Operator's Manual
Verdi™ V-2/V-5
Diode-Pumped Lasers

COHERENT.
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

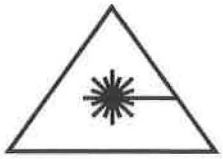
LIST OF TABLES

LIST OF CHARTS

Preface

This manual contains user information for the Verdi™ V-2/V-5 Diode-Pumped Lasers.

Read this manual carefully before operating the laser for the first time. Special attention should be given to the material in Section One, Laser Safety, that describes the safety features built into the laser.



Use of controls or adjustments or performance of procedures other than those specified in this manual may result in hazardous radiation exposure.

Use of the system in a manner other than that described herein may impair the protection provided by the system.

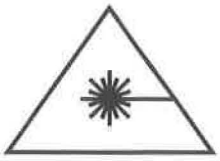
U.S. Export Control Laws Compliance

It is the policy of Coherent to comply strictly with U.S. export control laws.

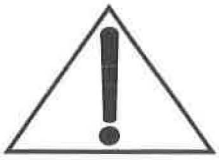
Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification should be obtained from Coherent or an appropriate U.S. Government agency.

Symbols Used in This Manual and on the Laser System



This symbol is intended to alert the operator to the danger of exposure to hazardous visible laser radiation.

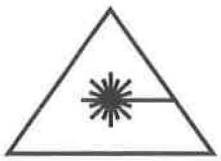


This symbol is intended to emphasize the presence of important operating instructions.

SECTION ONE: LASER SAFETY

Optical Safety

Laser light, because of its special properties, poses safety hazards not associated with light from conventional sources. The safe use of lasers requires that all laser users, and everyone near the laser system, are aware of the dangers involved. The safe use of the laser depends upon the user being familiar with the instrument and the properties of coherent, intense beams of light.



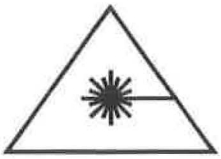
Direct eye contact with the output beam from the laser will cause serious damage and possible blindness.

The greatest concern when using a laser is eye safety. In addition to the main beam, there are often many smaller beams present at various angles near the laser system. These beams are formed by specular reflections of the main beam at polished surfaces such as lenses or beamsplitters. While weaker than the main beam, such beams may still be sufficiently intense to cause eye damage.

Laser beams are powerful enough to burn skin, clothing or paint. They can ignite volatile substances such as alcohol, gasoline, ether and other solvents, and can damage light-sensitive elements in video cameras, photomultipliers and photodiodes. The laser beam can ignite substances in its path, even at some distance. The beam may also cause damage if contacted indirectly from reflective surfaces. For these reasons, and others, the user is advised to follow the precautions below.

1. Observe all safety precautions in the preinstallation and operator's manual.
2. Extreme caution should be exercised when using solvents in the area of the laser.
3. Limit access to the laser to qualified users who are familiar with laser safety practices and who are aware of the dangers involved.
4. Never look directly into the laser light source or at scattered laser light from any reflective surface. Never sight down the beam into the source.
5. Maintain experimental setups at low heights to prevent inadvertent beam-eye encounter at eye level.

6. As a precaution against accidental exposure to the output beam or its reflection, those using the system should wear laser safety glasses as required by the wavelength being generated.
7. Avoid direct exposure to the laser light. The intensity of the beam can easily cause flesh burns or ignite clothing.
8. Use the laser in an enclosed room. Laser light will remain collimated over long distances and therefore presents a potential hazard if not confined.
9. Post warning signs in the area of the laser beam to alert those present.
10. Advise all those using the laser of these precautions. It is good practice to operate the laser in a room with controlled and restricted access.



Laser safety glasses can present a hazard as well as a benefit; while they protect the eye from potentially damaging exposure, they block light at the laser wavelengths, which prevents the operator from seeing the beam. Therefore, use extreme caution even when using safety glasses.

Safety Features and Compliance to Government Requirements

The following features are incorporated into the instrument to conform to several government requirements. The applicable United States Government requirements are contained in 21 CFR, subchapter J, part II administered by the Center for Devices and Radiological Health (CDRH). The European Community requirements for product safety are specified in the Low Voltage Directive (LVD) (published in 73/23/EEC and amended in 93/68/EEC). The Low Voltage Directive requires that lasers comply with the standard EN 61010-1 "Safety Requirements For Electrical Equipment For Measurement, Control and Laboratory Use" and EN60825-1 "Radiation Safety of Laser Products". Compliance of this laser with the (LVD) requirements is certified by the CE mark.

Laser Classification

The governmental standards and requirements specify that the laser must be classified according to the output power or energy and the laser wavelength. The Verdi V-2/V-5 Lasers are classified as Class IV based on 21 CFR, subchapter J, part II, section 1040-10 (d). According to the European Community standards, Verdi V-2/V-5 lasers are classified as Class 4 based on EN 60825-1, clause 9. In this manual, the classification will be referred to as Class 4.

Protective Housing

The laser head is enclosed in a protective housing that prevents human access to radiation in excess of the limits of Class I radiation as specified in the Federal Register, July 31, 1975, Part II, Section 1040.10 (f) (1) and Table 1-A/EN 60825-1, clause 4.2 except for the output beam, which is Class IV.

Laser Radiation Emission Indicators

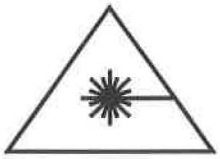
The appropriately labeled lights on both the power supply and the laser head illuminate approximately 30 seconds before laser emission can occur. Amber lights are used so that they will be seen when the proper type of safety glasses are used [CFR 1040.10(f)(5)/EN 60825-1, clause 4.6].

Beam Attenuator

A beam attenuator, or shutter, prevents contact with laser radiation without the need to switch off the laser [CFR 1040.10 (f)(6)/EN 60825-1, clause 4.7].

Operating Controls

The laser controls are positioned so that the operator is not exposed to laser emission while manipulating the controls [CFR 1040.10(f)(7)/EN 60825-1, clause 4.8].



Use of controls or adjustments or performance of procedures other than those specified in the manual may result in hazardous radiation exposure.

Use of the system in a manner other than that described herein may impair the protection provided by the system.

Location of Safety Labels

Refer to Figure 1-1 for a description and location of all safety labels. These include warning labels indicating removable or displaceable protective housings, apertures through which laser radiation is emitted and labels of certification and identification [CFR 1040.10(g), CFR 1040.2, and CFR 1010.3/ EN60825-1, Clause 5]].

Electromagnetic Compatibility

The European requirements for Electromagnetic Compliance (EMC) are specified in the EMC Directive (published in 89/336/EEC).

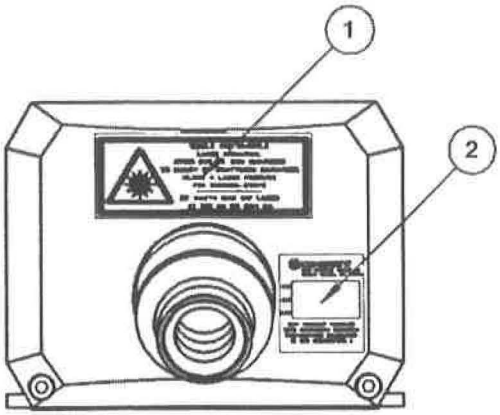
Conformance (EMC) is achieved through compliance with the harmonized standards EN55011 (1991) for emission and ENC50082-1 (1992) for immunity.

The laser meets the emission requirements for Class B, group 1 as specified in EN55011 (1991).

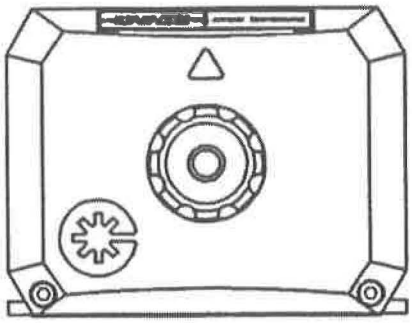
Compliance of this laser with the (EMC) requirements is certified by the CE mark.

LASER HEAD

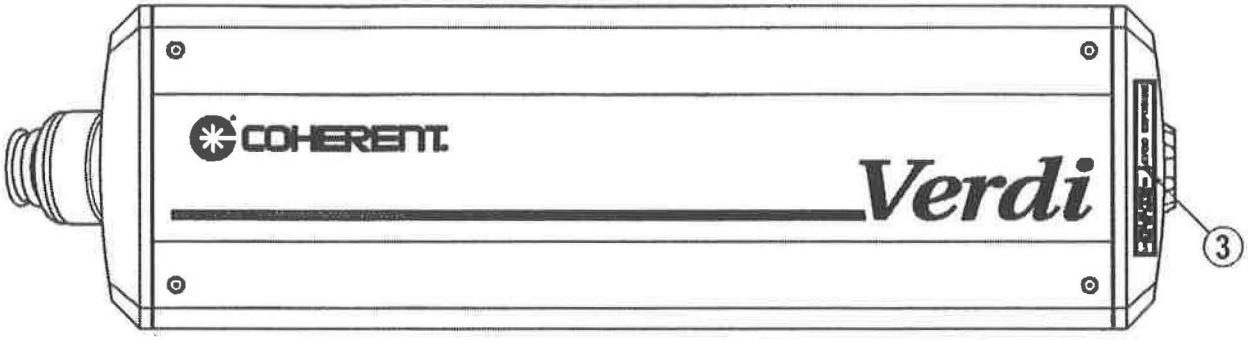
REAR VIEW



FRONT VIEW



TOP VIEW



POWER SUPPLY

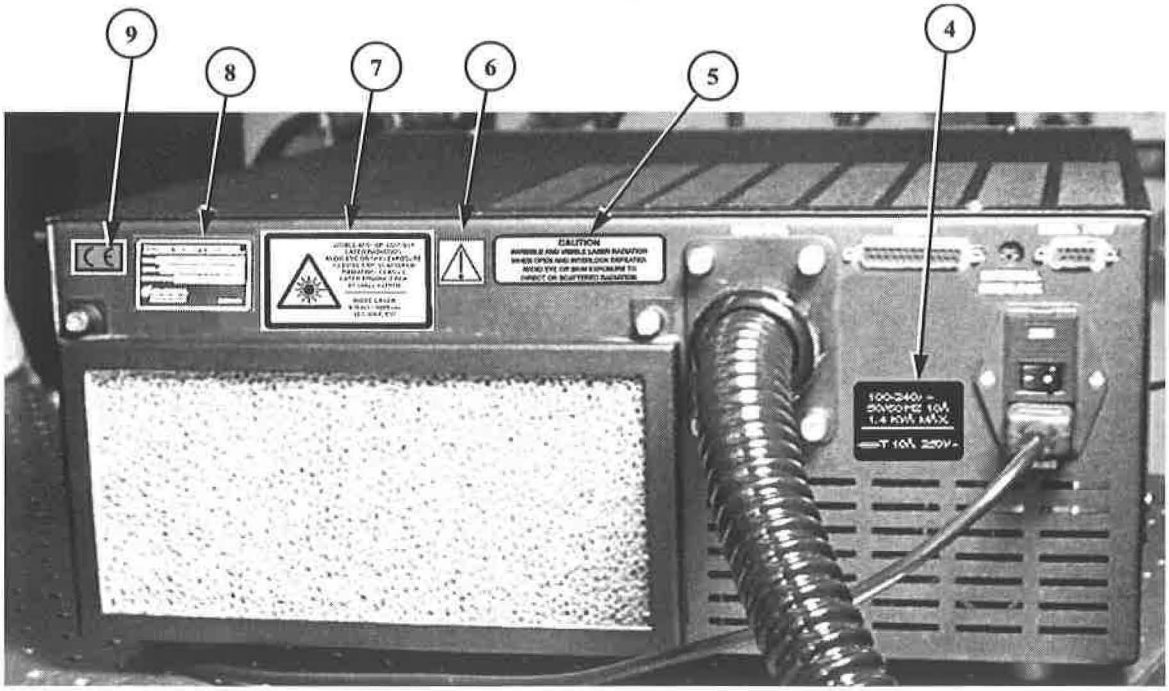


Figure 1-1. Safety Features and Labels (Sheet 1 of 3)

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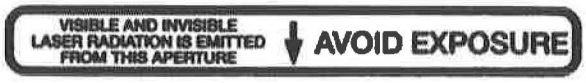
2.



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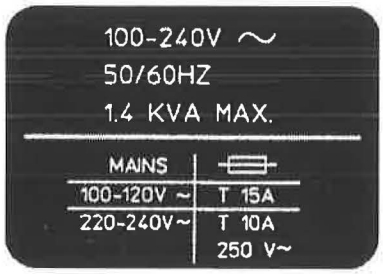

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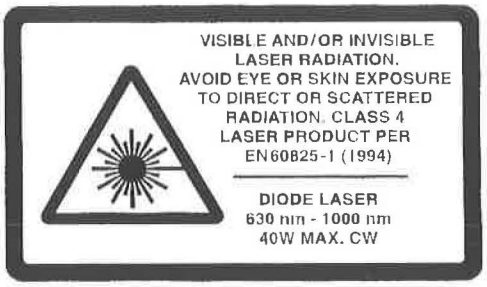
Figure 1-1. Safety Features and Labels (Sheet 2 of 3)

6.



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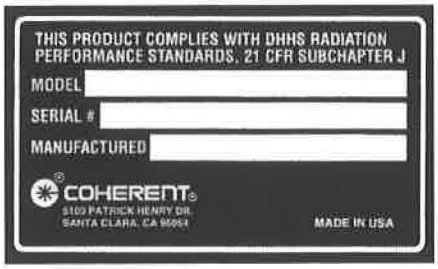


8.

9.

Figure 1-1. Safety Features and Labels (Sheet 3 of 3)

SECTION TWO: DESCRIPTION AND SPECIFICATIONS

System Description

The Verdi V-2/V-5 laser (Figure 2-1) is a compact solid-state diode-pumped, frequency-doubled Nd:Vanadate (Nd:YVO_4) laser that provides single-frequency green (532 nm) output at power levels greater than 2 Watts/5 Watts. Single frequency operation results in lower noise in the green output.

The Verdi V-2/V-5 laser consists of the laser head and power supply connected by an umbilical. The umbilical contains fiber optic cables to transmit light from the diode bar in the power supply to the laser head. It also houses electrical cables that provide control and monitoring signals between the laser head and power supply.

The laser head is shown mounted on a riser/heat sink. The riser/heat sink can be the passive version or the water cooled version depending on the operating environment.

The passive riser/heat sink alone does not possess sufficient mass to maintain the laser head base below 55°C and accordingly should be mounted on a thermally conductive surface as described in the installation section.

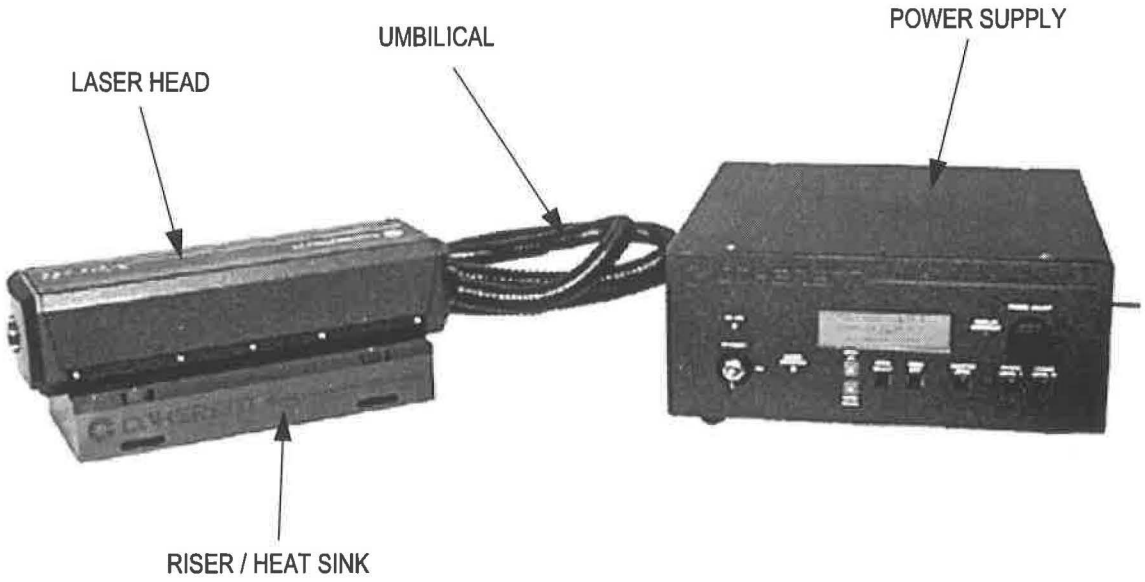


Figure 2-1. Verdi V-2/V-5 Laser

Laser Head

The major optical elements, Figure 2-2, in the hermetically sealed head include: Vanadate, as the gain medium, LBO, as the doubling crystal, an etalon, as the single-frequency optic, an optical diode, astigmatic compensator, two pump mirrors, and two end mirrors. All optical components are mounted on Invar for strength and stability.

The temperature of the Vanadate and etalon are controlled by TECs (thermo-electric coolers) which are capable of heating or cooling the optical element. The temperature of the LBO is controlled by a resistive heater. Accumulated heat in the laser head is dissipated by an optional riser/heat sink mounted on the laser head baseplate. Baseplate temperature is monitored by a CPU in the power supply which will shut the system down if the laser head temperature reaches 55°C.

The laser head utilizes a Neodymium Vanadate (Nd:YVO_4) crystal with the pump power provided by fiber delivery.

The nonlinear medium is a Type I, non-critically phase matched LBO crystal held at approximately 148°C. Unidirectional operation is achieved using an optical diode. Since the laser is a unidirectional, homogeneously broadened system, it tends to run naturally single frequency, with the etalon reinforcing this behavior.

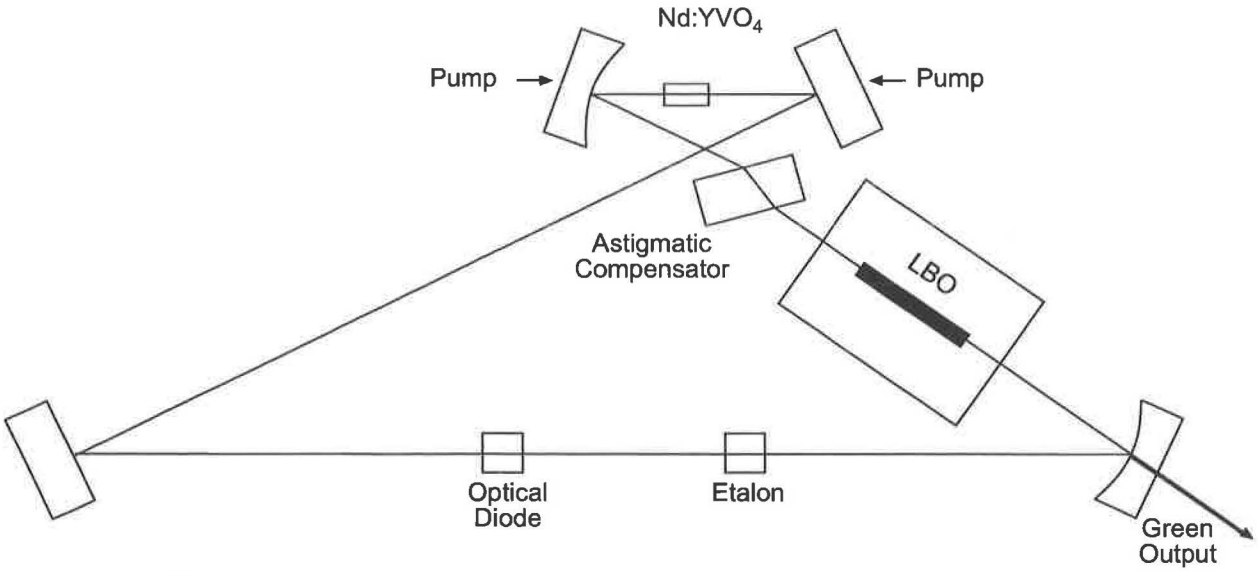


Figure 2-2. Laser Head Optical Schematic

Power Supply

The main functions of the power supply are: to supply DC power for the laser diode system that pumps the gain medium in the laser head, control six servo loops, provide cooling for the laser diode assemblies, control and monitor the laser output, and to provide data storage and a user interface.

Servo Loops

The CPU controlled servo loops are briefly described below. Additional information is located in Section Seven, Principles of Operation.

- Light loop – A photodiode in the laser head monitors the laser output through the CPU. The CPU controls the output power from the Verdi V-2/V-5 lasers based on the photodiode and in conjunction with the requested power from the power supply front panel.
- LBO temperature – The LBO doubling crystal is held at approximately 148°C by a resistive heater. To prevent rapid change of temperature that may cause LBO crystal damage during warm-up, the CPU regulates a slow ramp-up to operating temperature. This typically lasts less than 30 minutes. In case of loss of AC power due to a power failure or inadvertantly turning off the rear panel power switch, the laser is equipped with a battery powered, CPU controlled, cool down feature. This feature gradually lowers the LBO temperature to room temperature.
- Diode temperature – Diode operating temperature is held constant by TEC's. Excess heat is dissipated by forced air cooling through heat sinks. The diode heat sinks are located within the power supply.
- Vanadate and etalon temperature – These optical components are maintained at preset levels by TECs.

Laser Diode Assembly

Two laser diode assemblies are located in the power supply. Each assembly is controlled and monitored by the CPU. The assembly contains a FAP-I™ (fiber array package- integrated) which houses a diode bar and a TEC.

For additional information on the laser diode assemblies, refer to Section Seven, Principles of Operation.

Specifications

Specifications for the Verdi V-2/V-5 lasers are listed in Table 2-1.

Table 2-1. Specifications

PARAMETER	SPECIFICATION
Output Power	2 watts (V-2), 5 watts (V-5)
Wavelength	532 nm
Beam Diameter[1]	2.25 mm ±10%
Beam Divergence[2]	0.35 mrad ±10%
M^2	<1.1
Power Stability[3]	±1%
Noise[4]	<.02% rms
Polarization	>100:1, vertical, linear
Linewidth[5]	< 5 MHz rms
Pointing Stability[6]	<5 µrad/°C

All specifications are subject to change without notice.

[1] $1/e^2$ at exit port.

[2] Full-angle divergence.

[3] Measured over 2 hours after a 15 minute warm-up.

[4] Measured from 10 Hz to 1 GHz.

[5] Measured over 50 msec with a thermally stabilized reference etalon.

[6] 25°C to 40°C temperature change.

SECTION THREE: INSTALLATION

Receiving and Inspection

Inspect shipping containers for signs of rough handling or damage. Indicate any such signs on the bill of lading. Report any damage immediately to the shipping carrier, and to Coherent Order Administration Department (800-438-6323) or to an authorized Coherent representative.

Retain shipping containers. The containers will be required if the system is returned to the factory for service. The containers may also be needed to support a shipping damage claim.

Three people are recommended to unpack and transport the Verdi V-2/V-5. The power supply which weighs 70 pounds should be lifted by two people while the laser head which weighs 22.2 pounds can be lifted by the third person. The laser head and power supply are connected by the umbilical.

Installation Kit

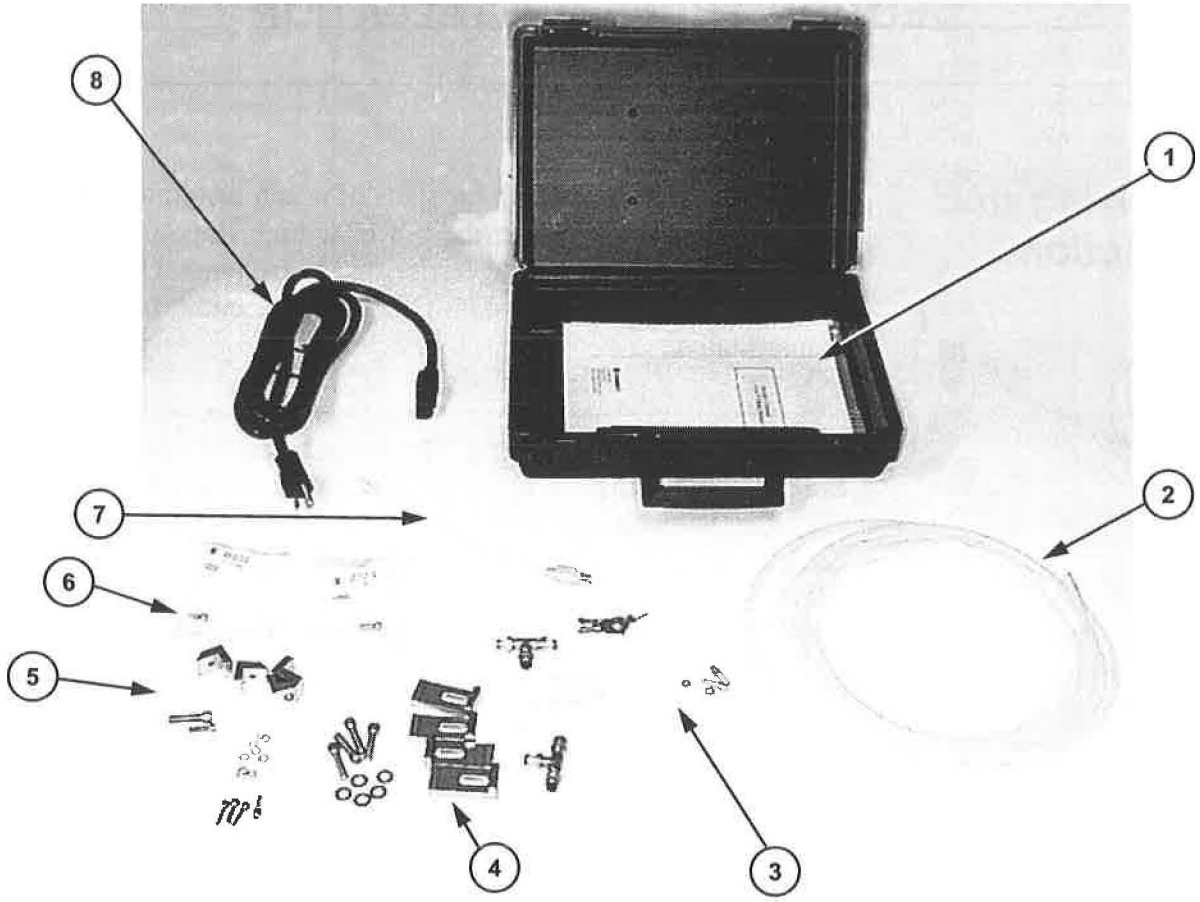
The installation kit (Figure 3-1) contains the necessary hardware for Verdi V-2/V-5 installation.

Installing the Laser Head

The laser head is shipped with either a passive or a water-cooled riser/heat sink. This riser/heat sink maintains the Verdi V-2/V-5 output beam at a suitable height for pumping a laser such as the Coherent Mira.

A passive riser/heat sink when mounted on a thermally conductive surface (such as an optical table) provides sufficient heat dissipation for the laser head under normal ambient conditions. The temperature of the laser head baseplate is monitored by the Verdi V-2/V-5 power supply and is displayed on the power supply front panel. Power dissipation through the baseplate is typically 30 to 35 Watts (50 Watts maximum). The Verdi V-2/V-5 will shut down if the baseplate temperature exceeds 55°C.

An optional water-cooled riser/heat sink is available for use with a chiller.



1. Operator's manual
2. Cooling water lines
3. Cooling water lines hardware
4. Riser/heat sink installation hardware
5. Laser head/heat sink mounting hardware
6. Dowel pins - laser head/heat sink
7. Interlock connector
8. AC power cord

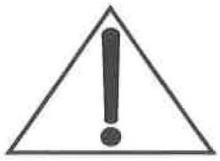
Figure 3-1. Installation Kit

The laser head is shipped with a protective plastic plate installed over the baseplate. Leave the plastic plate in place until laser head is ready for installation.

1. Remove the packing material from the riser/heat sink (Figure 3-2).
2. Insert two dowel pins (Figure 3-1, item 6) into the riser/ heat sink dowel holes (Figure 3-2, item 1) ball end up.

Avoid damage to the laser head baseplate which is milled to a flatness of ±0.1 mm. This tolerance provides maximum thermal conduction between the baseplate and the mounting surface.

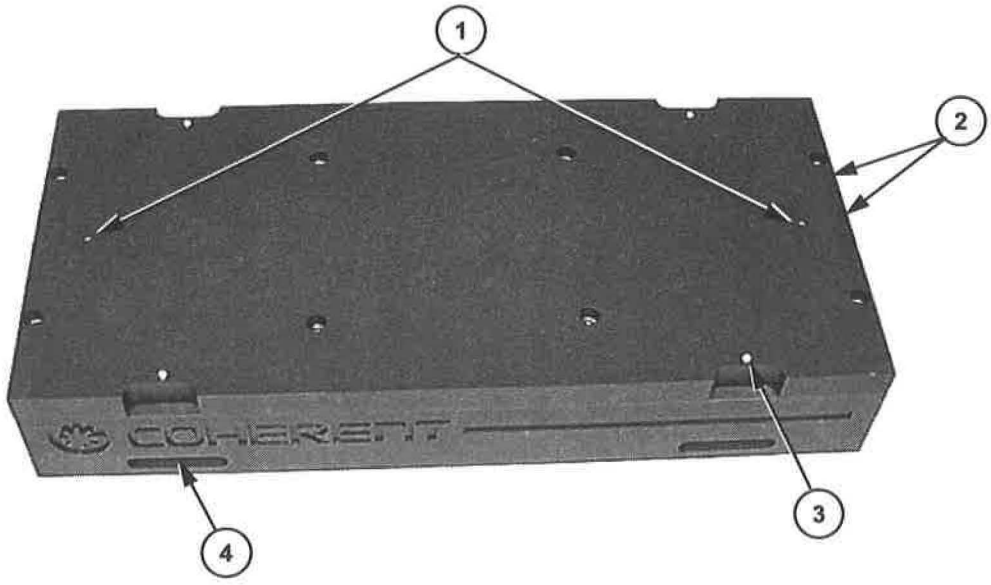
Keep the umbilical as straight as possible while avoiding rotating the laser head with respect to the power supply.



Do not apply thermal compound or any other material on the laser head baseplate or on the riser/heat sink.

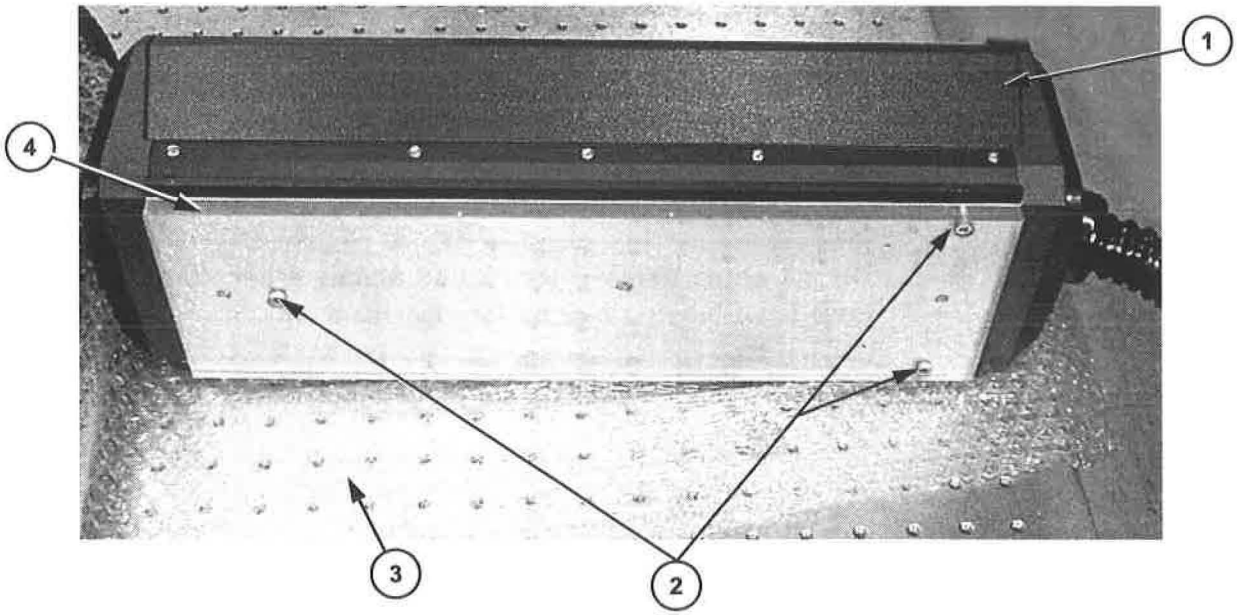
3. Remove the laser head and power supply from the shipping crate and place the laser head on a protected surface (to avoid scratching the cover) on its side as shown on Figure 3-3. Remove the 3 screws (Figure 3-3, item 2) securing the protective plastic cover (item 4) to the laser head baseplate. Any scratches, damage, or contamination of the baseplate will reduce the thermal conduction between the baseplate and the mounting surface.

4. Refer to Figure 3-4 for the dowel pin positions on the bottom of the laser head and carefully place the laser head over the dowel pins and onto the riser/heat sink.



1. Dowel holes (2)
2. Cooling water inlet and outlet
3. Laser head clamp screw holes (4)
4. Optical table clamp mounts (4)

Figure 3-2. Riser/Heatsink



1. Laser head
2. Protective plastic cover retaining screws (3)
3. Protective material
4. Protective plastic cover

Figure 3-3. Laser Head Base – Protective Cover Installed

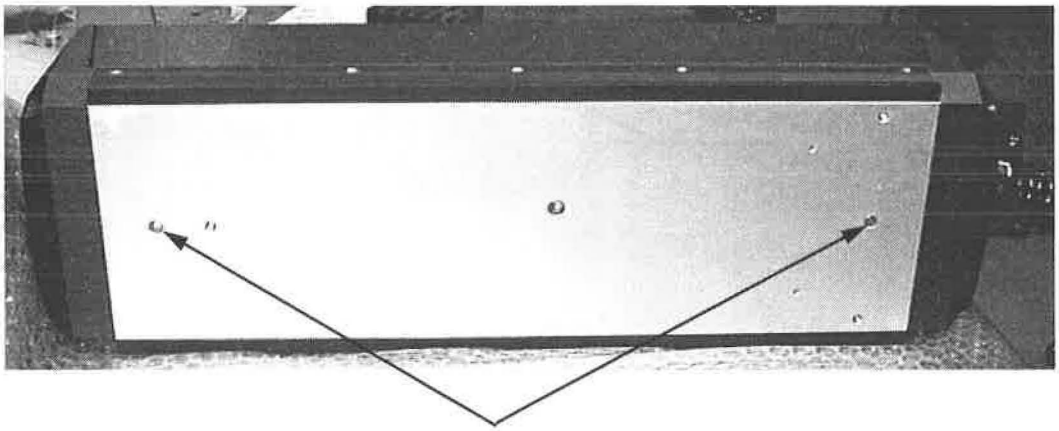


Figure 3-4. Laser Head Base – Protective Cover Removed

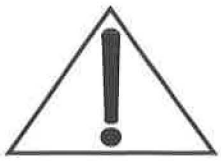
Do not use excessive force when clamping the Verdi V-2/V-5 to the riser/heat sink.

5. Use 4 laser head clamps (Figure 3-1, item 5) to secure the laser head to the riser/heat sink as shown on Figure 4-1. Tighten the 4 clamps firmly using an Allen head wrench.

6. Proceed to the section titled, Installing the Power Supply. The riser/heat sink clamps and chiller connection will be installed during the final installation procedures.

Installing the Power Supply

1. Locate the power supply in a convenient location, preferably away from heat producing sources. Ensure the cooling intake and exhaust (rear, top, and left side) are not blocked or obstructed.



The system will not operate with the interlock open. For additional information on the interlock including the connection of an external interlock circuit, refer to the section titled, External Interlock.

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2. Install the interlock connector (Figure 3-1, item 7) on the rear of the power supply in the location shown on Figure 4-2.

   The interlock connector may be located in the installation kit or may be attached to the umbilical.

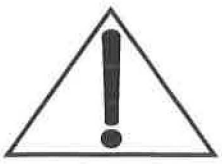
3. Install the AC power cord on the rear of the power supply in the location shown on Figure 4-2. Do not connect the AC power cord at this time.

   Each locality should inspect the power cord and install the proper connector if necessary. The connector should be installed in a properly grounded outlet with a maximum of 16 Ampere service for proper overcurrent and earth fault protection.

4. Proceed to the section titled, Final Installation and Initial Turn-On.

Final Installation and Initial Turn-On Procedures

After installing the laser head and power supply in accordance with paragraphs titled, Installing the Laser Head, and Installing the Power Supply, complete the installation as follows:



Excessively tight fiber bends (less than a 5 inch radius) can cause permanent damage.

1. Position the power supply and laser head in the operating position with the umbilical as straight as possible. Ensure that the umbilical has a bend radius of 5 inches or greater. A distance of 6 to 24 inches is recommended between the Verdi V-2/V-5 output and the laser being pumped.
2. If a water-cooled system is used, position the chiller in the operating position. Fill and prepare the chiller in accordance with the chillers' operator's manual.
3. Cut the cooling water lines (Figure 3-1, item 2) to the appropriate lengths and use the water lines hardware (Figure 3-1, item 3) to connect the riser/heat sink to the chiller. Use teflon tape on the threads and install the 2 washers from the installation kit over the threads, when connecting the brass ferrule to the riser/heat sink. Check the system for leaks.
4. If a passive riser/heat sink will be used, ensure the riser/heat sink is mounted on a thermally conductive surface (such as an optical table) that provides sufficient heat dissipation to maintain the laser head baseplate below 55°C, preferably below 40°C.
5. Use 4 riser/heat sink clamps (Figure 3-1, item 4) to secure the system to the optical table as shown on Figure 4-1. Tighten the two front clamps firmly using an Allen head wrench. Tighten the two rear clamps finger tight only.
6. Connect power supply to facility power. Ensure all packing materials have been removed.
7. Perform the cold start procedure located in Section Three, Operation, in the operator's manual.

External Interlock

The system will not operate with the interlock open. An interlock connector is located on the power supply rear panel. The interlock status is monitored by the CPU. If the interlock is open, a message will be displayed on the power supply front panel.

An external interlock circuit can be connected to the laser system and wired to a door switch to provide additional operating safety. When the door is opened, the laser will shut down. Press MENU EXIT key to clear the fault and continue operation.

To incorporate an external safety interlock circuit into the laser system, turn off the laser and remove the jumper from the interlock connector on the power supply rear panel. Attach a user furnished external interlock circuit to this connector. Any external interlock circuit should be equivalent to a mechanical closure of the circuit.

Table 3-1. Utility Requirements

PARAMETER	REQUIREMENT
Power Requirements	100 to 240 VAC[1][2]
Maximum Current	10 Amps @ 100 VAC
Cooling: Laser head: Power supply:	 Riser/heat sink[3] Air-cooled with ambient air

Note: All specifications and requirements are subject to change without notice.

[1] The power supply is autoranging and will accommodate the full range of input voltages without hardware changes.

[2] The electrical service should have a main power disconnect switch located in close proximity to the laser. The main power disconnect switch shall be clearly marked as the disconnecting device for the laser, and shall be within easy reach of the operator.

[3] The passive riser/heat sink must be mounted on a conductive surface capable of maintaining the laser head baseplate at less than 55°C. An optional riser/heat sink and chiller or chill plate can also be used. Refer to the paragraph titled, Installing the Laser Head, for additional information on removing waste heat from the laser head.

Table 3-2. Environmental Requirements

PARAMETER	REQUIREMENT
Operating temperature	15 to 35°C (50 to 104°F)
Relative humidity	5 to 95%
Altitude	Sea level to 10,000 feet

Table 3-3. Dimensions and Weights

	POWER SUPPLY	LASER HEAD	UMBILICAL	HEAT SINK
Length	45.09 cm (15.75 in)	45.7 cm (18.3 in)	3 meters (10 feet)	38.2 cm (15.28 in)
Width	43.51 cm (17.13 in)	13.97 cm (5.5 in)	——	17.5 cm (7.0 in)
Height	17.78 cm (7.0 in)	10.92 cm (4.3 in)	——	6.5 cm (2.6 in)
Weight	31.5 kg (70 lbs)	10 kg (22.2 lbs)	1.8 kg (4 lbs)	11.9 kg (26.55 lbs)
Diameter	——	——	3.75 cm (1.5 in)	——

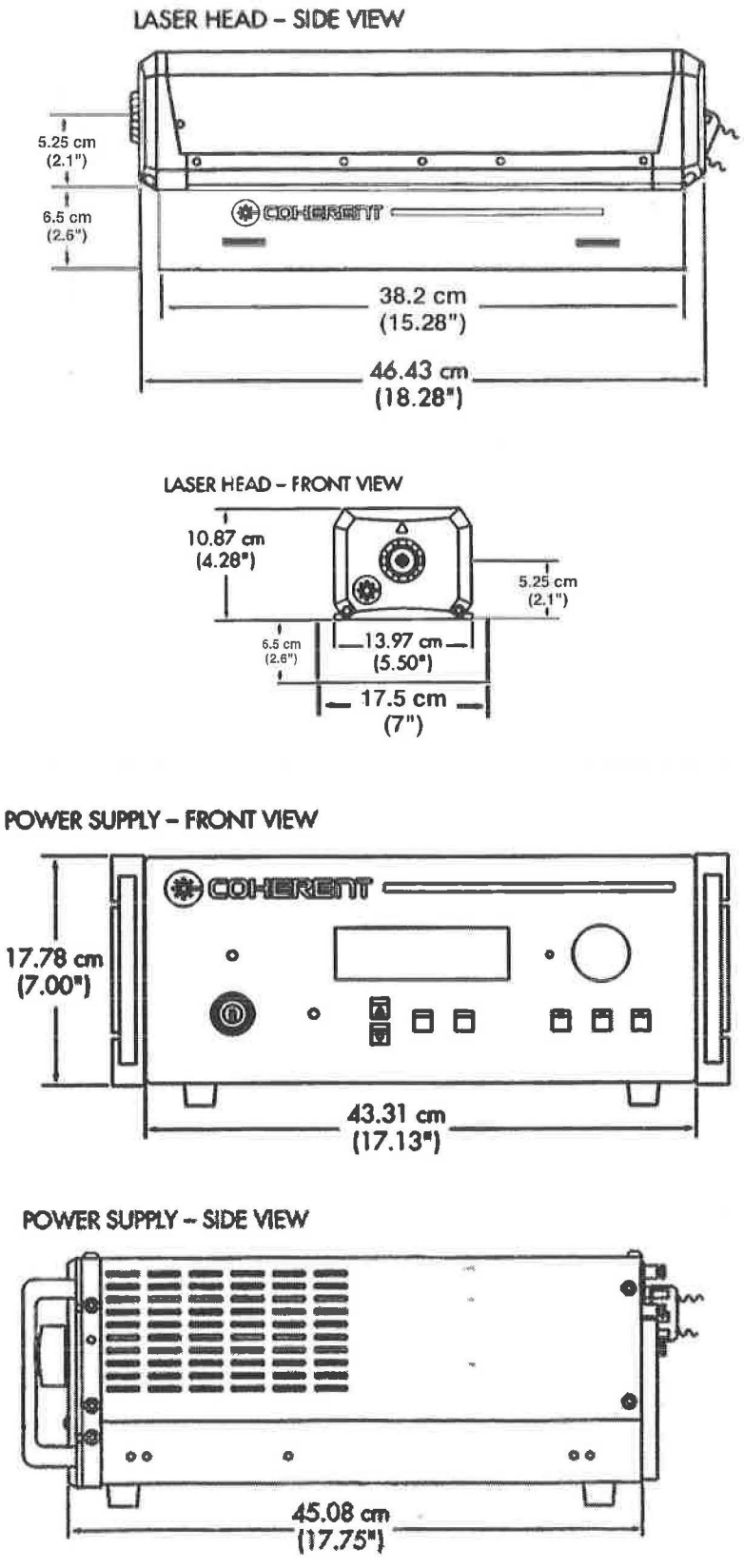
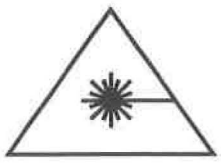


Figure 3-5. Dimensions

SECTION FOUR: OPERATION

Operation



Wear laser safety glasses to protect against the radiation generated from the laser. It is assumed that the operator has read Section One, Laser Safety, and is familiar with laser safety practices and the dangers involved. Ensure all personnel in the area are wearing laser safety glasses.

Table 4-1. Operating States

STATE	SWITCH POSITION	STATUS
OFF	• Power Switch (rear panel): OFF. • All other switches: Any position.	All functions off (except LBO CPU until cool-down is complete).
STANDBY	• Power Switch (rear panel): ON. • Key switch: STANDBY.	Laser diodes off. Vanadate temperature servo on. LBO temperature servo on. Etalon temperature servo on.
ON	• Power Switch (rear panel): ON. • Key switch: ON.	Laser diodes on. Vanadate temperature servo on. LBO temperature servo on. Etalon temperature servo on.

Turn-on

Ensure the keyswitch is in the STANDBY position prior to performing the "Cold Start" Turn-on procedure. Turning the keyswitch to the On position will result in a fault being displayed until the LBO reaches operational temperature.

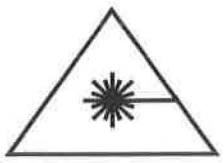
Turn-on (Cold Start)

The cold start procedure should be used when the Verdi V-2/V-5 power supply rear panel power switch has been Off for more than 30 minutes (laser in the OFF state as described in Table 4-1). In this condition, all servos are off and the Verdi V-2/V-5 has to stabilize the servos which can take up to 30 minutes. During this time, the laser diodes cannot be turned on. For additional information on the LBO heater ramp-up and stabilization, refer to the paragraph titled, Thermal Management, located in Section Seven, Principles of Operation.

Cold start can also be accomplished when the laser is being externally controlled using a computer. Refer to Tables 5-3 and 5-4 for a list of RS-232 commands and queries.

1. Set the Power Switch on the power supply rear panel to On. The AC power and LASER EMISSION indicators will light. If an indicator does not light, refer to Section Six, Maintenance and Service.
2. If the laser system is equiped with a chiller, it should now be turned on. Verify that there are no cooling line connection leaks at the Verdi riser/heat sink, and at the chiller.
3. The power supply display will indicate "System warming up". Refer to Figure 4-4 for the front panel displays and menus.
4. If the system is equiped with a chiller, verify that the chiller water temperature is set to approximately 20 °C. Adjust the temperature setpoint as required.
5. Set the output power to the desired level using the POWER ADJUST knob. The output power can be adjusted to 0.01 watts to facilitate beam alignment.
6. Allow 30 minutes for the heaters and TE coolers to achieve operating temperature. The status of all servos can be viewed by scrolling to the Servo Status Screen.

   Once this process is complete, the display will indicate "Standby". The system is now ready for key on.



Ensure the laser output is blocked or is directed at an intended target. Ensure all personnel in the area are wearing laser safety glasses.

7. Open the shutter by pressing the SHUTTER OPEN pushbutton on the power supply front panel.

8. Laser light will be available from the laser head after a delay of approximately 5 seconds.

It is highly recommended that a weekly log book of diode current (read from front screen) vs. output power level be maintained. Such a record would prove to be very useful should the performance of the laser system come into question.

LBO Optimization (Optional Step)

If diode current increases 10% or more over the initial installation value (or current baseline value) to achieve the same output power, use the "LBO Optimization" menu shown in Table 4-5 to perform the LBO optimization routine. The procedure for running the LBO Temperature Optimization routine can be found in Section Six.

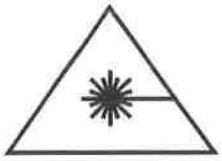
Daily Turn-on (Warm Start)

A warm start can be performed when the Verdi V-2/V-5 power supply rear panel power switch has been on for more than 30 minutes (laser in standby as described in Table 4-1). The recommended daily operation of the Verdi V-2/V-5 is to use this warm start turn-on procedure in conjunction with the turn-off procedure that leaves the rear panel power switch in the ON state.

If the laser power supply has been off for more than 30 minutes (AC ON indicator not lit), refer to the procedure titled, "Turn-on (Cold Start)".

Warm start can also be accomplished when the laser is being externally controlled using a computer. Refer to Tables 5-3 and 5-4 for a list of RS-232 commands and queries.

1. If the system is equiped with a chiller, verify that there are no cooling line connection leaks at the Verdi riser/heat sink, and at the chiller. Verify that the chiller water temperature is set to approximately 20 .°C. Adjust the setpoint temperature as required.
2. The LASER EMISSION indicator should be on. If the indicator is not on, refer to Section Six, Maintenance and Service. Turn the key switch on the power supply front panel to ON.
3. The main menu will appear on the power supply front panel display. Refer to Figure 4-4 for a description of the display menus.



Ensure the laser output is blocked or is directed at an intended target. Ensure all personnel in the area are wearing laser safety glasses.

4. Laser light will be available from the laser head after a delay of at least 5 seconds.
5. Open the shutter by pressing the SHUTTER OPEN pushbutton on the power supply front panel.
6. If necessary, adjust the POWER ADJUST knob for the desired output power level. The output power can be adjusted to 0.01 watts to facilitate beam alignment.

It is highly recommended that a weekly log book of diode current (read from front screen) vs. output power level be maintained. Such a record would prove to be very useful should the performance of the laser system come into question.

LBO Optimization (Optional Step)

If diode current increases 10% or more over the initial installation value (or current baseline value) to achieve the same output power, use the "LBO Optimization" menu shown in Table 4-5 to perform the LBO optimization routine. The procedure for running the LBO Temperature Optimization routine can be found in Section Six.

Turn-off

Turn-off (Daily Use)

When the Verdi V-2/V-5 is being used on a daily basis, turn-off normally consists of turning the key switch to the STANDBY position. This shuts off the laser diodes and places the Verdi V-2/V-5 in standby as described in Table 4-1. This method avoids the heater ramp-up cycle described above in the paragraph titled, Turn-on (Cold Start).

Do not turn off the power switch on the power supply rear panel. Refer to the paragraph below titled, Complete Shutdown, if all power is to be removed from the system.

For additional information on heater ramp-up and ramp-down, refer to Section Seven, Principles of Operation.

Turn-off can also be accomplished when the laser is being externally controlled using a computer. Refer to Tables 5-3 and 5-4 for a list of RS-232 commands and queries.

Turn-off (Complete Shut-down)

This procedure will remove all power from the Verdi V-2/V-5 and is recommended for performing system maintenance or if no operation is anticipated for extended periods of time. Use the cold start procedure to turn the Verdi V-2/V-5 back on after a complete shut-down.

Complete shut-down can also be accomplished when the laser is being externally controlled using a computer. Refer to Tables 5-3 and 5-4 for a list of RS-232 commands and queries.

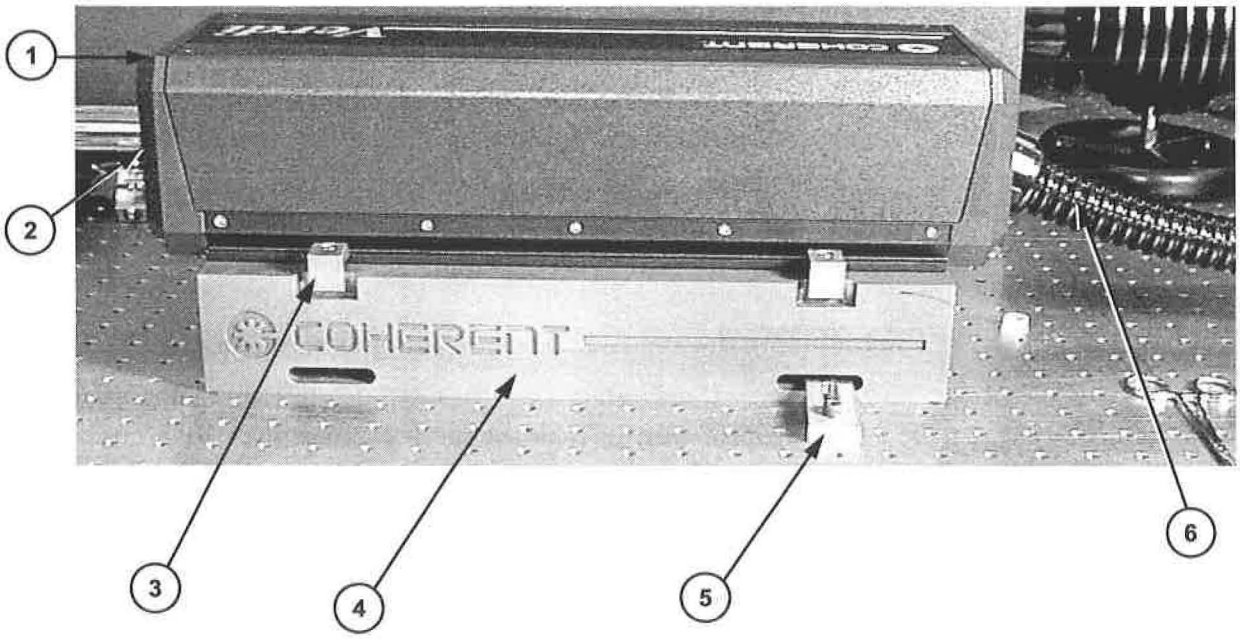
1. Turn the key switch power supply front panel to STANDBY.
2. Access and select the LBO SETTINGS submenu. Press the MENU SELECT pushbutton to start the LBO cool-down cycle.

To avoid unnecessary use of the backup battery, do not turn off the power switch on the power supply rear panel while the Verdi V-2/V-5 is in the cool-down cycle. This takes approximately 45 minutes.

3. When the LBO temperature decreases below 40°C, turn off the power switch on the power supply rear. During the cool-down cycle the LBO temperature can be monitored from the MAIN SCREEN or from the LBO SETTINGS submenu.

   Turning off the power switch (or removing AC power from the power supply) will cause the internal battery to be used to complete the LBO cool-down cycle rather than AC power. This causes unnecessary drain on the battery. For maximum battery life, use the LBO cool down menu. For additional information, refer to the paragraph titled, Thermal Management located in Section Seven, Principles of Operation.
4. If the system is equiped with a chiller it should be turned off at this time.
5. Remove the key to prevent inadvertant turn-on.

Controls, Indicators, and Features

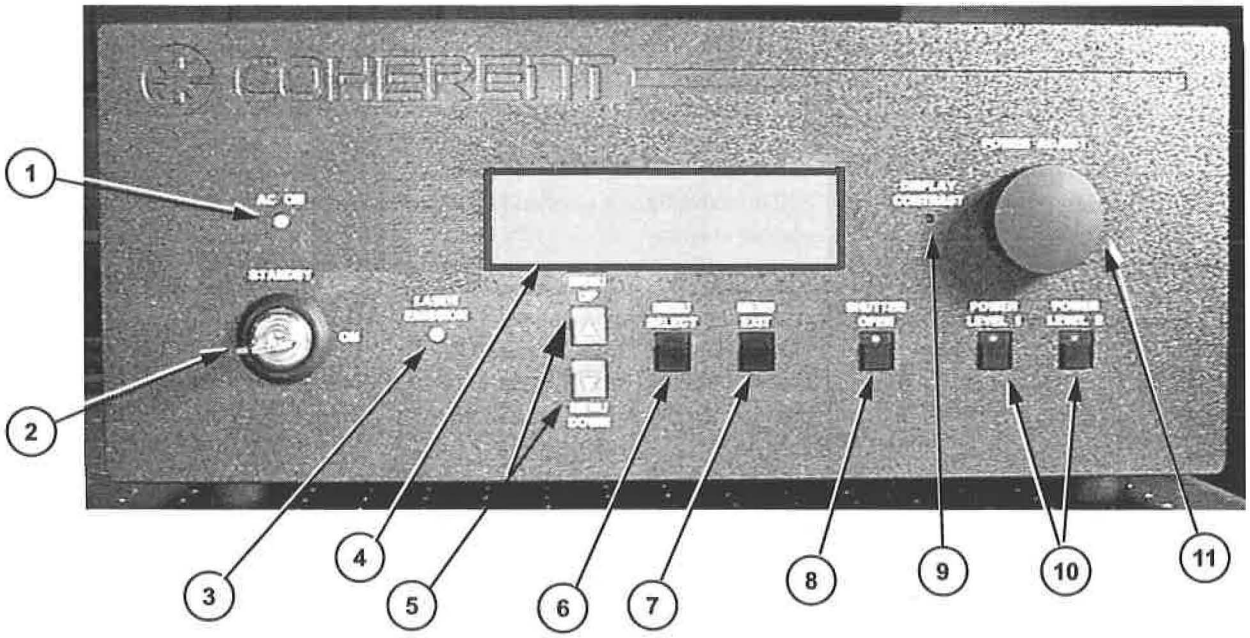


1. Emission indicator
2. Exit window
3. Clamps (4)
4. Riser/heat sink
5. Stable table clamps (4)
6. Umbilical

Figure 4-1. Laser Head Features

Table 4-2. Laser Head Features

ITEM	CONTROL	FUNCTION
1	Emission indicator	Lights when laser emission is possible.
2	Exit window	532 nm laser light is emitted from this window when the laser is on and the shutter is open.
3	Clamps (4)	Secures the laser head to the riser/heat sink.
4	Riser/Heat sink	The passive riser/heat sink transfers heat from the laser head baseplate to the mounting surface. The mounting surface must be capable of dissipating the transferred heat such that the baseplate temperature does not exceed 55°C. The optional water-cooled riser/heat sink needs no additional mounting surface to maintain the base temperature below 55°C.
5	Optical table clamps (4)	Secures the heat sink to the mounting surface. The mounting surface must be capable of dissipating the transferred heat such that the baseplate temperature does not exceed 55°C.
6	Umbilical	Houses the fiber optic and electrical cables that provides an interface between the laser head and power supply.

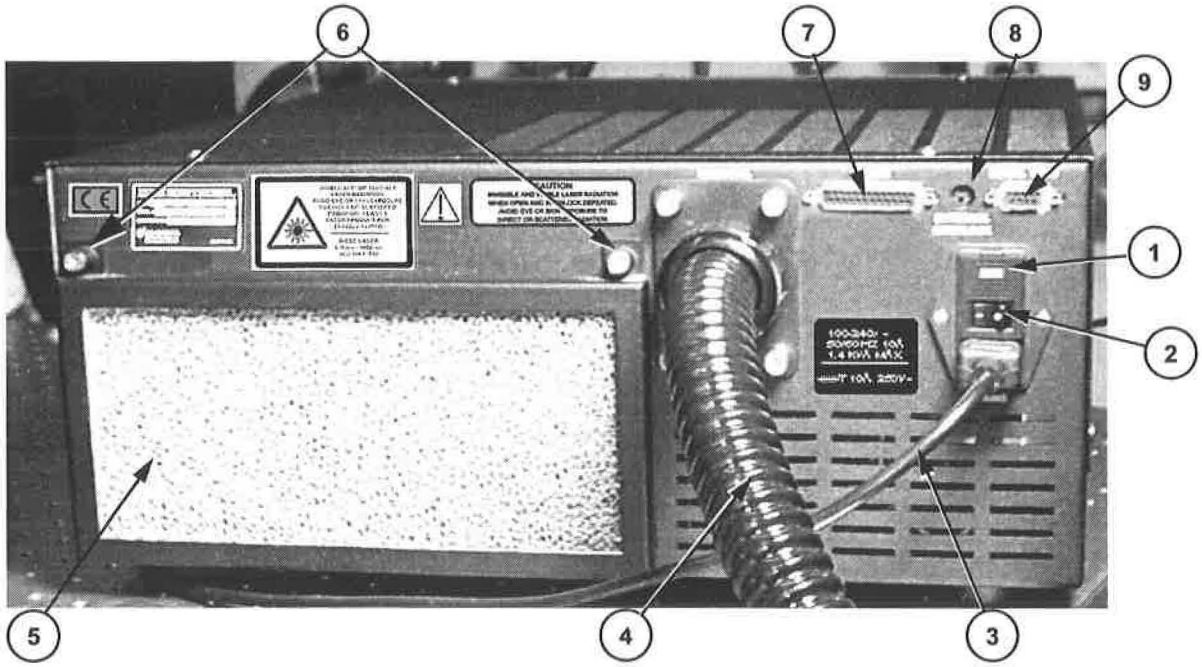


1. AC ON indicator
2. Key switch
3. LASER EMISSION indicator
4. Display
5. MENU UP/DOWN pushbuttons
6. MENU SELECT pushbutton
7. MENU EXIT pushbutton
8. SHUTTER OPEN pushbutton indicator
9. DISPLAY CONTRAST adjust
10. POWER LEVEL 1/2 pushbutton indicators
11. POWER ADJUST knob

Figure 4-2. Power Supply Front Panel Controls and Indicators

Table 4-3. Power Supply Front Panel Controls and Indicators

ITEM	CONTROL	FUNCTION
1	AC ON indicator	Lights when power is applied to the power supply via the power switch on the rear panel.
2	Key switch	The key switch can place the Verdi V-2/V-5 either in the STANDBY or ON state. Functionality in these states are summarized in Table 4-1. The key can be removed when in STANDBY position to prevent unauthorized operation. The key cannot be removed when in ON position.
3	LASER EMISSION indicator	Lights when laser emission is possible.
4	Display	Displays system status, operating parameters, and diagnostic data. Refer to Figure 4-3 for a description of the displays.
5	MENU UP/DOWN pushbuttons	Allows scrolling through the menus. Refer to Figure 4-3 for a description of the displays and menus.
6	MENU SELECT push-button	Allows selection of the indicated menu.
7	MENU EXIT push-button	Exits current menu. Can also be used to clear inactive faults as described in the troubleshooting charts in Section Six, Maintenance and Service.
8	SHUTTER OPEN pushbutton indicator	Remotely opens and closes the external shutter on the laser head. When the shutter is closed, the laser will go to idle at minimum power. If the POWER ADJUST knob is not touched after the shutter is closed, the laser will return that power setting once the shutter is opened. If the POWER ADJUST knob is adjusted after the shutter is closed, then the laser will ramp to the new setting after the shutter is opened.
9	DISPLAY CONTRAST adjust	Allows adjustment of the display by user for best viewing.
10	POWER LEVEL 1/2 pushbutton indicators	Allows selection of 2 preset laser output power levels. To preset a power level, press the pushbutton to light the LED. Use the POWER ADJUST knob to set the power, then press the pushbutton again so that the LED is off. The new power value is then stored.
11	POWER ADJUST knob	Allows continuous adjustment of output power level from threshold to maximum power.



1. Fuses
2. Power ON/OFF switch
3. Power cord
4. Umbilical
5. Air filter
6. Air filter retaining nuts (2)
7. Reserved connector
8. EXTERNAL INTERLOCK connector
9. SERIAL PORT connector

Figure 4-3. Power Supply Rear Panel Controls and Indicators

Table 4-4. Power Supply Rear Panel Controls and Indicators

ITEM	CONTROL	FUNCTION
1	Fuse	250 V, 10A, time delay fuse provides electrical protection.
2	Power ON/OFF switch	Applies/removes all power from the Verdi V-2/V-5. Refer to the shut-down procedures to avoid unnecessary use of the internal battery.
3	Power cord	Connects the power supply to 110 VAC facility power.
4	Umbilical	Houses electrical cables and the fiber optic cables.
5	Air filter	Removes dirt and contamination from the power supply cooling air.
6	Air filter retaining nuts	Secures air filter to power supply.
7	Reserved connector	Reserved for future use.
8	EXTERNAL INTER-LOCK connector	Allows connection of an external interlock. The laser will not operate when this connector is open. Refer to the Section Three, Installation, for additional information on the interlock.
9	SERIAL PORT connector	Allows external computer control of the Verdi V-2/V-5. Refer to Section Five for additional information on external computer control including commands, queries, and system requirements.

Menu Displays

Figure 4-4 shows the Verdi V-2/V-5 Main Display and the Base Menu screen. The base menu screen can be reached from the Main Display screen by depressing the SELECT pushbutton on the power supply front panel. Once in the Base Menu screen, the user can return to the Main Display screen by depressing the power supply EXIT pushbutton.

Navigation through a list of submenus, such as that in the Base Menu screen, is achieved by depressing the UP and DOWN arrow keys on the power supply front cover. When the selection arrow (see Figure 4-4) points to the desired submenu, that item can be activated by depressing the SELECT pushbutton. Depressing the EXIT pushbutton will deactivate the submenu, and re-display the Base Menu screen. Examples and explanations for all Verdi V-2/V-5 submenus can be found in Table 4-5.

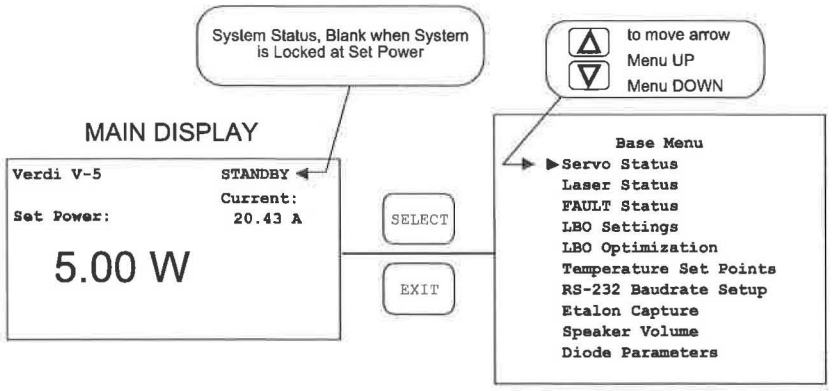


Figure 4-4. Menus

System Status Messages

The current status of the laser system is displayed in the upper right-hand corner of the Main Display screen of the software, see Figure 4-4. Possible messages are:

- **System Warming Up:** Displayed while LBO crystal is heating.
- **Standby:** Displayed if power supply front panel keyswitch is in the STANDBY position.
- **Laser Seeking:** Displayed while system is ramping the diode current up to achieve set power. If the system is displaying this message, but the diode current is not changing, there is most likely one or more servo loops in the seek mode of operation. See the software Servo Status Screen for additional information.

- **Shutter Closed:** Displayed if system head shutter has not been opened.
- **Fault Active:** Displayed if there is an active system fault. See the Fault Status Screen for additional information.
- **RS232 Key Standby:** Displayed if the laser system is placed in STANDBY via the RS-232 command.

Fault Handling

In case of a fault, the CPU closes the shutter, sets the laser diode current to zero, and displays the Fault Status Screen. For example:

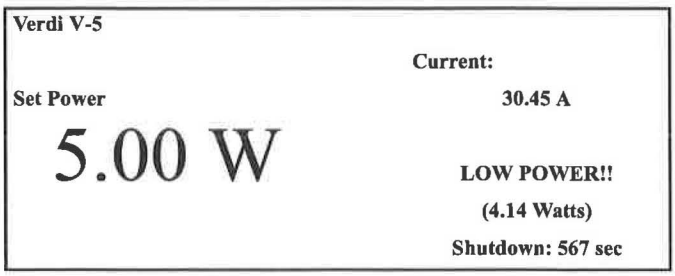
```
!!!!!!!!!!!!!!!!!!!!!
FAULT CONDITION!
ERROR CODE #16
Diode 1 Over Current Fault
!!!!!!!!!!!!!!!!!!!!!

Push EXIT to continue
```

To clear a fault the appropriate troubleshooting steps should be taken (refer to Section Six for a complete listing of system faults and troubleshooting procedures), the power supply key switch should be turned to the Standby position, and the EXIT pushbutton depressed.

If the fault condition no longer exists, exiting the Fault Status Screen clears the fault, once the keyswitch is turned to the On position, laser operation returns to the state it was in before the fault occurred except for the shutter, which remains closed. If the fault condition still exists, the system message FAULT ACTIVE will be displayed in the Main Display screen.

Low Power Warning

If the system maximum diode drive current is reached, and the requested output power is not obtained, the power supply will beep and a LOW POWER warning message will be displayed in the lower right-hand corner of the Main Display screen.



If this message is observed, the output power setpoint should be decreased until it is less than the value in the warning message and the LBO optimization routine should be run. If the warning message reappears after the LBO optimization has been performed, the local Coherent service representative should be contacted.

If the output power setpoint is not decreased the system will shut down with a Diode Over Current fault after 600 seconds.

Table 4-5. Submenus (Sheet 1 of 3)

Servo Status Screen			
Servo:	State	W/deg	C Drive
Laser:	lock	5.00	21000
LBO:	lock	146.00	4784
Vanadate:	lock	35.00	-1776
Etalon:	lock	46.00	428
Diode 1:	*seek	16.51	-1413
Diode 2:	lock	15.97	-2158

Displays the Verdi servo status': OPEN, LOCKED, SEEKING, *SEEK, or FAULT. The value for the laser light loop servo is in Watts and the other values (temperature servos) are °C.

*SEEK indicates the algorithm optimizing the diode temperature is running. This algorithm optimizes the diode temperature such that maximum Vanadate absorption of the IR pump is achieved. Functionally, this lowers the diode pump, and thus operating current, necessary to achieve specified power. *SEEK is invoked automatically provided the system is running at 80% or greater output power.

Laser Status Screen			
S/W Version	:	6.00, 9/2/99	
Heatsink #1 T	:	22.32 C	
Heatsink #2 T	:	23.50 C	
Baseplate T	:	28.40 C	
HEAD Hrs	:	54.75	Sys: 7/23/99
DIODE1 Hrs	:	64.05	I: 24.40 A
DIODE2 Hrs	:	54.15	I: 22.00 A

Displays Verdi V-2/V-5 status and system information.

Table 4-5. Submenus (Sheet 2 of 3)

Fault Status Screen SYSTEM OK:	If faults are active, the fault codes and descriptions will be displayed. Refer to Table 6-1 for a complete list of faults and associated corrective actions. Refer to the paragraph titled, Fault Handling, for additional information such as how to clear faults.
LBO Settings T: 146.04 Set: 146.00 Drive: 4788 LBO Heating Press SELECT to start COOLING Press EXIT for NO CHANGE	Access this menu to initiate a heating or cooling of the LBO crystal. For example, the cool-down cycle is initiated from this menu during the "complete shutdown" procedure. Displays the state of the LBO servo (heating or cooling).
LBO Optimization T: 143.90 Pwr: 4.74 Drv: 6007 OK to OPTIMIZE LBO Temp Press SELECT to OPTIMIZE Tlbo Press EXIT to ABORT	This menu is used to initiate LBO optimization. Refer to the paragraph titled, LBO Temperature Optimization, located in Section Six for additional information and procedures regarding LBO Temperature Optimization.
Temperature Set Points Set Pt: 144.00 Drive: 5950.0 Read T: 144.00 Status: lock Set Pwr: 5.00W Avg I: 23.28A ->LBO Temperature Vanadate Temperature ...Etalon Temperature Diode #1 Temperature Diode #2 Temperature	Displays the various system temperature set points, actual temperatures and DAC drives required by the servo loops. Temperatures cannot be changed from this menu although the LBO temperature can be optimized using the LBO Temperature Optimization submenu.
RS-232 Baudrate Setup RS-232 Protocol: 38400, 8, N, 1 Use KNOB to adjust rate values Press SELECT to ACCEPT Press EXIT to ABORT	Allows adjustment of the baud rate (factory set to 19,200) for RS-232 communications. Refer to Section Five, External Computer Control, for additional information on baud rate.

Table 4-5. Submenus (Sheet 3 of 3)

Etalon Capture Screen Press SELECT to Capture Mode Press EXIT to return to menus	The Etalon Capture Screen flashes the laser output below lasing threshold to allow the single-frequency mode to re-center. Re-centering is automatically implemented each time the laser is turned on.
Speaker Volume Screen -> Speaker Volume HIGH Speaker Volume MEDIUM Speaker Volume LOW Speaker Volume OFF Press SELECT to change Press EXIT when done	The Speaker Volume Screen allows the audible beep (fault) volume to be adjusted.
Diode Parameters Screen Diode 1 Voltage : 1.80V Diode 1 Current : 17.50A Diode 1 Photocell : 2.50V Diode 2 Voltage : 1.79V Diode 2 Current : 17.50A Diode 2 Photocell : 2.49V	Displays diode voltage, current, and photocell values for the diodes. Recording these values on a periodic basis can be useful in evaluating the health of the system. The diode photocell voltage should be approximately 2.50 V, at maximum output power level.

SECTION FIVE: EXTERNAL COMPUTER CONTROL

How to Interface to The Verdi V-2/V-5 Lasers

This section provides details on how to interface a Verdi V-2/V-5 lasers to a remote computer through the RS-232 connector on the rear of the power supply.

The RS-232 interface is based on a set of laser control instructions, consisting of commands that affect laser operation, and queries that request the laser to return status information to the host. The instruction set is sufficient to support user-written programs that emulate the functions of the Verdi V-2/V-5 front panel.

RS-232 Command Language

Instruction Syntax for RS-232 Communication

Communication with the Verdi V-2/V-5 is by two types of instructions: commands which set the values of laser operating parameters, and queries which request the laser to return the value of an operating parameter.

Any instruction to the laser consists of a command or query written as a string of ASCII characters and terminated by a carriage return and linefeed (<CR><LF>) or a semicolon (;).

For example:

LASER = 1<CR><LF>Switches the Verdi V-2/V-5 from STANDBY to ON.

?LIGHT;Requests the laser to return the measured laser output power.

The laser will always respond to an instruction by returning a message terminated by a carriage return and linefeed. Table 5-1 lists the possible responses from the laser.

For proper handshaking, communication programs should wait until the <CR><LF> has been returned from the laser before sending the next instruction.

Table 5-1. Response from Laser after Receiving Instruction

INSTRUCTION SENT TO LASER	RESPONSE FROM LASER			
	ECHO OFF PROMPT OFF	ECHO OFF PROMPT ON	ECHO ON PROMPT OFF	ECHO ON PROMPT ON
Command + <CR><LF>	<CR><LF>	Verdi><CR> <LF>	Command + <CR><LF>	Verdi> Command + <CR><LF>
Query + <CR><LF>	Data + <CR><LF>	Verdi> Data + <CR><LF>	Query + Data + <CR><LF>	Verdi> Query + Data + <CR><LF>
Command + <CR><LF> (Illegal operand)	RANGE ERROR: + Command + <CR><LF>	Verdi> RANGE ERROR: + Command + <CR><LF>	Command + RANGE ERROR: + Command + <CR><LF>	Verdi> Command + RANGE ERROR: + Command + <CR><LF>
Command <CR><LF> (Illegal instruction)	Command Error: + Command + <CR><LF>	Verdi> Command Error: + Command + <CR><LF>	Command + Command Error: + Command + <CR><LF>	Verdi> Command + Command Error: + Command + <CR><LF>
Query<CR><LF> (Illegal instruction)	Query Error: + Query + <CR><LF>	Verdi> Query Error: + Query + <CR><LF>	Query + Query Error: + Query + <CR><LF>	Verdi> Query + Query Error: + Query + <CR><LF>

1. Multiple items will be separated by the **&** character. For example, a list of system faults will be returned as **3&5&6**.

ECHO Mode

The Verdi V-2/V-5 provides an echo mode in which each character transmitted to the laser is echoed to the host. This feature can be turned on or off using the ECHO command (see below).

PROMPT Mode

The Verdi V-2/V-5 provides an prompt mode for terminal operation in which the laser returns, for example: "Verdi> " after each command. This feature can be turned on or off using the PROMPT command (see below).

?

The single character **?** may be substituted for **PRINT** in all queries. For example:

?LIGHT is equivalent to **PRINT LIGHT**

= or :

The single characters = and : are equivalent delimiters between text and data in all commands. For example:

LASER = 0 is equivalent to **LASER: 0**

RS-232 Interface Connection

The Verdi V-2/V-5 Lasers RS-232 port configuration is described in Table 5-2, and typical cable requirements are shown in Figure 5-1. The 9-pin RS-232 port is configured as DCE (data communications equipment) device using only pins 2 (serial data out), 3 (serial data in) and 5 (signal ground). Handshake lines RTS, CTS, DTR and DSR (pins 4, 6, 7 and 8) are not used and have no connections inside the power supply.

RS-232 Port Configuration

Table 5-2. RS-232 Port Description

CONFIGURATION	DCE, NO HANDSHAKING
Data bits	8
Stop bits	1
Parity	none
Baud rate	User selectable: 1200 2400 4800 9600 19200 (default factory setting) 38400 57600 115200

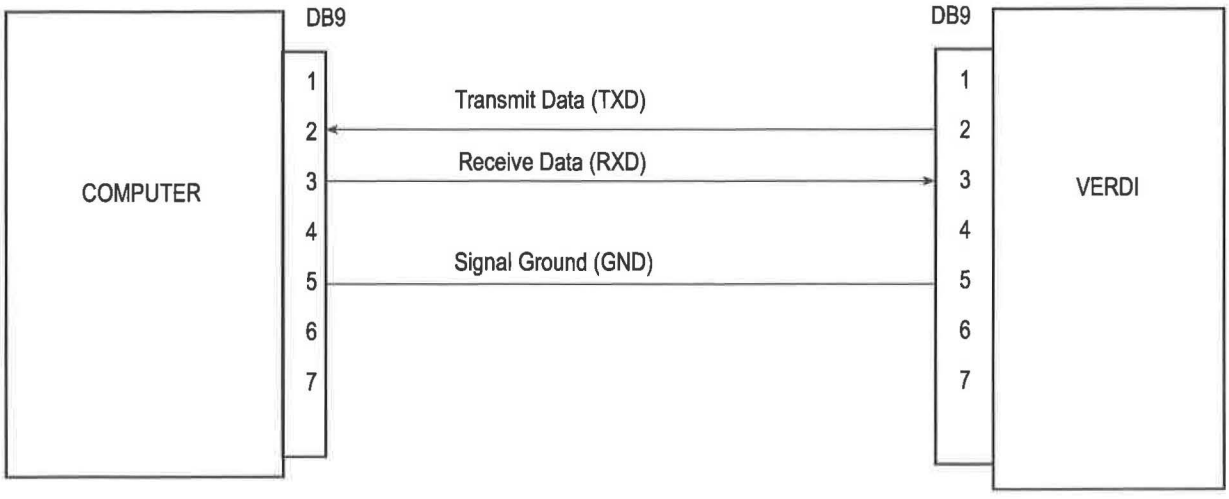


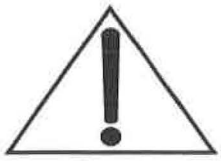
Figure 5-1. RS-232 Pin Configuration

Setting The Baud Rate

The baud rate of the 9-pin RS-232 port can be adjusted through the front panel (Figure 4-4) or by means of the SERIAL BAUDRATE = NNN command described in Table 5-1 and Table 5-2. After the baud rate is changed, the new setting will be used until it is changed (even if the system power is switched off).

To set the baud rate by the remote computer, send the **SERIAL BAUDRATE = NNN** command to the laser at the currently set baud rate. After sending this baud rate command, host computer communications port must be reinitialized to the new baud rate.

The factory set baud rate is 19200.



When an RS-232 command is issued to change a setting, the display may not update to reflect the changes taking place in the system. The user should press MENU EXIT and MENU SELECT to update the display.

Instruction Set

Tables 5-3 and 5-4 describe the instructions (long and short forms) for use in RS-232 with the Verdi V-2/V-5.

Table 5-3. RS-232 Commands

COMMANDS	ACTION PERFORMED
ECHO = n E = n	If n = 0: turn OFF echo. Characters transmitted to the laser will not be echoed to the host. If n = 1: turn ON echo. Characters transmitted to the laser will be echoed to the host. A change in echo mode will take effect with the first command sent after the echo command.
PROMPT = n > = n	If n = 0: turn ON "Verdi>" prompt. If n = 1: turn OFF "Verdi>" prompt.
LASER = n L = n	If n = 0: put laser in STANDBY (note: key OFF, then ON overrides). If n = 1: reset faults and turn on laser (key must by in ON position). Clears fault screen on power supply and fault history (?FAULT HISTORY) so lasing will resume if no active faults.
SHUTTER = n S = n	If n = 0: close external shutter. If n = 1: open external shutter.
LIGHT = nn.nnnn P = nn.nnnn	Set to light regulation at the specified output power.
LBO HEATER = n LBOH = n	If n = 0: turn off LBO heater (COOL DOWN). If n = 1: turn on LBO heater (HEATING).
FLASH = 1 FL = 1	Flash laser output below lasing threshold to allow single-frequency mode to recenter.
BAUDRATE = nnnnn B = n	Set the RS-232 Serial port baud rate to the specified value. nnnnn = 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200.
POWER = n P = nn.nnnn	Set to light regulation at the specified output power.
PRINT	Print command works the same as a query must be followed by a space
LOCK FRONT PANEL = n LFP = n	Disables user input from the front panel.

Table 5-4. RS-232 Queries

QUERIES	RETURNED INFORMATION
PRINT LASER ?L	Return: 0 if the laser is OFF (STANDBY). 1 if the laser is in ON. 2 if the laser is OFF because FAULT occurred (check faults or fault history).
PRINT KEYSWITCH ?K	Return: 0 if the keyswitch is OFF. 1 if the keyswitch is ON.
PRINT FAULTS ?F	Return a list of number codes of all active faults, separated by an **&**, or return "SYSTEM OK" if no active faults Fault codes: 1=Laser Head Interlock Fault, 2=External Interlock Fault, 3=PS Cover Interlock Fault, 4=LBO Temperature Fault, 5=LBO Not Locked at Set Temp, 6=Vanadate Temp. Fault, 7=Etalon Temp. Fault, 8=Diode 1 Temp. Fault, 9=Diode 2 Temp. Fault, 10=Baseplate Temp. Fault, 11=Heatsink 1 Temp. Fault, 12=Heatsink 2 Temp. Fault, 16=Diode 1 Over Current Fault, 17=Diode 2 Over Current Fault, 18=Over Current Fault, 19=Diode 1 Under Volt Fault, 20=Diode 2 Under Volt Fault, 21=Diode 1 Over Volt Fault, 22=Diode 2 Over Volt Fault, 25=Diode 1 EEPROM Fault, 26=Diode 2 EEPROM Fault, 27=Laser Head EEPROM Fault, 28=Power Supply EEPROM Fault, 29=PS-Head Mismatch Fault, 31=Shutter State Mismatch, 40=Head-Diode Mismatch Fault,
PRINT FAULT HISTORY ?FH	Return a list of number codes (see ?F) of all faults that have occurred since the last LASER ON command, separated by an **&**, or return "SYSTEM OK" if no latched faults. The LASER ON command or the EXIT button on the power supply when the fault screen is active will clear the fault history and fault screen.
PRINT SHUTTER ?S	Return the status of the external shutter: 0 if the shutter CLOSED. 1 if the shutter OPEN.
PRINT LIGHT ?P	Return the calibrated output power, nn.nnn, in watts.
PRINT SET LIGHT ?SP	Return the light regulation set power, nn.nnnn, in watts.

Table 5-4. RS-232 Queries (Continued)

QUERIES	RETURNED INFORMATION
PRINT CURRENT ?C	Return the measured average diode current, nn.n, in amps.
PRINT CURRENT DELTA ?CD	Return the diode current delta calibration, n.n, in amps.
PRINT DIODE1 CURRENT ?D1C	Return laser diode #1 measured current, nn.n, in amps.
PRINT DIODE2 CURRENT ?D2C	Return laser diode #2 measured current, nn.n, in amps.
PRINT BASEPLATE TEMP ?BT	Return laser head baseplate measured temperature, nn.nn, in °C.
PRINT DIODE1 TEMP ?D1T	Return laser diode #1 measured temperature, nn.nn, in °C.
PRINT DIODE2 TEMP ?D2T	Return laser diode #2 measured temperature, nn.nn, in °C.
PRINT VANADATE TEMP ?VT	Return vanadate measured temperature, nn.nn, in °C.
PRINT LBO TEMP ?LBOT	Return LBO measured temperature, nnn.nn, in °C.
PRINT ETALON TEMP ?ET	Return etalon measured temperature, nn.nn, in °C.
PRINT DIODE1 SET TEMP ?D1ST	Return laser diode #1 set temperature, nn.nn, in °C.
PRINT DIODE2 SET TEMP ?D2ST	Return laser diode #2 set temperature, nn.nn, in °C.
PRINT VANADATE SET TEMP ?VST	Return vanadate set temperature, nn.nn, in °C.
PRINT LBO SET TEMP ?LBOST	Return LBO set temperature, nnn.nn, in °C.
PRINT ETALON SET TEMP ?EST	Return etalon set temperature, nn.nn, in °C.
PRINT DIODE1 TEMP DRIVE ?D1TD	Return laser diode #1 temperature servo drive setting.

Table 5-4. RS-232 Queries (Continued)

QUERIES	RETURNED INFORMATION
PRINT DIODE2 TEMP DRIVE ?D2TD	Return laser diode #2 temperature servo drive setting
PRINT VANADATE DRIVE ?VD	Return vanadate temperature servo drive setting
PRINT LBO DRIVE ?LBOD	Return LBO temperature servo drive setting
PRINT ETALON DRIVE ?ED	Return etalon temperature servo drive setting
PRINT DIODE1 HEATSINK TEMP ?D1HST	Return laser diode #1 heat sink measured temperature, nn.nn, in °C.
PRINT DIODE2 HEATSINK TEMP ?D2HST	Return laser diode #2 heat sink measured temperature, nn.nn, in °C.
PRINT LBO HEATER ?LBOH	Return the status of the LBO heater: 0 if the LBO heater is OFF (COOL DOWN). 1 if the LBO heater is ON (HEATING).
PRINT LIGHT REG STATUS ?LRS	Return the status of the light loop servo: 0 if the servo is OPEN (current regulation). 1 if the servo is LOCKED. 2 if the servo is SEEKING. 3 if the servo has a FAULT.
PRINT DIODE1 SERVO STATUS ?D1SS	Return the status of diode #1 temperature servo: 0 if the servo is OPEN. 1 if the servo is LOCKED. 2 if the servo is SEEKING. 3 if the servo has a FAULT. 4 if the servo is OPTIMIZING.
PRINT DIODE2 SERVO STATUS ?D2SS	Return the status of diode #2 temperature servo: 0 if the servo is OPEN. 1 if the servo is LOCKED. 2 if the servo is SEEKING. 3 if the servo has a FAULT. 4 if the servo is OPTIMIZING.

Table 5-4. RS-232 Queries (Continued)

QUERIES	RETURNED INFORMATION
PRINT VANADATE SERVO STATUS ?VSS	Return the status of the vanadate temperature servo: 0 if the servo is OPEN. 1 if the servo is LOCKED. 2 if the servo is SEEKING. 3 if the servo has a FAULT.
PRINT LBO SERVO STATUS ?LBOSS	Return the status of the LBO temperature servo: 0 if the servo is OPEN. 1 if the servo is LOCKED. 2 if the servo is SEEKING. 3 if the servo has a FAULT. 4 if the servo is OPTIMIZING.
PRINT ETALON SERVO STATUS ?ESS	Return the status of the etalon temperature servo: 0 if the servo is OPEN. 1 if the servo is LOCKED. 2 if the servo is SEEKING. 3 if the servo has a FAULT.
PRINT DIODE1 HOURS ?D1H	Return the number of operating hours on laser diode 1.
PRINT DIODE2 HOURS ?D2H	Return the number of operating hours on laser diode 2.
PRINT HEAD_HOURS ?HH	Return the number of operating hours on the system head.
PRINT SOFTWARE ?SV	Return the version number of the power supply software.
PRINT AVG CURRENT AND DELTA ?ACAD	Returns the average diode current and the difference between them.
PRINT DIODE1 PHOTOCELL ?D1PC	Return light output power from diode 1 photocell.
PRINT DIODE1 5VREF SENSE ?D15V	Returns a reference voltage used to measure the temperature of Diode 1
PRINT DIODE2 PHOTOCELL ?D2PC	Return light output power from diode 1 photocell.
PRINT DIODE2 5VREF SENSE ?D25V	Returns a reference voltage used to measure the temperature of Diode 2

Table 5-4. RS-232 Queries (Continued)

QUERIES	RETURNED INFORMATION
PRINT PS HOURS ?PSH	Return number of power supply operating hours.
PRINT DIODE1 RATED CURRENT MAX ?D1RCM	Returns the maximum current diode 1 will be allowed to operate at.
PRINT DIODE2 RATED CURRENT MAX ?D2RCM	Returns the maximum current diode 2 will be allow to operate at.
PRINT DIODE1 RATED CURRENT FACTOR ?D1RCF	Returns the factor that accounts for diode aging for diode 1.
PRINT DIODE2 RATED CURRENT FACTOR ?D2RCF	Returns the factor that accounts for diode aging for diode 2.
LBO OPTIMIZER STATUS ?LBOOS	Returns the LBO optimizer status: 1 if busy optimizing 0 if not
PRINT BAUD RATE ?B	Returns the baud rate of the Verdi V-2/V-5 serial port.

SECTION SIX: MAINTENANCE AND SERVICE

Do not open the Verdi V-2/V-5 laser head. There are no user serviceable components or adjustments inside. There are dangerous high voltage currents and hazardous levels of laser energy inside the laser head. There is no cover interlock to eliminate these dangers upon removal of the laser head cover.

Troubleshooting

Table 6-1 lists possible problems/error messages with a reference to the associated troubleshooting chart located in this section.

Table 6-1. Troubleshooting/Fault Messages

PROBLEM	TROUBLESHOOTING REFERENCE
Laser does not start (no laser output)	Chart 1
Laser shuts down	Chart 2
Laser output unstable	Chart 3
AC ON indicator on power supply front panel does not light when power switch on rear panel is ON.	Chart 4
LASER EMISSION indicator on power supply front panel or on the laser head does not light when key switch is in the ON position.	[1]
[1] Contact Coherent or an authorized representative. If the laser system or components are being returned directly to Coherent, an RMA (Return Material Authorization) number is required.	
FAULT MESSAGES:	
Fault Code 1: Head Laser Emission Lamp Fault	Chart 5
Fault Code 2: External Interlock Fault	Chart 6

Table 6-1. Troubleshooting/Fault Messages (Continued)

PROBLEM	TROUBLESHOOTING REFERENCE
Fault Code 3: PS Cover Interlock Fault	Chart 7
Fault Code 4: LBO Temperature Fault	Chart 8
Fault Code 5: LBO Not Locked at Set Temperature	Chart 12
Fault Code 6: Vanadate Temperature Fault	Chart 8
Fault Code 7: Etalon Temperature Fault	Chart 8
Fault Code 8: Diode 1 Temperature Fault	Chart 8
Fault Code 9: Diode 2 Temperature Fault	Chart 8
Fault Code 10: Baseplate Temperature Fault	Chart 9
Fault Code 11: Diode Heat Sink 1 Temperature Fault	Chart 10
Fault Code 12: Diode Heat Sink 2 Temperature Fault	Chart 10
Fault Code 16: Diode 1 Over Current Fault	Chart 11
Fault Code 17: Diode 2 Over Current Fault	Chart 11
Fault Code 18: Over Current Fault	Chart 11
Fault Code 19: Diode 1 Under Voltage Fault	Chart 12
Fault Code 20: Diode 2 Under Voltage Fault	Chart 12
Fault Code 21: Diode 1 Over Voltage Fault	Chart 12
Fault Code 22: Diode 2 Over Voltage Fault	Chart 12
Fault Code 25: Diode 1 EEPROM Fault	Chart 12
Fault Code 26: Diode 2 EEPROM Fault	Chart 12
Fault Code 27: Laser Head EEPROM Fault	Chart 12
Fault Code 28: Power Supply EEPROM Fault	Chart 12

Table 6-1. Troubleshooting/Fault Messages (Continued)

PROBLEM	TROUBLESHOOTING REFERENCE
Fault Code 29: Power Supply-Head Mismatch Fault	Chart 12
Fault Code 31: Shutter State Mismatch	Chart 12
Fault Code 40: Head-Diode Mismatch Fault	Chart 12

Chart 1. Laser Does Not Start (No Light Output)

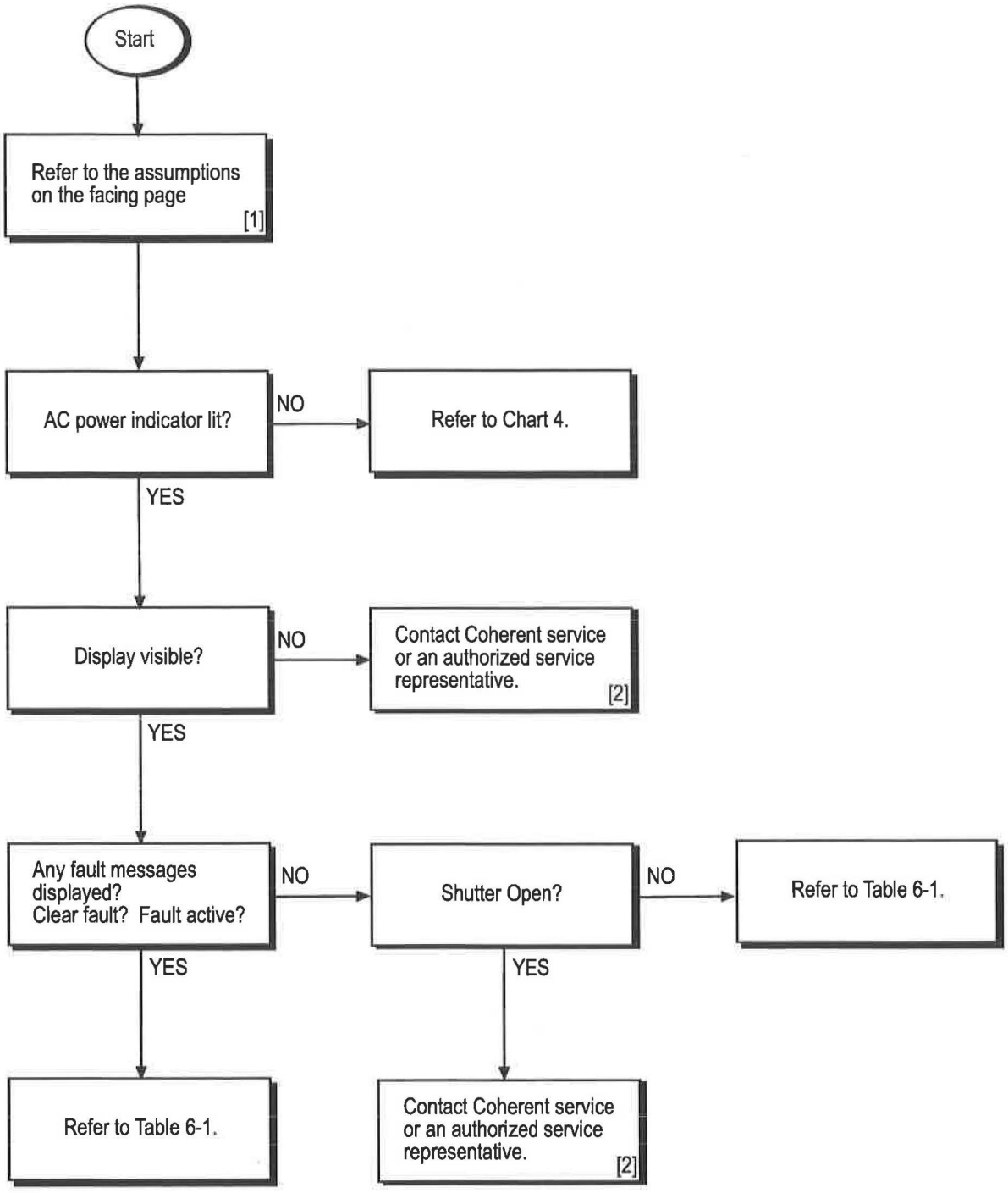


Chart 1. Laser Does Not Start (No Light Output) [Continued]

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] ASSUMPTIONS:

- The laser system has been installed in accordance with the installation procedures in Section Three, Installation.
- This procedure is not intended for re-starting a laser after it has shut down due to a fault.
- A closed shutter is not blocking output light.
- The appropriate turn-on procedures are being performed and the laser is not in a warm-up cycle.

[2] If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 2. Laser Shuts Down (No Light Output)

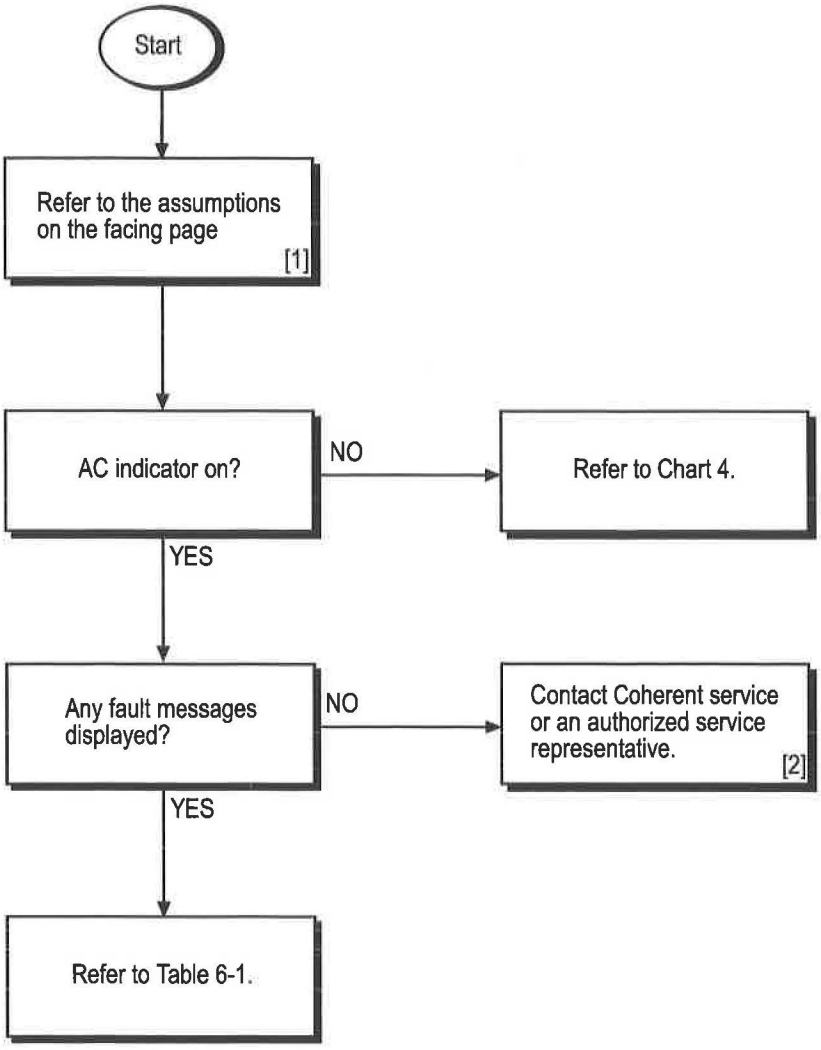


Chart 2. Laser Shuts Down (No Light Output) [Continued]

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] ASSUMPTIONS:

- The laser system had been operating immediately prior to shutdown.
- The interlocks are closed as described in Section Three, Installation. The laser will not operate with an interlock circuit open.

  If a user interlock is installed, the user interlock can be verified by temporarily replacing it with the interlock supplied with the system.

[2] If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 3. Laser Output Unstable

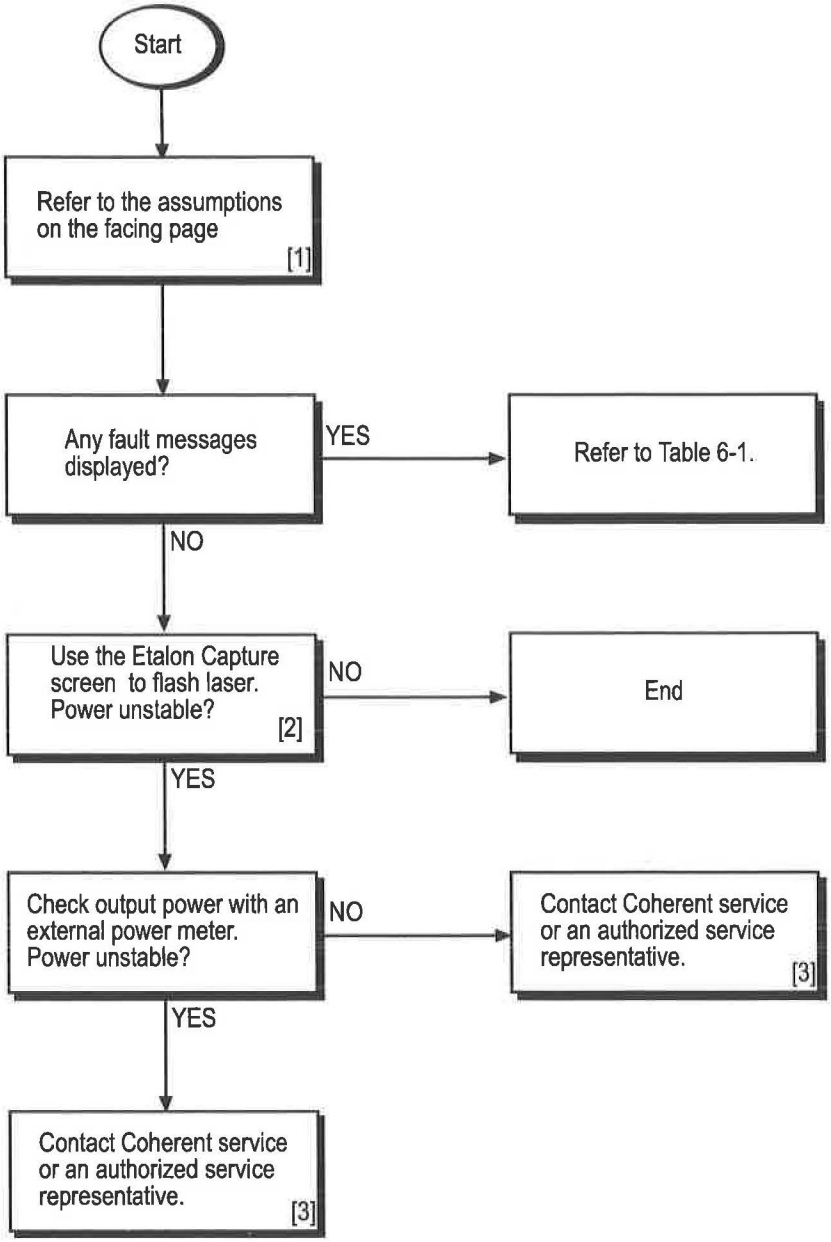


Chart 3. Laser Output Unstable [Continued]

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] ASSUMPTIONS:

- The laser system has been installed in accordance with the installation procedures in Section Three, Installation.

[2] Refer to Figure 4-4 to access the Etalon Capture Screen. Press SELECT from within the screen to flash the laser.

[3] If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 4. AC ON Indicator Does Not Light

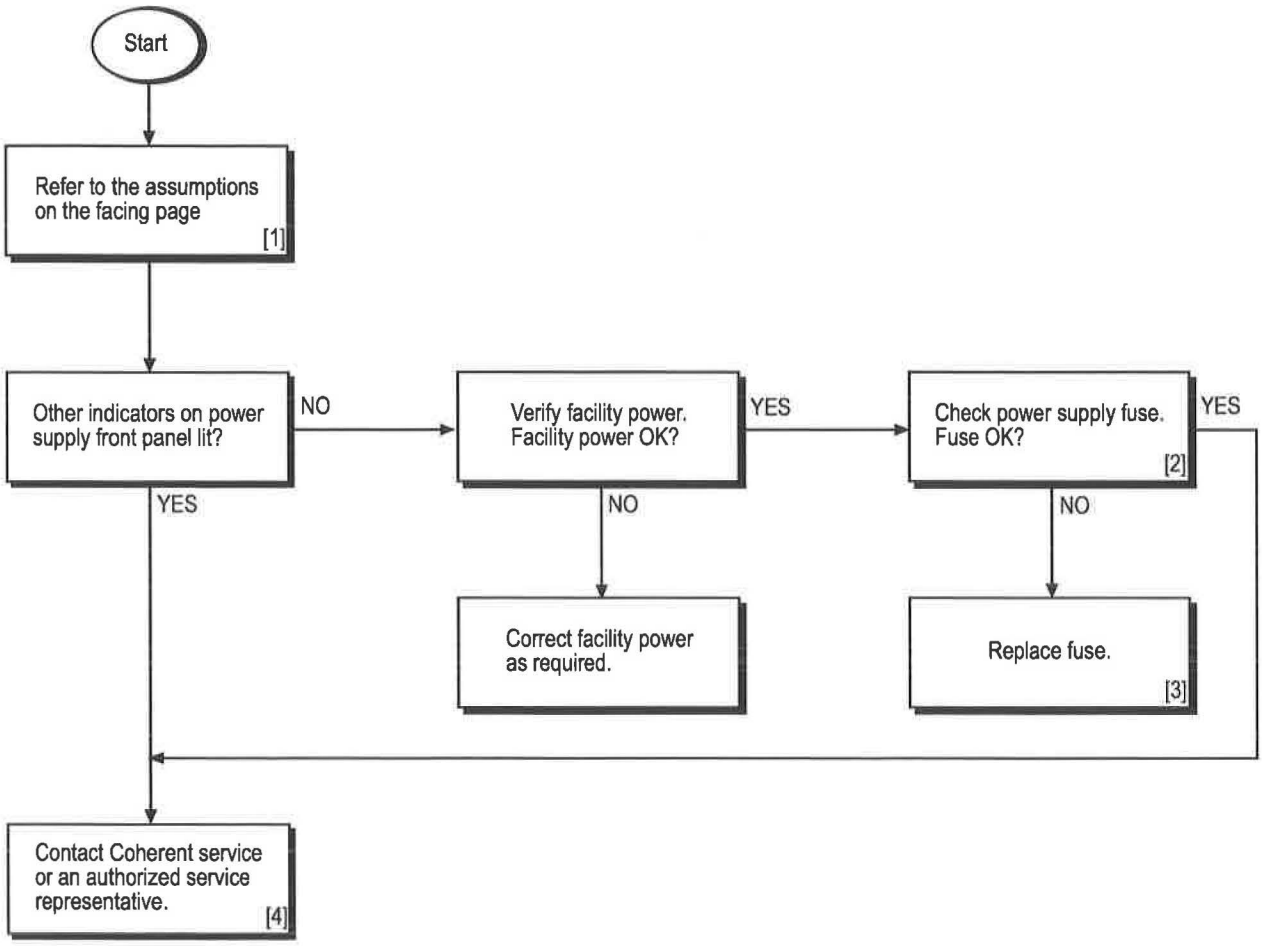


Chart 4. AC ON Indicator Does Not Light [Continued]

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] ASSUMPTIONS:

- The laser system has been installed in accordance with the installation procedures in Section Three, Installation.
- The power cord is connected to an active facility power source and the power switch on the power supply rear panel is on.

[2] After performing the Turn-Off (Complete Shut down) procedures located in Section Four, disconnect the laser system from facility power and remove the fuse (Figure 4-3, item 1) using the fuse replacement procedures located in this section. Verify continuity (closed circuit) between the two fuse terminals.

[3] Refer to the fuse replacement procedures located in this section. If the fault persists, contact Coherent or an authorized representative.

[4] If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 5. Head Laser Emission Lamp Fault

[1] Press MENU EXIT to clear the fault display.

If the fault does not clear, a fault message will appear on the main menu and on the fault status menu (Figure 4-4).

If the fault clears, open the shutter and resume operation.

[2] Ensure the umbilical is not strained or cut and that bend radius of the armored fibers is 5 inches or greater.

[3] Turn the power switch on the power supply rear panel to Off for approximately 20 seconds. Then turn the switch back to On.

[4] If the fault persists, contact Coherent or an authorized representative. If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 6. External Interlock Fault

The laser system will not operate with an open interlock circuit. Ensure the external interlock supplied with the system or an user furnished interlock is installed. Refer to the paragraph titled, External Interlock, located in Section Three, Installation.

[1] Press MENU EXIT to clear the fault display.

If the fault does not clear, a fault message will appear on the main menu and on the fault status menu (Figure 4-4).

If the fault clears, open the shutter and resume operation.

[2] Ensure the connector that is connected to the EXTERNAL INTERLOCK connector on the power supply rear panel is firmly seated.

[3] If a user interlock is installed, turn the key switch to STANDBY and replace the user interlock circuit with the external interlock supplied with the system. If the fault clears, the user interlock circuit is defective.

If the fault does not clear, verify continuity of the interlock connector.

If the fault clears, open the shutter and resume operation.

[4] Turn the power switch on the power supply rear panel to Off for approximately 20 seconds. Then turn the switch back to On.

[5] If the fault persists, contact Coherent or an authorized representative. If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 7. PS Interlock Fault

It is possible that the top cover of the power supply is not secure, turn the key switch to STANDBY and verify the power supply top cover is securely closed with all fasteners fully tightened.

[1] Press MENU EXIT to clear the fault display.

If the fault does not clear, a fault message indication will appear on the main menu and on the fault status menu (Figure 4-4).

If the fault clears, open the shutter and resume operation.

[2] Turn the power switch on the power supply rear panel to Off for approximately 20 seconds. Then turn the switch back to On.

[3] If the fault persists, contact Coherent or an authorized representative. If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 8. LBO Temperature Fault
Vanadate Temperature Fault
Etalon Temperature Fault
Diode Temperature Fault

[1] Press MENU EXIT to clear the fault display.

If the fault does not clear, a fault message will appear on the main menu and on the fault status menu (Figure 4-4).

If the fault clears, open the shutter and resume operation.

[2] Verify the set point is the same as on the test sheet. If different, contact Coherent or an authorized representative.

[3] Turn the power switch on the power supply rear panel to Off for approximately 20 seconds. Then turn the switch back to On.

[4] If the fault persists, contact Coherent or an authorized representative. If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 9. Baseplate Temperature Fault

[1] Press MENU EXIT to clear the fault display.

If the fault does not clear, a fault message will appear on the main menu and on the fault status menu (Figure 4-4).

If the fault clears, open the shutter and resume operation.

[2] Verify the laser head is installed on a riser/heat sink and the riser/heat sink is located on a surface that will dissipate heat at a rate that will maintain the baseplate temperature below 55°C.

Ensure that the ambient temperature is not abnormally high and the laser head is not located near a heat generating source.

If a suitable ambient temperature cannot be maintained or if the laser head must be located in a less than optimum location, an optional water cooled riser/heat sink is available from Coherent.

[3] Turn the power switch on the power supply rear panel to Off for approximately 20 seconds. Then turn the switch back to On.

[4] If the fault persists (and the ambient temperature and laser head location meet the above requirements), contact Coherent or an authorized representative. If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 10. Diode Heat Sink Temperature Fault

[1] Press MENU EXIT to clear the fault display.

Turn the key switch on the power supply front panel to STANDBY for a few seconds. Then turn the key switch back to ON.

Open the shutter and resume operation.

[2] Verify the following:

- The cooling fans are not obstructed,
- The rear, top, and left side of the power supply are not obstructed,
- The air filter is not clogged (do not remove the air filter when the fans are rotating),
- The power supply is not located near a heat source,
- The ambient temperature is not excessively high.

[3] If the fault persists (and the ambient temperature and power supply location meet the above requirements), contact Coherent or an authorized representative. If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 11. Diode Over Current Fault
Over Current Fault

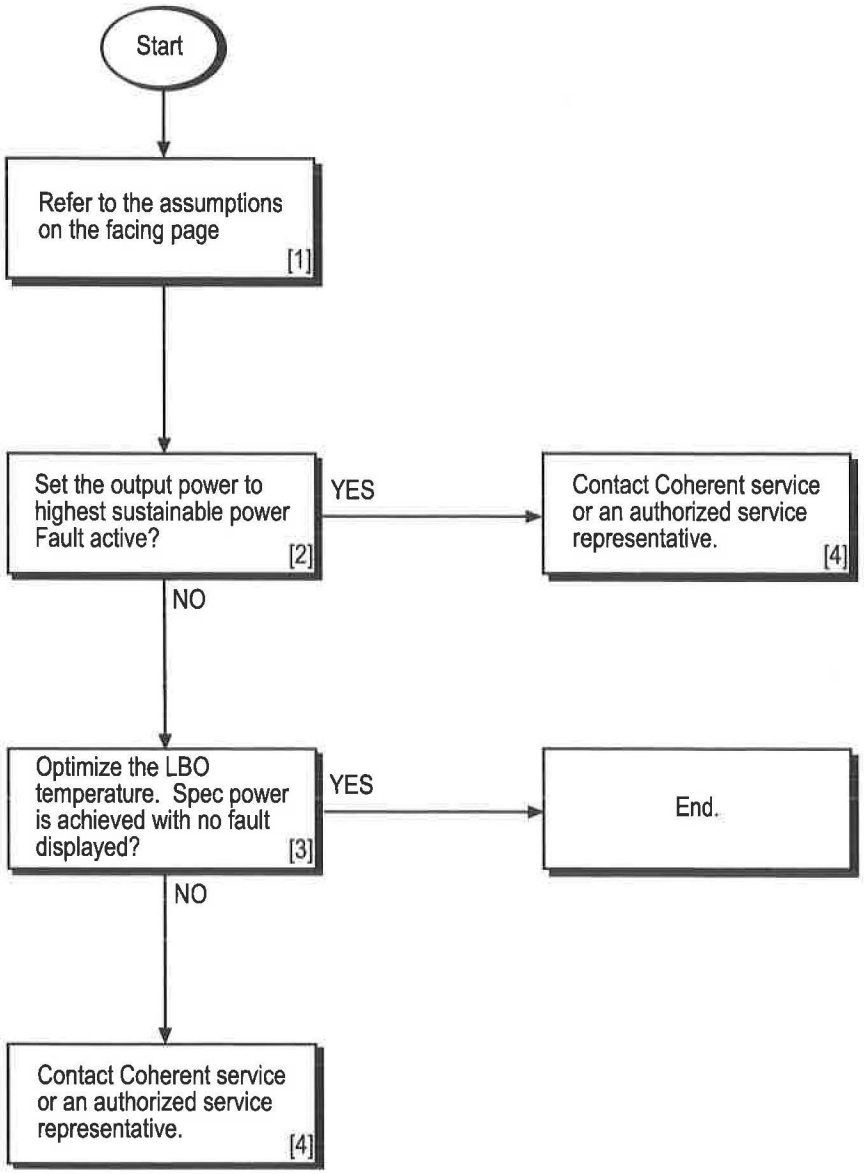


Chart 11. Diode Over Current Fault [Continued]
Over Current Fault

[1] ASSUMPTIONS:

- The laser system has been installed in accordance with the installation procedures in Section Three, Installation.

[2] If the fault is displayed, press EXIT to clear the fault.

[3] Use the "LBO Optimization" menu shown on Figure 4-4 to perform the LBO optimization routine. This can take up to 45 minutes.

[4] If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

Chart 12. Diode Under Voltage Fault
Diode Over Voltage Fault
Diode EEPROM Fault
LBO Not Locked at Set Temperature
Laser Head EEPROM Fault
Power Supply EEPROM Fault
Power Supply-Head Mismatch Fault
Shutter State Mismatch
Head-Diode Mismatch Fault

[1] To clear a fault the power supply key switch should be turned to the Standby position, and the EXIT push-button depressed. If the fault condition no longer exists, exiting the Fault Status Screen clears the fault, once the keyswitch is turned to the On position, laser operation returns to the state it was in before the fault occurred except for the shutter which remains closed. If the fault condition still exists, the system message FAULT ACTIVE will be displayed in the Main Display screen.

If the fault does not clear, a fault message will continue to appear on the fault status menu (Figure 4-4).

If the fault clears, open the shutter and resume operation.

Note: it may be necessary to wait for the LBO crystal to equilibrate at the set temperature before resuming operation.

[2] Turn the power switch on the power supply rear panel to Off for approximately 20 seconds. Then turn the switch back to On.

[3] If the fault persists, contact Coherent or an authorized representative. If the laser system must be returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

FAP-I Replacement

Refer to the troubleshooting charts prior to replacing the FAP-I. Contact Coherent technical support or a local service representative to assist in determining the need for FAP-I replacement.

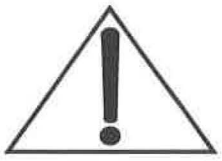
Preliminary Steps and Data

1. With the laser system in "Standby" mode, record the following system parameters:
   a. LBO temperature set point
   b. Vanadate temperature set point
   c. Etalon temperature set point
   d. FAP-I temperature set point(s)
2. Perform the "Turn-off (Complete Shut Down)" procedure located in Section Four of the Operator's Manual. The associated cool-down cycle will take approximately 45 minutes. The front panel display will indicate when the cool-down cycle is complete.

Do not turn off the power switch or disconnect the AC power input until the cool down cycle is complete.

3. When the LBO cool down cycle is complete, turn off the power switch on the power supply rear panel.

   Do not disconnect the power cord from facility power. The power supply chassis must be grounded either by the power cord or a separate ground to avoid ESD.
4. Remove the top cover of the power supply.



The FAP-I can be damaged by electro-static discharge (ESD). To avoid ESD, a personal grounding strap should be used at all times.

FAP-I Handling Precautions

1. The FAP-I can be damaged (electro-static discharge, ESD) by improper handling. To avoid ESD, a personal grounding strap should be used at all times. Follow the instructions that accompany the personal grounding strap.

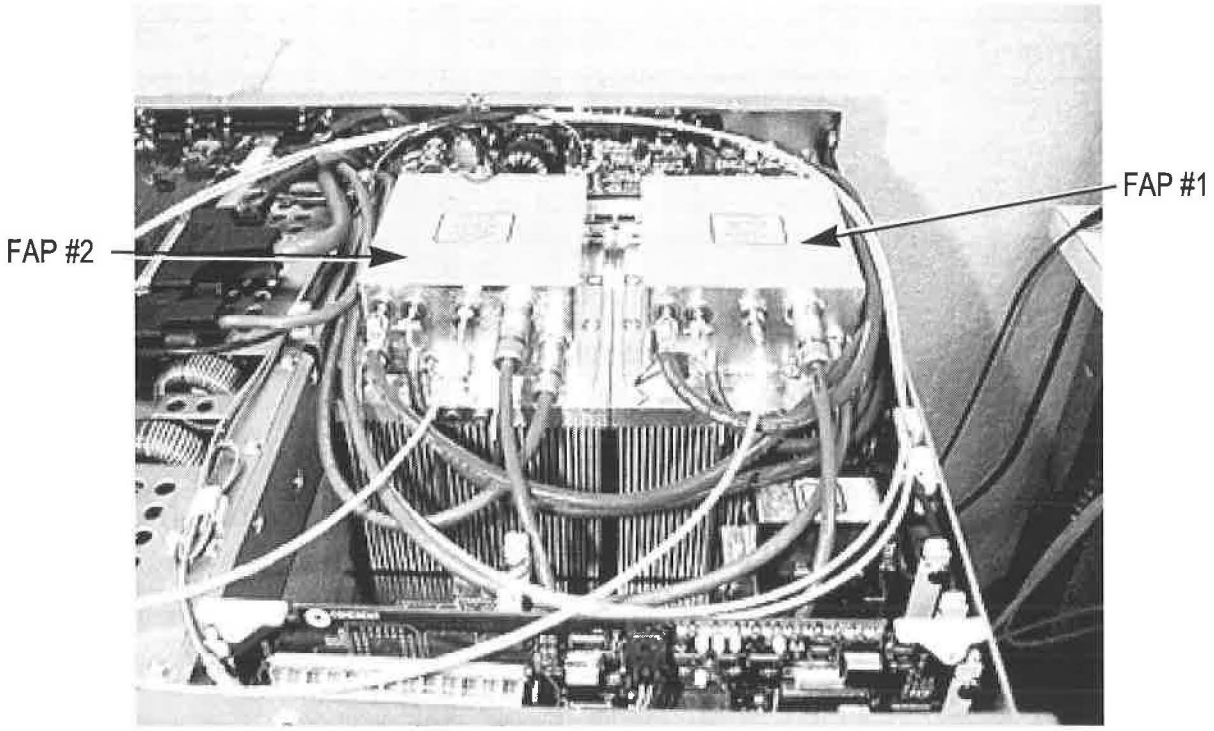


Figure 6-1. Location of FAP-I Assemblies

2. A shorting clip (Figure 6-2) must be installed between the anode and cathode terminals to avoid inadvertent ESD before the leads are disconnected from the terminals.

3. When disconnecting the fiber optic cable from the FAP-I assembly, a cap (Figure 6-2) should be installed over both the FAP-I optical emission port and the end of the fiber optic cable to protect them from accidental damage or contamination.

The end of the fiber optic cable constitutes an optical surface. Do not allow the end of the fiber optic cable to make contact with any surface including the fingers.

A contaminated optical surface can cause system damage. To minimize exposure to the environment, the blue protective plastic cap should be installed whenever the fiber is disconnected.

When removing or installing the fiber optic cable, do not allow the fiber optic cable to rotate while loosening the ferrule connector.

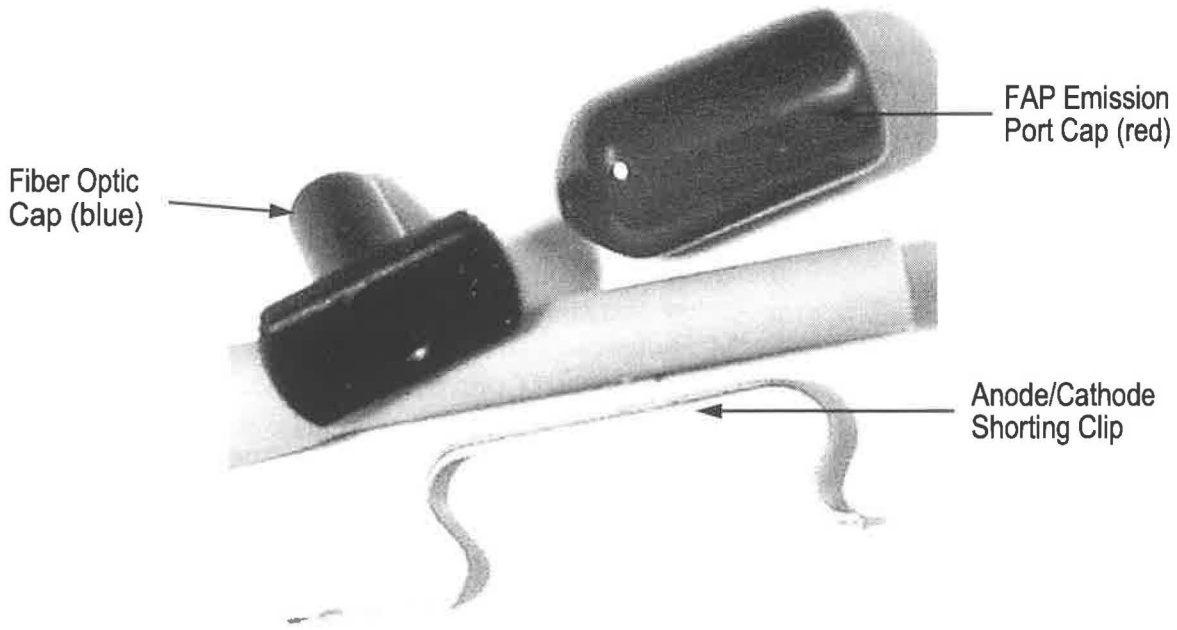


Figure 6-2. Fiber Optic Cap and FAP-I Anode/Cathode Shorting Clip

Fiber Cable Handling Precautions

1. When removing or installing a fiber optic cable, do not allow the fiber optic cable to rotate while loosening the ferrule connector (Figure 6-4).
2. The end of the fiber optic cable constitutes an optical surface. Do not allow the end of the fiber optic cable to contact any surface including the fingers. To minimize exposure to the environment, the protective plastic cap should be left in place until a connection is made and immediately installed over the fiber end when a connection is disassembled.
3. Do not allow the end of the fiber optic cable to contact the diode (FAP-I) assembly or any other surface including the fingers. Failure to do so can damage the optical surface.

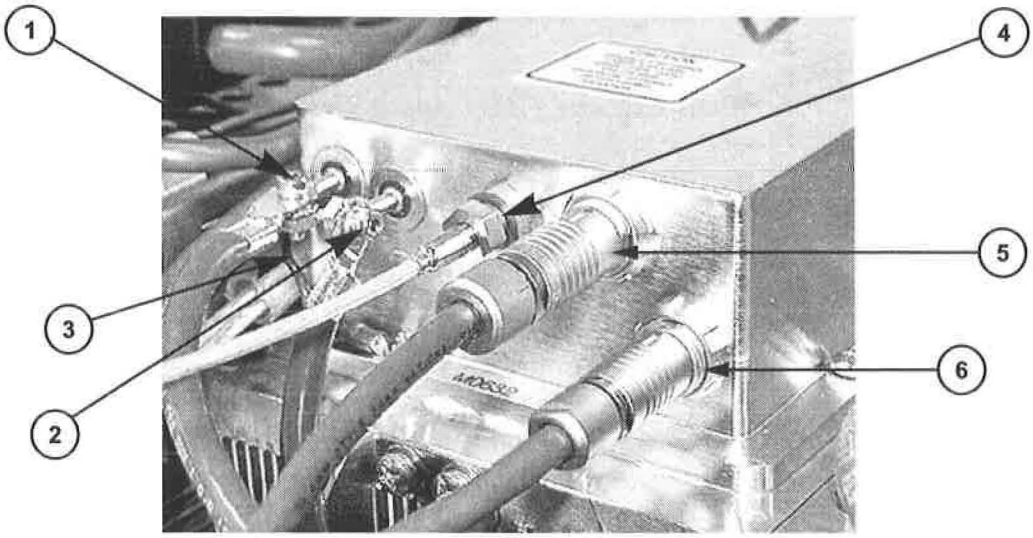
Inspect the fiber optical surface to verify there is a need to clean prior to performing the cleaning procedure.

4. Do not install a contaminated or damaged fiber optic cable to the FAP-I. Doing so will cause a failure of the laser system. Contamination or damage can be difficult to detect. A magnifier will be helpful during examination.

Do not use acetone as a cleaning solvent on the fiber optical surfaces. It will dissolve the matrix which supports the fiber and permanently destroy the optical transport fiber.

5. The end of the fiber optic cable should be cleaned using the drop and drag procedure located in the section titled, Cleaning the Optical Transport Fiber End Face. Do not use any other procedure or method. If scratches or other damage is noted, the FAP-I replacement should be terminated and the plastic cap reinstalled. Contact Coherent or an authorized local representative.

6. Excessively tight fiber umbilical bends (less than a 5 inch radius) can cause permanent damage.



1. Anode Connector
2. Cathode Connector
3. Case/Anode Ground Jumper
4. Fiber Optic Connector
5. Personality Module, Thermistors, Head Hours Connector
6. TEC Coolers Inputs/Outputs Connector

Figure 6-3. FAP-I Assembly Interface

FAP-I Removal

1. Install shorting clip (Figure 6-2) between anode and cathode of FAP-I assembly to be removed. Disconnect the anode and cathode connectors, see Figure 6-3.
2. Disconnect the Case/Anode ground jumper from the FAP-I assembly.

Wear finger cots (supplied with the replacement FAP-I) while handling the fiber optic cable.

3. Disconnect the fiber optic cable as follows:
   a. While firmly holding the fiber optic cable, loosen the ferrule connector securing the fiber optic cable to the FAP-I. It may be necessary to use a small wrench to loosen the connector.
   b. Note that the ferrule is cutout, see Figure 6-4. Carefully extract the fiber optic cable from the FAP-I and remove the ferrule. Immediately install the two plastic protective caps, one over the end of the fiber cable and the second over the FAP-I optical output port (Figure 6-2).
4. Disconnect the Personality module and TEC connectors from the FAP-I assemblies by pulling back on the outer sleeve and then unplugging the connector.
5. Remove eight screws securing the FAP-I to the heat sink (two on each side).

Due to the thermal grease on the bottom of the FAP-I assembly, it may be necessary to work the old assembly loose by rotating (wiggling) it back and forth around its center.

6. Remove the FAP-I and clean the thermal grease from the FAP-I and the mounting surface (alcohol works well for this).

FAP-I Installation

1. Remove the new FAP-I from the shipping container. Leave the shorting clip and protective plastic cap in place to avoid possible ESD and contamination damage, respectively.
2. Place masking tape over the edges of the FAP-I baseplate as illustrated in Figure 6-5.
3. Using a clean metal, plastic, or wooden applicator, apply an even coating of thermal grease to the bottom of the FAP-I. The

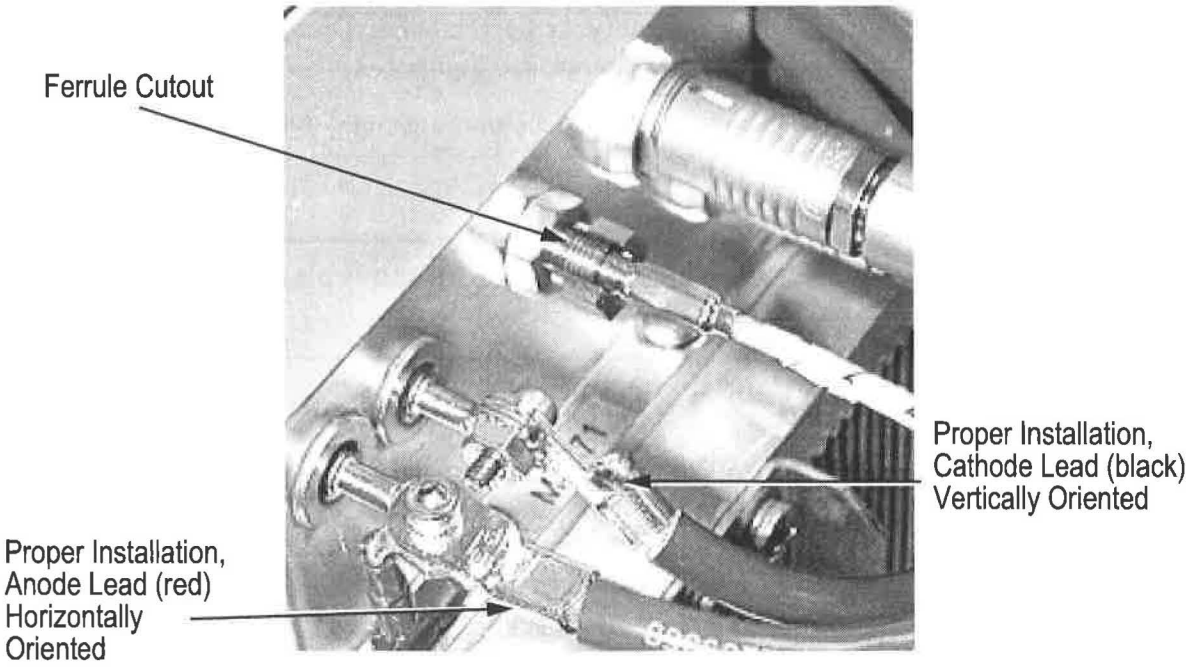


Figure 6-4. FAP-I Fiber Optic Connector

thickness of the grease film should be less than the thickness of the masking tape.

4. Position the FAP-I assembly on the heat sink and reattach the Case/Anode ground jumper to the FAP-I baseplate.

5. Secure the FAP-I to the heat sink using the remaining seven mounting screws. Remove any excess thermal grease from around the assembly.

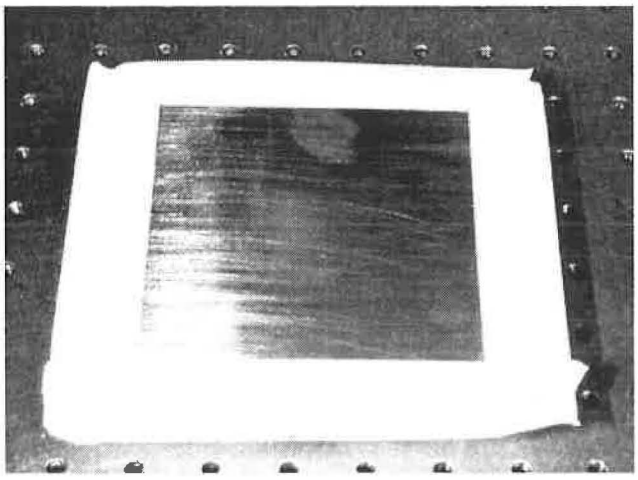


Figure 6-5. Preparation of the Replacement FAP-I Assembly

After connection, the red anode lead should be horizontally oriented and the black cathode lead should be vertically oriented. This is illustrated in Figure 6-4 and is done to minimize the potential of generating/picking-up EM noise.

6. Re-connect the anode and cathode leads. Be sure to reconnect the case/anode ground jumper when connecting the anode lead. Remove the anode/cathode shorting clip.
7. Re-connect the Personality module and TEC connectors, and reconnect the fiber optic cable.
8. If disconnected, connect the power supply power cord to facility power. If a ground wire was used, remove it.
9. Replace the power supply cover and perform the cold start turn-on procedures.
10. Verify system parameters.

Cleaning the Optical Transport Fiber End Face

In the event that the optical transport fiber end face becomes contaminated, use the procedure outlined below to clean the end face.

This procedure should not be required as part of normal operation. If the fiber end face becomes continually contaminated, contact 1-800-367-7890 or your local Coherent representative.

1. Hold the fiber by the connector or cable as shown in Figure 6-6. Place a drop of spectroscopic grade methanol in the center of a lens tissue. Place the wet portion of the lens tissue on the optical surface and slowly drag it across the surface.

Do not use acetone as a cleaning solvent on the fiber optical surfaces. It will dissolve the matrix which supports the fiber and permanently destroy the optical transport fiber.

2. Examine the surface of the optic using a magnifier. If streaks or contamination remain, repeat the process using a fresh lens tissue.

3. Immediately install the end face into the FAP-I or place a protective cover over the end face to avoid further contamination.

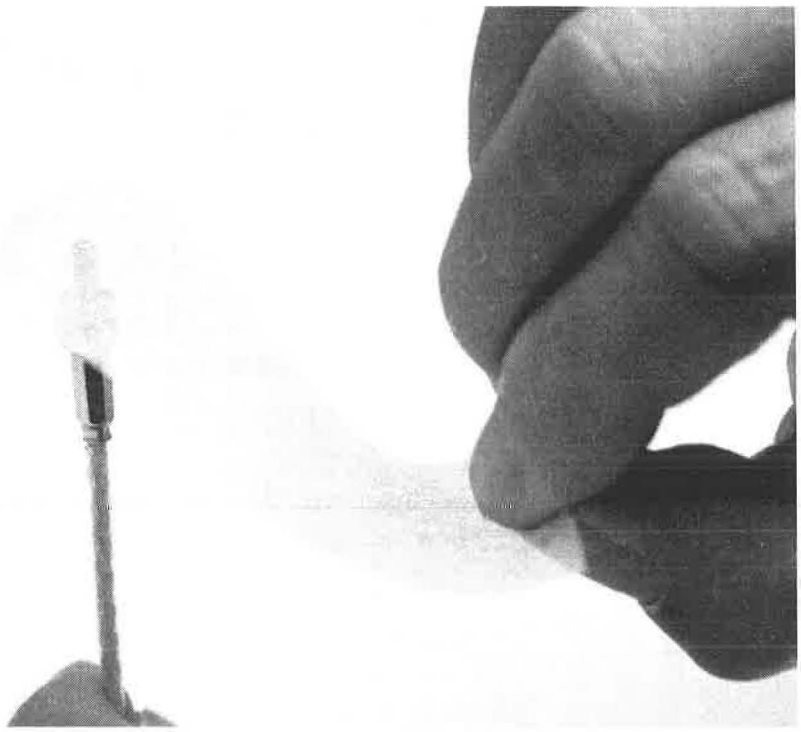


Figure 6-6. Cleaning the Optical Transport Fiber End Face

LBO Temperature Optimization

The conversion efficiency of the LBO frequency doubler is heavily dependent upon temperature. A temperature change of 1 °C can reduce the doubling efficiency by more than 50%. To compensate for the reduced efficiency the laser will drive the diodes harder (more current) to produce the desired 532 nm output. This will reduce the lifetime of the diodes.

As a solution to this potential problem, the Verdi V-2/V-5 software contains a menu routine which will automatically perform a LBO temperature optimization to maximize the conversion efficiency of the doubler. The LBO Optimization routine should be run when diode current is observed to be 10% greater than baseline values.

It is important to note that the shutter is still active during the LBO optimization. Since the laser power will be changing while the routine executes, it is recommended to leave the shutter closed throughout the process.

To find an accurate LBO setpoint temperature, set the output power level as close to 2 W or 5 W (depending on system type) as possible. Once the routine is complete the system will display "TLBO optimized" and return the laser to light regulation mode at the preset power level.

Performing the Optimization

1. Turn the Verdi V-2/V-5 On at a power level that is typically used.
2. Scroll to the LBO Optimization Menu and select the optimization routine. The LBO optimization requires approximately 20 minutes to run.
3. Once the routine is complete, record the diode current as the new "baseline" value in the system weekly log book.

Once selected, the LBO temperature will be increased and decreased with the software recording the Verdi V-2/V-5 Output Power at each LBO temperature. (This routine is performed with a constant diode current.) Optimum LBO temperature will be determined based on the Verdi V-2/V-5 Output Power vs. LBO Temperature curve. The new temperature will be stored as the LBO temperature set point.

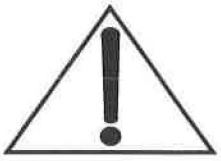
LBO Error Message

If the system is not able to determine an optimum LBO temperature the message "TLBO < 2 °C Temperature not changed" will be displayed. If this should occur the local Coherent Service representative should be contacted.

Fuse Replacement

Criteria for Replacement

Defective fuse per Chart 1.



Do not turn off the power switch or disconnect the AC power input until the cool down cycle is complete.

1. Perform the "Turn-off (Complete Shut-Down)" procedures located in Section Four, Operation. The associated cool-down cycle will take approximately 45 minutes. The front panel display will indicate when the cool-down cycle is complete.
2. Turn off the power switch on the power supply rear panel and disconnect the power cord from facility power.

A fuse that repeatedly fails is an indication of a more serious problem. In this case, the system should be returned to the factory. If the laser system or components are being returned directly to Coherent, an RMA (Return Material Authorization) number is required. Contact Coherent or an authorized representative.

3. The location of the fuse is shown on Figure 4-2. Insert a small screwdriver and twist to remove the fuse holder.
4. Replace the fuse with the appropriate fuses and reinstall the fuse holder. Connect the power supply power cord to facility power.
5. Perform the "Turn-on (Cold Start)" procedures located in Section Four, Operation.

Verification of Successful Installation

6. The AC ON indicator on the power supply front panel will light.

Battery Replacement

The battery in the power supply is not user replaceable. Contact Coherent or an authorized representative if the battery requires replacement.

Cleaning the Air Filter

The air filter is located on the power supply rear panel as shown on Figure 4-3.

Criteria for Cleaning

Visual inspection on a periodic basis. Inspect more frequently if the operating environment is less than ideal.

Clean the air filter when the laser is turned off.

Removal

Do not turn off the power switch or disconnect the AC power input until the cool down cycle is complete.

Do not remove the air filter while the fan is running. The fan is operational when the key switch is in the STANDBY position.

1. Perform the "Turn-off (Complete Shut-Down)" procedures located in Section Four, Operation. The associated cool-down cycle will take approximately 45 minutes. The front panel display will indicate when the cool-down cycle is complete.
2. Turn off the power switch on the power supply rear panel and disconnect the power cord from facility power.

Air Filter Removal and Cleaning Procedure

3. Loosen the two retaining nuts (Figure 4-3, item 6) and remove the air filter.
4. Clean the air filter by rinsing with water and dry with a blower.
5. Re-install the air filter and perform the "Turn-on (Cold Start)" procedures located in Section Four, Operation.

Verification of Cleaning

6. Visual inspection.

SECTION SEVEN: GENERAL OPERATING PRINCIPLES

Laser Head

The Verdi V-2/V-5 laser resonator is a robust unidirectional single-frequency ring cavity design employing intracavity second harmonic generation to produce multi-watt- level continuous-wave green (532 nm) visible light output. Permanently aligned within a clean-room manufacturing environment, the resonator optics are rigidly mounted upon a proprietary grade Invar™ slab.

Coherent-grade Super Invar™ combines a true zero coefficient of thermal expansion at room temperature with a high specific heat, resulting in a resonator superstructure with extraordinarily good passive thermal stability. The Invar slab is kinematically mounted to the laser head base plate, minimizing the influence of external mechanical forces upon the resonator alignment. The aligned assembly is housed within a sealed enclosure to isolate optical components from exposure to environmental contaminants.

Unidirectional oscillation in a ring laser resonator design is essential to establish and maintain reliable single-frequency operation through the elimination of spatial hole-burning. In Verdi, single-direction lasing is accomplished with an intracavity optical diode that induces lower losses for light traveling around the ring in the preferred direction in comparison to the counter-propagating direction. The single-frequency selectivity associated with unidirectional oscillation is further enhanced with a temperature-stabilized intracavity etalon. The Verdi V-2/V-5 resonator also incorporates a Brewster-plate compensator to eliminate the astigmatism associated with the use of spherically curved mirror surfaces at non-normal incidence angles.

The Verdi V-2/V-5 resonator can be categorized as an "end-pumped" design, in which the pump light from the diode bars propagates collinear to the optical axis within the gain medium. Careful control of the spatial overlap between the mode volume defined by the resonator geometry and the actively pumped volume of the gain medium constrains laser oscillation to the lowest-order transverse mode (TEM_{00} mode operation). Transverse mode control is consequently achieved without the need for "hard" apertures that can introduce undesirable beam distortions through diffraction effects.

Gain Medium

The gain medium employed in Verdi V-2/V-5 is Nd:YVO4 (neodymium-doped yttrium orthovanadate), commonly referred to as vanadate. Vanadate offers several significant advantages over alternative solid-state laser media common to diode- pumped lasers.

Neodymium ions doped into a vanadate host exhibit a comparatively large absorption coefficient centered at a wavelength convenient for readily available pump diode lasers (~808 nm) that is also spectrally rather broad and therefore insensitive to the precise wavelength or bandwidth of an optical pump source. Both these characteristics contribute ease-of-operation to the overall efficiency of diode-pumping. In addition, vanadate exhibits strong intrinsic birefringence, eliminating the need for secondary means of polarizing the laser output and minimizing the consequences of thermally induced depolarization that may be encountered at high pump power density.

The characteristic lasing wavelength of neodymium-doped vanadate is nominally 1064 nm, in the near-infrared region of the optical spectrum. This infrared light is in fact the oscillating or "fundamental" wavelength of the Verdi V-2/V-5 resonator rather than the visible green output associated with the device. The multilayer dielectric coatings of the four mirrors that define the ring resonator are designed to provide high reflectance centered at 1064 nm to sustain circulating infrared power levels that typically exceed 100 watts. Conversion of a fraction of this circulating power into visible light is accomplished through the process of non-resonant intracavity second harmonic generation (SHG).

Second Harmonic Generator

The nonlinear optical medium used for SHG in Verdi V-2/V-5 is the birefringent crystal lithium triborate (LBO). The efficiency of the SHG process (that is, how much of the power circulating within the resonator is converted from the infrared into the visible at precisely one half the fundamental wavelength) is determined by the crystal orientation as defined with respect to the direction of light propagation, the polarization state of the incident light, and by the nominal crystal temperature. Given a fixed crystal orientation established during the initial construction of the resonator, temperature tuning the refractive indices of LBO provides an adjustable means of optimizing the SHG conversion efficiency.

The LBO doubler in Verdi V-2/V-5 is housed within an oven that is designed to maintain the crystal temperature at a typical value of 150°C. Given the proper crystal orientation and considering appropriate polarization states, the refractive indices of the birefringent crystal can be arranged to be identical for both the fundamental 1064 nm wavelength and its second harmonic at 532 nm for a

temperature close to this value. When the "phase-matching" condition between the two different wavelengths implied by these considerations is satisfied, substantial power flow from the fundamental to the second harmonic is obtainable during a single pass through the doubler.

The particular crystal "cut" and temperature tuning scheme employed in the Verdi V-2/V-5 doubler is termed a Type I non-critical or 90° phase-matching scheme. In this scheme both the infrared and green light beams are linearly polarized with orthogonal polarization states. The plane of polarization for the fundamental is parallel to the laser base plate while the green polarization is perpendicular to it. Although the infrared and green beams are orthogonal in polarization they propagate collinearly and remain undistorted in profile as power is transferred from the fundamental to the second harmonic. The green light is separated from the circulating infrared light shortly after exiting the LBO crystal and extracted from the resonator by means of a dichroic outcoupling mirror that is coated to be highly reflecting at 1064 nm but essentially completely transparent to 532 nm.

The temperature dependence of the SHG process has important implications for the design and operation of the LBO oven servo. A change in the nominal temperature of only ~1°C away from the optimal value will cause a reduction in the conversion efficiency and subsequent laser output power of ~50%. Accordingly, the Verdi V-2/V-5 SHG crystal temperature is actively stabilized to a precision much better than 0.1°C. Further, because of otherwise insignificant variations in resonator alignment, crystal orientation, and oven construction, the highest efficiency doubler temperature can differ from unit to unit by a few degrees. Therefore each Verdi V-2/V-5 is individually optimized during the system integration phase of manufacturing to determine the proper value for that system.

Temperature Servos

In addition to the SHG oven, the temperatures of two other optical components within the laser head are also actively monitored and stabilized by servo systems.

The temperature of the vanadate gain medium is held fixed at a nominal setting of ~30°C, independent of the pump power level, to maintain consistent coupling efficiency between the diode pump light and the neodymium ion absorbers. While this setting is adjustable, in practice changes to the specified value of the vanadate temperature are unlikely to be warranted.

The intracavity etalon temperature is set to a nominal value that must fall within the range between 25°C and 75°C. As is the case for the LBO doubler, the value of the etalon temperature giving optimal laser performance can be expected to differ slightly from unit to unit and is subject to optimization during manufacture. The exact value therefore has no intrinsic significance so long as the temperature remains well-stabilized and within the range of servo adjustment.

Output Optics

External to the laser resonator but still within the sealed resonator enclosure are located a pair of high-reflectance beam- steering mirrors and a collimating lens. The mirrors allow adjustment of the output beam position and pointing during the latter stages of the laser head manufacture to obtain good unit-to-unit reproducibility. The optical power of the lens is selected and its precise positioning is adjusted to bring the output beam characteristics (spot size, divergence, waist location and astigmatism) within specifications.

Power Monitor

A silicon photodiode monitors the laser output to provide a continuous power level readout as well as a servo feedback signal to establish the operating current of the diode bar(s). The beam is sampled and directed to the photodiode by the first-surface reflection from an uncoated fused-silica beamsplitter. The beamsplitter and photodiode are both located within the sealed resonator enclosure for protection from environmental disturbances or contaminants. The photodiode has been selected to be insensitive to variations in the ambient temperature, avoiding one of the more common sources of error associated with light-sampling laser power servos.

Shutter

A solenoid-actuated remote-controlled mechanical shutter and beam dump mechanism is mounted within the laser head external to the sealed resonator enclosure. This mechanism is intended to be used in conjunction with an external interlock circuit for laser operator safety, not as a process control device. Manual control of the shutter state is accomplished by means of a dedicated push-button located on the front panel of the power supply or can be accessed remotely via commands issued through the RS-232 serial port. The shutter is designed as a "fail-closed" mechanism that completely blocks the exit aperture of the laser head unless the solenoid is energized.

Heat Sinking

Depending upon the specific laser model and the actual operating conditions encountered, a Verdi V-2/V-5 laser head can generate tens of watts of "waste" heat that must be properly managed to maintain optimal laser performance. Essentially all of this heat must flow through the base plate, with comparatively negligible heat transfer through either the top or the sides of the head. The base plate is machined flat to tight tolerances in anticipation of minimizing the thermal impedance between the head and an underlying heat spreader or heat sink by maximizing the available contact area.

The laser head base-plate temperature is monitored by the operating system and can be displayed on the front panel of the power supply or reported via RS-232. The system will declare a fault condition and shut down when the base-plate temperature exceeds 55°C. Note, however, that simple heat-transfer considerations dictate that the temperature of the mounting surface beneath the laser head must be held at a value lower than the fault set-point to sustain heat flow out of the head.

How much lower a temperature will be acceptable depends upon the thermal impedance of the scheme used to secure the head to the mounting surface. For example, when securing a laser head directly upon a Coherent-supplied riser block, the maximum temperature of the upper surface of the block that will be tolerated before a temperature fault is registered by the system will typically be ~45°C. For higher power models of Verdi, in particular, water-cooling of the riser block would be recommended to satisfy this requirement if the ambient temperature is anticipated to approach this value.

Another significant benefit of using the water-cooled riser in conjunction with a temperature-stabilized source of cooling water (most conveniently provided by a small recirculating water chiller) is the minimization of any changes in beam pointing associated with temperature changes in the mounting scheme. Applications that are notoriously sensitive to beam pointing errors such as launching the Verdi V-2/V-5 output into a single-mode optical fiber or pumping a Ti:sapphire laser may necessitate active temperature stabilization of the mount, especially if ambient conditions are subject to uncontrolled fluctuations.

Umbilical

The umbilical is permanently attached to the laser head and is not intended to be removed from the head. It houses the optical fibers that deliver pump power to the head as well as several electrical cables that carry electrical power and various signals between the power supply and the head. The umbilical is designed to provide protection from mechanical abrasion and to maintain a safe minimum bend radius for the optical fibers.

The laser head, umbilical, and power supply are shipped by Coherent connected together as an integrated unit. Disconnection of the umbilical from the power supply should only be attempted under the supervision of trained personnel. Care should be taken during system installation to avoid excessive twisting or any kinking of the umbilical which might damage the internal components.

Power Supply

The Verdi V-2/V-5 power supply houses several circuit boards, a switching electrical power supply rated at 1-kilowatt DC, a lead-acid storage battery that provides emergency backup electrical power, and, depending upon the specific model, either one or two laser diode bar assemblies along with appropriate means of heat-sinking these assemblies. Several specific functions are addressed by the power supply:

- Generation of wavelength-optimized optical pump energy to be delivered to the gain medium within the laser resonator situated in the laser head;
- Provision of a full-function user interface, completely accessible from the front panel or remotely through an RS-232 serial port interface;
- Implementation of the monitoring and control servo loops required for operation of the laser system.

Laser Diodes

The laser diode bar modules employed as a pump source in Verdi V-2/V-5 are designated by the acronym FAP-I™ (Fiber Array Package – Integrated). Within each FAP-I is housed a sealed diode bar subassembly (incorporating a close-coupled array of optical fibers to individually address and efficiently collect the light output from the various discrete emitters on the bar into a single output port), several large thermo-electric coolers (to control the temperature and consequently the emission wavelength of the diode bar), various signal conditioning and monitoring electronics, and several essential electrical connectors.

The laser diode bar within the FAP-I efficiently converts low-voltage high-current electrical power into tunable laser light. Electrical-to-optical conversion efficiencies typically approach ~50%, with the non-radiated power contributing primarily to heating of the device. The coupling efficiency obtained in launching light from the bar through the fiber array and into a single transport fiber is conservatively specified to be no less than 80%, with typical values exceeding 90%.

The emission bandwidth of diode bars is typically between 2 nm and 4 nm (considering 50% power roll-off levels). When the nominal wavelength is adjusted to be centered on the strong absorption band associated with neodymium ions in a vanadate host near 808 nm, more than 90% of the incident diode laser light can readily be absorbed in only a few millimeters of crystal to generate high optical gain within a small volume. The tuning rate of diode bars as a function of operating temperature is typically 0.3 nm/°C, higher temperatures implying longer wavelengths. The temperature of each FAP-I in Verdi V-2/V-5 is individually monitored and adjusted to optimize the coupling efficiency. Optimum efficiency is typically obtained when the nominal operating temperature falls within the range of 5°C to 35°C.

The optical output power of diode laser bars is observed to be linearly proportional to drive current above a threshold lasing level that is at least several amps in magnitude but generally does not exceed 15 amps. Conversely, when the drive current is increased to a value typically several times greater than the lasing threshold, the electrical-to-optical conversion efficiency eventually begins to deteriorate and a noticeable departure from linearity in the output becomes evident. With a further increase in current catastrophic failures occur and bars can be irreversibly damaged. The Verdi V-2/V-5 operating system is designed to maintain diode bar operation well within the linear output regime and prohibits damage due to excessive diode current.

Laser diode bars tend to exhibit a couple of characteristic changes in performance as a consequence of aging. First, diode bars often experience a slow decay in efficiency usually associated with an accumulation of optical or electrical defects within the material of the bar or upon its surfaces. This deterioration can be offset by slight compensating increases in the drive current level if constant output power is desired. Second, the nominal output wavelength of a diode bar tends to "red shift" over the life of a bar, requiring re-optimization of the operating temperature to somewhat lower values to maintain a specific wavelength. Verdi V-2/V-5 handles each of these areas of concern without any need for operator intervention.

The long-term deterioration in efficiency of diode bars is addressed first by generous de-rating of the nominal operating power level demanded (to establish substantial overhead for future adjustment and to stay well within the linear operating regime) and secondarily by automatically adjusting the drive current during operation to maintain fixed output power. To compensate for possible changes in diode wavelength, during extended periods of continuous operation each diode bar temperature is slowly dithered to determine the

minimum drive current setting and maximize the overall system efficiency. Both these strategies are designed to ensure thousands of hours of operation free from the need for other corrective actions.

Laser diode modules represent the only consumable components in Verdi V-2/V-5 that should be explicitly recognized when establishing maintenance schedules. Refer to the sections of this manual addressing trouble-shooting for appropriate procedures to determine when a module may be approaching the point where replacement is indicated. Also refer to the detailed description of the procedure for FAP-I replacement for a more complete appreciation of the modest level of effort required for this straightforward operation.

Battery Backup

The lead-acid storage battery in the Verdi V-2/V-5 power supply provides a backup electrical current source to allow the system to execute a graceful shutdown in the event that AC power is prematurely terminated during system operation. The battery is continuously trickle-charged during normal system operation and will automatically recharge itself after being depleted. Status of the battery is accessible from both the front panel and through serial port queries.

Activation of a secondary microprocessor occurs automatically if AC power is lost when the system is in either STANDBY or ON key-switch modes when the AC power switch is ON. The primary function of this processor is to ensure that the temperature of the LBO doubling crystal is ramped down in a controlled fashion to avoid any risk of thermal shock or coating damage. The battery stores sufficient energy to continue supplying power to the secondary microprocessor and the doubler oven throughout the time required to bring the temperature down from its nominal operating value to room temperature (typically ~45 minutes).

Cooling Issues

Two different approaches are available to provide adequate cooling to the Verdi V-2/V-5 power supply. In lower-power versions intended for use in climate-controlled environments, a pair of large ducted fans pull air through a dust filter and drive air flow through the two finned heat sinks situated directly underneath the diode bar modules. For higher-power versions, as well as for use in environments in which the ambient temperature cannot be well controlled, a water-cooled chill plate replaces the finned heat sinks beneath the diode modules and must be connected to an adequate water source (usually provided by a small standalone recirculating water chiller).

When the air-cooled heat sinks are employed, the dust filter should be inspected periodically to verify free air flow. Appropriate maintenance procedures are described elsewhere in this manual. The heat-sink temperatures can be monitored from the front panel of the panel supply in the Laser Status Screen, or queried via the RS-232 port. A fault condition will be declared if the temperature of either heat sink exceeds 65°C.

APPENDIX A: PACKING PROCEDURE

The following is the factory recommended packing procedure for the Verdi V-2/V-5 laser systems. This procedure should be followed if the laser system is to be shipped to another location after initial installation.

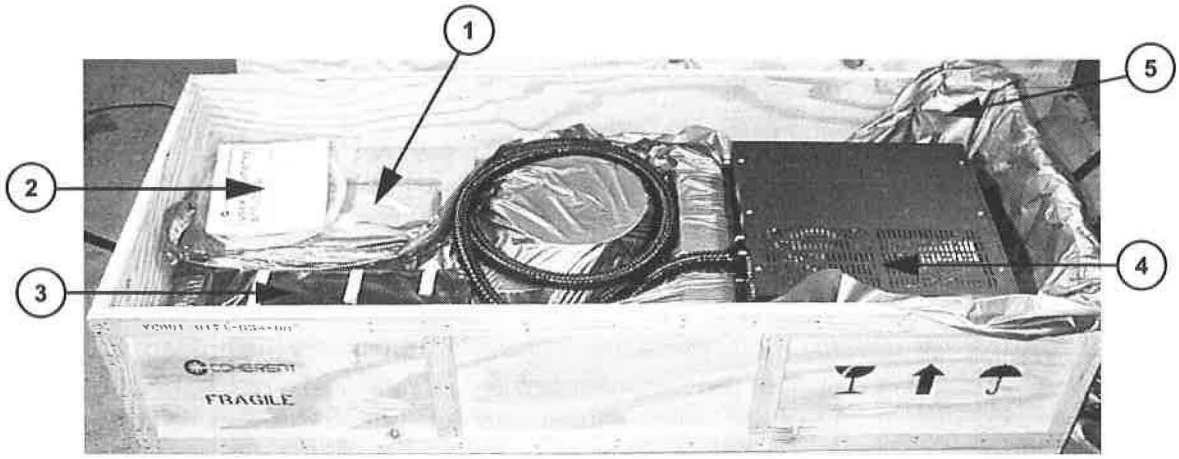
The Verdi V-2/V-5 laser systems requires one shipping crate, part number 0171-654-00. Table A-1 gives a complete listing of the contents of the shipping crate when the system is shipped from Coherent.

The Verdi V-2/V-5 laser systems crate consists of a single molded foam compartment. Figure A-1 illustrates the proper placement of each of the components listed in Table A-1. Before placing the laser head and power supply into the crate, to prevent ESD damage, the compartment should be lined with anti-static material. Enough anti-static material should be used so that after the crate is completely packed, the excess can be folded over to cover the top of the power supply, see Figure A-2.

Table A-1. Verdi V-2/V-5 Laser Shipping Crate Contents

1. Laser Head
2. Power Supply
3. Riser/Heat Sink
4. Operator's Manual
5. Final Test Data Sheet
6. System Accessories Package
   a. 1/4 inch Water Tubing
   b. Tubing Connectors
   c. Laser Head/Riser/Heat Sink Clamps (4x)
   d. Riser/Heat Sink/Stable Table Clamps (4x)
7. Maintenance Kit
   a. System Fuses (2x)
   b. Diode Shorting Clips (2x)
   c. Fiber Optic Cable End Caps (2x)
   d. Diode Fiber Connector End Caps (2x)
   e. External Interlock Plug, Shorted
   f. External Interlock Plug, Disassembled.

Note that the riser/heat sink, system documentation, and the accessories package should be placed under the anti-static liner and that the laser head is separately wrapped in anti-static material (see Figures A-1 and A-2).



1. Riser/Heat Sink
2. Documentation/Accessories
3. Laser Head
4. Power Supply
5. Static Wrap Liner

Figure A-1. Packed Verdi V-2/V-5 Laser Shipping Crate

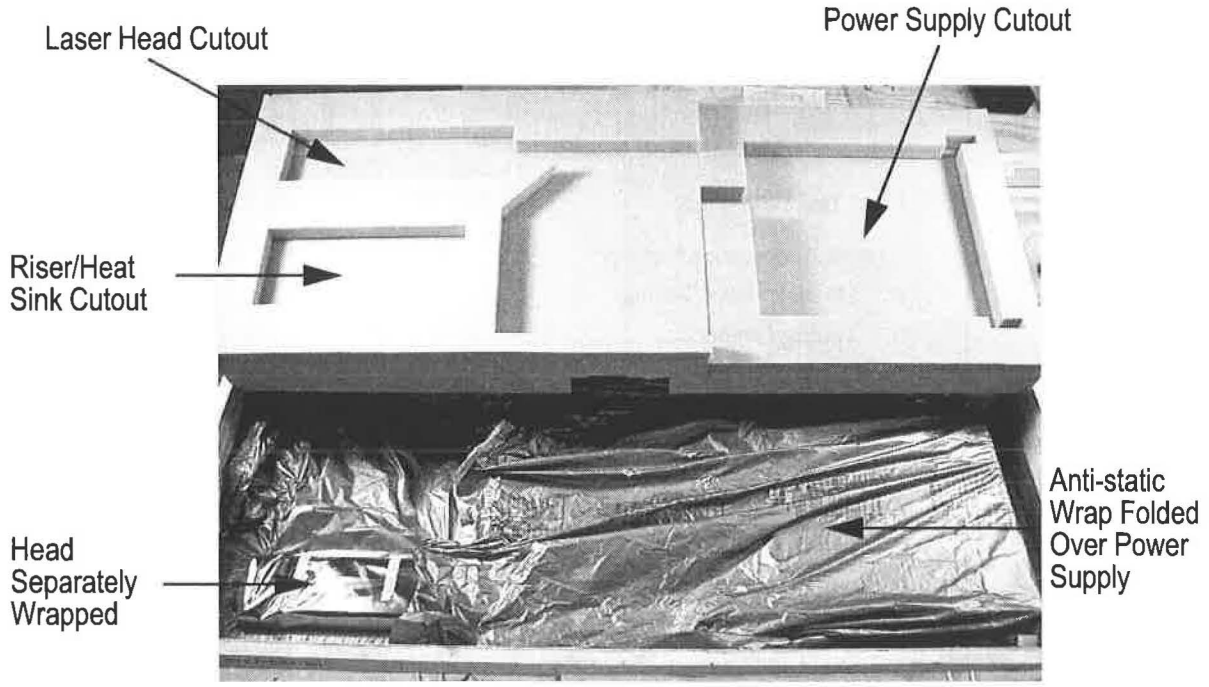


Figure A-2. Top Foam for Verdi V-2/V-5 Laser Shipping Crate

Three people are recommended for packing the Verdi V-2/V-5. The laser head and power supply are connected by the umbilical. To prevent damage to the fiber optic delivery cables running between the head and the power supply, the umbilical should be wound loosely in the foam cutout as illustrated in Figure A-3.

Excessively tight fiber bends (less than a 5 inch radius) can cause permanent damage to the fiber optic cables.

Place the Verdi V-2/V-5 in the shipping crate as follows:

1. Place the power supply in the cutout as shown in Figure A-1.
2. A second person carrying the laser head should walk clockwise around the shipping container while the first person guides the umbilical onto the cutout as shown in Figure A-1.
3. Place the laser head into the cutout.

Once all components are placed into the shipping crate the top foam should be positioned. Figure A-2 presents the purpose of each of the cutouts in the top foam piece. After positioning the top foam, the Verdi V-2/V-5 Maintenance Kit is position in the outer cutout before the crate lid is attached, see Figure A-4.

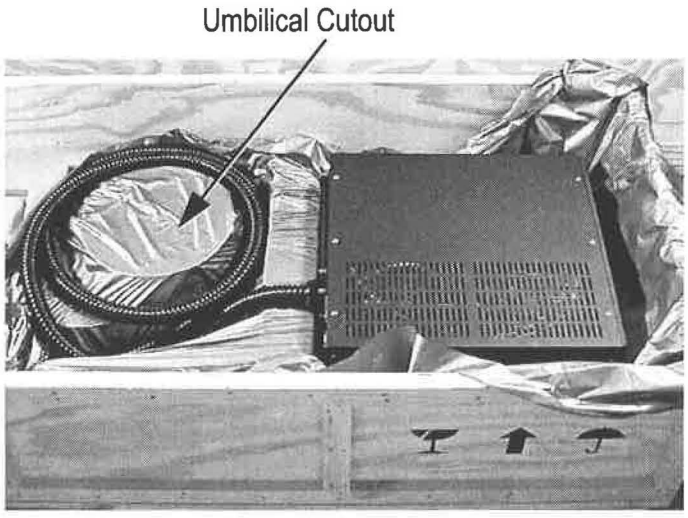


Figure A-3. Proper Packing of System Umbilical

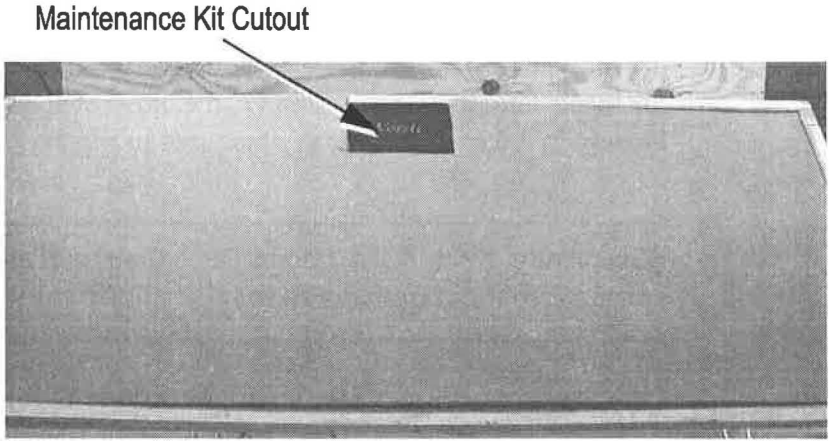


Figure A-4. Location of Packed Verdi V-2/V-5 Laser Maintenance Kit

PARTS LIST

DESCRIPTION	PART NUMBER
Fuses: 10 A, 250 V 15 A	 5100-0072 5110-0002
Shipping Crate (System)	0171-654-00
Rack Mount Kit	0172-720-00
Riser/Heat Sinks (Passive)	0171-530-00
Riser/Heat Sinks (Water-cooled)	0171-531-00
Clamps	0172-826-00

WARRANTY

Coherent, Inc. warrants Diode-Pumped Solid State laser systems to the original purchaser (the Buyer) only, that the laser system, that is the subject of this sale, (a) conforms to Coherent's published specifications and (b) is free from defects in materials and workmanship.

Laser systems are warranted to conform to Coherent's published specifications and to be free from defects in materials and workmanship for a period of 12 months or 5000 hours of operation, whichever occurs first.

Responsibilities of the Buyer

The buyer is responsible for providing the appropriate utilities and an operating environment as outlined in the product literature. Damage to the laser system caused by failure of buyer's utilities or failure to maintain an appropriate operating environment, is solely the responsibility of the buyer and is specifically excluded from any warranty, warranty extension, or service agreement.

The Buyer is responsible for prompt notification to Coherent of any claims made under warranty. In no event will Coherent be responsible for warranty claims made later than seven (7) days after the expiration of warranty.

Limitations of Warranty

The foregoing warranty shall not apply to defects resulting from:

- Components and accessories manufactured by companies, other than Coherent, which have separate warranties,
- Improper or inadequate maintenance by the buyer,
- Buyer-supplied interfacing,
- Operation outside the environmental specifications of the product,
- Unauthorized modification or misuse,
- Improper site preparation and maintenance, or
- Opening the pump laser head housing.

Coherent assumes no liability for customer-supplied material. The obligations of Coherent are limited to repairing or replacing, without charge, equipment which proves to be defective during the warranty period. Replacement sub-assemblies may contain reconditioned

parts. Repaired or replaced parts are warranted for the duration of the original warranty period only. The warranty on parts purchased after expiration of system warranty is ninety (90) days. Our warranty does not cover damage due to misuse, negligence or accidents, or damage due to installations, repairs or adjustments not specifically authorized by Coherent.

Warranty applies only to the original purchaser at the initial installation point in the country of purchase, unless otherwise specified in the sales contract. Warranty is transferable to another location or to another customer only by special agreement which will include additional inspection or installation at the new site. Coherent disclaims any responsibility to provide product warranty, technical or service support to a customer that acquires products from someone other than Coherent or an authorized representative.

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GLOSSARY

°C	Degrees centigrade or Celsius
°F	Degrees Fahrenheit
µ	Microns
µrad	Microradian(s)
µsec	Microsecond(s)
$1/e^2$	Beam diameter parameter
AC	Alternating current
Amp	Amperes
CDRH	Center for Devices and Radiological Health
CFR	Code of Federal Regulation
cm	Centimeter(s)
DC	Direct current
EEPROM	Electrically erasable programmable read only memory
EMC	Electromagnetic Compliance
FAP-I™	Fiber array package-integrated
FSR	Free spectral range
I/O	Input/output
kg	Kilogram(s)
LBO	Lithium Triborate, LiB_3O_5
LD	Laser diode
LED	Light emitting diode
LVD	Low Voltage Directive
m	Meter(s)
mAmp	Milliampere(s)
MHz	Megahertz
mm	Millimeter(s)
mrad	Milliradian(s)
msec	Millisecond(s)
mV	Millivolt(s)
mW	Milliwatt(s)
Nd:YAG	Neodymium:Yttrium Aluminum Garnet
Nd:YVO	Neodymium:Yttrium Orthovanadate
nm	Nanometer(s)
OEM	Original equipment manufacturer
rms	Root mean square
TEC	Thermo-electric cooler

TEM	Transverse electromagnetic (cross-sectional laser beam mode)
VAC	Volts, alternating current
VDC	Volts, direct current
W	Watt(s)

INDEX

Verdi V-2/V-5 Lasers Operator's Manual

Part No. 0171-750-00, Rev I