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THORLABS GmbH

PAT 9000 SYSTEMS

PMD, PDL & Polarization Measurement Solutions



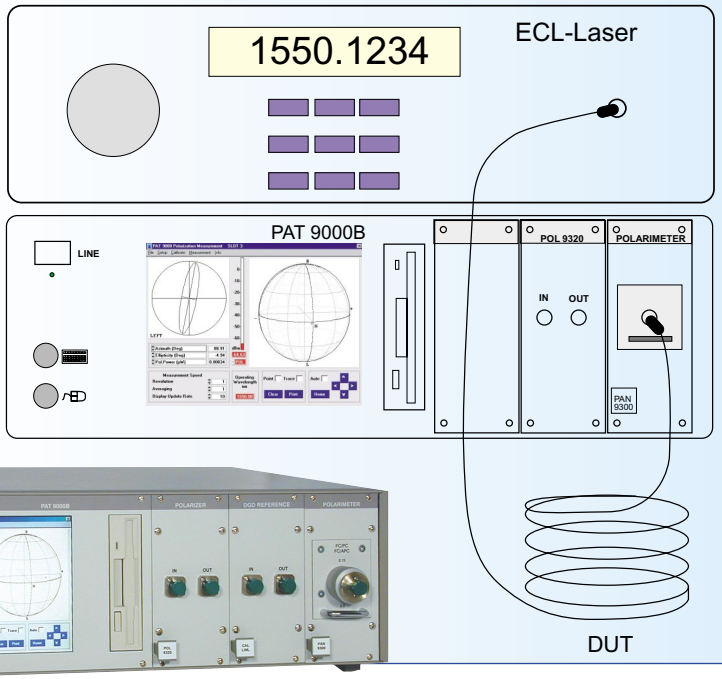
PAT 9000

The **Blueline**™ family of instruments
Engineered for performance by
Thorlabs GmbH, Munich Germany

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The PAT 9000 series polarization analysis instrumentation line provides accurate measurements of Polarization Mode Dispersion (PMD), Polarization Dependent Loss (PDL) and Polarization Stokes Parameters. Listed below are some features of this instrument line:

- Polarization Mode Dispersion (PMD) Meter: 0.001ps … 400ps @ 1550nm
- Polarization Dependent Loss (PDL) Meter: 0 … 50dB
- Polarimeter: Ellipticity Angle Accuracy <0.25º
- Based on Jones-Matrix Eigenanalysis for Fiber Optical Components & Fibers.
- Wide Wavelength Range from 960 … 1160nm & 1200 … 1700nm
- High Sensitivity & Large Dynamic Range: –70dBm … +8dBm
- Interfaces to Many Commercial Tunable Laser Sources
- Modular Design for Fiber Optic & Free Space Measurements
- Removable & Compact Optical Polarimeter Head







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

The PAT 9000B has been specifically designed for accurate measurements of polarization related effects in fiber and in free space optical applications. The PAT 9000B comprises an unparalleled polarization-tailored measurement set for fiber optical and free space applications. It is an ideal tool for all kinds of polarization related measurements tasks in R&D laboratories and for final inspection in manufacturing.

The applications comprise measurement capabilities for all parameters of polarization mode dispersion and polarization dependent loss, for the azimuth and ellipticity angles of the polarization ellipse and for the degree of polarization. The PAT 9000B can also be used for optimal polarization alignment of two cascaded optical elements, e.g. laser chips to polarization maintaining fiber pigtails.

The PMD measurements are primarily based on the Jones-Matrix Eigenanalysis (JME) method yielding all four elements of the Jones matrix for a device under test (DUT). The Jones matrix of a DUT allows a complete characterization of the polarimetric transformation properties of any input polarization state.

The JME method is known to yield the most accurate results compared to other techniques. In combination with a tunable laser source controlled via the GPIB interface the JME method gives complete wavelength dependent information on polarization dependent losses and polarization mode dispersion including the differential group delay distribution, the location of the principal states of polarization as well as higher order polarization mode coefficients.

Modularity and Flexibility

The PAT 9000 chassis can be equipped with three different plug-in modules. There are FIR modules for the far infrared wavelength region ranging from 1200 … 1700nm covering all fiber optic transmission windows and NIR modules for the near infrared range from 960 … 1160nm for the 980nm pump laser Telcom application.

The polarimeter modules PAN 9300NIR/FIR are the measurement tools for any polarization analysis and for all JME measurement applications (PMD and PDL measurements). The PAN-9300NIR/FIR comprises the module and a very compact optical head. The optical head is removable from the module and the PAT 9000 chassis to allow for excellent handling and positioning of the optical head in free space measurement applications. The optical head accepts angled and non-angled FC connectors and can be equipped with 10dB or 17dB attenuators for high power applications. The fiber adapter is removable and allows free space optics measurements with a wide aperture photodiode.

The polarizer modules POL 9320NIR/FIR deliver highly linear polarization states rotatable to any inclination angle with regard to the horizontal axis. It is needed for all JME measurement applications. It can be operated in the PAT 9000 without the polarimeter module for applications where no polarimeters are needed.

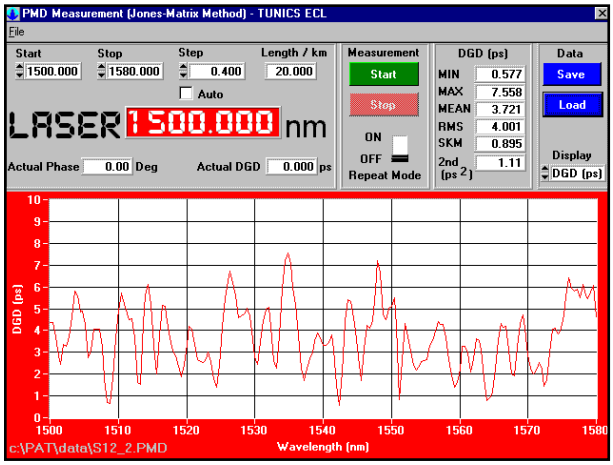
The PAT 9000 offers an automatic optimization routine for optimal transmission through the POL-9320 module and the DUT and thus eliminates the problem of unfavorable measurement conditions on PMD or PDL that can occur during a wavelength scan.

The PAT 9000 supports almost all commercially available, wide range tunable laser sources controllable via GPIB interface.

A completely passive DGD reference module can be provided which enables a user to demonstrate PMD measurements with a certified PMD reference value in the range of a few ps PMD. The module is one slot wide and fits in a PAT 9000.

Polarization Mode Dispersion Analysis

The key parameters on polarization mode dispersion (PMD) in fibers or optical components are the differential group delay (DGD), the principal states of polarization (PSP), the PMD value and its variation with wavelength. For any component or fiber there exists an input polarization state with the slowest and with the fastest signal propagation speed, called the fast and the slow principal states (PSP). The DGD is the difference in group delay at a specific wavelength between the slow and the fast PSP. The PMD value is the mean



or the RMS value of the distribution of the DGDs over wavelength.

The PAT 9000 offers the Jones-Matrix-Eigenanalysis (JME) method for the most complete characterization of the polarization mode dispersion. By scanning the tunable laser over a wavelength range the DGD and PSPs versus wavelength are measured and plotted on the screen. The mean and RMS PMD values are then evaluated. The DGD distribution can be visualized in a histogram with Maxwellian fit as well. The measurements can be repeated automatically to monitor temporal variations.

This method can be ideally applied to measure DGD and PMD in fibers with random mode coupling and in optical components like isolators or demultiplexers with low mode coupling. The software package SW NBC offers enhanced analyzing capabilities which are very suitable for narrowband components characterization, e.g. multiplexer, fiber bragg gratings.

The step size for JME PMD measurements on fibers can be dynamically adapted for optimal speed and accuracy.

The PMD of installed fiber links can be done with the package SW PMD EXT/JM and two PAT 9000 mainframes.

The PMD measurement methods 3 Stokes parameter-wavelength-scanning method (WLS) and the arc-angle method (ARC) are included in the software package SW PMD for convenience.

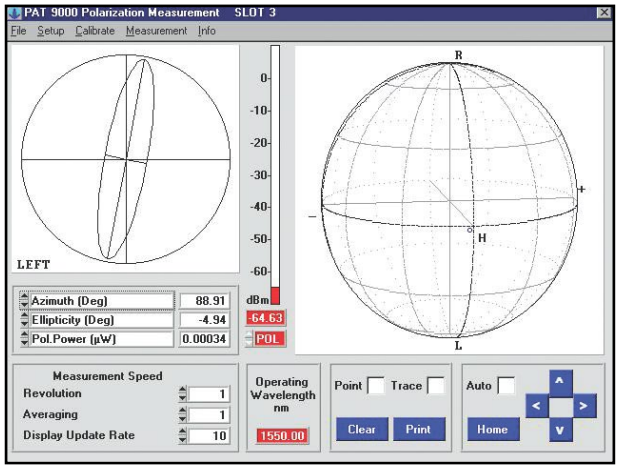
PDL measurements with the PAT 9000

The PAT 9000 allows the determination of the polarization dependent loss or gain of an optical element based on the Jones Matrix Eigenanalysis. For a single wavelength measurement it is possible to store a reference Jones matrix without DUT that is subtracted from subsequent measured Jones Matrices with the DUT. This allows the elimination of all spurious PDL contributions in free space measurements.

The software add-on SW PDL WL is available to determine the wavelength dependency of the PDL.

Polarization State and Degree of Polarization measurements

The polarimeter module PAN 9300NIR or FIR is used to analyze the state of polarization (SOP) and the degree of polarization (DOP) of optical signals. The polarimeter set up uses a rotating quarter-waveplate followed by a high extinction ratio polarizer and a photodiode.



The various parameters of the measured polarization state are displayed numerically, in the form of the polarization ellipse and are represented as a Stokes vector on the Poincaré sphere. The main polarimeter window indicates the measured polarized, unpolarized or total optical power.

Polarization Alignment to PM fibers

The extinction ratio (ER) is a key qualifier for the optimal launch of polarized light into certain optical elements. The optimal polarization alignments of a laser chip or a polarization maintaining fiber (PMF) to a subsequent PMF are typical applications. The changes of output polarization states are recorded with the PAN-9300 module while manual stress, temperature or wavelength variations are applied to the second PMF. These changes follow ideally a circular trace on the Poincaré sphere. The diameter of the circle is a measure for the misalignment into the PMF and is referred to as extinction ratio. The software option SW PAN ER ideally covers this application.

PAT 9000 operating information

The PAT 9000 is based on a Pentium class CPU and uses Windows® as operating system with 3 user slots for the POL 9320 and PAN 9300 modules. It is menu driven via graphical user interface. An external VGA monitor may be operated optionally for enhanced display capabilities. The measurement results can be stored in ASCII-type data log files on a hard or floppy disc with a date and time stamp. A TCP/IP ethernet card is included for interfacing with your local network.

Software packages

The standard software package coming with any PAT 9000 allows to operate the polarimeter and any polarization state analysis including longterm measurements of polarization variations. The option SW TURBO increases the acquisition speed to 200 SOP/DOP values per second. There are different SW packages for each measurement application and for the drivers for the different tunable lasers.

ECL Tunable Laser sources

The PAT 9000 supports almost all commercially available, wide range tunable laser sources.

PMD measurement	Jones-Matrix Eigenanalysis Method (recommended)	Arc-angle method	3-Stokes parameter wavelength scanning method
DGD measurement range 1310nm 1550nm [1]	 0.001ps … 280ps 0.001ps … 400ps	 0.001ps … 280ps 0.001ps … 400ps	 0.050ps … 280ps 0.050ps … 400ps
Repeatability	< 0.01ps [2]	< 0.01ps [3]	< 0.05ps [4]
Max. Insertion loss of DUT [5]	55dB	60dB	60dB
Typ. Measuring time for 1/100 datapoints [6]	2s/100s	1s/50s	1s / 50s

The technical data are valid at 23 ± 5°C and 45 ±15% RH

[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

[5] At $P_{in} \geq 1$ mW

[6] If the scan speed of the laser is not a limiting factor

PDL & PDG Measurements	Jones-Matrix Eigenanalysis Method
PDL measurement range	0 … 50dB
Repeatability	± 0.02dB [1]
Dynamic Range	> 55dB [2]
Measurement time	> 0.5 s

The technical data are valid at 23 ± 5°C and 45 ±15% RH

[1] For PDL < 3dB

[2] For Pin ≥ –0dBm@input port of POL-9320

SOP and DOP Measurements	
Input power range	-70 … +8dBm
Accuracy of the elevation angle [1]	< 0.25° [2] [3]
Accuracy of the ellipticity angle [1]	< 0.25° [3]
Accuracy of the normalized Stokes components S1, S2, S3	< 0.005 [2] [3]
Accuracy of the degree of polarization (DOP)	± 2% f.s. [4]

The technical data are valid at 23 ± 5°C and 45 ±15% RH

[1] Elevation 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 $P_{in} \geq$ -40dBm at 1550nm, w/o optical attenuator; for other wavelengths guaranteed by design

POL 9320 NIR/FIR SPECIFICATIONS	
Wavelength Range	POL 9320NIR: 960 … 1160nm POL 9320FIR: 1200 … 1700nm
Insertion Loss	< 1.5dB [1]
Return Loss	> 30dB
Extinction Ratio	> 50dB
Step size resolution	0.18°
Rotation range	0 … 179.82°
PAT 9000 slot width	1
Optical Connectors	FC/APC

[1] for optimal aligned input polarization

PAN 9300 NIR/FIR SPECIFICATIONS	
Wavelength Range	PAN 9300 NIR: 960 … 1160nm PAN 9300 FIR: 1200 … 1700nm
Speed	Standard/Turbo mode: 33 / 200sec[1]
Input power range	-70 … +8dBm
Active area of photodiode	7 mm^2
Optical Attenuator Options [4]	10dB/17dB
Input Port FO Connector free space operation	 FC [2] ≤ 3mm Ø aperture
PAT 9000 slot width	1
Dimensions of optical head [3]	W x H x D: 48 x 60.5 x 139mm^3

[1] Option SW TURBO required

[2] The receptacle accepts FC/PC or FC/APC connectors due to internal free space propagation

[3] Removable from module; optional extension cable required for remote operation

[4] PAT 9000 calibration parameters factors are dependent on the attenuator setting; when ordered with the PAT 9000 the factory calibration is done with the attenuator.

Packages for typical measurement applications

PAT 9000F: for PMD and PDL measurements on random mode coupled devices like fibers includes the PAT 9000 chassis, the PAN 9300FIR polarimeter, the POL 9320FIR motorized polarizer for 1200-1700nm wavelength range, the DGD (calibration) Reference card, the analyzing software SW PMD and the tunable laser driver package SW DRV

PAT 9000N: for PMD and PDL measurements on fixed mode coupled devices like fiber optic components (filters, isolators) includes the PAT 9000 chassis, the PAN 9300FIR polarimeter, the POL 9320FIR motorized polarizer for 1200-1700nm wavelength range, the DGD (calibration) Reference card, the analyzing software SW NBC and the tunable laser driver package SW DRV

PAT 9000P1: for polarimetric measurements including optimal alignment of PM fiber includes the PAT 9000 chassis, the PAN 9300FIR polarimeter for 1200-1700nm wavelength range, the extension cable PAN EXT to operate the optical head remotely, the analyzing software SW Turbo for high speed polarization measurements and the analyzing software SW PAN ER for optimizing the alignment of PM fibers

PAT 9000P2: like PAT 9000P1 except for 960 – 1160nm

Contact the Thorlabs technical support for individual applications

CHASSIS – PAT 9000	
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, ext. VGA monitor, mouse, keyboard
Line voltage (autom. Switching)	115V+15%/-20% 230 V + 15% / -20%
Line frequency	50 … 60Hz
Operating temperature	10 … 40 °C
Storage temperature	-30 … 70 °C
Dimensions (W x H x D) [1]	449 x 132 x 419mm^3
Weight [2]	< 10kg

[1] Dimensions of chassis without feet, including PAN head

[2] Including POL 9320 and PAN 9300

SUPPORTED TUNABLE LASER SOURCES [1]	
ANDO	Series AQ 4320 A/D, AQ 4321 A/D
Anritsu	MG 9637 A, MG 9638 A (all types)
Agilent	8164A, 81640A, 81642A, 81680A, 81682A, HP 8167/8168/8164
New Focus	series 6300 (all types)
NetTest	series TUNICS (all types)

[1] ECL lasers of other manufacturers on request

ITEM - OPTION	$	£	€	¥	DESCRIPTION
PAT 9000F	$39,900	£36,309	€39.900	¥6,822,900	Fiber PMD/PDL
PAT 9000N	$42,900	£39,039	€42.900	¥7,335,900	Component PMD/PDL
PAT 9000P1	$23,900	£21,749	€23.900	¥4,086,900	1550nm Polarization Measurements
PAT 9000P2	$24,900	£22,659	€24.900	¥4,257,900	980nm Polarization Measurements

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