Operator's Manual
Micra-5 Modelocked Titanium:Sapphire
Laser System

COHERENT®
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Santa Clara, CA 95054 USA

Technical Support

In the U.S.:

Should you experience any difficulties with your laser or need any technical information, please visit our Web site **www.Coherent.com**. Should you need further assistance, please contact Coherent Technical Support via e-mail **Product.Support@Coherent.com** or telephone, 1-800-367-7890 (1-408-764-4557 outside the U.S.). Please be ready to provide model and laser head serial number of your laser system as well as the description of the problem and any corrective steps attempted to the support engineer responding to your request.

Telephone coverage is available Monday through Friday (except U.S. holidays and company shutdowns). Inquiries received outside normal office hours will be documented by our automatic answering system and will be promptly returned the next business day.

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If you are located outside the U.S., please visit **www.Coherent.com** for technical assistance, or phone our local Service Representative. Service Representative phone numbers and addresses can be found on the Coherent web site.

Coherent provides telephone and web-based technical assistance as a service to its customers and assumes no liability thereby for any injury or damage that may occur contemporaneous with such services. Under no circumstances do these support services affect the terms of any warranty agreement between Coherent and the buyer. Operation of any Coherent laser with any of its interlocks defeated is always at the operator's own risk.

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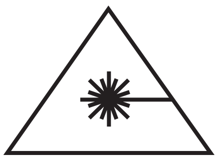
Preface

This manual contains user information for the Micra-5™ Mode-locked Ti:Sapphire Oscillator.

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

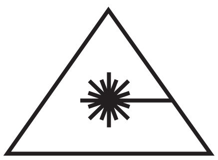
It is the policy of Coherent to comply strictly with U.S. export control laws.

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.

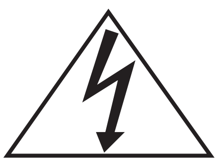
The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification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

Symbols Used in This Manual and on the Laser System

This symbol alerts the operator to the presence of important operating and maintenance instructions.



This symbol alerts the operator to the danger of exposure to hazardous visible and/or invisible laser radiation.

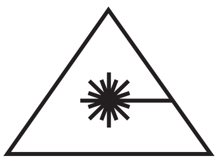


This symbol alerts the operator to the presence of dangerous voltages within the product enclosure that may be of sufficient magnitude to constitute a risk of electric shock.

This symbol alerts the operator to the danger of Electro-Static Discharge (ESD) susceptibility.

SECTION ONE: LASER SAFETY

This user information is in compliance with section 1040.10 of the CDRH Performance Standards for Laser Products from the Health and Safety Act of 1968.



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

This laser safety section must be thoroughly reviewed prior to operation of the Micra laser system. Safety instructions presented throughout this manual must be followed carefully.

Hazards

Hazards associated with lasers generally fall into the following categories:

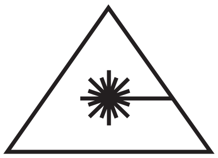
- Exposure to laser radiation that may damage the eyes or skin
- Electrical hazards generated in the laser power supply or associated circuits
- Chemical hazards resulting from contact of the laser beam with volatile or flammable substances, or released as a result of laser material processing

The above list is not intended to be exhaustive. Anyone operating the laser must consider the interaction of the laser system with its specific working environment to identify any potential hazards.

Optical Safety

Laser light, because of its special qualities, poses safety hazards not associated with light from conventional sources. The safe use of lasers requires all operators, and everyone near the laser system, to be aware of the dangers involved. Users must be familiar with the instrument and the properties of coherent, intense beams of light.

The safety precautions listed below are to be read and observed by anyone working with or near the laser. At all times, ensure that all personnel who operate, maintain or service the laser are protected from accidental or unnecessary exposure to laser radiation exceeding the accessible emission limits listed in 'Performance Standards for Laser Products,' *United States Code of Federal Regulations*, 21CFR1040 10(d).



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

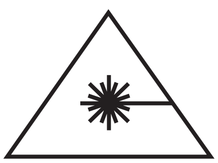
The greatest concern when using a laser is eye safety. In addition to the main beam, there are often smaller beams present at various angles near the laser system. These beams are formed by specular reflections of the main beam at polished surfaces such as lenses or beamsplitters. While weaker than the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

Laser beams are powerful enough to burn skin, clothing or paint even at some distance. 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 user is advised to follow the precautions below.

Recommended Precautions and Guidelines

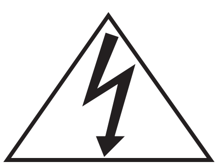
1. Observe all safety precautions in the preinstallation and Operator's Manuals.
2. All personnel should wear laser safety glasses rated to protect against the specific wavelengths being generated. Protective eye wear vendors are listed in the *Laser Focus World, Lasers and Optronics,* and *Photonics Spectra* buyer's guides. Consult the ANSI, ACGIH, or OSHA standards listed at the end of this section for guidance.
3. Avoid wearing watches, jewelry, or other objects that may reflect or scatter the laser beam.
4. Stay aware of the laser beam path, particularly when external optics are used to steer the beam.
5. Provide enclosures for beam paths whenever possible.
6. Use appropriate energy-absorbing targets for beam blocking.
7. Block the beam before applying tools such as Allen wrenches or ball drivers to external optics.
8. Limit access to the laser to qualified users who are familiar with laser safety practices. When not in use, lasers should be shut down completely and made off-limits to unauthorized personnel.

9. Use the laser in an enclosed room. Laser light may remain collimated over long distances and therefore presents a potential hazard if not confined. It is good practice to operate the laser in a room with controlled access.
10. Post warning signs in the area of the laser beam that the laser is in use.
11. Exercise extreme caution when using solvents in the area of the laser.
12. Never look directly into the laser light source or at scattered laser light from any reflective surface. Never sight down the beam.
13. Set up the laser so that the beam height is either well below or well above eye level.
14. Avoid direct exposure to the laser light. Laser beams can easily cause flesh burns or ignite clothing.
15. Advise all those working with or near the laser of these precautions.



Laser safety glasses protect the user from eye damage by blocking light at the laser wavelengths. However, this also prevents the operator from seeing the beam. Use extreme caution even while wearing safety glasses.

Electrical Safety



Normal operation of the Micra should not require access to the power supply circuitry. Removing the power supply cover will expose the user to potentially lethal electrical hazards. Contact an authorized service representative before attempting to correct any problem with the power supply.

Recommended Precautions and Guidelines

The following precautions must be observed by anyone working with potentially hazardous electrical circuitry:

1. Disconnect main power lines before working on any electrical equipment when it is not necessary for the equipment to be operating.

2. Do not short or ground the power supply output. Protection against possible hazards requires proper connection of the ground terminal on the power cable, and an adequate external ground. Check these connections at the time of installation, and periodically thereafter.
3. Never work on electrical equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who is competent to administer assistance.
4. When possible, keep one hand away from the equipment to reduce the danger of current flowing through the body if a live circuit is accidentally touched.
5. Always use approved, insulated tools.
6. Special measurement techniques are required for this system. A technician who has a complete understanding of the system operation and associated electronics must select ground references.

Component Lasers

The Micra system incorporates a Coherent Verdi™ laser as a subcomponent. The beam from this laser is hazardous. Refer to the Verdi Operator's Manual for additional safety information.

Maximum Accessible Radiation Level

The Micra and its component lasers produce visible and invisible radiation over a wavelength range of 500 to 1100 nm, with a maximum of 40 Watts continuous wave power, and 25 nJ maximum energy per < 300 fs pulse [CFR 1040.10 (h)(2)/ EN 60825-1/ IEC 608225-1, Clause 6].

Safety Features and Compliance with 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 1040 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/IEC 61010-1 "Safety Requirements For Electrical Equipment For Measurement, Control and Laboratory Use" and EN 60825-1/IEC 60825-1 "Safety of Laser Products". Compliance of this laser with the LVD requirements is certified by the CE mark.

Laser Classification

Governmental standards and requirements specify that the laser must be classified according to the output power or energy and the laser wavelength. The Micra is classified as Class IV based on 21 CFR, Subchapter J, part 1040, section 1040.10 (d). According to the European Community standards, Micra lasers are classified as Class 4 based on EN 60825-1/IEC 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 21CFR, Part 1040 Section 1040.10 (f)(1) and Table 1-A/EN 60825-1/IEC 60825-1 clause 4.2 except for the output beam, which is Class 4.

Safety Interlocks

The system incorporates multiple safety interlocks which activate when the top cover of the laser head or power supply is removed. An interlock fault initiation will terminate all lasing by activating a shutter mechanism as well as removing power from the infrared diodes in the power supply. While installed, the interlock defeats are directly visible by anyone near the laser. It is not possible to replace the laser cover while the interlocks are installed.

The laser interlocks should be defeated only for the purpose of maintenance and service by trained personnel. Extreme caution must always be observed when operating the laser with its covers removed [CFR 1040.10 (f)(2)/ EN 60825-1/IEC 608225-1, Clause 4.3].

Remote Interlock Connector

The Micra laser system is equipped with an external interlock connector on the rear panel of the power supply. The terminals of this connector must be electrically joined for the laser to operate [CFR 1040.10 (f)(3)/ EN 60825-1/IEC 608225-1, Clause 4.4].

Key Control

Operation of the Micra requires that the power supply keyswitch be in the ON position. The key is removable and the system cannot be operated when the key is removed [CFR 1040.10 (f)(4)/ EN 60825-1/IEC 60825-1, Clause 4.5].

Laser Radiation Emission Indicators

The LASER EMISSION indicators on both the power supply and the laser head illuminate approximately 30 seconds before laser emission can occur. The indicators are visible without exposing the operator to laser emission. Amber lights are used which are visible while wearing the proper type of safety glasses [CFR 1040.10(f)(5)/EN 60825-1/IEC 60825-1, clause 4.6].

Beam Attenuator

An internal shutter prevents exposure to all laser radiation without removing power from the system [CFR 1040.10 (f)(6)/EN 60825-1/IEC 60825-1, clause 4.7].

Operating Controls

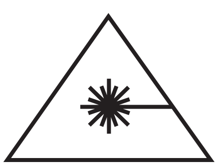
The laser controls are positioned so that the operator is not exposed to laser emission while manipulating the controls [CFR 1040.10(f)(7)/EN 60825-1/IEC 60825-1, clause 4.8].

Display Screen

The display screen on the front panel of the power supply may be viewed without exposing the operator to laser emission [CFR 1040.10(f)(8)/EN 60825-1/IEC 60825-1, clause 4.9].

Manual Reset Mechanism

Following an interlock fault or unexpected loss of electrical power, laser operation is resumed by pressing the SHUTTER OPEN push-button on the power supply front panel [CFR 1040.10(f)(10)/EN 60825-1/IEC 60825-1, clause 4.11].



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 1-2 for the 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/ EN 60825-1/IEC 60825-1, Clause 5].

Electromagnetic Compatibility

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

Conformance to the EMC requirements 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.

Waste Electrical and Electronic Equipment (WEEE, 2002)

The European Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) is represented by a crossed-out garbage container label (see Figure 1-1). The purpose of this directive is to minimize the disposal of WEEE as unsorted municipal waste and to facilitate its separate collection.

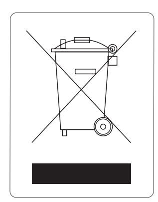
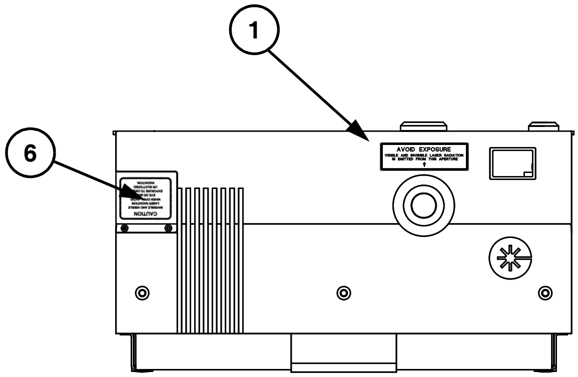
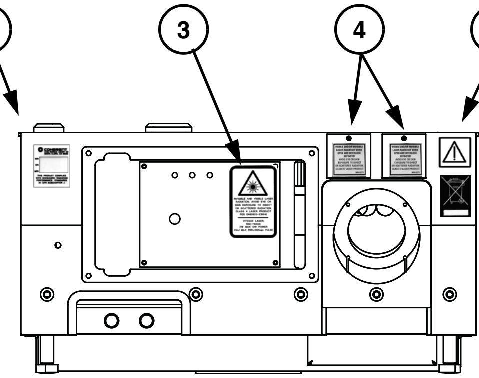


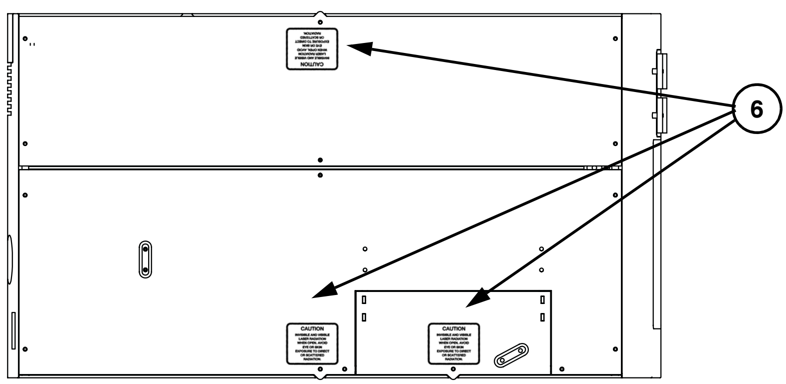
Figure 1-1. Waste Electrical and Electronic Equipment Label



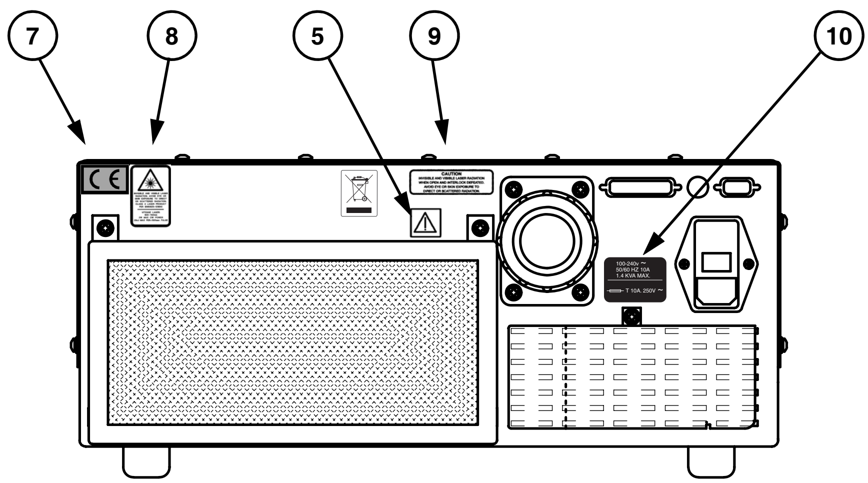
LASER HEAD - FRONT VIEW



LASER HEAD - REAR VIEW



LASER HEAD - TOP VIEW



POWER SUPPLY - REAR VIEW

Figure 1-2. Micra Safety Features and Labels (Sheet 1 of 4)

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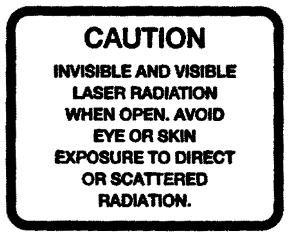
2.

3.

4.

Figure 1-2. Micra Safety Features and Labels (Sheet 2 of 4)

5.



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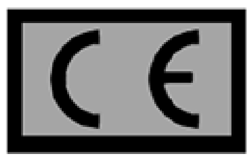

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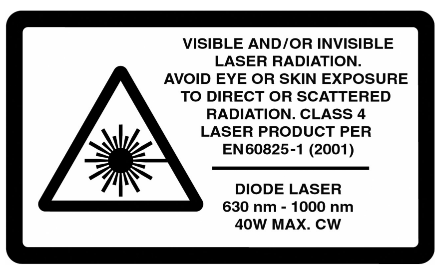

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Figure 1-2. Micra Safety Features and Labels (Sheet 3 of 4)

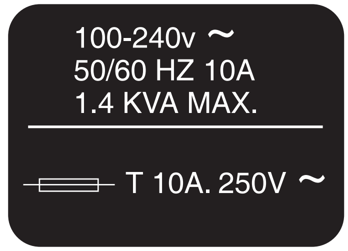

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Figure 1-2. Micra Safety Features and Labels (Sheet 4 of 4)

Sources of Additional Information

The following are sources for additional information on laser safety standards and safety equipment and training.

Laser Safety Standards

Safe Use of Lasers (Z136.1)
American National Standards
Institute (ANSI)
1430 Broadway
New York, NY 10018
Tel: (212) 354-3300

Occupational Safety and Health Administration (OSHA)
U.S. Department of Labor
200 Constitution Avenue N.W.
Washington, DC 20210

A Guide for Control of Laser Hazards
American Conference of Governmental
and Industrial Hygienists (ACGIH)
6500 Glenway Avenue, Bldg. D-7
Cincinnati, OH 45211
Tel: (513) 661-7881

Laser Safety Guide
Laser Institute of America
12424 Research Parkway, Suite 130
Orlando, FL 32826
Tel: (407) 380-1553

Equipment and Training

Laser Focus Buyer's Guide
Laser Focus World
One Technology Park Drive
P.O. Box 989
Westford, MA 01886-9938
Tel: (508) 692-0700

Photonics Spectra Buyer's Guide
Photonics Spectra
Berkshire Common
Pittsfield, MA 01202-4949
Tel: (413) 499-0514

Lasers and Optronics Buyer's Guide
Lasers and Optronics
301 Gibraltar Dr.
P.O. Box 650
Morris Plains, NJ 07950-0650
Tel: (210) 292-5100

SECTION TWO: GENERAL DESCRIPTION

System Description

The Micra-5 is a Titanium:sapphire laser oscillator system capable of producing modelocked pulses with bandwidths exceeding 100 nanometers. Excellent power stability is achieved by integrating the proven Coherent Verdi™ pump laser, PowerTrack™ beam steering technology, and a compact cavity design into a single laser head. Bandwidth and center wavelength are conveniently adjusted through a hatch in the top cover.

The primary components are the laser head and power supply, connected by an umbilical as shown in Figure 2-1. Also included is a stand-alone water chiller to provide thermal stability for the entire system.

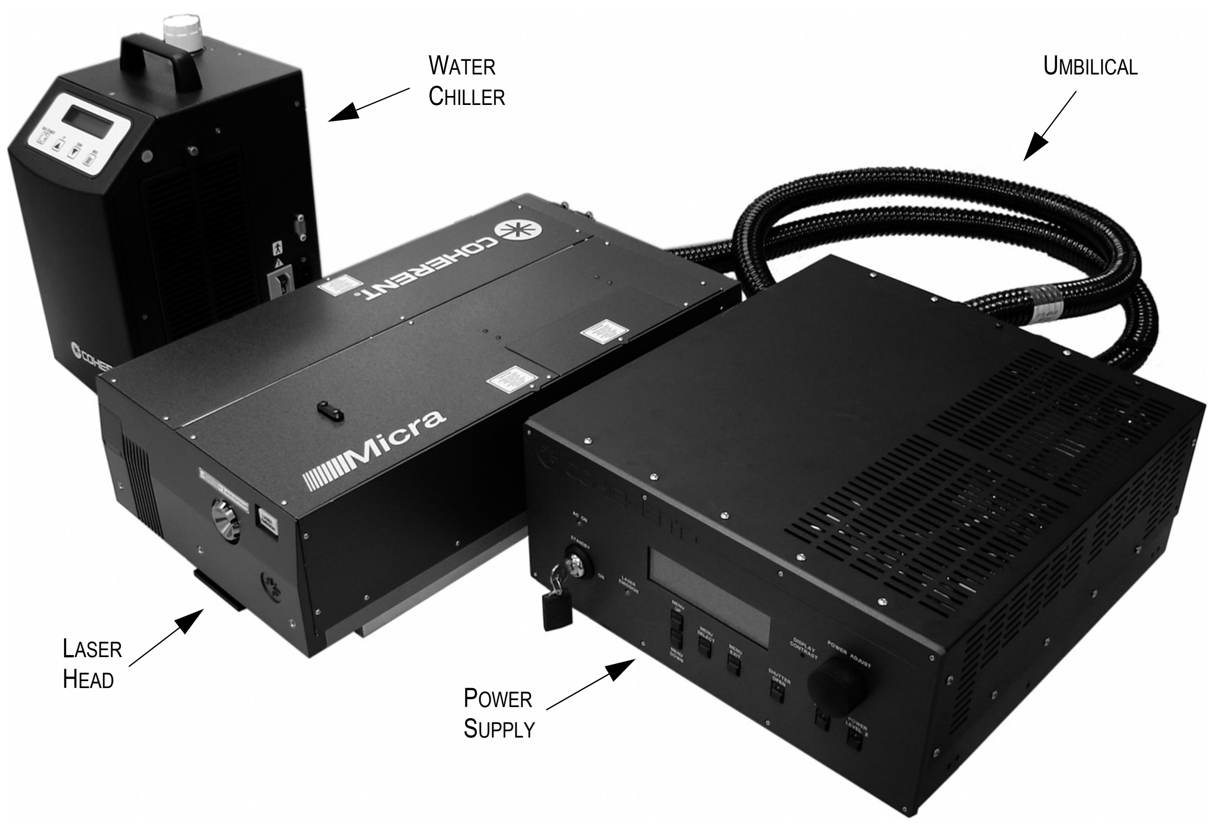


Figure 2-1. Micra Laser System

Micra Laser Head

A key feature of the Micra laser system is the incorporation of the Verdi pump laser into one box with the oscillator cavity (Figure 2-2). Advantages of this design include a smaller overall footprint as well as increased stability due to several factors: the pump source is fixed at a short distance from the Ti:sapphire crystal, any air currents along the pump beam path are greatly reduced, and the entire system remains in thermal equilibrium with the water-cooled baseplate.

Optimal alignment of the pump beam into the oscillator cavity is maintained by the PowerTrack beam steering system. A feedback loop controls the orientation of the first pump steering optic while monitoring the Micra output power level. In addition to correcting any long-term drift associated with the Verdi beam pointing, this mechanism greatly reduces system warm-up time.

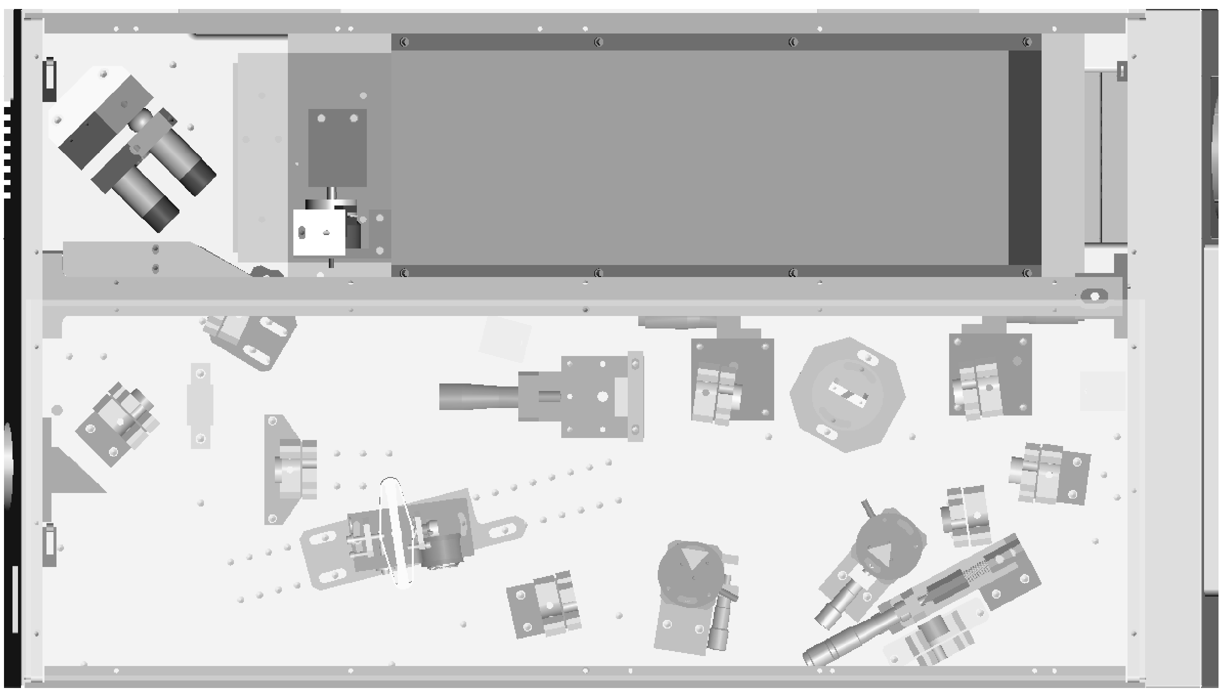


Figure 2-2. Micra Laser Head Layout Drawing

The oscillator itself employs Kerr lens modelocking in combination with an intracavity prism pair to generate low-noise, large-bandwidth, and high-peak power ultrafast pulses. The prisms are adjustable along with a slit assembly to provide tunability of the bandwidth and center wavelength. Precise control of the spatial mode profile allows stable operation at bandwidths in excess of 100 nm while maintaining high-quality mode. The cavity also features automated modelocking initiation by means of a solenoid-driven movable mirror mount.

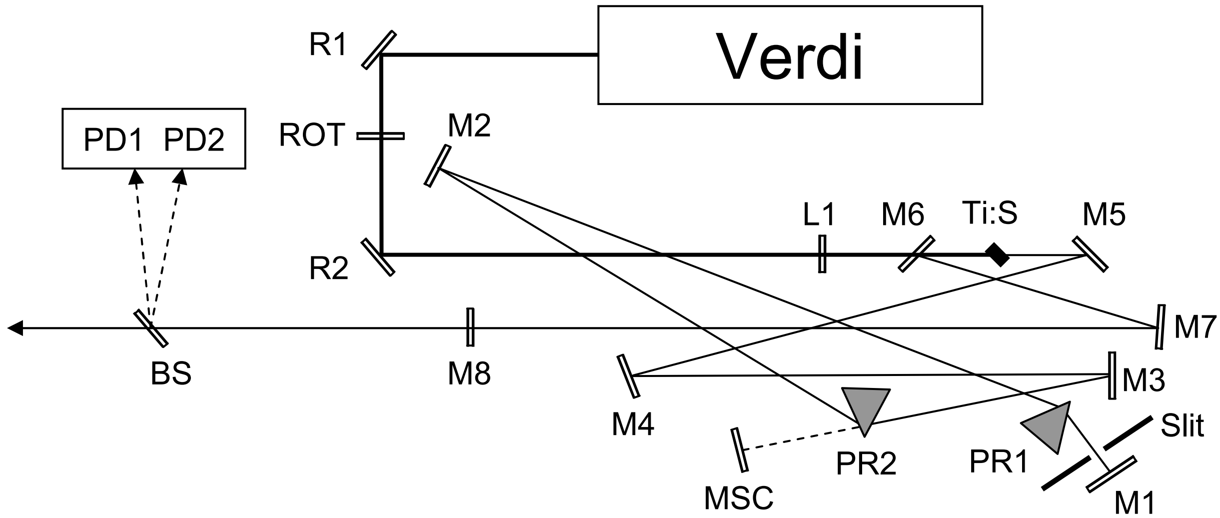


Figure 2-3. Micra Laser Head Layout Diagram

PUMP BEAM PATH		OSCILLATOR CAVITY OPTICS	
R1	Pump beam routing optic with PowerTrack beam steering actuators	M1-M8	Oscillator cavity mirror
		MSC	Auxiliary cavity end mirror
ROT	Polarization rotator	PR1, PR2	Prism pair
R2	Pump beam routing optic	BS	Beamsplitter
L1	Pump beam focusing lens	PD1, PD2	Fast and slow photodiodes
Ti:S	Titanium:sapphire laser crystal		

Verdi Laser Head

The Coherent Verdi has established new standards of performance for a continuous-wave green laser. The extremely low noise, narrow linewidth, and diffraction-limited mode quality which characterize its output qualify it as an ideal source of pump energy for Ti:sapphire systems.

The Verdi head is sealed in a factory cleanroom to ensure optimal performance over the lifetime of the laser. The Coherent PermAlign™ manufacturing process provides high durability to the resonator structure, which is displayed in Figure 2-4. The gain medium is Neodymium Yttrium orthovanadate ($Nd:YVO_4$), which generates a fundamental wavelength of 1064 nm. Frequency doubling occurs within a Lithium triborate (LBO) nonlinear crystal to produce green light at 532 nm, allowing for efficient absorption by the Ti:sapphire crystal.

The enhanced stability of the Verdi can be traced to the resonator design, all solid-state construction, and the use of semiconductor diode lasers as a pump source. Diode lasers directly convert electrical energy to laser light with high efficiency, and offer precisely tunable output wavelength along with lifetimes in the thousands of hours. In the Micra-5 laser system, a pre-packaged diode module is installed in the power supply, and the diode output is relayed to the Verdi head through fiber optic cables in the umbilical.

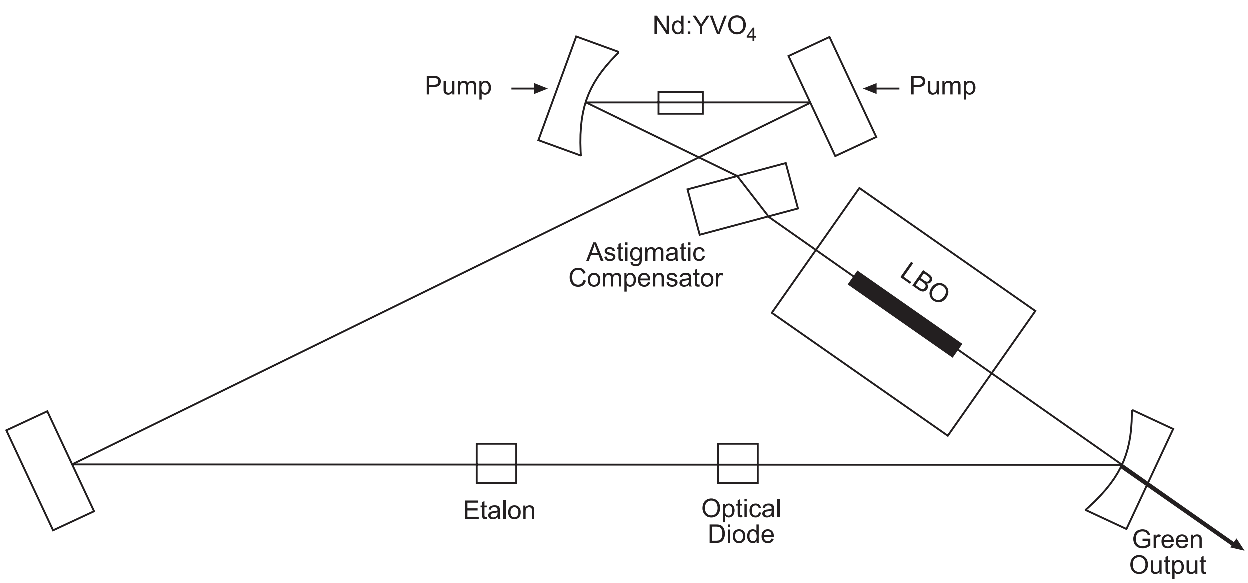


Figure 2-4. Pump (Verdi) Laser Head Layout Drawing

Power Supply

Aside from its primary function of providing energy for the entire system, the power supply contains several features to ensure optimal quality of the Verdi, and in turn the Micra, output beams. Of central importance is the proprietary noise-suppression circuitry used to deliver electrical current to the diode assembly. There are also several servo loops which allow the power supply to monitor and control important system parameters, including the diode current as well as the individual temperatures of the doubling crystal, vanadate and etalon optical elements, and diode heat sink. The electrical cables necessary for these utilities are housed within the umbilical along with the fiber optics.

The doubling crystal is held at a particularly elevated temperature (~150 ^{o}C). Because the crystal material may be damaged by a rapid change in temperature, it is heated and cooled in a controlled fashion. The power supply handles this automatically as soon as the switch on the rear panel is turned on. The system is also equipped with a rechargeable battery which allows the cool-down routine to execute in the event of a power loss.

The diode array temperature is carefully maintained because the diode output wavelength is slightly dependent on temperature. Again using proprietary Min-I™ closed-loop temperature optimization, the diode wavelength is precisely tuned into the absorption band of the Neodymium gain material. This minimizes the diode current necessary to achieve a given power level, which results in improved stability and extended diode lifetime.

Finally, the power supply serves as the user interface. Operating parameters, diode and laser head hours, fault handling, and the various system controls are accessible either directly on the front panel or remotely through the RS-232 serial port.

Specifications

A complete list of specifications for all Coherent products may be found at www.Coherent.com.

SECTION THREE: INSTALLATION

Receiving and Inspection

Inspect shipping containers for signs of rough handling or damage. Report any damage immediately to the shipping carrier and to the Coherent Order Administration Department or authorized 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.

The following items are included in the standard Micra laser system:

1. Laser head and power supply connected by the umbilical. Water hoses are also attached to the laser head.
2. Water chiller (Thermotek Model T-255P or equivalent)
3. Micra maintenance kit

Utility, Environmental, and Space Requirements

The following tables provide pertinent information concerning installation of the Micra:

Table 3-1. Utility Requirements

PARAMETER	REQUIREMENT
Electrical Power	90 to 250 VAC[1][2]
Maximum Current	Max. 14.5 Amp @ 90 VAC
Line Frequency	47 to 63 Hz

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 should be clearly marked as the disconnecting device for the laser, and should be within easy reach of the operator.

Table 3-2. Environmental Requirements

PARAMETER	REQUIREMENT
Ambient temperature	15 to 30 °C (59 to 86 °F)
Relative humidity	5 to 95% non-condensing

Table 3-3. Water Chiller Specifications

PARAMETER	REQUIREMENT
Flow rate	1.0 to 1.5 liters/minute (0.2 to 0.4 gallons/minute)
Maximum pressure	200 kPa (30 psi)
Operating water temperature	21 ^{o}C (70 °F)

Table 3-4. Dimensions and Weights

	LASER HEAD	POWER SUPPLY	UMBILICAL	CHILLER
Length	59.1 cm (23.3 in)	65.2 cm (25.7 in)	3 meters (10 feet)	27.7 cm (10.9 in)
Width	32.9 cm (12.9 in)	43.5 cm (17.1 in)	— —	20.3 cm (8.0 in)
Height	17.5 cm (6.9 in)	19.6 cm (7.7 in)	— —	38.6 cm (15.2 in)
Weight	46.2 kg (93 lbs)	31.5 kg (70 lbs)	4.5 kg (10 lbs)	8.8 kg (19.4 lbs)
Diameter	— —	— —	6.35 cm (2.5 in)	— —

Dimensions

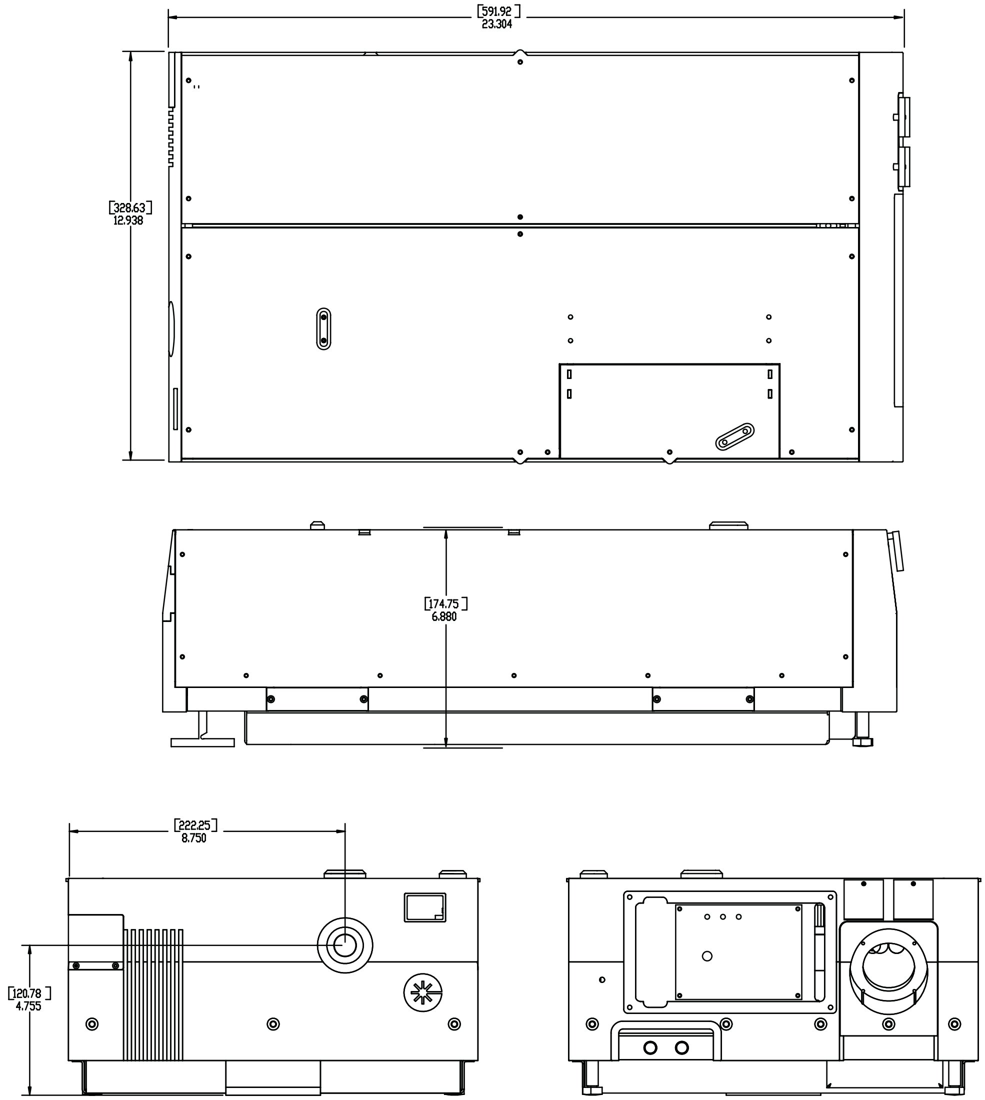


Figure 3-1. Laser Head Dimensions. Values are Listed in [Millimeters] and Inches.

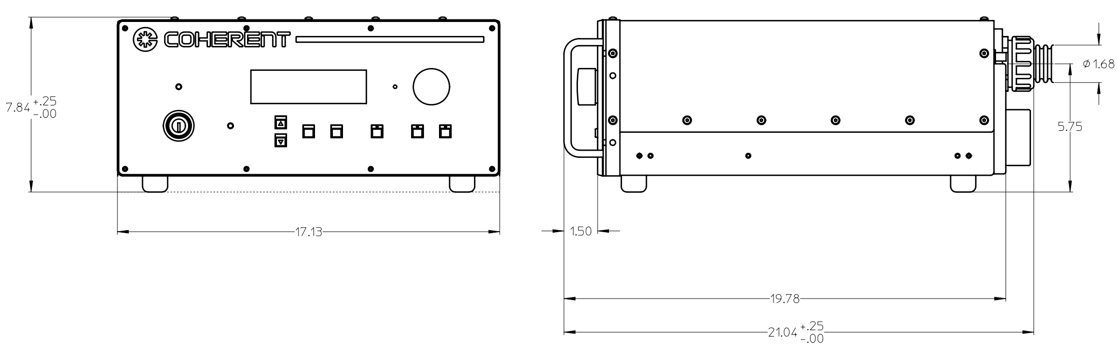


Figure 3-2. Power Supply Dimensions

External Interlock

An interlock connector is located on the power supply rear panel, and the system will not operate with this circuit open. The Micra accessory kit contains an interlock defeat which should be installed to close the interlock loop.

Alternatively, the interlock connector may be wired to an external circuit such as a door switch. Many types of switch may be used, but the switch should have its contacts closed when it is safe to operate the laser and open when it is not safe. The interlock circuit operates from a +/-12 VDC circuit, with a current limit of approximately 1 milliAmpere. For these ratings a "dry circuit" type of switch will give the most reliable operation.

To incorporate an external safety interlock circuit into the laser system, perform the following steps:

1. The laser should be in either the "OFF" or "STANDBY" state (See Section Five: Operation). Remove the interlock defeat from the back of the power supply. This type of connector is called a "three pin mini-DIN".
2. Slide the plastic cover off of the connector, and locate the two pins that have a wire soldered between them. These are pins 1 and 2. Remove the shorting wire and solder the interlock wires to these two pins. Make sure the wires have adequate strain relief.
3. Solder the other ends of the wires to an interlock switch.

Figure 3-3 shows the wiring diagram for the switch. One wire runs from pin 1 of the connector to the normally open contact of the switch. The other wire runs from pin 2 to the common terminal of the switch. The switch is shown in the open position, which is the condition where the laser will not operate.

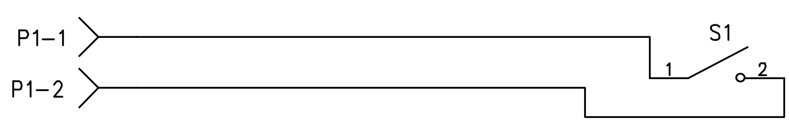


Figure 3-3. External Interlock Circuit

In the event of an interlock fault during normal operation, the shutter inside the Micra head is closed and the diode current is ramped down to zero. This process is accompanied by a beep from the power supply and the appearance of a fault message on the front panel. Once the interlock circuit has been re-closed, press the MENU EXIT key on the front panel to clear the fault. The shutter may then be reopened to resume operation.

Installation

At least two people are recommended to unpack the Micra. The power supply and laser head each weigh close to 100 pounds (45 kg). A curve radius of at least 13 cm (5 inches) must be maintained in the umbilical at all times.

Both the laser head and power supply should be located away from heat sources. The power supply cooling intake and exhaust (rear, top, and left sides) must not be obstructed, and the front panel display should be easily accessible.

Excessively tight umbilical bends (less than a 13 cm or 5 inch radius) can cause permanent damage to the fiber optics inside.

Foot Clamping

Once an appropriate location for the laser head has been selected, secure it in place with the foot clamps provided in the accessory kit.

Clamping down the Micra feet while not level introduces a torsional stress to the entire enclosure. Long-term power instabilities will result.

---

1. Before tightening the rear foot clamps, verify that the laser is level. Apply downward pressure to the front-center and back-left of the laser head at the same time. Repeat this with the front-center and back-right of the laser head. The laser should be completely immovable; any rocking motion indicates that the feet are not level.
2. If necessary, loosen the locking nut and then adjust the height of one of the rear feet. When the laser is level, use one wrench to hold the foot in place while using another wrench to tighten the locking nut against the laser baseplate.
3. Do not clamp on top of the front foot. Install the foot clamp upside down, pushed against the front foot, as shown in Figure 3-4.

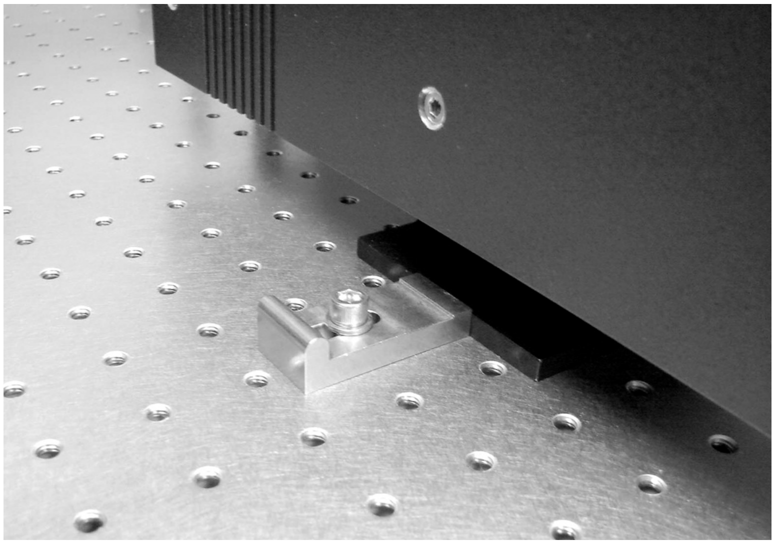


Figure 3-4. Micra Front Foot Clamp Orientation

Inspect the power cord and install the proper connector if necessary, in a properly grounded outlet with a maximum of 16 Ampere service.

System Connections

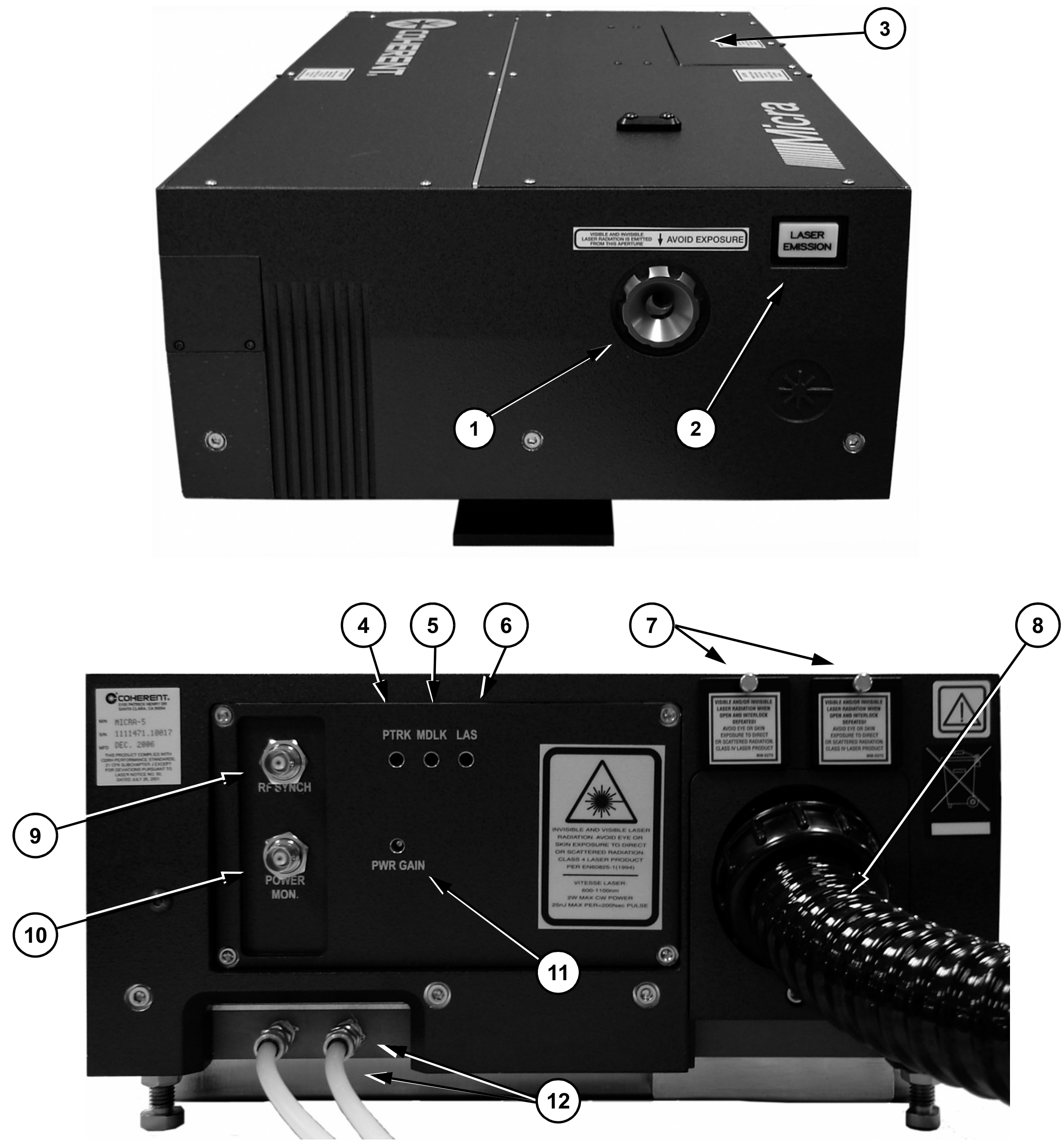
1. Connect the power supply and the chiller to facility power.
2. Remove the plugs from the inlet and outlet on the chiller. Note that water may escape from the chiller when this occurs.
3. Connect the water lines from the laser head to the chiller. The direction of flow is not important.
4. Connect the interlock defeat to the EXTERNAL INTERLOCK connector on the back of the power supply, or ensure that any external interlocks are closed. The interlock defeat is located in the accessory kit or taped to the rear of the power supply. If an interlock fault appears on the front panel, press the MENU EXIT key to clear it.

The system is ready to be activated. Follow the Turn-on (Cold Start) procedure located in Section Five: Operation.

Section Four: Controls and Indicators

Control and Indicator Locations

On the following four pages, Figure 4-1 and Table 4-1 identify and describe the features of the Micra laser head, while Figure 4-2 and Table 4-2 convey similar information for the power supply.

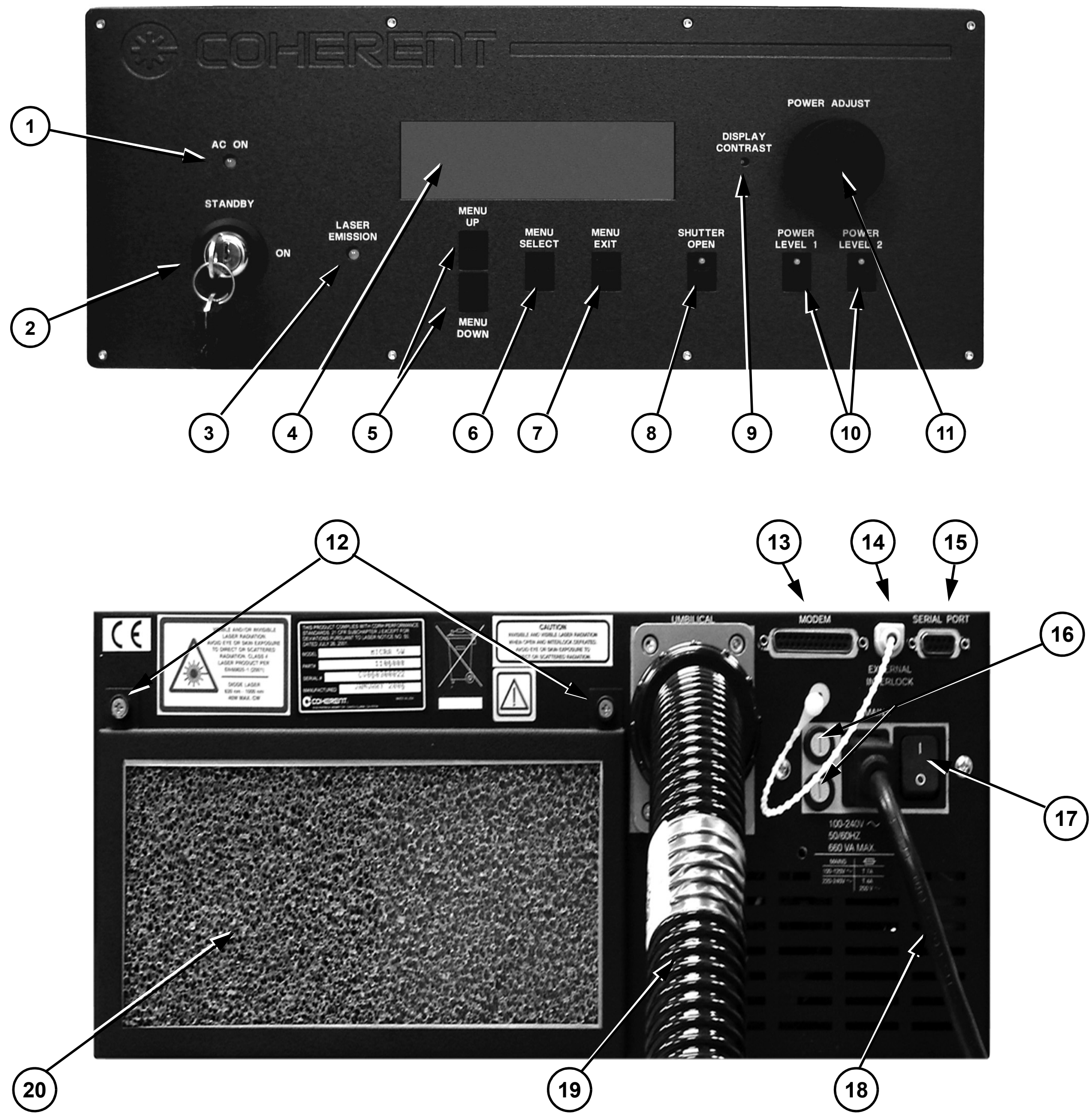


1. Exit window
2. Emission indicator
3. Tuning access cover
4. PowerTrack LED
5. Modelocked LED
6. Lasing LED
7. Cover interlock defeats
8. Umbilical
9. Fast photodiode voltage monitor (RF sync out)
10. Slow photodiode voltage monitor (Power Monitor)
11. Slow photodiode gain
12. Cooling water inlet and outlet lines

Figure 4-1. Laser Head Features

Table 4-1. Laser Head Features

ITEM	CONTROL	FUNCTION
FRONT PANEL		
1	Exit window	Laser light at approximately 800 nm is emitted from this window when the laser is on and the shutter is open.
2	Emission indicator	Lights when laser emission is possible
3	Tuning access cover	Allows adjustments to the prism micrometers and slit assembly without removing the entire head cover
BACK PANEL		
4	PowerTrack LED	Lights when the PowerTrack control loop is active and locked
5	Modelocked LED	Lights when the fast photodiode detects pulses, indicating that the Micra is modelocked
6	Lasing LED	Lights when the Ti:Sapphire oscillator has reached CW lasing threshold
7	Cover interlock defeats	The cover interlocks are located just underneath the cover on the front (output end) and rear sides of the laser head.
8	Umbilical	Houses the fiber optic and electrical cables that provide connectivity between the laser head and power supply
9	Fast photodiode voltage monitor (RF sync out)	BNC connector for synchronizing external equipment with the Micra pulses. This output can also be used to monitor the modelocked pulses with an oscilloscope.
10	Slow photodiode voltage monitor (Micra power)	The slow photodiode voltage is directly proportional to the Micra output power level, in either CW or modelocked operation.
11	Slow photodiode gain	Potentiometer which adjusts the gain of the slow photodiode.
12	Cooling water inlet and outlet lines	Connects to facility water or a closed loop chiller. The inlet and outlet connectors are non-directional.



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 and 2 pushbutton indicators
11. POWER ADJUST knob
12. Air filter retaining nuts (2)
13. MODEM connector
14. EXTERNAL INTERLOCK connector
15. SERIAL PORT connector
16. Fuses
17. Power ON/OFF switch
18. Power cord
19. Umbilical
20. Air filter

Figure 4-2. Power Supply Controls and Indicators

Table 4-2. Power Supply Controls and Indicators

ITEM	CONTROL	FUNCTION
1	AC ON indicator	Lights when the power supply is plugged in and the power switch on the rear panel is in the on position
2	Key switch	The key switch may be turned to either the STANDBY or ON position. Functionality in these states is summarized in Table 5-2, “Micra Operating States,” on page 5-2. The key may only be removed when in the STANDBY position.
3	LASER EMISSION indicator	Lights when laser emission is possible
4	Display	The primary user interface to the Micra laser system. Refer to Figure 4-3 for a description of the available menus.
5	MENU UP/DOWN pushbuttons	Provide scrolling through the menus
6	MENU SELECT push-button	Allows selection of the highlighted menu
7	MENU EXIT push-button	Exits the current menu, and returns the user to the previous menu. Clears inactive faults, as described in Section Seven: Maintenance and Trouble-shooting.
8	SHUTTER OPEN pushbutton indicator	Remotely opens and closes the shutter on the laser head. The pushbutton indicator LED lights when the shutter is open.
9	DISPLAY CONTRAST	Allows adjustment of the display for best viewing by the user
10	POWER LEVEL 1 and 2 pushbutton indicators	Allows selection of two preset pump laser 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	Provides adjustment of the pump laser output power level from threshold to maximum power
12	Air filter retaining nuts	Secure the air filter to the power supply
13	MODEM connector	Reserved for future use
14	EXTERNAL INTER-LOCK connector	The Micra will not operate when this connector is open. An interlock defeat is included in the Micra accessory kit. Refer to Section Three: Installation for additional information.
15	SERIAL PORT connector	Allows external computer control of the Micra
16	Fuses	250 V, 10 A, time-delay fuses
17	Power ON/OFF switch	Applies/removes all power to the Micra. Refer to the shutdown procedures in Section Five: Operation to avoid unnecessary use of the internal battery.
18	Power cord	Connects the power supply to facility power
19	Umbilical	Houses the fiber optic and electrical cables that provide connectivity between the laser head and power supply
20	Air filter	Removes dirt and contamination from the power supply cooling air

Menu Displays

Figure 4-3 shows the top level menus. Refer to Table 4-3 for the submenus.

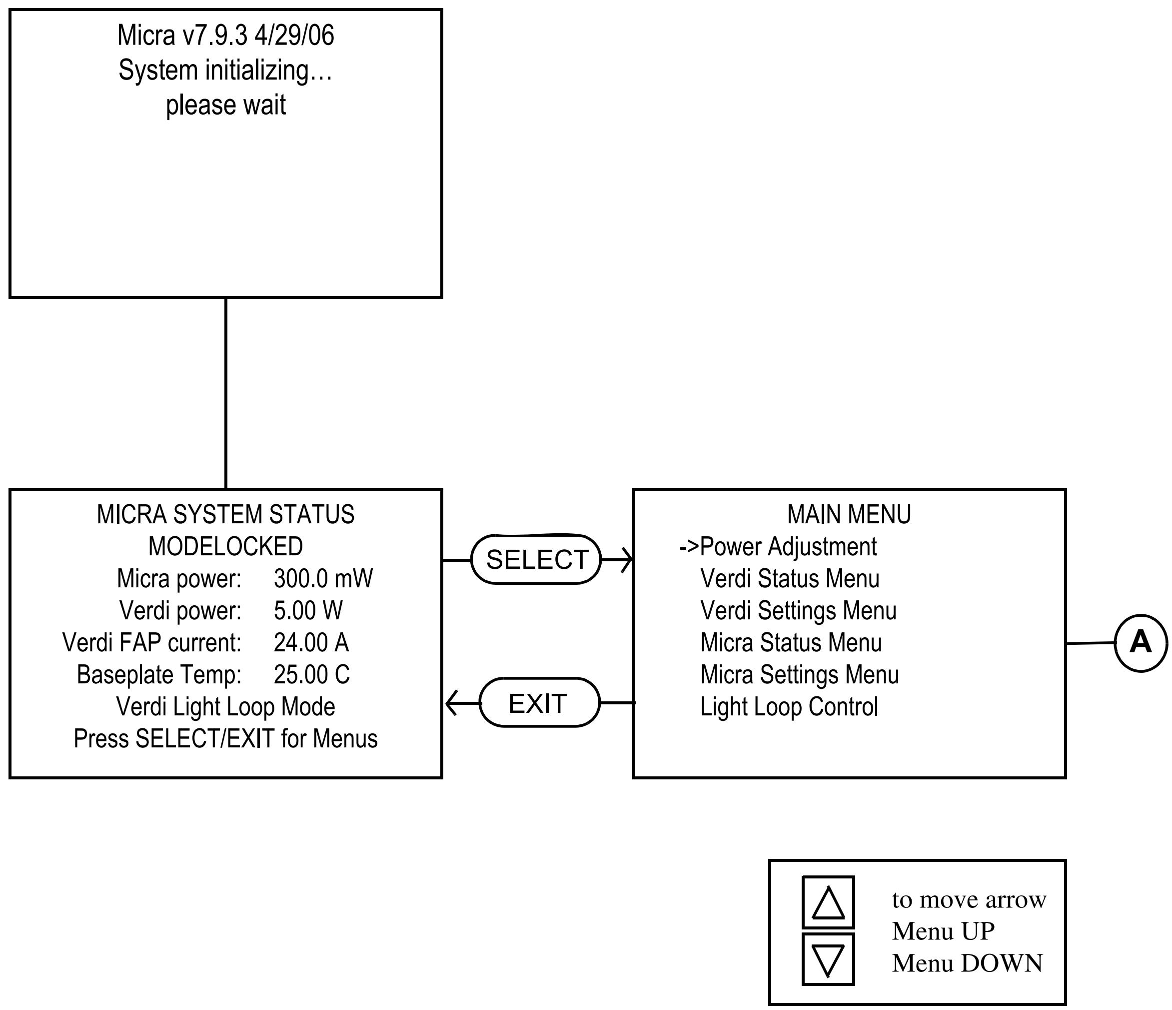
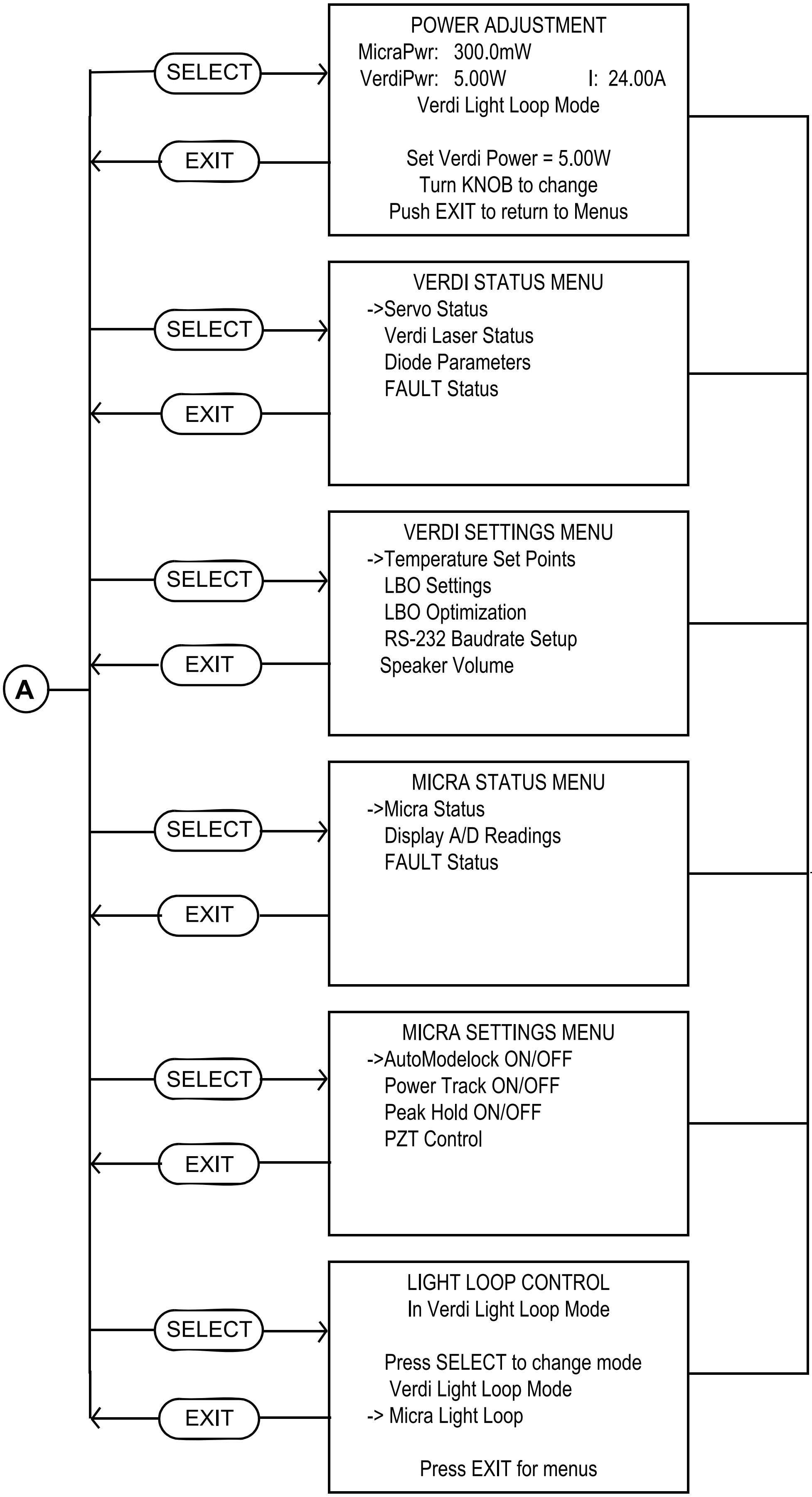


Figure 4-3. Top Level Menus

The user must access this menu to adjust Verdi power (when in Verdi light loop) or Micra power (when in Micra light loop). Coherent recommends operating the laser in Verdi light loop mode.



Refer to Table 4-3 for a description of the submenus.

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

VERDI STATUS MENUS

SERVO STATUS

Servo:	State	W/Deg C	Drive
Laser:	lock	5.02	25150
LBO:	lock	150.82	5490
Vanadate:	lock	30.09	-1933
Etalon:	lock	33.06	-2256
Diode 1:	lock	23.60	-1203

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

OPEN indicates that the servo loop is not currently active.

LOCKED is displayed when the servo loop is holding steady at its set point.

SEEKING indicates that the servo loop is unstable as it searches for the optimal drive value.

*SEEK is displayed when the algorithm optimizing the diode temperature is running.

FAULT indicates a problem with the servo loop. See Section Seven: Maintenance and Troubleshooting.

VERDI LASER STATUS

S/W Version	:	7.93	9/ 5/ 6
Heatsink1 T	:	32.93 C	
Baseplate T	:	24.35 C	
HEAD Hrs	:	361.98	
DIODE 1 Hrs	:	381.84,	I: 25.86A

Displays Verdi status and system information.

DIODE PARAMETERS

Diode1 Voltage	:	1.80V
Diode1 Current	:	25.86A
Diode1 Photocell	:	2.63V

Displays voltage, current, and photocell values for the laser diodes in the power supply. Recording these values on a periodic basis is useful for evaluating the health of the system.

FAULT STATUS

System OK!

If faults are active, the fault codes and descriptions will be displayed. Refer to Table 7-1 on page 7-2 for a complete list of faults and associated corrective actions.

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

VERDI SETTINGS MENUS

TEMPERATURE SET POINTS Set Pt: 150.30 Drive: 6216.9 Read T: 150.31 Status: lock Set Pwr: 5.00W Avg I: 24.01A ->LBO Temperature Vanadate Temperature ...Etalon Temperature	Displays the set points, and continuously updates the actual readings, drive values, and status of each temperature servo loop.
LBO SETTINGS T: 150.27 Set: 150.30 Drive: 6224 LBO HEATING Press SELECT to start COOLING Press EXIT for NO CHANGE	Displays the LBO temperature servo information, and is used to initiate heating or cooling of the LBO crystal when performing a cold start or complete shutdown of the system. These procedures are detailed in Section Five: Operation.
LBO OPTIMIZATION T: 150.31 Pwr: 1.85 Drv: 6210 OK to OPTIMIZE LBO Temp Press SELECT to OPTIMIZE Tlbo Press EXIT to ABORT Or ALL NEEDED SERVOS NOT LOCKED! LBO CANNOT BE OPTIMIZED NOW! Press EXIT to ABORT	This menu is accessed to run the automated LBO temperature optimization routine. See "LBO Temperature Optimization" on page 7 - 19 for a detailed description of this procedure. This feature is available only after the LBO temperature has stabilized following a cold start.
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, bits, parity, and stop bits for RS-232 communication.

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

MICRA STATUS MENUS

Ver	:	7.12	Pwr	:	300.0mW
Mdlk	:	YES	Bw	:	
PTrk	:	ON	Cw	:	1200mW
Strt	:	ON	SetP	:	300.5mW
PHld	:	OFF	QSw	:	50.0mW
MLL	:	OFF	LS	:	2.29 V
Pzt	:	Auto	SDac	:	2.72 V
Stat	:	0	Verd	:	0.01 W

Ver = software version
Mdlk = modelock status (yes or no)
PTrk = power track status (on or off)
Strt = starter status (on or off)
PHld = peak hold (on or off)
MLL = Micra light loop (on or off)
Pzt = Piezo control (auto or manual)
Stat = Micra light loop state
- 0 = Micra light loop not on
- 1 = Micra light loop seeking
- 2 = Micra light loop locked

Pwr = Micra power output
Cw = CW breakthrough point (upper operation limit)
SetP = power set point
QSw = Q-Switching onset power level (lower operation limit)
LS = loop snoop voltage, normally between 2.1 V to 2.9 V
SDac = voltage used with Micra light loop (approx. 2.72 V)
Verd = Verdi power output

DISPLAY A/D READING

slow photodiode :	2.02V
PZT X Rd :	2.40 V
PZT Y Rd :	2.42 V
Micra loop snoop :	2.00 V
Therm V :	2.99 V
Green Photocell :	3.42 V

Press EXIT to return to Menus

Displays system device voltages. Slow photodiode voltage should be approximately 2.5 V at full power. PZT voltages should be between 1 and 4 Volts when PowerTrack is on. Micra loop snoop voltage should be between 2.1 V to 2.9 V. Therm V voltage (voltage on the Ti:Sapphire crystal) should be approximately 3 V. Green photocell (voltage on the 532 nm photocell) should be about 2.1 V.

FAULT STATUS

System OK!

If faults are active, the fault codes and descriptions will be displayed. Refer to Table 7-1 on page 7-2 for a complete list of faults and associated corrective actions.

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

MICRA SETTINGS MENUS

AUTOMODELOCK ON/OFF Automodelock setting : OFF Press SELECT to toggle Setting Press EXIT to return to Menus	Allows the automodelock function to be turned on or off by pressing the MENU SELECT pushbutton. During normal operation this is set to on. This function is described in Section Five: Operation.
POWER TRACK ON/OFF Power Track setting : OFF Power Track status : OFF Press SELECT to toggle Setting Press EXIT to return to Menus	Allows the PowerTrack function to be turned on or off by pressing the MENU SELECT pushbutton. Coherent recommends that this function be set to on at all times. This function is described in Section Five: Operation.
PEAK HOLD ON/OFF Peak Hold status : OFF Press SELECT to toggle Setting Press EXIT to return to Menus	Allows the peak hold function to be turned on or off by pressing the MENU SELECT pushbutton. During normal operation this is set to off. This function is described in Section Five: Operation. **Note that this menu setting has no effect if either 1) PowerTrack is set to OFF, or 2) PZT Control is set to MANUAL.**
PZT CONTROL PZT X: 2.30V VitPwr: 300.0mW PZT Y: 2.30V MODELOCKED Press SELECT to toggle ->PZT mode = AUTO Set PZT X Voltage = *Auto* Set PZT Y Voltage = *Auto* Set AutoModeLock = ON	Allows the PZT control to be set to auto or manual, and the auto modelock function to be turned on or off. During normal operation the settings are auto and on, respectively. Use the MENU UP/DOWN pushbuttons to move the arrow to the desired function, and the MENU SELECT pushbutton to change the PZT and automodelock settings. In PZT MANUAL mode, the PZT Voltages may be changed individually by rotating the POWER ADJUST knob. The actual voltage readings are displayed in the upper left corner. **Note that the settings of this menu override the settings of the AUTOMODELOCK, POWER TRACK, and PEAK HOLD menus**

Fault Handling

In case of a fault, the system closes the internal shutter and ramps the laser diode current down to zero. The power supply sounds a warning beep and the front panel display identifies the fault condition. For example:

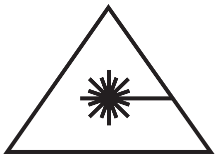
```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
FAULT CONDITION!
ERROR CODE #16
Diode 1 Over Current Fault
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

Push EXIT to continue
```

After exiting the fault display (MENU EXIT pushbutton), the front panel will indicate whether the fault is still active. If the fault condition no longer exists, the laser returns to its previous state, except for the shutter which remains closed. The SHUTTER OPEN pushbutton may then be pressed to resume operation.

If the fault condition still exists, the front panel will display "FAULT ACTIVE" on the first line. Active faults may also be seen by accessing the MAIN MENU --> Verdi Status --> FAULT Status or MAIN MENU --> Micra Status --> FAULT Status menus.

Some fault messages are for information purposes only and will not set the diode laser current to zero. Refer to Table 7-1 on page 7-2 for a complete list of fault messages.

SECTION FIVE: OPERATION



All personnel in the area must wear laser safety glasses to protect against laser radiation. Read Section One: Laser Safety and be familiar with proper laser safety practices. Contact Coherent customer service (800-367-7890) with any questions or potential issues concerning laser safety.

Laser safety eye wear must be rated to protect against the following wavelengths:

Table 5-1. Wavelengths of Radiation Generated by the Micra

MICRA CONDITION	WAVELENGTHS
Covers in place (normal operation)	700 to 900 nm
Head cover removed	532 nm, 700 to 900 nm
Fiber optic cable disconnected	808 nm, 1064 nm

The Micra is normally operated with the laser head and power supply covers in place. Operation of the laser with the head cover removed allows access to hazardous visible and invisible radiation. Removal of the power supply cover allows access to dangerous voltage and current levels in addition to laser radiation. Covers must only be removed for service and maintenance by trained personnel.

System Activation

Table 5-2 summarizes the four operating states of the Micra laser system.

Table 5-2. Micra Operating States

State	Switch Position	Status
OFF	• Main Power Switch (power supply rear panel): OFF	All functions off (except LBO servo until cool-down is complete)
STANDBY	• Main Power Switch: ON • Key switch: STANDBY	Laser diodes off. Vanadate temperature servo off. LBO temperature servo on. Etalon temperature servo on.
SIMMER	• Main Power Switch: ON • Key switch: ON • Shutter: closed (SHUTTER OPEN pushbutton indicator LED off)	Laser diodes at simmer current (near lasing threshold). Vanadate temperature servo on. LBO temperature servo on. Etalon temperature servo on.
ON	• Main Power Switch: ON • Key switch: ON • Shutter: open (SHUTTER OPEN pushbutton indicator LED on)	Laser diodes at normal operating current. All temperature servos on. Laser light present.

Turn-on (Cold Start)

The cold start procedure should be used when the main power switch on the power supply rear panel is in the off position. This corresponds to the OFF state in Table 5-2.

1. Ensure that the key switch on the power supply front panel is in the STANDBY position.
2. Set the power switch on the power supply rear panel to ON. The AC ON and LASER EMISSION indicators will light. If an indicator does not light, refer to Section Seven: Maintenance and Troubleshooting.
3. Turn on the external water chiller, and confirm that it is set to 21 ^{o}C.

The system will not activate the laser diodes unless the LBO temperature is stabilized at its normal operating value (~150 ^{o}C). From room temperature, the warm-up process requires approximately 30 minutes.

Turning the key switch to ON prematurely will result in a fault display. Progress may be monitored by accessing the LBO SETTINGS menu:
MAIN MENU --> Verdi Settings --> LBO Settings.

4. After the LBO temperature has stabilized, turn the key switch to ON. The diode current will increase to the simmering level over a period of a few seconds. Laser light is not available during this time.

5. Confirm that the system is set to Verdi Light Loop Mode in the LIGHT LOOP CONTROL menu:
MAIN MENU --> Light Loop Control.

6. Access the POWER ADJUSTMENT menu: MAIN MENU --> Power Adjustment. Set the output power to the desired level using the POWER ADJUST knob. The normal operating value is listed on the Customer Data Sheet, and should correspond to the preset POWER LEVEL 2 pushbutton indicator.

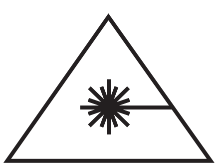
7. Confirm the following menu settings:

   MAIN MENU --> Micra Settings --> AutoModelock ON/OFF --> Automodelock setting: ON

   MAIN MENU --> Micra Settings --> Power Track ON/OFF --> Power Track setting: ON

   MAIN MENU --> Micra Settings --> Peak Hold ON/OFF --> Peak Hold status: OFF

   MAIN MENU --> Micra Settings --> PZT Control -->
   PZT mode = AUTO



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

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8. Press the SHUTTER OPEN pushbutton. The opening of the shutter is accompanied by an audible click, and the diode current ramps to achieve the requested power level. Micra output will be available after a delay of a few seconds.

Daily Turn-on (Warm Start)

A warm start may be performed when the system is in the STANDBY state described in Table 5-2. The recommended daily operation of the Micra is to use this warm start procedure in conjunction with the daily turn-off procedure described below. The main power switch is not cycled during daily operation, allowing the LBO temperature to remain at an elevated value. Coherent also recommends that the water chiller be left on to minimize the time required to reach optimal thermal stability.

If the main power switch on the power supply rear panel is in the off position (AC ON indicator not lit), refer to the above procedure "Turn-on (Cold Start)."

1. Confirm that the external water chiller is operating at 21 ^{o}C.
2. Turn the key switch on the power supply front panel to ON. The diode current will increase to the simmering level over a period of a few seconds. Laser light is not available during this time.

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

3. Press the SHUTTER OPEN pushbutton. The opening of the shutter is accompanied by an audible click, and the diode current ramps to achieve the requested power level. Micra output will be available after a delay of a few seconds.
4. The laser will return to its previous operating state. If settings have been changed, refer to the "Turn-on (Cold Start)" procedure above for the appropriate menu selections.

System Turn-off

Turn-off (Daily Use)

When the Micra is being used on a daily basis, turn-off normally consists of closing the shutter by pressing the SHUTTER OPEN pushbutton indicator, and turning the key switch to the STANDBY position. This shuts off the laser diodes and places the pump laser in STANDBY as described in Table 5-2.

The external chiller can be left on or turned off. For daily use, Coherent recommends that the chiller remain on. This decreases the time required for the Micra to fully stabilize following turn-on.

Do not turn off the main power switch on the power supply rear panel. Refer to the "Turn-off (Complete Shutdown)" procedure below if all power is to be removed from the system.

Turn-off (Complete Shutdown)

This procedure removes all power from the Micra. It is recommended if no operation is anticipated for a long period of time, or as required for system maintenance.

1. Close the shutter if necessary by pressing the SHUTTER OPEN pushbutton indicator.
2. Turn the key switch on the power supply front panel to STANDBY.
3. Access the LBO SETTINGS menu: MAIN MENU --> Verdi Settings Menu --> LBO Settings. Press the MENU SELECT pushbutton to start the LBO cool-down cycle. "LBO COOLING" will appear on the display. The LBO temperature may also be monitored from this display as it cools.

To avoid unnecessary use of the backup battery, do not turn off the power switch on the power supply rear panel while the LBO temperature servo is in the cool-down cycle. The cool-down cycle requires approximately 45 minutes.

4. Turn off the water chiller. The Thermotek chiller has a RUN/STANDBY button on the front panel. Additionally, turn the power switch on the side of the chiller to OFF.

Do not turn off the power switch on the rear of the power supply or disconnect AC power from the power supply if an "LBO Battery" fault is active. Refer to "LBO Battery Fault" on page 7-13.

5. When the LBO temperature is below 40 °C, turn off the power switch on the power supply rear panel.
6. The key may be removed to prevent inadvertent turn-on.

Bandwidth and Center Wavelength Adjustments

The Micra spectrum is controlled using the slit assembly and PR1 (See Figure 2-2 and Figure 2-3). To achieve a given center wavelength and bandwidth, iterate between prism and slit adjustments as described below.

Always wear powderless latex or nitrile gloves when making adjustments inside the Micra head. The introduction of dirt or oils into the cavity can cause degradation of system performance.

PR2 Positioning

PR2 does not need to be regularly adjusted. If it has been moved or the laser has been realigned, follow the procedure below to reset it:

1. Translate PR2 out of the beam (clockwise rotation of the micrometer) until the power just begins to drop.
    a. If the laser is modelocked, the power will increase as the bandwidth narrows, and then decrease as the beam begins to clip on the prism.
    b. If the laser is CW, the power will remain constant, and then decrease as the beam begins to clip on the prism.
2. From the point where the power just begins to drop, rotate the micrometer one turn counterclockwise (adding glass back in).

PR1 Positioning

Use PR1 to set the desired bandwidth:

- Clockwise rotation introduces more glass into the oscillator cavity and increases the bandwidth.
- Counterclockwise rotation removes glass and decreases the bandwidth.
- The output power is dependent on the bandwidth, with narrower bandwidth yielding higher power.
- The center wavelength can shift when the bandwidth is changed. Iterate with the slits to compensate for this, as described in the "Slit Positioning" section below.

If too much glass is present in the cavity, a continuous wave (CW) spike will appear in the spectrum. An example of this is shown in Figure 5-1. This represents the upper limit of the attainable bandwidth. Remove glass until the spike disappears. Too much glass can also result in the laser falling out of modelock and/or being difficult to modelock.

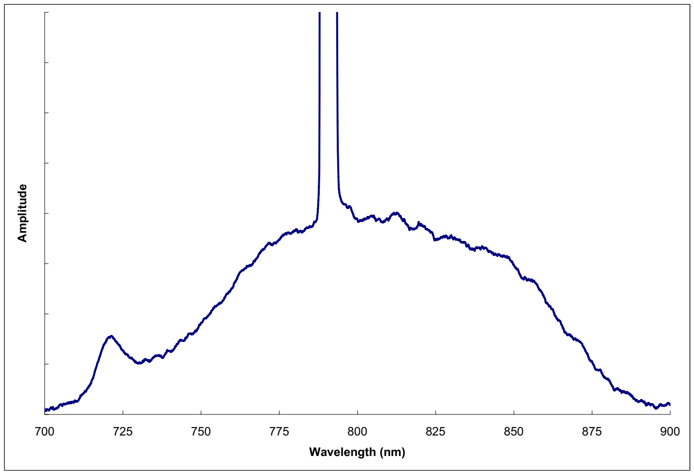


Figure 5-1. CW Breakthrough in the Micra Spectrum. The Spike at 790 nm is Due to CW Light (the shoulder at 720 nm is a normal part of the spectrum).

As glass is removed, the bandwidth will decrease and the power will increase slightly. However, the power will decrease if the prism is pulled out too far.

Slit Positioning

Slit control comprises two micrometer adjustments:

- The top knob changes the separation between the slits by moving one blade.
- The bottom knob moves both blades without changing the separation.

After passing through PR2, the Micra wavelengths spread out horizontally. As shown in Figure 5-2, the slits and/or PR1 can clip the spectrum.

- Turning the bottom slit micrometer clockwise clips the red side of the spectrum, and the center wavelength shifts to the blue.
- Turning the bottom or top slit micrometer counterclockwise clips the blue side of the spectrum, and the center wavelength shifts to the red.
- The bandwidth can change when the center wavelength is tuned. Iterate with PR1 to compensate for this, as described in the "PR1 Positioning" section above.

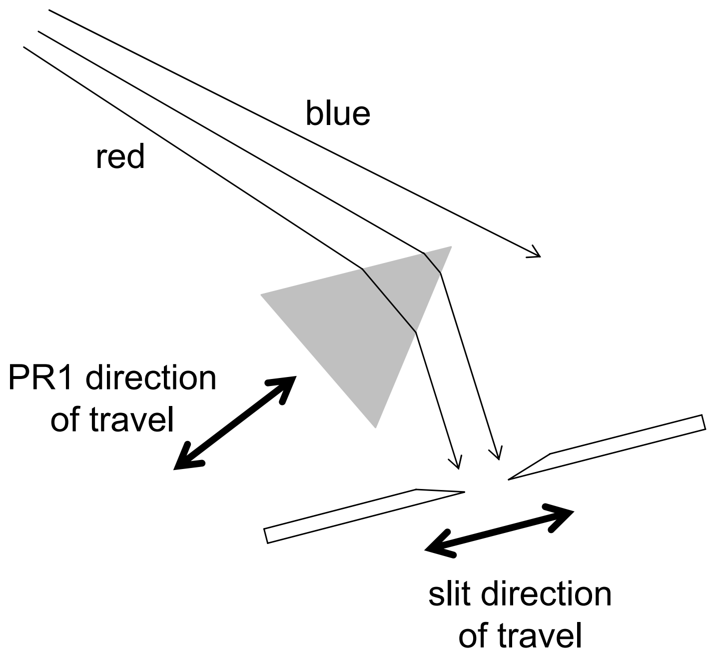


Figure 5-2. Diagram of PR1 and the Slits Intersecting the Beam

- For bandwidths < 40 nm, use the slits to clip the spectrum on both sides if necessary.

PowerTrack

The PowerTrack system steers the pump beam in response to the Micra output power. Beam steering is achieved by control of the first pump beam routing optic (R1 in Figure 2-3 on page 2-3). The X and Y dimensions are adjusted individually by actuators contained within the optic mount. The power supply sends a control voltage between 0 and 5 Volts to adjust each actuator, and these values may be monitored in the Micra Settings --> PZT Control menu (See "Menu Displays" on page 4-6).

Before shipment, the Micra is aligned so that optimal power is obtained at a setting between 2 and 3 V. During normal operation, these values will undergo small changes as PowerTrack maintains the ideal pump beam alignment. If the voltage falls below 0.5 V or exceeds 4.7 V, a PZT fault will occur (See Section Seven: Maintenance and Troubleshooting).

Setting PowerTrack to OFF (Micra Settings --> PowerTrack ON/OFF menu) removes the voltage from both actuators (PZT X = PZT Y = 0 V). In all likelihood the cavity will not lase under these conditions. Coherent recommends that PowerTrack be set to ON at all times.

Manual PZT Control

To disable the PowerTrack functionality, access the Micra Settings --> PZT Control menu and set PZT Mode = Manual. This setting holds the actuator voltages constant at the values shown in the upper left corner of the front panel display. This menu also allows the PZT X and PZT Y voltages to be changed manually.

Peak Hold

Turning Peak Hold = ON fixes the PZT voltages in their current positions. This function is only useful when PowerTrack = ON and PZT Mode = Auto.

Automodelock

The Micra oscillator cavity is equipped with a movable mirror (M4 in Figure 2-3 on page 2-3) which initiates modelocking. When the laser is turned on, a few seconds are required for the diode currents to ramp up to their nominal operating levels. The system waits for a specified CW lasing threshold and then activates the starter mechanism. When a modelocked pulse train is detected, the starter deactivates. Setting Automodelock = OFF (Micra Settings --> Automodelock ON/OFF menu) disables this functionality.

Micra Settings Menu Hierarchy

The settings of the PZT Control menu override both the Peak Hold and PowerTrack menu settings. In other words, if PZT Control is set to MANUAL, then the Peak Hold and PowerTrack menu settings have no effect.

In all cases, the existing PZT voltages are displayed in the upper left corner of the PZT Control menu.

The Automodelock setting in the PZT Control menu is synchronized to the Automodelock ON/OFF menu.

SECTION SIX: EXTERNAL COMPUTER CONTROL

Contact Coherent technical support for information on controlling the Micra by an external computer.

RS-232 Command Language

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 Micra front panel.

Instruction Syntax for RS-232 Communication

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 Micra 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 6-1 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.

ECHO Mode

The Micra 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 Table 6-3, “RS-232 Commands,” on page 6-5).

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

PROMPT Mode

The Micra provides a prompt mode for terminal operation in which the laser returns "MICRA" after each command. This feature can be turned on or off using the PROMPT command (see Table 6-3, "RS-232 Commands," on page 6-5).

?

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 Micra RS-232 port configuration is described in Table 6-2, and typical cable requirements are shown in Figure 6-1. The 9-pin RS-232 port is configured as a 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 6-2. 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 38400 (default factory setting) 57600 115200

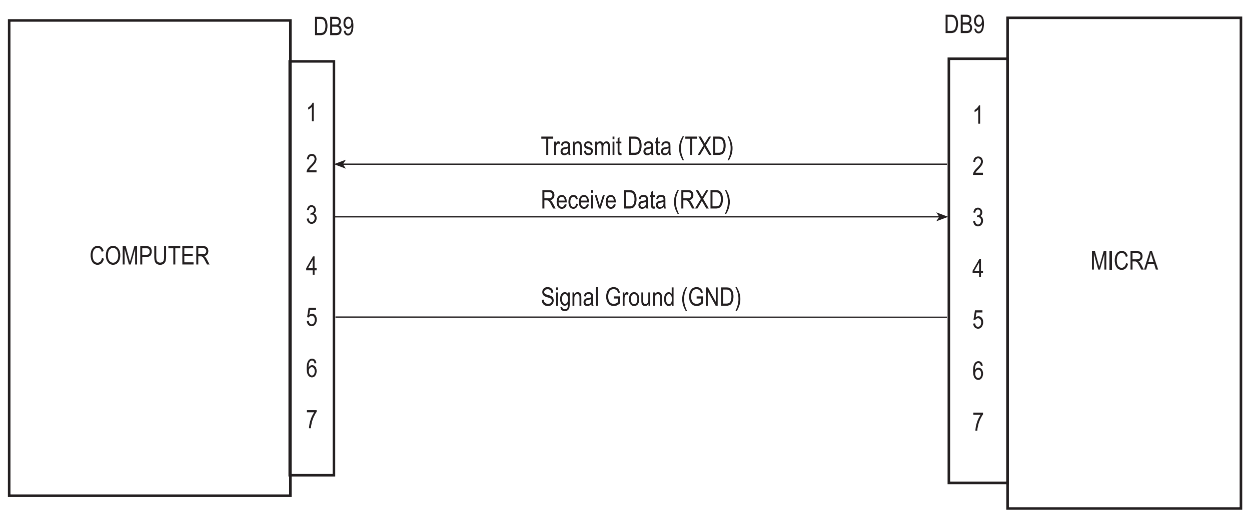


Figure 6-1. RS-232 Pin Configuration

Setting the Baud Rate

The baud rate of the 9-pin RS-232 port can be adjusted through the front panel (Table 6-3) or by means of the SERIAL BAUDRATE=NNN command described in Table 6-1 and Table 6-2. After the baud rate is changed, the new setting will be used until it is changed (even if the system power is cycled).

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 default factory-set baud rate is 38400.

When an RS-232 command is issued to change a setting, the front panel display on the power supply 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

Table 6-3 and Table 6-4 describe the instructions (long and short forms) for use in RS-232 with the Micra.

Table 6-3. RS-232 Commands

Commands	Action Performed
AUTOMODELOCK = n AMDLK = n	If n = 0: turns off automodelock (starter). If n = 1: turns on automodelock.
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.
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.
FLASH = 1 FL=1	Flash laser output below lasing threshold to allow single-frequency mode to recenter.
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.
LBO HEATER = n LBOH=n	If n = 0: turn off LBO heater (COOL DOWN). If n = 1: turn on LBO heater (HEATING).
LBO OPTIMIZE=n LBOOPT=n	If n=0: no optimization in process. If n=1: begin optimization routine.
LIGHT = nn.nnnn P=nn.nnnn	Set to light regulation at the specified output power.
LOCK FRONT PANEL=n LFP=n	Disables user input from the front panel.
POWER = n P=nn.nnnn	Set to light regulation at the specified output power.
POWER TRACK = n PTRK = n	If n = 0: turn off power track. If n = 1: turn on power track.
PROMPT = n >=n	If n = 0: turn OFF "VERDI>" prompt. If n = 1: turn ON "VERDI>" prompt.
SHUTTER = n S=n	If n = 0: close external shutter. If n = 1: open external shutter.
UF POWER = nnn.nn UF=nnn.nn	Sets UF (Micra) power setpoint to the specified value in milliwatts. Only when in Micra Light Loop.
MICRA LIGHT LOOP = n VLL = n	If n = 0: disable Micra light loop. Defaults to Verdi Light Loop. If n = 1: enable Micra light loop.

Table 6-4. RS-232 Queries

QUERIES	RETURNED INFORMATION
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, 17=Diode 2 Over Current Fault, 16=Diode 1 Over Current Fault, 19=Diode 1 Under Volt Fault, 18=Over Current Fault, 21=Diode 1 Over Volt Fault, 20=Diode 2 Under Volt Fault, 25=Diode 1 EEPROM Fault, 22=Diode 2 Over Volt Fault, 27=Laser Head EEPROM Fault, 26=Diode 2 EEPROM Fault, 29=PS-Head Mismatch Fault, 28=Power Supply EEPROM Fault, 31=Shutter State Mismatch, 30=LBO Battery Fault, 33=Head PROM Checksum Fault, 32=CPU PROM Checksum Fault, 35=Diode2 PROM Checksum Fault, 34=Diode1 PROM Checksum Fault, 37=Head PROM Range Fault, 36=CPU PROM Range Fault, 39=Diode2 PROM Range Fault, 38=Diode1 PROM Range Fault, 41=Lost Power Track Fault, 40=Lost Modelock Fault, 43=Below Q-Switch Power Fault, 42=Exceeded CW Power Fault, 45=Lost UF Lasing Fault, 44=Ti-Sapph Temp. Fault, 47=PZT Y Fault. 46=PZT X Fault,
PRINT BASEPLATE TEMP ?BT	Return laser head baseplate measured temperature, nn.nn, in °C.
PRINT CURRENT DELTA ?CD	Return the diode current delta calibration, n.n, in amps.
PRINT CURRENT ?C	Return the measured average diode current, nn.n, in amps.
PRINT DIODE1 CURRENT ?D1C	Return laser diode 1 measured current, nn.n, in amps.
PRINT DIODE1 HEATSINK TEMP ?D1HST	Return laser diode 1 heat sink measured temperature, nn.nn, in °C.
PRINT DIODE1 HOURS ?D1H	Return the number of operating hours on laser diode 1.

Table 6-4. RS-232 Queries (Continued)

QUERIES	RETURNED INFORMATION
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.
PRINT DIODE1 SET TEMP ?D1ST	Return laser diode 1 set temperature, nn.nn, in °C.
PRINT DIODE1 TEMP DRIVE ?D1TD	Return laser diode 1 temperature servo drive setting.
PRINT DIODE1 TEMP ?D1T	Return laser diode 1 measured temperature, nn.nn, in °C.
PRINT ETALON DRIVE ?ED	Return etalon temperature servo drive setting
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 ETALON SET TEMP ?EST	Return etalon set temperature, nn.nn, in °C.
PRINT ETALON TEMP ?ET	Return etalon measured temperature, nn.nn, in °C.
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 HEAD_HOURS ?HH	Return the number of operating hours on the system head.
PRINT KEYSWITCH ?K	Return: 0 if the keyswitch is OFF. 1 if the keyswitch is ON.
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).

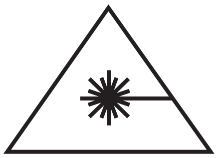
Table 6-4. RS-232 Queries (Continued)

QUERIES	RETURNED INFORMATION
PRINT LBO DRIVE ?LBOD	Return LBO temperature servo drive setting
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 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.
PRINT LBO SET TEMP ?LBOST	Return LBO set temperature, nnn.nn, in °C.
PRINT LBO TEMP ?LBOT	Return LBO measured temperature, nnn.nn, in °C.
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 LIGHT ?P	Return the calibrated output power, nn.nnn, in watts.
PRINT MODE ?M	Returns the laser operating mode: 0 if in current regulation. 1 if in light regulation.
PRINT MODELOCKED ?MDLK	Return: 0 if Micra is off (standby). 1 if Micra is modelocked. 2 if Micra is CW.
PRINT POWER TRACK ?PTRK	Return: 0 if power track is off. 1 if power track is on.
PRINT SET LIGHT ?SP	Return the light regulation set power, nn.nnnn, in watts.
PRINT SHUTTER ?S	Return the status of the external shutter: 0 if the shutter CLOSED. 1 if the shutter OPEN.

Table 6-4. RS-232 Queries (Continued)

Queries	Returned Information
PRINT SOFTWARE ?SV	Return the version number of the power supply software.
PRINT UF POWER ?UF	Return: Actual UF (Micra) power, nnn.nn, in milliwatts
PRINT VANADATE DRIVE ?VD	Return vanadate temperature servo drive setting
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 VANADATE SET TEMP ?VST	Return vanadate set temperature, nn.nn, in °C.
PRINT VANADATE TEMP ?VT	Return vanadate measured temperature, nn.nn, in °C.
PRINT MICRA LIGHT LOOP ?VLL	Return: 0 if Micra light loop is off. 1 if Micra light loop is on.

SECTION SEVEN: MAINTENANCE AND TROUBLESHOOTING



The Micra is normally operated with the laser head and power supply covers in place. Removal of either cover allows access to dangerous voltage and current levels in addition to visible and invisible laser radiation. Covers should only be removed for service and maintenance by qualified personnel.

Contact the Coherent service department (800-367-7890, or 408-764-4557) if further assistance is needed.

Disabling PowerTrack

PowerTrack functionality is extremely useful for maintaining power and pointing stability. However, a common cause of Micra misalignment is the adjustment of cavity optics while PowerTrack is engaged. This feature should be disabled when optic adjustments are necessary. See “Disengaging PowerTrack” on page 8-2.

Troubleshooting

Table 7-1 lists potential problems along with a reference to the associated troubleshooting procedure. In all cases it is assumed that the system was properly installed by authorized personnel, and that system warm-up is complete.

Table 7-1. Troubleshooting Reference List

PROBLEM	TROUBLESHOOTING REFERENCE
Active fault condition	Table 7-2
No Micra output	Table 7-3
Micra power low or unstable Micra bandwidth or spectrum degraded	Chart 2
Modelocking difficulty or fault Lasing dropping in and out	Chart 3

Table 7-2. Fault Reference List

FAULT CODE AND NAME	TROUBLE-SHOOTING REFERENCE	FAULT CODE AND NAME	TROUBLE-SHOOTING REFERENCE
1: Head interlock fault	Chart 4	11: Diode heat sink 1 temperature fault	Chart 9
2: External interlock fault	Chart 5	12: Diode heat sink 2 temperature fault	Chart 9
3: Power supply cover interlock fault	Chart 6	16: Diode 1 over current fault	Chart 10
4: LBO temperature fault	Chart 7	17: Diode 2 over current fault	Chart 10
5: LBO Not Locked at Set Temperature	Chart 11	18: Over current fault	Chart 10
6: Vanadate temperature fault	Chart 7	19: Diode 1 under voltage fault	Chart 11
7: Etalon temperature fault	Chart 7	20: Diode 2 under voltage fault	Chart 11
8: Diode 1 temperature fault	Chart 7	21: Diode 1 over voltage fault	Chart 11
9: Diode 2 temperature fault	Chart 7	22: Diode 2 over voltage fault	Chart 11
10: Baseplate temperature fault	Chart 8	25: Diode 1 EEPROM fault	Chart 11
26: Diode 2 EEPROM fault	Chart 11	40: Head-Diode Mismatch Fault	Chart 11
27: Laser Head EEPROM Fault	Chart 11	41: Chiller not found	Chart 11
28: Power Supply EEPROM Fault	Chart 11	42: Chiller not initialized	Chart 11

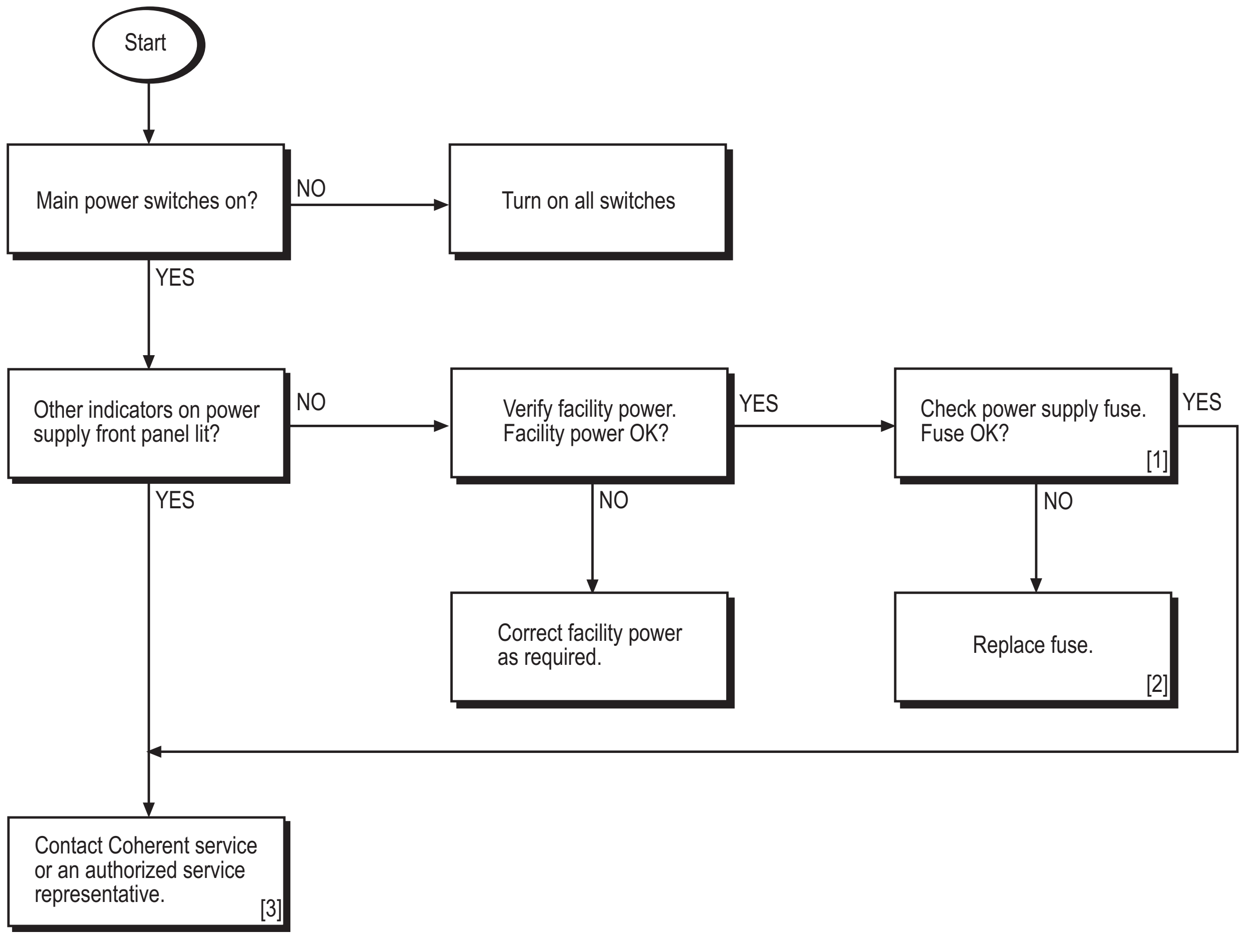
Table 7-2. Fault Reference List (Continued)

Fault Code and Name	Trouble-shooting Reference	Fault Code and Name	Trouble-shooting Reference
29: Power supply-head mismatch Fault	Chart 11	43: Lost Modelock Fault	Chart 3
30: LBO battery Fault	Chart 12	44: Lost Power Track Fault	Chart 13
31: Shutter state mismatch Fault	Chart 11	45: Exceeded CW Power Fault	Chart 11
32: CPU PROM Checksum Fault	Chart 11	46: Below Q-Switch Power Fault	Chart 11
33: Head PROM Checksum Fault	Chart 11	47: Ti-Sapphire Temperature Fault	Chart 7
34: Diode1 PROM Checksum Fault	Chart 11	48: Lost UF Lasing Fault	Chart 3
35: Diode 2 PROM Checksum Fault	Chart 11	49: PZT X Fault	Chart 13
36: CPU PROM Range Fault	Chart 11	50: PZT Y Fault	Chart 13
37: Head PROM Range Fault	Chart 11	51: PZT Dithered for Power Drift	Chart 13
38: Diode1 PROM Range Fault	Chart 11	52: Lost Serial Link Fault	Chart 14
39: Diode2 PROM Range Fault	Chart 11		

Table 7-3. No Micra Output

Possible Cause	Indicator	Corrective Action or Reference
Active fault	Fault Status screen	Table 7-2
Main power not present	AC ON indicator on power supply front panel not lit	Chart 1
Shutter is closed	SHUTTER pushbutton indicator on power supply front panel not lit	Press the SHUTTER pushbutton.
Pump laser not at normal power	Pump power displayed on front panel or measured with a power meter	Set pump power to the value listed on the Customer Data Sheet.

Chart 1. AC ON Indicator on the Power Supply Front Panel Not Lit

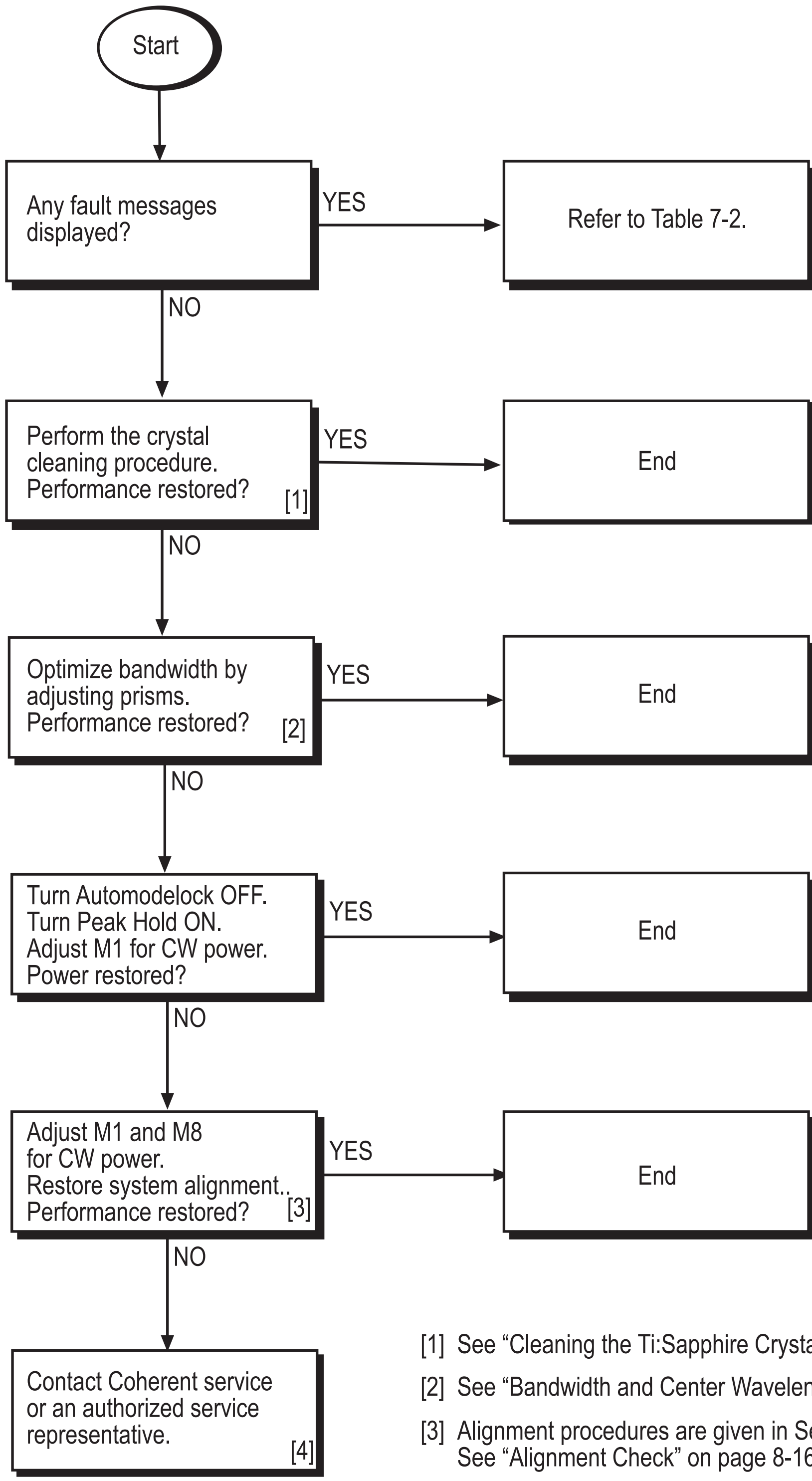


[1] Turn the main power switch OFF and disconnect the system from facility power. Verify electrical continuity (a closed circuit) between the two fuse terminals.

[2] Refer to the fuse replacement procedure in this section.

[3] If the system or any component must be returned to Coherent, a Return Material Authorization (RMA) number is required.

Chart 2. Micra Power Low or Unstable Micra Bandwidth or Spectrum Degraded



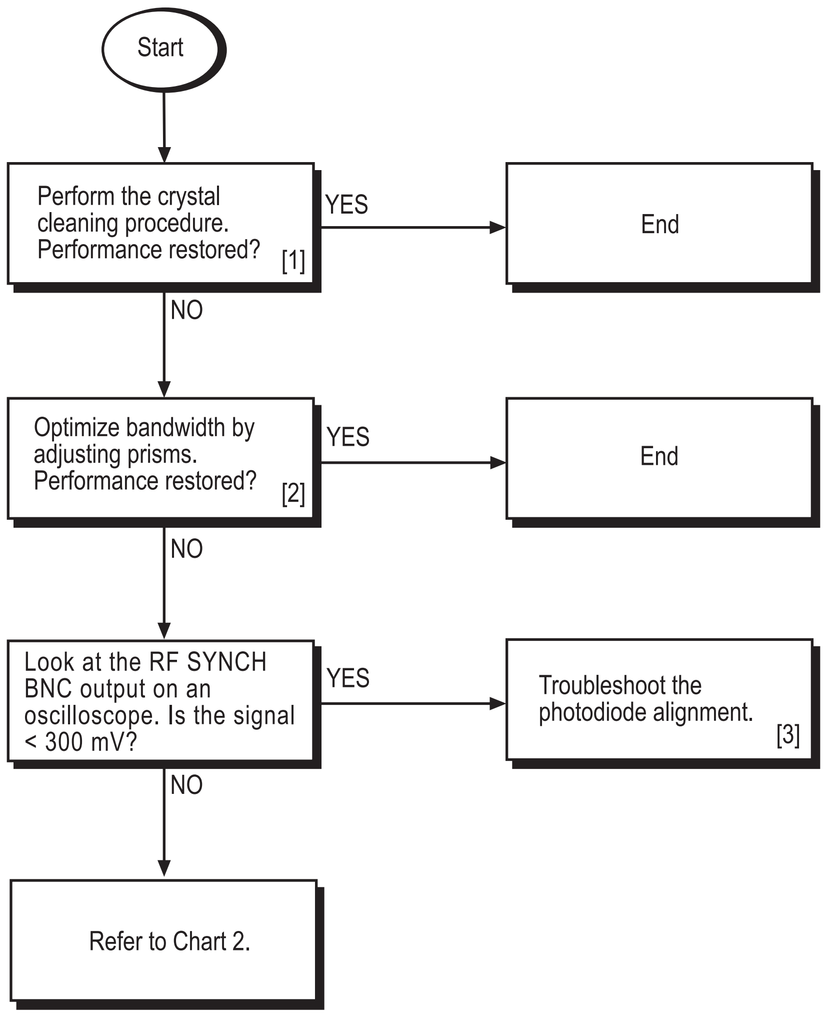
[1] See “Cleaning the Ti:Sapphire Crystal” on page 7-25.

[2] See “Bandwidth and Center Wavelength Adjustments” on page 5-6.

[3] Alignment procedures are given in Section Eight: Optical Alignment. See “Alignment Check” on page 8-16.

[4] If the system or any component must be returned to Coherent, a Return Material Authorization (RMA) number is required.

Chart 3. Modelocking Difficulty
Lasing Dropping In and Out
Lost Modelock Fault
Lost UF Lasing Fault



[1] See "Cleaning the Ti:Sapphire Crystal" on page 7-25.

[2] See "Bandwidth and Center Wavelength Adjustments" on page 5-6.

[3] See "Photodiode Alignment" on page 8-3.

Chart 4. Head Interlock Fault

[1] Press MENU EXIT on the power supply front panel, or send “L=1” to the power supply to clear the fault.

Go to the “Fault Status” screen, or send “?F” to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the “?F” query.

If there are no faults active (“SYSTEM OK”), open the shutter and resume operation.

[2] Ensure that the umbilical is not strained and that the bend radius is 13 cm (5 inches) or greater.

[3] Turn the main power switch on the power supply rear panel to OFF for approximately 20 seconds. Turn the switch back to ON.

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

Chart 5. External Interlock Fault

[1] Press MENU EXIT on the power supply front panel, or send “L=1” to the power supply to clear the fault.

Go to the “Fault Status” screen, or send “?F” to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the “?F” query.

If there are no faults active (“SYSTEM OK”), open the shutter and resume operation.

[2] Verify that the interlock defeat supplied with the system or a user-furnished interlock is firmly attached to the EXT INT connector on the power supply rear panel.

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

If the fault does not clear, verify continuity between pins 1 and 2 of the interlock connector.

[4] Turn the main power switch on the power supply rear panel to OFF for approximately 20 seconds. Turn the switch back to ON.

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

Chart 6. Power Supply Cover Interlock Fault

[1] Turn the key switch to STANDBY and verify that the power supply top cover is securely closed with all fasteners.

[2] Press MENU EXIT on the power supply front panel, or send "L=1" to the power supply to clear the fault.

Go to the "Fault Status" screen, or send "?F" to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the "?F" query.

If there are no faults active ("SYSTEM OK"), open the shutter and resume operation.

[3] Turn the main power switch on the power supply rear panel to OFF for approximately 20 seconds. Turn the switch back to ON.

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

Chart 7. LBO Temperature Fault
Vanadate Temperature Fault
Etalon Temperature Fault
Diode Temperature Fault
Ti-Sapph Temp. Fault

[1] Press MENU EXIT on the power supply front panel, or send "L=1" to the power supply to clear the fault.

Go to the "Fault Status" screen, or send "?F" to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the "?F" query.

If there are no faults active ("SYSTEM OK"), open the shutter and resume operation.

[2] Verify that the temperature set point is the same as on the Test Data Sheet. If different, contact Coherent or an authorized representative.

[3] Turn the main power switch on the power supply rear panel to OFF for approximately 20 seconds. Turn the switch back to ON.

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

Chart 8. Baseplate Temperature Fault

[1] Press MENU EXIT on the power supply front panel, or send “L=1” to the power supply to clear the fault.

Go to the “Fault Status” screen, or send “?F” to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the “?F” query.

If there are no faults active (“SYSTEM OK”), open the shutter and resume operation.

[2] Verify the following:

- Air flow around the laser head is not obstructed
- The laser head is not located near a heat source
- The ambient temperature is not excessively high

[3] Turn the main power switch on the power supply rear panel to OFF for approximately 20 seconds. Turn the switch back to ON.

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

Chart 9. Diode Heat Sink Temperature Fault (Power Supply)

[1] Press MENU EXIT on the power supply front panel, or send "L=1" to the power supply to clear the fault.

Go to the "Fault Status" screen, or send "?F" to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the "?F" query.

If there are no faults active ("SYSTEM OK"), open the shutter and resume operation.

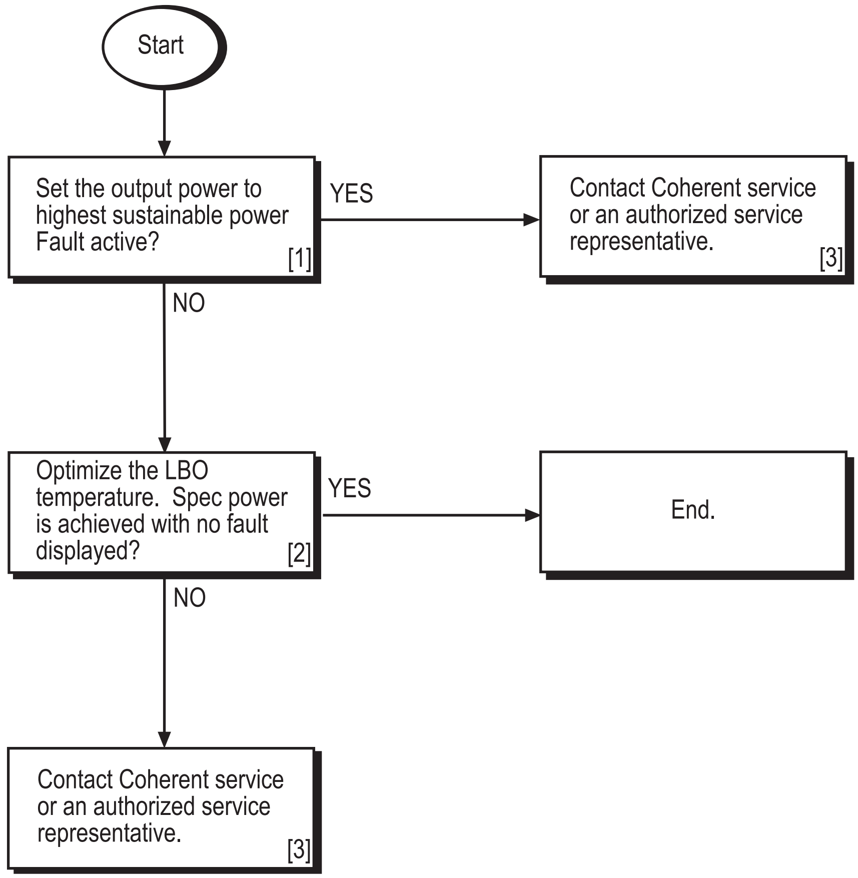
[2] Verify the following:

- The cooling fan is not obstructed
- The rear, top, and left sides 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] Turn the main power switch on the power supply rear panel to OFF for approximately 20 seconds. Turn the switch back to ON.

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

Chart 10. Over Current Fault
Diode Over Current Fault



[1] Press EXIT if necessary to clear the fault.

[2] See “LBO Temperature Optimization” on page 7-23.

[3] If the system or any component must be returned to Coherent, a Return Material Authorization (RMA) number is required.

Chart 11. Below Q-Switch Fault
CPU PROM Checksum Fault
CPU PROM Range Fault
Diode Under Voltage Fault
Diode Over Voltage Fault
Diode EEPROM Fault
Diode PROM Range Fault
Diode PROM Checksum Fault
Exceeded CW Power Fault
Head PROM Checksum Fault
Head PROM Range Fault
Laser Head EEPROM Fault
LBO Not Locked at Set Temperature
Power Supply EEPROM Fault
Power Supply-Head Mismatch Fault
Shutter State Mismatch Fault

[1] Press MENU EXIT on the power supply front panel, or send "L=1" to the power supply to clear the fault.

Go to the "Fault Status" screen, or send "?F" to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the "?F" query.

If there are no faults active ("SYSTEM OK"), open the shutter and resume operation.

[2] Turn the main power switch on the power supply rear panel to OFF for approximately 20 seconds. Turn the switch back to ON.

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

Chart 12. LBO Battery Fault

[1] Press MENU EXIT on the power supply front panel, or send "L=1" to the power supply to clear the fault.

Go to the "Fault Status" screen, or send "?F" to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the "?F" query.

If there are no faults active ("SYSTEM OK"), open the shutter and resume operation.

If necessary, perform shutdown using the "LBO SETTING" menu. Do not turn off the power supply switch on the rear panel (or remove AC power) when an LBO Battery fault is active.

[2] If the fault persists, contact Coherent or an authorized representative. If the system or any component must be returned to Coherent, a Return Material Authorization (RMA) number is required.

Chart 13. PZT Fault
Lost Power Track Fault

[1] Press MENU EXIT on the power supply front panel, or send "L=1" to the power supply to clear the fault.

Go to the "Fault Status" screen, or send "?F" to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the "?F" query.

If there are no faults active ("SYSTEM OK"), open the shutter and resume operation.

[2] Perform the crystal cleaning procedure, as described on page 7-17.

[3] Look at the RF SYNCH BNC output on an oscilloscope. If the signal is < 300 mV, troubleshoot the photodiode alignment as described in "Photodiode Alignment" on page 8-3.

[4] Use the MICRA STATUS menu to verify that the PZT is out of range (in range is 0.5 to 4.7V).

[5] Use the PZT CONTROL menu to ensure the PZT is in the AUTO mode. If not, set the PZTs to AUTO.
If PZT MANUAL mode is desired, adjust the PZT voltages within range.

[6] If the fault persists, contact Coherent or an authorized representative. If the system or any component must be returned to Coherent, a Return Material Authorization (RMA) number is required.

Chart 14. Lost Serial Link Fault

[1] Press MENU EXIT on the power supply front panel, or send "L=1" to the power supply to clear the fault.

Go to the "Fault Status" screen, or send "?F" to the power supply.

If the fault is active, a fault code will appear on the fault status menu or be returned from the "?F" query.

If there are no faults active ("SYSTEM OK"), open the shutter and resume operation.

[2] Verify the Serial Port connections on the rear panel of the power supply and on the computer.

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

Optics Maintenance Introduction

This section contains procedures for cleaning and replacing .

Contaminated optics are the cause of many of the preventable problems in the operation of lasers. Keeping the outside environment of the Micra clean and free of dust will help avoid degradation of performance due to contamination.

If an optic must be replaced due to damage, refer to the appendix for the appropriate replacement optic part number. Use the optics replacement procedures detailed in this section.

Equipment Used During Optic Replacement and Cleaning

- **Powderless latex or nitrile gloves.** It is critical to avoid the introduction of any oils or dirt inside the Micra laser head. Gloves must be worn for all intracavity work, including the following cleaning procedures.
- Laser safety glasses to protect against the wavelengths listed in Table 5-1, “Wavelengths of Radiation Generated by the Micra,” on page 5-1.
- Lens tissue, hemostats, and spectroscopic-grade methanol and acetone

Cleaning Optics

Proper cleaning is necessary to maintain optimum performance of high-grade optics. Laser optical components are routinely exposed to high energy levels. When optical surfaces are clean, this energy is either reflected or transmitted. Contaminants, however, absorb energy to create hot-spots that can burn the coating and dramatically reduce laser efficiency. Absorption caused by contaminated optical surfaces will degrade performance and shorten mirror life.

Contaminants that can cause absorption include a variety of particles that may fall on the optical surface or condense from surrounding vapors. Oils from the skin (even from the cleanest hands or transferred by contact with lens tissue used for cleaning), fibers of lens tissue themselves, or plastic gloves can be a source of contaminants. Exercise extreme care when handling and cleaning optics.

Spectroscopic / spectrophotometric-grade or electronic-grade methanol and acetone are the recommended solvents for cleaning optics. Other solvents and other grades can leave residues or otherwise degrade optical coatings.

Do not store solvent bottles capped with rubber droppers. Over time the solvent will dissolve the rubber and become impure.

Lens tissue of high quality is the recommended material for cleaning optics. When cleaning optics with lens tissue, use each tissue for only *one* pass in *one* direction and then discard it. Do not reuse a tissue or swipe back in the opposite direction. Repeat if necessary with a clean tissue, going in the same direction as the original swipe. Reusing tissue or going back in the opposite direction may lead to damage of the optic by dragging loose particles back across the surface.

Cleaning Installed Optics

In the case of dust visible on an optic, blowing a puff of air across an optic may be used as an initial step in cleaning. However, do not use compressed air that contains propellants, do not blow with your mouth, and do not use anything that contains any other residue or that may cause condensation on the optic. Also, be careful not to stir up dust in the air that will then settle on the optic.

The following procedure is used to clean optics while in place in the laser head. When possible, clean the optic while it is installed in the laser head to minimize disturbance to the optical alignment.

1. Record the output power, and then close the pump beam shutter by pressing the SHUTTER OPEN pushbutton if necessary.
2. Neatly fold a sheet of lens tissue several times into a rectangular shape, ending with a folded edge that is 1/4 in. to 3/4 in. long, clamped with a hemostat, with approximately 1/8 in. of the tissue paper protruding from the side of the hemostat. To avoid scratching an optic, ensure that the hemostat is not clamped too close to the fold of the lens tissue.

While folding the tissue, be careful not to contaminate it with soiled or oily fingers in the place the tissue will eventually touch the optic to be cleaned.

3. Moisten the tissue with methanol or acetone. Two or three drops are sufficient for this purpose. Gently shake the hemostat to remove unwanted excess solvent.

4. Wipe across the optic in one direction. Use enough pressure to make even contact between the tissue and the optic, but no more. Use extreme care for those optics that might dislodge or break off of their mounts.
5. Activate the laser and monitor the CW power. If power has degraded, optimize power with the mount of the optic being cleaned.
6. Repeat the above steps until the optic is clean, using a new lens tissue for each pass.

Cleaning Removed Optics

The following technique is recommended for optics that have been removed from the laser or are being put into the laser.

1. Hold the optic element gently by the edge or place it on a clean work surface covered with lens tissue.
2. Place a few drops of acetone or methanol on one end of the lens tissue. Handle the optic gently while cleaning it to avoid microfine abrasions.
3. Place the wet end of the lens tissue on the optic and pull it across the optic in one direction only. Ensure that the optic does not move by holding it by the sides while doing this. Do not rub the tissue back and forth. Note that the dry part of the tissue helps remove any acetone or methanol residue.
4. Repeat the above steps until the optic is clean, using a new lens tissue for each pass. Contaminants are more readily seen by looking at the reflection of a bright light off the optic surface.

Cleaning the Ti:Sapphire Crystal

The Ti:Sapphire crystal should be cleaned whenever the mode-locked power has declined by 5 to 10%, or whenever any contaminants are observed on the crystal surface. Contaminants may be observed by using the pump beam:

- A low-power (<0.1 W) pump beam will scatter from a surface contaminant and show a bright spot on the crystal surface.
- A full-power pump beam will scatter from a surface contaminant and create a speckle pattern on the M5 mount.

Clean the crystal surfaces before adjusting cavity optics.

The crystal cleaning procedure is given below.

1. **Wear powderless latex or nitrile gloves.**
2. Close the pump beam shutter by pressing the SHUTTER OPEN pushbutton if necessary.
3. Neatly fold a sheet of lens tissue several times into a rectangular shape, ending with a folded edge that is ~1/8 inch long, clamped with a hemostat, with ~1/8 inch of the tissue paper protruding from the front of the hemostat.

While folding the tissue, be careful not to contaminate it with soiled or oily fingers in the place on the tissue that will eventually touch the optic to be cleaned.

4. Moisten the tissue with methanol or acetone. Two or three drops are sufficient for this purpose. Shake the hemostat to remove excess solvent.
5. Wipe one of the surfaces of the crystal. The crystal does not have an optical coating. The material is very hard and very difficult (but not impossible) to scratch. It is acceptable to apply more pressure than when cleaning other optics. Furthermore, if a contaminant is not removed with a single wipe, it is acceptable to use a back-and-forth motion on the crystal surface. Do not do this for other optics, whether coated or uncoated.
6. Using a new piece of lens tissue, repeat steps 3-5 for the second face.
7. **Visually verify that the crystal surface is clean, as described at the beginning of this section.**

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 use more current to produce the desired 532 nm output. This will reduce the lifetime of the diodes.

The Micra software contains a menu routine which will perform an LBO temperature optimization automatically 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.

Note that the shutter is active during the LBO optimization. Because laser power will change while the routine executes, Coherent recommends that the shutter remain closed throughout the process.

To find an accurate LBO setpoint temperature, set the Verdi power level to the normal operating power. However, the routine will not run if the laser power level is less than 80% of the maximum power.

Once the routine is complete, the system will display “LBO optimized” and return the laser to Verdi Light Loop mode at the preset power level.

Performing the Optimization

1. Turn the Verdi on at the maximum power level. Record the LBO setpoint temperature.
2. Scroll to the LBO OPTIMIZATION menu (Main Menu --> Verdi Settings --> LBO Optimization) and select the LBO optimization routine. Two to four hours are required for the cycle to complete.
3. Once the routine is finished, record the new LBO temperature.

During optimization, the software changes the LBO temperature while recording the Verdi output power. The routine is performed with a constant diode current. Optimum LBO temperature is determined based on the Verdi 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, contact Coherent Service.

FAP-I Temperature Optimization (Micra-18 only)

The Verdi V-18 software has an on-demand routine that performs both diode optimizations automatically. By varying the FAP-I temperature, the software will determine the optimum diode current. The FAP-I optimization should be completed when diode currents are greater than 10% of their baseline values and after the LBO optimization has been completed.

Note that the shutter is active during the LBO optimization. Coherent recommends the shutter remain closed throughout the process since the laser power will change while the routine executes.

To find optimum diode temperatures, set the output power level as close to operating power as possible. As with the LBO optimization, the FAP-I optimization will not run if the laser power level is less than 80% of the specified maximum power. Once the routine is complete, the system will display "Diodes OPtimized" and will return the laser to light regulation mode at the preset power level.

Performing the Optimization

1. Turn the Verdi on at the maximum power level.
2. Record the Diode temperature setpoints.
3. Scroll to the Diode Optimization menu from the Base Menu and select the optimization routine. The FAP-I optimization requires one-half hour to several hours to complete.
4. Once the routine is complete, record the diode current as the new baseline value in the system weekly log book.

Fuse Replacement

Criteria for Replacement

Defective fuse per troubleshooting Chart 1.

Do not turn the power switch on the rear panel to the OFF position or disconnect the AC power input until the LBO cool-down cycle is complete.

1. Perform the Turn-off (Complete Shutdown) procedure described in Section Five: Operation. The associated cool-down cycle requires approximately 45 minutes. The front panel display will indicate when the cool-down cycle is complete.
2. Turn the power switch on the power supply rear panel to the OFF position and disconnect the power cord from facility power.

A fuse that fails repeatedly is an indication of a more serious problem. Contact Coherent Service if multiple fuse failures have occurred.

3. The location of the fuse is shown in Figure 4-2 on page 4-4. Insert a small straight-slotted screwdriver and twist counter-clockwise to remove the fuse holder.
4. Replace the fuse with an appropriate fuse and reinstall the fuse holder.
5. Reconnect the power cord to facility power.
6. Perform the Turn-on (Cold Start) procedure described in Section Five: Operation.

Verification of Successful Installation

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

Battery Replacement

The backup battery in the power supply must be replaced as soon as possible after the fault message “Battery Requires Service” is displayed on the power supply front panel. Failure to do so may result in damage to the system following a loss of AC power.

Do not turn the power switch on the rear panel to the OFF position or disconnect the AC power input until the LBO cool-down cycle is complete.

If the laser is to remain completely shut down (main power switch OFF) for an extended time, the power supply must be connected to facility power at least once every six months to allow the battery to charge. Otherwise, permanent charging capacity loss may occur.

Preliminary Steps and Data

1. With the keyswitch set to the ON position and the system in Verdi Light Loop operation, set the laser to its normal output power.
2. Record the following system data from the Temperature Set Points submenu.
   a. LBO temperature set point
   b. Vanadate temperature set point
   c. Vanadate2 temperature set point (Micra-18 only)
   d. Etalon temperature set point
   e. Diode1 temperature set point
   f. Diode2 temperature set point (Micra-10 and Micra-18 only)
3. Record the following system data from the Diode Parameters Screen submenu.
   a. Diode1 current (software value)
   b. Diode2 current (software value, Micra-10 and Micra-18 only)
   c. Diode current delta
4. Perform the Turn-off (Complete Shutdown) procedure from Section Five: Operation. The associated cool-down cycle requires approximately 45 minutes. The front panel display will indicate when the cool-down cycle is complete.

5. After the LBO cool-down cycle is finished, turn the main power switch on the power supply rear panel to the OFF position and disconnect the power cord from facility power.

Battery Removal and Installation

1. Using an Allen wrench, remove the top cover of the power supply. The Verdi backup battery is located toward the right-front corner of the Verdi power supply (with respect to the power supply front panel display). See Figure 7-1.
2. Remove the two Phillips-head screws that secure the battery retaining bracket in place, and remove the bracket.
3. Unplug the ground (black) wire and then the positive (red) wire.
4. Remove the depleted battery and install the replacement.
5. Reconnect the positive (red) wire before the ground wire is reconnected. Reconnect the ground (black) wire.
6. Reinstall the battery retaining bracket.
7. Reconnect the laser system to facility power.

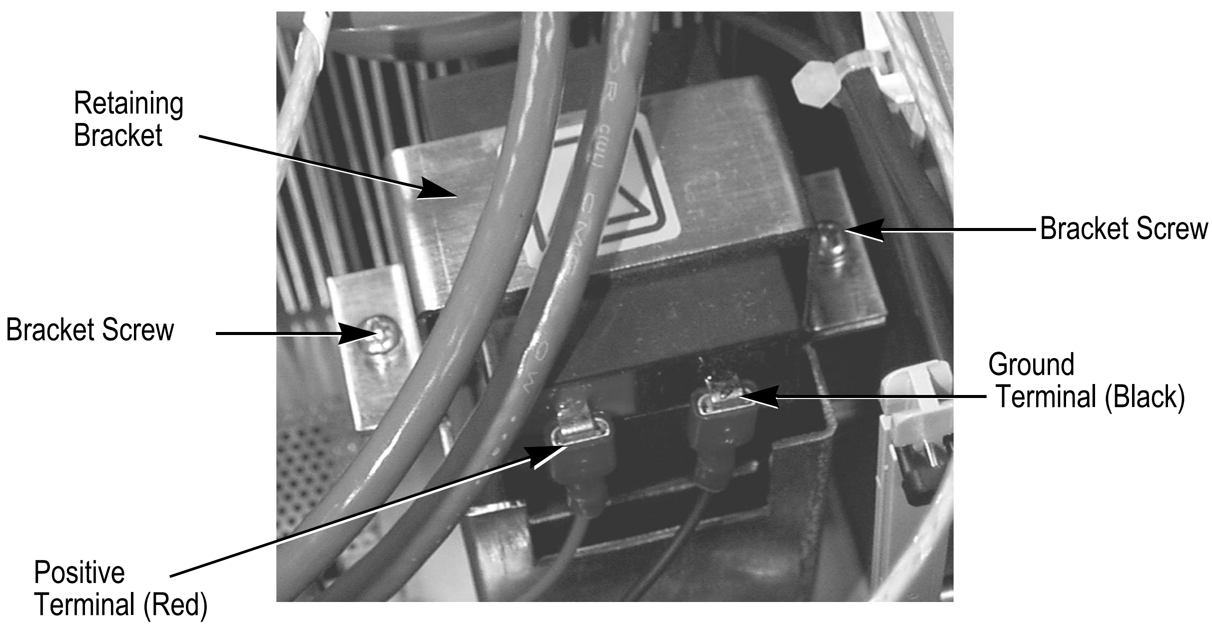


Figure 7-1. Power Supply Backup Battery

8. Perform the Turn-on (Cold Start) procedure in Section Five: Operation.

The charge on the battery can be monitored by connecting a digital voltmeter (DVM) across the terminals. Power to the laser system (main power switch on power supply rear panel) must be OFF when checking battery charge. A fully charged battery will read between 12 V and 13.4 V.

Battery Charge Circuit Verification

1. Attach a DVM across R8 on the motherboard (see Figure 7-2). The polarity of the connections is not important.
2. Turn the main power switch to the ON position. The meter should start reading at 245 mV and begin counting down. The voltage (and speed) to which the meter counts down will depend on the initial charge state of the battery. See Table 7-4.
3. After the charge voltage across R8 has stabilized, the voltage across the battery terminals should read between 13 V and 14.6 V.

Table 7-4. Battery Charge Circuit Voltages

BATTERY STATE	BATTERY VOLTAGE	CHARGE CIRCUIT VOLTAGE
Very Low	9 V to 11 V	245 mV
Low	11 V to 12 V	245 mV to 200 mV
Moderate	12 V to 13 V	160 mV to 100 mV
Fully Charged	13 V to 13.4 V	60 mV to 10 mV
Over Charged	Over 13.4 V	0 mV

Verification of Successful Installation

1. Perform the Turn-on (Cold Start) procedure in Section Five: Operation. The "Battery Requires Service" message should no longer be displayed on the power supply front panel.
2. Record the system data and compare with the data collected at the beginning of this procedure.
   a. LBO temperature set point
   b. Vanadate1 temperature set point

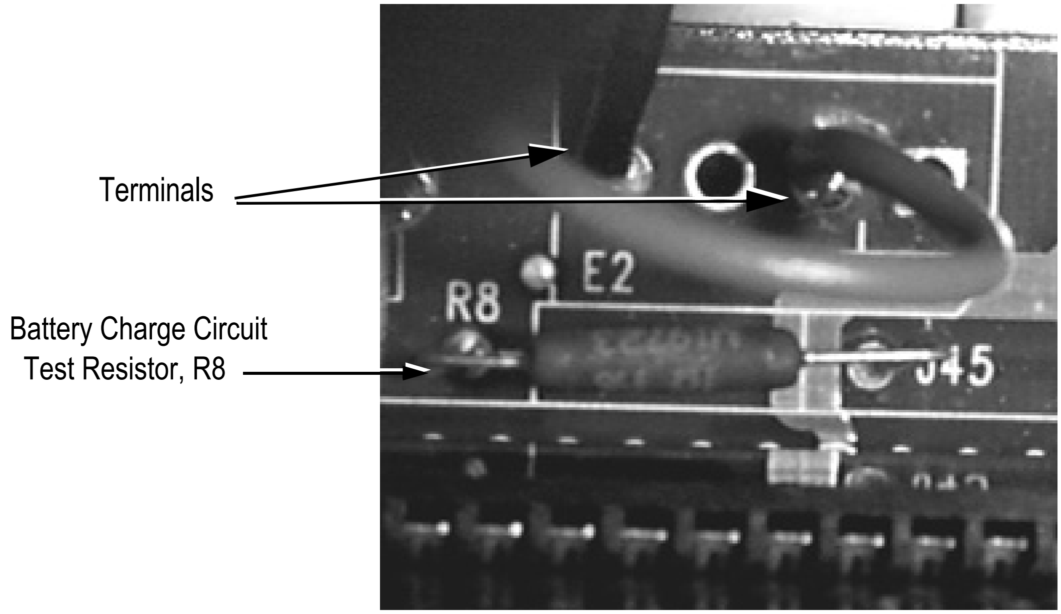


Figure 7-2. Location of Battery Charge Circuit Resistor, R8

c. Vanadate2 temperature set point (Micra-18 only)

d. Etalon temperature set point

e. Diode1 temperature set point

f. Diode1 current

g. Diode2 temperature set point (Micra-10 and Micra-18 only)

h. Diode2 current (Micra-10 and Micra-18 only)

i. Diode current delta

3. Reinstall the power supply top cover.

4. Verify that the laser system is clear of system faults.

Cleaning the Air Filter

The air filter is located inside the power supply.

Criteria for Cleaning

Visually inspect the air filter on a periodic basis. Inspect more frequently if the operating environment is not clean.

Clean the air filter when the laser is turned off.

Do not turn the power switch on the rear panel to the OFF position or disconnect the AC power input until the LBO cool-down cycle is complete.

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

Preliminary steps

1. Perform the Turn-off (Complete Shutdown) procedure in Section Five: Operation. The associated cool-down cycle requires approximately 45 minutes. The front panel display will indicate when the cool-down cycle is complete.
2. Turn the main power switch on the power supply rear panel to the OFF position and disconnect the power cord from facility power.

Air Filter Removal and Cleaning Procedure

3. Loosen the two retaining nuts and remove the air filter.
4. Clean the air filter by rinsing with water and drying with a blower.
5. Reinstall the air filter and retaining nuts. Perform the Turn-on (Cold Start) procedure in Section Five: Operation.

Verification of Cleaning

6. Visually inspect the air filter and confirm that the filter is free from visible contaminants.

SECTION EIGHT: OPTICAL ALIGNMENT

The procedures in this section cause significant changes to the Micra output characteristics. Even small adjustments may result in total loss of lasing. Only qualified personnel should make adjustments to the Micra cavity optics.

Preliminary Steps

Coherent strongly recommends reading through this entire section before beginning. It is likely that not all of the procedures described will be necessary to restore the original performance of the Micra. However, an understanding of the entire alignment strategy is extremely helpful when evaluating the system and deciding which steps to take.

Contact Coherent customer service with any questions before beginning these procedures.

Required Equipment

The following items should be readily available to the user:

1. **Powderless latex or nitrile gloves.** It is critical to avoid the introduction of any oils or dirt inside the Micra laser head. Gloves must be worn for all intracavity work, including brief adjustments of the bandwidth or center wavelength.
2. Infrared (IR) Viewer
3. Spectrometer capable of detecting wavelengths from 700 to 900 nm. For fiber optic spectrometers, it is helpful to pick off a small portion of the Micra output beam with a glass slide, and diffuse it (e.g., with lens tissue) in front of the entrance port.
4. Oscilloscope with a minimum bandwidth of 300 MHz and a BNC cable
5. Optic cleaning supplies, including lens tissue, hemostats, and ultrapure methanol and acetone. Detailed cleaning procedures may be found in “Cleaning Optics” on page 7-15.

6. The Customer Data Sheet shipped with the system
7. Cover interlock defeats, located in the accessory kit or attached to the rear panel of the Micra head

Water Chiller Temperature

Confirm that the chiller is operating at 21 ^{o}C. **If the chiller temperature must be changed or the chiller has just been turned on, wait at least 60 minutes before making any cavity adjustments.**

Verdi Warm-up

Allow the Verdi to operate at normal operating power for at least 20 minutes before making any cavity adjustments.

Crystal Cleaning

Clean the crystal surfaces whenever the modelocked power has declined by 5 to 10%, and before any cavity optics are adjusted. Refer to "Cleaning the Ti:Sapphire Crystal" on page 7-17.

Disengaging PowerTrack

As described in "Section Five: Operation", PowerTrack steers the Verdi beam in response to the Micra power level. The following alignment procedures result in temporary power losses, which cause PowerTrack to initiate large changes to the Verdi beam pointing. This function should be disabled when performing cavity adjustments.

If the system is lasing:

1. Confirm the following menu settings:

   Main Menu --> Micra Settings --> AutoModelock ON/OFF --> Automodelock setting: ON

   Main Menu --> Micra Settings --> Power Track ON/OFF --> Power Track setting: ON

   Main Menu --> Micra Settings --> Peak Hold ON/OFF --> Peak Hold status: OFF

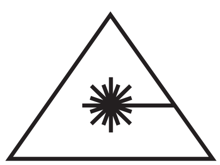
2. Wait one minute for PowerTrack to lock, as indicated by the PTRK LED on the back of the Micra head. If it does not lock, skip to the “If system is not lasing” steps below:
3. Access the PZT Control Menu:
   Main Menu --> Micra Settings --> PZT Control. Write down the PZT X and Y values in the upper left corner of the display.
4. Set Automodelock to OFF.
5. Set Peak Hold to ON.

If the system is not lasing:

1. Access the PZT Control Menu:
   Main Menu --> Micra Settings --> PZT Control.
2. Set PZT mode to MANUAL.
3. Set PZT X and PZT Y to 2.6 V.

Cover Interlock Defeats

Perform the following steps to allow operation of the Micra with the head cover removed:



With the head cover removed, the user is exposed to 532 nm light, in addition to the normal Micra operating range of 700 to 900 nm.

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1. If the laser is operating, close the shutter by pressing the SHUTTER OPEN pushbutton.
2. Remove the Micra head cover. This will activate a head cover interlock fault on the front panel.
3. Install the cover interlocks, which were included in the Micra accessory kit shipped with the system.
4. Clear the fault by pressing the MENU EXIT pushbutton.
5. Take appropriate laser safety precautions before reactivating the laser.

Photodiode Alignment

The Micra continuously monitors the fast and slow photodiode (PD) outputs as part of the PowerTrack and automodelocking control loops. Misalignment to these photodiodes can create a fault condition or otherwise adversely affect system performance. These signals can be easily checked using the RF SYNCH (fast PD) and POWER MON (slow PD) BNC connectors on the back of the Micra head.

Fast Photodiode Alignment

The fast PD has a smaller active area than the slow PD, so alignment to the fast PD also results in good alignment to the slow PD.

The system must be modelocked to give a fast PD signal. The signal must be > 500 mV peak-to-peak when measured on an oscilloscope (50 ohm termination, 200 to 300 MHz bandwidth).

To optimize the fast PD signal:

1. Turn Peak Hold ON: Main Menu --> Micra Settings -->
   Peak Hold ON/OFF --> Peak Hold status: ON
2. Check the system alignment ("Alignment Check" on page 8-15). Pay particular attention to the A7 and A8 apertures. Restoring the alignment should restore the fast PD signal.
3. If the fast PD signal is still low, walk (2-dimensional optimization) with M7 and M8 to optimize the fast PD signal:
   a. Break modelock and monitor the CW power.
   b. Make a small adjustment to M7 in the horizontal dimension. The power will drop, and the amount of drop can be used to track how large of an adjustment was made.
   c. Adjust M8 to optimize the power.
   d. Remodelock the system. If the fast PD signal is higher than before, move M7 again in the same direction. If the signal has dropped, move M7 in the opposite direction.
   e. Use A8 as a guide when walking the beam. Do not allow the beam to move far from center on A8.
   f. Iterate steps a. through e. to optimize the PD signal.
   g. Repeat steps a. through f. in the vertical dimension.
4. If system alignment is good but the fast PD signal is still low, loosen the screws on the beamsplitter mount and adjust the beamsplitter to optimize the fast PD signal. Use an IR viewer to look at where the beam is striking relative to the fast PD active area.

Slow Photodiode Gain

The fast PD has a smaller active area than the slow PD, so alignment to the fast PD also results in good alignment to the slow PD. See the section above to optimize the fast PD signal.

The Micra is designed to run with a slow PD voltage of ~5 V. If the output power has changed significantly (as a result of different bandwidth or center wavelength settings, for example), monitor the slow PD signal (POWER MON connector) on an oscilloscope, and adjust the PWR GAIN pot on the back of the Micra head (“Laser Head Features” on page 4-2) to maintain a signal of roughly 5 V.

Complete Optical Realignment

Figure 8-1 and Figure 8-2 provide optic labels and aperture positions. It may be helpful to make a copy of these diagrams for reference while performing the alignment steps.

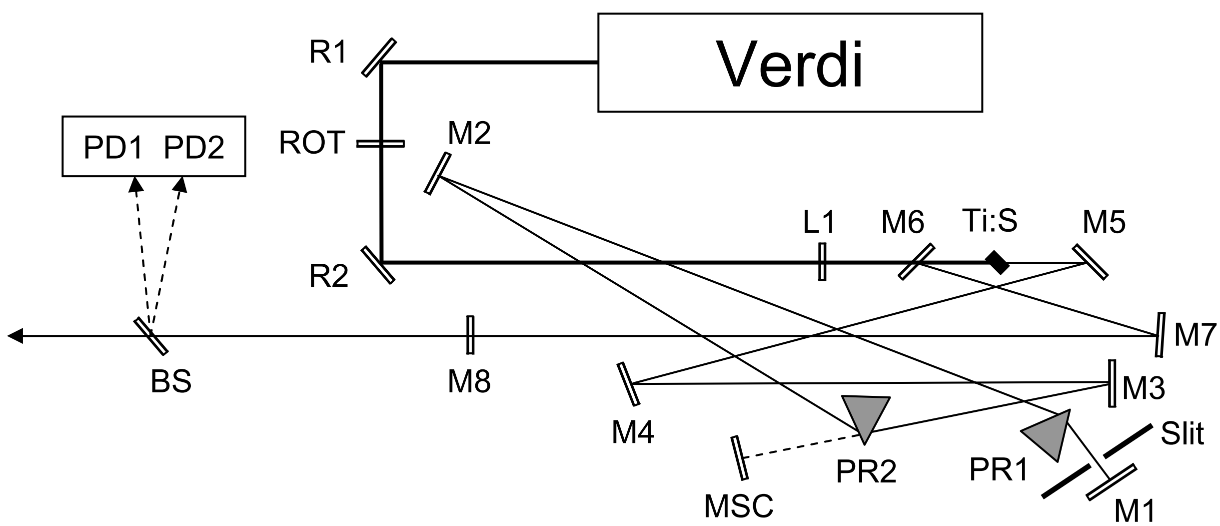

Figure 8-1. Micra Laser Head Layout Drawing

Overview

The alignment of the Micra may be subdivided as follows:

- Verdi pump beam alignment
- Lasing recovery (if possible)
- Oscillator cavity alignment (if necessary)
  - Output coupler leg
  - Prism leg
  - Short cavity leg (if necessary)

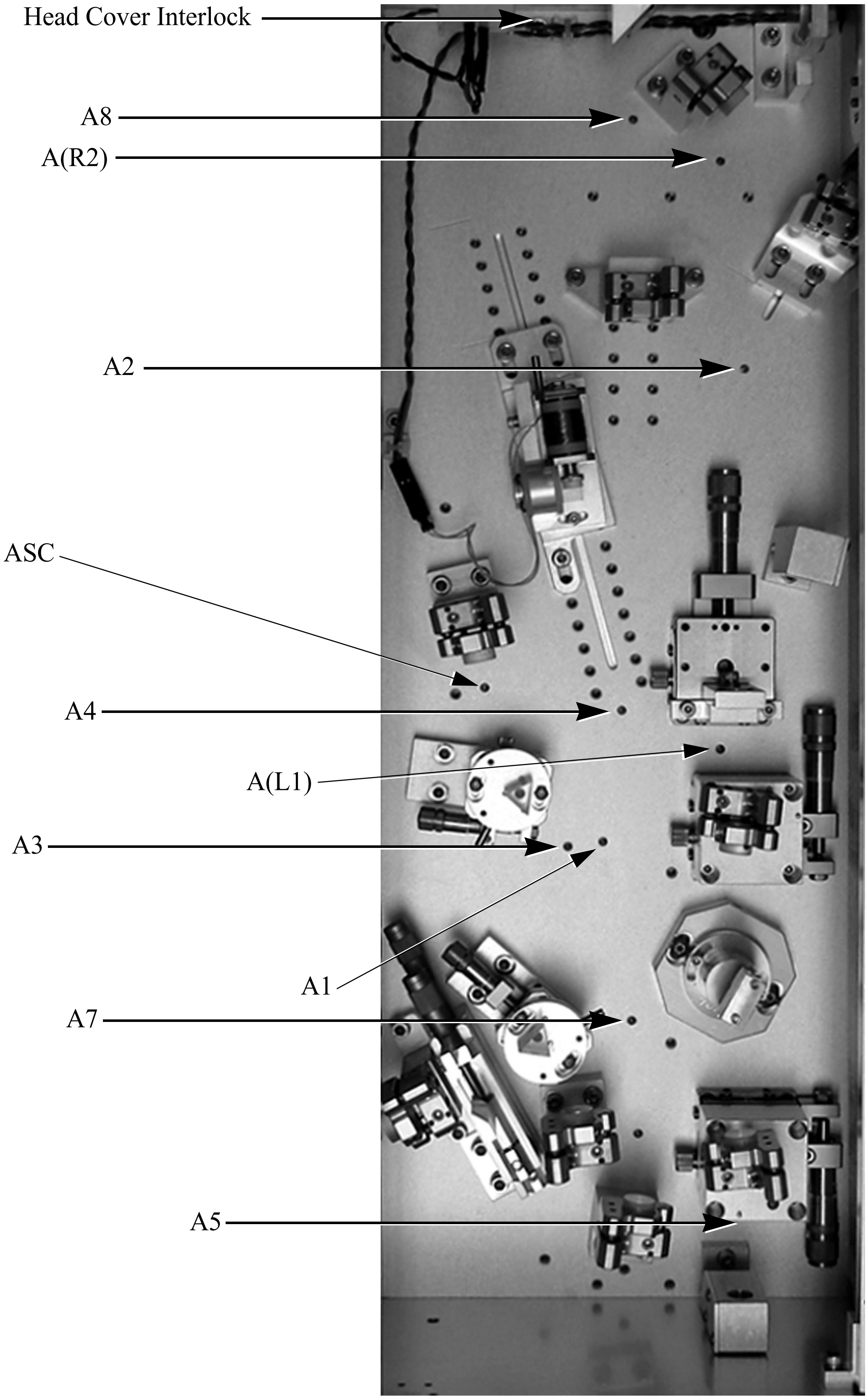

Figure 8-2. Photograph of the Micra-5 Oscillator Cavity Including Aperture Labels. The Aperture Holes are not Threaded.

- Oscillator cavity beam walking
  - Overlapping the beams in the crystal
  - Output coupler leg
  - Prism leg
- Alignment check
- Advanced fine-tuning of modelocked output characteristics
  - D-mirror or pump power adjustment
  - Pump lens position

Verdi Pump Beam Alignment

The pump beam is well-aligned when it passes through the center of A(R2), Ti:S, A5, and A4.

1. The beam height throughout the cavity is 2-1/8". Confirm that your alignment targets are the correct height. Throughout this procedure, A(#) corresponds to a target placed at the position indicated in the layout photograph. The holes for the targets in the baseplate have been machined to precisely match the diameter of the pins on the bottom of the alignment targets. They are not threaded. Gently place and remove the target to avoid distortions to the target post and/or the lip of the hole.
2. Set the Verdi power level to the minimum setting of 0.01 W. This corresponds to Power Level 1 when the unit leaves the factory. If the green light is unstable at this power level, use 0.02 or 0.03 W instead.

Warning: use a very low pump power (<0.1 W) when rough adjustments to the pump beam will be made. At no time should a high-power pump beam be allowed to stray off of the crystal surface. In addition to the obvious hazard of specular reflection from the crystal housing, it is possible to ablate metal onto the crystal surface and/or thermally damage the crystal.

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3. Open the shutter to allow green laser light into the cavity.
4. From the PZT Control Menu (Main Menu --> Micra Settings --> PZT Control), set the PZT X and PZT Y voltages to 2.6 V. The actual values displayed in the upper left corner will be slightly lower.
5. Remove the port on the outside of the Micra housing which allows access to the R1 adjustment screws.

6. Use R1 and R2 to align the green beam to A(R2) and A5, respectively. Iterate between the two adjustments (R1 to A(R2), R2 to A5) as necessary.
7. If the beam is far from the center of the lens, the following steps are necessary:
   - Unscrew the L1 mount from the micrometer baseplate and remove it from the cavity.
   - Repeat step 6 above.
   - Install L1 so that the beam is centered on the crystal. Small horizontal adjustments may also be made while setting the vertical position of the lens.

Lasing Recovery

If the pump beam has moved significantly, lasing may have been lost altogether. Follow the procedure below to recover it.

Use an IR viewer when looking for fluorescence.

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1. Setup a card inside the front wall of the laser, to view the beam after it passes through the output coupler. One large fluorescent spot should be visible, as well as two small spots which represent the retroreflections from each leg of the cavity. If multiple spots are not visible, skip to step 3.
2. Use the M1 and M8 adjustment screws to overlap the spots on top of each other. Systematically move the beams over each other while looking for a lasing flash. If lasing occurs, adjust M1 and M8 to optimize the power, and proceed to "Beam Walking: Precise Alignment on All Optics" on page 8-12.
3. If lasing does not occur, perform the following steps. After each one, repeat step 2. If lasing occurs at any time, adjust M1 and M8 to optimize the power, and proceed to "Beam Walking: Precise Alignment on All Optics" on page 8-12.

   a.) Using the M5 adjustment screws, center the pump beam reflection on A4.

   a.) Increase the pump power to 5.5 W.

   b. Place an alignment target at A2. When the alignment is close, the retroreflection (RR) from M1 is visible on the back side of A2 (side closest to the M2 surface), and the RR from M8 is visible on the front side of A2. Adjust M1 and M8 to center the RRs on the alignment target. Remove the target and repeat step 2.

c. Check that the beam is not clipping on either prism. Look at the fluorescence on A2. The position of PR2 can be monitored by looking at the shadow on A2. To monitor the PR1 position, place a card in front of M1, and again look for the shadow created by the prism. If necessary, move the prisms to avoid clipping.

d. M5 and M6 are curved mirrors, and the Micra output is very sensitive to the distances between these mirrors and the crystal. Changes as small as tens of microns can significantly affect the output power, mode quality, and attainable bandwidth. These distances are carefully optimized in the factory for the best overall performance of the system. However, more CW power may be obtained by increasing the M5-crystal distance. When looking for lasing it may therefore be helpful to adjust the micrometer below the M5 mount (increasing the M6-crystal distance would have a similar effect, but by default adjust M5). BEFORE DOING THIS, WRITE DOWN THE CURRENT READING OF THE MICROMETER. Verify that it corresponds to the value from the Customer Data Sheet. If they do not match, set the micrometer to the value from the data sheet and return to step 2. If lasing cannot be achieved, move M5 away from the crystal by turning the micrometer clockwise ~1 turn (500 microns), and return to step 2. Clockwise refers to the direction of turning while facing the M5 optical surface.

e. If the pump power and/or M5-crystal distance has been changed, reset them to the values given on the Customer Data Sheet.

Oscillator Cavity Alignment (CW Lasing)

If lasing cannot be recovered as described above, it may be necessary to align the entire system as described below. If lasing occurs at any time, adjust M1 and M8 to optimize the power, and proceed to “Beam Walking: Precise Alignment on All Optics” on page 8-12.

Output Coupler Leg

The output coupler leg refers to the beam path between the crystal and the output coupler.

1. Center the large-diameter fluorescence on A7 with M6. Note that the light strikes M6 first, and then passes through A7 on its way to the output coupler.

2. Center the fluorescence on A8 with M7.
3. Find the RR from M8, and center it on the front side of A7 (side closest to the Micra output aperture).

Prism Leg

1. Center the pump beam reflection on A4 with M5.
2. Center the fluorescence on A2 with M3.
3. Look on A2 for the shadow cast by PR2 and adjust the prism to be centered on the fluorescence.
4. Center the fluorescence on A1 with M2. The spot will have elongated horizontally since passing through PR2, and will look like a dash instead of a circle.
5. Ensure that the slits are fully open (top micrometer of slit assembly) and roughly centered around M1 (bottom micrometer of slit assembly).
6. Translate PR1 to center the prism on the fluorescence. The prism position may be monitored by setting a card between M1 and the slit assembly - be careful not to make contact with the M1 optical surface.

   When the fluorescence is centered through PR1, two shadows are visible on the card which represent the front and back edges of the prism. Do not confuse the prism shadows with the larger, more stark shadows of the slit assembly. Move PR1 while looking at the card through an IR viewer. Translate the prism until both shadows are visible.
7. Again the retroreflection (RR) from M1 must be located and aligned precisely on top of the forward beam. If the alignment is close, the RR will be visible on the back side of A2 (side closest to the M2 mirror face) as adjustments are made to M1. If the RR cannot be found here, look for it on the back of A1. Sweeping the horizontal knob of M1 may help. Once located, bring it close enough to the forward beam that it is visible on the back side of A2.

Note that the alignment aperture A2 is centered on the line between PR2 and M2. The beam path from M2 to M1 does not go through this aperture, but passes to the side of it. The RR leaves M1, strikes M2, and then strikes the back side of A2.

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8. Align the RR precisely back through A2.
9. To achieve lasing, refer to "Lasing Recovery" on page 8-8.

Short Cavity Leg

The short cavity leg refers to the beam path between the crystal and MSC. Aligning the short cavity is optional, but it can be done in cases where lasing cannot be achieved in the main cavity.

1. With the M5 adjustment screws, center the pump beam reflection on A4.

Unless the starter mirror assembly (M4) has been moved, the pump beam should be near center on M3. At this stage it is not important that the pump beam be precisely centered on these optics. If it is within 2-3 beam diameters of center, skip to step 3. If it is not, then the M4 mount must be adjusted as described below. Before doing this, confirm that the pump beam is precisely aligned with A(R2), A5, the center of the crystal, and A4.

2. Roughly center the pump beam reflection on M3 with M4. Horizontal and vertical adjustments are achieved by loosening set screws and moving the entire starter assembly. Alignment target A3 may be used as a reference for the vertical adjustment but not the horizontal. This is because the correct horizontal alignment is dependent on the precise position of M4 along the cavity length adjustment rail. The ideal position for the pump beam on M3 is approximately one beam diameter to the right of center.
3. Translate PR2 out of the beam path by turning the micrometer fully clockwise. This corresponds to moving the prism away from the side wall.
4. Center the pump beam reflection on ASC with the M3 adjustment screws.
5. Ensure that the pump beam path is unobstructed. After taking appropriate safety precautions, increase the pump power to 5.5 W.
6. Find the fluorescence retroreflection (RR) coming back from MSC. The goal is to precisely reflect the RR back on the path of the original beam. Center the RR on the back side of ASC (closest to the MSC surface) with the MSC adjustments screws.
7. Center the RR on the back side of A4 (closest to the M4 surface) with the MSC adjustments screws.
8. Achieve lasing by overlapping the RRs. Set up a card as described in “Lasing Recovery” on page 8-8. Alternatively, look on A8 while making adjustments to MSC, and look on ASC while making adjustments to M8 to find the RRs.
9. Before proceeding to main cavity alignment, detune MSC (~1 turn downward on the vertical adjustment screw) to prevent

interference from auxiliary cavity lasing when moving the prisms in and out of the beam during later adjustments.

Beam Walking: Precise Alignment on All Optics

Optimal operation of the laser is dependent on the overlap of the beam axis defined by the cavity optics with the pump beam in the Ti:sapphire crystal. Pump beam alignment should already have been established (see Pump Beam Alignment section above).

A common way to cause misalignment of the Micra is to walk the cavity beam while PowerTrack is engaged. Enable Peak Hold or set PZT control to manual before beginning, and write down the PZT X and Y voltages for future reference. See "Disengaging PowerTrack" on page 8-2 above.

The overall strategy for walking the beam is to start from the crystal and then proceed outward down each side of the cavity, aligning the beam to all apertures and mirrors. The IR beam path within the crystal itself is controlled by walking the end mirrors.

The following procedure may have to be done more than once. The first time through simply get the beams close to center, and then go back through with more precision.

Overlapping the Pump and Cavity Beams Within the Crystal

Walking the IR cavity beam involves making a discrete adjustment to M8 in one dimension only and then recovering power with M1. This constitutes a "step." As this process is repeated, the IR beam will move on all cavity optics. It will also move within the crystal to better (or worse) overlap with the fixed pump beam.

1. Observe the beam pattern on M5 with an IR viewer. The pump and IR beam spots should be separately visible. The IR spot should be significantly brighter, but the two spots may easily be distinguished by blocking and unblocking the cavity beam between PR2 and M3. Figure 8-3 shows the target positions of the pump and IR beams on M5, with approximately one beam diameter (1 to 1.5 mm) separating the two spots. It is the separation between the beams which is important, not their absolute positions on the optic.

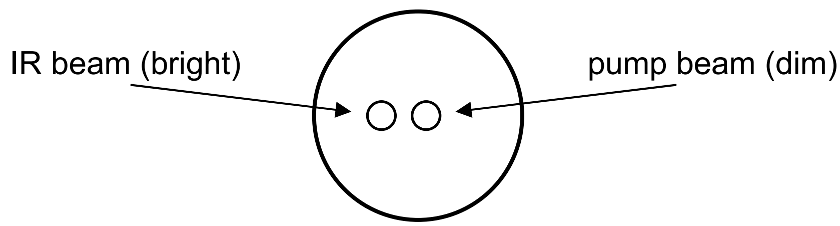


Figure 8-3. Graphical Representation of the Correct Beam Spot Positions on M5

If M5 is observed while M8 is adjusted, the movement of the beam can be detected before the laser beam fades out. As power is recovered with M1, the beam will again grow brighter, but in a different location than before.

Only one dimension should be moved at a time, i.e., if a horizontal adjustment is made to M8, be sure that you recover the power with a horizontal adjustment to M1.

If lasing is irretrievably lost, refer to “Lasing Recovery” on page 8-8.

2. Walk the IR cavity beam in the vertical dimension so that it is exactly the same height as the pump beam. This will correspond to the highest output power unless the beam is severely misaligned elsewhere in the cavity, or there is damage or contamination on any optics.
3. In the horizontal dimension, walk the IR beam so that it approximates the beam positions shown in Figure 8-3.
4. Walk with very small steps to precisely optimize the output power. This adjustment is quite sensitive. Several attempts should be made to maximize the power.
5. Every few steps, optimize both dimensions of M1 for power.
6. Maximum power should correspond to the beam positions shown in Figure 8-3. If it does not, recheck the pump beam alignment, and ensure that all optics are clean. Look on all optics for clipping. If clipping is present, walk the beam close to center on that optic (see the "Output Coupler Leg" and "Prism Leg" sections below) and return to step 2.
7. Check that the beam is at least close to center on all optics. If the beam is severely misaligned elsewhere in the cavity, the beam walking procedure may have to be done more than once.

The first time through the optimal power may not correspond to the beam positions shown in Figure 8-3, usually because the beam is severely misaligned elsewhere in the cavity. Try to emulate Figure 8-3 and then proceed.

Output Coupler Leg

1. Center the beam on the back side of A7 (side closest to the M7 surface - the beam strikes M7 before passing through A7 on its way to the output coupler): adjust M6 in the appropriate direction, and recover power with M8. Even if lasing is temporarily lost, a discrete adjustment to M6 followed by power recovery with M8 will move the beam on A7. Again be sure to recover power by adjusting the same dimension (H or V) on M6 and M8. Every few iterations, tweak both dimensions of M8 for power.
2. Center the lasing as closely as possible on A8 by making discrete adjustments to M7, removing A8, and recovering power with M8. When the laser is well-aligned inserting A8 results in negligible power loss.

Prism Leg

A similar process is followed for the prism leg of the cavity.

1. Adjust M5 to center the pump beam on A4. Optimize M1 for Micra output power. Note: If the IR beam spot is close to the edge of the M4 optic, adjust M5 to move the pump beam off-center to the left on A4. This will move the IR beam closer to center on M4.
2. If the beam is within one beam diameter of center on M3, skip to the next step. Otherwise, center the IR beam on M3 by making adjustments to the starter mount (M4), and recovering power with M1. The beam must be within one beam diameter of center on M3 to maintain the Angle of Minimum Deviation with the prisms.
3. Center the beam on A2 with M3. Remove the aperture and recover power with M1.
4. Center the beam on A1 with M2. Remove the aperture and recover power with M1.
5. If the beam pointing changes significantly in step 2 or 3, it may be necessary to translate the prisms. The beam should be roughly centered on the prism sides.
6. Optimize M1 and M8 for power.

Alignment Check

The Micra is well-aligned when the following are true:

1. The pump beam is centered on A4.
2. It is not possible to achieve more power by walking the end mirrors (M1 and M8).
3. The IR and pump beam positions on M5 closely resemble Figure 8-3 (precisely the same height, approximately one beam diameter between the beams).
4. Lasing occurs through A7 and A8 with minimal power loss. The beam may be off-center on the M7 and M8 mirror surfaces.
5. Lasing occurs through A2 and A1 with moderate power loss (<50% power drop).
6. The IR beam is centered on M1 and M3 to within one beam diameter of center.
7. The fast photodiode signal is > 500 mV (peak-to-peak, 50-ohm termination) when the laser is modelocked.

It is absolutely worth the time to achieve precise alignment. After walking either side of the cavity the beam pattern on M5 may have changed. In this case the end mirrors should be walked to optimize power and the entire process repeated.

Precise alignment with the above checkpoints will result in consistent modelocked operation.

Engaging PowerTrack

As a last step, activate PowerTrack (Peak Hold OFF, PZT mode AUTO). If the PZT voltages change by more than 0.5 V, the beam overlap in the crystal was not optimal.

Be careful when making any adjustments to the cavity with PowerTrack operational. Changes to the IR beam alignment, followed by PowerTrack steering the pump beam, can quickly cause significant degradation in the overall performance of the system. This is particularly true for M1 adjustments. If alignment has been lost, return the PZTs to their previous settings in manual mode, and recover performance with the beam walking procedure above.

Modelocking

If the Micra output power level meets or exceeds the value listed on the Customer Data Sheet, and the laser is aligned according to the above Alignment Check section, reengage modelocking:

1. Remove PR2 from the beam just until the power begins to drop. At this point the beam is clipping on the edge of the prism. Reinsert the prism into the beam ~1 turn.
2. Remove PR1 from the beam until the spectrum just begins to red shift. If the spectrum is not being monitored, remove PR1 until the power begins to drop, and reinsert the prism ~1 turn.
3. Access the PZT Control Menu (Main Menu --> Micra Settings --> PZT Control).
4. Set AutoModelock to ON.
5. Confirm the following menu settings:

   Main Menu --> Micra Settings --> AutoModelock ON/OFF --> Automodelock setting: ON

   Main Menu --> Micra Settings --> Power Track ON/OFF --> Power Track setting: ON

   Main Menu --> Micra Settings --> Peak Hold ON/OFF --> Peak Hold status: OFF
6. Verify that the fast photodiode signal is > 500 mV (peak-to-peak, 50-ohm termination).
7. If the laser does not modelock, turn the Automodelock function off. The starter vibration may be easily detected by lightly touching the M4 mount. Do not allow the starter mount to continually vibrate for periods longer than a few seconds.

Bandwidth and Center Wavelength Adjustments

Refer to "Bandwidth and Center Wavelength Adjustments" on page 5-6.

Advanced Alignment Techniques

In most cases, optimum performance will return once the Micra has been precisely realigned. If this is not the case, the following procedures outline additional adjustments which may be made.

D1 and D2

The Micra output is very sensitive to the crystal-M6 (D1) and crystal-M5 (D2) distances, in terms of power, mode quality, and attainable bandwidth. Increasing either D1 or D2 tightens the focus within the crystal. Although this will result in more CW power, the laser will become more difficult to modelock and unable to support high bandwidth. The "D's" are carefully set in the factory. In all likelihood the M5 and M6 micrometer settings should remain as indicated on the Customer Data Sheet.

In the event that a change to D1 or D2 is required, adjust the micrometers at the base of the M5 and M6 mirror mounts as described below.

It should not be necessary to move either distance by more than 200 microns. This is far less than one turn of the micrometer knob (1 turn = 500 microns). WRITE DOWN THE SETTINGS OF THE MICROMETERS BEFORE MOVING THEM.

D2 / Pump Power Adjustment

For a given cavity configuration, stable modelocking occurs only over a limited range of pump power. As the pump power increases, one of two things will eventually happen: 1) CW breakthrough will appear in the spectrum (Figure 5-1 on page 5-7), or 2) double pulsing will occur. Double pulsing means that more than one modelocked pulse is in the cavity at the same time. It can most easily be observed by monitoring the pulse train with the fast photodiode and an oscilloscope. However, it is not difficult to observe with a spectrometer either: smoothly increase the pump power while watching the spectrum. The onset of double pulsing corresponds to a sudden intensity jump across the entire spectrum by a factor of 1.5-2x.

Turning the pump power back down will again result in a sudden decrease in intensity without significant change to the spectral profile.

The lower pump power limit is marked by the onset of "self Q-switching." A stable laser is characterized by an equilibrium between the formation and depletion of the upper state of the lasing transition. If the pump power is too low, this equilibrium is disturbed, and oscillations in the output result. Although they do cause degradation of the spectrum, these oscillations are most easily observed on an oscilloscope as shown in Figure 8-4.

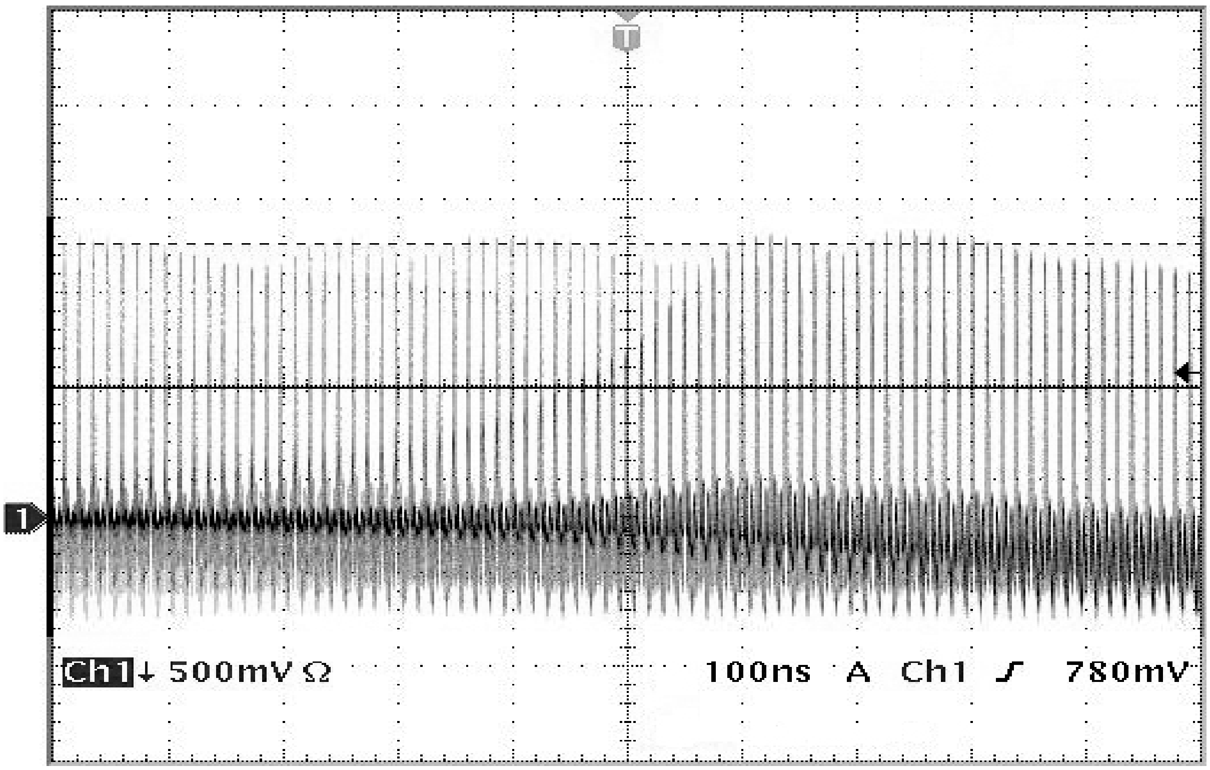


Figure 8-4. A Frame Capture from an Oscilloscope Showing the Irregular Behavior of the Pulse Train while Self Q-switching.

A healthy Micra-5 has a window of ~500 mW to 1 W between the upper and lower limits of pump power. It is recommended to operate at least 0.25 W below the onset of CW breakthrough or double pulsing, and at least 0.25 W above the Q-switching threshold. It is also useful for the window to be roughly centered around a pump power of 4.5 W. If the laser is too close to the upper limit, soften the focus in the crystal by decreasing D2. Conversely, if the laser is too close to Q-switching, increase D2 to tighten the focus. The changes required here are likely to be as small as 10 microns.

Alternatively, the pump power may simply be increased or decreased. If the center of the window is outside the range 4.0-5.0 W, an adjustment to D2 should be made. After changing D2, check the alignment as described in the Alignment Check section above.

Lens Position

It is also possible to change the focal point of the lens which focuses the pump beam. This distance should be optimized while the laser is in CW mode.

1. Disable the automodelocking function in the PZT Control menu.
2. Temporarily prevent lasing by blocking the IR beam between PR2 and M3. When the beam is unblocked the laser should be in CW mode.
3. Monitor the spectrum or pulse train to detect if the laser returns to modelocked operation. If it spontaneously modelocks, add glass with PR1 and repeat step 2.

Optimize the L1 micrometer for power in CW mode.

Final Optimization

The above procedures describe the various adjustments which may be used to fine-tune the system. It is important to be aware that they are all interrelated. For example, changing D1 or D2 affects the alignment of the IR beam throughout the cavity. Realignment will not proceed the same way for each laser. It will likely be necessary to iterate among the above procedures to achieve optimum performance.

SECTION NINE: PRINCIPLES OF OPERATION

Micra Laser Head

The Micra laser head consists of a Verdi pump laser, a PowerTrack routing mirror, and an ultrafast modelocked oscillator. The 532 nm output from the Verdi pumps the Micra oscillator.

Optimum pump beam (532 nm) alignment is provided by the PZT-controlled mirror. This pump optimization is known as PowerTrack. The Verdi laser head, PowerTrack function, Micra oscillator cavity, and the power supply are described in the following paragraphs.

Verdi Laser Head

The pump laser resonator is a robust unidirectional single-frequency ring cavity design employing intracavity second harmonic generation to produce multiwatt-level continuous-wave green (532 nm) visible light output. Constructed within a cleanroom environment, the resonator optics are rigidly mounted upon a proprietary grade Invar™ slab. These optics are installed using Coherent's exclusive PermAlign™ manufacturing process, resulting in a permanently aligned resonator structure that is completely immovable and stable.

Coherent-grade Super Invar™ combines a true zero coefficient of thermal expansion at room temperature with a high specific heat capacity, 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 the pump laser, 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 pump laser 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 pump laser resonator can be categorized as an "end-pumped" design, in which the pump light from the diode bar propagates collinearly 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 many undesirable characteristics, including beam distortions through diffraction effects, lowered efficiency, and lower pump- diode lifetimes.

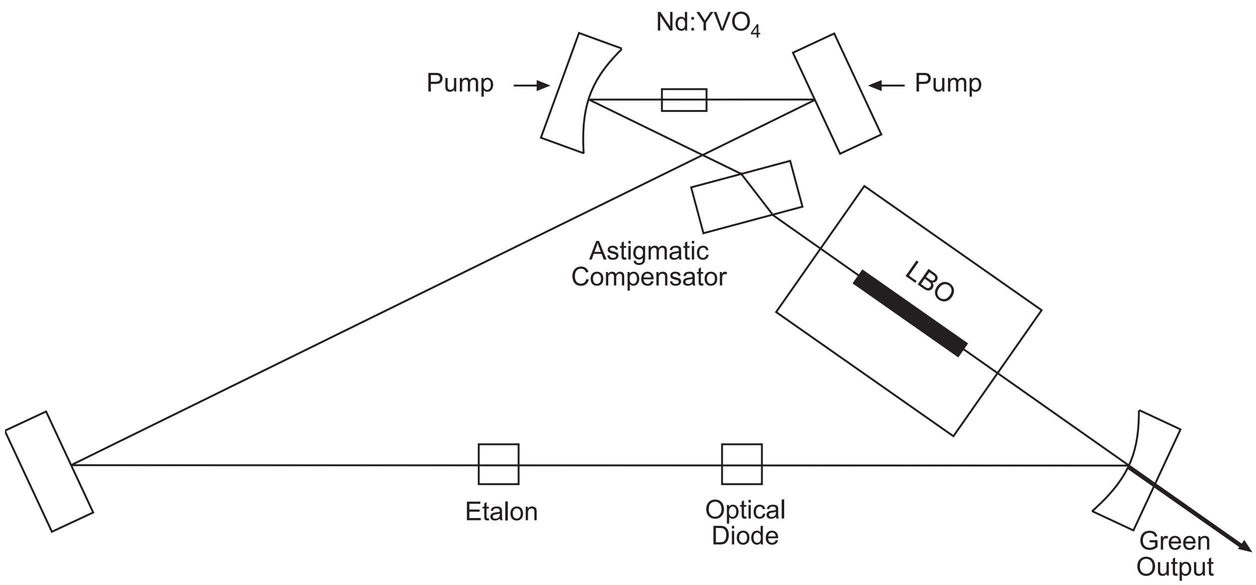


Figure 9-1. Verdi Laser Head Optical Schematic

Verdi Gain Medium

The pump laser gain medium is Nd:YVO_4 (Neodymium: Yttrium Orthovanadate), commonly referred to as Vanadate. Vanadate's high absorption coefficient at the 808 nm pump wavelength (a standard wavelength for high powered diodes for laser pumping) and large stimulated emission cross-section near 1064 nm make it an ideal choice for the pump laser.

Among Nd:YAG, Nd:YLF and Nd:YVO_4 as laser materials, Nd:YVO_4 has the highest absorption coefficient which allows a shorter crystal length. In addition, Nd:YVO_4 has the highest stimulated emission cross-section, almost four times larger than Nd:YAG. Vanadate also maintains a strong single-line emission around 1064 nm.

Vanadate is a uniaxial material that produces a polarized laser output, thus avoiding undesirable thermally induced birefringence. Optical properties are dependent on crystallographic direction.

Material properties like thermal conductivity, index of refraction and thermal expansion are different in directions parallel to the crystallographic axis and perpendicular to it. This anisotropy heavily impacts the optical design.

Verdi Thermal Focusing Characteristics

An optically pumped laser rod acts as a lens inside the laser resonator. The thermal gradient causes strain in the rod, which also contributes to focusing.

In Nd:YVO_4, for light polarized perpendicular to the optical axis, there are two focal lengths: one value for rays in a plane containing the optical axis and another value for rays in the perpendicular plane.

For light polarized parallel to the optical axis, there are also two focal lengths. The four values of focal length are all different. The pump laser is polarized parallel to the optical axis. The material is said to show astigmatism when, for a given polarization, there are two focal lengths.

In the pump laser, the Vanadate is temperature regulated in a configuration that minimizes thermal focusing, therefore reducing the astigmatism.

Verdi Second Harmonic Generator

LBO is used as the second harmonic generator. LBO takes advantage of higher intracavity powers. Intracavity power is greater than output power by a factor of 1/T where T = transmission of output coupler. The LBO crystal acts like an output coupler. The cavity uses two high reflectors to reach the highest fundamental intracavity power.

The advantages of LBO are:

- Low absorption across the visible and infrared.
- High damage threshold.
- Non-hygroscopic

LBO is a Type I, non-critical phase matching medium. The condition of phase matching occurs when the second harmonic and fundamental travel through the crystal at the same velocity. In Type I phase matching, the fundamental propagates as an e-ray and is perpendicular to the second harmonic which is an 0-ray.

Verdi – 90° Phase Matching

The fundamental wavelength propagates 90° to the optic axis. In this case, phase matching can be accomplished by temperature tuning. The fundamental wavelength of LBO at 1064 nm is phase matched with the second harmonic wavelength of 532 nm at a crystal temperature of approximately 148 °C. The advantages are:

- No dependence of conversion efficiency on beam divergence.
- No double refraction occurs. The fundamental does not walk off the second harmonic and longer crystals can be used to increase efficiency.

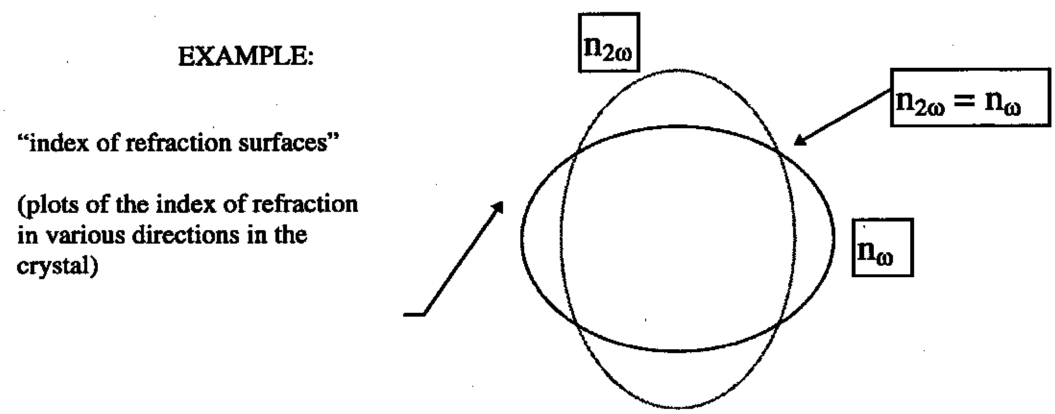


Figure 9-2. Index of Refraction Surfaces (Verdi)

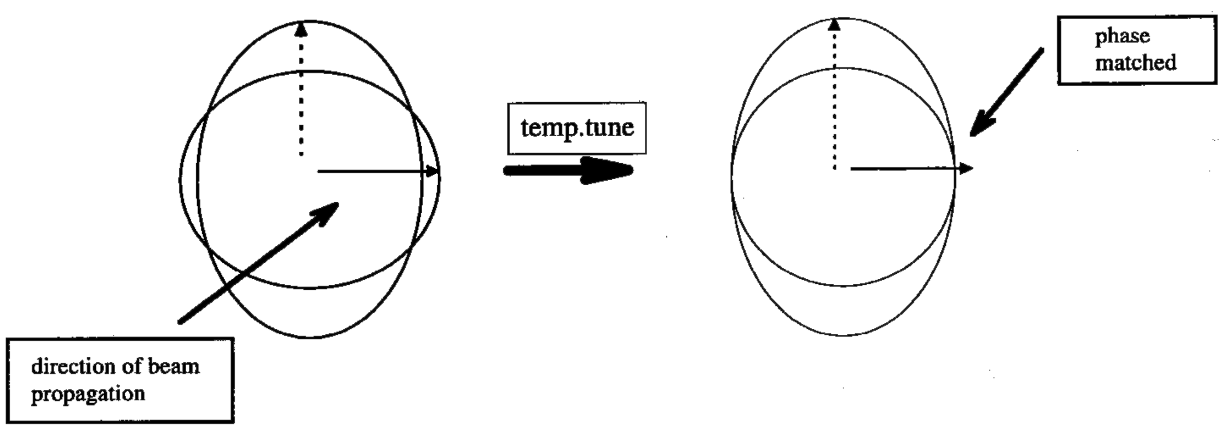


Figure 9-3. 90° Phase Matching (Verdi)

LBO Temperature

Temperature control of the LBO is critical since the optical coatings cannot tolerate rapid temperature changes. The LBO is heated to a temperature of approximately 148 °C under control of the main CPU. This temperature is maintained as long as the power switch on the rear of the power supply is set to ON. The correct procedure for shutting down the pump laser is described in Section Five: Operation.

The power switch on the rear of the power supply should be left on for approximately 45 minutes after the LBO cool-down has been initiated to avoid unnecessary use of the internal battery.

A slow warm-up cycle is initiated when the main power switch is turned on, and a cool-down cycle is executed when activated in the LBO Settings menu. The laser diodes will not activate until the LBO reaches the proper operating temperature. Refer to the turn-on and turn-off procedures in Section Five: Operation.

The power supply has a battery backup circuit that executes the cool-down procedure in the event of a sudden AC power loss.

The main power switch on the power supply rear panel should not be turned off without performing the cool-down routine. Doing so will cause the battery to be used (rather than AC power) for LBO cool-down. The battery is rechargeable but eventually will have to be replaced. The battery is charged when AC power is applied to the power supply.

PowerTrack

The PowerTrack function actively maintains optimum pump beam alignment into the Micra oscillator cavity, serving to minimize fluctuations in the output power. PowerTrack works as follows:

Piezo-electric transducer (PZT) driven levers alter the tip and tilt of the first pump beam routing mirror. When the laser is activated, the PZT controller provides voltage to these levers and functionally begins a Raster Scanning of the mirror in the X and Y directions (large changes in PZT voltage and hence pump beam position).

This Raster Scanning can be observed as large changes in the PZT X and PZT Y voltages in the PZT Control submenu. Once a preset threshold level of CW lasing is achieved the Raster Scan is switched to a smaller-amplitude Dither Scan (smaller changes in PZT voltage and hence pump beam position).

The Dither scan is centered about the Raster Scan voltages found to achieve the threshold level of CW lasing. System electronics then distinguish increases in power with changes in PZT voltage (pump beam alignment). This allows the Dither Scan to fine tune the PZT voltages for optimum pump beam alignment.

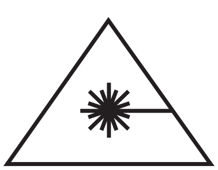
Power Supply

The power supply houses several circuit boards, an internal commercial power supply, a laser diode assembly, and cooling fans. The power supply provides the following functions for the pump laser:

- A light source (pump) for the gain medium in the laser head cavity via a fiber optic in the umbilical. Light is generated by the laser diode assembly as described in the next paragraph.
- A user interface. The user interface consists of the front and rear panel controls and indicators.
- Controls and monitors the various servo loops in the laser, which include:
    - TEC loops for the Vanadate, Etalon, and diodes
    - LBO heater
    - Verdi and Micra light loops
    - Heat sink
    - Baseplate temperature
- A source of DC voltage for all system functions. The internal power supply provides +48 VDC which is distributed throughout the laser.

Laser Diode Assembly

The hermetically sealed laser diode assembly contains a FAP-I™ (fiber array package-integrated), a circuit board with an EEPROM, and a heat sink sensor.



Note that the laser diode assembly is capable of emitting laser light when the fiber optic cable is disconnected. Do not look into the output of the laser diode assembly.

The FAP-I consists of a laser diode bar with collection and symmetrizing optics mounted within an environmentally sealed package. The FAP-I efficiently converts low-voltage, high-current electrical power into a circularly symmetric, multimode laser beam. The

FAP-I produces multiwatt continuous wave output power for thousands of hours. Waste heat from the laser diode bar is transferred through the FAP-I base to a heat sink.

The FAP-I contains a laser diode bar which efficiently converts electrical energy into optical laser energy. The laser diode bar consists of multiple independent emitters spaced linearly along a single semiconductor substrate. The output of each of these emitters is captured by a collecting optical fiber. This linear array of fibers is then bundled into a circularly symmetric output.

At low drive currents, the laser diode bar will have insufficient gain to lase. In this operating regime, some light, originating from spontaneous emission, will be visible. As the drive current is increased, the laser diode bar will reach threshold, where it will have sufficient gain to lase. This drive current is the threshold current. Further increases in current will cause a linear increase in output optical power up to the specified operating level.

In general, semiconductor devices perform better at lower operating temperatures. The optical-to-electrical conversion efficiency is higher and the device lifetime is longer. It is desirable to operate the FAP-I at low temperatures to improve performance and lifetime.

The precise semiconductor output wavelength is also a function of operating temperature. The operating temperature is in turn a function of the operating current and case temperature. Control of the temperature is important to match the diode output wavelength to the absorption window of Vanadate.

Diode/Heat Sink Temperature

The laser diode assembly which houses the FAP-I is mounted on a finned heat sink located in the power supply. The temperature of the diode bars located within the FAP-I is controlled by a TEC. Waste heat from the diode bars is transferred to the passive heat sink.

The heat sink is cooled by fans which exhaust waste heat from the laser diode assembly to the outside of the power supply. Incoming ambient air is filtered by an air filter which can be cleaned periodically depending on the environment.

The laser diodes have an operating temperature range of 5.0°C to 35°C.

Ti:Sapphire Oscillator Introduction

A laser is an optical oscillator that creates a very highly directed beam of light at a precise wavelength or frequency.

There are four important components of all lasers:

1. Energy (pump) source
2. Gain medium
3. High reflector
4. Output coupler/partial reflector

The region of space between the high reflector and the output coupler is referred to as the laser cavity.

If the atoms in the gain medium are properly "prepared", light passing through the medium will be intensified, or amplified. The high reflector at one end of the laser and the output coupler are aligned to cause the amplified light to return to the gain medium for further amplification. The light traveling strictly perpendicular to the high reflector and output coupler will make many passes through the gain medium without zigzagging off the mirrors and therefore be amplified significantly. This strong "preferential treatment" of light moving in a precise direction is what gives the laser its highly directed beam.

The output of the laser is simply a sampling of the light circulating in the cavity provided by the output coupler. The output coupler reflects most of the light incident on it but allows a fraction to be transmitted, forming the output of the laser.

The Gain Medium

In most materials, light is absorbed rather than amplified. The atomic explanation of absorption and amplification are similar; the difference is in the initial state of the atom.

Atoms are normally in their low energy state and pick up energy from incident light, thus absorbing the light. Upon absorbing this light, the atom is in an energetic state, and, when stimulated properly, falls to its original state and emits light.

Atoms in their energetic or excited states can be stimulated to emit light using light itself. If, moreover, the stimulating light and the stimulated light are identical in wavelength, more light of that wavelength leaves the region of the atom than arrived there. This light is "amplified".

Preparing the Atoms for Amplification: Pumping

Some means are required to raise the atoms to their high energy or excited state, because (at normal temperatures) most are in a lower energy state and will absorb rather than emit light. This process is referred to as pumping.

There are many methods of pumping, and different methods are appropriate for different atoms. In the case of the Ti:Sapphire laser, another laser is required as the pump source. In order to excite Titanium, each atom requires intense light and only a laser can provide this highly focussed and directed light.

Longitudinal Modes

Only certain wavelengths will be amplified, depending on the details of the amplifying medium and the mirrors. The wavelength may also be further restricted by filters or other devices.

Ti:Sapphire itself will amplify anywhere from 680 nm to 1100 nm. The cavity optics further restrict the wavelength range, as very high reflectivity is not realized over the entire range of fluorescence.

Each lasing wavelength must also be precisely an integral number of half wavelengths that “fit” between the mirrors. Since the integer is not specified, there can be many wavelengths that satisfy this criterion. Each of the wavelengths is referred to as a longitudinal mode.

Transverse Mode

The light contained between the mirrors within a very well-defined volume is much narrower than the physical diameter of the mirrors. This distribution is referred to as the “transverse mode” of the laser.

Theory of Modelocking

The following explanation of modelocking is presented in its simplest form, but is sufficient to explain the operation of the Micra.

Within the cavity of a modelocked laser, a single short pulse of light bounces back and forth between the mirrors.

At each bounce from the output coupler, a small portion of the pulse escapes to form the output of the laser. The time between pulses is equal to the time it takes for light to make one round trip from the output coupler to the high reflector at the other end of the cavity back to the output coupler. In the case of the Micra, this time is approximately 12.5 ns. Time and frequency are inversely related, so the inverse of this time is the number of pulses per second, commonly referred to as the repetition rate, rep rate, or sometimes as the frequency. The standard repetition rate for operation of the Micra is 80 MHz. However, this may be adjusted from 76 MHz to 82 MHz.

Once a pulse is formed within the cavity, most atoms that were in their excited state—i.e. prepared to emit light—have been stimulated by the passage of the pulse through the gain medium. For a period of time after passage, there are insufficient atoms in the excited state to form and amplify another pulse. This means that only a single pulse is formed at a time, and the output consists of a sample of this one pulse as it periodically arrives at the output coupler.

See the section titled “Origin of the Term “Modelocked”” on page 9-11 for more information on modelocking.

Formation of the Pulse

Many techniques for creating an ultrashort pulse have been developed. The Micra employs a passive modelocking technique. In passive modelocking, some material or mechanism is used that automatically opens to allow the pulses through but is closed otherwise, i.e., a self-adjusting modulator. A shutter or modulator with timing externally controlled is not necessary.

The Micra cavity was designed such that the beam diameter within the cavity changes by a small amount as the intensity of the light changes. More specifically, the beam diameter at certain locations within the cavity is large when the laser is operating as a continuous wave (CW) but becomes smaller when the laser is producing high intensity modelocked pulses.

Kerr Lens Modelocking

Mode discrimination between the larger CW lasing mode and the smaller modelocked lasing mode is provided by the soft gain aperture in the gain medium. The Gaussian pump mode distribution in the gain medium results in higher gain in the center of the lasing mode, and lower gain at the edges of the lasing mode. This gain distribution acts as a soft aperture, allowing the smaller modelocked mode to see higher gain than the CW mode.

Changing the Beam Diameter

The properties of light passing through any material depends on a property referred to as the index of refraction, or n.

The index of refraction manifests itself in two primary ways.

1. The velocity of light in a material is equal to the speed of light in a vacuum divided by the index of refraction. Thus, the higher the index of refraction (n), the lower the velocity of light.
2. The amount that a beam bends when it strikes a surface is defined by n (according to Snell’s law). If the velocity of light

is different for different parts of the light beam (that is, a spatially dependent *n*), then the beam will bend or otherwise be reshaped. This is known as refraction.

A common refractive element is the lens (e.g., a biconvex lens), which is thicker in the middle than at the edges, so that the center of the beam is slowed down more than the edges. This causes the light to bend toward the center. In the case of the lens, the index of refraction is the same everywhere, but since there is more glass in the middle than the edges, the edges are slowed down less.

A lens can also be formed by making the index of refraction at the center of the material larger than the index at the edges. This will also bend light and is referred to as a gradient index lens.

The most common way to change the index of a material is to change its chemical composition. However, in the Micra the index is changed by the light itself. At sufficiently high intensity, the electric fields associated with the light can actually distort the atoms of the material and alter its index. This effect is known as the optical Kerr effect. The beam is less intense at its edges as compared to the center, the index at the center is different, and a gradient index lens is formed. Because the optical Kerr effect alters the index, the lens thus formed is referred to as a Kerr lens.

The Kerr lens is formed only when the intensity of the light is extremely high. The instantaneous intensity of mode-locked light pulses are sufficient to form this lens, but the weak intensity of the laser that is operating CW is not. Therefore, the lens is only formed upon the arrival of a modelocked pulse. It is this lens that narrows the laser beam, and, consequently, creates a mechanism that narrows the beam only for modelocked pulses.

Origin of the Term "Modelocked"

From the explanation above, it is not obvious why this pulsed output operation is referred to as "modelocked". A laser can operate at a number of wavelengths that satisfy the condition that an integral number of half wavelengths will "fit" between the high reflector and output coupler. The wavelengths that satisfy this condition are called longitudinal modes. When several modes are lasing simultaneously, they constructively or destructively interfere with each other. At certain points the light from all the modes will add together to create an intense sum.

The larger the number of modes, the higher the instantaneous intensity. Figure 9-4 shows the intensity of light with varying number of modes, randomly phased or timed.

If the phase between each mode is adjusted non-randomly and held constant, the peak powers become much larger and the random spiking between these pulses diminishes. This is referred to as locking the modes together, hence the term “mode-locking.”

Once the modes are locked together, it can be shown that the larger the number of modes, the higher the pulse intensity and the narrower the pulse. Interestingly, the frequency of the pulses exiting the laser is precisely equal to the frequency separation of adjacent longitudinal modes.

The Starting Mechanism

Normally, the laser will operate in the CW mode with minor power fluctuations, none of which cause—even instantaneously—powers that are sufficiently high to cause a Kerr lens to form. Therefore, some mechanism must be introduced to create a sufficiently high peak power. By changing the cavity length at the proper speed, very high-power fluctuations can be induced. Once the instantaneous power in one of these fluctuations becomes sufficiently high, a slight Kerr lens is formed. This instantaneous power fluctuation is amplified and becomes the dominant pulse that will form the modelocked output.

Normally, in a laser such as Ti:Sapphire, only a limited number of longitudinal modes operate simultaneously. This is due to the fact that although the atoms within the lasing medium are capable of emitting light over a range of wavelengths, stimulated emission occurs at precisely the same wavelength as the stimulating light. Therefore, the earliest light to reach high intensity through the amplification process will establish the frequency for subsequent light. No atoms will remain in their upper state to amplify light at another frequency. In reality, two modes can operate simultaneously due to a phenomenon known as spatial hole burning that will not be covered here.

From the discussion above, the random fluctuations caused by two modes do not cause very high instantaneous powers. A prerequisite for high-intensity fluctuations is that the laser be encouraged to operate simultaneously with as many longitudinal modes as possible. Of all the longitudinal modes that can lase, a few are more likely than others. This is due to the fact that any wavelength-selecting element will cause more losses on either side of the selected wavelength. As the wavelength selector is changed, some modes are discouraged and others are encouraged. Alternately, the modes themselves can be shifted in wavelength by changing the cavity length, so a different set of wavelengths satisfy the “integral half waves between reflectors” criterion. If the cavity length is changed rapidly enough, the freshly discouraged modes (previously

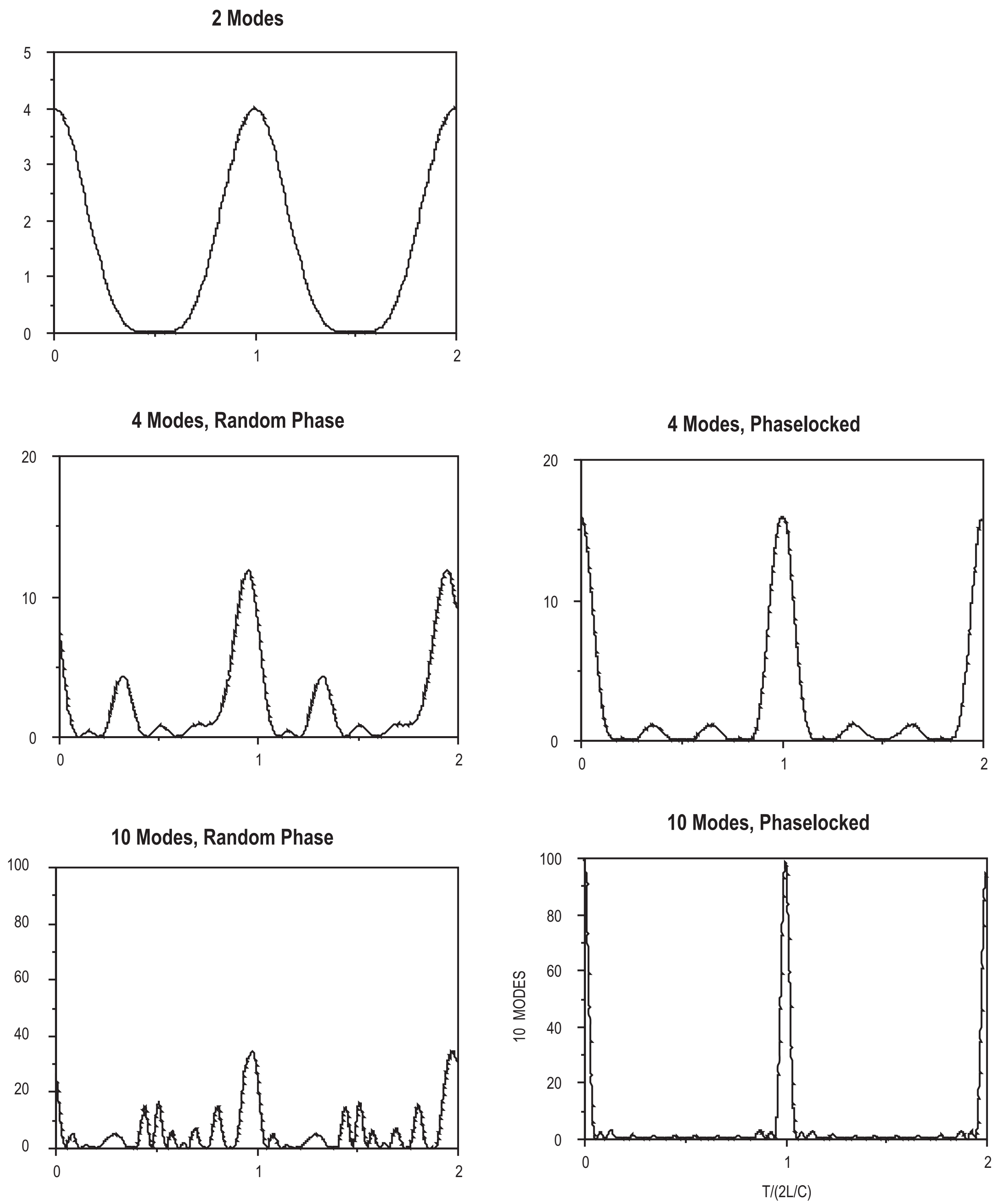


Figure 9-4. Intensity of Light with Varying Number of Modes
(note the difference in the vertical scales)

oscillating modes) will die out, leaving atoms available for the new modes. There will be a period during which both can be lasing simultaneously. We have therefore created a transient condition under which the output of the laser contains more longitudinal modes than normally possible.

Once a larger number of modes are lasing, peak intensities are produced to initiate Kerr lens formation and the modelocking process begins. An additional nonlinear process, called self-phase modulation (SPM), is initiated once these higher intensities are approached. SPM creates additional modes adjacent to the main pulse that result in an even more intense pulse and further reinforce the Kerr lensing process.

It is important to mention that once modelocking starts, it will continue without the need of the starting mechanism. The rapid length variation is therefore halted.

The length of the cavity is changed by increasing the distance between the mirrors. This is accomplished by mounting the high reflector end mirror on a solenoid-driven spring.

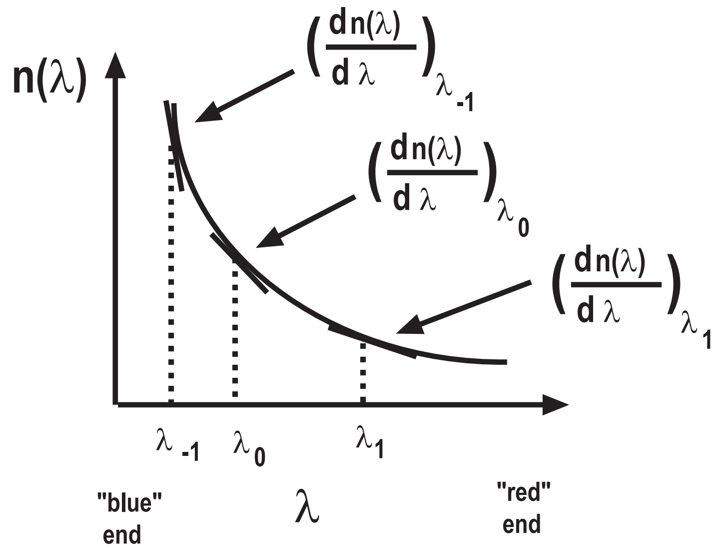
Transmission of Ultrashort Pulses of Light Through Glass

The wavelength of an ultrashort pulse of light cannot be determined precisely because it is formed by the sum of a distribution of wavelengths on either side of the center wavelength. The width of the distribution is inversely proportional to the length of the pulse, as governed by the Heisenberg uncertainty relation between energy and time. For a given spectrum (distribution of wavelengths), there is a minimum achievable pulsewidth, known as the transform limit (the minimum pulsewidth is directly related to the Fourier transform of the spectrum).

To produce transform-limited pulses, the timing or phase between each component wavelength must be precisely correct, or the pulse will not be as short as it could be. It is easily demonstrated that an ultrashort pulse will lengthen after it has passed through glass. This is due to the fact that in all normal materials, the index of refraction (and therefore the speed of light through the material) depends nonlinearly on the wavelength.

Group Velocity Dispersion

Figure 9-5 shows a hypothetical dispersion curve; i.e., a graph of refractive index (n) versus wavelength (λ) with a shape typical of many materials that are transparent in the optical spectrum. The shape is typical in the sense that the index decreases monotonically with increasing wavelength while maintaining a gradual upward curvature. This is referred to as positive or “normal” dispersion, whereas a material with a downward curvature is referred to as having negative or “anomalous” dispersion.”



The curvature and hence GVD is determined by the 2nd derivative of the dispersion relation.

$$\frac{d^2 n(\lambda)}{d\lambda^2} \propto \text{"Group Velocity Dispersion"}$$

Figure 9-5. Group Velocity Dispersion Derivative

At a given wavelength, the refractive index $n(\lambda)$ determines the phase velocity or the velocity of a single mode (monochromatic wave). The slope of the refractive index curve, $\frac{dn(\lambda)}{d\lambda}$, determines the group velocity and thus defines the velocity of a wave packet (short light pulse) with a central wavelength λ. The second derivative of the curve, $\frac{d^2n(\lambda)}{d\lambda^2}$, determines the group velocity dispersion, which governs the rate at which the frequency components of a wave packet change their relative phases. Group velocity dispersion causes temporal reshaping of wave packets; this can be a broadening or a shortening change depending upon the initial conditions (chirp) of the wave packet spectrum. The term “chirp” means that the pulse is not uniform with respect to wavelength. Temporal chirp refers to the leading edge of a pulse being composed of different wavelengths than the trailing edge. A pulse is said to be “positively chirped” if its instantaneous frequency increases from leading edge to trailing edge, i.e., the redder components lead the bluer components. This is the type of chirp that is normally imparted to a pulse by traversing most optical materials (positive dispersion, upward curvature depicted in Figure 9-5). The blue spectral components are retarded with respect to the red, creating a systematic variation of phase with respect to wavelength. Similarly, a pulse is said to be "negatively chirped" if its red spectral components have been retarded with respect to the blue.

Because these effects are dependent on wavelength, pulses which include a wider range of wavelengths are more susceptible to the effects of dispersion. Shorter pulses show more broadening when passing through optical materials because they are necessarily composed of a wider range of wavelengths.

Self Phase Modulation

In addition to the phenomena already described, pulses in ultrafast lasers are also affected by self-phase modulation (SPM). Due to the optical Kerr effect, intense light pulses propagating through dense media create a local index of refraction that is dependent on the light field intensity. Therefore, the leading and trailing edges of the pulse will cause less change in the index than the center where the intensity is highest. This will subsequently cause parts of the pulse to move faster, thus altering the pulse shape.

Frequency components propagating through the material are thus phase-shifted differently, depending upon where they occur in the pulse. This phenomena actually generates new frequencies (or eliminates old ones depending upon the initial conditions). These frequency components are inherently chirped and can broaden the pulse unless the chirp is compensated. It can be shown that chirp which results from SPM has the same sign (positive) as the chirp introduced through normal material GVD.

Dispersion Compensation

Because of self-phase modulation and the GVD from the many dispersive elements within the laser cavity, some method must be employed to allow the slow frequencies or wavelengths to catch up to the faster ones. Each time it traverses the cavity, the circulating pulse receives a slight chirp from the dispersive elements it encounters. Without compensation, the cumulative effect of even a very small chirp per round-trip would create broadening and pulse substructure. We thus require an element or system of elements that has negative GVD: the relationship between wavelength and speed or index must be the reverse of what it is in a normal material. In principle, negative chirp could be introduced by propagating the pulse through a material at a wavelength in which the index vs. wavelength plot shows downward curvature. To introduce negative chirp with some variability in the magnitude of the desired compensation, some type of special optical system must be constructed.

In the previous paragraph on group velocity dispersion, the concept of GVD was introduced within the context of index of refraction. It was noted that the existence of a finite second derivative of the index with respect to the wavelength was required in order to create GVD. In fact, this description does not only apply to simple material dispersion curves, but can also be generalized to any optical system. A a more general description of GVD requires the existence of a finite second derivative of the optical path length with respect to wavelength.

For a given wavelength and a given optical system, one can express the phase evolution of the light wave traveling through the system by taking into account all of the effects that occur along the optical path, including refraction at surfaces. A path length curve, analogous to that shown in Figure 9-5, can be constructed for any complex optical structure having wavelength-dependent beam paths. Therefore, group velocity dispersion can be regarded as a property of an optical construction.

There are several common optical configurations that can introduce a negative chirp. Which optical configuration that is used depends on the bandwidth of the pulse and the amount of negative chirp that needs to be introduced. The optical system used in the Micra consists of a pair of prisms separated by a distance oriented in a specific way with respect to each other.

It can easily be shown that the net GVD of a prism pair can be made negative by proper choice of prism material and the distance between the prisms. The GVD compensation scheme operates as follows (refer to Figure 9-6): A pulse is formed and chirped by self-phase modulation in the Ti:Sapphire crystal and by GVD in the various intracavity components in the laser. The chirped pulse enters prism 1. Since prisms bend or refract different wavelengths into different angles, the beam spreads as it heads for the second prism. The blue components are bent more severely than the red ones, thus creating the possibility of wavelength-dependent path lengths for the various rays. The longer wavelength components (red) travel a shorter geometrical path as compared to the shorter wavelength components (blue). However, because the velocity of the light is significantly reduced as it travels through glass (the prisms), the optical path length of the red components is actually *longer* than that of the blue components since they spend more time in the prisms.

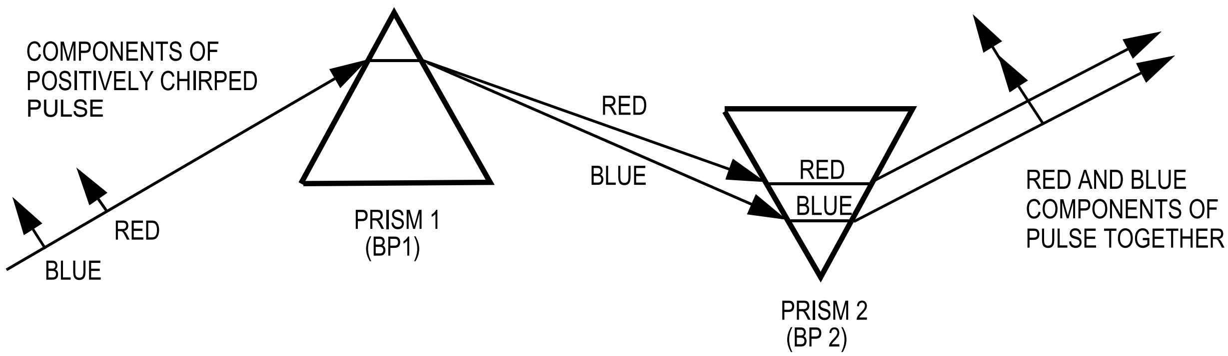


Figure 9-6. GVD Compensation

The GVD of this system is said to be negative, because the blue part of the pulse travels through the system faster than the red. The magnitude of the GVD compensation can be controlled over a range by prism glass path adjustment (see below); the tuning range is sufficient to allow the "net cavity GVD" to be tuned through zero.

Finally, in the Micra, a mirror is placed after the second prism to retroreflect the beam back through the pair and spatially re-combine the beam, thus completing the GVD compensation. The figure shows one pass for simplicity.

Changing GVD

The total round-trip chirp of the system is the sum of the chirps arising from SPM, positive material GVD and negative GVD of the prism pair. A simple way to adjust the GVD component of the chirp is to change the amount of glass within the cavity. Translating one of the prisms in the compensator is a very convenient way of inserting more or less glass. Thus the proper GVD can be adjusted very simply.

The Formation of Final Pulse Width

In practice, the pulse-forming mechanism is dynamic in nature. Although the prisms and optical material within the cavity define the total dispersion within the cavity, self phase modulation depends on the intensity of the pulse. As the pulse gets shorter, its intensity becomes higher because all of the energy in the pulse is now emitted over a shorter interval. There is therefore more self phase modulation and hence more broadening.

Soliton Pulse Formation

The pulse eventually reaches a stable width and pulse amplitude. This process of establishing an equilibrium pulse, which remains unchanged after each roundtrip through the cavity, is related to a nonlinear pulse formation process called soliton formation. The periodically reforming wave is referred to as a soliton. Soliton-like pulse formation has many attractive features. Most importantly, if the pulse becomes more intense for some reason, the increased self phase modulation will cause the pulse to broaden, distributing the pulse energy over a longer period of time and thus reducing the pulse intensity. The laser, therefore, is self-regulating and exhibits stable output pulses.

The relationship governing soliton pulse shaping in homogeneous media (such as an optical fiber) is given below:

Equation [9-1]. Relationship Governing Soliton Pulse Shaping

$$\tau^2 = \frac{\beta}{\lambda P}$$

β = Sum of positive material GVD and prism pair negative GVD

γ = SPM coefficient

τ = pulse width

P = peak power in pulse

P is regulated by the soliton formation mechanism and can be considered constant for a given pump power, output coupler and wavelength.

γ is related to the nonlinear properties of Ti:Sapphire and is also a constant. It represents the nonlinear phase shift in Ti:Sapphire per unit length per unit power.

β can be varied in the Micra by translating BP1 through the beam. With this scheme, the total β increases from negative towards zero to slightly positive.

Strictly speaking, the equation above does not apply to an inhomogeneous medium (such as a laser cavity) in which the sources of SPM, and negative and positive GVD are physically separated but it nonetheless offers considerable guidance in scaling the laser behavior and understanding the phenomena that pertain in the Micra cavity. This is the reason the pulse formation is referred to as "soliton-like."

The equation above indicates that as more negative GVD is inserted in the cavity, the pulse shortens; i.e., the magnitude of β decreases.

The pulse formation is stable only when the dispersion from SPM, material GVD, and prism pair negative GVD satisfy the above equation. Only under these conditions will the pulse maintain its shape after each roundtrip through the cavity. Because the chirp from SPM is equivalent to that from positive GVD (to first order), the glass in the system plus the negative GVD of the prism pair must be less than zero.

Micra is designed to allow the material GVD plus the prism pair negative GVD to be varied total negative to just slightly total positive. High negative GVD accompanied by longer pulses can be obtained by translating the prisms so the beam strikes as close to the prism tips as possible. Shorter pulses are obtained as the prisms are translated further into the beam. As the pulse becomes narrower, a point will be reached beyond which further reduction of GVD (from negative towards positive) will cause pulse formation to stop.

Tuning the Micra

As the wavelength is adjusted, two changes in the pulse will be observed:

1. Change in pulsewidth
2. Change in spectral width

Both of these changes are due to the same phenomenon. An examination of the prism compensator Figure 9-6 reveals that as the wavelength changes, the angle of refraction from the first prism changes. This means that the center of the beam will strike the second prism in a different location. In particular, as the wavelength is shifted towards the red (longer wavelengths) the beam is refracted less. The beam therefore strikes the second prism further from the apex and therefore passes through more prism glass. Since the GVD is negative, more positive GVD causes a decrease in the absolute value of GVD towards zero. According to Equation [9-1], this results in a decrease in pulsewidth. In order to maintain the same pulsewidth as the wavelength is changed, it is necessary to translate the prism to "follow" the beam.

Factors Influencing Modelocked Operation

Since SPM is dependent on intensity, stable modelocked operation depends on maintaining the proper power inside the cavity. Therefore any problem that reduces the output power from its nominal value will compromise the ability of the system to produce stable pulses.

Alignment

If the system is not optimally aligned, the reduced power within the cavity may affect the output stability. Both the pump beam and laser cavity mirrors must be optimally aligned. Procedures for alignment and cleaning are covered in Sections Seven and Eight, respectively.

Mode Quality of Pump Laser

If the transverse mode quality of the pump laser is not nominal, pumping efficiency will be compromised and laser power will be lost.

Differential Overlap

Another issue intimately related to the mode quality of the pump laser involves the overlap between the pumping laser beam and the intracavity beam inside the gain medium. In the design of the Micra, the size/shape change between CW and modelocked operation has been optimized for the nominal pump volume created by standard Coherent pump sources. Substantial deviation from the standard pump volume criteria will generally lead to unpredictable results.

Pump Power

System output power stability and starting reliability may be compromised if pump power is varied more than 20% from nominal value. Coherent strongly recommends that the pump power used during the factory alignment be maintained unless Coherent advises otherwise.

Contaminated Optics

Any loss within the laser reduces the power and affects the pulse stability.

Beam Clipping

It is possible through mechanical misalignment that the beam may not pass clearly through the various intracavity apertures. This results in losses that reduce the intracavity power.

Ti:Sapphire Temperature

There is a weak dependence of output power on Ti:Sapphire temperature. Elevated temperatures reduce power and make pulse formation less stable. To minimize the total variation in output power, the closed loop chiller regulates the water temperature to within ± 0.1 °C.

Purge Gases

The Micra housing allows the intracavity space to be purged with water-free gas. A hose fitting is included in the accessories kit.

Time-Bandwidth Product

Multiplying together the spectral bandwidth and the real temporal width produces the time-bandwidth product, which has a theoretical minimum value known as the transform limit. This section defines this terminology.

The time-dependent electric field $E(t)$ associated with any laser pulse at a fixed point in space can be written in general form as in Equation [9-2].

Equation [9-2]. Time-Dependent Electric Field

$$E(t) = A(t)\exp(-i\omega_0 t)$$

In this expression, $A(t)$ is the envelope function and ω_0 is the carrier frequency. Both $A(t)$ and $E(t)$ are complex functions. The frequency spectrum associated with the pulse $E(t)$ is given by the Fourier transform of $E(t)$, that is designated $E'(\omega)$.

Equation [9-3]. Fourier Transform of *E*(*t*)

$$E(\omega) = \left(\frac{1}{2\pi}\right)\int E(t)e^{-i\omega t}dt$$

Equation [9-4]. Fourier Transform of *E'*(*t*)

$$E'(\omega) = A'(\omega - \omega_0)$$

While the functions $A(t)$ and $A'(\omega)$ are complex, only the square of the field; i.e., $|E(t)|^2$ or $|E(\omega)|^2$, is generally observable due to the fact that photodetectors respond to intensity (power) and not to E-field. Thus information about the imaginary parts of $E(t)$ and $E'(\omega)$ that relate to phase variation within the pulse is not directly observable. However, this information can be inferred by comparing the pulse envelope intensity $|A(t)|^2$ with the power spectrum $|A(\omega)|^2$. A simple approach to this can be taken in cases where the envelope functions $A(t)$ and $A'(\omega)$ are smoothly varying. One can then define the intensity temporal width and the pulse bandwidth of the power spectrum as:

Equation [9-5]. Pulse Width (Seconds)

$$\tau_p = FWHM(|A(t)|)^2$$

Equation [9-6]. Bandwidth (Hz)

$$\Delta\nu = 2\pi FWHM(|A'(\omega)|)^2$$

FWHM denotes the full width at half maximum.

The observable quantities τ_p and $\Delta\nu$ determine the time-bandwidth product (T).

Equation [9-7]. Time-Bandwidth Product

$$\tau_p \times \Delta\nu = T$$

The time-bandwidth product is a measurable characteristic of ultra-fast pulses. It provides a useful estimate of pulse quality, since it achieves its minimum value when $A(t)$ is purely real and the pulse is fully phase coherent. For ultrafast pulses, however, interpretation of time-bandwidth product data suffers from the limitation that the pulse envelope function $|A(t)|^2$ can only be measured indirectly by means of autocorrelation techniques. It is possible to examine several model functions for $A(t)$ (see Table 9-1) and calculate the minimum time-bandwidth product for each model using Equation [9-2] through Equation [9-6].

Table 9-1. Time-Bandwidth Products for Typical Model Pulse Shapes

FUNCTION	$\tau_p / \tau_{ac} =$	$(\Delta\nu)(\tau_{ac}) >$	$(\Delta\nu)(\tau_p) >$
Square	1	1	1
Gaussian	0.707	0.624	0.441
Hyperbolic secant	0.648	0.486	0.315
Lorentzian	0.500	0.441	0.221
Symmetric exponential	0.413	0.344	0.142
τ_p = pulse width, FWHM; τ_{ac} = autocorrelation width, FWHM; $\Delta\nu$ = spectral bandwidth, FWHM			

Autocorrelation

For sub-100 fs laser pulses, the measurement of the temporal pulse-shape is not directly possible with electronics. The most common procedure to measure the pulseshape is using the combination of a mechanical scan of optical delay and a nonlinear optical measurement to convert from the femtosecond range to microsecond or slower rates easily measured with conventional electronics.

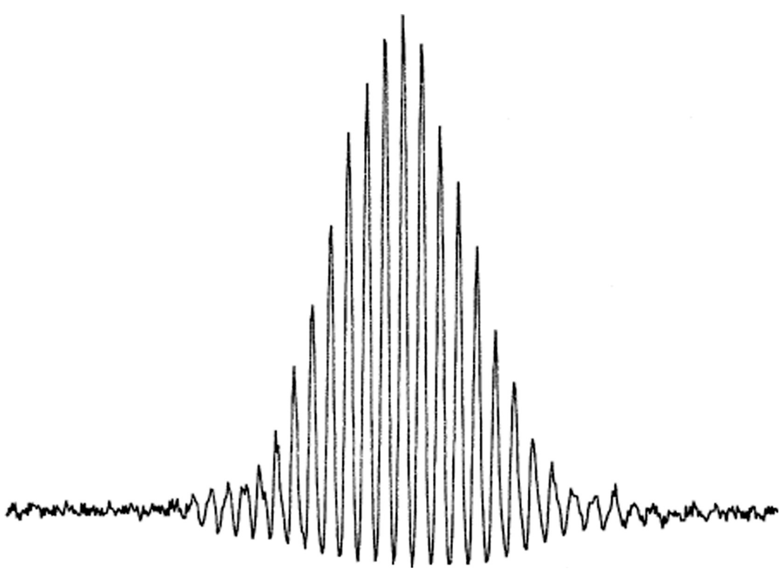
The simplest realization of this is the second harmonic autocorrelator. A number of commercial instruments are available that perform this operation. Summarized here are the expected results with the two commonly available architectures: the non-collinear background-free intensity autocorrelation and the collinear interferometric autocorrelation.

Non-Collinear Intensity Autocorrelation

A good non-collinear intensity autocorrelation displays zero background and a smooth pulse envelope, as shown in Figure 9-7. All autocorrelation measurements should be totally symmetric. Any lack of symmetry is an indication of a lack of dispersion balance between the two arms of the autocorrelator or of detector saturation.

Determination of autocorrelation width also requires accurate calibration, which is normally obtained by measuring the delay on the oscilloscope versus the movement of one of the autocorrelator arms. The total optical path delay is twice the movement of the arm (there and back) divided by the speed of light.

A. Intensity autocorrelation: t_{ac} = 30 fs FWHM
Assuming sech^2 pulse shape: t_p = 30 fs x 0.648 = 19 fs



B. Interferometric autocorrelation: t_{ac} =10 cycles FWHM x 2.67 fs/ cycle = 27 fs
Assuming sech^2 pulse shape: t_p = 27 fs x 0.648 = 17 fs

Figure 9-7. Examples of Typical Autocorrelation Traces

Collinear Interferometric Autocorrelation

A good collinear interferometric autocorrelation, also shown in Figure 9-7, shows a background level exactly 1/8 of the peak level and a 100% modulated envelope. Saturation is exhibited in a less than 1/8 ratio of peak to background. Chirp is indicated by a lack of symmetry between the top and bottom, or a rise in the lower limit of the modulation.

The principal advantages of the interferometic technique are this clear signature of chirp and the clean calibration provided by the fringes. Each fringe corresponds to one optical cycle or directly:

$$1 fringe = \frac{\lambda}{c}$$

For example, at 800 nm:

$$1 fringe = \frac{800nm}{c} = 2.67fs$$

Both types of autocorrelation are susceptible to inaccurate pulse-length measurement if the autocorrelation crystal is too thick. For example, with an 800 nm, 20 fs duration pulse, a BBO Type I SHG crystal will lead to about a 10% over-estimate of pulsewidth.

Deriving the laser pulsewidth from the autocorrelation requires an assumption about the laser pulse shape. The ratio of the measured autocorrelation to the actual pulse can then be calculated (see Table 9-1 on page 23).

In addition to simple autocorrelators, which are unable to resolve differences between symmetric and unsymmetric distortions, there is an array of more detailed measurement schemes described in the literature that aim to give total characterization of laser pulse intensity and phase versus time, frequency, and/or spatial position. The more popular include spectrally resolved cross-correlations, frequency-resolved optical gating (FROG) and temporal imaging with phase modulators.

Appendix A: Micra-18 Systems

General Description

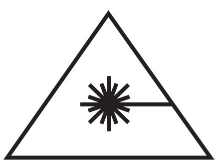
The Micra-18 is in large part identical to the Micra-5. The pump laser and power supply have been upgraded to the high-power Coherent Verdi-V18. The total pump laser output is approximately 18 Watts; however, this output is split into two beams. Approximately 5.5 Watts of power is sent into the oscillator, with the remainder exiting the Micra through a side port for external use.

This appendix describes differences in layout and operation between the Micra-5 and Micra-18.

Optical Layout

Figure A-1 shows the additional optical components included in the Micra-18 head. Refer to Figure 8-2 on page 8-6 for the entire layout.

The waveplates and polarizers allow the power at the side exit port and the pump power supplied to the oscillator to be individually adjusted. The system was optimized in the factory with the Verdi set to 18.0 Watts of output power on the power supply front panel. Contact Coherent Service if the Verdi pump power must be changed.



Activation of the pump laser results in two output beams: oscillator output from the front port and pump laser output from the side port. Safely account for both of these beams before starting the system.

System Warm-up

The Verdi-V18 generates an increased heat load when compared to the Verdi-V5. Coherent recommends the following procedures:

- Leave the chiller on overnight. If the chiller has been turned off, turn the chiller on at least 30 minutes before activating the pump laser. Chiller temperature for the Micra-18 is 17 ^{o}C.
- Allow the pump laser to run at full power (18.0 W) for at least 30 minutes before making any adjustments to Micra cavity optics.
- The Micra-18 may not lase for the first few minutes of warm-up. In some cases this can cause a Lost PowerTrack fault, and if the fault persists the Verdi will shut down. If the fault

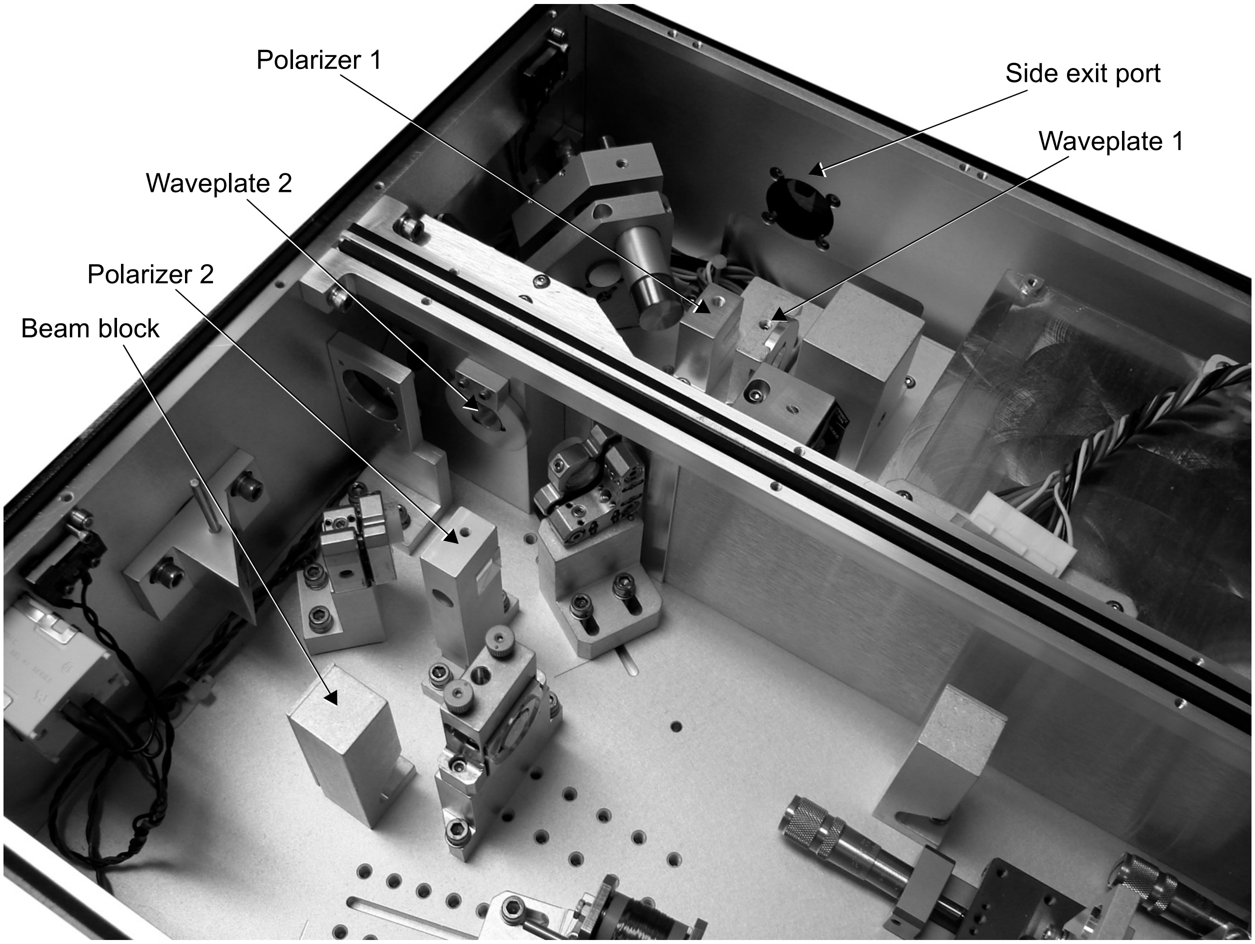


Figure A-1. Micra-18 Optical Components

occurs, simply clear it by pushing EXIT. To prevent this fault, turn PowerTrack OFF for the first few minutes of warm-up.

- Do not leave the pump laser at a low-power setting for more than a few minutes. This includes the SIMMER state at turn-on (keyswitch on, shutter closed, see Section Five: Operation). Operating the V-18 below full power will cause a gradual rise in the baseplate temperature. This will not damage the system, but may cause a baseplate temperature fault or diode over-current fault and shut down the Verdi. If this occurs, perform the following:

1. Push EXIT to clear the fault.
2. Close the shutter.
3. Cycle the keyswitch. In case of a baseplate temperature fault, wait a couple of minutes before turning the key back on.
4. Open the shutter, and set Verdi power to 18.0 W.

Access to 18 W Verdi Output

The Micra oscillator and the RegA amplifier cannot be used when the 18 W Verdi beam exits the side panel.

Wear powder-free latex or nitrile gloves when removing the laser cover or handling any parts in the laser head.

1. Record the Verdi power setting on the power supply front panel.
2. Turn PowerTrack OFF.
3. Measure and record the power of the green beam at the Micra side exit port (see Figure A-1).
4. Remove the pump-side Micra top cover.
5. Loosen the set screw securing Waveplate 1 (see Figure A-1), and rotate the half-wave plate to maximize the power of the green beam at the side exit port.
6. Retighten the set screw, and reinstall the Micra cover.
7. Adjust the Verdi power setting on the power supply to obtain the desired green beam power.

Restoring Original Micra Operation

1. Set the Verdi power setting to its original value.
2. Remove the pump-side Micra top cover.
3. Loosen the set screw securing Waveplate 1 (see Figure A-1), and rotate the half-wave plate to restore the original power level at the side exit port
4. Retighten the set screw, and reinstall the Micra cover.
5. Turn PowerTrack ON.

PACKING PROCEDURE

The following is the factory-recommended packing procedure for the Micra laser system. This procedure should be followed if the system is to be shipped to another location after initial installation.

The Micra laser system requires one shipping crate. Table B-1 gives a complete listing of the contents of the shipping crate when the system is shipped from Coherent.

The Micra system crate consists of a single molded foam compartment. Figure B-1 illustrates the proper placement of each of the components listed in Table B-1. Before placing the laser head and power supply into the crate, the compartment should be lined with anti-static material to prevent ESD damage. 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 B-2.

Note that the system documentation and the accessories kit should be placed in the cut-out in the top of the foam liner (see Figure B-3).

Table B-1. Micra Shipping Crate Contents

1. Laser Head
2. Power Supply
3. Operator's Manual
4. Final Test Data Sheet
5. System Accessories Package
   a. 1/4 inch Water Tubing
   b. Tubing Connectors
   c. Stable Table Clamps (3x)
6. 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 Defeat

1. Laser Head
2. Power Supply
3. Anti-static Material

Figure B-1. Packed Micra Shipping Crate

Figure B-2. Packed Micra Crate with Anti-Static Material Folded Over

Three people are recommended when packing the Micra. The laser head and power supply are connected by the umbilical. To prevent damage to the fiber optic cables running between the head and the power supply, the umbilical should be wound loosely in the foam cutout as illustrated in Figure B-1.

Excessively tight fiber bends (less than a 5 inch or 13 cm radius) can cause permanent damage to the fiber optic cables.

Place the Micra in the shipping crate as follows:

1. Place the power supply in the cutout as shown in Figure B-1.
2. Two people should carry the laser head clockwise around the shipping container while the third person guides the umbilical onto the cutout as shown in Figure B-1.
3. Place the laser head into the cutout.
4. Fold the excess anti-static material over the top of the system.

Once all components are placed into the shipping crate the top foam should be positioned. After positioning the top foam, the Micra Accessory Kit should be placed in the outer cutout before the crate lid is attached, see Figure B-3.

Figure B-3. Location of Packed Micra Accessory Kit

PARTS LIST

The following parts can be ordered by contacting Technical Support (1-800-367-7890, or 1-408-764-4557 outside the U.S.), E-mail (clg.tech.services@Coherent.com), or your local Coherent service representative. The model and laser head serial number will be required by the support engineer responding to your request. Note that due to vendor supply changes, these part numbers are subject to change without notice.

Parts List Table

DESCRIPTION	PART NUMBER
OPTICS AND OPTICAL ASSEMBLIES	
Oscillator cavity mirror (M1, M2, M3)	0158-791-10
Starter mirror assembly (M4), tested	1133308
Curved cavity mirror (M5)	0163-050-04
Pump input curved mirror assembly (M6)	1133311
Oscillator cavity mirror, dispersion correction (M7)	1113991
Output coupler assembly (M8)	1133318
Pump routing mirror (R1, R2)	0161-712-00
PowerTrack pump routing mirror assembly, tested	1133313
Pump focusing lens assembly (L1)	1133315
Output collimation lens (L2)	701-1157
Ti:sapphire rod assembly	1133310
Polarization rotator assembly	1133314
Beamsplitter assembly	1133316
Prism assembly	1133317
MECHANICAL ASSEMBLIES	
Oscillator cavity mirror mount (M2, M3, M5, R2)	1121894
L1 translation stage	1121945
M5 translation stage	1121898

Parts List Table (Continued)

DESCRIPTION	PART NUMBER
M6 translation stage	1121899
PR1 translation stage	1123489
PR2 translation stage	1121900
Slit assembly	1133320
Shutter assembly	1133321
Purge assembly	1133319
Alignment aperture	1133322
Micra maintenance kit	1108473
ELECTRONICS	
Photodiode electronics board	1008267
Verdi head board	1133306
Micra laser head board	1133305
Ribbon cable 26 pin Micra to Verdi PCBs	174-231-00
Ribbon cable 26 pin Micra PCB to rear PCB	1126277
Cable Micra PCB to starter	1126278
Cable, Micra PCB to photodiode PCB	1126280
Cable, Micra PCB to PowerTrack mirror	1126279
Cable Verdi PCB to emission light and interlocks	1126281
Cable Micra PCB to rear panel RF SYNC OUT	1126282
Cable, rear PCB to rear panel PWR MTR	1126283
Cable Verdi PCB to Head 6 pin	1126284
Cable, Micra PCB to Umbilical 8 pin	1126285
Cable, Verdi PCB to Head 10 pin	1126287
Cable, Micra PCB to Umbilical 10 pin	1126288
Cable Verdi PCB to Head 11 pin	1126289
Cable Verdi PCB to Shutter 6 pin	1126290
Cable Verdi PCB to Umbilical 12 pin	1126291

Parts List Table (Continued)

DESCRIPTION	PART NUMBER
MISCELLANEOUS	
Verdi FAP-I kit, tested, Verdi Uno, ROHS compliant	1117191
Shipping crates	1133307
FUSE, 0.25 x 1.25 L, 15.00 A,250 V	110-0002
FUSE, 0.25 x 1.25 L, 10.00 A, 250 V	110-0072
Laser head foot-clamps	160-912-00
Cover interlock defeat	1133303
Power supply interlock connector	0171-642-00

WARRANTY

Coherent, Inc. warrants 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 twelve (12) months. This warranty covers travel expenses for the first ninety (90) days. For systems that include installation in the purchase price, this warranty begins at installation or thirty (30) days from shipment, whichever occurs first. For systems which do not include installation, this warranty begins at date of shipment.

Optical Products

Coherent optical products are unconditionally warranted to be free of defects in materials and workmanship. Discrepancies must be reported to Coherent within thirty (30) days of receipt, and returned to Coherent within ninety (90) days. Adjustment is limited to replacement, refund or repair at Coherent's option.

Conditions of Warranty

On-site warranty services are provided only at the installation point. If products eligible for on-site warranty and installation services are moved from the original installation point, the warranty will remain in effect only if the Buyer purchases additional inspection or installation services at the new site.

For warranty service requiring the return of any product to Coherent, the product must be returned to a service facility designated by Coherent. The Buyer is responsible for all shipping charges, taxes and duties covered under warranty service.

Parts replaced under warranty shall become the property of Coherent and must be returned to Coherent, Inc., Santa Clara, or to a facility designated by Coherent. The Buyer will be obligated to issue a purchase order for the value of the replaced parts and Coherent will issue credit when the parts are received.

Other Products

Other products not specifically listed above are warranted to (a) conform to Coherent's published specifications and (b) be free from defects in materials and workmanship. This warranty covers parts and labor and is for a period of twelve (12) months from the date of shipment.

Responsibilities of the Buyer

The Buyer must provide the appropriate utilities and operating environment outlined in the product literature and/or the Pre-installation manual. Damage to the laser system caused by failure of Buyer's utilities or the Buyer's 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 later than seven (7) days after the expiration of the warranty.

Limitations of Warranty

The foregoing warranty shall not apply to defects resulting from:

1. Components or accessories with separate warranties manufactured by companies other than Coherent.
2. Improper or inadequate maintenance by Buyer.
3. Buyer-supplied interfacing.
4. Operation outside the environmental specifications of the product.
5. Improper site preparation and maintenance.
6. Unauthorized modification or misuse.

Coherent assumes no responsibility 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. Repaired or replaced parts are warranted for the duration of the original warranty period only. This warranty does not cover damage due to misuse, negligence or accidents, or damage due to installations, repairs or adjustments not specifically authorized by Coherent.

This warranty applies only to the original Buyer 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 Buyer only by special agreement which will include additional inspection or installation at the new site.

THE WARRANTY SET FORTH ABOVE IS EXCLUSIVE IN LIEU OF ALL OTHER WARRANTY, WHETHER WRITTEN, ORAL OR IMPLIED, AND DOES NOT COVER INCIDENTAL OR CONSEQUENTIAL LOSS. COHERENT SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Glossary

°C	Degrees centigrade or Celsius
°F	Degrees Fahrenheit
μ	Micron(s)
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)
CW	Continuous wave
DC	Direct current
DVM	Digital voltmeter
EEPROM	Electrically erasable programmable read only memory
EPROM	Electrically programmable read only memory
EMC	Electromagnetic Compliance
fs	Femtosecond(s)
FAP-I™	Fiber array package-integrated
FSR	Free spectral range
I/O	Input/output
IR	Infrared
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)
NDM	Negative dispersive mirror
$Nd:YVO_4$	Neodymium:Yttrium Orthovanadate
nm	Nanometer(s)
ns	Nanosecond(s)

OEM	Original equipment manufacturer
PD	Photodiode
ps	Picosecond(s)
RR	Retroreflection
rms	Root mean square
TEC	Thermo-electric cooler
TEM	Transverse electromagnetic mode
UV	Ultraviolet
VAC	Volt(s), alternating current
VDC	Volt(s), direct current
W	Watt(s)

INDEX

Micra-5 Laser Operator’s Manual

Part No 1107299, Rev AB