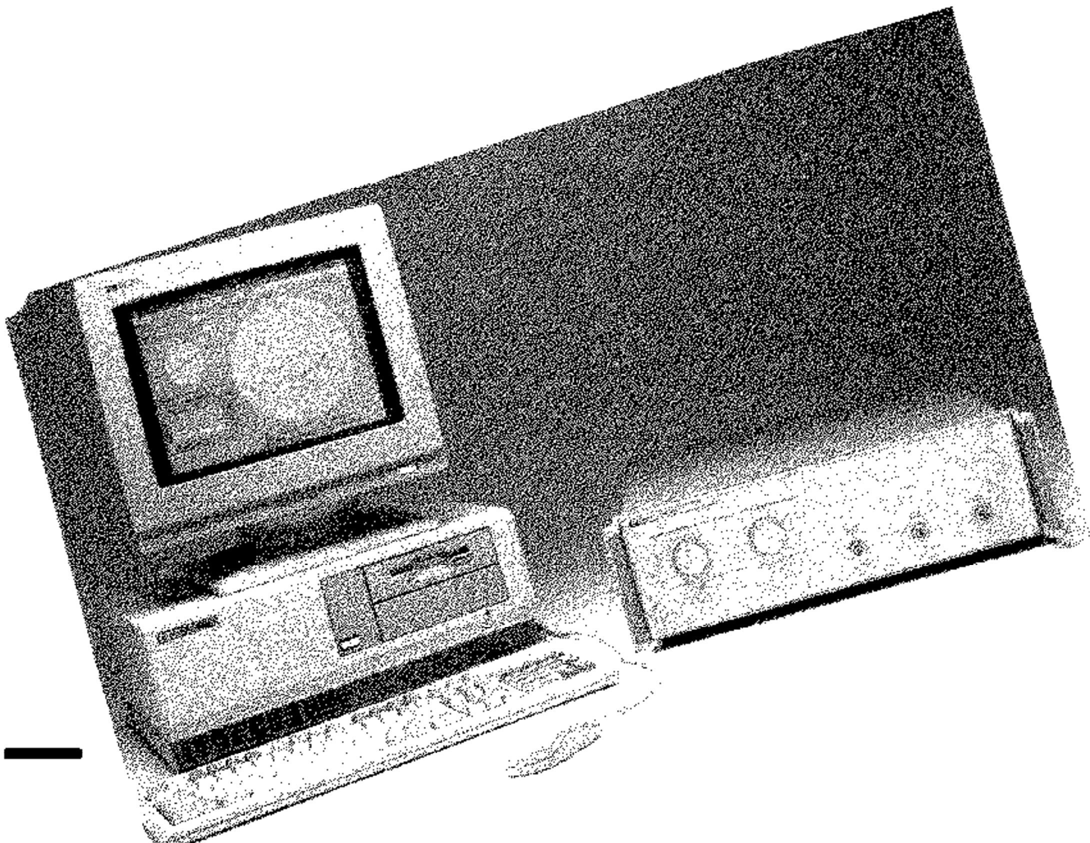
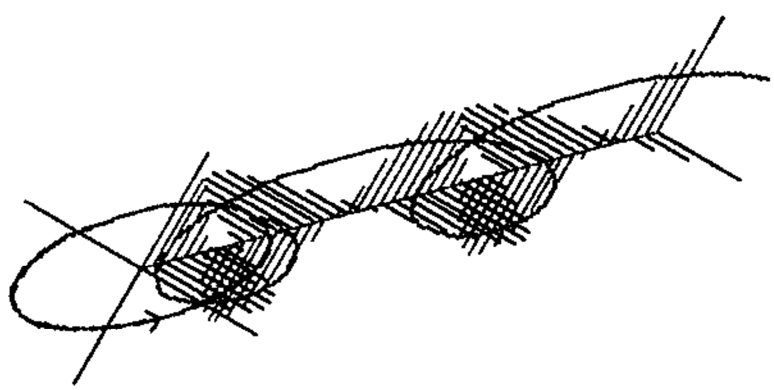
HP 8509A/B Lightwave Polarization Analyzer

Technical Data

Optical polarization measurements of signal and components

1200 nm to 1600 nm



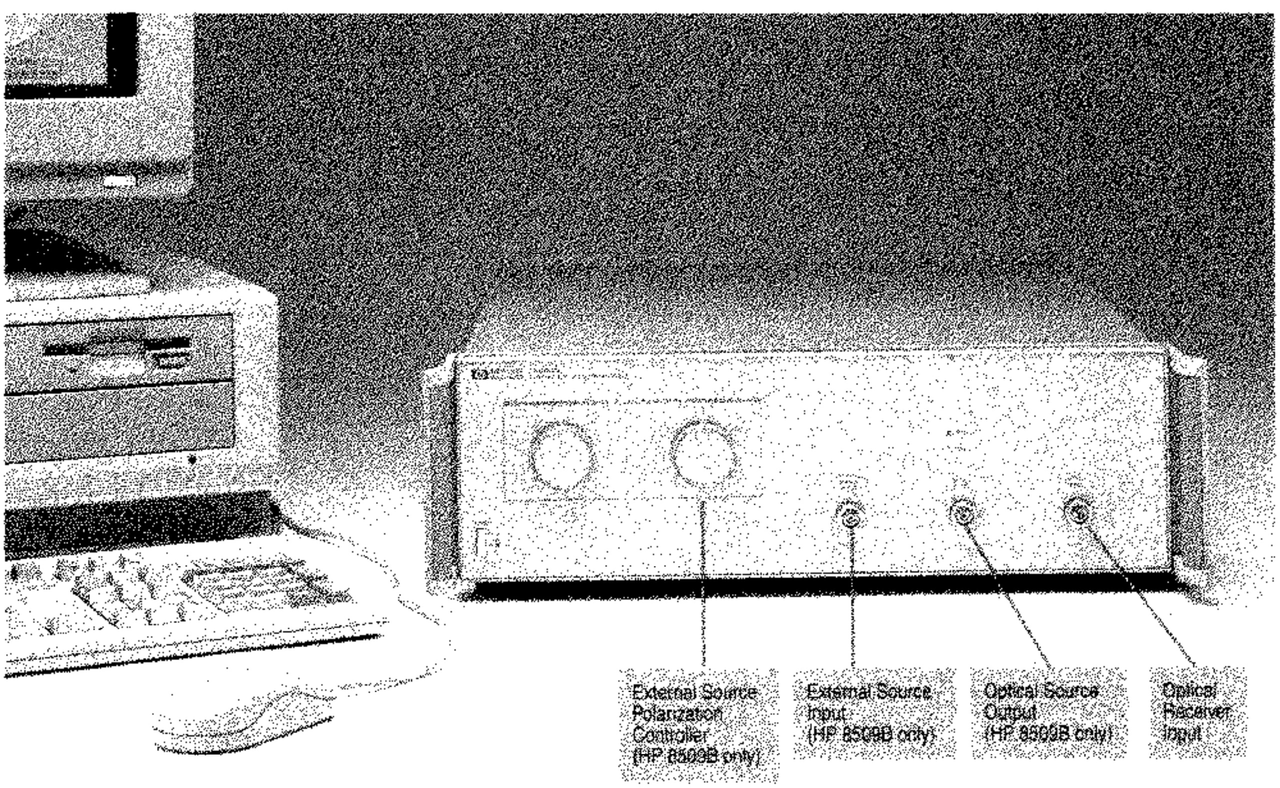


The HP 8509A and HP 8509B Lightwave Polarization Analyzers

A greater understanding of the polarization properties of lightwave signals and materials is helping to develop higher-performance lightwave components and systems, as well as more effective test and manufacturing processes. These developments involve many types of polarization-sensitive devices which are used in communications, sensors, optical computing and material analysis; devices such as single-mode fibers, polarization-maintaining fibers, isolators, optical switches, lasers, beamsplitters, modulators, interferometers, retardation plates and, of course, polarizers and polarization adjusters.

Polarization characteristics affect all lightwave transmissions. The polarization of a lightwave signal is defined by its E-field components. As a signal propagates, interaction with optical components and other lightwave signals (in interferometric applications) modifies the magnitude and phase of the signal's E-field components. Polarization-dependent loss, gain or even signal distortion may occur depending on the application.

The HP 8509A/B lightwave polarization analyzer system is one of the first systems to offer high-speed, calibrated polarization measurements of both optical signals and components. These new capabilities are provided by innovations in hardware, software, and applications of Jones matrix and Stokes vector mathematics.



Accurate, easy-to-understand data in less time

In order to maintain a competitive edge, R&D and manufacturing operations need fast, accurate, easy-to-understand measurement data. This reduces the time and expense of bringing a product to market. The HP 8509A/B can help.

Test times are reduced by the system's versatile and powerful combination of hardware and software technology. A four-diode detection scheme delivers real-time polarization information by constantly monitoring all signal polarization states from 1200 nm to 1600 nm. Test setup is easier with the choice of using external lightwave sources or using the HP 8509B internal 1300 nm and 1550 nm Fabry-Perot lasers. Polarization control is available using the automatic, three-state polarization generator of the HP 8509B. Polarization mode dispersion and polarization-dependent loss measurements are quick and simple using the HP 8509 automatic measurement procedures.

Measurement accuracy is provided by the system's accuracy enhancement techniques. HP 8509A/B polarization reference frames enable accurate testing in bulk optics and fiber cables by removing unwanted fiber cable effects. The HP 8509A/B wavelength calibration capability automatically optimizes the system receiver for the best performance based on the polarization and wavelength of a test signal.

Polarization is easier to understand when data is presented in the appropriate display formats. When tuning the polarization of a lightwave signal, for example, the Poincare sphere is the best format because the tuning process is visually guided by a moving polarization trace on the sphere. For mathematical specifications of signal polarization, the Stokes parameter format is best because it is used in polarization calculations. Whichever format is needed, the HP 8509A/B can meet the need with simultaneous data displays in a variety of different formats.

In the lab and on the production line, scientists, engineers and technicians depend on the speed, accuracy and convenience of the HP 8509A/B to accurately measure and predict the polarization of signals and the polarization transmission properties of components.

HP 8509A/B measurement capability and data format summary

- **Polarization Ellipse**
- **Poincare Sphere**
- **Degree of Polarization**
- **Stokes Parameters**
- **Average Power**
- **Jones Matrix**
- **Polarization Mode Dispersion (HP 8509B only)**
- **Polarization-Dependent Loss**
- **Polarization-Maintaining-Fiber Launch Conditions**

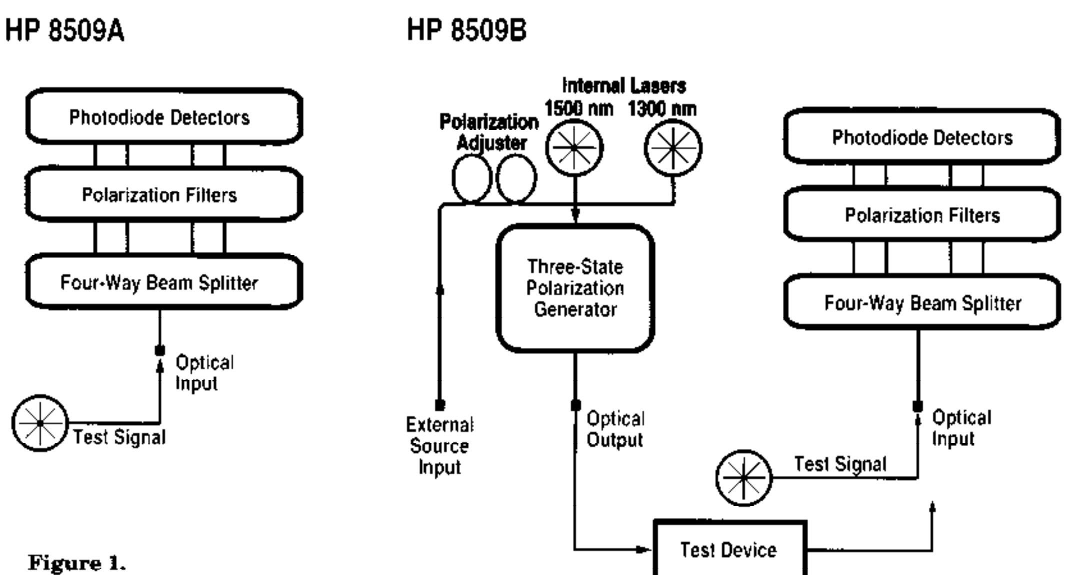


Figure 1.
HP 8509A and HP 8509B Block Diagrams

Measure optical signal polarization

Increase accuracy and make polarization easier to understand with polarization reference frame procedures and multiple, simultaneous display formats.

State of Polarization

In fiber cables and bulk-optics, the HP 8509A/B delivers high-speed signal polarization analysis by performing over 1000 polarization measurements per second. Data averaging can be applied before it is displayed as average power, polarization ellipse, Stokes parameters and points on a Poincare sphere. Three data markers provide Stokes parameter analysis and relative angle comparisons between specific data points on the Poincare sphere.

Polarization Reference Frame

Polarization reference frames are especially valuable for optical sensor and bulk-optic sub-system applications where location-specific signal polarization information is needed. In these cases the test system must remove its own responses from the test data to minimize measurement uncertainty. Improved accuracy makes measurement results easier to interpret, document and reproduce.

The HP 8509A/B quickly defines a polarization reference frame at a specific location using three polarization standards. The absolute polarization accuracy of the reference frame depends largely on the standards used.

Jones Matrix

A 2 X 2 complex Jones matrix, measured by the HP 8509A/B, mathematically describes how an individual optical component will affect the magnitude and polarization of a transmitted signal. The Jones matrices of many components can be mathematically combined. A combined Jones matrix can be used to calculate the total polarization effect that would be measured by actually connecting the components. This can be helpful when attempting to select a combination of components that will produce a certain polarization effect. Jones-matrix analysis is also used to calculate polarization mode dispersion and polari-zation-dependent loss of systems and components.

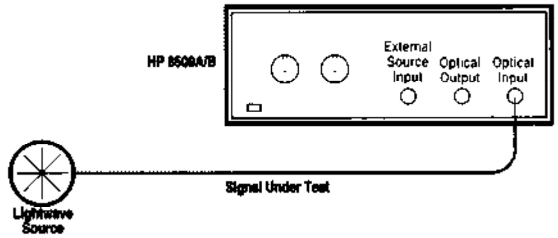


Figure 2. Signal polarization measurement setup

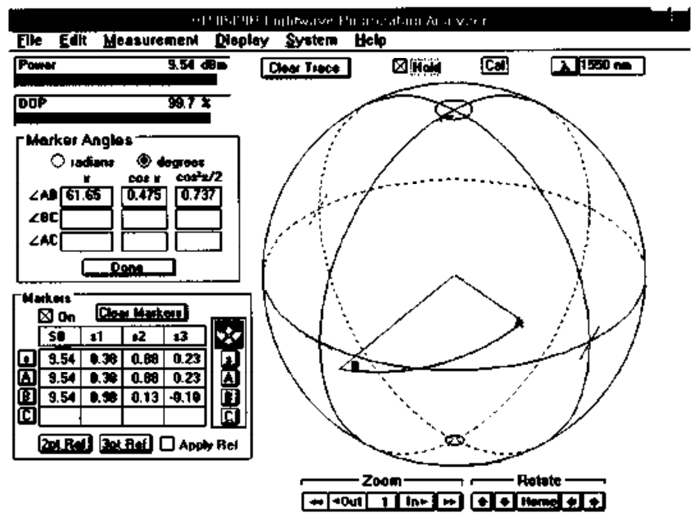


Figure 3. Angular relationships between different signal polarization states can be analyzed using HP 8509A/B Poincare sphere data markers.

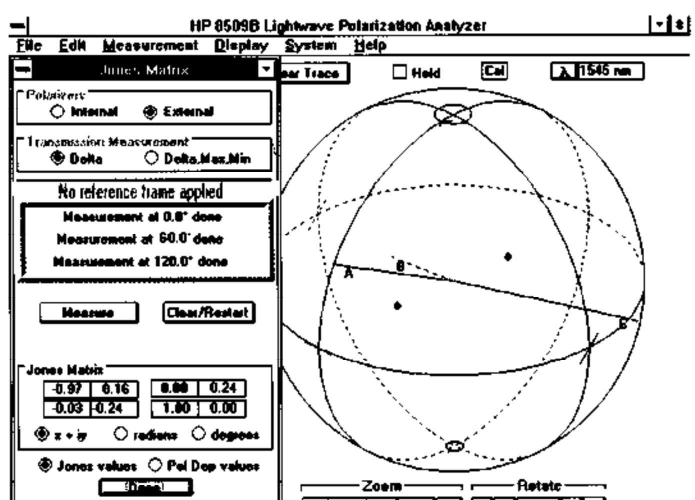


Figure 4. The HP 8509A/B displays the Jones matrix of two-port optical components and systems.

Measure polarization transmission properties of components

Reduce design and manufacturing uncertainties by measuring the effects of the polarization-dependent transmission properties of optical components and systems.

Polarization Mode Dispersion

Polarization mode dispersion (PMD) is an intramodal distortion mechanism (like chromatic dispersion) that causes optical devices, such as single-mode fibers, optical switches and optical isolators, to distort transmitted signals. Negative effects appear as random signal fading, increased composite second order distortion and increased digital error rates. Designers and application engineers can take action to reduce PMD and specify maximum tolerances for specific applications when PMD is quantified.

Fast, accurate and repeatable, the HP 8509B's automatic Jones-matrix eigenanalysis technique measures PMD with typically better than 60 fs accuracy. Jones matrices of a component are measured at consecutive wavelength steps. Sets of Jones matrices are then analyzed to calculate PMD with 1 fs resolution.

A tunable lightwave source, like the HP 8168A tunable laser or HP 83424A temperature-tuned DFB laser, is needed for this measurement and connects with the HP 8509B EXTERNAL SOURCE INPUT.

Figure 5. Polarization mode dispersion measurement setup using the HP 8509B and HP 8168 or HP 83424 lightwave sources.

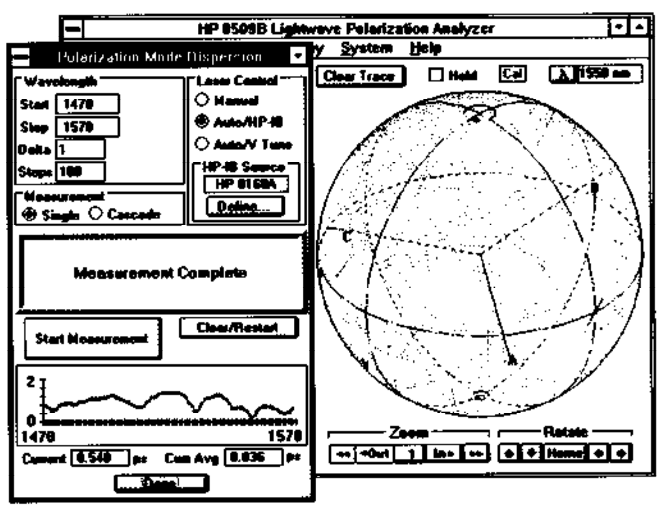


Figure 6. Polarization mode dispersion data for a 40 km length of SMF cable is shown on a graph and on the HP 8509B Poincare sphere.

Measure polarization transmission properties of components

Polarization-Dependent Loss

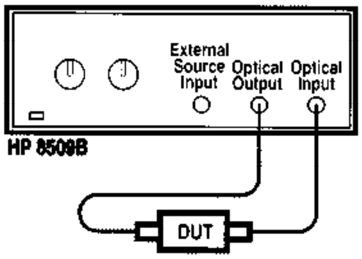


Figure 7. Polarization-dependent loss measurement setup.

Polarization-dependent loss (PDL) is a power-loss mechanism which varies as the polarization of the input signal changes. When components are connected in a system, their individual polarization-dependent losses combine to affect system performance. Chances of performance degradation are minimized by considering polarization-dependent loss in worst-case power calculations and in bit error-rate estimations.

In seconds, the HP 8509B uses an automated Jones-matrix technique to measure the maximum, minimum and delta optical insertion loss of a component for all possible input states of polarization. PDL markers on the Poincare sphere (Figure 8.0) show the relative location of the output states of polarization where the maximum and minimum losses occur.

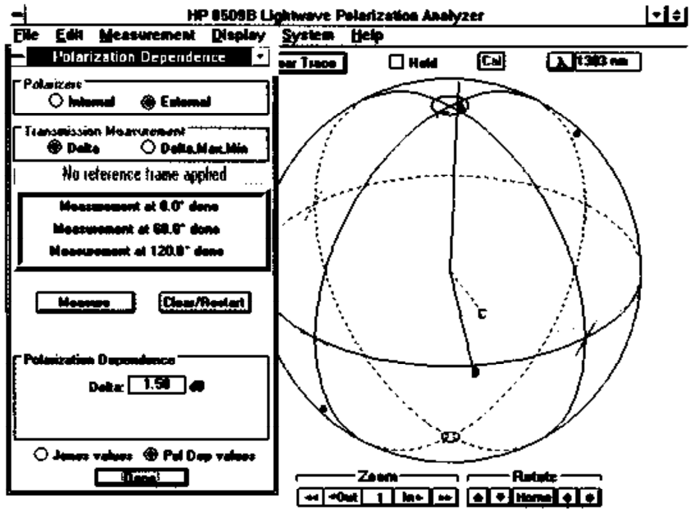


Figure 8. Polarization-dependent loss data is displayed numerically and graphically.

Polarization-Maintaining Fiber Launch

Whenever a single-mode fiber is moved, it changes the polarization of the transmitted lightwave. A polarization-maintaining fiber, however, can deliver a linearly polarized lightwave signal regardless of its position. Maximum performance of 30 dB to 40 dB extinction ratios are only possible when linearly polarized light is correctly launched onto one of the fiber's polarization axis. Fiber alignments with 40 dB extinction ratios are easily achieved in seconds using the system's Poincare sphere display technique.

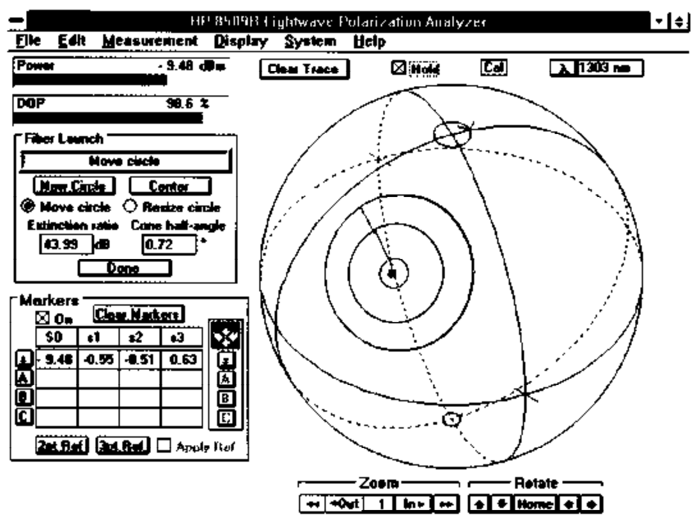


Figure 9. Typical display of polarization maintaining fiber launch alignment process.

Data Output and Remote Operation

Measurement displays and numerical data are directly output to paper or transparency using an external printer or plotter. Graphic enhancements and additional mathematical manipulation are possible on an external computer. This can be done via HP-IB data extraction or by using a disc. External controllers remotely control the HP 8509A/B system using HP-IB.

Specifications
for the HP 8509A and HP 8509B
Lightwave Polarization Analyzer

Specifications describe the instrument's warranted performance over the 23 +/-3°C temperature range, except where noted. All specifications apply after the instrument's temperature has stabilized (typically 1 hour after turn-on). **Characteristics** provide information about non-warranted instrument performance. These are also denoted as typical.

Receiver Characteristics

Wavelength operating range: 1200 nm to 1600 nm
Input power operating range: +10 dBm to -55 dBm
Input average power damage level: +16 dBm
Average power measurement linearity: ±0.06 dB
Average power measurement uncertainty: ±15%
Degree of polarization measurement:
1200 nm to 1280 nm, ±5.0%
1280 nm to 1340 nm, ±2.0%
1470 nm to 1580 nm, ±2.0%
1580 nm to 1600 nm, ±3.0%
Poincare sphere display:
1200 nm to 1340 nm, ±1.5 degrees
1470 nm to 1600 nm, ±1.5 degrees
Polarization state measurement rate:
>1000 per second
Polarization state display update rate:
>1000 per second
Return loss: -50 dB

HP 8509B Internal Source Characteristics

	λ	Min	Typical	Max
Average Optical Power Output	1310 nm	200 uW	300 uW	500 uW
	1550 nm	150 uW	230 uW	400 uW
Wavelength	1310 nm		±20 nm	
	1550 nm		±20 nm	
Spectral width (RMS)	1310 nm		5 nm	
	1550 nm		5 nm	
Return loss	17 dB			
Laser type		Fabry-Perot		

HP 8509B External Source Input Port Characteristics

Wavelength operating range: 1200 nm to 1580 nm
Internal path insertion loss: 6 dB
(EXTERNAL SOURCE INPUT to OPTICAL OUTPUT)
Input power operating range: +16 dBm to -49 dBm
Input average power damage level: +22 dBm
Return loss (based on OPTICAL OUTPUT connection with return loss of 30 dB or greater): 35 dB

HP 8509B Polarization Mode Dispersion (PMD) Specifications Using Eigenanalysis Technique

Typical wavelength operating range:
1280 nm to 1340 nm
1470 nm to 1580 nm
Warranted wavelength operating range:
1540 nm to 1560 nm.

Maximum Measurable PMD Delay:

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

Delay Uncertainty:

Wavelength Step	Uncertainty (±)
0.10 nm	310 fs
1.0 nm	90 fs
10.0 nm	60 fs

Resolution: 1 fs

Polarization Dependence Measurement Characteristics Using Jones-Matrix Analysis Technique

Wavelength operating range:
1280 nm to 1340 nm
1470 nm to 1580 nm
Measurement range: <3 dB
Uncertainty: ±0.1 dB

Polarization-Maintaining Fiber Launch Alignment Characteristics Using Poincare Sphere Technique

Extinction ratio range: 0 dB to 50 dB
Resolution: 0.01 dB

General Specifications

Compatible fiber: 9/125 um
Dimensions: (H x W x D)
133.4 mm x 425.5 mm x 546.1 mm
5.25 in x 16.75 in x 21.5 in
Weight (without computer and monitor):
Net : 10.5 kg (23 lbs)
Shipping: 16.0 kg (23 lbs)
Power Requirements
(without computer and monitor):
47.5 Hz to 66 Hz
90 V to 132 V or 198 V to 264 V
100 VA

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Ordering Information

The HP 8509 lightwave polarization analyzer system includes the HP 8509A or HP 8509B lightwave polarization analyzer instrument, an HP Vectra 486 computer, system operating software operating in a Microsoft® Windows 3.1 environment, a computer-to-HP 8509 interconnect cable and an operating manual set.

Table 1.0: Summary of HP 8509A and HP 8509B measurement capabilities.

	State of Polarization	Degree of Polarization	Jones Matrix	Polarization-Dependent Loss	Polarization Mode Dispersion	Polarization Maintaining Fiber
HP 8509A	X	X	X*	X*		X
HP 8509B	X	X	X*	X		X
HP 8509B + tunable source	X	X	X*	X	X	X

*The HP 8509A and B perform this measurement with external polarizers. Only the HP 8509B can also use its internal polarizers for this measurement.

Instrument Configuration:
[ ] HP 8509A Lightwave Polarization Analyzer
[ ] HP 8509B Lightwave Polarization Analyzer

Lightwave Interface Connector Option:
Each HP 8509A/B order must be accompanied by only one of the following connector options.
[ ] Option 011 Diamond connector
[ ] Option 012 FC/PC connector
[ ] Option 013 DIN 47256
[ ] Option 014 ST connectors
[ ] Option 015 Biconic connectors

Delete HP 8509B Internal Source Option:
[ ] Option 210 Delete internal 1300 nm source
[ ] Option 220 Delete internal 1550 nm source

Additional Lightwave Interface Connectors:
[ ] HP 81000 AI Diamond HMS-10
[ ] HP 81000 FI FC/PC
[ ] HP 81000 GI D4
[ ] HP 81000 KI SC
[ ] HP 81000 SI DIN 47256
[ ] HP 81000 VI ST
[ ] HP 81000 WI Biconic

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Printed in U.S.A. 4/93
5091-6258E