# Agilent 8509C Lightwave Polarization Analyzer User's/Reference Guide

Agilent Technologies

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CAUTION

The *caution* sign denotes a hazard. It calls attention to a procedure which, if not correctly performed or adhered to, could result in damage to or destruction of the product. Do not proceed beyond a caution sign until the indicated conditions are fully understood and met.

WARNING

The *warning* sign denotes a hazard. It calls attention to a procedure which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a warning sign until the indicated conditions are fully understood and met.

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.

❍ The OFF symbols are used to mark the positions of the instrument power line switch.

The CE mark is a registered trademark of the European Community.

The CSA mark is a registered trademark of the Canadian Standards Association.

The C-Tick mark is a registered trademark of the Australian Spectrum Management Agency.

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

**Typographical Conventions.**
The following conventions are used in this book:

Key type for keys or text located on the keyboard or instrument.

*Softkey type* for key names that are displayed on the instrument's screen.

`Display` type for words or characters displayed on the computer's screen or instrument's display.

**User type** for words or characters that you type or enter.

*Emphasis* type for words or characters that emphasize some point or that are used as place holders for text that you type.

# General Safety Considerations

This product has been designed and tested in accordance with IEC Publication 61010-1, Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use and the standards listed on the Manufacturer's Declaration of Conformity, and has been supplied in a safe condition. The documentation contains information and warnings that must be followed by the user to ensure safe operation and to maintain the product in a safe condition.

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

**WARNING** **For continued protection against fire hazard, replace line fuse only with same type and ratings, (type T 0.315A/250V for 100/120V operation and 0.16A/250V for 220/240V operation). The use of other fuses or materials is prohibited.**

**WARNING** **Verify that the value of the line-voltage fuse is correct.**

- For 100/120V operation, use an IEC 127 5×20 mm, 0.315 A, 250 V, Agilent part number 2110-0449.
- For 220/240V operation, use an IEC 127 5×20 mm, 0.16 A, 250 V, Agilent Technologies part number 2110-0448.

**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** **To prevent electrical shock, disconnect the Agilent 8509C from mains before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not attempt to clean internally.**

**WARNING** **If this instrument is not used as specified, the protection provided by the equipment could be impaired. This product must be used in a normal condition (in which all means for protection are intact) only.**

**WARNING** **Do not stare directly into any optical port or into the ends of optical fiber patch cords. Any emitted light, although divergent, will cause permanent eye damage at sufficient power levels. Avoid exposure to light reflected by mirrors or other reflective surfaces.**

**WARNING** **When a laser source is connected to the Agilent 8509C external source input, the Optical Output will emit laser light. This light, although divergent, will cause permanent eye damage at sufficient power levels.**

**WARNING** **To avoid inadvertent exposure to laser light, extinguish the external laser source and enable the Agilent 8509C internal shutter before removing optical connectors from any optical port on the Agilent 8509C. Refer to "Using the Shutter functions" on page 6-19 for more details on activating the internal shutter.**

**WARNING** **Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.**

**CAUTION** Always use the three-prong ac power cord supplied with this product. Failure to ensure adequate earth grounding by not using this cord may cause product damage.

**CAUTION** This product is designed for use in Installation Category II and Pollution Degree 2 per IEC 61010-1 and 664 respectively.

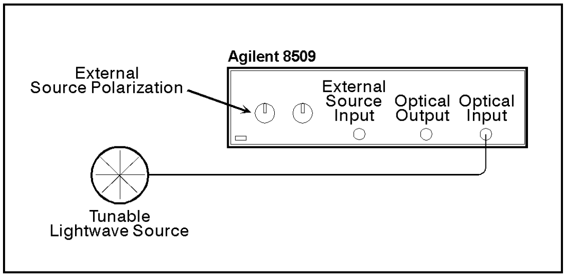
**CAUTION** VENTILATION REQUIREMENTS: When installing the product in a cabinet, the convection into and out of the product must not be restricted. The ambient temperature (outside the cabinet) must be less than the maximum operating temperature of the product by 4°C for every 100 watts dissipated in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

**CAUTION** Maximum input power: The optical damage level for the Agilent 8509C Optical Input port is +16 dBm. Exceeding this power level may result in permanent damage to the instrument. Refer to "Receiver characteristics" on page 9-10 for more information.

Maximum output power: The power appearing at the Agilent 8509C Optical Output is the power inserted at the External Source Input port minus the External Source path insertion loss. Refer to "External Source Input Port, Fiber Size, and Analog Output Range Characteristics" on page 9-12.

Optical Output Port beam divergence: The Agilent 8509C input and output ports use standard SMF-28 9-micron single-mode fiber with a numerical aperture of 0.14. This results in a beam divergence angle of 8° at 1550 nm.

## Laser Aperture Location




**Measurement accuracy—it's up to you!**

Fiber-optic connectors are easily damaged when connected to dirty or damaged cables and accessories. The Agilent 8509C's front-panel INPUT connector is no exception. When you use improper cleaning and handling techniques, you risk expensive instrument repairs, damaged cables, and compromised measurements.

Before you connect any fiber-optic cable to the Agilent 8509C, refer to "Cleaning Connections for Accurate Measurements" on page 7-14.

## General Safety Considerations

# Contents

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# Setting Up the Lightwave Polarization Analyzer

# Setting Up the Lightwave Polarization Analyzer

This chapter shows how to set up your lightwave polarization analyzer, connect power and accessories, and verify general operation.

Refer to Chapter 7, “Reference” for the following information:

- Tips on avoiding costly repairs by proper optical connection cleaning techniques.
- List of available options, accessories, and power cords.
- Instructions on returning your instrument to Agilent Technologies for service.
- Agilent Technologies service offices.
- Accuracy enhancement and troubleshooting information.

# Installation

The lightwave polarization analyzer is preconfigured at the factory and requires a minimal amount of time to complete. All that is required to install the system is to unpack the pieces, correctly connect them, and turn them on.

For the quickest installation of your Agilent 8509C system, use the *Installation Quick Reference Card* that came attached to the top cover of your lightwave polarization analyzer.

**Tools needed**

No special tools are required for the basic installation of the Agilent 8509C system. A small flat-blade screwdriver may be used to secure the monitor and analyzer interconnect cables.

**Installation overview**

The installation consists of unpacking the pieces of the system, correctly connecting them, and then turning them on.

After installation is complete, operation verification is performed to verify that the system is operating properly.

If you encounter a problem while performing the installation or operation verification, refer to "If You Have a Problem" on page 7-24.

# Power Requirements

The power requirements include line frequency in the range of 47 to 66 Hz, and 200 VA maximum. Other power requirements for the lightwave polarization analyzer are listed in Table 1-1.

**Table 1-1. Fuses**

| Available ac Voltage | Voltage Range | Fuse Type | Agilent Part Number |
|---|---|---|---|
| 100 V | 90 to 110 V rms | 2.00 A F | 2110-0002 |
| 120 V | 108 to 132 V rms | 2.00 A F | 2110-0002 |
| 220 V | 198 to 242 V rms | 1.00 A F | 2110-0001 |
| 240 V | 216 to 250 V rms | 1.00 A F | 2110-0001 |

On the lightwave polarization analyzer, set the line-voltage selector to the voltage corresponding to the power source used. The line voltage selector is located on the rear panel of the polarization analyzer.

**Note**

If you need to change the switch setting or the fuse, refer to Figure 1-1 and use a small flat-blade screwdriver to pry open the line module cover door.

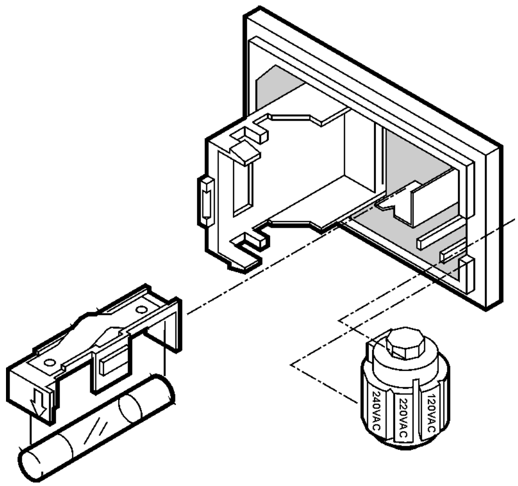



**Figure 1-1. Voltage selector**

**CAUTION** Do not attempt to rotate the voltage selector cam while it is installed in the line module or non-repairable damage will result. The cam must be completely removed from the line module, rotated to the proper position, and reinstalled. Refer to the instruction below.

Replacement of Fuse

**1** Pry open line module cover door.

**2** Pull out fuse carrier.

**3** Insert fuse of proper rating.

**4** Place carrier back into line module.

Selection of Operating Voltage

**1** Pry open line module cover door.

**2** Remove cam from the line module.

**3** Rotate the cam to the desired voltage. (When the line module cover is closed, the selected voltage will be visible through a small window).

**4** Insert the cam back into the line module.

**5** Close the line module cover door.

# Step 1. Unpack and Inspect the System

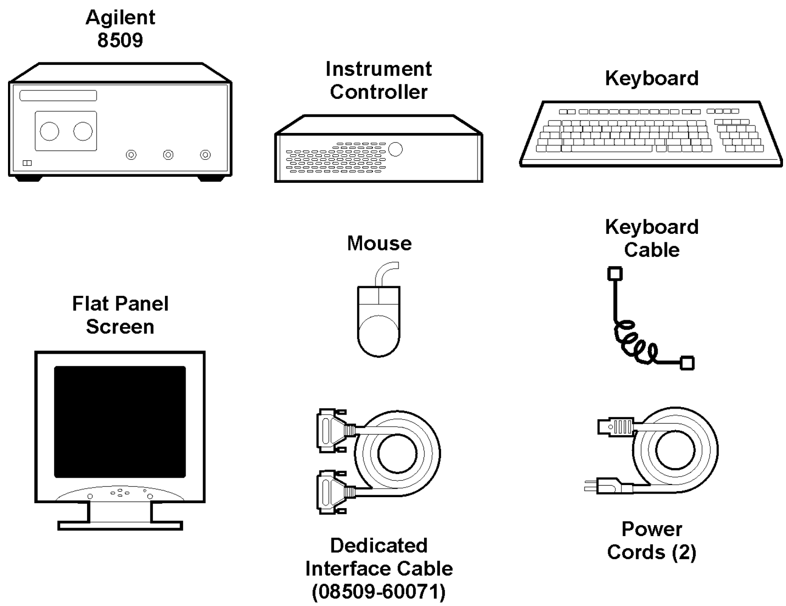



**Figure 1-2. Package contents for the Agilent 8509C**

- ❒ Inspect the shipping container for damage.
- ❒ Inspect the instrument.
- ❒ Verify that you received the options and accessories you ordered.
- ❒ Gather the items shown in Figure 1-2, and put all other hardware, documentation, and software aside for now.

Keep the shipping container and cushioning material until you have inspected the contents of the shipment for completeness and have checked the lightwave polarization analyzer mechanically and electrically.

If anything is missing or defective, contact your nearest Agilent Technologies Sales Office. If the shipment is damaged, contact the carrier, then contact the nearest Agilent Technologies Sales Office. Keep the shipping materials for the carrier's inspection. The Agilent Technologies Sales Office will arrange for repair or replacement at Agilent Technologies' option without waiting for claim settlement.

# Step 2. Stack and Connect the System

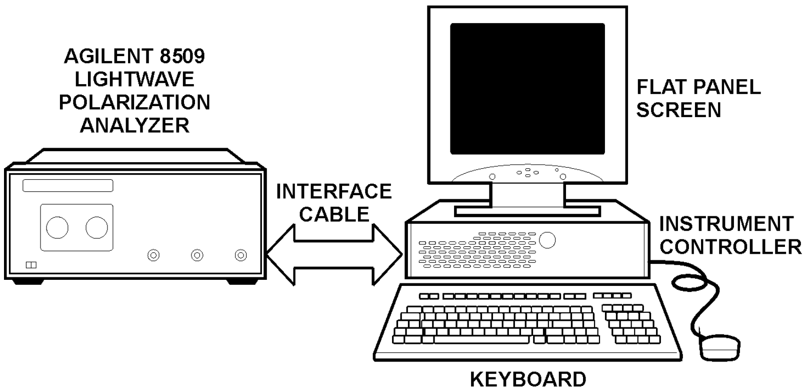



**Figure 1-3. Agilent 8509C system**

**1** Set the lightwave polarization analyzer on your work surface. Place the instrument controller next to the lightwave polarization analyzer, place the monitor on top of the instrument controller. Place the keyboard in front of the instrument controller and place the mouse to the side of the system. Refer to Figure 1-3 for an example of how to stack your system.

> **Note**
>
> Do *not* stack the instrument controller or monitor on top of the lightwave polarization analyzer.

**2** Connect the system as shown in Figure 1-4.

**a** Connect the lightwave polarization analyzer to the instrument controller using the dedicated interface cable.

**b** Connect the monitor, keyboard, and mouse to the instrument controller. Refer to Figure 1-4 for locations of ports.

**c** Tighten connections with a small flat-blade screwdriver.

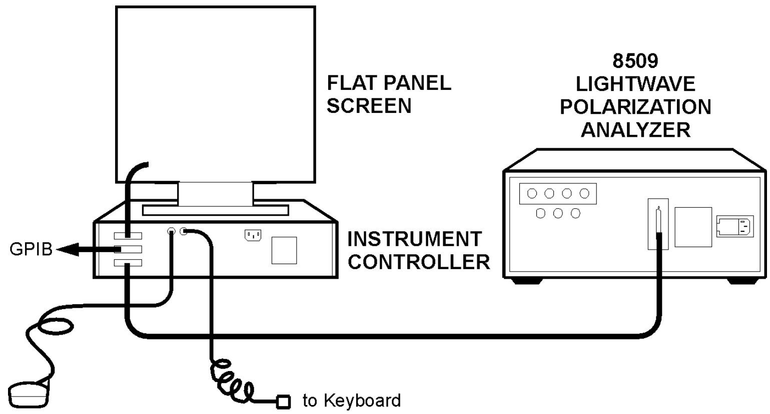



**Figure 1-4. System connections**

# Step 3. Power Up the System

**1** Connect the three power cords (one each from the instrument controller, the monitor and the analyzer) to the line voltage.

**2** Press the front-panel power switches on the analyzer, instrument controller, and monitor.

**3** After the instrument controller is turned on, Microsoft Windows[1] and the Agilent 8509C software are automatically loaded. After about 45 seconds the basic measurement screen should appear on the instrument controller display, similar to Figure 1-5.

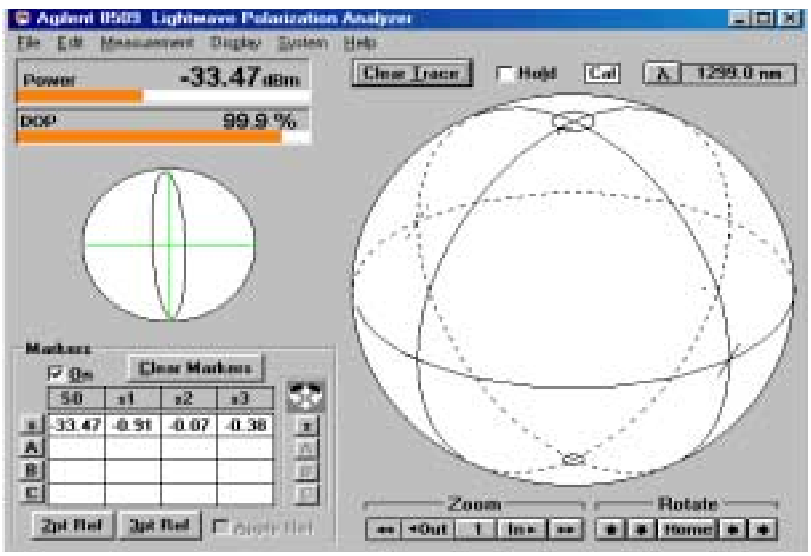



**Figure 1-5. The Agilent 8509C user interface basic measurement screen**

You will hear a series of clicks as the internal mechanical polarizer is initialized; then the zeroing routine is performed. You will notice a green zeroing message in the power display while this procedure is being executed.

1. Microsoft Windows is a U.S. registered trademark of Microsoft Corporation.

**4** Perform the operation verification now to ensure the lightwave polarization analyzer is working properly.

If you encounter a problem while performing the installation or operation verification, refer to "If You Have a Problem" on page 7-24.

# Step 4. Operation Verification

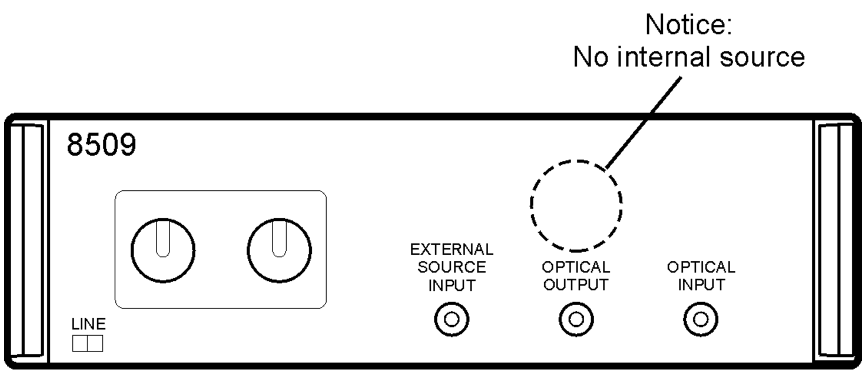



**Figure 1-6. Agilent 8509C front panel**

The operation verification is designed to be performed when you first receive and install your Agilent 8509C (option 210, 220) and thereafter on a regular basis. If performed successfully, it will give you a high degree of confidence that your analyzer is working properly.

**Required Equipment**

The following items are needed to perform the operation verification:

- Optical source of known wavelength in one of the two following ranges.

  between 1280 and 1340 nm
  between 1470 and 1640 nm

- High-quality single mode patchcords. Refer to Table 1-2.

**Table 1-2. Recommended Patchcords**

| Connector Type | Option Number |
|---|---|
| HMS-10 | 011 |
| FC/PC | 012 (shipped with instrument) |
| DIN | 013 |
| ST | 014 |
| Biconic | 015 |
| SC | 017 |

### *Preliminary Steps*

**1** Turn on the lightwave polarization analyzer and allow it to warm up for at least one hour.

**2** Clean all optical connectors and adapters using isopropyl alcohol and cotton swabs. Refer to “Cleaning Connections for Accurate Measurements” on page 7-14.

**3** Ensure that the optical cable connecting the external source to the lightwave polarization analyzer’s OPTICAL INPUT is stable. This can be accomplished by taping the cable to the work surface if necessary.

**4** Connect the equipment as shown in Figure 1-7 on page 1-14.

**5** Zero the analyzer by selecting *System* and then *Zero*. You will notice the green `zero` message will appear in the Power display while the analyzer is zeroing.

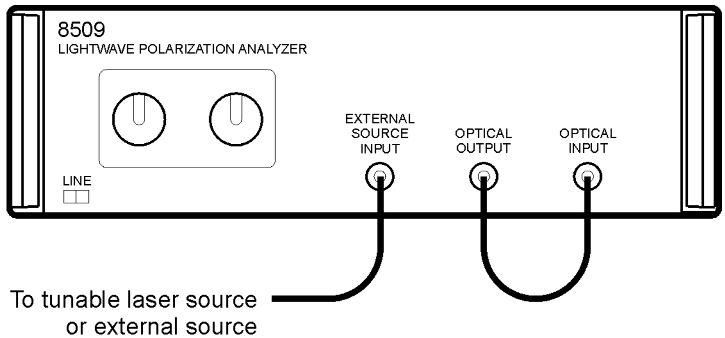



**Figure 1-7. Equipment setup**

### *Setup Your Source*

**6** Select λ. The Optical Source Setup window will appear on the display, as shown in Figure 1-8.

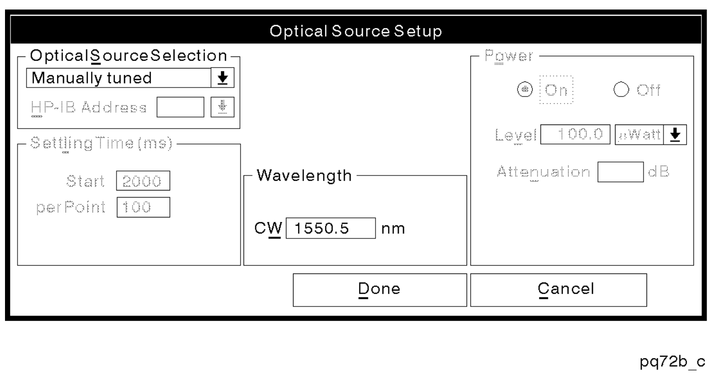



**Figure 1-8. Optical Source Setup window**

**7** Select your source type from the *Optical Source Selection* menu.

**8** Input the wavelength of your optical source (to an accuracy of ±1 nm) using the keyboard.

**9** Select Done. The optical source setup window will disappear.

### *Adjust For Maximum Power*

**10** Adjust the two large External Source Polarization knobs to obtain maximum power into the receiver. Observe the power display while turning the knobs to monitor power.

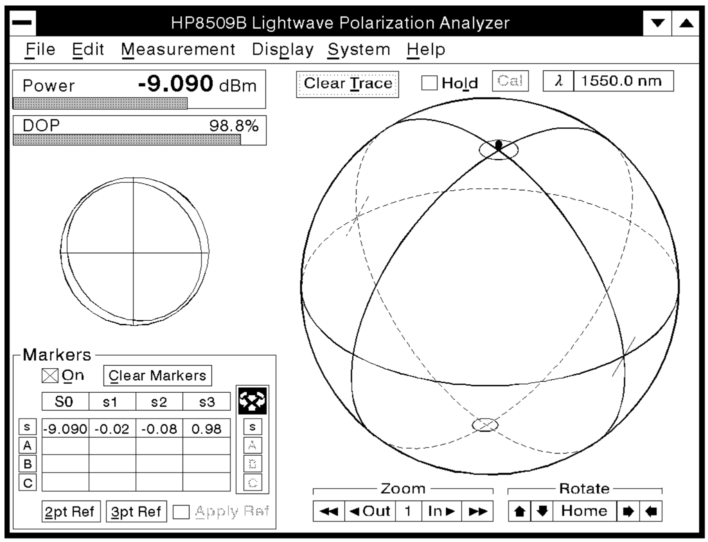



**Figure 1-9. Agilent 8509C basic measurement screen**

### *Operation Verification*

The operation verification procedure is a fully automatic pass/fail indicator of your system's performance.

**11** Make sure that 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 if necessary.

**12** Select *System* from the main window display, then select *Operation Verification*.

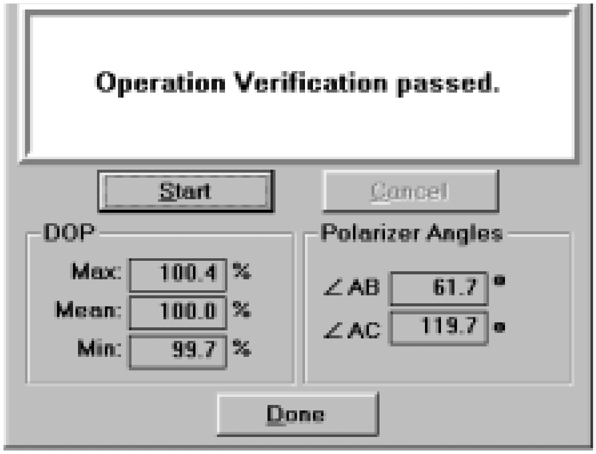



**Figure 1-10. Operation Verification window**

**13** Select Start. When the verification procedure is finished, the message `Operation Verification passed` will be displayed in the message window, and the Max, Min, and Mean DOP values and polarizer angles will be displayed.

**14** The operation verification is now complete. You may select Done to clear the window and begin your measurement.

If you encounter a problem while performing the installation or operation verification, refer to "If You Have a Problem" on page 7-24.

2



# A Quick Tour

# A Quick Tour

The Agilent 8509C lightwave polarization analyzer offers high-speed, calibrated polarization measurements of optical signals and components.

This chapter describes the functions that are available from the basic measurement screen initially displayed when the analyzer is turned on and a brief overview of the functions accessed from the main menu.

# The Main Menu

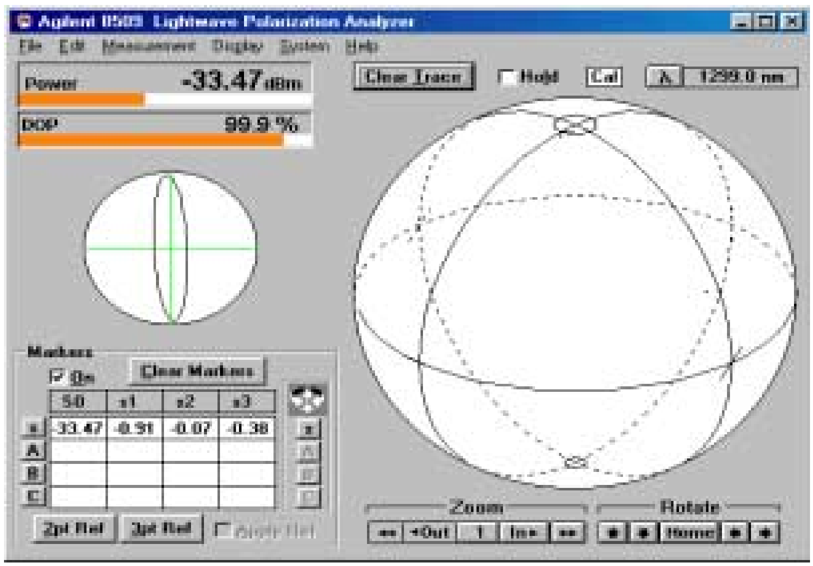



**Figure 2-1. The Agilent 8509C basic measurement screen**

Screen shots may reflect an older software version than the currently used version.

# Data Displays

Refer to Figure 2-1 on page 2-3 for the location of the displays on the basic measurement screen.

## Power

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

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.

## 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.

# Markers

The marker window, in the lower-left corner of the Agilent 8509C 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 additional information regarding Stokes parameters, refer to "Stokes parameters" on page 4-100.

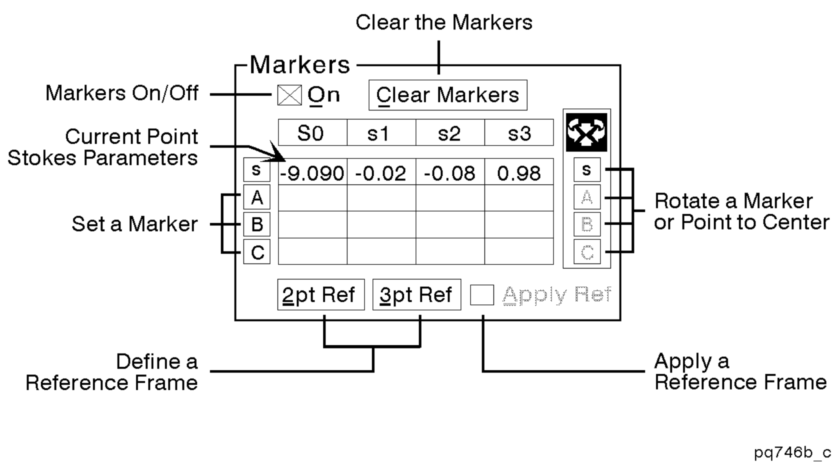



**Figure 2-2. The Marker window**

## To set 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.

## To set 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 2-3.)

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.

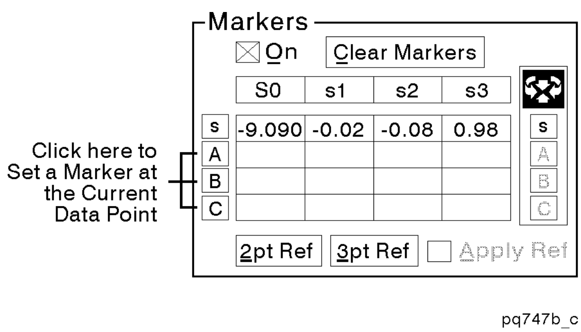



**Figure 2-3. Setting a marker**

## To set 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 2-4).

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.

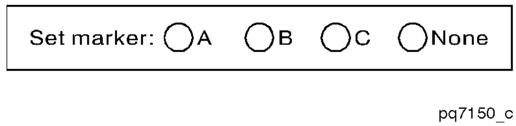



**Figure 2-4. Set marker window**

## To turn the markers on and off

When the markers are turned ON, there is an "X" in the Markers On box (see Figure 2-5).

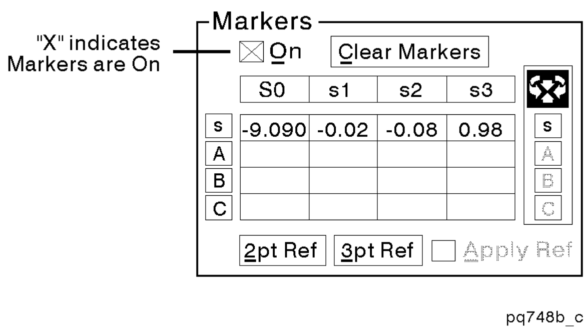



**Figure 2-5. Turn markers on/off**

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.

## To clear the markers

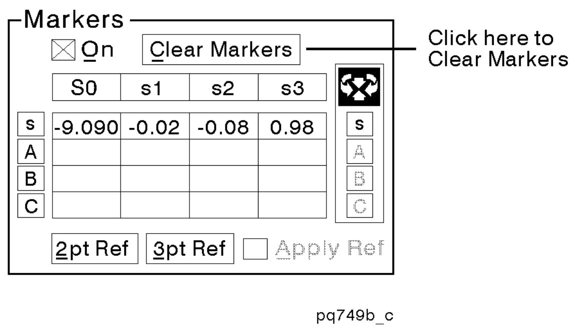



**Figure 2-6. Clear markers**

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.

## To center the sphere on a marker or current point

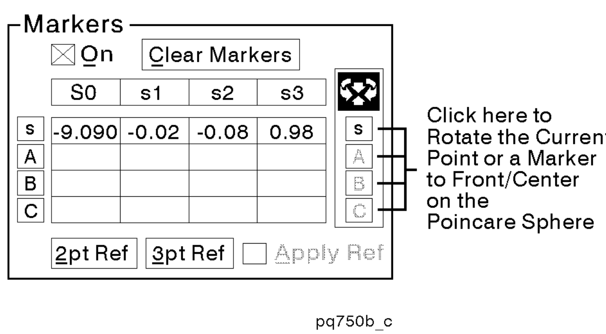



**Figure 2-7. Center sphere on marker**

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.

### To set a two- or three-point polarization reference

For information on setting a two- or three-point polarization reference frame, refer to “Making Polarization Reference Frame Measurements” on page 4-85.

## Poincare sphere

The Agilent 8509C 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.

## Zoom and Rotate

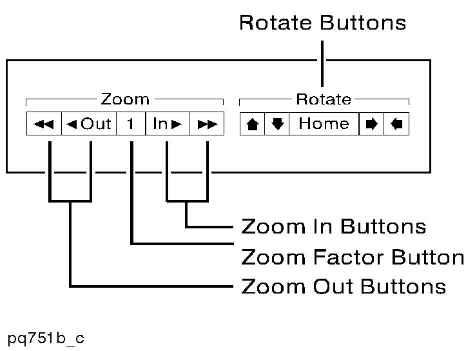



**Figure 2-8. Zoom and Rotate**

### To zoom in or out

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

## To set the zoom factor

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.

## To rotate the sphere

To rotate the sphere, select any of the four arrows in the Rotate area (refer to Figure 2-8). The sphere will rotate in the direction of the selected arrow.

## To return the sphere to the default orientation

To return the sphere 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. (Refer to Chapter 3, "Using the File Menu".) In these cases, the recalled trace will not be cleared as the sphere is rotated.

**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.

# Clear Trace and Hold

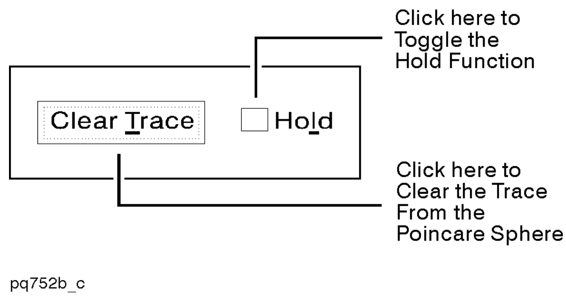



**Figure 2-9. Clear Trace and Hold**

## To clear the Poincare sphere of previously displayed data points

Select Clear Trace. The Agilent 8509C will immediately resume data display unless the Hold function has been activated.

## To activate the hold function

When Hold is activated, the Agilent 8509C 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 (refer to Figure 2-9). Putting the instrument on Hold dramatically speeds up graphics and computational activity in the computer. Put the Agilent 8509C in Hold when running other software programs.

# λ and Cal

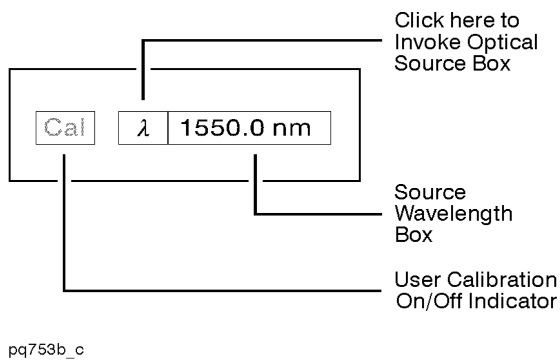



**Figure 2-10. λ and Cal**

## To display the Optical Source window

Select λ. Refer to "Using the Optical Source functions" on page 6-4 for more information.

## To display the source wavelength

The source wavelength is displayed next to the λ function.

## To display whether a user-performed calibration has been applied

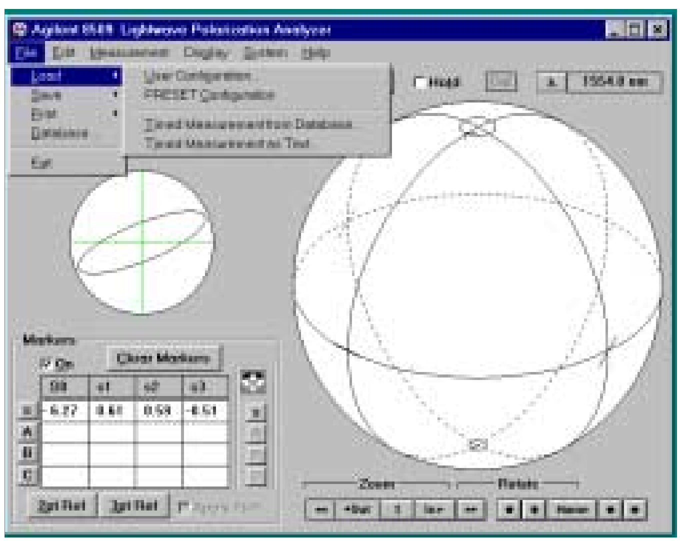
The Cal function indicates whether or not a user-performed calibration has been applied. If a wavelength calibration has been applied, the word `Cal` appears in bold (black) lettering. If a calibration has not been applied, the word `Cal` appears in gray lettering. Refer to "Using the Calibration functions" on page 6-6 for instructions on performing a wavelength specific calibration.

# The Menu Bar

The Menu bar includes the File, Edit, Measurement, Display, System, and Help drop down menus.

## File menu

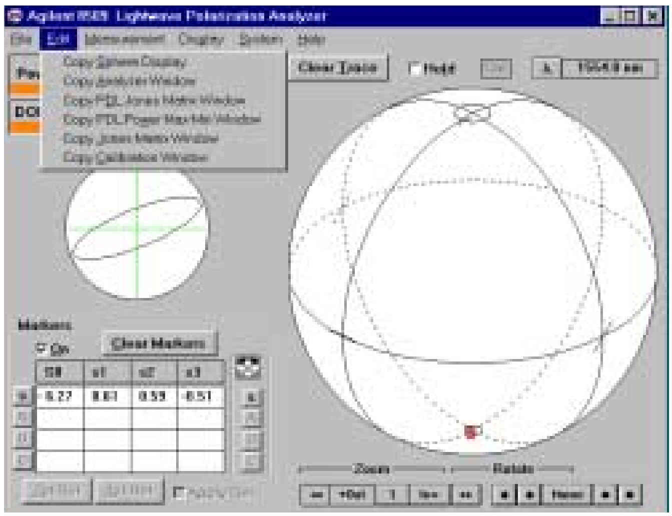
Most of the menu items under this selection are explained in Chapter 3, “Using the File Menu”.



# Edit menu

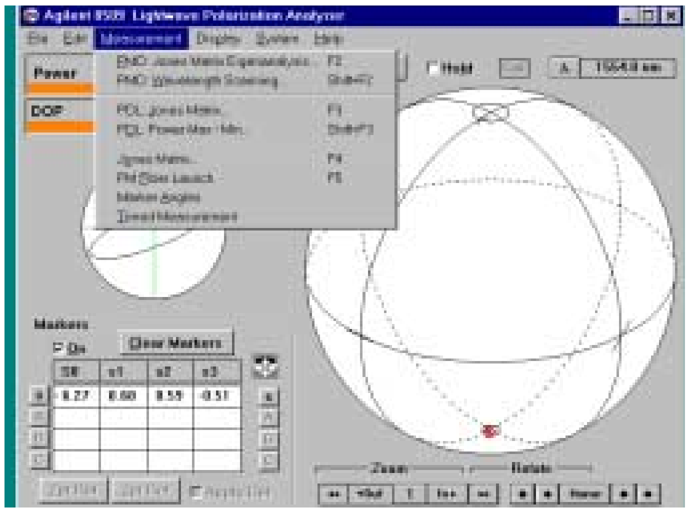
This selection allows you to copy the display or a measurement window to the Clipboard.

**Note**: The Edit Menu allows you to print the screen in bitmap format, but will not print the data.



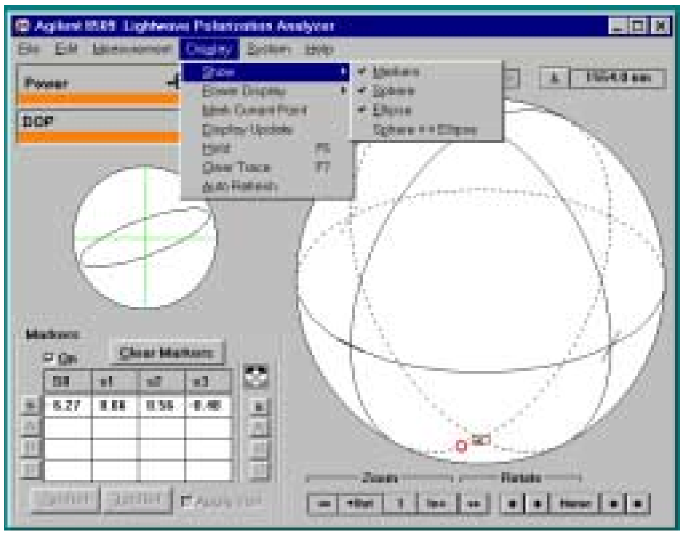
## Measurement menu

The measurement selections are discussed in Chapter 4, “Using the Measurement Menu”.



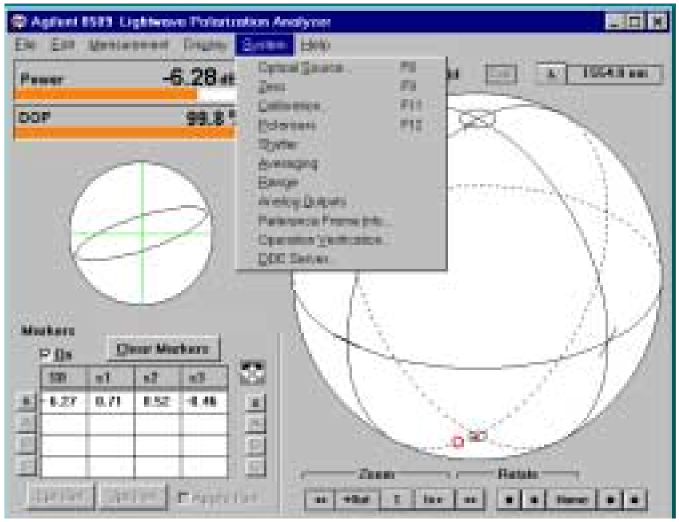
# Display menu

The items in the Display menu are discussed in Chapter 5, “Using the Display Menu”.



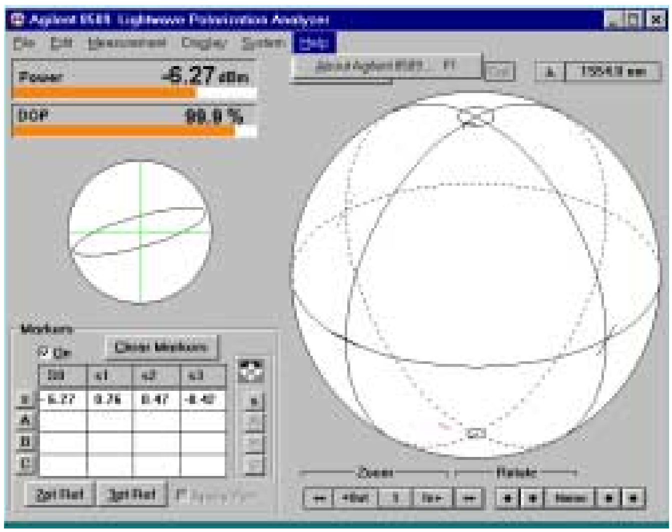
# System menu

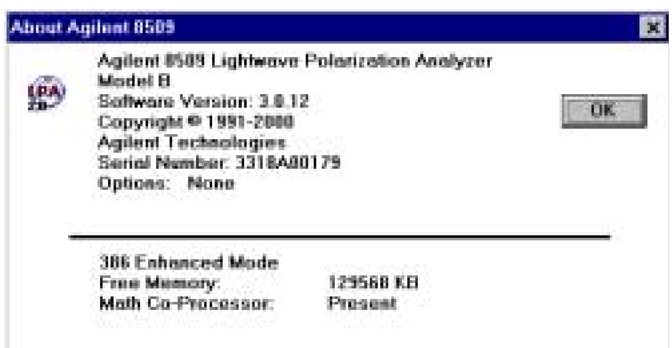
The system functions are described in Chapter 6, “Using the System Menu”.



# Help menu

The About Agilent 8509 menu allows you to determine information such as the software version, free memory, and the 8509 serial number.



# Using the File Menu

# The File Menu

This chapter contains information about the File menu (in the main window), which allows you to print, save, and recall measurement results and instrument configurations.

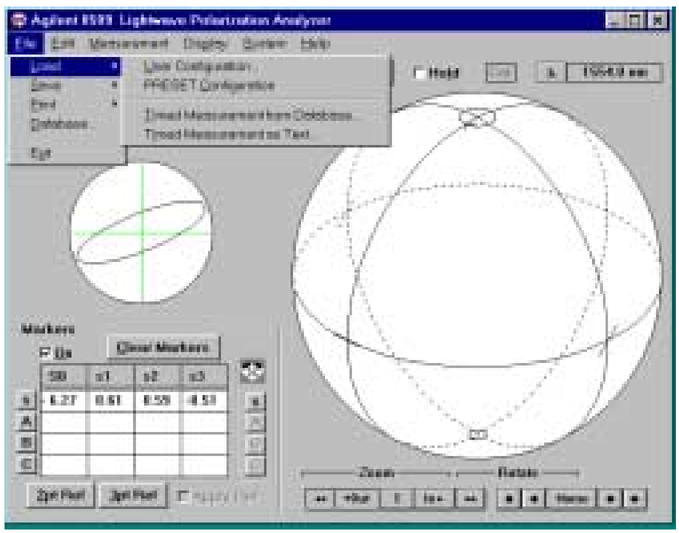



**Figure 3-1. File menu**

The following functions are available:

| Function | See.... |
| --- | --- |
| Load | "To save and recall instrument configurations" on page 3-4<br>"To create a configuration file with factory defaults" on page 3-5<br>"To recall the preset configuration" on page 3-5<br>"To recall a user configuration" on page 3-6<br>"To recall measurement results" on page 3-7 |
| Save | "To save measurement results" on page 3-11<br>"To save a user configuration" on page 3-13 |
| Print | "To print measurement results" on page 3-14 |
| Database.... | "To retrieve previously archived measurements" on page 3-18<br>"To perform database operations" on page 3-19 |

**Additional Information**

For step-by-step instructions on making measurements and for more detailed information about a particular measurement, refer to Chapter 4, "Using the Measurement Menu". For information regarding calibrations, refer to Chapter 6, "Using the System Menu".

# Using the Load functions

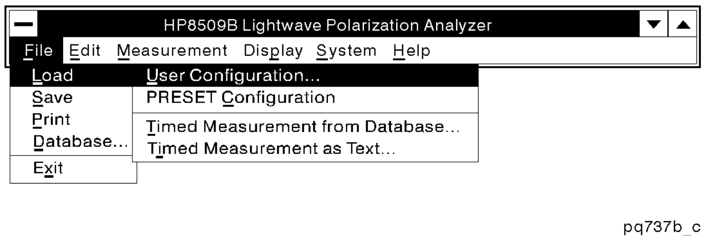



**Figure 3-2. Load menu**

## To save and recall instrument configurations

The Agilent 8509C 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 start-up.

You can change conditions via the 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.

**Note**: 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 Agilent 8509C recalls the configuration file hp8509.cfg at start-up. 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 cannot find a file, the polarization analyzer uses the preset configuration. The preset configuration is set in the factory and never changes.

To start the Agilent 8509C with other than the default hp8509.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 Agilent 8509C icon and selecting File, Properties in the Windows Program Manager, or pressing ALT+ ENTER on the keyboard.

### 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.

### To recall 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.

***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 Figure 3-3. Select OK to load the preset configuration, or select Cancel to cancel the command.

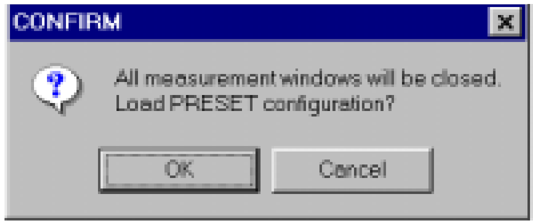



**Figure 3-3. PRESET confirmation window**

## To recall 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.

***Procedure***

To call up an instrument state that has been stored:

1 Select *File*, *Load* in the main menu.

2 Select *User Configuration*.

3 The Load: Configure File window opens. See Figure 3-4 on page 3-6.

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.

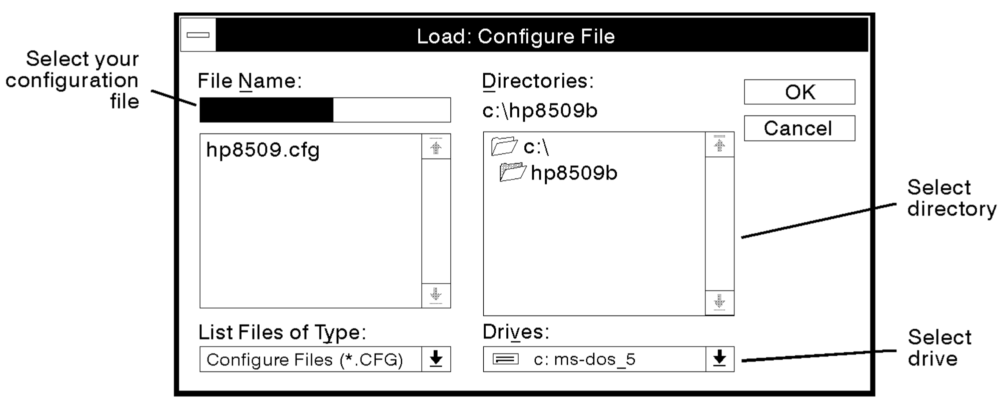



**Figure 3-4. Load: Configure File window**

## To recall measurement results

After saving measurement results, you can recall and view the results as summarized in Table 3-1 on page 3-17. Recall the results using the Agilent 8509C instrument controller software and/or separate word processor, spreadsheet, or database program as noted. Agilent 8509C procedures are discussed in detail below. Numeric word processor, spreadsheet, or database file formats are discussed briefly at the end of this section.

### Agilent 8509C 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 in Chapter 4, "Using the Measurement Menu".

1. Select *FILE*, *LOAD*, and then one of the Load sub-menu selections shown in Figure 3-2 on page 3-4.
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 3-1 on page 3-17.
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 Figure 3-5 on page 3-8. 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.

4. For a detailed description of the database file loading operation, refer to "To perform database operations" on page 3-19.
5. To resume normal operation of the lightwave polarization analyzer, toggle the Hold function by selecting Hold. See Figure 3-5 on page 3-8.

## Agilent 8509C File Recall

### *Results*

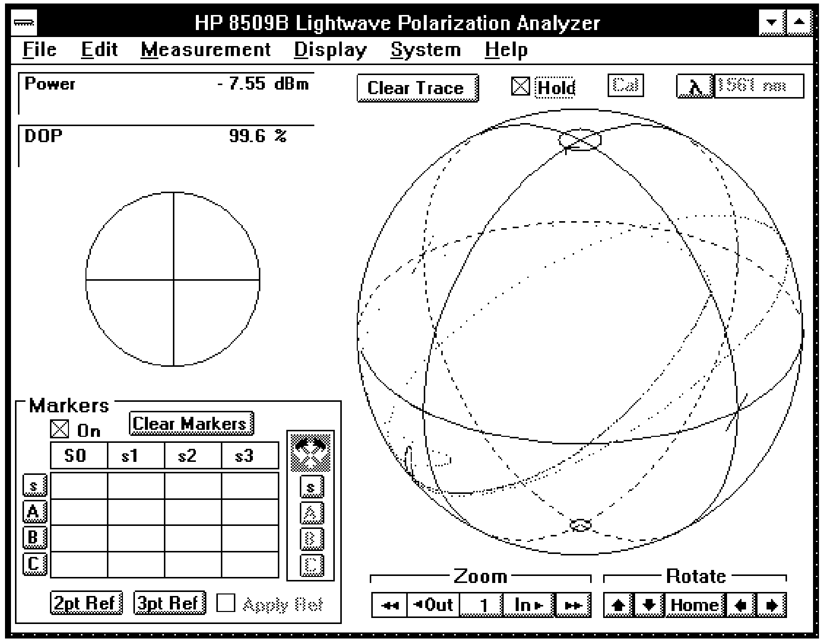



**Figure 3-5. Viewing a stored Timed measurement trace on the Poincare sphere**

## 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.

$\lambda$ = 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

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.

## PMD: Jones Matrix Eigenanalysis Save

***Format***

$\lambda_n$,$\lambda_{n+1}$,DGD (units are unspecified)

***Example***

1500,1501,.2310215

## PMD: Wavelength-Scanning Save

***Format***

$\lambda_n$(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***

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***

$\lambda_n$(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.

# Using the Save functions

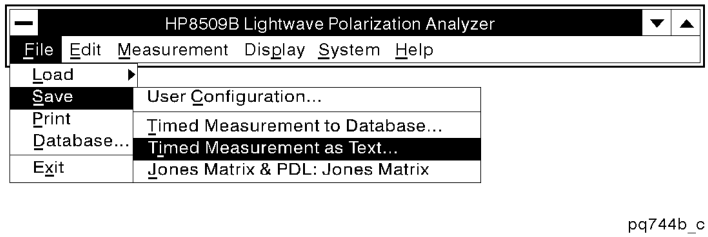



**Figure 3-6. Save menu**

## To save measurement results

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

The Agilent 8509C provides two ways to save data for PMD:JME, PMD:WS, and Timed measurements: Microsoft Access database and text files. The data stored in Agilent 8509C 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 instrument. For example, you may wish to examine the PMD measurements for a particular device type during the month of May. Since the Agilent 8509C 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 Agilent 8509C, 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 Agilent 8509C program group for additional information and for a map of the Agilent 8509C database.

After performing a measurement, the results can be saved as summarized in Table 3-1 on page 3-17. Use the *FILE*, *SAVE* menu selections shown in Figure 3-6. 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 Figure 3-6.

**Additional Information**

Refer to Figure 3-6. 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.

### *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.

*Timed Measurement to Database*
*Timed Measurement as Text*
*Jones Matrix & PDL: Jones Matrix*

4 You will see either the Save As: Text File window (Figure 3-7), or a dialog box for adding the measurement to the database.

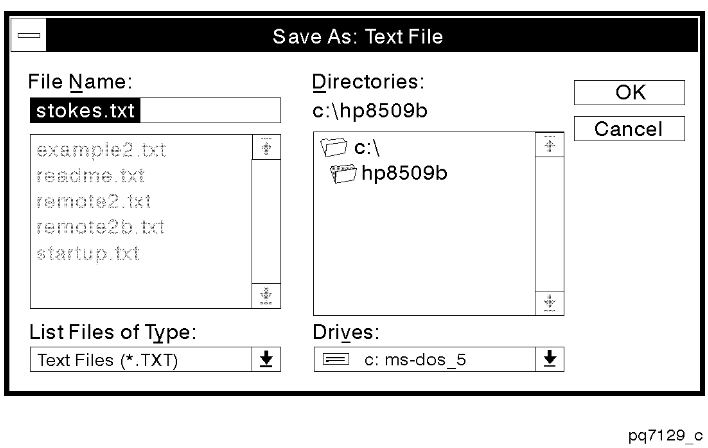



**Figure 3-7. Save As: Text File window**

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.

## To save 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.

### *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 menu.

2 Select *User Configuration*.

3 The Save As: Configure File window opens. See Figure 3-8 on page 3-13.

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.

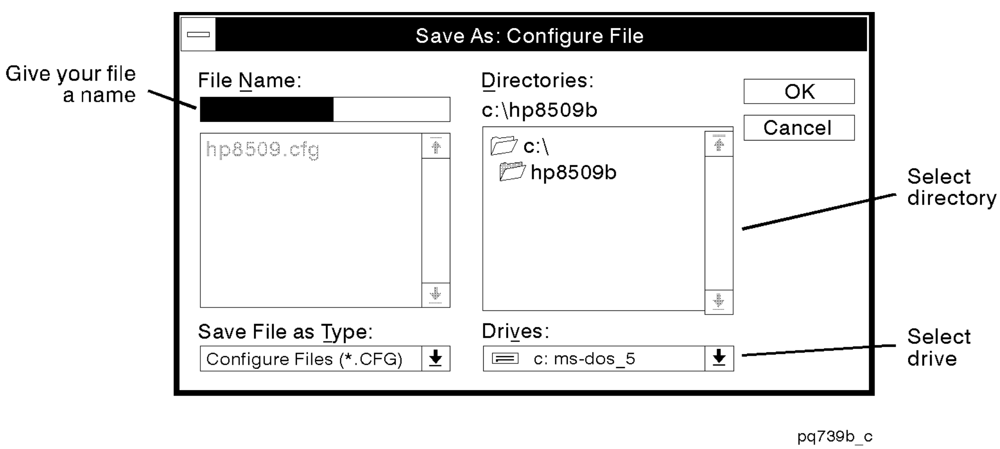



**Figure 3-8. File Save As: Configure File window**

# Using the Print functions

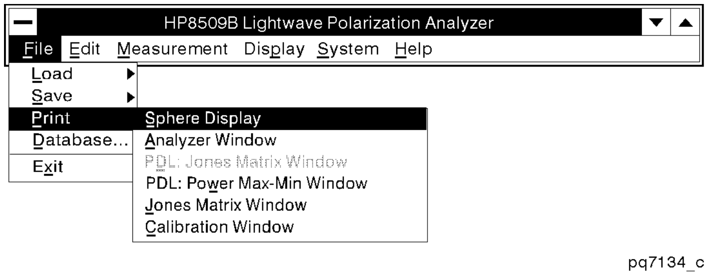



**Figure 3-9. Print menu**

## To print 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

***Procedure***

Once you make a measurement, you can print the results.

1 Select *File*, *Print*.

2 Select one of the following options:

| | |
|---|---|
| *Sphere Display* | Prints only the Poincare sphere. |
| *Analyzer Window* | Prints the entire main measurement window display. |
| *PDL: Jones Matrix Window* | Prints the Jones matrix PDL measurement window. |
| *PDL: Power Max-Min Window* | Prints the power max-min PDL measurement window. |
| *Jones Matrix Window* | Prints the entire Jones matrix measurement window. |
| *Calibration Window* | Prints the entire wavelength calibration measurement window. |

## Customized printing

An Agilent 8509C 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 in Figure 3-10. This procedure uses the Clipboard and Paintbrush graphics program which are included with the Agilent 8509C instrument controller.

### *Results*

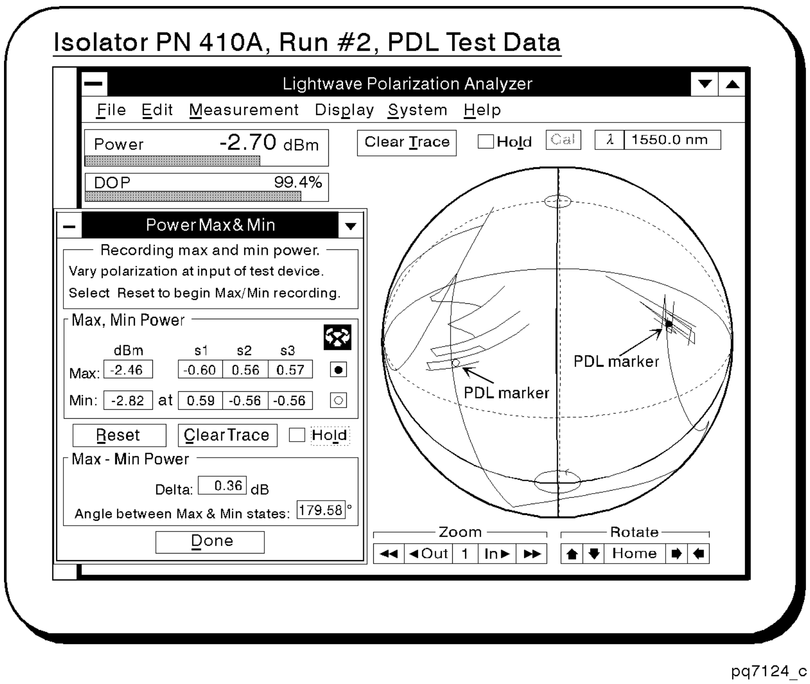



**Figure 3-10. Customized printing example**

### *Procedure*

1 Create the desired Agilent 8509C measurement display. You may choose to maximize the display by selecting the double carrot located in the upper-right corner of the Agilent 8509C measurement window.

2 Press Print Screen on the upper-right side of the Agilent 8509C instrument controller keyboard.

3 Select Hold.

4 Use the mouse to minimize the Agilent 8509C measurement window by selecting the down carrot in the upper-right corner of the Agilent 8509C measurement window. This will cause the Agilent 8509C 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.

Measurement data is saved and recalled according to the formats and viewing options listed in Table 3-1.

**Table 3-1. Summary of Agilent 8509C 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[a], 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[a], Spreadsheet | File Contents |
| PDL: Jones Matrix | Jones Matrix & PDL: Jones Matrix | Comma Delimited ASCII | Word Processor[a], Spreadsheet | File Contents |
| Jones Matrix | Jones Matrix & PDL: Jones Matrix | Comma Delimited ASCII | Word Processor[a], 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[a], 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[a], Spreadsheet | File Contents |

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

# Using the Database functions

The database interface allows you to retrieve previously archived measurements, create a new database file, open a previously created database, repair a corrupted database structure, reduce the database size, and close the currently open database.

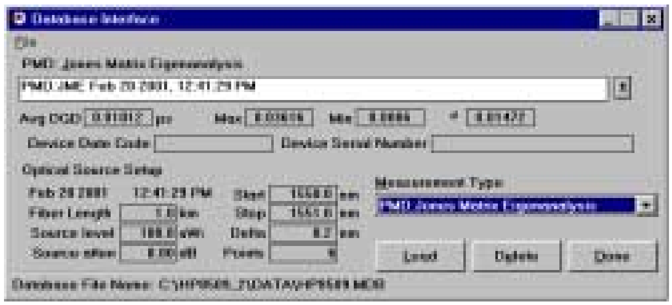



**Figure 3-11. Database Interface**

## To retrieve previously archived measurements

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 the polarization state. The Jones matrix eigenanalysis (JME) method is a typical measurement result showing the differential group delay as a function of wavelength. Refer to “Using the Jones matrix eigenanalysis method” on page 4-5 for additional information and measurement setup.

The wavelength-scanning (WS) method includes the 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 usable number of peaks and valleys in the response within the system passband. Refer to “Using the wavelength-scanning method” on page 4-38 for additional information and measurement setup.

The Timed Measurements provide a means for measuring and saving the polarization parameters of an optical signal as a function of time. Saved measurements can be recalled for viewing on the Poincare sphere or imported to a spreadsheet for analysis. Timed Measurement data is preserved when the Poincare sphere is rotated or zoomed. Refer to "Making Timed Measurements" on page 4-103.

The three measurement retrievals are:

- PMD:JME
- PMD:WS
- Timed: Timed Measurement

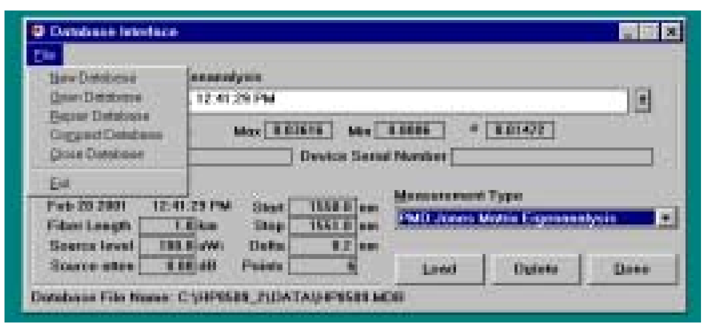
The Database Interface window displays the saved information at the time of the measurement. Such as:

- Date and Time
- Wavelength ranges and step sizes
- Device date codes and serial number
- Data points
- PMD values (PMD only)

You can Load or Delete a particular measurement from the database.

## To perform database operations

You can create, open, repair, reduce database size, and close currently opened databases from this menu.



The following database menus are available:

**New Database** creates a new database file
**Open Database** opens a previously created database
**Repair Database** attempts to repair a corrupted database structure
**Compact Database** attempts to reduce the database size
**Close Database** closes the currently open database

Refer to "Accuracy Enhancement and Troubleshooting" on page 7-2 for information regarding measurement accuracy enhancements and troubleshooting information.

# Using the Measurement Menu

# The Measurement Menu

This chapter contains information about the Measurement menu (in the main window), which allows you to make polarization mode dispersion (PMD), polarization dependent loss (PDL), Jones matrix, PM fiber launch alignments, marker angles, and timed measurements.

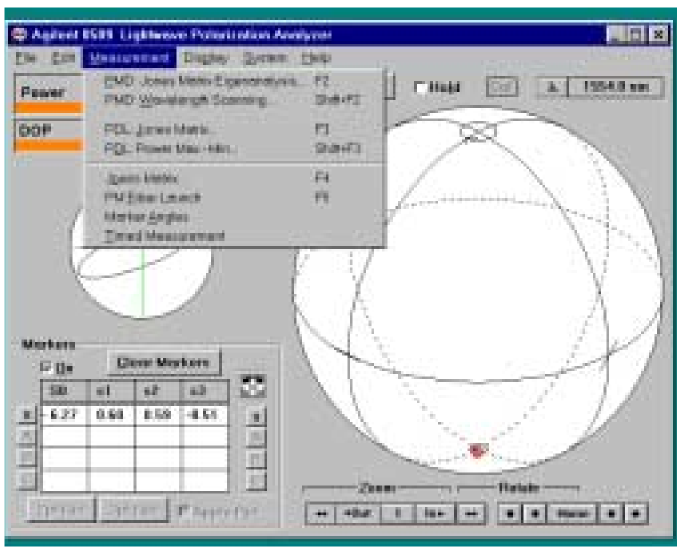



**Figure 4-1. Measurement menu**

The following functions are available:

| Function | See.... |
|---|---|
| PMD measurements | “Making PMD Measurements” on page 4-4 |
| PMD:Jones Matrix Eigenanalysis.... | “Using the Jones matrix eigenanalysis method” on page 4-5 |
| PMD:Wavelength Scanning.... | “Using the wavelength-scanning method” on page 4-38 |
| PDL measurements | “Making PDL Measurements” on page 4-54 |
| PDL: Jones Matrix.... | “Using the Jones matrix method” on page 4-54 |
| PDL: Power Max - Min.... | “Using the power max-min method” on page 4-64 |
| Jones Matrix.... | “Making Jones Matrix Measurements” on page 4-70 |
| PM Fiber Launch | “Making Polarization Maintaining Fiber Launch Alignments” on page 4-79 |
| Marker Angles | “Making Marker Angles” on page 4-101 |
| Timed Measurement | “Making Timed Measurements” on page 4-103 |

# Making PMD Measurements

# Using the 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 Agilent 8509C. A typical measurement result, showing the differential group delay as a function of wavelength, is shown in Figure 4-2.

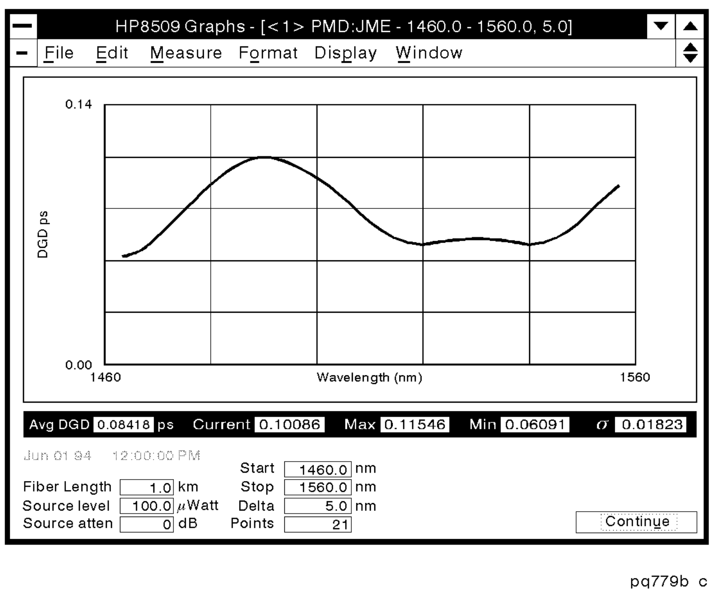



**Figure 4-2. Example of data display for a PMD:JME measurement**

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.

## To make a PMD:JME measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the Agilent 8509C lightwave polarization analyzer to make a PMD:JME measurement. Other specialized measurement applications and techniques are included later in this section.

### *Measurement setup*

**1** Connect your measurement system as shown in Figure 4-3. Install the thru cable for the one-time adjustment of external source polarization.

**Enhancing Accuracy**

The fiber cable leading from the external source to the Agilent 8509C 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.

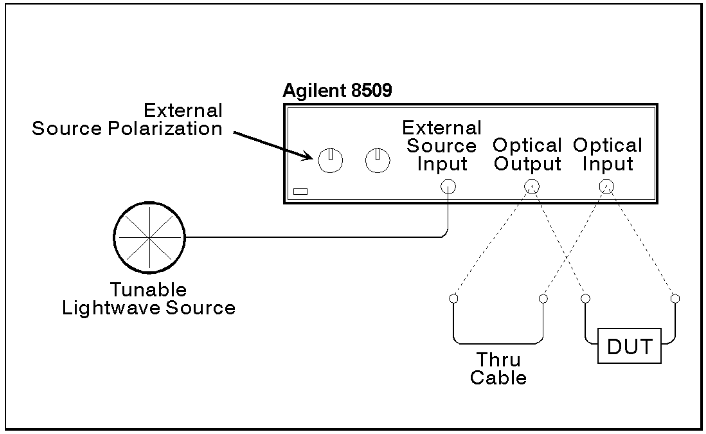



**Figure 4-3. Measurement setup**

### *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 Agilent 8509C. The following procedure will guide you through the process.

> **Additional Information**
>
> The Agilent 8509C 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 Agilent 8509C 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.

**2** 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.

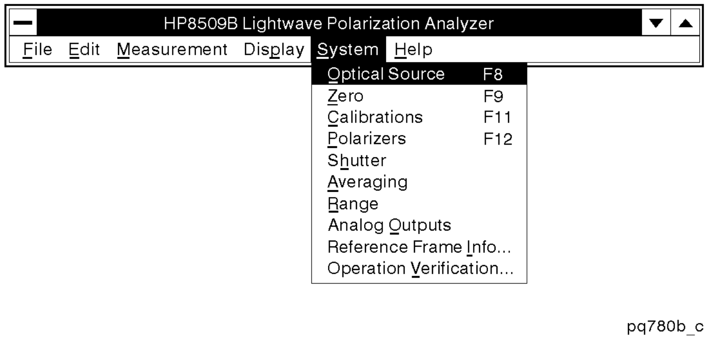



**Figure 4-4. System menu**

3 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 instrument controller looks similar to Figure 4-5, select Done.

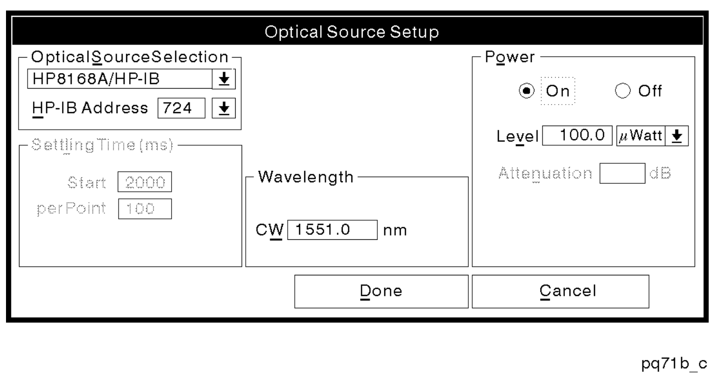



**Figure 4-5. Optical Source Setup window**

4 Select *System* from the main menu, and then select *Polarizers*.

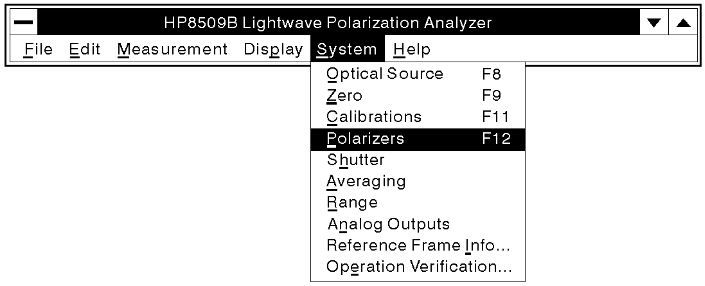



**Figure 4-6. Polarizer selection menu**

5 Set the polarizers to Internal and select No Polarizer. If the screen on your instrument controller looks like Figure 4-7, select Done.

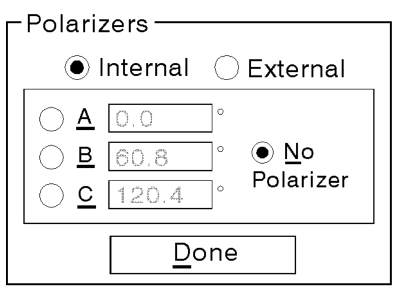



**Figure 4-7. Polarizer setup window**

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

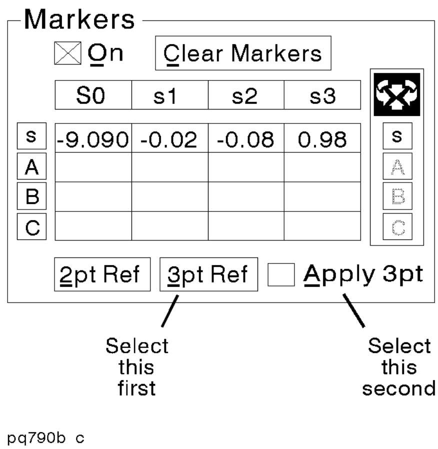



**Figure 4-8. 3pt reference applied window**

> **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.

**7** Adjust the External Source Polarization knobs on the front panel of the Agilent 8509C 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.

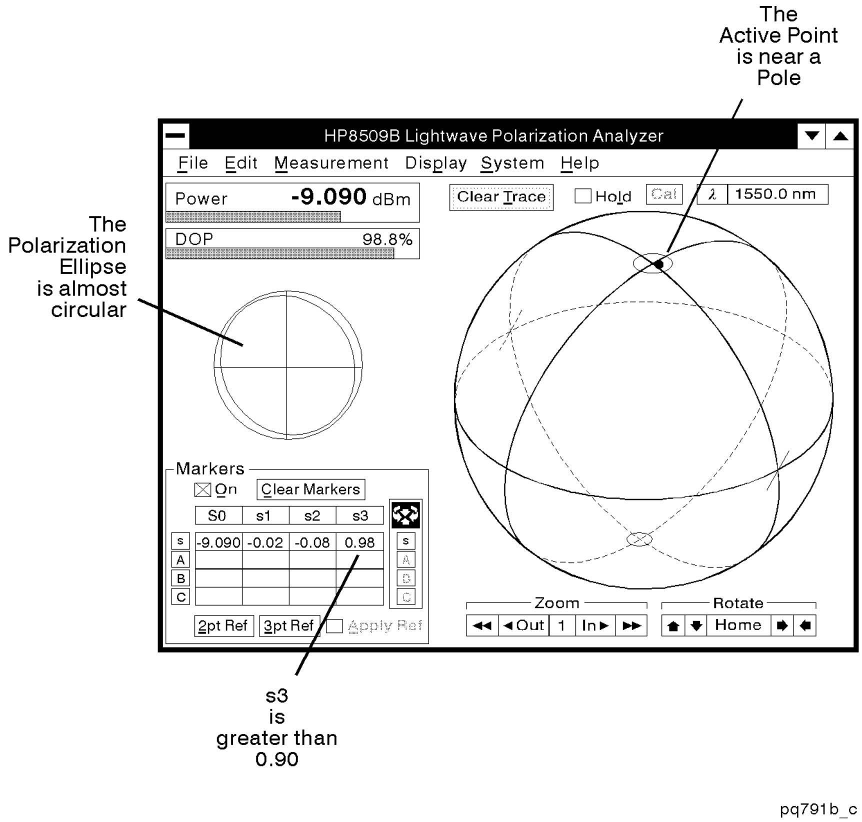



**Figure 4-9. Circular polarization display**

### *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.

**8** Remove the fiber cable connecting the optical output to the optical input on the Agilent 8509C.

**9** Connect your test device between the optical output and the optical input.

**Enhancing Accuracy**

The fiber path leading from the optical output of the Agilent 8509C to the DUT and from the DUT to the optical input of the Agilent 8509C 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 "Cleaning Connections for Accurate Measurements" on page 7-14.

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

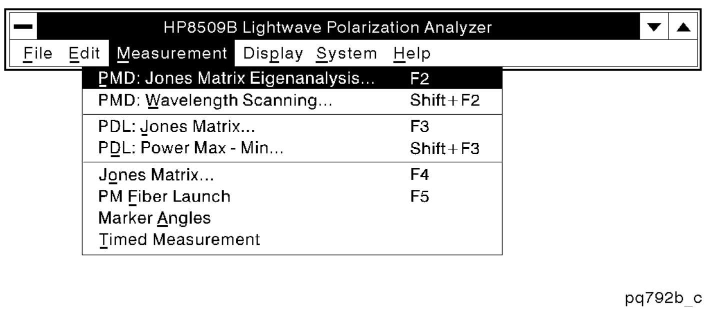



**Figure 4-10. JME measurement selection menu**

**11** 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 instrument controller looks like Figure 4-11, select *Find Minimum # of Points*.

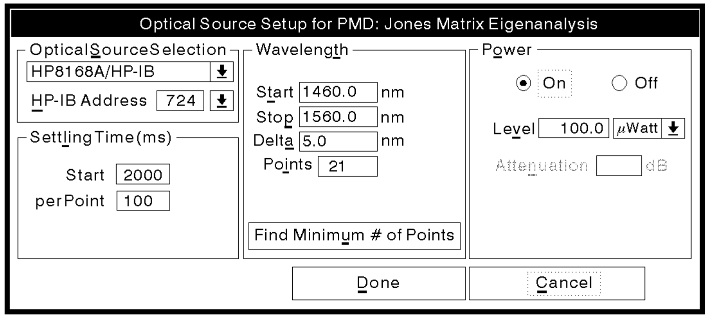



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**Figure 4-11. JME Source Setup window**

**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.

**12** 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.

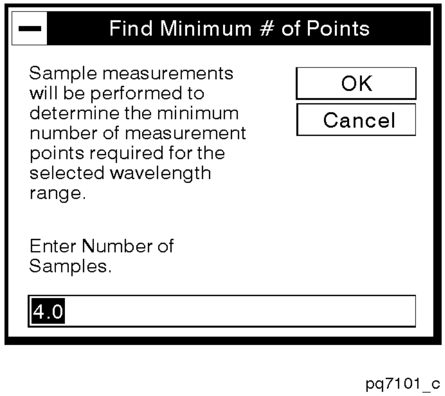


**Figure 4-12. Segment selection window**

**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).

**13** 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.

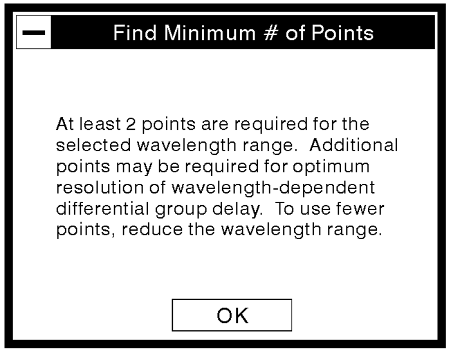


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**Figure 4-13. Find Minimum # of Points window**

> **Enhancing Accuracy**
>
> 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.

**14** Select Done in the Optical Source Setup window.

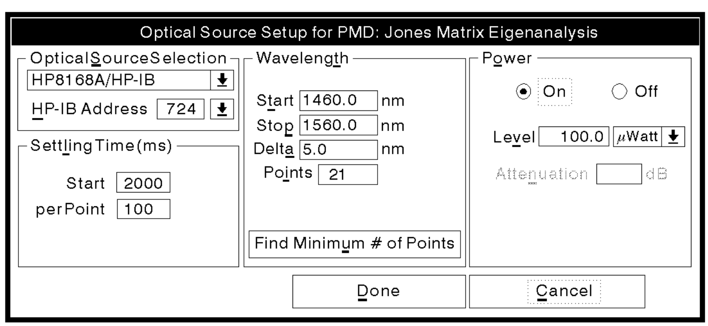


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**Figure 4-14. Optical Source Setup for PMD: JME window**

**15** Select Start Measurement from the Agilent 8509C Graphs screen.

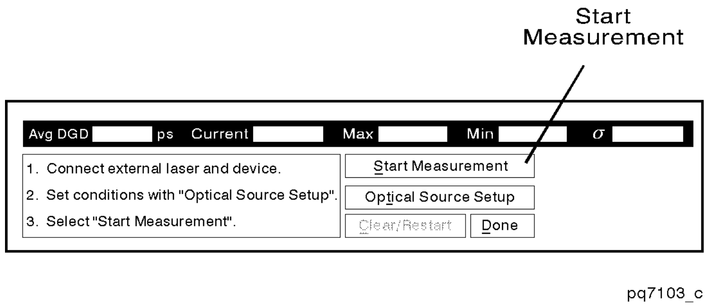


**Figure 4-15. PMD: JME measurement start window**

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.

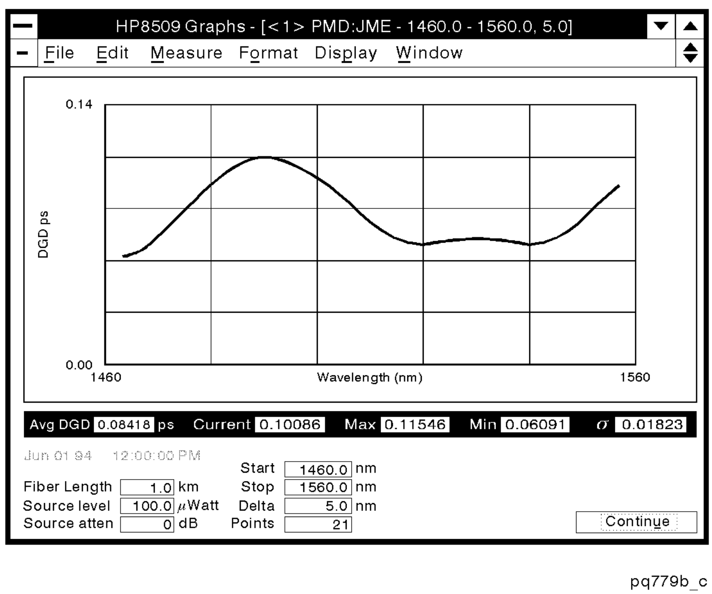


**Figure 4-16. Measurement results window**

Your measurement is complete. The screen on your instrument controller should look similar to Figure 4-16.

## To manipulate 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 Agilent 8509C.
- 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

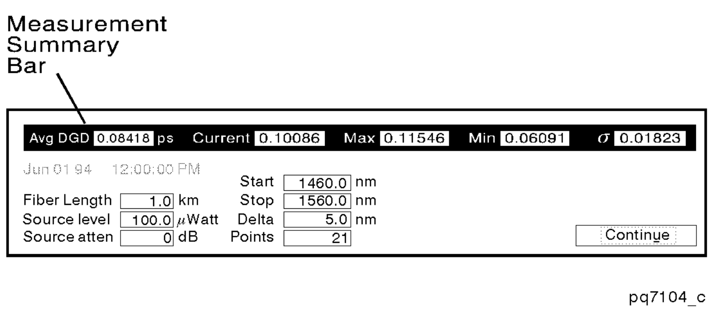


**Figure 4-17. The Measurement summary bar window**

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.

## The Measurement annotation area

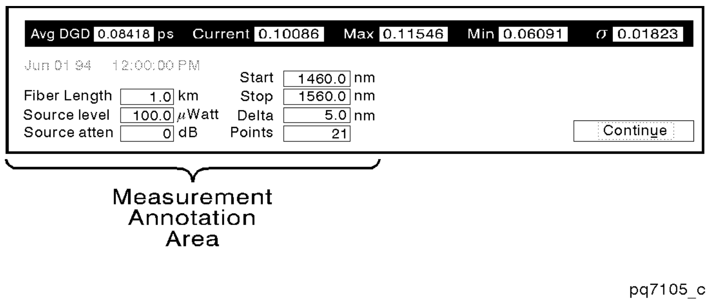


**Figure 4-18. The Measurement annotation area window**

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.

### The Cursor Bar window

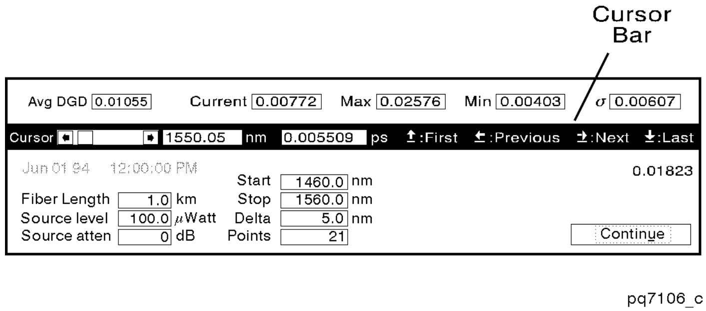


**Figure 4-19. The Cursor bar window**

Maximize the PMD:JME window within the Agilent 8509C 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 Alt and then the arrow keys), or by editing the wavelength display.

## To change the measurement format

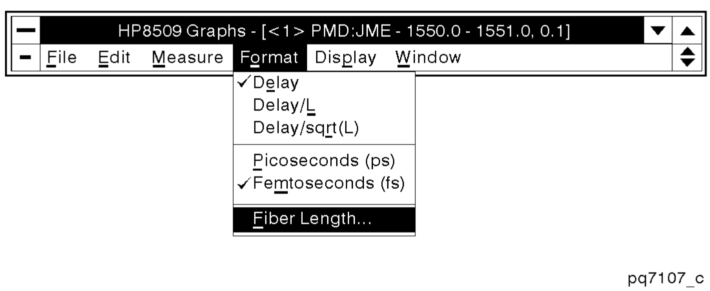


**Figure 4-20. Graphs Format menu**

**1** 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.

**2** 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.

## To change the graph's Y-scale

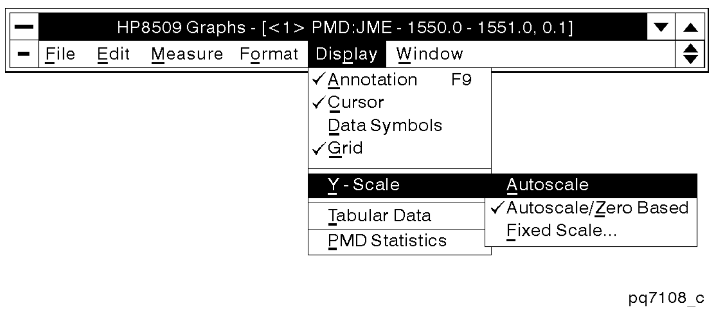


**Figure 4-21. Graphs Y-Scale menu**

**1** 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:

*Autoscale/Zero Based*
Autoscales the maximum Y-axis value but uses zero as the minimum value. This is the default selection.

*Autoscale*
Optimizes both the minimum and maximum Y-axis values to expand the measurement curve to fill the graph area.

*Fixed Scale...*
Allows specification of the maximum Y-axis value and uses zero as the minimum value.

## To display data in tabular format

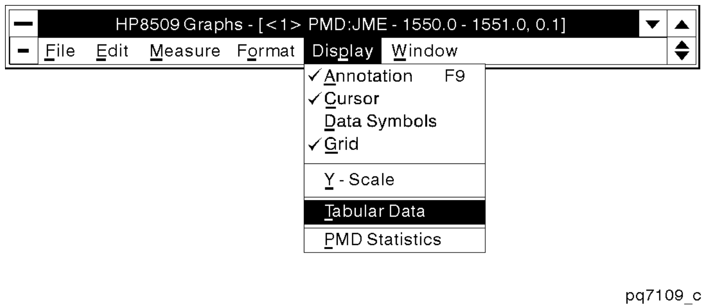


**Figure 4-22. Graphs Tabular Data menu**

1 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 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.

## To print data in tabular format

All or a portion of the text box information may be printed. Printing uses the default printer selected in the Windows control panel.

1 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, highlight the desired text with the mouse before pressing the Print tabular data button.

2 To return to the graphic display, press the Return to graph button or re-select *Tabular Data* under the *Display* menu.

## To display data in a statistical format

Data from PMD:JME measurements can be displayed in statistical format using the PMD Statistics feature. See "Fiber PMD statistics" on page 4-35 in for a discussion of its application.

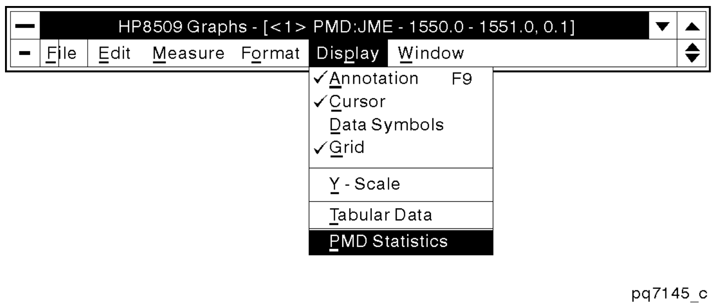


**Figure 4-23. Graphs PMD Statistics menu**

1 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.

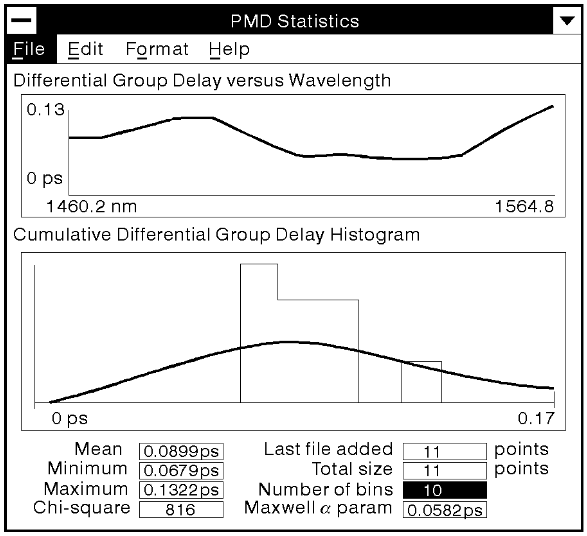


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**Figure 4-24. Displaying data in a statistical format window**

Figure 4-24 is an example of the PMD statistics window. A Maxwell curve is automatically fitted to the histogram.

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

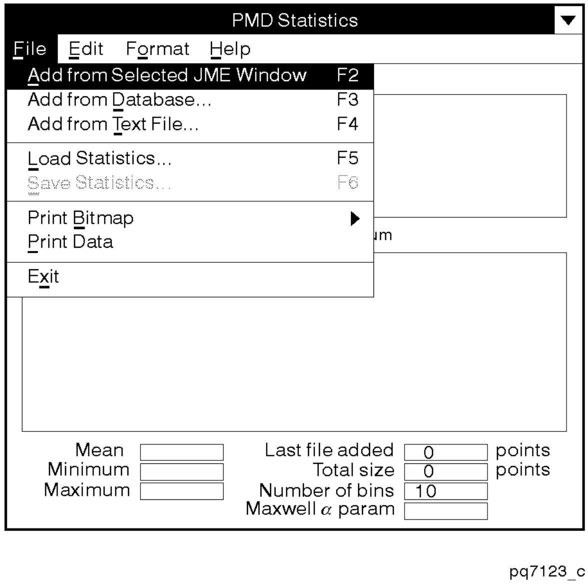


**Figure 4-25. PMD Statistics File menu**

## 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.

### *Add from Database...F3*

Selecting this menu item will open the PMD Statistics Database Interface window. 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 open the "Load: Text File" window. 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 the "Load: Text File" window. You can then load previously stored PMD statistics data into the PMD Statistics window.

***Save Statistics...F6***
Selecting this menu item opens the "Save: Text File" window. 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: print the DGD versus Wavelength graph, the Histogram or the entire window.

***Print Data***
Selecting this menu will print the data, using 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.

**Note**: The Edit Menu allows you to print the screen in bitmap format, but will not print the data.

***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 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.

## To print the PMD:JME graph

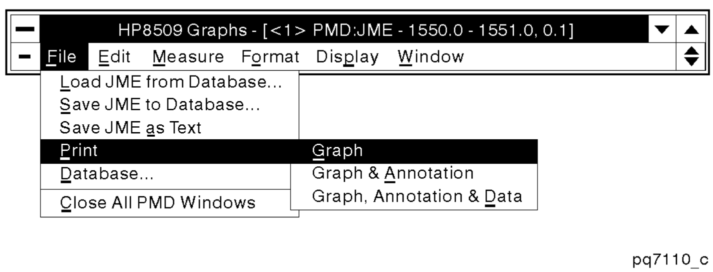


**Figure 4-26. Printing the PMD:JME graph menu**

**1** Select *File* and then *Print* from the Graphs main window.

***Graph***
Prints only the graph.

***Graph & Annotation***
Prints the graph and the annotation information discussed in "The Measurement Annotation Area."

***Graph, Annotation, & Data***
Prints the graph, annotation information and list the measurement wavelengths and the corresponding data points.

## To save your measurement as text

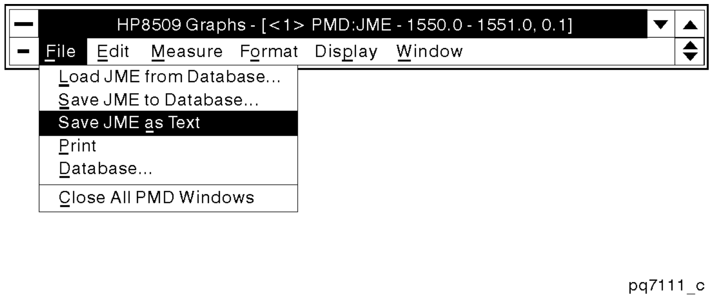


**Figure 4-27. Save as Text menu**

1 Select *File* and then *Save JME as Text* from the Graphs main window. A standard window Save screen will be displayed.

2 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.

## To save in database format

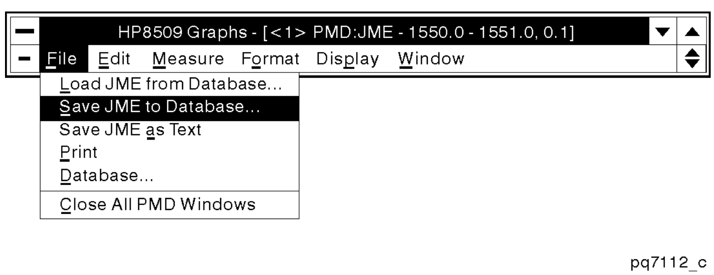


**Figure 4-28. Saving in database format menu**

1 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.

# Specialized measurement methods

## To perform 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 Agilent 8509C 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 Agilent 8509C 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 Figure 4-29) can be mathematically removed from the total PMD response, leaving behind the response of the targeted test device (DUT in Figure 4-29). This technique is most effective when the PMD response of the test device (DUT) and the undesired PMD of the optical source interfacing (DCO) are approximately the same and individually greater than 100 fs.

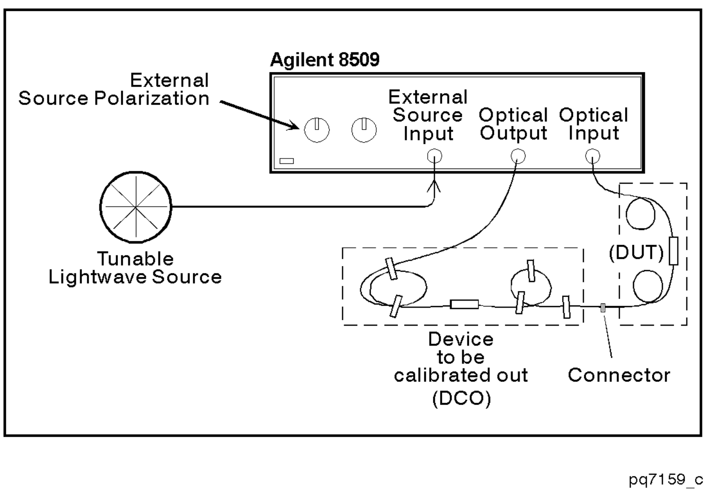


**Figure 4-29. Targeted test device**

### *Setting up the system*

**1** Attach the device to be calibrated out (DCO), between the OPTICAL OUTPUT and the OPTICAL INPUT of the Agilent 8509C, as outlined in Figure 4-30. 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.

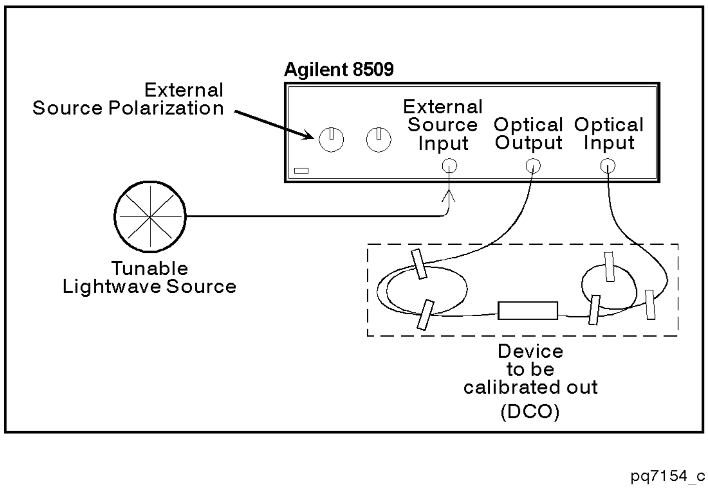


**Figure 4-30. Measurement setup**

### *Making the measurement*

**2** Prepare the external source to provide a circular state of polarization by following the procedure described in "External source preparation" on page 4-7.

**3** Select *Measurement* from the main window menu selections, and then *PMD: Jones Matrix Eigenanalysis... F2*.

**4** Set up the optical source for the desired wavelength range and the number of points, then select Done.

**5** Select *Measurement* from the graphs main window menu selections, and then *Cascaded Device*.

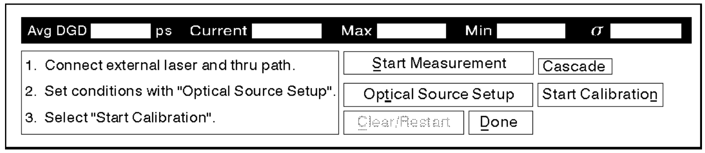


**Figure 4-31. Measurement start window**

**6** 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.

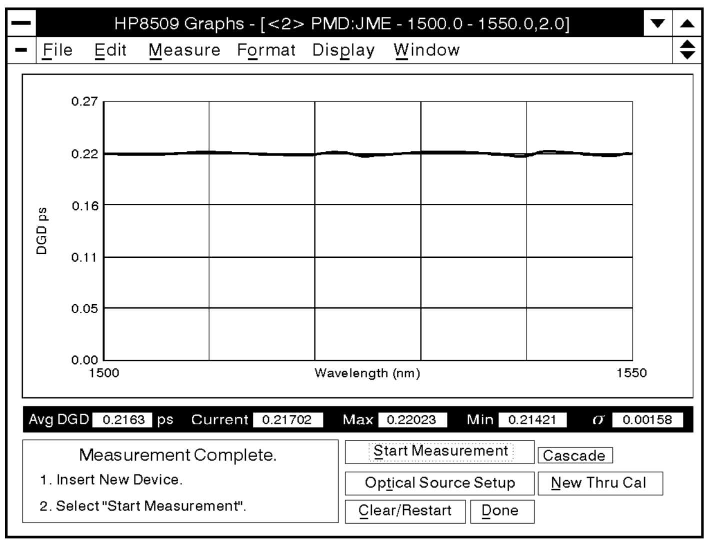


**Figure 4-32. Thru calibration window**

**7** 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.

**8** Remove the output pigtail of the DCO from the optical input of the Agilent 8509C, 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.

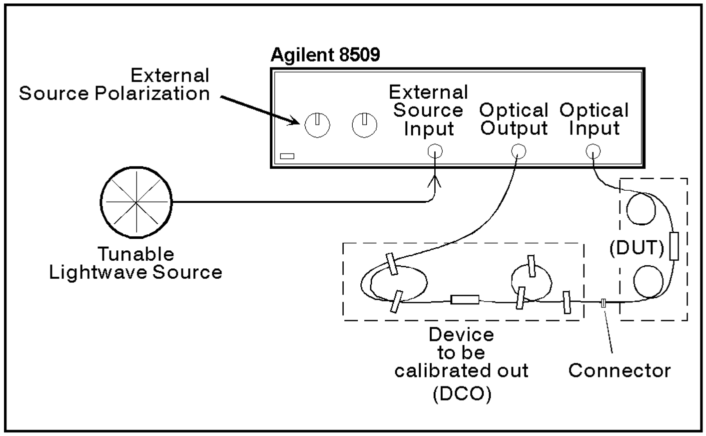


**Figure 4-33. Connecting the device**

**9** 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 Figure 4-34.

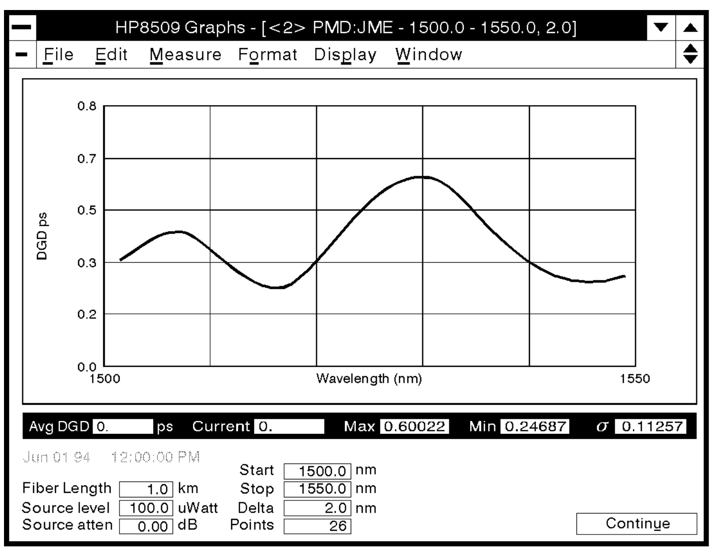


**Figure 4-34. The results**

**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.

## To use 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.

1. To perform a measurement with a voltage-tuned source, open a JME PMD window and select Optical Source Setup.
2. Use the 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.
3. Enter the wavelength parameters and number of points as you would for an HPIB source.
4. 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.
5. Set the settling times as required for your source, or use the default values.
6. Connect the tuning voltage from BNC connector "A" on the rear panel of the Agilent 8509C to the voltage-tuned laser.
7. Close the Optical Source Setup window and start the measurement.

### To use 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.

1. To perform a measurement with a manual source, open a JME PMD window and select Optical Source Setup.
2. Use the Optical Source Selection to choose the manually tuned mode. The settling time parameters are no longer relevant and are grayed out.
3. Enter the wavelength parameters and number of points as you would for an HPIB source.
4. Close the Optical Source Setup window 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.

## 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 femtoseconds (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).

## 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 Agilent 8509C 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 Agilent 8168A Tunable Laser Source, are recommended for the Jones matrix eigenanalysis PMD measurement method.

## 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 Agilent 8509C 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.

# Using the 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 Figure 4-35.

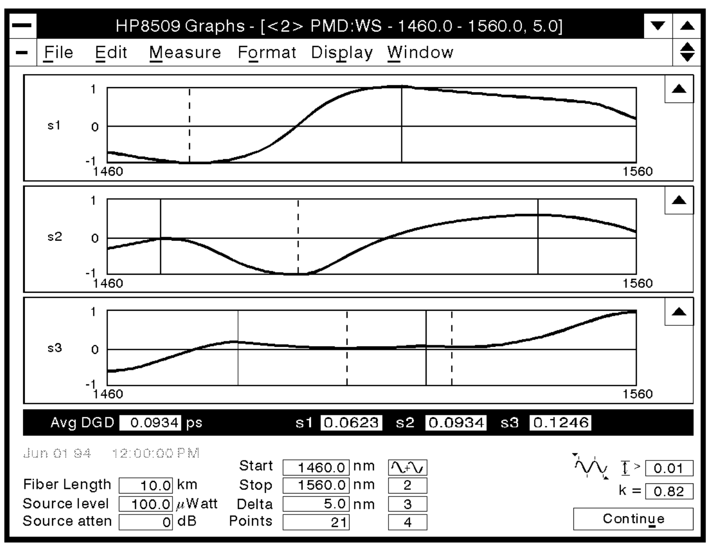


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**Figure 4-35. Example of data display for a wavelength-scanning PMD measurement**

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 usable 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 Agilent 8509C.
- 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.

## To make a PMD:WS measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the Agilent 8509C lightwave polarization analyzer operating system software to make a wavelength-scanning PMD measurement.

***Measurement setup***

**1** Connect your measurement system as shown in Figure 4-36.

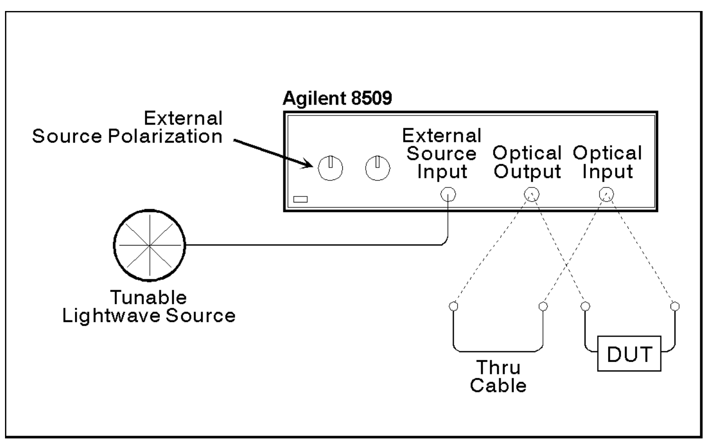


**Figure 4-36. Wavelength-scanning system setup**

### *External source preparation*

If the source signal is applied to the EXTERNAL SOURCE INPUT of the Agilent 8509C, external source polarization should be adjusted for circular polarization as described in "External source preparation" on page 4-7.

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.

2 Connect your test device between the OPTICAL OUTPUT of the laser source and the OPTICAL INPUT of the analyzer.

**Enhancing Accuracy**

The fiber path leading from the tunable laser source to the DUT and from the DUT to the Agilent 8509C 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.

**CAUTION** Observe proper connection techniques. Refer to "Cleaning Connections for Accurate Measurements" on page 7-14.

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

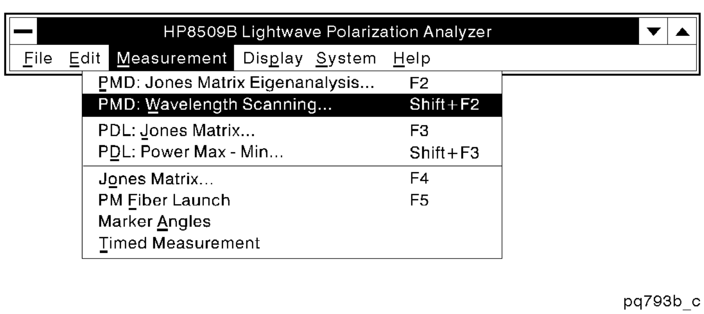


**Figure 4-37. Wavelength-scanning measurement menu**

**4** Verify that the source and wavelength are correct for your measurement, and that the power is on. If the screen on your instrument controller looks like Figure 4-38, select Done.

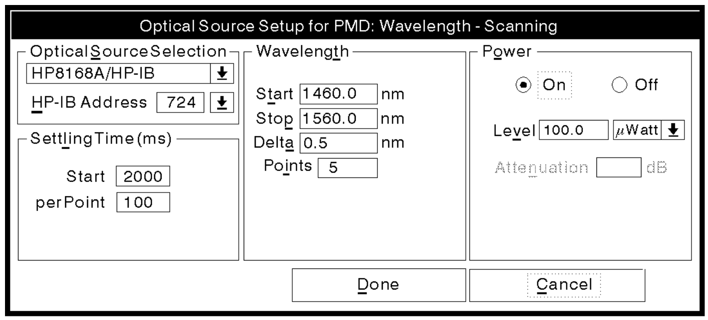


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**Figure 4-38. Optical source setup for PMD:wavelength scanning window**

### 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.

**5** Select Start Measurement from the Agilent 8509C 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.

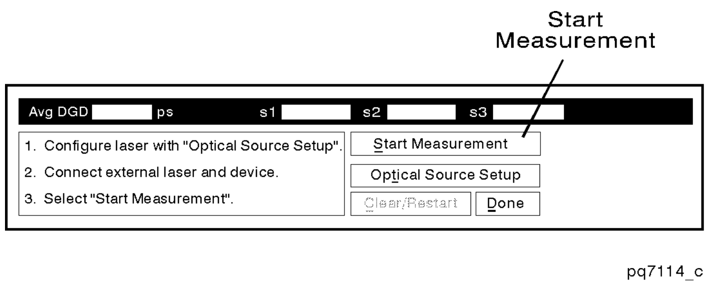


**Figure 4-39. PMD: WS measurement start window**

> **Enhancing Accuracy**
>
> 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.

Your measurement is complete. The screen on your instrument controller should look similar to Figure 4-40.

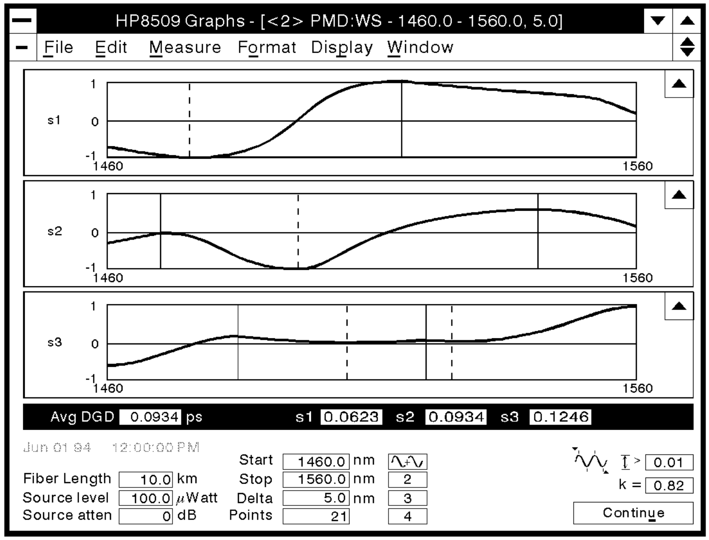


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**Figure 4-40. Measurement results**

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.

## To manipulate 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 Agilent 8509C.

- 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

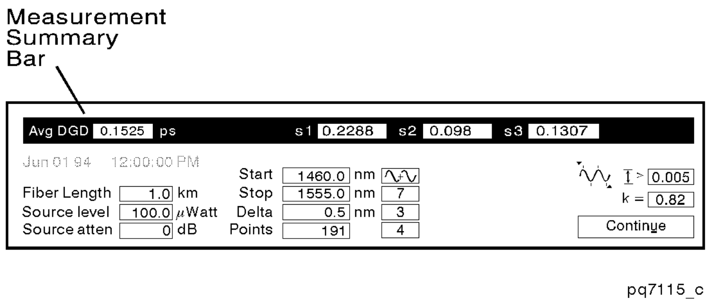



**Figure 4-41. Measurement summary bar window**

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.

## The Measurement annotation area

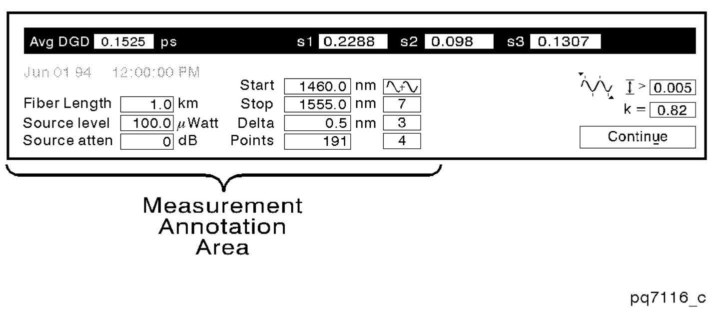



**Figure 4-42. Measurement annotation area window**

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 titles "Analysis mode" on page 4-52 and "Minimum feature size" on page 4-53. The measurement annotation area can be toggled on and off by selecting *Display* from the main window menu, and then *Annotation*.

## The Cursor bar

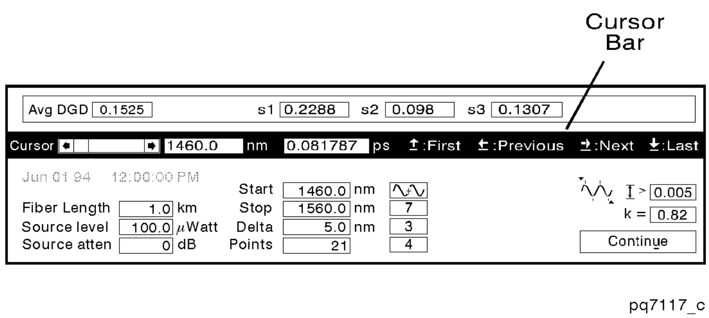



**Figure 4-43. Cursor bar window**

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.

## To change the measurement format

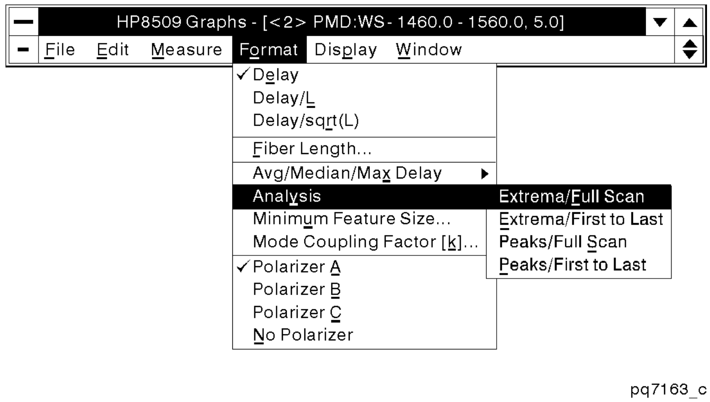



**Figure 4-44. Changing the measurement format menu**

1 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" on page 4-51.

***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 section with that title in "PMD:WS concepts" on page 4-51.

*Extrema/Full Scan*
Causes the Agilent 8509C 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 Agilent 8509C 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 Agilent 8509C to count only peaks and to use the endpoints of the wavelength scan in the wavelength-scanning formula.

*Peaks/First to Last*
Causes the Agilent 8509C to count only peaks and to use the wavelengths of the first and last (peak) in the wavelength-scanning formula.

### *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 section of the same title in "PMD:WS concepts" on page 4-51.

### *Mode Coupling Factor (k)...*

The mode coupling factor must be set according to the type of test device. See the section of the same title in "PMD:WS concepts" on page 4-51.

### *Polarizer A, Polarizer B, Polarizer C, No Polarizer*

These selections control the use of the internal polarizer and are available only in the Agilent 8509C. See the section titled Polarizers in "PMD:WS concepts" on page 4-51.

**2** 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.

## To display data in tabular format

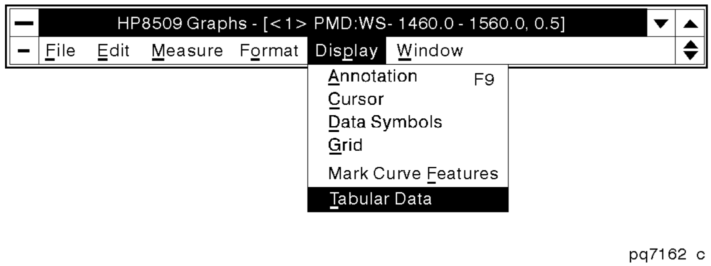



**Figure 4-45. Displaying data in tabular format menu**

1 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.

## To print data in tabular format

All or a portion of the text box information may be printed. Printing uses the default printer selected in the Windows Control Panel.

1 To print all of the text box information just press Print tabular data on the Graphs window area.

2 To print a portion of the text box information, select the desired text with the mouse before pressing Print tabular data.

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

## To print the PMD:WS graph

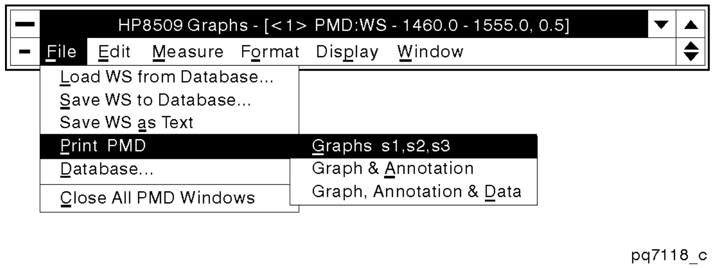



**Figure 4-46. Printing your graph menu**

**1** 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” on page 4-18.
- Selecting *Graph, Annotation, & Data* will print the graph, annotation information and list the measurement wavelengths and the corresponding data points.

## To save your measurement as text

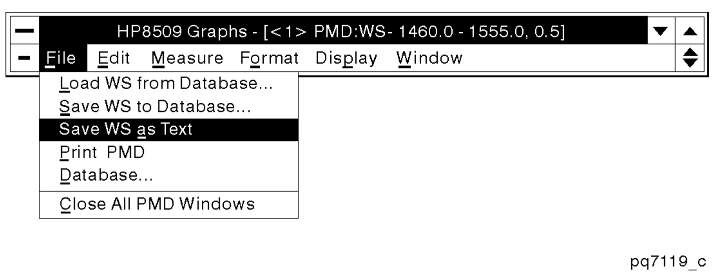



**Figure 4-47. Saving as text menu**

**1** Select *File* and then *Save WS as Text* from the Graphs main window. A standard window Save screen will be displayed.

**2** 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.

## To save in database format

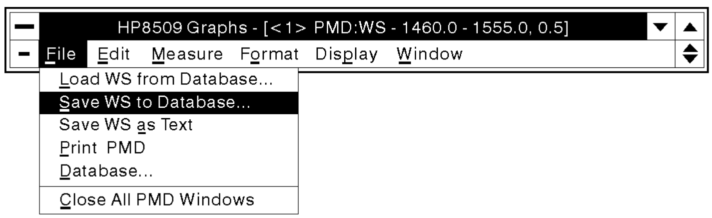



**Figure 4-48. Saving in database format menu**

**1** 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.

**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 femtoseconds (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 Agilent 8509C'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.

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.

# Making PDL Measurements

| Function | See.... |
|---|---|
| **PDL:JME measurements** | "To make a PDL:JME measurement" on page 4-55<br>"To save the measurement results" on page 4-63 |
| **PDL:PMM measurements** | "To make a PDL:PMM measurement" on page 4-65<br>"To save the measurement results" on page 4-69 |

## Using the 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 Figure 4-49.

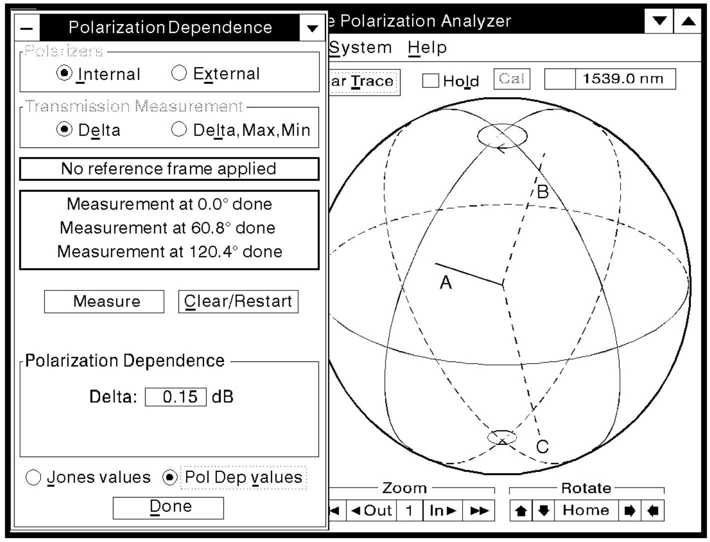



**Figure 4-49. Example of a Jones matrix PDL measurement data display**

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.

## To make a PDL:JME measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the Agilent 8509C lightwave polarization analyzer operating system software to make a PDL: Jones Matrix measurement.

### *Measurement setup*

1 Connect your measurement system as outlined in Figure 4-50. Begin by connecting the thru cable as shown.

**Enhancing Accuracy**

The fiber cable leading from the external source to the Agilent 8509C 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.

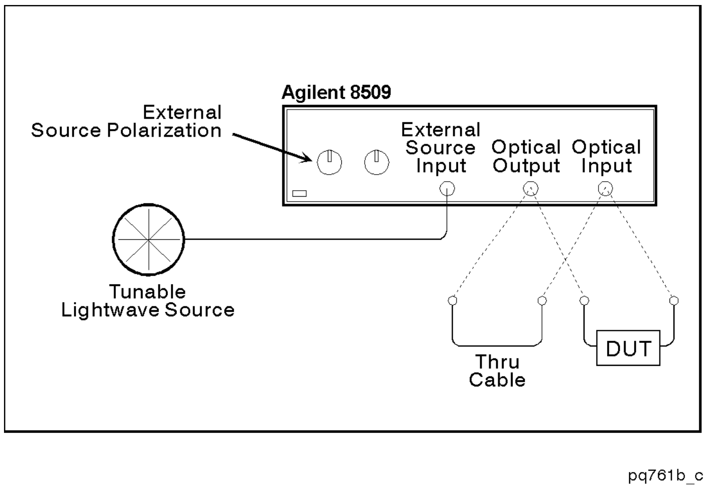



**Figure 4-50. Measurement setup**

### *External source preparation*

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

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

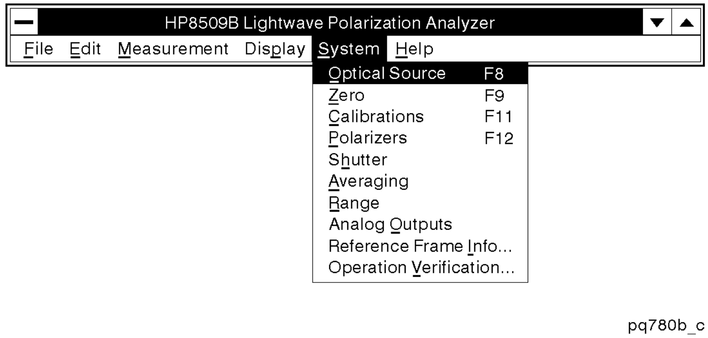



**Figure 4-51. System menu**

**3** 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 instrument controller looks similar to Figure 4-52, select Done.

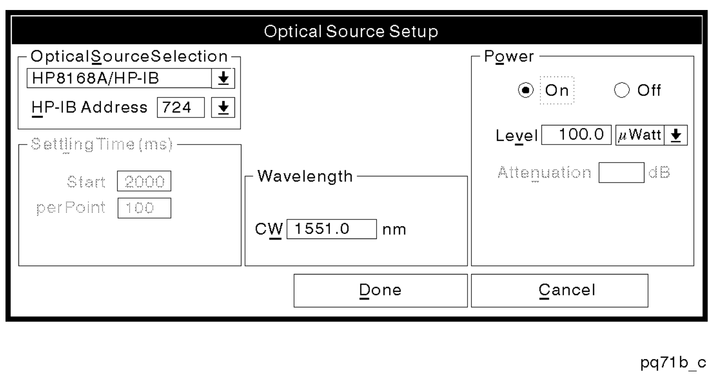



**Figure 4-52. Optical Source Setup window**

**4** Select *System* from the main menu, and then select *Polarizers*.

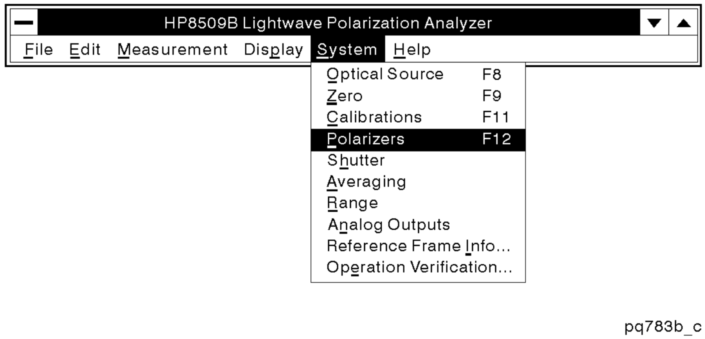



**Figure 4-53. Polarizer selection menu**

5 Set the polarizers to Internal and select No Polarizer. If the screen on your instrument controller looks like Figure 4-54, select Done.

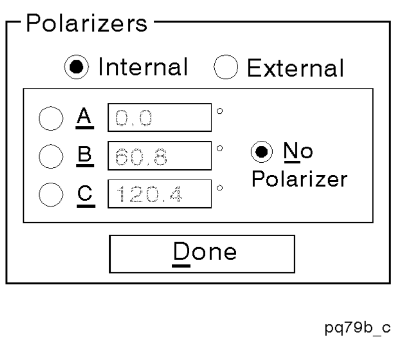



**Figure 4-54. Polarizer setup window**

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

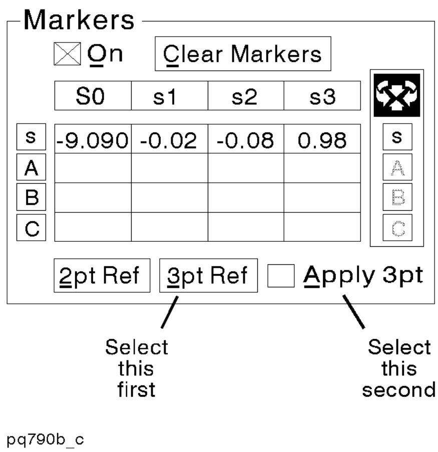



**Figure 4-55. 3pt reference applied window**

**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.

**7** Adjust the External Source Polarization knobs on the front panel of the Agilent 8509C 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 PDL measurements. Do not move the cable or the external source polarization knobs.

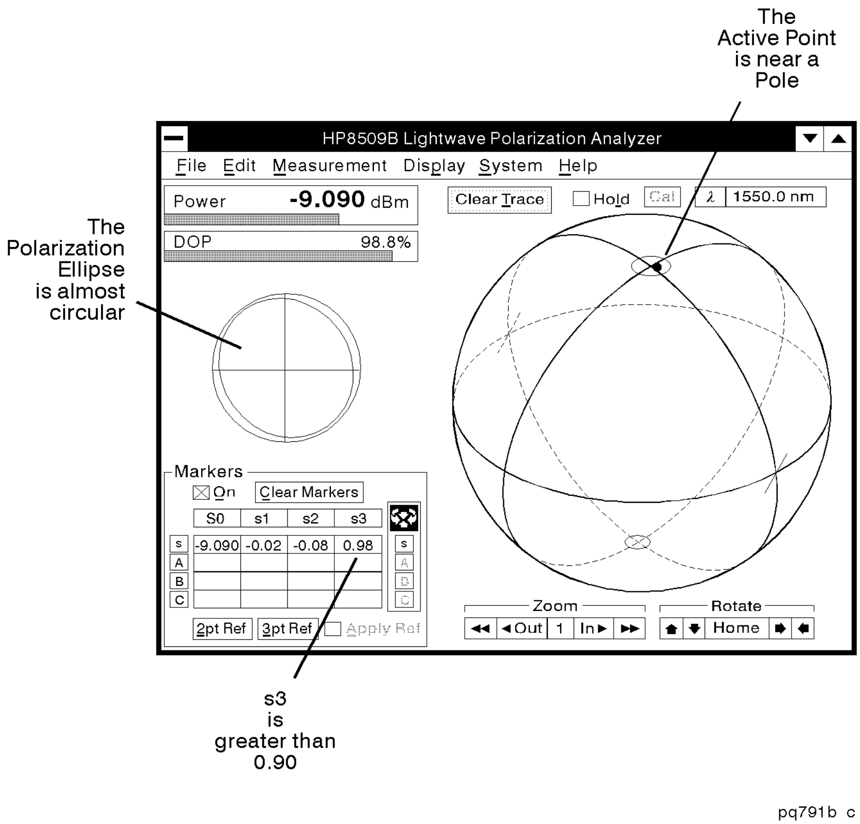



**Figure 4-56. Circular polarization display**

### *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.

**8** Remove the fiber thru cable connecting the optical output to the optical input on the Agilent 8509C.

**9** Connect your test device between the optical output and the optical input.

**Enhancing Accuracy**

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 "Cleaning Connections for Accurate Measurements" on page 7-14.

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

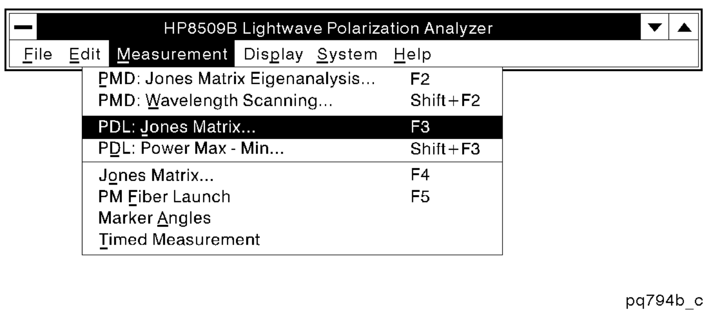



**Figure 4-57. Jones matrix measurement menu**

11 Select Internal polarizers and Delta transmission measurement from the Polarization Dependence setup window.

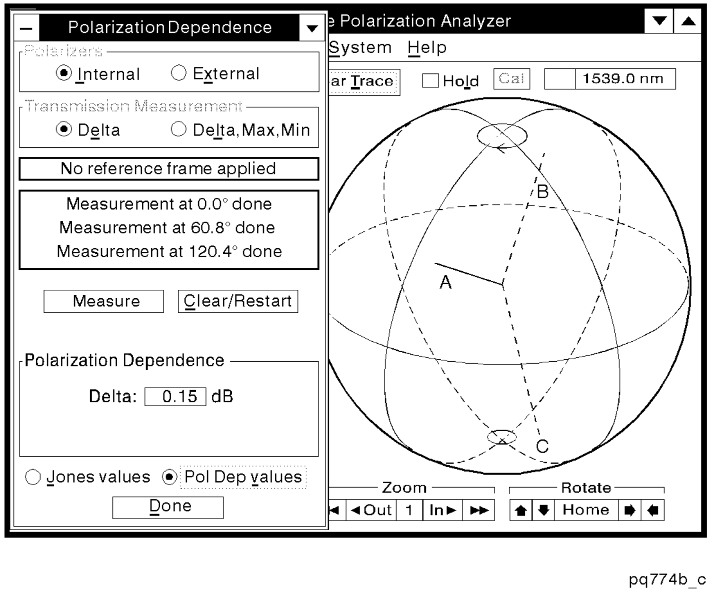
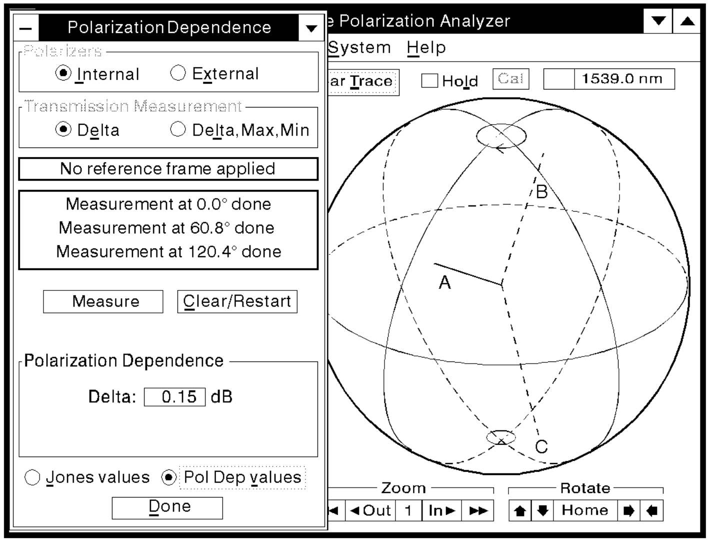



**Figure 4-58. Jones matrix measurement window**

**12** Connect the device you wish to measure.

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




pq774b_c

**Figure 4-59. Measurement results**

Your measurement is complete. The screen on your instrument controller should look similar to Figure 4-59.

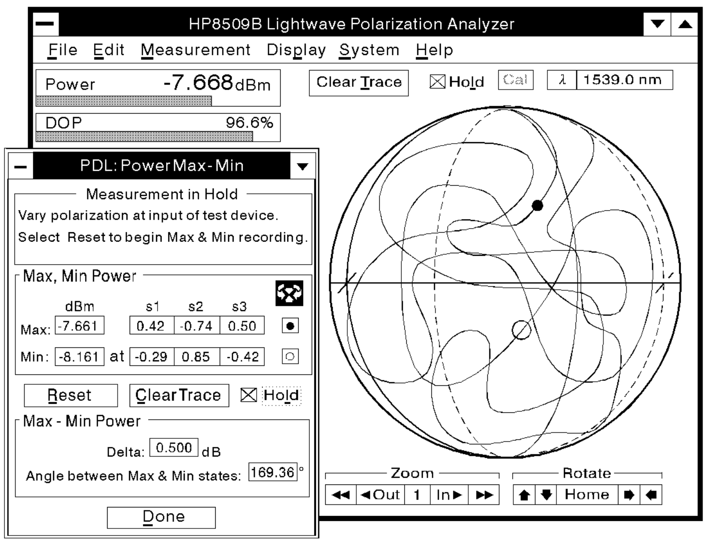
## To save the measurement results

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 3, “Using the File Menu” for further information.

# Using the 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 Figure 4-60.




pq775b_c

**Figure 4-60. 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.

## To make a PDL:PMM measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the Agilent 8509C lightwave polarization analyzer operating system software to make a PDL: Power Max-Min measurement.

### *Measurement setup*

**1** Connect your measurement system as shown in Figure 4-61. The Agilent 11896A Polarization Controller is recommended for this application.

**Enhancing Accuracy**

Avoid fiber movement to eliminate errors due to bending loss.

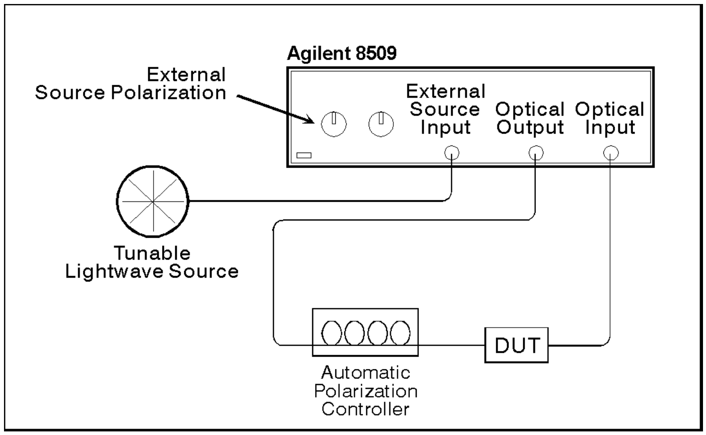



**Figure 4-61. Measurement setup**

### *External source preparation*

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

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

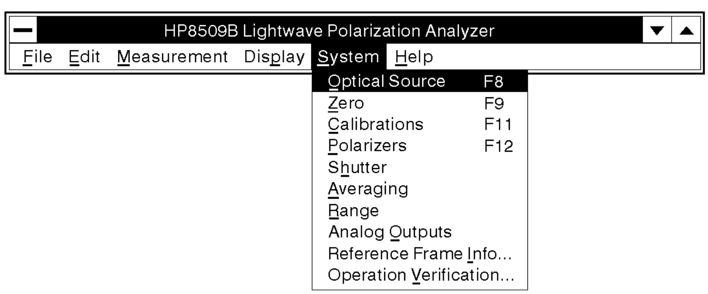
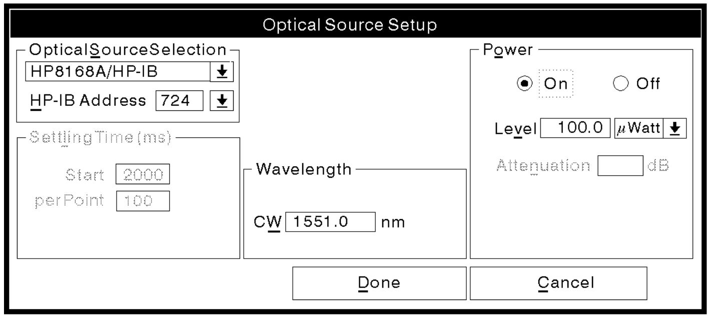



**Figure 4-62. System menu**

**3** Select the external laser source and set the wavelength. Use the default power level or set as desired. If the screen on your instrument controller looks similar to Figure 4-63, select Done.




pq71b_c

**Figure 4-63. Optical Source Setup window**

### *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.

**4** Connect your test device between the polarization controller and the optical input.

> **Enhancing Accuracy**
>
> 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 “Cleaning Connections for Accurate Measurements” on page 7-14.

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

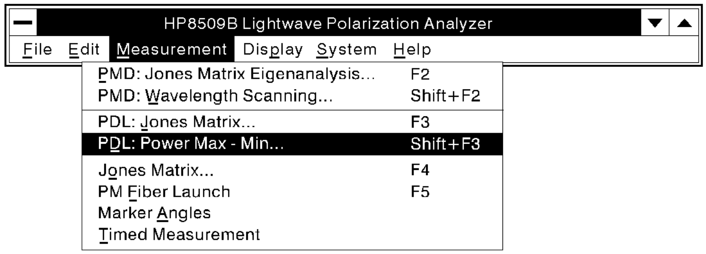



**Figure 4-64. PDL measurement menu**

**6** Select the Reset button with your mouse pointer.

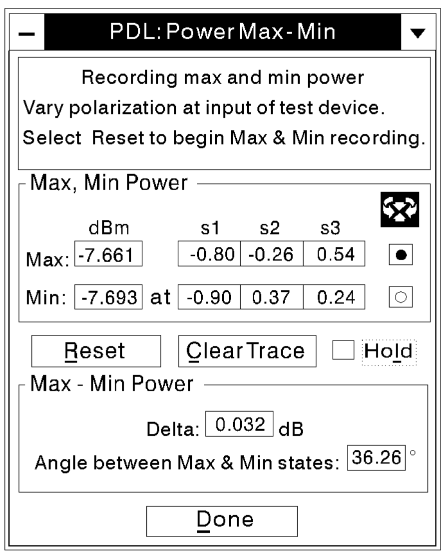
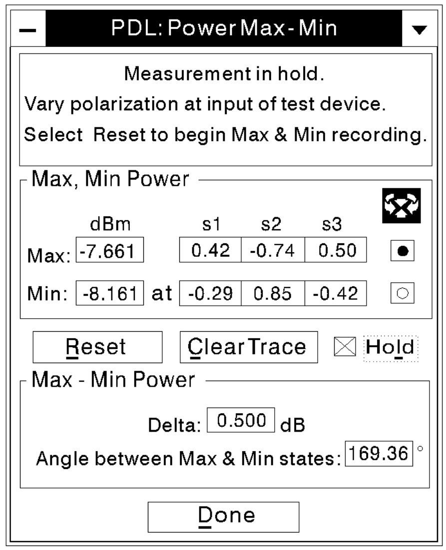



**Figure 4-65. PDL:Power Max-Min measurement window**

**7** Vary the polarization at the input of your device under test, preferably using an automatic (like the Agilent 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.

Your measurement is complete. The screen on your instrument controller should look similar to Figure 4-66.




pq7122_c

**Figure 4-66. Measurement results window**

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

For the Agilent 11896A polarization controller, automatic polarization scan rates of #4 to #5 are recommended, depending on the PDL of the test device.

## To save the measurement results

Saving data capability is not available for this measurement.

# Making Jones Matrix Measurements

| Function | See.... |
|---|---|
| **Jones matrix measurements** | "To make a Jones matrix measurement" on page 4-71<br>"To establish the polarization reference frame" on page 4-74<br>"To measure the Jones matrix of a device" on page 4-74 |
| Concepts | "The relative Jones matrix" on page 4-77<br>"The sign of s3" on page 4-77<br>"Description of the Jones matrix measurement algorithm" on page 4-77<br>"Application of the Jones matrix" on page 4-78 |

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 Figure 4-67.

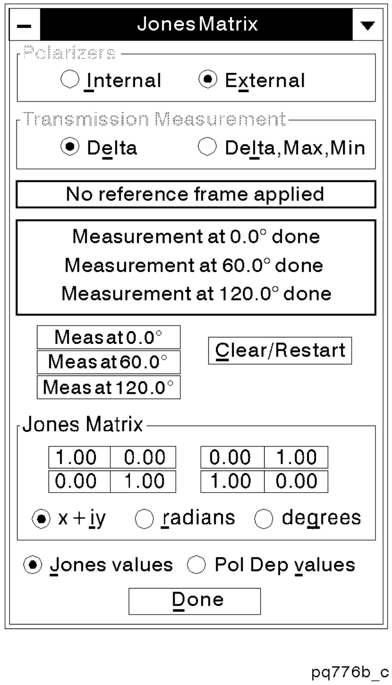



**Figure 4-67. Example of data display for a Jones matrix measurement**

## To make a Jones matrix measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the Agilent 8509C lightwave polarization analyzer operating system software to make a Jones matrix measurement.

### *Measurement setup*

1 Connect your measurement system as shown in Figure 4-68. The Agilent 11896A polarization controller is recommended as the polarization adjuster for this application.

**Enhancing Accuracy**

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

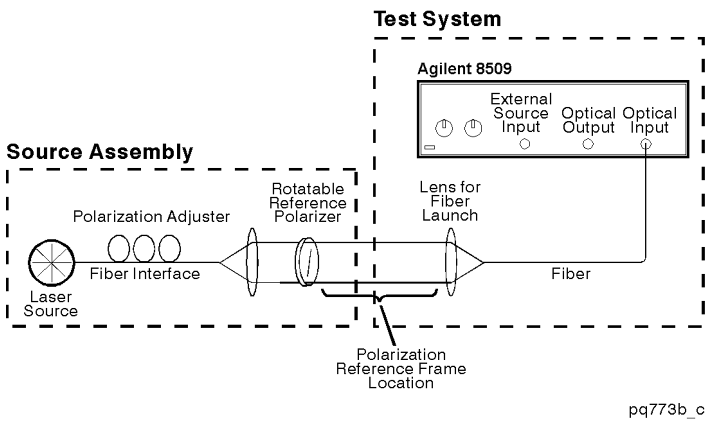



**Figure 4-68. Measurement setup**

***External source preparation***

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

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

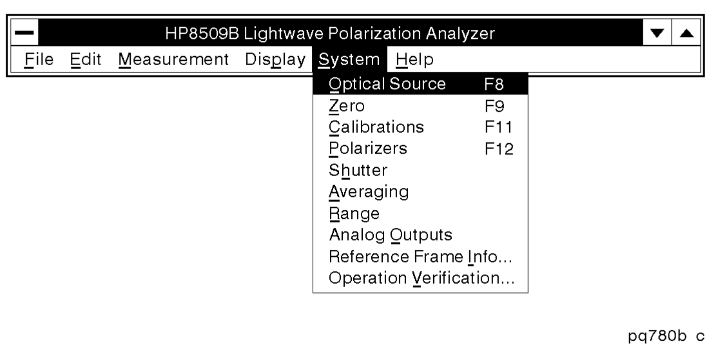



**Figure 4-69. System menu**

**3** 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 instrument controller looks similar to Figure 4-70, select Done.

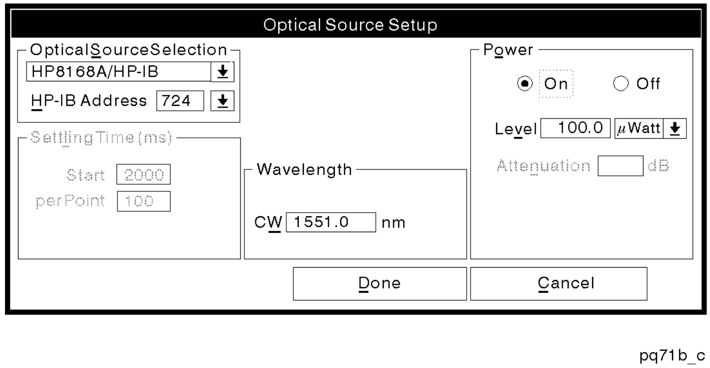



**Figure 4-70. Optical Source Setup window**

**4** Set the Agilent 8509C to use external polarizers. In the main window, select *System* menu and *Polarizers*. When the Polarizers controls appear, select *External* with the mouse and select Done.

**5** 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.

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

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

**c** 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*).

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

### *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 quarter-wave retarder oriented 45° to horizontal.

The measurement has two parts:

- 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 Agilent 8509C.

- 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.

## To 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.

> **Enhancing Accuracy**
>
> From this point on, the fiber path and optics between the reference polarizer and the Agilent 8509C 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 "Cleaning Connections for Accurate Measurements" on page 7-14.

## To measure the Jones matrix of a device

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

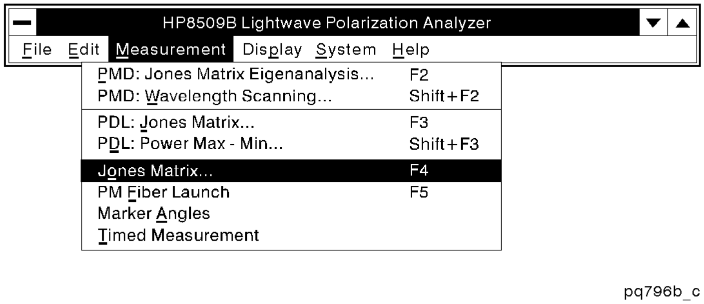



**Figure 4-71. Jones matrix measurement menu**

7 Select External Polarizers and Delta Transmission Measurement.

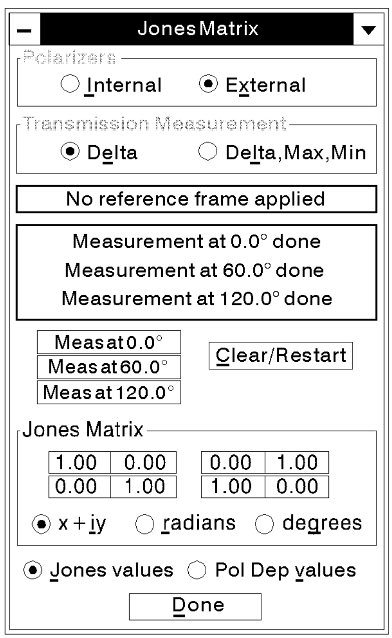



**Figure 4-72. Jones matrix measurement window**

8 Insert the test device into the polarization reference frame location with the desired angular orientation relative to the first reference polarizer setting.

9 Set the external polarizer angle to 0 degrees and then select Meas at 0.0 from

the Jones Matrix window.

**10** Set the external polarizer angle to 60 degrees and then select Meas at 60.0 from the Jones Matrix window.

**11** Set the external polarizer angle to 120 degrees and then select Meas at 120.0 from the Jones Matrix window.

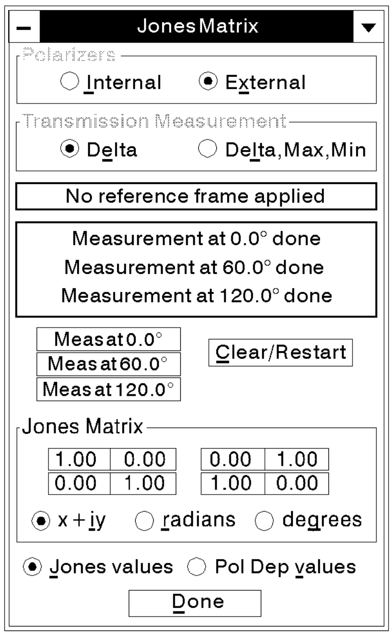



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**Figure 4-73. Measurement results window**

Your measurement is complete. The screen on your instrument controller should look similar to Figure 4-73. 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.

# Concepts

## The relative Jones matrix

The Agilent 8509C 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 Agilent 8509C.

## The sign of s3

Different reference texts use different conventions for the sign of normalized Stokes parameter s3. The convention used in the Agilent 8509C is shown in "Generating of Right-Hand Circularly Polarized Light" on page 7-9.

## Description of the Jones matrix measurement algorithm

The Agilent 8509C 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 Agilent 8509C or an external, rotatable, linear polarizer as shown in Figure 4-74. 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 Agilent 8509C to calculate a Jones matrix. The simple case where the known polarized inputs are 0, 45, and 90 degrees is shown in Figure 4-74.

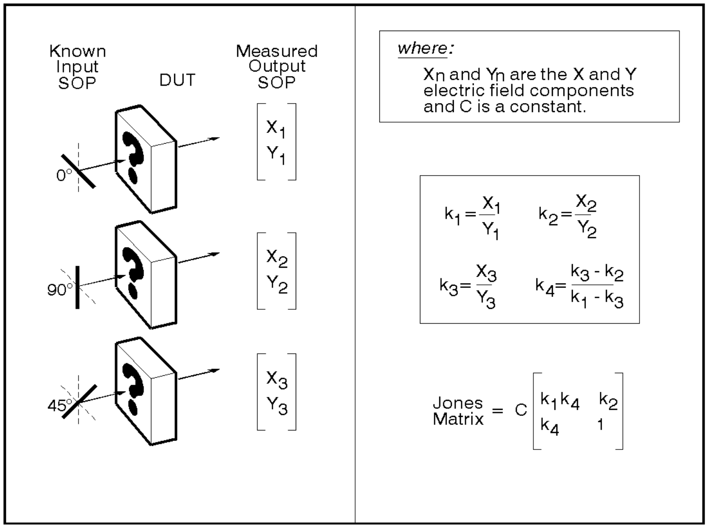


**Figure 4-74. Comparing the output Jones vectors to 3 known input Jones vectors**

## 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.

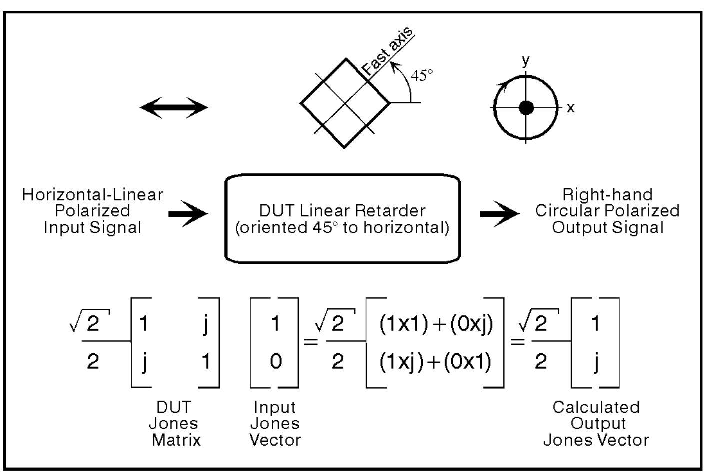


**Figure 4-75. Jones matrix application**

# Making Polarization Maintaining Fiber Launch Alignments

| Function | See.... |
|---|---|
| **PMF Launch Alignments** | "To make a PMF alignment" on page 4-80 |
| Concepts | "Explanation of polarization maintaining fiber launch mathematics" on page 4-84 |

This measurement section explains how to align an input signal relative to a principal polarization state of a PMF cable. An Agilent 8509C 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 Figure 4-76.

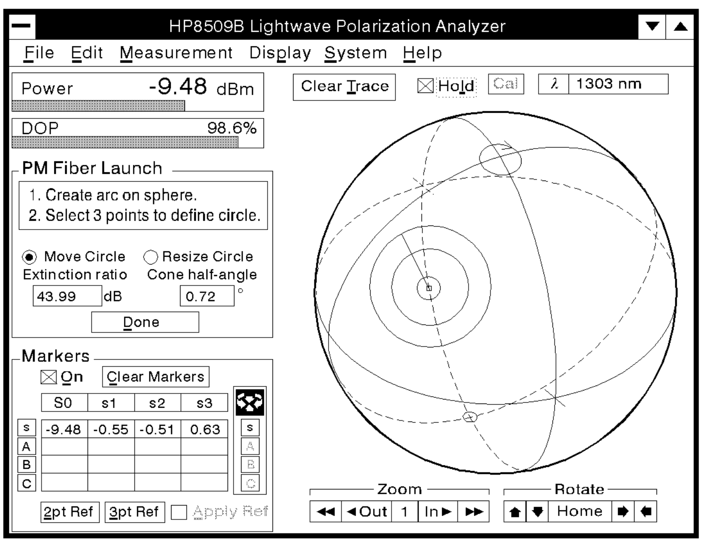


**Figure 4-76. Example of a polarization maintaining fiber alignment data display**

## To make a PMF alignment

The following measurement procedure illustrates the simplest and most straightforward path in using the Agilent 8509C lightwave polarization analyzer operating system software to make a PM Fiber Launch measurement.

### *Measurement setup*

**1** Connect your measurement system as shown in Figure 4-77.

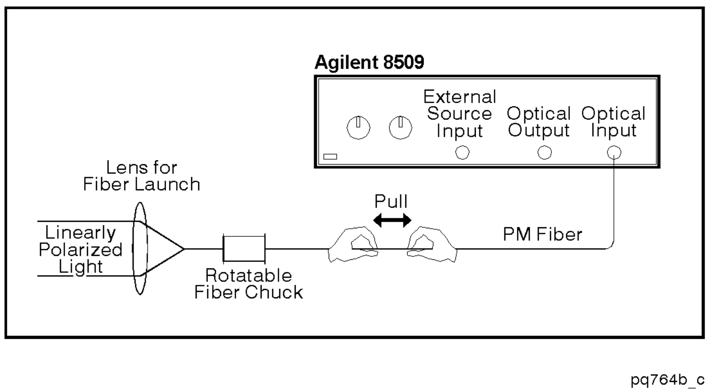


**Figure 4-77. Measurement setup**

### *External source preparation*

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

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

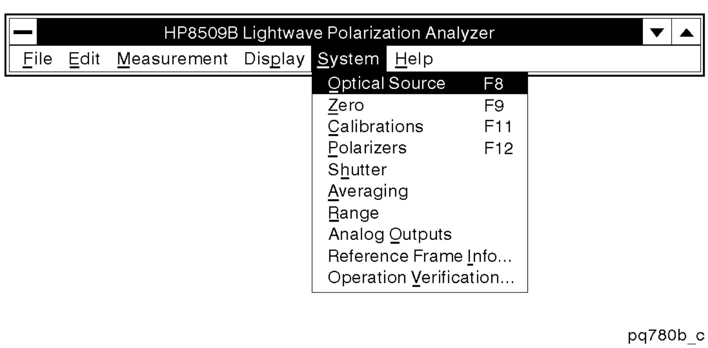


**Figure 4-78. System menu**

**3** 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 instrument controller looks similar to Figure 4-79, select Done.

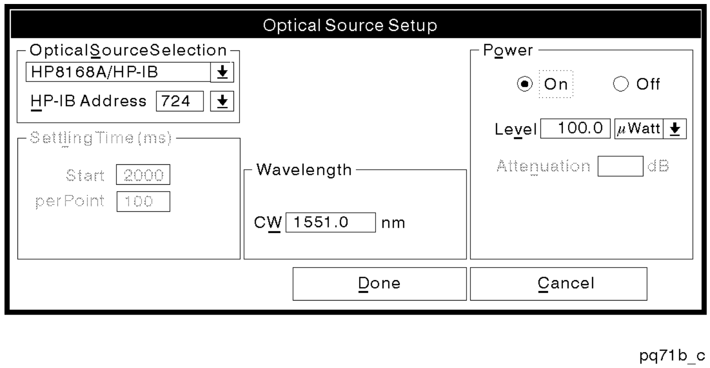


**Figure 4-79. Optical Source Setup window**

### *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 "Cleaning Connections for Accurate Measurements" on page 7-14.

**4** Select *Measurement* from the main menu, and then select *PM Fiber Launch*.

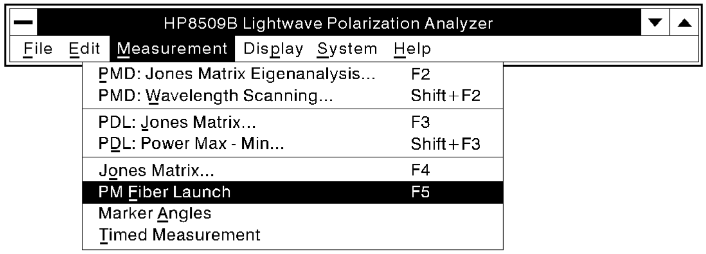


**Figure 4-80. PM fiber launch measurement menu**

5 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.

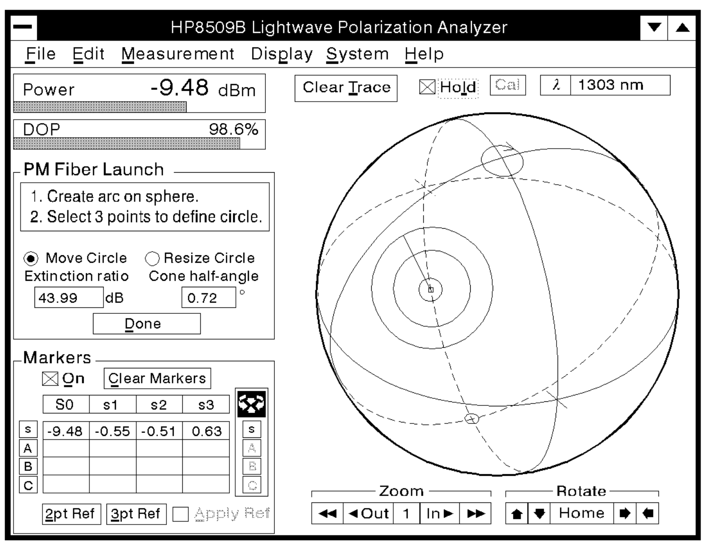


**Figure 4-81. PM fiber launch alignment window**

6 Place three points along this arc by using the mouse pointer and then clicking the left mouse button.

7. Select the Center button to center the display.
8. Rotate the fiber chuck until the active point on the Poincare sphere approaches the center of the circle.
9. Use the Poincare display Zoom and PM Fiber Launch Center functions to optimize the view of the arc.
10. Slightly stress the PMF cable by pulling or heating it until an arc appears again.
11. Select the New Circle button, place three points on the arc using the mouse pointer.
12. Continue the previous steps until the value in the dB extinction ratio window is maximized.
13. Select the Done button to finish this procedure.
14. To align another PMF cable, connect it to the analyzer and repeat the previous procedure.

# 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 Figure 4-82.

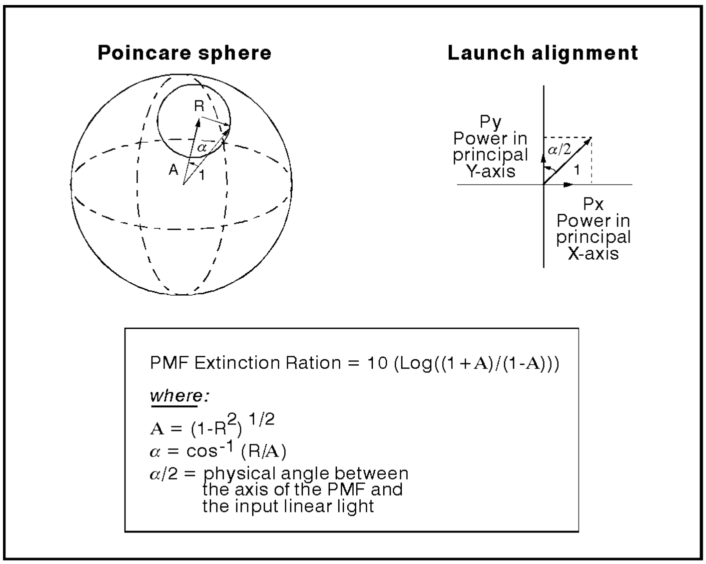


**Figure 4-82. How PMF cable launch extension ratio is calculated**

# Making Polarization Reference Frame Measurements

| Function | See.... |
|---|---|
| **Polarization reference frame measurements** | "To make a polarization reference frame measurement" on page 4-86<br>"To choose the polarizers" on page 4-88<br>"To set the reference frame" on page 4-88<br>"To check the reference frame quality" on page 4-89<br>"To set a circular state of polarization" on page 4-89<br>"To use the reference frame" on page 4-89 |
| Additional measurement applications | "2pt and 3pt polarization reference frames" on page 4-90<br>"Measurement of the retardance of an optical device" on page 4-90<br>"Measurement of output polarization of an optical integrated circuit" on page 4-90<br>"Measuring polarization state at a connector surface" on page 4-91 |
| Concepts | "Explanation of polarization reference frame mathematics" on page 4-91<br>"Transmission ratio (3pt reference frame)" on page 4-91 |

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 Figure 4-83, which 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.

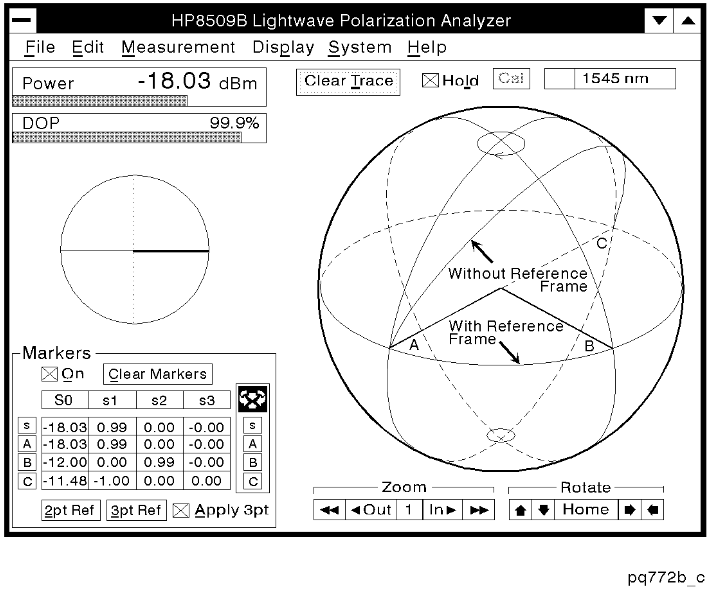


**Figure 4-83. Example of the results that can be achieved with and without a polarization reference frame**

## To make a polarization reference frame measurement

The following measurement procedure illustrates the simplest and most straightforward path in using the Agilent 8509C lightwave polarization analyzer operating system software to create a 3pt polarization reference frame, using an external polarizer.

### *Measurement setup*

1 Connect your measurement system as shown in Figure 4-84.

> **Enhancing Accuracy**
>
> The fiber leading from the second lens to the Agilent 8509C optical input must be taped down to prevent movement during or following the creation of the reference frame.

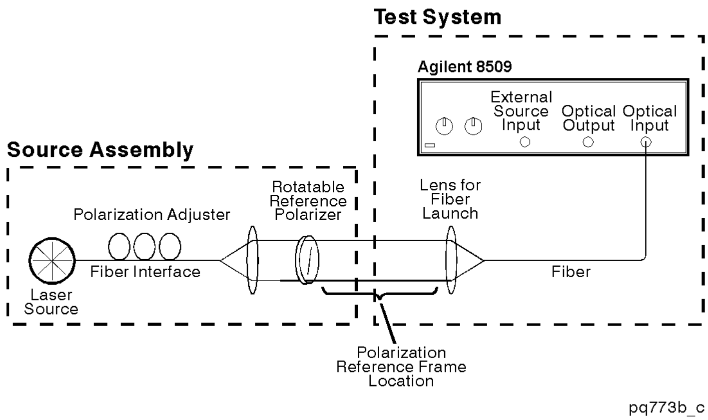


**Figure 4-84. Measurement setup**

### *External source preparation*

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

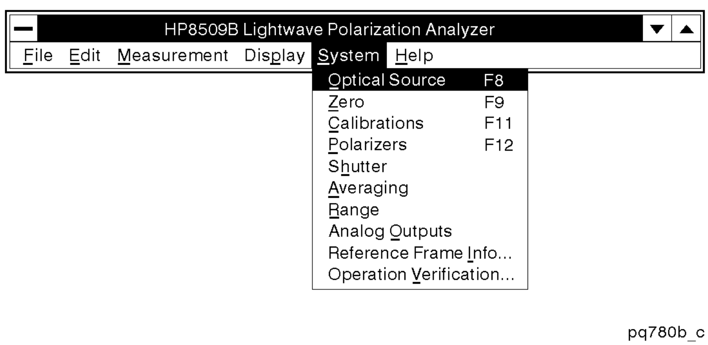


**Figure 4-85. System menu**

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

3 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 instrument controller looks similar to Figure 4-86, select Done.

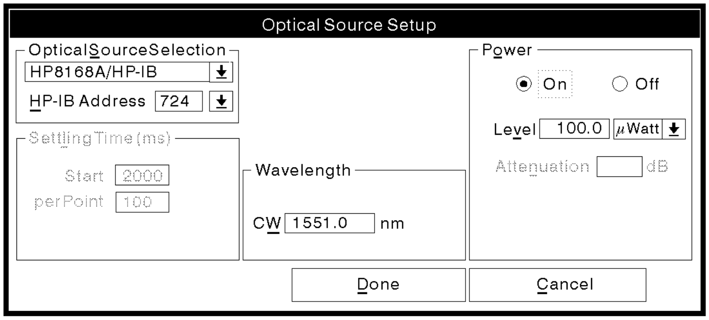


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**Figure 4-86. Optical Source Setup window**

## To choose the polarizers

To set a reference frame in an open beam environment you must select the external polarizers option on the analyzer.

1. You may choose the external polarizers by first selecting *System*, with your mouse pointer, from the main window menu, and then *Polarizers*.
2. When the Polarizers window appears, select *External* with the mouse pointer, then select Done.

## To set 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.

1. Set the external polarizer to horizontal linear polarization, and select the A Marker.
2. Rotate the external polarizer 60 degrees from original position and select the B Marker.
3. Rotate the external polarizer an additional 60 degrees, to a position 120° from the original. Select the C Marker.
4. 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.

## To check the reference frame quality

1. To check the quality of the reference frame, select *System* and then *Reference Frame Info...*.
2. If the quality is poor then you must repeat the previous steps, starting at "To choose the polarizers" on page 4-88.
3. If the quality is good, select OK to continue, then select Apply 3pt with your mouse pointer from the Markers window.

## To set 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.

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

## To use 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 Agilent 8509C 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.

**Enhancing Accuracy**

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 Agilent 8509C PMD measurements.

**CAUTION** Observe proper laser safety; refer to “General Safety Considerations” at the front of this manual. Observe proper connection techniques. Refer to “Cleaning Connections for Accurate Measurements” on page 7-14.

## 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 “Making Jones Matrix Measurements” on page 4-70.

### *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 Agilent 8509C. 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 "Making Polarization Maintaining Fiber Launch Alignments" on page 4-79 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 "Making Polarization Maintaining Fiber Launch Alignments" on page 4-79 for details on launching light into a single polarization mode of PMF.

## Concepts

### Explanation of polarization reference frame mathematics

The Agilent 8509C produces a polarization reference frame using Jones Matrix calculus. The Agilent 8509C measures the Jones Matrix of the test system. 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 "Making Jones Matrix Measurements" on page 4-70 for further information.

### 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 Agilent 8509C 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 Agilent 8509C. 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.

# Making State of Polarization Measurements

| **Function** | **See....** |
|---|---|
| **State of polarization measurements** | “To make signal polarization parameters measurements” on page 4-94 |
| Concepts | “Degree of polarization” on page 4-97<br>“Electric fields and polarization” on page 4-97<br>“Elliptical displays of polarization” on page 4-98<br>“Poincare sphere” on page 4-99<br>“Stokes parameters” on page 4-100 |

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 Agilent 8509C and are discussed in this section. A typical measurement window is shown in Figure 4-87.

Unless a polarization reference frame is specifically created by the user (see “Making Polarization Reference Frame Measurements” on page 4-85), the Agilent 8509C uses the reference frame of the polarimeter receiver inside the instrument.

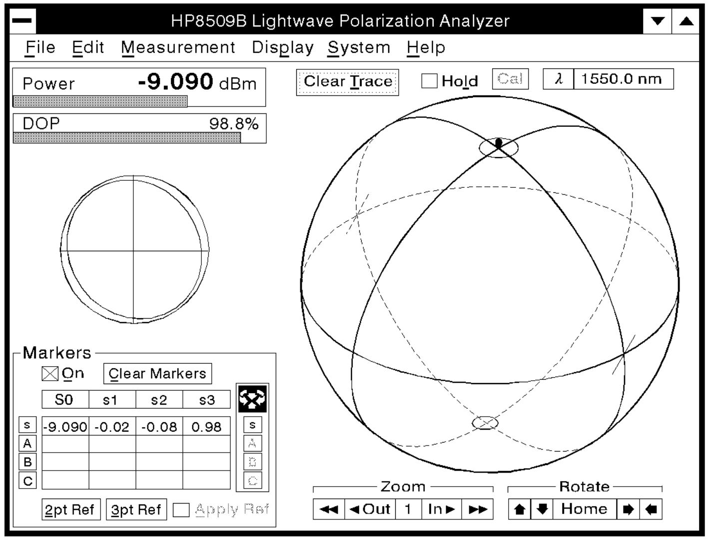


**Figure 4-87. Example of a SOP measurement data display**

## To make signal polarization parameters measurements

The following measurement procedure illustrates how to use the Agilent 8509C lightwave polarization analyzer operating system software to measure the polarization parameters of a signal.

### *Measurement setup*

1 Connect your measurement system as shown in Figure 4-88.

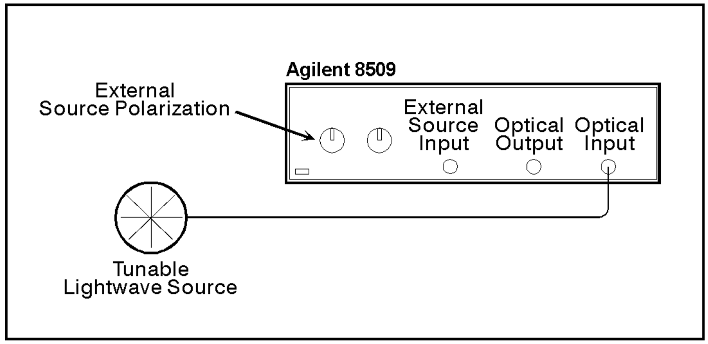


**Figure 4-88. Measurement setup**

### *External source preparation*

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

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

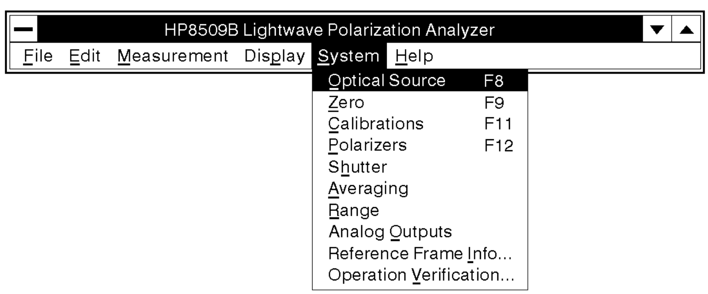


**Figure 4-89. System menu**

**3** Select the external laser source and set the desired wavelength.

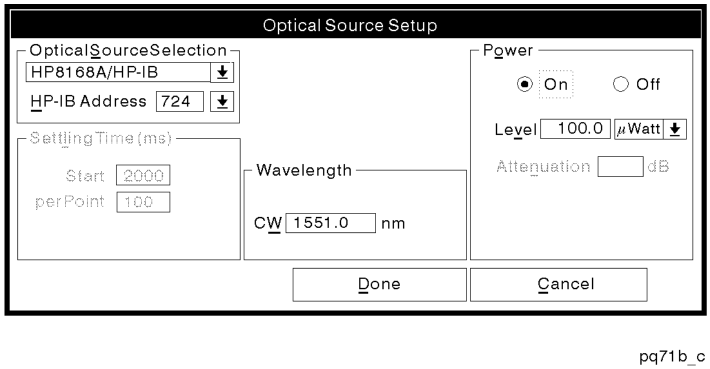


**Figure 4-90. Optical Source Setup window**

### *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.

1 Activate the laser source and ensure that the fiber and the laser are thermally and vibrationally stable.

2 The main window should now display the correct input state of polarization, DOP, and power level (see Figure 4-91).

**CAUTION** Observe proper connection techniques. Refer to “Cleaning Connections for Accurate Measurements” on page 7-14.

Your measurement is complete. Signal polarization parameters are presented on the basic Agilent 8509C measurement screen and should look similar to Figure 4-91.

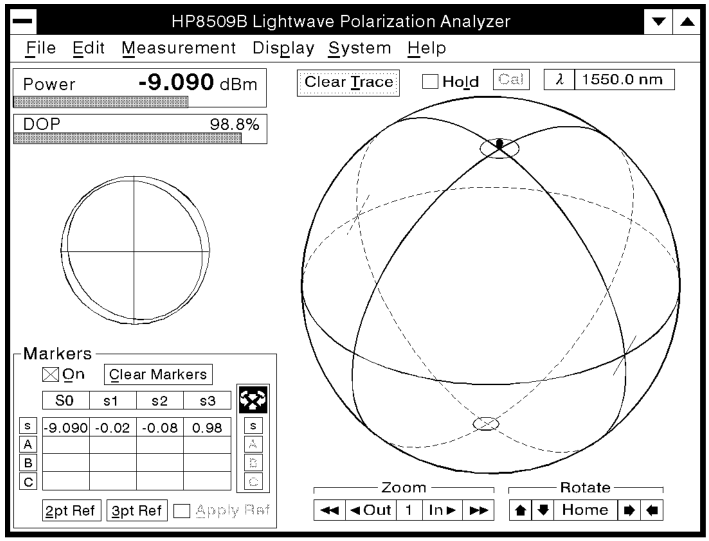


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**Figure 4-91. SOP and DOP measurement results screen**

# 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.

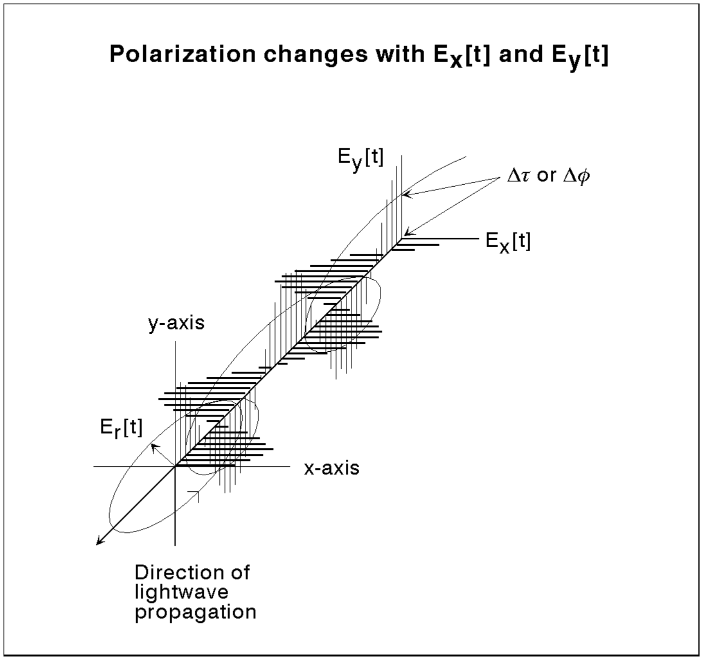



**Figure 4-92. Polarization changes with Ex(t) and Ey(t)**

### *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 Figure 4-93. Notice the E-field magnitude and phase relationships for each case.

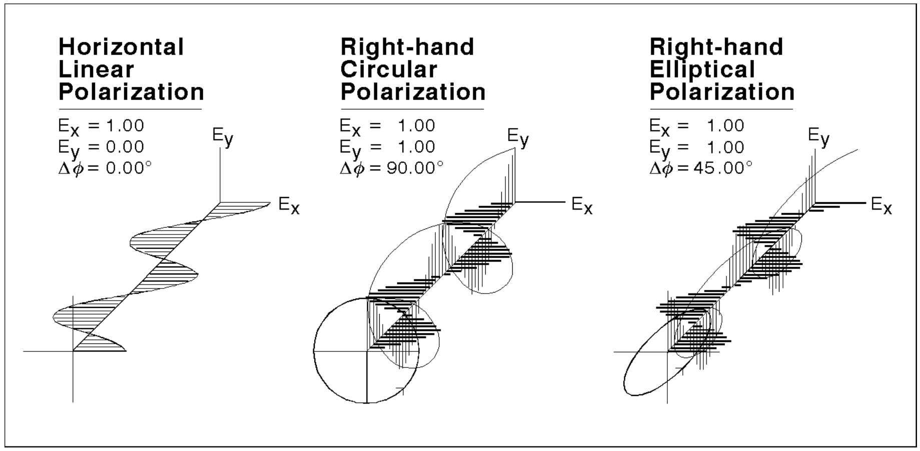



**Figure 4-93. Elliptical displays of polarization**

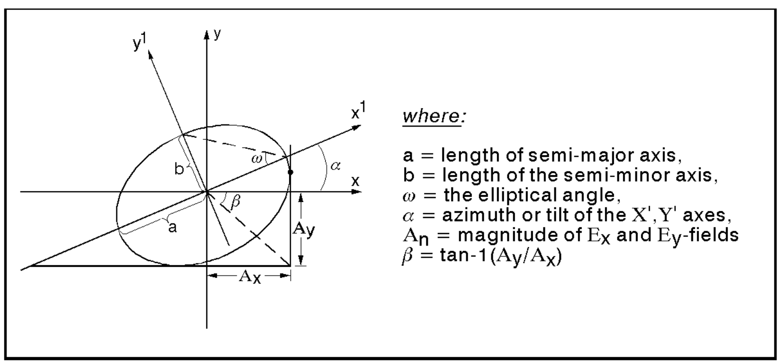



**Figure 4-94. Mathematical description of an elliptical display of polarization**

***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 Agilent 8509C 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.

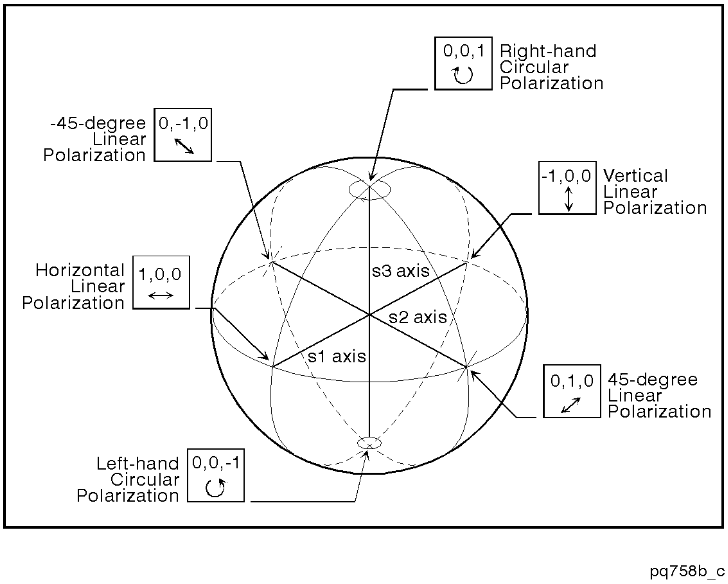



**Figure 4-95. Polarization states on a poincare sphere**

### *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 Agilent 8509C 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.

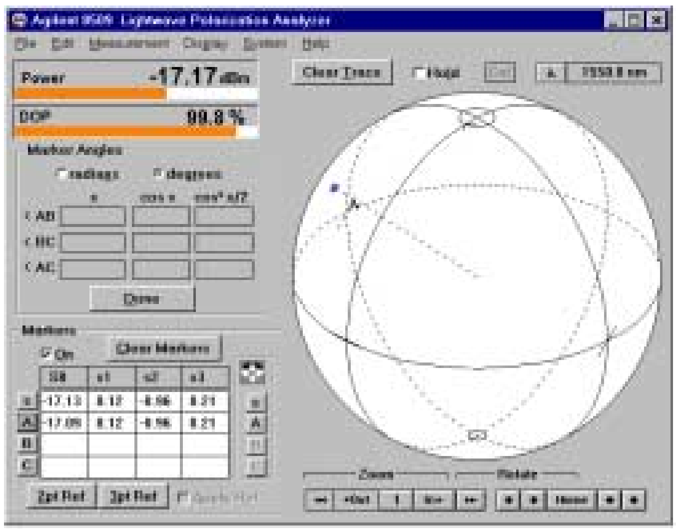
# Making Marker Angles

The marker angles function allows you to calculate angles between any two marked points on the Poincare sphere. When at least two markers have been defined, the angle between those markers will be printed in the marker angles group.

| Function | See.... |
|---|---|
| Marker angles | "To make a marker angles measurement" on page 4-102 |
| Free Run Mode Measurement | "To make a free run mode measurement" on page 4-105 |
| Timed Mode Measurement | "To make a timed mode measurement" on page 4-106 |
| Single Mode Measurement | "To make a single mode measurement" on page 4-108 |
| Timed Measurement Viewing | "To view timed measurements on the Poincare sphere" on page 4-109 |
| Saving Timed Measurement | "To save timed measurements" on page 4-110 |
| Recalling (Loading) Timed Measurements | "To recall (load) timed measurements" on page 4-111 |

## To make a marker angles measurement

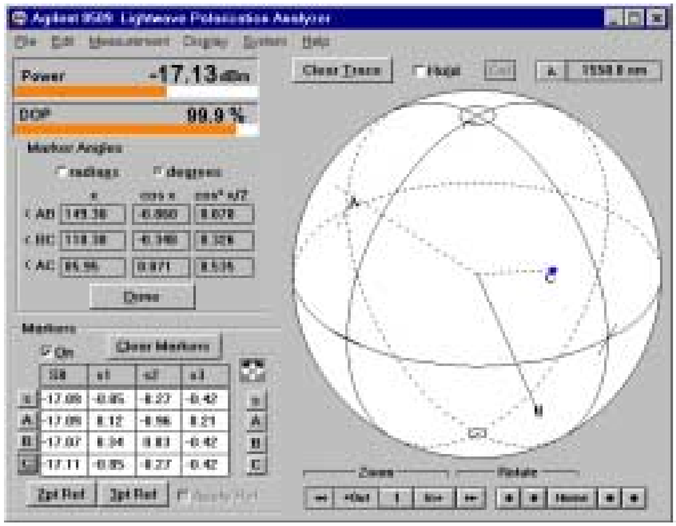
**1** Select *Measurement* and then *Marker Angles*. A Marker Angles group will appear in the main window. The angle will be measured between two points.




**2** Check the On box from the Markers area to set a marker.

**3** Click on *Clear Markers* to clear any previous data.

**4** Select *A* to define your first marker for your first state of polarization measurement. Define markers B and C in the same manner.




**5** Read the Marker Angles from the Marker angles group just below the power meter and DOP bars.

Once the Markers have been defined, you can view the results in the Marker Angles group. Both the angle and its cosine are displayed. Notice that you can view the marker values in either radians or degrees.

**6** When finished, select *Done* to close the marker angles group.

## Making Timed Measurements

The timed measurement feature provides a means for measuring and saving the polarization parameters of an optical signal as a function of time. Saved measurements can be recalled for viewing on the Poincare sphere or imported to a spreadsheet for analysis. Timed measurement data is preserved when the Poincare sphere is rotated or zoomed.

**Note**: When the Poincare sphere is rotated or zoomed, you will lose your sphere traces, but will keep your markers.

From the Measurement menu, select Timed Measurement Refer to “Timed Measurement selection” on page 4-104.

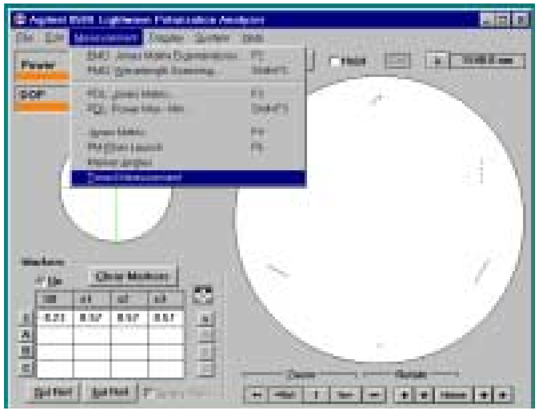



**Figure 4-96. Timed Measurement selection**

The Timed Measurement controls appear in the area normally occupied by the Polarization Ellipse display. Refer to “Timed Measurement” on page 4-104.

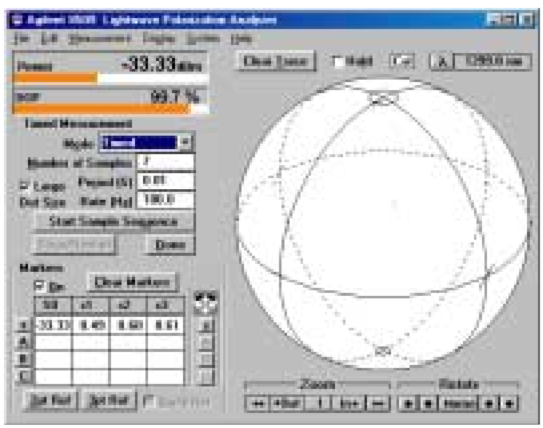



**Figure 4-97. Timed Measurement**

The drop-down list provides three operating modes:

**Free Run mode**, a user-specified number of measurements, are taken at the normal, untimed, open-loop rate of the Agilent 8509C, typically 2000-3500 samples per second.

**Timed mode**, a user-specified number of measurements, are taken at specified time intervals.

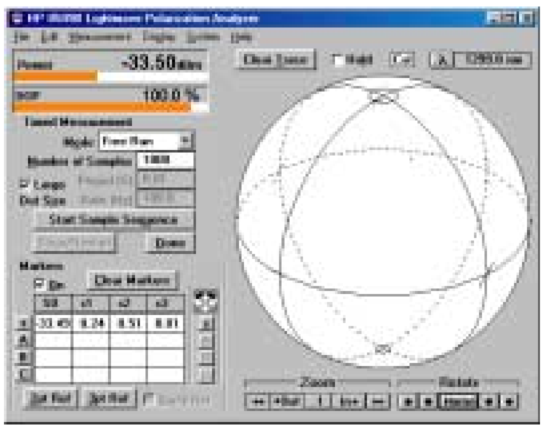
**Single mode**, measurements are taken one at a time as specified by the user.

In all three modes, the Agilent 8509C automatically clears the Poincare sphere display and puts the instrument in hold when the measurement is started. The instrument is left in hold at the end of the measurement to prevent the display of unwanted measurements on the Poincare sphere.

## To make a free run mode measurement

1 Select *Free Run* from the drop-down list of the Timed Measurement Mode.

2 In the Number of Samples box, enter the number of measurement samples you want to collect. A maximum of 16,381 is allowed.




3 Check the Large Dot Size to display the Poincare Sphere using 9x9 pixel display or clear the check box to display the Poincare Sphere using a single pixel. The large dot size makes the display easier to see.

4 Select Start Sample Sequence to begin the measurement.

Measurements are automatically taken at the open-loop measurement rate of the Agilent 8509C, typically 2000-3500 samples per second (refer to “Receiver characteristics” on page 9-10). The measurement cannot be interrupted or cancelled. The screen and mouse are inactive.

The measurement is complete when the mouse pointer returns. The Poincare sphere can be rotated or zoomed without loss of data. The Poincare sphere display is refreshed after it has been hidden behind another window. The amount of time required to reformat or refresh the Poincare sphere display increases with the number of samples.

Measurement samples may be sequentially averaged using the Display Averaging feature found in the main window of the Agilent 8509C under System > Averaging. Display averaging produces a moving, unweighted average from a user-specified number of samples.

## To make a timed mode measurement

1 Select Timed from the drop-down list of the Timed Measurement Mode.

2 In the Number of Samples box, enter the number of measurement samples you want to collect. A maximum of 16,381 is allowed.

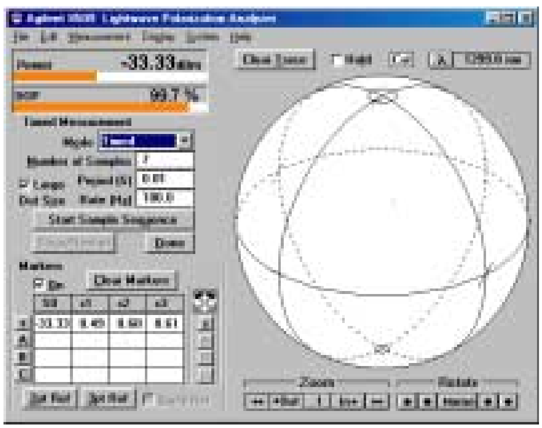



**Figure 4-98. Timed measurement mode.**

3 Enter either the period (0.010 to 7209 seconds) or rate (0.00013 to 100 Hz) of the time measurement.

Period is rounded to the nearest millisecond; the rate is given by 1/period.

4 Select *Start Sample Sequence* to start the measurement. The data acquisition status box appears, refer to “Status of the time measurement” on page 4-107, showing the status of the time measurement.

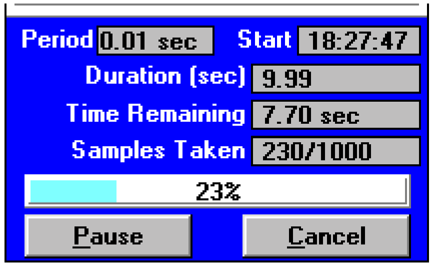



**Figure 4-99. Status of the time measurement**

**Period** of the time measurement ranges from 0.010 to 7209 seconds.
**Start** shows the start time in 24-hour format.
**Duration** displays the measurement time which is dependent of the number of samples taken.
**Time Remaining** displays the remaining time of the measurement.
**Samples Taken** displays the number of samples requested.
**Pause** stops data collection at the current sample count. Pause is available when the measurement requires more than 8 seconds. To select pause, press Alt and the underline character. (Tip: the underline character is normally selected by pressing shift hyphen.)
**Continue** restarts the data collection at the current sample count. Continue replaces Pause once the measurement has been stopped.
**Cancel** stops the measurement entirely, but data measured before the button is pressed is preserved. The number of measurements taken before cancel was pressed appears in the number of samples display. The measurement can be restarted by selecting Timed Mode from the drop-down list.
When the measurement is complete, the Poincare sphere can be rotated or zoomed without loss of data. The Poincare sphere display is refreshed after it has been hidden behind another window. The amount of time required to re-format or refresh the Poincare sphere display increases with the number of samples.

**Note**: When the Poincare sphere is rotated or zoomed, you will lose your sphere traces, but will keep your markers.

Measurement samples may be sequentially averaged using the display averaging feature found in the main window of the Agilent 8509C under System > Averaging. In the timed mode of operation, two modes of averaging are available. The moving average mode forms the unweighted average of recent samples as specified by the user and operates the same as averaging in free run mode. When the period is large or the rate is small, the refreshed average mode is automatically selected. In this mode, each displayed measurement point is the result of a fresh set of samples taken at the open-loop measurement rate of the Agilent 8509C. Each displayed measurement point is totally independent of any other displayed measurement point. Averaging automatically switches to the refreshed average mode when the period is larger than the time value stored in the parameter `MsecToAvgEachPt` in the WIN.INI file in the Windows Directory. This parameter can be edited by double clicking on the WIN.INI file name in the Windows Directory, finding the item in the file and editing the value (in milliseconds). The default value is 50 milliseconds. The value chosen must be large enough to allow the use-specified number of display averages to be taken at the open-loop measurement rate of the Agilent 8509C. The Agilent 8509C application must be ended and restarted to access the changed parameter value. Additional detail is provided in CONFIG.WRI.

**Note**: Timed measurement accuracy is approximately +/–1 millisecond when intervals are less than 65.565 seconds, and +2/–12 milliseconds for other timed intervals. Actual timed interval accuracy can be determined by observing the hold output BNC connector on the rear panel of the Agilent 8509C LPA instrumentation during a timed measurement. This is an active low TTL signal with a 10 microsecond pulse for each stokes measurement. Turn Agilent 8509C averaging off to see only a single pulse for each timed interval.

## To make a single mode measurement

1 Select *Single* from the drop-down list of the Timed Measurement Mode. Refer to “Single mode measurement” on page 4-108.

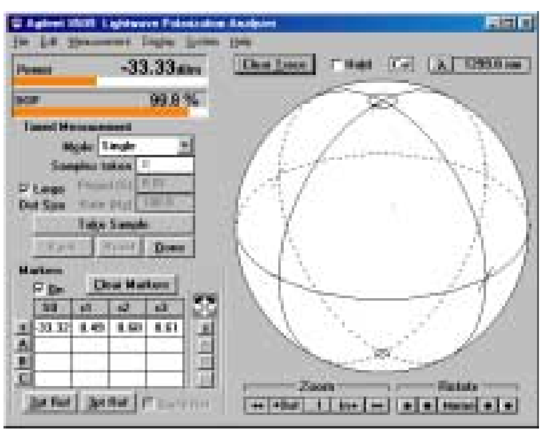



**Figure 4-100. Single mode measurement**

2 Press *Take Sample* once for each polarization measurement desired.

3 From the System > Averaging menus, select *Display Averaging On* and specify the number of samples to be averaged. Each time the Take Sample button is pressed, that number of samples is taken at the open-loop measurement rate of the instrument and averaged to produce a single measurement value.

**Samples taken** displays the number of samples taken. The maximum number of samples is 16,381.
**Take Sample** starts the number of samples taken for each desired polarization measurement.
**Back** step button erases the most recent measurement point. It may be pressed more than once.
**Reset** resets the entire measurement.

When the measurement is complete, the Poincare sphere can be rotated or zoomed without loss of data. The Poincare sphere display is refreshed after it has been hidden behind another window. The amount of time required to re-format or refresh the Poincare sphere display increases with the number of samples.

**Note**: When the Poincare sphere is rotated or zoomed, you will lose your sphere traces, but will keep your markers.

## To view timed measurements on the Poincare sphere

Polarization data taken in any of the Timed Measurement modes is preserved when the Poincare sphere is rotated or zoomed. The controls to rotate and zoom are located below the Poincare sphere display. Refer to “Rotate and zoom controls” on page 4-110.

**Note**: When the Poincare sphere is rotated or zoomed, you will lose your sphere traces, but will keep your markers.

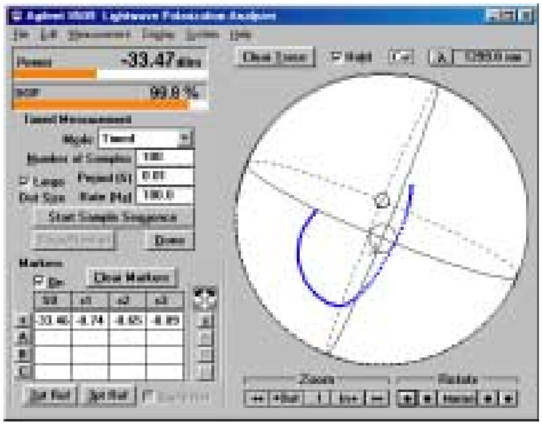


**Figure 4-101. Rotate and zoom controls**

## To save timed measurements

1 Select *File* > *Save* > *Timed Measurement to Database* to save a time measurement to the database. Refer to “Save a timed measurement” on page 4-110.

or

2 Select *File* > *Save* > *Timed Measurement As Text* to save a timed measurements to a text file.

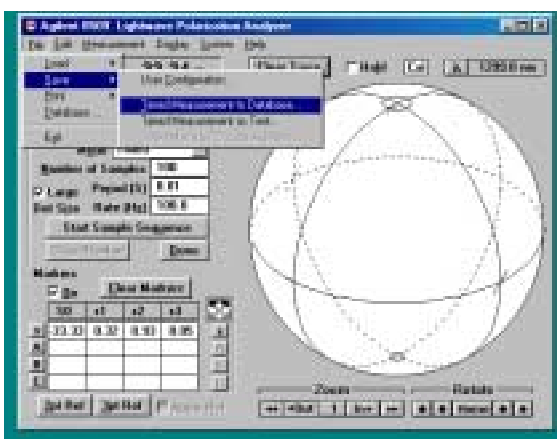


**Figure 4-102. Save a timed measurement**

When a timed measurement is saved as text, the Stokes parameters (optical power $S_0$ and $S_1$, $S_2$, $S_3$) are expressed in milliwatts and the Degree of Polarization (DOP) in percent.

## To recall (load) timed measurements

1. Select *File* > *Save* > *Timed Measurement to Database As Text* to load a timed measurement from the database. Refer to “Load a timed measurement from text file” on page 4-111.

   or

2. Select *File* > *Load* > *Timed Measurement As Text* to load a timed measurement from a text file.

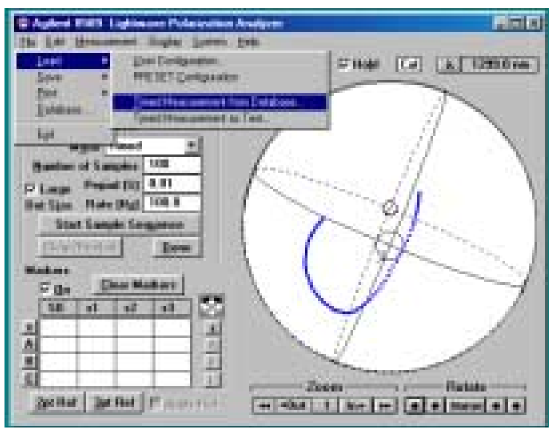


**Figure 4-103. Load a timed measurement from text file**

Other display functions, such as zoom, rotate, and marker functions, are discussed in Chapter 2, “A Quick Tour”.

# Using the Display Menu

# The PRESET Configuration

Figure 5-1 shows the PRESET configuration of the Agilent 8509C 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.

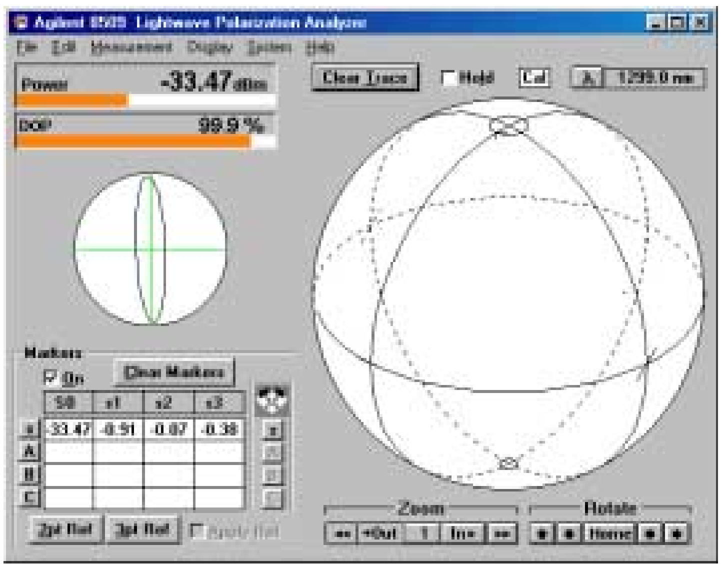



**Figure 5-1. PRESET configuration window**

# The Display Menu

This chapter contains information about the Display menu (in the main window).

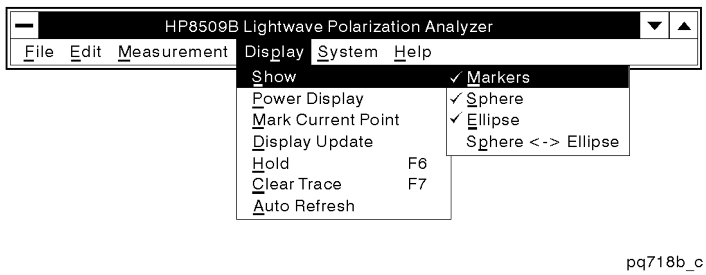


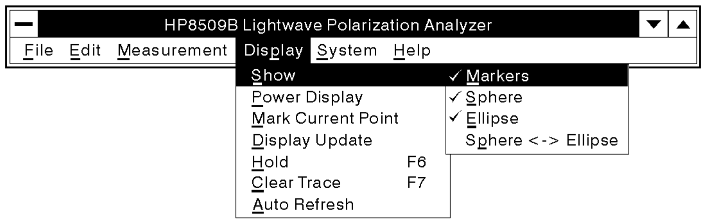

**Figure 5-2. Display menu**

The following functions are available:

| Function | See.... |
|---|---|
| Show | |
| Markers | "To display the marker table" on page 5-4 |
| Sphere | "To display the Poincare sphere" on page 5-6 |
| Ellipse | "To display the polarization ellipse" on page 5-7 |
| Sphere < - > Ellipse | "To exchange the Poincare sphere and the polarization ellipse" on page 5-8 |
| Power Display | "To change the power display units" on page 5-10 |
| Mark Current Point | "To mark the current point" on page 5-12 |
| Display Update | "To change the display update frequency" on page 5-14 |
| Hold | "To hold the data display" on page 5-16 |
| Clear Trace | "To clear the trace from the sphere" on page 5-18 |
| Auto Refresh | "To set the display to refresh automatically" on page 5-19 |

# Using the Show functions

## To display the marker table




pq718b_c

**Figure 5-3. 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.

Figure 5-4 on page 5-5 shows what the display looks like with the marker window hidden.

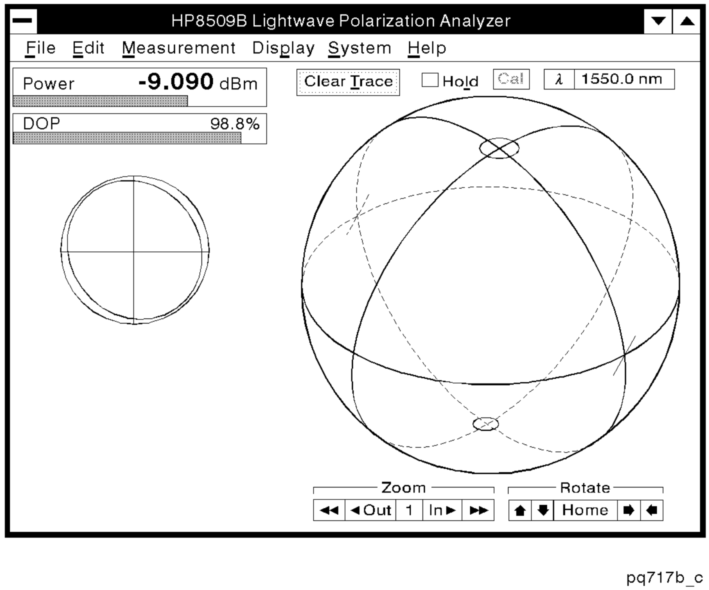



**Figure 5-4. Marker window hidden display**

The marker window, in the lower-left corner of the Agilent 8509C 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 "Stokes parameters" on page 4-100.)

## To display the Poincare sphere

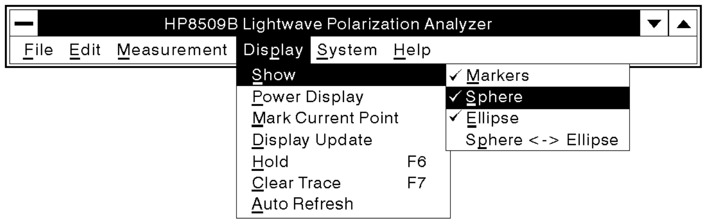



**Figure 5-5. Show Sphere menu**

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.

Figure 5-6 on page 5-7 shows what the Agilent 8509C display looks like with the sphere turned off.

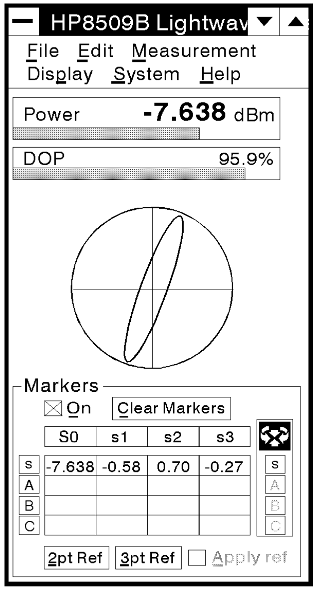



**Figure 5-6. Poincare sphere display turned off window**

## To display the polarization ellipse

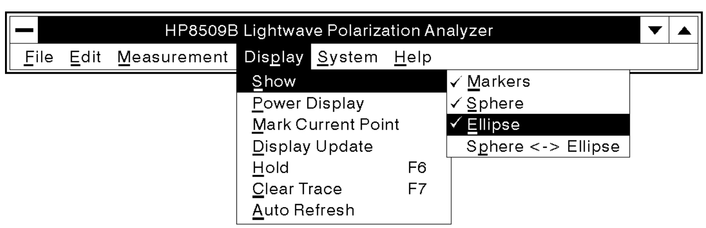
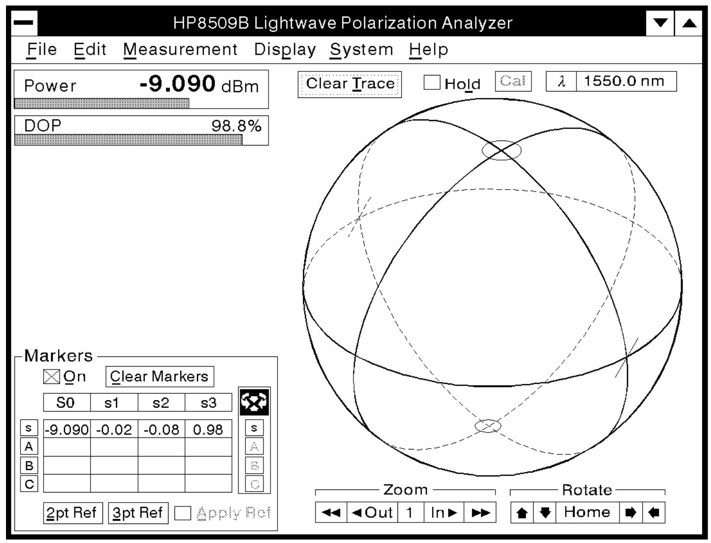



**Figure 5-7. Show Ellipse menu**

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.

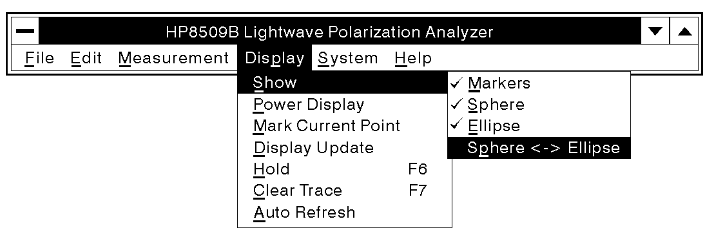
Figure 5-8 on page 5-8 shows what the Agilent 8509C display looks like with the ellipse turned off.




pq722b_c

**Figure 5-8. Polarization ellipse display turned off window**

## To exchange the Poincare sphere and the polarization ellipse




pq723b_c

**Figure 5-9. Show Sphere <-> Ellipse menu**

The default configuration has the Poincare sphere and the polarization ellipse displayed as shown in Figure 5-1 on page 5-2. You may exchange the two so that the ellipse has the more prominent position by selecting *Display, Show, Sphere <-> Ellipse*.

Figure 5-10 on page 5-9 shows what the display looks like with the Poincare sphere and the polarization ellipse exchanged.

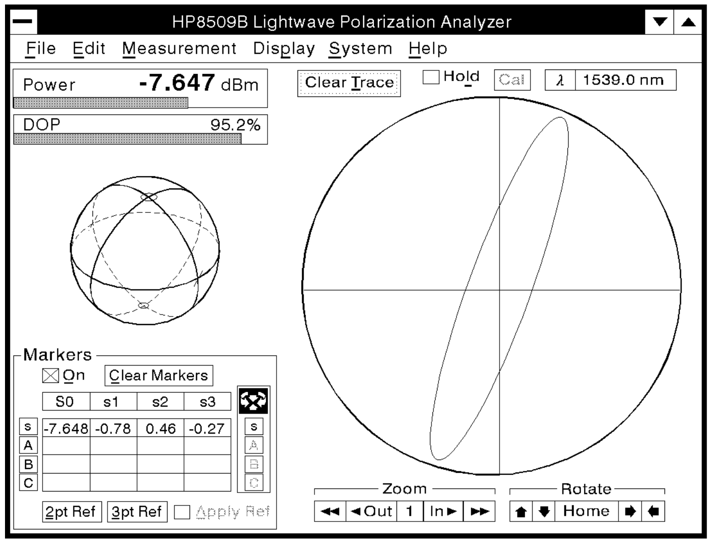



**Figure 5-10. Sphere and ellipse exchanged display window**

# Using the Power Display functions

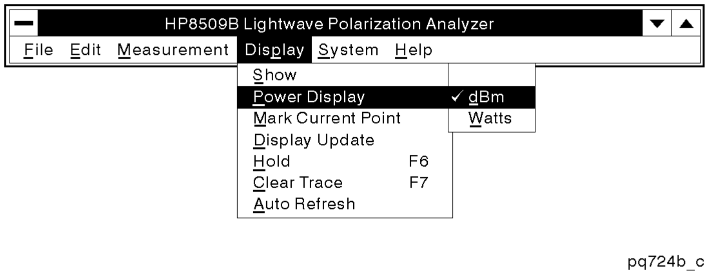



**Figure 5-11. Power Display menu**

## To change the power display units

The default state for the power mode is dBm. See Figure 5-1 on page 5-2. 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.

Figure 5-12 on page 5-11 shows the power mode changed from dBm to Watts.

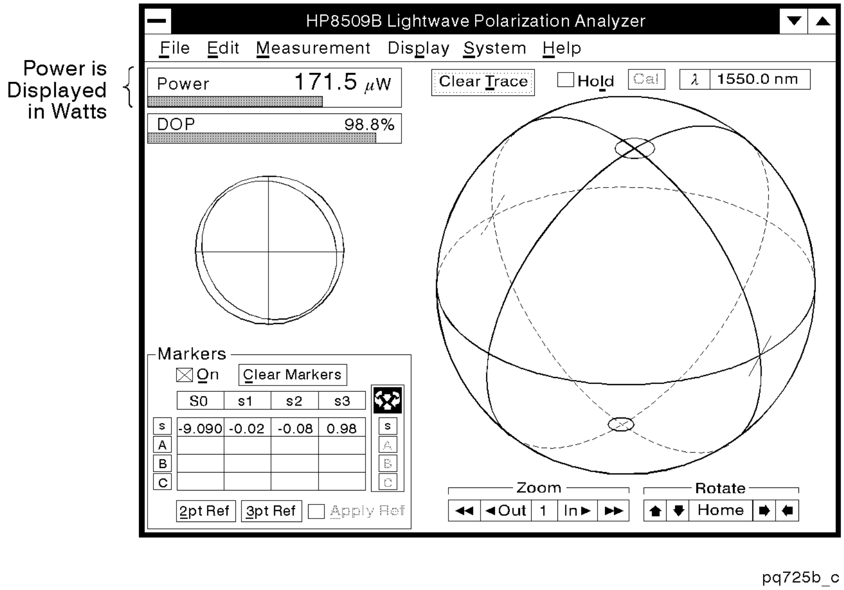



**Figure 5-12. Power display in watts mode window**

# Using the Mark Current Point functions

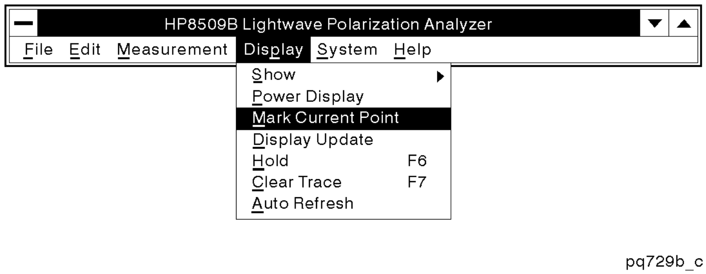



**Figure 5-13. The Mark Current Point menu**

## To mark the current point

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.

Figure 5-14 on page 5-13 shows what the display looks like with the mark current point feature turned on.

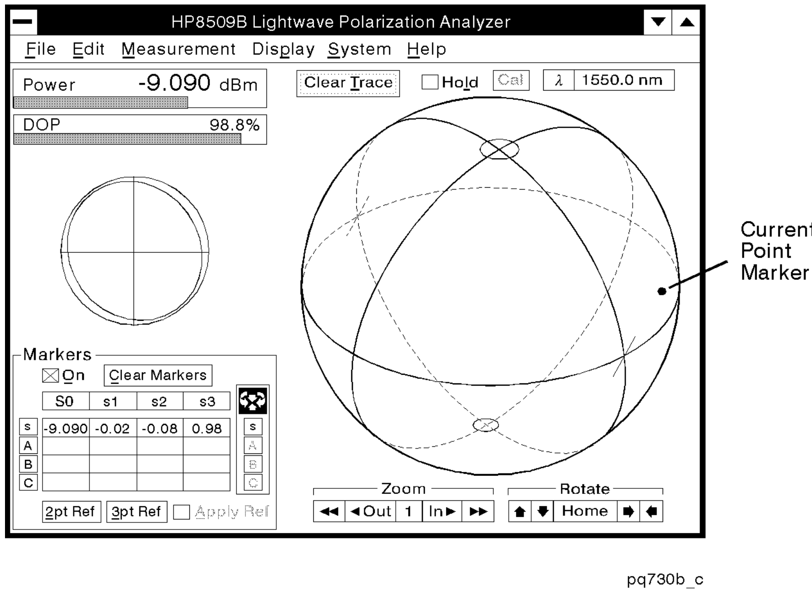



**Figure 5-14. Mark current point activated display window**

# Using the Display Update functions

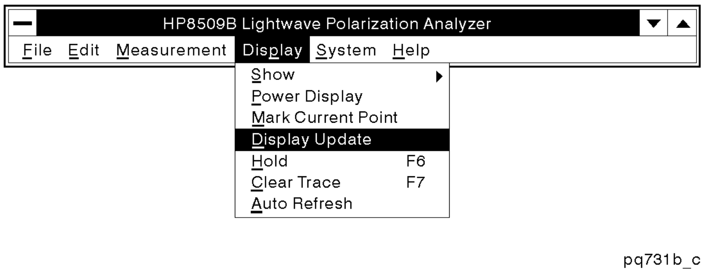



**Figure 5-15. Display Update menu**

## To change the display update frequency

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.

Figure 5-16 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.

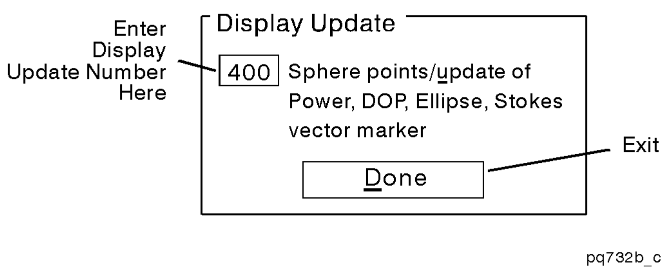



**Figure 5-16. Display Update window**

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.

# Using the Hold functions

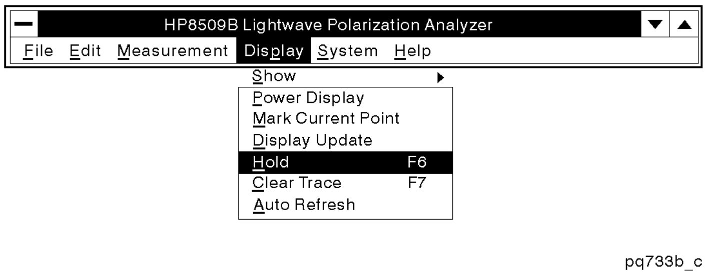



**Figure 5-17. Hold menu**

## To hold the data display

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 Agilent 8509C basic measurement screen. See Figure 5-18 on page 5-17.

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.

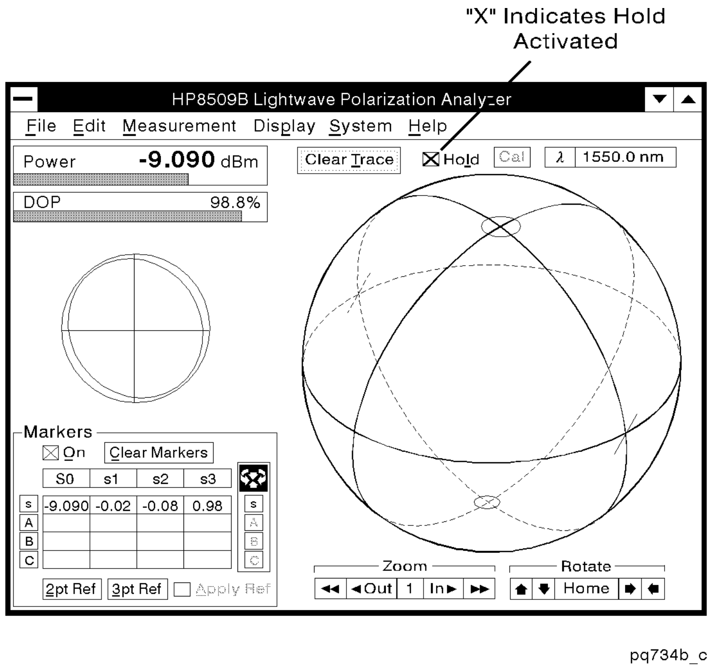



**Figure 5-18. Hold function display window**

# Using the Clearing Trace functions

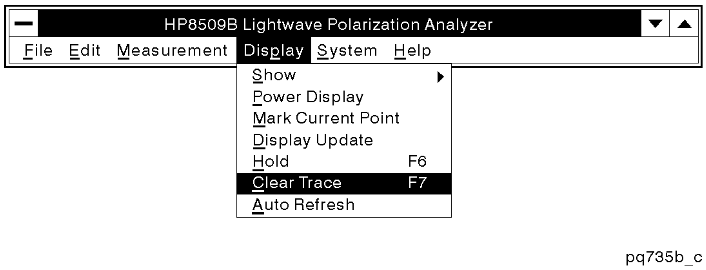



**Figure 5-19. Clear Trace menu**

## To clear the trace from the sphere

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.

# Using the Auto Refresh functions

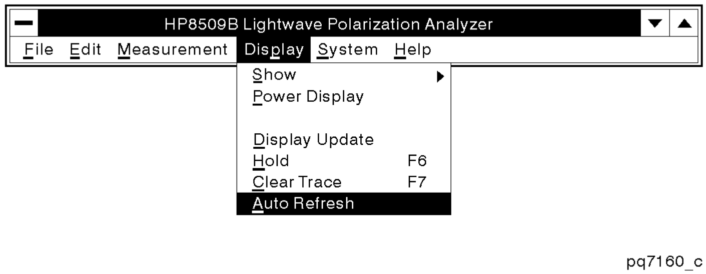



**Figure 5-20. Auto Refresh menu**

## To set the display to refresh automatically

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*.

# Using the System Menu

# The System Menu

The System menu on the Agilent 8509C 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.

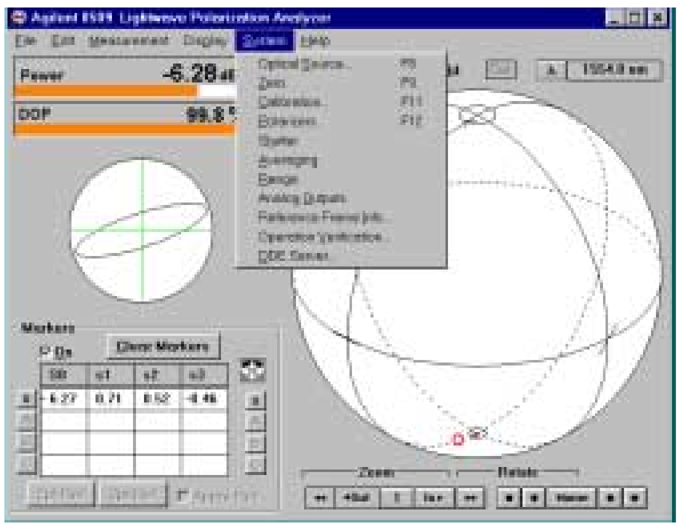



**Figure 6-1. System menu**

The following functions are available:

| **Function** | **See....** |
|---|---|
| Optical Source | "To open the Optical Source Setup window" on page 6-4 |
| Zero | "To initiate the receiver zeroing routine" on page 6-5 |
| Calibrations | "To calibrate for use with a fixed wavelength source" on page 6-7<br>"To select the source to be calibrated" on page 6-7<br>"To calibrate at the selected wavelength" on page 6-8<br>"To save and/or apply the calibration" on page 6-9<br>"To calibrate for use with a tunable wavelength source" on page 6-10<br>"To select an external source and input wavelength" on page 6-10<br>"To calibrate at the selected wavelength" on page 6-11<br>"To save wavelength calibrations" on page 6-13<br>"To apply a calibration" on page 6-13<br>"To delete a calibration" on page 6-15 |
| Polarizers | "To open the Polarizers window" on page 6-17<br>"To select an internal polarizer" on page 6-17<br>"To select an external polarizer" on page 6-18 |
| Shutter | "To put the shutter into the signal path manually" on page 6-19 |
| Averaging | "To open the Averaging window" on page 6-20<br>"To select Display Averaging" on page 6-20<br>"To select Measurement Averaging" on page 6-21 |
| Range | "To open the Range window" on page 6-22<br>"To select Autorange" on page 6-22<br>"To select a specific gain state" on page 6-22 |
| Analog Outputs | "To open the Analog Outputs window" on page 6-24<br>"To use the DOP and normalized Stokes parameters mode" on page 6-24<br>"To use the raw photodiode currents" on page 6-25 |
| Reference Frame Info.... | "To open the Reference Frame Info window" on page 6-26 |
| Operation Verification.... | "To verify that your system is working properly" on page 6-28 |
| DDE Server | "To establish a Dynamic Data Exchange (DDE) link between the 8509 and another application" on page 6-29 |

# Using the Optical Source functions

## To open the Optical Source Setup window

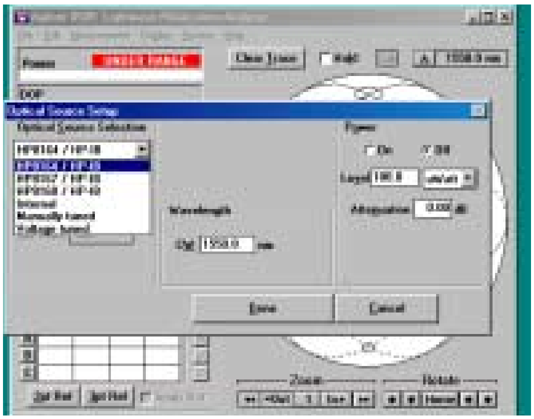



**Figure 6-2. Optical Source Setup window**

You can open the Optical Source Setup window in one of three ways:

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

If the source you select within the Optical Source Setup window is an 8164/8167/8168 tunable laser source connected to the Agilent 8509C system via HPIB, source wavelength, power and attenuation control can be done through this Optical Source Setup window. After selecting the Agilent 8164, Agilent 8167, or Agilent 8168, you will be able to enter the HPIB address of the laser.

Agilent 8164, Agilent 8167, and Agilent 8168 sources, if connected via HPIB, are automatically turned on and off as you select the sources. Other types of external sources must be turned on and off manually.

# Using the Zero functions

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

## To initiate 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.

You will *not* be prompted to block the external laser, but you *must* either cover the OPTICAL INPUT connector with a connector cap or a piece of dark paper, *or* turn off your external source. If the external source is connected to the Agilent 8509C 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 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.

# Using the Calibration functions

The Agilent 8509C lightwave polarization analyzer has a built-in calibration feature that allows you to calibrate your instrument for specific wavelengths.

Use the calibration functions to:

- Optimize performance when using a source whose wavelength is uncertain to greater than ±1 nm.
- 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.

**Additional Information**

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

Follow the instructions for "To calibrate for use with a fixed wavelength source" on page 6-7 when calibrating with sources which will not be tuned.

Follow the instructions for "To calibrate for use with a tunable wavelength source" on page 6-10 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.

The following information is provided in this section.

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

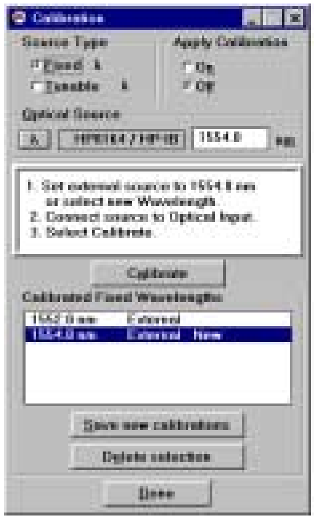


**Figure 6-3. Calibration window**

> **Enhancing Accuracy**
>
> Calibration is optional. Calibration is not required for Agilent 8509C operation.

## To calibrate 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 "Using the Zero functions" on page 6-5 for information on how to zero the instrument.

## To select the source to be calibrated

1 Open the Optical Source Setup window by selecting λ.

2 Select an external source.

Be sure to input the wavelength. Refer to "Using the Optical Source functions" on page 6-4 for more information on selecting a source.


**Figure 6-4. Optical Source Setup window**

## To 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.

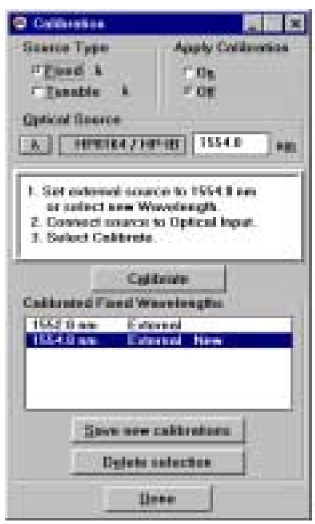



**Figure 6-5. Calibration window**

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 Agilent 8509C OPTICAL INPUT. Insert an external polarizer or pass the signal through one of the internal polarizers. 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 (if necessary) to assure a good signal level through the polarizer.

**6** Select Calibrate.

> **Enhancing Accuracy**
>
> Signal power and DOP must be constant during the calibration process.

**7** You will hear some clicking from inside the Agilent 8509C as the calibration is being performed. The calibration takes about 60 seconds. The Agilent 8509C automatically averages 250 measurements at each state.

**8** Calibrate at other wavelengths by repeating the above procedure.

## To save and/or apply the calibration

**1** The calibration list for fixed wavelengths provides the following information:

- The wavelength(s) that have been calibrated.
- Whether the calibration has been saved or not.

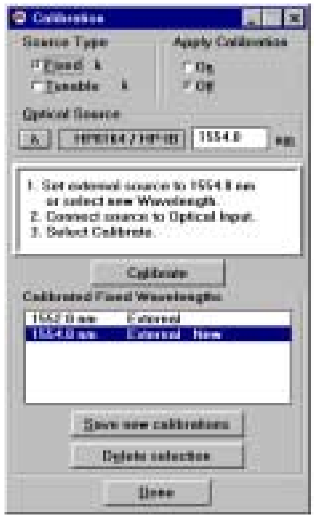



**Figure 6-6. Calibration list window**

**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 “To apply a calibration” on page 6-13.)

> **Additional Information**
>
> A calibration does not have to be saved in order to be applied. However, unsaved calibrations will be lost when the Agilent 8509C software is closed.

## To calibrate for use with a tunable wavelength source

Make sure the instrument has warmed up for at least one hour and then zero the instrument. Refer to “Using the Zero functions” on page 6-5 for information on how to zero the instrument.

## To select an external source and input wavelength

**1** Open the Optical Source Setup window by selecting λ.

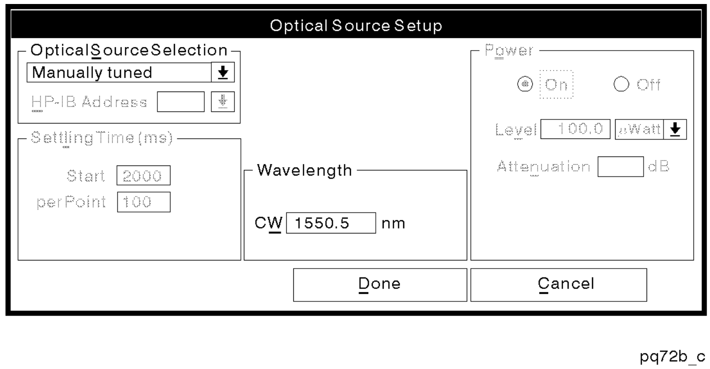



**Figure 6-7. Optical Source Setup window**

**2** Select an external source, such as the Agilent 8168A.

**3** Select Manually tuned for other, non-automatic tunable sources.

**4** Input the first wavelength you want to calibrate.

## To 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.

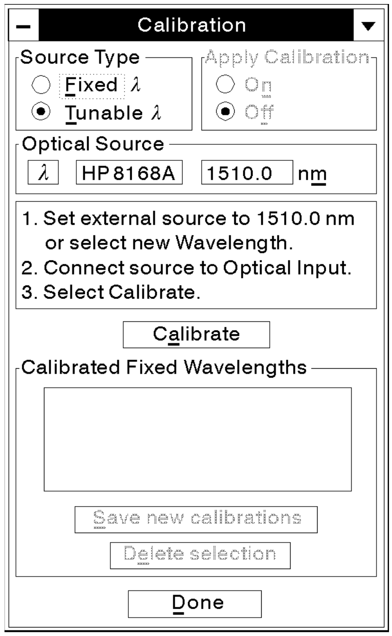



**Figure 6-8. Calibration window**

2 Select a tunable wavelength source.

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 Agilent 8509C OPTICAL INPUT. Insert an external polarizer or pass the signal through one of the internal polarizers. 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 (if necessary) to assure a good signal level through the polarizer.

6 Select Calibrate.

7 You will hear clicking from inside the Agilent 8509C as the calibration is being performed. The calibration takes about 60 seconds. The Agilent 8509C automatically averages 250 measurements at each state.

8 To calibrating subsequent wavelengths, 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 Setup window.

**9** Select Calibrate.

## To save wavelength calibrations

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

To save all the calibrations in the list with the "New" designation, select Save new calibrations as shown in Figure 6-9.

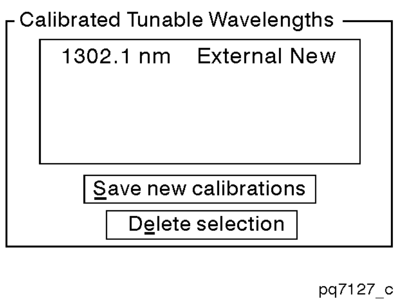



**Figure 6-9. Calibration list window**

## To apply 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 Calibration On if necessary.

**Additional Information**

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

### *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.

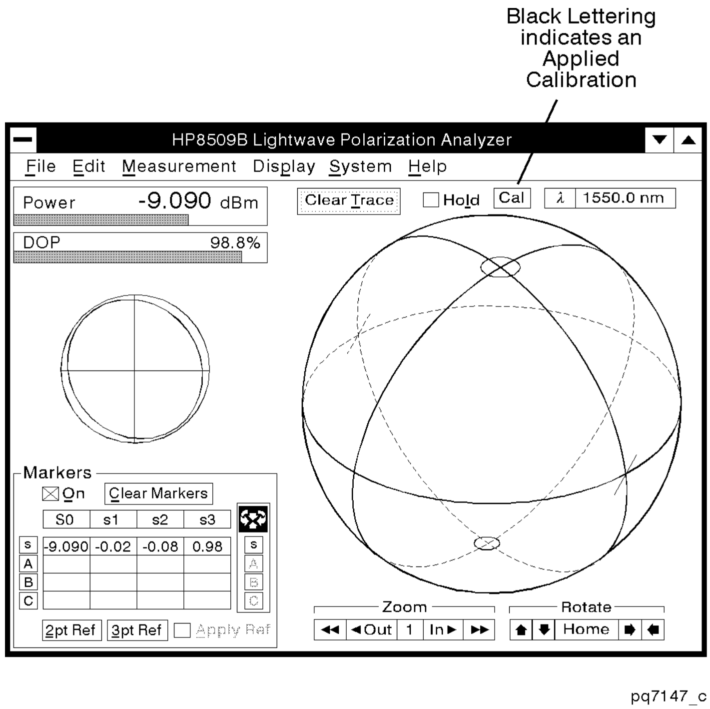



**Figure 6-10. Calibration applied window**

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).

## To delete a calibration

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

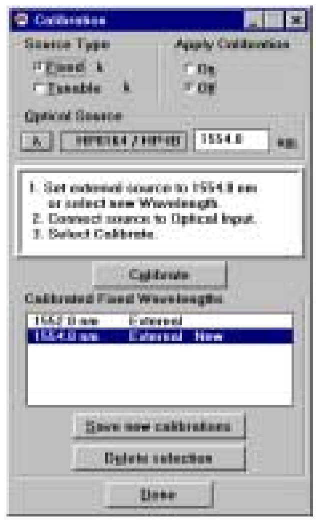


**Figure 6-11. Deleting a selection in the Calibration window**

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.

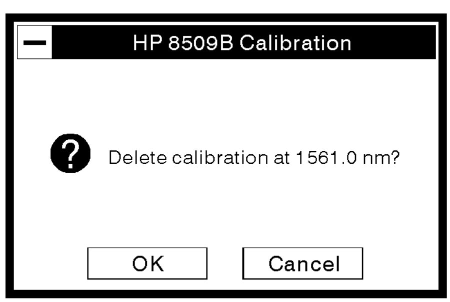



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**Figure 6-12. Confirm or abort the deletion process window**

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

# Using the Polarizers function

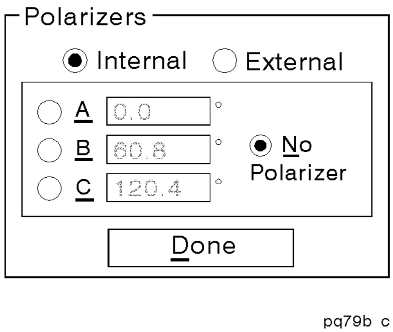


**Figure 6-13. Polarizers window**

## To open the Polarizers window

To open the Polarizers window, select *System*, *Polarizers* or press F12 on your keyboard.

## To select an internal polarizer

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.

### *About internal polarizers*

Internal polarizers are effective only when using an external source that is routed through the Agilent 8509C 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.

## To select an external polarizer

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

1 Select External 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.

# Using the Shutter functions

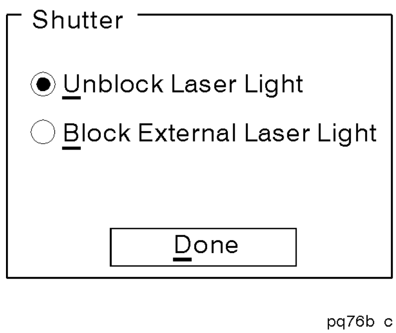


**Figure 6-14. Shutter window**

## To put the shutter into the signal path manually

A shutter can be engaged to block light routed through the Agilent 8509C via the EXTERNAL SOURCE INPUT. This shutter can be put into the signal path manually by selecting *System, Shutter*.

# Using the Averaging functions

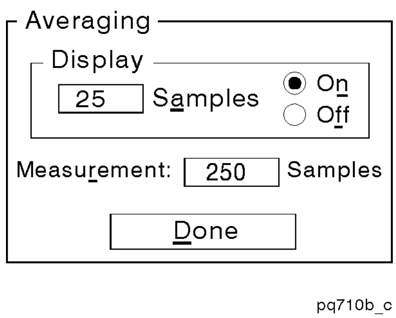


**Figure 6-15. Averaging window**

## To open the Averaging window

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

## To select 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 "Using the Display Update functions" on page 5-14) *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.

## To select 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.

# Using the Range functions

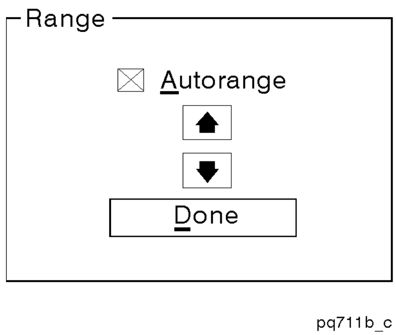


**Figure 6-16. Range window**

## To open the Range window

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

## To select Autorange

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

## To select 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.

# Using the Analog Outputs functions

Analog outputs are disabled when using a Vtune source.

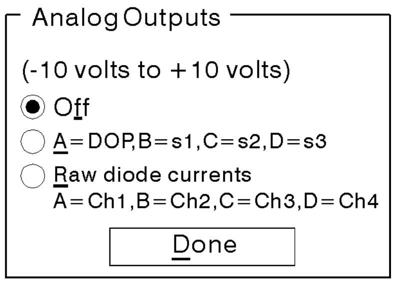


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**Figure 6-17. Analog Outputs window**

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.

## To open the Analog Outputs window

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

## To use the DOP and normalized Stokes parameters mode

In this mode the BNC outputs provide the modes listed in Table 6-1.

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

| Parameter | Connector | Output Voltage |
|---|---|---|
| DOP, 0 to 100% | A | (%DOP – 100)/10 |
| $S_1$, –1 to +1 | B | –10 to +10 |
| $S_2$, –1 to +1 | C | –10 to +10 |
| $S_3$, –1 to +1 | D | –10 to +10 |

### To use the 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 "Using the Range functions" on page 6-22). 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 Table 6-2.

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

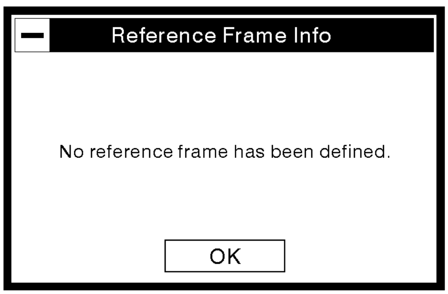
| Stokes Channel | Connector |
|---|---|
| 0 | A |
| 1 | B |
| 2 | C |
| 3 | D |

# Using the Reference Frame Info functions

## To open the Reference Frame Info window

Open the Reference Frame Info window by selecting *System*, *Reference Frame Info*.

If a reference frame has not been defined, the window shown in Figure 6-18 appears.




pq714b c

**Figure 6-18. No Defined Reference Frame Info 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

Figure 6-19 and Figure 6-20 are examples of the information given when a two- or three-point reference frame has been defined.

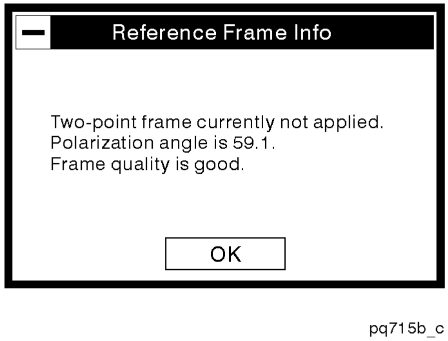



**Figure 6-19. Two-Point Reference Frame Info window**

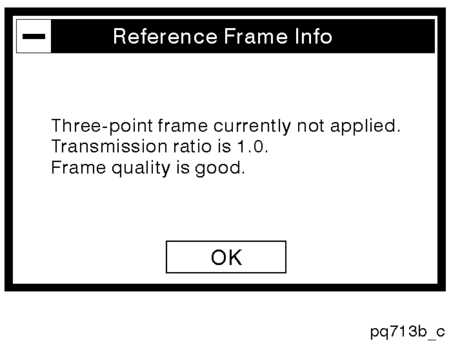



**Figure 6-20. Three-Point Reference Frame Info window**

# Using the Operation Verification functions

This 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.

**Note**: Operation verification requires a 100% polarized external source for proper operation.

## 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. Operation Verification window**

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.

The relative angles between internal polarizers is also displayed. If the verification fails, refer to the Degree of Polarization topic in Figure 7-1, "Measurement troubleshooting matrix," on page 7-3.

5 The operation verification is complete. Select Done to clear the window and begin your measurement.

# To establish a Dynamic Data Exchange (DDE) link between the 8509 and another application

DDE enables the Agilent 8509 to directly and continuously exchange data with other Windows based applications that support DDE. DDE data exchanges are called “conversations”. DDE conversations are started by establishing DDE links. Applications using DDE to converse with the Agilent 8509 for automatic control can be custom programs using a computer language such as ‘C’ or Visual BASIC for Windows to create a custom application for programmed control of the Agilent 8509 using DDE. Refer to “HPIB for the Agilent 8509” on page 8-5 for programming examples.

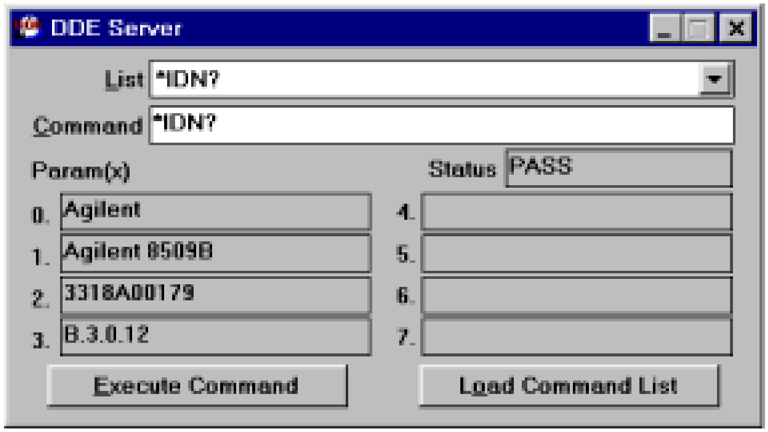
## Establishing DDE links

The Agilent 8509 allows other applications to establish DDE links to test based controls called ‘labels’ in the Agilent 8509 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 Agilent 8509 application may change with future updates of the firmware, the programmer of a DDE application should provide a mechanism for the Agilent 8509 application to change without requiring the program to be re-compiled. What follows is a VB code fragment that allows the user to specify the Agilent 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.

**Note**: The DDE and HPIB commands follow the same HPIB/SICL format.




## To execute a DDE command manually

1 Select *System* and then *DDE Server* from the drop-down list.

2 Click on the *Execute Command* to send the command to the 8509.

When the command is finished, the application will return a status and data.

In the example above, the 8509 returns a status, pass, for the *IDN query along with information about the current 8509 instrument.

## To update the list of DDE commands available from the DDE server window

Click the *Update Command List* button. This is primarily for Agilent internal debugging purposes.

When an external application commands the 8509, the box beneath the drop-down command list will print the last executed command.

7



# Reference

# Accuracy Enhancement and Troubleshooting

This section contains reference information regarding measurement accuracy and measurement troubleshooting. Verify the following conditions.

- Connect the electrical power and turn the instrument on.
- Connect the interface cable between the instrument controller and the Agilent 8509C.
- Connect the HPIB 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.

**Note**

Operating the Agilent 8509C requires instrument controller system resources. When you run multiple software applications, or have several Agilent 8509C 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 Agilent 8509C 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 instrument controller every day.

**Measurement Troubleshooting Matrix**

| Symptom / Possible Solution | 1. Connector Care/Reflections | 2. Fiber Cable Layout/Movement | 3. Zeroing | 4. Wavelength & Wavelength Calibration | 5. Polarizer | 6. Lightwave Source Performance | 7. Temperature Stability of DUT Environment | 8. Instrumentation Temperature Stability | 9. Wavelength Step-Size (Delta) | 10. Wavelength Span (Start, Stop) | 11. Feature Size | 12. Analysis Mode | 13. Mechanical Vibration | 14. Polarization Reference Frame | 15. Mode Coupling Factor | 16. Fiber & Connector Type | 17. Circular State of Polarization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High/low power reading, power over/under range | ● | ● | ● | ● | ● | ● | | | | | | | | | | ● | ● |
| Power variations with wavelength | ● | ● | | ● | ● | ● | | | | | | | | | | ● | ● |
| PMF alignment problems | ● | ● | | ● | | ● | ● | ● | | | | | ● | | | ● | |
| Wandering point on Poincare Sphere | ● | ● | | | | ● | ● | ● | | | | | ● | | | ● | |
| Polarization reference frame quality is poor. | ● | ● | ● | ● | ● | ● | ● | ● | | | | | ● | ● | | ● | ● |
| Low measurement accuracy/repeatability | | | | | | | | | | | | | | | | | |
| ◆ PMD:JME Accuracy | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | ● | ● | | ● | ● |
| ◆ PMD:WS Accuracy | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● |
| ◆ PDL:Jones Matrix Accu. | ● | ● | ● | ● | ● | ● | ● | ● | | | | | ● | ● | | ● | ● |
| ◆ PDL:Power Max-Min Accu. | ● | ● | ● | ● | | ● | ● | ● | | | | | ● | | | ● | |
| ◆ Jones Matrix Accuracy | ● | ● | ● | ● | ● | ● | ● | ● | | | | | ● | ● | | ● | ● |
| ◆ Polarization Ref. Frame | ● | ● | | ● | | ● | ● | ● | | | | | ● | ● | | ● | ● |
| ◆ Poincare Sphere | ● | ● | | ● | | ● | ● | ● | | | | | ● | ● | | ● | |
| ◆ Degree of Polarization | ● | ● | ● | ● | | ● | ● | ● | | | | | | | | ● | |

pq7149_c

**Figure 7-1. Measurement troubleshooting matrix**

## Symptoms

The measurement symptoms listed in Figure 7-1 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, refer to "Step 4. Operation Verification" on page 1-12.

## 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 Agilent 8509C system has passed the Operation Verification procedure (discussed in Chapter 1, "Setting Up the Lightwave Polarization Analyzer") 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 "Cleaning Connections for Accurate Measurements" on page 7-14 for further information about procedures for avoiding connector related problems.<br><br>The following information explains why reflections from dirty or damaged connectors may cause measurement uncertainty.<br><br>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).<br><br>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 Agilent 8509C 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. |

| | |
|---|---|
| **2.Fiber Cable Layout/ Movement** | Fiber cables, used in the instrument setup of an Agilent 8509C 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.<br><br>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 warm-up period.<br><br>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 Agilent 8509C 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.<br><br>The Agilent 8509C 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 Chapter 6, "Using the System Menu". |

| | |
|---|---|
| **5.Polarizer** | Polarizers may include the polarizers internal to the Agilent 8509C, an external reference polarizer used for an Agilent 8509C 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.<br><br>The Agilent 8509C 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.<br><br>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 Agilent 8509C 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 Chapter 4, “Using the Measurement Menu”.<br><br>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.<br><br>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%.<br><br>Wavelength accuracy and stability are important because the calibration factors in the Agilent 8509C 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 Agilent 8509C then measurement uncertainties will result. See item 4, Wavelength & Wavelength Calibration for more detail, or refer to the Calibration section of Chapter 6, “Using the System Menu”. |
| **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 Agilent 8509C 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 Agilent 8509C 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.<br><br>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 "Using the wavelength-scanning method" on page 4-38. |
| **11.Feature Size** | Feature Size, located in the Format menu, affects the peak and valley count during an Agilent 8509C 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 "Using the wavelength-scanning method" on page 4-38. |
| **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 Agilent 8509C offers four analysis modes. Refer to "Using the wavelength-scanning method" on page 4-38 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 Agilent 8509C is equipped with the ability to mathematically remove the birefringence and PDL of the path between a reference polarizer and the Agilent 8509C 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 "Making Polarization Reference Frame Measurements" on page 4-85 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 discussions on mode coupling in Chapter 4, "Using the Measurement Menu" for more detail. |

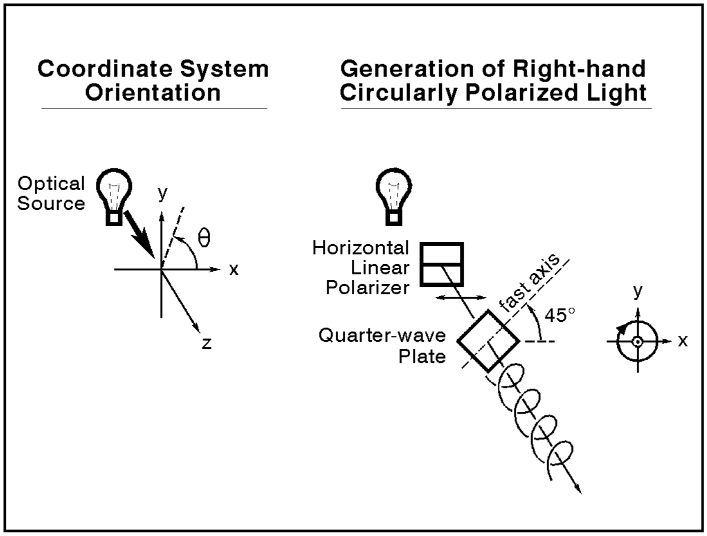
| | |
|---|---|
| **16.Fiber & Connector Type** | Multimode fibers (MMF) and damaged single-mode fibers and connectors (SMF) cause a number of polarization measurement problems and should be replaced with high quality single-mode fibers and connectors.<br><br>MMF should not be used for polarization measurements 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.<br><br>Connectors may exhibit small values of PDL.<br><br>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. |
| **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. |

# Generating 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.

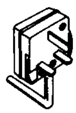
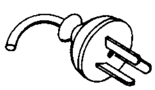
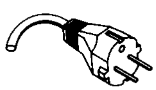
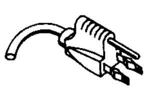
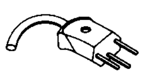
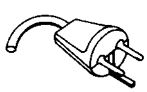

Coordinate System Orientation
Generation of Right-hand Circularly Polarized Light
Optical Source
y
θ
x
z
Horizontal Linear Polarizer
fast axis
45°
Quarter-wave Plate
y
x

circ_c

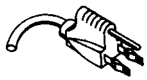
# Options and Accessories

| Option | Description |
| --- | --- |
| 1CM | Rack Mount Kit |
| 1CN | Front Handles |
| 1CP | Rack Mount Kit with Handles |
| **Interface Connectors** The Agilent 8509C is shipped with FC/PC connectors (Option 012). To designate a different connector interface, order one of the following options. | |
| 011 | Diamond HMS-10 |
| 012 | FC/PC (shipped with instrument) |
| 013 | DIN |
| 014 | ST |
| 015 | Biconic |
| 017 | SC |

# Power Cords

| Plug Type | | Cable Part No. | Plug Description | Length (in/cm) | Color | Country |
|---|---|---|---|---|---|---|
| 250V |  | 8120-1351<br>8120-1703 | Straight *BS1363A<br>90° | 90/228<br>90/228 | Gray<br>Mint Gray | United Kingdom, Cyprus, Nigeria, Zimbabwe, Singapore |
| 250V |  | 8120-1369<br>8120-0696 | Straight *NZSS198/ ASC<br>90° | 79/200<br>87/221 | Gray<br>Mint Gray | Australia, New Zealand |
| 250V |  | 8120-1689<br>8120-1692 | Straight *CEE7-Y11<br>90° | 79/200<br>79/200 | Mint Gray<br>Mint Gray | East and West Europe, Saudi Arabia, So. Africa, I |
| 125V |  | 8120-1378<br>8120-1521 | Straight *NEMA5-15P<br>90° | 90/228<br>90/228 | Jade Gray<br>Jade Gray | United States, Canada, Mexico, Philippines, Taiwan |
| 250V |  | 8120-2104<br>8120-2296 | Straight *SEV1011<br>1959-24507<br>Type 12 90° | 79/200<br>79/200 | Mint Gray<br>Mint Gray | Switzerland |
| 220V |  | 8120-2956<br>8120-2957 | Straight *DHCK107<br>90° | 79/200<br>79/200 | Mint Gray<br>Mint Gray | Denmark |
| 250V |  | 8120-4211<br>8120-4600 | Straight SABS164<br>90° | 79/200<br>79/200 | Jade Gray | Republic of South Africa<br>India |

* Part number shown for plug is the industry identifier for the plug only. Number shown for cable is the Agilent part number for the complete cable including the plug.

| Plug Type | | Cable Part No. | Plug Description | Length (in/cm) | Color | Country |
|---|---|---|---|---|---|---|
| 100V |  | 8120-4753 | Straight MITI | 90/230 | Dark Gray | Japan |
| | | 8120-4754 | 90° | 90/230 | | |

* Part number shown for plug is the industry identifier for the plug only. Number shown for cable is the Agilent part number for the complete cable including the plug.

# Cleaning Connections for Accurate Measurements

Today, advances in measurement capabilities make connectors and connection techniques more important than ever. Damage to the connectors on calibration and verification devices, test ports, cables, and other devices can degrade measurement accuracy and damage instruments. Replacing a damaged connector can cost thousands of dollars, not to mention lost time! This expense can be avoided by observing the simple precautions presented in this book. This book also contains a brief list of tips for caring for electrical connectors.

## Choosing the right connector

A critical but often overlooked factor in making a good lightwave measurement is the selection of the fiber-optic connector. The differences in connector types are mainly in the mechanical assembly that holds the ferrule in position against another identical ferrule. Connectors also vary in the polish, curve, and concentricity of the core within the cladding. Mating one style of cable to another requires an adapter. Agilent Technologies offers adapters for most instruments to allow testing with many different cables. Figure 7-2 on page 7-15 shows the basic components of a typical connectors.

The system tolerance for reflection and insertion loss must be known when selecting a connector from the wide variety of currently available connectors. Some items to consider when selecting a connector are:

- How much insertion loss can be allowed?
- Will the connector need to make multiple connections? Some connectors are better than others, and some are very poor for making repeated connections.
- What is the reflection tolerance? Can the system take reflection degradation?
- Is an instrument-grade connector with a precision core alignment required?
- Is repeatability tolerance for reflection and loss important? Do your specifica-

tions take repeatability uncertainty into account?

- Will a connector degrade the return loss too much, or will a fusion splice be required? For example, many DFB lasers cannot operate with reflections from connectors. Often as much as 90 dB isolation is needed.

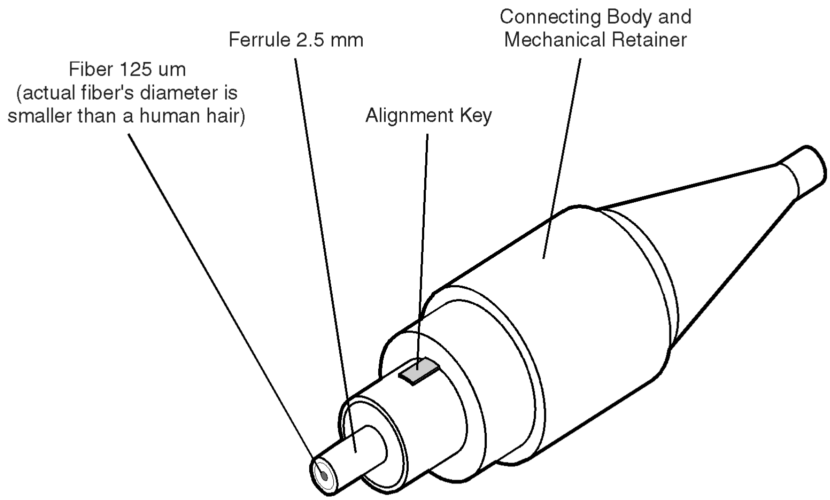



**Figure 7-2. Basic components of a connector**

Over the last few years, the FC/PC style connector has emerged as the most popular connector for fiber-optic applications. While not the highest performing connector, it represents a good compromise between performance, reliability, and cost. If properly maintained and cleaned, this connector can withstand many repeated connections.

However, many instrument specifications require tighter tolerances than most connectors, including the FC/PC style, can deliver. These instruments cannot tolerate connectors with the large non-concentricities of the fiber common with ceramic style ferrules. When tighter alignment is required, Agilent Technologies instruments typically use a connector such as the Diamond HMS-10, which has concentric tolerances within a few tenths of a micron. Agilent Technologies then uses a special universal adapter, which allows other cable types to mate with this precision connector. See Figure 7-3.

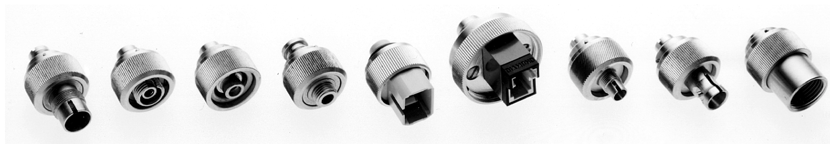


**Figure 7-3. Universal adapters to Diamond HMS-10**

The HMS-10 encases the fiber within a soft nickel silver (Cu/Ni/Zn) center which is surrounded by a tough tungsten carbide casing, as shown in Figure 7-4.

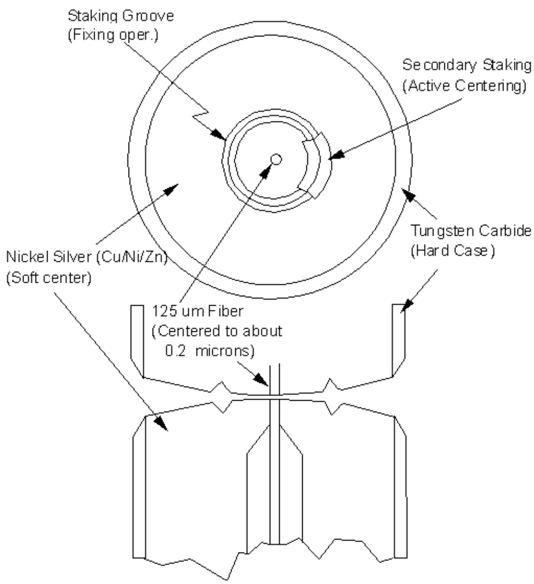



**Figure 7-4. Cross-section of the Diamond HMS-10 connector**

The nickel silver allows an active centering process that permits the glass fiber to be moved to the desired position. This process first stakes the soft nickel silver to fix the fiber in a near-center location, then uses a post-active staking to shift the fiber into the desired position within 0.2 µm. This process, plus the keyed axis, allows very precise core-to-core alignments. This connector is found on most Agilent Technologies lightwave instruments.

The soft core, while allowing precise centering, is also the chief liability of the connector. The soft material is easily damaged. Care must be taken to minimize excessive scratching and wear. While minor wear is not a problem if the glass face is not affected, scratches or grit can cause the glass fiber to move out of alignment. Also, if unkeyed connectors are used, the nickel silver can be pushed onto the glass surface. Scratches, fiber movement, or glass contamination will cause loss of signal and increased reflections, resulting in poor return loss.

## Inspecting connectors

Because fiber-optic connectors are susceptible to damage that is not immediately obvious to the naked eye, poor measurements result without the user being aware. Microscopic examination and return loss measurements are the best way to ensure good measurements. Good cleaning practices can help ensure that optimum connector performance is maintained. With glass-to-glass interfaces, any degradation of a ferrule or the end of the fiber, any stray particles, or finger oil can have a significant effect on connector performance. Where many repeat connections are required, use of a connector saver or patch cable is recommended.

Figure 7-5 shows the end of a clean fiber-optic cable. The dark circle in the center of the micrograph is the fiber's 125 μm core and cladding which carries the light. The surrounding area is the soft nickel-silver ferrule. Figure 7-6 shows a dirty fiber end from neglect or perhaps improper cleaning. Material is smeared and ground into the end of the fiber causing light scattering and poor reflection. Not only is the precision polish lost, but this action can grind off the glass face and destroy the connector.

Figure 7-7 shows physical damage to the glass fiber end caused by either repeated connections made without removing loose particles or using improper cleaning tools. When severe, the damage of one connector end can be transferred to another good connector endface that comes in contact with the damaged one. Periodic checks of fiber ends, and replacing connecting cables after many connections is a wise practice.

The cure for these problems is disciplined connector care as described in the following list and in "Cleaning connectors" on page 7-20.

Use the following guidelines to achieve the best possible performance when making measurements on a fiber-optic system:

- Never use metal or sharp objects to clean a connector and never scrape the connector.
- Avoid matching gel and oils.

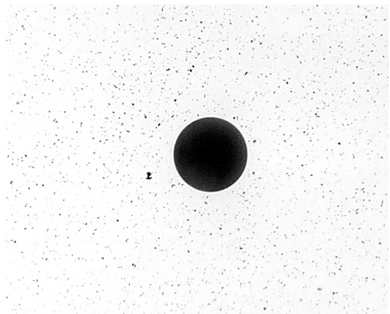


**Figure 7-5. Clean, problem-free fiber end and ferrule**

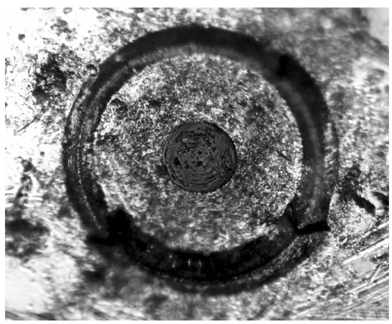


**Figure 7-6. Dirty fiber end and ferrule from poor cleaning**

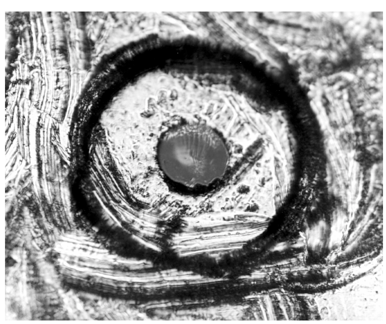


**Figure 7-7. Damage from improper cleaning**

While these often work well on first insertion, they are great dirt magnets. The oil or gel grabs and holds grit that is then ground into the end of the fiber. Also, some early gels were designed for use with the FC, non-contacting connectors, using small glass spheres. When used with contacting connectors, these glass balls can scratch and pit the fiber. If an index matching gel or oil must be used, apply it to a freshly cleaned connector, make the measurement, and then immediately clean it off. Never use a gel for longer-term connections and never use it to improve a damaged connector. The gel can mask the extent of damage and continued use of a damaged fiber can transfer damage to the instrument.

- When inserting a fiber-optic cable into a connector, gently insert it in as straight a line as possible. Tipping and inserting at an angle can scrape material off the inside of the connector or even break the inside sleeve of connectors made with ceramic material.
- When inserting a fiber-optic connector into a connector, make sure that the fiber end does not touch the outside of the mating connector or adapter.
- Avoid over tightening connections.

  Unlike common electrical connections, tighter is *not* better. The purpose of the connector is to bring two fiber ends together. Once they touch, tightening only causes a greater force to be applied to the delicate fibers. With connectors that have a convex fiber end, the end can be pushed off-axis resulting in misalignment and excessive return loss. Many measurements are actually improved by backing off the connector pressure. Also, if a piece of grit does happen to get by the cleaning procedure, the tighter connection is more likely to damage the glass. Tighten the connectors just until the two fibers touch.
- Keep connectors covered when not in use.
- Use fusion splices on the more permanent critical nodes. Choose the best connector possible. Replace connecting cables regularly. Frequently measure the return loss of the connector to check for degradation, and clean every connector, every time.

  All connectors should be treated like the high-quality lens of a good camera. The weak link in instrument and system reliability is often the inappropriate use and care of the connector. Because current connectors are so easy to use, there tends to be reduced vigilance in connector care and cleaning. It takes only one missed cleaning for a piece of grit to permanently damage the glass and ruin the connector.

### *Measuring insertion loss and return loss*

Consistent measurements with your lightwave equipment are a good indication that you have good connections. Since return loss and insertion loss are key factors in determining optical connector performance they can be used to determine connector degradation. A smooth, polished fiber end should produce a good return-loss measurement. The quality of the polish establishes the difference between the “PC” (physical contact) and the “Super PC” connectors. Most connectors today are physical contact which make glass-to-glass connections, therefore it is critical that the area around the glass core be clean and free of scratches. Although the major area of a connector, excluding the glass, may show scratches and wear, if the glass has maintained its polished smoothness, the connector can still provide a good low level return loss connection.

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. Typical values are less than 0.5 dB of loss, and sometimes as little as 0.1 dB of loss with high performance connectors. Return loss 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 50 dB, although 30 to 40 dB is more common.

### *Visual inspection of fiber ends*

Visual inspection of fiber ends can be helpful. Contamination or imperfections on the cable end face can be detected as well as cracks or chips in the fiber itself. Use a microscope (100X to 200X magnification) to inspect the entire end face for contamination, raised metal, or dents in the metal as well as any other imperfections. Inspect the fiber for cracks and chips. Visible imperfections not touching the fiber core may not affect performance (unless the imperfections keep the fibers from contacting).

**WARNING** **Always remove both ends of fiber-optic cables from any instrument, system, or device before visually inspecting the fiber ends. Disable all optical sources before disconnecting fiber-optic cables. Failure to do so may result in permanent injury to your eyes.**

## Cleaning connectors

The procedures in this section provide the proper steps for cleaning fiber-optic cables and Agilent Technologies universal adapters. The initial cleaning, using the alcohol as a solvent, gently removes any grit and oil. If a caked-on layer of material is still present, (this can happen if the beryllium-copper sides of the ferrule retainer get scraped and deposited on the end of the fiber during insertion of the cable), a second cleaning should be performed. It is not uncommon for a cable or connector to require more than one cleaning.

**CAUTION**

Agilent Technologies 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.

**Table 7-1. Cleaning Accessories**

| Item | Agilent Part Number |
|---|---|
| Cotton swabs | 8520-0023 |
| Small foam swabs | 9300-1223 |

**Table 7-2. Dust Caps Provided with Lightwave Instruments**

| Item | Agilent Part Number |
|---|---|
| Laser shutter cap | 08145-64521 |
| FC/PC dust cap | 08154-44102 |
| Biconic dust cap | 08154-44105 |

### *To clean a non-lensed connector*

**CAUTION**

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.

1. Apply pure isopropyl alcohol to a clean lint-free cotton swab or lens paper.

   Cotton swabs can be used as long as no cotton fibers remain on the fiber end after cleaning.

2. Clean the ferrules and other parts of the connector while avoiding the end of the fiber.
3. Apply isopropyl alcohol to a new clean lint-free cotton swab or lens paper.
4. Clean the fiber end with the swab or lens paper.

   Do *not* scrub during this initial cleaning because grit can be caught in the swab and become a gouging element.

**5** Immediately dry the fiber end with a clean, dry, lint-free cotton swab or lens paper.

**6** Blow across the connector end face from a distance of 6 to 8 inches using filtered, dry, compressed air. Aim the compressed air at a shallow angle to the fiber end face.

Nitrogen gas or compressed dust remover can also be used.

**CAUTION** Do not shake, tip, or invert compressed air canisters, because this releases particles in the can into the air. Refer to instructions provided on the compressed air canister.

**7** As soon as the connector is dry, connect or cover it for later use.

If the performance, after the initial cleaning, seems poor try cleaning the connector again. Often a second cleaning will restore proper performance. The second cleaning should be more arduous with a scrubbing action.

### *To clean an adapter*

The fiber-optic input and output connectors on many Agilent Technologies instruments employ a universal adapter such as those shown in the following picture. These adapters allow you to connect the instrument to different types of fiber-optic cables.

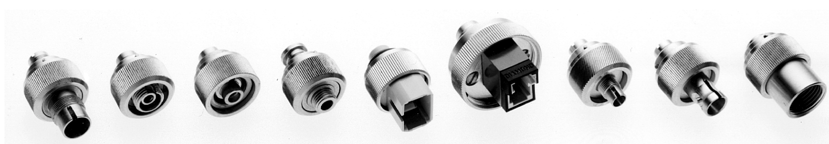


**Figure 7-8. Universal adapters**

**1** Apply isopropyl alcohol to a clean foam swab.

Cotton swabs can be used as long as no cotton fibers remain after cleaning. The foam swabs listed in this section’s introduction are small enough to fit into adapters.

Although foam swabs can leave filmy deposits, these deposits are very thin, and the risk of other contamination buildup on the inside of adapters greatly outweighs the risk of contamination by foam swabs.

**2** Clean the adapter with the foam swab.

**3** Dry the inside of the adapter with a clean, dry, foam swab.

**4** Blow through the adapter using filtered, dry, compressed air.

Nitrogen gas or compressed dust remover can also be used. Do not shake, tip, or invert compressed air canisters, because this releases particles in the can into the air. Refer to instructions provided on the compressed air canister.

# If You Have a Problem

This section will help correct problems that may be encountered while performing the installation and operation verification. The problem or symptom is listed at the top of each page. Most problems have a brief description or explanation to provide additional information regarding the problem. Following is a checklist of items that could cause the problems. Using the checklist of possible solutions will help to correct the problem.

### *Problems requiring additional resources*

Problems that are internal to the lightwave polarization analyzer will require additional technical information. Contact an Agilent Technologies sales or service office if you cannot solve your problem with the information in this chapter. Refer to "Agilent Technologies Service Offices" on page 7-30. For instructions for returning your instrument to Agilent Technologies, refer to "Returning the Instrument for Service" on page 7-27.

### *The system appears to be dead*

When the instrument controller, monitor and lightwave polarization analyzer are initially turned on, the following observations can be made:

- The instrument controller's fan and disk drive will make a certain amount of noise when the instrument controller is turned on.
- The monitor has an indicator light on the power button that should light up when the monitor is turned on.

If these things do not occur, check the following conditions:

- ❐ That the instrument controller, monitor and analyzer are all connected to the ac power source.
- ❐ Check the line voltage selector switch on the rear of the Agilent 8509C to ensure that it is set to the correct voltage for the power source. Refer to Figure 1-1 on page 1-5 for instructions on setting the switch.
- ❐ Check the line fuse on the lightwave polarization analyzer to ensure that it is not damaged. The fuse is located inside the power-cord receptacle housing on the rear panel of the analyzer. Refer to "Fuses" on page 1-4 for replacement part numbers. Refer to Figure 1-1 on page 1-5 for exact location of fuse.

### *If the instrument controller does not respond*

The mouse and keyboard cable connectors look the same and therefore may accidentally be interchanged on the back of the instrument controller. If this happens, the instrument controller will not respond to the mouse or the keyboard, and you may hear lots of beeping when trying to use one or the other.

If you have any of these problems check the following:

- ❒ Make sure that the mouse and keyboard are plugged into the correct sockets on the back of the instrument controller. There are icons on the instrument controller rear panel and on the mouse and keyboard connectors to help you determine the correct socket. (Refer to Figure 1-4 on page 1-9 for the exact location of mouse and keyboard ports.)
- ❒ Make sure that the mouse and keyboard cables are plugged in all the way and that a good connection is being made.

### *If you get the "EEprom not formatted or Box on?" error message*

When you start up the software, the program expects the lightwave polarization analyzer to be turned on and connected to the instrument controller via the dedicated interface cable. This error message occurs when it appears to the instrument controller that the lightwave polarization analyzer is not connected or turned on.

If you see the error message, check the following conditions:

- ❒ Ensure that the lightwave polarization analyzer voltage selector switch is properly set, that it is connected to the ac power source, and that line switch has been turned on. (Refer to Figure 1-1 on page 1-5 for instructions on setting the voltage selector switch.)
- ❒ Ensure that the dedicated interface cable is properly connected to both the lightwave polarization analyzer and the instrument controller. Be sure to finger tighten the screws on the connectors.

## If operation verification fails

### *DOP measurement is out of specification*

If you are able to detect power after connecting an optical source to the lightwave polarization analyzer's OPTICAL INPUT (look at the power display in the upper-left corner of the measurement screen), but the DOP measurement is out of specification, there is a good chance that dirty or improperly seated connectors are at fault.

If you are detecting power but your measurements are out of specification, check the following:

- ❒ Ensure the connectors are clean. Use isopropyl alcohol and cotton swabs to clean optical connectors. For detailed instructions, and cleaning supply part numbers, refer to refer to “Cleaning Connections for Accurate Measurements” on page 7-14.

- ❒ Ensure that the optical connections are properly seated and finger tightened.
- ❒ If the operation verification still fails, perform and apply a calibration for the particular source and wavelength you are using to make the measurements. Refer to “Using the Calibration functions” on page 6-6.
- ❒ If the operation verification still fails, contact Agilent Technologies. Refer to “Agilent Technologies Service Offices” on page 7-30.

***Power display reads underrange***

If, after connecting power to the OPTICAL INPUT the power display reads underrange, the problem may be more severe.

Check the following:

- ❒ If you are using an external source, ensure that the source is turned on.
- ❒ If the source is turned on and the power display still reads underrange, contact Agilent Technologies. Refer to “Agilent Technologies Service Offices” on page 7-30.

# Returning the Instrument for Service

The instructions in this section show you how to properly return the instrument for repair or calibration. Always call the Agilent Technologies Instrument Support Center first to initiate service *before* returning your instrument to a service office. This ensures that the repair (or calibration) can be properly tracked and that your instrument will be returned to you as quickly as possible. Call this number regardless of where you are located. Refer to "Agilent Technologies Service Offices" on page 7-30 for a list of service offices.

Agilent Technologies Instrument Support Center. . . . . . . . . . . (800) 403-0801

If the instrument is still under warranty or is covered by an Agilent Technologies maintenance contract, it will be repaired under the terms of the warranty or contract (the warranty is at the front of this manual). If the instrument is no longer under warranty or is not covered by an Agilent Technologies maintenance plan, Agilent Technologies will notify you of the cost of the repair after examining the unit.

When an instrument is returned to a Agilent Technologies service office for servicing, it must be adequately packaged and have a complete description of the failure symptoms attached. When describing the failure, please be as specific as possible about the nature of the problem. Include copies of additional failure information (such as the instrument failure settings, data related to instrument failure, and error messages) along with the instrument being returned.

# Preparing the instrument for shipping

1 Write a complete description of the failure and attach it to the instrument. Include any specific performance details related to the problem. The following information should be returned with the instrument.

- Type of service required.
- Date instrument was returned for repair.
- Description of the problem:
  - Whether problem is constant or intermittent.
  - Whether instrument is temperature-sensitive.
  - Whether instrument is vibration-sensitive.
  - Instrument settings required to reproduce the problem.
  - Performance data.
- Company name and return address.
- Name and phone number of technical contact person.
- Model number of returned instrument.
- Full serial number of returned instrument.
- List of any accessories returned with instrument.

2 Cover all front or rear-panel connectors that were originally covered when you first received the instrument.

**CAUTION** Cover electrical connectors to protect sensitive components from electrostatic damage. Cover optical connectors to protect them from damage due to physical contact or dust.

**CAUTION** Instrument damage can result from using packaging materials other than the original materials. Never use styrene pellets as packaging material. They do not adequately cushion the instrument or prevent it from shifting in the carton. They may also cause instrument damage by generating static electricity.

3 Pack the instrument in the original shipping containers. Original materials are available through any Agilent Technologies office. Or, use the following guidelines:

- Wrap the instrument in antistatic plastic to reduce the possibility of damage caused by electrostatic discharge.
- For instruments weighing less than 54 kg (120 lb), use a double-walled, corrugated cardboard carton of 159 kg (350 lb) test strength.
- The carton must be large enough to allow approximately 7 cm (3 inches) on

all sides of the instrument for packing material, and strong enough to accommodate the weight of the instrument.

- Surround the equipment with approximately 7 cm (3 inches) of packing material, to protect the instrument and prevent it from moving in the carton. If packing foam is not available, the best alternative is S.D-240 Air Cap™ from Sealed Air Corporation (Commerce, California 90001). Air Cap looks like a plastic sheet filled with air bubbles. Use the pink (antistatic) Air Cap™ to reduce static electricity. Wrapping the instrument several times in this material will protect the instrument and prevent it from moving in the carton.

**4** Seal the carton with strong nylon adhesive tape.

**5** Mark the carton “FRAGILE, HANDLE WITH CARE”.

**6** Retain copies of all shipping papers.

# Agilent Technologies Service Offices

Before returning an instrument for service, call the Agilent Technologies Instrument Support Center at (800) 403-0801, visit the Test and Measurement Web Sites by Country page at http://www.tm.agilent.com/tmo/country/English/index.html, or call one of the numbers listed below.

**Agilent Technologies Service Numbers**

| | |
|---|---|
| Austria | 01/25125-7171 |
| Belgium | 32-2-778.37.71 |
| Brazil | (11) 7297-8600 |
| China | 86 10 6261 3819 |
| Denmark | 45 99 12 88 |
| Finland | 358-10-855-2360 |
| France | 01.69.82.66.66 |
| Germany | 0180/524-6330 |
| India | 080-34 35788 |
| Italy | +39 02 9212 2701 |
| Ireland | 01 615 8222 |
| Japan | (81)-426-56-7832 |
| Korea | 82/2-3770-0419 |
| Mexico | (5) 258-4826 |
| Netherlands | 020-547 6463 |
| Norway | 22 73 57 59 |
| Russia | +7-095-797-3930 |
| Spain | (34/91) 631 1213 |
| Sweden | 08-5064 8700 |
| Switzerland | (01) 735 7200 |
| United Kingdom | 01 344 366666 |
| United States and Canada | (800) 403-0801 |

# 8



# Measurement Programming and Examples

# HPIB Overview

HPIB (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 the instruments and controllers in a measurement system, including some frequently used commands.

HPIB cables provide the physical ink 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 HPIB system contains more than one device with controller capabilities, only one of the devices is allowed to control data exchanges is called the Active Controller. Also, only one of the controller-capable devices can be designated as the system controller. The Agilent 8509 can function as a talker, a listener, or a controller at different times.

## Bus Structure

HPIB addresses provide a way to identify devices on the bus. The active controller uses HPIB 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 Agilent 8509 is 29.

## 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 Agilent 8509. In addition, every byte transferred over HPIB undergoes a handshake to ensure valid data.

## Handshake Lines

A three-line handshake scheme coordinates the transfer of data between talker 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 Agilent 8509 makes explicit use of the EOI line through the HPIB END statement used to terminate all command transmissions. A brief description of the five HPIB control lines is provided below.

- **IFC (Interface Clear)**. Only the system controller uses this line. When this line is true (low) all devices (addressed or not) not addressed and go to an idle state.
- **ATN (Attention)**. This 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 used 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 HPIB 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 HPIB via a controller's language system, such as IBASIC, QuickBasic, or C. The keywords used by a controller to send HPIB commands vary among systems. When determining the correct keywords to use, keep in mind that there are two different kinds of HPIB commands:

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

Language systems usually deal differently with these two kinds of HPIB 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 Agilent 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 HPIB device at address 729. If the device is an Agilent 8509, the command instructs the analyzer to clear all measured traces from the Poincare sphere.

**Note**: The HPIB care select code is 7 and the HPIB address is 29. The select code is set by adjusting switches on the HPIB card inside the computer.

# HPIB for the Agilent 8509

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

Given that the Agilent 8509 software is a Windows application, Dynamic Data Exchange (DDE) can be used to communicate with and control the Agilent 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 HPIB with the Agilent 8509 system, HPIB messages must be translated to DDE messages. Under these conditions, the HPIB interface is seen as a Windows application directly communicating with the Agilent 8509 system software.

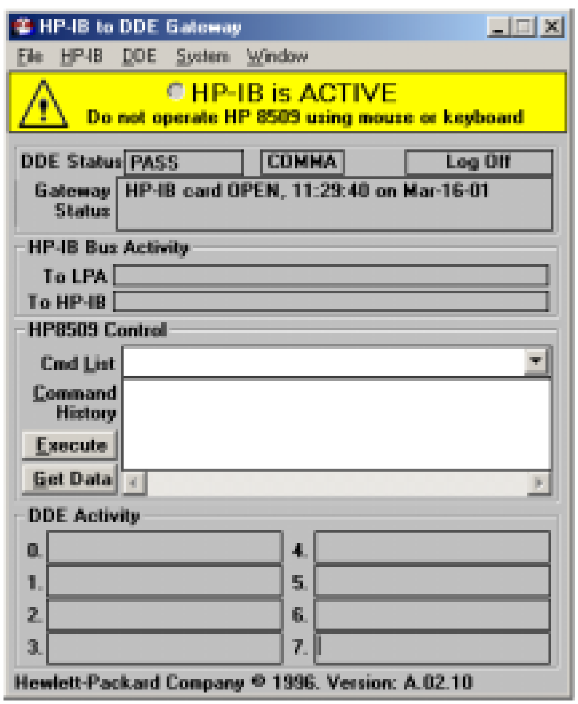
A second Windows application called HPIB2DDE provides the translation between HPIB commands and the DDE message for the Agilent 8509 software. The HPIB2DDE program is accessible within the Agilent 8509 system window. In order to run HPIB2DDE, an HPIB interface board must be installed on the Agilent 8509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

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

## HPIB to DDE Interface

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

There are three basic parts to this window, the Agilent 8509 Control frame, the 'HPIB' frame, and the Dynamic Data Exchange (DDE) frame. The HPIB2DDE.EXE application window appears when the application starts. The HPIB 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.



## ‘Command Line’ Setup Options

The HIPB gateway program may be configured using command line parameters at run time. Two command line parameters are available and may be added to the HPIB 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 HPIB gateway to record only HPIB bus errors, DDE link errors, Windows critical errors, and Agilent 8509 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>

The Windows DDE system uses the name of the executable file to establish a DDE link to the Agilent 8509 program. Future versions of the Agilent 8509 may use a different name to establish this link. This command line parameter is useful only if your Agilent 8509 software is updated to a version greater than version 2.0. If this parameter is not used, the <Name> used is HP8509_2.

**Note**: Agilent 8509C command is A8509.

## /HP8509TimeOut=<Number of Minutes>

This parameter specifies the number of minutes the HPIB to DDE Gateway program should wait for data from the Agilent 8509 when the HPIB controller requests data (sends a query). If this parameter is not specified, the default value used is 1 minute. If the Agilent 8509 takes longer than the specified time to return data to the HPIB controller, the HPIB to DDE Gateway will reset the DDE channel in an attempt clear the problem, and record the attempt in the log file (if open) as a DDE time-out error. The HPIB to DDE Gateway will reset itself in this manner ten times. After ten attempts, the HPIB to DDE Gateway program will issue a critical error and HPIB operation will stop until the user acknowledges the critical error issued by the HPIB to DDE Gateway.

**Note**: This time-out occurs only when the HPIB controller requests data. The HPIB to DDE Gateway queues all commands from the HPIB bus a synchronous to Agilent 8509 operation. The programmer should hard code appropriate delays in the controlling program after sending Agilent 8509 commands that take more than 30 seconds (or 1/2 the time-out limit) to complete. Remember - commands may still be in the HPIB 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 time-out limit.

## Agilent 8509 Control Frame

The elements in this frame provide a path for the development of HPIB remote programs. With the HPIB to DDE Gateway, you can send HPIB commands, retrieve data, and save bus traffic to a file for later analysis. The elements of the Agilent 8509 Control Window are described below.

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

**Command** text box is used to specify a command to send via DDE to the Agilent 8509 application. During normal operation of the HPIB to DDE Gateway, the individual commands that are being transmitted to the Agilent 8509 also appear in this text box.

**Log On** when checked, HPIB 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 HPIB 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 Agilent 8509 application.

**Get Data** retrieves data via DDE from the Agilent 8509 application. The data is linked to the text boxes found in the Dynamic Data Exchange (DDE) window.

**Exit** closes the HPIB2DDE gateway application.

## HPIB Frame

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

**To LPA** shows the user the command being sent to the Agilent 8509 that was received on the HPIB bus.

**To HPIB** shows the user the data being sent to the HPIB bus that was read from the Agilent 8509.

**Status** shows the HPIB card status and the time and date of any error. HPIB bus errors, DDE errors, and Windows system errors are also logged to file when Log On is selected.

**EOL** is selected is every HPIB bus action is to end with a line feed. This setting is saved in the file C:\WINDOW\WIN.INI under the heading HPIB2DDE and is restored to this setting the next time the HPIB2DDE application is started.

**Address** puts the address of the Agilent 8509 here. To change the address, select Terminate DDE Link to enable Address. Change the Agilent 8509 device address then select Initiate DDE Link to re-enable the HPIB bus and the DDE link. Terminate DDE Link and Initiate DDE Link are toggle selections.

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.

**Timeout** allows you to set the HPIB time-out. This setting is saved in the file C:\WINDOW\WIN.INI under the heading HPIB2DDE and is restored to this setting the next time the HPIB2DDE application is started.

**Data Separator** is saved in the file C:\WINDOW\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.

**HPIB Exit State** allows you to set the HPIB card to Controller or Non-Controller when the program exits. This setting is saved in the file C:\WINDOW\WIN.INI under the heading HPIB2DDE and is restored to this setting the next time the HPIB2DDE application is started.

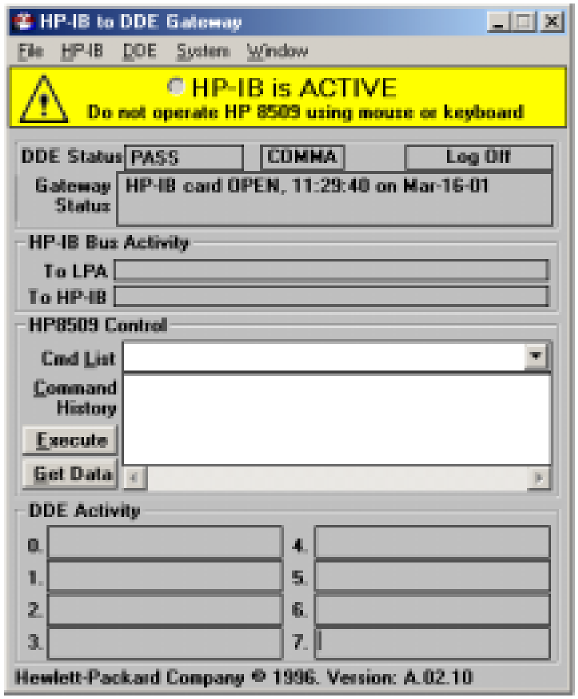
**Controller** (HPIB card) is the setting used when the Agilent 8509 is not being controlled by the HPIB bus. Other systems may require that the HPIB card never becomes a controller while on the HPIB bus.

**Non-Controller** (HPIB card) is 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.

- **Pyrex) from Agilent 8509** is used to establish a DDE link for data from the Agilent 8509 and the HPIB2DDE.EXE application.
- **Terminate DDE Link/Initiate DDE Link** is used to connect or disconnect the HIPB to the DDE. When the DDE link is established (selection shows Terminate DDE Link, the HPIB card is opened and the DDE transactions can take place. When there is no DDE link (selection shows Initiate DDE Link, the Agilent 8509 Status selection show NO DDE LINK in yellow and the HPIB 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 HPIB bus to close, and allow the HIPB gateway to be used for a DDE client, without interference from the HIPB bus.




Given the translation mode under which HPIB control is achieved for the Agilent 8509 system, certain constraints exist dictated by the HIPB2DDE application. The constraints are relative to the full set of capabilities provided by the HPIB interface. 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 HIPB 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 HPIB 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

HPIB END statement serves as the line terminator.

- Use only ENTER/OUTPUT (formatted data transfers).
- Set the time-out to a least five seconds to give the instrument controller time to recognize and respond to HPIB activity. The HPIB2DDE is polling the HPIB card and needs time to see the request.

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

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

A second alternative for remote control of the Agilent 8509, other than using an external PC controller, is to use an Agilent 9000 series 200/300 controller running HP BASIC Version 5.0 or later. The platform is the same as that shown in Figure 4-2, except that the PC controller is replaced by an Agilent 9000 series 200/300 controller. The Agilent 8509 system can be thought of as just another instrument on the HPIB 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 functionalit7y. Utilities exist under the UNIX operating system to translate DOS formatted files to LIF format and vice versa.

## Basic Instrument Control

A computer controls the Agilent 8509 by sending it commands over HPIB. The command sent are specific to the Agilent 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 HPIB 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 Agilent 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 (HPIB), and on out to the device address 29 (the Agilent 8509). |
| "POINCARE: CLEAR" END | The Agilent 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 Agilent 8509 HPIB 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 Agilent 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 Agilent 8509 Command Reference section of this document or to the Remote Access files in the Agilent 8509 instrument window for specific command information.

The END following the CLEAR terminates the command inside the Agilent 8509 (EOI set true) and prepares the Agilent 8509 for the next command. If there is a syntax error in the command, the Agilent 8509 will ignore the command nd 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 Agilent 8509 will accept. It will also accept commands that require specific, user defined operands. For example, execute:

```
OUTPUT 729; “SETMAKER:1:0:1:0:A” END
```

In response, the Agilent 8509 will place a 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 Agilent 8509 will also accept commands that turn various functions on or off. Execute:

```
OUTPUT 729; “POINCARE:HOLD:ON” END
```

This causes the Agilent 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 Agilent 8509 does not distinguish between upper and lower case letters. For example, execute:

```
OUTPUT 729; “Poincare:Hold:{Off” END
```

Some of the Agilent 8509 HPIB commands deal with data storage and retrieval using the Agilent 8509 system instrument controller memory. For example, execute:

```
OUTPUT 729; “DRIVE:C” END
```

This sets drive C in the Agilent 8509 system instrument controller 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 Agilent 8509 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 Agilent 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; “LOAD:CONFIG:\HP8509\SYSTEM.CFG” END
```

Through this command, a suer determined instrument state can be achieved. Note that the appropriate path to the configuration file must be specified.

## Data Requesting Commands

Some of the HPIB commands request data from the Agilent 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 Agilent 8509 to conduct a Jones matrix measurement of an inserted DUT. The results are requested through the JONES? command. The data is transferred through the ENTER remote command and placed in a string variable named String$.

There are two types of HPIB commands which request data from the Agilent 8509 system. Some commands, such as JONES:MEASURE, cause a measurement to be conducted by the Agilent 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 Agilent 8509 system to return the letter of the drive which is currently set up for data transfers. This letter is read from the Agilent 8509 into the string variable named String$.

The IBASIC statement ENTER addresses the Agilent 8509 to talk. This allows the Agilent 8509 to transmit information to the controller PC. Specifically, the ENTER statement takes the stream of binary data output by the Agilent 8509 and reformats it back into an ASCII string through the HPIB2DDE application. The controller PC places the data transmitted by the Agilent 8509 into the string variable listed in the ENTER statement. The string variable dimensions must match the data the Agilent 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 Agilent 8509. For instance, a program should not have the operator connect the DUT while the Agilent 8509 is still measuring the measurement through path.

To provide such information, the Agilent 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 Agilent 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; "JONES:CALIBRATE;*OPC?" END | Conduct the through path calibration and OPC the through path calibration measurement |
| 40 | DISP "MEASURING" | |
| 50 | ENTER 729; String$ | The program will halt at this point until the Agilent 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 through path calibration in preparation for an absolute Jones matrix measurement. The controller PC will display DONE just as the instrument completes the measurement procedure. When the DONE message appears, the program could then continue on, being assured that there is a valid through path calibration in memory.

Some operations on the Agilent 8509 may take more time than the HPIB bus provides for a time-out. Therefore, when you send *OPC?, either execute a delay before ENTER, or trap the HPIB time-out error using ON TIMEOUT... in the IBASIC program to allow for this delay.

## Preparing for HPIB Control

At the beginning of a program, the Agilent 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 Agilent 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 Agilent 8509 ready to receive HPIB commands. The next step is to put the Agilent 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”>.

Running the following program brings the Agilent 8509 to a known state, ready to respond to HPIB control.

| | | |
|---|---|---|
| 10 | ABORT 7 | This halts all bus action and gives active control to the computer. |
| 20 | CLEAR 729 | This clears all HPIB errors, resets the HPIB interface, and clears syntax errors. |
| 30 | OUTPUT 729; “LOAD;CONFIG:PRESET” END | Presets the instrument. This resets all instrument window menu settings. |
| 40 | END | |

# Interacting with the Agilent 8509C Through the DDE

This chapter focuses on using Microsoft Visual BASIC for Windows (VB) to create a custom application for programmed control of the Agilent 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 Agilent 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 Agilent 8509 allows other applications to establish DDE links to test based controls called ‘labels’ in the Agilent 8509 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 Agilent 8509 application may change with future updates of the firmware, the programmer of a DDE application should provide a mechanism for the Agilent 8509 application to change without requiring the program to be re-compiled. What follows is a VB code fragment that allows the user to specify the Agilent 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 Agilent 8509
‘ application at run time. The command line parameter
‘ that this code fragment looks for is:
‘ /HP8509=<Name of Agilent 8509 Program>
```

‘If parameter not present, use the default name.

‘ Use the variable Agilent8509DdeName# when establishing DDE links.

```
Const Agilent8509_DDE_DEFNAME$=”AGILENT8509_2” ‘ Get the name of the Agilent8509 Application
    UCaseCmd# = Trim$(UCase(Command$))
    i% = InStr (UCaseCmd$, “/HP8509=”)
    If i% = 0 Then
    Agilent8509DdeName$ = Agilent8509_DDE_DEFNAME$
    Else
    i% - i% + 8
    j% = Instr (i%,UCaseCmd$,””)
    If j% = 0 Then j% = Len (UCaseCmd$) +1
    Agilent8509DdeName$ = MID$ (UCaseCmd$, i%, j% - i%)
    End If
```

The Agilent 8509 uses in 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 ar 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 Agilent 8509 is “lpadde”, so combined with the application name, the VB Link-Topic property is “Agilent 8509_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.

For the Agilent 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 Agilent 8509 from a users application follows.

```
‘ This code fragment establishes a DDE link to the
‘Agilent 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 Agilent 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 = Agilent8509DdeName$ & "| 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 = Agilent8509DdeName# & "| lpadde
lblStatus .LinkItem = "Status"
lblStatus .LinkMode = LINK_AUTOMATIC
DoEvents ' Free Windows to allow it to do the Link

' Use to be sure that Agilent 8509 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
```

## Sending Agilent 8509 Commands via DDE

To send command to the Agilent 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 Agilent 8509 data buffers (Param(x) labels). It is required that these buffers are empty before any commands are sent to the Agilent 8509. Generally the data buffer is empty unless a previous command prepared a response by the Agilent 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

' User to be sure that Agilent 8509 data buffers are clear
lblStatus .LinkExecute"ClearParams"

lblStatus .LinkExecute "Poincare:Center:A"
DoEvents ' Free Windows to allow it to do the LinkExecute
```

### Retrieving Agilent 8509 Data via DDE

To retrieve Agilent 8509 data, use the VB LinkRequest method. The Agilent 8509 places data in the Param(x) labels. Use LinkRequest with the controls which are linked to the Param(x) labels in the Agilent 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 Agilent 8509 after getting the data. The following VB code fragment illustrates how to get data from the Agilent 8509 via DDE.

```
Do While lblStatus .Caption = "BUSY"
    DoEvents
Loop

For i% = 0 To 7
    lblParm(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 Agilent 8509 data
frmHpib .lblStatus .LinkExecute "ClearParams"
```

## Measurement Sequence

To organize the commands into a measurement sequence requires 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.

**7** You will *not* be prompted to "Block the external laser", but you *must* either cover the OPTICAL INPUT connector with a connector cap or a piece of dark paper *or* turn off your external source. If the external source is connected to the Agilent 8509C 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 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 Agilent 8509C, 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.

## Set up the instrument

All pertinent measurement parameters must be set. Set the type of source 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 device under test (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 can be read from the instrument using the ENTER remote command. All measured data is returned by the Agilent 8509C system as a sequence of comma-separated strings. The operator must take care to reformat or parse this data if so desired.

## HPIB Programming Examples

The following examples show how to initiate measurements and retrieve data via the HPIB interface to the Agilent 8509. These examples will also work using the DDE; see Chapter 6, "To establish a Dynamic Data Exchange (DDE) link between the 8509 and another application" on page 6-29 for more details.

**Example 1**. This example retrieves the state of polarization, the degree-of-polarization, and the measured power. A 1550 nm source is connected to the 8509 optical input.

| | |
|---|---|
| OUTPUT 729; "SOURCE:EXTERNAL:1550NM" END | Set 8509 wavelength to 1550 nm |
| OUTPUT 729; "SOURCE:EXTERNAL?" END | Query current 8509 wavelength setting |
| ENTER 729; String$ | |
| DISP String$ | Print out the wavelength |
| OUTPUT 729; "STOKES?:500" END | Take measurement using 500-point averaging |
| ENTER 729; String$ | |
| DISP String$ | Print out the test results |

Resulting printout (an example only):

1550
0.0001,.15,-0.75324,.23434,.989

This printout tells you that the 8509 is currently set to give correct readings at 1550 nm, the measured power is 0.0001 milliwatts, the normalized Stokes parameters are (.15, -0.75324,.23434), and that the degree-of-polarization (DOP) is 98.9%.

**Example 2.** This example performs a manually-tuned PMD:JME measurement using an 81640A Tunable Laser Source (TLS). The TLS is connected to the HPIB bus at address 724. Its optical output is connected to the 8509 external source input. A DUT is connected between the 8509 optical output and the 8509 optical input.

| | |
|---|---|
| OUTPUT 729; "ZERO" END | Zero the 8509 |
| OUTPUT 729; "DISPER" END | Open the PMD:JME Measurement Window |
| OUTPUT 729; "DISPER:MANUAL" END | Send the 8509 into manually-tuned PMD mode so that you control the TLS from this program |
| OUTPUT 729; "DISPER:WLEN:START:1550NM" | Set the start wavelength to 1550 nm |
| OUTPUT 729; "DISPER:WLEN:STOP:1551NM" | Set the stop wavelength to 1551 nm |
| OUTPUT 729; "DISPER:WLEN:DELTA:1NM | Set the wavelength step size to 1 nm |
| OUTPUT 724; "SOUR0:CHAN1:POW:STATE ON" | Turn the TLS output on |
| OUTPUT 724; "SOUR0:CHAN1:WAVE 1550NM: | Set the TLS to 1550 nm |
| OUTPUT 729; "DISPER;MEASURE" | Measure start wavelength (1550 nm) |
| OUTPUT 724; "SOUR0:CHAN1:WAVE 1551NM: | Set TLS to 1551 nm |
| OUTPUT 729: "DISPER:MEASURE" | Measure start wavelength (1550 nm) |
| OUTPUT 729; "DISPER?" | Get the PMD measurement |
| ENTER 729; String$ | |
| DISP String$ | Print it out |
| OUTPUT 724; "SOUR0:CHAN1:POW:STATE OFF" | Turn the TLS output off |
| OUTPUT 729; "DISPER:CLOSE" END | Close the PMD:JME Measurement Window |

Resulting printout (an example only):

1550.5,.218,.218

This printed result tells you that the average measured differential group delay (DGD) was 0.218 picoseconds at an average wavelength of 1550.5 nm.

**Example 3**. This example performs a Jones Matrix Method PDL measurement. It is assumed that a 1550 nm source is connected to the 8509 external source input and the DUT is connected between the 8509 optical output and optical input.

| | |
|---|---|
| OUTPUT 729; “SOURCE:EXTERNAL:1550NM” END | Set 8509 wavelength to 1550 nm |
| OUTPUT 729: “SOURCE:EXTERNAL?” END | Query current 8509 wavelength setting |
| ENTER 729; String$ | |
| DISP String$ | Print out the wavelength |
| OUTPUT 729; “POLDEP:INTERNAL” END | Select PDL measurement with internal polarizers |
| OUTPUT 729; “POLDEP:EXTERNAL?” END | Select the relative measurement mode |
| OUTPUT 729; “POLDEP:MEASURE” END | Make relative PDL measurement |
| OUTPUT 729; “POLDEP:POLDEPDATA?” END | Retrieve the PDL measurement |
| ENTER 729; String$ | |
| DISP String$ | Print out the test results |
| OUTPUT 729; “POLDEP:DONE” END | Close the PDL window |

Resulting printout (an example only):

1550

.23

This printed result tells you that the PDL was 0.23 dB at 1550 nm.

# Command Syntax

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 HPIB. Any restrictions to the use of a command are noted in the command description.

When receiving HPIB commands, the Agilent 8509C does not lock out manual operation. Do *not* disrupt remote control through manual command execution. Furthermore, HPIB commands which lock out manual operations are not currently available for remote control of the Agilent 8509C. When you begin remote operation of the Agilent 8509C, quit, then restart the application if there has been any manual operation during the current session of the Agilent 8509C application.

**Table 8-1. 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 Agilent 8509C application directory, but can be changed in the Windows Program Manager by highlighting the Agilent 8509C 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. |
| <“title”> | | The title to use for a Save/Load operation with the Agilent 8509C 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 Agilent 8509C 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 Agilent 8509C 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. |

# Abbreviations/Definitions

| | |
|---|---|
| analyzer window | The first window to open when the Agilent 8509C lightwave polarization analyzer software starts. |
| DDE | Dynamic Data Exchange. A mechanism Microsoft Windows uses for applications to communicate with each other. Agilent 8509C supports DDE links. |
| 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 Agilent 8509C is an LPA. |
| Not Recommended | The particular command is supported in this version. However, it may not be supported in future versions of the Agilent 8509C. |
| 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 HPIB bus communications for messages. Codes 13, 10 (<CR><LF>) are often used for EOL (end of line) (see HPIB configuration and setup information). |
| TLS | Tunable Laser Source. Agilent 8164, Agilent 8167, and Agilent 8168 are tunable laser sources. |
| VTUNE | Tunable Laser Source controlled by analog voltage output VOUT A of the Agilent 8509C. 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. |

# Changes from Version 1.2 Software

Every effort has been made to assure the compatibility of version 3.0 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 Agilent 8509C 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 HPIB bus transactions by grouping the commands together, separated by a semicolon. Four thousand (4,000) characters may be sent in one HPIB bus transaction to the Agilent 8509C. It is recommended to send *OPC? to the Agilent 8509C as part of the same HPIB 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 HPIB or DDE, the Agilent 8509C system will be occupied performing the calibration. No other activity on the Agilent 8509C instrument controller will take place until the calibration completes. The command *OPC[?] has no effect, since the Agilent 8509C system will not respond to any commands while a calibration is in progress. The Cal:Calibrate command takes about 25 seconds on a instrument controller. The programmer should hard code a delay in the program which controls the Agilent 8509C, 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 3.0 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 Agilent 8509C 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 Agilent 8509C instrument. This is not true for version 3.0 of the Agilent 8509C software. In version 3.0 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 3.0 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.

# 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: "AGILENT TECHNOLOGIES,Agilent 8509C,3206A00156,2.10"

HPIB 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} [?]" on page 8-33).

`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 Agilent 8509C. If "stokes" is sent, the output of the four BNC connectors will be four voltages proportional to the Stokes parameters $S_0$, $s_1$, $s_2$ and $s_3$. When raw is sent, the four voltages will be proportional to the currents induced on the four photodiodes of the Agilent 8509C 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. The query returns "1" if the particular control is selected in the Analog frame of the analyzer window, and "0" if not selected.

`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}" on page 8-34.)

`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}" on page 8-34.)

`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.

`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.

`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.

`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 HPIB 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 Agilent 8509C instrument display. Be sure to send ‘Disper’ before sending any other ‘Disper:....’ commands.

`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.

`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.

`Disper:Atten{? | :<dBm value>}`

The attenuation for the HPIB tunable laser source. The query returns the attenuation in dBm. Using <dBm value> sets the attenuation for an HPIB tunable laser source.

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.

`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.

`Disper:Chain[?]`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: "Disper:{Cascade | Single}[?]" on page 8-37.

`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 thru-path calibration corrections.

`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 3.0 the PMD:JME window is a child of the Agilent 8509C Graphs window. The Graphs window closes when the last graph is closed.

`Disper:DBase:Load:<"title">`

Loads a measurement from the current database using the specified title.

`Disper:DBase:Save:<"title"> [ :<"date code"> [ :<"serial number">]]`

Saves a measurement to the current database using the specified title.

`Disper:Done`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: "Disper:Close" on page 8-38.

`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.

`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 HPIB Agilent 8164, Agilent 8167, and Agilent 8168 and VTune tunable laser sources. Agilent 8509C control of the HPIB bus is available only using DDE. Therefore, this feature will not work for the Agilent 8164, Agilent 8167, and Agilent 8168 tunable laser sources when using the HPIB bus for remote operation of the Agilent 8509C. Only the VTune tunable laser source can be used with HPIB. 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.

`Disper:HPIB[?]`

Sets the tunable laser source for a PMD:JME measurement to an HPIB tunable laser source. The Agilent 8509C looks for a tunable laser source at the address specified with TLS:Address and uses it if it is an Agilent 8164, Agilent 8167, or Agilent 8168 tunable laser source. Be sure that the wavelength range is set correctly for the connected HPIB tunable laser source before issuing this command. To change the tunable laser source selection, Agilent 8164, Agilent 8167, or Agilent 8168:

1. Issue the command Disper:Manual
2. Change the wavelength range using Disper:WLen:
3. Change the HPIB address using TLS:Address:<HPIB Address>
4. Issue the command Disper:HPIB

The query returns an ASCII "1" if the PMD:JME next measurement process will be in HPIB mode and a "0" if it will not be in this mode. Also returns the name of the current laser source.

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?’.

---

`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.

---

`Disper:Measure`

Triggers a PMD:JME measurement at the current source wavelength setting.

---

`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” on page 8-37.

---

`Disper:Power?`

Returns the power and the power units for the tunable laser source.

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.

DDE Only.

```
Disper:Restart
```

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “Disper:Clear” on page 8-38.

```
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” on page 8-27.

```
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}{? | :<Delay msec>}” on page 8-66.

```
Disper:Start
```

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “Disper:Measure” on page 8-40.

```
Disper:Trace:<“filename”>
```

***Not Recommended***

Command may not be available in future versions. Plan your programming to use the alternate command: “Disper:Save:<“filename”>” on page 8-41.

```
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.

```
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.

```
Disper:VTune:{Start | Stop}{? | :<Voltage>}
```

The VTUNE start or stop voltage. The query returns the voltage value, the parameter <Voltage> sets the value.

```
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."

```
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:

$$WlenDelta = (WlenStop - WlenStart) / (WlenPoints - 1)$$

The query returns the number of points specified in the current PMD:WS measurement settings.

```
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:

$$WlenPoints = ((WlenStop - WlenStart) / WlenDelta) + 1$$

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 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.

```
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>}" on page 8-42.

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.

---

`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}” on page 8-34.

---

`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}[?]” on page 8-33.

Sets the displayed angles to degrees or radians (see “Display:Angles:{Off | On}” on page 8-44).

---

`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.

---

`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 HPIB initiated data storage.

---

`Drive:<MS-DOS Drive Spec>`

Sets the specified drive for HPIB initiated data transfers. Drive C is the Agilent 8509C system default drive. If using drive C, all saved data files using HPIB will be placed in the Agilent 8509C 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 HPIB, transfer an ASCII data file from the Agilent 8509C system instrument controller to the external controller. The file is transferred as an ASCII string. An ENTER HPIB command must be used to access the file from the Agilent 8509C instrument controller. 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 HPIB command statement. For path information on "filename", see “Command Syntax” on page 8-27.

HPIB Operation only.

---

`GetMarker:{A | B | C}`

***Not Recommended***
See “GetMarker:{A | B | C}” on page 8-45.

---

`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.

---

`Jones?`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “PolDep:{JonesData? | PolDepData?}” on page 8-51.

---

`Jones:{Absolute | Relative}[?]`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “PolDep:{Absolute | Relative}[?]” on page 8-50.

`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]" on page 8-50.

`Jones:Clear`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: "PolDep:Clear" on page 8-50.

`Jones:Done`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: "PolDep:Done" on page 8-51.

`Jones:{External | Internal}[?]`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: "PolDep:{Internal | External}[?]" on page 8-51.

`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 | Real-Imag}[?]" on page 8-52.

`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]" on page 8-52.

---

`Jones:NewThruCal`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “PolDep:NewThruCal” on page 8-52.

---

`Jones:ReStart`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “PolDep:Clear” on page 8-50.

---

`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 Agilent 8509C application directory.
3. The Windows directory (usually C:\WINDOWS).

For path information on "filename", see “Command Syntax” on page 8-27.

---

`Load:Single:<“filename”>`

Loads a timed measurement from the file <“filename”>.

For path information on "filename", see “Command Syntax” on page 8-27.

---

`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 Agilent 8509C 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.

`Per?`

Returns the polarization extinction ratio (dB) for a previously performed polarization maintaining (PM) fiber launch alignment.

`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.

`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 Agilent 8509C 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}" on page 8-50.

`Polarizer:Done`

Closes the Polarizers frame in the analyzer window.

`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.

`PolDep?`

***Not Recommended***

Command may not be available in future versions. Plan your programming to use the alternate command: “PolDep:{JonesData? | PolDepData?}” on page 8-51.

`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:Calibrate[A | B | C]`

This 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>}” on page 8-49.) 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.

`PolDep:Clear`

Aborts or restarts a polarization dependent loss measurement process. Any current measurements are cleared. The command does not erase the thrupath calibration corrections from memory.

`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 Agilent 8509C system. The user must implement and specify external polarizers through the polarizer command. The query returns the selected polarizers.

`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.

`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? HPIB 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>}” on page 8-49.)

`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.

`PolDep:ReStart`

***Not Recommended***

Command may not be available in future versions. Plan your programming to use the alternate command: “PolDep:Clear” on page 8-50.

`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}” on page 8-53.

`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 Agilent 8509C. (See “Range:Auto{? | :Off | :On}” on page 8-53). 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}” on page 8-53.

`RawDat?`

Returns the raw ADC voltages, with offsets subtracted, associated with the four photodiode detectors within the Agilent 8509C 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?`

Returns 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}[?]” on page 8-55.) 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.

---

`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}[?]” on page 8-55.

---

`Save:Config:<“filename”>`

Saves the current instrument configuration into the file <“filename”>. For path information on "filename", see “Command Syntax” on page 8-27.

---

`Save:Disper:<“filename”>`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “Disper:Save:<“filename”>” on page 8-41.

---

`Save:Jones:<“filename”>`

***Not Recommended***
Command may not be available in future versions. Plan your programming to use the alternate command: “Save:PolDep:<“filename”>” on page 8-56.

---

`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” on page 8-27.

---

`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” on page 8-27.

---

`SerialNum?`

Returns the serial number of the Agilent 8509C 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`

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.

`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 Agilent 8509C 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
Agilent8164A/HPIB
Agilent8167A/HPIB
Agilent8168A/HPIB
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.

`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 (HPIB controlled Agilent 8164/8167/8168 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}" on page 8-58 for information on TLS.

---

`Source:HPIB[?]`

Sets the tunable laser source for the analyzer window to an HPIB TLS. The Agilent 8509C looks for a tunable laser source at the address specified with TLS:Address and uses it if it is an Agilent 8164, Agilent 8167, or Agilent 8168 tunable laser source.

The query returns two parameters.

first: "0" (not HPIB TLS), "1" (HPIB 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 HPIB source. When turned on or set using <Wavelength nm>, the Agilent 8509C system automatically determines which tunable laser source (Agilent 8164, Agilent 8167, or Agilent 8168) is connected to the HPIB bus at the address set using TLS:<HPIB address>.

DDE 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}" on page 8-60.

---

`Source:Shutter:{Off | On}`

This command controls the shutter located in the path to the OPTICAL OUTPUT port of the Agilent 8509C. Any external source coupled into the external source port of the Agilent 8509C share a common instrument internal path to the optical output port of the Agilent 8509C. 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.

---

`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"<br><Optional Description> | Command failed. |
| "PROBLEMS"<br><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>" on page 8-61.

`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).

`TLS?`

Returns the name of the current tunable laser source. Valid return values are:

Voltage tuned
Agilent8164A/HPIB
Agilent8167A/HPIB
Agilent8168A/HPIB
Manually tuned

`TLS:Address{? | :<HPIB Address>}`

This setting is used for all windows. The HPIB address of a tunable laser source on the HPIB bus.

DDE only.

```
TLS:Isc{? | :<HPIB card ISC>}
```

This setting is used for all windows. The ISC of the HPIB card installed in the Agilent 8509C instrument controller.

DDE only.

```
TLS:Power{?| :<Power>}
```

This setting is used for the analyzer window only. The power setting of the HPIB 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}{? | :<Delay msec>}" on page 8-41.

DDE only.

```
TLS:Power:Unit{? | :dBm | :Watt}
```

The units of power for the HPIB tunable-laser-source power. This setting is used for the analyzer window only. See also: "Disper:Power:{dBm | uWatt}[:<value>]" on page 8-40 and "WaveScan:Power:{dBm | uWatt}[:<value>]" on page 8-66. 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>}" on page 8-57.

```
Version?
```

Returns the current version number of the Agilent 8509C 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

`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 HPIB tunable laser source. The query returns the attenuation in dBm. Using <dBm value> sets the attenuation for an HPIB 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.

`WaveScan:HPIB[?]`

Sets the tunable laser source for a PMD:WS measurement to an HPIB tunable laser source. The Agilent 8509C looks for a tunable laser source at the address specified with TLS:Address and uses it if it is an Agilent8164, Agilent 8167, or Agilent 8168 tunable laser source. Be sure that the wavelength range is set correctly for the connected HPIB tunable laser source before issuing this command. To change tunable laser source selections between Agilent8164, Agilent 8167, and Agilent 8168:

1. Issue the command WaveScan:Manual
2. Change the wavelength range using WaveScan:WLen:
3. Change the HPIB address using TLS:Address:<HPIB Address>
4. Issue the command WaveScan:HPIB

The query returns an ASCII "1" if the PMD:WS next measurement process will be in HPIB 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.

---

`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.

---

`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. 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” on page 8-27.

```
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}{? | :<Delay msec>}” on page 8-41.

```
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".

`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.

# Specifications and Characteristics

# Specifications and Regulatory Information

This chapter lists specification and characteristics of the instrument. The distinction between these terms is described as follows:

Specifications are the warranted performance.

- Specifications describe warranted performance standards or limits against which the Agilent 8509C can be tested over the temperature range 23°C ±5°C and relative humidity <95% (unless otherwise noted). All specifications apply with the instrument oriented upright on a horizontal surface and warmed up for at least one hour.
- *Characteristics* provide useful information by giving functional, but nonwarranted, performance parameters. *Characteristics are printed in italics.*

### *Calibration Cycle*

This instrument requires periodic verification of performance. The instrument should have a complete verification of specifications once every year.

# General Specifications

**Table 9-1. General Specifications**

| | |
|---|---|
| Use | Indoor |
| Power (without instrument controller or monitor) | 90 V to 132 V or 198 V to 264 V<br>100 VA |
| Voltage | Mains supply voltage fluctuations not to exceed ±10% of the nominal voltage |
| Frequency | 47.5 Hz to 66 Hz |
| Altitude | Up to 2000 m |
| Operating temperature | 5°C to 40°C |
| Maximum relative humidity | 80% for temperatures up to 31°C decreasing linearly to 50% relative humidity at 40°C (unless otherwise specified) |
| Weight (without instrument controller or monitor) | 10.5 kg (23 lbs) |
| Dimensions (H × W × D) | 133.4 mm x 425.5 mm x 546.1 mm<br>5.25 in x 16.75 in x 21.5 in |

# Warranted Specifications

The warranted specifications on the lightwave polarization analyzer 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, JME method

The Jones matrix eigenanalysis (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 Agilent 8168A Tunable Laser Source. The JME measurement is operational over the ranges of 1280 to 1340 nm and 1470 to 1640 nm, however, the DGD uncertainty specification is warranted over the wavelength range of 1540 to 1560 nm.

**Table 9-2. Maximum Measurable DGD Using JME Delay**

| Maximum Measurable DGD Using JME Method[a] | | |
|---|---|---|
| **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 |

a. Maximum measurable PMD delay = $\pi$ / radian optical frequency interval.

## Table 9-3. PMD Measurement Uncertainty Using the JME Method

| PMD Measurement Uncertainty [a,b,c,d] | |
|---|---|
| **Wavelength Step** | **Uncertainty (±)** |
| 0.10 nm | 310 fs |
| 1.0 nm | 90 fs |
| 10.0 nm | 60 fs |

a. Receiver input level –20 to –40 dBm.
b. Does not include external laser tuning accuracy.
c. Measurement averaging set to 500 points.
d. PMD is the average value of DGD across the measurement wavelength range.

# Characteristics

## Jones matrix eigenanalysis PMD measurement

Table 9-4 shows the repeatability of a measurement of a 0.218 ps quartz PMD standard in which the fibers do not move between measurements.

**Table 9-4. Repeatability of JME PMD Measurement with Fixed Pigtail Positions**

| **Repeatability of JME PMD Measurement [a,b,c,d]** | |
|---|---|
| Number of measurements | *20 measurements* |
| Expected value of DGD | *0.218 ± 0.010 ps* [e] |
| Mean | *0.2173525 ps* |
| Standard deviation | *0.0000085 ps* |
| Maximum - minimum | *0.00003 ps* |
| Maximum | *0.21737 ps* |
| Minimum | *0.21734 ps* |

a. Test device is a pigtailed quartz PMD standard, under development.
b. Measurement wavelength range of 1500 to 1560 nm.
c. Measurement wavelength interval of 10 nm.
d. No movement of test device or pigtails between measurements.
e. The ± 0.010 ps tolerance is provided to allow for the effects of pigtails and packaging.

Table 9-5 shows the repeatability of 20 measurements of a pigtailed quartz PMD standard in which Pigtail positions are randomized before each measurement.

**Table 9-5. Repeatability of JME PMD Measurement with Randomized Pigtail Positions**

| **Repeatability of JME PMD Measurement** [a,b,c,d] | |
|---|---|
| Number of measurements | *20 measurements* |
| Expected value of DGD | *0.218 ± 0.010 ps* [e] |
| Mean | *0.21821 ps* |
| Standard deviation | *0.00246 ps* |
| Maximum - minimum | *0.00787 ps* |
| Maximum | *0.22271 ps* |
| Minimum | *0.21484 ps* |

a. Test device is a pigtailed quartz PMD standard, under development.
b. Measurement wavelength range of 1500 to 1560 nm.
c. Measurement wavelength interval of 10 nm.
d. Reposition pigtails randomly before each measurement.
e. The ± 0.010 ps tolerance is provided to allow for the effects of pigtails and packaging.

# Wavelength scanning PMD measurement

Table 9-6 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.

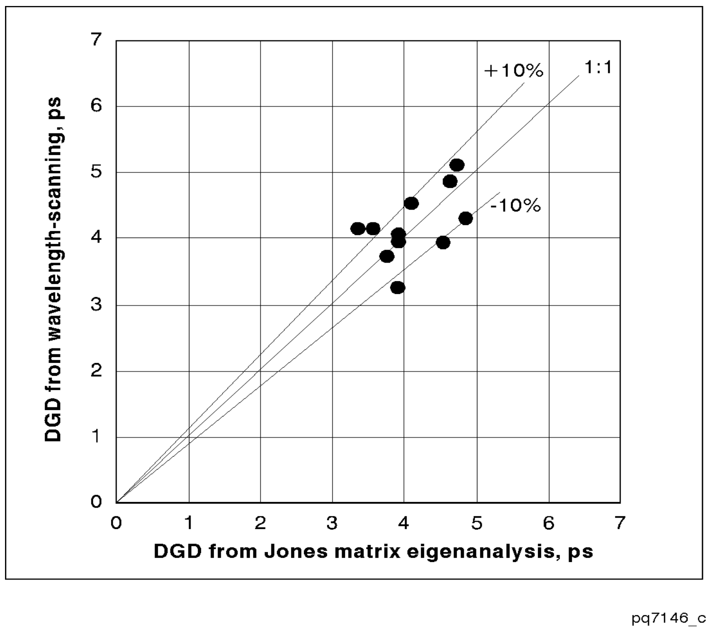
**Table 9-6. Minimum Measurable PMD Using the Wavelength Scanning Method**

| **Minimum Measurable PMD[a]** | |
|---|---|
| **Type of test device** | **Minimum measurable PMD value** |
| non-mode-coupled devices [b]<br>(most components) | *0.040 ps* |
| highly mode-coupled devices [c] (long fibers) | *0.195 ps* |

a. Assumes 100 nm wavelength tuning range.
b. Assumes a single peak and a single valley.
c. Assumes an average of 3 cycles of polarization change (4 peaks).

# Comparison of JME and wavelength scanning methods

The figure below is a comparison between the Jones matrix eigenanalysis and wavelength scanning measurement methods. Agilent 8509C JME and WS measurements agree to within approximately +15% for this test device.




**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. 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.

# Receiver characteristics

### Table 9-7. Receiver Characteristics

| | |
|---|---|
| Wavelength operating range [a] | *1280 to 1640 nm* |
| Input power operating range | *+10 to –55 dBm* |
| Input average power damage level | *+16 dBm* |
| Average power measurement uncertainty [b] | *±15%* |
| Degree of polarization measurement uncertainty [c,d,e] | *1280 to 1340 nm, ±2.0%*<br>*1470 to 1580 nm, ±2.0%*<br>*1580 to 1630 nm, ±3.0%*<br>*1630 to 1640 nm, ±5.0%* |
| Poincare representation uncertainty [d,f,g,h] | *1200 to 1340 nm, ±1.5 °*<br>*1470 to 1640 nm, ±1.5 °* |
| Measurement rate | *> 3500 per second* |
| Display update rate | *> 3500 per second* |

a. The Agilent 8509C performs polarization measurements over this range. See individual measurement specifications or characteristics for details.
b. Does not include the effects of optical connectors.
c. Uncertainty introduced in defining an external reference frame in open beam applications is not included.
d. 500 point display averaging (running average).
e. Characteristic applies for 100% polarized light for the purpose of practical verification.
f. Characterized in degrees on the Poincare sphere.
g. For input light at least 98 percent polarized. Uncertainty increases as degree of polarization decreases.
h. For uncertainty in the angle between two displayed points, multiply by two.

# Polarization dependence, Jones matrix method

### Table 9-8. Measurement of Polarization Dependence Jones Matrix Method

| **Measurement of Polarization Dependence, Jones Matrix Method** [a,b] | |
|---|---|
| Polarization dependence wavelength operating range | *1280 to 1340 nm*<br>*1470 to 1620 nm* |
| Polarization dependence uncertainty [c,d,e] | *±0.1 dB* |

a. Polarization dependence is the peak to peak variation in transmission of the device under test over all polarization states.
b. Specified with single-line laser source.
c. For measured values less than 3 dB, receiver input level > –20 dBm.
d. Does not include the effect of optical connectors.
e. Measurement averaging set to 500 points.

# Polarization dependence, power max–min method

### Table 9-9. Measurement of Polarization Dependence Power Max–Min Method

| **Measurement of Polarization Dependence Power Max - Min Method** [a,b] | |
|---|---|
| Polarization dependence wavelength operating range | *1280 to 1340 nm*<br>*1470 to 1620 nm* |
| Polarization dependence uncertainty [c,d,e] | *±0.1 dB* |

a. Polarization dependence is the peak to peak variation in transmission of the device under test over all polarization states.
b. Specified with single-line laser source.
c. For measured values less than 3 dB, receiver input level > –20 dBm.
d. Does not include the effect of optical connectors.
e. Measurement averaging set to 500 points.

# Other characteristics

**Table 9-10. External Source Input Port, Fiber Size, and Analog Output Range Characteristics**

| | |
|---|---|
| Wavelength operating range | *1280 to 1640 nm* |
| Insertion loss [a] | *8.5 dB* |
| Return loss [b,c] | *35 dB* |
| Compatible fiber | *9/125 micron* |
| Analog output range | *±10 volts* |

a. Internal path loss between EXTERNAL SOURCE INPUT and OPTICAL OUTPUT connectors with no polarizer selected.

b. Does not include the effects of optical connectors.

c. When optical output is connected with return loss of 30 dB or better.

# Regulations and Licensing

## Notice for Germany: Noise Declaration

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

# Declaration of Conformity

## DECLARATION OF CONFORMITY

According to ISO/IEC Guide 22 and CEN/CENELEC EN 45014

**Manufacturer's Name:** Agilent Technologies, Inc.

**Manufacturer's Address:** 1400 Fountaingrove Parkway
Santa Rosa, CA 95403-1799
USA

**Declares that the product:**

**Product Name:** Lightwave Polarization Analyzer System

**Model Number:** 8509C

**Product Options:** This declaration covers all options of the above product.

**Is in conformity with:**

Safety: IEC 61010-1:1990 +A1:1992+A2:1995 / EN 61010-1:1994+A2:1995
CAN/CSA-C22.2 No. 1010.1-92

EMC: CISPR 11:1990/EN 55011:1991 Group 1, Class A
IEC 61000-4-2:1995+A1:1998 / EN 61000-4-2:1995, 4 kV CD, 8 kV AD
IEC 61000-4-3:1995 / EN 61000-4-3:1995, 3 V/m, 80-1000 MHz
IEC 61000-4-4:1995 / EN 61000-4-4:1995, 0.5 kV sig. lines, 1 kV pow. lines
IEC 61000-4-5:1995 / EN 61000-4-5:1995, 0.5 kV l-l, 1 kV l-e
IEC 61000-4-6:1996 / EN 61000-4-6:1996, 3V 80% AM, power line
IEC 61000-4-11:1994 / EN 61000-4-11:1994, 100 %, 20 ms

**Supplementary Information:**

The product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the CE-marking accordingly.

Santa Rosa, CA, USA 26 Feb 2001

Greg Pfeiffer/Quality Engineering Manager

For further information, please contact your local Agilent Technologies sales office, agent or distributor.

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