polarization, PMD, PDL & ER measurement system...page 1 of 9

Visit www.thorlabs.com/polarization for our application notes on Polarization, Polarization Mode Dispersion, Polarization Dependent Loss and PMF alignment.

Polarimeter PMD/PDL
Laser/TEC Controllers
Laser Mounts
WDM Sources & Switches
Optical Sources & Switches
Detectors & Power Meters
Laser Lab Instruments
TXP Systems Measurement & Control

Introduction
PAT9000 Series Instrumentation

The PAT9000 polarization analysis system provides accurate measurements of Polarization Mode Dispersion (PMD), Polarization Dependent Loss (PDL) and Polarization Stokes Parameters.

Within this instrumentation series are four pre-configured instruments that are available from stock, over the following pages we will present an overview of the extensive capabilities of these systems.

Two of the models are polarization analysis systems that fully characterize the state and degree of polarization of a light field. The other two systems are advanced PMD/PDL analysis systems. The PMD/PDL systems build on our polarization analysis instrument with additional hardware plug-ins combined with an extensive software tool-kit.

A short summary of the PAT9000 polarization analysis capabilities is presented first, followed by specific details on the PMD/PDL systems. Ordering information for the PMD system is found on page 331. Additional data on the polarimeter is found on page 332, ordering information is on page 334.

Thorlabs offers a comprehensive tutorial that includes details on: Polarization analysis, Polarization Mode Dispersion measurements, Polarization Dependent Loss in optical components, and polarization maintaining fiber alignment techniques.

For Details please visit:
www.thorlabs.com/polarization

System Capabilities

Polarization Analysis

- Dynamic polarization measurements in real time, fiber or free space.
- Long-term observation of polarization effects.
- Polarimeter measurements with Azimuth & Ellipticity Angle Accuracy <0.25º.
- High Sensitivity & Large Dynamic Range: –70dBm to +8dBm.
- Measurement wavelength range: 960nm to 1.7µm.

PMD Measurement

- PMD measurements based on the Jones-Matrix Eigen analysis.
- PMD measurement of installed fibers according to the Jones-Matrix method.
- PMD measurement in accordance with ITU-T G.650.
- DGD measurement range 0.001 to 400ps with 0.01ps reproducibility.
- High resolution PMD measurement of narrow-band components.
- Mean and RMS values of PMD, plus 2nd order PMD coefficient.
- Measurement of time dependent PMD changes.
- Measures the principal states of polarization as a function of wavelength.
- PMD measurement utilizes commercially available external cavity lasers.

ER Measurement

- Extinction ratio measurements of polarizers or alignment of PM fiber.
- Measurement range 0 to 42dB.

PDL Measurement

- PDL measurements based on Jones-Matrix Eigen analysis.
- PDL measurement in the range of 0 to 50dB with < 0.02dB reproducibility.
- Measurement of the wavelength dependency of the PDL.
- Measurement of time dependent PDL changes.

Section Contents

Introduction - PAT9000 Series PMD/PDL/Polarization Measurement systems

The PAT9000 system has been designed to provide highly accurate measurements of polarization related effects in fiber-optic, and free space, optical components and systems. It is capable of providing extensive measurement and analysis of polarization mode dispersion (PMD) on both broad-band and narrow-band components, optical fibers, and installed optical systems. It is capable of determining polarization dependent loss (PDL) and gain (PDG) as well as making extinction ratio measurements in polarization maintaining devices.

The PAT9000 system architecture is modular and flexible. It is designed around a mainframe system, powered by a Pentium class CPU, that accepts plug-in modules. This approach allows systems to be configured for specific applications. Four pre-configured systems are presented below, the first two are instruments that provide complete characterization of the state and degree of polarization of a light field. These polarimeters utilize the rotating quarter waveplate measurement method.

Polarization Analyzer

One instrument, the PAT9000P1, operates from 1200 to 1700nm. And a second instrument, the PAT9000P2 operates from 960 to 1160nm. A summary of these two products is shown in the insert below, a detailed presentation is also provided on pages 332 to 334.

PAT9000P
Polarization Analyzer

- High Precision State of Polarization Measurements
- Long Term Measurement & Analysis of Polarization Effects
- Jones-Matrix Measurements of Optical Elements
- Analysis of Extinction Ratio for Alignment of PM Fibers
- Time & Wavelength Dependent Polarization Measurements

PMD Analyzer for Optical Fibers

The PAT9000F is the third pre-configured off-the-shelf instrument. It is a PMD/PDL analysis system designed to characterize bulk optical, as well as fiber-optical elements over a broad wavelength range.

The PAT9000F is a versatile instrument that is based on the Jones-Matrix Eigen analysis (JME) method, which is regarded as the most accurate technique among the standards bodies (ITU-T G.650, 2.7.1). A summary of this system is provided below with more details following on page 331.

PAT9000F
PMD/PDL Analyzer

- DGD Meter with a Range of 0.001ps to 400ps.
- Jones Matrix PMD Measurement Method.
- Ideal for PMD & PDL on Optical Fiber.
- Includes a Polarimeter & Linear Polarization Generator.
- DGD Reference Module for PMD Calibration Verification.
- Includes All the Features of the PAT9000P Polarimeter.

PMD Analyzer for Narrow-Band WDM Components

The fourth system, the PAT9000N, builds on the second PMD/PDL system by adding additional software tools for analyzing narrow band components - optical filters, Bragg gratings, and OADM - typically found in WDM systems. The extensive capabilities of the PAT9000N to accurately measure devices that operate only over a narrow wavelength range greatly enhances the value of this instrument. The measurement techniques used are covered in detail on page 329.

PAT9000N
PMD/PDL Analyzer

- PMD Measurement of Narrow-Band Optical Components
- DGD Meter with a Range of 0.001ps to 400ps.
- Single Wavelength Scan Measures DGD, IL, and PDL.
- Includes All the Features of the PAT9000F PMD Analyzer.
- Includes All the Features of the PAT9000P1 Polarimeter.
- Time & Wavelength Dependent Polarization Measurements

An additional system is available for characterizing installed fiber-optic cables and systems. This system is available by special order due to the high degree of customization that is offered when configuring the system. Please call one of our local offices for additional information.

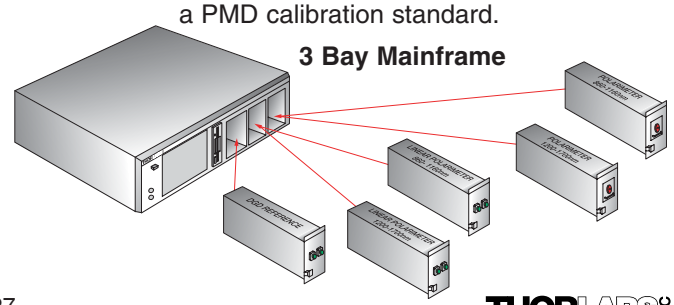
An Introduction to the PAT9000 Hardware

The PAT9000 system architecture is modular and flexible. It is designed around a Pentium class CPU and a Windows® operating system.

The PAT9000 chassis includes a 640 x 480 high-resolution display, an internal hard drive, a 3-1/2" disc drive, and it supports three PAT9000 series system plug-in modules. It is menu driven via a user-friendly graphical user interface (GUI). Measurements may be stored as ASCII-type files on the hard-drive or floppy-disc. Also included is a TCP/IP Ethernet card to facilitate interfacing with your local area network (LAN).

There are three plug-in modules available for the PAT9000, the first is the polarimeter module which comes in two models. One for the wavelength range of 960 to 1160nm, and a second one for the wavelength range of 1200 to 1700nm. A polarimeter is included with all of the PAT9000 systems. The second plug-in module is an automated linear polarization state generator for use in PMD/PDL measurements. The third module, a differential group delay reference (DGD), is provided for calibration verification purposes (see 335 for details).

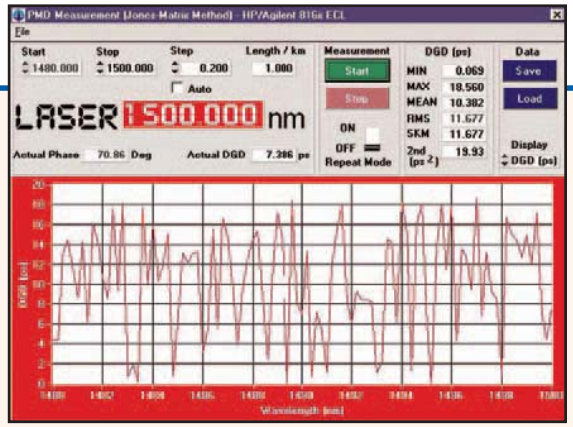
PAT9000 Series Modules
The available modules: two polarimeters, a linear polarization state generator, and a PMD calibration standard.



PMD Measurement Techniques

As transmission rates increase for fiber-optic systems, polarization mode dispersion (PMD) becomes a critical factor; at 2.5Gbit/s the PMD of the fiber needs to be managed to ensure stringent bit-error-rate requirements are met. Moving from 2.5Gbits/s to 10Gbits/s, or 40Gbit/s requires management of the PMD at the component level. The PAT9000F uses the Jones Matrix Eigen analysis (JME) method to ensure accuracy when making measurements on a large variety of optical elements.

Visit www.thorlabs.com/polarization for our application notes on Polarization, Polarization Mode Dispersion, Polarization Dependent Loss and PMF alignment.



PMD measurement according to the Jones-Matrix-Eigen analysis method

Polarization Mode Dispersion, PMD, originates from the polarization dependency of the propagation speed of an optical signal. This dependency results in a delay in the arrival time for a bit stream for orthogonal launch polarization states and leads to bit errors. The maximal delay between all pairs of orthogonal polarization states at a given time for a given wavelength is called differential group delay, DGD, and it is measured in picoseconds (ps). The polarization states associated with the fastest and slowest speeds are called principal states of polarization (PSP). In general, the PSP's are not identical with the fast and slow axes (the eigen-polarizations) of a birefringent component.

DGD is the primary measurement parameter for all PMD meters. The measurement of the DGD delay involves the determination of a phase change (~ arrival time difference) for a given frequency (wavelength) change. Therefore, a PMD meter must use either a broadband LED source in combination with a spectrometer or a tunable laser. The PAT9000 systems determine the Jones Matrices, the polarimetric transfer functions, at many different wavelengths over the scan wavelength range. The changes in the phases of the Jones matrices divided by the wavelength step sizes yields the DGD values.

PMD in Optical Fiber

Fibers can be modeled as being constructed of many infinitesimally small fiber sections, each of them having a different birefringence and eigen-polarization axes. Thermal and mechanical stresses affect the polarization properties of these sections. The large number of sections, the randomness in the transformation properties and their environmental sensitivities requires a statistical analysis to fully account for the DGD behavior. In a long length of fiber, the DGD, either as a function of time at fixed wavelength or as a function of wavelength at a fixed time, have Maxwell distributions. The average of the DGD distribution is defined by the ITU standard bodies as the PMD value. Therefore, PMD is independent of time and wavelength range.

The PAT9000F is ideally suited for characterizing DGD / PMD devices with random mode coupling, such as optical fibers, by using the Jones Matrix Eigenvalues analysis (JME) method. The JME method is the only technique providing wavelength dependent information about the DGD and the PSP. It is also the only method that shows agreement between the measured DGD histogram and the theoretical Maxwell distribution.

PMD in Fiber Components

Fiber optic components differ from long lengths of fiber in their thermal and mechanical sensitivity of DGD / PMD. The fixed optical elements integrated in the components are significantly less sensitive to environmental conditions.

Fiber optical components have DGD values that are nearly fixed with respect to wavelength. A DGD measurement instrument would produce a normal (Gaussian) distribution. Depending on the test instrument, the width of the distribution is determined by the instrument's performance and not the intrinsic randomness of the polarization modes through the component. As in the fiber PMD, the average value of the distribution is the PMD value. Unlike the fiber PMD measurement,the width of the distribution is not linked to the PMD value. The average value is of more importance to the user since it quantifies the amount of delay generated by the component.

For some fiber optic components, DGD / PMD can not be measured using the same procedure as those used for systems with random mode coupling. For example, DEMUX filters, with their narrow pass bands, do not allow relatively large frequency steps for high accuracy DGD measurements. Therefore, these filter components require special measurement attention.

Thorlabs introduces the PAT9000N DGD / PMD measurement system, which includes the new NBC analysis tool. The NBC package addresses the different statistical DGD behaviors to measure the DGD in narrow-band components.

Additionally, the NBC analysis tool simultaneously measures polarization dependent loss (PDL) based on the JME method. One scan over wavelength provides all the essential parameters and provides PDL versus wavelength.

General PMD Measurements

The PAT9000F is recommended for general polarization mode dispersion measurements, The system will also measure polarization dependent loss (PDL) or gain (PDG), extinction ratio, as well as provide an alignment tool for polarization maintaining fibers.

The system consists of a mainframe along with three plug-in modules: a polarimeter module operating from 1200nm to 1700nm, a polarizer module that delivers highly polarized light that can be programmed to transmit any state of linear polarization, and a differential group delay (DGD) reference for verifying the calibration of the PMD measurement system.

For PMD measurement, a tunable laser source is required. The PAT9000F comes with a library of software drivers that interface with most commercial tunable lasers; see the list shown below.

Supported Tunable Laser Sources

ANDO	Series AQ 4320 A/D, AQ 4321 A/D
Anritsu	MG 9637 A, MG 9638 A (all types)
Agilent	8163A, 8164A, 8166A, 81640A, 81642A, 81680A, 81682A, HP8167 HP8168
New Focus	series 6200 (all types)
NetTest	series TUNICS (all types)
ECL lasers of other manufacturers on request	

The PMD of both passive components (fibers, couplers, isolators) and active components (EDFAs and PDFAs) can be analyzed using the PAT9000F. This is accomplished by using the Jones Matrix Eigen analysis (JME) method. The table at the bottom of the page provides the details on the range of DGD values that can be measured as well as the corresponding repeatability.

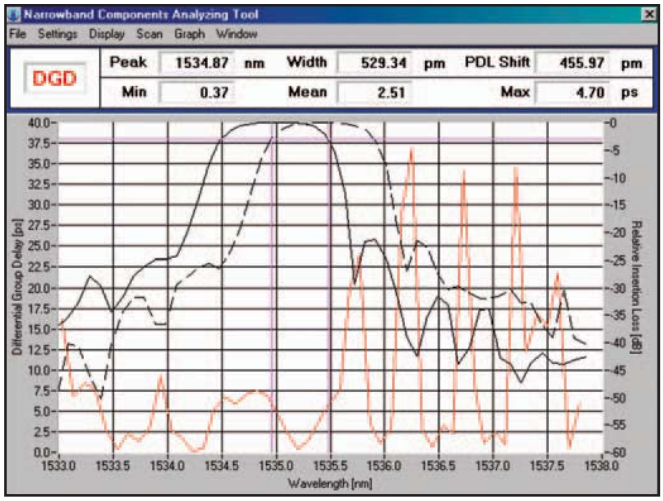
PMD Measurements on Narrow Band WDM Components

The PAT9000N is a turn-key system that is ideally suited for measuring PMD in narrow band, as well as extended band components. Broad wavelength devices such as optical isolators, EDFA's, and couplers are relatively uncomplicated devices to evaluate on either the PAT9000F, or on the enhanced PAT9000N. Easy to use instructions are provided in the PAT9000N operating manual, and copies are available at www.thorlabs.com, search on PAT9000N.

Narrow bandwidth components such as optical filters, bragg gratings, and OADM, that all have limited wavelength ranges, are considerably more challenging to characterize.

This is where the PAT9000N excels. The PAT9000N is an upgraded version of our PAT9000F; it has advanced software features that allow it to characterize narrow band fiber optic components. With a single wavelength scan, it measures DGD, relative insertion loss (IL) and PDL versus wavelength. The figure below shows the measured PDL and relative IL for a test device. The solid black curve (dashed black curve) shows the IL calculated from the raw data and the measured system Jones matrix as if the launched SOP was aligned with the PDL axis (orthogonal for dashed curve). Any other SOP would yield an IL between the solid and dashed curves, different for each wavelength. The red curve is the resulting PDL.

The system calculates the polarization dependent wavelength



shift: defined as the average separation between the solid black curve and the red curve at the passband edges. For narrow band component manufacturing it is important to assess the PDL in the "wings" of the pass-band (typically around 20dB IL) to determine if the component meets the isolation requirement between adjacent channels. The PAT9000N facilitates this assessment and can increase production yield.

ER Measurement on Polarization Maintaining Fibers

Extinction ratio (ER) is a key qualifier of PM fibers and PM couplings. Using the standard features built into the PAT9000F, ER measurements can be made quickly and reliably in the range from 0 to 50dB. While manually stressing the fiber, or by scanning the wavelength of the light in the fiber under test, the polarimeter software records the variations in polarization at the fiber output and then calculates the extinction ratio. This allows the optimization of the alignment of PM fiber to laser diodes.

DGD Measurement Specifications

Technical Data for the PAT9000F and PAT9000N, Valid at 23 ± 5°C and 45 ±15% RH

	Jones-Matrix Eigen analysis Method (Recommended)
DGD measurement range, 1310nm	0.001ps to 280ps
DGD measurement range, 1550nm [1]	0.001ps to 400ps
Repeatability	< 0.01ps [2]
Max. Insertion loss of DUT [3]	55dB
Typ. Measuring time for 1 (100) data points [4]	2s (100s)

[1] The max. meas. DGD is limited by the smallest possible wavelength step. The given values are for a 10 pm step size.
[2] For PMD <0.3 ps
[3] For PMD <0.3 ps; if the DUT is free of random mode coupling and the optimal input polarization is hit
[4] At 100 nm scanning range

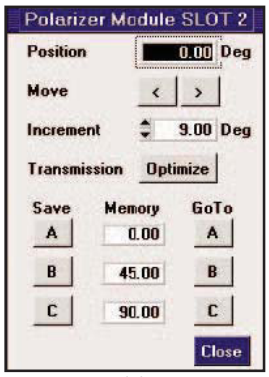
The PMD/PDL measurement systems are all equipped with an adjustable linear polarizer module, see figure 1(a). One module is designed for the 960 to 1160nm range, and one for the 1200 to 1700nm range. Both polarizers have an extinction ratio of more than 50dB and are automatically operated by the PAT9000 when the system makes PDL or PMD measurements.

PMD/PDL PAT9000 Series

Polarizer module	POL9320NIR	POL9320FIR
PDL / PDG measurement (based on JME method)		
Wavelength range	960 to 1160nm	1200 to 1700nm
PDL measurement range	0 to 50 dB	
Reproducibility	± 0.02 dB (for PDL < 3dB)	
Dynamic range	> 55 dB (for P_{LASER} ≥ 0dBm)	
Minimum measurement time	0.5 s	

For manual operation, a control window is provided from a pull down menu, where the desired angle and step-width may be selected in degrees. Furthermore, three positions can be stored and readily recalled.

PAT9000 Adjustable Polarizer Plug-in Module
(a)



(b)

Figure 1

Figure 1 shows the polarizer plug-in module for the PAT9000 along with the corresponding windows pull-down menu.

PDL measurement with PAT9000B

The PAT9000F, and the PAT9000N systems are both equipped with a polarimeter module, as well as a polarizer module. This allows both systems to measure PDL or PDG in the wavelength range from 1200 to 1700nm, see figure 2.

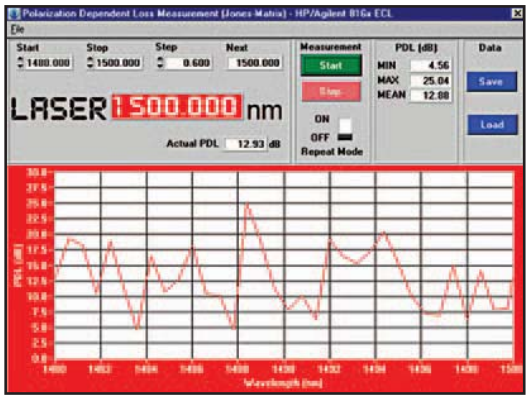


Figure 2

Figure 2 shows the PAT9000 PDL measurement control and display window. The resulting PDL measurement is displayed as a function of wavelength along with the MIN, MAX, and MEAN values.

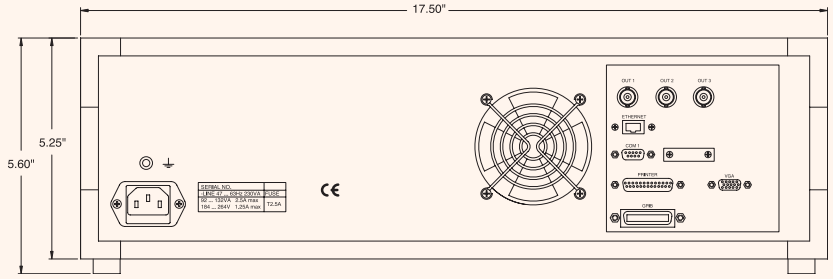
To measure wavelength dependent PDL, the PAT9000 software supports all common external cavity lasers, see page 329.

PDL measurement by Jones-Matrix-Eigen analysis

The PAT9000 polarizer modules automatically set the polarization at the input of the device under test (DUT) to three linear polarization states. The three states of polarization can be automatically adapted to the DUT. The three corresponding polarizations at the output of the DUT are measured by the system. The Jones-Matrix, which completely describes the polarization behavior of the device under test, is then calculated. By analyzing the Jones-Matrix, the PDL values are calculated. It is possible to eliminate all influences resulting from optical components in a free space setup, excluding the DUT, by taking a reference measurement.

PAT9000 Chassis Specifications

Number of slots	3	Line voltage	115V +15%/-20%, 230V +15%/-20%
Processor	Pentium® class or compatible	Line frequency	50 to 60Hz
Drives	> 2GB HD, 3.5" floppy disc	Operating temperature	10 to 40 °C
Printer interface	LPT1	Storage temperature	-30 to 70 °C
IEEE 488 interface	24 pin IEEE 488	Dimensions (W x H x D)	449 x 132 x 419mm³
Output Ports	3 analog outputs, external VGA monitor, mouse, & keyboard	Approximate Weight	< 10kg



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PMD/PDL Systems Feature Guide

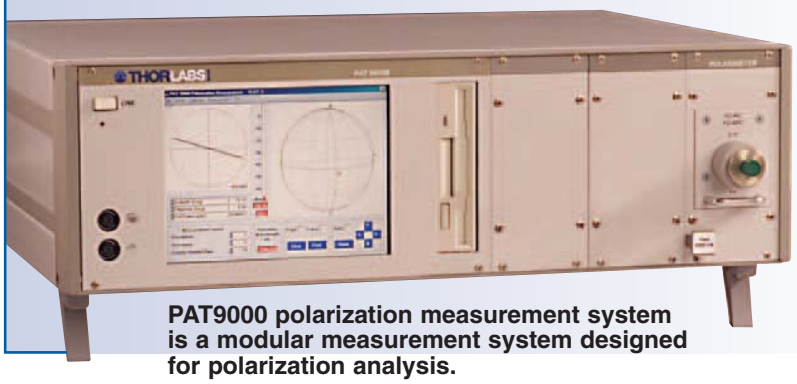
FEATURES	PAT9000F	PAT9000N
Rotatable linear polarizer for 1200nm to1700nm. Required for all JME measurement applications.	✓	✓
Polarimeter Module for 1200nm to 1700nm.	✓	✓
Certified DGD reference in the range of 1 to 2ps.	✓	✓
PMD analysis software.	✓	✓
Measures wavelength dependence of PDL.	✓	✓
Software package that offers enhanced analyzing capabilities for characterizing narrow-band FO components (e.g. multiplexers & FBG's).	–	✓
Full package of tunable laser drivers.	✓	✓
High speed polarimetric analysis tools 200/sec.	–	✓
Extinction Ratio tool for optimizing PM fiber alignment.	✓	✓
PMD Jones Matrix analysis on deployed fibers.	**Special feature call for details.**	

The **PAT9000F** is configured for PMD and PDL measurements on random mode coupled devices, such as optical fiber. Included is a polarimeter module, a motorized polarizer module, a DGD reference module, and all the software required for measuring and analyzing PMD, PDL, & ER. Also included are the software drivers for most of the commercially available tunable lasers.

The **PAT9000N** is configured for PMD and PDL measurements on fixed mode coupled devices, such as fiber optic components (eg. filters & isolators). It includes everything that is included in the PAT9000F as well as an additional PMD software tool kit.

Supports most IEEE controllable tunable lasers

ITEM#	$	£	€	¥	DESCRIPTION
PAT9000F	$40,250.00	£24,500.00	€35.000,00	¥5,600,000	Fiber PMD/PDL Meter, 1200nm to 1700nm
PAT9000N	$44,850.00	£27,300.00	€39.000,00	¥6,240,000	Component PMD/PDL Meter, 1200nm to 1700nm



PAT9000 polarization measurement system is a modular measurement system designed for polarization analysis.

Removable optical head for remote measurements

Head Dimensions: 48mm x 61mm x 139mm

PAT9000 Applications

- Accurate and Precise DGD / PMD Measurements.
- High Precision State of Polarization Measurements.
- Birefringence Characterization of Optical Components.
- Long Term Analysis of Polarization Effects.
- Jones-Matrix Measurements of Optical Elements.
- Precise Measurements of Polarization Dependent Losses.
- Analysis of Extinction Ratio in PM Fibers.

Polarimeter PMD/PDL
Laser/TEC Controllers
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WDM Sources & Switches
Optical Sources & Switches
Detectors & Power Meters
Laser Lab Instruments
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Polarization Measurement Systems:

The PAT9000 system has been specifically engineered for accurate measurements of polarization related effects in both fiber, and free space optical systems. The PAT9000 is an ideal tool for all kinds of polarization related measurements tasks in R&D laboratories, as well as for final inspection in manufacturing. Developed by our engineering group based in Munich, Germany, this instrument has earned a reputation for being the "Gold Standard" in polarization measurement.

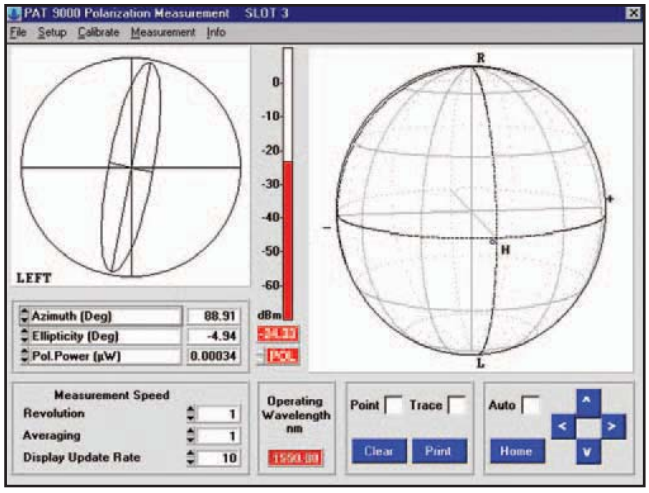


Figure 1

Figure 1 shows the PAT9000 primary state of polarization measurement screen.

SOP and DOP measurement

The PAT9000 analyzes the state of polarization (SOP) and the degree of polarization (DOP) of optical signals in either free space or in optical fibers. The resulting data can be viewed on the monitor screen, which has user configurable parameters and provides for the complete characterization of the state of polarization of an input signal - see figure 1 for a representative display screen. Three of fifteen parameters can be displayed on the primary display screen in the area just below the polarization ellipse. Figure 4, on the following page, shows the complete list of parameters that are available for display.

SOP & DOP Measurement Specifications

Input Power Range	-70 to +8dBm
Azimuth Angle Accuracy [1, 2, 3]	< 0.25°
Ellipticity Angle Accuracy [1, 3]	< 0.25°
Normalized Stokes Vector Accuracy [2, 3]	S1, S2, S3 <0.005
Degree of Polarization	0 ≤ DOP ≤ 100%
Degree of Polarization Accuracy [4]	± 2% f.s.

1 Azimuth angle is defined as the inclination angle of the major axis of the polarization ellipse to the horizontal axis. The ellipticity angle is given as arctan (b/a) with b the length of the minor axis and a the length of major axis of the polarization ellipse.
2 For any SOP with –30° < ellipticity < 30°.
3 Typically a factor of 2 less accuracy in turbo mode.
4 For Pin ≥ -40dBm at 1550nm, w/o optical attenuator; for other wavelengths guaranteed by design.

PAT9000P Series Polarimeter Specifications

Wavelength Range	PAT9000P2: 960 to 1160nm PAT9000P1: 1200 to 1700nm
Input Power Range	-70 to +8dBm
Speed	Standard/Turbo mode: 33Hz/200Hz
Optical Attenuator	Optional 10dB or 17dB
SM Fiber Input	FC/PC
Free Space Input	Ø3mm, <3mrad Beam Divergence

Our polarimeter utilizes a rotating λ/4-waveplate, a fixed polarizer, and a large area photodetector. After the input signal passes through the rotating λ/4-waveplate, the polarization state incident on the polarizer changes with time as the waveplate rotates.

The linear polarizer then converts the time varying state of polarization to a linear state with a time varying/modulating intensity. This time varying intensity is monitored via the photodetector, and the resulting signals can be viewed via the photo-current display window, see figure 2 on the following page.

An analysis algorithm based on a discrete Fourier transform is used to accurately calculate both the state of polarization as well as the degree of polarization - SOP and DOP.

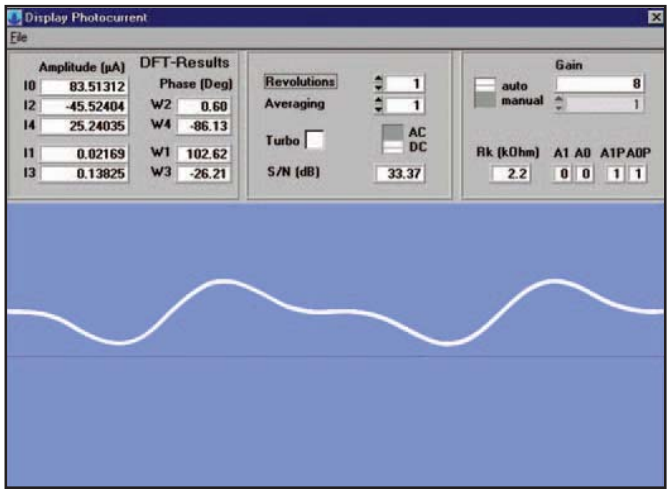


Figure 2

Figure 2 shows a typical photodiode signal that results from the rotating λ/4 waveplate.

As can be seen in Figure 1, the polarization data is presented in a number of forms, as a point on the Poincaré sphere, as the commonly known Stokes parameters, or as a polarization ellipse with the handedness noted. Additionally, the degree of polarization and the total optical power are also provided.

Long Term Polarization Measurements

Also included as a standard software feature is a measurement screen that allows long term polarization analysis, see Figure 3. The user can define the measurement interval as well as the total number of data points acquired. The data screen shown in Figure 3 allows real-time monitoring of the system's polarization behavior.

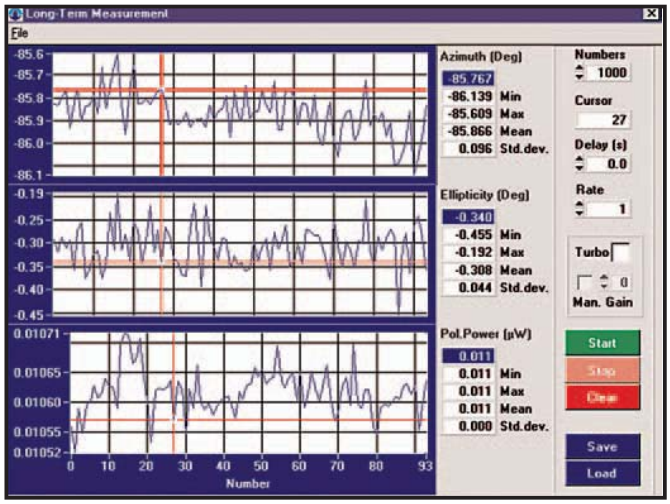


Figure 3

Figure 3 shows the PAT9000 long term polarization measurement screen.

The system allows the time dependent variations in the state of polarization to be shown as a trace on the Poincaré sphere or recorded in an ASCII format file. The data file contents can be viewed with any text editor and can be further processed using third party software packages such as MathCAD, MatLAB, or Mathematica.

High Speed Data Capture – Turbo Mode

The turbo mode allows a higher measurement rate than normally available. The standard mode of operation has the λ/4 waveplate rotating at a rate of 33 rev/sec. Turbo mode increases the rotational speed to 100 rev/sec. Each revolution results in two state of polarization (SOP) measurements; hence, turbo mode results in a measurement rate of 200Hz. In this case, a measurement is defined as a single set of polarization angles (azimuth and ellipticity) and all related parameters.

While operating in turbo mode the system does not have sufficient time to display the polarization data; therefore, the measured data is stored as a set of voltages that represent the photodiode signal. This signal can then be processed and displayed after up to 5 seconds of data is recorded.

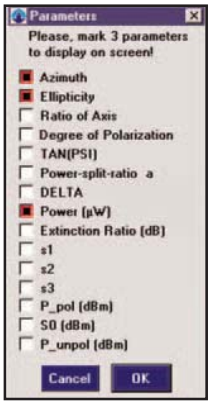


Figure 4

Figure 4 shows the setup screen for controlling the parameters that are recorded during long term measurements.

GPIB Interface

The PAT9000 offers an IEEE 488.2 interface; a 24-pin IEEE 488 connector is located on the rear panel of the PAT9000 chassis. This interface provides for remote control of all essential features of the instrument. A series of simple open language commands can be used to fully control the operation of the system as well as providing static reporting of all device parameters. Figure 5 shows the basic GPIB Interface window used to configure the interface protocol.

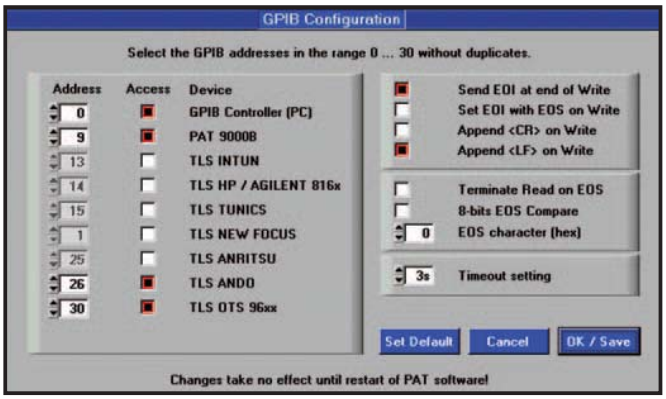


Figure 5

PAT9000 system screen showing the GPIB configuration menu.

LabVIEW™ and LabWindows/CVI™ external cavity laser drivers are delivered standard with the PAT9000F and PAT9000N. These drivers are useful when making wavelength dependent PMD and PDL measurements. Contact Thorlabs for special driver requirements.

Removable Polarimeter Optical Assembly

The removable optical head of the PAT9000 polarization measurement system facilitates polarization analysis in free space setups.

The PAT9000 systems are all supplied with a fiber optic FC receptacle that contains an internal collimation optic. This receptacle can be used with either FC/PC or FC/APC optical cables. Optional input attenuators are available to extend the power range of the system.

(a) **Photograph 1** (b)

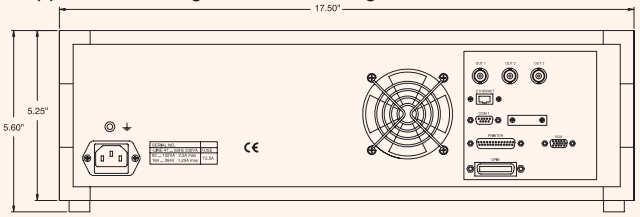
Polarimeter module shown separate from PAT9000 mainframe: (a) shows the FC input port installed. And, (b) shows the fiber input adapter removed for free space laser applications.

For free space measurements, the polarimeter optical assembly - see photograph 1 - can be easily removed from the mainframe and operated remotely (the required extension cable is included with the PAT9000P1 & P2). The optical light field to be measured should enter the aperture of the system nearly perpendicular to the front panel of the optical head. The waist should be below 3mm to guarantee all light reaches the detector. An oversized photodiode is used to ensure that slight misalignments of the input light do not lead to large measurement errors. The oversized sensor, and opto-mechanical design, allow the system to accept fiber optic cables that are finished with either normal or angled polish.

PAT9000 Chassis Specifications

Number of slots	3
Processor	Pentium® class or compatible
Drives	> 2GB HD, 3.5" floppy disc
Printer interface	LPT1
IEEE 488 interface	24 pin IEEE 488
Output ports	3 analog outputs, plus an external VGA monitor, mouse, and keyboard
Operating temperature	10 to 40 °C
Storage temperature	-30 to 70 °C

Line voltage (auto. Switching)	115V + 15%/-20% 230 V + 15% / -20%
Line frequency	50 to 60Hz
Dimensions (W x H x D)	449 x 132 x 419mm
Approximate Weight	< 10kg



All technical data is valid at 23 ± 5°C and 45 ±15% Relative Humidity

ITEM#	$	£	€	¥	DESCRIPTION
PAT9000P1	$20,125.00	£12,250.00	€17.500,00	¥2,800,000	1200nm to 1700nm Polarization Measurements
PAT9000P2	$21,275.00	£12,950.00	€18.500,00	¥2,960,000	960nm to 1160nm Polarization Measurements