Integrator's Guide
Diamond™ GEM, G & K Lasers

COHERENT
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Technical Support

In the US:

Should you experience any difficulties with your laser or need any technical information, please visit our web site **www.coherentinc.com**. Additional support can be obtained by contacting our Technical Support Hotline at 800-367-7890. Telephone coverage is available Monday through Friday (except US holidays).

If you call outside our office hours, your call will be taken by our answering system and will be returned when the office reopens.

If there are technical difficulties with your laser that cannot be resolved by support mechanisms outlined above, please E-mail or telephone Coherent Technical Support with a description of the problem and the corrective steps attempted. When communicating with our Technical Support Group, via the web or telephone, the model and Laser Head serial number of your laser system will be required by the Support Engineer responding to your request.

Outside the US:

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

Coherent provides telephone and web 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. These support services do not affect, under any circumstances, 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 integration information for the Diamond GEM, G, and K-Series CO_2 laser systems.

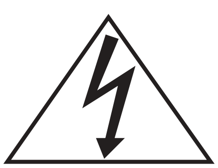
U.S. Export Control Laws Compliance

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

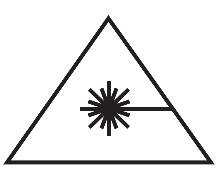
Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

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 Document



This symbol is intended to alert the operator to the presence of dangerous voltage within the product's enclosure that may be of sufficient magnitude to constitute a risk of electric shock and to indicate possible risk of equipment damage.



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

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

INTRODUCTION

The Coherent Diamond™ lasers are a group of compact, high-performance, sealed carbon dioxide (CO_2) lasers. They have many packaging advantages over older styles of lasers that greatly facilitate their integration into OEM equipment. They may be installed in any orientation and are able to function while being accelerated. These capabilities, combined with their small physical size, allow Diamond lasers to be installed on robot arms or gantries. There are, however, several areas where the integrator must be careful to consider the details of the laser installation so that the system performs reliably. This document highlights these areas, gives examples of good practice and provides tools for the system builder to design a robust product that delivers all of the performance that the Diamond can provide.

SAFETY

General Laser Safety Requirements

The information presented in this section is provided to give the System integrator some recommendations on safety requirements when incorporating a laser into an end product. It is by no means complete. The System integrator is responsible for insuring that their system will meet all of the necessary safety regulations and requirements.

The manufacture of laser products is Federally regulated, in the U.S. and the exportation of laser products into Europe also requires conformance to new EC Directives, laws and standards.

All Laser Products are subject to regulation under the Radiation Control for Health and Safety Act of 1968 (Public Law 90-602, hereinafter "the Act"). The Regulations for the Administration and Enforcement of the Act, Title 21 Code of Federal Regulation (21 CFR), require adherence to the Federal Laser Performance Standard contained in 21 CFR §1040, as well as compliance to other reporting, record keeping and administrative requirements contained in 21 CFR Sub-chapter J.

System Integrators

A "laser manufacturer" is anyone who supplies (or modifies) a laser product. The definition of a laser product, as presented in 21 CFR includes ". . . any manufactured product or assemblage of components which constitutes, incorporates or is intended to incorporate a laser or laser system. . ."

This means no matter what relative percentage of your product is laser related, if the product is intended to incorporate a laser, it becomes a laser product. A "manufacturer," according to 21 CFR, is "any person engaged in the business of manufacturing, assembling or importing" of (the subject laser) electronic product.

Manufacturers have certain compliance responsibilities "before entering commerce". Commerce is defined, for the purpose of the regulation, as any Interstate commerce and includes exchange "for value" or as a prize or award. "Entering commerce" may include shipping to a beta test site, a trade show, or even (in some circumstances) transferring the product to another part of the company.

Your Compliance Responsibilities

A “purchaser” is the end user, or one who receives the product for purposes other than resale. If you have purchased the laser to integrate into a system, it is important to note that a given manufacturer and a given purchaser may be part of the same company. This can occur when the product is subject to interstate commerce, or when it can be shown that one entity has the “manufacturer’s” role and the other the “purchaser’s” role; also inter-division transfer pricing may be considered “for value”). It’s especially important to note these requirements when dealing with a foreign subsidiary, parent or division bringing laser products into the U.S.

The text of the Federal Law is available from the Government printing office as well as directly through the Office of the Center for Devices and Radiological Health. There are also guideline documents and “A Guide To Preparing Product Reports For Lasers And Products Containing Lasers” (dated September 1995). You may request this material from:

U.S. Department of Health and Human Services
Public Health Service, Food and Drug Administration
Center for Devices and Radiological Health
Division of Small Manufacturers’ Assistance
Rockville, Maryland 20857
www.fda.gov/cdrh
(800) 638-2041

Material Processing Lasers

Coherent Diamond lasers are predominantly used in material processing applications (operations in which there is sufficient laser energy to cause a phase change in the incident material). An important resource standard for integrating laser processing machines is American National Standards Institute (ANSI) B11.21.

The ANSI B11.21 Standard encompasses the appropriate design, construction, care and use of laser processing machines, and includes references to other requirements, such as electrical construction, noise, vibration and mechanical hazards, and so on. The B11.21 also contains the appropriate references to ANSI Z 136.1, which is the User standard for laser radiation safety (used as a basis for OSHA compliance).

You can obtain the ANSI B11.21 information from:

Association for Manufacturing Technology
7901 Westpark Drive
McLean VA 22102
www.mfgtech.org

You can obtain ANSI Z 136.1 from:

Laser Institute of America
12424 Research Parkway Suite 125
Orlando FL 32826
www.laserinstitute.org

You may obtain a listing of ANSI standards directly from:

American National Standards Institute
11 West 42nd Street
New York, NY 10036
www.ansi.org

There are also several consulting companies who can assist you, for a fee, in preparing for CDRH, ANSI and OSHA and EC laser safety compliance.

Workplace Safety

As an "incorporator" of lasers you not only are a manufacturer of laser products, but a tester and servicer as well. For these reasons you need to become familiar with guidelines for using and working on those products safely (manufacturers are also required by CDRH to provide their customers with safe use information, among other things). Perhaps the most important and widely accepted such standard in the U.S. is the American National Standard Institute (ANSI) Z 136.1-2000 Standard for Safe Use of Lasers.

This standard is in fact the basis for the current OSHA Guideline on Laser Safety in the Workplace (OSHA Instruction Publication 8-1.7), and the ANSI model state standard is used as the outline of many existing and proposed state regulations. ANSI Z 136.1 is available through a number of sources, including the Laser Institute of America or the American National Standards Institute (see addresses above).

Additionally, for machine manufacturers, or system integrators, of laser processing machines, the ANSI B11.21 Standard for the Construction, Care and Use of Machine Tools using Lasers for Material Processing will be essential. It should be available for distribution, through ANSI or AMT (see addresses above) in the late 1997 time frame. The ANSI B11.21 standard addresses a wide range of manufacturers' responsibilities, including hazardous by-product issues related to laser processing of materials.

Basic Performance Requirements

All laser products must be designed and built to the lowest hazard class (Class IV most hazardous, Class I not hazardous) possible for the product to still perform its function. In the U.S. this means there are instances when a Class IV product would be allowed (although human exposure to radiation is not permitted). In Europe, for laser processing machines, only Class I machines are permitted.

In Material Processing applications, obviously, the laser must be powerful enough to effect the process, so the method to achieve Class I is to completely enclose the beam or otherwise prevent human access to laser radiation.

Coherent Diamond lasers, like other CO_2 infrared lasers, can really only be classified as Class I or Class IV (Class II to IIIb are virtually limited to visible lasers). Shipped from the factory, they are either Certified Class IV or uncertified OEM component products (with an inherent Class IV hazard level).

All laser products, regardless of Class, require protective housings which prevent human access to laser and collateral radiation to all but the radiation emitted to perform the product function. This means if you have purchased the OEM package you will have to fabricate and provide a protective housing for the laser, regardless of the application or class of the final use.

When incorporating Diamond products into systems, you, the integrator, must provide the required features (or extend those as provided by Coherent).

If you are completely enclosing the entire product and its process to achieve a Class I product Classification, you must still make certain warnings and features, which are appropriate for Class IV, available on the product for application during service or other times (other than normal operation) when the unit may be functioning with a Class IV hazard present.

In addition to protective housings, Class IV laser products require performance features under both 21 CFR 1040 and IEC 825-1:

- Key Control – controlling main power, must be removable, no operation with key removed
- Remote Interlock Connector – in series with safety interlock circuit, available to the end-user
- Safety Interlock – at any portion of housing which could provide access to radiation, intended for operation or maintenance
- Emission Indicator – audible/visible, indicates prior to laser emission
- Beam Attenuator – to block all access to radiation

- Aperture Label – indicating where the radiation is emitted
- Warning Logotype – Label stating the nature and class of hazard

In the following table, an ‘X’ indicates whether the Diamond GEM, G, & K-series model contains the required feature. An ‘O’ indicates the feature is not provided and the integrator must design and provide one. In any case, even features which are provided by Coherent must be extended or replicated for end users of the final product.

Table 1. Diamond GEM,G& K-Series Features

CLASS IV REQUIRED FEATURES	K-SERIES			G-SERIES	GEM-SERIES
	OEM	BASIC	PERFORMANCE		
Protective Housing	O	X	X	O	O
Beam Attenuator	O	X	X	O	O
Remote Interlock Connector	O	X	X	O	O
Key Control	O	X	X	O	O
Safety Interlocks	O	X	X	O	O
Warning Labels	O	X	X	O	O

Basic Compliance Guidelines

In designing a laser product, manufacturers must first determine what level of accessible radiation is required to perform the necessary function of the product. Laser radiation which is not necessary must be eliminated or contained within a protective housing (in the EC all radiation must be inaccessible).

Manufacturers must then determine the Class of their product according to the highest level of radiation accessible during operation. The Class of the product determines the requirements for controls, indicators, labels, warnings and literature statements. The wording of any warning is determined by the injury causing potential of the accessible laser radiation.

Classification

Laser products are classified according to the highest level of laser radiation to which human access is possible during operation only. In this way very high-powered lasers can be enclosed within very low hazard rated laser products, if the radiation access is prohibited during the time of actual operation.

Laser Classes are determined by the power and energy level of the accessible radiation. Each class has a limit determined by a formula whose arguments are the energy, wavelength and duration of the accessible radiation.

Class IV is unlimited in power and is the most potentially hazardous (skin, eye damage), to humans. Class I is the lowest hazard rating and products in this Class are considered nonhazardous (for infrared the power limit to Class I is virtually zero for the purpose of this guideline. i.e. no radiation is accessible during operation).

For G & K-series CO_2 (infrared) lasers, there are really only two alternatives (Class I or IV), since Class II, IIIa and IIIb are used only for visible lasers (red to blue). Most CO_2 (infrared) laser systems, as delivered from laser manufacturers, without beam delivery and workstations attached, are Class IV lasers (very hazardous) and carry the highest warnings and controls (like a loaded rifle). If workstations and beam guards are added to such a product, such that no radiation is emitted (or leaks) during operation, then we can Classify the product as Class I and apply fewer or less restrictive warnings and controls for the protection of operators and casual observers.

There are occasions when a supplier or system integrator would, himself, supply a Class IV product (if, for example he was a subcontractor to another supplier who would finish the installation). Such a subcontractor is permitted to sell the Class IV product, but must still certify it as such. Also, if other than a Class I product is being sold or entered into commerce, the access to necessary radiation must be documented and justified (manufacturers are required to reduce the accessible radiation to lowest Class that allows the product to function. For infrared that means provide a Class I product unless you can justify a Class IV situation).

As more end user customers become more educated in laser safety, though, almost all laser products are being required (by purchase order) to be Class I configuration at the completion of installation (especially true in automotive industry and EC countries) to facilitate worker safety.

Performance

A Protective Housing is required for all laser products. The protective housing must prevent human access to radiation in excess of Class I (as above) at all places and times the radiation is not necessary in order for the product to accomplish its function. The laser system must be produced to the lowest possible class. This means if the beam and its reflections can be completely enclosed (practically and feasibly) then they must be enclosed (to the Class I, or light-tight level).

There are two criteria for ascertaining the integrity of the protective housing: first, no part of the human body may be inserted into the beam or its reflections; and second, no reflection from a single flat reflecting surface (hypothetical) may exit any hole or opening in the housing.

Generally, for manufacturers of work enclosures with material handling equipment, etc., the most difficult portion of the protective housing is that which must be opened to allow part entrance/exit, or for operators to clear jams, etc. Normally, a designer would simply cut a hole for this purpose, or if concerned about some aspect of safety, install a door over the hole. For matters of radiation safety, however, the door mechanism can become complex from at least two respects:
1.) A door designed to be closed during the laser operation, but open to allow parts or humans to enter or exit, must then be interlocked, [by some approved means] to disable laser operation when the door is open; and
2.) once you choose the mechanical door and interlock scheme you must then conduct statistically significant life or endurance testing for the reliability of the mechanism; predict its life and maintenance or replacement cycle; and report such information to both the CDRH and your customers. For these reasons (and reliability as well), it is generally preferable to provide protection with as few moving parts as possible. Since light travels only in straight lines, it may be feasible to construct machinery which by configuration and use of light baffles, meets the criteria for protective housings.

Safety Interlocks may be required on any laser product. They must prevent human access to radiation that exceeds the limits of Class I whenever a protective housing is opened during operation or maintenance (and the said human access is not necessary to the product function).

If access to the interior radiation is sometimes needed (to verify alignment, for example) then the interlock may be defeatable (and the product labeled accordingly). Safety interlocks need not prevent access to radiation accessible during service only. Service only panels of the protective housing need not be interlocked, but should be removable only with the use of a tool.

Operation means functions by which the product accomplishes its intended purpose; may include loading/unloading parts, documents, setting/manipulating external controls. Maintenance means functions performed by the user to assure performance (preventative maintenance). Service means, usually, repair. It may be performed by trained service personnel or by sophisticated users following instructions specifically indicated as service instructions. The manufacturer stipulates which functions are service and which are maintenance.

Snap action spring switches are subject to short circuit and are not approved as fail-safe safety switches. Switches in series with solenoid-actuated doors could, under certain circumstances, be used, if the door remained latched-up on failure. Shorting bars and plugs are generally acceptable, under certain terms of correct usage.

A Remote Interlock Connector is required on all Class III and IV laser products. The purpose is to allow a user to connect a remote barrier interlock (or daisy chain) or emergency stop switch or similar device. It must be in the interlock circuit such that when the terminals are open, human access to laser radiation is prevented. Electrical potential must not be greater than 130 V rms. A shorted mating connector may be provided by the manufacturer to allow the product to be operated when the remote interlock is not being used.

Key control is required for Class IIIb and IV laser products in order that the user may prevent unauthorized operation (The key must not be removable with switch in “ON” position).

An Emission Indicator(s) is required on Class II, IIIa IIIb and IV laser systems. The indicator may be audible or visible. On Class IIIb and IV laser systems the indicator must precede emission of radiation by a sufficient amount of time for users and observers to recognize that the product has been energized (so they can avoid accidental exposure). Usually 2-7 seconds before lasing is adequate. Emission indicators must be duplicated on control panels and laser heads if they are capable of being separated by 2 meters or more.

A Beam Attenuator is required on all lasers above Class I. The beam attenuator is a mechanical or electrical device such as a shutter that blocks laser emission. The beam attenuator blocks bodily access to radiation above the limits of Class I, without the need to turn the laser off. The beam attenuator must be available for use at all times during operation. Power switches and key controls do not satisfy the requirement for beam attenuator(s). The beam attenuator must be separate from control or main power.

Operating Controls must be located so as to make exposure to radiation unnecessary while the user is manipulating them.

View optics, Viewports or Display Screens may not provide human access to radiation greater than the limits of Class I during operation or maintenance.

Windows, microscopes on welders, drillers, surgical devices, view ports and other such things are considered in this category. The compliance of viewports and viewing optics can be complex, requiring attenuation and other eye-safety measures. Consult the standard for details and measurement requirements. You may also need advice from welding safety or other technical expertise.

Manual Reset is required on all Class IV lasers manufactured after August 20, 1986. It must prevent automatic restart after an interruption due to remote interlock activation or from an interruption of more than 5 seconds due to unexpected loss of main electrical power.

Labeling

Warning logotypes are required on all laser above Class I. For infrared the warning must include the warnings for invisible, as well as visible radiation. For a Class IV product, the labels which are attached to the embedded laser are usually not sufficient for the higher level product. The OEM must post new ones of their own, in prominent, visible locations. An example of a Class IV logotype is shown in Figure 1.

Removable or replaceable protective housing sections that are not interlocked or are interlocked with defeatable interlock switches are required to be labeled with a warning. Examples are shown in Figure 2.

Aperture warning labels are required wherever radiation in excess of Class I is emitted through an opening in the protective housing during operation. Wording is specific; x-radiation, collateral and invisible must be indicated if present; see the example in Figure 3.

Certification labels and Identification labels are frequently combined on a single piece of material for simplicity. Certification labels declare the product compliance (wording specified) and date of manufacture; and I.D. labels name the manufacturer and plant location. The month and year must be spelled out with no abbrevia-

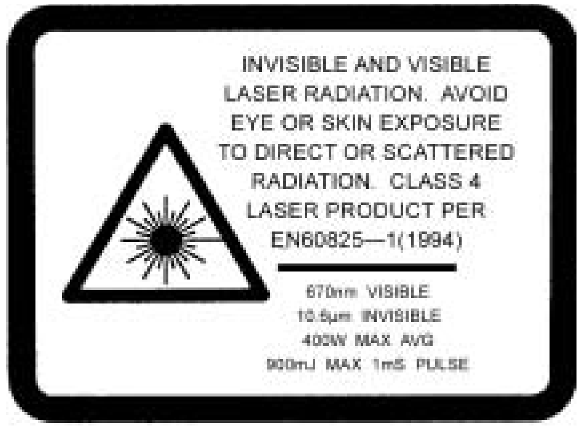


Figure 1. Warning Logotype (Example)

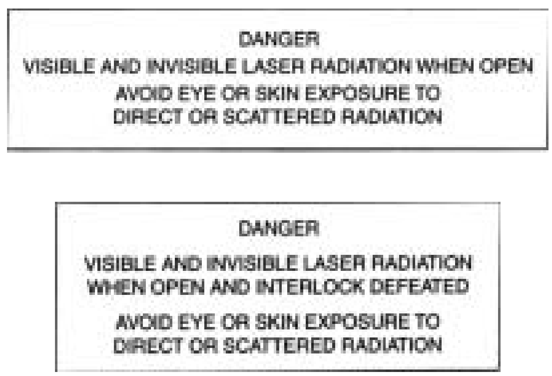


Figure 2. Labels for Removable Housings (Example)

Figure 3. Aperture Warning Label

tions (e.g. December 1989). Codes may be used only if on file with CDRH via model report. Figure 4 is an example of a certification and identification label.

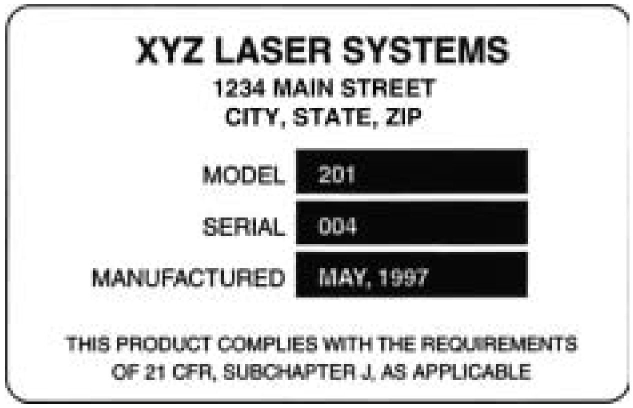


Figure 4. Certification and Identification Label for a Laser System

Other Guidance

Product compliance also includes requirements for providing certain information to users (customers’ manuals, brochures and data sheets); record keeping and notification; product recall administration; variances and exemptions; and model reporting and notification requirements.

As these issues relate more to the sales and administration of the product, they are not included in this design aid. For further information, please contact a laser safety certification service.

As stated in the beginning of this section, the information presented here is provided to give the System integrator some recommendations on safety requirements when incorporating a laser into an end product. It is by no means complete. The System integrator is responsible for insuring that their system will meet all of the necessary safety regulations and requirements.

DIAMOND GEM-SERIES LASER PRODUCTS

There are nine models of Diamond GEM-series lasers. The models are:

Table 2. GEM-Series Lasers Models

MODEL	POWER RATING	AIR/LIQUID	AC/DC
GEM-25A	25 watts	Air	DC
GEM-25L	25 watts	Liquid	DC
GEM-30A	30 watts	Air	DC
GEM-30L	30 watts	Liquid	DC
GEM-50A	50 watts	Air	DC
GEM-50L	50 watts	Liquid	AC
GEM-60L	60 watts	Liquid	AC
GEM-100A	100 watts	Air	DC
GEM-100L	100 watts	Liquid	AC

DIAMOND G & K-SERIES PRODUCTS AND PACKAGES

There are nine models of Diamond G & K-series Diamond lasers. The models are:

Table 3. Diamond Lasers Models

MODEL	POWER RATING
Diamond G-100	100 watts
Diamond G-150	150 watts
Diamond K-125i	125 watts
Diamond K-150	150 watts
Diamond K-225i	225 watts
Diamond K-250	250 watts
Diamond K-500	500 watts
Diamond K2K	145 watts

K-series lasers are available in three packages: OEM, Basic and Performance. The G-series lasers are only available in OEM packages.

OEM Package

The OEM package comprises a laser and an RF power supply. For K-series lasers, where the laser head and power supply are separate, connecting cables are also supplied. Neither the laser nor the power supply are enclosed. The power supply requires 48 VDC (Coherent can supply an air-cooled DC power supply as an option). The laser is not provided with a shutter or alignment laser.

When integrating a system with the OEM package, the builder must provide an enclosure and shutter for the laser.

Basic Package (K-Series Lasers Only)

For the Basic package, the Diamond laser head is enclosed in a housing with a manual shutter (an electric shutter with an alignment laser is available as an option) and a Diamond Digital Interface

(DDI) is provided to facilitate communication with the power supply. Additional options for this package include an air-cooled DC power supply and a remote control.

The Basic package provides everything needed for a fully functional system. In most cases, the power supplies may be installed in the system's electrical cabinet. Where this is not appropriate, the Performance Package may be used.

Performance Package (K-Series Lasers Only)

The Performance Package comprises a fully optioned Basic package (a laser with an electric shutter, an RF power supply with Diamond Digital Interface, a DC power supply with a heat exchanger and a remote control) with all of the electrical components installed in a sealed cabinet. It is therefore the package of choice when it is not desired to install the laser's power supply in the system's electrical cabinet.

FACILITIES REQUIREMENTS

The exact facilities requirements for each Diamond laser is detailed in the table titled "Utility Requirements" in the Operator's Manual for that laser. Since the laser gas is sealed inside the cavity, the lasers require only prime electrical power and cooling (air or liquid) for their operation.

Electrical Power

Some versions of the Diamond GEM-series lasers operator on 220 VAC power (They have integral DC supplies) and some require customer supplied DC power.

Table 4. Electrical Power for the Diamond GEM-Series Lasers

MODEL	AC/DC	VOLTAGE	CURRENT
GEM-25A	DC	28 VDC	18 A
GEM-25L	DC	28 VDC	18 A
GEM-30A	DC	48 VDC	12 A
GEM-30L	DC	48 VDC	12 A
GEM-50A	DC	48 VDC	25 A
GEM-50L	AC	220 VAC	7 A
GEM-60L	AC	220 VAC	7 A
GEM-100A	DC	48 VDC	49 A
GEM-100L	AC	220 VAC	13 A

DC Power Supply Requirements

The following are the requirements for the customer supplied DC power supplies for the GEM-series.

Regulation:	<± 2%
Regulation Sensing:	Remote at load (4 wire connection)
Ripple and Noise:	<1% p-p (20 MHz BW limit)
Overload and Short Circuit Protect	Automatic Recovery

The Diamond G & K-series RF power supplies operate on 48 VDC. Coherent offers DC power supplies (included in the K-series Performance Package) that convert incoming AC power to the voltage used by the laser. With the exception of an optional single phase power supply for the G-series lasers, Coherent DC power supplies operate on 3 phase current. These 3 phase power supplies may be damaged by the loss of a phase in the supply current. A phase imbalance detector should be installed to shut down input power upon loss of a phase in locations where the electrical supply is subject to such problems.

System Cooling

Diamond lasers are relatively insensitive to variations in cooling water temperature. For most applications, any temperature in the range of 10ºC (15ºC for GEM-series) to 35°C (30°C max for the K-500) with regulation to ±4°C is adequate. Water lines should be large enough for the flow to be maintained at or above the specification requirement at all times. For runs under 50 feet (15 meters), 3/8 inch (9.5 mm) ID hose is satisfactory. If longer hoses than this are needed, the diameter should be increased to 1/2 inch (13 mm). Nylon reinforced PVC is a suitable material for flexible water hoses.

While the G & K-series laser will run quite satisfactorily on tap water as long as its hardness is less than the equivalent of 250 mg/liter of $CaCO_3$, most installations will use some form of recirculating chiller to minimize water use. Recirculated water should be filtered to remove particulate matter from the coolant, and algaecide should be added to prevent biological fouling. For filtration, a Balston 53/18 filter with an LP-200-18-10 cartridge, providing 75 micron filtration, is sufficient for any Diamond laser.

The GEM-series requires +25% Dow Frost coolant in order to avoid damage to the aluminum cooling passages of the laser head. Chloramine-T algaecide in the amount of 1 gram for every gallon of chiller water volume will control algae growth. To eliminate problems from corrosion, the water loop should not contain aluminum or carbon steel, and dissimilar metals should not be in contact with one another. Stainless steel, copper alloys and plastic are the best materials for maintaining coolant quality.

Cooling water should be maintained above the dew point to avoid condensation on laser optics and electronics. Damage from condensation is not covered under the laser warranty. It is advisable, then, in humid environments, to maintain the coolant temperature at or above ambient and to circulate coolant at all times to avoid condensation when the laser is not operating.

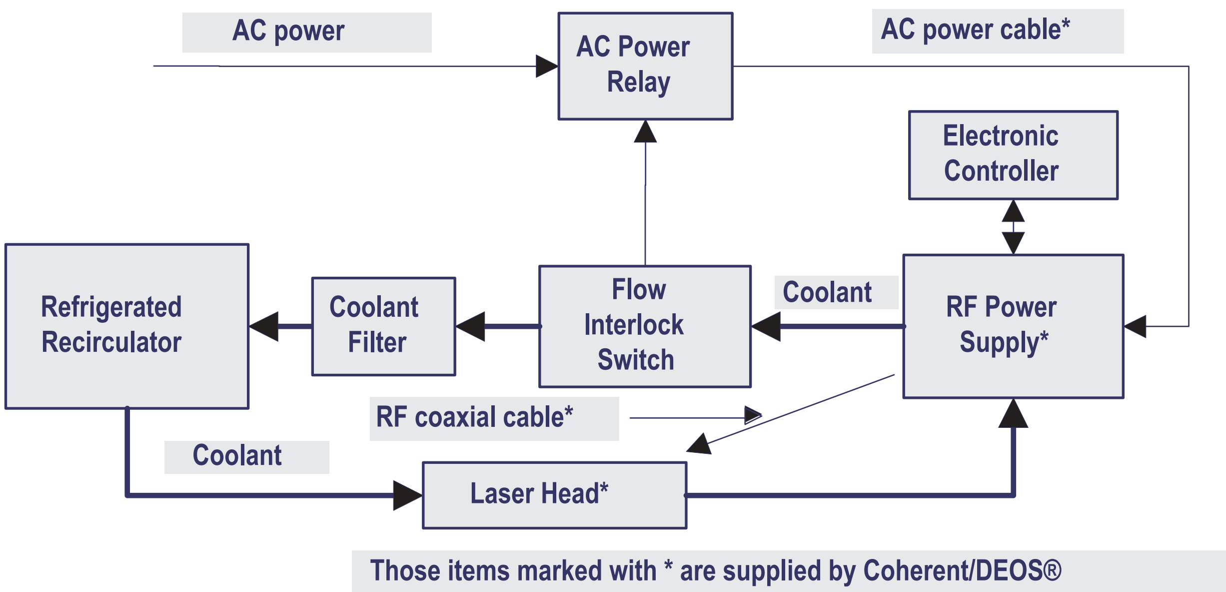


Figure 5. Recommended Cooling System Functional Block Diagram for GEM-Series Lasers

Water Flow Interlock

The cooling water flow to Diamond lasers must be monitored at all times. Diamond K-series laser heads are already equipped with water flow switches, while the system integrator must supply one for the GEM and G-series laser. Suitable switches may be obtained from Proteus Industries. There are many common situations where there is not enough water flow to the laser: a valve may not be open, the pump may not be operating, a filter may be clogged, a hose may be kinked. On the Basic and Performance packages for the K-series, the switch is monitored by the control electronics so that the laser shuts down and indicates a water fault when the switch detects insufficient flow. With the OEM packages, the system integrator must incorporate the water flow switch in the interlock circuitry so that the laser cannot operate when the water flow is low. The water flow monitor used on K-series OEM lasers incorporates a relay, and therefore cannot handle inductive loads such as relays, solenoids or transformers. Use a low-voltage solid state input to sense closure of this switch. It is important to incorporate the water flow interlock: operating an OEM laser with insufficient water flow voids the warranty.

The RF amplifier also requires water cooling. The water lines on GEM-series lasers should be hooked up in series. Since the separate amplifier on K-series lasers does not have its own flow switch, the water lines on OEM and Basic K-series lasers should be hooked up in series with those running to the laser head as indicated in the section titled "Installation" in the Operator's Manuals. On G-series lasers, the integral RF power supply is internally connected to the water flow ports. The Diamond Performance Package, which has a water-to-air heat exchanger for the DC power supply, is set up so both the water source and return are connected to the power module. Supply and return lines for the laser head are connected to the module as indicated in Figure titled “Cooling System Diagram” in the Performance Package Operator’s Manual.

Shutter

On the GEM-series the shutter is customer supplied. To meet US regulations, all high-power (Class IV) laser systems must have shutters capable of absorbing the full output of the laser. The K-series Basic and Performance laser heads are already equipped with such shutters, while OEM heads are not. Shutters added to Diamond lasers should have apertures large enough to transmit the beam (their clear aperture should be at least 1.5 times the beam diameter) and should signal their status in both the closed and open positions.

INSTALLATION

Diamond lasers may be installed in any orientation, and may be either stationary or mobile. The least favorable orientation is vertical with the beam exiting upwards, because it is easy for contaminants to settle on the laser's output optic. If this orientation is selected, it is necessary to be very careful to avoid damaging the optic during installation and maintenance, and to supply purge gas at all times afterwards. On the GEM-series, we recommend this orientation be avoided.

Fixed Beam

For a fixed laser with a fixed beam delivery system (Figure 6), it is only necessary that all the optical elements be securely attached to their support structure.

The GEM liquid cooled laser head models come with mounting feet which attach to the liquid chill plate. The GEM air cooled laser heads come equipped with tapped holes which accommodate optional mounting brackets. These brackets provide rigid mounting while allowing thermal expansion. For more information please refer to the appropriate section in the operator's manual. Because these lasers can be distorted if inappropriately mounted, instructions in the operator's manual regarding mounting of the laser should be strictly followed.

The Diamond base plate isolates the laser resonator from mounting stresses, so a simple flat mounting surface is adequate. K-series lasers have alignment slots for 0.25 inch (6.35 mm) pins as noted on the laser head mounting drawing (figure titled "Laser Head Dimensions and Mounting Hardware Locations" in the Operator's Manual). If a pair of these pins are incorporated on the mounting plate, it is possible to remove and reinstall the laser without loss of alignment. Similarly, G-series lasers have an integral optical rail which allows lasers to be switched while maintaining alignment.

It is possible, with a Basic or Performance K-series laser head, or with a G-series laser, to attach beam delivery components directly to the output bezel of the laser (Figure 7). This is a very simple solution to beam delivery problems, but it is not suitable for heavy loads. The front panel of the K-series enclosure is a relatively thin aluminum plate and will deflect if force is put on it. The front panel of the G-series lasers is attached to a resonator optic, so excessive loads on it can affect output mode quality. Attaching more than 10 lb. (5 kg) of equipment to the front bezel without providing additional bracing is discouraged.

The laser and beam delivery should be connected to the same structure. If they are on separate frames, floor movement can cause system misalignment.

Provision must be made for beam delivery alignment. Either the laser or the first beam delivery optic must be adjustable to allow the beam to be centered on the optic. Slotted mounting holes with washer stacks for vertical adjustment will work, but more sophisticated systems such as jack screws are easier to use.

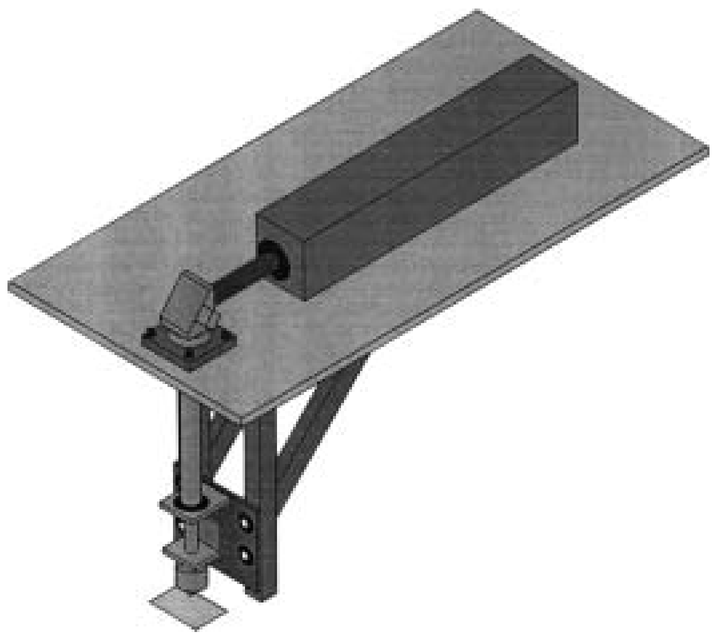


Figure 6. Fixed Laser with Fixed Beam Delivery System

Moving Beam

If the laser is to send its beam to a moving optic (Figure 8), complete adjustability of the laser support is necessary to maintain alignment through the optic's range of travel. Vertical and horizontal jack screws at both the front and rear mounting hole locations will greatly facilitate this alignment. If, as is often the case, polarizing and expanding optics are interposed between the laser and the moving optic, the best design is to incorporate everything on a sub-plate and provide adjustments to it (Figure 9).

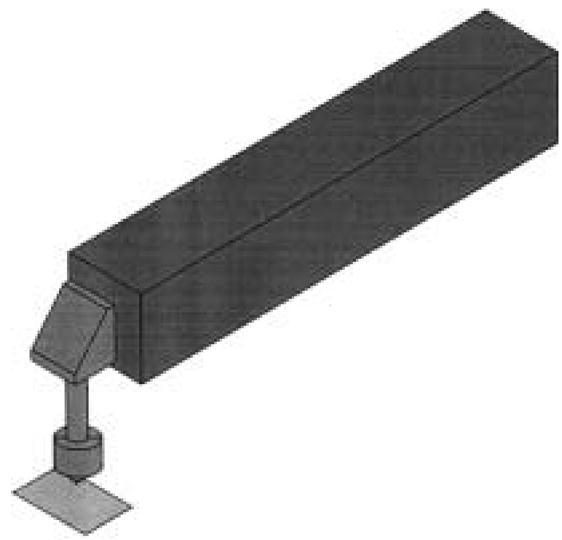


Figure 7. Beam Delivery Components Attached Directly to Laser

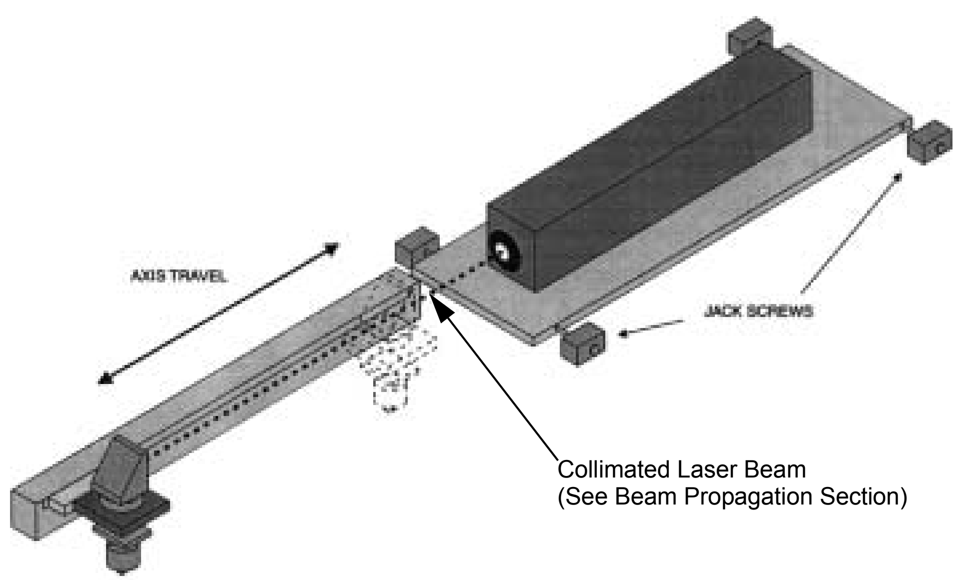


Figure 8. Laser Mount with Adjustments for Moving Axis

Moving Laser

When the laser itself is set on a moving axis, the beam delivery is generally fixed with respect to the laser. Beam delivery concerns, therefore, are the same as for a fixed beam. For GEM and K-series lasers, which have their RF power supplies separate from the laser heads, and so an additional consideration is added, handling the RF cable.

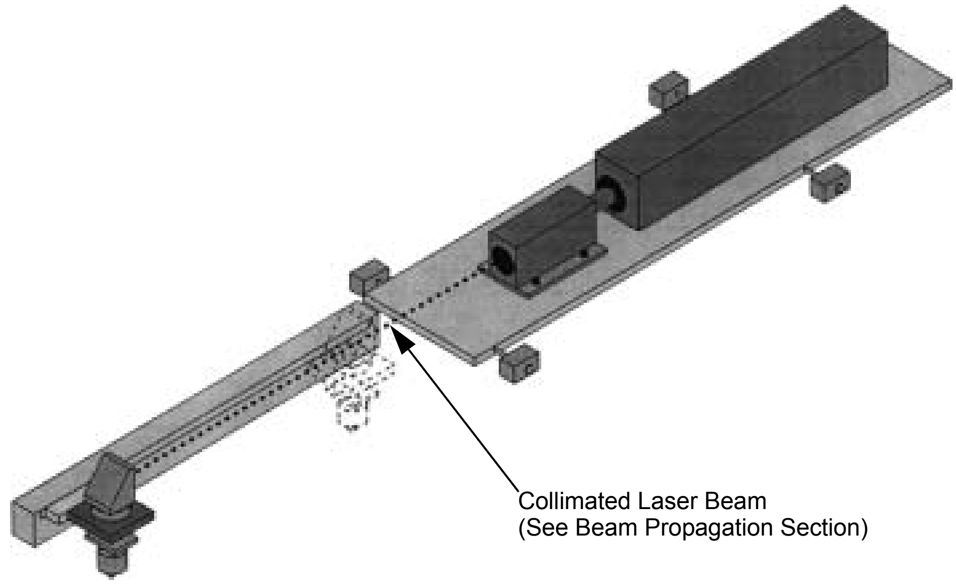


Figure 9. Laser and Additional Optics on Adjustable Mounting Plate

The RF Cable

RF cables have a finite life in terms of the number of bends they can withstand. As the bend radius is reduced, the life becomes shorter. Coherent provides cables with an extended flex life for use on systems with moving lasers. Even with these cables, it is good practice to do the following:

- Use the shortest RF cable possible.
- Select the longest-lived cable type available.
- Run the cable in its own track (put the water hoses in another track) and allow it to take the largest possible bend radius.
- Do not tie wrap or otherwise constrain the cable.
- Make sure that nothing can abrade the cable as the axes traverse their full range of motion.
- Avoid stress to the cable (torsion, shear, or tension).
- Allow for cable replacement as a maintenance operation.

For those applications where they are suitable, the GEM & G-series lasers, with their integral RF power supplies, are better choices for systems where the laser is on a moving axis.

BEAM DELIVERY

Many difficulties in laser processing systems arise from deficiencies in the beam delivery system. The beam delivery system has the vital job of transmitting the initially high-quality beam emitted by the laser to the workpiece without having the beam degraded by misalignment or aberrations. In addition, the beam delivery system must protect itself and the laser from light reflected from the processing region. In almost all environments, the beam delivery system must be enclosed and purged to protect the optics from contamination by dirt.

Alignment

When designing a laser system, provision must be made for alignment of all the optical components. When a component moves, the beam alignment must be maintained throughout the excursion of that component. This, in general, requires that one of the elements on the moving beam path must be adjustable in both translation and angle. Most beam bending modules have adjustments for angular alignment, but need to be mounted on slotted carriers or slides to allow for translation. The visible alignment laser (optional on the Basic package and standard on the Performance package of K-series lasers) makes alignment of a complex beam delivery system much quicker and easier than aligning with the CO_2 beam. The visible alignment laser should only be used for approximate alignment. It is not the same wavelength as the CO_2 beam so some errors in beam positions could occur.

A detailed alignment procedure, as well as all necessary targets, should be supplied with every laser system.

Sealing

It is critically important to keep all of the optics in a high-power CO_2 laser system clean. Dirt on an optic does far more than reduce the beam quality; it damages, usually permanently, the optical surface itself. Particulate materials are heated quite strongly by the beam and conduct this heat to the surface on which they sit. The coating under the particle is destroyed by this heat. Cleaning the optic may remove the particle, but the damage remains.

Industrial lasers often work in relatively dirty surroundings. In many cases, the laser process itself contributes to local airborne contamination. The only way to preserve the laser and beam delivery optics in industrial environments is to have the beam path from the laser to the final focusing lens completely sealed, and purged with clean gas.

Purge Gas

Diamond K-series lasers have a purge gas inlet. The recommended gas is dry nitrogen, which is most conveniently obtained from a Dewar (nitrogen from cylinders, in addition to being more expensive than cryogenic nitrogen, is more subject to contamination with oil or water). It is also possible to use air as long as it meets the following criteria:

- Filtration 1 micron
- Dew point 10°C below incoming water temperature
- 99.995% oil free

To achieve this quality of air from most standard industrial compressed air supplies requires the use of a coalescing filter and an air drier. One suitable arrangement consists of a Balston A912A-DX coalescing filter followed by a Balston 7601 drier. A Balston 41-071 indicator on the coalescing filter will signal when the element must be replaced. The use of unfiltered compressed air (which typically contains water and oil) will almost certainly cause premature failure of the laser optics.

On industrial systems, the gas supply should be interlocked to prevent operation unless the purge gas is flowing. A flow switch rather than a pressure switch should be used as a sensor, since line blockage after a pressure switch will not generate a fault indication. Use Teflon, polyethylene or polypropylene tube to deliver the purge gas. Do not use PVC or similar materials which can outgas.

In order to keep the flow of purge gas to a reasonable level, the beam delivery system must be sealed. Starting at the laser, a carrier for a shaft seal or O-ring may be attached to the 1.75-20 threads on the front bezel of Basic and Performance K-series laser heads. Since this bezel is isolated from the laser resonator, it may be subjected to considerable load without affecting the output. On the OEM K-series models, however, the exit tube is attached to the beam shaping optics. When attaching a seal to this 1 inch (25.4 mm) tube, it is important that no loads be transmitted to the tube. A flexible bellows such as a Gortiflex CT-1 (from A and A Manufacturing) is the best solution to this problem.

For G-series systems, a combination purge gas inlet and beam tube seal should be attached to the laser’s output plate.

Where the beam path is fixed, aluminum tubing makes a good beam guard. It is available in many diameters and has a smooth outer surface that seals well. In most systems, beam guard tubes are black anodized although this has no effect on their performance.

Mirages

Nitrogen has a extremely small but finite absorption of 10.6 µm light. At high average laser powers, the gas in the beam delivery system will consequently be heated by the laser beam. If there is no gas flow, the warmer gas will rise. In a long horizontal path, this creates a gradient index lens that causes mode degradation. In severe cases, an initially circular mode can be deformed into a semicircle. The remedies for this are to increase the tube diameter (which decreases the gradient for any given amount of heating) or turn up the purge gas flow.

Seals for Moving Beams

It is more difficult to seal moving elements than static ones. Where the travel is less than half the distance between a pair of moving elements, two telescoping rigid tubes with an oil seal work well. Telescoping tubes do not work so well when there are more than two of them because they tend to bind. Bellows can have a large expansion ratio, but they are usually made of organic materials which can be decomposed by reflected laser light. Spiral lead screw covers (available from Centryco) resist light reflections, but they do not seal well and can deform into the laser beam. Putting a bellows (for a gas seal) over a spiral cover (for laser light resistance) is a reasonably robust solution. For long runs, the bellows must be guided on rods to keep it on the beam line.

Many other types of beam delivery optic protection for moving beams have been tried. Some success has been achieved with open beam paths by having the individual optics protected by ejectors (Figure 10). This arrangement does not seem to protect upward-facing optics, and works best if it is always on, even when the system is shut down.

Pumping

A properly sealed moving axis acts as a pump. When the axis extends, the volume of the beam delivery system increases by the product of the distance traveled and the cross-sectional area of the beam guard. At a sufficiently high travel rate, this can exceed the purge gas flow and cause a negative pressure inside the beam path. In most cases, this can be solved by calculating the maximum volume increase rate with all moving axes extending and supplying more purge gas than that value. It is helpful for such systems to have

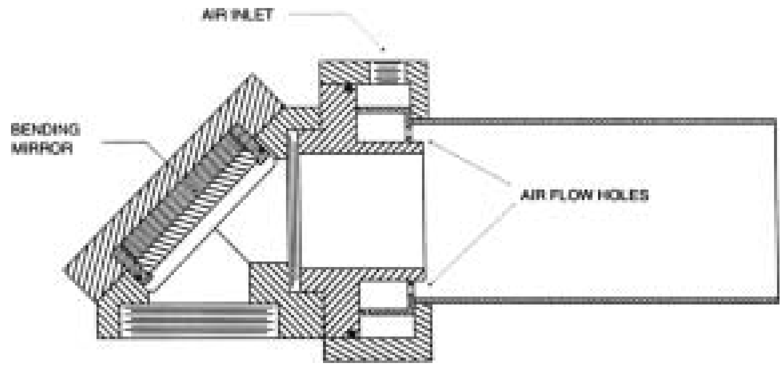


Figure 10. Cross Section of Air Ejector for Protecting Bending Mirror

one-way valves in the beam delivery system to allow excess purge gas to leave when the axes contract. For very high-speed systems, it may be necessary to have the purge gas flow switch from a normal rate to a higher rate when the axes extend.

Polarization

Diamond lasers have a highly polarized output. The direction of polarization is horizontal for all Diamond lasers but the K-400 and K-500, where it is vertical. In some applications, notably ceramic scribing and metal cutting, superior results are achieved with circular polarization. A quarter wave plate is required to convert the linear polarization to circular. For high-power CO_2 lasers, reflective optics are generally used as wave plates. Such optics must be set to reflect the beam at 45º to the direction of polarization of the incoming beam. The Coherent CQE module, Part Number 5701-0059, (Figure 11) allows this to be done easily.

To preserve circular polarization, all beam bending mirrors after the CQE must be “zero phase shift” optics. Despite their name, these optics typically have up to 6° of phase shift each, so it is best to put the CQE near the process end of the beam line to avoid loss of circular polarization.

Back Reflection

High power laser systems are very sensitive to light reflected back from the work or from support tooling. If, for example, cloth is cut on an aluminum backing plate, a large fraction of the laser power will be returned through the beam delivery optics. This light is fairly well-collimated by the focusing lens and can enter the laser cavity with possibly catastrophic effects. Even if laser damage does not

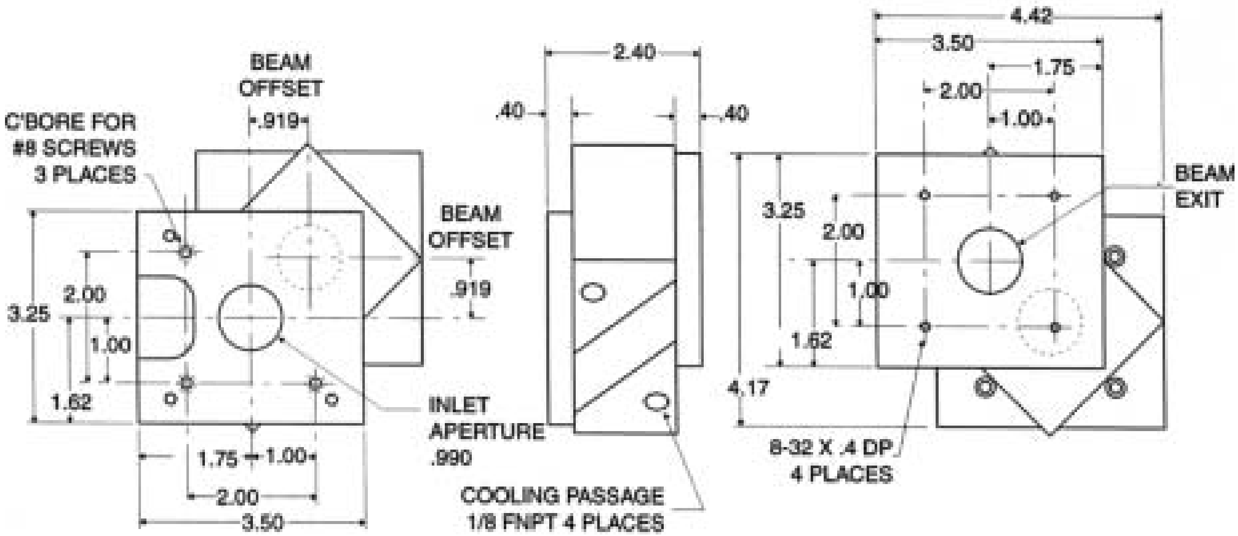


Figure 11. Installation Dimensions for Coherent CQE Module 0175-989-00

occur, back reflections alter the laser output and degrade the beam quality. In other cases, the returned light may be focused on beam delivery optics so that they are destroyed.

It is essential for GEM-series laser systems used in high beam return (back reflection) modes, to have an optical isolator in the beam delivery system. An isolator is a mirror with a coating that reflects S-polarized light (light polarized normal to the plane of reflection) and absorbs P-polarized light (light polarized parallel to the plane of reflection).

It is essential for G & K-series systems used to cut metal, or working over metal supports, to have an optical isolator in the beam delivery system. An isolator is a mirror with a coating that reflects S-polarized light (light polarized normal to the plane of reflection) and absorbs P-polarized light (light polarized parallel to the plane of reflection). This mirror is set in the beam line before an CQE module so that the incoming beam is S-polarized. The CQE, as noted above, converts the light to circular polarization. Any reflected light returns to the CQE with circular polarization. The geometry is such that when the light exits the module, it is linearly polarized at right angles to the laser's initial plane of polarization. This is intercepted by the isolator as P-polarized light and is absorbed before it can do any damage. Isolators may have to absorb substantial power, requiring them to be water-cooled. The isolator/CQE assembly, part number 0175-990-00, (Figure 12) should be located as near the focusing lens as possible to protect all the beam delivery optics. The CQE and isolators referred to are for operation at 10.6 µm. For operation at 9.4 µm use CQE part number 0175-989-01 and isolator part number 0175-990-01.

Damage to the laser due to back reflection is not covered by warranty, so the system designer should protect against it.

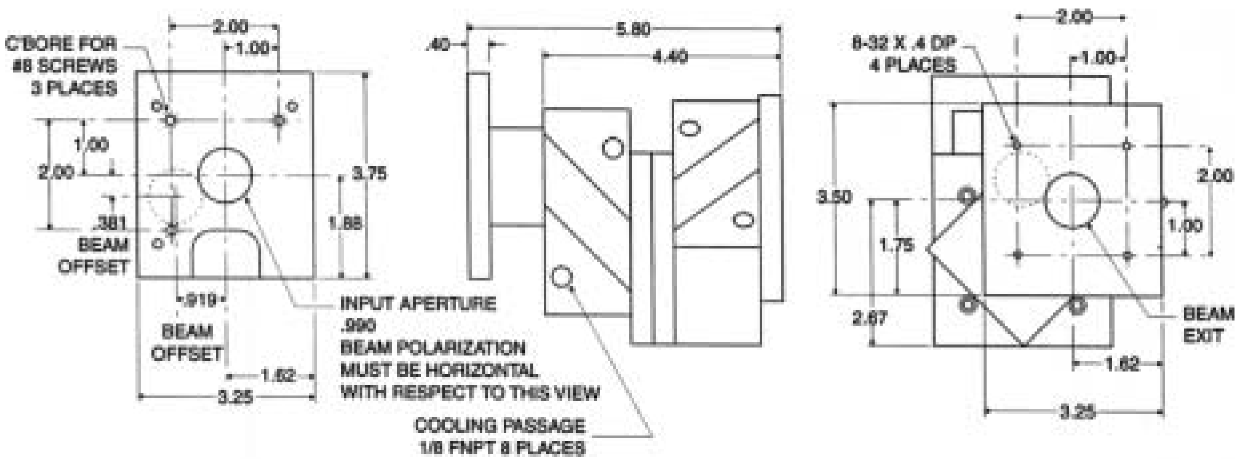


Figure 12. Installation Dimensions for Coherent Isolator/CQE Assembly 0175-990-00

BEAM PROPAGATION

Optics Basics

It is not the intent here to have an exhaustive discussion of optics theory and beam propagation. That information is readily available in optics and laser text books. The following basic optics information will be helpful when designing a beam delivery system.

Beam Diameter

The typical Coherent CO_2 laser beam is very close to an ideal Gaussian beam profile where the peak intensity of the beam is at the center. In Figure 13, the intensity profile cutting through a laser beam is shown for the ideal case. For these beams, the beam diameter is defined as the width of the beam where the intensity is 13.5% of the peak intensity. Based on the mathematical description of the beam profile, this is a good first approximation of beam diameter. The practical information here is selecting the clear aperture of optics that the laser beam must go through. In order to allow at least 99% of the laser beam though an aperture it should be at least 1.5 times the beam diameter at that point. In actual practice, the clear aperture should be selected to be several millimeters larger so it is easy to align the beam through the optic. The laser beam information provided in the data sheets is based on measurements using specific instruments designed to measure beam diameters.

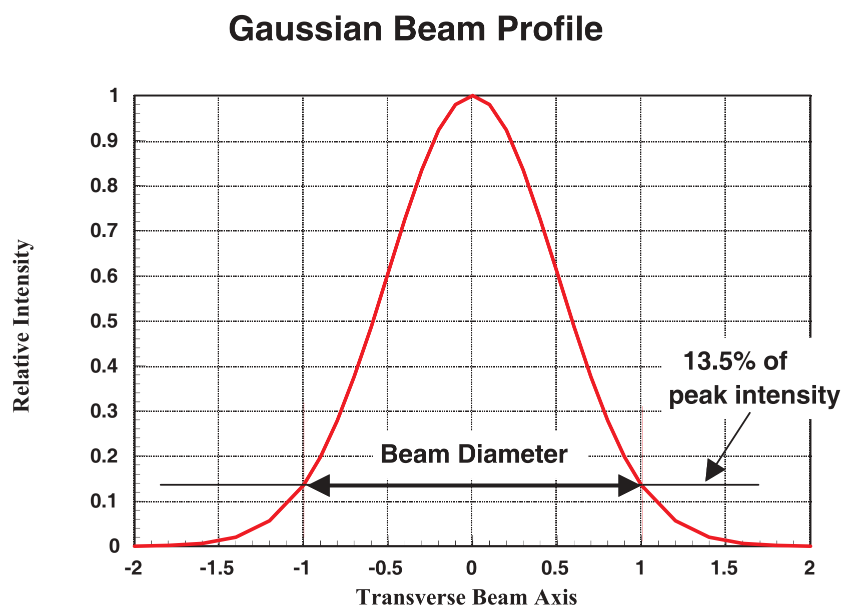


Figure 13. Beam Profile

M^2 (M Squared) Factor

The actual laser beams differ somewhat from the ideal Gaussian profile shown in Figure 13. To handle the handle the deviation from the ideal case, the factor M^2 or K has been developed and is often quoted in laser specifications. For the ideal beam the M^2 factor is 1 and the factor increases as the beam deviates more from ideal behavior. For a beam with an M^2 factor of 1.2, the beam is actually $\sqrt{1.2} = 1.1$ larger than an ideal Gaussian beam. It basically relates to the factor by which the beam diameter is different from ideal. As will be shown in the later examples, it has practical use to determine the beam size at various locations in a beam delivery system. Note that the $M^2 = 1/K$ and is also in common use.

Beam Propagation

As a laser beam propagates away from it narrowest point or beam waist, it will increase in size in a very predictable fashion. To calculate the beam size at a specific location, one must know the size of the beam waist and its location. Thus the beam diameter, D at a distance Z away from the beam waist with a beam diameter of D_0 follows the equation:

$$D = \sqrt{D_o^2 + \Theta^2 Z^2}$$

The factor Θ is the beam divergence. The beam divergence depends on some basic properties of the beam including the wavelength, λ and the beam waist size D_0. The relationship for the beam divergence at full angle, then is:

$$\Theta = \frac{4\lambda M^2}{\pi D_o}$$

Often the beam divergence is a value included in the specifications of a laser. If a calculation is being made of the divergence, the units of the wavelength and the beam waist diameter must be the same. As an example a laser operating at a wavelength of 10.6 μ, a 7 mm beam waist diameter, and an M^2 of 1.2 the calculated divergence is as follows:

$$\Theta = 4 \text{ x } 0.0106 \text{ mm x } 1.2 / (3.14 \text{ x } 7) = 0.0023 \text{ rad} = 2.3 \text{ mrad}$$

Now calculating the beam diameter for the same laser as above at 2 meters from the beam waist;

$$D = \sqrt{(49 \text{ mm}^2 + 0.0023^2 \text{ x } 2000\text{mm}^2)}$$

$$D = \sqrt{(49 \text{ mm}^2 + 5.29 \text{ x } 10^{-6} \text{ x } 4 \text{ x } 10^{6} \text{ mm}^2)} = 8.4 \text{ mm}$$

Focusing a Beam

Most laser processing applications call for focusing the laser beam to a small spot so that the high power density can accomplish the desired work. This is true for applications involving cutting, drilling, scribing, welding, and others on a wide range of material. The typical question is what is the spot size that will be achieved for this application. In order to achieve the smallest spot size, the beam must be focused with a lens that transmits the laser wavelength. In order to achieve the desired spot size, one must size the clear aperture for the diameter of the beam at that point using the guidelines covered in the section on beam diameters. The approximate spot size of the focused laser beam using a lens with focal length *f* is:

$$D_f = \frac{4f\lambda M^2}{\pi D_e}$$

Where D_e is the beam diameter at the focusing lens and D_f is the focused beam diameter. Calculating for the same beam in the beam propagation example with a 5 inch (127 mm) focal length lens for a beam a 2 meters from the beam waist

$$D_f = (4 \text{ x } 127 \text{ mm x } 0.0106 \text{ mm x } 1.2)/\ (3.14 \text{ x } 8.4 \text{ mm})$$

$$D_f = 0.245 \text{ mm} = 245\ \mu$$

One important note that to reduce the focused spot size the designer reduce the focal length of the lens or increase the spot size on the focusing lens. The danger either approach is that the aberrations and non-ideal behavior in the optics can lead to larger spot sizes that calculated here. As a general guide, the equation above will give valid answer if the lens focal length divided by the beam diameter on the lens (f/D_e) is greater than 10. The beam waist will be located near the focal length of the lens. The location of the focused beam waist also depends on the distance from the beam waist to the focusing lens.

Rayleigh Range and Depth of Focus

When processing material it is important to have knowledge of the work range where the process will function properly. The major issue is the acceptable range in the distance between a focusing lens and the work surface. A convenient model for this is to calculate the Rayleigh range for the focused beam as an initial evaluation of the optical design. The Rayleigh range is the difference in distance between the beam waist location and the point at which the beam is 1.4 times larger.

$$Z_r = \frac{\pi D_o^2}{4\lambda M^2}$$

The beam waist diameter can be for a focused beam in this issue but it could also be any other beam waist and the equation is still applicable. For the same focused beam in the previous example, the Rayleigh range or depth of focus is:

Z_r = (3.14 x(0.245 mm)^2) /(4 x 0.0106 mm x 1.2)

Z_r = (0.188 mm^2) /(0.051 mm) = 3.7 mm

It should be noted that reducing the spot size will reduce the depth of focus more rapidly than the spot size is reduced. Thus when reducing spot size the process can become much more intolerant to variability in the distance between the focusing lens and the work piece. The Rayleigh range provides a guide to the range of acceptable working distances but the actual value will depend on the process, the equipment, and dynamics between the two factors.

Beam Expansion

As noted above, an increase in the beam diameter on a focusing lens can produce smaller focused spot size. The other issue that beam expansion addresses is variation in the focused spot size on gantry based system. In these later systems, the beam size on the focusing lens will vary as the distance between the laser and the focusing lens is moved which in turn causes the focused spot size to change as well as the distance to the beam waist. Beam expansion will reduce the change in the focused spot size and changes in focal point. The simplest beam expanders use two lenses with different focal lengths (see figure 14). The ratio of the focal lengths gives the magnification of the beam. Galilean beam expanders use a negative lens followed by a positive lens for expansion.

Using the simple beam expander as an example, the combination of a 2.5 inch and 5 inch lenses will magnify the beam by a factor of two. The proper separation of the two lenses is the sum of their focal lengths. Small adjustment of the separation is required to correct for the effect of the distance from the first lens to the beam waist. As a general guide line for design keep the ratio of the focal length divided by the beam diameter for each lens greater than 10 to minimize effects of aberration. Also the same guidelines on acceptable clear apertures and beam diameters given above are still applicable

On gantry based systems, the beam expander can be used to adjust focus at the work surface. This is accomplished by setting the final objective lens to exactly it's back focal length (BFL) from the work surface (along the middle of the optical axis). The BFL is specified by the lens manufacturer. Focusing is then done by adjusting the spacing of the lenses in the beam expander.

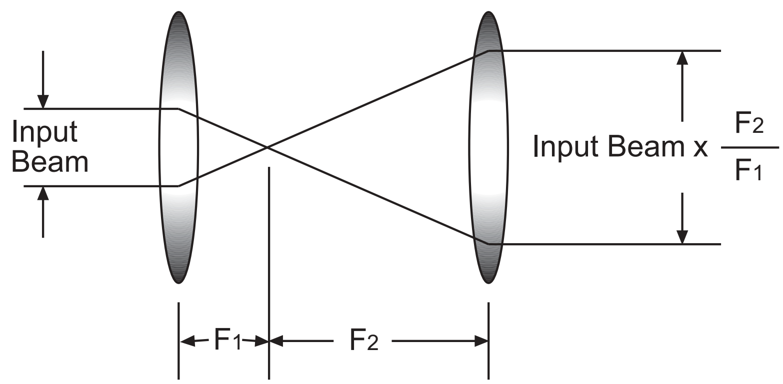


Figure 14. Simple Beam Expander

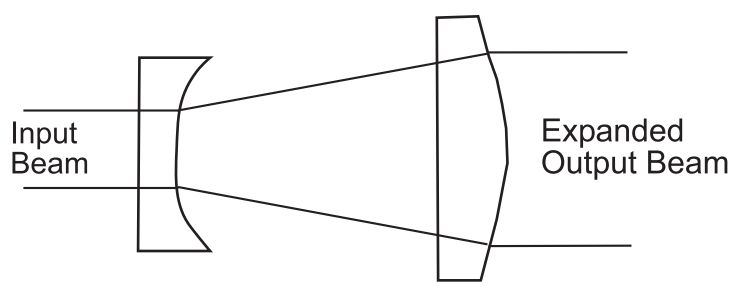


Figure 15. Galilean Beam Expander

Interfacing Diamond GEM-Series Lasers to Systems

The GEM-series laser control is via the 15-pin D-type connector on the RF power supply. The exception is the GEM-30 where control is via the RJ-45 interface connector. The information that follows is a summary and more detailed information on interfacing the laser is contained in the respective operator's manual.

Interlocks

External interlocks must often be connected to the GEM-series laser. These include safety interlocks such as door signals, process interlocks such as assist gas flow sensors and mechanical interlocks such as axis limit signals. In most cases, key switches and similar safety-related devices should be connected to the laser enable signal.

Table 5. Signal Interface Description and Connector Pinout for GEM-25/50/60/100/200

PIN NO.	FUNCTION	DESCRIPTION
1	RS-423 MODULATION Input signal (unbalanced)	The RS-423 specification requires a driver capable of delivering a signal between 4 V and 6 V into a test load of 450 Ω.
2(+) and 3(–)	MODULATION Differential input signal (RS-422)	The RS-422 balanced specification requires a driver that is capable of developing a differential signal between 2 V and 10 V into a load of 100 Ω.
4	ANALOG FORWARD Voltage output signal	Analog representation of the RF power supply's forward RF output voltage. 0 V to 5 V, 5 V = full scale. Signal will drive ≥10 kΩ load. A voltage level lower than 2.5 V indicates a bad RF power supply. See representative signal curves for the particular GEM-series RF power supply.
5	ANALOG REFLECTED Voltage output signal	Analog representation of the RF power supply's reflected RF output voltage. 0 V to 5 V, 5 V = full scale. Signal will drive ≥10 kΩ load. A voltage level greater than 1.0 V may indicate either a bad laser head, a bad RF cable, or both.
6	VSWR Fault Open collector output	Will sink 25 mA of current when an VSWR fault occurs. This indicates an excessive mismatch between the laser head and the RF power supply.
7	–	Not currently used.
8	VDC Voltage output signal	+15 VDC ± 0.5 VDC, 0.25 amp max output available from RF power supply to user equipment.
9	GND Ground	Customer ground. Return line for all signals. Is also chassis ground.
10	Power Supply Enable TTL input signal	Enables internal DC power supply. TTL high will enable this pin.
11	MODULATION SELECT Input signal	Selects between unbalanced TTL modulation or Differential modulation signal. No connection selects unbalanced input (Pins 1 and 9). Ground this pin to selected balance inputs (Pins 2 and 3).
12	OVER TEMPERATURE Open collector output	Will sink 25 mA of current when an OVER TEMPERATURE fault occurs. This indicates that the RF power supply has gone over temperature.
13	DUTY CYCLE FAULT Open collector output	Will sink 25 mA of current when a DUTY CYCLE FAULT error occurs. This indicates a duty cycle exceeding 50% when the RF power supply is set to the Enhanced Pulse Mode. Fault automatically reset when fault condition is removed.
14	–	Not currently used.
15	MODE CONTROL Input signal	Selects between CW Mode or Enhanced Pulse Mode. 0 V to 7 V = CW Mode 7.2 V to 10 V = Enhanced Pulse Mode

Table 6. Signal Interface Description and Connector Pinout for GEM-30

Pin No.	Signal Description
1	RF Enable TTL logic input; 1=RF ON, 0=RF OFF; 1 kΩ impedance This input turns on the laser. See also Pin 7, Control Enable, below.
2	SWR OK TTL logic output; 1=SWR OK, 0=SWR Fault; I_{OH} = -0.4 mA, I_{OL}= 8 mA Output is asserted when DC supply current (I_{DD}) is below max. value.
3	LASER OK TTL logic output; 1=LASER OK, 0=LASER Fault; I_{OH} = -0.4 mA, I_{OL}= 8 mA Output is asserted when no faults (SWR, Temp. or Volt.) are detected.
4	Temperature OK TTL logic output; 1=Temp OK, 0=Temp Fault; I_{OH} = -0.4 mA, I_{OL}= 8 mA Output is asserted when temperature is below maximum value.
5	Voltage OK TTL logic output; 1=Voltage OK, 0=Voltage Fault; I_{OH} = -0.4 mA, I_{OL}= 8 mA Output is asserted when DC supply voltage (V_{DD}) is below max. value.
6	Internal Coherent use. Must be grounded by OEM.
7	Control Enable TTL logic input; 1=Laser Control Enabled, 0=Laser Control Disabled This input must be asserted before RF enable can be used to turn on laser.
8	Customer Logic Ground for all interface signals
Notes: 1) Connector used is RJ-45 type. 2) These specifications are subject to change.	

INTERFACING DIAMOND G & K-SERIES LASERS TO SYSTEMS

Diamond lasers have three types of interfaces. For OEM lasers, connection is made directly to the RF amplifier. Basic and Performance lasers have the Diamond Digital Interface and, optionally, may be connected through the remote control. The information that follows is a summary and more detailed information on interfacing the laser is contained in the respective operator's manual.

OEM Interface

To operate an OEM laser, the system control must be connected to the DC power supply, the RF power supply, the water flow switch and the (external) laser shutter.

DC Power Supply

The Coherent DC power supply manufactured by HC Power, may be turned on by connecting Pin 6 to Pin 14 in its DB25 connector. Table titled "DC Power Supply DB25 Connector Pinout" in the OEM manual lists the other signals available from this connector; they are generally not of use other than for maintenance purposes.

The laser's water flow switch may be put in series with the power supply enable signal so that everything shuts down if the water flow is low. While this is simple to do, it does not provide any fault information, leading to mysterious laser shutdowns. Also, if the low flow is intermittent, the power supply will keep turning on and off until the problem is corrected. It is better practice to latch the low water flow signal and associate it with a fault output so that the problem can be identified and corrected.

The DC supply shuts down if it detects overcurrent or overvoltage. This can be reset only by cycling the AC power to the unit. It is helpful, then, to have the DC supply on its own circuit breaker to allow this. The status of the DC power supply can be sensed by looking for +5 V on Pin 14 relative to Pin 13. There will be no voltage if the supply has shut down.

The Coherent DC Power supply manufactured by Power One may be turned on by connecting the REMOTE ENABLE (pin 8) and +5 V LOGIC (pin 5) in the 25 pin cable assembly will cause the DC power supplies to turn on. These leads can be tied into the main interlock circuit of the end users system. One suggestion is to connect this output in series with the water flow switch contacts as part of an interlock system. It can provide up 50 mA of current at 5 VDC and is on as soon as the AC power is applied. Note that if an over-current or over-voltage situation occurs, the DC supplied must have the AC input power turned off and then back on to reset the DC supply and also reset the +5 V logic voltage

RF Power Supply

Control of the laser is performed through the DB25 connector on the RF power supply. Two inputs are required to operate the laser, and four outputs are available for monitoring its function. There are, in addition, two analog outputs that are useful for maintenance purposes only.

The RF amplifier is enabled by connecting Pin 3 to Pin 16. This is the preferred signal to use for the water flow interlock and should also be connected to safety interlocks.

Laser modulation is enabled by driving Pin 7 to a TTL high level with respect to Pin 20. A differential line driver such as an AM26LS31 is suitable for this. The laser is on whenever the line is high and off when it is low. Laser “On” times, referred to as pulse widths, can be any length less than 1000 µs, although the actual laser discharge may not respond to very short pulse widths. Incoming pulse widths longer than 1000 µs will be automatically limited by the RF amplifier. In addition, the duty cycle of pulsing must not exceed a maximum (depending on the laser model). The RF amplifier will automatically limit duty cycles. If either the commanded pulse width or duty cycle exceed the limits, the amplifier will issue a warning signal.

The RF amplifier provides output signals to monitor its performance and warn of potential problems. These outputs are to be interfaced to a differential line receiver such as an AM26LS33, and are:

Digital Reflected Power (Pin 8+, Pin 21–)

This signal goes high when the laser is operating correctly. In the case of a problem, it will change state with the laser modulation. It should therefore be monitored by the system control, with a warning message issued if it drops out when the laser is running. The control should wait 100 milliseconds after modulation starts to monitor the reflected power to allow transients to dissipate.

Digital Forward Power (Pin 9+, Pin 22–)

This signal is synchronized with the modulation when the laser is operating correctly. If it stays high during laser operation, there is a problem with the RF amplifier. The system control should issue a warning message if this signal stays high more than 1 millisecond. The control should wait 100 milliseconds after modulation starts to monitor the forward power to allow transients to dissipate.

Duty Cycle Limit (Pin 10+, Pin 23–)

The duty cycle is the ratio of the pulse width to the pulse interval. Each model of the Diamond laser has a specified maximum duty cycle. The Duty Cycle Limit signal goes high if the incoming duty cycle exceeds the laser's limit, or if the incoming pulse duration exceeds 1000 µs. Note that the power supply limits its output to allowable conditions; a Duty Cycle Limit signal indicates that there is a difference between the commanded output and the actual output.

VSWR Limit (Pin 11+, Pin 24–)

The VSWR (voltage standing wave ratio) limit signal is issued when the ratio of the reflected RF to the forward RF exceeds a preset limit. This signal is momentary; its duration is on the order of the pulse width. The control should wait 100 milliseconds after modulation starts to monitor the VSWR limit to allow transients to dissipate.

The normal practice with all of these warning signals is to indicate the warning on the system control until a reset is commanded to clear them.

Water Flow Switch

Low water flow is a system fault. A low water signal from the flow switch should be interpreted as such and prevent laser operation until the fault is cleared.

Shutter

If an electrically-controlled shutter is used, it should be interlocked to the system control so that it closes whenever a safety interlock is opened. Shutter position should also be monitored, indicating a fault condition if the commanded position is not achieved after a short time. If a manual shutter is used, opening any safety interlock must disable the RF amplifier.

DDI Interface

The Diamond Digital Interface, used on Basic and Performance lasers, simplifies system connection and status monitoring. With the DDI, the system control need only communicate with one device rather than four. All connections except for external interlocks are made through a single DB37 plug (J1 on Basic systems, Controller on the Performance power supply). Interlock signals are accessed through the DB9 plug marked User on Basic lasers and Interlock on Performance lasers.

The DDI provides many more inputs and outputs than the OEM interface. In addition to the enable and modulation signals, inputs are provided for shutter control, the aiming laser, turning the DC power supply on, clearing faults and selecting output signals. The inputs are optically isolated and are to be driven by devices such as an MC74HCT240A.

The DDI's outputs, with the exception of shutter position and an alert signal, are multiplexed through four lines. When an alert signal is received, the system control must interrogate the DDI by cycling the A and B inputs while monitoring Out 0 through Out 3 to determine the exact fault (See table titled "Diamond Digital Interface Multiplexer" in the Diamond Operator's Manual).

The User or Interlock connector is meant to be used for safety interlocks. The system interlock string, including key switches, connects pins 8 and 9. Any break in this string shuts the laser down, so it is not a good idea to put work chamber door switches on it. These should be interlocked to the laser shutter (or to RF enable for systems with manual shutters) instead.

When the DC power supply is on, Pins 1 and 2 are switched together by a relay in the DDI. This can be used as a signal for "Laser On" warning lights. Note that the relay contacts can only take 0.2 A at 25 V, so it is not appropriate to directly connect lights to this line.

Remote Control Interface

The main reason for controlling a Diamond laser through the Remote Control is that the pulse period and duration may be set on the remote's thumbwheel switches. This allows system controllers without pulse outputs to be used. The remote also displays faults and warnings, allows for their reset, and minimizes interface requirements. It is, in general, an inefficient way to set up a permanent interface but is useful for temporary setups.

Inputs to the remote may be made through BNC connectors or through the Interlock + Control connector J11. Tables titled "Remote Control Unit Controls and Indicators" in the Operator's Manual indicate how the remote may be set up for external control.

Interlocks

External interlocks must often be connected to the Diamond laser. These include safety interlocks such as door signals, process interlocks such as assist gas flow sensors and mechanical interlocks such as axis limit signals. In most cases, key switches and similar safety-related devices may be put across pins 8 and 9 of the User connector on the DDI. It is better to connect operator access doors to the shutter signal, since opening the User interlock shuts the laser down. Systems using OEM lasers must incorporate comparable interlock functionality.

Beam Propagation Characteristics of Diamond GEM-Series and K-Series Lasers

GEM, G, and K-Series Beam Propagation

The following charts describe the beam propagation characteristics for the GEM-series, G-series, and K-series laser. In the following tables, the distance is referenced from the front end plate of the laser head. The tables show only beam diameters up to 1.0 inch (25 mm) clear aperture optics. Beam diameters that are larger are unsuitable for most applications. It is recommended that beam expansion be used for beams propagating over extended distances..

Table 7. Beam Diameter (MM) vs. Distance From Laser (MM)

Distance From Laser (mm)	GEM 30/50	GEM 60/100	G50/100	K150	K250	K500
0	1.8	3.8	1.9	7.0	6.8	11.0
250	2.7	3.9	2.9	7.0	6.83	11.0
500	4.5	4.3	4.7	7.1	6.9	11.0
750	6.4	4.8	6.7	7.2	7.0	11.1
1000	8.4	5.4	8.7	7.4	7.2	11.1
1500	12.5	7.0	12.9	7.8	7.7	11.3
2000	16.6	8.7	17.2	8.4	8.3	11.5
2500	-	10.5	-	9.1	9.0	11.8
3000	-	12.3	-	9.9	9.9	12.2
3500	-	14.2	-	10.7	10.8	12.5
4000	-	16.1	-	11.6	11.7	13.0
4500	-	-	-	12.6	12.7	13.4
5000	-	-	-	13.5	13.7	14.0

Table 8. Beam Diameter (Inches) vs. Distance From Laser (Feet)

Distance From Laser (Feet)	GEM 30/50	GEM 60/100	G50/100	K150	K250	K500
0	0.07	0.15	0.07	0.28	0.27	0.43
0.5	0.09	0.15	0.09	0.28	0.27	0.43
1.0	0.12	0.16	0.13	0.28	0.27	0.43
2.0	0.21	0.18	0.22	0.28	0.27	0.44
3.0	0.31	0.21	0.32	0.29	0.28	0.44
4.0	0.40	0.24	0.42	0.30	0.29	0.44
5.0	0.50	0.28	0.52	0.31	0.30	0.45
6.0	0.60	0.32	0.62	0.32	0.32	0.45
8.0	-	0.40	-	0.35	0.35	0.46
10.0	-	0.49	-	0.39	0.39	0.48
12.0	-	0.58	-	0.43	0.44	0.50
15.0	-	-	-	0.50	0.51	0.53
20.0	-	-	-	0.62	0.63	0.60

ACCESSORY MANUFACTURES AND SERVICES

Air filtration

Balston, Inc.
260 Neck Road, Box 8223
Haverhill, MA 01835-0723
(800) 343-4048
fax (508) 374-7070

Beam delivery components

Laser Mechanisms, Inc.
24730 Crestview Court
Farmington Hills, MI 48335
(810) 474-9480
fax (810) 474-9277

Beam seals, way covers

A and A Manufacturing Co. Inc.
2300 S. Calhoun Road
New Berlin, WI 53131
(414) 786-1500
fax (414) 786-3280

Centryco
300 West Broad Street
Burlington, NJ 08016
(800) 257-9537
fax (609) 386-6739

Coolants and Coolant additives

The Dow Chemical Company
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(800)447-4369

Union Carbide Corporation
U.S.A.
(800)568-4000

Tokyo Fine Chemical Co., Ltd.
Japan
+81 3 3506 7666

Virginia KMP Corp.
U.S.A.
(800)285-8567

Safety consultants

LAI International
1132 Hilford Court
San Jose, CA 95132
(408) 923-7656
fax (408) 923-6675

Water flow switches

Proteus Industries
340 Pioneer Way
Mountain View, CA 94041

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