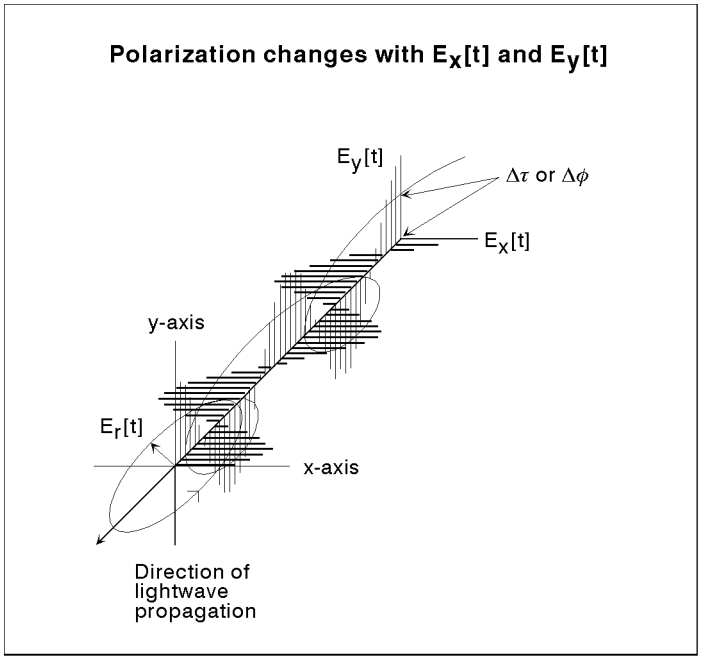
Degree of polarization of lightwave signal is related to that signals Stokes parameters as shown below:

$$DOP = (S_1^2 + S_2^2 + S_3^2)^{1/2} / S_0 = (s_1^2 + s_2^2 + s_3^2)^{1/2}$$

S_x is a standard Stokes parameter while $s_x (= S_x/S_0)$ is a normalized Stokes parameter.

Electric Fields and Polarization

- The electric field of a lightwave can be resolved into two arbitrary, orthogonal vector components, **Ex**(t) and **Ey**(t). The relative magnitude and phase of these E-field vector components determine the polarization of the signal.

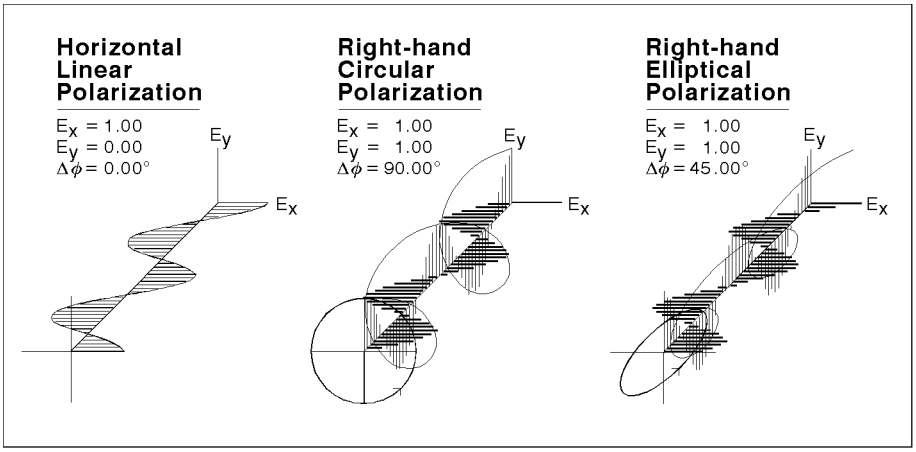


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Figure 2-91. Polarization changes with Ex(t) and Ey(t).

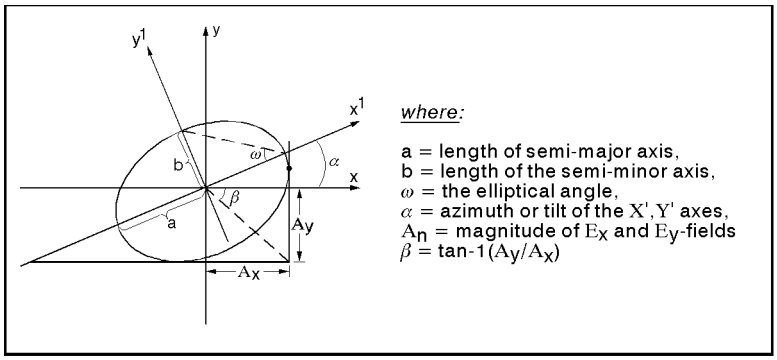
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- **Elliptical Displays of Polarization**: Any state of polarization can be created by adjusting the magnitude and phase relationships of the **Ex**(t) and **Ey**(t) components of a lightwave signal. All polarization states can be shown as unique elliptical displays. Several classical examples are shown in the following figure. Notice the E-field magnitude and phase relationships for each case.



pq756b_c

Figure 2-92. Elliptical displays of polarization



pq757b_c

Figure 2-93. Mathematical description of an elliptical display of polarization

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- **Poincare Sphere**: The Poincare sphere is an excellent display format for monitoring signal polarization changes, because all possible states of polarization presented at the same time. This is accomplished by assigning each state of polarization its own specific point on the Poincare sphere. Points on the equator represent states of linear polarization, the poles represent right-hand and left-hand circular polarization, and other points on the sphere represent elliptical polarization. Each point on the HP 8509A/B Poincare sphere has a unique set of coordinates defined by the sphere's three dimensional axes s1, s2, and s3. These coordinates are called normalized Stokes parameters.

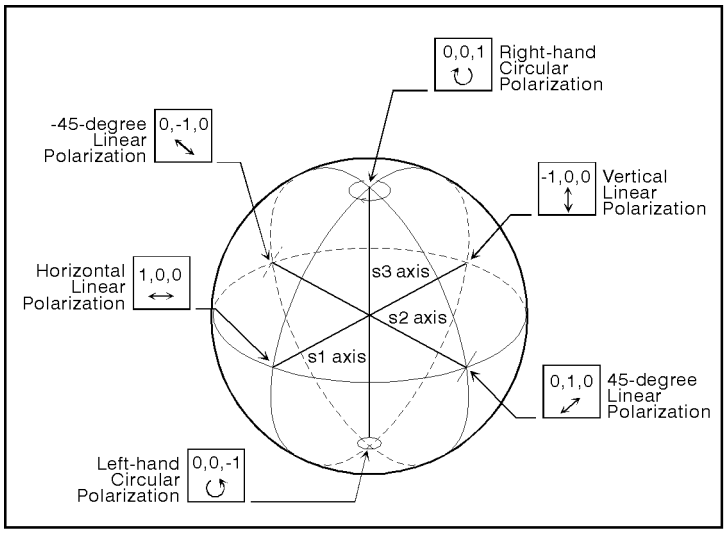


Figure 2-94. Polarization states on a Poincare Sphere

- **Stokes Parameters**: A Stokes vector is a 4 x 1 real matrix of Stokes parameters (S_0, s_1, s_2,and s_3) that completely describes the SOP of a lightwave. Each element of the matrix is based upon measured power levels. S_0 is the average power of the entire light beam. S_1 is the difference in power between the horizontal and vertical linear polarization components of the beam. S_2 indicates the power difference between +45 degree and −45 degree linear polarization. S_3 is the power difference between the right-hand and left-hand circular polarization. The Stokes vector has a magnitude equal to $(S_1+S_2+S_3)^{1/2}$ and originates from the center of the Poincare sphere. The HP 8509A/B graphically projects the normalized Stokes vector termination point onto the surface of a unity radius sphere, even when the magnitude of the normalized Stokes vector is not equal to one.

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3

Accuracy Enhancement and Troubleshooting

This chapter contains reference information regarding measurement accuracy and measurement troubleshooting.

Before You Proceed

Verify the following conditions before you proceed with this chapter.

- Connect the electrical power and turn the instrument on.
- Connect the interface cable between the computer and the HP 8509A/B.
- Connect the HP-IB cable to the external optical source, if necessary.
- Allow the instrument to warm up for at least one hour and zero the instrument following warm-up.
- Allow the tunable laser source to warm up completely, if used.
- Clean all connector surfaces.
- Stabilize the optical fiber during some types of measurements.

For help with operating the keyboard or the mouse, or with Windows conventions, use the Windows Help menu in the Windows Program Manager. Select the background of the screen and select Program Manager from the dialog box.

ATTENTION

Operating the HP 8509A/B requires computer system resources. When you run multiple software applications, or have several HP 8509A/B windows open, system resources can be exhausted, severely slowing operations such as moving from window to window. Check system resources by going to the Program Manager, selecting the Help menu and About Program Manager. At least 25% of the system resources should be free. Close applications or HP 8509A/B windows as needed to free up system resources and increase operating speed and responsiveness. In addition, it is a good idea to re-start your computer every day.

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Measurement Troubleshooting Matrix

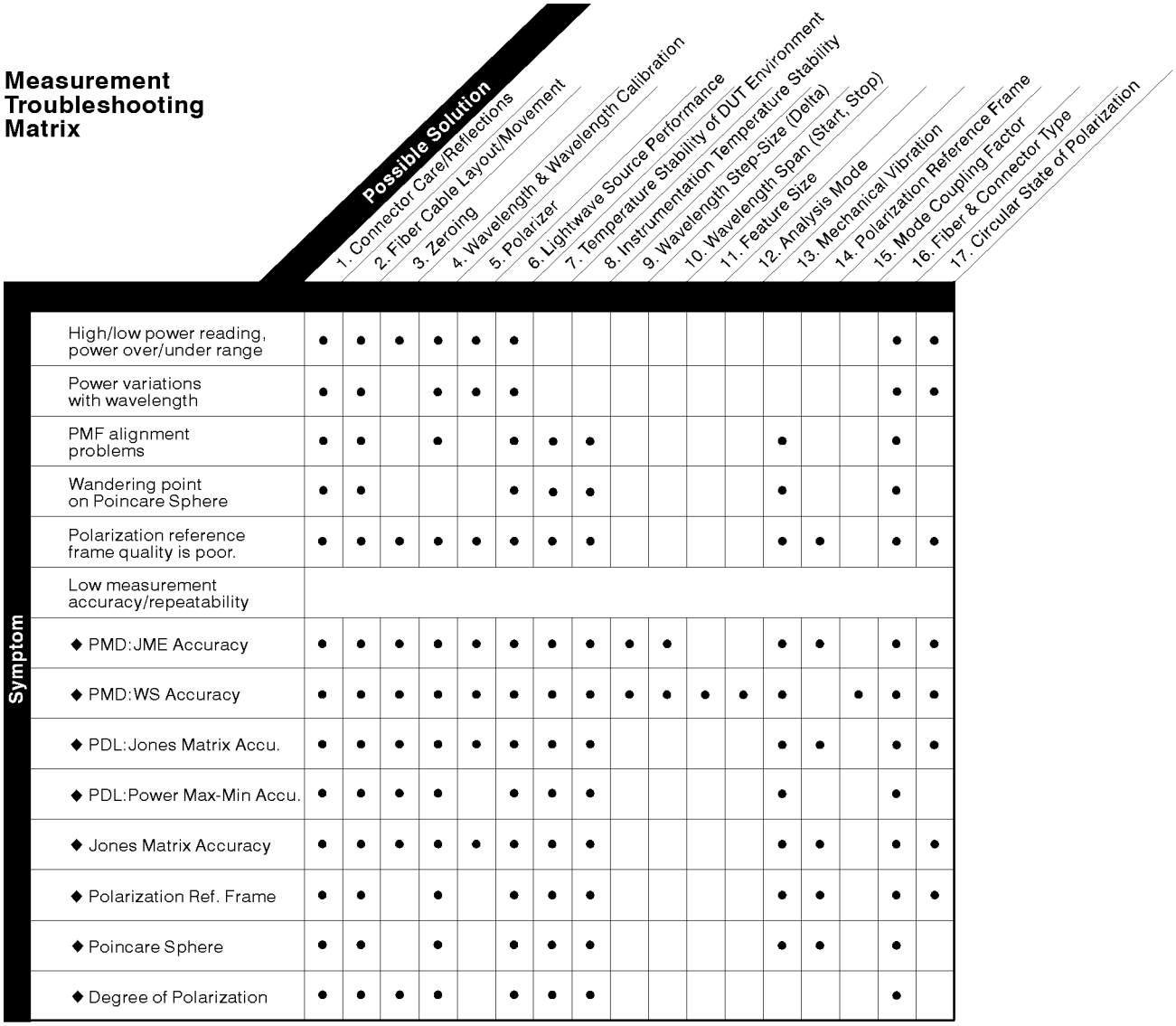


Figure 3-1. Measurement Troubleshooting Matrix

3-2 Accuracy Enhancement and Troubleshooting

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Symptoms

The measurement symptoms listed in Figure 3-1 describe conditions that can often be corrected or improved by addressing the appropriate areas described in the Solutions section of the measurement troubleshooting matrix. Appearance of these conditions does not necessarily indicate a need for service nor does it confirm a system failure to perform within specified performance specifications. If a system failure is suspected, however, refer to the Operation Verification section of the Installation and Quick Start Guide included with this manual.

Solutions

The following is a list of various ways to address the symptoms listed in the measurement troubleshooting matrix. In all cases, it is assumed that the HP 8509A/B system has passed the Operation Verification procedure (discussed in the Installation and Quick Start Guide) and is operating properly.

1. **Connector Care/Reflections**

   Connector insertion loss and return loss of the test system and the test device can affect polarization measurements in a number of ways. Refer to the Connector Care chapter of this manual for further information about procedures for avoiding connector related problems. Following is an explanation of why reflections from dirty or damaged connectors may cause measurement uncertainty.

   If a set of large optical reflections are present in the test system or the test device, some optical energy will re-reflect, travel three times the length between the two reflection points (triple-travel signal), finally emerge and combine with that portion of the signal that traveled straight through (straight-through signal).

   This triple-travel signal has a different amount of phase shift because it has passed through a different birefringence path than the path used by the straight-through signal. The polarization state of the combined output signal can be modeled as two polarization components. One component represents the straight-through signal. The second component represents the energy from the triple-travel signal that is orthogonal to the straight through signal. As the wavelength changes, the phase relationships change and an arc is drawn on the Poincare sphere. The radius of the arc increases with the magnitude of the reflections. The radius of the arc represents measurement uncertainty and should be at least 30 to 40 dB for normal measurements. Check this value using the PMF Launch tool provided under the Measurement menu of the HP 8509 main window. The arc required for this PMF Launch tool can be created by manually changing the input wavelength. The dB ratio related to the radius of the arc will be automatically calculated and displayed. Connectors should be properly mating, physical contacting types with a reflection level better than 40 dB.

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2. **Fiber Cable Layout/Movement**

Fiber cables, used in the instrument setup of an HP 8509 polarization measurement, should be laid-out and secured in a relaxed and flowing manner, free from sharp kinks and tight radius curves (<2 inch). Secure the fiber using tape or some other technique to prevent the fiber from moving and to reduce the waiting time for fiber relaxation. A few minute relaxation time is recommended in any case to allow the stress pattern within the fiber to stabilize. Changing stress patterns alter the birefringence within a fiber, changing the polarization of a signal being transmitted through the fiber. Unstable polarization from an improperly deployed fiber cable increases measurement uncertainty.

After caring for the fiber layout, random vibration may still cause unstable polarization. Display averaging may be used to minimize the effect of these vibrations on the Poincare sphere display. Measurement averaging will reduce the effect of vibration on PMD and PDL measurements, and any measurements using the markers.

3. **Zeroing**

As in all measurements with the polarization analyzer, effective zeroing of analog circuit offsets is required for measurement accuracy. Refer to the Zeroing section of this manual for information about this procedure and feature. Although zeroing is automatically performed at power-on, zero the instrument again after a one hour warmup period.

Zeroing with optical power applied to the optical input creates offsets in the instrument which seriously degrade accuracy and can result in power overrange or underrange warnings.

4. **Wavelength & Wavelength Calibration**

The HP 8509A/B contains (in memory) a set of factory calibration coefficients that optimize the accuracy of the polarimeter at a series of discrete wavelengths. For accurate operation of the instrument, enter the operating wavelength to at least 1 nm accuracy. Wavelength errors affect all measurements. The effect is apparent in the DOP measurement. When measuring fully polarized light from a fiber, the DOP fluctuates about 100% as the fiber is moved. Larger wavelength error produces a greater DOP fluctuation.

The HP 8509A/B provides a wavelength calibration process that allows the operator to augment the built-in calibration for a particular source, even if you don't know the wavelength of the source. See the Calibration procedure in the System Menu chapter of this manual.

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5. **Polarizer**

Polarizers may include the polarizers internal to the HP 8509B, an external reference polarizer used for an HP 8509A/B application, a polarizer in the signal path, or the test device itself. In general, the last polarizer in the test signal path determines the polarization of the signal.

The HP 8509B contains an internal polarizer unit with three insertable linear polarizers. These may be enabled or disabled using the Polarizer controls accessed under the System menu of the main software window. Various measurement applications use different cases; you must select the appropriate condition.

Signal level can drop if the polarization of the input signal to a polarizer is crossed with, or blocked by, the polarizer. This can be an issue in any of the HP 8509A/B applications in which the Jones matrix is measured with internal or external reference polarizers, and in measurements of PMD and PDL by the Jones matrix method. It can also affect power level in the wavelength scanning PMD measurement if the source light is passed through an internal or external polarizer prior to the DUT. Adjust the source polarization for a circular state at the reference polarizer. The process for doing this is discussed under the measurement types in the Making Measurements chapter.

Setting the input polarization relative to the test device can affect wavelength-scanning PMD measurements by changing the relative illumination of the polarization modes of the device. This can introduce measurement variability versus the position of the polarizer or the position of the input fiber to the DUT. If variability is severe, average the results of several measurements with the input fiber in different positions.

6. **Lightwave Source Performance**

Optical source wavelength and output power level should be stable and within the operating range of each element of the test system.

For all measurements involving a Jones matrix, the spectral line width ($\Delta\lambda$) of the optical test signal should be narrow enough to guarantee that the coherence time (approximately equal to $\lambda^2/c\Delta\lambda$) of the test signal is less than 1/3 of the differential group delay (DGD) of the test device. This will reduce any measurement uncertainty that may be introduced by depolarization of the test signal. Best performance is achieved when the lightwave test signal DOP is near 100%.

Wavelength accuracy and stability are important because the calibration factors in the HP 8509 are based upon accurately knowing the wavelength of the test signal. If the test signal's true wavelength differs from the wavelength expected by the HP 8509 then measurement uncertainties will result. See item 4, Wavelength & Wavelength Calibration for more detail, or refer to the Calibration section of the System Menu chapter of this manual.

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7. **Temperature Stability of DUT and Environment**

Accurate polarization measurements must be performed in a thermally stable environment. Changes in room temperature during a measurement will cause the ambient temperature of the instrument and the test device to drift. This will adversely affect measurement accuracy and repeatability until all temperature transients have stabilized once again. Conditions are stable if the output polarization drifts less than one degree per minute on the Poincare sphere. Test devices should be allowed to settle in temperature before measurements are started. Re-zero the HP 8509A/B if the temperature has changed.

8. **Instrumentation Temperature Stability**

Typically, one hour of test system warm-up time within a thermally stable environment is required. Re-zero the HP 8509A/B if the temperature changes.

9. **Wavelength Step-Size (Delta)**

Wavelength step size, or Delta, or wavelength interval, is important to the two PMD measurement methods. In each case, error can result from a step size that is very large or very small. In the JME method, large step size can cause the measurement to produce alias results, and can limit the ability to resolve, or identify, the wavelength dependence of the DUT. In the WS method, large step size can result in missing certain peaks or valleys in the counting process. For both JME and WS methods, very small steps may be unnecessary and can introduce error (JME) and increase measurement time. See the JME and WS measurement application sections for more information.

10. **Wavelength Span (Start, Stop)**

Wavelength span affects both of the PMD measurement methods, particularly in the measurement of fiber PMD. For fiber PMD measurements, use the full wavelength range of the optical source. This will give the broadest possible exposure to the random polarization behavior of fiber PMD and provide the most statistically meaningful measurement.

In wavelength scanning measurements, choice of Analysis mode, under the Format menu, determines how the start and stop wavelengths for the wavelength scanning formula will be derived. This can dramatically influence accuracy in measurements of components and short fibers. See the discussion in the Wavelength-Scanning PMD section of this manual.

11. **Feature Size**

Feature Size, located in the Format menu, affects the peak and valley count during an HP 8509A/B wavelength-scanning measurement. The value of the feature size determines whether a variation in a trace is ignored or counted as a peak or valley. This value can affect PMD results so much that it should be stated with measurement results in order to compare and repeat measurement data. Increase feature size if vibration or movement are causing false peaks in the wavelength-scanning response. Refer to PMD Measurements: Wavelength-Scanning Method for further information.

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12. **Analysis Mode**

Wavelength-scanning PMD measurement accuracy can be improved by using the analysis mode appropriate to the test device. This is why the HP 8509A/B offers four analysis modes. Refer to PMD Measurements: Wavelength-Scanning Technique for further information about Analysis Mode.

13. **Mechanical Vibration**

Mechanical vibration picked up by the measurement instrument or the DUT can degrade measurement accuracy. Differential motion between the instrument and DUT can also affect accuracy. Isolate the DUT as much as possible from fan vibrations, bumps and shocks. Use averaging to reduce the effects of unavoidable vibrations.

14. **Polarization Reference Frame**

The HP 8509A/B is equipped with the ability to mathematically remove the birefringence and PDL of the path between a reference polarizer and the HP 8509A/B polarization receiver using a 2pt (birefringence compensation only) or 3pt (birefringence and PDL compensation) polarization reference frame (PRF). Reference frames become invalid if this path moves during creation of the reference frame or during subsequent measurements. A polarization reference frame should not be applied for PMD measurements. Refer to the PRF section of this manual for further information about creating a PRF and deciding between a 2pt or 3pt PRF.

15. **Mode Coupling Factor**

The wavelength-scanning (WS) PMD measurement method uses the mode coupling factor in determining PMD from the measured curves. The value used relates to the degree of mode coupling in the DUT. For long fibers that are highly mode-coupled, use 0.82. For most components and non-mode coupled devices, use 1.0. Refer to the discussion on mode coupling in the PMD measurement sections for more detail.

16. **Fiber & Connector Type**

Multimode fibers (MMF) and damaged single-mode fibers and connectors (SMF) cause a number of polarization measurement problems and should be replaced with high quality single-mode fibers and connectors.

MMF should not be used for polarization measurements because it supports a variety of spacial modes, each of which experiences a different delay and birefringence as it passes along the fiber. These multiple paths can depolarize the test signal is some cases. In MMF, the output polarization is not well defined nor uniquely related to fiber birefringence. This makes all polarization measurements extremely difficult in MMF.

Connectors may exhibit small values of PDL.

Damaged SMF and connectors attenuate optical power and may cause triple-travel reflections. See item 1, Connector Care/Reflections for details. Connectors should be properly-mating, physical contacting types with reflection level better than 40 dB.

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17. **Circular State of Polarization**

For measurements involving the Jones matrix, it is recommended that the reference polarizers be supplied with circular states of polarization. This is in order to avoid low power points during linear polarizer adjustments. Information about confirming a circular state of polarization can be found in the measurement application sections.

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4

Printing, Saving, and Recalling Measurement Results and Instrument Configurations

This chapter contains information about the File menu (in the main window) and the measurement windows.

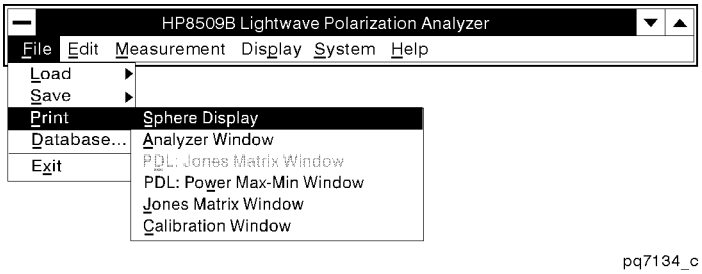


Figure 4-1. The File Menu

- Printing measurement results: allows you to print the results of measurements you make.
- Saving measurement results: allows you to save the results of measurements you make.
- Recalling measurement results: allows you to recall (load) previously saved measurements.
- Loading the preset configuration: allows you to recall the PRESET instrument configuration.
- Saving an instrument configuration: allows you to save an instrument configuration for use later.
- Loading an instrument configuration: allows you to recall a previously saved instrument configuration.

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Conventions

In this document, HP 8509 menu items appear in shaded boxes `Like This`. HP 8509 main window items appear in unshaded boxes (Like This).

Illustrations and examples in this chapter show operation of an HP 8509B. There are minor differences for an HP 8509A, the most significant is that the Jones matrix eigenanalysis polarization mode dispersion measurement is not available with the HP 8509A.

For Additional Information

For step-by-step instructions on making measurements and for more detailed information about a particular measurement, refer to the "Making Measurements" chapter of this manual.

For information regarding calibrations, refer to "The System Menu" chapter of this manual.

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Printing Measurement Results

The lightwave polarization analyzer print function uses the Microsoft Windows print drivers. It is necessary that you use the proper Microsoft Windows print drivers to print your documents. The printer used is the default printer in the Windows control panel.

Detailed instructions for installing serial (RS 232) and parallel interfaced printers are provided in the Microsoft Windows *User's Guide*.

Standard Printing

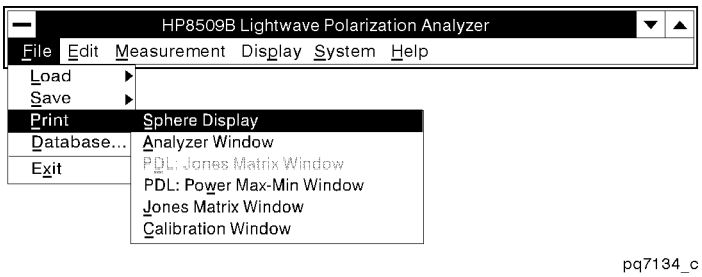


Figure 4-2. The Print Menu

Procedure

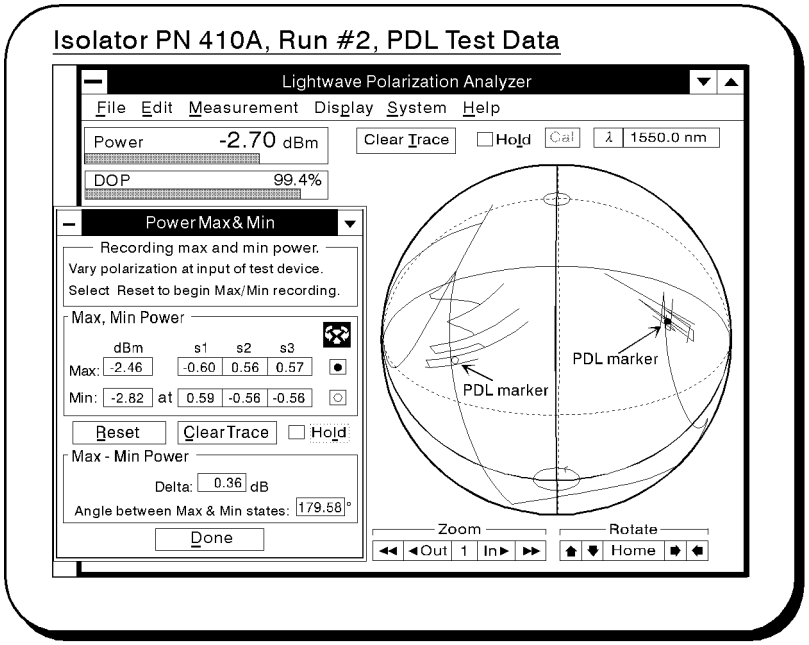
Once you make a measurement you can print the results.

1. Select `File`, `Print`
2. Select one of the following items.
   a. `Sphere Display`: prints only the Poincare Sphere
   b. `Analyzer Window`: prints the entire main measurement window display
   c. `PDL: Jones Matrix Window`: prints the Jones matrix PDL measurement window
   d. `PDL: Power Max-Min Window`: prints the power max-min PDL measurement window
   e. `Jones Matrix Window`: prints the entire Jones matrix measurement window
   f. `Calibration Window`: prints the entire wavelenth calibration measurement window

Customized Printing

An HP 8509A/B measurement window can be customized and inserted into a text document or slide presentation for printing by using the following procedure. An example is shown below. This procedure uses the Clipboard and Paintbrush graphics program which are included with the HP 8509 system computer.

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Figure 4-3. Customized Printing Example

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Procedure

1. Create the desired HP 8509A/B measurement display. You may choose to maximize the display by selecting the double carrot located in the upper right corner of the HP 8509 measurement window.
2. Press (Print Screen) on the upper right side of the HP 8509 system computer key board.
3. Select (Hold).
4. Use the mouse to minimize the HP 8509 measurement window by selecting the down carrot in the upper right corner of the HP 8509 measurement window. This will cause the HP 8509 window to become a small icon at the bottom of the screen and reveal the Windows Program Manager.
5. Locate the Accessories icon and select it using the mouse.
6. When the Accessories icon opens, select the Paintbrush icon.
7. When the Paintbrush program is running select the View menu at the top of the screen. Select Zoom Out.
8. Highlight the Edit menu and select Paste and Paste again.
9. From the View menu, select Zoom In and begin customizing graphics and text.
10. When the desired Paintbrush display is achieved save it to a file name using the appropriate format. The appropriate format depends on the word processor or graphics program that will be used. AmiPro and Freelance for example can easily import or receive pasted graphics using a bit map (BMP) or PCX format.

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Measurement data is saved and recalled according to the formats and viewing options listed in Table 4-1.

Table 4-1. Summary of HP 8509 Measurement Results Save/Recall Features

MEASUREMENT DATA	SAVE OPTIONS	FORMAT	RECALL (LOAD) OPTIONS	VIEWING OPTIONS
PMD: Jones Matrix Eigenanalysis	PMD JME to Database	Microsoft Access Database Format	PMD JME from Database	Graph, Tabular Data
	PMD JME to Text	Comma Delimited ASCII	Word Processor[1], Spreadsheet	File Contents
			PMD Statistics program	DGD vs Wavelength and DGD Histogram
PMD: Wavelength-Scanning	PMD WS to Database	Microsoft Access Database Format	Microsoft Access Database	Graph Poincare Sphere Tabular Data
	PMD WS to Text	Comma Delimited ASCII	Word Processor[1], Spreadsheet	File Contents
PDL: Jones Matrix	Jones Matrix & PDL: Jones Matrix	Comma Delimited ASCII	Word Processor[1], Spreadsheet	File Contents
Jones Matrix	Jones Matrix & PDL: Jones Matrix	Comma Delimited ASCII	Word Processor[1], Spreadsheet	File Contents
State of Polarization (using timed measurement only)	Timed Measurement to Database	Microsoft Access Database Format	Timed Measurement from Database	Poincare Sphere
	Timed Measurement to Text	Comma Delimited ASCII	Timed Measurement from Text,	Poincare Sphere
			Word Processor[1], Spreadsheet	File Contents via other software applications
Degree of Polarization (using timed measurement only)	Timed Measurement to Database	Microsoft Access Database Format	Microsoft Access only	
	Timed Measurement to Text	Comma Delimited ASCII	Word Processor[1], Spreadsheet	File Contents

1 Refer to the Microsoft 7410 Windows User's Guide for information regarding "Notepad" and "Write", the word processors provided with Microsoft Windows.

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Saving and Recalling Measurements

PMD, PDL, Jones matrix, and Timed polarization measurements can be saved for future use.

The HP 8509A/B provides two ways to save data for PMD:JME, PMD:WS, and Timed measurements: Microsoft Access database and text files. The data stored in HP 8509 text files is very limited and is primarily useful for importing data into a spreadsheet. Database files are much more versatile. You can move the database file to another computer to do sophisticated analysis of the measurements, and continue using the HP 8509 instrument. For example, you may wish to examine the PMD measurements for a particular device type during the month of May. Since the HP 8509 database is a relational database, it allows you to filter out all the unwanted data and view only those measurements that are of interest. In addition, Microsoft access also has many mathematical functions built in, so that the measurements can be analyzed statistically. This is helpful in a production environment where Statistical Process Control (SPC) can spot production trends early and lead to improved processes. You can extend the Microsoft Access database file, created by the HP 8509, to add fields and tables which are updated by other stages in the production process or by sales or shipping departments.

See the database read-me file in the HP 8509A/B program group for additional information and for a map of the HP 8509A/B database.

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Saving Measurements

After performing a measurement, the results can be saved as summarized in Table 4-1. Use FILE, SAVE menu selections shown in the figure below. The measurement FILE menus for the PMD measurements are located within the PMD: JME and PMD: wavelength-scanning measurement sections of this manual. All other measurement FILE menus are located in the analyzer's main window as shown in the figure below.

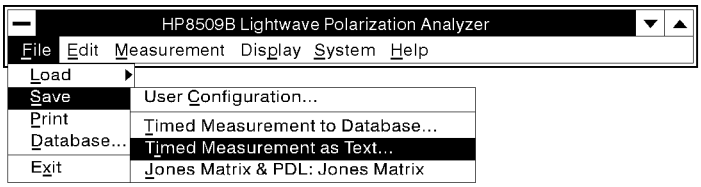


Figure 4-4. The Save Menu

ADDITIONAL INFORMATION

Refer to Figure 4-4. You must make a measurement before the lightwave polarization analyzer allows you to save data. Once you make a measurement, the corresponding command in the Save menu appears in black lettering.

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Procedure

1. To save measurement results, first make the desired measurement.
2. Save the resulting data by selecting `File`, `Save`.
3. Select one of the following items.
   a. `Timed Measurement to Database`
   b. `Timed Measurement as Text`
   c. `Jones Matrix & PDL: Jones Matrix`
4. You will see either the Save As: Text File window (Figure 4-5), or a dialog box for adding the measurement to the database.

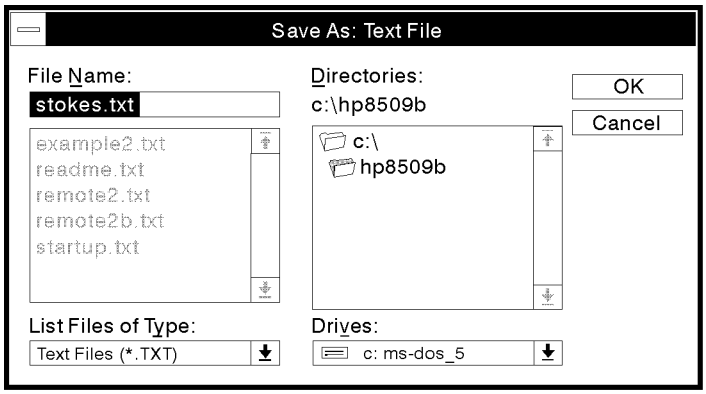


Figure 4-5. The Save As Window

5. Specify the drive, path and filename by typing it in the File Name window, or type the filename in the File Name window and use the mouse to select the drive and the directory.

   The filename will have the default extension ".txt".
6. Once you have named the file, drive and directory, select OK, and the measurement data will be stored.

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Recalling Measurements

After saving measurement results, you can recall and view the results as summarized in Table 4-1. Recall the results using the HP 8509 system software and/or separate word processor, spreadsheet, or database program as noted. HP 8509 procedures are discussed in detail below. Numeric word processor, spreadsheet, or database file formats are discussed briefly at the end of this section.

HP 8509 File Recall Procedure

The following procedure describes how to use the analyzer's FILE, LOAD menus to recall measurement results. The measurement FILE, LOAD menus for the PMD measurements are explained within the PMD: JME and PMD: Wavelength-Scanning measurement sections of this manual.

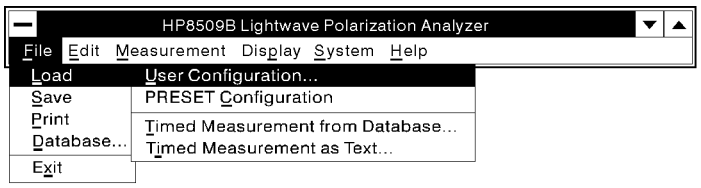


Figure 4-6. The Load Menu

1. Select FILE, LOAD, and then one of the Load sub menu selections shown in the figure above.
2. For text files, select the drive, directory, and file where the desired trace is stored, and then select OK. Measurement results will be recalled and displayed as summarized in Table 4-1.
3. For database files, select the desired measurement from the drop-down list then select LOAD.

ADDITIONAL INFORMATION

While a recalled trace is being viewed on the Poincare sphere, the lightwave polarization analyzer data displays become inactive. See the following figure. Also note that the wavelength readout in the upper right corner is gray (inactive). This is to remind the user that the displayed wavelength is the wavelength with which the Single Sweep was taken, but not necessarily the current wavelength.

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4. To resume normal operation of the lightwave polarization analyzer, toggle the Hold function by selecting Hold. See the following figure.

HP 8509 File Recall Results

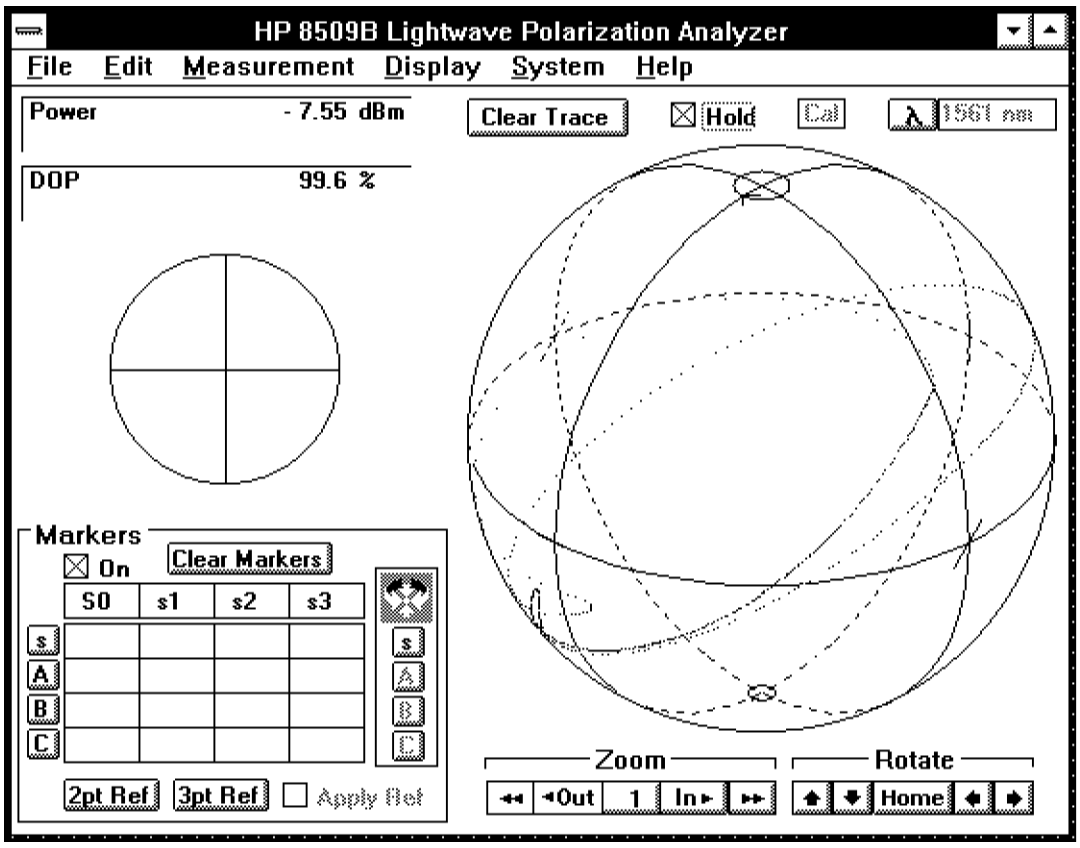


Figure 4-7. Viewing a Stored Trace on the Poincare Sphere

Word Processor, Spreadsheet and Database Numeric File Format

The "comma delimited ASCII format" for each measurement is shown below. This format is useful for spreadsheet users and database analysis programs.

The following symbols are used in the format descriptions of this section.

λ = wavelength

S_x = Stokes parameter

S_0 = average optical power

s_x = normalized Stokes parameter (= S_x / S_0)

DGD = differential group delay

DOP = degree of polarization

( ) = units

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Refer to the appropriate user information outside of this manual if measurement results are being recalled using a separate word processor, spreadsheet or database program.

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PMD: Jones Matrix Eigenanalysis Save Format.

Format: λ_n,λ_{n+1},DGD (units are unspecified)

Example: 1500,1501,.2310215

PMD: Wavelength-Scanning Save Format.

Format: λ_n(nm),S_0(dBm),s_1,s_2, s_3,DOP(%)

Example: 1525,-2.704419,-.9104293,-.3429706,.2233345,99.81926

PDL: Jones Matrix and Jones Matrix Save Format.

Format:

```
Absolute Measurement Flag, PDL Delta, PLD Max, PDL Min
J00.real, j00.imag
J01.real, j01.imag
J10.real, j10.imag
J11.real, j11.imag
```

where Absolute Measurement Flag is "1" if the Jones matrix PDL measurement is absolute and "0" if it is relative. In the case of a relative measurement, PDL Max and PDL Min are both "0".

Example:

```
1,3.017851E-02,.0171138,-1.306471E-02
.296185061242171,-.746302479489197
.137726371786746,.58206929707534
.488929498642804,.3450943751558
.800210126957622,0
```

Timed Measurement As Text Save Format.

Format:
λ_n(nm)
S_0(mW),S_1,S_2,S_3,DOP(%)

Example:
1537
.1844145,-8.568172E-02,-.1516657,-5.691557E-02,99.37248

ADDITIONAL INFORMATION
The Save format for Timed Measurements to database uses normalized Stokes parameters.

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Saving and Recalling Instrument Configurations

The HP 8509A/B always starts up with a set of default conditions. These sets of conditions are called “configurations”, and the necessary parameters are stored in configuration files which are loaded at startup.

You can change conditions via the HP 8509A/B pull-down menus. If you want to save particular sets of conditions to use later without having to reset all the conditions manually, you can save configurations in files and recall them later.

CAUTION At start-up, the default configuration file, hp8509.cfg, is used to initialize the lightwave polarization analyzer. Any changes to the default configuration file will change the default power-on conditions of the analyzer.

The HP 8509A/B recalls the configuration file HP8509.CFG at startup. The polarization analyzer searches in the following sequence:

- First in the windows working directory.
- Second in the application’s directory.
- Finally in the Windows system directory.

The polarization analyzer uses the first file it finds. If it can not find a file, the polarization analyzer uses the preset configuration. The preset configuration is set in the factory and never changes.

To start the HP 8509A/B with other than the default HP 8509.CFG configuration file, add this command line parameter to the icon’s properties: /CFG=*filename*, where *filename* is the name of the configuration file you want to use. A command line parameter follows the name of the program in the Windows Program Manager properties Command Line entry. This window is accessed by highlighting the HP 8509 icon and selecting File/Properties in the Windows Program Manager, or pressing ALT+ENTER on the keyboard.

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To create a configuration file with factory defaults:

1. From the lightwave analyzer Windows menu, select `File`, `Load`, `PRESET Configuration`.
2. Select `File`, `Save`, `User Configuration`.
3. Name the file. The application default file name is HP8509.CFG. Give the file this name if you wish to restore the default configuration to the preset (factory default) configuration.

ADDITIONAL INFORMATION

Some instrument conditions are saved automatically to the database when you use the Save to Database features. Examples include the wavelength start, stop, and delta parameters for PMD measurements. However, these parameters alone are not sufficient to configure the instrument.

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Recalling the Preset Configuration

The default or preset configuration puts the lightwave polarization analyzer in the default state. This is the configuration the lightwave polarization analyzer is in at power-on.

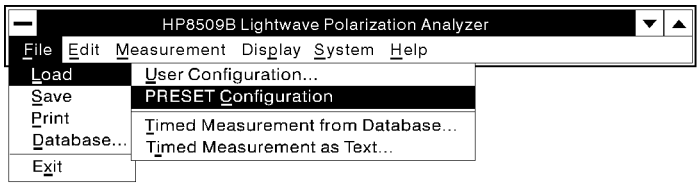


Figure 4-8. The Load PRESET Configuration Menu

Procedure

1. Load the preset condition by selecting `File`, `Load`, `PRESET Configuration`.
2. A window appears asking you to confirm the load preset command. See the following figure. Select OK to load the preset configuration, or select Cancel to cancel the command.



Figure 4-9. The Preset Confirmation Window

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Saving a User Configuration

You can save any instrument configuration to a file for later use. This is useful for recalling the configuration of an instrument setup you use frequently.

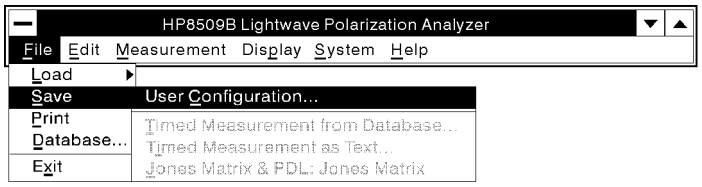


Figure 4-10. The Save Menu

Procedure

To save a particular configuration, first set the lightwave polarization analyzer to the configuration you want to save, and then follow the steps below:

1. Select `File` `Save` from the main HP 8509 menu.
2. Select `User Configuration`.
3. The Save As: Configure File window opens. See the following figure.
4. Enter the drive, path and filename by typing it in the File Name box, or by typing the filename in the File Name box and using the mouse to select the drive and directory.

   The filename will have the default extension “cfg”.

5. Select OK, and the file is stored.

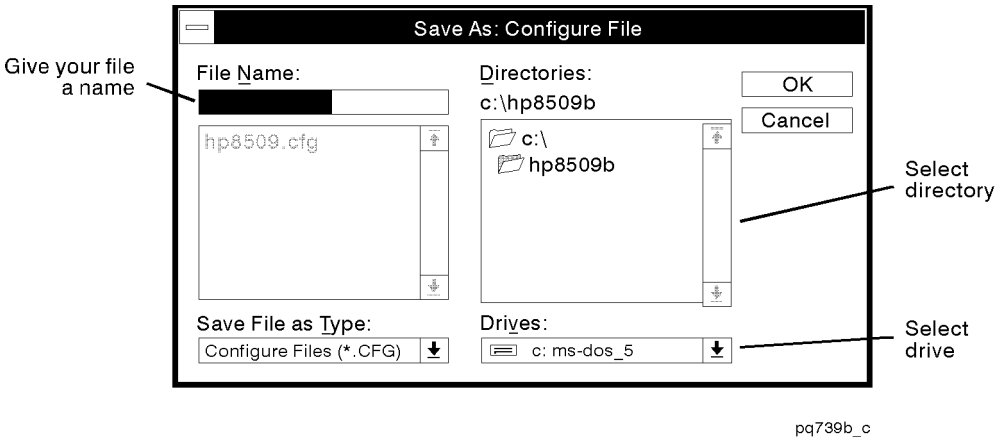


Figure 4-11. The File Save As: Configure File Window

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Recalling a User Configuration

User configurations allow you to store instrument states you want to use again. Use the procedure below to recall a user configuration.

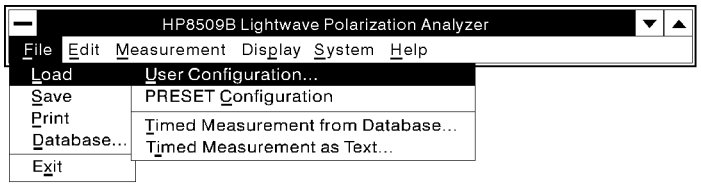


Figure 4-12. The Load Menu

Procedure

To call up an instrument state that has been stored:

1. Select `File Load` in the main HP 8509 menu.
2. Select `User Configuration`.
3. The Load: Configure File window opens. See the following figure.
4. Choose a configuration to open by specifying the drive, directory and filename by typing the complete path in the File Name box. You can also use the mouse to select the drive, path and file.
5. Select OK when the file you want appears in the File Name box.

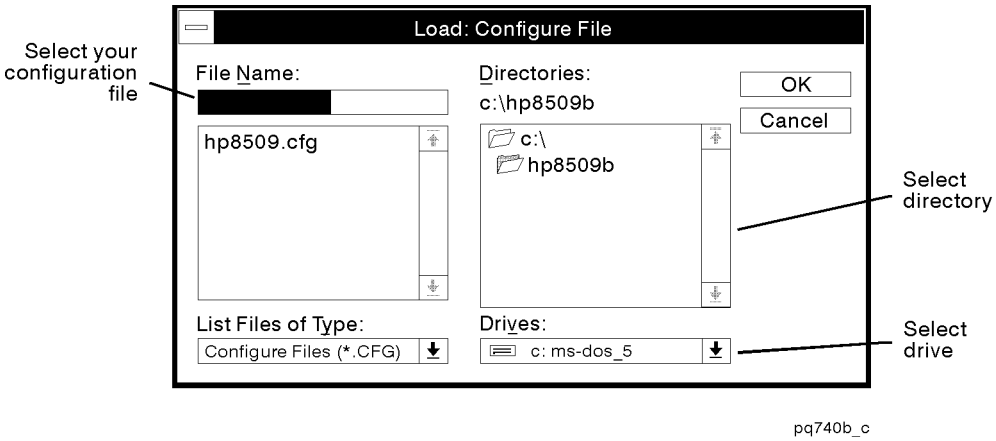


Figure 4-13. The Load Window

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5

The Display Menu

This chapter contains information on the following subjects.

- Displaying the marker window
- Displaying the Poincare sphere
- Displaying the polarization ellipse
- Exchanging the Poincare sphere and the polarization ellipse
- Changing the power mode from dBm to watts
- Marking the current point
- Changing the display update frequency
- Holding the data display
- Clearing the trace from the sphere
- Setting the display to Auto Refresh mode

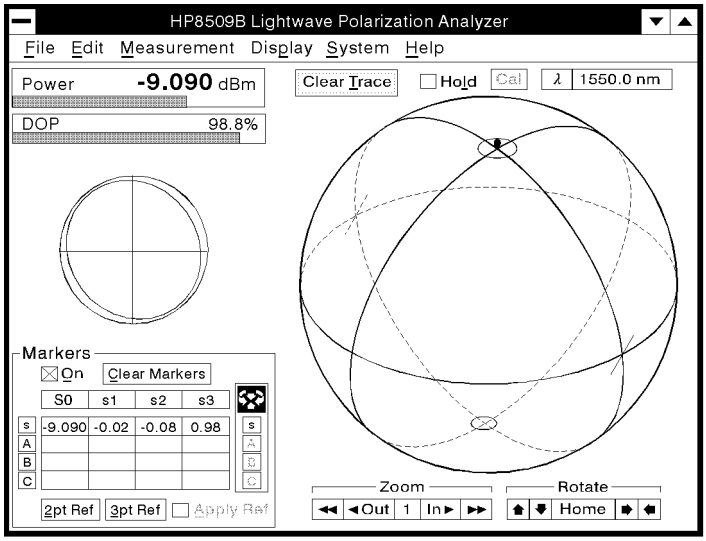
For Additional Information

Other display functions, such as zoom, rotate, and marker functions, are discussed in the "Getting Started" chapter.

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The PRESET Configuration

The following figure shows the PRESET configuration of the HP 8509 display. You can change the display to meet your needs. For example, the Poincare sphere and the polarization ellipse can be exchanged, the power mode can be changed from dBm to Watts, and the marker window can be removed.



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Figure 5-1. The PRESET Configuration

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Displaying the Marker Table

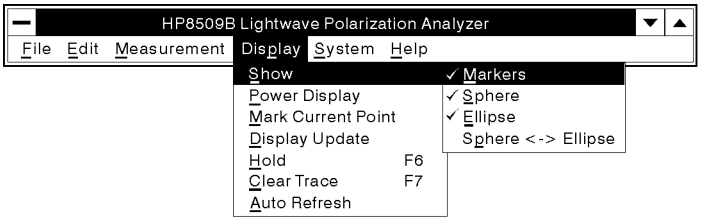


Figure 5-2. The Show Markers Menu

The marker table is displayed in the PRESET configuration, but it may be turned off or "hidden" by selecting `Display`, `Show`, `√Markers`. This menu selection toggles the marker table on and off. When the marker table is displayed, a check mark appears next to the menu selection.

The following figure shows what the display looks like with the marker window hidden.

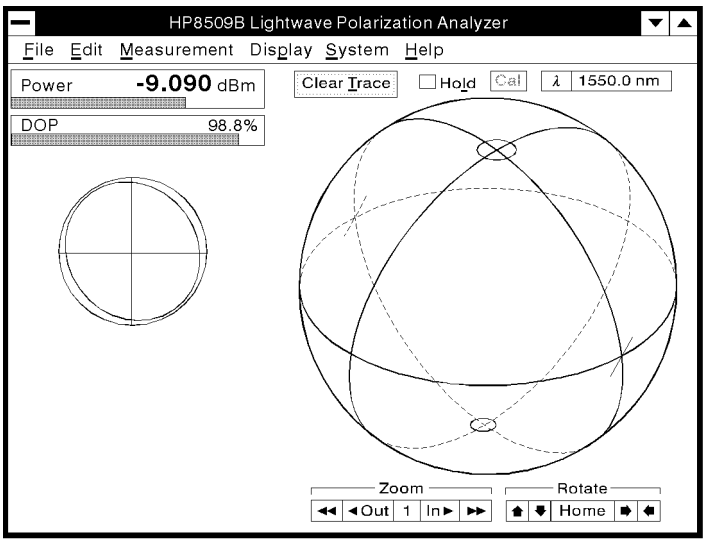


Figure 5-3. Marker Window Hidden

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Displaying the Poincare Sphere

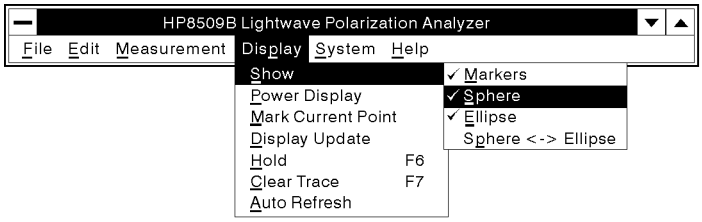


Figure 5-4. The Show Sphere Menu

The Poincare sphere is displayed in the PRESET configuration, but it may be turned off or "hidden" by selecting `Display`, `Show`, `√Sphere`. This menu selection toggles the Poincare sphere on and off. When the sphere is displayed, a check mark appears next to the menu selection.

The following figure shows what the HP 8509 display looks like with the sphere turned off.

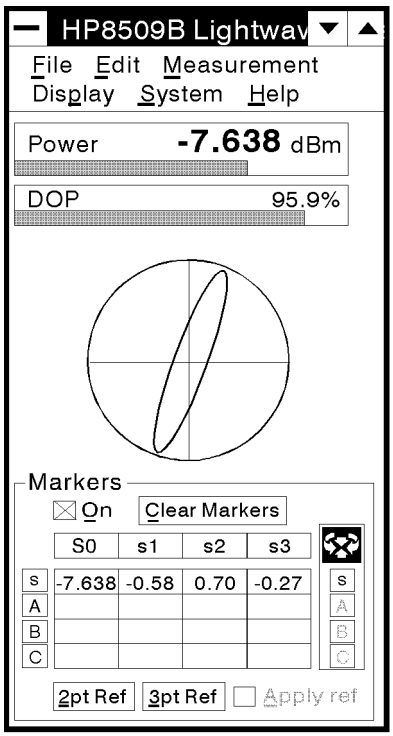
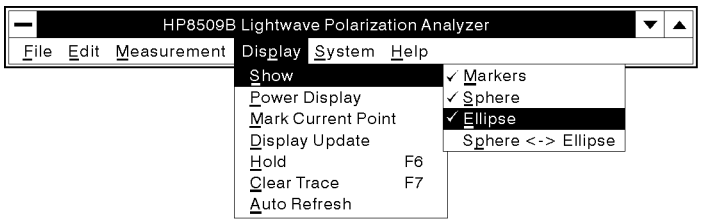


Figure 5-5. Poincare Sphere Turned Off

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Displaying the Polarization Ellipse

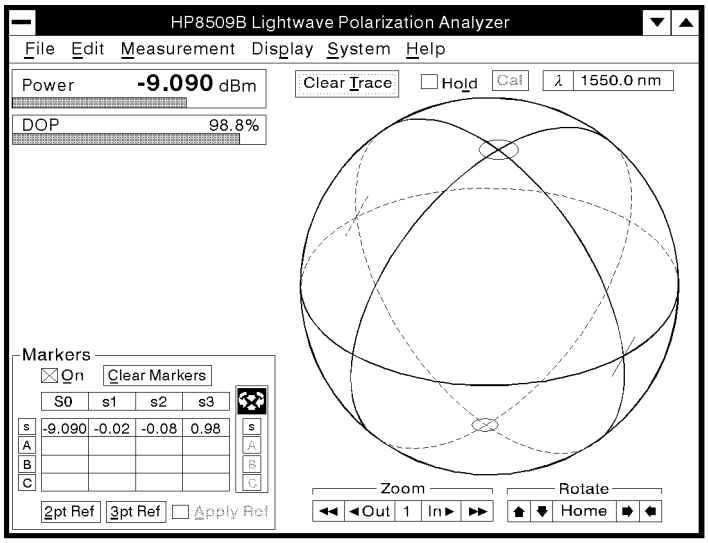


pq721b_c

Figure 5-6. The Show Ellipse Menu

The polarization ellipse is displayed in the PRESET configuration, but it may be turned off or "hidden" by selecting `Display`, `Show`, `√Ellipse`. This menu selection toggles the polarization ellipse on and off. When the ellipse is displayed, a check mark appears next to the menu selection.

The following figure shows what the HP 8509 display looks like with the ellipse turned off.

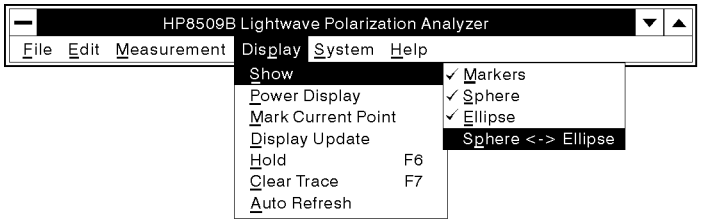


pq722b_c

Figure 5-7. Polarization Ellipse Turned Off

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Exchanging the Poincare Sphere and the Polarization Ellipse

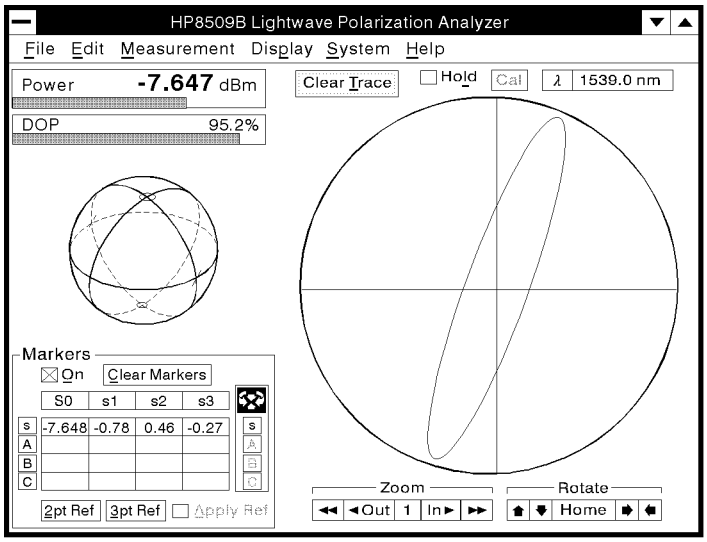


pq723b_c

Figure 5-8. The Show Sphere <-> Ellipse Menu

The default configuration has the Poincare sphere and the polarization ellipse displayed as shown in Figure 5-1. You may exchange the two so that the ellipse has the more prominent position by selecting `Display`, `Show`, `Sphere <-> Ellipse`.

The following figure shows what the display looks like with the Poincare sphere and the polarization ellipse exchanged.



pq728b_c

Figure 5-9. Sphere and Ellipse Exchanged

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Changing the Power Display Units

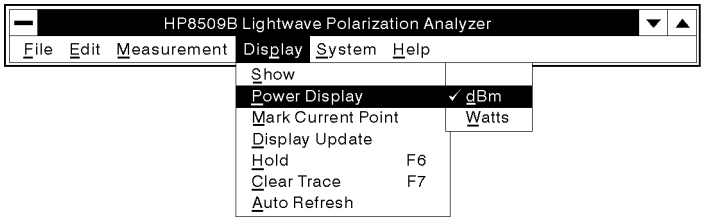


Figure 5-10. The Power Display Menu

The default state for the power mode is dBm. See Figure 5-1. Change the power mode to Watts by selecting `Display`, `Power Display`, `Watts`. This menu selection allows you to toggle between Watts and dBm. A check mark appears next to the menu selection that is currently activated.

The following figure shows the power mode changed from dBm to Watts.

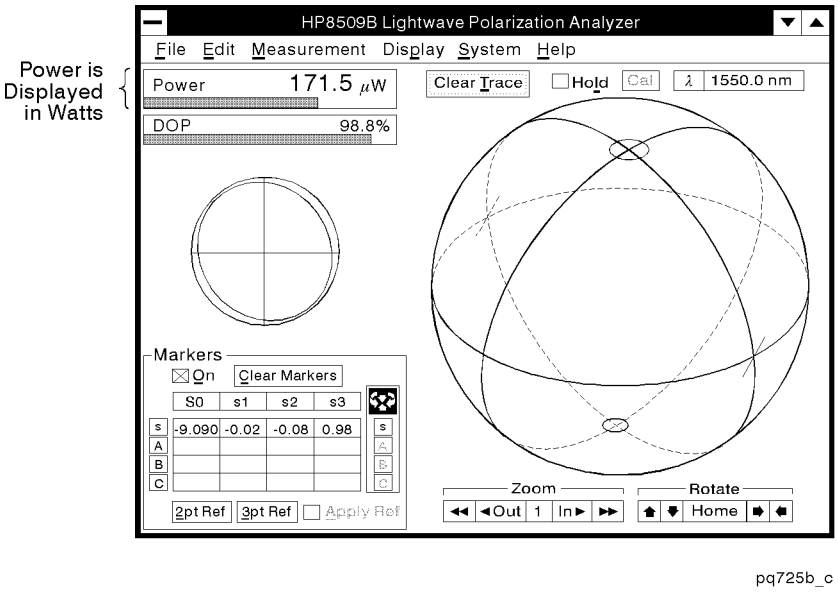


Figure 5-11. Power Display in Watts Mode

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Marking the Current Point

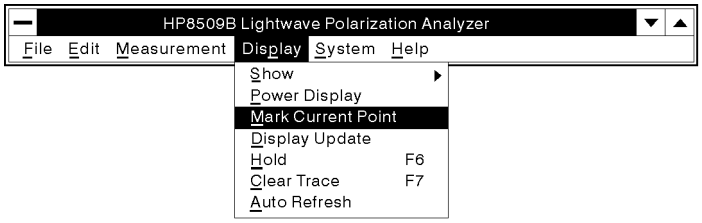


Figure 5-12. The Mark Current Point Menu

Often when data is being displayed on the Poincare sphere, it is desirable to know where the current data point is. You can turn on a feature that puts a flashing dot at the current data point by selecting `Display`, and `Mark Current Point`. When this feature is activated, a check mark appears next to the menu selection.

The dot will be red if the data is on the front of the sphere, and blue if it is on the back side of the sphere.

The following figure shows what the display looks like with the mark current point feature turned on.

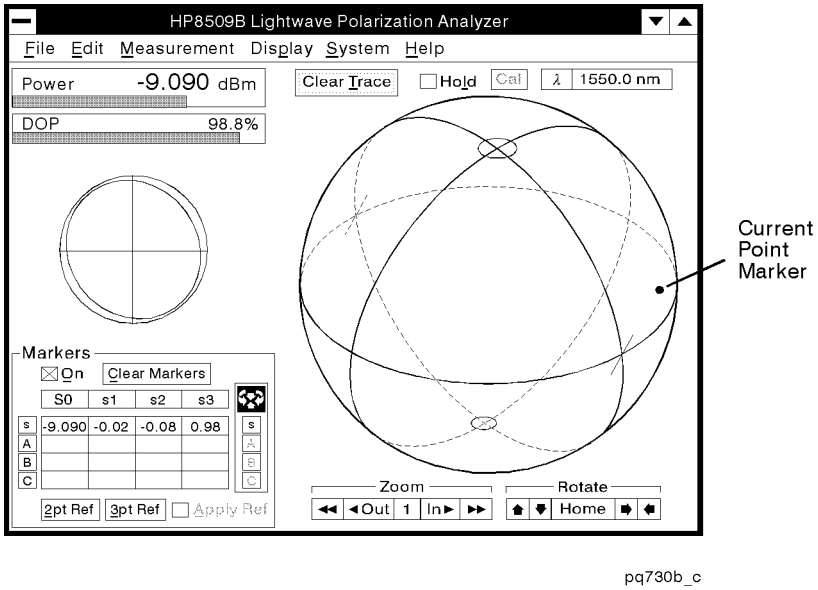


Figure 5-13. Mark Current Point Activated

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Changing the Display Update Frequency

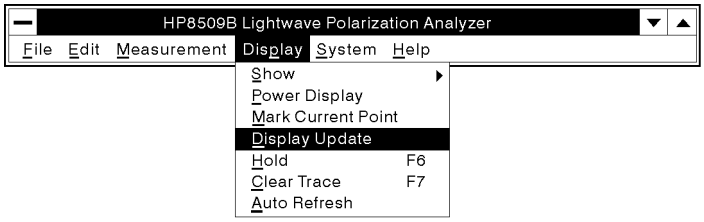


Figure 5-14. The Display Update Menu

The power measurement, DOP measurement, polarization ellipse, and Stokes displays are updated after the display of a user-selected number of points on the Poincare sphere. The default display update rate is once every 400 sphere points. The acceptable range of values for the display update number is 1 to 2000.

The following figure shows the Display Update window that appears when you select `Display`, `Display Update`.

To change the display update number, select the existing number and enter your new value.

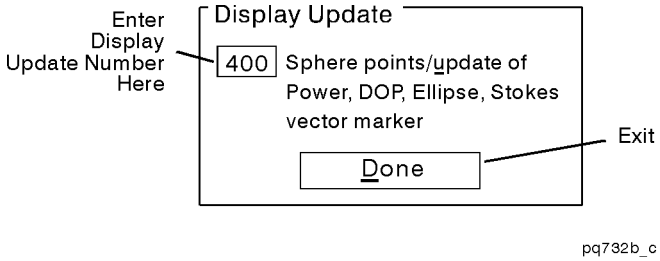


Figure 5-15. The Display Update Box

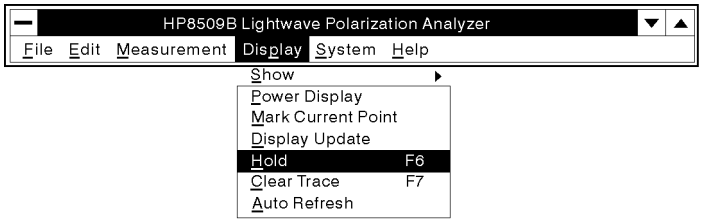
To maximize the update rate of the Poincare sphere display, set the Display Update value at the maximum (2000).

CAUTION

The display update frequency cannot be smaller than the display averaging factor. Display averaging factor is automatically reduced to avoid this condition.

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Holding the Data Display



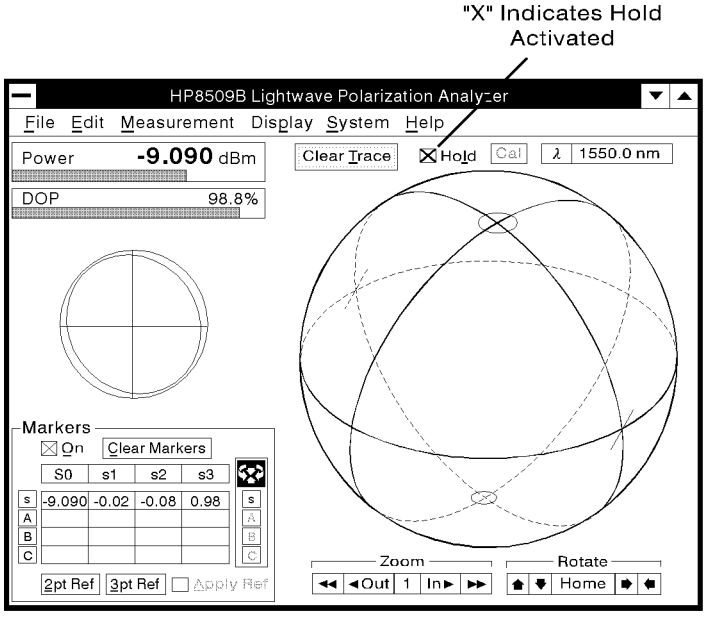
pq733b_c

Figure 5-16. The Hold Menu

If you wish to hold the current data display and not see new data put up on the Poincare sphere, you can activate the Hold function by selecting `Display`, `Hold`. This menu selection toggles the hold function on and off. When the Hold function is activated, a check mark appears next to the menu selection. Also, there will be an "X" in the Hold box on the HP 8509 basic measurement screen. See the following figure.

The Hold function can also be toggled on and off with the F6 key on your keyboard, or by selecting the Hold window on the basic measurement screen.

Putting the instrument in hold allows windows operations such as screen repaints, and other software applications to run faster.



pq734b_c

Figure 5-17. The Hold Function

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Clearing the Trace From the Sphere

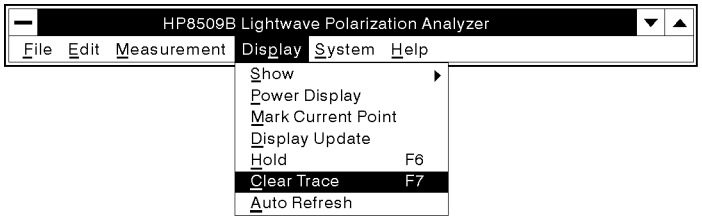


Figure 5-18. The Clear Trace Menu

To clear data from the Poincare sphere via the Display menu, select `Display`, `Clear Trace`. After the sphere is cleared data taking will continue.

You can also activate the Clear Trace function by pressing F7 on your keyboard, or by selecting (Clear Trace) on the basic measurement screen.

Setting the Display to Refresh Automatically

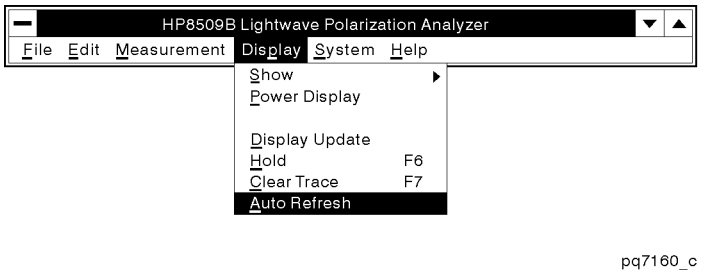


Figure 5-19. The Auto Refresh Menu

Usually, `Auto Refresh` should not be selected. Use it only if there are many tasks running in windows and the screen is not being repainted properly. If this feature is needed, select `Display`, and then `Auto Refresh`.

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6

The System Menu

This chapter contains information on the following subjects.

- Optical Source
- Zero
- Calibration
- Polarizers
- Shutter
- Averaging
- Range
- Analog Outputs
- Reference Frame Info
- Operation Verification

The System menu on the HP 8509 allows you to make changes to the system that are necessary to perform measurements. The receiver can be zeroed and calibrated for specific wavelengths, the optical source can be selected, the polarizers can be selected, and so on.

Conventions

In this document, HP 8509 menu items appear in shaded boxes `Like This`. HP 8509 main window items appear in unshaded boxes (Like This).

Illustrations and examples in this chapter show operation of an HP 8509B. There are minor differences for an HP 8509A, the most significant is that the HP 8509A does not have an internal source or internal polarizers.

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Optical Source

Opening the Optical Source Setup Window

You can open the Optical Source setup window on your HP 8509 in one of three ways:

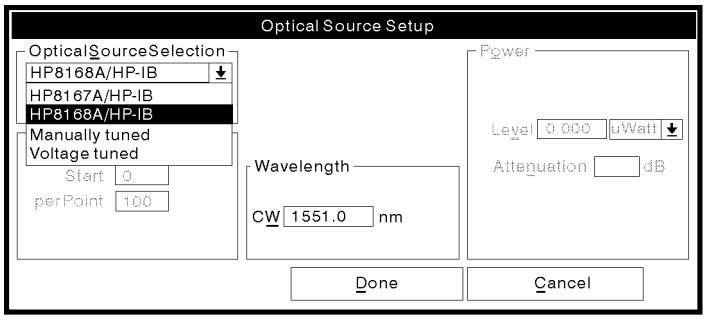
- Select `System`, `Optical Source`,
- Select (λ) (located in the upper right corner of the HP 8509 basic measurement screen), or
- Press F8 on your keyboard.

If the source you select within the Optical Source Setup window is an HP8167/8168 Tunable Laser Source connected to the HP8509A/B system via HP-IB, source wavelength, power and attenuation control can be done through this Optical Source Setup window. After selecting the HP8167 or HP8168, you will be able to enter the HP-IB address of the laser.

Internal lasers and the HP8167 and HP8168 sources, if connected via HP-IB, are automatically turned on and off as you select the sources. Other types of external sources must be turned on and off manually.

CAUTION External sources connected to the External Source Input of the HP8509B must be turned off when internal sources are turned on, to prevent both source signals from coming out of the Optical Output of the HP8509B.

Selecting an Optical Source (HP 8509A Only)



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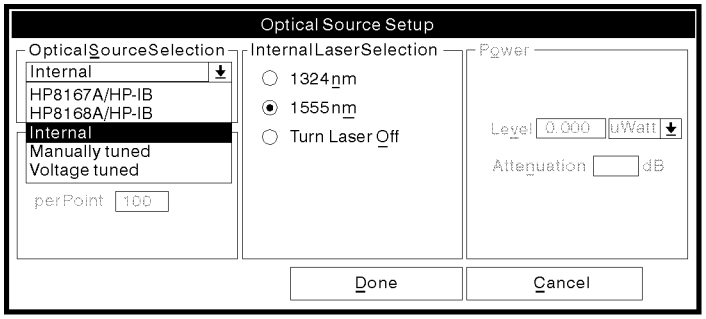
Figure 6-1. The HP 8509A Optical Source Window

The HP 8509A has no internal sources. Opening the Optical Source window allows you to select the source you want to use with your HP 8509A, and set the wavelength.

The default wavelength is 1550 nm. To enter a different wavelength, use the mouse to select the existing numbers in the wavelength box, and then input the correct wavelength for your measurement.

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Selecting an Optical Source (HP 8509B Only)



pq7125_c

Figure 6-2. The HP 8509B Optical Source Window

If your HP 8509B is standard, it is equipped with two internal sources. If you have one or both of the delete-source options, you will have either one internal source or no internal sources. In any case, when you open the Optical Source window, the choices available to you will appear.

Use the mouse to select the desired source. The source can be turned off by selecting Turn Laser Off.

NOTE

The actual wavelength of your internal source is probably different from the nominal values of 1310 nm and 1550 nm used in this procedure. The optical source setup window and the wavelength display in the basic measurement screen will reflect the factory measured value of your internal source, to the nearest nm.

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Zero

The zeroing routine is performed automatically at instrument startup. However it should be performed again after the instrument has warmed up for approximately one hour or after large ambient temperature changes.

Initiating the Receiver Zeroing Routine

The zeroing routine can be initiated in one of two ways:

- Select `System`, `Zero`.
- Press F9 on your keyboard.

Making Accurate Measurements

For accurate measurements, it is important that the receiver is not detecting any power while the zeroing routine is being performed.

1. If you have an HP 8509A you will be prompted to "Block the external laser." To do this, cover the OPTICAL INPUT connector with a connector cap or a piece of dark paper.
2. If you have an HP 8509B, you will *not* be prompted to, but you *must* either cover the OPTICAL INPUT connector as in step 1, above, *or* turn off your external source. If the external source is connected to the HP 8509B External Source input, its power will be blocked automatically so that no power will emerge from the Optical Output connector during the zeroing operation.

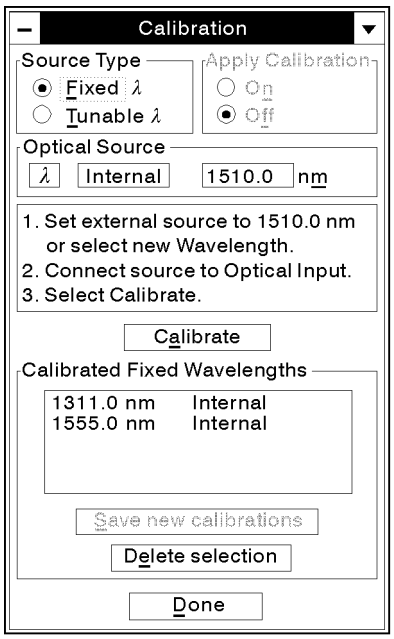
While the zeroing routine is running, a green "zero" message will appear inside the power display in the upper left corner of the HP 8509 basic measurement screen, and the mouse pointer appears as an hourglass. When the "zero" message disappears, and the mouse pointer changes back to an arrow, the zeroing routine is finished.

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Calibration

The following information is provided in this section.

- Fixed wavelength source calibration
- Tunable wavelength source calibration
- Applying and deleting calibrations



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Figure 6-3. The Calibration Window

ACCURACY ENHANCEMENT NOTE

Calibration is optional. Calibration is not required for HP 8509 operation.

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The HP 8509A/B Lightwave Polarization Analyzer has a built-in calibration feature that allows you to calibrate your instrument for specific wavelengths. The purpose of using the calibration feature is to:

- Optimize performance when using a source whose wavelength is uncertain to greater than ±1nm.
- Optimize performance when using a source with broad optical spectrum, such as a Fabry-Perot laser or an LED.
- Minimize any uncertainty caused by ambient temperature change or instrument aging.

The illustrations in this section show windows that appear on the HP 8509B interface. Remember that the HP 8509A does not come equipped with an internal source.

ADDITIONAL INFORMATION

The calibration must be performed with the source that will be used to make measurements.

Follow the Fixed Wavelength Source instructions when calibrating with sources which will not be tuned.

Follow the Tunable Wavelength Source instructions when you expect to use a single tunable source at a number of different wavelengths. This avoids confusion with calibrations taken at the same wavelength(s) using sources that have other spectral characteristics.

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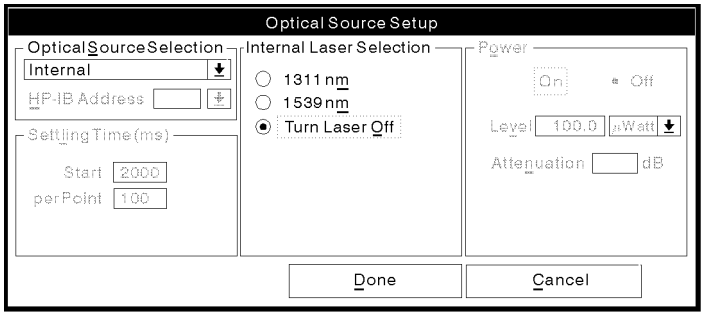
Calibrating For Use With a Fixed Wavelength Source

Make sure the instrument has warmed up for at least one hour and then zero the instrument. Refer to "Zero," in this chapter for information on how to zero the instrument.

Select the Source to be Calibrated

1. Open the Optical Source window by selecting (λ).
2. Select either an internal or an external source.

   If you select an external source, be sure to input the wavelength. Refer to "Optical Source" in this chapter of the manual for more information on selecting a source.



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Figure 6-4. The Optical Source Window

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Calibrate at the Selected Wavelength

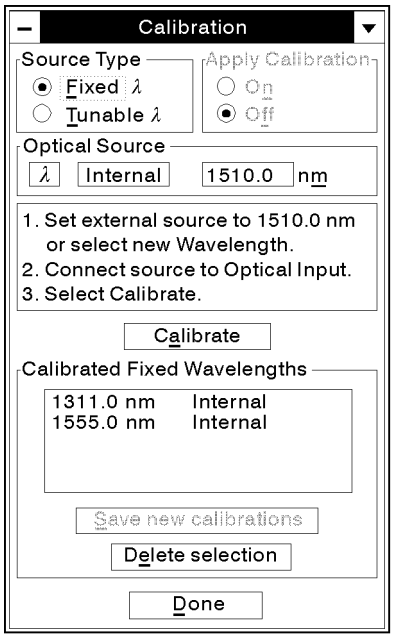
1. Open the Calibration window by using the mouse to select `System`, `Calibration`, *or* by pressing F11 on your keyboard. See Figure 6-5.
2. Select the "Fixed λ" source type.
3. Be sure that your source is turned on and tuned to the desired wavelength (if it is an external source).
4. The calibration works best if the optical signal is polarized before it is applied to the HP 8509A/B Optical Input. Insert an external polarizer or pass the signal through one of the internal polarizers of the HP 8509B. Select the polarizer using `System`, `Polarizers`. Select any of the three polarizers. Remember to remove the polarizer when the calibration is complete.
5. Move the fiber ahead of the polarizer, or adjust the front panel knobs of the HP 8509B (if necessary) to assure a good signal level through the polarizer.
6. Select Calibrate.

ACCURACY ENHANCEMENT NOTE

Signal power and DOP must be constant during the calibration process.

---

7. You will hear some clicking from inside the HP 8509 as the calibration is being performed. The calibration takes about 60 seconds. The HP 8509 automatically averages 250 measurements at each state.
8. Calibrate at other wavelengths by repeating the above procedure.



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Figure 6-5. The Calibration Window

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Save and/or Apply the Calibration

1. The calibration list (see Figure 6-6) for fixed wavelengths provides the following information:
   a. The wavelength(s) that have been calibrated.
   b. Whether it is an internal or external source.
   c. Whether the calibration has been saved or not.
2. To save all calibrations in the list with the "New" designation, select Save new calibrations.
3. To apply a calibration, select "Apply Calibration" "On" in the Calibration window. (See "Applying Your Calibration," later in this chapter.) (Also, refer to "Fixed Wavelength Source Calibrations," later in this chapter.)

ADDITIONAL INFORMATION

A calibration does not have to be saved in order to be applied. However, unsaved calibrations will be lost when the HP 8509A/B software is closed.

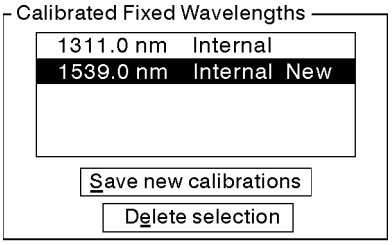


Figure 6-6. The Calibration List

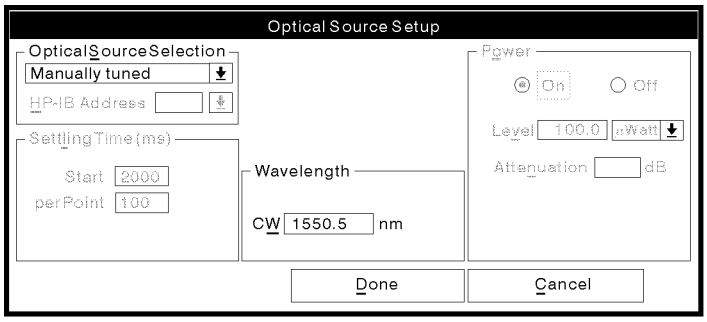
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Calibrating For Use With a Tuneable Wavelength Source

Make sure the instrument has warmed up for at least one hour and then zero the instrument. Refer to "Zero," earlier in this chapter for information on how to zero the instrument.

Select External Source and Input Wavelength

1. Open the Optical Source window, shown below, by selecting (λ).
2. Select an external source such as the HP 8168A.
3. Select Manually tuned for other, non-automatic tunable sources.
4. Input the first wavelength you want to calibrate.



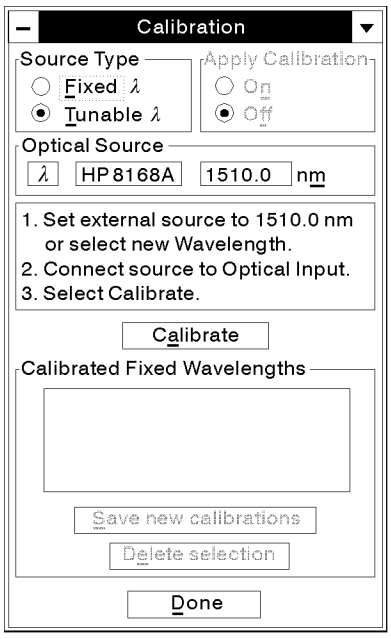
pq72b_c

Figure 6-7. The Optical Source Window

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Calibrate at the Selected Wavelength

1. Open the Calibration window by using the mouse to select `System`, `Calibration`, *or* by pressing F11 on your keyboard.
2. Select a tunable wavelength source as shown in Figure 6-8.
3. Be sure your source is turned on and tuned to the desired wavelength.
4. The calibration works best if the optical signal is polarized before it is applied to the HP 8509A/B Optical Input. Insert an external polarizer or pass the signal through one of the internal polarizers of the HP 8509B. Select the polarizer using `System`, `Polarizers`. Select any of the three polarizers. Remember to remove the polarizer when the calibration is complete.
5. Move the fiber ahead of the polarizer, or adjust the front panel knobs of the HP 8509B (if necessary) to assure a good signal level through the polarizer.
6. Select Calibrate.
7. You will hear clicking from inside the HP 8509 as the calibration is being performed. The calibration takes about 60 seconds. The HP 8509 automatically averages 250 measurements at each state.
8. Calibrating subsequent wavelengths:
   a. Enter the new wavelength in the wavelength box in the Calibration window by selecting the existing entry, then writing over it. You may also input the new wavelength using the Optical Source window.
   b. Select Calibrate.



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Figure 6-8. The Calibration Window

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Saving Wavelength Calibrations

When all desired wavelengths have been calibrated, save the calibrations according to the following procedure.

1. To save all the calibrations in the list with the "New" designation, select Save new calibrations as shown below.

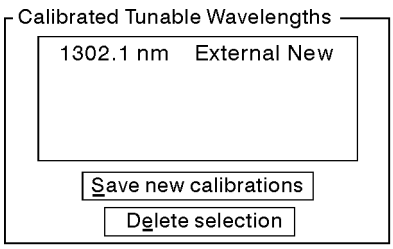


Figure 6-9. The Calibration List

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Applying A Calibration

In the Calibration "Off" condition, the analyzer uses the factory calibration constants. In the Calibration "On" condition, the analyzer uses the calibration you have performed to modify the internal cal constants for the current wavelength.

Applying a Calibration

- If you are still working within the Calibration window and wish to apply your calibration, use the mouse to select "Apply Calibration", "On."
- To apply another calibration, select the item in the calibration list. Select apply "on" if necessary.

ADDITIONAL INFORMATION

If you have calibration turned on, and enter a wavelength for which there is no calibration, calibration,is automatically turned off. The HP 8509 warns you that no calibration exists. The HP 8509 does not interpolate between calibrations.

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How to Tell If a Calibration is Applied

When a user-performed calibration is applied, the word “Cal” in the box in the upper right corner of the measurement screen will be bold (black letters) on a white background.

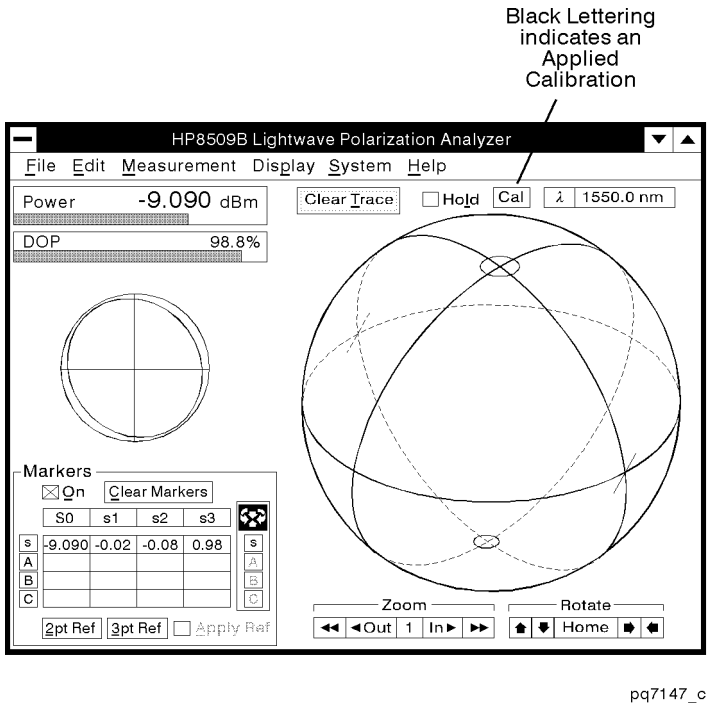


Figure 6-10. Calibration Applied

When a user-performed calibration is *not* applied, the word “Cal” in the box in the upper right corner of the measurement screen will be gray (inactive).

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Deleting a Calibration

1. A calibration can be deleted by selecting an entry in the Calibration List, and then selecting Delete selection.

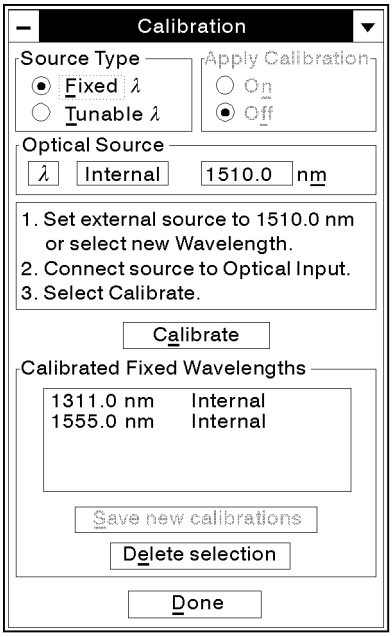
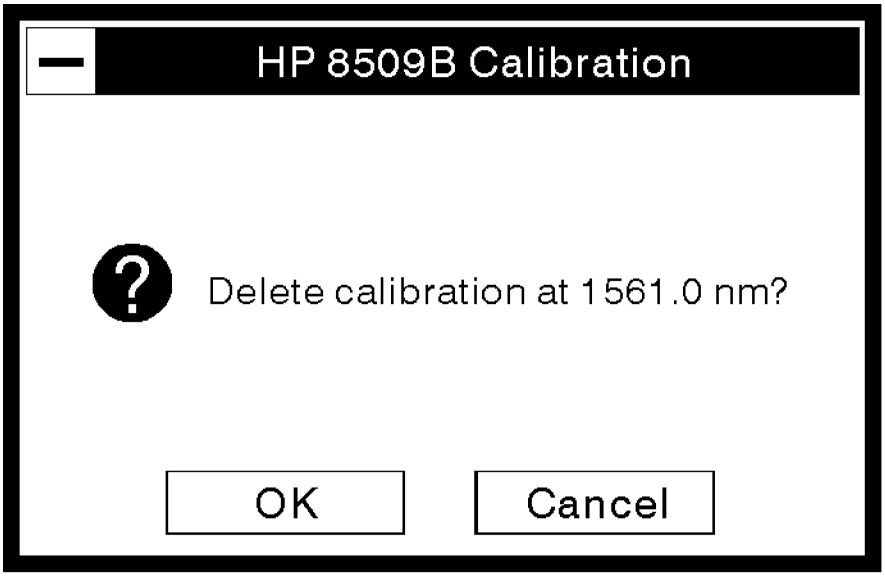


Figure 6-11. Deleting a Calibration

2. A window appears to confirm that you want to delete the calibration or cancel the delete calibration. Select OK to proceed with the deletion, or Cancel to abort the delete calibration process.

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pq7135_c

Figure 6-12. Confirm or Abort the Deletion Process

3. When calibration data is deleted, it is deleted from memory and from the disk file.

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Polarizers

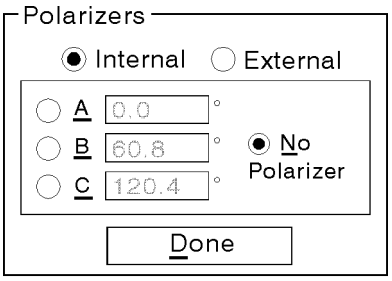


Figure 6-13. The Polarizers Window

Opening the Polarizers Window

You can open the Polarizers window on your HP 8509 in one of two ways:

1. Select `System`, `Polarizers`.
2. Press F12 on your keyboard.

HP 8509A only The illustration above shows the Polarizers window for an HP 8509B.

The HP 8509A is not equipped with internal polarizers. Please disregard all references to internal polarizers if you are using an HP 8509A.

Selecting a Polarizer

Selecting an Internal Polarizer (HP 8509B Only)

The internal polarizer angles are fixed, and their angles are measured at the factory. The nominal relative angles for internal polarizers A, B, and C are 0, 60, and 120 degrees, respectively. The values shown on your screen for these polarizers will be the measured angle values unique to your instrument.

1. To select an internal polarizer, select Internal in the Polarizers window.
2. Select polarizer A, B, or C.
3. Select "No Polarizer" to remove an internal polarizer from the signal path.

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About Internal Polarizers

Internal polarizers are effective only when using an internal source, or an external source that is routed through the HP 8509B via the EXTERNAL SOURCE INPUT.

Internal polarizers are inserted automatically during several types of measurements, and may be inserted manually to polarize light from an external source.

Selecting an External Polarizer

When using external polarizers to make certain measurements, you must input the angles of your polarizers into the HP 8509.

HP 8509A users should go directly to step 2.

1. Select External polarizers from the Polarizers window.

NOTE

The angles displayed are the default values for use with a rotatable external polarizer. The buttons for polarizer selection are gray (inactive) and no longer apply, however they continue to show the status (inserted or not) of the internal polarizers.

---

2. Input your angle values, in degrees, for external polarizers A, B, and C: select the numbers in the appropriate polarizer angle box and then input the value for your external polarizer angle.

Polarizer Angles and the Poincare Display

There is a 1:2 relationship between rotation of a linear polarizer and the resultant angle swept out on the Poincare sphere. For example, a 180° rotation of a linear polarizer produces a 360° “great circle” on the Poincare sphere display.

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Using the Shutter (HP 8509B only)

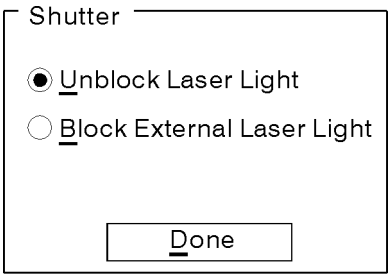


Figure 6-14. The Shutter Menu

In the HP 8509B, a shutter can be engaged to block light from internal sources, and from external sources that are routed through the HP 8509B via the EXTERNAL SOURCE INPUT. This shutter can be put into the signal path manually by selecting `System`, `Shutter`.

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Averaging

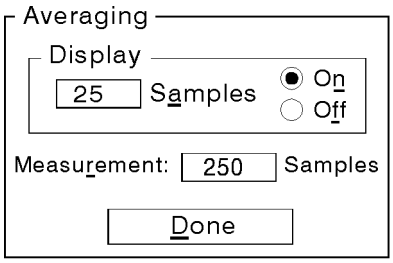


Figure 6-15. The Averaging Window

Opening the Averaging Window

Open the Averaging window by selecting `System`, `Averaging`.

Selecting Display Averaging

The default number (N) of display samples is 25 while the range is 0 to 1000. To enter a different number of samples, select the existing number in the display samples box, then enter your new selection for Display Averaging.

ADDITIONAL INFORMATION

The Display Averaging entry must be less than the Display Update entry (see "Changing the Display Update Frequency" in "The Display Menu" chapter of this manual), *and* less than 1000. The lightwave polarization analyzer will only accept numbers that meet these criteria.

Turn Display Averaging Off or On from the Averaging window.

About Display Averaging. When display averaging is on, every point on the sphere is a running average of the preceding N measurements of the incoming lightwave signal. Displays of average power, DOP, Stokes parameters and the elliptical display are also subject to Display Averaging.

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Selecting Measurement Averaging

The range of numbers that Measurement Averaging will accept is 0 to 100,000.

The default number (N) of measurement samples is 250. To enter a different number of samples, select and edit the displayed value.

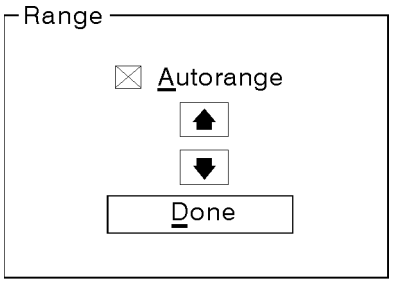
About Measurement Averaging. Measurement averaging is a straight average of N measurement samples and is used when:

- a polarizer is used in a measurement and
- when markers are set, as in the setting of an external reference frame.

The lower the measurement averaging value the faster measurements can be made. There will be an increase in measurement uncertainty if measurement averaging is set too low for the application.

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Range



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Figure 6-16. The Range Window

Opening the Range Window

Open the Range window by selecting `System`, `Range`.

Selecting Autorange

The default condition for Range is Autorange. Note that when autorange is selected there is an "X" in the box next to it.

Selecting a Specific Gain State

1. Deselect Autorange.
2. To accommodate high signal levels, select ▲. For operation with low level signals, select ▼.
3. Continue pressing ▲ or ▼ until the power display (in the upper left corner of the lightwave polarization analyzer measurement screen) reads "Overrange" or "Underrange."
4. Once you have reached the Overrange or Underrange condition, press ▲ or ▼ once to remove the "Overrange" or "Underrange" indication on the power display.
5. The gain will stay in this state until a different range is selected or until Autorange is selected.

About Range

To provide the large input dynamic range, the lightwave polarization analyzer operates over seven possible gain states or input power ranges. In some measurements it is helpful to put the instrument in a specific gain state. This eliminates interruption of data taking by the gain switching process, and allows operation at levels below −55 dBm.

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Analog Outputs

Analog outputs are disabled when using a Vtune source.

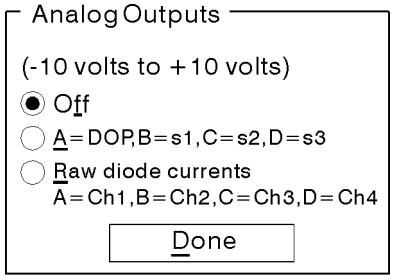


Figure 6-17. The Analog Outputs Window

The analog outputs for the lightwave polarization analyzer are four BNC connectors located on the rear panel of the lightwave polarization analyzer. They are labeled "A", "B", "C", and "D".

Opening the Analog Outputs Window

Open the Analog Outputs window by selecting `System`, `Analog Outputs`.

DOP and Normalized Stokes Parameters Mode

In this mode the BNC outputs provide the modes listed in the following table.

Table 6-1. Analog Outputs for DOP and Normalized Stokes Parameters Mode

Parameter	Connector	Output Voltage
DOP, 0 to 100 %	A	(%DOP − 100)/10
s1, −1 to +1	B	−10 to +10
s2, −1 to +1	C	−10 to +10
s3, −1 to +1	D	−10 to +10

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Raw Photodiode Currents

In this mode the BNC connectors provide signals proportional to the channel levels in the polarization receiver. These signals are corrected for front-end analog offset, but are not processed by the receiver calibration or ranging algorithms. These signals are developed from the output of the system ADC, which means that their values are linearly related to channel levels within any particular range (see "Range," earlier in this chapter). In other words, as the input power is increased from very low levels to high levels, the rear panel outputs will rise in each range, and then drop and again start to rise as the next range is switched in.

The output voltage covers the range of −10 volts to +10 volts as the ADC goes from zero to full counts. The connector assignments are listed in the following table.

Table 6-2. Analog Outputs for Raw Diode Currents Mode

Stokes Channel	Connector
0	A
1	B
2	C
3	D

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Reference Frame Info

Opening the Reference Frame Information Window

Open the Reference Frame Information window by selecting `System`, `Reference Frame Info`.

If a reference frame has not been defined the following window appears.

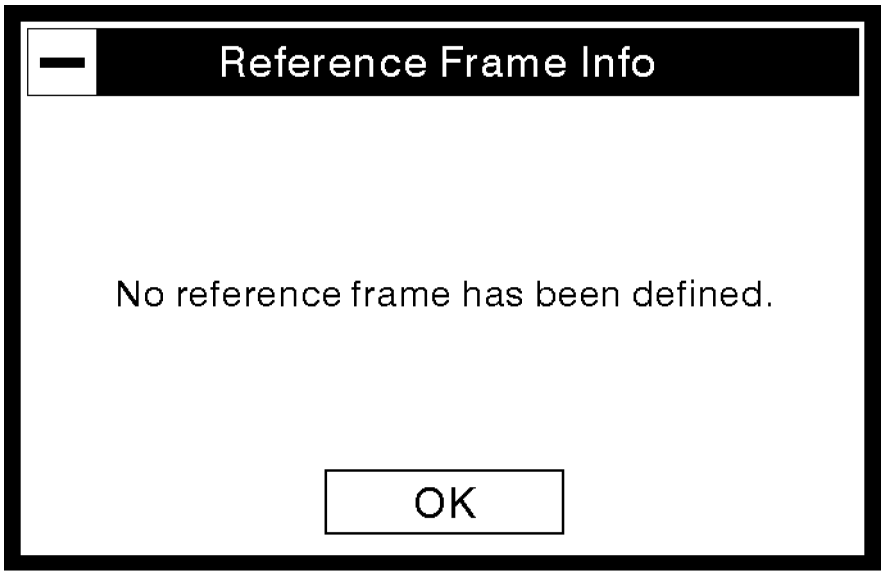


Figure 6-18. No Reference Frame Defined Window

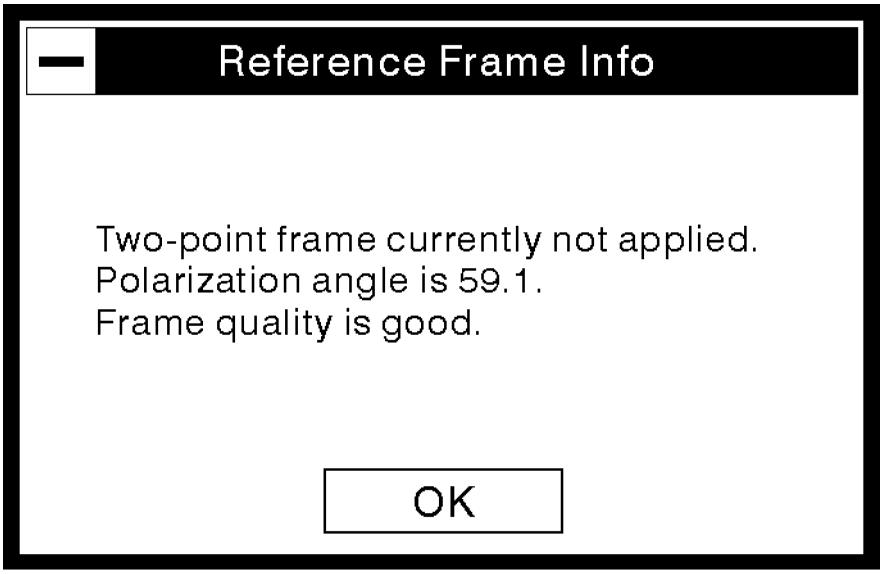
If a reference frame *has* been defined, a window will appear with the following information:

- The type of reference frame (two- or three-point), and whether or not it has been applied.
- The polarization angle (two-point reference only) *or* the transmission ratio (three-point only).
- The quality of the reference frame (one of the following):

  good
  fair
  poor
  very poor

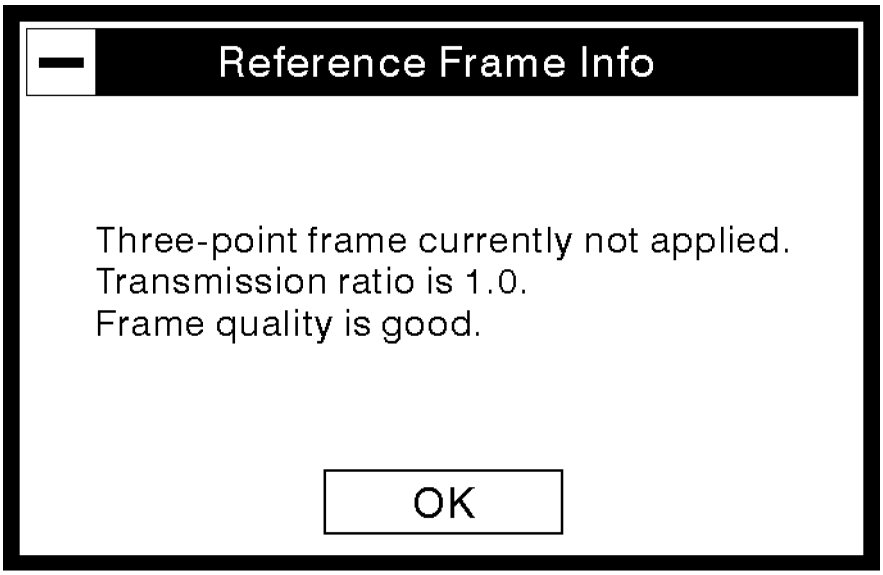
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Following are examples of the information given when a two- or three-point reference frame has been defined.



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Figure 6-19. Two-Point Reference Frame Information Window



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Figure 6-20. Three-Point Reference Frame Information Window

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Operation Verification

The operation verification procedure is a fully automatic pass/fail indicator of your system's performance. Perform this procedure after you install your system to verify that your system is working properly.

1. Allow the instrument to warm up for at least 1 hour and then zero the instrument.
2. Make sure the optical cable connecting the polarizer to the lightwave polarization analyzer's OPTICAL INPUT is stable. This can be accomplished by taping the cable to the work surface.
3. Select `System`, `Operation Verification` from the main window display.

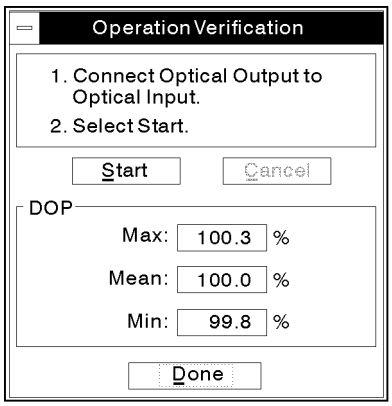


Figure 6-21. The Operation Verification Window for the HP 8509A

4. Select (Start). When the verification procedure is finished, the message `Operation Verification passed` is displayed in the message window, and the Max, Min, and Mean DOP values are displayed. For the HP 8509B, the relative angles between internal polarizers is also displayed. If the verification fails, see the Degree of Polarization topic in Chapter 3, Accuracy Enhancement and Troubleshooting.
5. The operation verification is complete. Select (Done) to clear the window and begin your measurement.

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7

User Interface Reference

This section briefly describes all of the controls and displays you may encounter while manually operating the HP 8509A/B. It supplements the measurement applications section of the manual by providing quick access to the description of a particular control or display. Remote control features of the instruments are discussed in the Programming chapter.

- Main window
- Optical source setup
- Calibration
- Operation Verification
- PMD: Jones Matrix Eigenanalysis
- PMD Statistics
- PMD: Wavelength-scanning
- Timed Measurements
- PDL: Jones Matrix/Jones Matrix
- PDL: Power Max - Min
- PM Fiber Launch
- Marker Angles

Information is presented in sections corresponding to the major windows, such as Main Window, PMD: Jones matrix eigenanalysis, PMD: Wavelength-scanning and so on. Within the sections, the descriptions are presented in chart format with the control or data display names arranged in the first column in alphabetical order. The items in the first column are menu selections unless otherwise noted. The next column gives the path by which the control or display is found. For example, in the Main Window section, the Calibration feature is found in the System menu. The last column describes the use of the control or display.

Additional information on the use of these features is found in the corresponding sections of Chapter 2, Measurement Applications. Specialized terminology is defined in the Glossary.

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Main Window

Table 7-1. Main Window

Control or Data	Path	Description
Analog outputs	Main window System menu	Selects analog output signals at the rear panel connectors A, B, C, D.
Apply 2pt	Main window	Applies an existing polarization reference frame.
Apply 3pt	Main window	Applies an existing polarization reference frame.
Auto Refresh	Main window Display menu	When enabled, this forces the operating system to redraw the main window whenever it receives the focus. Use only when System Resources are severely limited. Check System Resources using Program Manager, Help, About Program Manager.
Averaging	Main window System menu	Provides control of display and measurement averaging. Display average specifies the number of successive samples which are averaged to produce each point on the Poincare sphere display. Measurement average specifies the number of successive samples which are averaged during PMD, PDL, Jones matrix, and marker measurements.
Calibration	Main window System menu	Provides an automated calibration of the polarization receiver to optimize performance at a particular wavelength. Not necessary for PMD measurements, but may be helpful for Jones matrix PDL measurements and optimal DOP measurements in some cases.
Clear trace	Main window button or F7 or Main window Display menu	Clears all displayed points from the Poincare sphere display.
Copy sphere display	Main window Edit menu Copy bitmap	Copies only the Poincare sphere display to the Windows clipboard as a bitmap.
Copy analyzer window	Main window Edit menu Copy bitmap	Copies the entire main window to the Windows clipboard as a bitmap.
Display update	Main window Display menu	Sets the number of Poincare sphere points which are displayed between successive updates of the power, DOP and Stokes parameter displays.
DOP display	Main window	Displays the degree of polarization of the optical input.

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Table 7-1. Main Window (continued)

Control or Data	Path	Description
Ellipse display	Main window	Describes the state of polarization of the polarized portion of the optical signal in elliptical format.
Hold	Main window check box or Main window Display menu	Freezes displays in current condition and stops the internal measurement process. Allows graphical operations and other computer tasks to run faster.
Jones matrix	Main window Measurement menu	Enables user to set up and perform a measurement of the Jones matrix of the device under test. This is a relative measurement.
Load >	Main window File menu	Provides access to stored Timed Measurements and Configurations (see User and Preset Configuration).
Mark current point	Main window Display menu	Enables a blinking dot to identify the current measurement point on the Poincare sphere.
Marker angles displays	Main window Measurement menu	Lists the angle between rays from the center of the Poincare sphere to any two of the markers A, B & C following a great circle arc. Provides results in radians and degrees. Also provides commonly used trigonometric functions of these angles.
Markers on Check box	Main window Marker area	Toggles display of the markers without clearing them.
Markers displays & buttons	Main window	Capture up to three Stokes vectors, triggered by pressing buttons A, B, C to the left of the marker display chart. Parameters s_1, s_2, and s_3 are the normalized Stokes parameters. S_0 is the total power in dBm.
Operation verification	Main window System menu	Automatically verifies system operation, including the programmable polarizer and the optical receiver (polarimeter). Requires user to install a thru patchcord.
Optical source	Lambda button or Main window System menu Optical Source	Provides access to the optical source setup window for selection and control of internal or external optical source, especially setting of wavelength.
PDL: Jones matrix	Main window Measurement menu	Enables user to set up and perform a PDL measurement in which PDL is derived from a Jones matrix measurement of the device under test.

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Table 7-1. Main Window (continued)

Control or Data	Path	Description
PDL: Power max - min	Main window Measurement menu	Enables user to set up and perform a PMD measurement based on the variation in output power of the test device as its input polarization state is changed. May be performed with manual or automated polarization adjuster at input of the device. Polarization adjustment may be random or systematic.
PM Fiber launch	Main window Measurement menu	Provides graphical tools for launching light onto a principal axis of polarization maintaining fiber. Provides a measurement of the resulting extinction ratio.
PMD: Wavelength scanning	Main window Measurement menu	Enables user to set up and perform a PMD measurement using the wavelength-scanning method.
PMD: Jones matrix eigenanalysis	Main window Measurement menu	Enables user to set up and perform a PMD measurement using Jones matrix eigenanalysis.
Poincare sphere display	Main window	Describes the state of polarization of the polarized portion of the optical signal.
Polarizers	Main window System menu	Provides access to the internal polarizers used in Jones matrix based measurements. Also allows selection of internal or external polarizers and entry of the angles of external polarizers.
Power display	Main window	Displays the power level of the optical input. See the Display menu for dBm versus Watts selection.
Preset Configuration (Load)	Main window File menu	Loading the Preset Configuration loads the default conditions set at the factory. See the Printing, Saving, and Recalling section of the manual for changing the default configuration.
Print >	Main window File menu	Provides for printing various measurement displays or windows.
Range	Main window System menu	Allows operation in autorange (default) or fixed gain range. Press up button to accommodate large level signals.
Reference frame info	Main window System menu	Provides feedback on the quality of the applied polarization reference frame.
Rotate buttons	Main window	Rotates the Poincare sphere in 22.5 degree (1/16 revolution) increments. The Home button returns the display to the default view.
Save >	Main window File menu	Allows saving a Configuration of the instrument (see User Configuration) or various measurements.

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Table 7-1. Main Window (continued)

Control or Data	Path	Description
Show >	Main window Display menu	Allows the user to customize the appearance of the main window by deleting or interchanging displays.
Shutter	Main window System menu	Inserts shutter in the optical beam between internal or external optical source and the device under test. The shutter is situated in the switchable polarizer assembly.
Stokes vector display	Main window Marker area (top row)	Lists characteristics of the optical input in the form of the Stokes vector: Power level (always dBm) Stokes parameters (normalized)
Three-point reference button	Main window Marker area	Defines a polarization reference frame. Requires three measurements with a linear polarizer inserted in the beam at each of three known relative angles. The first polarizer orientation defines horizontal linear polarization. Removes birefringence and polarization dependent loss (PDL) from the path following the polarizer. Apply the reference frame by checking “Apply 3pt”.
Timed measurement	Main window Measurement menu	Enables the user to measure a desired number of points on a single, timed or free running basis. Points may be saved to the database or a text file. Points on the Poincare sphere rotate with the sphere in this mode.
Two-point reference button	Main window Marker area	Defines a polarization reference frame. Requires two measurements with a linear polarizer inserted in the beam at roughly 45-60 degree relative angles. The first polarizer orientation defines horizontal linear polarization. Removes birefringence from the path following the polarizer. Apply the reference frame by checking “Apply 2pt”.
User Configuration (Load or Save)	Main window Filemenu	Use the User Configuration features to save and recall instrument setup conditions.
Wavelength display & button	Main window	Displays currently selected wavelength in all measurement modes, including PMD measurements. Button provides access to the optical source setup window for selection and control of internal or external optical source, especially setting of wavelength. If wavelength numerals are grey, the source is turned off.

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Table 7-1. Main Window (continued)

Control or Data	Path	Description
Zero	Main window System menu	Removes offsets due to internal analog circuitry. During zero process, internal sources are automatically turned off and a shutter is inserted between "External source input" and "Optical output". Signals applied directly to the "Optical input" must be blocked by the user prior to zeroing.
Zoom	Main window	Changes magnification of Poincare sphere display to allow detailed examination of a small area. Center button toggles between normal and zoomed conditions. Points on sphere are erased by this operation unless they were collected by a timed measurement. (See "Timed measurements" under Measurement menu.)

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Optical Source Setup

The Optical Source Setup window presents the source control features appropriate to the selected measurement in PMD or main window applications. In PMD measurements, once `Measurement` has been selected, the source control parameters are associated with that measurement. If multiple PMD measurement setups are configured, each is associated with a unique Optical Source Setup window.

Table 7-2. Optical Source Setup

Control or Data	Path	Description
Attenuation entry box	Optical source setup window	Sets the attenuation of compatible external HP-IB optical sources.
Cancel button	Optical source setup window	Closes the dialog box with its original settings.
Delta wavelength entry box	Optical source setup window	The wavelength interval for a PMD measurement.
Find minimum # of points button	Optical source setup window	In PMD: Jones matrix eigenanalysis measurement mode, automatically determines the minimum number of measurement wavelengths required for the device under test. Additional points may be required to resolve the change in differential group delay with wavelength.
HP-IB address entry box	Optical source setup window	Allows specification of HP-IB select code and the address of the HP-IB programmable optical source. The default source is the HP 8168A, and the default address is 24. If the address must be changed, it can be saved for future use by saving user configuration before the end of the session. The HP-IB address function is accessible only when the HP 8167A or HP 8168A are selected.
HP 8167A (source selection)	Optical source setup window	Selects the HP 8167A Tunable Laser Source. If the HP-IB source address is incorrect, wait 5 seconds for timeout, then change the address to correspond to the laser. Alternatively, change the address at the laser to 24.
HP 8168A (source selection)	Optical source setup window	Selects the HP 8168A Tunable Laser Source. If the HP-IB source address is incorrect, wait 5 seconds for timeout, then change the address to correspond to the laser. Alternatively, change the address at the laser to 24.

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Table 7-2. Optical Source Setup (continued)

Control or Data	Path	Description
Internal laser (source selection)	Optical source setup window Internal	Allows user to select one of the internal lasers. Only available if internal laser option is installed.
Level entry box	Optical source setup window	Sets the output power level of compatible external HP-IB optical sources.
Optical source selection drop-down list	Optical source setup window	Allows selection of an internal or external optical source.
Points entry box	Optical source setup window	In PMD measurement modes, allows control of the number of measurement wavelengths.
Power on, off controls	Optical source setup window	Turns optical power on and off at the source when used with internal or compatible external HP-IB optical sources.
Settling time entry box	Optical source setup window	In PMD measurement modes, provides time for the tunable external source to settle at each wavelength prior to taking a measurement point. The wait may be increased for the starting wavelength to allow the source to reset from a previous measurement.
Start wavelength entry box	Optical source setup window	The first wavelength of a PMD measurement series.
Stop wavelength entry box	Optical source setup window	The last wavelength of a PMD measurement series.
Turn laser off	Optical source setup window	Turns both of the internal lasers off.
Voltage tuned (source selection)	Optical source setup window	Sets up the instrument for use of an external, voltage tuned source.
Vtune entry boxes	Optical source setup window	In PMD measurement modes, when an external voltage tuned source is used, allows user to set up the tuning voltage profile. Also displays the voltage change corresponding to a single wavelength delta.

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Calibration

Calibration is provided to optimize the accuracy of the HP 8509A/B at the current wavelength and with the current source. Calibration is optional. The term "calibration" in the following chart refers only to the wavelength calibrations performed by the user, and not to the calibration constants stored in instrument ROM at the factory.

Table 7-3. Calibration

Control or Data	Path	Description
Apply calibration (on, off)	Main window System menu Calibration	When this control is in the On condition, calibration is applied to all measurements. Apply calibration can only be turned on if a calibration exists for the current wavelength.
Calibrate selection	Main window System menu Calibration	Starts the calibration process. The HP 8509A/B takes 32 measurements with different settings of fiber coil polarization adjusters in the input path of the polarimeter receiver.
Calibrated tunable wavelengths display	Main window System menu Calibration	When the tunable wavelength source is selected, this list shows the existing calibrations available for use with a tunable laser source. Calibrations labeled as New have not yet been saved and will be lost if the instrument is turned off. If you wish to recalibrate at a wavelength listed here, double click on the desired wavelength. It will appear in the wavelength display.
Calibrated fixed wavelengths display	Main window System menu Calibration	When the fixed wavelength source is selected, this list shows the existing calibrations available for use with fixed wavelength (non-tunable) sources. Calibrations labeled as New have not yet been saved and will be lost if the instrument is turned off. If you wish to recalibrate at a wavelength listed here, double click on the desired wavelength. It will appear in the wavelength display.
Delete selection	Main window System menu Calibration	Pressing Delete selection deletes the highlighted wavelength calibration.
Done	Main window System menu Calibration	Exits the calibration form. No calibration data is lost.
Optical source display	Main window System menu Calibration	Specifies whether the selected source is a laser internal to the HP 8509B or is an external source and lists the type of external source.
Save new calibration selection	Main window System menu Calibration	Saves any calibration performed since the previous save. Calibrations are saved to hard disk.

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Table 7-3. Calibration (continued)

Control or Data	Path	Description
Source type (fixed wavelength, tunable wavelength)	Main window System menu Calibration	Specifies which of two categories of wavelength calibrations is to receive the focus of the wavelength calibration form. The fixed wavelength calibration should be used for single wavelength sources, internal or external. The tunable wavelength calibration should be used for a tunable external source.
Wavelength display	Main window System menu Calibration Optical source	When the calibration is performed, the resulting calibration data is assigned to the wavelength displayed here.
Wavelength selection	Main window System menu Calibration	Provides convenient access to the optical source setup window for the main window.

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Operation Verification

The operation verification feature checks the functionality of the HP 8509B. It exercises the polarimeter, the internal polarizer assembly, and the polarization adjuster assembly which precedes the polarimeter for use in calibration. The instrument measures polarization with each of the three polarizers inserted for each of 32 polarization adjuster settings. The results are analyzed and compared with expected values. A pass/fail message appears. No save feature is available. If you need a hard copy of the results, use Print Screen on the keyboard and the Paintbrush program (see the Printing, Saving, and Recalling chapter).

Table 7-4. Operation Verification

Control or Data	Path	Description
Cancel selection	Main window System menu Operation Verification	Cancels the operation verification process without closing the window.
Done	Main window System menu Operation Verification	Exits the operation verification window.
DOP, Max Mean, Min displays	Main window System menu Operation Verification	Displays the statistical results of the DOP measurement portion of the operation verification. The target value is 100%. See the Specifications chapter for tolerances.
Polarizer Angles (AB,AC) displays	Main window System menu Operation Verification	Displays the mean value of the polarizer angles as measured by the polarimeter. These values are compared with values stored in instrument ROM. The stored values can be inspected by selecting System menu and Polarizers.
Start selection	Main window System menu Operation Verification	Starts the operation verification process. Install a short jumper between Optical Output and Optical Input before starting the verification process.

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PMD: Jones Matrix Eigenanalysis

All PMD measurements take place within the Graphs window, a "parent" window in Windows terminology. The individual measurements are "child" windows within it. Each new measurement configuration produces a new child window. Select among the measurement setups using the Windows menu. Change between PMD setups and open new PMD measurement setups from the Windows menu, rather than returning to the Main window.

Table 7-5. PMD: Jones Matrix Eigenanalysis

Control or Data	Path	Description
Analyzer window	Graphs window Window menu	Selects the main analyzer window. Graphs window drops to the background but remains open.
Annotation	Graphs window Display menu	Places documentation of the most recent measurement at the bottom of the graphs window.
Autoscale	Graphs window Display menu Y scale >	Automatically adjusts minimum and maximum values of the graph's vertical axis to accommodate measurement results.
Autoscale/zero based	Graphs window Display menu Y scale >	Automatically adjusts the maximum value of the graph's vertical axis to accommodate measurement results. The minimum value is held at zero.
Cascaded device	Graphs window Measure menu	Selects the cascade method, in which the PMD of an element in the measurement path can be removed prior to measuring the actual device under test.
Copy window	Graphs window Edit menu	Places bitmap of the graphs window on the clipboard.
Copy to clipboard selection	Graphs window Display menu Tabular data	Copies the selected text to the clipboard. If no text is selected, the entire text box is copied. Capacity of the text box is 60,000 characters.
Copy graph	Graphs window Edit menu	Places bitmap of the selected graph on the clipboard.
Cursor	Graphs window Display menu	Places cursor controls and display directly below the graph area, allowing detailed examination of the measurement graph.
Data symbols	Graphs window Display menu	Places measurement point markers on the graph.
Database . . .	Graphs window File menu	Opens the database interface dialog box, allowing user to view database items and load saved measurement results and setup conditions into the graphs window.

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Table 7-5. PMD: Jones Matrix Eigenanalysis (continued)

Control or Data	Path	Description
Delay, Delay/L, Delay/sqrt(L)	Graphs window Format menu	Formats the differential group delay measurement results as simple delay in units of time (for fiber or component measurements), as ratio to fiber length, or as ratio to square root of fiber length for measurement of highly mode coupled devices such as long fibers.
Fiber length ...	Graphs window Format menu	Allows entry of the length of a fiber under test, in kilometers.
Fixed scale ...	Graphs window Display menu Y scale >	Allows the user to select the maximum value of the graph's vertical axis. The minimum value is fixed at zero.
Grid	Graphs window Display menu	Enables grid lines for the graph of measured results.
Load JME from database	Graphs window File menu	Sets up a new JME child window and loads stored JME measurement data and selected setup parameters from the database.
New JME window	Graphs window Window menu	Creates a new child window for a JME measurement.
New WS window	Graphs window Window menu	Creates a new child window for a WS measurement.
Optical Setup	Graphs window Measurement menu	Provides access to the optical source setup window.
Picoseconds/ femtoseconds	Graphs window Format menu	Selects units of differential group delay. One picosecond is 10^{-12} seconds, one femtosecond is 10^{-15} seconds.
PMD Statistics	Graphs window Display menu	Opens the PMD Statistics software application for the purpose of displaying one or more PMD measurements in statistical form.
Print graph & annotation	Graphs window File menu Print >	Prints the currently selected graph and the annotation information which appears in the top portion of the text box found under Display/Tabular Data.
Print tabular data selection	Graphs window Display menu Tabular Data	Prints the selected portion of, or entire text box.
Print graph, annotation & data	Graphs window File menu Print >	Prints the currently selected graph and the annotation information and data lists which appear in the text box found under Display/Tabular Data.

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Table 7-5. PMD: Jones Matrix Eigenanalysis (continued)

Control or Data	Path	Description
Print graph	Graphs window File menu Print >	Prints the currently selected graph.
Return to graph selection	Graphs window Display menu Tabular Data	Closes the Tabular Data text box and returns the display to the graph.
Save JME to database ...	Graphs window File menu	Saves the current JME measurement data and selected setup parameters to the database.
Save JME as text	Graphs window File menu	Saves JME measurement data as an ASCII text file.
Single device	Graphs window Measure menu	Selects the single device PMD measurement (default case). See "Cascaded device" for the alternative.
Tabular data	Graphs window Display menu	Places a text box in the graph area, listing measurement conditions and actual measurement results. Notes may be added by the user. Text can be selected and copied or printed. Capacity of the text box is 60,000 characters.
Window menu	Graphs window	Provides management of windows.
Y scale >	Graphs window Display menu	Provides control of the vertical scale of the measurement graph.

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PMD Statistics

The PMD Statistics feature provides a statistical representation of fiber DGD data measured with the Jones matrix eigenanalysis method. This is a separate software application which is accessed through a Display menu selection from the PMD measurement window.

Table 7-6. PMD Statistics

Control or Data	Path	Description
Add from Selected JME Window	File	Imports to the graphical displays the JME measurement result currently displayed in the HP8509 Graphs window.
Add from Database ...	File	Adds to the graphical displays a JME measurement result selected from the Database.
Add from Text File ...	File	Adds to the graphical displays a JME measurement result selected from a text file.
Auto Range	Format Wavelength Range >	Autorange sets the minimum and maximum displayed wavelengths to accommodate the minimum and maximum value of wavelength of the measurement data.
Autoscale	Format Histogram X-Axis >	Autoscale sets the maximum value of DGD displayed in the cumulative DGD histogram to accommodate the maximum DGD value of the measurement data. The minimum displayed DGD value is always zero.
Clear All Data	Edit	Removes all data, clearing both graphical displays. This operation cannot be undone.
Copy Bitmap to Clipboard >	Edit	Copies a bitmap of the selected item to the clipboard. Selections are DGD versus wavelength, the DGD histogram and the entire PMD Statistics window.
Cumulative differential group delay histogram	Lower graphical display	Displays a histogram of the DGD values corresponding to the individual wavelength intervals of one or more single JME PMD measurement sweeps.
Differential group delay vs wavelength display	Upper graphical display	Displays the DGD vs wavelength measurement result(s) from one or more JME PMD measurements.
Exit	File	Closes the PMD Statistics application without saving the results.

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Table 7-6. PMD Statistics (continued)

Control or Data	Path	Description
Fixed range ...	Format Wavelength Range >	Fixed Range allows the user to define the wavelength range. The cumulative DGD histogram is composed only of points which fall within the displayed wavelength range.
Fixed Scale	Format Histogram X-Axis >	Fixed Scale allows the user to define the maximum value of DGD displayed in the cumulative DGD histogram. The minimum displayed DGD value is always zero.
Histogram X-Axis >	Format	Allows selection of range mode for the cumulative DGD histogram display. Selections are Autoscale or Fixed Scale. Autoscale sets the maximum displayed DGD value to accommodate the maximum DGD value of the measurement data. The minimum displayed DGD value is always zero. Fixed Scale allows the user to define the maximum displayed DGD value in the cumulative DGD histogram.
Last file added	Numeric display	Shows number of data points contained in the last file added to the histogram.
Load as Text	File	Loads a histogram saved as text.
Maximum display		Displays the actual maximum value of DGD from JME measurement results shown in the graphical displays.
Maxwell alpha parameter display		Shows the value of the alpha parameter, the single parameter which specifies the shape of the Maxwell curve automatically fitted to the cumulative DGD histogram.
Mean display		Displays the actual mean value of DGD from JME measurement results shown in the graphical displays.
Minimum display		Displays the actual minimum value of DGD from JME measurement results shown in the graphical displays.
Number of bins entry box	Editable numeric display	Allows the user to specify the number of equal-sized bins in the cumulative DGD histogram.
Print Bitmap >	File	Prints a bitmap of the selected item. Selections are DGD vs wavelength, the DGD histogram and the entire PMD Statistics window.
Print Data	File	Prints a listing of the data which makes up the cumulative DGD histogram.

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Table 7-6. PMD Statistics (continued)

Control or Data	Path	Description
Save Statistics ...	File	Saves a histogram as text. May be retrieved to the PMD Statistics application with the Load Statistics ... feature.
Total size display		Shows the total number of data points contained in the histogram, including undisplayed wavelengths.
Undo Last Add	Edit	The curve last added to the DGD versus wavelength display is shown in red. Undo Last Add removes the red trace from the display and removes the corresponding points from the cumulative DGD histogram data set.
Wavelength Range >	Format	Allows selection of range mode for the DGD vs wavelength display. Selections are Autorange or Fixed Range. Autorange sets the minimum and maximum displayed wavelengths to accommodate the minimum and maximum value of wavelength of the measurement data. Fixed Range allows the user to define the wavelength range. The cumulative DGD histogram is composed only of points which fall within the displayed wavelength range.

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PMD: Wavelength-Scanning

All PMD measurements take place within the Graphs window, a “parent” window in Windows terminology. The individual measurements are “child” windows within it. Each new measurement configuration produces a new child window. Select among the measurement setups using the Windows menu. Change between PMD setups and open new PMD measurement setups from the Windows menu, rather than returning to the Main window.

Table 7-7. PMD: Wavelength-Scanning

Control or Data	Path	Description
Analysis >	Graphs window Format	Enables user to customize the wavelength scanning analysis performed on individual normalized Stokes parameter traces.
Annotation	Graphs window Display	Places documentation of the most recent measurement at the bottom of the graphs window.
Avg/Median/ Max delay >	Graphs window Format	Specifies how the final PMD result is derived from results of the three individual normalized Stokes parameter measurements. Selects the average, median, (central) or maximum of the three results.
Copy graph s1 (or s2, or s3)	Graphs window Edit menu	Places bitmap of the normalized Stokes parameter s1(or s2, or s3) measurement graph on the clipboard.
Copy window	Graphs window Edit menu	Places bitmap of the entire graphs window on the clipboard.
Copy to clipboard selection	Graphs window Display menu Tabular data	Copies the selected text to the clipboard. If no text is selected, the entire text box is copied.
Cursor	Graphs window Display menu	Enables the cursor function, allowing detailed examination of the measurement graph. Only accessible when a single normalized Stokes parameter graph is expanded vertically.
Data symbols	Graphs window Display menu	Places measurement point markers on the graph.
Database . . .	Graphs window File menu	Opens the database interface dialog box, allowing user to view database items and load saved measurement results and setup conditions into the graphs window.

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Table 7-7. PMD: Wavelength-Scanning (continued)

Control or Data	Path	Description
Delay, Delay/L, Delay/sqrt(L)	Graphs window Format menu	Formats the differential group delay measurement results as simple delay in units of time, for component measurements, as ratio to fiber length, or as ratio to square root of fiber length for measurement of highly mode coupled devices such as long fibers.
Extrema/first to last	Graphs window Format menu Analysis >	Counts the number of peaks and valleys which occur in the full measurement wavelength scan. Subtracts one from the total, divides by two and uses the result as N in the wavelength scanning formula. Uses the wavelengths of the first and last peak or valley as the start and stop wavelengths in the wavelength scanning formula.
Extrema/full scan	Graphs window Format menu Analysis >	Counts the number of peaks and valleys which occur in the full measurement wavelength scan. Divides total by two and uses result as N in the wavelength scanning formula. Uses wavelength extremes of the scan as the start and stop wavelengths in the wavelength scanning formula.
Fiber length ...	Graphs window Format menu	Allows entry of the length of a fiber under test, in kilometers.
Grid	Graphs window Display menu	Enables grid lines for the graph of measured results.
Load WS from database ...	Graphs window File menu	Opens a new WS child window and loads stored WS PMD measurement data and selected setup parameters from the database
Minimum feature size ...	Graphs window Format menu	Specifies the threshold for detection of peaks and valleys in the normalized Stokes parameter graphs. Corresponds to the vertical separation of adjacent peak and valley. The value is dimensionless and may range from .001 to 1.99. Default value is 0.01.
Mode coupling factor k ...	Graphs window Format menu	Specifies the value of mode coupling factor for the wavelength scanning formula. Use 0.82 for highly mode coupled devices (long fibers) and 1.0 for most optical components.
No polarizer	Graphs window Format menu	Specifies that no internal polarizer will be placed in the source path during the WS PMD measurement. Note that a polarized source such as the HP 8167/68A may be connected directly to the device under test. HP 8509B only.

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Table 7-7. PMD: Wavelength-Scanning (continued)

Control or Data	Path	Description
Peaks/first to last	Graphs window Format menu Analysis >	Counts the number of peaks which occur in the full measurement wavelength scan. Subtracts one from the total and uses the result as N in the wavelength scanning formula. Uses the wavelengths of the first and last peak as the start and stop wavelengths in the wavelength scanning formula.
Peaks/full scan	Graphs window Format menu Analysis >	Counts the number of peaks which occur in the full measurement wavelength scan and uses result as N in the wavelength scanning formula. Uses wavelength extremes of the scan as the start and stop wavelengths in the wavelength scanning formula.
Polarizer A (or B, or C)	Graphs window Format menu	Specifies which of the internal polarizers will be inserted in the source path during the WS PMD measurement. The three linear polarizers differ in rotational angle by approximately 60 degrees. Note that a polarized source such as the HP 8167/68A may be connected directly to the device under test. HP 8509B only.
Print tabular data selection	Graphs window Display menu Tabular data	Prints the selected portion of, or entire text box.
Print PMD >	Graphs window File menu	Accesses print controls.
Print graphs & annotation	Graphs window File menu Print >	Prints graphs of the three normalized Stokes parameters and the annotation information which appears in the top portion of the text box found under Display/Tabular data.
Print graphs, annotation & data	Graphs window File menu Print PMD >	Prints the three normalized Stokes parameter graphs and the annotation information and data lists which appear in the text box found under Display/Tabular data.
Print graphs s1, s2, s3	Graphs window File menu Print PMD >	Prints graphs of the three normalized Stokes parameters.
Return to graph selection	Graphs window Display menu Tabular data	Closes the Tabular Data text box and returns the display to the graph.

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Table 7-7. PMD: Wavelength-Scanning (continued)

Control or Data	Path	Description
Save WS to database ...	Graphs window File menu	Saves the current WS PMD measurement data and setup parameters to the database.
Save WS as text	Graphs window File menu	Saves WS PMD measurement data as an ASCII text file.
Tabular data	Graphs window Display	Places a text box in the graph area, listing measurement conditions and actual measurement results. Notes may be added by the user. Text can be selected and copied or printed.

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Timed Measurements

The Timed Measurements feature captures measurement points in computer memory. This allows saving to a file or as a database record, and allows rotation of the Poincare sphere without erasure of the displayed data. Data may be taken in a free running, timed, or single mode.

Table 7-8. Timed Measurements

Control or Data	Path	Description
Back step selection	Main window Measurement menu Timed measurement (Single mode)	In the single mode, removes the previous sample from memory and Poincare sphere display and sets up to replace it with the next single sample.
Free run (mode selection)	Main window Measurement menu Timed measurement mode	Sets instrument to collect data at its normal, open loop rate, which is about 1 kHz for the 486/33 computer and 2 kHz for the 486/66 computer.
Mode	Main window Measurement Timed measurement	Specifies the timing format. Choices include free running, timed or single measurements.
Number of samples entry box	Main window Measurement menu Timed measurement (Timed or free run mode)	Specifies the number of samples that will be taken. Samples may be free run or timed. The maximum number of samples is 16,381.
Rate entry box	Main window Measurement menu Timed measurement (Timed mode)	Specifies the sampling rate in the timed mode. The rate is the inverse of the sample period.
Sample period entry box	Main window Measurement menu Timed measurement (Timed mode)	Specifies the time in seconds between samples in the timed mode. Minimum time is 0.002, maximum value is 7,209,070.000 in increments of 0.001.
Samples taken display	Main window Measurement menu Timed measurement (Single mode)	Records the number of samples taken in the current series of single samples. The number of samples is limited to 16,381. There is no timeout.
Single (mode selection)	Main window Measurement menu Timed measurement mode	Sets instrument to collect a single data point each time it is triggered by the user.

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Table 7-8. Timed Measurements (continued)

Control or Data	Path	Description
Start sample sequence selection	Main window Measurement menu Timed measurement (Timed or free run mode)	Starts a measurement series in the free run or timed mode.
Take sample selection	Main window Measurement menu Timed measurement (Single mode)	Triggers a single sample in the single mode.
Timed (mode selection)	Main window Measurement menu Timed measurement mode	Set instrument to collect data at intervals set by the timing controls.

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PDL: Jones Matrix & Jones Matrix

The PDL: JONES MATRIX feature determines the PDL of a two-port device from measurement of the Jones matrix. The resulting value corresponds to the variation of optical insertion loss (or gain) for all possible states of polarization.

Table 7-9. PDL: Jones Matrix & Jones Matrix

Control or Data	Path	Description
Cal at (angle) selection	Main window Measurement menu PDL: Jones Matrix (using external polarizers)	These three controls appear when using external polarizers. The angles given are those which appear in the Polarizers control frame to be found under the Main Window System menu under Polarizers. These angles are editable by the user, but the same angles must be used for both calibration and measurement.
Calibrate	Main window Measurement menu PDL: Jones Matrix (using internal polarizers)	Starts the calibration measurement of a thru path in preparation for a Delta, Max, Min measurement.
Clear/Restart	Main window Measurement menu PDL: Jones Matrix (using internal polarizers)	Clears the measurement displays and sets up for a new measurement.
Degrees control	Main window Measurement menu PDL: Jones Matrix (Jones matrix mode)	Selects the polar format for the elements of the Jones matrix, with angles given in degrees.
Jones Values control	Main window Measurement menu PDL: Jones Matrix	Selects display of the measured Jones matrix.
Meas at (angle) selection	Main window Measurement menu PDL: Jones Matrix (using external polarizers)	These three controls appear when using external polarizers. The angles given are those which appear in the Polarizers control frame to be found under the Main Window System menu under Polarizers. These angles are editable by the user.
"No reference frame applied" message	Main window Measurement menu PDL: Jones Matrix	This message indicates that no polarization reference frame has been applied.
Pol Dep Values control	Main window Measurement menu PDL: Jones Matrix	Selects display of the polarization dependence value(s) derived from the Jones matrix measurement.

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Table 7-9. PDL: Jones Matrix & Jones Matrix (continued)

Control or Data	Path	Description
Polarization Dependence displays	Main window Measurement menu PDL: Jones Matrix	Provides display of measurement result, which may be Delta or Delta, Max, Min values of the polarization dependence.
Polarizer Controls (Internal or External)	Main window Measurement menu PDL: Jones Matrix	Specifies whether internal or external polarizers will be used for the Jones matrix measurement. Internal polarizers are automatically inserted as part of the measurement algorithm. External polarizers must be inserted by the user. External polarizers are typically used when it is necessary to measure only the PDL of a bulk-optic assembly, without the residual PDL of pigtails and connectors.
Radians control	Main window Measurement menu PDL: Jones Matrix	Selects the polar format for the elements of the Jones matrix, with angles given in radians.
"Reference frame applied" message	Main window Measurement menu PDL: Jones Matrix	This message indicates that a polarization reference frame has been applied.
Transmission measurement (Delta or Delta, Max, Min) controls	Main window Measurement menu PDL: Jones Matrix	Specifies the type of measurement. Delta mode produces the variation in insertion loss (or gain) corresponding to all possible states of polarization. The Delta, Max, Min mode produces the maximum and minimum insertion loss (or gain) as well as the delta value. The Delta, Max, Min mode requires a calibration measurement of a thru fiber.
x + iy control	Main window Measurement menu PDL: Jones Matrix Main window Measurement menu PDL: Jones Matrix	Selects the real plus imaginary format for the elements of the Jones matrix.

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PDL: Power Max - Min

The PDL: POWER MAX - MIN feature determines the PDL of a two-port device from measurement of the optical power as the input polarization state to the device under test (DUT) is changed over all possible states. The resulting value corresponds to the variation of optical insertion loss (or gain) for all possible states of polarization. The method is most convenient when the DUT input polarization is changed by an automatic, motorized controller, but the method also improves the convenience of measurements employing manual polarization controllers.

Table 7-10. PDL: Power Max - Min

Control or Data	Path	Description
Angle between Max and Min states display	Main window Measurement menu PDL: Power Max - Min	Displays the relative angle between the Poincare sphere markers of maximum and minimum power. This angle approaches 180 degrees for most test devices having large PDL. The angle will deviate greatly from 180 degrees for low values of PDL. It is provided only as supplemental information and is not part of the measurement result.
Clear Trace selection	Main window Measurement menu PDL: Power Max - Min	Clears the Poincare sphere display. This may be useful when performing the measurement with a manual polarization adjuster.
Delta (Max - Min Power) display	Main window Measurement menu PDL: Power Max - Min	Displays the variation in the detected level of optical signal since the Reset button was pressed.
Hold box	Main window Measurement menu PDL: Power Max - Min	Interrupts the measurement process.
Max Power display	Main window Measurement menu PDL: Power Max - Min	Displays the maximum power which has been detected since the Reset button was pressed.
Min Power display	Main window Measurement menu PDL: Power Max - Min	Displays the minimum power which has been detected since the Reset button was pressed.
Reset selection	Main window Measurement menu PDL: Power Max - Min	Clears the stored values of maximum and minimum power and resets both to the current power. This is used before a new measurement.

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Table 7-10. PDL: Power Max - Min (continued)

Control or Data	Path	Description
s1, s2, s3 displays	Main window Measurement menu PDL: Power Max - Min	Displays the normalized Stokes parameters corresponding to the maximum and minimum power that have been detected since the Reset button was pressed. The normalized Stokes vector is extended to the surface of the sphere and markers are placed at these points. A solid circle marks the maximum power location and an open circle marks the minimum. These polarization states are relative, because they are measured at the polarimeter receiver, separated from the output of the device under test by some length of optical fiber. The two buttons located to the right of these controls allow rotating the Poincare sphere to bring the maximum or minimum points to the center of view, allowing more detailed operator scrutiny in the case of manual polarization controller operation.
center selection	Main window Measurement menu PDL: Power Max - Min	Rotates the Poincare sphere to bring the maximum or minimum power point to the center of view.

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PM Fiber Launch

The PM FIBER LAUNCH feature provides a very sensitive measurement of the extinction ratio of light in polarization maintaining fiber, providing feedback for launching light into a principal axis.

Table 7-11. PDL: Power Max - Min

Control or Data	Path	Description
Cone half-angle display	Main window Measurement menu PM Fiber Launch	Displays the half-angle of the cone represented by the circle on the Poincare sphere. This is the angle subtended at the center of the sphere by the center of the circle and a point on its circumference.
Extinction ratio display	Main window Measurement menu PM Fiber Launch	Displays the ratio of power in orthogonal polarization modes corresponding to the diameter of the circle on the Poincare sphere.
Move circle selection	Main window Measurement menu PM Fiber Launch	Sets the instrument to allow movement of the circle on the Poincare sphere. Move the circle by placing the cursor anywhere on the sphere (need not be within the circle) and dragging in the desired direction.
New circle selection	Main window Measurement menu PM Fiber Launch	Erases any existing circle and sets the instrument to allow creation of a new circle. A new circle is formed after the user clicks in three places on the Poincare sphere.
Resize circle selection	Main window Measurement menu PM Fiber Launch	Sets the instrument to allow changing of the diameter of the circle on the Poincare sphere. Resize the circle by clicking with the mouse either within the circle, to make it smaller, or outside the circle, to make it bigger. Size can also be changed by clicking or click/dragging anywhere on the sphere.

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Marker Angles

The MARKER ANGLES feature allows the user to determine the relative angle between pairs of markers on the Poincare sphere. The angle is defined between rays originating at the center of the sphere.

Table 7-12. Marker Angles

Control or Data	Path	Description
AB, BC, AC display	Main window Measurement menu Marker Angles	Identifies the pair of markers represented in the measurements displayed on the same row.
Cos x display	Main window Measurement menu Marker Angles	Marks the column in which the cosine of the relative angles are displayed.
Cos2(x/2) display	Main window Measurement menu Marker Angles	Marks the column in which the square of the cosine of half of the angle is displayed.
Degrees control	Main window Measurement menu Marker Angles	Expresses the measured angles in degrees.
Radians control	Main window Measurement menu Marker Angles	Expresses the measured angles in radians.
x display	Main window Measurement menu Marker Angles	Marks the column in which the angles between markers are displayed.

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8

Lightwave Connector Care

Introduction

Lightwave cable interfaces can be damaged by improper cleaning and connection procedures. Dirty or damaged lightwave interfaces can result in nonrepeatable or inaccurate measurements. This chapter will suggest some best practices to clean, care for, connect, and inspect lightwave connectors.

Lightwave connectors are used to connect two fiber ends together. These connections may be used to join cables between optical ports on devices, laser sources, receivers, patch panels, terminals and many other types of systems or components.

Fiber optic cables are used at different wavelengths, in single or multi-mode, and in different environments. There are a variety of sizes, core/cladding combinations, jackets, and indexes of refraction. In general, different types of cables do not work well together: cables must match each other and the system.

However, regardless of the cable type, the connectors have only one function: to provide a direct and low-loss optical signal transition from one fiber end to another. When these connectors are used in a measurement system, repeatability becomes an important factor.

Lightwave connectors differ from electrical or microwave system connectors. In a fiber optic system, light is transmitted through an extremely small fiber core. Because fiber cores are often 9 microns (0.009 mm) or less in diameter, and dust particles range from tenths of a micron to several microns in diameter, dust and very minute contamination on the end of the fiber core can degrade the performance of the connector interface (where the two cores meet). Therefore, the connector must be precisely aligned and the connector interface free of trapped foreign material.

Connector (or insertion) loss is one important performance characteristic of a lightwave connector. Typical values are less than 1 dB of loss, and sometimes as little as 0.1 dB of loss with high performance connectors. Return loss is another important factor. It is a measure of reflection: the less reflection the better (the larger the return loss, the smaller the reflection) . The best physically contacting connectors have return losses better than 40 dB, although 20 to 30 dB is more common.

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Causes of connector loss and reflections include core misalignment; differences in the numerical aperture of two fibers; spacing and air gaps; reflections caused by damaged, worn, or loose fiber ends; and the improper use and removal of index matching compounds.

Achieving the best possible connection, where the fiber end faces are flush (no air gap) and properly aligned, is dependent upon two things: 1) the type of connector and 2) using the proper cleaning and connecting techniques. If the connection is lossy or reflective, light will not make a smooth transition. If the transition is not smooth or the connection is not repeatable, measurement data will be less accurate. For this reason, lightwave connections can make a critical difference in optical measurement systems.

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Cleaning and Handling

Proper cleaning and handling of lightwave connectors is imperative for achieving accurate and repeatable measurements with your Hewlett-Packard lightwave equipment. Lightwave interfaces should be cleaned before each measurement using the techniques described in this handbook. Information on protecting and storing your connectors/cables and tips on how to properly mate connectors are also included in this section.

Definition of Terms

To avoid confusion, the following definitions are used in this handbook.

Connector

Houses the fiber end, most open at the end of a lightwave cable or on the front panel of an instrument or accessory.

Adapter

Does not contain optical fiber. Used to mate two optical connectors.

Handling

Always handle lightwave connectors and cable ends with great care. Fiber ends should never be allowed to touch anything except other mating surfaces or cleaning solutions and tools.

CAUTION Hewlett-Packard strongly recommends that index matching compounds NOT be applied to their Instruments and accessories. Some compounds, such as gels, may be difficult to remove and can contain damaging particulates. If you think the use of such compounds is necessary, refer to the compound manufacturer for information on application and cleaning procedures.

Always keep connectors and cable ends covered with a protective cap when they are not in use. (See "Storage.")

Cleaning

Three cleaning processes are provided. The first process describes how to clean non-lensed lightwave connectors. The second process describes how to clean lightwave adapters. The third process describes how to care fa lensed lightwave connections.

CAUTION These cleaning processes apply only when dry connections are used (no Index matching compounds). Hewlett-Packard strongly recommends against the use of index matching compounds, particularly gels, as they may be difficult to remove and can contain damaging particulates. If an index matching compound is used, contact the compound manufacturer for specific information about recommended solvents and cleaning procedures.

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Cleaning Non-Lensed Lightwave Connectors

Equipment

The following is a list of the items that should be used to clean non-lensed lightwave connectors.

Isopropyl alcohol ..... HP part number 8500-5344
Cotton swabs ..... HP part number 8520-0023
Compressed air ..... HP part number 8500-5262

CAUTION Hewlett-Packard recommends that you do not use any type of foam swab to clean optical fiber ends. Foam swabs can leave filmy deposits on fiber ends that can degrade performance.

Process

Before cleaning the fiber end, clean the females and other parts of the connector. Use isopropyl alcohol, clean cotton swabs, and clean compressed air. Then use alcohol to clean the fiber end. Some amount of wiping or mild scrubbing of the fiber end can help remove particles when application of alcohol alone will not remove them. This can be done by applying the alcohol to a cotton swab and moving it back and forth across the fiber end several times. This technique can help remove or displace particles smaller than one micron.

Allow the connector to dry (about a minute) or dry it immediately with clean compressed air. Compressed air lessens the chance of deposits remaining on the fiber end after the alcohol evaporates. It should be blown horizontally across the fiber end. Visually inspect the fiber end for stray cotton fibers. As soon as the connector is dry, the connection should be made.

CAUTION Inverting the compressed air canister while spraying will produce residue on the sprayed surface. Refer to instructions provided on the compressed air canister.

Cleaning Lightwave Adapters

Equipment

All of the items listed above for leaning connectors may be used to clean lightwave adapters. In addition, small foam swabs may be used along with isopropyl alcohol and compressed air to clean the inside of lightwave connector adapters.

NOTE:

As noted in a previous caution statement, the foam swabs can leave filmy deposits. These deposits are very thin however, and the risk of other

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contamination buildup on the inside of adapters greatly outweighs the risk of contamination of foam swab deposits left from cleaning the inside of adapters.

Process

Clean the adapter by applying isopropyl alcohol to the inside of the connector with a foam swab. Allow the adapter to air dry, or dry it immediately with clean compressed air.

Cleaning Lensed Connections

Some instruments may have a connector that is "lensed." in other words: the connection does not provide a physically contacting connection, but the light is received into a lens rather than into a connecting fiber. These receiving lenses usually have an anti-reflective coating that is very easily damaged. Therefore, these connectors should NEVER have cleaning solutions or any other substance applied to them unless it is specifically recommended by the manufacturer. You may wish to use clean compressed air to rid them of dust from time to time.

Storage

All of Hewlett-Packard's lightwave instruments are shipped with either laser shutter caps or dust caps on the lightwave adapters that come with the instrument. Also, all of the cables that are shipped have covers to protect the cable ends from damage or contamination. These dust caps and protective covers should be kept on the equipment at all times except when in use.

The adapters that were shipped on your instrument can be removed from the connectors on the instrument. If you remove these adapters you should keep the exposed connector of your instrument covered until the next use. Protective covers for these exposed connectors are not provided with the instruments, so it is best to keep the adapters on the instrument with the dust covers on.

The list below provides the HP part numbers for the laser shutter cap and dust caps that are provided with lightwave instruments and accessories.

Item	HP Part No.	Connector Option
Laser shutter cap	08145-64521	All options
FC/PC dust cap	08154-44102	Opt O12
Biconic dust cap	08154-44105	Opt 015
DIN dust cap	5040-9364	Opt 013
HMS 10/HP dust cap	5040-9361	Opt 011
ST dust cap	5040-9366	Opt 014

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Making Connections

Proper connection technique require attention to connector compatibility, insertion technique and torque requirements. Connectors must be the same connector type in order to ensure mechanical and optical compatibility. Attempting to connect incompatible connector types may prevent the connection from functioning properly and even cause damage to the fiber surfaces. A visual inspection of the mechanical interfaces may not be enough because some connector types have the same mechanical interface but have different optical fiber interfaces (for example, angled-no-contact, angled-contact or straight-contact fiber interfaces). Refer to the manufacturer's data sheet to confirm connector type compatibility before connecting.

When you insert the ferrule into a connector or adapter, make sure that the fiber end does not touch the outside of the mating connector or adapter. In this way, you will not rub the fiber end against any undesirable surface. Many connectors have a keyed slot provided for optimum measurement repeatability that also helps to align and seat the two connectors. After the ferrule is properly seated inside the other connector, use one hand to keep it straight, rotate it to align the key, and tighten it with the other hand.

Most connectors using springs to push fiber ends together exert one to two pounds of force. Over-tightening or under-tightening these connectors can result in misalignment and nonrepeatable measurements. Always finger tighten the connector in a consistent manner. Refer to the manufacturer's data sheet for any torque recommendations.

Summary

When making measurements with lightwave instruments or accessories, the following precautions will help to insure good, reliable, repeatable measurements:

- confirm connector type compatibility.
- Use extreme care in handling all lightwave cables and connectors.
- Be sure the connector interfaces are clean before making any connections.
- Use the cleaning methods described in this handbook.
- Keep connectors and cable ends covered when not in use.

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Inspection

Visual Inspection

Although it is not necessary, visual inspection of fiber ends can be helpful. Contamination and/or imperfections on the cable endface can be detected as well as cracks or chips in the fiber itself.

Several fiber inspection scopes are on the market, but any microscope with an enlargement range of 100X to 200X can be used. It is helpful to devise some method to hold the fiber in place while viewing in this range.

Inspect the entire endface for contamination, raised metal, or dents in the metal as well as any other imperfections. Inspect the fiber core for cracks and chips.

Visible imperfections not touching the fiber core may not affect the performance of the lightwave connection (unless the imperfections keep the fibers from contacting). Consistent optical measurements are the best assurance that your lightwave connection is performing properly.

Optical Performance Testing

Introduction

Consistent measurements with your lightwave equipment are a good indication that you have good connections. However, you may wish to know the insertion loss and/or return loss of your lightwave cables or accessories. If you test your cables and accessories for insertion loss and return loss upon receipt, and retain the measured data for comparison, you will be able to tell in the future if any degradation has occurred.

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Insertion Loss

Insertion loss can be tested using a number of different test equipment configurations. Some of these are: an HP 8702 or HP 8703 lightwave component analyzer system, an HP 83420 lightwave test set with an HP 8510 network analyzer, an HP 8153 lightwave multimeter with a source and power sensor module. Many other possibilities exist. The basic requirements are an appropriate lightwave source and a compatible lightwave receiver. Refer to the manuals provided with your lightwave test equipment for information on how to perform an insertion loss test.

As mentioned earlier in this handbook, typical insertion loss for cables is less than 1 dB, and can be as little as 0.1 dB. For actual specifications on your particular cable or accessory, refer to the manufacturer.

Return Loss

Return loss can be tested using a number of different test equipment configurations. Some of these are: an HP 8703 lightwave component analyzer; an HP 8702 analyzer with the appropriate source, receiver and lightwave coupler; an HP 8504 precision reflectometer; and an HP 8153 lightwave multimeter with a source and power sensor module in conjunction with a lightwave coupler. Many other possibilities exist. The basic requirements are an appropriate lightwave source, a compatible lightwave receiver, and a compatible lightwave coupler.

Refer to the manuals provided with your lightwave test equipment for information on how to perform a return loss test.

As mentioned earlier in this handbook, typical return loss is better than 20 to 30 dB, and can be better than 40 dB. For actual specifications on your particular cable or accessory, refer to the manufacturer.

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9

Safety and Regulatory Information

This chapter includes required regulatory and safety information that is not included elsewhere in the manual. The first part of this chapter includes regulations and licensing information including the Manufacturer's Declaration of Conformity. The second part of the chapter contains required safety information that is not included elsewhere in the manual.

Regulations and Licensing

United States - FDA Class 1. The HP 8509 Lightwave Polarization Analyzer is rated USFDA (United States Food and Drug Administration) Class 1 Laser Product according to Part 1040, Performance Standards for Light Emitting Products, from the Center for Devices and Radiological Health.

International - IEC Class 1. The HP 8509 is rated as an IEC (International Electrotechnical Commission) Class 1 Laser Product according to IEC 825. Hewlett-Packard designs to the intent of IEC 348.

Canada - The HP 8509 is certified to the Canadian Electrical Code, CAN/CSA-C22.2 No. 231 Series M89.

Notice for Germany: Noise Declaration
LpA < 70 dB
am Arbeitsplatz (operator position)
normaler Betrieb (normal position)
nach DIN 45635 T. 19 (per ISO 7779)

Acoustic Noise Emission/Geraeuschemission	
LpA < 70 dB	LpA < 70 dB
Operator position	am Arbeitsplatz
Normal operation	normaler Betrieb
per ISO 7779	nach DEN 45635 t. 19

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DECLARATION OF CONFORMITY

according to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name:	Hewlett-Packard Company
Manufacturer's Address:	1400 Fountaingrove Parkway Santa Rosa, California 95403 U.S.A.

declares that the product

Product Name:	Lightwave Polarization Analyzer
Model Numbers:	HP 8509A, HP 8509B
Product Options	This declaration covers all options of the above product.

conforms to the following Product Specifications:

Safety:	IEC 348 (1978) IEC 1010 (1990)
EMC:	EN 55011 (1991)/CISPR 11 (1990) Group 1 Class A EN 50082-1 (1991) IEC 801-2 (1991), 4kV CD, 8 kV AD IEC 801-3 (1984), 3V/m (27 - 500 MHz) IEC 801-4 (1988), 500 V signal, 10000 V AC

Santa Rosa	__/__/__	_____
(location)	(date)	John Lamy, Quality Manager

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Safety Information

Environmental Conditions

The HP 8509 may be operated safely if the following environmental conditions are met:

- Indoor use
- Altitude up to 2000 m
- Temperature 5° C to 40° C
- Maximum relative humidity: 80% for temperatures up to 31° C decreasing linearly to 50% RH at 40° C
- Mains supply voltage fluctuations not to exceed ± 10% of the nominal voltage
- Pollution degree 2
- Installation category II

Ventilation Requirements

When installing the instrument in a cabinet, the convection into and out of the instrument must not be restricted. The ambient temperature (outside the cabinet) must be less than the maximum operating temperature of the instrument by 4° C for every 100 Watts dissipated in the cabinet. If the total power dissipated in the cabinet is greater than 800 Watts then forced convection must be used.

Cleaning Instructions

The connectors on the HP 8509 should be cleaned in accordance with the instructions provided in the `Connector Care` chapter in this manual. The cabinet should only be cleaned using a damp cloth.

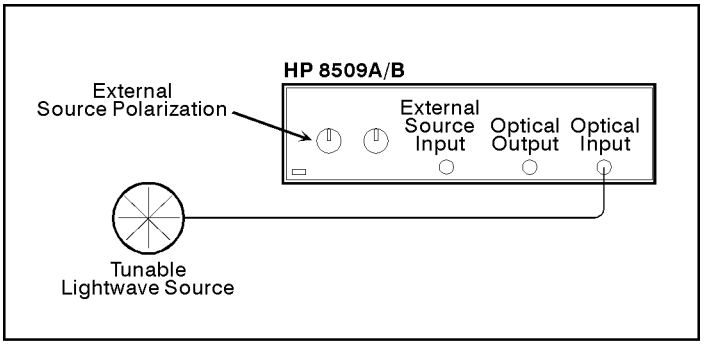
Instrument Conforms

The 8509B complies with the following product specifications:

LASER SOURCE 21 CFR 1040.10 and 1040.11

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Laser Aperture Location



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Figure 9-1. Laser Aperture Location

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10

Programming

This chapter is an introduction to programming the HP 8509 polarization analyzer over HP-IB (Hewlett-Packard Interface Bus) and over the DDE (dynamic data exchange). Its purpose is to provide concise information about the operation of the instrument under remote control. Some background information on the HP-IB and DDE is provided. A tutorial introduction using elementary programming examples illustrates the basics of HP 8509 remote control. The document also provides a command reference with a brief description of each HP-IB/DDE command recognized by the HP 8509. Examples are provided on two disks that are included with the *HP 8509 Users/Reference Guide.* The programs on these two disks illustrate the exact executable syntax, but the code is not explained in great detail. See the README.TXT files on each disk for more information.

- Example Programs Disk - DOS Format, IBASIC and VISUAL BASIC/DDE example.
- Example Programs Disk - LIF Format, HP BASIC example for an HP 9000 series 200/300 controller.

The main focus of this chapter is on HP-IB control of the HP 8509 polarization analyzer through an external PC controller running IBASIC for Windows. Most of the commands in the command reference (section 8) are available using Microsoft Windows DDE, as well as HP-IB. The material presented in this chapter is not intended to teach programming or to discuss HP-IB or DDE theory except at an introductory level. Related information can be found in the following references:

- Information concerning HP Instrument BASIC for Windows is available in *Installing and Using HP Instrument BASIC for Windows* (HP part no. E2200-90000).
- Information on HP Instrument BASIC is available in the *HP Instrument BASIC User's Handbook* (HP part no. E2083-90000).
- Information on using the HP-IB is available in the *Tutorial Description of the Hewlett-Packard Interface Bus* (HP literature no. 5952-0156).
- Microsoft documentation of DDE.

Additional information about the HP 8509 measurement procedures can be found in the following references:

- *HP 8509 User's/Reference Guide* (HP part no. 08509-90010).

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Starting Up the System For HP-IB Control

The HP 8509 can be remotely controlled from HP-IB according to the setup illustrated in Figure 10-1 and the procedures described below:

1. Power up the HP 8509 system according to the instructions provided in the *Installation and Quick Start Guide* document (HP part no. 08509-90002).
2. Connect an HP-IB cable from the HP-IB board of the system controller PC to the HP 8509 Vectra HP-IB board connector. The board connector is in the back of the HP 8509 Vectra.
3. Start up the HP 8509 application by double-clicking on the HP 8509 icon in the HP 8509 instrument window.
4. Start the HPIB2DDE application by double-clicking on the HPIB2DDE

   icon in the HP 8509 window. The HP 8509 window is within the Program Manager window. If the Program Manager window is obscured by the HP 8509 instrument window, merely double-click anywhere outside the existing windows. This will bring up a window called the Task List. Double-click on the Program Manager entry to bring its window to the front of the screen. The HP 8509 window should become visible. The HPIB2DDE icon resides within the HP 8509 window. Once the HPIB2DDE application has been started, if desired, the HPIB2DDE window can be minimized by clicking on the down arrow in the top right-hand corner of this window.
5. Begin sending HP-IB Commands from the controlling external PC.

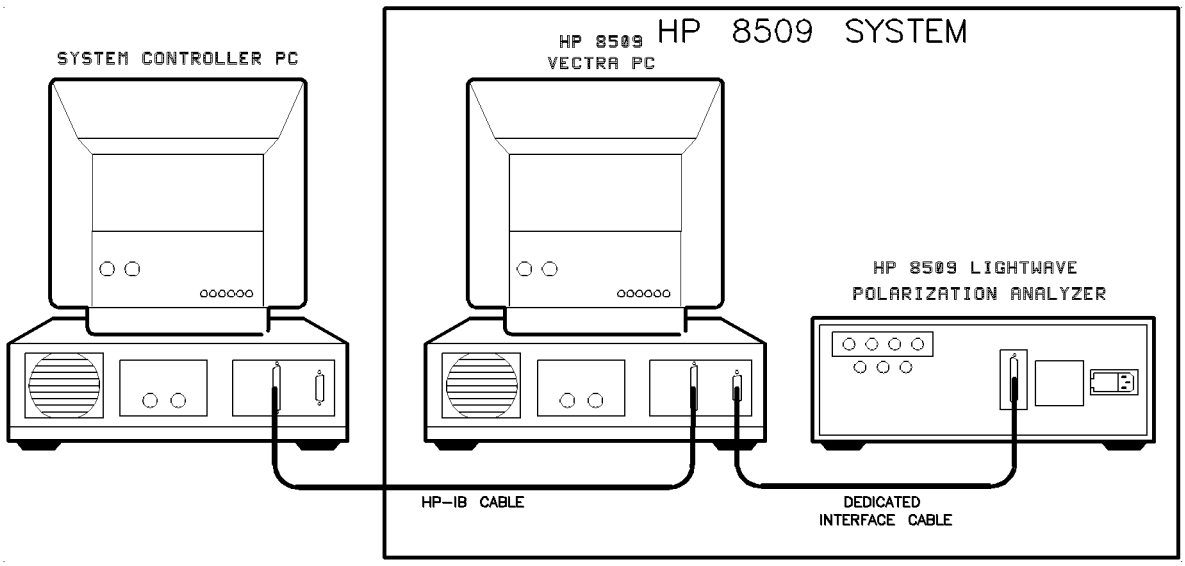


Figure 10-1. HP-IB Setup

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HP-IB Overview

HP-IB (the Hewlett-Packard Interface Bus) is a high-performance bus that allows individual instruments and computers to be combined into integrated test systems. The bus and its associated interface operations are defined by the IEEE 488.1 standard. The IEEE 488.1 standard defines the interface capabilities of instruments and controllers in a measurement system, including some frequently used commands.

HP-IB cables provide the physical link between devices on the bus. There are eight data lines on each cable that are used to send data from one device to another. Devices that send data over these lines are called **Talkers**. **Listeners** are devices that receive data over the same lines. There are also five control lines on each cable that are used to manage traffic on the data lines and control other interface operations. **Controllers** are devices that use these control lines to specify the talker and listener in a data exchange.

When an HP-IB system contains more than one device with controller capabilities, only one of the devices is allowed to control data exchanges at any given time. The device currently controlling data exchanges is called the **Active Controller**. Also, only one of the controller-capable devices can be designated as the system controller. The HP 8509 can function as a talker, a listener, or a controller at different times.

HP-IB addresses provide a way to identify devices on the bus. The active controller uses HP-IB addresses to specify which device talks and which device listens during a data exchange. This means that each device's address must be unique. A device's address is set on the device itself, using either a front-panel key sequence or a rear-panel switch. The factory default address for the HP 8509 is 29.

Bus Structure

Data Bus

The data bus consists of eight lines that are used to transfer data from one device to another. Programming commands and data sent on these lines is typically encoded in the ASCII format, although binary encoding is often used to speed up the transfer of large arrays. Only ASCII format is available to the HP 8509. In addition, every byte transferred over HP-IB undergoes a **handshake** to ensure valid data.

Handshake Lines

A three-line handshake scheme coordinates the transfer of data between talkers and listeners. This technique forces data transfers to occur at the speed of the slowest device, and ensures data integrity in multiple listener transfers. With most computing controllers and instruments, the handshake is performed automatically, which makes it transparent to the programmer.

Control Lines

The data bus also has five control lines that the controller uses both to send bus commands and to address devices. The HP 8509 makes explicit use of the EOI line through the HP-IB END statement used to terminate all command transmissions. A brief description of the five HP-IB control lines is provided below.

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IFC Interface Clear. Only the system controller uses this line. When this line is true (low) all devices (addressed or not) unaddress and go to an idle state.

ATN Attention. The active controller uses this line to define whether the information on the data bus is a **command** or is **data**. When this line is true (low) the bus is in the

command mode and the data lines carry bus commands. When this line is false (high) the bus is in the data mode and the data lines carry device-dependent instructions or data.

SRQ Service Request. This line is set true (low) when a device requests service; the active controller services the requesting device.

REN Remote enable. Only the system controller uses this line. When this line is set true (low) the bus is in the remote mode and devices are addressed either to listen or talk. When the bus is in remote and a device is addressed, it receives instructions from HP-IB rather than from its front panel. When this line is set false (high) the bus and all devices return to local operation.

EOI End or Identify. This line is used by a talker to indicate the last data byte in a multiple byte transmission, or by an active controller to initiate a parallel poll sequence. The analyzer recognizes the EOI line as a terminator and it pulls the EOI line with the last byte of a message output (data, markers, plots, prints, error messages).

Sending Commands

Commands are sent over the HP-IB via a controller's language system, such as IBASIC, QuickBasic or C. The keywords used by a controller to send HP-IB commands vary among systems. When determining the correct keywords to use, keep in mind that there are two different kinds of HP-IB commands:

- Bus management commands, which control the HP-IB interface.
- Device commands, which control analyzer functions.

Language systems usually deal differently with these two kinds of HP-IB commands. For example, for most HP instrumentation, HP BASIC can use a unique keyword to send each bus management command, but always uses the keyword OUTPUT to send device commands. It must be noted, however, that for the HP 8509, all commands must be sent using the OUTPUT statement.

The following example shows how to send a typical device command in IBASIC:

```
OUTPUT 729; "POINCARE:CLEAR" END
```

This sends the command within the quotes (POINCARE:CLEAR) to the HP-IB device at address 729. If the device is an HP 8509, the command instructs the analyzer to clear all measured traces from the Poincare sphere.

ADDITIONAL INFORMATION
The HP-IB card select code is 7 and the HP-IB address is 29. The select code is set by adjusting switches on the HP-IB card inside the computer.

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HP-IB For the HP 8509

The HP 8509 system can be described as a Windows application, running on a Vectra PC, which controls an external instrument containing the system hardware. The system hardware consists of all devices required by the HP 8509 software to conduct polarization measurements. Remote control of the HP 8509 system is achieved through direct communication with the system's Windows application software. Use an external controller for remote control of the HP 8509.

Given that the HP 8509 software is a Windows application, Dynamic Data Exchange (DDE) can be used to communicate with and control the HP 8509 system. DDE is a "standard" communication technique which is provided by a majority of Windows applications. In effect, in order to remotely communicate via HP-IB with the HP 8509 system, HP-IB messages must be translated to DDE messages. Under these conditions, the HP-IB interface is seen as a Windows application directly communicating with the HP 8509 system software.

A second Windows application called HPIB2DDE provides the translation between HP-IB commands and the DDE messages for the HP 8509 software. The HPIB2DDE program is accessible within the HP 8509 system window. In order to run HPIB2DDE, an HP-IB interface board must be installed on the HP 8509 system Vectra PC and configured for running under Microsoft Windows. The external PC controller running Windows IBASIC must also have an HP-IB interface board configured for running under Microsoft Windows. The controller PC can send HP-IB messages directly to the HP 8509 system and to other HP-IB controllable instruments. The current version of HPIB2DDE assumes, as a default, that the HP-IB select code of the HP 8509 system is 7 and that the HP-IB board address is set to 29. Figure 10-3 demonstrates a typical system configuration.

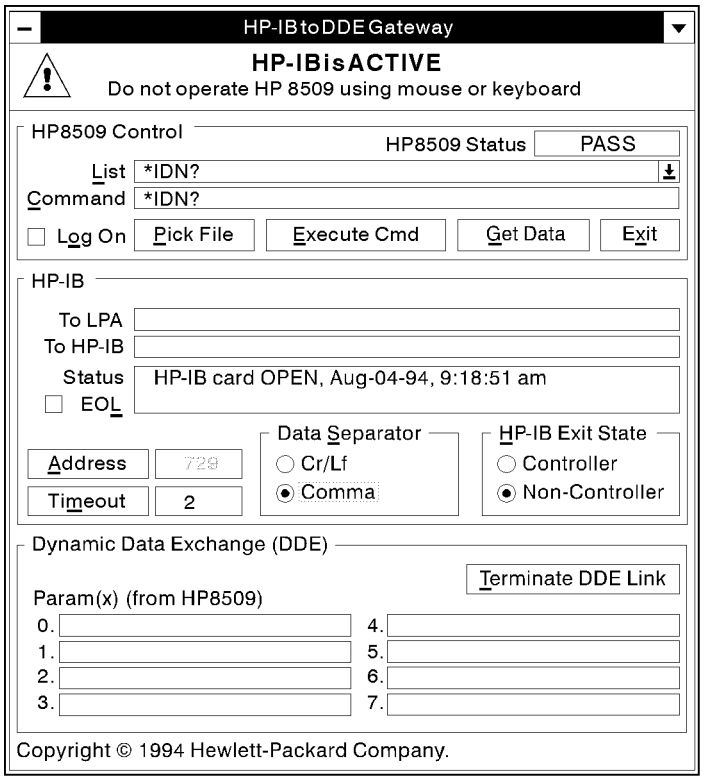
Warning **When receiving HP-IB commands, the HP 8509 does not lock out manual operation. Take care not to disrupt remote control through manual command execution. Furthermore, HP-IB commands which lock out manual operations are not currently available for remote control of the HP 8509. When beginning remote operation of the HP 8509, be sure to quit, then restart the application if there has been any manual operation of the HP 8509 during the current session of the HP 8509 application.**

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HP-IB to DDE Interface

The HP 8509B Lightwave Polarization Analyzer uses Dynamic Data Exchange (DDE) for remote operation. The HPIB2DDE.EXE application connects the DDE system to the HP-IB bus. Therefore, it is required to run this application before attempting remote operation of the HP 8509B using HP-IB. To start the HPIB2DDE.EXE application, select the `HPIB TO DDE GATEWAY` icon in the HP 8509 Group.

There are three basic parts to this window, the 'HP 8509 Control' frame, the 'HP-IB' frame, and the 'Dynamic Data Exchange (DDE)' frame. The HPIB2DDE.EXE application window appears as below when the application starts. The 'HP-IB to DDE Gateway' is a floating window when the program starts. This means that the window will always appear on top of any other window. To defeat this feature, minimize the window by clicking once on the down arrow in the top right corner. When the application is restored by double clicking on its icon, the window will no longer float.



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Figure 10-2. HP-IB to DDE Gateway

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'Command Line' Setup Options

The HP-IB gateway program may be configured using command line parameters at runtime. Two command line parameters are available and may be added to the HP-IB gateway icon's properties. This selection can be found by highlighting the icon by clicking once on it, then selecting "File | Properties" in the Windows Program Manager. Add the command line parameter after the name of the program in the 'Command Line' text box.

/Errors Only

Add this command line parameter to configure the HP-IB gateway to record *only* HP-IB bus errors, DDE link errors, Windows critical errors, and HP8509 commands which did not return a status of PASS, when 'Log On' is checked. If this parameter is not specified, all bus transactions, including errors, are recorded in the log file. During program execution this feature may be turned on and off by clicking the right mouse button on the 'Log On' check box.

/HP8509=<Name of executable>

The Windows DDE system uses the name of the executable file to establish a DDE link to the HP8509 program. Future versions of the HP8509 may use a different name to establish this link. This command line parameter is useful only if your HP8509 software is updated to a version greater than version 2.0. If this parameter is not used, the <Name of executable> used is HP8509_2.

/HP8509TimeOut=<Number of Minutes>

This parameter specifies the number of minutes the 'HP-IB to DDE Gateway' program should wait for data from the HP8509 when the HP- IB controller requests data (sends a query). If this parameter is not specified, the default value used is 1 minute. If the HP8509 takes longer than the specified time to return data to the HP-IB controller, the 'HP-IB to DDE Gateway' will reset the DDE channel in an attempt to clear the problem, and record the attempt in the log file (if open) as a DDE timeout error. The 'HP-IB to DDE Gateway' will reset itself in this manner ten times. After ten attempts, the 'HP-IB to DDE Gateway' program will issue a critical error and HP-IB operation will stop until the user acknowledges the critical error issued by the 'HP-IB to DDE Gateway.'

Note This timeout occurs only when the HP-IB controller requests data. The 'HP-IB to DDE Gateway' queues all commands from the HP-IB bus a synchronous to HP8509 operation. The programmer should hard code appropriate delays in the controlling program after sending HP8509 commands that take more than 30 seconds (or 1/2 the timeout limit) to complete. Remember – commands may still be in the 'HP-IB to DDE Gateway' command queue when the controlling program requests data. The execution time to complete the commands still in the queue may exceed the timeout limit.

HP 8509 Control Frame

The elements in this frame provide a path for the development of HP-IB remote programs. With the HPIB to DDE Gateway, you can send HP-IB commands, retrieve data, and save bus

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traffic to a file for later analysis. The elements of the HP 8509 Control Window are described below.

`HP 8509 Status`

Shows the status of the current DDE operation. Valid choices are:

PASS: the remote command successfully completed.

FAIL: the remote command failed and did not complete.

PROBLEMS: the remote command experienced a problem during execution.

UNKNOWN: the remote command was not recognized.

BUSY: the remote command is in the process of execution.

NO DDE LINK: the DDE link is not established.

`List`

This is a list of all the DDE commands. This list drops down to select a command for the **Command** text box. This list box is loaded by reading in the file "DDE_CMD.TXT" located in the application directory.

`Command`

This text box is used to specify a command to send via DDE to the HP 8509 application. During normal operation of the HP-IB to DDE Gateway, the individual commands that are being transmitted to the HP 8509 also appear in this text box.

Log On

When checked, HP-IB bus transactions are recorded to the file selected with Pick File, and the Pick File button is disabled. The /ErrorsOnly feature may be turned on and off by clicking the right mouse button on the 'Log On' check box.

Pick File

Selects a file for logging HP-IB bus transactions. This button is disabled when Log On is selected. This filename is saved in the file C:\Windows\WIN.INI under the heading [HPIB2DDE] and is restored the next time the HPIB2DDE application is started.

Execute Cmd

Sends the command in the **Command** text box via DDE to the HP 8509 application.

Get Data

Retrieves data via DDE from the HP 8509 application. The data is linked to the text boxes found in the Dynamic Data Exchange (DDE) window.

Exit

Closes the HPIB2DDE gateway application.

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HP-IB Frame

This frame provides you with an interface to the HP-IB bus parameters. The elements of the HP-IB window are described below.

`To LPA`

Shows the user the command being sent to the HP 8509 that was received on the HP-IB bus.

`To HP-IB`

Shows the user the data being sent to the HP-IB bus that was read from the HP 8509.

`Status`

Shows the HP-IB card status and the time and date of any error. HP-IB bus errors, DDE errors, and Windows system errors are also logged to a file when [Log On] is selected.

[EOL]

Select this box if every HP-IB bus action is to end with a line feed. This setting is saved in the file C:\WINDOWS\WIN.INI under the heading [HPIB2DDE] and is restored to this setting the next time the HPIB2DDE application is started.

[Address]

Put the address of the HP 8509 here. To change the address, select [Terminate DDE Link] to enable [Address]. Change the HP 8509 device address then select [Initiate DDE Link] to re-enable the HP-IB bus and the DDE link.

This setting is saved in the file C:\WINDOWS\WIN.INI under the heading [HPIB2DDE] and is restored to this setting the next time the HPIB2DDE application is started.

ADDITIONAL INFORMATION
[Terminate DDE Link] and [Initiate DDE Link] are toggle selections.

[Timeout]

Allows you to set the HP-IB timeout. This setting is saved in the file C:\WINDOWS\WIN.INI under the heading [HPIB2DDE] and is restored to this setting the next time the HPIB2DDE application is started.

Data Separator

This setting is saved in the file C:\WINDOWS\WIN.INI under the heading [HPIB2DDE] and is restored to this setting the next time the HPIB2DDE application is started.

Cr/Lf. Sets the data separator to carriage return/line feed delimited.

Comma. Sets the data separator to comma delimited.

HP-IB Exit State. Allows you to set the HP-IB card to Controller or Non-Controller when the program exits. This setting is saved in the file C:\WINDOWS\WIN.INI under the heading [HPIB2DDE] and is restored the next time the HPIB2DDE application is started.

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Controller. Some applications may require that the HP-IB card in the HP 8509 is set to Controller when the HP 8509 itself is not being controlled by the HP-IB bus. Other systems may require that the HP-IB card never becomes a controller while on the HP-IB bus.

Non-Controller. The HP-IB card is Non-Controller while the HPIB to DDE gateway application is running.

Dynamic Data Exchange (DDE) Frame

This frame is used to display data that is being transmitted via DDE to the HPIB to DDE Gateway application. The elements of this frame are described below.

Param(x) (from HP 8509)

Used to establish a DDE link for data from the HP 8509 and the HPIB2DDE.EXE application.

Terminate DDE Link / Initiate DDE Link

Used to connect or disconnect the HP-IB bus to the DDE. When the DDE link is established (selection shows Terminate DDE Link), the HP-IB card is opened and DDE transactions can take place. When there is no DDE link (selection shows Initiate DDE Link), the HP 8509 Status selection show "NO DDE LINK" in yellow and the HP-IB card is closed and the device address may be changed. Clicking the right mouse button on this command button while in 'Terminate Link' mode will cause only the HP-IB bus to close, and allow the HP-IB gateway to be used for a DDE client, without interference from the HP-IB bus.

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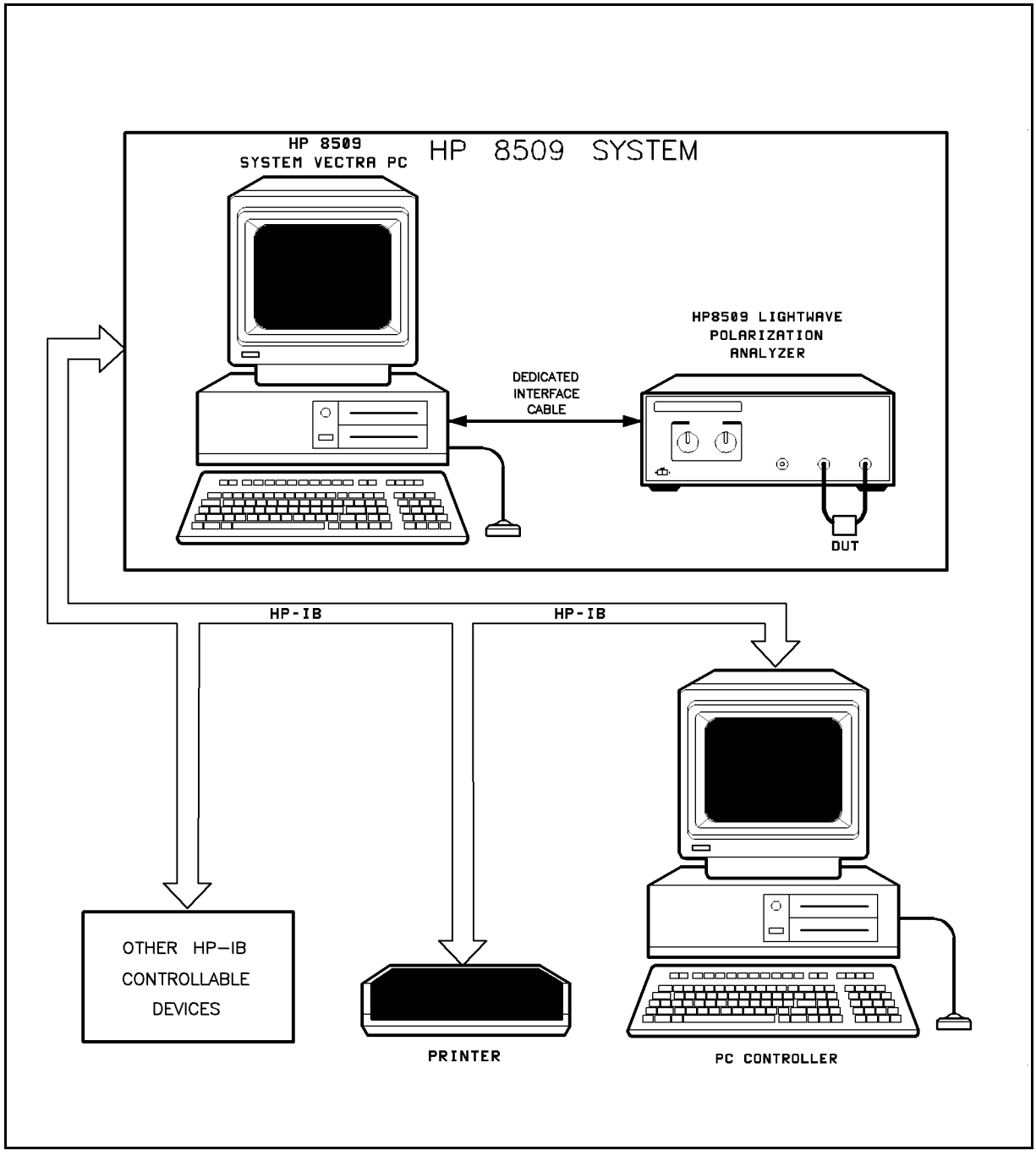


Figure 10-3. HP-IB Connections In a Typical Setup

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Given the translation mode under which HP-IB control is achieved for the HP 8509 system, certain constraints exist dictated by the HPIB2DDE application. The constraints are relative to the full set of capabilities provided by the HP-IB interface (see references). The constraints are listed below.

- Data is transmitted and received as ASCII strings. In other words, only formatted data transfers are possible.
- EOI is used to indicate the completion of data transmission. The EOI can be set by using an HP-IB **END** statement to

  terminate the sending of a command.
- EOL (default <cr><lf>) is NOT used by default. This can be

  toggled from the HPIB2DDE application window and will stay at the last setting. EOL should be toggled "on" for HP-IB control

  through an external PC controller running IBASIC for Windows. EOL stands for End Of Line and refers to a string which defines the end of a command line when an OUTPUT statement is sent. The HP-IB END statement serves as the line terminator.
- Use only ENTER/OUTPUT (formatted data transfers).
- Set the timeout to at least five seconds to give the PC time to recognize and respond to HP-IB activity. The HPIB2DDE is polling the HP-IB card and needs time to see the request.

It is important to note that the HP 8509 utilizes only a subset of the HP-IB bus capabilities. Only two HP-IB bus management commands are supported by the current HP 8509 system. These are *OPC? and *IDN?. Other bus management commands, commonly supported by Hewlett-Packard instrumentation, are not available for the remote control of the HP 8509.

When receiving HP-IB commands, the HP 8509 does not lock out manual operation. The user must take care not to disrupt remote control through manual command execution. Furthermore, HP-IB commands which lock out manual operations are not currently available for remote control of the HP 8509. When beginning remote operation of the HP 8509, quit, then restart the application if there has been any manual operation of the HP 8509 during the current session of the HP 8509 application.

A second alternative for remote control of the HP 8509, other than using an external PC controller, is to use an HP 9000 series 200/300 controller running HP BASIC Version 5.0 or later. The platform is the same as that shown in Figure 10-3, except that the PC controller is replaced by an HP 9000 series 200/300 controller. The HP 8509 system can be thought of as just another instrument on the HP-IB bus.

IBASIC syntax is fully compatible with HP BASIC syntax. In effect, the same syntax can be used to create both IBASIC and HP BASIC programs. However, the user should be aware that IBASIC and HP BASIC file formats differ. IBASIC files are usually created in DOS text format, while HP BASIC files are created in LIF format. In effect, a program created in IBASIC will not directly run under HP BASIC though the same syntax can be utilized under HP BASIC to create a program with identical functionality. Utilities exist under the UNIX operating system to translate DOS formatted files to LIF format and vice versa.

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Basic Instrument Control

A computer controls the HP 8509 by sending it commands over HP-IB. The commands sent are specific to the HP 8509. Each command is executed automatically upon receipt. During remote control, the analyzer is receptive to manual control. The user must take care not to disrupt remote operations. Most commands are equivalent to front panel functions. For example, after preparing the system for HP-IB control, type:

```
OUTPUT 729; "POINCARE:CLEAR" END
```

on the alpha command line and execute by clicking the RUN button on the IBASIC control pad.

The Poincare sphere on the HP 8509 display is now cleared from all measurement traces and measurement continues at the current state of polarization. The construction of the command is:

`OUTPUT 729;`	*The BASIC data output statement. The data is directed to interface 7 (HP-IB), and on out to the device address 29 (the HP 8509).*
`"POINCARE:CLEAR" END`	*The HP 8509 mnemonic for clearing the Poincare sphere. The mnemonic, less the quotation marks, is sent literally by the OUTPUT statement, followed by the terminating END statement.*

The **POINCARE:CLEAR** command performs the same function as selecting the DISPLAY menu and within that menu selecting the **CLEAR SPHERE** option. As can be noted, the command mnemonic **CLEAR** is derived from the menu option for equivalent manual control. Most of the HP 8509 HP-IB commands, where possible, are derived from the equivalent menu option label. Otherwise, they are derived from the common name for the function.

As can be noted from the example above, the HP 8509 command syntax is in the form of COMMAND:P1:P2:P3: ... where P1:P2:P3 ... are the parameters pertaining to the command and the number of parameters depends on the function performed by the command. If, for example, the function of the command is to perform a type of measurement, the number of required parameters will vary with measurement process complexity. Please refer to the HP 8509 Command Reference section of this document or to the Remote Access files in the HP 8509 instrument window for specific command information.

The **END** following the **CLEAR** terminates the command inside the HP 8509 (EOI set true) and prepares the HP 8509 for the next command. If there is a syntax error in the command, the HP 8509 will ignore the command and look for the next terminator. When it is found, incoming commands process normally. Characters between the syntax error and the next terminator are lost.

The **OUTPUT 729;** statement will transmit one item at a time when a terminating **END** is used. It will transmit literal information enclosed in quotes, numeric variables, and string variables. Without the **END**, a carriage return, line feed is transmitted after each item. This is suppressed by terminating the command with an **END** statement.

Setting a display state is just one form of command the HP 8509 will accept. It will also accept commands that require specific, user defined operands. For example, execute:

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```
OUTPUT 729; "SETMARKER:1:0:1:0:A" END
```

In response, the HP 8509 will place marker A at the Poincare sphere location corresponding to the Stokes parameters S_0=1, s_1=0, s_2=1, and s_3=0. This corresponds to full 45 degree linear polarization. The HP 8509 will also accept commands that turn various functions on and off. Execute:

```
OUTPUT 729; "POINCARE:HOLD:ON" END
```

This causes the HP 8509 to freeze the Poincare sphere display at the current measurement trace. To initiate continuous measurement, execute:

```
OUTPUT 729; "POINCARE:HOLD:OFF" END
```

As can be noted, the command is **POINCARE**. The accompanying parameters are the **HOLD** function and the function indicator of **ON** or **OFF**.

The HP 8509 does not distinguish between upper and lower case letters. For example, execute:

```
OUTPUT 729; "poincare:hold:on" END
```

Some of the HP 8509 HP-IB commands deal with data storage and retrieval using the HP 8509 system Vectra PC memory. For example, execute:

```
OUTPUT 729; "DRIVE:C" END
```

This sets drive C in the HP 8509 system Vectra PC as the location for all data storage. Some commands directly store information into the designated drive. For example, execute:

```
OUTPUT 729; "SAVE:CONFIG:SYSTEM.CFG" END
```

This causes the current system state or configuration to be saved into the file **SYSTEM.CFG**. The file is created in the HP8509 directory of the drive, (usually drive C) known as the working directory. This directory is specified by the program manager in the "File/Properties" menu. The default working directory is the directory where HP 8509 software is installed. The file can be saved in another directory if an appropriate DOS format directory path is specified. A saved system state can later be recalled by executing:

```
OUTPUT 729; "LOAD:CONFIG:\HP8509\SYSTEM.CFG" END
```

Through this command, a user determined instrument state can be achieved. Note that the appropriate path to the configuration file must be specified. Refer to the "Command Reference" section of this document for command specific information.

Data Requesting Commands

Some of the HP-IB commands request data from the HP 8509. This data is returned as an ASCII string or as a series of ASCII strings separated by commas. It can be accessed by following the data-request command with an **ENTER** remote command. An example is given below:

```
OUTPUT 729; "JONES:MEASURE" END
OUTPUT 729; "JONES?" END
ENTER 729; String$
```

The device command **JONES:MEASURE** directs the HP 8509 to conduct a Jones matrix measurement of an inserted DUT. The results are requested through the **JONES?** command.

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The data is transferred through the **ENTER** remote command and placed in a string variable named **String$**.

There are two types of HP-IB commands which request data from the HP 8509 system. Some commands, such as **JONES:MEASURE**, cause a measurement to be conducted by the HP 8509 while others request information regarding a particular instrument state. As an example of the second type execute:

```
OUTPUT 729; "DRIVE?" END
ENTER 729; String$
```

The command **DRIVE?** causes the HP 8509 system to return the letter of the drive which is currently set up for data transfers. This letter is read from the HP 8509 into the string variable named **String$.**

The IBASIC statement **ENTER** addresses the HP 8509 to talk. This allows the HP 8509 to transmit information to the controller PC. Specifically, the **ENTER** statement takes the stream of binary data output by the HP 8509 and reformats it back into an ASCII string through the HPIB2DDE application. The controller PC places the data transmitted by the HP 8509 into the string variable listed in the **ENTER** statement. The string variable dimensions must match the data the HP 8509 has to transmit. If the variable is not sufficiently large, data is lost.

Operation Complete

Occasionally there is a need to find out when certain operations have completed inside the HP 8509. For instance, a program should not have the operator connect the DUT while the HP 8509 is still measuring the measurement thrupath.

To provide such information, the HP 8509 has an Operation Complete reporting mechanism that will indicate when certain key commands have completed operation. The mechanism is activated by sending ***OPC?** immediately after an OPC'able command. The HP 8509 will output a 1 when the command completes execution. The ***OPC?** command should occur in the same output statement as the command being OPC'd.

As an example, when ready for remote control, type in the following program:

```
10    OUTPUT 729; "JONES:ABSOLUTE" END     Set up for an absolute measurement.

20    OUTPUT 729;                          Conduct the thrupath calibration and OPC the
      "JONES:CALIBRATE;*OPC?" END           thrupath calibration measurement.

40    DISP "Measuring"

50    ENTER 729; String$                   The program will halt at this point until the HP
                                            8509 completes the measurement and issues a 1.

60    DISP "DONE"

70    END
```

This program causes the controller PC to display the **Measuring** message for about 3 seconds while the instrument executes a thrupath calibration in preparation for an absolute Jones matrix measurement. The controller PC will display **DONE** just as the instrument completes

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the measurement procedure. When the **DONE** message appears, the program could then continue on, being assured that there is a valid thrupath calibration in memory.

ADDITIONAL INFORMATION
Some operations on the HP 8509 may take more time than the HP-IB bus provides for a timeout. Therefore, when you send ***OPC?**, either execute a delay before **ENTER**, or trap the HP-IB timeout error using **ON TIMEOUT** ... in the IBASIC program to allow for this delay.

Preparing For HP-IB Control

At the beginning of a program, the HP 8509 has to be taken from an unknown state and brought under computer control. One way to do this is with an abort/clear sequence. **ABORT 7** is used to halt bus activity and return control to the computer. **CLEAR 729** will then prepare the HP 8509 to receive commands by clearing syntax errors, the input command buffer, and any messages waiting to be output.

The abort/clear sequence makes the HP 8509 ready to receive HP-IB commands. The next step is to put the HP 8509 into a known state. The easiest way to do this is to send **LOAD:CONFIG:PRESET**, which returns the instrument to the preset state.

The user can specify different configuration parameters and then save them by sending **SEND:CONFIG:<"filename">**.

To load the user specified configuration parameters send **LOAD:CONFIG:<"filename">**. For syntax, see Chapter 8, Remote Command Reference.

Running the following program brings the HP 8509 to a known state, ready to respond to HP-IB control.

```
10      ABORT 7                                  This halts all bus action and gives active control
                                                 to the computer.

20      CLEAR 729                                This clears all HP-IB errors, resets the HP-IB
                                                 interface, and clears syntax errors.

30      OUTPUT 729; "LOAD:CONFIG: PRESET"        Preset the instrument. This resets all
        END                                      instrument window menu settings.

40      END
```


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Interacting with the HP 8509A/B Through the DDE

This chapter focuses on using Microsoft Visual BASIC for Windows (VB) to create a custom application for programmed control of the HP 8509 to directly and continuously exchange data with other Windows-based applications that support the Dynamic Data Exchange (DDE). DDE data exchanges are called "conversations". DDE conversations are started by establishing DDE links. Applications using DDE to converse with the HP 8509 for automatic control can be custom programs using a computer language such as 'C' or Visual BASIC for Windows. They can also be applications such as Microsoft Excel, that allow users to interface to the DDE system.

Establishing DDE Links

The HP8509 allows other applications to establish DDE links to text-based controls called 'labels' in the HP8509 firmware. To establish a DDE link an application must know three things about the item it wants to link to:

- The name of the application it wants to talk to.
- The subject of the conversation, called a topic.
- The name of the item with which the DDE conversation should take place.

Since the name of the HP 8509 application may change with future updates of the firmware, you should provide a mechanism for the HP 8509 application to change without requiring the program to be re-compiled. Following is a VB code fragment that allows you to specify the HP 8509 application name as a command line parameter to his program. The command line parameter may be specified in the Windows Program Manager properties dialog, accessed in the menu File|Properties. Place the parameter after the name of the program in the Command entry.

```
' Use this code fragment to get the name of the HP8509
' application at run time. The command line parameter
' that this code fragment looks for is:
'  /HP8509=<Name of HP8509 Program>
' If parameter not present, use the default name.
' Use the variable Hp8509DdeName$ when establishing DDE links.
```


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```
Const HP8509_DDE_DEFNAME$ = "HP8509_2" ' Get the name of the HP8509 Application
   UCaseCmd$ = Trim$(UCase(Command$))
   i% = InStr(UCaseCmd$, "/HP8509=")
   If i% = 0 Then
       Hp8509DdeName$ = HP8509_DDE_DEFNAME$
   Else
       i% = i% + 8
       j% = InStr(i%, UCaseCmd$, " ")
       If j% = 0 Then j% = Len(UCaseCmd$) + 1
       Hp8509DdeName$ = Mid$(UCaseCmd$, i%, j% - i%)
   End If
```

The HP8509 uses nine link items. One item is used to convey DDE status information. The name of this DDE link item is: Status. Eight items are used to send data to the application via DDE. The name of these DDE link items are:

- Param(0)
- Param(1)
- Param(2)
- Param(3)
- Param(4)
- Param(5)
- Param(6)
- Param(7)

The DDE link items are specified in VB with the LinkItem property. The DDE Application and the DDE topic are combined in VB, separated by the pipe character (|), and is called the LinkTopic property. The DDE link topic of the HP8509 is "lpadde", so combined with the application name, the VB LinkTopic property is "HP8509_2|lpadde".

Microsoft Windows uses 3 types of DDE links for DDE conversations.

- **Automatic**: The source supplies data to the application every time the data defined by the LinkItem changes. This link is also commonly called a HOT Link.
- **Manual**: The source supplies data only when the destination requires it. This link is also commonly called a COLD Link.
- **Notify**: The source notifies the destination when the data changes, but supplies data only when the destination requests it.

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For the HP 8509, use Automatic links for the DDE link item **Status** and Manual links for the DDE link items **Param(x)**. A VB Code fragment that establishes a DDE link to the HP 8509 from a users application follows.

```
' This code fragment establishes a DDE link to the
' HP 8509 application from the labels
'  lblParam(0) to lblParam(7), and lblStatus
' in the user's application.

On Error GoTo Err_cmdLink_click

' Establish a new link with the HP 8509
For i% = 0 To 7
   ' Remove any existing link first
   lblParam(i%).LinkMode = LINK_NONE
   DoEvents ' Free Windows to allow it to do the Link
   lblParam(i%).LinkTopic = Hp8509DdeName$ & "|lpadde"
   lblParam(i%).LinkItem = "Param(" & Format(i%) & ")"
   lblParam(i%).LinkMode = LINK_MANUAL
   DoEvents ' Free Windows to allow it to do the Link
Next i%

lblStatus.LinkMode = LINK_NONE
DoEvents ' Free Windows to allow it to do the Link
lblStatus.LinkTopic = Hp8509DdeName$ & "|lpadde"
lblStatus.LinkItem = "Status"
lblStatus.LinkMode = LINK_AUTOMATIC
DoEvents ' Free Windows to allow it to do the Link

' Use to be sure that HP8509 data buffers are clear
lblStatus.LinkExecute "ClearParams"
DoEvents ' Free Windows to allow it to do the Link
Exit Sub

Err_cmdLink_click:
   Select Case Err
   Case 200 To 299
      MsgBox "Failed to Link to HP8509", 0, "DDE Link Error"
   Case Else
      ' Other error handler here
   End Select
   Exit Sub
```


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Sending HP 8509 Commands via DDE

To send commands to the HP 8509 using DDE use the LinkExecute method in VB. Be sure that a previous DDE conversation is complete before sending the DDE command. The following VB code fragment illustrates how to send the DDE command "Poincare:Center:A" once the DDE Links have been established. The "ClearParams" command is sent as a precaution to clear out the HP 8509 data buffers (Param(x) labels). It is required that these buffers are empty before any commands are sent to the HP 8509. Generally the data buffer is empty unless a previous command prepared a response by the HP 8509. If you are not sure if the buffers were previously cleared, clear them before sending a command.

```
Do While lblStatus.Caption = "BUSY"
   DoEvents
Loop

' Use to be sure that HP 8509 data buffers are clear
lblStatus.LinkExecute "ClearParams"

lblStatus.LinkExecute "Poincare:Center:A"
DoEvents ' Free Windows to allow it to do the LinkExecute
```


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Retrieving HP 8509 Data via DDE

To retrieve HP 8509 data, use the VB LinkRequest method. The HP 8509 places data in the Param(x) labels. Use LinkRequest with the controls which are linked to the Param(x) labels in the HP 8509. Be sure that there are no pending DDE conversations before attempting to get the data, otherwise all the data may not be present. Also, clear the data buffers (Param(x) labels) in the HP 8509 after getting the data. The following VB code fragment illustrates how to get data from the HP 8509 via DDE.

```
Do While lblStatus.Caption = "BUSY"
   DoEvents
Loop

For i% = 0 To 7
   lblParam(i%).LinkRequest
   DoEvents ' Free Windows to allow it to do the Link
   ' Since data is sequential, once there is an
   ' empty label we're done.
   If lblParam(i%).Caption = "" Then Exit For
Next i%

' Required to do after getting the HP8509 data
frmHpib.lblStatus.LinkExecute "ClearParams"
```

Measurement Programming

Earlier sections of this document outlined how to get commands into the HP 8509. The next step is to organize the commands into a measurement sequence. A typical measurement sequence consists of the following steps:

1. Zero the instrument.
2. Calibrate the instrument.
3. Set up the instrument.
4. Connect the device.
5. Take data.
6. Transfer data.

The actions within each step in the measurement sequence depend upon the type of measurement conducted. The instrument should be zeroed prior to starting a measurement sequence. Zeroing can be done remotely by sending the `ZERO` command.

For accurate measurements, it is important that the receiver is not detecting any power while the zeroing routine is being performed.

1. If you have an HP 8509A you will be prompted to "Block the external laser." To do this, cover the OPTICAL INPUT connector with a connector cap or a piece of dark paper.
2. If you have an HP 8509B, you will *not* be prompted to, but you *must* either cover the OPTICAL INPUT connector as in step 1, above, *or* turn off your external source. If the external source is connected to the HP 8509B External Source input, its power will be blocked automatically so that no power will emerge from the Optical Output connector during the zeroing operation.

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While the zeroing routine is running, a green “zero” message will appear inside the power display in the upper left corner of the HP 8509 basic measurement screen, and the mouse pointer appears as an hourglass. When the “zero” message disappears, and the mouse pointer changes back to an arrow, the zeroing routine is finished.

Calibrate the Instrument

A wavelength calibration can be automatically performed on the HP 8509, if desired. This can be done remotely by sending the **CAL:CALIBRATE** and **CAL:ON** commands. It should not be necessary to perform more than one instrument calibration per day or even one per week, depending on room temperature changes and the accuracy required. If in doubt, a calibration should be performed. For more information on instrument calibration please refer to the HP 8509 *User's/Reference Guide*.

Set Up the Instrument

All pertinent measurement parameters must be set. Set the type of source (internal/external, wavelength) and set for internal or external polarizers. The number of steps in the set up procedure depends on the type of measurement to be conducted. Some of the measurements require a thrupath measurement calibration and/or application of a two-point or three-point reference frame prior to the execution of the DUT measurement. One of the measurements, polarization mode dispersion, requires setting parameters such as the start and stop wavelengths, the number of steps, and the step wavelength separation.

Connect the Device

Have the operator connect and adjust the device under test (DUT). All adjustments take place at this stage so that there is no danger of taking data from the device while it is being adjusted.

Take Data

With the device connected and adjusted, conduct the desired measurement. The process of taking data is different depending upon the type of measurement that is conducted. For the majority of measurements, the taking of data is automatically performed. Certain measurements, however, such as PMD under manual mode, require a high degree of operator interaction.

When taking data, the operator must ensure proper synchronization. This can be done by using the *OPC? command.

Transfer Data

Lastly, read the results out of the instrument. The data output command is designed to ensure that the data transmitted reflects the current state of the instrument. The data, as previously discussed, can be read from the instrument using the **ENTER** remote command. All measured data is returned by the HP 8509 system as a sequence of comma-separated strings. The operator must take care to reformat or parse this data if so desired.

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Remote Command Reference

None of the commands are case dependent. Commands may be sent in upper case, lower case, or mixed case. Any item not enclosed in angle brackets (`<,>`) must be considered a literal command.

Most of the commands in this chapter are available using Microsoft Windows DDE, as well as HP-IB. Any restrictions to the use of a command are noted in the chapter for that command.

When receiving HP-IB commands, the HP 8509 does not lock out manual operation. Do not disrupt remote control through manual command execution. Furthermore, HP-IB commands which lock out manual operations are not currently available for remote control of the HP 8509. When you begin remote operation of the HP 8509, quit, then restart the application if there has been any manual operation of the HP 8509 during the current session of the HP 8509 application.

Table 10-1. Conventions

: colon	Command Separator	Separates parameters. A parameter must be supplied to the right of every colon.
? question	Query	The command causes the instrument to prepare a response. No further commands may be sent until the response is retrieved.
{} braces	Mandatory Selection	Select one of the options in the braces as a parameter. If braces indicate option is part of a parameter, select option and append it to the parameter.
[] brackets	Optional Selection	Similar to Mandatory Selection except that selecting a parameter is optional.
| pipe	Selection Separator	Separates mandatory selection and optional selection parameters. Spaces may be added in this document for clarity.
<> angle brackets	Described parameter	A description of the parameter. Supply a parameter corresponding to the description in the brackets.
<"filename">		The filename of the file to save or load. The path, if specified, should exist, or an error will occur. If the path is not specified the default path will be used. The default path for any filename is the windows working directory. This is usually the same as the HP8509 application directory, but can be changed in the Windows Program Manager by highlighting the HP8509 icon and selecting `File | Properties`. If the current drive is changed using the `Drive:<Drive Spec>` command, then the default directory is the default directory of the current drive. The filename must be enclosed in double quotes (") if it includes any colons (:), otherwise the double quotes are optional.

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Table 10-1. Conventions (continued)

<“title”>		The title to use for a Save/Load operation with the HP8509 database. A maximum of 80 characters can be used for the `<"title">`. Use only printable characters in the range of ASCII 32 (space) and ASCII 126 (˜ tilde) for titles. Trailing spaces are ignored, leading spaces are not ignored. The title must be enclosed in double quotes (") if it includes any colons (:), otherwise the double quotes are optional.
<“serial number”>		The serial number of the device under test for the measurement being saved. Used for a Save operation with the HP 8509 database. This field is optional. If it is not provided, this entry in the database is left blank. A maximum of 25 characters can be used for the serial number. Use only printable characters in the range of ASCII 32 (space) and ASCII 126 (˜ tilde). Trailing spaces are ignored, leading spaces are not ignored. The serial number must be enclosed in double quotes (“) if it includes any colons(:), otherwise the double quotes are optional.”
<“date code”>		The date code of the device under test for this measurement being saved. used for a Save operation with the HP 8509 database. This field is optional. If it is not provided, this entry in the database is left blank. A maximum of 16 characters can be used for the date code. use only printable characters in the range of ASCII 32 (space) and ASCII 126 (˜ tilde). Trailing spaces are ignored, leading spaces are not ignored. The date code must be enclosed in double quotes (") if it includes any colons (:), otherwise the double quotes are optional.

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Abbreviations / Definitions

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analyzer window	The first window to open when the HP 8509A/B lightwave polarization analyzer software starts.
DDE	Dynamic Data Exchange. A mechanism Microsoft Windows uses for applications to communicate with each other. HP 8509A/B supports DDE links as documented in the HP 8509A/B manual.
DGD	Differential Group Delay. Differential propagation time of polarization modes. Usually expressed in units of time.
frame	A boxed-in region within a window, usually with a title, that contains user interface elements such as option buttons, command buttons, text boxes, etc.
JME	Jones Matrix Eigenanalysis. Mathematical technique used to calculate optical parameters such as DGD.
LPA	Lightwave Polarization Analyzer. The HP 8509A/B is an LPA.
Not Recommended	The particular command is supported in this version. However, it may not be supported in future versions of the HP 8509A/B.
OSS	Optical Source Setup- The window used to adjust the optical source (laser) parameters.
PDL	Polarization Dependent Loss. The loss (or gain) variation of an optical signal due to polarization.
PMD	Polarization Mode Dispersion. Average DGD over wavelength range.
string	A series of characters. The codes for string characters range from 0 to 128 and are the same as those defined by the ASCII character set. Only the printable characters, codes 32 to 126, are used in HP-IB bus communications for messages. Codes 13, 10 (`<CR><LF>`) are often used for EOL (end of line) (see HP-IB configuration and setup information).
TLS	Tunable Laser Source. HP 8167/8 are tunable laser sources.
VTUNE	Tunable Laser Source controlled by analog voltage output VOUT A of the HP 8509A/B. Using a VTUNE source prevents the use of the analog outputs for any other purpose.
WS	Wavelength-Scanning. A method used to determine the polarization mode dispersion of an optical system by examining cyclical characteristics of the output polarization (using the normalized Stokes parameters) over a wavelength range.

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Changes from Version 1.2 Software

Every effort has been made to assure the compatibility of version 2.0 remote commands with version 1.2 remote commands. In some instances this has not been possible due to fundamental changes in the design of the HP 8509 software. Please note the changes below and change your existing programs to accommodate the changes, if necessary.

`*OPC[?]`

On some fast controllers, the windows operating system may not release system resources fast enough to acknowledge an `*OPC?` that is sent in a separate bus transaction. In general, it is a good idea to limit the number of HP-IB bus transactions by grouping the HP 8509 commands together, separated by a semicolon. Four thousand (4,000) characters may be sent in one HP-IB bus transaction to the HP 8509. It is recommended to send `*OPC?` to the HP 8509 as part of the same HP-IB bus transaction as the command that is being `*OPC`'d.

`Cal:Calibrate`

This command will always return "PASS" when used with DDE. After this command is issued, either from HP-IB or DDE, the HP 8509 system will be occupied performing the calibration. No other activity on the HP 8509 Vectra PC will take place until the calibration completes. The command `*OPC[?]` has no effect, since the HP 8509 system will not respond to any commands while a calibration is in progress. The `Cal:Calibrate` command takes about 25 seconds on a Vectra 486/66. The programmer should hard code a delay in the program which controls the HP 8509, after issuing this command. After the delay, issue the `Status?` command to determine if the `Cal:Calibrate` command was successful.

`Disper:Close`

In version 1.2 this command caused the PMD window to close. In version 2.0 there can be many PMD child windows open, all within a main "Multiple Document Interface" (MDI) parent window. This command will close only the first PMD:JME child window which was opened. The MDI parent window, which holds all of the PMD child windows, will close automatically after the last PMD child window is closed.

`Source? Source:External? Source:Internal?`

Version 1.2 of the HP 8509 had only one set of settings to control a TLS, so when querying the TLS, the returned value was the setting of the TLS for the HP 8509 instrument. This is not true for version 2.0 of the HP 8509 software. In version 2.0 each PMD window and the analyzer window each have their own set of TLS settings. When using the above `Source: ...` commands, be aware that the TLS settings returned are for the ANALYZER WINDOW ONLY. Version 2.0 provides other commands to query the TLS settings for the PMD windows.

Note: When *setting* the TLS parameters using the `Source:External:<Wavelength nm>,Source:External:{Off|On},` and `Source:Internal:{Off|1310|1550}` commands, all windows' TLS settings are changed. This conforms to version 1.2 operation.

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Common Commands

`*IDN?`

Returns a string that uniquely identifies the analyzer. The string is in the form:

`<Manufacturer>,<Model Number>,<Serial Number>,<Firmware Version>` for example:

`"HEWLETT-PACKARD,HP 8509B,3206A00156,2.10"`

HP-IB Operation Only

`*OPC[?]`

Operation complete. The query will return an ASCII "1" when all pending overlapped operations have been completed. The command is used to ensure the completion of a particular function as requested by a prior command. Append this command to the command being OPC'd, separated with a semicolon.

Device Specific Commands

`Analog?`

Returns `Off`, `Raw`, or `Stokes` depending on the setting of the analog outputs (see `Analog:{ Off | Raw | Stokes }`).

`Analog:Done`

Closes the `Analog` frame in the analyzer window.

`Analog:{ Off | Raw | Stokes } [?]`

Selects and turns on or off the output of the four BNC connectors on the rear panel of the HP8509. If "stokes" is sent, the output of the four BNC connectors will be four voltages proportional to the Stokes parameters S0, s1, s2 and s3. When raw is sent, the four voltages will be proportional to the currents induced on the four photodiodes of the HP8509 receiver. The voltages are always in the range of −10 to 10 volts. When "off" is sent, the four BNC outputs will be turned off. Please refer to the HP 8509 User's/Reference Guide for more in depth information. The query returns "1" if the particular control is selected in the `Analog` frame of the analyzer window, and "0" if not selected.

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`Angles:{ AB? | AC? | BC? }`

Returns the angle between the specified markers, its cosine, and the cosine squared of half the angle. The largest angle measurable is 180 degrees or PI radians. The angles and appropriate markers must be turned on in order to obtain the desired angle. (See `Angles:{ Off | On }`)

`Angles:{ Degrees | Radians }[?]`

Sets the units of the displayed angles to either radians or degrees. The query returns `"1"` if the condition is true, `"0"` otherwise. (See `Angles:{ Off | On }`.)

`Angles:Done`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Angles:Off`

Closes the `Marker Angles` frame in the analyzer window.

`Angles:{ Off | On }`

Displays the angles between markers A and B, markers A and C, and markers B and C. The measured angles are displayed in the `Marker Angles` frame in the analyzer window. The angles are measured from the Poincare sphere coordinate location of the markers. The markers must be turned on in order to obtain the measured angles.

`Average:Display:{ Off | On }`

Turns on or off the moving average of a measurement trace on the Poincare sphere display.

`Average:Display{ ? | :<NumPoints> }`

Specifies the number of points `<NumPoints>` to be used in the moving average of the Poincare sphere display. The query returns the number of points set in the `Averaging` frame of the analyzer window and the state of the display averaging; `"0"` if off, `"1"` if on.

`Average:Done`

Closes the `Averaging` frame in the analyzer window.

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`Average:Measure{ ? | :<NumPoints> }`

The number of points (NumPoints) to be averaged, at each measurement point, when conducting any measurement. This number may be set using `<NumPoints>`, or queried using `?`.

`Cal?`

Returns the status of the Calibration apply option buttons; "0" means Calibration is Off, "1" means Calibration is On.

`Cal:Calibrate`

Performs an instrument calibration which optimizes the measurement performance of the analyzer. The calibration is performed at the current user-defined source wavelength. Refer to the HP 8509A/B User's/Reference Guide for more in-depth information on the instrument calibration capabilities of the HP 8509A/B.

`Cal:{ Done | Save }`

The `Done` parameter terminates the instrument calibration sequence. The `calibration` window is removed from the screen. The `Save` parameter saves in memory, an instrument calibration performed at a given source wavelength. The source wavelength is specified through the source command. All saved calibrations can be accessed when the `Cal:On` command is sent.

`Cal:Delete:<Wavelength nm>`

Deletes from memory the instrument calibration performed at the specified source wavelength.

`Cal:List?`

Returns a list, in the form of a comma-separated string, of the wavelengths for which calibrations have been performed. The wavelengths are given in nanometers.

`Cal:{ Off | On }`

The `Off` and `On` parameters enable or disable the instrument calibration corrections. When enabling a calibration, the instrument will search for a saved instrument calibration performed at the current source wavelength. If a calibration is not present, then calibration corrections cannot be enabled.

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`ClearParams`

Used to clear the DDE parameters in the LPA after data is retrieved. A DDE LinkPoke can also be used to clear the parameter boxes. DDE Parameters should always be cleared after data is retrieved so that another query isn't confused by residual data that was previously left behind. The HP-IB gateway automatically sends this DDE command after retrieving data.

DDE only.

`DBase:Close`

Closes the currently opened database file.

`DBase:Compact`

Compacts the currently opened database file.

`DBase:Filename?`

Returns the name of the currently opened database file.

`DBase:Open:<"filename">`

Opens the database file specified in <"filename">.

`DBase:Repair`

Repairs the currently opened database file.

`Disper`

Displays the `PMD:JME` window on the HP 8509B instrument display. Be sure to send 'Disper' before sending any other 'Disper: ... ' commands.

HP 8509B only.

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`Disper?`

Upon command execution, the analyzer returns the current wavelength, the measured dispersion at the current wavelength, and the average of the measured dispersion up to and including the current wavelength. The command can be used under manual mode to check the status of a running measurement process. The data is returned as a comma separated ASCII string in the following format:

`<Wavelength(nm)>, <Current Dispersion>, <Average Dispersion>`

The units for the returned dispersion data are selected with `Disper:Units:`. The default units are ps.

HP 8509B only.

`Disper:ActiveWindow?`

Upon command execution, the analyzer returns the comma separated data from the currently active `PMD:JME` window. The number of data points is returned in `Param(0)`. The wavelengths are returned in `Param(1)`. The polarization mode dispersion delay is returned in `Param(2)`. The units for the returned dispersion data are selected with `Disper:Units:`. The default units are ps.

HP 8509B only.

`Disper:Atten{ ? | :<dBm value> }`

The attenuation for the HP-IB tunable laser source. The query returns the attenuation in dBm. Using `<dBm value>` sets the attenuation for an HP-IB tunable laser source.

HP 8509B only.

DDE Only.

`Disper:Calibrate`

Clears any current thrupath calibration and begins a new PMD:JME calibration sequence at the current wavelength setting. This command is used when the command `Disper:Cascade` has been sent to specify that a thrupath calibration is required prior to the PMD:JME measurement of a given device under test. Once the PMD:JME controls have been accessed, the `Disper:Calibrate` command must be sent before any `Disper:Measure` commands can be sent.

HP 8509B only.

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`Disper:{ Cascade | Single }[?]`

Sets the polarization mode dispersion measurement (PMD) process for measuring a single device under test or for the measuring of a device under test included in a chain of devices under test. The `Cascade` parameter is used to de-embed the effects of components inserted along the measurement path of the desired device under test. If `Cascade` is set, a thrupath calibration must first be conducted at each measurement wavelength. Once the thru calibration process is completed, the PMD measurement process can be executed. The query returns an ASCII `1` if the specified setting (single or cascade) is being used in the PMD measurement and a `0` if it is not.

HP 8509B only.

`Disper:Chain[?]`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate commands:

`Disper:Cascade` and `Disper:Cascade?`

HP 8509B only.

`Disper:Clear`

Aborts a PMD:JME measurement process. This command is valid only if the optical source is set to manual. The command does not erase the current thrupath calibration corrections.

HP 8509B only.

`Disper:Close`

Closes the PMD:JME measurement window. The PMD:JME measurement process is ended. The original version 1.0 command closed the PMD:JME window. In version 2.0 the PMD:JME window is a child of the `HP8509 Graphs` window. The HP 8509 Graphs window closes when the last graph is closed.

`Disper:DBase:Load:<"title">`

Loads a measurement from the current database using the specified title.

HP 8509B only.

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`Disper:DBase:Save:<"title"> [ :<"date code"> [ :<"serial number"> ]]`

Saves a measurement to the current database using the specified title.

HP 8509B only.

`Disper:Done`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Disper:Close`

`Disper:FiberLen{ ? | :<km> }`

The length of optical fiber used to normalize PMD:JME measurements. The query returns the length of the fiber. Using the parameter `<km>` sets the length of optical fiber.

HP 8509B only.

`Disper:FindMinPoints[:<Num Samples>]`

Activates the PMD:JME feature that automatically determines the minimum number of points required to prevent aliasing in the specified wavelength range. PMD:JME measurements are activated with this feature. The only tunable laser sources supported with this feature are HP-IB HP 8167/8 and VTune tunable laser sources. HP 8509B control of the HP-IB bus is available only using DDE. Therefore, this feature will not work for the HP 8167/8 tunable laser sources when using the HP-IB bus for remote operation of the HP 8509B. Only the VTune tunable laser source can be used with HP-IB. The `<Num Samples>` value specifies the number of sections of the Poincare sphere the test for aliasing. The default value for `<Num Samples>` is `4` if no value is specified.

HP 8509B only.

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`Disper:HPIB[?]`

Sets the tunable laser source for a PMD:JME measurement to an HP-IB tunable laser source. The HP 8509B looks for a tunable laser source at the address specified with `TLS:Address` and uses it if it is either an HP 8167 or HP 8168 tunable laser source. Be sure that the wavelength range is set correctly for the connected HP-IB tunable laser source before issuing this command. To change tunable laser source selections between HP 8167 and HP 8168:

1. Issue the command `Disper:Manual`
2. Change the wavelength range using `Disper:WLen:`
3. Change the HP-IB address using `TLS:Address:<HP-IB Address>`
4. Issue the command `Disper:HPIB`

The query returns an ASCII "1" if the PMD:JME next measurement process will be in HP-IB mode and a "0" if it will not be in this mode. Also returns the name of the current laser source.

HP 8509B only.

DDE only.

`Disper:Manual`

Places the polarization mode dispersion measurement in manual control mode. When the instrument is under manual control, the user must set the external source to the appropriate wavelength for each wavelength step between the start and stop wavelengths. In manual control mode, you must send the command 'Disper:Measure' once to begin the measurement process and once for each wavelength point as returned by the command 'Disper:WLen:Points?'.

HP 8509B only.

`Disper:Manual?`

Returns an ASCII "1" if the PMD:JME next measurement process will be in manual mode and a "0" if it will not be in this mode. Also returns the name of the current laser source.

HP 8509B only.

`Disper:Measure`

Triggers a PMD:JME measurement at the current source wavelength setting.

HP 8509B only.

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`Disper:NewThruCal`

Not Recommended This command is ignored. It is provided for compatibility with old code. Command will not be available in future versions. Plan your programming to use the alternate commands:

`Disper:Calibrate`

HP 8509B only.

`Disper:Power?`

Returns the power and the power units for the tunable laser source.

HP 8509B only.

DDE Only.

`Disper:Power:{ dBm | uWatt }[:<value>]`

Sets the units for the tunable laser source. If the `<value>` parameter is specified, the power setting can also be changed. If the power setting is not valid for the TLS, the command fails.

Note: When changing only the units, the numerical value of the power does not change. Be sure to change the value of the power to correspond to the new units.

HP 8509B only.

DDE Only.

`Disper:Restart`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Disper:Clear`

HP 8509B only.

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`Disper:Save:<"filename">`

Saves a polarization mode dispersion measurement trace into the file `<"filename">`. The trace is saved as a series of ASCII strings separated by commas. The saved trace information is in the form of:

wavelength_1 (nm), wavelength_2 (nm), dispersion

wavelength_2 (nm), wavelength_3 (nm), dispersion

...

...

...

wavelength_n-1 (nm), wavelength_n (nm), dispersion

The above is for the dispersion measurement at "n" user defined wavelengths. The units for the dispersion measurement are selected using the `Disper:Units:` command. The default units are ps. For path information on "filename", see "Command Syntax" at the beginning of this chapter.

HP 8509B only.

`Disper:Settle:{ Point | Start }{ ? | :<Delay msec>}`

The settling time to wait, either initially (`Start`) or per point (`Point`), after setting a tunable laser source to the desired wavelength in the sweep range during a PMD:JME measurement. The query returns the current value.

See also: `WaveScan:Settle:{ Point | Start }{ ? | :<Millisec's> }`

HP 8509B only.

`Disper:Start`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Disper:Measure`

HP 8509B only.

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`Disper:Trace:<"filename">`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Disper:Save:<"filename">`

HP 8509B only.

`Disper:Units{ ? | :ps | :ps/L | :ps/sqrtL | :fs | :fs/L | :fs/sqrtL }`

Sets the units to use in PMD:JME measurements. The query returns the units of measure for PMD:JME.

HP 8509B only.

`Disper:VTune[?]`

Sets the `Optical Source Setup` source selection to VTune in order to control a VTUNE tunable laser source.

The query returns an ASCII "1" if the PMD:JME next measurement process will be in VTUNE mode and a "0" if it will not be in this mode. Also returns the name of the current laser source.

HP 8509B only.

`Disper:VTune:{ Start | Stop }{ ? | :<Voltage> }`

The VTUNE start or stop voltage. The query returns the voltage value, the parameter `<Voltage>` sets the value.

HP 8509B only.

`Disper:WLen?`

Returns the next wavelength (in nm) at which the PMD:JME measurement will be conducted. This command is typically used only when the tunable laser source is "Manually Tuned."

HP 8509B only.

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`Disper:WLen:Points{ ? | :<NumPoints> }`

Sets the number of points between the start and stop wavelengths for the polarization mode dispersion (PMD) measurement. Each point corresponds to a wavelength for PMD measurement. If the number of points does not correlate with the delta value and the start and stop wavelengths, the delta value is reset to accommodate the number of points according to:

$$\text{WlenDelta} = (\text{WlenStop} - \text{WlenStart}) / (\text{WlenPoints} - 1)$$

The query returns the number of points specified in the current PMD:WS measurement settings.

HP 8509B only.

`Disper:WLen:{ Start | Stop | Delta }{ ? | :<Wavelength nm>}`

Specifies the Start, Stop, or Delta wavelengths for the PMD:JME measurement. Changing any of these values causes the number of points in the `Optical Source Setup` window to change according to:

$$\text{WlenPoints} = ((\text{WlenStop} - \text{WlenStart}) / \text{WlenDelta}) + 1$$

The query returns the value of the setting in nanometers. Using the `<Wavelength nm>` parameter sets the value.

Note: The `Start` and `Stop` values can never have the same value. For example, when segmenting a wavelength range over several measurements and sweeping from low to high, always issue the command `Disper:WLen:Stop` before the command `Disper:WLen:Start` when specifying the next wavelength segment. This will prevent the `Start` and `Stop` values from being equal when switching from one segment to the next.

HP 8509B only.

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`Disper:WLen:Steps{ ? | :<NumPoints> }`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Disper:WLen:Points{ ? | :<NumPoints>}`

Sets the number of steps between the start and stop wavelengths for the polarization mode dispersion (PMD) measurement. Each step corresponds to two adjacent wavelengths for PMD measurements. If the number of steps does not correlate with the delta value and the start and stop wavelengths, the delta value is reset to accommodate the number of steps according to:

WlenDelta = (WlenStop − WlenStart) / WlenSteps

The query returns the number of steps specified in the current PMD:WS measurement settings.

Note: The value returned/set by `Disper:WLen:Points` is one more than the value returned/set by `Disper:WLen:Steps`. `Steps` are transitions between the `Points`.

HP 8509B only.

`Display:Angles:{ Off | On }`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Angles:{ Off | On }`

`Display:Angles:{ Degrees | Radians }`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Angles:{ Degrees | Radians}`

Sets the displayed angles to degrees or radians (see `DISPLAY:ANGLES: { ON,OFF }`).

`Display:Power:{ Linear | Log }`

The lightwave power measurement can be displayed either in log format (dBm) or linear format (uW). The setting can be changed through this command.

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`Display:Update{ ? | :<NumPoints> }`

The number of points plotted to the Poincare sphere between updates of the other displays, power, DOP, and Stokes. A large number of points plotted to the Poincare sphere will slow down updates of the other displays. A small number of points plotted to the Poincare sphere will slow down the plotting on the Poincare sphere. This number may be set using `<NumPoints>`, or queried using `'?'`.

`Drive?`

Returns the letter of the drive currently set up for HP-IB initiated data storage.

`Drive:<MS-DOS Drive Spec>`

Sets the specified drive for HP-IB initiated data transfers. Drive C is the HP 8509A/B system default drive. If using drive C, all saved data files using HP-IB will be placed in the HP 8509A/B directory unless a specific directory path is specified for the file. If another drive, such as A or B, is designated, all files will be saved to the root directory unless an alternate path is specified.

`GetFile:<"filename">`

This command will, via HP-IB, transfer an ASCII data file from the HP 8509A/B system Vectra PC to the external controller. The file is transferred as an ASCII string. An `ENTER` HP-IB command must be used to access the file from the HP 8509A/B Vectra PC. The file must be placed into a large enough string variable. Otherwise, data will be lost. In the `HPIB2DDE` window, the user can specify whether the string separator is a comma or a carriage return/linefeed. The user should specify the format which coincides with the string variable specified in the `ENTER` HP-IB command statement. For path information on `"filename"`, see "Command Syntax" at the beginning of this chapter.

HP-IB Operation only.

`GetMarker:{ A | B | C }`

Not Recommended. See `GetMarker?:{ A | B | C }`.

`GetMarker?:{ A | B | C }`

Places the specified marker at the current state of polarization and returns the results S_0, s_1, s_2, s_3. S_0 is the power in milliwatts, and s_1, s_2, s_3 are the normalized Stokes parameters which serve as coordinates on the Poincare sphere.

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`Jones?`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:{ JonesData? | PdlData?}`

HP 8509B only.

`Jones:{ Absolute | Relative }[?]`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:{ Absolute | Relative}[?]`

HP 8509B only.

`Jones:Calibrate[A | B | C]`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:Calibrate[A | B |C]`

HP 8509B only.

`Jones:Clear`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:Clear`

HP 8509B only.

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```
Jones:Done
```

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

```
PolDep:Done
```

HP 8509B only.

```
Jones:{ External | Internal }[?]
```

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

```
PolDep:{ External | Internal}[?]
```

HP 8509B only.

```
Jones:{ MagRadians | MagDegrees | RealImag }[?]
```

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

```
PolDep:{ MagRadians | MagDegrees | RealImag}[?]
```

HP 8509B only.

```
Jones:Measure[A | B | C]
```

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

```
PolDep:Measure[A | B | C]
```

HP 8509B only.

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`Jones:NewThruCal`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:NewThruCal`

HP 8509B only.

`Jones:ReStart`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:Clear`

HP 8509B only.

`Load:Config:Preset`

Loads the factory default configuration for the LPA.

`Load:Config:<"filename">`

Loads the user created configuration file `<"filename">`. For compatibility with previous versions, the search path for `"filename"` is:

1. The windows working directory.
2. The HP 8509A/B application directory.
3. The Windows directory (usually C:\WINDOWS).

For path information on `"filename"`, see "Command Syntax" at the beginning of this chapter.

`Load:Single:<"filename">`

Loads a timed measurement from the file `<"filename">`.

For path information on `"filename"`, see "Command Syntax" at the beginning of this chapter.

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`OperVer[?]`

Opens the `Operation Verification` window. The query returns the results of the operation verification procedure in the following format:

`<Result of OperVer>,<Max DOP%>,<Mean DOP%>,<Min DOP%>,<Angle AB>,<Angle AC>`

where `<Result of OperVer>` is `"1"` if success, `"0"` if fail.

`OperVer:{ Start | Cancel | Done }`

Opens the `Operation Verification` window, if not already open, and activates the specified command button.

`PdlMaxMin[?]`

Shows the `PDL:Max-Min` window on the HP 8509A/B screen. The query returns the `PDL:Max-Min` data as follows:

`Dbm Max, s1 Max, s2 Max, s3 Max, Dbm Min, s1 Min, s2 Min, s3 Min`

`PdlMaxMin:{ Max | Min }`

Centers the Poincare Sphere on the Max or Min point

`PdlMaxMin:Delta?`

Returns the Max-Min power in dBm

`PdlMaxMin:{ Reset | Clear | Done }`

Activates the appropriate button on the `PDL:Max-Min` window

`Poincare:Center:{ Stokes | A | B | C }`

If the parameters `A`, `B`, or `C` are sent; upon command execution, the Poincare sphere is rotated so that the specified marker is at the center of the Poincare sphere display. The marker must first be set before the command is executed. If the parameter `Stokes` is sent, the Poincare sphere is rotated so that the current state of polarization is at the center of the Poincare sphere display.

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`Poincare:Clear`

Clears all visible measurement traces on the Poincare sphere. After clear, measurement continues at the current state of polarization.

`Poincare:Hold:{ Off | On }`

Toggles `Hold` on or off. When toggled, on the Poincare sphere display is held at the current measurement state. When toggled off, continuous measurement is initiated.

`Poincare:Marker:{ A | B | C }`

Places the specified marker at the currently measured state of polarization as shown on the Poincare sphere. The specified marker is turned on and the marker measurement is displayed on the HP 8509A/B instrument window. The marker measurement is in terms of the normalized Stokes parameters S_0, s_1, s_2, s_3.

`Poincare:Marker:Clear`

Clears all measurement markers from the Poincare sphere and turns them off.

`Polarizer:{ A | B | C | None } [?]`

When using internal polarizers, the command inserts the specified polarizer at the source output. The query returns `1` if the particular polarizer is inserted, `0` if not.

`Polarizer:Angle{ A | B | C }{ ? | :<Degree Value> }`

The `<Degree Value>` parameter sets the angle for the specified external polarizer. The user must be careful to enter the correct angles. Each polarizer will pertain to a marker as defined by the user. The query returns the value of the specified internal or external polarizer, depending on the setting. Note: Using `<Degree Value>` is valid only when the polarizers are `External` as the internal polarizers are fixed. This command will execute when the polarizers are in internal mode, but the angles specified will not be used in calculations until the polarizers are put in external mode using `Polarizer:External`. See also: Polarizer:{ External | Internal }

HP 8509B only.

`Polarizer:Done`

Closes the `Polarizers` frame in the analyzer window.

HP 8509B only.

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`Polarizer:{ External | Internal }`

Sets up the analyzer for the use of internal or external polarizers. When using internal polarizers, the specified polarizer is automatically inserted. When set to external polarizers, the appropriate polarizer must be inserted by the user when so required.

HP 8509B only.

`PolDep?`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:{ JonesData? | PolDepData? }`

`PolDep:{ Absolute | Relative }[?]`

Specifies the type of polarization dependent loss (PDL) measurement. An absolute measurement requires a thrupath calibration prior to the PDL measurement. A relative measurement does not require a thrupath calibration. The query returns `"1"` if the condition is true, `"0"` otherwise.

PolDep:Absolute is HP 8509B only.

`PolDep:Calibrate[A | B | C]`

The command is used for an absolute polarization dependent loss (PDL) measurement. Triggers a measurement-thrupath calibration. If a PDL calibration was previously performed, execute `PolDep:NewThruCal` before `PolDep:Calibrate`. Otherwise the calibration constants will NOT be updated. When optional selections `A`, `B`, or `C` are used, external polarizers are assumed to be used. The user must insert the appropriate polarizer and send a command for each polarizer. The polarizer angles pertaining to each of the three markers (a, b, and c) must be specified using the polarizer command. (See `Polarizer:Angle{ A | B | C }:<Degree value>`.) The `PolDep:NewThruCal` and the `PolDep:Calibrate[A | B | C]` commands are valid only for absolute measurements, that is, when the transmission measurement is either Delta, Max, or Min.

HP 8509B only.

`PolDep:Clear`

Aborts or re-starts a polarization dependent loss measurement process. Any current measurements are cleared. The command does not erase the thrupath calibration corrections from memory.

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`PolDep:Done`

Ends a polarization dependent loss (PDL) measurement process. The PDL measurement controls are removed from the screen.

`PolDep:{ Internal | External }[?]`

Specifies whether internal or external polarizers will be utilized in a polarization dependent loss measurement. Internal polarizers are those which are a part of the HP 8509B system. The user must implement and specify external polarizers through the polarizer command. The query returns the selected polarizers.

HP 8509B only.

`PolDep:{ JonesData? | PolDepData? }`

When the mandatory selection is `PolDepData?`, the instrument returns data in one of two ways, depending on whether it is in absolute mode or relative mode.

For absolute measurements the analyzer returns the polarization dependent loss as either Delta, Max, Min.

```
delta_transmission, max_transmission, min_transmission
```

For relative measurements it returns the polarization dependent loss as Delta.

```
delta_transmission
```

When the mandatory selection is `JonesData?`, the analyzer returns the Jones matrix as:

```
j00.real,j00.imag,j01.real,j01.imag,...,j11.imag
```

or

```
J00.magnitude,j00.phase,j01.magnitude,j01.phase,...,j11.phase.
```

Before sending this command using either selection, be sure that a measurement has been taken. To take a measurement: If the analyzer is in absolute mode, a calibration is performed first using `PolDep:Calibrate[A | B | C ]`. The measurement is performed using `PolDep:Measure[A | B | C ]`. Use optional selection `A`, `B`, or `C` when external polarizers are selected.

`PolDep:{ JonesMode | PolDepMode }[?]`

Selects the data format as polarization dependent loss values or Jones values. This is similar to selecting the option button at the bottom of the window. Use this command to open the `Polarization Dependence` window. The query returns `"1"` if the condition is true, `"0"` otherwise.

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`PolDep:{ MagRadians | MagDegrees | RealImag }[?]`

Sets the format of the Jones matrix numerical results to a polar (magnitude and phase) or rectangular (real, imaginary) format. Through this command, the angle of the polar numerical results can be presented either in radians, degrees, or as complex numbers. The query returns "1" if the indicated format is selected, "0" if not selected.

`PolDep:Measure[A | B | C]`

Calculates the polarization dependent loss of a given device under test. The results can be read from the analyzer through the use of the `poldep?` HP-IB remote command. With internal polarizers, the measurement is performed automatically. When optional selections `A`, `B`, or `C` are used, then external polarizers are assumed to be used. The user must insert the appropriate polarizer and send a command for each polarizer. The polarizer angles pertaining to each of the three markers (A, B, and C) must be specified using the polarizer command.(See `Polarizer:Angle{ A | B | C }:<Degree value>`.)

`PolDep:Measure` is HP 8509B only.

`PolDep:NewThruCal`

Clears any current thrupath calibration and begins a new calibration sequence. A calibration must first be done using `PolDep:Calibrate[A | B | C]`. The `PolDep:NewThruCal` and the `PolDep:Calibrate[A | B | C]` commands are valid only for absolute measurements, that is, when the transmission measurement is either Delta, Max, or Min.

HP 8509B only.

`PolDep:ReStart`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolDep:Clear`

`PolMarker:{ A | B | C }`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`PolMarker?:{ A | B | C }`

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`PolMarker?:{ A | B | C }`

When using the internal polarizers, the parameters for this command are such that `A` refers jointly to polarizer A and marker A, similarly for parameters `B` and `C`. When the internal polarizers are used, this command inserts the specified polarizer (A for 0 °, B for 60 °, and C for 120 °) at the source output. The marker pertaining to the specified polarizer (A, B, or C) is placed, as observed on the Poincare sphere, at the resulting state of polarization. Command execution also returns the resulting state of polarization in the form of the normalized Stokes parameters S_0, s_1, s_2, s_3.

When external polarizers are used, this command should be executed when the desired state of polarization has been set using an external polarizer. The command execution places the specified marker, as observed on the Poincare sphere, at the resulting state of polarization. The resulting state of polarization is returned as the normalized Stokes parameters S_0, s_1, s_2, s_3.

The main purpose of this command is for use in placing and reading markers when external polarizers are utilized. Specifically, this is done when performing a Jones matrix measurement, a polarization dependent loss measurement, or when the application of a two- or three-point reference frame is required.

`Range:Auto{ ? | :Off | :On }`

Through this command, the range function auto mode is, as specified by the user, turned `On` or `off`. The query returns an ASCII `"1"` if the range function is in auto mode and an ASCII `"0"` if it is not.

`Range:{ Done | Down | Up }`

When the auto function is turned `Off`, the user may, through this command, increase `Up` or decrease `Down` the power measurement range of the HP 8509A/B. (See `Range:Auto{ ? | :Off | :On }`). Using the `Done` parameter closes the `Range` frame in the analyzer window.

`Range{ ? | :<GainValue> }`

The query returns the gain range and the state of the autorange check box in the `Range` frame. “0” = not checked, “1” = checked.

Using `<GainValue>` allows the range to be set and returns an error if autorange is on. The valid values for `<GainValue>` are 0 to 6, where 0 is the highest gain and 6 is the lowest gain. (This corresponds to `Range:{ Done | Down | Up }`). See `Range:Auto:{ Off | On }`.

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`RawDat?`

Returns the raw ADC voltages, with offsets subtracted, associated with the four photodiode detectors within the HP 8509A/B receiver. The voltages are returned in terms of a scaled value in the range 0 to 65,535. Each value within that scale is proportionally related to a value from −10 to 10 volts. The subtracted offsets correspond to the voltage values generated by the detectors under zero input conditions. The resulting information can be converted to voltage through the following equation:

rawdat (volts) = (obtained rawdat/65536 * 20) − 10

`RefFrame?`

This command will return information regarding the quality of a currently applied reference frame. If a two-point reference frame has been established, the command will return the polarization angle and a grade for the frame quality. If a three-point reference frame has been established, the command will return the transmission ratio and a grade for the frame quality. The definitions of the returned parameters are provided below:

polarization angle = 90 / (pi * Acos(angle between 2pts))

In the above equation, “angle between 2pts” refers to the angular separation, as observed in the Poincare sphere, between the two state-of-polarization points used to establish the two-point reference frame.

transmission ratio = The ratio of the highest polarization dependent loss to the lowest polarization dependent loss of the thrupath used to establish the three-point reference frame. A small transmission ratio is a desirable result.

The grading system for the applied reference frame is:

* invalid = 0
* very poor = 1
* poor = 2
* fair = 3
* good = 4

`RefFrame:{ Off | On }[?]`

Applies or un-applies a two- or three-point reference frame. (See

`RefFrame:{ 2pt,3pt }[?]`.) If using internal polarizers, the reference frame is set up and applied (or not applied) automatically. With external polarizers, the appropriate markers must first be placed and read using the `PolMarker?:{ A | B | C }` command. The query returns an ASCII `"1"` if the specified function (`Off | On`) is active and a `"0"` is returned if it is not active.

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`RefFrame:{ 2pt | 3pt }[?]`

Specifies the type of reference frame to be applied. The query returns an ASCII "1" if the specified function `{ 2pt | 3pt }` is active and a "0" if it is not active. See `RefFrame:{ Off | On }[?]`.

`Save:Config:<"filename">`

Saves the current instrument configuration into the file `<"filename">`. For path information on "filename", see "Command Syntax" at the beginning of this chapter.

`Save:Disper:<"filename">`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Disper:Save:<"filename">`

`Save:Jones:<"filename">`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Save:PolDep:<"filename">`

`Save:PolDep:<"filename">`

Saves a Jones matrix measurement/polarization dependent loss measurement to the file "filename". The file format is:

`<Absolute Measurement Flag>,<PDL Delta>,<PDL Max>,<PDL Min>`

`<J00.real>,<j00.imag>`

`<J01.real>,<j01.imag>`

`<J10.real>,<j10.imag>`

`<J11.real>,<j11.imag>`

Where `<Absolute Measurement Flag>` is "1" if the measurement is absolute and "0" if the measurement is relative. In the case of a relative measurement, `<PDL Max>` and `<PDL Min>` are both "0". For path information on "filename", see "Command Syntax" at the beginning of this chapter.

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`Save:Single:<"filename">`

Saves a timed measurement to the "filename". The file format for the data is:

<Wavelength of Source>

<S0, milliWatts>, <S1>, <S2>, <S3>, <DOP %>

.

. (one line for each point)

.

The Stokes parameters are un-normalized. For path information on "filename", see "Command Syntax" at the beginning of this chapter.

`SerialNum?`

Returns the serial number of the HP 8509A/B lightwave polarization analyzer.

`SetMarker:<S0>:<s1>:<s2>:<s3>:{ A | B | C }`

Sets the specified marker to a polarization state given by the normalized Stokes parameters s_1, s_2, s_3 and S_0, the power in milliwatts. The placed marker can be observed on the Poincare-sphere-coordinates pertaining to S_0, s_1, s_2, s_3.

`Single`

Places the `Timed measurement` frame on the analyzer window.

`Single:Done`

Using `Done` closes the `Timed measurement` frame in the analyzer window.

`Single:DBase:Load:<"title">`

Loads a measurement from the current database with the specified title.

`Single:DBase:Save:<"title"> [ :<"date code"> [ :<"serial number">]]`

Saves a measurement to the current database with the specified title.

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`Single:Freq{ ? | :<Hertz> }`

Sets the timed measurement sampling frequency to be used. The frequency must correspond to a period with a resolution of 1 millisecond. The query returns the frequency.

`Single:Mode{ ? | :Single | :Timed | :FreeRun }`

Sets the timed measurement mode. The query returns the mode.

`Single:Period{ ? | :<Seconds> }`

Sets the timed measurement period. The query returns the period.

`Single:Points{ ? | :<NumPoints> }`

Sets the number of sample points used in the reading of a timed measurement trace.

`Single:Start`

Triggers the reading of a timed measurement trace.

`Source?`

Upon command reception, the analyzer returns a string which specifies the source settings of the `HP 8509 analyzer` window. In addition, the wavelength, in nm, of the active source is returned. If a source is not currently turned on, the parameter `off` is returned instead of the source wavelength. The string is in the form of:

```
<Name of Laser Source>,{ <Wavelength nm> | off }
```

The names of the laser sources are:

```
Voltage tuned
HP8167A/HP-IB
HP8168A/HP-IB
Internal
Manually tuned
```

Note: The source settings for the analyzer window, the `PMD:JME` window, and the `PMD:WS` window are independently set. When a polarization mode dispersion measurement (PMD) is initiated, the analyzer window inherits the settings of that PMD measurement. The `Source?` command returns the setting of the analyzer window at the time of the command.

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`Source:External?`

The analyzer returns the wavelength, in nm, of the currently activated external source for the analyzer window.

`Source:External:{ Off | On }`

Not Recommended Command may not be available in future versions. Plan your programming accordingly.

Specifies the use of an external source and the state `{ Off | On }` of the utilized external source.

DDE only.

Note: The external TLS controlled is the last TLS selected. The LPA will automatically select the Manual TLS as the default unless another TLS (HP-IB controlled HP 8167/8 or Voltage Tuned) has previously been selected.

`Source:External:<Wavelength nm>`

Specifies the external source wavelength. The wavelength should be specified in nm. The settings for all open windows are affected. See Note in `Source:External:{Off|On}` for information on TLS.

`Source:HPIB[?]`

Sets the tunable laser source for the analyzer window to an HP-IB TLS. The HP 8509A/B looks for a tunable laser source at the address specified with `TLS:Address` and uses it if it is either an HP 8167 or HP 8168 tunable laser source. The query returns two parameters.

first: `"0"` (not HP-IB TLS), `"1"` (HP-IB TLS)

second: The name of tunable laser source.

DDE only.

`Source:Hpib:{ Off | On | <Wavelength nm> }`

Specifies the state, `Off | On`, or the wavelength setting of the HP-IB source. When turned on or set using `<Wavelength nm>`, the HP 8509A/B system automatically determines which tunable laser source (HP 8167 or HP 8168) is connected to the HP-IB bus at the address set using `TLS:<HP-IB address>`

DDE only.

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`Source:Internal?`

Returns the wavelength, in nm, of the currently activated internal source in the analyzer window.

HP 8509B only.

`Source:Internal:{ Off | 1310 | 1550 }`

Specifies the internal source in the analyzer window. If the parameters `1310` or `1550` are sent, the specified internal source (1310 or 1550 nm) is turned on. If the `off` parameter is sent, any currently active internal source is turned off.

HP 8509B only.

`Source:Manual[?]`

Places the analyzer window in manual control mode. When the instrument is under manual control, the user must set the tunable laser source to the appropriate wavelength for each wavelength point. The query returns two parameters.

first: `"0"` (not manually tuned), `"1"` (manually tuned)

second: The type of optical-source-setup source.

`Source:Shutter?`

Returns an ASCII `"1"` if the shutter is currently activated (on) and returns an ASCII `"0"` if the shutter is not activated (off). See `Source:Shutter:{ Off | On }`.

HP 8509B only.

`Source:Shutter:{ Off | On }`

This command controls the shutter located in the path to the optical output port of the HP 8509A/B. The two HP 8509A/B internal sources and any external source coupled into the external source port of the HP 8509A/B share a common instrument internal path to the optical output port of the HP 8509A/B. By sending the parameter `on`, a shutter in the path to the optical output port can be activated so that the source output is blocked. The shutter can also be removed by sending the parameter `off`.

HP 8509B only.

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`Source:VTune[?]`

Sets the `Optical Source Setup` source selection to VTune in order to control a VTUNE tunable laser source. The query returns two parameters.

first: `"0"` (not VTUNE), `"1"` (VTUNE)

second: The type of optical-source-setup source.

`Source:VTune:{ Start | Stop }{ ? | :<Voltage> }`

The VTUNE start or stop voltage. The query returns the voltage value, the parameter `<Voltage>` sets the value. The settings for the analyzer window is affected if not a query. The query returns settings for the analyzer window.

`Status?`

This command waits until all previous commands have executed and then returns the status of the last command. In this way it is similar to `*OPC?`. Append the `Status?` command to the command whose status is requested (separate the commands with a semicolon). If `Status?` returns either "FAIL" or "PROBLEMS", then a description of the problem may follow the return value. Return values are:

`"PASS"`	- Command successful.
`"FAIL" <Optional Description>`	- Command failed.
`"PROBLEMS" <Optional Description>`	- Errors occurred during execution.
`"UNKNOWN"`	- Command not recognized.

`Stokes:<NumPoints>`

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

`Stokes?:<NumPoints>`

`Stokes?:<NumPoints>`

Measures the input signal and returns degree of polarization (DOP) and Stokes parameter test data in the form of S_0, s_1, s_2, s_3, DOP. The measurement is made by averaging over "npnts" points. S_0 is linear power (milliwatts), s_1, s_2, s_3 are the normalized Stokes parameters (range $+1.0$ to -1.0), and DOP is the degree of polarization (range 0 to ˜1.2).

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TLS?

Returns the name of the current tunable laser source. Valid return values are:

Voltage tuned

HP8167A/HP-IB

HP8168A/HP-IB

Manually tuned

Unknown

TLS:Address{ ? | :<HP-IB Address> }

This setting is used for all windows. The HP-IB address of a tunable laser source on the HP-IB bus.

DDE only.

TLS:Isc{ ? | :<HP-IB card ISC> }

This setting is used for all windows. The ISC of the HP-IB card installed in the HP 8509A/B Vectra PC.

DDE only.

TLS:Power{ ? | :<Power> }

This setting is used for the analyzer window only. The power setting of the HP-IB tunable laser source. The units are set in TLS:Unit:<units>.

DDE only.

TLS:{ SettlePoint | SettleStart }{ ? | :<Millisec's> }

Not Recommended Command may not be available in future versions. Plan your programming to use the alternate command:

Disper:Settle{ Point | Start }{ ? |:<Millisec's> }

DDE only.

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`TLS:Power:Unit{ ? | :dBm | :Watt }`

The units of power for the HP-IB tunable-laser-source power. This setting is used for the `analyzer` window only. See also: `Disper:Power:{ dBm | uWatt }[:<value>]` and `WaveScan:Power:{ dBm | uWatt }[:<value>]`. If the power setting is not valid for the TLS, the command fails.

DDE only.

`Trace:Points:<NumPoints>`

Not Recommended Although this command was documented for Version 1.x code, it was never implemented. This command is NOT VALID. Command will not be available in future versions. Plan your programming to use the alternate command:

`Single:Points{ ? | :<NumPoints>}`

`Version?`

Returns the current version number of the HP 8509A/B software.

`WaveScan[?]`

Shows the `PMD:WS` window on the display. Be sure to send 'WaveScan' before sending any other 'WaveScan: ... ' commands. The query returns the polarization mode display (PMD) values of the measurement as follows:

Current wavelength (nm), Total PMD, PMD for s_1, PMD for s_2, PMD for s_3

Note: The running totals are returned. The measurement may not be complete.

`WaveScan:Analysis?`

Returns the type of analysis used to calculate the polarization mode display (PMD). Valid values are:

`Peaks,FullScan`

`Peaks,FirstToLast`

`Extrema,FullScan`

`Extrema,FirstToLast`

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`WaveScan:Analysis:{ Extrema | Peaks }:{ FullScan | FirstToLast }`

Sets the type of analysis to use in calculating the polarization mode dispersion (PMD).

`WaveScan:Atten{ ? | :<dBm value> }`

The attenuation for the HP-IB tunable laser source. The query returns the attenuation in dBm. Using `<dBm value>` sets the attenuation for an HP-IB tunable laser source. If the attenuation setting is not valid for the TLS, the command fails.

DDE Only.

`WaveScan:Clear`

Aborts a PMD:WS measurement process. This command is valid only if the optical source is set to Manual.

`WaveScan:Close`

Closes the `PMD:WS measurement` window. The PMD:WS measurement process is ended.

`WaveScan:DBase:Load:<"title">`

Loads a measurement from the current database using the specified title.

`WaveScan:DBase:Save:<"title"> [ :<"date code"> [<"serial number"> ]]`

Saves a measurement to the current database using the specified title.

`WaveScan:Feature{ ? | :<Min Feature Size> }`

The query returns the minimum size of features (maxima and minima) that are considered for the analysis type selected. The query returns the value for the minimum size of features.

`WaveScan:FiberLen{ ? | :<km> }`

The query returns the length of optical fiber used to normalize PMD:WS measurements. Using `<km>` sets the length of optical fiber.

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`WaveScan:Hpib[?]`

Sets the tunable laser source for a PMD:WS measurement to an HP-IB tunable laser source. The HP 8509A/B looks for a tunable laser source at the address specified with `TLS:Address` and uses it if it is either an HP 8167 or HP 8168 tunable laser source. Be sure that the wavelength range is set correctly for the connected HP-IB tunable laser source before issuing this command. To change tunable laser source selections between HP 8167 and HP 8168:

1. Issue the command `WaveScan:Manual`
2. Change the wavelength range using `WaveScan:WLen:`
3. Change the HP-IB address using `TLS:Address:<HP-IB Address>`
4. Issue the command `WaveScan:HPIB`

The query returns an ASCII "1" if the PMD:WS next measurement process will be in HP-IB mode and a "0" if it will not be in this mode. Also returns the name of the current laser source.

DDE Only.

`WaveScan:Manual[?]`

Places the PMD:WS measurement in manual control mode. When the instrument is under manual control, set the tunable laser source to the appropriate wavelength for each wavelength point between the start and stop wavelengths. The query returns two parameters. In manual control mode, send the command "WaveScan:Measure" once to begin the measurement process and once for each wavelength point as returned by the command "WaveScan:WLen:Points?"

The query returns an ASCII "1" if the PMD:WS next measurement process will be in MANUAL mode and a "0" if it will not be in this mode. Also returns the name of the current laser source.

`WaveScan:Measure`

Initiates a PMD:WS measurement. If the tunable laser source is "Manually Tuned", then send this command for each point in the wavelength range.

`WaveScan:Mode{ ? | :<Mode Constant> }`

The Mode Calculation Constant (k) is set or queried.

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`WaveScan:PmdResult{ ? | :Avg | :Max | :Median}`

The PMD:WS total is calculated in one of three different ways, using the average, maximum, or median value of the polarization mode display (PMD) values calculated for the s_1, s_2, and s_3 traces. This command selects the type of PMD total to calculate. the query returns the type of PMD result.

`WaveScan:Polarizer{ ? | :A | :B | :C | :None }`

The internal polarizer to insert before starting the PMD:WS measurement. The query returns the selected polarizer.

HP 8509B Only

`WaveScan:Power?`

Returns the power and the power units for the tunable laser source.

DDE Only.

`WaveScan:Power:{ dBm | uWatt }[:<value>]`

Sets the power units for the tunable laser source (TLS). If the `<value>` parameter is specified, the power setting can also be changed. If the power setting is not valid for the TLS, the command fails.

Note: When changing only the units, the numerical value of the power does not change. Be sure to change the value of the power to correspond to the new units.

DDE Only.

`WaveScan:Save:<"filename">`

Saves a PMD:WS measurement trace into the file `<"filename">`. The trace is saved as a series of ASCII strings separated by commas. The each line of the saved trace information is in the form of:

Wavelength_1, Power(dBm), s_1, s_2, s_3, DOP(%)

.

.

.

Wavelength_n, Power(dBm), s_1, s_2, s_3, DOP(%)

The above is for the dispersion measurement at "n" user defined wavelengths. The Stokes parameters are normalized. For path information on "filename", see "Command Syntax" at the beginning of this chapter.

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---

`WaveScan:Settle:{ Point | Start }{ ? | :<Delay msec> }`

The settling time to wait, either initially (Start) or per point (Point), after setting a tunable laser source to the desired wavelength in the sweep range during a PMD:WS measurement. The query returns

the current value. See also: `Disper:Settle:{ Point | Start }{ ? | :<Millisec's> }`

`WaveScan:Units:{ ? | :ps | :ps/L | :ps/sqrtL }`

The units to use in PMD:WS measurements. The query returns the selected units.

`WaveScan:VTune[?]`

Sets the `Optical Source Setup` source selection to VTune in order to control a VTUNE tunable laser source.

The query returns an ASCII "1" if the PMD:WS next measurement process will be in VTUNE mode and a "0" if it will not be in this mode. Also returns the name of the current laser source.

`WaveScan:VTune: { Start | Stop }{ ? | :<Voltage> }`

The VTUNE start or stop voltage. The query returns the voltage value, the parameter <Voltage> sets the value.

`WaveScan:WLen?`

Returns the next wavelength (in nm) at which the PMD:WS measurement will be conducted. This command is typically used only when the tunable laser source is "Manually Tuned".

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`WaveScan:WLen:{ Start | Stop | Delta }{ ? | :<Wavelength nm>}`

Specifies the Start, Stop, or Delta wavelengths for the PMD:WS measurement. Changing any of these values causes the number of points to change according to:

WLenPoints = ((WLenStop − WLenStart) / WLenDelta) + 1

The query returns the value of the setting in nanometers. Using the `<Wavelength nm>` parameter sets the value.

Note: The `Start` and `Stop` values can never have the same value. For example, when segmenting a wavelength range over several measurements and sweeping from low to high, always issue the command `WaveScan:WLen:Stop` before the command `WaveScan:WLen:Start` when specifying the next wavelength segment. This will prevent the `Start` and `Stop` values from being equal when switching from one segment to the next.

`WaveScan:WLen:Points{ ? | :<NumPoints> }`

Sets the number of points between the start and stop wavelengths for the polarization mode display (PMD) measurement. Each point corresponds to a wavelength for PMD measurement. If the number of points does not correlate with the delta value and the start and stop wavelengths, the delta value is reset to accommodate the number of points according to:

WLenDelta = (WLenStop − WLenStart) / (WLenPoints − 1)

The query returns the number of points specified in the current PMD:WS measurement settings.

`Zero`

Causes the measurement offsets to be referenced as a zero measurement state. The measurement offsets correspond to the voltages generated by the receiver photodiodes under a zero input condition. A zero valued measurement state can thus be established by the user at any time during a measurement process.

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Example Programs

The example programs are provided on two disks that are included with the *HP 8509 User's/Reference Guide*. The programs on these disks demonstrate the exact executable syntax of the code. One disk is in DOS format and the other is in LIF format. The DOS formatted disk is for system operation with Windows. There are example programs on the DOS disk for controlling the HP 8509. One example illustrates remote operation of the HP 8509 over the HP-IB bus. This program is written using HP IBasic for Windows and runs on a PC configured as an HP-IB controller and connected to the HP 8509 via the HP-IB bus. Another example illustrates remote operation of the HP 8509 using Windows DDE on the HP 8509 Vectra PC. This program is written using VisualBasic for Windows and runs simultaneously with the HP 8509 software on the HP 8509 Vectra PC. The LIF formatted disk is for system operation under HP BASIC running in an HP 9000 series 200/300 external controller.

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11

Specifications and Characteristics

Specifications are the warranted performance standards or limits against which the HP 8509 can be tested.

Characteristics are not specifications, but are typical parameters provided for use in applying the instrument. Characteristics are representative of most, though not necessarily all HP 8509 lightwave polarization analyzers.

Warranted Specifications

The warranted specifications on the HP 8509 are valid over the temperature range of 23°C ±5°C, with the instrument oriented upright on a horizontal surface and warmed up for at least one hour.

Polarization Mode Dispersion (PMD) Specifications, Jones Matrix Eigenanalysis (JME) Method (HP 8509B only)

The JME method measures the differential group delay (DGD) of the test device as a function of wavelength. Average DGD (or PMD) is taken as the average of the DGD values across the wavelength range. The measurement requires a tunable wavelength, single-line laser source such as the HP 8168A Tunable Laser Source. The JME measurement is operational over the ranges of 1280 to 1340 nm and 1470 to 1580 nm, however, the DGD uncertainty specification is warranted over the wavelength range of 1540 to 1560 nm.

Table 11-1. Maximum Measurable DGD Using JME Delay (HP 8509B)

Maximum Measurable DGD Using JME Method[1]		
Wavelength Step	**1310 nm**	**1550 nm**
0.01 nm	280 ps	400 ps
0.10 nm	28 ps	40 ps
1.0 nm	2.8 ps	4 ps
10.0 nm	0.28 ps	0.4 ps

1 Maximum measurable PMD delay = π / radian optical frequency interval.

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Table 11-2.
PMD Measurement Uncertainty Using the JME Method (HP 8509B Only)

PMD Measurement Uncertainty[1,2,3,4]	
Wavelength Step	**Uncertainty (±)**
0.10 nm	310 fs
1.0 nm	90 fs
10.0 nm	60 fs

1 Receiver input level −20 to −40 dBm.

2 Does not include external laser tuning accuracy.

3 Measurement averaging set to 500 points.

4 PMD is the average value of DGD across the measurement wavelength range.

Characteristics

Jones Matrix Eigenanalysis PMD Measurement

Table 11-3 shows the repeatability of a measurement of a 0.218 ps quartz PMD standard in which the fibers do not move between measurements.

Table 11-3.
Repeatability of JME PMD Measurement with Fixed Pigtail positions

Repeatability of JME PMD Measurement[1,2,3,4]	
Number of measurements	20 measurements
Expected value of DGD	0.218 ± 0.010 ps[5]
Mean	0.2173525 ps
Standard deviation	0.0000085 ps
Maximum - minimum	0.00003 ps
Maximum	0.21737 ps
Minimum	0.21734 ps

1 Test device is a pigtailed quartz PMD standard, under development.

2 Measurement wavelength range of 1500 to 1560 nm.

3 Measurement wavelength interval of 10 nm.

4 No movement of test device or pigtails between measurements.

5 The ± 0.010 ps tolerance is provided to allow for the effects of pigtails and packaging.

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Table 11-4 Shows the repeatability of 20 measurements of a pigtailed quartz PMD standard in which Pigtail positions are randomized before each measurement.

Table 11-4.
Repeatability of JME PMD Measurement with Randomized Pigtail Positions

Repeatability of JME PMD Measurement[1,2,3,4]	
Number of measurements	20 measurements
Expected value of DGD	0.218 ± 0.010 ps[5]
Mean	0.21821 ps
Standard deviation	0.00246 ps
Maximum - minimum	0.00787 ps
Maximum	0.22271 ps
Minimum	0.21484 ps

1 Test device is a pigtailed quartz PMD standard, under development.

2 Measurement wavelength range of 1500 to 1560 nm.

3 Measurement wavelength interval of 10 nm.

4 Reposition pigtails randomly before each measurement.

5 The ± 0.010 ps tolerance is provided to allow for the effects of pigtails and packaging.

Wavelength Scanning PMD Measurement

Table 11-5 shows the minimum measurable PMD for the wavelength scanning method for two types of devices. Non-mode coupled devices include most components. Highly mode coupled devices include most long, single-mode optical fibers.

Table 11-5.
Minimum Measurable PMD Using the Wavelength Scanning Method

Minimum Measurable PMD[1]	
Type of test device	**Minimum measurable PMD value**
non-mode-coupled devices[2] (most components)	0.040 ps
highly mode-coupled devices[3] (long fibers)	0.195 ps

1 Assumes 100 nm wavelength tuning range.

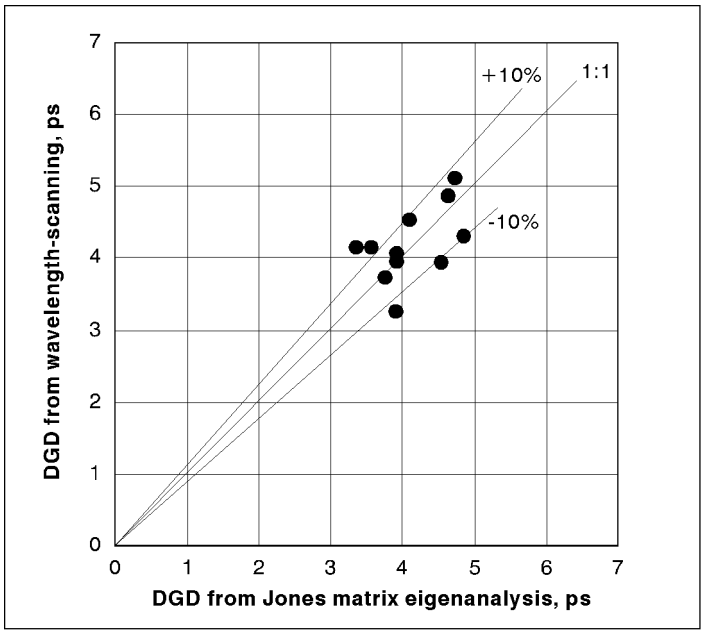
2 Assumes a single peak and a single valley.

3 Assumes an average of 3 cycles of polarization change (4 peaks).

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Comparison Between Jones Matrix Eigenanalysis and Wavelength Scanning Methods

Figure 11-1 is a comparison between the Jones matrix eigenanalysis and wavelength scanning measurement methods. HP 8509B JME and WS measurements agree to within approximately +15% for this test device.



pq7146_c

Figure 11-1.
Comparison of JME and WS Measurement Methods for Long Optical Fiber Test

Comparison of JME and WS Measurement Methods for Long Optical Fiber Test[1,2,3].

1 The test device was 14 km of loosely-spooled, dispersion-shifted fiber. Eleven measurements of each type were taken with random arrangements of the loose turns of the fiber.

2 Wavelength scanning responses typically exhibited 16 extrema (# of extrema = # of peaks + # of valleys).

3 Wavelength scanning measurements use mode coupling factor of 0.82.

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Receiver Characteristics

Table 11-6. Receiver Characteristics

Receiver Characteristics	
Wavelength operating range[1]	1200 to 1600 nm
Input power operating range	+10 to −55 dBm
Input average power damage level	+16 dBm
Average power measurement uncertainty[2]	±15%
Degree of polarization measurement uncertainty[3,4,5]	1200 to 1280 nm, ±5.0% 1280 to 1340 nm, ±2.0% 1470 to 1580 nm, ±2.0% 1580 to 1600 nm, ±3.0%
Poincare representation uncertainty[4,6,7,8]	1200 to 1340 nm, ±1.5° 1470 to 1600 nm, ±1.5°
Measurement rate	>2000 per second
Display update rate	>2000 per second

1 The HP 8509 performs polarization measurements over this range. See individual measurement specifications or characteristics for details.

2 Does not include the effects of optical connectors.

3 Uncertainty introduced in defining an external reference frame in open beam applications is not included.

4 500 point display averaging (running average).

5 Characteristic applies for 100% polarized light for the purpose of practical verification.

6 Characterized in degrees on the Poincare sphere.

7 For input light at least 98 percent polarized. Uncertainty increases as degree of polarization decreases.

8 For uncertainty in the angle between two displayed points, multiply by two.

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Source Characteristics

Table 11-7. Source Characteristics

Source Characteristics				
	λ	**Min**	**Typical**	**Max**
Average Optical Power Output	1310 nm 1550 nm	180 μW 125 μW	315 μW 220 μW	600 μW 400 μW
Wavelength Accuracy	1310 nm 1550 nm		$\pm$20 nm $\pm$20 nm	
Spectral width (RMS)	1310 nm 1550 nm		5 nm 5 nm	
Return loss			17 dB	
Laser type	Fabry-Perot			

Table 11-8. External Source Input Port Characteristics

External Source Input Port Characteristics	
Wavelength operating range	1200 to 1580 nm
Insertion loss[1]	6 dB
Return loss[2,3]	35 dB

1 Internal path loss between EXTERNAL SOURCE INPUT and OPTICAL OUTPUT connectors with no polarizer selected.

2 Does not include the effects of optical connectors.

3 When optical output is connected with return loss of 30 dB or better.

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Polarization Dependence, Jones Matrix Method

Table 11-9.
Measurement of Polarization Dependence (HP 8509B Only)
Jones Matrix Method

Measurement of Polarization Dependence Jones Matrix Method[1,2]	
Polarization dependence wavelength operating range	1280 to 1340 nm 1470 to 1580 nm
Polarization dependence uncertainty[3,4,5]	±0.1 dB

1 Polarization dependence is the peak to peak variation in transmission of the device under test over all polarization states.

2 Specified with single-line laser source.

3 For measured values less than 3 dB, receiver input level > −20 dBm.

4 Does not include the effect of optical connectors.

5 Measurement averaging set to 500 points.

Polarization Dependence, Power Max-Min Method

Table 11-10.
Measurement of Polarization Dependence (HP 8509B Only)
Power Max - Min Method

Measurement of Polarization Dependence Power Max - Min Method[1,2]	
Polarization dependence wavelength operating range	1280 to 1340 nm 1470 to 1580 nm
Polarization dependence uncertainty[3,4,5]	±0.1 dB

1 Polarization dependence is the peak to peak variation in transmission of the device under test over all polarization states.

2 Specified with single-line laser source.

3 For measured values less than 3 dB, receiver input level > −20 dBm.

4 Does not include the effect of optical connectors.

5 Measurement averaging set to 500 points.

Fiber Size and Analog Output Range

Table 11-11. Other Characteristics

Other Characteristics	
Compatible fiber	9/125 micron
Analog output range	±10 volts

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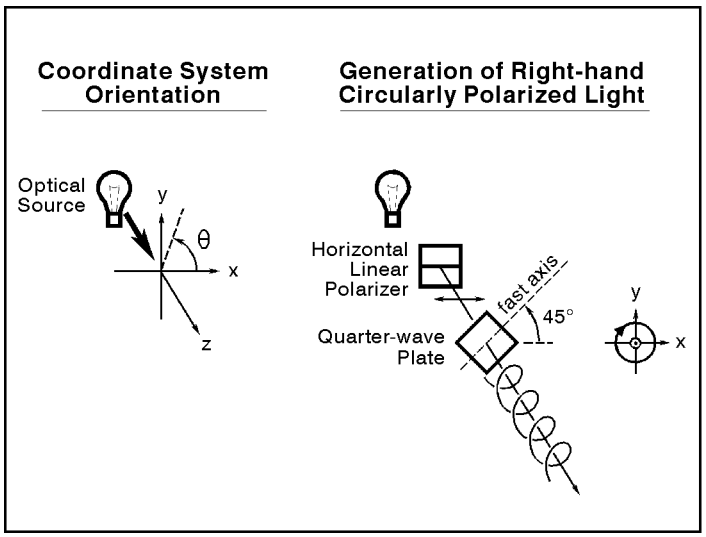
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Coordinate System and Generation of Right-Hand Circularly Polarized Light

An explicit coordinate system must be specified in order to unambiguously describe a state of polarization. For description of polarization, a conventional coordinate system is oriented so that the z axis is horizontally oriented in the direction of propagation of the light. The y axis is vertically oriented pointing up, and the x axis is horizontally oriented to form a right-handed rectangular coordinate system. Angles are measured referenced to the x axis, a positive angle indicating the sense of rotation from x toward y.

The electric field vector of elliptically polarized light is said to rotate in either a right-hand sense or a left-hand sense, corresponding to either a positive or negative third normalized Stokes parameter, respectively. In the case of right-hand circularly polarized light, at any instant in time the electric field of the wave is a function of z, and is described by a right-handed helix (like a screw thread). As this helix propagates through a fixed xy plane, the electric field vector in that plane rotates in a clockwise sense when viewed looking in the direction of propagation.

Right-handed circularly polarized light can be generated by passing horizontal, linearly polarized light through a quarter-wave plate whose fast axis is oriented at 45 degrees in the coordinate system described below.



circ_c

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Glossary

address
An identification, as represented by a name, label, or number, for a register, location in storage, or any other data source or destination such as the location of a station in a communications network or a device on the Hewlett-Packard Interface Bus.

antireflection coating
A thin dielectric or metallic film (or several such films) applied to an optical surface to reduce the reflectance and to increase the transmittance.

attenuation
The diminution of signal amplitude or power. In optical waveguides, attenuation results from several mechanisms that may operate simultaneously: absorption, scattering, and losses into radiation modes. Attenuation is generally expressed in dB/km for cables, assuming approximate uniformity with length.

attosecond
10^{-18} seconds

calibration
The process by which measurement accuracy is improved by removing systematic and repeatable errors. Wavelength calibration optimizes accuracy at a chosen wavelength. See wavelength calibration.

cladding
The layer of glass surrounding the light-carrying core of an optical fiber. It has a lower refractive index than the core. Coatings may be applied over the cladding.

controller
1. A device capable of specifying the talker and listeners for an information transfer.
2. An external computer connected to an instrument to control its operation.

core
The central part of an optical fiber in which the light propagates.

coupler
A device that connects three or more waveguide ends, dividing one input between two or more outputs or combining two or more inputs into one output.

coupling
The transfer of light in or out of an optical fiber. (Note that coupling does not require a coupler.)

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cursor

An electronically generated pointer which moves across the trace to identify point values or interfaces to a windows application..

cut-off wavelength

The shortest wavelength at which a single-mode fiber carries only one mode.

database

The HP8509A/B provides users with two ways to save data for PMD:JME, PMD:WS, and Timed measurements: Microsoft Access database and text files. The data stored in HP 8509 text files is very limited and is primarily useful for importing data into a spreadsheet. Database files are much more versatile. A user can move the database file to another computer to do sophisticated analysis of the measurements, and continue using the HP 8509 instrument. For example, a user may wish to examine the PMD measurements for a particular device type during the month of May. Since the HP 8509 database is a relational database, it allows a user to filter out all the unwanted data and view only those measurements that are of interest. In addition, Microsoft Access also has many mathematical functions built in, so that the measurements can be analyzed statistically. This is helpful in a production environment where Statistical Process Control (SPC) can spot production trends early and lead to improved processes. The Microsoft Access database file created by the HP 8509 can be extended by the user to add fields and tables which are updated by other stages in the production process or by a sales or shipping departments.

dB

An abbreviation for Decibel. A relative unit of measure.

dBm

Power in decibels referenced to 1 mW.

default

A known set of conditions used by the analyzer in the absence of user-defined conditions.

degree of polarization

The degree of polarization (DOP) describes the percentage of the total power of an optical signal that is in polarized form, that is, the portion that can be described systematically in terms of components having determined phase. DOP is given by the square root of the sum of the squares of the normalized Stokes parameters. It is also given by the square root of the sum of the squares of the Stokes parameters. all divided by the optical power.

detector

A device that generates an electric signal when illuminated by light. The most common in fiber optics are photodiodes, photodarlingtons, and phototransistors.

differential group delay

The difference in propagation time of the polarization modes of a lightwave signal through a test device. The differential group delay may be a function of wavelength, especially in optical fibers. The average differential group delay over wavelength is commonly referred to as PMD.

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distortion
An undesirable change of signal waveform shape.

DOP
See degree of polarization.

ellipse
See polarization ellipse.

ellipticity
The ratio of optical powers corresponding to the minor and major axes, respectively, of the polarization ellipse.

effective DOP
The degree of polarization (DOP) of a lightwave signal is defined as the ratio of the power of the polarized component of the signal to the total power. The HP 8509 calculates DOP from the square root of the sum of the squares of the normalized Stokes parameters, which in turn are calculated from the ratios of the measured Stokes parameters to the total power. The HP 8509 can be used to measure the effective DOP of a polarization modulated signal by taking advantage of the display averaging feature. This is called effective DOP. When display averaging is used, every normalized Stokes parameter produced by the measurement system represents the average of the most recent N measurement samples, where N is the number of display averages selected by the user. Because DOP is calculated from these averaged normalized Stokes parameters, the DOP value represents the average of the most recent N measurement samples.

external modulation
Modulation of a light source by an external device.

>Extrema
Peaks and valleys in a measurement response curve, as in the wavelength scanning PMD application.

femtosecond
10^{-15} seconds

fresnel reflection
The reflection of a portion of incident light at the normal interface between two media of different refractive index.

graticule
An electronically drawn grid on the CRT.

great circle
A circular path on the Poincare sphere which is of the same diameter as the sphere itself. This is the locus of the state of polarization of a lightwave in which orthogonal components are shifting in phase relative to one another.

hold
An instrument feature that allows the user to suspend or halt temporarily the processing and display of new data.

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horizontal resolution
The spacing of the horizontal data points taken over the full sweep.

HP-IB
An abbreviation for Hewlett-Packard Interface Bus.

index matching compound
A fluid with refractive index close to glass that reduces the refractive-index discontinuities caused by air gaps.

index of refraction
The ratio of the speed of light in a vacuum to the speed of light in a material, usually abbreviated n.

initialize
The process in which information locations are assigned to a disk.

insertion loss
The power loss in a transmission system caused by the insertion of a component.

intensity
Brightness; emitting or reflecting light; luminosity, optical power.

interface cable
A multi-wire cable connecting two instruments. Can include the HP-IB cable or a multi-wire cable of the type that connects the computer to the HP 8509 hardware.

interpolate
To determine the value of a signal between two known points by a procedure or algorithm.

Jones calculus
An analytic method for describing fully polarized light and the effects of a two-port optical device or network on the polarization state of fully polarized light. Determination of the Jones matrix is the basis for the Jones matrix eigenanalysis method of PMD measurement and the Jones matrix method of PDL measurement.

Jones matrix
A description of the polarization transforming effect of a two-port optical device or network. The two-by-two complex matrix relates the input and output Jones vectors. The HP8509A/B determines the Jones matrix to within a complex constant which relates to the absolute delay of the signal through the device under test. In other words, the Jones matrix only describes the differences between input and output light, not the time delay.

When the Jones matrix is measured in the fashion described in the basic measurement example above, the results are normalized before they are displayed. In general, the four elements of the matrix are normalized to the value in the lower right hand corner. Both amplitude and angle are normalized. Therefore, the lower right element may be displayed as 1 + j0 in the case of real and imaginary format, or 1.0 at an angle of 0.0 in the case of polar format. If the amplitude of the lower right element is very small and therefore vulnerable to noise, the instrument normalizes to one of the other elements of the matrix. This will be apparent from inspection of the results.

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Jones matrix eigenanalysis

The extraction of information about the polarization behavior of a two-port optical device from the Jones matrix, including the analysis of pairs of Jones matrices measured at different optical frequencies. Also the name given to a PMD measurement method.

Jones vector

An analytical description of the state of polarization. It specifies the amplitude and phase of two orthogonal electric field components within a physical frame of reference (reference directions of orthogonal electric fields).

launch

Typically the condition of coupling light into an optical fiber. May refer to the effectiveness of coupling or the polarization condition of the coupled power.

LED

Light-Emitting diode.

local lock out

A condition or command that prevents any analyzer front panel entries (specifically LOCAL).

local operation

To operate manually from the front panel.

loss

Attenuation of optical signal, normally measured in decibels.

marker

Typically an indicator placed by the user on a graphical display of measurement results.

Maxwell function

The Maxwell function or curve is described by the formula:

$$f(\Delta\tau) = \sqrt{\frac{2}{\pi}}\left(\frac{\Delta\tau^2}{\alpha^3}\right)e^{\frac{-\Delta\tau^2}{2\alpha^2}}$$

where delta tau is the independent variable, corresponding to the value of DGD in this application. Alpha is the single parameter which specifies the shape of the Maxwell curve. The expected value of a Maxwellian probability function is given by alpha*(8/pi)^1/2. The peak or mode of the distribution occurs at alpha*2^1/2.

micron

10^{-6} meters.

modal dispersion

Dispersion arising from differences in the times that different modes take to travel through multimode fiber.

mode

An electromagnetic field distribution that satisfies theoretical requirements for propagation in a waveguide or oscillation in a cavity (e.g., a laser). Light has modes in a fiber or laser.

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mode coupling
The phenomenon which occurs when light travels through a device that consists of sections having different polarization modes. As an example, consider several lengths of PMF spliced randomly together. Light in the principal modes of the first section does not exactly align with the second section, and so on. As a result, each mode is continually split or coupled into new modes. This phenomenon gives long fiber DGD its strong wavelength dependency.

mode coupling factor
A parameter used in the wavelength-scanning formula to account for the wavelength dependence of the principal states of polarization. Use the value 1.0 for non mode coupled devices (most components) and 0.82 for highly mode coupled devices (long fibers).

modulation
A controlled variation with time of any property of a wave for the purpose of transferring information.

multimode
Transmits or emits multiple modes of light.

multiplexer
A device that combines two or more signals into a single output.

NA
Numerical aperture.

nanometer
10^{-9} meters

nanosecond
10^{-9} seconds

normalize
To subtract one trace from another to eliminate calibration data errors or to obtain relative information.

Normalized Stokes Parameters
The parameters displayed in the table at the lower left corner of the main window are the normalized Stokes parameters, referred to as a group as the normalized Stokes vector. The normalized Stokes parameters s1, s2 and s3 are derived by dividing the Stokes parameters S1, S2 and S3 respectively by the total optical power S0.

numerical aperture
NA, the sine of half the angle over which a fiber can accept light. This is multiplied by the refractive index of the medium containing the light, but that equals 1 for air, the normal medium in which NA is measured.

optical cable
A fiber, multiple fibers, or a fiber bundle in a structure fabricated to meet optical, mechanical, and environmental specifications in an installed lightwave system.

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optical coupler

1. A device whose purpose is to distribute optical power among three or more ports.

2. A device whose purpose is to couple optical power between a waveguide and a source or detector.

optical detector

A transducer that generates an electrical signal that is a function of irradiance.

optoelectronic

Pertaining to a device that responds to optical power, emits or modifies optical radiation, or utilizes optical radiation for its internal operation. Any device that functions as an electrical-to-optical or optical-to-electrical transducer.

optical path length

In a medium of constant refractive index (n), the product of the geometrical distance and the refractive index. If n is a function of position, then optical path length = fnds, where ds is an element of length along the path. This expression simplifies to n if the medium has a constant refractive index.

optical waveguide

Any structure (generally a fiber designed to transmit optical signals), capable of guiding optical power.

PDL

See polarization dependent loss.

phase velocity

Velocity of the signal modulating a propagating electromagnetic wave. It is given by c/n where c is the velocity of light in vacuum and n is the refractive index.

phase

The angular relationship between two lightwaves of nominally identical wavelength. In the context of polarization it sometimes refers to the angular relationship between orthogonal electric field components of a lightwave, as defined within a physical frame of reference.

photodetector

A light detector.

PMD

See polarization mode dispersion.

Poincare sphere

A spherical representation of polarization states. Each point on the sphere represents the same information as the more familiar polarization ellipse along with the handedness (left or right) of the polarization. All linearly polarized states fall on the equator. Right- and left-handed polarization fall at the north and south poles, respectively. All elliptical states are between the equator and the poles, right-handed elliptical in the northern hemisphere and left-handed in the southern. Orthogonal polarization states are diametrically opposite one another on the Poincare sphere. For example, rotation of a linear polarizer by 90 degrees in a light beam moves the point on the sphere along the equator by 180 degrees. Phase shift between orthogonal electric field components of a lightwave is represented by a circular path on the Poincare sphere. If the components are of equal magnitude, the circle is a great circle (having the diameter of the sphere itself).

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polarized light

Fully polarized (or simply "polarized") light can be represented by a pair of orthogonal electric field components of defined magnitude and relative phase. Fully polarized light has no unpolarized component, therefore the degree of polarization is 100 %.

polarization

Refers to the behavior of the electric field vector of an optical signal. If the path of the instantaneous electric field vector of a lightwave falls in a plane, it is linearly polarized. It follows a circular spiral path, it is circularly polarized. If it follows an elliptical spiral path, it is elliptically polarized. Polarized light may contain more than a single frequency. However, light of non-zero spectral width may depolarize as it passes through dispersive devices.

polarization state

See State of Polarization

polarization controller

A device used to adjust the relative phase of orthogonal electric field components of a lightwave. A polarization controller may consist of loops of fiber, cascaded optical retarders, or a material of adjustable birefringence such as liquid crystal.

polarization dependent loss

Abbreviated PDL, polarization dependent loss refers to the maximum variation of optical insertion loss of a fiber or component as a function of polarization state. The term is also loosely used in connection with the same principle in amplifier gain, although the more specific polarization dependent gain (PDG) may be used.

polarization ellipse

The elliptical representation of lightwave polarization in which the locus of the propagating electric field vector is traced in a plane normal to propagation. The polarization ellipse is typically described within a physical reference frame (reference directions for orthogonal electric field components) in terms of ellipticity and azimuthal angle. Circular and linear polarized light represent the extremes of ellipticity.

polarization mode dispersion (PMD)

PMD is a fundamental property of optical devices by which an optical signal is split into two waves of different propagation velocity according to polarization state. The difference of propagation time between the fast and slow mode at a given wavelength is called the differential group delay (DGD). The term "PMD" also refers to the average DGD across a wide wavelength range of across a wide range of environmental conditions.

polarization reference frame

A polarization reference frame may be created at any point in an open beam environment with the use of a precision rotatable polarizer and the Jones matrix measurement capability of the HP 8509A/B Lightwave Polarization Analyzer. Reference frames are of two types:

The 3pt frame of reference mathematically removes birefringence and polarization dependent loss from the path between the reference polarizer and the polarization analyzer receiver. This method requires that the reference polarizer be set precisely to the angles listed in the polarizers display, found by selecting the Polarizers from the System menu in the main window.

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The 2pt frame of reference mathematically removes only birefringence from the path between the reference polarizer and the polarization analyzer receiver. This method requires only two orientations of the polarizer and the angle between them is not critical.

Following application of a reference frame, rotation of the reference polarizer should cause the point on the Poincare sphere to move along the equator.

polarizer
An optical device, sometimes called a polarization filter, which passes light of a selected polarization state.

port
An input or output point of a circuit or device.

power
See irradiance; radiant power.

preset
1. A predefined instrument state (which also runs a self-test in the analyzer).

2. The action of pushing the PRESET key.

reference frame
See polarization reference frame.

reference polarizer
Creation of a polarization reference frame requires a reference polarizer. Measurements of two or three angular rotations of the polarizer are required.

reflection
The phenomenon in which a traveling wave that strikes a discontinuity is returned to me original medium.

refraction
The bending of light as it passes between materials of a different refractive index.

remote
A mode of operation where an instrument is controlled by another device or computer via the HP-IB or from the HP 8509's computer via DDE.

return loss
The ratio in dB between power incident upon and power reflected from a device. Represented by a p symbol.

self-test
A group of tests performed at power-up or preset to verify proper instrument operation.

shutter
A device which can block the optical beam upon command.

signal-to-noise ratio
The ratio of signal to noise, measured in decibels, and indication of signal quality in analog systems.

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single mode
Containing only one mode. Beware of ambiguities because of the difference between transverse and longitudinal modes. A laser operating in a single transverse mode typically does not operate in a single longitudinal mode.

single-frequency laser
A laser that emits a range of wavelengths small enough to be considered a single frequency.

SOP
See State of Polarization

source
A device which supplies signal power. Used in this document:

1. To refer to sweep oscillators or synthesized sweepers, and;
2. To refer to the signal source integrated in the analyzer.

splice
A permanent junction between two fiber ends.

standard deviation
The root sum of the squares of the deviation of individual data points from the mean or average value.

State of Polarization
As a description of a lightwave signal, the term "State of Polarization" is an overall label that includes several pieces of information; total optical power, degree of polarization, and a description of the polarized portion of the light within some polarization reference frame. All of these parameters are measured by the HP8509A/B. Sometimes the term SOP is used informally to denote the polarization state displayed on the Poincare sphere.

Stokes parameters
The Stokes parameters are the four fundamental measurements produced by an optical polarimeter. The first parameter, S0, describes the total average optical power, including polarized and unpolarized elements. The second parameter, S1, describes the difference in power between the horizontal and vertical linearly polarized components of the signal. The S2 parameter describes the difference in power between the +45 and -45 degree linearly polarized components. The last parameter, S3, describes the difference in power between the right and left hand circularly polarized components. See also Normalized Stokes Parameters.

termination
A load connected to a transmission line or other device.

thru
An abbreviation for "through" which is used to refer to the calibration technique in which the measurement planes are connected together and the through path is measured.

timed
The name given to the HP 8509 A/B feature which captures the polarization characteristics of a signal at intervals of time. Available modes include free-run, timed and single.

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toggle
To switch states, usually to change a function from on to off or off to on.

transfer function
A complex function (magnitude and phase) equal to the ratio of output to input as a function of modulation frequency.

transmission
The measurement of the insertion loss or gain of a network or device.

Transmission Ratio (3pt Reference Frame)
Transmission ratio is a measure of the equivalent PDL of the path between the reference polarizer and the HP8509A/B polarization receiver, expressed in linear terms, for a 3pt polarization reference frame. The equivalent PDL is found by multiplying the log to base ten of the displayed number by ten. An excellent reference frame shows a transmission ratio of 1.0, equivalent to a PDL of 0 dB.

The equivalent PDL specified by the transmission ratio does not necessarily describe real PDL in the measurement bath between reference polarizer and HP8509A/B. The quality of the reference frame can be degraded by not only weak or strong polarizing elements, but also by low signal level, incorrect setting of the reference polarizer angles or movement of fibers between polarizer rotations.

variable
A symbol, the numeric value of which changes from one iteration of a program to the next or within each iteration of a program.

vector
A quantity that has both magnitude and phase.

vertical Resolution
The degree to which an instrument can differentiate between two closely spaced signal amplitudes.

waveguide
A structure that guides electromagnetic waves along its length. An optical fiber is an optical waveguide.

wavelength
The distance an electromagnetic wave travels in the time it takes to oscillate through a complete cycle. Wavelengths of light are measured in nanometers (10^{-9}m) or micrometers (10^{-6}m).

wavelength calibration
The HP8509A/B provides a wavelength calibration process that allows the operator to improve upon the built-in calibration for a particular source, even if the wavelength of the source is not accurately known. The HP8509A/B contains in memory a set of factory calibration coefficients that optimize the accuracy of the polarimeter at a series of discrete wavelengths. Between these wavelengths, the instrument interpolates special calibration coefficients. For accurate operation of the instrument, the user must enter the operating wavelength to at least 1 nm accuracy. It is suggested that the wavelength be entered to 0.1 nm accuracy if the source is a single line source and the wavelength is well known. Errors in the entry of wavelength will affect all measurements. The effect is quite apparent in

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the DOP measurement. When measuring fully polarized light from a fiber, the DOP will fluctuate about 100% as the fiber is moved. Larger wavelength error produces a greater DOP fluctuation.

wavelength-scanning

A method for measurement of PMD in which the source wavelength is changed over a broad range and the output polarization state is monitored. The number of "cycles" of change in the output polarization state over the given wavelength range indicates the amount of PMD present in the test device.

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