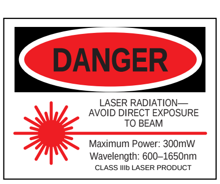
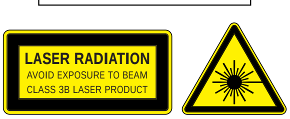
PTS-PUMP Series

Fiber Amplifier Pump Light Source Modules

Key Features

- *F-P pump laser diodes available in 980 nm and 1480 nm wavelengths*
- *Kink-free output*
- *Temperature control for wavelength stabilization*
- *Integrated fiber Bragg grating available for 980 nm module*
- *Available with various fiber optic output connector styles*





The PTS-PUMP Stabilized Light Source Modules incorporate high-power Fabry-Perot laser diodes, emitting at 980 or 1480 nm. These lasers are used in pumping erbium doped fiber gain media, which are key building blocks in long-haul fiber optic telecom networks. 980 nm pump modules are also available with an optional built-in fiber Bragg grating, assuring enhanced wavelength stability and narrow spectral linewidth.

Specifications

Description		980 nm Pump LD with Bragg Grating			980 nm Pump LD		1480 nm Pump LD	
Option Code	90	91	92	95	96	97	40	41
Center Wavelength (nm)		980±5			980±5		1480±15 nm	
Spectral Width, with grating (nm)		1						
Spectral Width, without grating (nm)					5		10 nm	
Max Output Power	100 mW	130 mW	150 mW	100 mW	130 mW	150 mW	120 mW	140 mW
Power Adjustment (dB)(1)				6				
Power Stability (typ) (dB)								
Short-Term - 15 min				±0.02				
Long-Term - 8 h(2)				±0.05				
Fiber Type			4.2/125 µm SM				9/125 µm SM	
Dimensions (H x W x D) [in. (cm)]				5.23 (13.3) x 1.39 (3.5) x 9.09 (23.1)				
Weight [lb (kg)]				1.75 (0.8)				
Operating Temperature				0°C to 40°C				
Storage Temperature				-20°C to 60°C				

1) Spectral characteristics vary with power
2) After 1 hr. stabilization at 23 ±3.0°C ambient

Ordering Information

When ordering a Pump Light Source Module, please specify the following Model number:

PTS-PUMP-□□-□□

Wavelength Code – see specification table

Connector Output Style: 55 – FC/APC, 75 – SC/APC

Order example: PTS-PUMP-41-55

Pump Laser Diode Module with center wavelength of 1480 nm, 140 mW of output power, 9/125 µm SM fiber pigtail and FC/APC connector output.

PTS-OPM Series

Optical Power Meter Modules

Key Features

- *Free-space and fiber optic measurements*
- *Compatible with all of Newport's low-power 818 Series, semiconductor detectors, including 818-IS-1 integrating sphere based systems*
- *Wide power range—from 1 pW up to 2 W (-90 to +33 dBm)*
- *Wide wavelength range—190 nm to 1800 nm*
- *Analog output for connection to external instruments*

The PTS-OPM Series Optical Power Meter Modules give the Model 8800 and 8200 Photonics Test System mainframes the utility of a benchtop optical power meter along with the convenience of a modular platform.

Single and dual-channel versions of this module are available, featuring an analog output for monitoring the detector input directly with an oscilloscope or volt meter.

The **PTS-OPM** modules utilize any one of Newport's new **918 Series** low-power, semiconductor detectors.

This makes these meters extremely versatile for measuring free-space and fiber optic lights sources, with power levels from 1 pW (-90 dBm) up to 2 W (+33 dBm), and wavelengths in the 190 nm to 1800 nm regime. The modules are also backward compatible with Newport's full range of **818 Series** detectors, using the **818-ADAPT-OPM** adaptor cable (requires a calibration module).

The optical power meter modules are individually calibrated using NIST traceable, precision current sources, and are shipped with a certificate of calibration.

Ordering Information

Model	Module Type
PTS-OPM-1	Single-Channel
PTS-OPM-2	Dual-Channel

Specifications

Model	PTS-OPM-1	PTS-OPM-2
Module Type	Single-Channel	Dual-Channel
Signal Ranges	Up to 8 decades (detector dependent)	
Auto-Ranging Time (typ)	200 ms	
Maximum Detector Input Current (mA)	5	
Analog Output (into 1 MΩ)	0–2 V	
DC Accuracy	<±2 %	
Detector Input	14-pin circular connector	
Connector, Analog Output	Mini-SMA	
Dimensions (H x W x D) [in. (cm)]	5.23 (13.3) x 1.39 (3.5) x 9.09 (23.1)	
Weight [lb (kg)]	1.75 (0.8)	
Operating Temperature	0°C to 40°C	
Storage Temperature	-20°C to 60°C	

Module/Detector System Specifications

Detector Model	918-UV/818-UV	918-SL/818-SL	918-IR/818-IR	918-IG/818-IG	818-IS-1
Material	Silicon	Silicon	Germanium	Indium Gallium Arsenide	InGaAs/Si
Active Diameter (cm)	1.13	1.13	0.3	0.3	
Wavelength (nm)	190–1100	400–1100	780–1800	800–1650	400–1650
Power Range (dBm)	-83 to +23	-90 to +33	-70 to +21.5	-90 to +21.5	-70 to +23
Accuracy (w/o attenuator)	±2%	±2%	±3%	±2%	±2.5%
Linearity (%)	0.5%	0.5%	±0.5%	±0.5%	±0.5%
NEP @ 5 Hz and 1 A/W (fW/√Hz)	50	50	4	30	3[1]

1) 0.01 A/W for the 818-IS-1

PTS-FOPM Series

Fiber Optic Power Meter Modules

Key Features

- *Direct fiber input for fiber optic component measurements*
- *Single and dual-channel versions offered*
- *Three modules cover 400–1800 nm wavelength range*
- *Measurement range from -100 to +3 dBm*
- *Analog output for connection to external instruments*
- *Available with variety of fiber connector styles*

Accessories

Please see the Fiber Optics and Accessories Section for fiber optic patchcords, adaptors, and many more accessories that can be used with these modules.

The PTS-FOPM Series Fiber Optic Power Meters accept a direct fiber input to acquire power measurements in the 400–1800 nm wavelength range. Both single and dual-channel versions are offered, with five different input connector options to select from.

The low-noise 300 µm diameter detector and eight gain ranges, enable continuous power measurements from a low -100 dBm up to 3 dBm (2 mW).

Each module is individually calibrated to NIST-traceable standards using Newport's in-house calibration facility. Calibration data is taken in 10 nm increments, and electronically stored inside the module, resulting in accurate power measurements over the entire wavelength band.

A certificate of calibration as well as the actual calibration curves recorded are shipped with each module. Annual re-calibration is recommended to assure measurement accuracy.

Specifications

Option Code	SL	IR	IG
Module Type	Si	Ge	InGaAs
Active Diameter (µm)		1000	
Wavelength (nm)	400–1100	780–1800	800–1650
Power Input Range	-100 to +3 dBm (100fW - 2mW)	-80 to +3 dBm (10pW - 2mW)	-100 to +3 dBm (100fW - 2mW)
Accuracy		±5%	
Linearity		±0.5%	
NEP @ 5 Hz and 1 A/W (fW/√Hz)	20	1	10
Dimensions (H x W x D) [in. (cm)]		5.23 (13.3) x 1.39 (3.5) x 9.09 (23.1)	
Weight [lb (kg)]		1.75 (0.8)	
Operating Temperature		0°C to 40°C	
Storage Temperature		-20°C to 60°C	

Ordering Information

When ordering a Fiber Optic Power Meter Module, please specify the following Model number:

PTS-FOPM-□□ □□ □□

Detector Code — See specification table

Number of Channels — 01, 02

Connector Input Style — 25–ST/PC, 45–FC/PC, 55–FC/APC, 65–SC/PC, 75–SC/APC

Order example: PTS-FOPM-SL0265

Dual-channel Fiber Optic Power Meter Module with Silicon detector, operating in the 400–1100 nm wavelength range, and SC/PC connector input.

PTS-VFOA

Variable Fiber Optic Attenuator Module

Key Features

- *Wide attenuation range of 0–60 dB*
- *High resolution and repeatability*
- *Factory calibrated at 1310 or 1550 nm*
- *Direct fiber input for automated fiber optic component measurements*
- *Available with variety of fiber connector styles*

The PTS-VFOA Variable Fiber Optic Attenuator Module enables automated adjustment of optical power in the 1280–1670 nm wavelength range.

The module can be used for a variety of fiber optic test and measurement applications such as: automated bit-error-rate testing of fiber optic transmission links; dynamic range measurements of detectors and receivers; and characterization of fiber optic amplifiers.

The VFOA module features a wide attenuation range, incremental attenuation adjustments of 0.2 dB, low insertion loss and high repeatability.

To assure precise and repeatable measurements, the module is factory calibrated for operation at 1310 or 1550 nm, with calibration curves stored in the module's non-volatile memory.

The module is offered with various fiber optic connector options.

Accessories

Please see the Fiber Optics and Accessories Section for fiber optic patchcords, adaptors, and many more accessories that can be used with these modules.

Specifications

Attenuation Range (dB)[1]	1.5–70
Resolution (dB)	0.2
Repeatability (dB)[2]	0.2
Absolute Accuracy (dB)[2]	±0.25
Insertion Loss[2]	1.5 dB
Polarization Dependent Loss (PDL) (dB) (PDL)[2]	0.3
Back Reflection (dB)[2]	-50
Tuning Speed (ms)	50–1400
Maximum Input Power (mW)	300
Fiber Type	9/125 µm SM
Dimensions (H x W x D) [in. (cm)]	5.23 (13.3) x 1.39 (3.5) x 9.09 (23.1)
Weight (kg)	0.8
Operating Temperature	5°C to 40°C
Storage Temperature	-20°C to 60°C

1) Low end of the range may vary between 0.7 and 1.5 dB
2) Without connectors

Ordering Information

When ordering a Variable Fiber Optic Attenuator Module, please specify the following Model number:

PTS-VFOA-□□ □□ □□

Attenuation
60 = 60dB

Wavelength
13 =1310 nm 15 =1550 nm

Connector Style
55 = FC/APC
25 = ST/PC 45 = FC/PC
65 = SC/PC 75 = SC/APC

Order example: PTS-VFOA-601365

Variable Fiber Optic Attenuator Module calibrated at 1310 nm with SC/PC connectors

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FIBER OPTIC TEST INSTRUMENTATION
POWER METERS & DETECTORS
FIBER ALIGNMENT & ASSEMBLY
LASERS
FIBER OPTIC COMPONENTS
OPTICAL FIBERS & ACCESSORIES

Newport

PTS-FOSW

Fiber Optic Switch Modules

Key Features

- *Fast switching times with high repeatability*
- *Ideal for testing of multi-port fiber optic components*
- *Wide variety available—1x2, 2x2, 1x4, 1x8, 1x16*
- *Select switches with SM or MM fibers*
- *Variety of fiber connector styles available*

The PTS-FOSW Fiber Optic Switch Modules feature fast switching times, high repeatability and low polarization dependent loss (PDL). These switches are optically passive which make them bi-directional and transparent to bit rates or data formats.

The PTS-FOSW modules are ideal for testing multiple passive fiber optic devices or multi-port devices with a single light source and a single optical meter. Components or instruments can also be selectively bypassed.

Remote switch control with a PC enables automated test sequences, used in long term burn-in and environmental testing.

The switch module is offered in a wide variety of standard port configurations—1x2, 2x2, 1x4, 1x8 and 1x16—allowing the user to choose the appropriate module for the specific task at hand. Various fiber optic connector options are available.

Accessories

Please see the Fiber Optics and Accessories Section for fiber optic patchcords, adaptors, and many more accessories that can be used with these modules.

Specifications

Switch Type	1x2 / 2x2[4]		1xN (N = 4,8,16)[1] [5]	
	Typ.	Max.	Typ.	Max.
Wavelength (nm)	1270–1630 (SM or MM) or 750–940 (MM only)			
Insertion Loss (dB)[2] (SM)	0.6	1.2	0.4	0.9
Return Loss (dB)[2]	60	>55	60	>55
Polarization Dependent Loss (PDL) (dB)[2] (PDL)	0.06	0.1	0.02	0.05
Repeatability, Sequential (dB)[3]	±0.03	±0.05	±0.005	±0.02
Repeatability, Random (dB)[3]			±0.01	±0.05
Isolation/Crosstalk (dB)	-65	-60	-90	-80 dB
Switching Time, One Channel (ms)	5	8	75	
Switching Time, Additional Channels (ms)			15	
Maximum Input Power (mW)		300		300 mW
Fiber Type	62.5/125 µm MMF or 9/125 µm SMF			
Dimensions (H x W x D) [in. (cm)][6]	5.23 (13.3) x 1.39 (3.5) x 9.09 (23.1)			
Weight [lb (kg)]	1.75 (0.8)			
Operating Temperature	0°C to 40°C			
Storage Temperature	-20°C to 60°C			

1) Call Newport for availability of versions with higher channel count.
2) Without connectors.
3) Optimum value after 1 hour warm-up.
4) Only IS type available.
5) Multimode 1xN's do not have APC connector offering.
6) 1x16 is double-wide.

Ordering Information

When ordering a Fiber Optic Switch Module, please specify the following Model number:

Order example: PTS-FOSW-14IS55

1x4 Fiber Optic Switch Module with 9/125 SMF that operates at 1270–1630 nm with FC/APC connectors

PTS-FOSW-□□ □□ □□

Switch Type
12=1x2
22=2x2
14=1x4
18=1x8
16=1x16

Fiber Type and Wavelength Range
IS=9/125 SMF 1270–1630 nm
IM=62.5/125 MMF 1270–1630 nm
SM=62.5/125 MMF 750–940 nm

Connector Style
25=ST/PC
45=FC/PC
55=FC/APC
65=SC/PC
75=SC/APC

Gas & Vapor Reference Cells and Instrumentation

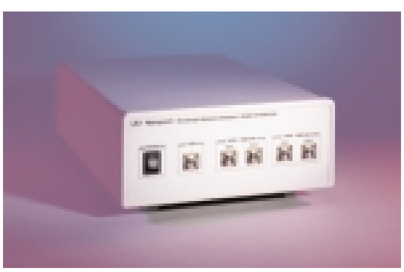
Wavelength Reference Standard

Cell Absorption Lines

- *633 nm*
- *770 nm*
- *780 nm & 795 nm*
- *852 nm*
- *Multiple-line Cells (Refer to Tables)*

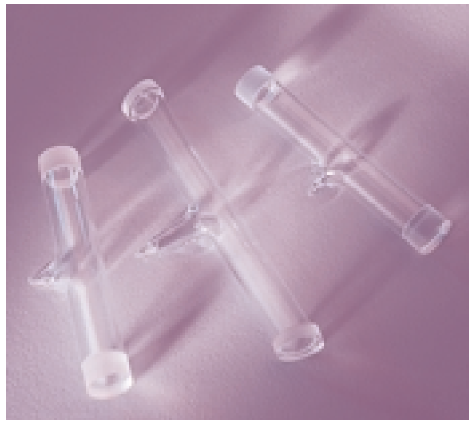
Instrument Key Features

- *Utilizes ultra-pure Acetylene and Hydrogen Cyanide Cells*
- *Includes temperature-controlled, broadband LED source*
- *High resolution via direct single-mode fiber output*



Applications

- *WDM source calibration and locking*
- *OSA Calibration*



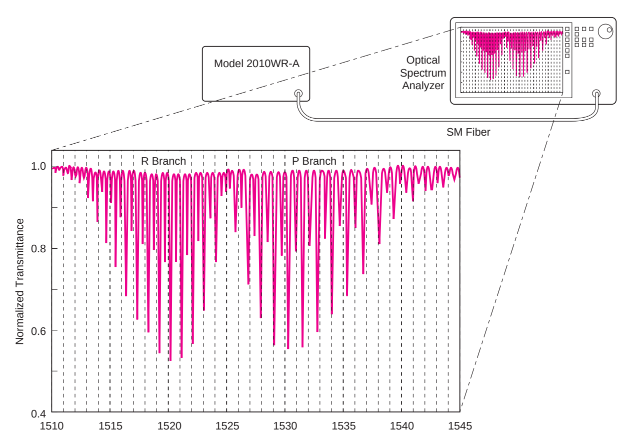
The Newport Reference Cells are offered in several configurations and elements when used in conjuction with a broadband optical energy source will create a molecular absorption at specific wavelengths. These are utilized as an intrinsic wavelength reference standard for any spectral based measuring device or instrument. See reference table below for descriptions and absorption lines for each vapor and gas type. **The 2010WR WDM Reference Standard** utilizes a built-in broadband, temperature-controlled LED light source, centered at 1550 nm; to generate the complete set of molecular absorption lines of Acetylene and Hydrogen Cyanide; as depicted in the table. These spectral patterns are very useful in calibrating optical spectrum analyzers (OSAs) across the complete ITU dense wavelength division multiplexing (DWDM) grid and to measure drift in fiber optic transmitters or WDM telecommunication systems operating in the 1550 nm region.

The Acetylene cell uses ultra-pure (99.94%) $^{12}C_2H_2$, creating absorption lines that are 2–3 GHz wide, with absorption varying from 3–60% in the 1512–1542 nm range.

The Hydrogen Cyanide cell uses ultra-pure HCN, creating absorption lines in the 1528–1563 nm wavelength range. The proximity of the cell's transition lines to the ITU DWDM grid is ideal for calibrating **Optical Spectrum Analyzers** used in testing of **Erbium Doped Fiber Amplifiers (EDFAs)** having their gain band in the 1535–1560 nm region.

Both Acetylene and HCN cells' input and output are coupled into a single-mode fiber, preventing a frequency drift in calibration associated with changes in fiber mode structure. All cells are leak tested to a leak rate of <5 x 10^{-11} cm^3/sec.

The 2010WR can be ordered with either the Acetylene cell, the HCN cell, or with both cells for coverage of the entire 1512–1563 nm range.



Optical spectrum analyzer calibration by using absorption of LED light by Acetylene ($^{12}C_2H_2$)

1) 225 ±10% Torr internal pressure
2) 100 ±10% Torr internal pressure

Acetylene Absorption Lines

Wavelength (nm)	Wavelength (nm)
1512.45	1525.76
1513.20	1526.87
1513.97	1528.01
1514.77	1529.18
1515.59	1530.37
1516.44	1531.39
1517.31	1532.83
1518.21	1534.10
1519.14	1535.39
1520.09	1536.31
1521.06	1538.06
1522.06	1539.43
1523.09	1540.83
1524.14	1542.25

Hydrogen Cyanide Absorption Lines

Wavelength (nm)	Wavelength (nm)
1528.05	1543.11
1528.49	1543.81
1528.93	1544.52
1529.38	1545.23
1529.94	1545.96
1530.31	1546.69
1530.79	1547.44
1531.28	1548.19
1531.77	1548.96
1532.28	1549.73
1532.80	1550.52
1533.33	1551.31
1533.87	1552.12
1534.42	1552.93
1534.97	1553.76
1535.54	1554.59
1536.12	1555.46
1536.70	1556.29
1537.30	1557.16
1537.91	1558.03
1538.52	1558.92
1539.15	1559.81
1539.79	1560.72
1540.43	1561.64
1541.09	1562.56
1541.75	1563.50

Reference Cell Specifications and Ordering Instructions

Model (Metric)	Description	Size (mm)
Vapor Reference Cells		
2010-I	Iodine Vapor Cell (633 nm)	25 x 76
2010-K	Potassium Vapor Cell (770 nm)	13 x 51
2010-RB-01	Rubidium Vapor Cell (780 and 795 nm)	25 x 25
2010-RB-02	Rubidium Vapor Cell (780 and 795 nm)	25 x 51
2010-RB-03	Rubidium Vapor Cell (780 and 795 nm)	25 x 76
2010-CS-01	Cesium Vapor Cell (852 nm)	25 x 25
2010-CS-02	Cesium Vapor Cell (852 nm)	25 x 51
2010-CS-03	Cesium Vapor Cell (852 nm)	25 x 76
Gas Reference Cells		
2010-AC12	Acetylene Gas Cell[1]—see table	8 x 51
2010-HCN	Hydrogen Cyanide Gas Cell[2]—see table	7 x 75
Accessories		
818-SL	Silicon Detector (400–1100 nm)	
818-IR	Germanium Detector (800–1800 nm)	
LCM-2 (M-LCM-2)	Self-Centering Lens Mount	

2010WR Standard Instrument Specifications

Gas Cells	Acetylene ($^{12}C_2H_2$) Hydrogen Cyanide ($H^{13}CN$)
LED Light Source	
Center Wavelength (nm)	1550
Linewidth (nm)	±40
Typical Output Power (µW)	30
Fiber Type	9/125 µm single-mode
Fiber Output Connectors	FC/PC, FC/APC
Chassis Ground	4mm banana jack
Power Requirements	90–132 volts (1 Amp max) 198–250 volts (0.5 Amp max) 50–60 Hz
Size (H x W x D) [in. (mm)]	3.5 (88) x 8.5 (215) x 11 (280)
Weight (dual-cell model) [lb (kg)]	6.5 (2.9)
Operating Temperature	0°C to 40°C
Storage Temperature	-20°C to 60°C

Ordering Information

Model	Description
2010WR-A-AP	Wavelength Reference Source with Acetylene Cell
2010WR-A-PC	Wavelength Reference Source with Acetylene Cell
2010WR-AHC-AP	Wavelength Reference Source with both Acetylene and Hydrogen Cyanide Cells
2010WR-AHC-PC	Wavelength Reference Source with both Acetylene and Hydrogen Cyanide Cells
2010WR-HC-AP	Wavelength Reference Source with Hydrogen Cyanide Cell
2010WR-HC-PC	Wavelength Reference Source with Hydrogen Cyanide Cell

Tutorial

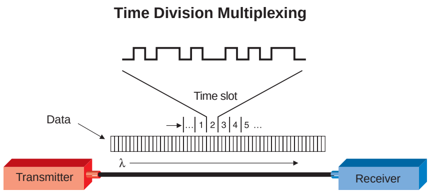
Introduction

With the increase in voice and data communications over recent years, the need for bandwidth is growing at an exponential rate. The Internet, as well as other voice, data and video applications, are pushing the limits of today's communications systems infrastructure.

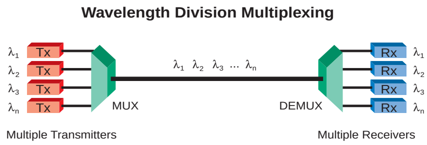
Fiber Optic Communications Advantages

The theoretical bandwidth of optical fiber transmission in the 1550 nm window alone is on the order of terabits. In contrast, coaxial transmission generally has a bandwidth limit of 500 MHz. Current fiber optic systems have not even begun to utilize the enormous potential bandwidth that is possible.

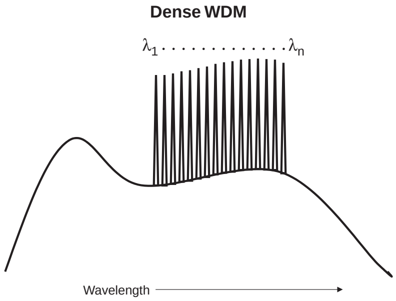
There are two methods that are employed to achieve an increase in bandwidth. The first is known as Time Division Multiplexing or TDM. Multiple channels are transmitted on a single carrier by increasing the modulation rate and allotting a time slot to each channel. However, increasing the bit rate of a system requires more sophisticated high-speed electronics at the transmitting and receiving ends of the communications link. And as the bit rate increases, inherent modulation limiting characteristics of optical fibers become dominant. Chromatic and polarization mode dispersion cause pulse spreading, which affects the signal quality over longer transmission distances.



An alternate method for increasing the capacity of fiber optic communications systems is known as wavelength division multiplexing, or WDM. Using this method, the capacity can be increased by using more than one optical carrier (wavelength) on a single fiber. Therefore, adding a second transmitter and receiver to an optical fiber can double the bandwidth of that communications system. This method of increasing the capacity of an optical system has appeal for a variety of reasons. If a system was to increase in capacity using TDM alone, the existing transmitter and receiver would be replaced with a faster and more expensive transmitter/receiver pair. Using WDM, the existing transmitter and receiver do not need to be replaced. A second transmitter/receiver pair of a different wavelength is simply added. This is done by coupling, or multiplexing the output of the two lasers into a single fiber. At the receiving end, the two wavelengths are thenseparated, or demultiplexed, and each optical carrier is routed to its own receiver. For transmission systems using a 1310 nm laser, a second laser at 1550 nm is usually added. The reason for choosing these wavelengths is that they lie in the "windows" or ranges of least attenuation. This allows the signal to travel a longer distance.



The idea of WDM has recently been extended in an attempt to fully exploit the potential bandwidth of optical fiber. The ITU (International Telecommunication Union) has proposed a set of closely-spaced wavelengths in the 1550 nm window. This method of WDM is known as Dense Wavelength Division Multiplexing, or DWDM. These different wavelengths or channels, are spaced 100 GHz apart, which is approximately 0.8 nm. This set of channels is commonly known as the ITU-T grid, and is specified in frequency. The reason the 1550 nm window was chosen by the ITU is twofold: it is in one of the windows that have the smallest amount of attenuation; and it also lies in the band in which erbium doped optical amplifiers operate.



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FIBER OPTIC TEST INSTRUMENTATION
POWER METERS & DETECTORS
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Fiber Optic Testing

Test Environments

Fiber optic testing can occur in a number of different settings, all of which require different testing conditions as well as different parameters.

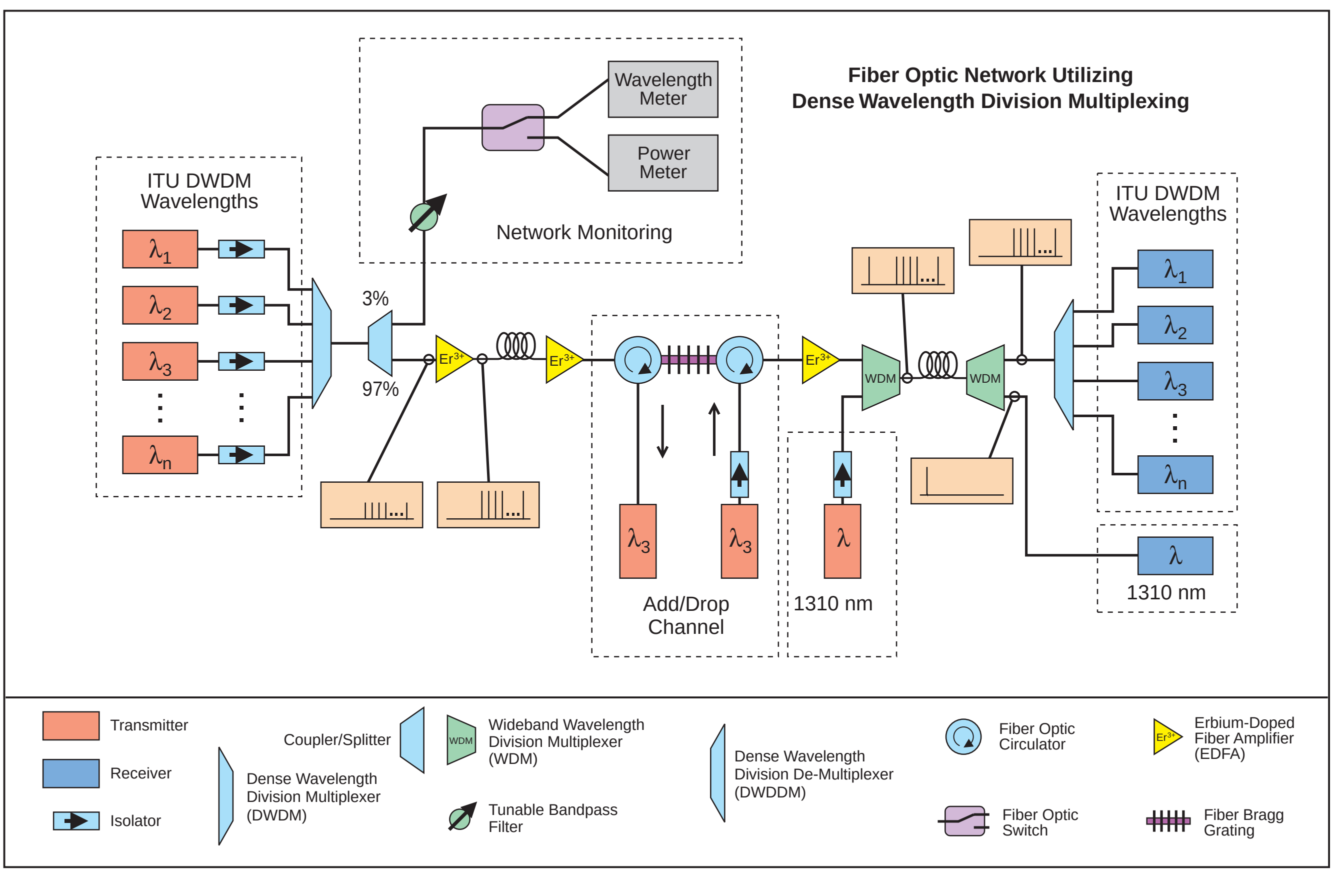
Field Test

Testing in the field is aimed at already deployed systems and components in the field. These measurements are typically performed by field service technicians who use rugged hand-held and portable test equipment for testing parameters such as insertion loss, return loss, continuity, and link length and attenuation. Tests in the field are performed to verify that fiber and components of a fiber optic system are performing to specification after deployment.

ITU-T DWDM Grid

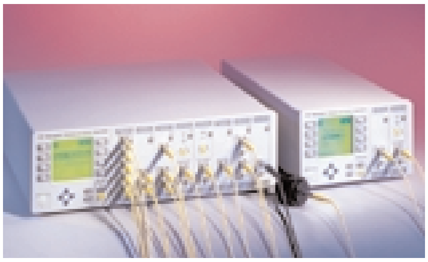
Channel Code	λ (nm)	Channel code	λ (nm)	Channel code	λ (nm)	Channel code	λ (nm)
18	1563.05	30	1553.33	42	1543.73	54	1534.25
19	1562.23	31	1552.53	43	1542.94	55	1533.47
20	1561.42	32	1551.72	44	1542.14	56	1532.68
21	1560.61	33	1550.92	45	1541.35	57	1531.90
22	1559.80	34	1550.12	46	1540.56	58	1531.12
23	1558.98	35	1549.32	47	1539.77	59	1530.33
24	1558.17	36	1548.52	48	1538.98	60	1529.55
25	1557.36	37	1547.72	49	1538.19	61	1528.77
26	1556.56	38	1546.92	50	1537.40	62	1527.99
27	1555.75	39	1546.12	51	1536.61		
28	1554.94	40	1545.32	52	1535.82		
29	1554.13	41	1544.53	53	1535.04		

It is envisioned that in the near term, a combination of TDM and WDM will be utilized to further increase network bandwidth. The following diagram is a conceptual example of a fiber optic network.



Laboratory Test

Tests performed in a laboratory environment usually have more relaxed environmental requirements. Laboratory tests may be performed for researching new component technologies or developing new optical systems. Laboratory test environments typically use benchtop test equipment or rack mounted test systems. Due to the unpredictable nature of research testing that needs to be performed, it is often desirable to have test equipment that has flexibility and can be used for a number of different types of tests. It is not always practical to have an entire test system dedicated to performing a single test.



QA and Manufacturing Test

As optical components are manufactured, they are often tested and monitored as they pass through each step of the manufacturing process, including insertion loss, accuracy and back-reflection measurements, to name a few. These tests are performed both under ambient operating temperatures as well as under rigorous environmental conditions per Telcordia (formerly Bellcore) qualification requirements. In these testing conditions it is beneficial to have a semi or fully automated testing platform for performing repetitive measurements for these optical components, in high volume.

Testing is also performed to ensure that components meet specifications and to obtain additional critical test data. QA departments may perform a number of set tests to verify important parameters such as insertion loss, return loss, polarization dependent loss and bandwidth (in the case of wavelength division multiplexers and optical filters). These tests may be performed under the same Telcordia environmental conditions to ensure operation in extreme environments. This test data isused to accept/reject components as well as provide data that may be used in network design and link budget analysis.

Telcordia (formerly Bellcore) Qualification

Telcordia qualification requirements are standardized to ensure that components and instruments will perform properly when deployed in the field. Environmental tests include temperature storage tests from -40 to +85°C, thermal cycling, vibration and impact tests. The Telcordia qualification requirements are highly rigorous and are recognized around the world as the de facto standard for optical component environmental testing.

TIA/EIA Fiber Optic Test Procedures

The Telecommunications Industry Association (TIA) as part of the Electronics Industry Association (EIA) has established a set of fiber optic test procedures (FOTPs) in an attempt to standardize the way fiber optic measurements are performed and specifications are obtained and reported.

Newport's Model 8800 and Model 8200 platforms have been designed for testing of fiber optic components and systems in both laboratory and manufacturing environments. The systems' modular design provides the flexibility to perform most of the following tests.

Types of Tests

Component Testing

Insertion Loss [dB]

Insertion loss is the amount of optical power that is lost by "inserting" a device or component into an optical link. Insertion loss is typically performed at a specific wavelength, but may also be performed over an entire spectral region. Insertion loss calculation follows where P_{in} is the optical power entering the device under test (DUT) and P_{out} is the optical power exiting the device.

$$IL\left[dB\right] = P_{in}\left[dB\right] - P_{out}\left[dB\right]$$

Return Loss [dB]

Return loss, also known as optical return loss, is a ratio between the incident power and the reflected power. Reflected optical power should be minimized to reduce the overall loss in a system and to eliminate the possibility of multipath interference and oscillations and instabilities in DFB lasers, EDFAs and other active components. Return loss is calculated as:

$$RL\left[dB\right] = 10\log_{10}\left(\frac{P_{in}}{P_{reflected}}\right)$$

and is a positive number. Because the amount of reflected power is desired to be a minimum, a higher return loss number means better performance. Another term that is often used is reflectance. This is calculated as:

$$\text{Reflectance}\left[dB\right] = 10\log_{10}\left(\frac{P_{reflected}}{P_{in}}\right)$$

and is the inverse ratio of return loss. Therefore, the two terms can often be used interchangeably by adding a negative sign for reflectance, which also implies that a smaller number means better performance.

Polarization Dependent Loss (PDL) [dB]

The polarization state in an optical network is affected by many parameters ranging from stress on a fiber to the movement of a fiber jumper, making it almost impossible to predict. The varying loss associated with changing polarization is called polarization dependent loss. PDL is measured by monitoring the change in insertion loss as the polarization is changed through all of the possible polarization states with a polarization controller. PDL is expressed as the difference between the maximum and minimum insertion loss.

Polarization Mode Dispersion (PMD) [dB]

Polarization mode dispersion is another form of material dispersion. Single-mode fibers support one mode, which consists of two orthogonal polarization modes. Ideally, the core of an optical fiber has an index of refraction that is uniform over the entire cross section (unless the fiber has a graded index of refraction). However mechanical stresses (i.e. bending, pulling, squeezing) can cause slight changes in the index of refraction in one dimension. This can cause one of the orthogonal polarization modes to travel faster than the other, hence causing dispersion of the optical pulse. The effects of dispersion can introduce errors as pulses spread into one another, eventually limiting error-free transmission of the fiber optic link.

Bandwidth [nm]

Optical filters and wavelength division multiplexers have an associated “bandwidth” in the optical domain, which is analogous to the bandwidth of a RF filter in the frequency domain. Optical bandwidth is the spectral bandwidth, expressed in nanometers. There are three different levels that bandwidth is typically specified at, relative to the maximum optical power level: -3 dB, full width at half maximum (FWHM) and -20 dB.

Stimulated Brillouin Scattering (SBS)

SBS is the strongest non-linear effect in optical fibers. It occurs when very narrow linewidth, high-power signals are used. This effect occurs when an acoustic wave is created in the fiber due to a strong electric field, which is a result of high-power densities. The result is a new optical wave that is reflected back at the transmitter, creating attenuation in the transmitted wave. Hence, knowing where this threshold is, with respect to the signal power being transmitted and amplified in the network, is of great interest to system designers. Because of the bulk amplification of an EDFA, if one wavelength drops out, all the other wavelengths will experience an increase in power. If these wavelengths were already close to the SBS threshold, this boost may push them beyond this threshold and cause a system wide link failure.

Four Wave Mixing

Four wave mixing is a non-linear effect that occurs in dispersion shifted fiber. Two or more wavelengths may experience non-linear mixing that introduces “phantom” carriers at new wavelengths, if the optical power is high enough. This presents a problem for two reasons. First, the new carriers may lie closely or directly over an existing carrier wavelength. This will interfere with the existing carrier thus degrading the performance of that channel. Second, optical power is robbed from the wavelengths that create the mixing, thus reducing the signal to noise ratio of these channels.

$$\mathrm{IL}\left[\mathrm{dB}\right]=\mathrm{P_{in}}\left[\mathrm{dB}\right]-\mathrm{P_{out}}\left[\mathrm{dB}\right]$$

Instrumentation

Erbium Doped Fiber Amplifiers (EDFAs)

Noise Figure

Noise figure is a figure of merit for an EDFA. It is defined as the ratio of the signal to noise ratio at the input of an EDFA to the signal to noise ratio at the output. This requires that the EDFA system be quantum-limited (i.e., shot-noise limited).

Gain Tilt

Uneven gain profile over the EDFA amplification band causes gain tilt, with longer wavelengths usually amplified slightly more than shorter wavelengths. The effect of gain tilt is particularly significant in longer transmission links when a signal travels through multiple EDFAs. As the signals exit the last EDFA, the shorter wavelength power level will be very small and the longest wavelength power will be very large. EDFA manufacturers are beginning to address this problem by flattening the gain spectrum of their devices, and by using gain-flattening filters.

Small Signal Gain

The small signal gain of an EDFA is the gain provided by the amplifier while operating in the linear or non-saturated region. In this region, the gain should be independent of the input signal power, as well as all other operating conditions such as wavelength, temperature, etc.

System

Signal to Noise Ratio (SNR)

Signal to noise ratio is the ratio between the optical carrier power and the noise (which corresponds to non-carrier signal) at the receiver. A rule of thumb is that the SNR should not fall below 20 dB for most optical communication systems.

Crosstalk

In DWDM networks, crosstalk is an important parameter. There are two types of crosstalk that can have detrimental effects on the performance of an optical system. The first is known as inter-channel crosstalk or “intensity” crosstalk. The second is intra-channel crosstalk, sometimes termed as ”coherent” crosstalk.

Intensity Crosstalk

Intensity crosstalk occurs between channels and is a result of non-ideal optical filtering, where light from neighboring channels can leak through and be detected along with the filtered signal of interest. When the leakage level of a neighboring channel is higher than the noise floor that is associated with the channel of interest, it becomes the dominant noise factor in the SNR. As a rule of thumb, the intensity crosstalk of neighboring channels must be at least 20 dB below the target signal level. This type of crosstalk can be dealt with by using a high quality optical filter to eliminate all unwanted signals outside of the target channel bandwidth.

Coherent Crosstalk

Coherent crosstalk is less common than intensity crosstalk and only applies to networks that reuse wavelengths and have non-ideal wavelength routing elements, or networks that suffer from four wave mixing effects. This type of crosstalk occurs when the leakage signal (the crosstalk term) is of the same wavelength as the signal. This makes it impossible to remove the crosstalk once it is present because it cannot be filtered out optically. This has similar effects on the SNR as intensity crosstalk. Furthermore, when the crosstalk wavelength differs very slightly from the wavelength of the signal, coherent beat noise, which manifests itself in the form of intensity beats at the photodetector, may occur if the difference frequency falls within the electrical bandwidth of the receiver.

Wavelength

The measurement of wavelength is critical in DWDM systems. Channel spacings are extremely tight; therefore the tolerance of wavelength registration becomes increasingly important.

Absolute Wavelength

An absolute wavelength measurement is often measured with a wavelength meter or optical spectrum analyzer. While an optical spectrum analyzer can provide wavelength measurements, the resolution of an OSA is typically on the order of 0.1 nm, which does not provide enough accuracy. A wavelength meter can often measure wavelength with resolution in picometers.

Wavelength Stability

Wavelength stability is of extreme importance in a DWDM network. With channel spacings of 0.8 nm, even the slightest drift in wavelength of an optical carrier can severely affect the performance of the system. The stability of a channel can be monitored with a wavelength meter, which monitors the absolute wavelength.

Optical Power

Measurement of the optical power of DWDM carriers is also important.

Absolute Power

Absolute power measurements allow one to monitor the power levels of the carriers to ensure that they do not exceed the specifications of various fiber optic components and instrumentation.

Power Stability

Power stability through an optical network is important because fluctuations in power may cause link failures. If the power of a single channel in a DWDM network fluctuates, it can affect the power of all other carriers due to the bulk amplification of all the carriers in an EDFA. An increase in power of one wavelength can reduce the amplification of the other wavelengths, pronouncing gain tilt and possibly causing some wavelengths to saturate their receivers and others to fall below the minimum sensitivity.

Dynamic Range

Dynamic range of an optical system is often defined by the maximum amount of power that can be accepted by the receiver before saturation occurs to the minimum amount of power that is acceptable at the receiver to realize the BER necessary for performance requirements. DWDM systems must be specially designed to account for failures. The failure of a single transmitter in a DWDM network may push other channel powers outside of the dynamic range of the system because of the gain sharing properties of EDFAs. Care must be taken to factor in appropriate error margins to ensure that a single failure does not bring the entire network down.

The All Optical Network

The 21st century has already been labeled by some as "the century of light". This label is very appropriate considering the current growth rate of DWDM and the even greater demand for bandwidth. The all-optical network will be the next evolution in optical communications. Current DWDM systems are point-to-point links meaning that the signals have a single distinct starting and ending point. Research is being performed to help these networks evolve into fully configurable networks, which are not limited to fixed point-to-point links.

Transparency in the optical layer opens many possibilities for the future. Digital and analog transmission can occur on the same fiber. Different bit rates using different protocols will all travel together. Current research is being performed on reconfiguring an optical network in real time. Wavelength selective switching allows wavelengths to be routed through the network individually. Some of the applications of this are for network restoration and redundancy, which may reduce or entirely eliminate the need for an entire back up system to help the network recover from failures such as equipment malfunctions or fiber breaks. A reconfigurable network may offer bandwidth on demand to configure itself to optimize for traffic bottlenecks. The future may also include wavelength translation to convert traffic on one wavelength to another wavelength in the optical domain.

All optical switching is still in the research phase; however, researchers are looking for ways to create reliable, low loss switches with fast switching speeds. Investigation into the possibility of optical packet switching and other novel technologies are currently underway. The all optical network may be just around the corner.

Please call Newport for Applicaton Notes depicting how fiber optic parameters can be measured by using Newport's test equipment.