Operator's Manual
Harmonic Generation System (HGS)

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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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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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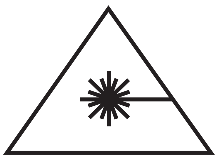
Preface

This manual contains user information for the HGS, an ultrafast amplifier accessory.

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

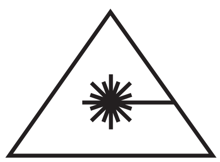
It is the policy of Coherent to comply strictly with U.S. export control laws.

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.

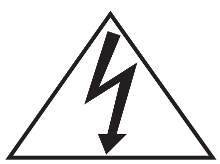
The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification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

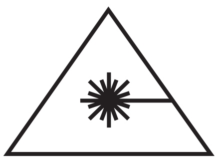


This symbol alerts the operator to the presence of dangerous voltages within the product enclosure that may be of sufficient magnitude to constitute a risk of electric shock.

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 HGS system. Safety instructions presented throughout this manual must be followed carefully.

Hazards

Hazards associated with lasers generally fall into the following categories:

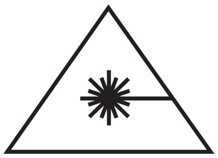
- Exposure to laser radiation that may damage the eyes or skin
- Electrical hazards generated in the laser power supply or associated circuits
- Chemical hazards resulting from contact of the laser beam with volatile or flammable substances, or released as a result of laser material processing

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.

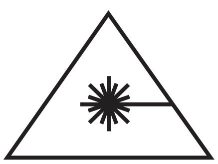
The greatest concern when using a laser is eye safety. In addition to the main beam, there are often many smaller beams present at various angles near the laser system. These beams are formed by specular reflections of the main beam at polished surfaces such as lenses or beamsplitters. While weaker than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

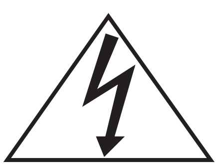
1. Observe all safety precautions in the preinstallation and operator's manuals.
2. All personnel should wear laser safety glasses rated to protect against the specific wavelengths being generated. Protective eye wear vendors are listed in the *Laser Focus World, Lasers and Optronics,* and *Photonics 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 to alert those present.
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 HGS does not require access to dangerous electrical voltage. Refer to the amplifier Operator's Manual for additional safety information.

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 first aid.
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 touched accidentally.
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.

Input Laser Beam

The HGS uses a high-energy infrared pulse as an input energy source. This input beam is hazardous. Refer to the Operator's Manual provided with the laser for additional safety information.

Maximum Accessible Radiation Level

The output beams of the HGS are hazardous. The specific output energies and wavelengths are directly dependent on the input beam characteristics. The maximum accessible radiation level is equivalent to the input radiation level. The output wavelengths are the input wavelengths, as well as the 2nd, and/or 3rd, and/or 4th harmonics of the input wavelengths.

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.

Protective Housing

The HGS assembly 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.

Sources of Additional Information

The following are sources of 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: SYSTEM DESCRIPTION

Product Overview

The Coherent Harmonic Generation System (HGS^{TM}) converts the fundamental output of a high-energy Titanium:Sapphire amplifier into its higher-frequency harmonics. Nonlinear crystals and dichroic optics are employed to generate and then separate the different wavelengths. With the appropriate options installed, the HGS can perform second harmonic generation (SHG), third harmonic generation (THG), and/or fourth harmonic generation (FHG). Three different configurations are available, depending on the desired output wavelengths and output power.

The HGS is designed to operate with a Coherent ultrafast amplifier, such as a Legend Elite, Legend, Libra, or Hidra. Please contact Coherent with any questions or to obtain additional information about these systems.

Figure 2-1. Harmonic Generation System

Outline of Operation

The HGS is designed for short (~30 to 130 fs) or long (~0.5 to 2 ps) pulses. The input beam wavelength, energy, and pulsewidth determine the characteristics of the harmonic crystals needed.

The HGS uses a collinear configuration to minimize its footprint. The standard HGS fits on a base of 12 x 16 inches. The height may be varied to match that of the input beam.

For Second and Third Harmonic Generation, the HGS employs a type-1 BBO crystal. The standard thickness for a < 130 fs input beam is 1 mm. Thinner crystals may be used for higher-energy pulses, although special handling is required. The crystals are also mounted on rotation stages to allow phase matching angle optimization.

Standard crystals have an aperture of 15 mm, although larger apertures can be used to accommodate larger (usually higher-energy) input beams. In some cases, when the incident beam is too small, an expanding telescope may be used.

The technique to generate the Third Harmonic is to spatially and temporally overlap the SHG and IR pulses. A variable-delay line is included in the IR beam path to optimize temporal overlap. Since both the SHG and THG crystals are Type 1, the polarization between the SHG and IR beams must be matched to produce THG light. A waveplate is included in the IR beam path to accomplish this.

The HGS platform is designed to maximize the stability of the harmonic laser beam by using a heavy aluminum base frame. In addition, the optical bench is elevated on steel balls to isolate it from the base, which could be thermally affected by the environment or any external stresses. See Figure 2-2.

Configurations

The HGS is available in three configurations for both femtosecond and picosecond pulses, as shown in Figure 2-3:

- HGS-D (Doubler, provides fundamental and SHG)
- HGS-T (Tripler, provides fundamental, SHG, and THG)
- HGS-Q (Quadrupler, provides fundamental, SHG, THG, and FHG). There are two options for fourth harmonic output. In the double-SHG configuration, the second harmonic is frequency-doubled to produce fourth harmonic light. In the mixing design, a sum-frequency process of the third harmonic and the fundamental is carried out in a second HGS unit. Although this is a more complicated arrangement, it results in greater fourth harmonic power.

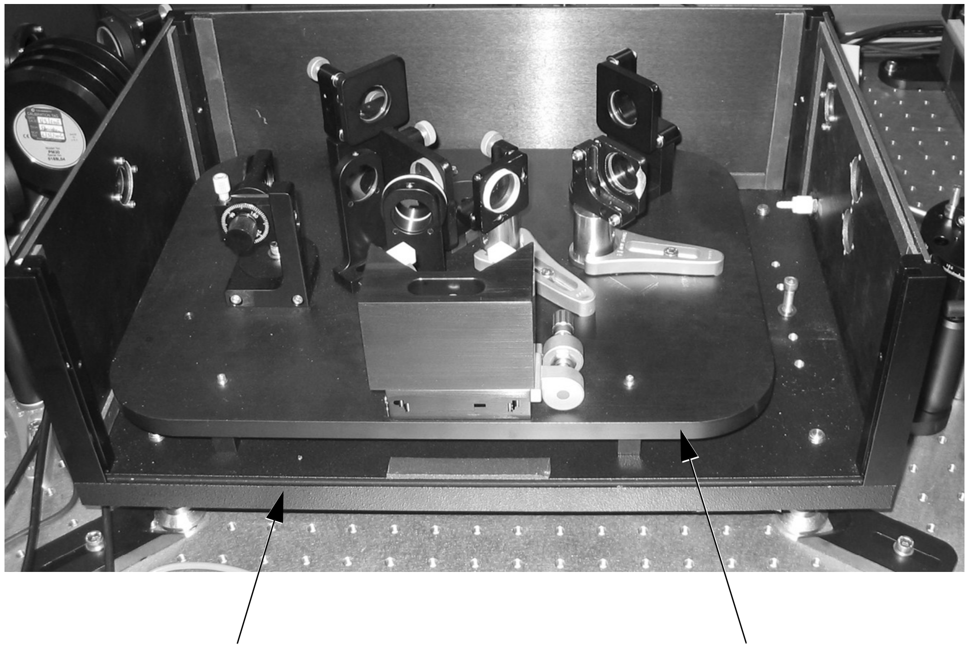


Figure 2-2. Optical Base Frame and Optical Bench

Specifications

Specifications for all Coherent products can be found at www.Coherent.com.

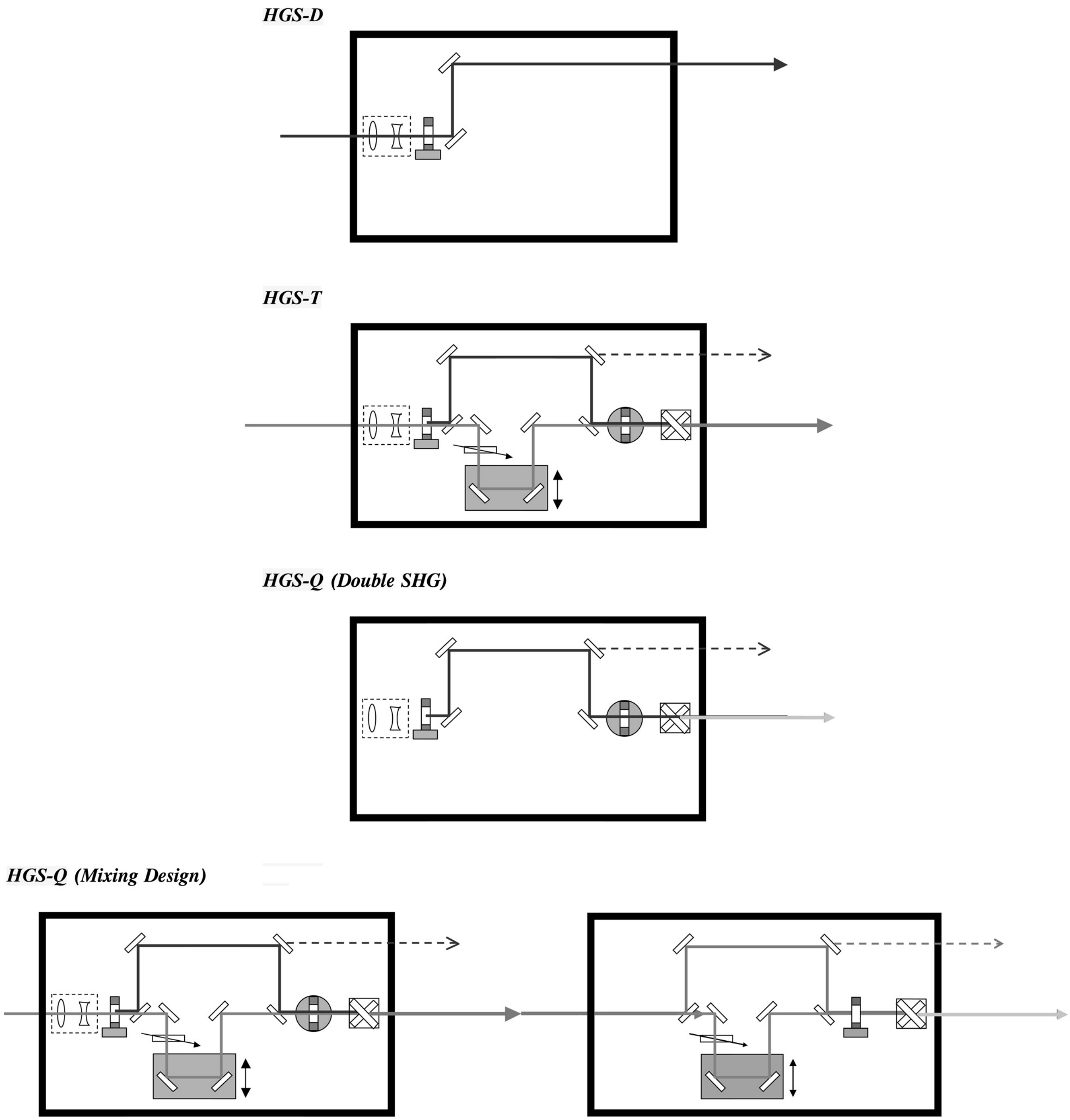


Figure 2-3. HGS Configurations for Doubler, Tripler, and Quadrupler (Double SHG or Mixing Design)

SECTION THREE: INSTALLATION

Installation

The customer may perform installation when the HGS is purchased as a stand-alone component. In the event that the HGS was purchased as part of a larger system, Coherent strongly recommends that a representative of Coherent perform the installation. The customer may, however, unpack and locate the unit in the laboratory where it will be used.

Damage as a result of customer error during installation is not covered by the warranty. Do not attempt to install the HGS before carefully reading this Operator's Manual. Contact Coherent Service with any questions or for further assistance.

Requirements for Installation

Amplifier System

The HGS input beam (amplifier output beam) should be operating within specifications and within the following performance parameters:

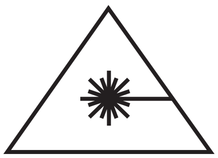
Wavelength:	775 nm-825 nm
Pulse length:	< 130 fs (femtosecond version) < 2 ps (picosecond version)
Beam Diameter:	< 8 mm (after external telescope)
Polarization:	Linear, horizontal (P)

Utility Requirements

The HGS does not require any utilities. However, a supply of dry nitrogen gas may be used to purge the system, particularly if the ambient air has high relative humidity.

Location

The HGS must be placed close to the amplifier, preferably on the same optical table. The HGS requires a table space of roughly 0.3 m x 0.5 m (1 ft. x 1.5 ft.).



Do not position the HGS such that an exposed laser beam must travel long distances. This is a safety hazard.

In high-power amplifier systems, self-phase modulation occurs in air and can generate hot spots in the beam profile. Use short beam paths to minimize this process.

The ambient temperature must be controlled within ± 2° C (± 3.6° F) of 23° C (73.4° F) throughout the day. The room must be as dry as possible to avoid deterioration of the harmonic crystals; a relative humidity level below 30% is recommended.

For best control and flexibility, use two mirrors to route the amplifier beam into the HGS.

Recommended Equipment

The following equipment is recommended at install:

- Power meter capable of measuring between 10 mW and 10 W average power
- Two mirrors to steer the beam into the HGS. Input height is roughly 3 inches above the optical table surface.
- Two alignment irises, mounted roughly 3 inches above the table surface
- Carpenter's level
- IR viewer
- White paper or card approximately 4 inches square and a piece of lens tissue

Unpacking

Carefully unpack each optical and mechanical component. Inspect each component and verify that no damage has occurred. Report any damage to Coherent and the transportation carrier.

Input Beam Conditioning

Prior to positioning the HGS on the table, use the following procedure to ensure that the beam is collimated, level, and propagates along a straight line according to the screw holes of the optical table:

For optimal conversion efficiency, the IR beam must be perfectly collimated. A slight divergence or convergence in the IR beam will have a strong impact on the HGS output power. If the input beam is not collimated the internal telescope may need to be adjusted as described below.

1. Place the HGS on the table. Use a level tool, and adjust the legs to level the unit.
2. Measure the height from the optical table to the optical bench. The laser beam height at the input of the HGS is $H_{opt.\ bench}$ + 2.5 inch, as shown in Figure 3-1.

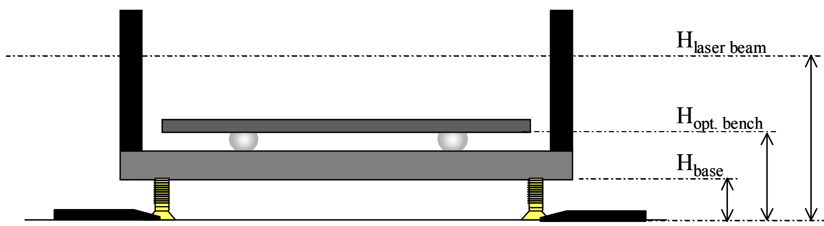


Figure 3-1. Input Beam Height

3. Refer to Figure 3-2. Position two routing mirrors and two post holders for alignment irises as shown. The post holders should be the same height, and installed in the same row of screw holes. For increased precision, use a large separation between the irises. Terminate the beam into a beam block.
4. Without the HGS in place, set a removable iris (post, iris and a collar) to the height determined in step 2.
5. Position the iris at location A1. Adjust M1 to center the beam on A1.
6. Move the iris to location A3. Adjust M2 to center the beam on A3.
7. Iterate steps 5 and 6 until the beam is centered on the iris at both locations.

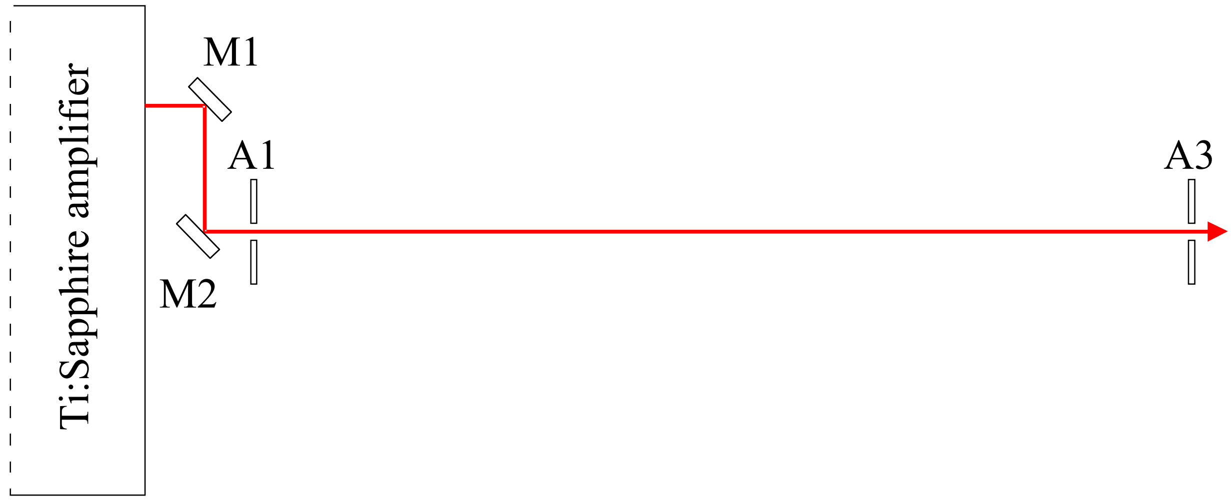
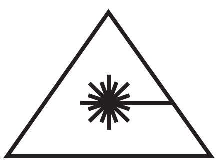


Figure 3-2. Input Beam Alignment

HGS Positioning



Reduce the amplifier beam energy to a low level for alignment purposes.

1. Remove the cover and side panels of the HGS.
2. Carefully remove all protective lens tissue.
3. Holding only the corner brackets, gently lift and position the HGS so that it is parallel to the laser beam. This step is intended to position the HGS as closely as possible to its location during optimization in the factory. The better the initial alignment, the easier the fine-tuning will be. Position the box so that the input beam is centered on the optics in the IR beam path, and the SHG beam is centered on the SHG optics.
4. Verify that the IR beam propagates through the HGS input port by temporarily replacing the front panel. If not, recalculate the height as described above and repeat the input beam alignment.
5. Install the foot clamps shipped with the system. The clamps may be used as a reference, so that the HGS can be removed and replaced in the same location on the optical table, by installing them "upside down" and pushed against the HGS feet.

HGS Alignment

Figure 3-3 shows the optical layout of the HGS-T. Other configurations are shown in Figure 2-3 on page 2-4.

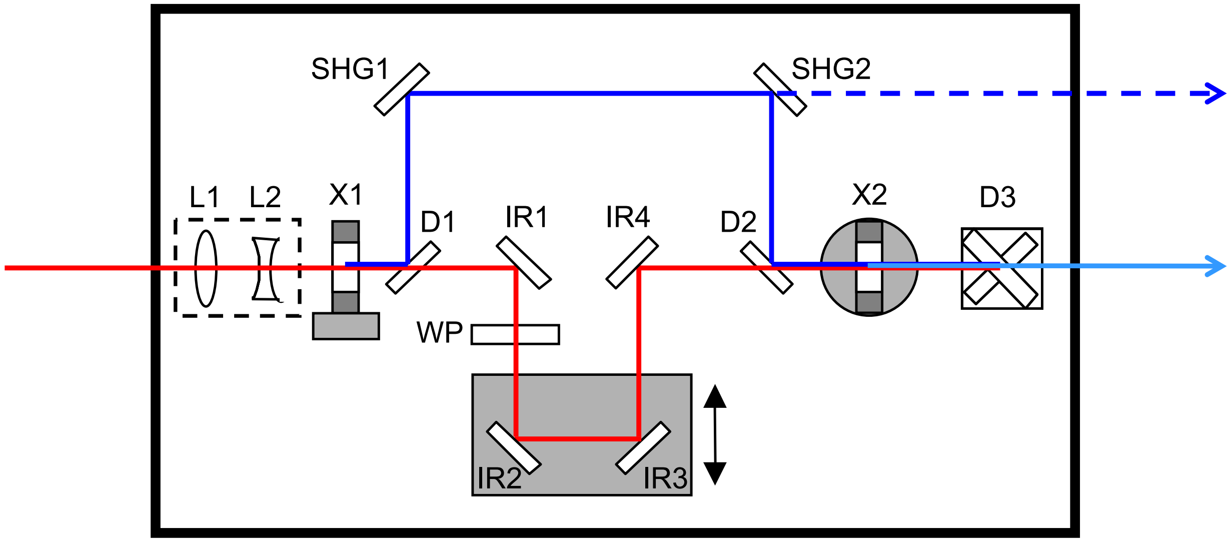


Figure 3-3. Optical Layout of the HGS-T

Beam Collimation

1. Remove the top part only of the SHG1 mount. Leave the bottom part of the mount screwed down to the baseplate. The HGS side panel should already have been removed.
2. Verify that the IR input beam is centered on L1 and L2, X1, D1 and IR1. If it is not, refer to "HGS Positioning" above.
3. Check the far-field beam collimation.
   a.) After taking appropriate safety precautions, allow a full-power beam to propagate as far as possible in the room.
   b.) Adjust L2 if necessary to perfectly collimate the beam.
4. Replace the SHG1 mount.

IR Beam Line

1. Install a post holder at the “A2” position shown in Figure 3-4. The post holder should be the same height and installed in the same row of screw holes as A1 and A3.
2. Remove the assembly D3 from its base. Unscrew the two retaining screws at the bottom of the assembly, and leave the base screwed down on the optical bench.
3. Install the removable iris at A2.

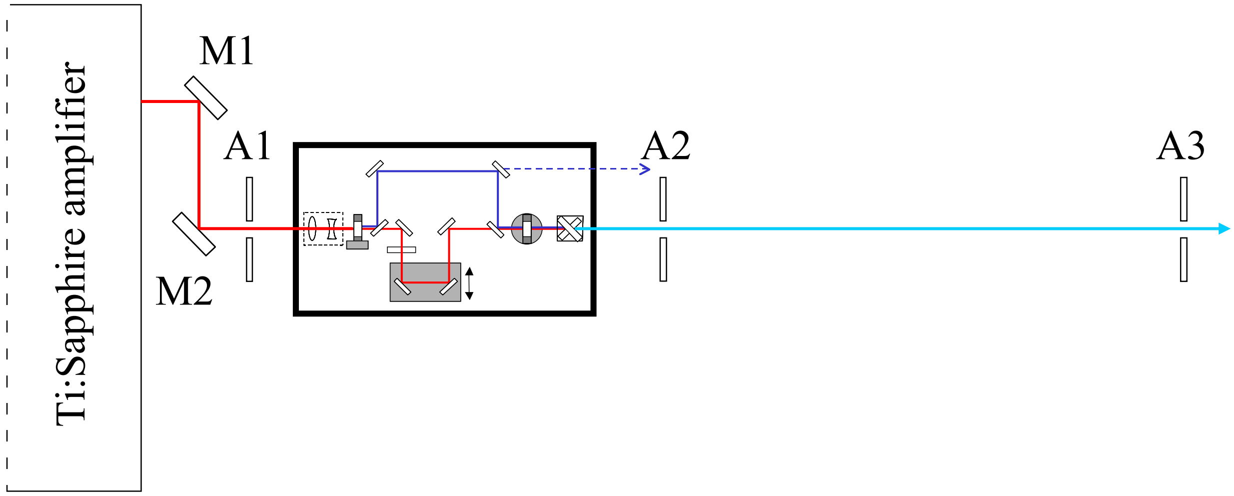


Figure 3-4. Alignment Aperture Locations for the HGS-T

4. Adjust IR1 to center the beam on A2. Ensure that there is no clipping on any optics or mounts.
5. Move the iris to location A3.
6. Adjust IR4 to center the IR beam on A3.
7. Iterate steps 3 to 6 until the IR beam is centered on the iris at A2 and A3.
8. If the beam is clipped at any location, it may be necessary to reposition the HGS and repeat the previous steps.

Crystal Installation

The harmonic crystals are shipped assembled in their housings and packed individually to avoid damage or humidity exposure. To install:

Wear gloves while performing this procedure. Avoid touching the crystal with your fingers or applying any pressure close to the crystal mount. Any damage that occurs to the crystal during installation is not covered by the warranty.

1. Block the input beam.
2. Securely tighten the SHG crystal mount into its rotation stage. The mount rotates on a horizontal axis. Verify that the mount is oriented so that the INPUT arrow is pointing along the path of the input beam.

3. Secure the THG mount on its rotation stage. The mount rotates on a vertical axis. Verify the INPUT arrow as described above.
4. Rotate the crystals so that they are perpendicular to the incident beams.

SHG Beam Line

1. Block the beam between D1 and IR1.
2. Verify that the SHG beam is centered on SHG1 from D1. If not, move the whole HGS body, or tilt the D1 mount (no X, Y adjustment) to horizontally center the beam on SHG1. Verify that the base is properly leveled. Recheck the IR beam alignment and repeat that procedure if necessary.
3. Install the removable iris at A2.
4. Adjust SHG1 to center the beam on A2. Ensure that there is no clipping on any optics or mounts.
5. Move the iris to location A3.
6. Adjust SHG2 to center the beam on A3.
7. Iterate steps 3 to 6 until the SHG beam is centered on the iris at A2 and A3. The IR and SHG beams are now spatially overlapped.
8. Install a power meter between SHG1 and SHG2 to monitor the SHG output.
9. Using the X1 micrometer, rotate the SHG crystal to maximize the SHG power.
10. Adjust the amplifier compressor length to maximize the SHG power.
11. Iterate steps 9 and 10 until no further improvement is made.
12. Check for beam clipping, particularly after the SHG crystal mount. It may be necessary to adjust the height of the SHG crystal mount once the phase matching angle has been set. If the beam is clipped at any location, recheck the previous alignment steps before moving any mounts.

HGS-Q (Double SHG)

The following procedure is applicable only to the HGS-Q (Double SHG) configuration:

FHG Optimization

1. Block the beam into the HGS.
2. Replace the dichroic filter assembly D3 (screw it back onto its base).
3. Move the power meter to the FHG output port, after the D3 assembly.
4. Unblock the IR beam. Iterate adjustments of the SHG crystal angle, FHG crystal angle, and compressor length to optimize the FHG output power.
5. Verify that the FHG beam is not clipped. Recheck all alignment steps before moving any mounts. In some cases, it is necessary to adjust the height of the top mirror mount of the D3 assembly. Loosen the retaining screw to do this. Make sure that the reflected beam is at the center of the bottom mirror of the D3 assembly. When tightening the top mirror, verify the beam pointing out of the HGS.

THG Optimization

For configurations which include Third Harmonic Generation, follow the procedure below:

1. Block the beam into the HGS.
2. Replace the dichroic filter assembly D3 (screw it back onto its base).
3. Move the power meter to the THG output port, after the D3 assembly.
4. Unblock the IR input beam. With a white card, look for THG at the power meter location. It may be helpful to block the upper port of the D3 mount, which may leak residual IR or SHG light. If there is no THG light, perform the following steps:
    a.) Rotate the THG crystal. If THG light is detected, move to step 5. If not, reset the crystal angle to a perpendicular position.
    b.) Record the micrometer reading of the delay stage. Scan the delay stage until THG light is detected. If THG light is detected, move to step 5. If not, reset the delay stage to the initial position.

c.) Place a reference pencil mark on the waveplate WP. Rotate the waveplate slowly and look for THG signal. If THG light is detected, move to step 5. If not, reset WP to its initial position.

d.) Adjust the amplifier compressor length.

5. Iterate steps 4a through 4d to maximize the THG power. If THG cannot be generated, contact Coherent Service.

6. Verify that the THG beam is not clipped. Recheck all alignment steps in this chapter before moving any mounts. In some cases, it is necessary to adjust the height of the top mirror mount of the D3 assembly. Loosen the retaining screw to do this. Make sure that the reflected beam is at the center of the bottom mirror of the D3 assembly. When tightening the top mirror, verify the beam pointing out of the HGS.

HGS-Q (Mixing Design)

The HGS-Q (Mixing Design) configuration is shown in Figure 3-5. Complete the IR, SHG, and THG optimization procedures before performing the steps in this section.

FHG Alignment

FHG optimization runs entirely in parallel with the IR, SHG, and THG procedures described above. The IR and THG beams must be spatially and then temporally overlapped. The SHG beam propagates through the HGS-Q module but does not contribute to the mixing process. Most of the SHG power is lost during propagation through the IR beam line in the HGS-Q.

Typical layout is shown in Figure 3-5. Note that the HGS-Q (Mixing Design) does not use the dichroic mirror assembly D3 (see Figure 3-3), but does include the dichroic mirror assembly D6.

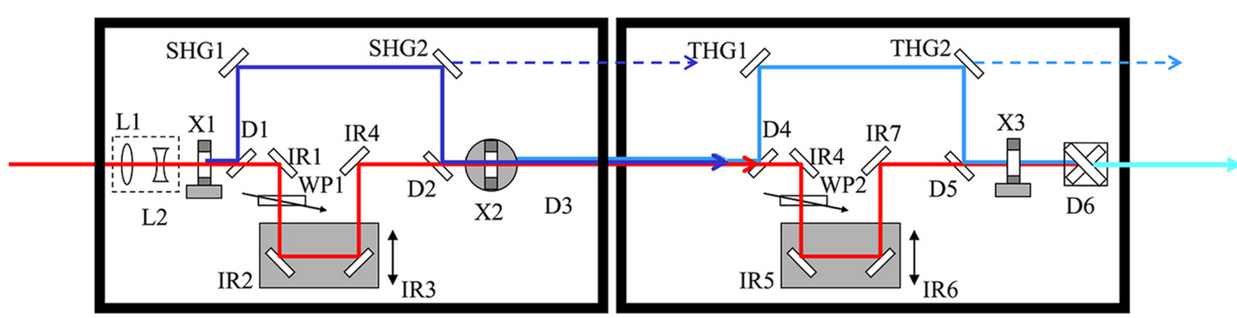


Figure 3-5. Optical layout of the HGS-Q (Mixing Design)

IR Beam Line

1. Install a post holder at the A4 position shown in Figure 3-6. Again use the same height and same row of screw holes as A1, A2, and A3.

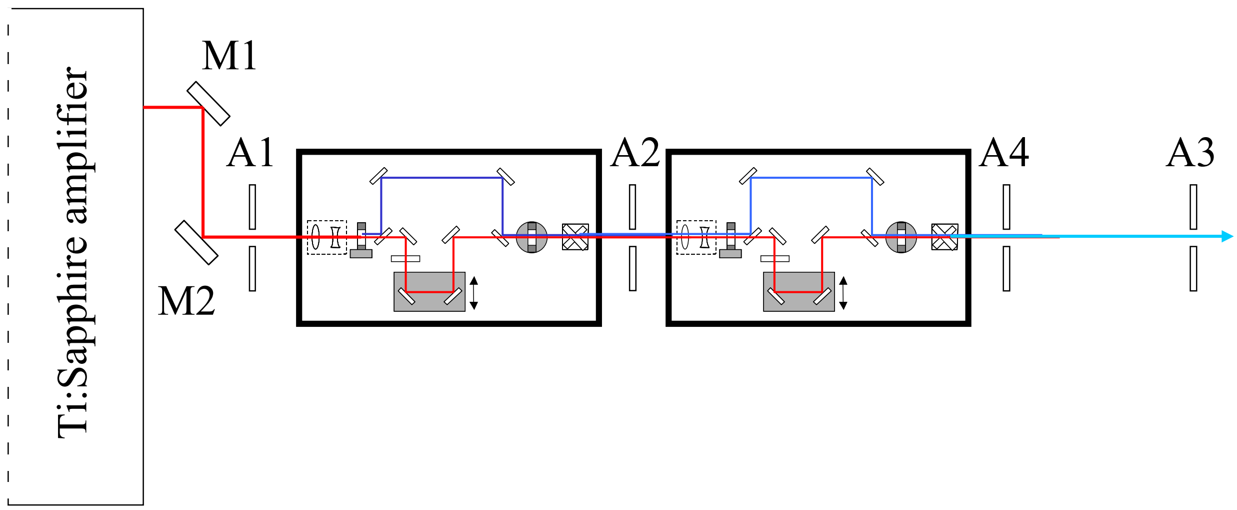


Figure 3-6. Alignment Aperture Locations for HGS-Q (Mixing Design).

2. Remove the assembly D6 from its base. Unscrew the two retaining screws at the bottom of the assembly, and leave the base screwed down on the optical bench.
3. Block the THG beam between THG1 and THG2.
4. Install the removable iris at A4.
5. Adjust IR4 to center the IR beam on A4. Ensure that there is no clipping on any optics or mounts.
6. Move the iris to location A3.
7. Adjust IR7 to center the IR beam on A3.
8. Iterate steps 4 to 7 until the IR beam is centered on the iris at A4 and A3.
9. If the beam is clipped at any location, it may be necessary to reposition the HGS and repeat the previous steps.

THG Beam Line

1. Block the IR beam between D4 and IR4, and unblock the THG beam.
2. Install the removable iris at A4.
3. Adjust THG1 to center the THG beam on A4. Ensure that there is no clipping on any optics or mounts.

4. Move the iris to location A3.
5. Adjust IR7 to center the IR beam on A3.
6. Iterate steps 11 to 14 until the THG beam is centered on the iris at A4 and A3.

FHG Crystal Installation

1. Block the input beam.
2. Securely tighten the FHG crystal mount into its rotation stage. The mount rotates on a horizontal axis. Verify that the mount is oriented so that the INPUT arrow is pointing along the path of the input beam.
3. Rotate the crystal so that it is perpendicular to the incident beams.

FHG Optimization

1. Block the beam into the HGS.
2. Replace the dichroic filter assembly D6 (screw it back onto its base).
3. Move the power meter to the FHG output port, after the D6 assembly.
4. Unblock the input beam. With a white card, look for FHG at the power meter location. It may be helpful to block the upper port of the D6 mount, which may leak residual IR or THG light. If there is no FHG light, perform the following steps:
   a.) Rotate the FHG crystal. If FHG light is detected, move to step 5. If not, reset the crystal angle to a perpendicular position.
   b.) Record the micrometer reading of the delay stage. Scan the delay stage until FHG light is detected. If FHG light is detected, move to step 5. If not, reset the delay stage to the initial position.
   c.) Place a reference pencil mark on the waveplate WP2. Rotate the waveplate slowly and look for FHG signal. If FHG light is detected, move to step 5. If not, reset WP2 to its initial position.
   d.) Adjust the amplifier compressor length.
5. Iterate steps 4a through 4d to maximize the FHG power. If FHG cannot be generated, contact Coherent Service.
6. Verify that the FHG beam is not clipped. Recheck all alignment steps in this chapter before moving any mounts. In some cases, it is necessary to adjust the height of the top mirror

mount of the D6 assembly. Loosen the retaining screw to do this. Make sure that the reflected beam is at the center of the bottom mirror of the D6 assembly. When tightening the top mirror, verify the beam pointing out of the HGS.

SECTION FOUR: MAINTENANCE AND TROUBLESHOOTING

Block all input beams when performing maintenance on the HGS. Exceptional care must be taken when operating the HGS with the cover removed. Laser protective eyewear must be worn to protect against all wavelengths present.

Optical Inspection

Regular inspection of the optics is the only required maintenance for the HGS. Cleaning procedures are given below in the event of a contaminated optic.

Cleaning Optics

If a contaminant is visible on an optic, first attempt to remove it by blowing dry air or nitrogen across the optic. Use a manual bellows or dry air or nitrogen line. Do not blow with your mouth, and do not use pressurized containers that contain propellants.

When necessary, Coherent recommends cleaning the optics of the HGS using spectroscopic-grade methanol or acetone.

Do not clean the harmonic crystals. These crystals are very delicate and any contact with them may crack and damage them. If cleaning is necessary, contact Coherent Service.

Optics and optic coatings can be easily chipped or scratched. To prevent damage when removing or replacing mirrors, always grasp the optic by the outer edge. Never touch an optical surface.

Wear latex or nitrile gloves or finger cots when handling optics, and use a clean, cushioned work surface.

Optic Inspection

1. Remove optic from holder and place the optic on its edge on a clean piece of lens tissue. Do not allow the optic to rest on one of its polished surfaces.
2. Examine the optic at different light angles for signs of contamination or scratches. A bright flashlight, held at a glancing angle of incidence with respect to the optical surface, can be helpful in identifying contaminated optics.
3. If contamination exists, clean the optic using the procedure below. If the scratches or contamination cannot be removed, the optic must be replaced.

Optic Cleaning

Optics should not be cleaned unless contamination is clearly visible on the optic surface. Unnecessary cleaning will shorten the life span of the optical coating.

Materials required

- Latex or nitrile gloves or finger cots
- Hemostats (surgical pliers)
- Lens tissue
- Spectroscopic-grade methanol or acetone
- Eyedropper

Optics and optic coatings can be easily damaged. Never touch the optical surfaces with bare skin, hemostats, or materials other than moistened lens tissue.

Procedure

1. Fold a lens tissue into a ~1-cm (3/8-in.) wide strip. Do not touch the portion of the tissue that will contact the optic.
2. Fold this strip upon itself twice and grasp near the fold with clean hemostats as shown in the figure below.
3. Place a few drops of solvent on the fold with the eyedropper.
4. Vigorously shake off excess solvent.

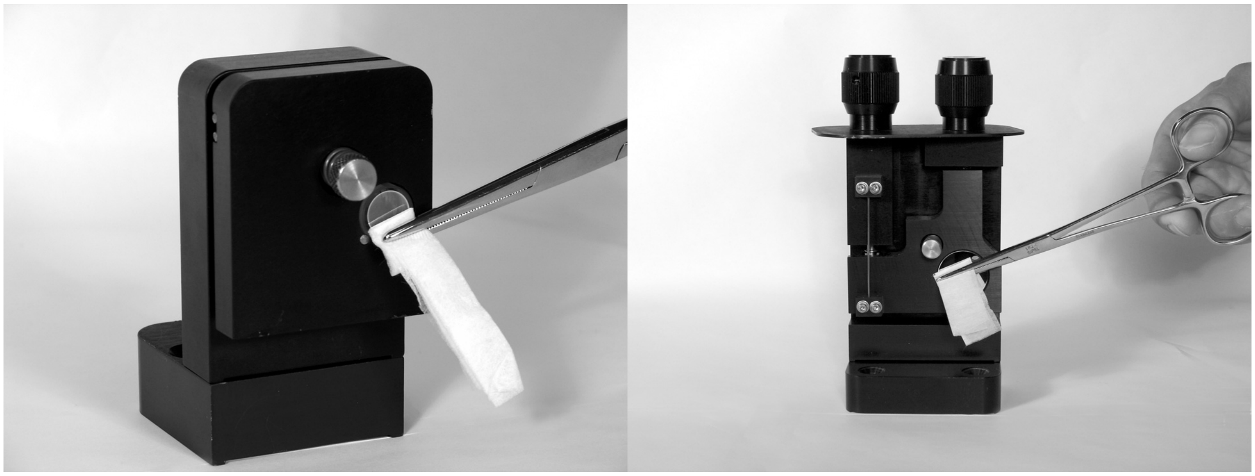


Figure 4-1. Cleaning Mounted Optics with Hemostat and Lens Tissue

5. Make a single swipe across the surface of the optic.

Do not re-use the lens tissue. Particles of dust and other contaminants picked up from the surface of the optic may scratch if dragged across with a second swipe. Swipe only in one direction.

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6. Examine the surface of the optic as outlined above. If streaks or contamination are visible, repeat the cleaning process using a fresh lens tissue.

Do not clean another optic until the system performance meets or exceeds its previous performance.

Self-Phase Modulation

The HGS uses optics with high resistance to damage, so that the power conversion is not limited by the damage threshold of the optics. However, in cases where the IR beam contains very high energies and short pulses, the resultant high peak power can generate hot spots in the beam profile through self-phase modulation. Consequently, as the IR beam propagates in the HGS some optics may become damaged, limiting the beam quality as well as the conversion efficiency. Minimizing the beam path through air will limit self-phase modulation.

Appendix A: Hygroscopic Crystal Care

Introduction

This addendum addresses the cleaning and storage of the customer-accessible hygroscopic crystals (e.g., LBO and BBO crystals) in Coherent ultrafast lasers.

Cleaning

Hygroscopic crystals are delicate. Do not handle a crystal outside of its housing. Do not try to remove a crystal from its housing and do not handle the crystal housing without wearing latex or nitrile gloves.

In most cases, directing a gentle stream of dry air or Nitrogen across the face of the crystal is sufficient to clean the crystal surface. The use of solvents (e.g. acetone, methanol, isopropyl alcohol) can damage the coating or crystal itself.

If you believe a more aggressive cleaning is necessary, contact Coherent Service or your local representative for assistance. The use of solvents without consulting a Coherent representative will void the crystal warranty.

Storage

A hygroscopic crystal readily takes up and retains moisture. This retention will slowly degrade the performance of the crystal. Anti-reflective coatings can offer some protection, but absorption still occurs at the crystal sides and through the interface between the coating and crystal surface.

Do not breathe on the crystal or expose it to moisture of any kind.

During regular use, the degradation due to atmospheric water vapor is generally mild. When not in use, Coherent strongly recommends that the crystal be stored in a dry storage container or exposed to a dry nitrogen flow. Maintain the relative humidity of the storage environment at < 5%.

Depending on the local environment, a noticeable degradation could be observed if the crystal is not properly stored and the system remains idle for several weeks or more. Improper storage of the crystal may void the crystal warranty.

APPENDIX B: PARTS LIST

The following parts can be ordered by contacting Coherent Service at 1-800-367-7890 (408-764-4557 outside the U.S); through E-mail (Product.Support@Coherent.com); or your local Coherent service representative. When communicating with our Technical Support Department, the model and Laser Head serial number of your laser system will be required by the Support Engineer responding to your request.

Table B-1. Parts List

OPTIC LABEL	DESCRIPTION	PART NUMBER
L1	Telescope Lens, +100 mm	701-4057
L2	Telescope Lens, -50 mm	702-3649
X1	Second Harmonic Crystal	SHG-F
D1	Dichroic Mirror	705-1868
D2	Dichroic Mirror	705-1866
IR1-IR7	IR Reflective Mirror	705-2527
WP	Waveplate	709-5996
SHG1-SHG2	SHG Reflective Mirror	705-1867
X2	Third Harmonic Crystal	THG-F
D3a	Dichroic Mirror	705-1950
D3b	Dichroic Mirror	705-1951

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

μJ	Microjoules = 10^{-6} Joules
μm	Micrometer = 10^{-6} meters
BBO	Beta-Barium Borate
CDRH	Center for Devices and Radiological Health (U.S. Government)
CFR	Code of Federal Regulation
CW	Continuous wave
ESD	Electrostatic discharge
fs	Femtoseconds = 10^{-15} seconds
FWHM	Full width half maximum
GVD	Group velocity dispersion
Hz	Hertz or cycles per second (frequency)
IR	Infrared
kg	Kilograms = 10^{3} grams
kHz	Kilohertz = 10^{3} Hertz
LBO	Lithium Triborate
LED	Light emitting diode
MHz	Megahertz = 10^{6} Hz
mJ	Millijoules = 10^{-3} Joules
mm	Millimeters = 10^{-3} meters
mW	Milliwatts = 10^{-3} Watts (power)
nm	Nanometers = 10^{-9} meters (wavelength)
OPA	Optical parametric amplifier
SHG	Second harmonic generation
SPM	Self phase modulation
UV	Ultraviolet
W	Watts

INDEX

Harmonic Generation System (HGS) Operator's Manual

Part No. 1109616, Rev AA