WDM Channel Simulator (WCS)

User's Guide

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Digital Lightwave®

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Technical Support

Technical Support is available by calling toll free (in the US) **1.877.929.HELP (4357),** or (outside the US) **1-727-519-2860**. Technical support is available 24 hours/day, 7 days/week.

Return Shipping Instructions

If it is necessary to return the unit, obtain a **Return Material Authorization (RMA) number** and **Return Shipping Address** by contacting Technical Support between 8:00 a.m. and 6:30 p.m. EST, Monday through Friday.

Please enclose a letter that briefly describes the reason for returning the unit and include the following information:

- Unit Serial Number
- Customer Name and Shipping Address
- Customer Contact Name and Telephone Number
- Secondary Customer Contact Name and Telephone Number
- Customer Supplied Purchase Order Number (if applicable)

If the original shipping container (box) is available, place the unit (and letter that describes the reason for the return) into the original Digital Lightwave, Inc. shipping container. **Do not include personal items such as jumper cords or cables. Digital Lightwave, Inc. will not be responsible for these items.** Use the original foam inserts to protect all six sides of the unit.

Securely seal the shipping container, and mark **FRAGILE** on the container to ensure careful handling.

Include the **RMA number** on the outside of the shipping container.

If the original shipping container is not available, use the following general instructions to repack the unit, or individual circuit packs, (and letter that describes the reason for the return) using commercially available materials:

– Use a strong shipping container. (Use a shipping container that is similar to the original shipping box. Verify that the substitute container is rated at **350 lbs. per square inch** pressure durable.

- Make sure that the unit is satisfactorily protected by using a layer of ESD-protected shock absorbing foam material that is applied to all six sides of the unit to provide adequate protection. Make sure that the unit cannot move or shift within the container.
- Securely seal the shipping container, and mark **FRAGILE** on the container to ensure careful handling.
- Include the **RMA number** on the outside of the shipping container.

Contact Technical Support for the Repair Department's Return Shipping Address.

When service is complete, your unit will be returned to you postage paid if the shipment is within the United States. You are responsible for paying all shipping charges, duties, taxes, and other charges for products returned to Digital Lightwave, Inc. from any location within or outside of the United States.

Safety Information

Read and follow all warnings, cautions, and instructions marked on the product and included in this document. Only qualified personnel should perform installation or service. Use of controls or adjustments or procedures other than those specified herein may result in hazardous radiation exposure.

General

Before operation, you should review the instrument and manual for safety markings and instructions. You must follow these to ensure safe operation and to maintain the instrument in safe condition.

Some circuits are powered whenever the instrument is connected to the AC power source. To disconnect from the line power, disconnect the power cord either at the rear power inlet or at the AC power line receptacle. One of these must always be accessible.

WARNING

To avoid hazardous electrical shock, do not power on the unit if there are signs of shipping damage to any portion of the outer enclosure.

Line Power Requirements

The WDM Channel Simulator (WCS) power supply complies with UL 1950, CE, FCC, CSA/cUL, and TUV EN 60950 regulatory standards and can operate from any single-phase AC power source that supplies between 100 and 240 V at a frequency range from 50 to 60 Hz. The maximum power consumption is 250 W.

Operating Environment

The unit is designed to meet all specifications operating from 15°C to 35°C.

Storage and Shipment

The unit is designed to be stored or shipped at temperatures from -10°C to 65°C. Please allow 1 hr. warm-up time after long-term exposure to temperatures below 0°C.

Input/Output Signals

The unit has one optical output and 2 optical inputs on the front panel. All have FC/APC bulkhead connections. On the rear of the unit there is a GPIB connector and a VGA out. These connections are all outputs and therefore any input signal applied to these connections may pose a hazard to the instrument.

Input power ratings:

- 115 Volts, 8 Amps, 50 or 60 Hz
- 230 Volts, 4 Amps, 50 or 60 Hz

Operating environment

- Indoor use
- Altitude up to 2000 meters
- Operating temperature 15°C to 35°C
- Maximum relative humidity 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40° C.

Rack mounting Instructions (It is recommended that the unit be mounted on a shelf in addition to rack mounting ears):

- Locate the rack mounting holes on both sides of the unit. The mounting holes are the three holes on each side near the front of the unit.
- Install rack-mounting ears on both sides of unit using the supplied bolts. Tighten bolts with wrench.
- Install unit in rack using appropriate nuts and bolts provided by the rack manufacturer.

Elevated operating ambient - If installed in a closed or multi-unit rack assembly, the operating ambient of the rack may be greater than the room ambient (35° C maximum). Therefore considerations should be given to the Tmra.

Reduced air flow - Installation of the equipment in a rack should be such that the amount of airflow required for safe operation of the equipment is not compromised.

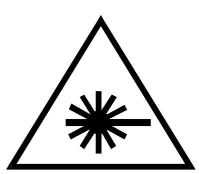
Mechanical loading - Mounting of equipment in a rack should be such that a hazardous condition is not achieved due to uneven loading.

Circuit overloading - Consideration should be given to the connection of the equipment to the supply circuit and the effect that overloading of circuits could have on overcurrent protection and supply wiring. Appropriate consideration of equipment nameplate ratings should be used when addressing this concern.

Reliable earthing - Reliable earthing of rack-mounted equipment should be maintained. Particular attention should be given to supply connection other than direct connection to the Branch (use of power strips).

Laser Safety Information

The laser within the Swept-Laser Dynamic Component Test System is an Er-doped fiber ring laser. The laser output is enabled once the display GUI is visible on the display. The maximum average laser power is approximately 0 dBm and peak pulse energy is below 0.1 nJ. Therefore, according to ANSI Z136.1 and FDA 21 CFR 1040.1, it is a Class 1 laser.



Class 1 Laser Product

NOTICE

Unterminated optical connectors may emit laser radiation. Do not view with optical instruments.

Contents

1 Introducing the WCS

Overview

The WCS system is comprised of two matched and thermally tunable *pico*Wave® Fiber Fabry-Perot Interferometer (FFPI) filters. The two filters can be used independently, as shown in Figure 1-1 below, or configured in series to double the contrast ratio, as depicted in Figure 1-2.

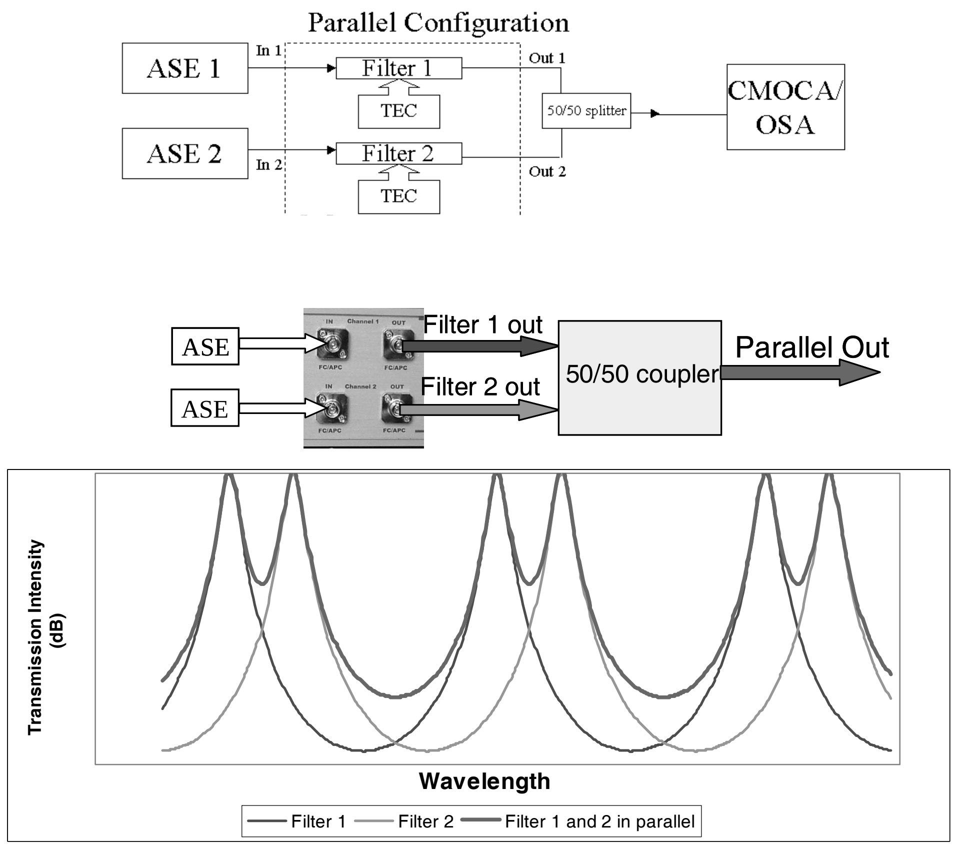


Figure 1-1. Parallel WCS configuration.

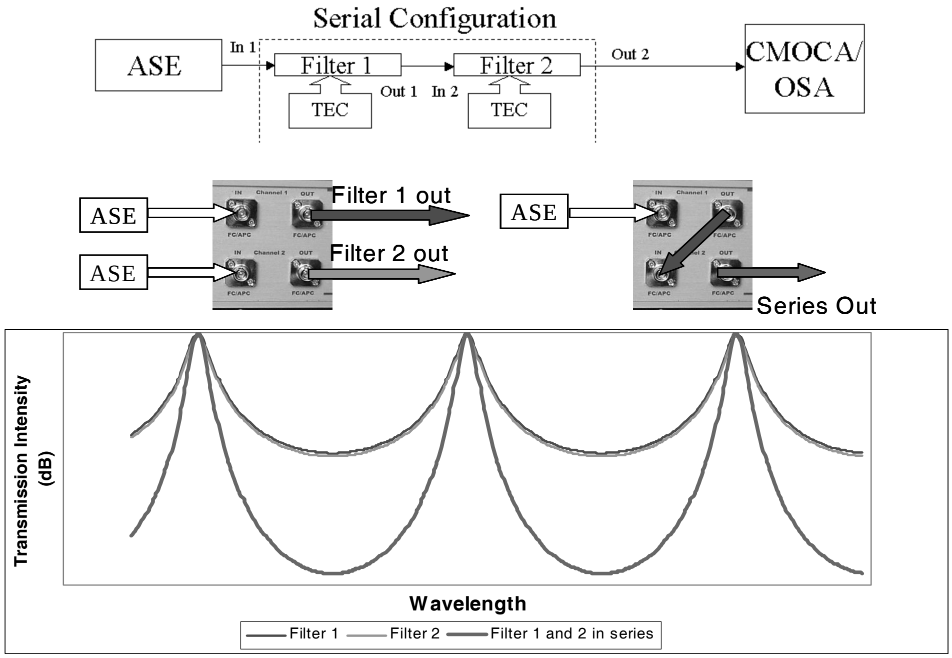


Figure 1-2. Series WCS configuration.

The table below summarizes the contrast and bandwidth specifications for the standard FSR and Finesse WCS filters.

Filter FSR (GHz)	Filter Contrast F=10	F=40	Filter Bandwidth F=10 (GHz)	F=40	Series Contrast F=10	F=40	Series Bandwidth F=10 (GHz)	F=40
25	16 dB	28 dB	2.5	0.625	32 dB	56 dB	1.6	0.4
50	16 dB	28 dB	5	1.25	32 dB	56 dB	3.2	0.8
100	16 dB	28 dB	10	2.5	32 dB	56 dB	6.4	1.6

The individual WCS filters are made to have a uniform peak-response, as shown in Figure 1-3 below. Furthermore, the measured etalon transmission profile matches the theoretical Airy function curve, as illustrated in Figure 1-4Figure 1-5.

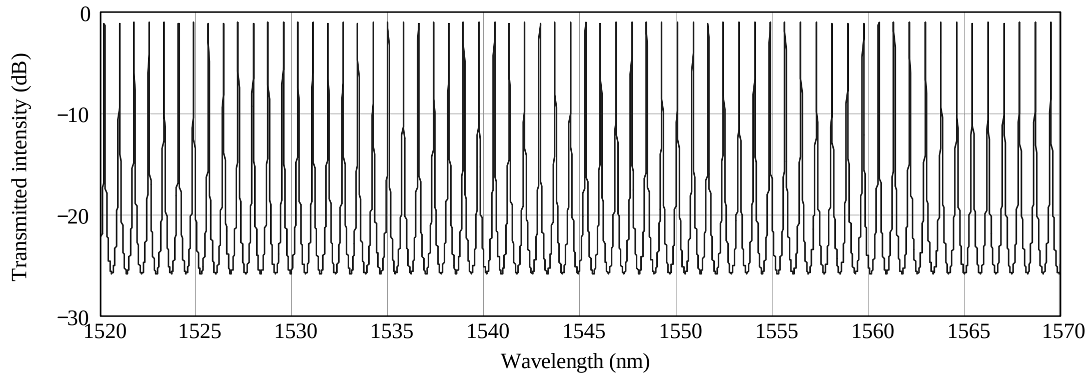


Figure 1-3. Typical transmission profile from a single Finesse 40, 100 GHz FSR filter.

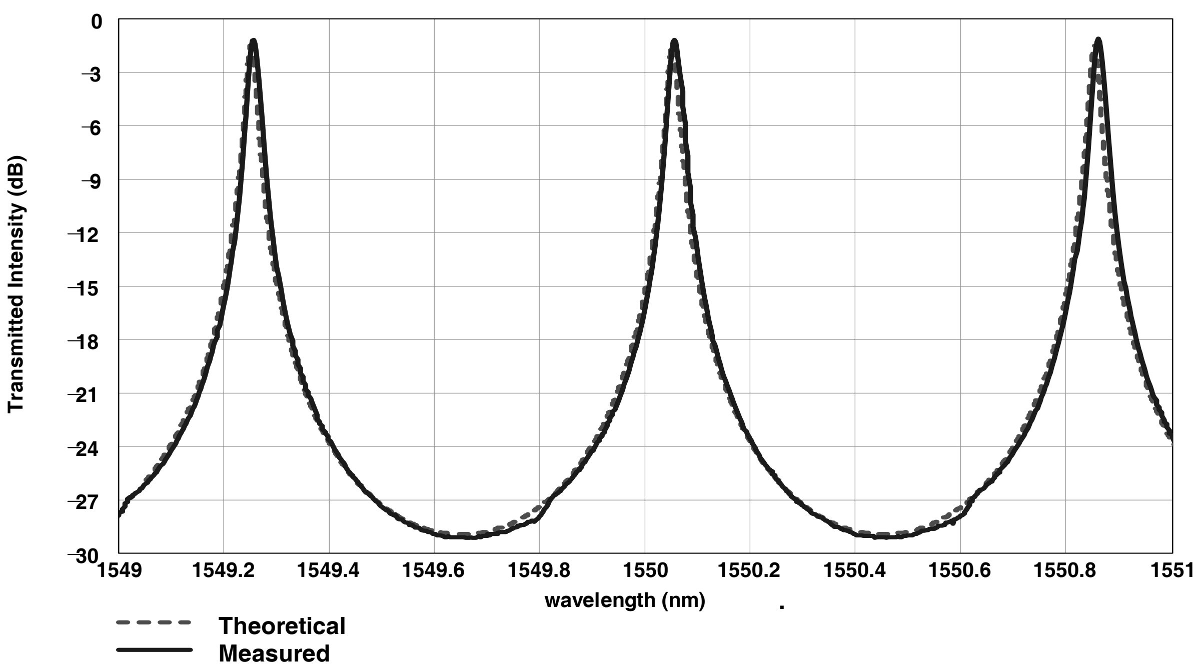


Figure 1-4. A comparison between theoretical and measured WCS transmission spectra for a single filter.

The ability to accurately produce such a flat response in the series configuration relies predominately on the FSR matching of the two filters to within less than 50 MHz of one another. As an example, Figure 1-5 below shows a somewhat exaggerated mismatching of two filters, and the resulting transmission profile that would result in a series configuration of the two mismatched filters.

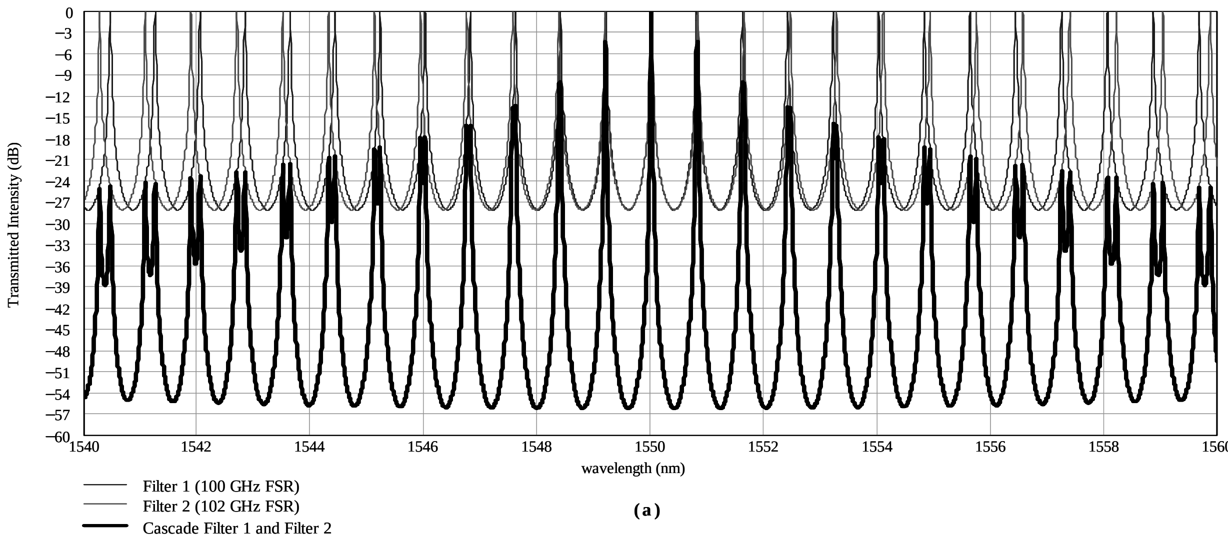


Figure 1-5. Resultant cascade transmission profile (black line) from two filters (red and blue lines) that differ in FSR by 2 GHz. The large FSR difference is used here to illustrate the effects of filter mismatch.

The resulting series transmission flatness for filters that differ in FSR by 50 MHz is approximately 3 dB over a 50 nm span. Fortunately, the thermal tuning range of the FSR is 0.05%, which is 50 MHz for the 100 GHz FSR filter. This means that the FSR can be thermally fine tuned to give much better than 3 dB of flatness for the series filter combination.

It is important for the user to understand that the WCS output spectral profile is predominantly governed by the spectral profile of the input light source. For example, Figure 1-6 below indicates the typical spectral output curve of the WCS when the built-in ASE source option is used as the input light source.

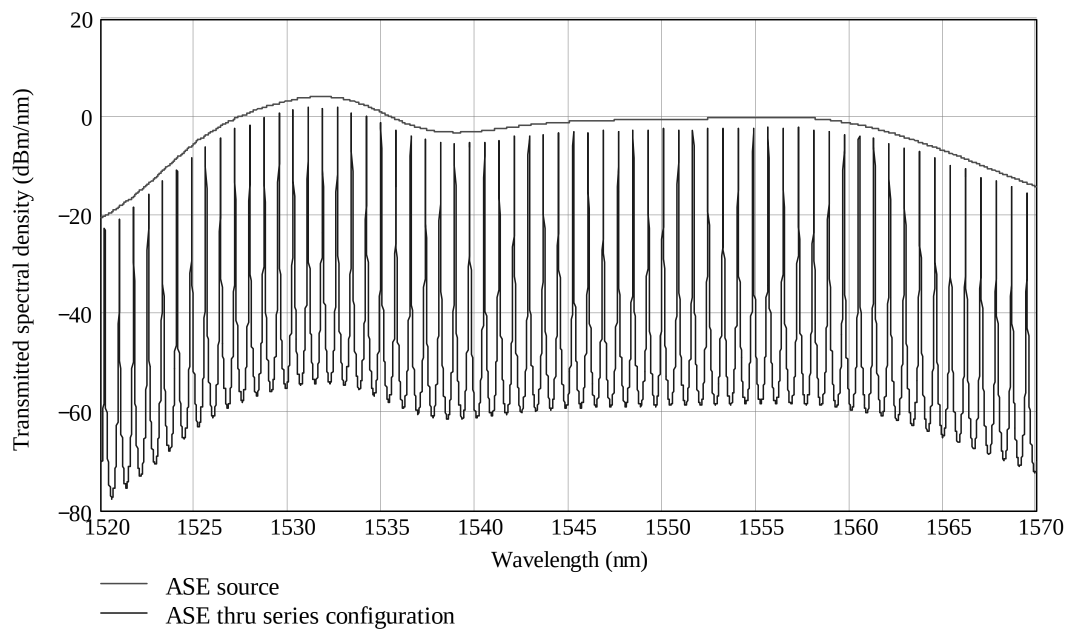


Figure 1-6. Typical spectral density plot of the series WCS configuration using the built-in ASE source. The resultant peak output profile of the WCS (blue curve) follows the profile of the input light source (red curve).

An important consideration for use in WDM systems is the ability of the WCS to maintain proper channel spacing over the band of interest. The WCS is manufactured to a target FSR, but due to statistical variance, each filter will have a slight FSR error. The impact of the FSR error may or may not be significant, depending on the specifications of the system that is being emulated.

Let's consider, for example, a WDM system where it is desirable to place emulated channels directly on the ITU grid. A typical system design parameter would be to specify the worst case offset to the ITU grid of any emulated channel. The table below indicates the filter FSR tolerance that would be necessary in order to keep all emulated channels within a worst-case channel offset to the ITU grid. All of the values stated in the table assume that the emulator is perfectly centered on the channel at the center of the band of interest.

For example, if the worst-case tolerable channel offset (or deviation) from the 100 GHz spacing ITU grid is 3 GHz, then one would need to specify a 0.095% FSR tolerance for C-band operation in order to maintain the correct channel alignment. One would need a tighter tolerance (0.049%) for the same worst-case offset if the WCS were expected to cover the entire C&L band.

Target FSR	Worst Case Channel Offset	1520-1570 nm Max FSR Error	Tolerance (C-Band)	1520-1620 nm Max FSR Error	Tolerance (C&L Band)
50 GHz	0.5 GHz	7.9 MHz	0.016%	4.1 MHz	0.008%
	1 GHz	15.87 MHz	0.032%	8.2 MHz	0.016%
	2 GHz	31.75 MHz	0.064%	16.4 MHz	0.032%
	3 GHz	47.62 MHz	0.095%	24.6 MHz	0.049%
100 GHz	0.5 GHz	16.13 MHz	0.016%	8.2 MHz	0.008%
	1 GHz	32.26 MHz	0.032%	16.4MHz	0.016%
	2 GHz	64.52 MHz	0.064%	32.8 MHz	0.032%
	3 GHz	99.77 MHz	0.095%	49.2 MHz	0.049%

Acronyms

FFP-TF	Fiber Fabry-Perot Tunable Filter
FFPI	Fiber Fabry Perot Interferometer
FWHM	Full Width Half Maximum
TEC	Thermo Electric Cooler
WCS	WDM Channel Simulator

2 Quick Start

Setting up the WCS

Unpacking the WCS

1. Unpack the unit and plug the AC cord into any available AC power (85-265 Volts AC, 47-440 Hz).
2. Turn on the main power switch on rear panel and the sub power switch on the front panel. Both power switches are included for ease of use with rack mount systems. Both switches must be in the On position for operation.
3. Set the Red switches on the far right side of the front panel to PRESET.
4. Set the red switches in the center of the front panel to ACTUAL. Note: Use only angled physical connection (APC - green boots) to connect to the unit.

Make connections

Parallel Configuration (Figure 1-1)

1. Connect a separate broadband source to each input.
2. Use a 50/50 splitter on the outputs to recombine the signals.

Serial Configuration (Figure 1-2)

1. Connect a broadband light source (ASE, LED, or SLED) to Channel 1 Input.
2. Connect Channel 1 Output to Channel 2 Input.
3. Connect a detector to the Channel 2 Output.

Operation

Note: When the far right switches are in the PRESET position, the manual control knobs are disabled and the emulator filters are tuned to the initial factory setting. It is a good idea to make a note of the display readings with the red switch in the PRESET position.

1. Flip the red Manual/Preset switch (for one channel) to the Manual position and turn the manual control knob until the temperature reading approximately matches the preset value as noted above.
2. Adjust the manual control to fine tune the filters to the desired offset resonance (if in parallel mode) or overlap resonance (if in serial mode).

Note: Displayed readout values are related to the temperature of the etalon. A value of 1100 corresponds to room temperature; higher values correspond to hotter temperatures. It is not necessary to display the absolute temperature of the device; however, a chart is included (Figure 1-6) that converts the readout value and the actual temperature.

It is recommended that both channels operate in the 1100 to 1200 range for the best stability and the minimum power dissipation.

Shutdown

Turn off the sub power switch on the unit's front panel, or the main power switch on the unit's back panel.

3 WCS Controls and Basic Operation

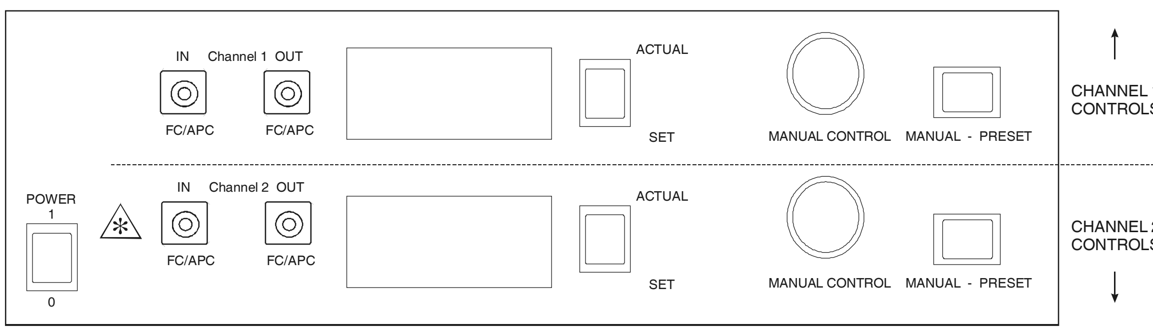
What is Included

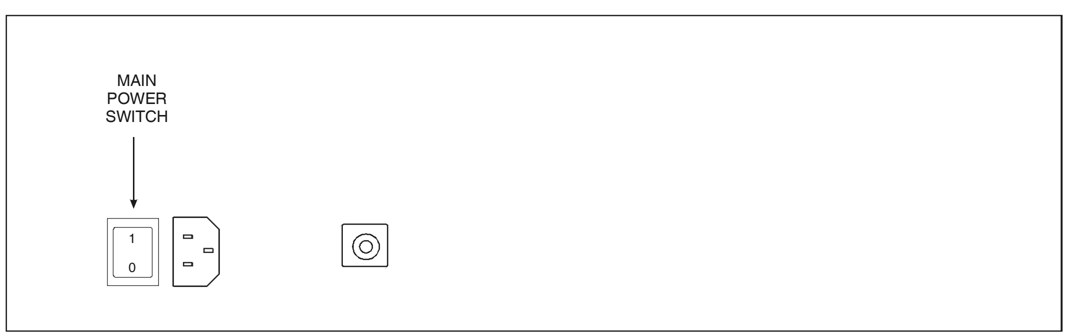
The items listed below should be included with the WCS. If any of these items are missing, contact Digital Lightwave immediately.

- WCS unit
- Power cord
- Instruction manual
- Final functional test report

Panel Layout

Use this following images to locate the WCS front and rear panel controls.





Connections

Temperature Control: Extremely accurate temperature control is required (a) to adjust the effective etalon length of the two filters, and (b) to maintain the effective length so that filter resonance drift does not occur.

Temperature control of the etalons is very important for stability and control of the WCS. For example, if the effective lengths of the two etalons differ by as little as ¼ micron, the comb signal can drop nearly 50 dB for the Finesse-40 system in the series configuration.

To aid in the setup process, a factory "Preset" circuit has been designed to tune the filters to approximately the same effective etalon length. This circuit simply switches a fixed resistance value in place of the manual control for the temperature feedback circuit. The preset resistance value may need to be recalibrated periodically.

When thermally tuning the etalon by changing the temperature on the thermo electric cooler (TEC), a time delay exists between the desired (set) temperature and the actual temperature. Furthermore, if you attempt to set the TEC temperature outside of the normal operating range of the device, the actual temperature may not be able to reach the set temperature (due to thermal resistance and current limitations). Therefore, we have designed the readout display circuit in a way that will allow the user to monitor either the "Set" (desired) or the "Actual" temperature value by simply switching the red switches in the middle of the front panel.

The figure below indicates the relationship between the display reading and the actual temperature on the TEC surface and etalon. The most stable and efficient operating range is between 1100 -1200 (23° to 30°C).

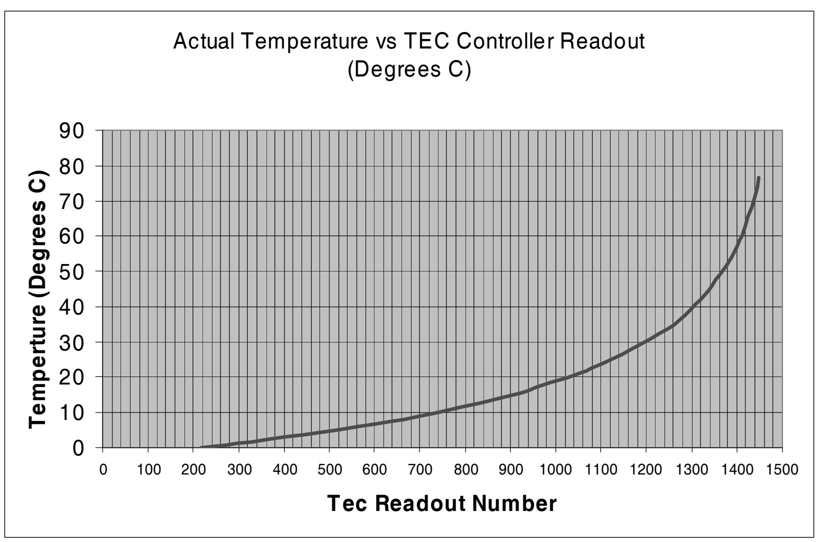


Figure 3-1. Chart showing the relationship between the LED display readout and the actual temperature on the interferometer cavity.

Loss and Contrast Ratio Measurement Description

The most accurate method for determining the loss and contrast ratio of the individual WCS channels is to utilize an ECL laser (at 1550nm) and a power meter.

To perform the measurement, the reference power level is found by first launching the laser directly into the power meter, and recording the reference power. Then the laser is launched into the channel input, and the output is monitored with the power meter. The WCS manual-adjust control is rotated until a maximum power is achieved at the power meter (i.e., the filter lines are aligned with the 1550 nm laser). The difference between this value and the reference power level is the loss.

A similar technique is utilized for the measurement of the contrast ratio, however, the WCS manual control is rotated for the minimum power. The contrast ratio is the difference between the maximum and minimum power levels (dB).

Fine-tuning the WCS for Perfect Overlap

1. Double check the ASE total integrated power by measuring it with a photodetector. The reading should be approximately 10 dBm.
2. Connect your ASE source to the input of Filter 1, then connect the WCS filters in series. Monitor the total power throughput using the photodetector.
3. Leave Filter 2 in the **Preset** mode position. Make a note of the display reading for Filter 1.
4. Flip the **Actual/Set** switch on Filter 1 to the **Set** position so that you are reading the set temperature reading on the top display.
5. Take Filter 1 out of the **Preset** mode (change the far-right top switch to the **Manual** position.
6. Adjust the top far right knob so that the display reads the same value that it did in Preset mode - then change Filter 1's **Actual/Set** switch to the **Actual** position. Wait until the display reads the previous set value before going to next step.
7. While watching your photodetector power level, make slight adjustments using the **Manual Control** knob. Maximize the power to the detector, and make a note of the top display reading. This is the value to use for maximum contrast.

A typical total integrated power attenuation value that will be measured through two series, F-40, 100 GHz filters is approximately 19 dB. The single filter will have a total integrated power attenuation of approximately 15 dB.

A WCS Formulas

Overview

Formulas for etalon cavity length and mirror reflectivity are shown below.

Length of the etalon cavity

$$L := \frac{c}{2 \cdot nc \cdot FSR}$$

where

c = speed of light (3x10^8 m/s)

nc = effective refractive index of the fiber core (1.465)

FSR = Free Spectral Range (spacing between resonance peaks) in Hz
(for example, 100 GHz)

Reflectivity of the cavity mirrors as a function of the Finesse (F) (for example, F = 40)

$$R := \frac{\left[\left(2 + \frac{\pi^2}{F^2}\right) - \sqrt{\left(-2 - \frac{\pi^2}{F^2}\right)^2 - 4}\right]}{2}$$

Optical round-trip phase of the incoming light as a function of the cavity length L and the input wavelength, lambda.

$$\theta_k := \frac{-4 \cdot \pi \cdot nc \cdot L}{\lambda_k}$$

Transmittance function of the Fabry-Perot filter.

$$T_k := \frac{1}{1 + \left[\frac{4 \cdot R}{(1 - R)^2}\right] \cdot \left(\sin\left(\frac{\theta_k}{2}\right)\right)^2}$$