SPI Lasers UK Limited

Product Manual

High Power Fibre Laser Systems

Note: Illustration shows water cooled variant with LLK-Q beam delivery optic

Definition of Symbols and Terms

This symbol alerts the user to the hazard of exposure to hazardous invisible laser radiation

This symbol alerts the user to the hazard arising from dangerous voltages

This symbol alerts the user to the hazard caused by the weight of the Fibre Laser

This general warning symbol emphasizes important information needed during installation and operation

This symbol identifies the protective conductor terminals (ground point)

DANGER: Describes hazards that could directly or indirectly lead to serious personal injury or death.

WARNING: Describes hazards or practices that could directly or indirectly lead to serious personal injury or death.

CAUTION: Describes hazards that could lead to personal injury or product damage.

PRODUCT: The definition of "Product" as used herein means the item that was procured from SPI Lasers UK Limited. The Product is sold ready for use for its intended purpose as a laser Product for Incorporation.

LASER INTEGRATOR: Any person that integrates the Fibre Laser into their equipment, or any person who uses the Fibre Laser in the form as supplied by SPI.

Warnings

WARNING: If the Fibre Laser described in this Product Manual is used in a manner not specified by SPI Lasers UK Ltd, the protection provided by the equipment may be impaired.

CAUTION: Attempts to modify or alter the Product, or the use of controls, adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

CAUTION: Modifications to the Product or the use of controls or adjustments or performance of procedures other than those specified herein:

- may be unsafe
- will invalidate the warranty
- may result in patent infringement

You are not authorised to modify the specification of the Product.

Ensure that operators are fully aware of all safety implications identified in the Safety Section of this Manual before attempting to install, operate or maintain the unit.

Laser Hazard Information

DANGER

- The Fibre Laser described in this Product Manual carries a Class 4 Laser rating and emits invisible laser radiation in the region of 1050–1250nm that is invisible to the human eye.
- The maximum output power in the event of a single fault condition can be up to 1.5x the rated output power of the Product. Additionally, the product contains embedded laser devices that emit invisible radiation in the region of 900–1000nm.
- Under no circumstances should the laser casing be opened unless by SPI approved service personnel.
- AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.
- Contact with direct or scattered laser radiation can cause damage to the eyes, burn human tissue and start fires.

CAUTION: The visible pilot laser described in this Product Manual carries a Class 3R laser rating and emits visible laser radiation in the region of 630-680nm with an output power up to 1mW.

This Laser may emit powers of up to 5mW under a single fault condition.

AVOID DIRECT EYE EXPOSURE.

DANGER: Before carrying out any of the maintenance tasks detailed in this Manual, ensure that power to the Fibre Laser is disconnected. Failure to do so may lead to serious personal injury or death.

CAUTION: The protective cap attached to the beam delivery optic is intended to protect the output optics from contamination during shipping and when the laser is not in use for extended periods. It SHOULD NOT be treated as a beam stop. Operating the laser with the end cap in place may result in damage to the Fibre Laser. In addition, due to the elevated temperatures associated with operating the Fibre Laser at high power with the cap in place, contact may lead to personal injury.

Electrical Hazard Information

CAUTION: Hazardous voltages exist within the Fibre Laser.

CAUTION: This Product must be grounded for safety and to comply with regional electrical codes.

Weight Hazard Information

CAUTION: This Product is heavy and can cause serious injury unless precautions are taken when lifting and moving.

Pressure Hazard Information

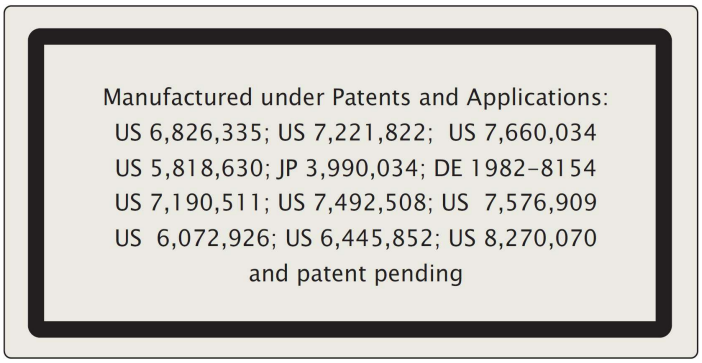
CAUTION: Ensure an approved overpressure safety device compliant with ISO4126-1 (or equivalent) is installed when connecting the Fibre Laser to an external chiller or factory water supply.

Licensing

This product carries no license by IMRA America, Inc. for pulsed operation less than 100ps.

Prior to importing into the United States of America, Germany, or Japan, please verify that United States patent no. US 5,818,630 is identified on a label attached to the Product. Please contact your sales representative if United States patent no. US 5,818,630 is NOT identified on a label attached to the Product.

An example of the label is as shown below:



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1.0 Health and Safety

The following section details all health and safety issues regarding the safe installation, operation and maintenance of the lasers described in this product manual. Also included is information on laser and electrical safety compliance.

CAUTION – If the Fibre Laser is used in a manner not specified in this manual the protection provided by the Fibre Laser may be impaired.

1.1 Intended Use of the Fibre Laser

The Fibre Laser has been designed exclusively for processing:

- solid metals, including metal alloys and metal powders
- ceramics in both solid and powder form
- plastics
- composite materials

Operating the device within the limits of its designated use requires the user to:

- observe the instructions set out in this operating manual
- install and use the Fibre Laser in compliance with international, national and local regulations regarding laser safety, for example IEC/EN 60825-1 and 21 CFR 1040.10
- install and use the Fibre Laser in compliance with international, national and local regulations regarding the safety of machinery, for example EN ISO 13849-1
- wire and connect the electrical lines to the Fibre Laser in compliance with international, national and local regulations regarding electromagnetic compatibility (EMC), for example the relevant sections of IEC/EN 61000 and FCC CFR47
- not move the Fibre Laser when it is switched on (except the output connector may be moved provided that the bending limits of the cable are observed)
- carry out necessary inspection and maintenance work

The laser is not intended:

- for processing in connection with flammable or explosive materials
- for use in an explosion prone environment

SPI cannot be held liable for any damage resulting from such use. The risk lies entirely with the system integrator.

1.2 Hazards

Laser Hazards

The Fibre Laser described in this Product Manual carries a Class 4 Laser rating and emits both invisible laser radiation up to approximately 500W CW (800W CW rated for single fault event) in the region of 1050-1250nm that is invisible to the human eye, and visible radiation of <1mW (Class 3R <5mW for a single fault event) in the region of 630-680nm. Additionally, the product contains embedded laser devices that emit invisible radiation in the region of 900-1000nm up to approximately 850W CW (1kW CW rated for single fault event).

CAUTION: Contact with direct or scattered laser radiation can cause damage to the eyes, burn human tissue and start fires.

AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.

NOTE: Where there is potential for exposure to radiation above the Maximum Permitted Exposure limit (IEC/EN 60825-1) the end user is advised to complete a documented risk assessment before operating the laser.

Materials Processing Hazards

Materials Processing can generate vapour, fumes, solid particulates and other air contaminants that may irritate, be toxic, or even fatal. It is the responsibility of the end user to ensure that all relevant safety precautions are followed and that any legal requirements are adhered to in accordance with local legislation. It is advised that Material Safety Data Sheets (MSDS) for any material to be processed are evaluated and that adequate measures for fume extraction and venting are considered.

CAUTION: The output of the laser is not optically isolated. The laser has been designed to withstand typical levels of back-reflections from material processing applications but strong back-reflections from highly reflecting surfaces can degrade the laser performance or damage the optical system.

Other Hazards

In addition to the hazards described above, the user should be aware of the following additional hazards that may be present when attempting to install, operate or maintain this equipment.

- It is recommended that the Fibre Laser should be installed sufficiently far above the floor to reduce electric risk in the case of flooding: at least 250mm is recommended.
- The user is advised to enclose the beam path wherever possible.
- The use of other optical equipment not supplied with, or intended for use with, this product may lead to an increased risk of personal injury due to exposure to optical radiation (for example equipment to focus the beam).
- The user should be aware of the increased risk of exposure to radiation and personal injury if there is a failure to use appropriate and proper eye protection (refer to Section 1.3) and a failure to adhere to and follow appropriate laser safety procedures.
- Any modification to the Fibre Laser, such as defeating or removing interlocks, housings or panels should not be attempted other than those described within the routine operation and maintenance requirements as set out in this Product Manual.

- Mechanical hazards may include moving parts in cutting, welding and material handling systems.
- High temperatures and fire hazards may also result from the operation of Class 4 lasers.

1.3 Protective Eyewear

WARNING: In circumstances where the laser beam path is exposed protective eyewear must be worn to prevent accidental exposure to laser radiation. Based on the product specification detailed in this manual, the following ratings are advised for protective eyewear in accordance with the European Standard for Personal Eye Protection EN 207:

Laser Rated Output Power	150W - 500W
Maximum Output Power [under single fault conditions]	800W
Wavelength Range	1050-1250nm
CW Mode	D LB8
Modulated Mode	I LB8

Wavelength Range	400-700nm
Alignment Goggles	RB1 (EN 208)

It is a requirement of the European Laser Safety Standard (IEC/EN 60825-14) and the US Laser Safety Standard (ANSI Z136.1) that a Laser Safety Officer (LSO) is appointed when operating Class 3B and Class 4 lasers.

The information provided above is for guidance only and your local LSO should be consulted to determine the correct level of protective eyewear for your installation.

Ensure that you select protective eyewear according to the laws, regulations and requirements applicable to your local geographical region. Contact the appropriate national and local agencies for these requirements.

WARNING: Any reduction in beam diameter conducted by the end user, e.g. resulting from the use of focus optics, will increase the optical density required for protective eyewear. It is the responsibility of the end user to ensure correct protection is in place.

WARNING: When operating in a modulation configuration, peak powers up to 5x the rated CW output power may be generated at the beginning of the pulse. Ensure that all safety eyewear is rated accordingly.

1.4 Compliance

This product is specifically designed to be an OEM laser product for incorporation or integration into other equipment. It is CE marked and is compliant with the requirements of the Low Voltage Directive, 2006/95/EC, and the EMC Directive 2004/108/EC if used and installed according to the recommendations in this document. It is the responsibility of the laser integrator to meet all of the regulatory requirements for the full system.

1.4.1 Laser Safety

CAUTION: This product is a Class 4 laser.

The product is specifically designed to be an OEM laser product for incorporation or integration into other equipment. As such, it DOES NOT MEET the full requirements for a stand-alone laser system as defined by 21 CFR 1040.10 and IEC/EN 60825-1.

Within the EU, the equipment is supplied with a Declaration of Conformity indicating the harmonised standards with which this product conforms. Within the USA, the equipment is shipped with an appropriately completed FDA 2877 form. It is the responsibility of the laser integrator to meet all of the regulatory requirements for the full system. Nonetheless, most of the electronic and labelling requirements have been incorporated into the product to facilitate final system compliance with regulatory requirements.

During installation it is vital that the laser hazard is fully managed. In particular, the laser integrator is required to provision the engineering requirements detailed in IEC/EN 60825-1. These include, but are not limited to:

- Provision of a fail-safe or redundant audible or visible emission indicator. This should be repeated at the laser aperture if it is located more than 2m from the original emission indicator (IEC 60825-1 section 4.7).
- Provision of one or more permanently attached means of attenuation (e.g. beam stop, attenuator or switch). The beam stop or attenuator shall prevent access to laser radiation in excess of Class 1M (IEC 60825-1 section 4.8)

Note that the visible Pilot Laser carries a Class 3R laser rating as defined by IEC/EN 60825-1.

Where there is potential for exposure to radiation above the Maximum Permitted Exposure limit (IEC/EN 60825-1) the end user is advised to complete a documented risk assessment before operating the laser. If this risk assessment determines that protective eyewear should be considered then an appropriate specification for alignment eyewear is defined in section 1.3.

1.4.2 Safety Related Control Circuitry

The product is specifically designed to be an OEM laser product for incorporation or integration into other equipment. The safety related control circuitry contained within the Equipment is compliant with:

- EN ISO 13849-1: part 1- Safety related parts of control systems
  - Performance Level E : PL'e'

The control standard EN954-1 has been replaced by EN ISO 13849-1 which introduces several new requirements including performance levels.

Refer to section 4.4 for further details relating to the implementation of the safety related control circuitry. It is the responsibility of the laser integrator to meet all of the regulatory requirements for the full system.

1.4.3 EMC

This equipment is specifically designed to be an OEM laser product for incorporation or integration into other equipment and is compliant with the EMC Directive 2004/108/EC when installed according to the installation instructions (section 5.0).

Within the EU, the equipment is supplied with a Declaration of Conformity against the EMC Directives. The equipment is compliant with:

- IEC/EN 61000-6-1: Electromagnetic compatibility (EMC) - Part 6.1: Generic standards-Immunity for residential, commercial and light-industrial environments
- IEC/EN 61000-6-2: Electromagnetic compatibility (EMC) - Part 6.2: Generic standards-Immunity for industrial environments
- IEC/EN 61000-6-3: Electromagnetic compatibility (EMC) - Part 6.3: Generic standards-Emission standard for residential, commercial and light-industrial environments
- IEC/EN 61000-6-4: Electromagnetic compatibility (EMC) - Part 6.4: Generic standards-Emission standard for industrial environments
- IEC/EN 61000-3-2: Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16A per phase)
- IEC/EN 61000-3-3: Electromagnetic compatibility (EMC). Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection

In addition, the equipment is compliant with:

- FCC CFR47:Part 15, subpart B: Unintentional Radiators

It is the responsibility of the laser integrator to meet all of the regulatory requirements for the full system.

1.4.4 Electrical Safety

This equipment is specifically designed to be an OEM laser product for incorporation or integration into other equipment and is compliant with the Low Voltage Directive 2006/95/EC when installed according to the installation instructions (section 4.2).

Within the EU, the equipment is supplied with a Declaration of Conformity against the Low Voltage Directive. This equipment is compliant with:

- IEC/UL/CSA/EN 61010-1: Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General Requirements

In addition, the equipment is compliant with the following National differences:

- USA & Japan

It is the responsibility of the laser integrator to meet all of the regulatory requirements for the full system.

1.4.5 RoHS Directive

Beam Delivery Connector Type: RIC and QCS (with Collimated Output)

This OEM Fibre Laser is RoHS compliant. Within the EU, the equipment is supplied with a Declaration of Conformity against the RoHS Directive.

Beam Delivery Connector Type: LLK-Q and QBH (with Divergent Output)

This OEM Fibre Laser is not compliant with the RoHS directive 2002/95/EC. However, when incorporated into large-scale stationary industrial tools as defined in the directive, the OEM Fibre Laser is exempt from the requirements for RoHS compliance in Europe. Further information can be provided by request to SPI Lasers.

1.4.6 WEEE Directive

This symbol indicates that, at end of life this product should be separately collected from unsorted waste with a view to meeting the recovery and recycling targets specified in the appropriate national regulations implementing Directive 2002/96/EC on waste electrical and electronic equipment (WEEE) for a product of its class.

1.5 Safety Features

The following safety features are incorporated within the Fibre Laser System:

Feature	Location	Description
Remote Interlock Circuit Connector	Rear Panel	Dual redundant monitored safety interlock circuit compliant with EN ISO 13849-1 PL'e'. Dual circuit connector provided for connection to safety interlock system on customer process equipment or similar. Key-switch recycle required to reset safety relay.
Key Control	Front Panel	Enables or disables the fibre laser output when safety relay is closed. Hardware controlled, overrides all system inputs. Key non-removable in the ON (laser enabled) position.
Remote Key Connector	Rear Panel	Connector provided at rear of unit for connection to remote key-switch. Wired in series with the front panel key control.
Thermal Shut Down	Internal	Thermal over-temperature protection switches to isolate the power supply to the laser pump diodes.
BDO integrity monitor: Over-temperature Sensor	Internal to Delivery Optic	A hardware thermal protection sensor is incorporated in the beam delivery optic [BDO]. If the BDO temperature exceeds the control limit the interlock circuit will open.
BDO integrity monitor: Fibre Break Sensor	Internal to Beam Delivery Optic Cable	An electrical circuit designed to detect a break in the external delivery fibre cable is wired in series with the over temperature sensor. In the event of a fibre break the interlock circuit will open.
BDO connection monitor: LLK-Q and QBH connectors only	External to Beam Delivery Connector	Proximity detection contacts are provided on the beam delivery optic which must be electrically connected when installed into a mating connector. This is wired in series with the BDO integrity monitor circuit and must be integrated such that closure enables operation of the laser.
Status Indicators (LED)	Front Panel	Series of LEDs indicating operating status of Fibre Laser. Includes Laser Emission Indicator. LED status reported on I/O to facilitate provision of remote emission indicator.
Safety Labels	Unit Exterior Unit Interior	Various location and type to warn of potential hazard or danger and to provide product and supplier contact information.

Table 1.5: Safety Features

1.5.1 Safety Interlocks

A rear panel connection is provided for integration with a closure switch operated by the customer's interlock circuit. The laser interlock circuit includes a safety relay and dual redundant monitored input circuits that are compatible with the safety and integration requirements of EN ISO 13849-1 PL'e' (refer to section 4.4).

When either pair of the terminal pins are open-circuit the Fibre Laser output will be immediately disabled and the front panel LED - ENABLED - will turn from GREEN to RED. Re-arming of the laser requires either the front panel or remote key control to be recycled. These are both hardware only based protection circuits.

1.5.2 Front Panel / Remote Key-Switch Control

There are two key controls which are connected in series, the front panel key control and the rear panel remote key control interface. Both the front panel and the remote key controls must be in the **ON** position for the laser to recognise the key state as **ON**. If either key control is switched to the **OFF** position then the laser will recognise the key state as **OFF**. While the system is running, the key control can be operated at any time. The front panel key cannot be removed when in the **ON** position.

If system power has been interrupted then either the front panel or rear panel remote key control must be reset to the **OFF** position before the Fibre Laser output can be re-enabled.

Switching either key control to **OFF** will immediately disable the Fibre Laser output. Switching the key control to **ON** will cause the front panel indication LED - ENABLED - to flash continuously from RED to GREEN during a preset arming delay (default value = 5 seconds) after which the ENABLED LED remains GREEN and laser output is enabled.

1.5.3 Thermal Protection

For safety compliance the laser is fitted with a hardware level over temperature switch that will shut down the laser if the internal temperature exceeds 60℃. Once activated, the unit will not be able to be reset until the internal temperature falls below 45℃. If this occurs, check the alarms condition status and notify SPI before restarting the laser.

Water cooled variants

If the laser cooling sub-system temperature exceeds a preset value the laser output may be disabled as a protection measure. It will not be possible to reset the alarm status until the sub-system temperature falls below the preset threshold. If this occurs check that the cooling water temperature and flow rate and the ambient operating temperature are within the specified limits.

Air cooled variants

If the laser cooling sub-system temperature exceeds a preset value the laser output may be disabled as a protection measure. It will not be possible to reset the alarm status until the sub-system temperature falls below the preset threshold. If this occurs check that the fans are operating normally, that there are no obstructions to the cooling air flow and the ambient operating temperature is within the specified limits.

Beam delivery optic

A thermal sensor is incorporated to disable the laser output if the delivery optic reaches a preset temperature. This could be caused by high ambient temperature, inadequate heat-sinking of the mounted BDO, or excessive levels of light reflected from the work piece. Once activated, the laser will not be able to be reset until the BDO temperature falls below the reset temperature at which point the reported alarm will need to be cleared (refer to table 1.5.3).

Beam Delivery Option	Activation Temperature	Reset Temperature
RIC Connector	70℃ ± 5℃	50℃ ± 5℃
QCS Connector	50℃ ± 7℃	35℃ ± 7℃
LLK-Q Connector	65℃ ± 5℃	42℃ ± 7℃
QBH Connector	70℃ ± 7℃	55℃ ± 7℃

Table 1.5.3: BDO Thermal sensor activation and reset temperatures

1.6 Product Labelling – Safety and Compliance

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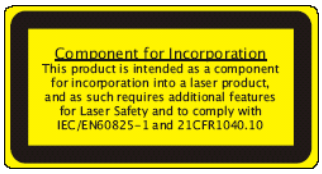
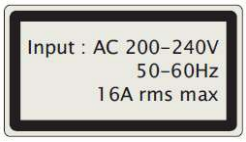
<tr><td colspan="2"> 
</td><td> 
</td></tr>
<tr><td colspan="2">Component for Incorporation
Top panel</td><td>Class 4 Laser Product
Front panel</td></tr>
<tr><td colspan="2"> 
</td><td> 
</td></tr>
<tr><td colspan="2">Wavelength and output power
Rear panel</td><td>Class 3R Laser Product for Pilot Laser
Front panel</td></tr>
<tr><td colspan="2"> 
</td><td>  </td></tr>
<tr><td colspan="2">Laser aperture warning
Beam Delivery Output</td><td>Laser Emission
Front panel</td></tr>
<tr><td>200W – 500W
products</td><td> 
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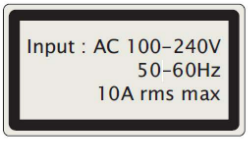
products</td><td> 
</td></tr>
<tr><td colspan="2">Mains input rating
Rear panel</td><td>Electrical hazard
Rear Electrical Connection Panel</td></tr>
</table>

Figure 1.6.1: Safety and Compliance Labels

Additional Labels- Safety and Compliance:

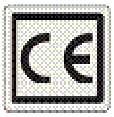
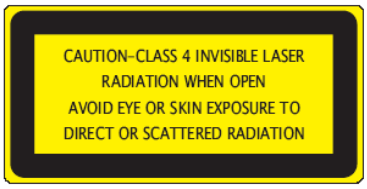
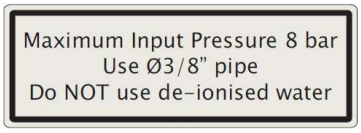
	
Protective Earth Label Internal to Electrical Connection Panel	Mains input conductor terminal designations Internal to Electrical Connection Panel
	 
Product I.D. Label Front and Rear panels	Manufacturer I.D. Label and CE Mark Rear panel
	
Warning for Class 4 Radiation behind non-interlocked access panels Internal	Warning for Class 3R and Class 4 Radiation behind non-interlocked access panels Internal
	
WEEE Label - Rear Panel	De-ionised Water Warning - Rear Panel Water Cooled Lasers Only
	
Replace Bungs Warning - Rear Panel Water Cooled Lasers Only	

Figure 1.6.1: Safety and Compliance Labels - Continued

Additional Labels - General

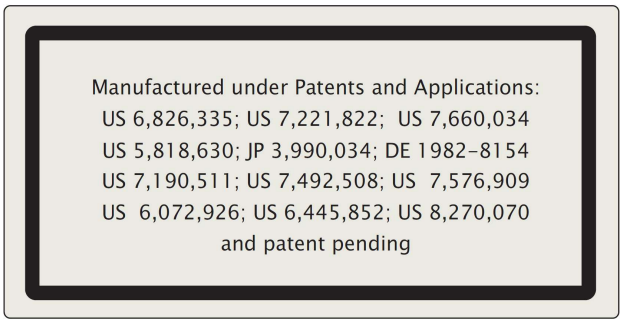
	
Beam Delivery Optic handling warning **Beam Delivery Output**	**Intellectual Property Label** Note : For illustration purposes only, and is subject to change without notification **Rear Panel**

Figure 1.6.2: Additional Labels - General

2.0 General Information

The following section details information useful to the end user and provides a means of reference and contact.

2.1 Introduction

This Product Manual describes the installation, operation and performance characteristics of the R4 High Power Fibre Laser. It also includes information regarding the safe operation and maintenance of the unit. Please read this Manual carefully before connecting the laser to any power supplies.

The laser is a complete Fibre Laser system. By 'complete' it is meant a laser system as sold and ready for use for its intended purpose without modifications to the specification of the product.

2.2 Trade Marks

The *SPI* logo, GTWave, redPOWER and redENERGY are trademarks or service marks (registered or applied for) of SPI Lasers UK Limited in at least one of the United States of America, the United Kingdom, the European Community, and various other territories throughout the world. All other trademarks are the property of their registered owners.

2.3 Warranties

SPI Lasers UK Limited reserves the right to change the information and specification contained in this manual without prior notice.

SPI expressly warrants the equipment it manufactures as set forth in the standard Terms and Conditions of sale. SPI makes no other warranties, expressed or implied, including and without limitation, warranties as to merchantability of fitness for a particular purpose.

2.4 Unpacking and Inspection

The R4 High Power Fibre Lasers are shipped in a package designed to give maximum protection. If the package shows any signs of external damage then check the laser for damage and contact the shipping agent immediately.

CAUTION: The total weight of the Fibre Laser can be up to 48kg. Improper handling may lead to personal injury or damage to the laser. Please follow the instructions included in the packaging regarding the safe removal of the unit from the packing case.

CAUTION: The Fibre Laser is supplied with 4 fixed carrying handles located at each corner of the unit. The handles have been designed and positioned to distribute the full weight of the unit evenly and safely. When lifting or moving the laser, always use all 4 carry handles to avoid risk of personal injury or damage to the laser. Lift with 2 people and use a trolley or similar mechanical assistance when moving over distance.

CAUTION: Do not lift the OEM Fibre Laser by the cooling water pipes or the fibre optic cable.

The Fibre Laser is heavy and can cause serious injury unless precautions are taken when lifting, including removing from the packing case. Suitable lifting and moving aids such as hoists and trolleys should be used whenever possible.

If manual lifting and handling are required then they should only be attempted by two able-bodied persons lifting together as a team. The duration of lifts and movements should be kept to a minimum.

The Fibre Laser should be set down in a position which facilitates further lifting. For example the Fibre Laser should not be placed on the floor or at high level but should be left at waist height whenever practicable. It is recommended that those lifting or moving the Fibre Laser wear protective footwear.

Remove all contents of the packing case, taking care to retain all packaging materials and inserts. Particular care must be taken when removing the unit from the packing case to ensure that the fibre optic cable is not snagged and damaged.

A comprehensive packing list is included with the system documentation. Upon receipt of the laser, check all items against this list and contact SPI immediately if any of the items are missing or if any damage to the unit is evident. If any damage to the unit is evident or suspected, DO NOT attempt to install or operate the laser.

Retain all packaging for future transportation or storage needs.

3.0 General Product Description

The range of R4 High Power Fibre Lasers are designed as a **PRODUCT FOR INCORPORATION** for integration into industrial and manufacturing equipment.

The Fibre Laser unit comprises semiconductor pump laser diodes, a Fibre Laser module based on SPI's GTWave™ fibre technology, electrical component drivers, thermal management and an optical fibre delivery cable with either a collimated or a divergent output beam.

The system status and output power level can be monitored and controlled by external RS232 and I/O analogue interfaces. An integrated red pilot laser is provided as an aid to process set-up and beam targeting.

The robust, monolithic design, using a fibre-based MOPA architecture, requires no optical or mechanical adjustments. The laser output power is delivered via a flexible, ruggedised fibre optic cable to allow integration with third party optical process units.

The Fibre Laser can be operated as a CW or Modulated high power laser source. It can be configured for operation in closed loop power control or open loop current control configurations, either under computer control or via an external analogue control interface depending on the required process operating conditions and the integrated system configuration.

The unit is powered from either 100-240Vac (50-60Hz) mains electricity for the 150W product or 200-240Vac (50-60Hz) mains for the 200-500W products. Internal cooling is provided by either forced air or interfaces are provided for connection to a chiller unit or factory water supply depending on the product variant.

3.1 Product Variants

The product variants covered by this manual have order codes:

SP	-	**150** **200** **250** **400** **500**	C	-	**A** **W**	-	HS	-	**S** **B** **Q** **K** **N**	-	**06** **10** **20**	-	**RIC** **QCS** **LKQ** **QBH**			

Where the bolded letters and numbers represent the following:

- The first set of bolded numbers represents the rated output power
- The first set of bolded letters represents the cooling type, where:
  - A: Air Cooled
  - W: Water Cooled
- The second set of bolded letters represent the optical interface according to Table 3.1.1, and the second set of numbers represents the output cable length
- The 3-letter reference represents the output connector type

LETTER	FIBRE TYPE	M^2 (nominal)	Core Diameter / µm (nominal)	CONNECTOR TYPE
S	SM	1.1	11	–
B	SM	1.1	20	–
Q	MM	3.5	35	–
K	MM	6.5	50	–
N	MM	15	100	–
–	–	–	–	RIC: Collimated Output
				QCS: Collimated Output
				LKQ: Divergent Output
–	–	–	–	QBH: Divergent Output

Table 3.1.1: Optical interface options

Not all combinations are available. For information regarding specific variant options contact SPI Customer Support.

4.0 Connections and Indicators

4.1 Electrical Connections

All operation connectors are situated on the rear of the unit except the LLK-Q and QBH BDO proximity detection contacts which are located on the side of the LLK-Q and QBH connector.

For connection requirements and sections relating to specification and pin designation, refer to table 4.1 below.

CAUTION: All external interconnection components and power supplies should be rated and approved to the appropriate IEC standards according to the local region of installation.

Function	Connector Type	Section	Cable / Connector Supplied
AC Mains	Harting Han® Q2/0	4.2	Unwired Connector
Remote Interlock	Circular 5-pin DIN	4.3.2	Unwired Connector
Remote Key-switch	Circular 4-pin DIN	4.3.3	Yes Pre-Wired Connector
Analogue I/O	25-pin female D-Type	4.3.4	No
Modulation Input	BNC	4.3.5	Yes Pre-Wired Connector
RS232 Communications	9-pin female D-Type	4.3.6	Yes Pre-Wired Connector
BDO Proximity Detector [LLK-Q and QBH Beam Delivery Options Only]	Contact pads	4.3.8	No

Table 4.1: Electrical Connection Check List

4.2 Power Supply Requirements and Connections

CAUTION: This equipment must be protected by an appropriately rated and approved Branch Circuit Protection device

CAUTION: It is recommended that this equipment is connected to a mains supply source with external Residual Current Device (RCD) protection

CAUTION: Do not conduct a PAT test (resistance test) or insulation test (flash or Hi-Pot test) on the Fibre Laser using an AC applied voltage.

A DC applied voltage must be used.

To ensure compliance with IEC/EN 61010-1, the electrical safety isolation barrier within the power supply is subjected to a 2.2kV DC isolation test (primary to secondary and primary to earth) during the power supply manufacturing process and also as part of laser production line testing.

The internal AC-DC power supply is CE marked and compliant with:

- IEC/EN 60950-1: Information technology equipment - Safety - General requirements.

CAUTION: Depending on the model type the Fibre Laser must only be connected to either **100-240V (±10%) (50-60Hz)** or **200-240V (±10%) (50-60Hz) AC** mains power source. The power supply cable must be rated to the specification defined in this section and must also comply with the regulatory requirements of the country in which the laser is installed.

Connection to an AC power source is made by a user-wired Harting Han® Q2/0 connector (refer to Section 4.2.1 for wiring instructions). The electrical input is protected using a two pole 20A miniature circuit breaker (MCB) with a Type B trip characteristic.

The maximum continuous supply current is listed in tables 4.2 and 10.3. The Fibre Laser rating plate labels are shown in figure 1.6.1:

Laser Output Power	Operating Voltage	Maximum Continuous Supply Current
150W	100-240Vac (±10%) (50-60Hz)	10A
200W - 500W	200-240Vac (±10%) (50-60Hz)	16A

Table 4.2: Maximum Continuous Supply Current Rating

4.2.1 Mains Wiring Connections to the Equipment

WARNING: This equipment must be earthed or grounded

CAUTION: This equipment must be protected by an appropriately rated and approved Branch Circuit Protection device

DANGER: The laser system must be isolated or disconnected from the mains supply before opening the power connection panel.

CAUTION: The power cord must be provided with a means of disconnection from the supply. It shall be in close proximity to the equipment and within easy reach of the operator, it shall be marked as the disconnect device for the equipment.

WARNING: On completion of the power supply cable wiring procedure and before connecting to a power source:

1. Ensure the Harting connector assembly is secure and the cable gland has been tightened.
2. Verify and test the cable according to local regional electrical codes.

1. Select an appropriate mains power supply cable type with minimum specification / rating equivalent to the following example:
   - Type: SJO
   - Cross section: 3 core x 14AWG or 2.5mm^2
   - Voltage rating: 300V
   - Current rating: ≥20A
   - Temperature rating: 90°C
   - Flammability: VW-1
   - Cable type: Flexible conductor

2. Refer to table 4.2.1 for a component parts list for the Harting Han® Q2/0 connector.

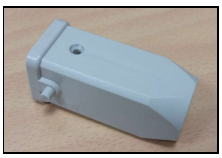
Description	Harting Han® Part Number	Illustration
Connector Insert	09 12 002 2753	
Cable Gland: M20 x1.5 [For cable diameter 6mm – 12mm]	19 00 000 5182	
Straight Connector Housing	19 20 003 0420	
Right Angled Connector Housing	19 20 003 0620	

Table 4.2.1: Harting Han® Q2/0 connector part numbers

3. Prepare the power supply cable according to the stripping diagram, figure 4.2.1.

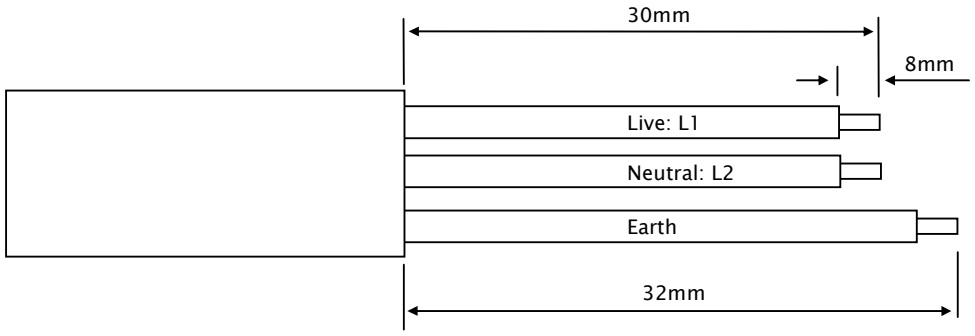


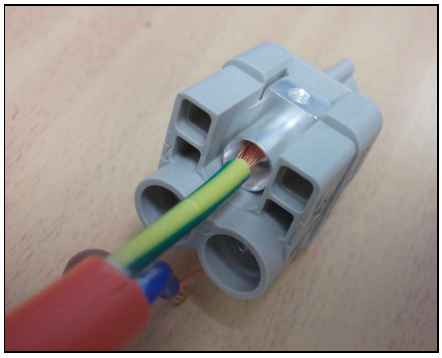
Figure 4.2.1: Power Supply Cable Preparation Diagram

4. Pass the pre-prepared power supply cable through the cable gland and housing of the Harting Han® Q2/0 connector as shown in figure 4.2.2.

Figure 4.2.2: Harting Han® Q2/0 connector – cable gland and housing

5. Push the stripped end of the earth conductor into the central connector insert; this is clearly marked with an earth symbol. The bare conductors should be pushed over the cone (refer to figure 4.2.3).

6. Tighten the cone with a 2mm hexagonal driver (Allen key) to a torque of 1.8Nm as shown in figure 4.2.3.



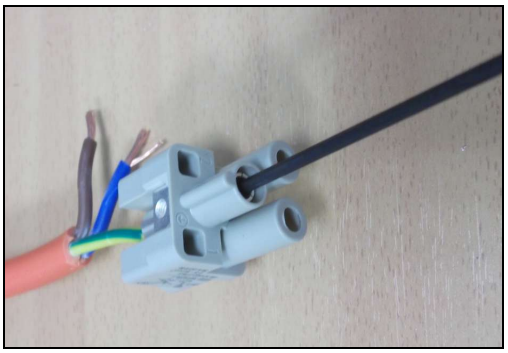


Figure 4.2.3: Harting Han® Q2/0 connector insert – cone connection technique

7. Repeat these steps for the Live (L1) and Neutral (L2) conductors as shown in figure 4.2.4. Note that UK wiring colours are displayed in the photo.

CAUTION: It is important that the Live conductor is connected to the insert marked 1 on the housing (the photo shows UK wiring colours and convention and is the brown wire in this case).

The Neutral conductor should be connected to the insert marked 2 on the housing (the photo shows UK wiring colours and convention and is the blue wire in this case).

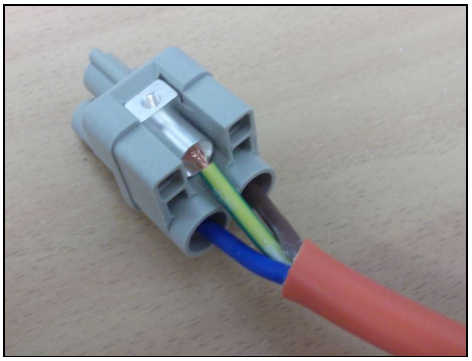


Figure 4.2.4: Harting Han® Q2/0 connector insert – UK wiring orientation

8. Push the insert into the connector housing and tighten the locking screw to a torque of 0.5Nm (refer to figure 4.2.5).
9. Tighten the cable gland nut as shown in figure 4.2.5 and confirm the cable is secure.

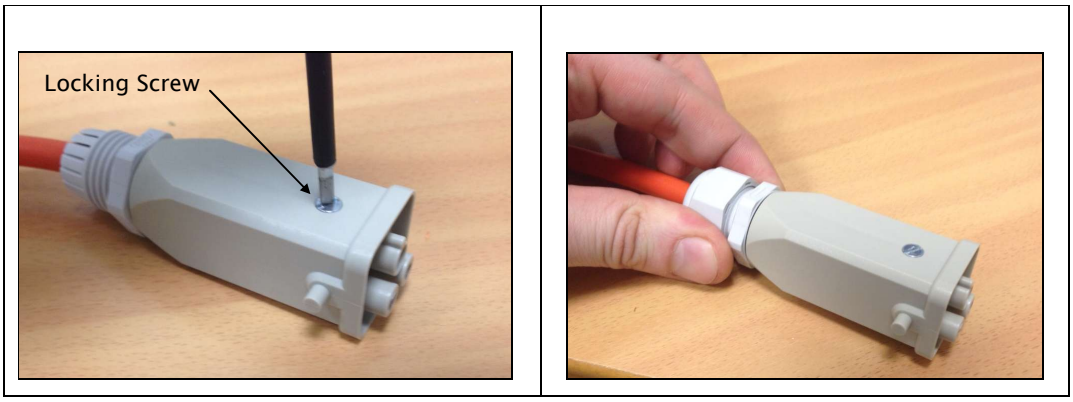


Figure 4.2.5: Harting Han® Q2/0 connector – fully assembled

10. Ensure the cable assembly is isolated or disconnected from the mains supply; connect the cable assembly to the laser and ensure the locking clip is closed (refer to figure 4.2.6).

Figure 4.2.6: Harting Han® Q2/0 connector – connection to the laser

11. Note that a right angled version of the Harting Han® Q2/0 connector is available from SPI as an optional accessory (refer to figure 4.2.7). This connector should be assembled using the same procedure as for the straight connector shown above. Please contact SPI for further details.

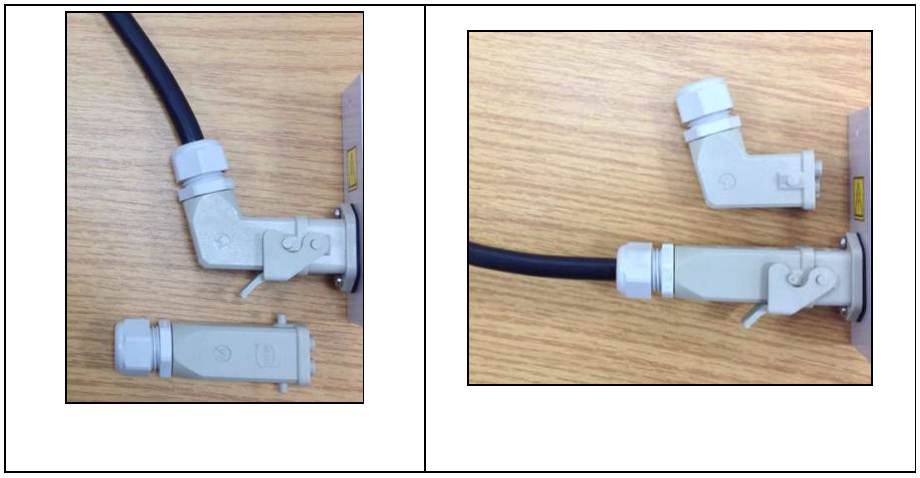
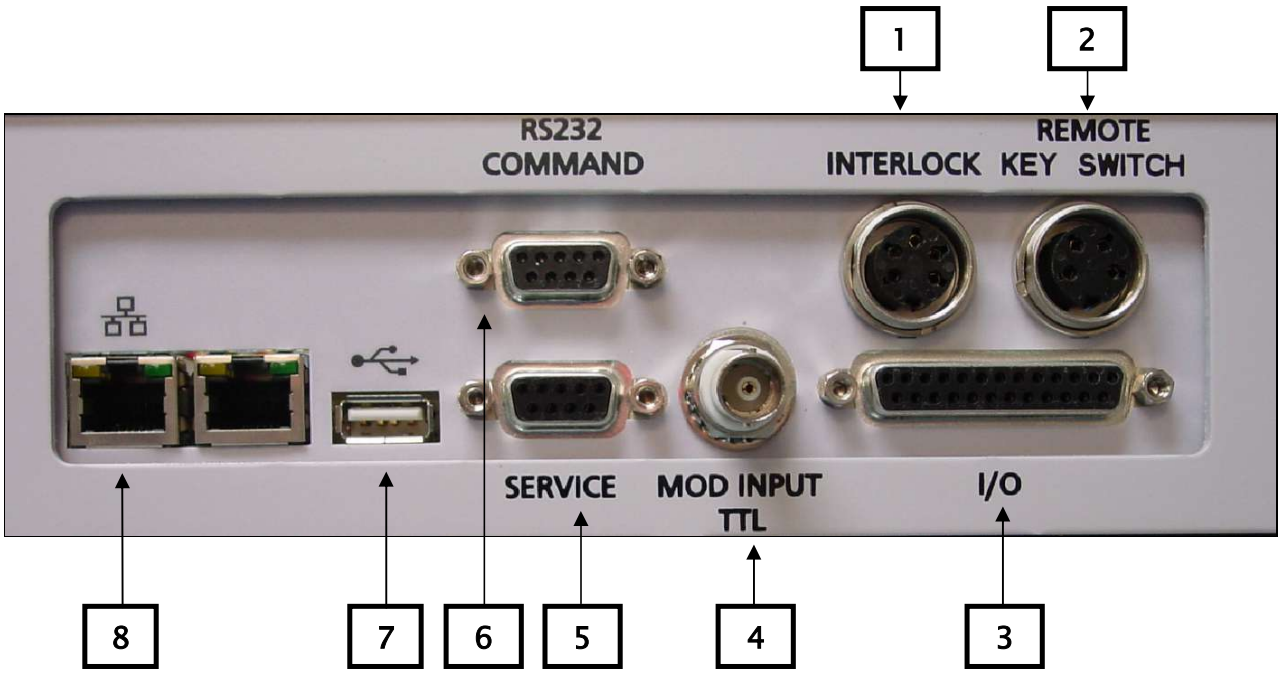


Figure 4.2.7: Harting Han® Q2/0 connector – right angled connector option

12. Verify and test the cable according to local regional electrical codes.

4.3 Control and Communication Interfaces

4.3.1 Rear Panel Connections



Interface I.D.	Description	Connector Type	Refer to section
1	Interlock	5-pin circular DIN	4.3.2
2	Remote Key switch	4-pin circular DIN	4.3.3
3	I-O connector	25-Pin Female D Type	4.3.4
4	Modulation connector	BNC 50Ω	4.3.5
5	Service comms port	9-Pin Female D Type	SPI Use only
6	RS232 comms port	9-Pin Female D Type	4.3.6
7	USB comms port	USB	Not enabled
8	Ethernet comms port	RJ45	4.3.6

Table 4.3.1: Rear panel control interface connections

4.3.2 Rear Panel Interlock Connector

A rear panel connection is provided for integration with the customer safety interlock circuit. The laser interlock circuit includes a safety relay and dual redundant monitored input circuits that are compatible with the safety and integration requirements of EN ISO 13849-1 PL'e' when connected to the customer side safety interlock circuit closures that conform to the same safety level (refer to section 4.4).

The five-pin circular DIN socket situated on the rear panel provides a 24V dual circuit which must be wired into a dual switch closure provided by the customer.

An unwired plug is supplied to facilitate customer integration. The rear panel socket pin designation is as shown below.

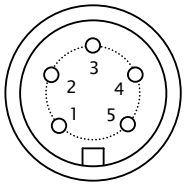


Figure 4.3.2: Remote Interlock Connector Pin Diagram

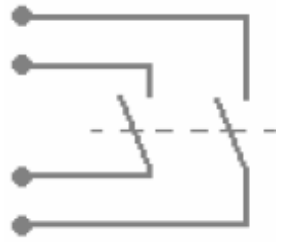
Pin	Signal Description	Diagram	Notes
1	Interlock return circuit 1 (input)		**IMPORTANT** The dual circuit interlock connections require switch closures only. Do not connect any external voltages to these pins
2	Interlock return circuit 2 (input)		
3	No connection		
4	Interlock feed circuit 2 (output)		
5	Interlock feed circuit 1 (output)		

Table 4.3.2 Interlock Connector Pin Designation

CAUTION: When linking the rear panel interlock connector to an external interlock system use only foil screened cable. Ensure that the screen is attached through 360° to both ends of the metal connector shell (ground) and the cable length is less than 30m. The cable selected must be rated to carry the 24V DC (with respect to chassis ground) interlock signals. The cable must also be rated to carry 100mA per conductor.

If either or both of the two interlock circuits are opened the interlock circuit will disable the Fibre Laser output and make the unit safe. Both circuits must be closed in order to operate the unit.

If a replacement plug is required, please contact SPI for part number and ordering information.

4.3.3 Rear Panel Remote Key switch Connector

The rear panel remote key-switch is a four-pin circular DIN socket enabling connection of a remote key-switch. The pin designations are shown in Table 4.3.3 , however the laser is supplied with a pre-wired jumper plug should a remote key-switch not be required.

If a replacement plug is required, please contact SPI for part number and ordering information.

CAUTION: When using an external key-switch use only foil screened cable, ensure that the screen is attached through 360° to both ends of the metal connector shell (ground) and the cable length is less than 30m.

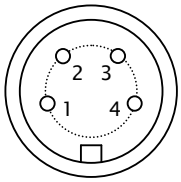


Figure 4.3.3: Remote Key Control Pin Diagram

Pin	Signal Description
1	+24 V DC Closure Feed
2	+24V DC Closure Return
3	Safety relay status monitor zero voltage contacts OPEN = INTERLOCK ENABLED CLOSED= INTERLOCK OPEN
4	

Table 4.3.3: Remote Key Control Pin Designations

4.3.4 Analogue Input and Output Interface Specifications

The I/O control interface is used to monitor the laser system status and provide analogue control of the laser output in conjunction with the RS232 communications interface. The I/O connector is a 25 pin female D-Type situated on the rear of the unit with pin designations as defined in table 4.3.4(ii).

Considerations when selecting 5V or 24V operation

- Where the voltage level is defined in table 4.3.4(ii) as 0V-24V the electrical response will be faster if a 5V TTL signal is used. It is recommended that a 5V signal is used for high speed modulation requirements.
- The digital inputs incorporate internal protection against over-voltage conditions. Refer to table 4.3.4(i) for impedance values associated with the I/O connector.

Signal Type	Impedance
Analogue Input	4.8 kΩ
Analogue Output	1.0 kΩ
Digital Input	10 kΩ
Digital output	Open collector transistor
Photodiode Output (pin 24)	50 Ω

Table 4.3.4(i): Analogue I/O Port Impedance Values

CAUTION: When connecting to the I/O control interface use only foil screened cable and ensure that the cable screen is attached through 360° to the laser end of the metal connector shell (ground). Ensure the cable is less than 30m in length and the signal ground input is connected to the cable screen or drain wire.

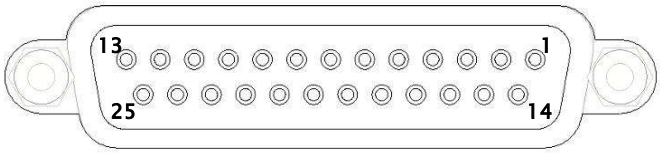


Figure 4.3.4: Analogue I/O Port 25- Pin Numbering

PIN	TYPE	SIGNAL DESCRIPTION	LEVEL	ACTIVE	FUNCTION
1	INPUT	MODULATION	0V –24V	TTL level switching threshold HIGH = LASER EMISSION	Laser will emit when HIGH provided ENABLE (pin 2) is LOW or ENABLE is disconnected.
2	INPUT	ENABLE	0V –24V	TTL level switching threshold LOW = ENABLE	Enables MODULATION (pin 1) when LOW. When HIGH laser does not emit. To emit MODULATION must be HIGH and ENABLE LOW or ENABLE disconnected.
3	INPUT	USE EXTERNAL INTERFACE	0V –24V	TTL level switching threshold HIGH = USE EXTERNAL I/O	Specifies this interface to be used for control. When active this will disable some computer interface commands.
4	INPUT	OPEN/CLOSED LOOP	0V –24V	TTL level switching threshold HIGH = OPEN LOOP	Defines which mode should be used. Only valid when the USE THIS INTERFACE input is active.
5	INPUT	TARGET LASER CONTROL	0V –24V	TTL level switching threshold HIGH = Pilot laser ON	Visible pilot laser control
6	INPUT	ALARM RESET 1	0V –24V	TTL level switching threshold HIGH = Reset Last Alarms	Reset alarms with user level authorisation
7	INPUT	ALARM RESET 2	0V –24V	TTL level switching threshold HIGH= Reset Last Alarms	Reset alarms with supervisor level authorisation
8	N/A	NOT USED	N/A	NO CONNECTION	
9		DIGITAL I/P GND			This pin must be used as a ground for any of the digital inputs in this table

Table 4.3.4(ii): Analogue I/O Port Pin Diagrams

10	OUTPUT	ALARM INDICATOR	O/C	Open collector (no pull up) LOW = ALARM PRESENT	Indicates an alarm is present. Replicates the ALARM LED on front panel.
11	OUTPUT	EMISSION INDICATOR	O/C	Open collector (no pull up) LOW = EMITTING	Indicates that laser emission is taking place. This output will persist for 0.5 seconds after the rising edge of the modulation signal. Replicates the EMISSION LED on front panel.
12	INPUT	PPC/APC MODE	0V –24V	TTL level switching threshold HIGH = PPC/ LOW=APC	Select Pulse Power Control (PPC) / Average Power Control (APC)
13	OUTPUT	LASER ENABLED INDICATOR	O/C	Open collector (no pull up) LOW = LASER ENABLED	Indicates the laser is ready to emit. Replicates the EMISSION LED on front panel.
14	OUTPUT	TARGET LASER STATUS	O/C	Open collector (no pull up) LOW = PILOT LASER ON	Indicates if the pilot laser is on.
15	OUTPUT	STATUS 1	O/C	Open collector (no pull up)	Indicates the state of unit in combination with Status 2, Status 3 and Status 4. Up to 16 states available.
16	OUTPUT	STATUS 2	O/C	Open collector (no pull up)	See Status 1
17	OUTPUT	STATUS 3	O/C	Open collector (no pull up)	See Status 1
18	OUTPUT	STATUS 4	O/C	Open collector (no pull up)	See Status 1
19	OUTPUT	WARNING	O/C	0V= Warning ON	Warning level. Indicates that a level is close to triggering an alarm.
20		NOT USED	O/C	Open collector (no pull up)	
21		DIGITAL O/P GROUND	.		This pin is connected to the grounds of all the O/C outputs. Refer to 6.2.5 for wiring details
22	INPUT	SET POWER	0V –10V	Protected against inputs up to 24V DC 0V = 0 watts 10V = rated power in watts	Sets the optical power output
23	OUTPUT	POWER LEVEL INDICATOR	0V –10V	0V = 0 watts 10V = rated power in watts	Indicates the power level in pulse or CW mode
24	OUTPUT	PHOTO DIODE	0V–0.7V	Output impedance of 50Ω	Buffered analogue output of output power photodiode.
25		ANALOGUE GROUND			This pin must be used as the ground for both analogue inputs and analogue outputs.

Table 4.3.4(ii): Analogue I/O Port Pin Diagrams – continued

4.3.5 External Modulation Input

An alternative modulation input to the laser is provided by a high impedance BNC connector situated on the rear panel of the unit.

CAUTION: Do not use this connector if the modulation input provided by Pin 1 of the Analogue I/O port is connected. Refer to Section 4.3.4

The modulation signal is used to switch the laser output power between the Mark power level and the Idle power level. This is a TTL voltage level signal with corresponding electrical requirements as given in Table 4.3.5(i) below

Parameter	Units	Specification	
		Minimum	Maximum
High Level Input Voltage	V	3.2	24
Low Level Input Voltage	V	0	0.8

Table 4.3.5(i): TTL Signal Levels

The following pin designation applies to the connector:

Pin	Signal
Centre	Positive: 0-5V/24V DC
Case	Ground

Table 4.3.5(ii): Modulation Input Connector Pin Designation

CAUTION: SPI recommend use of the 50Ω fully screened co-axial cable supplied. If an alternative screened cable is used then ensure the screen is attached through 360° to both ends of the metal connector shell (ground), is less than 30m in length and the cable is of style RG58.

4.3.6 RS232 Communications

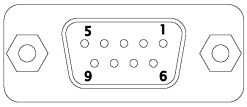
The RS232 interface is a ±12V DC voltage level implementation of the RS-232C standard. It is used to exchange messages, commands and enquiries between the Fibre Laser and the host PC.

The RS232 connector is a 9 pin female D-Type situated on the rear of the unit with the following pin designations:

CAUTION: When connecting to the RS232 interface use only the foil screened RS232 cable supplied by SPI. If an alternative screened cable is used then ensure the foil screen is attached through 360° to both ends of the metal connector shell (ground), the cable length is less than 30m and that pin 4 is not connected.

It is recommended that moulded style cables are not used.

RS232



Pin	Signal	Description
1	N/C	
2	Receive RS232	The communications data received from the PC. ±12VDC voltage levels are used
3	Transmit RS232	The communications data transmitted to the PC. ±12VDC voltage levels are used
4	-	SPI Use only
5	Ground	0V line, connected to case ground.
6	N/C	
Shell	Ground	The cable screen or drain wire should be connected to ground. The cable screen should be attached through 360° to the laser end of the metal connector shell.

Table 4.3.6(i): RS232 Pin Designations

RS232 communications protocol and data format is described in the following table:

Parameter	Specification
Baud Rate	Variable: 9600 - 115200
Start Bits	1
Data Bits	8
Parity	Even
Stop Bits	1
Flow Control	None

Table 4.3.6(ii): RS232 Communications Protocol

4.3.7 Front Panel LEDs

Figure 4.3.7: Front Panel LEDs

The LEDs on the front panel of the unit indicate the operational and alarm status of the Fibre Laser. When the LED colour is RED, an alarm function is being reported or a function is disabled. When the LED is GREEN, a function has been enabled. The Amber emission LEDs indicate that the Laser is active.

LED	Function	Modes
Laser Enabled (x2)	Indicates that the laser driver circuit is enabled and laser emission is under software control. Two laser enabled status LEDs are provided for component redundancy	RED = Laser disabled. RED/GREEN FLASHING = Laser driver circuit arming warning (default 5 second delay) GREEN = Laser driver circuit enabled
Laser Emission (x2)	Indicates a TTL Voltage Signal is present. Two laser emission status LEDs are provided for component redundancy	OFF = Laser TTL signal low (Laser OFF) AMBER = Laser TTL signal high (Laser ON)
System Error	Reports a system fault	RED = Alarm active. GREEN = No faults detected.
Pilot Laser	Indicates the status of the red pilot laser	AMBER = Pilot laser ON Not illuminated = Pilot laser OFF

Table 4.3.7: LED Status

4.3.8 LLK-Q and QBH Proximity Detector Contacts

An additional function is provided with the LLK-Q and QBH connectors which ensures that the laser cannot be enabled until the BDO is installed in a mating connector such as an external collimator or process head. This comprises two contact pads wired in series with the BDO integrity monitor circuit which must be electrically connected (short circuited) to complete the integrity circuit (refer to figure 4.3.8 below for the LLK-Q variant, figure 4.3.9 for the QBH variant and also to section 5.3).

In order to prevent the contacts from being accidentally short-circuited when the connector is not installed the LLK-Q connector incorporates an additional protective shroud which retracts as the connector is inserted into the external collimator or process head. The white shroud is shown in figure 4.3.8.

The pin designations are shown in table 4.3.8. Pin 1 should be connected to pin 2 and isolated from ground. Note that the laser may be supplied with the mechanical positions of pin 1 and pin 2 reversed.

Figure 4.3.8: LLK-Q Proximity Detector Contacts and Retractable Shroud

Figure 4.3.9: QBH Proximity Detector Contacts

Pin	Signal Description
1	+5 V DC Closure Feed or Return
2	+5 V DC Closure Return or Feed

Table 4.3.8: LLK-Q and QBH Proximity Detector Contact Designations

4.4 Safety Related Control Circuitry

This product is specifically designed to be an OEM laser product for incorporation or integration into other equipment. The safety related control circuitry contained within the equipment is compliant with:

- EN ISO 13849-1: part 1- Safety related parts of control systems
  - Performance Level E : PL'e'

The control standard EN954-1 has been replaced by EN ISO 13849-1 which introduces several new requirements including performance levels.

Two interlock detection circuits are provided from the rear panel interlock connector (refer to section 4.3.2). Both of these circuits must be wired in parallel through all interlock components and switches that form part of the user's external laser safety circuitry. These may include, but are not limited to, doors or aperture covers of a laser safety enclosure. If any interlock component in the user's external circuit is opened (e.g. door or aperture in the laser safety enclosure) then both of the interlock detection circuits must be broken. If either or both of the two interlock circuits are opened the interlock circuit will disable the Fibre Laser output and make the unit safe. Both circuits must be closed in order to operate the laser.

No other feature on the laser may be regarded as a safety feature. This includes the front or rear panel key switches.

4.4.1 Fault Exclusions

There are no fault exclusions taken into account to achieve the above safety rating.

4.4.2 Deviations

No deviations from the above safety rating have been accounted for.

4.4.3 Interface Description

Connection to the safety circuit is made though the rear panel connector marked "INTERLOCK" (refer to section 4.3.2). The safety circuit must be wired according to figure 4.4.3 below. Each Input (contact) pair MUST BE INDIVIDUALLY MONITORED to maintain an overall PL'e' performance.

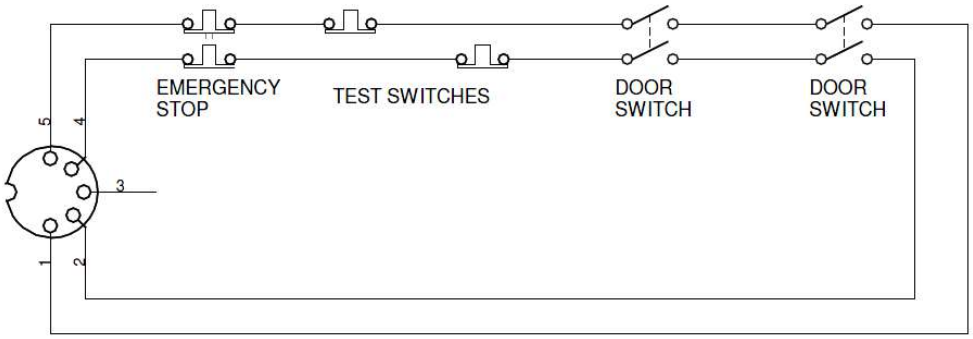


Figure 4.4.3: Safety Circuit Connection Requirements

4.4.4 Internal Architecture

The internal architecture of the fibre laser comprises dual redundant shut down circuits. If one of the safety circuits fails then the remaining circuit will put the laser into a safe condition. Following failure of one of the circuits the laser cannot be restarted.

4.4.5 Response Time

The typical delay between the interlock being broken and the laser being made safe is 30 milliseconds.

4.4.6 Operating Limits and Environmental Conditions

There are no additional operating limits or environmental conditions that affect the laser safety circuit other than those that apply to the laser in its entirety.

4.4.7 Muting and Suspension

The safety circuit cannot be muted or suspended.

4.4.8 Control Modes

The safety circuit has no control modes.

4.4.9 Troubleshooting

The safety circuit is normally armed by closing the key switch on the front panel. A successful sequence is as follows (refer to section 7.1 for laser start-up sequence):

- Turn on the mains power supply to the unit using the mains circuit breaker. The **Laser Enabled** (x2) LEDs shall be illuminated RED. The **System Error** LED shall be illuminated GREEN and both the **Laser Emission** (x2) and **Pilot Laser** LEDs shall be OFF.
- Ensure that the interlock circuit connected to the rear panel INTERLOCK connector is closed.
- If the rear panel connector does not have a remote key-switch attached then ensure the pre-wired plug is installed.
- Turn both the front and rear panel key controls to the **ON** position. Switching the key control to **ON** will cause the front panel indication LED – ENABLED – to flash continuously from RED to GREEN during a preset arming delay (default value= 5 seconds) after which the ENABLED LED remains GREEN and laser output is enabled

If this sequence is not completed check the following:

i. Check that the rear key switch is closed, otherwise the ENABLED LEDs will not flash. This indicates that the laser has not tried to arm the safety circuit.

ii. If the ENABLED LEDs do flash but then turn red the laser has attempted to arm the safety circuit but has failed because the interlock circuit is not complete. Check the integrity of both interlock circuits. Also check that the interlock circuits are not connected together as this will also prevent the safety circuit from arming.

The laser also carries out a self check of the safety circuit and if an error occurs an alarm may be generated (refer to section 8.0). If an alarm is generated when the user attempts to arm the laser then contact SPI for advice.

Refer to section 12.2 for maintenance requirements associated with this safety related control circuitry.

5.0 Installation

5.1 Laser Safety Provisions During Installation

This product is a Class 4 laser. The product is specifically designed to be an OEM laser product for incorporation or integration into other equipment. As such, it DOES NOT MEET the full requirements for a stand-alone laser system as defined by 21 CFR 1040.10 and IEC/EN 60825-1.

During installation it is vital that the laser hazard is fully managed. In particular:

- If not incorporated into a Class 1 enclosure or environment, the laser integrator is required to provide an emission indicator at the laser aperture (section 4.7.3 of IEC/EN 60825-1).

- If not incorporated into a Class 1 enclosure or environment, the laser integrator is required to incorporate one or more permanently attached means of attenuation (e.g. beam stop, attenuator or switch). The beam stop or attenuator shall be capable of preventing human access to laser radiation in excess of the AEL for Class 1M (section 4.8 of IEC/EN 60825-1).

Note that the visible Pilot Laser carries a Class 3R laser rating as defined by IEC/EN 60825-1.

Prevent direct eye exposure to the beam. Do not direct the beam at other people or into areas where other people unconnected with the laser work may be present.

Where there is potential for exposure to radiation above the Maximum Permitted Exposure limit (IEC/EN 60825-1) the end user is advised to complete a documented risk assessment before operating the laser. If this risk assessment determines that protective eyewear should be considered then an appropriate specification for alignment eyewear is defined in section 1.3.

5.2 General Installation and Cooling Requirements

The laser is designed as a rack-mounted sub assembly for integration into a standard 19" rack system. In all installation environments, ensure that sufficient space is allowed for at the rear of the laser to avoid tight bends on the fibre optic beam delivery cable and to allow for access to power, communications and interlock connectors. In particular, the miniature circuit breaker (MCB) at the rear of the unit should be readily accessible.

CAUTION: The weight of the Fibre Laser is up to 48kg. When mounting the laser in a 19" rack system, never rely on the front panel mounts to support the weight of the laser. Use rails with a load rating of >50kg to support the underside of the laser system. Failure to do so may lead to damage to the equipment and other equipment fitted in the rack.

5.2.1 Cooling Requirements for Air Cooled Lasers

For air cooled models, the laser components and power supplies within the unit are cooled by internal forced air drawn through a grille in the front panel and exhausted through the rear panel. For optimum airflow and cooling performance ensure that there is at least 40mm of clearance in front of the ventilation grilles at the front and rear of the unit and that they are kept free from obstructive materials.

The laser must be operated within the specified environmental temperature and humidity limits always above the dew point. Failure to comply with this will invalidate the warranty and may lead to accelerated component aging and some performance degradation. In addition, operation below the dew point may lead to catastrophic failure.

5.2.2 Cooling Requirements for Water Cooled Lasers

For water cooled variants a compatible 19" rack mounted re-circulating water to air heat exchanger may be supplied as an option. Specifications for the chiller unit are detailed in Table 10.4.

CAUTION: To avoid corrosion to the cooling circuit components within the Fibre Laser the use of deionised water is not permitted.

- It is recommended that a particle filter is installed when using either a factory water supply or an external chiller supply; this should have a filter grade of 100µm.
- Where there is a possibility that the water temperature may fall below 0°C then it is recommended that an appropriate anti-freeze additive is used to prevent frost damage to the laser. Please contact SPI for further advice.
- It is also recommended that anti-fungal inhibitor is added to the water supply. Please contact SPI for further advice.

The laser must be operated within the specified environmental temperature and humidity limits always above the dew point. Failure to comply with this will invalidate the warranty and may lead to accelerated component aging and performance degradation. In addition, operation below the dew point may lead to catastrophic failure.

5.3 Beam Delivery System: Installation

5.3.1 General Routing of the Fibre Delivery Cable

CAUTION: Fibre delivery cables and connectors are precision optical parts

- Avoid contamination and mechanical stress when handling
- Avoid shocks and impacts on optical connectors
- Avoid pulling, twisting and over-bending of the cables

Avoid kinking and twisting the cable by unrolling the coil, rather than pulling it straight.

When laying and connecting:

- Bend radius must be larger than that given in table 11.2.1 and table 11.2.2
- Maximum tensile loading: 200N (approximately 20kg)
- Remove protection caps slowly holding the optical connector downwards to avoid contamination settling on the optical surface
- Lay cables so that they are well-protected
- Do not grease optical connectors

The protection cap should only be removed after the cable is routed and immediately before it is connected to the processing optics. If the cable is fed through openings, the openings must be sufficiently large that the optical connector with protector can be fed through without applying any force. Each optical connector change incurs the risk of contaminating or damaging the connector, therefore optical connectors should only be changed when required. Immediately after optical connectors are removed protection caps must be fitted.

Optical connectors must be inspected, and cleaned if necessary, before being replaced (refer to section 12.1).

When connecting to a robot, route the cable separately from the other lines to avoid dynamic stresses and strains on the BDO, which can occur when the robot moves quickly.

If a balancer is used, tie the cable to the rope of the balancer so that:

- The rope takes the tensile loading and not the optical connector
- The cable has sufficient slack for all kinds of robot motions without bending below the minimum bend radius

5.3.2 LLK-Q Beam Delivery System (divergent output)

It is essential that the LLK-Q connector is adequately cooled with a separate source of clean, chilled water in accordance with the specifications listed in table 10.5.1(i). The connector contains an internal mode stripper designed to remove light coupled into the fibre cladding in the event of a back reflection from the work piece. Operating the laser without an adequate flow of cooling water may result in catastrophic damage to the LLK-Q connector.

The cooling circuit is terminated with Parker Rectus type 21 couplings as shown in figure 5.3.2(i) and table 5.4.

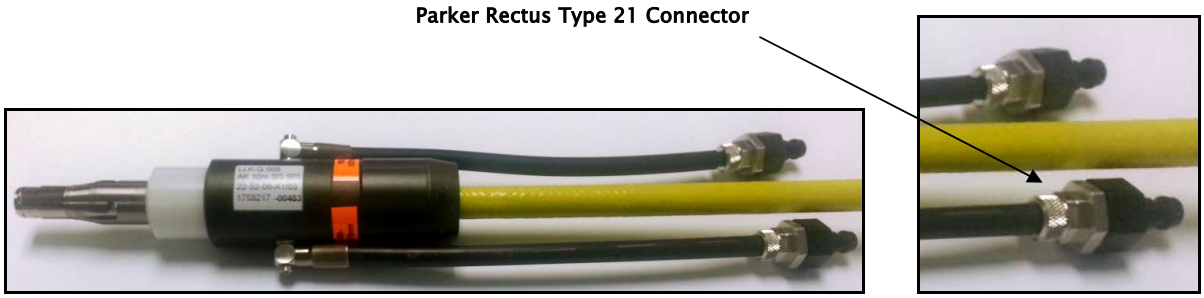


Figure 5.3.2(i): Water Cooling: LLK-Q BDO Connections

The LLK-Q connector should be installed as follows:

1. Carefully route the delivery fibre following the instructions in section 5.3.1 taking care not to exceed the minimum bend radius as specified in table 11.2.1.
2. Position the focussing optics or process head so that the shaft of the receptacle for the connector is horizontal.
3. Remove the sealing plug from the receptacle.
4. Remove the protective plastic cap from the LLK-Q connector (refer to figure 5.3.2(ii)). This is used only to protect the connector from contamination and damage during shipment and storage.

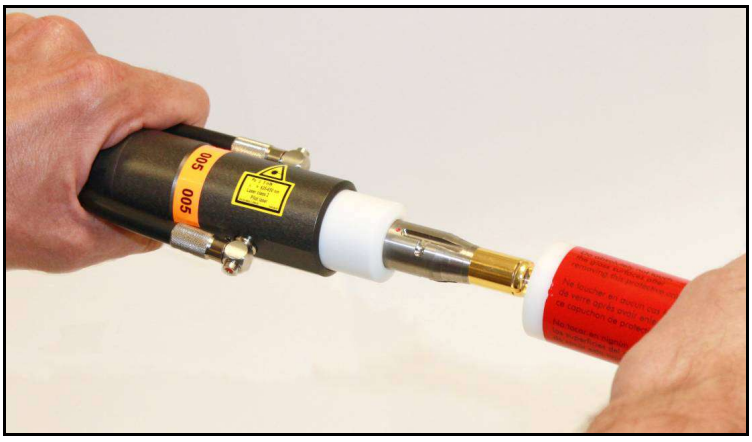


Figure 5.3.2(ii): LLK-Q Protection Cap Removal

5. Inspect the connector for contamination using appropriate magnification and illumination, and clean if necessary, following the instructions in Section 12.1.

6. Install the LLK-Q connector into the process head, collimating optics or adapter using the 2-step bayonet fitting on the front of the connector. Ensure the red dot on the connector is aligned with the two red dots on the receptacle (refer to figure 5.3.2(iii)).

Figure 5.3.2(iii): Installing the LLK-Q Connector

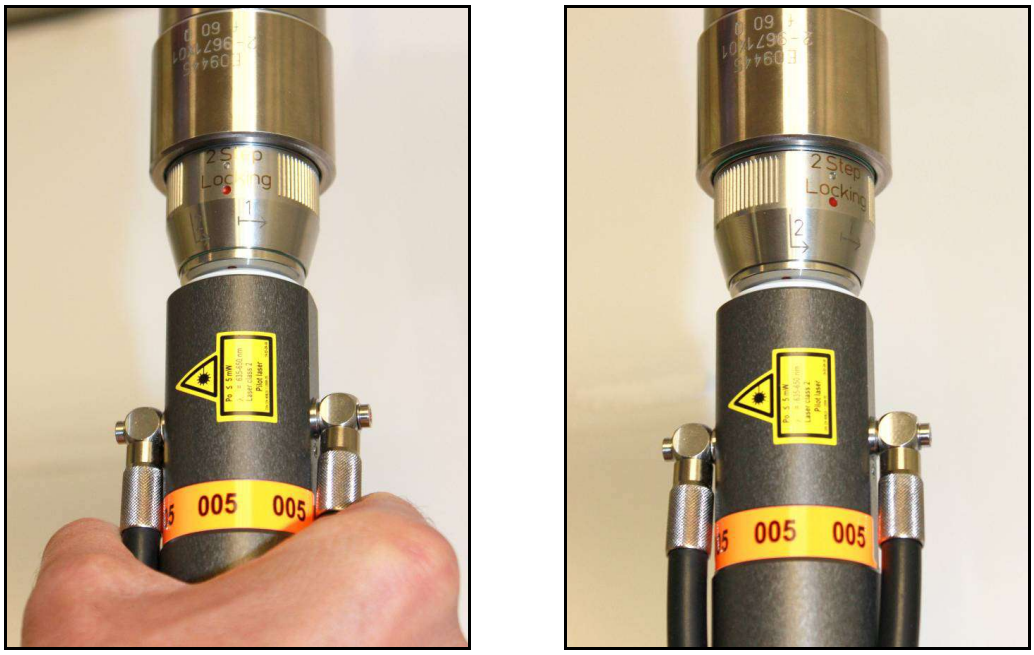


Figure 5.3.2(iv): Connector inserted into receptacle (left) and tightened (right)

7. Locking Step 1:
   a. Fully insert the connector and turn the bayonet sleeve through 37° in a clockwise direction (figure 5.3.2 (iv) – left)

8. Locking Step 2:
   - Pull the sleeve out by 2mm
   - Whilst in the pulled-out position rotate the bayonet sleeve until hand tight (figure 5.3.2 (iv) – right)
   - Tighten by hand only

The Beam Delivery Optic incorporates two sensors, both of which are connected in series with two contact pads on the side of the connector and in turn in series with the integrity monitor circuit:

1. The two contact pads must be electrically connected to complete the integrity circuit (refer to section 4.3.8). Third party process optics compatible with the LLK-Q connector may provide an internal 'shorting circuit' which provides this function. If the connection between these pads is broken, for instance by removing the BDO from its process head, then the laser output will be immediately disabled and the reported alarm will need to be cleared.
2. The fibre break sensor will detect a break in the delivery fibre, caused by mechanical failure or exceeding the minimum bend radius, and immediately disable the laser output.
3. The thermal sensor is designed to disable the laser output if the delivery optic reaches a temperature of over 65℃±5℃. This could be caused by failure of the water cooling circuit, high ambient water temperature or excessive levels of light reflected from the work piece. Once activated, the laser will not be able to be reset until the BDO temperature falls below the reset temperature, 42℃±7℃, at which point the reported alarm will need to be cleared (refer to table 1.5.3).

CAUTION: Ensure that the fibre optic cable exiting from the rear of the unit is not kinked or snagged. Allow sufficient space for correct routing of the cable such that the minimum bend radius and coil length are not exceeded. Failure to do so may result in permanent damage to the fibre optic cable. Ensure that the LLK-Q connector is clean and free from dust and other contaminants. For cleaning procedures refer to Section 12 of this manual. If damage to the fibre or LLK-Q connector is suspected, discontinue Fibre Laser use and contact an SPI representative immediately.

CAUTION: The plastic cap attached to the LLK-Q connector housing is intended to protect the connector from contamination during shipping and when the laser is not in use for extended periods. It SHOULD NOT be treated as a beam stop. Operating the laser with the end cap in place may result in damage to the laser equipment. In addition, due to the elevated temperatures associated with operating the laser at high power with the cap in place, contact may lead to personal injury.

5.3.3 QBH Beam Delivery System (divergent output)

The QBH connector contains an internal mode stripper designed to remove light coupled into the fibre cladding in the event of a back reflection from the work piece. Light removed by this mode stripper is absorbed directly by the circulating cooling water. It is essential that the connector is adequately cooled with a separate source of clean, chilled water in accordance with the specifications listed in table 10.5.2. Operating the laser without an adequate flow of cooling water may result in catastrophic damage to the QBH connector.

The cooling circuit is terminated with 4mm SMC water connections as shown in figure 5.3.3(i).

CAUTION: It is essential that the cooling water flows in the correct direction through the QBH connector. Observe the 'Water In' and 'Water Out' markings on the connector housing adjacent to the SMC water fittings.

Operating the laser with cooling water flowing in the wrong direction may result in catastrophic damage to the QBH connector.

Figure 5.3.3(i): Water Cooling: QBH BDO Connections

The QBH connector should be installed as follows:

1. Remove the protective plastic cap. This is used only to protect the QBH connector from contamination and damage during shipment and storage.

Figure 5.3.3(ii): QBH Protection Cap Removal

2. Install the QBH connector into the process head, collimating optics or adapter using the 2-step bayonet fitting on the front of the connector. Ensure the red dot on the connector is aligned with the two red dots on the adapter (refer to figure 5.3.3(iii))

3. Locking Step 1:
   a. Fully insert the connector and turn the bayonet sleeve through 37° in a clockwise direction

4. Locking Step 2:
   - Pull the sleeve out by 2mm
   - Whilst in the pulled-out position rotate the bayonet sleeve until hand tight
   - Tighten by hand only

5. Carefully route the delivery fibre so as not to exceed the minimum bend radius specified in Table 11.2.

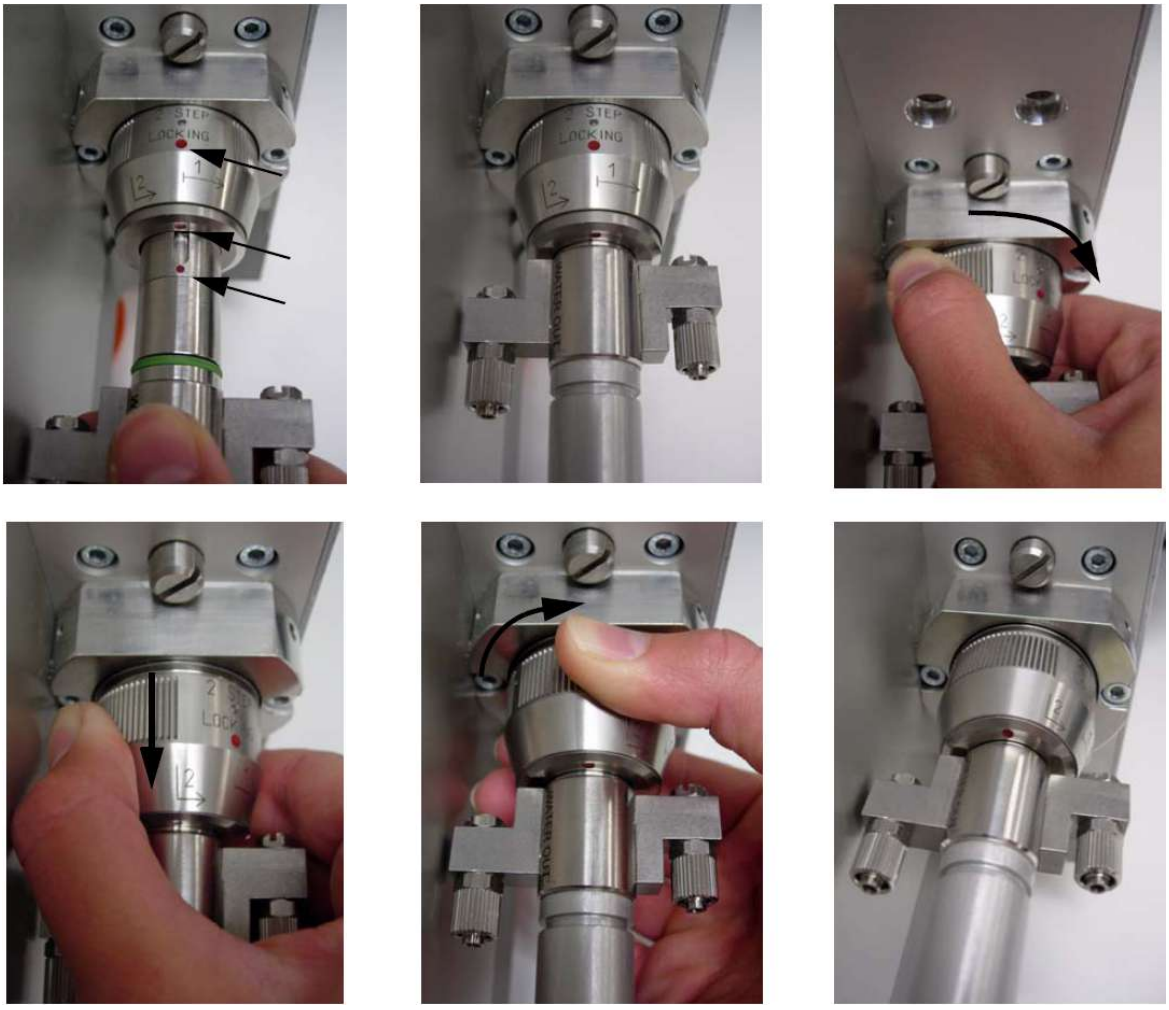


Figure 5.3.3(iii): Installing the QBH Connector

The Beam Delivery Optic incorporates two sensors, both of which are connected in series with two contact pads on the side of the connector and in turn in series with the integrity monitor circuit:

4. The two contact pads must be electrically connected to complete the integrity circuit (refer to section 4.3.8). Third party process optics compatible with the QBH connector may provide an internal 'shorting circuit' which provides this function. If the connection between these pads is broken, for instance by removing the BDO from its process head, then the laser output will be immediately disabled and the reported alarm will need to be cleared.
5. The fibre break sensor will detect a break in the delivery fibre, caused by mechanical failure or exceeding the minimum bend radius, and immediately disable the laser output.
6. The thermal sensor is designed to disable the laser output if the delivery optic reaches a temperature of over 70℃±7℃. This could be caused by failure of the water cooling circuit, high ambient water temperature or excessive levels of light reflected from the work piece. Once activated, the laser will not be able to be reset until the BDO temperature falls below the reset temperature, 55℃±7℃, at which point the reported alarm will need to be cleared.

CAUTION: Ensure that the fibre optic cable exiting from the rear of the unit is not kinked or snagged. Allow sufficient space for correct routing of the cable such that the minimum bend radius and coil length are not exceeded. Failure to do so may result in permanent damage to the fibre optic cable. Ensure that the QBH connector is clean and free from dust and other contaminants. For cleaning procedures refer to Section 12 of this manual. If damage to the fibre or QBH connector is suspected, discontinue Fibre Laser use and contact an SPI representative immediately.

CAUTION: The plastic cap attached to the QBH connector housing is intended to protect the connector from contamination during shipping and when the laser is not in use for extended periods. It SHOULD NOT be treated as a beam stop. Operating the laser with the end cap in place may result in damage to the laser equipment. In addition, due to the elevated temperatures associated with operating the laser at high power with the cap in place, contact may lead to personal injury.

5.3.4 RIC Beam Delivery System (integrated collimator)

The RIC connector contains an internal mode stripper designed to remove light coupled into the fibre cladding in the event of a back reflection from the work piece. Light removed by this mode stripper is absorbed by the connector and the associated heat dissipated by convective and contact cooling.

The RIC Beam Delivery Optic should be installed as follows:

1. Carefully route the delivery fibre following the instructions in section 5.3.1 taking care not to exceed the minimum bend radius as specified in table 11.2.3
2. Clamp the Beam Delivery Optic securely along the front reference surface section only ensuring the clamp load is evenly distributed and avoid point loading (refer to section 11.2.3). Take care not to place excessive loads on the rear section of the optic.
3. Clamp the optic in such a way as to maximise heat sinking for removal of excess heat that may be generated by back reflected light from the work piece.

The RIC BDO incorporates three sensors which are connected in series with the integrity monitoring circuit:

1. The fibre break sensor will detect a break in the delivery fibre, caused by mechanical failure or exceeding the minimum bend radius, and immediately disable the laser output.
2. The bi-metallic thermal snap-switch is designed to disable the laser output if the delivery optic reaches a temperature of over 70℃±5℃. This could be caused by failure of the water cooling circuit, high ambient water temperature or excessive levels of light reflected from the work piece. Once activated, the laser will not be able to be reset until the BDO temperature falls below the reset temperature, 50℃±5℃, at which point the reported alarm will need to be cleared (refer to table 1.5.3).
3. The thermal sensor enables continuous and simultaneous measurement of the BDO operating temperature which can be monitored directly from the GUI.

CAUTION: Ensure that the fibre optic cable exiting from the rear of the unit is not kinked or snagged. Allow sufficient space for correct routing of the cable such that the minimum bend radius and coil length are not exceeded. Failure to do so may result in permanent damage to the fibre optic cable. Ensure that the collimator optic is clean and free from dust and other contaminants. For cleaning procedures refer to Section 12 of this manual. If damage to the fibre or collimator optic is suspected, discontinue Fibre Laser use and contact an SPI representative immediately.

CAUTION: The protective cap attached to the RIC BDO is intended to protect the connector optics from contamination during shipping and when the laser is not in use for extended periods. It SHOULD NOT be treated as a beam stop. Operating the laser with the protective cap in place may result in damage to the laser equipment. In addition, due to the elevated temperatures associated with operating the laser at high power with the cap in place, contact may lead to personal injury.

5.3.5 QCS Beam Delivery System (integrated collimator)

The QCS connector contains an internal mode stripper designed to remove light coupled into the fibre cladding in the event of a back reflection from the work piece. Light removed by this mode stripper is absorbed by the connector and the associated heat dissipated by convective and contact cooling.

The QCS Beam Delivery Optic should be installed as follows:

1. Carefully route the delivery fibre following the instructions in section 5.3.1 taking care not to exceed the minimum bend radius as specified in table 11.2.4.
2. Clamp the Beam Delivery Optic securely along the front section only ensuring the clamp load is evenly distributed and avoid point loading (refer to section 11.2.4). Take care not to place excessive loads on the rear section of the optic.
3. Clamp the optic in such a way as to maximise heat sinking for removal of excess heat that may be generated by back reflected light from the work piece.

The QCS Beam Delivery Optic incorporates two sensors, both of which are connected in series with the laser interlock circuit:

1. The fibre break sensor will detect a break in the delivery fibre, caused by mechanical failure or exceeding the minimum bend radius, and immediately disable the laser output.
2. The bi-metallic thermal snap-switch is designed to disable the laser output if the delivery optic reaches a temperature of over 50℃±7℃. This could be caused by failure of the water cooling circuit, high ambient water temperature or excessive levels of light reflected from the work piece. Once activated, the laser will not be able to be reset until the BDO temperature falls below the reset temperature, 35℃±7℃, at which point the reported alarm will need to be cleared (refer to table 1.5.3).

CAUTION: Ensure that the fibre optic cable exiting from the rear of the unit is not kinked or snagged. Allow sufficient space for correct routing of the cable such that the minimum bend radius and coil length are not exceeded. Failure to do so may result in permanent damage to the fibre optic cable. Ensure that the collimator optic is clean and free from dust and other contaminants. For cleaning procedures refer to Section 12 of this manual. If damage to the fibre or collimator optic is suspected, discontinue Fibre Laser use and contact an SPI representative immediately.

Caution: The threaded cap attached to the QCS BDO is intended to protect the collimator optics from contamination during shipping and when the laser is not in use for extended periods. It SHOULD NOT be treated as a beam stop. Operating the laser with the end cap in place may result in damage to the laser equipment. In addition, due to the elevated temperatures associated with operating the laser at high power with the cap in place, contact may lead to personal injury.

5.4 Water Cooling: Connection to Laser (for water cooled variants only)

The laser is designed as a rack-mounted sub-assembly for integration into a standard 19" rack system. In all installation environments, ensure that sufficient space is allowed for at the rear of the laser to avoid tight bends on the water cooling hoses. Take particular care to avoid excessive bends and loads on the water cooling hoses where they connect to the laser.

When connecting the laser to a chiller unit or factory water supply, use water fittings and hose specified to operate under the conditions listed in Table 10.4. It is recommended that the commonly available push-on John Guest 'Speedfit' water connections are used. Ensure that the pipes are clean before adding the connections and that the correct locking clips are used. John Guest part numbers are given in Table 5.4.

Pipes should be routed so that any leaking cooling water will be kept away from the Fibre Laser, and provision should be made to shut down the Fibre Laser and shut off the cooling water flow when a leak is detected.

CAUTION: To avoid corrosion to the cooling circuit components within the Fibre Laser the use of deionised water is not permitted.

CAUTION: Ensure an approved overpressure safety device is installed when connecting the Fibre Laser to an external chiller or factory water supply. This should comply with ISO4126-1 (or equivalent) and be rated to protect the Fibre Laser against a flow or differential water pressure in excess of that specified in Table 10.4.

Description	Supplier Part Number	Illustration
Equal Elbow 3/8"	John Guest: PI0321S	
Equal Straight Connector	John Guest: PI0412S	
Locking Clip	John Guest: PIC 1812R	
Plug	John Guest: PI0812S	
Type 21Connector (for LLK-Q optical connector)	Parker Rectus: 21 KB KO 06 DPXS	
3/8" LLDPE Tubing (for laser)	John Guest: PE-12-EI-0500F-R	
6mm LLDPE Tubing (for LLK-Q & QBH optical connectors)	John Guest: PE-0604-0100M-N	

Table 5.4: Water tubing and fittings

Prepare the cooling hose as follows:

1. Cut the tube square and remove burrs and sharp edges. Ensure the outside diameter is free of score marks and the pipe is clean. For soft or thin walled tube SPI recommends the use of a tube insert.
2. Push the tube into the fitting, to the tube stop ensuring that the flow and return connections are correct (Figure. 5.4).
3. Fit the locking clip (supplied)
4. Pull on the tube to check it is secure.
5. Check for leaks before making electrical connections and powering up the Fibre Laser.

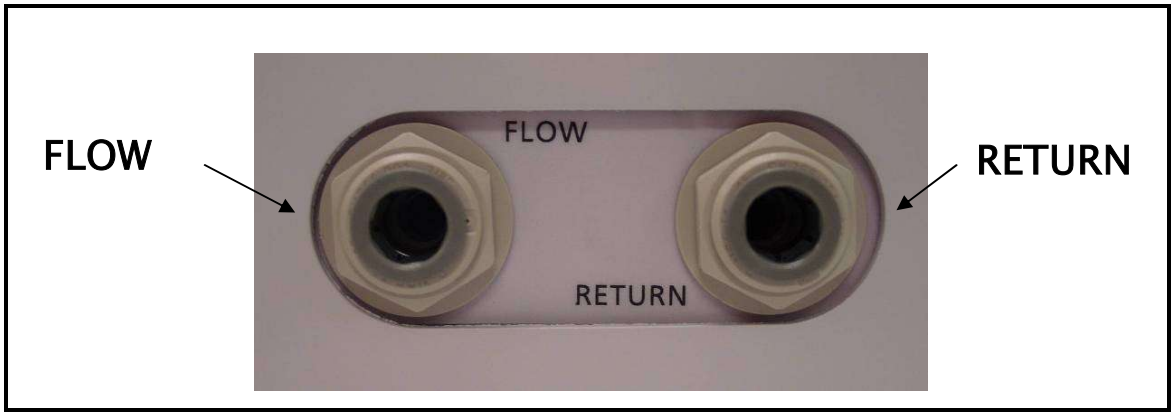


Figure 5.4: Water Cooler: Laser Connections

- It is recommended that a particle filter is installed when using either a factory water supply or an external chiller supply; this should have a filter grade of 100µm.
- Where there is a possibility that the water temperature may fall below 0°C then it is recommended that an appropriate anti-freeze additive is used to prevent frost damage to the laser. Please contact SPI for further advice.
- It is also recommended that anti-fungal inhibitor is added to the water supply. Please contact SPI for further advice.

In order to fill and prime the laser, a solenoid valve on the laser FLOW inlet must be opened. To do this a software command must be sent via the RS232 interface, refer to document FS-S00031 for details. It is also possible to use the GUI to perform this function; refer to document SM-S00064 for further details.

With the Key-switch in the OFF position send the command to open the valve. With the flow valve open and the chiller connected, switch on the chiller unit. It is likely that the water level will drop below the lower level limit. In any event, switch the chiller off and top up the water level before operating the laser for the first time and ensure the software command sent to override the Flow valve is disabled by cycling the mains power OFF then ON using the circuit breaker located at the rear of the unit.

CAUTION: The laser must be operated within the specified environmental temperature and humidity limits always above the dew point. Failure to comply with this will invalidate the warranty and may lead to accelerated component aging and performance degradation. In addition, operation below the dew point may lead to catastrophic failure.

5.5 Water Cooling: Disconnection from the Laser

If the Fibre Laser is to be placed in storage once the chiller unit has been disconnected then both the system and the water cooled Beam Delivery Connector (LLK-Q and QBH where fitted) must be disconnected from their respective chiller units and drained of all coolant.

To drain the Fibre Laser it will be necessary to open the inlet solenoid valve by sending a software command; refer to FS-S00031 for details. It is also possible to use the GUI to perform this function; refer to document SM-S00064 for further details. It is recommended that for drainage the FLOW and RETURN hoses are connected to the system.

With the mains power on and the key-switch in the "OFF" position, send the RS232 command to open the valve. When the laser has been completely drained, turn the power off and remove the mains lead.

To disconnect the water connection:

1. Ensure the system is depressurized
2. Remove the locking clip
3. Push the collet square against the fitting. With the collet held in this position the tube can be removed.

CAUTION: The Fibre Laser and the water cooled Beam Delivery Connector (LLK-Q or QBH where fitted) must both be drained of all coolant and the flow and return bungs (plugs) fitted prior to shipment.

If the laser is shipped without the cooling water bungs fitted then any residual coolant will escape during transit and cause permanent damage to the system.

6.0 Operating Instructions

The following section describes the operation of the CW/Modulated High Power Fibre Laser. Before proceeding with this section, please refer to all relevant sections in this manual covering safety, environmental and electrical specifications, component inspection and system installation.

6.1 Operational Mode Summary

Introduction

SPI's R4 family of CW-M High Power Fibre Laser Systems has been designed to offer maximum flexibility as a manufacturing tool capable of operating over a wide range of materials processing applications ranging from millisecond regime spot welding pulses to high speed ceramic engraving using pulse widths of a few microseconds. Over this range of operating conditions the dynamic response of the laser system changes considerably and therefore the control method of the laser must be adapted to optimize the laser performance depending on the processing conditions in use.

The control options for R4 lasers can be optimised for different processing conditions and each control mode can be operated under computer control or over the external I/O hardware interface. It is important to understand the differences between these control modes as the set-point definition and reported power returned by the laser are dependent on the mode of operation selected.

CW Operation

To operate the laser in CW mode a power set-point is given to the laser either via an RS232 command or using an analogue input voltage over the I/O port. When a TTL trigger signal is then applied and held high for the duration of the operating period, the internal controller operates in closed loop mode to adjust the pump diode drive current to maintain the laser output at its set power level (Po).

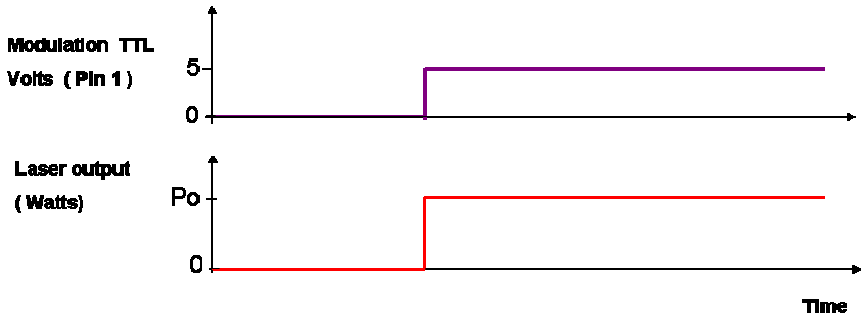


Figure 6.1(i) CW Operation

Modulated Operation

When operated in modulated mode a set power input (Po) is given to the laser and the TTL trigger signal is "pulsed" in order to modulate the CW emission synchronously with the TTL signal.

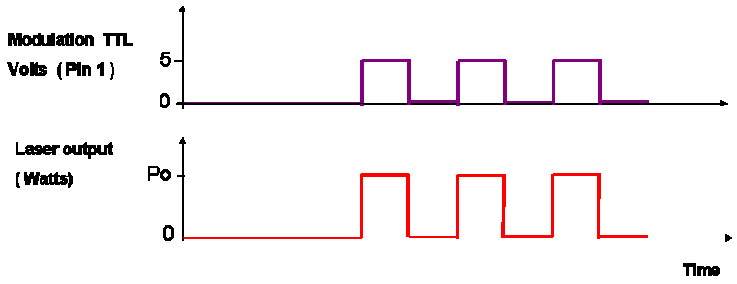


Figure 6.1(ii) Modulated Operation

In practice, due to the laser dynamic response there is typically a relaxation response at the start of each modulation pulse and the actual pulse shape response and turn on delay of the of the laser output is determined by the power set-point, modulation pulse width and repetition rate.

To illustrate this the pulse shape responses and the turn on delay times with respect to the modulation signal are shown below for two different modulation conditions. **Figure 6.1(iii)** shows the turn on relaxation oscillation overshoot at the leading edge of the optical pulse response, followed by a CW plateau at the set power level. This is a typical response shape for modulation pulse widths of >20us.

For pulse widths <20us, as the pulse width is reduced, the pulse shape is dominated by the relaxation oscillation response as shown in **Figure 6.1(iv).**

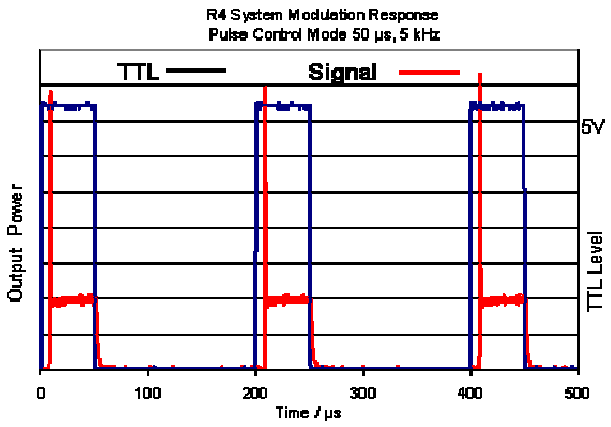


Figure 6.1(iii) PPC Mode

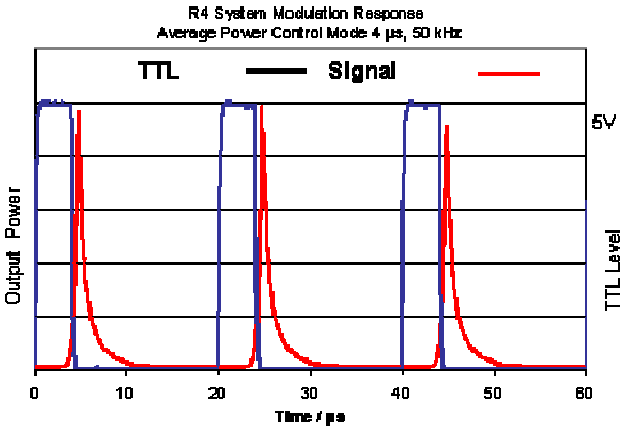


Figure 6.1(iv) APC Mode

For optimum process stability, operation of the laser in closed loop is desirable whenever possible. To achieve optimum performance over the wide range of operating conditions available, different modes of operation for the sampling and measurement of the optical output used for power monitoring and feedback are provided.

The power measurement and control options together with some simple guidelines for their respective operating regimes are:

- **Pulse Power Control (PPC)**
  - Modulation in constant amplitude, variable duty cycle pulse train with pulse width **>20µs** e.g. thin metal cutting
  - Single shot pulse mode with pulse widths >**20µs** e.g. Spot welding and rapid prototyping.

- **Average Power Control (APC)**
  - Modulation in "steady state" conditions at high repetition rates or with pulse widths **<20µs** e.g. high speed anilox processing, thin metal cutting.

The typical accuracy of the power monitoring for each of these control modes is shown below in **Figure 6.1(v)** as a function of the modulation pulse width.

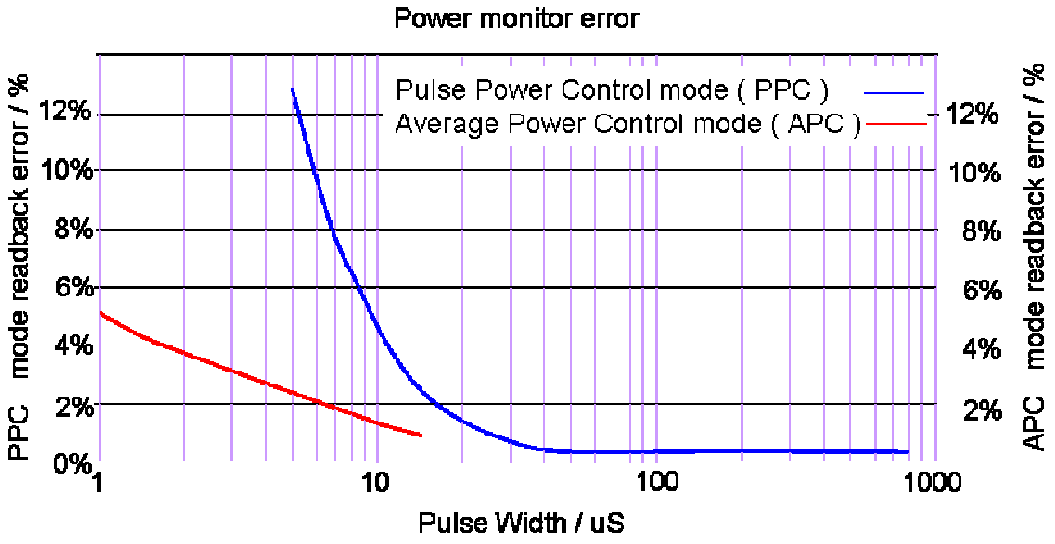


Figure 6.1(v) Power Monitor Error Versus Modulation Pulse Width

In certain applications the process operating conditions are incompatible with the response time of closed loop control systems. Examples include processes where the set power is constant but the pulse width is randomly variable (e.g. rapid prototyping systems) or processes where the power set-point is randomly variable (e.g. Heat Affected Zone (HAZ) minimization). In these applications the user can take direct control of the pump drive current and bypass the closed loop control system, using the power output signal for monitoring purposes only.

This mode of control is:

- **Direct Current Control (DCC)**
  - Modulation with irregular or ramped amplitude profiled pulses e.g. Seam welding or high resolution rapid prototyping

Power Set Point and Monitor Indications

The power set-point and power monitor read-back values have different interpretations according to the mode of operation. These are outlined below.

Pulse Power Control (PPC)

In closed loop Pulse Power Control (PPC) mode the laser set-point determines the required steady state amplitude of the laser pulse response after the initial turn-on relaxation oscillation overshoot has passed – **refer to Figure 6.1(iii).** After each modulation pulse the control algorithm calculates the difference error between the "dial up" pulse energy and the measured pulse energy and adjusts the pump diode current accordingly to minimise this difference for subsequent pulses.

The "dial up" pulse energy is calculated from the product of the power set point and the (electrical) modulation pulse width. The measured pulse energy is the integrated optical power over the sampled optical response.

The power level read-back is expressed as a percentage of the maximum rated power and is calculated by dividing the measured pulse energy divided by the (electrical) modulation pulse width.

This control mode is recommended for modulation pulse widths that are sufficiently long for the laser to reach steady state operation i.e. where the output optical pulse shape approximates to a square wave as in **Figure 6.1(iii).** For operation at maximum power this equates to a pulse width minimum setting of ~20µs to account for the turn-on delay and the turn-on relaxation oscillation. This minimum setting will increase as the set power is reduced due to the increase in the turn on delay of the laser.

Average Power Control (APC)

In APC mode the power set-point definition changes to become the average power set-point where 100% represents maximum rated power in the CW operating condition. Under the modulation conditions provided by the user the pump drive current is adjusted to achieve the required average power setting.

It should be recognized that the modulation conditions should be compatible with the average power set-point i.e. an average power set-point of >50% cannot be achieved with <50% modulation duty cycle, even at maximum diode current.

The power level read-back is a measurement of the average power expressed as a percentage of the maximum rated power.

INTERNAL RS232 / EXTERNAL Analogue I/O Control

Each of the above control modes can be operated using the laser under computer control using via an R2S232 Interface or using analogue/digital control and monitoring signals over the external I/O interface. Refer to sections 4.3.4 and 6.2 for details on the I/O interface and to document FS-S00031 for RS232 interfacing and control information.

An alternative way to control the laser via the RS232 link is to use the supplied GUI. Instructions for operation using the GUI are given in the appropriate section of the GUI manual [Document Reference SM-S00064].

6.1.1 Pulse Shape Equalisation "PSE"

Pulse Shape Equalisation, or PSE, is used to ensure the first pulse has similar characteristics to all subsequent pulses. First pulse non-uniformity is a well known phenomenon which occurs when the laser is triggered after being in the idle state for a period of time; for example in single shot mode or when using gated pulse trains. The degree of non-uniformity is dependent on the pulse energy and becomes increasingly significant as the pulse energy is reduced.

The PSE function allows the user to set a level of bias which is sufficient to hold the laser just below threshold. This ensures the first pulse turns on as quickly as the subsequent pulses and with the same energy. The turn-on delay of the laser can also be minimized using this feature (refer to figure 6.1.1)

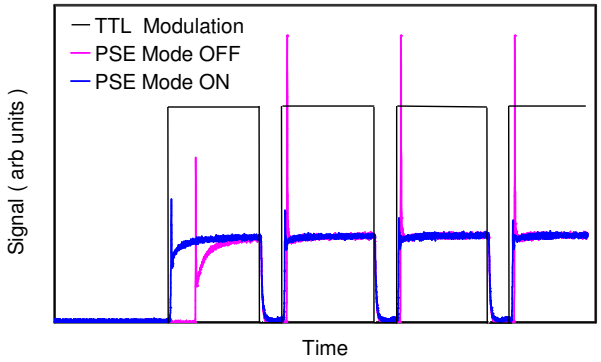


Figure 6.1.1 Effect of PSE Mode on Pulse Uniformity

IMPORTANT: It should be recognized that in PSE mode of operation, depending on the bias settings used, there will be a constant background level of Amplified Spontaneous Emission (ASE) up to a maximum level of 5W when the laser is in the ENABLED state. This is independent of whether the modulation input signal is in the HIGH or LOW state. For this reason the system integrator should give careful consideration to the use of a beam dump or optical shutter.

The feature can be enabled via the GUI shipped with the laser or customer specific software using the commands detailed in document FS-S00031. Instructions for operation using the GUI are given in the appropriate section of the GUI manual [Document Reference SM-S00064]. For more detailed instruction and assistance in applying this mode to your application, please contact SPI.

6.2 Signal Connections - Internal (RS232) Control

6.2.1 Inputs

By default the laser will operate under RS232 software control and analogue inputs to the 'External Laser Control' pin of the Analogue I/O connector are ignored (refer to Section 4.3.4).

However, some connections to the 25-way connector or BNC connector are still required in order to enable or modulate the laser output. Refer to Figure 6.2.1 for the two possible minimum I/O connection requirements to operate the laser under RS232 control.

Note: A connection to Pin 1 of the 25-way connector and a connection to the BNC connector must NOT be made at the same time.

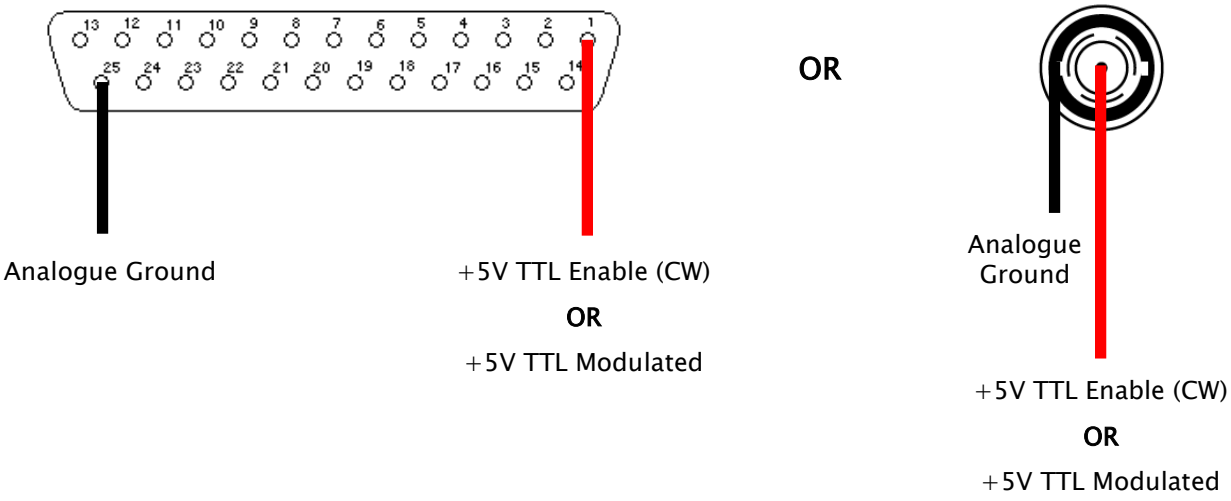


Figure 6.2.1: Minimum Connection Requirements for RS232 Operation

In addition a 0-24V signal with a TTL level switching threshold applied to the ENABLE input (pin 2) of the I/O interface can be used to gate the modulation signal input to the laser.

6.2.2 Signal Connections – External I-O Interface Control

Complete system control and monitoring capability can be achieved without the use of a host computer by using the digital and analogue signals which are provided via the rear panel I/O connector. Refer to table 4.3.4(ii) for pin designations and output specifications.

To enable External Laser Control apply a high level TTL signal to the 'External Diode Drive Enable' pin of the Analogue I/O connector (refer to Section 4.3.4) and cycle the remote or front panel key-switch. The laser is now in External Control Mode; laser emission will be enabled after a 5 second (default) delay and power command requests using the RS232 interface will be ignored.

The laser will remain in External Laser Control for as long as a high level is applied and the key switch is open. Once the key switch is closed the state is latched and will not be altered by a change in signal on pin 3. When External Laser Control is enabled some RS232 commands will be disabled as specific functions cannot be controlled from two sources at the same time.

Digital TTL/24V compatible inputs and Open Collector (5-24V) outputs are provided on the external interface to provide complete remote setup and monitoring capability.

6.2.3 Inputs

Refer to Figure 6.2.3(i) and Figure 6.2.3(ii) for alternative minimum I/O connection requirements to operate the laser under External Analogue control.

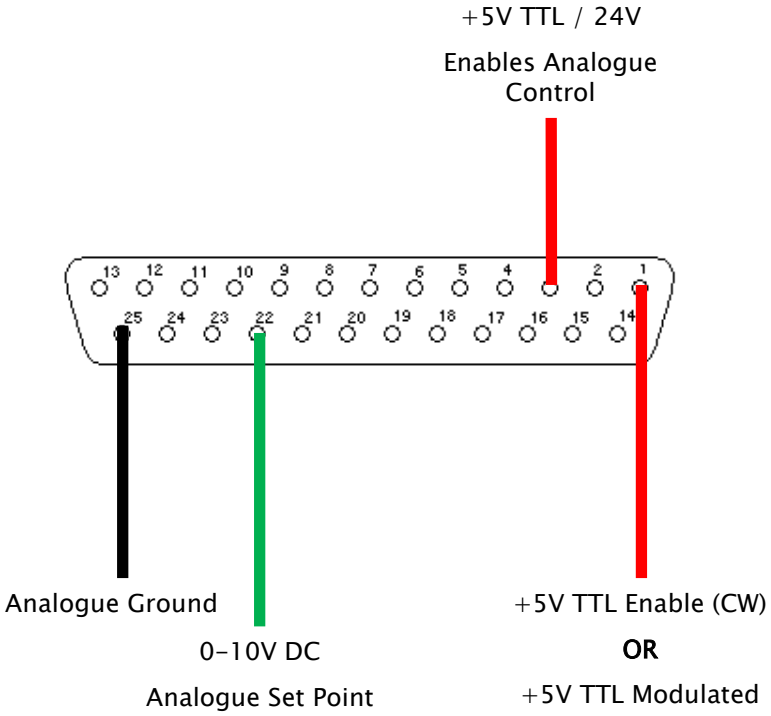


Figure 6.2.3 (i): Minimum Connection Requirements for External Analogue Operation

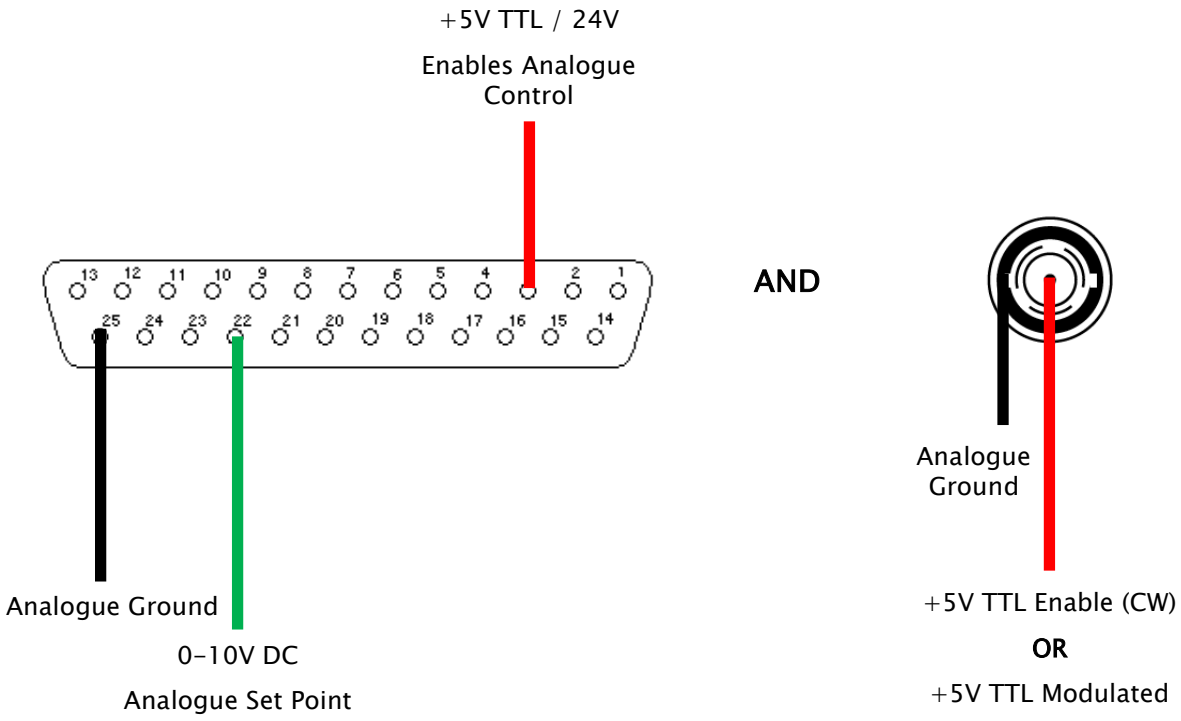


Figure 6.2.3 (ii): Alternative Minimum Connection Requirements for External Analogue Operation

In addition (refer to section 4.3.4 for details) :

- A 0-24V signal with a TTL level switching threshold applied to the ENABLE input (pin 2) of the I/O interface can be used to gate the modulation signal input to the laser.
- 0-24V signals with a TTL level switching threshold applied to pins 4 and 12 can be used to select the control mode of the laser (PPC/APC/DCC).
- 0-24V signal with a TTL level switching threshold applied to the pin 5 of the I/O interface can be used to control the visible pilot laser.
- 0-24V signals with a TTL level switching threshold applied to pins 6 and 7 can be used to reset alarm conditions with user and supervisor authorisation levels respectively.

6.2.4 Analogue Outputs

The output power can be read from a 0-10V scaled analogue output voltage from pin 23 of the I/O interface. The output level will be dependent on the mode of operation of the laser (refer to section 6.1)

PPC mode the reading from this pin will be scaled to 10V = maximum CW pulse power.

The power level read-back is a percentage of the maximum rated power and is calculated by dividing the measured pulse energy divided by the (electrical) modulation pulse width.

In APC mode the output level will be scaled to the 10V = maximum average power.

The power level read-back is a measurement of the average power expressed as a percentage of the maximum rated power.

In addition the output optical photodiode signal is available on pin 24. This is an unscaled 50Ω output impedance buffered analogue output.

- LASER ENABLE (Set / Read)
- LASER EMISSION (Set / Read)
- TARGET LASER EMISSION (Set / Read)
- WARNING (Read - indicates that a level is close to triggering an alarm)
- ALARM INDICATOR (Read - indicates an alarm condition is present)
- ALARM STATUS (Read - 4 input status bits for alarm condition interpretation)
- ALARM RESET (Set)

6.2.5 Digital Outputs

The complete laser operating status can be read from 0-24V opto-coupled open collector monitor outputs. These include :

- LASER ENABLED
- LASER EMISSION
- TARGET LASER EMISSION
- WARNING
- ALARM INDICATOR

In addition to the above, four 0-24V opto-coupled open collector status monitor pins provide an indication of the laser controller status including fault and alarm conditions for diagnostic purposes.

All digital outputs are open collector and rated to 100mA maximum current. Each opto-coupled output should be connected across the status monitor pin required (refer to Section 4.3.4) and pin 21 (digital output ground). Figure 6.2.5(i) and Figure 6.2.5(ii) show recommended connection schemes for the open collector outputs using connections to the LASER EMISSION status monitor as an example.

CAUTION: All digital outputs are open collector and are limited to 100mA maximum current.

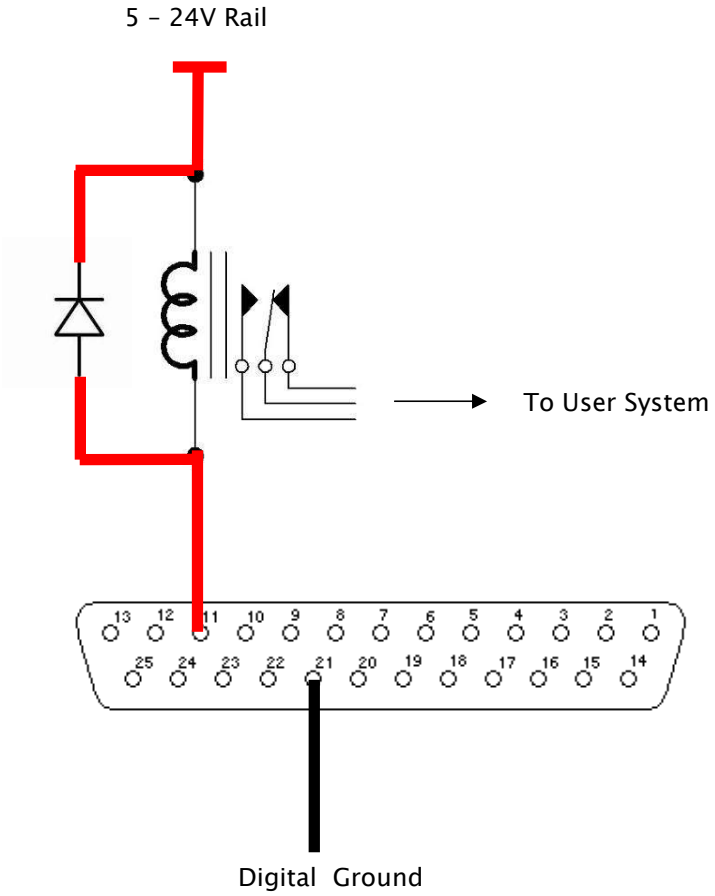


Figure 6.2.5 (i) : Open Collector Connections for an Inductive Load

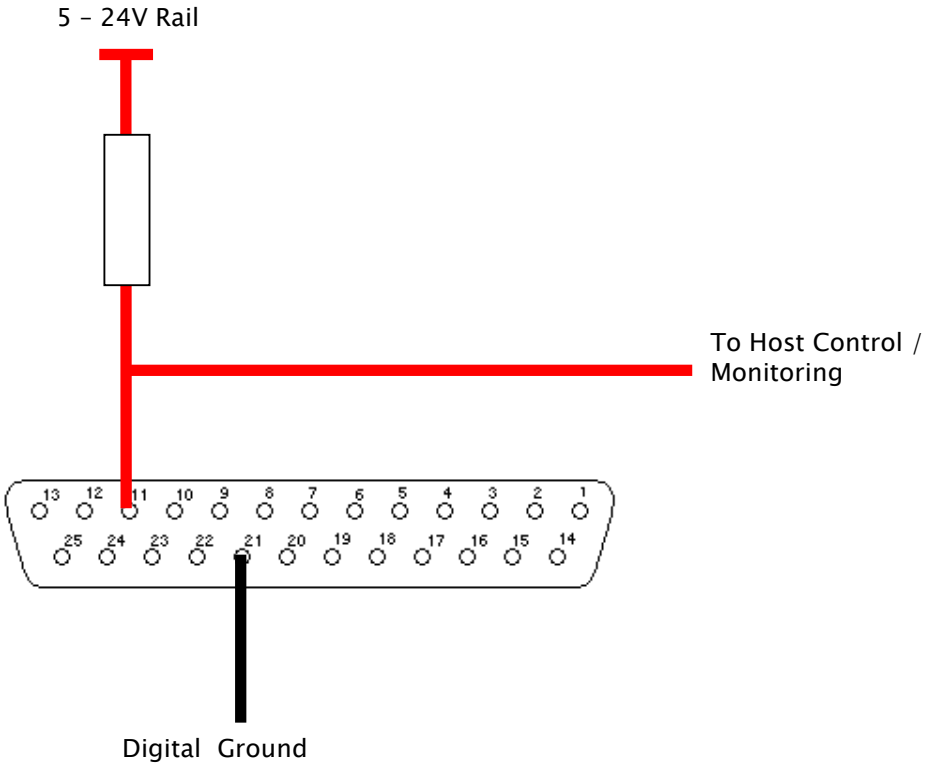


Figure 6.2.5 (ii) : Open Collector Connections for an A/D Interface

6.2.6 Pilot Laser Operation

An integrated visible pilot laser is provided as an aid to process set-up and beam targeting. Note: this is not intended for use as an accurate means of focus finding. The device has the following functionality:

1. **Safety:** The Pilot Laser does not require a TTL signal but by default can only be operated when the front panel key-switch is in the OFF position or the interlock circuit is open. If the key-switch is turned ON and the interlock circuit is closed, operation of the high power laser will be enabled and the Pilot Laser will be disabled.
2. **"Time Out":** To prevent premature ageing of the Pilot Laser, power to the device will automatically time out after 10 minutes.
3. **Front panel indicator:** An LED is provided on the front panel to indicate the Pilot Laser status (refer to Section 4.3.7 for details).
4. **Pilot laser configuration**: Configuration of the pilot laser can be changed using the GUI such that it can be operated in alternative states, for instance when the main high power laser is also operating. Refer to the GUI manual SM-S00064.
5. **RS232 control**: Refer to document FS-S00031 for full operating commands.
6. **External control**: Refer to Sections 6.2.2 and 4.3.4.

6.2.7 System Self-Calibration

The high reliability design of the system includes the provision of optical pump power overhead available at start of life of the laser in order to compensate for the random failure rate of the pump diodes over the system design life as well as any temperature dependence in the optical system. In the event of a pump diode failure the drive current to output power calibration will change. In power control mode this may prevent the laser from reaching power set-point. To prevent this a simple periodic recalibration procedure ensures that the available diode current is incrementally increased to maintain the rated laser output power over life.

Refer to document FS-S00031 for RS232 commands related to the calibration procedure.

A calibration log is maintained in memory and a calibration history is available to the user through software as detailed in document FS-S00031.

To calibrate the laser system

- Ensure the beam delivery optic is securely mounted, pointing towards a suitable beam dump and the end cap has been removed.
- Ensure the system is set to 'Internal RS232' control mode.
- Apply a CW TTL high signal to the external I/O modulation input.

CAUTION: During the self-calibration procedure the fibre laser will be set to full rated output power. Ensure the beam delivery optic is securely mounted, pointing towards a suitable beam dump and the end cap has been removed before starting calibration.

- Initiate the recalibration procedure using the RS232 command with Supervisor access.
- Once calibration is complete remove the modulation input signal and cycle the front panel or remote key-switch to reset the laser system.
- The laser is now calibrated and ready for use.

7.0 Operation Procedure

7.1 Start Up Sequence

Before turning the laser on for the first time, ensure the front or rear panel key control is in the **OFF** position, all the Analogue I/O connector input signals are set to 0V (or the I/O connector cable is unplugged) and the remote interlock connector is closed.

WARNING: Failure to follow procedures and instructions described in the following section may lead to harmful radiation exposure resulting in personal injury and/or damage to the equipment.

CAUTION: Ensure that the turn on sequence (this Section 7.1) and turn-off sequence (Section 7.2) are strictly adhered to, particularly when re-enabling the laser after interruption of mains power supply. This is particularly important when the laser has been configured for operation in external control mode.

CAUTION: Operation using **"PSE"** performance option.

IMPORTANT: It is important to recognize that in PSE mode of operation, depending on the settings used there will be a constant background level of ASE emission up to a maximum of 5W output when the laser is in the ENABLED state, independently of whether the laser modulation input signal is in the HIGH or LOW state. For this reason the system integrator should give careful consideration to the use of a beam dump or optical shutter.

CAUTION: Back reflection into the laser cavity can degrade the laser performance or in extreme cases cause laser failure. The laser has been designed for and tested in a range of processing applications where normal levels of back reflection can be tolerated, however for processing of highly reflective materials including for example gold, copper, aluminium or silicon an optical isolator must be used. If in doubt contact SPI for applications advice.

CAUTION: The protective cap attached to all the beam delivery connector types is intended to protect the connector optics from contamination during shipping and when the laser is not in use for extended periods. It SHOULD NOT be treated as a beam stop. Operating the laser with the end cap in place may result in damage to the laser equipment. In addition, due to the elevated temperatures associated with operating the laser at high power with the cap in place, contact may lead to personal injury.

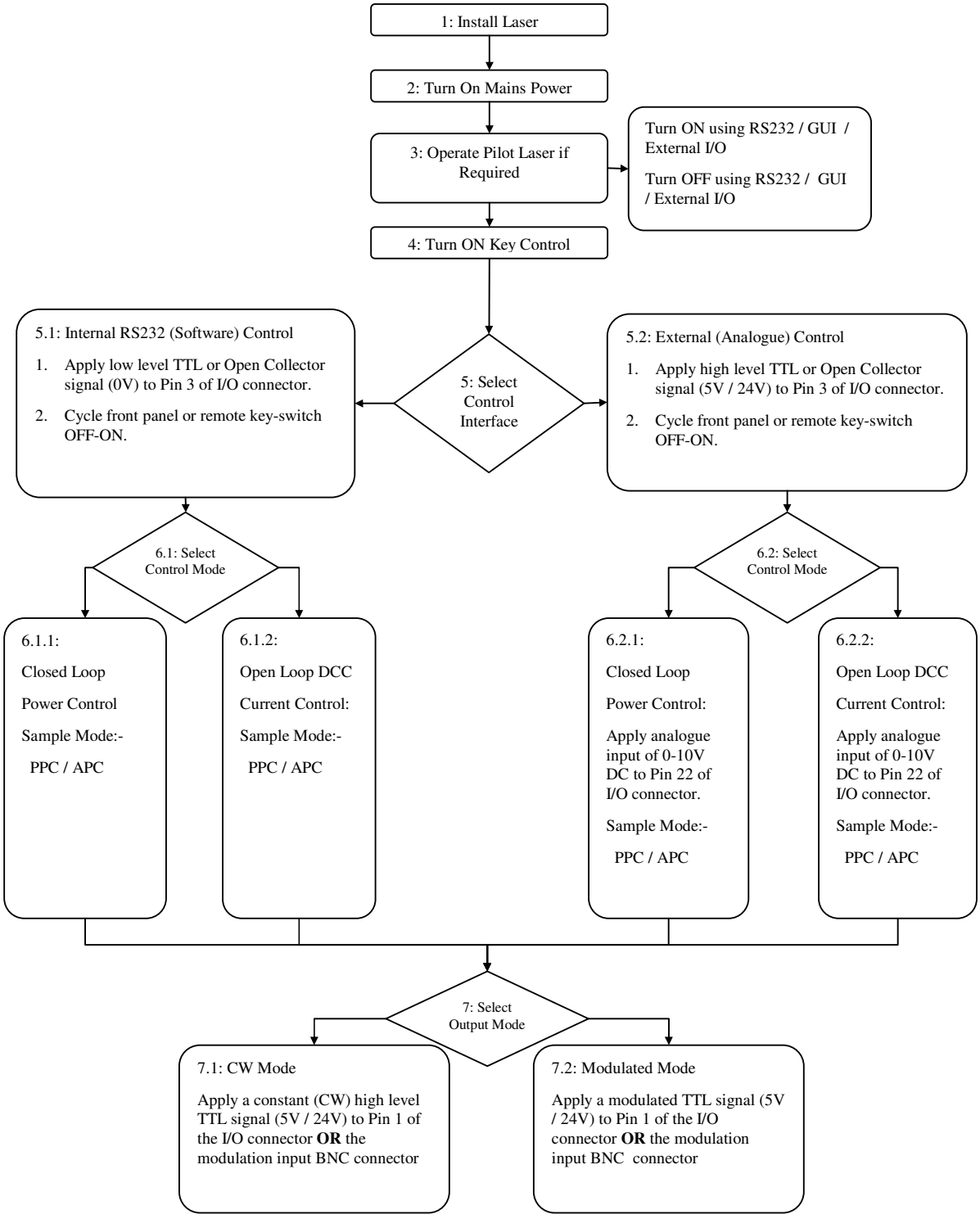


Table 7.1: Operational Mode Summary

- Remove the protective cap from the beam delivery connector. Ensure that the exposed quartz block on the QBH connector or the protective window on the LLK-Q, RIC and QCS connector types is free from dust or other contamination and damage. Refer to Section 12.1 if cleaning or replacement is required. If damage to the optical surface is suspected then switch the laser system off and contact an SPI representative immediately. Under no circumstances operate the Fibre Laser with a damaged beam delivery connector assembly.
- Ensure that the beam delivery connector assembly is securely mounted or installed securely within a collimator housing, process head or similar and that it is pointing towards the work piece target or appropriate beam dump. In the case of the LLK-Q and QBH connector types ensure that the proximity contact pads are electrically connected (refer to sections 4.3.8 and 5.3). Ensure that all laser safety precautions are adhered to and correct laser safety eyewear is worn at all times (see Section 1.3).
- Turn on the mains power supply to the unit using the mains circuit breaker. The **Laser Enabled** (x2) LEDs will be illuminated RED. The **System Error** LED will be illuminated GREEN and both the **Laser Emission** (x2) and **Pilot Laser** LEDs will be OFF.
- Ensure that the interlock circuit connected to the rear panel INTERLOCK connector is closed.
- If the rear panel connector does not have a remote key-switch attached then ensure the pre-wired plug is installed.
- A **Pilot Laser** is fitted to the laser. This can be operated either using RS-232 commands directly (see document FS-S00031), or via the GUI (see document SM-S00064).
- If the laser is to be operated in EXTERNAL control mode apply a TTL voltage to Pin 3 on the I/O port.
- Select the operating modes Closed Loop + PPC/APC or Direct Current Control (DCC) for the laser (Refer to Section 6.1 for details).
- Turn both the front and rear panel key controls to the **ON** position. Switching the key control to **ON** will cause the front panel indication LED – ENABLED – to flash continuously from RED to GREEN during a preset arming delay (default value= 5 seconds) after which the ENABLED LED remains GREEN and laser output is enabled
- Note that until a high level TTL signal is applied to the modulation trigger input of the Analogue I/O connector or the BNC input, the AMBER **Emission** LEDs will remain OFF
- Operate the laser in accordance with the control mode selected.

WARNING: The output power will return to its previous setting when the laser is rearmed following a process interruption.

The system integrator/user is responsible for compliance with the relevant laser safety regulations regarding the control of laser emission.

7.2 Turn Off Sequence

- Set the output power to zero using the RS232 communications command (see document FS-S00031) or reduce the analogue external control signal to 0V depending on the mode of operation.
- Isolate the TTL modulation signal or set to 0V.
- Turn the front panel key control to the **OFF** position.
- Isolate the power supply to the unit using the mains breaker (MCB) on the rear panel.
- Wait a minimum of 10 seconds before restarting the laser to allow the internal circuitry to fully shut down.

7.3 PSE Operation

An explanation of these features is included in Section 6.1.

This feature can be enabled via the GUI shipped with the laser or customer specific software using the commands detailed in document FS-S00031. Instructions for operation using the GUI are given in the appropriate section of the GUI manual [SM-S00064].

CAUTION: Operation using **" PSE "** performance option.

IMPORTANT: It is important to recognize that in PSE mode of operation, depending on the settings used there will be a constant background level of ASE emission up to a maximum of 5W output when the laser is in the ENABLED state, independently of whether the laser modulation input signal is in the HIGH or LOW state. For this reason the system integrator should give careful consideration to the use of a beam dump or optical shutter.

8.0 System Alarms

Alarm status is monitored by the system. In the event of an alarm, the Fibre Laser will shut down and the **ALARM** indicator will illuminate RED.

The alarm conditions can be considered as Resettable or System. Resettable alarms can be cleared by rectifying the source of the alarm and resetting the alarm condition. A System alarm indicates a subsystem malfunction and may require more detailed intervention.

Alarms can be reset either through the GUI or through applying a signal to the appropriate Alarm Reset pin on the 25-way connector (refer to table 4.3.4(ii)). Certain alarms require a higher level of authorisation to clear - alarms are clearable either by the operator, local supervisor, or SPI-authorised service engineer.

In the case of a non-resettable alarm, to limit the risk of damage to the laser, the laser should be isolated and SPI contacted for advice. Under no circumstances should the laser be restarted except in the case of an Output Power Alarm which has a specific reset method detailed in section 8.1.

Information on the status or nature of an alarm can be requested via the RS232 port or via the status voltages on the external I-O port.

Using the external I-O port the operating status or alarm condition can be interpreted by reading the outputs on four status pins (refer to table 4.3.4(ii)). The different states are listed in Table 8.0.

Code	Status Bit (Pin)				Alarm Type	Meaning	Detail
	4	3	2	1			
0	0	0	0	0	-	Emitting	
1	0	0	0	1	-	Idle	Waiting for modulation signal only before emitting
2	0	0	1	0	-	Safety Delay	Waiting for safety delay to complete
3	0	0	1	1	-	Key Switch Open	Waiting for key switch to close
4	0	1	0	0	-	Key Switch Cycle Required	
5	0	1	0	1	Resettable	BDO Alarm	BDO Open Circuit or Thermal Snap Switch Open
6	0	1	1	0	System	BDO Alarm	BDO Short Circuit (Damaged)
7	0	1	1	1	Resettable	System Over Temperature Alarm	Thermistor Alarm
8	1	0	0	0	Resettable	System Over Temperature Alarm	Thermal Snap Switch Alarm
9	1	0	0	1	System	Memory Error	
10	1	0	1	0	System	PSU Failure	
11	1	0	1	1	System	Ground Fault Alarm	
12	1	1	0	0	Resettable	Output Power Alarm	Output Power or Fibre Fail This alarm has a specific reset method. Refer to section 8.1
13	1	1	0	1	System	Internal Error	
14	1	1	1	0	Resettable	BDO Over Temperature	BDO Thermistor Alarm (RIC BDO type only)
15	1	1	1	1	-	Not Used	

Table 8.0 Controller Status Monitor

8.1 Conditional Reset of Output Power Alarms

An Output Power Alarm will be activated and the system safety shut down will activate if either:

1. The laser internal output power monitoring system detects a significant change in the system current to output power calibration.
2. The laser internal output power monitoring system detects the absence of an optical output in response to an input set-point and modulation signal.

Note: If the laser is being operated at very low average powers (outside the specified operating range or below threshold) a false Output Power alarm can trigger in some circumstances. To confirm whether the alarm is a true condition, an RS232 command can be used to perform a conditional reset (refer to FS-S00031 for RS232 commands and responses).

CAUTION: If the reset routine is unsuccessful after the first attempt, contact SPI immediately for advice.

CAUTION: During the conditional reset procedure the fibre laser will be set to emit optical power. Ensure the beam delivery optic is securely mounted, pointing towards a suitable beam dump and the end cap has been removed before starting the reset sequence.

CAUTION: Before starting the reset sequence ensure all laser safety precautions are adhered to and laser safety eyewear is worn at all times as defined in Section 1.3.

To reset the Output Power Alarm:

- Ensure the beam delivery optic is securely mounted, pointing towards a suitable beam dump and the protective cap has been removed.
- Apply a TTL high signal to the modulation input and ensure Keyswitch is in the “ON” position.
- Enter the Customer supervisor password and execute the RS232 command to clear the alarm. Refer to document FS-S00031. Alternatively use the GUI to clear the alarm, instructions can be found in SM-S00064.
- Confirm that reset procedure is successful, again the RSR232 commands or the GUI can be used, and cycle the front panel or remote key-switch to reset the laser system.
- The laser is now reset and ready for continued operation.
- If the reset procedure is NOT successful, then contact SPI immediately for advice.

9.0 RS232 Communications

The RS232 interface uses a series of Industrial Command Protocols to control the laser. Details of this control structure is given in document FS-S00031.

If the laser is to be operated using the legacy command set designed for human interaction using a terminal programme such as "Hyperterminal" please contact SPI and request a copy of :

- SM-S00052 Product Manual Addendum - R4 Products Backwards compatibility

9.1 GUI (Graphical User Interface)

SPI provides a Graphical User Interface on a USB Memory Stick which incorporates both the software and a user guide describing the individual functions of the GUI alongside screen images. Each screen provides a visual prompt and text. This enables the user to quickly install and control the laser from a suitable PC.

This GUI is described in document SM-S00064.

10.0 Specifications

The following section describes the full operating and performance specifications of the CW/Modulated High Power Fibre Laser. Included are details regarding electrical requirements for system installation and operation. Before attempting to install or integrate the system, please read this section to ensure all requirements are understood.

10.1 Operating Conditions

Parameter	Units	Specification
Temperature (Operating) (1)	℃	5-40
Humidity (Operating) (1)	%RH	5 – 85 (non condensing)
Warm-up time to CW rated power	min	<5
Warm-up time full operating conditions (Thermal Equilibrium)	min	<15
Altitude	m	Up to 3000
Pollution degree	-	3

1 Refer to Figure 10.1 for a chart showing the relationship between relative humidity, ambient air temperature and cooling water temperature for non-condensing operation

Table 10.1: Operating Conditions

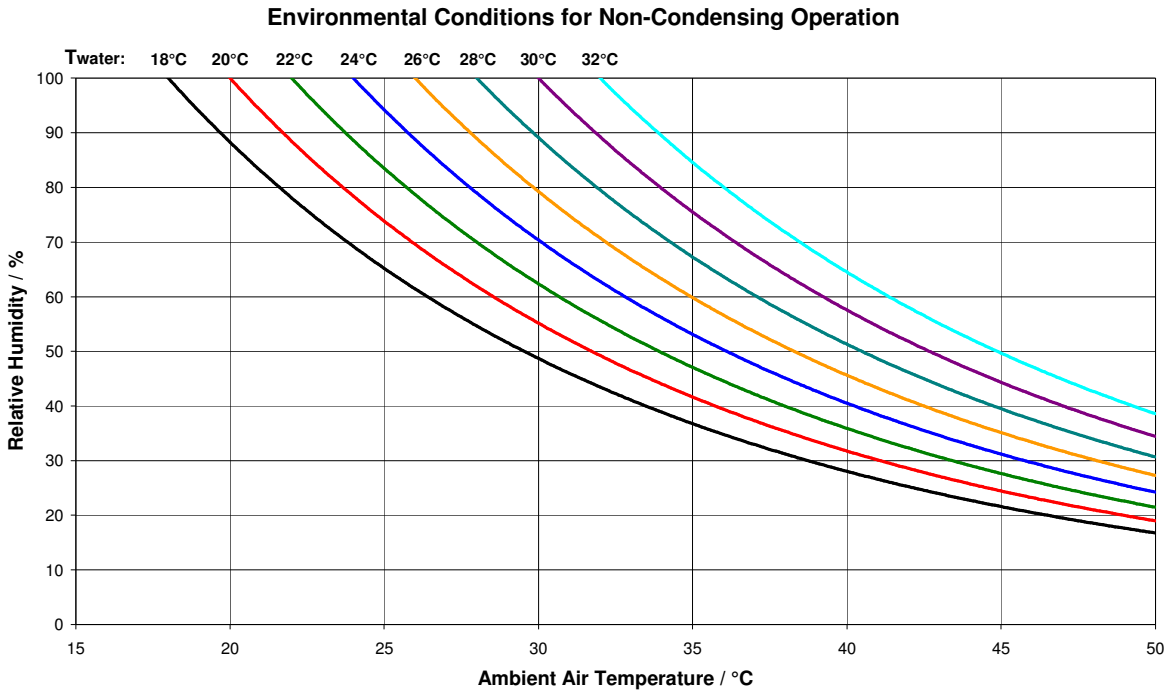


Figure 10.1: Environmental Conditions for Non-Condensing Operation

10.2 Non-Operating Conditions

Parameter	Units	Specification
Temperature (Storage)	℃	0 - 70
Humidity (Storage)	%RH	0 - 95 (non condensing)

Table 10.2: Non-Operating Conditions

10.3 Utilities

Parameter		Units	Specification
Operating Voltage	150W products	V AC	100-240 (±10%) Vac (47-63Hz - auto-ranging) Installation Category II
	200W - 500W products		200-240 (±10%) Vac (47-63Hz - auto-ranging) Installation Category II
Maximum current (RMS)	150W products	A	10
	200W - 500W products		16
Cooling Laser System	Air cooled laser products(1)	-	Internal forced air
	Water cooled laser products(1)		Water cooling supplied by external chiller or house water supply
Cooling Beam Delivery Optic	RIC & QCS	-	Contact cooling
	LLK-Q & QBH		Water cooling supplied by external chiller or house water supply

1 Refer to section 3.1 for a description of laser product variants

Table 10.3: Utilities

10.4 External Chiller Unit Requirements: Laser System (water cooled variants only)

CAUTION: To avoid corrosion to the cooling circuit components within the Fibre Laser the use of deionised water is not permitted.

Parameter	Units	200W	250W	400W	500W
Cooling capacity (@20℃ set-point) (1,2)	kW	0.8	1.0	1.6	2.0
Cooling water flow rate (minimum) (1)	l/m	5	5	8	8
Cooling water temperature	℃	20^{+10}_{-0}			
Maximum input (flow) pressure	bar	8			
Pressure drop between flow and return (3)	bar	2			
Connections provided at laser (4)	-	3/8" John Guest Speedfit			
Use of de-ionised water	-	Not permitted			

1 At an ambient temperature of 35℃ at rated power CW operation

2 It is important that the laser is always operated in a non-condensing environment, i.e. above the dew point. Refer to Figure 10.4 for a chart showing the relationship between relative humidity, ambient air temperature and cooling water temperature for non-condensing operation.

3 Refer to Figure 10.4 for a chart showing the nominal relationship between cooling water flow rate and the pressure drop between flow and return

4 Refer to table 5.4 for compatible fittings

Table 10.4: External Chiller Unit Requirements

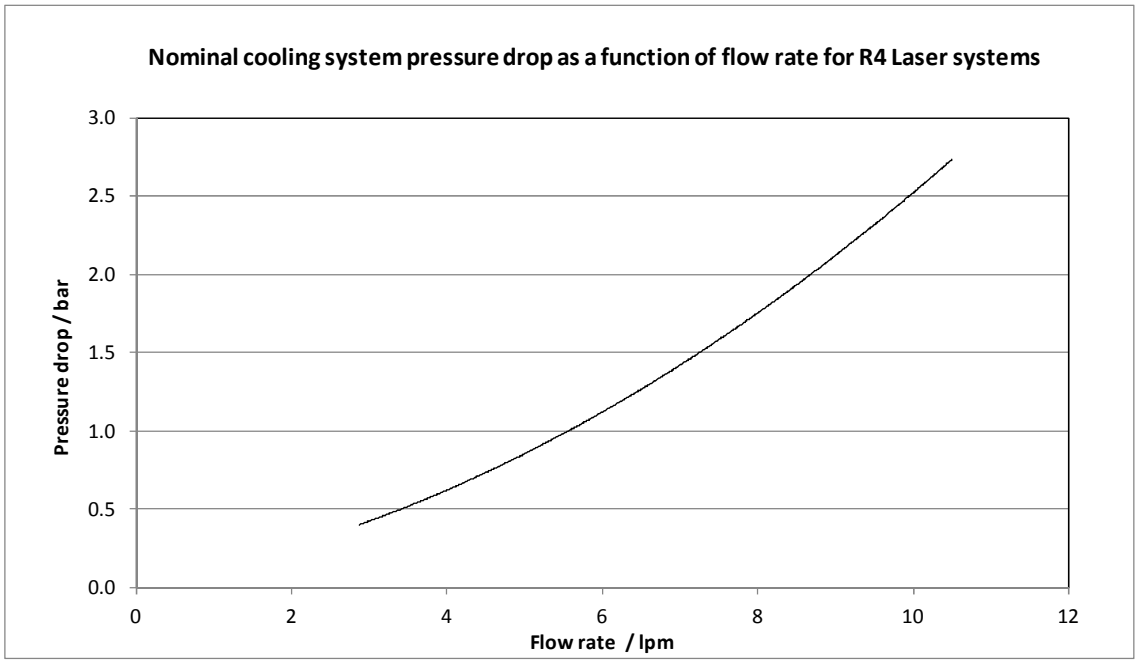


Figure 10.4: Nominal pressure drop as a function of flow rate

10.5 External Chiller Unit Requirements: Beam Delivery Optic

10.5.1 LLK-Q Beam Delivery Optic

Parameter	Units	Specification
Connections at LLK-Q BDO	-	Parker Rectus Type 21 Connector
Connection hose	-	Outer diameter: 6mm Inner diameter: 4mm
Cooling water flow rate	l/min	0.5 - 40
Maximum input (flow) pressure	bar	5
Pressure drop between flow and return (at 1bar input pressure)	bar	0.5
Pressure drop over hose with 4mm ID	bar/m	0.2
Maximum cooling water temperature	℃	35
Minimum cooling water temperature [1]	℃	> 5 above dew point
Chiller cooling capacity	kW	0.5
Cooling water type/quality [2,3]	-	VDI 3803 Appendix B, Table B3 (Refer to table 10.5.1(ii))
Maximum particulate size (diameter)	µm	135

[1] It is important that the LLK-Q Connector is always operated in a non-condensing environment, i.e. above the dew point. Refer to Figure 10.1 for a chart showing the relationship between relative humidity, ambient air temperature and cooling water temperature for non-condensing operation.

[2] Use of inhibitors is allowed if the specifications above regarding water quality and particles are met.

[3] When DI water is used, only these materials are allowed in the cooling circuit: high alloyed steel (V2A, V4A), bronze, PVC-U, EPDM, NBR.

Table 10.5.1(i): External Chiller Unit Requirements - LLK-Q Beam Delivery optic

Parameter	Symbol	Unit	Specification
Appearance			Clear and without sediment
pH Value			7.5 - 9.0
Total Salt Content	GSG	gm^{-3}	<1800
Electrical Conductivity At 25°C		mSm^{-1}	<220
		μScm^{-1}	<2200
Calcium	Ca2+	$Molm^{-3}$	>0.5
		gm^{-3}	>20
Carbonate Hardness	KH	°dH	<4

Parameter	Symbol	Unit	Specification
Carbonate Hardness with Hardness Stabilisation	KH	°dH	<20
Chloride	Cl^-	$Molm^{-3}$	<4.2
		gm^{-3}	<150
Sulphate	SO_4^{2-}	$Molm^{-3}$	<3.4
		gm^{-3}	<325
$KMnO_4$ Consumption		gm^{-3}	<100
Germ Count		$CFUml^{-1}$	<10000
Legionella Bacteria		$CFUml^{-1}$	<10

Table 10.5.1(ii): Summary of VDI 3803 Appendix B, Table B3

10.5.2 QBH Beam Delivery Optic

Parameter	Units	Specification
Connections at QBH BDO	-	SMC MS-5H-6
Connection hose	-	Outer diameter: 6mm Inner diameter: 4mm
Cooling water flow rate	l/min	1.7 ± 0.2
Maximum input (flow) pressure	bar	4
Pressure drop between flow and return (at 1.7l/min)	bar	<1
Pressure drop over hose with 4mm ID	bar/m	0.2
Maximum cooling water temperature	℃	45
Minimum cooling water temperature [1]	℃	> 5 above dew point
Cooling water type/quality [2]	-	Distilled Water Deionised Water Drinkable tap water
Maximum particulate size (diameter)	µm	100
Maximum conductivity	µS/cm	500
pH of cooling water	-	5.5 - 9.0

[1] It is important that the QBH Connector is always operated in a non-condensing environment, i.e. above the dew point. Refer to Figure 5.1 for a chart showing the relationship between relative humidity, ambient air temperature and cooling water temperature for non-condensing operation.

[2] Use of inhibitors is allowed if the specifications above regarding water quality, particles, conductivity and pH are met.

Table 10.5.2: External Chiller Unit Requirements - QBH Beam Delivery optic

10.6 Laser System Specifications

Parameter			Units	Specification	
Rated Output Power (CW)	Air Cooled Products		W	150	- 0% +10%
				200	
	Water Cooled Products			250	
				400	
				500	
Mode of Operation			-	CW / Modulated	
Polarisation			-	Random	
Central Emission Wavelength			nm	1070 ± 10	
Emission Bandwidth (FWHM)	Air Cooled Products		nm	< 4.0	
	Water Cooled Products			< 6.0	
Output Power Tunability (CW)			%	10 - 100 (1)	
Modulation Rise-time at rated power [turn-on delay]			µs	<10	
Modulation Fall-time at rated power			µs	< 10	
Modulation Frequency at rated power			kHz	DC to 100	
Minimum Pulse Width			µs	10	
Output Power Stability over an 8 hour period					
Air Cooled Products	Full operating temperature range	Closed loop	%	< 4.0	
		Open loop		< 6.0	
	Constant temperature	Closed loop		< 1.0	
		Open loop		< 3.0	
Water Cooled Products	Full operating temperature range	Closed loop	%	< 2.0	
		Open loop		< 3.0	
	Constant temperature	Closed loop		< 1.0	
		Open loop		< 2.0	
Pilot Laser Operation					
Emission Wavelength			nm	630 - 680	
Maximum Output Power			mW	1.0 (2)	
Timeout Period			min	10	

(1) For stable operation at percentage of rated output power - minimum target value 3%

(2) Up to 5mW under a single fault condition - refer to section 10.7

Table 10.6: Laser System Specifications

10.7 Single Fault Ratings

Parameter	Units	Specification
Maximum Output Power: 1050-1250nm (1,2)	W	Up to 1.5x the Rated Power for the Laser Product
Maximum Output Power: 630-680nm (1)	mW	<5

(1) This parameter defines the maximum expected CW output power under single fault conditions.

(2) When operating in a modulation configuration, peak powers up to 5x the rated CW output power may be generated at the beginning of the pulse

Table 10.7: Single Fault Ratings

10.8 Beam Delivery Specifications

10.8.1 RIC Beam Delivery System (integrated collimator)

Parameter	Units	Specification				
		Single Mode		Multimode		
Output Fibre Parameters						
Fibre Type (1)	-	S	B	Q	K	N
Mode Field Diameter (MFD)	µm	11.5	18.5	-		
Nominal Core Diameter	µm	-	-	35	50	100
Collimated Output Beam Parameters						
Collimated Beam Diameter ($1/e^2$)	mm	5.0 ± 0.7	3.1 ± 0.5	5.5 ± 1.5	7.0 ± 1.8	8.0 ± 2.0
Collimated Full Angle Divergence	mrad	0.3 ± 0.1	0.5 ± 0.1	1.1 ± 0.5	1.6 ± 0.7	3.2 ± 1.5
M^2	-	≤ 1.1		3.5 ± 0.5	6.5 ± 1.0	15 ± 2
Beam Parameter Product (BPP) (Half angle, waist radius definition)	mm.mrad	≤ 0.38	≤ 0.38	1.2 ± 0.2	2.2 ± 0.4	5.1 ± 0.7
Collimated Circularity	%	≥ 90.0				
Astigmatism	Z_R	≤ 0.25				
Eccentricity (Transverse Offset, XY) (2)	mm	≤ ± 1.0				
Concentricity (Pointing Error, Θ) (2)	mrad	≤ ± 1.0				

(1) Refer to table 3.1.1 for fibre type definitions

(2) Measured with respect to the reference surface Ø30mm +0/-0.02mm defined in figure 11.2.1

Table 10.8.1: Beam Delivery Specifications: RIC Integrated Collimator Option

10.8.2 QCS Beam Delivery System (integrated collimator)

Parameter	Units	Specification	
		Single Mode	Multimode
Output Fibre Parameters			
Fibre Type (1)	–	S	Q
Mode Field Diameter (MFD)	µm	11.5	–
Nominal Core Diameter	µm	–	35
Collimated Output Beam Parameters			
Collimated Beam Diameter ($1/e^2$)	mm	5.0 ± 0.7	3.3 ± 0.8
Collimated Full Angle Divergence	mrad	0.3 ± 0.1	1.5 ± 0.6
M^2	–	≤ 1.1	3.5 ± 0.5
Beam Parameter Product (BPP) (Half angle, waist radius definition)	mm.mrad	≤ 0.38	1.2 ± 0.2
Collimated Circularity	%	≥ 90.0	
Astigmatism	Z_R	≤ 0.25	
Eccentricity (Transverse Offset, XY) (2)	mm	≤ ± 1.2	
Concentricity (Pointing Error, Θ) (2)	mrad	≤ ± 2.0	

(1) Refer to table 3.1.1 for fibre type definitions

(2) Measured with respect to the reference surface Ø14mm defined in figure 11.2.2

Table 10.8.2: Beam Delivery Specifications: QCS Integrated Collimator Option

10.8.3 LLK-Q Beam Delivery System (divergent output)

Parameter	Units	Specification		
		Single Mode	Multimode	
Output Fibre Parameters				
Fibre Type (1)	–	B	K	N
Mode Field Diameter (MFD)	µm	18.5	–	
Nominal Core Diameter	µm	–	50	100
Output Beam Parameters				
Beam Parameter Product (BPP)	mm.mrad	≤ 0.38	2.2 ± 0.4	5.1 ± 0.7
M^2	–	≤ 1.10	6.5 ± 1.0	15 ± 2
Full Angle Divergence	mrad	81 ± 8	175 ± 30	200 ± 30
Circularity	%	≥ 90.0		
Eccentricity (Transverse Offset, XY) (2)	µm	± 25		
Axial error in position of optical fibre end (Z) (3)	µm	± 20		
Concentricity (Pointing Error)	mrad	≤ 8		

(1) Refer to table 3.1.1 for fibre type definitions

(2) The XY positioning accuracy of the fibre with respect to the mechanical housing

(3) Optical fibre end position is defined in Figure 11.2.3

Table 10.8.3: Beam Delivery Specifications: LLK-Q Connector

10.8.4 QBH Beam Delivery System (divergent output)

Parameter	Units	Specification		
		Single Mode	Multimode	
Output Fibre Parameters				
Fibre Type (1)	–	B	K	N
Mode Field Diameter (MFD)	µm	18.5	–	
Nominal Core Diameter	µm	–	50	100
Output Beam Parameters				
Beam Parameter Product (BPP) (Half angle, waist radius definition)	mm.mrad	≤ 0.38	2.2 ± 0.4	5.1 ± 0.7
M^2	–	≤ 1.10	6.5 ± 1.0	15 ± 2
Full Angle Divergence	mrad	81 ± 8	175 ± 30	200 ± 30
Circularity	%	≥ 90.0		
Eccentricity (Transverse Offset, XY) (2)	µm	< 10		
Axial error in position of optical fibre end (Z) (3)	µm	± 50		
Concentricity (Pointing Error)	mrad	≤ 20		

(1) Refer to table 3.1.1 for fibre type definitions

(2) The XY positioning accuracy of the fibre with respect to the mechanical housing

(3) Optical fibre end position is defined in Figure 11.2.4

Table 10.8.4: Beam Delivery Specifications: QBH Connector

11.0 Mechanical Specifications

11.1 Fibre Laser Enclosure

Parameter	Units	Specification
Dimensions (5U-19") - LxWxH	mm	507.0 x 482.6 x 221.4
	in	19.96 x 19.00 x 8.72
Weight	kg	<48
Water Connections (Water cooled products only)	-	3/8" John Guest Speedfit
Electrical connections	-	See Section 4.0

Table 11.1: Mechanical Specifications

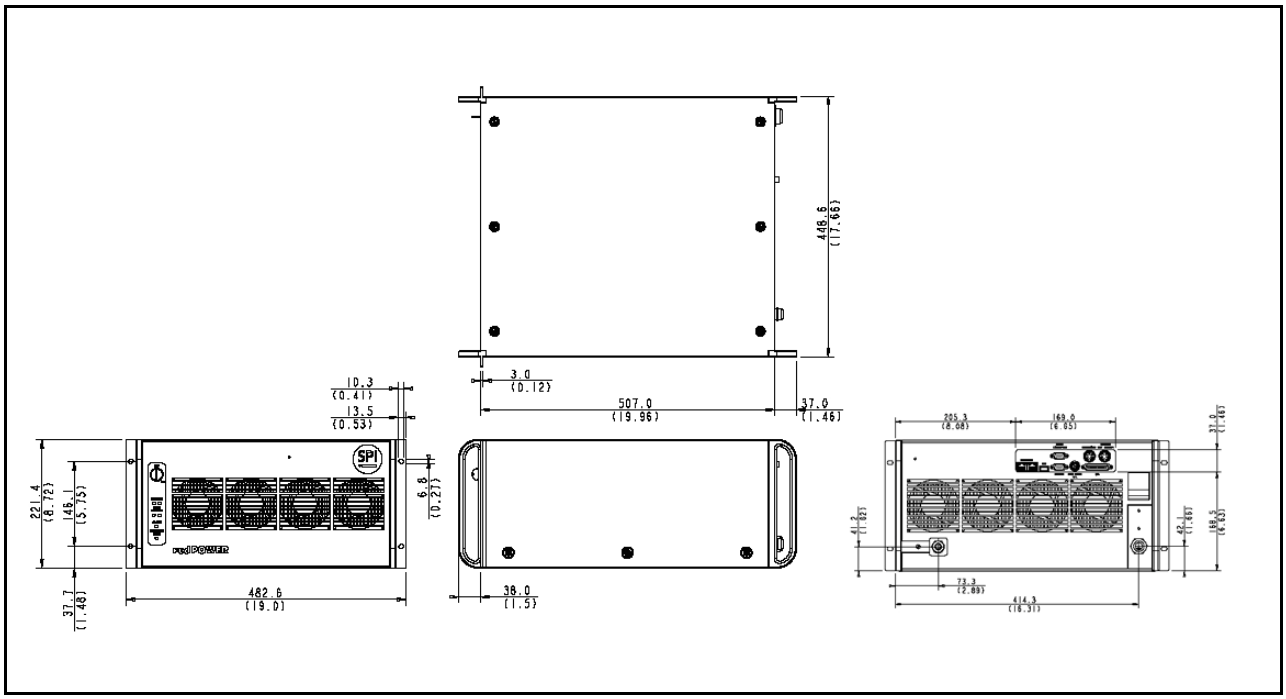


Figure 11.1.1: Outline Drawing - Laser System - Air Cooled Variants

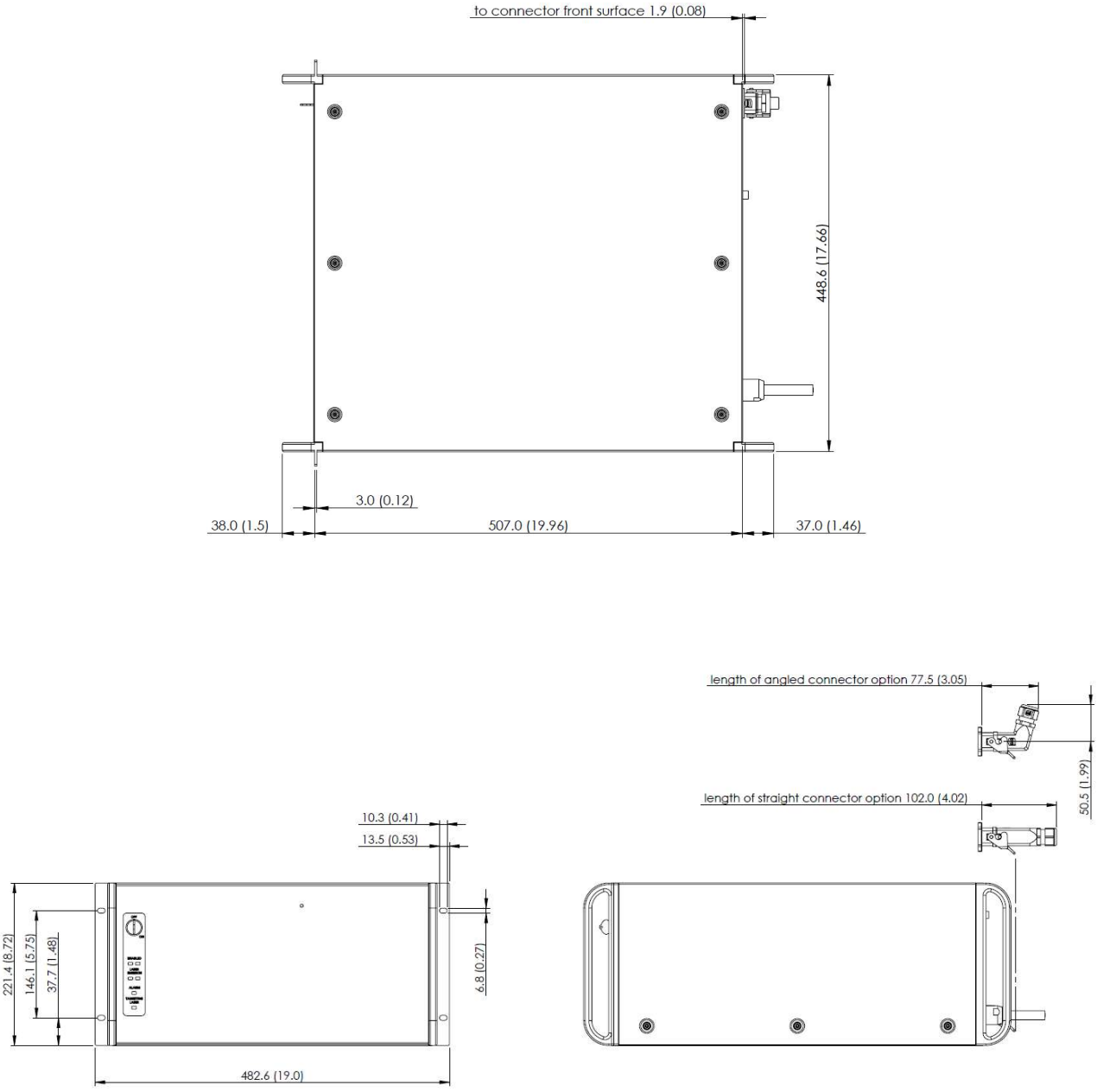


Figure 11.1.2: Outline Drawing - Laser System - Water Cooled Variants

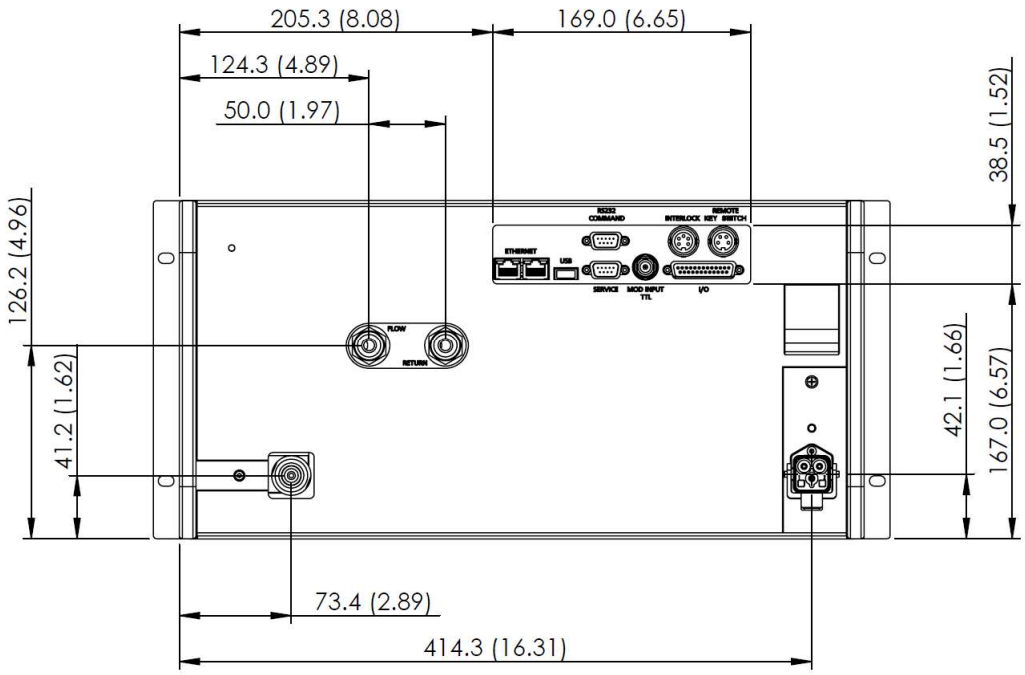


Figure 11.1.3 Rear Panel Detail – Water Cooled Variants

11.2 Optical Output Interface

11.2.1 RIC Beam Delivery System

Parameter		Units	Specification
Connector Optic Length		mm	178.0
Connector Optic Diameter (Reference surface) (1)		mm	30.00 (-0.02, +0.00)
Cable Diameter		mm	10.2 (-0.2, +0.0)
Cable Material (External)		-	PVC
Cable Length		m	6.0 (-0.0, +0.2)
		m	10.0 (-0.0, +0.2)
		m	20.0 (-0.0, +0.2)
Minimum Bend Radius	Static Bend	mm	80
	Dynamic Bend	mm	120
	Coil	mm	150

(1) This surface should be used for clamping and contact cooling

Table 11.2.1: Mechanical Specifications - RIC Beam Delivery System

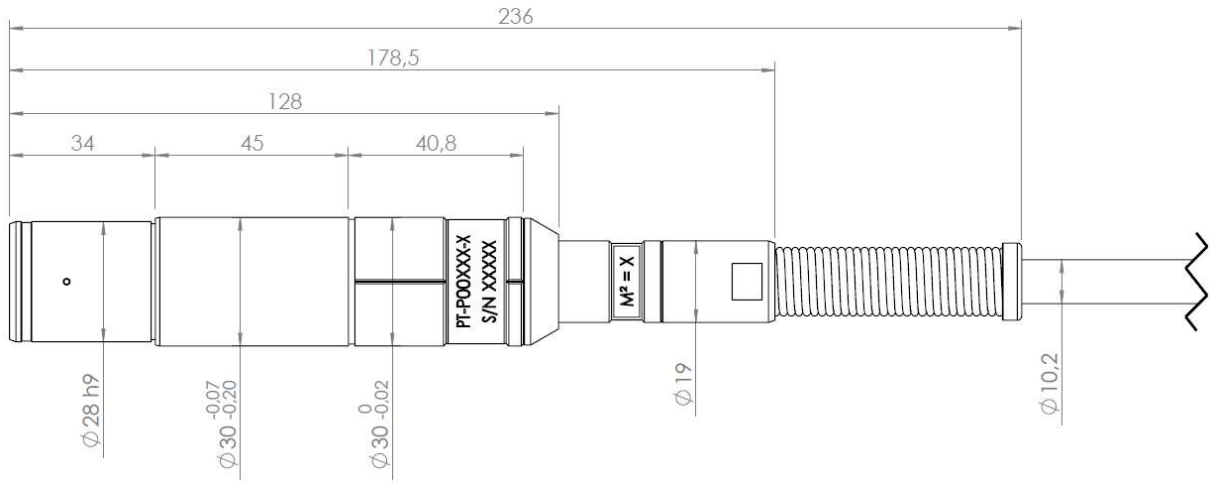


Figure 11.2.1: Outline Drawing - RIC Beam Delivery System

11.2.2 QCS Beam Delivery System

Parameter		Units	Specification
Connector Optic Length		mm	151.0 ± 0.7
Connector Optic Clamping Length		mm	101.0 ± 0.4
Connector Optic Diameter (Reference surface) (1)		mm	14.00 (+0.00, -0.03) h8
Cable Diameter		mm	7.5 ± 1.0
Cable Material (External)		-	Stainless steel round lock tube
Cable Length		m	6.0 (-0.0, +0.8)
		m	10.0 (-0.1, +0.5)
Minimum Bend Radius	Static Bend	mm	120
	Dynamic Bend	mm	120
	Coil	mm	120

(1) This surface should be used for clamping and contact cooling

Table 11.2.2: Mechanical Specifications - QCS Beam Delivery System

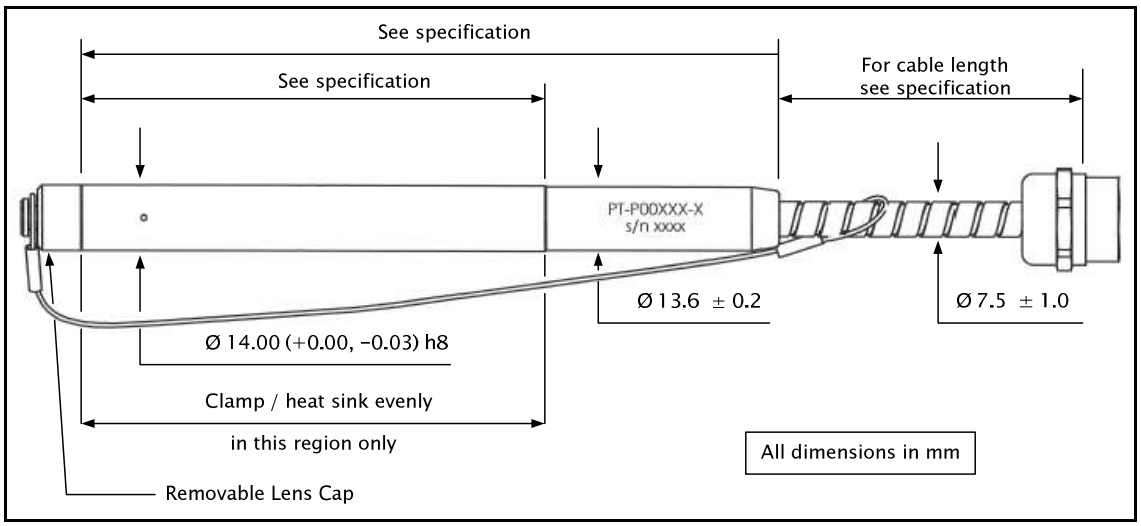


Figure 11.2.2: Outline Drawing - QCS Beam Delivery System

11.2.3 LLK-Q Beam Delivery System

Parameter		Units	Specification
Connector Optic Length		mm	165.35
Connector Optic Diameter		mm	32.0
Cable Diameter		mm	12.5
Cable Material (External)		-	Steel / PU
Cable Length		m	6.1 ± 0.1
		m	10.1 ± 0.1
		m	20.1 ± 0.1
Minimum Bend Radius	Static Bend	mm	150
	Dynamic Bend	mm	150
	Coil	mm	150
Locking Mechanism		-	Bayonet with two-stage locking - Bayonet rotation: 37° - Coupling force >25N

Table 11.2.3: Mechanical Specifications - LLK-Q Beam Delivery System

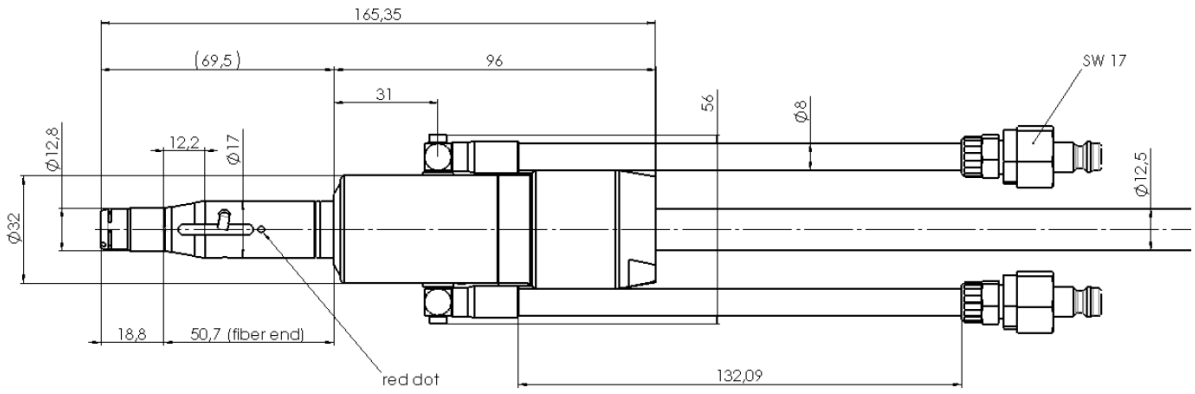


Figure 11.2.3: Outline Drawing - LLK-Q Beam Delivery System

11.2.4 QBH Beam Delivery System

Parameter		Units	Specification
Connector Optic Length		mm	199.4
Connector Optic Diameter		mm	19.0
Connector Flange Diameter		mm	25.8
Cable Diameter		mm	12.5 (+0.2, -0.0)
Cable Material (External)		-	PVC
Cable Length		m	6.15 ± 0.15
		m	10.15 ± 0.15
		m	20.15 ± 0.15
Minimum Bend Radius	Static Bend	mm	150
	Dynamic Bend	mm	150
	Coil	mm	150
Locking Mechanism		-	Bayonet with two-stage locking - Bayonet rotation: 37° - Coupling force >25N

Table 11.2.4: Mechanical Specifications - QBH Beam Delivery System

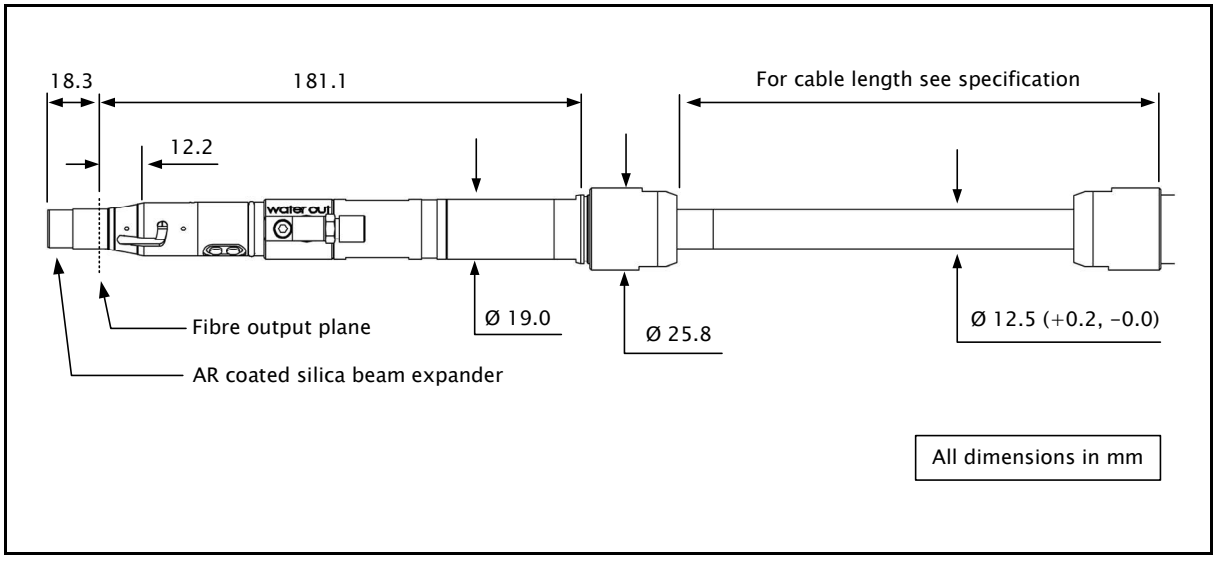


Figure 11.2.4: Outline Drawing - QBH Beam Delivery Optic

12.0 Maintenance

WARNING: Failure to follow procedures and instructions relating to laser maintenance as described in the following section may lead to personal injury and/or damage to the equipment.

WARNING: Before carrying out any of the maintenance tasks detailed in this section, ensure that power to the Fibre Laser is disconnected.

WARNING: Never attempt to modify internal or external components not covered in the scope of this section. Performance degradation and/or premature failure may result.

The **CW/Modulated High Power Fibre Laser** is designed to be maintenance free and as such there are no mechanical items within the unit that require replacement during the specified operating life of the laser. However, to ensure optimum laser performance it may be necessary to clean the output optic in environments with high levels of airborne contamination – see section 12.1

12.1 Output Optic Protective Window Cleaning and Replacement

12.1.1 Spare parts and accessories available from SPI

Component	SPI Part Number
Inspection and Cleaning Kit – RIC	PT-K00163
Inspection and Cleaning Kit – QCS	PT-K00151
Inspection and Cleaning Kit – LLK-Q	PT-K00150
Inspection and Cleaning Kit – QBH	PT-K00152
Portable Vacuum Handling Tool	PT-P00290
Window Removal Tool – RIC	PT-M04356
Window Removal Tool – QCS	PT-M01640
Window Removal Tool – LLK-Q	PT-M04403
Replacement Window Assembly – RIC	PT-P00798
Replacement Window Assembly – QCS	PT-P00340
Replacement Window Assembly – LLK-Q	PT-P00763

Table 12.1.1: Spare parts available from SPI

12.1.2 General Optical Cleaning and the Inspection and Cleaning Kit

The cleanliness of all optical surfaces is critically important. Contamination in the optical path from environmental dirt and dust, or finger grease from incorrect handling must be avoided otherwise contamination will be burned into the optical surface causing permanent damage. Before being exposed to high power, connector end faces should be inspected, preferably with a magnifying aid, and cleaned if any contamination is observed. SPI provide an Inspection & Cleaning kit for this purpose as detailed in table 12.1.1 and shown below in figure 12.1.2.

Figure 12.1.2: USB digital microscope with connector adaptor from the Inspection and Cleaning Kit

Key benefits and features:

1. The ability to inspect and clean the connector end face during installation and maintenance
2. Identification of contamination on optical surfaces

3. Ability to record findings of inspection
4. Does not require the removal of the BDO from the machine
5. Allows for the creation of an auditable trail

The cleaning kit is compatible with all connector types and the software provided with the cleaning kit is compatible with Windows XP, Vista and 7. Further information is provided in SPI data sheet SM-S00343.

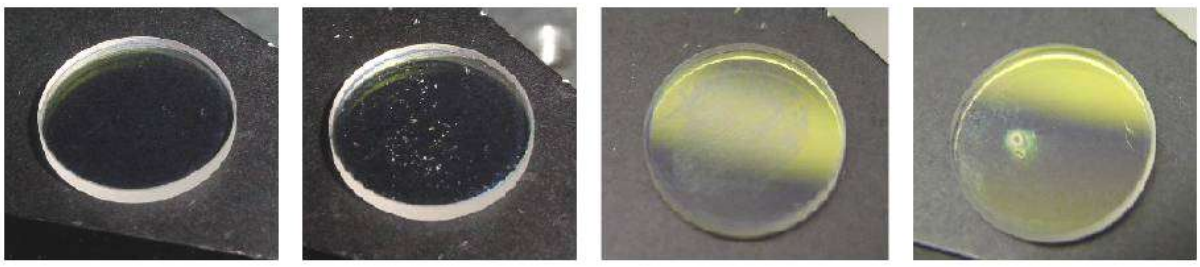
12.1.3 Inspecting the Connector Window for Contamination and Damage

WARNING: Isolate all electrical supplies to the laser to ensure that inadvertent operation of the laser cannot take place.

CAUTION: Ensure that the following procedures are conducted in a clean environment. When handling optical components, always wear powder free finger cots or gloves. Never touch the exposed optical surfaces. During re-assembly of the output optic do not use any form of thread locking compound to secure the window assembly. Failure to follow these guidelines may result in permanent damage to the optical assembly.

The RIC, QCS and LLK-Q connectors are supplied with a replaceable Anti Reflection (AR) coated window to protect the collimating lens and fibre termination from damage. It is possible that during use the window may become contaminated with airborne particles. To avoid damage to the collimating optics or fibre termination, routine inspection of the window is recommended.

Examples of typical optical surface contamination and damage are shown in Figure 12.1.3. Note that the figure shows a typical connector window for illustration purposes only.



Clean window	Dust particles: Window can be blown clean "in-situ"	Surface contaminant (often oily): Clean only when removed from BDO	Laser damage and coating scratch: Window **must** be replaced

Figure 12.1.3: Examples of Window Contamination

12.1.4 Cleaning the Protective Window and QBH Connector Quartz Block

CAUTION: Do not use any cleaning agents other than those detailed in this document.

CAUTION: Never attempt to use an abrasive material to remove contamination. Regular inspection is advised to avoid irreparable damage.

CAUTION: To reduce window contamination, fit the protective cover when the laser is not used for prolonged periods of time or when the laser is being transported or stored.

- Before removal of the Protective Window try to remove any surface contamination from the window using a clean air blower. Never use general "shop floor" or other unknown air sources as these can contain significant amounts of lubricating oil. Always wear gloves to avoid further contamination.

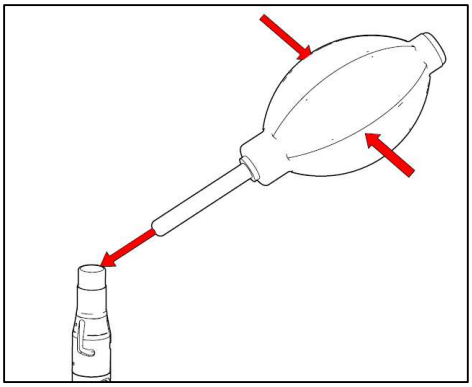


Figure 12.1.4: Clean Air Blower

- If contamination is still present, it is recommended that the window be removed before further attempts can be made to clean the window. If this is unsuccessful then the window will need to be replaced.

- Using a lint free cotton bud or lens tissue lightly wetted with Isopropyl Alcohol (IPA). Wipe in one direction across the window. Do not rub or scratch the surface. For each cleaning process use a new, clean tissue or bud. In some instances, it may not be possible to remove particles. Generally this indicates that the coating is damaged or scratched and must be replaced.

12.1.5 Removing the RIC or QCS Protective Window

WARNING: Isolate all electrical supplies to the laser to ensure that inadvertent operation of the laser cannot take place.

- Removal of the protective window should be conducted in a clean environment to reduce the possibility of dust particles being deposited onto the collimating lens surface.
- Prepare the replacement window and keep it in the dust free packaging; the optic is factory inspected and therefore should not require cleaning. If the window does need cleaning then please refer to the Window Cleaning section in this document.
- Holding the RIC or QCS connector facing downwards towards the floor use the removal tool locate the lugs in the recess positions of the lock ring (figure 12.1.5).
- Slowly unscrew the lock ring (anti-clockwise) and remove completely from the BDO.
- Hold the BDO (output end down) over a clean lens tissue and gently tap the BDO close to the output aperture with finger to release the window. DO NOT TAP THE BDO ON THE BENCH OR USE ANY OTHER IMPLEMENT TO DO THIS. Occasionally, the window can stick to the dust seal (located behind the window). In this case, the window can be removed using vacuum pick up tweezers. Prior to use, ensure that the rubber suction cup is cleaned with IPA. NEVER ATTEMPT TO PRISE THE WINDOW OUT WITH A SCALPEL BLADE OR OTHER SHARP INSTRUMENT.
- Check the internal threads for any debris or dust particles and if present blow away with clean air as described.

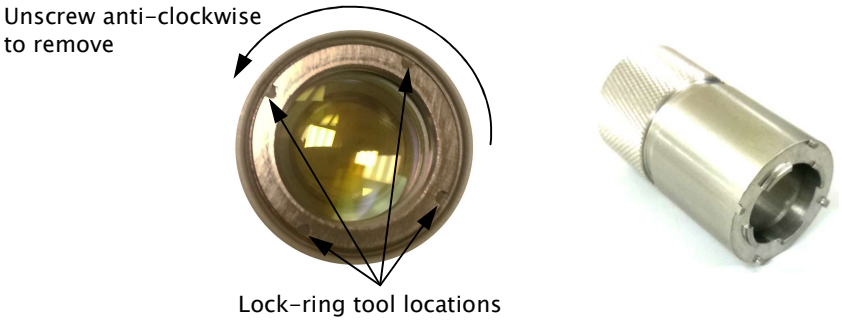


Figure 12.1.5(i): RIC Connector Lock Ring and Removal Tool Details

Figure 12.1.5(ii): QCS Connector Lock Ring and Removal Tool Details

12.1.6 Replacing the RIC or QCS Protective Window

CAUTION: The thread of the replacement window does not require any form of thread locking compound for re-assembly into the housing. Using such compounds may result in optical damage or failure.

- Remove the replacement collimator window from the protective packaging; ensure you are wearing finger cots or gloves to protect the surface of the window.
- Before locating the window into the BDO housing, check the threads, the dust seal and the optic of the assembly for contamination and clean if required.
- Hold the replacement window square to the BDO and drop into the housing. Before re-fitting the lock ring, ensure that the window is seated correctly against the O-ring seal (figure 12.1.6).
- Locate the lock ring on to the inner thread of the Beam Delivery Optic housing and screw in to position using the tool; be careful not to over tighten.
- Inspect the window face for dust particles and blow clean if necessary as described using the clean air can or clean filtered compressed air
- If the laser is not to be operated at this time then replace the protective cap.

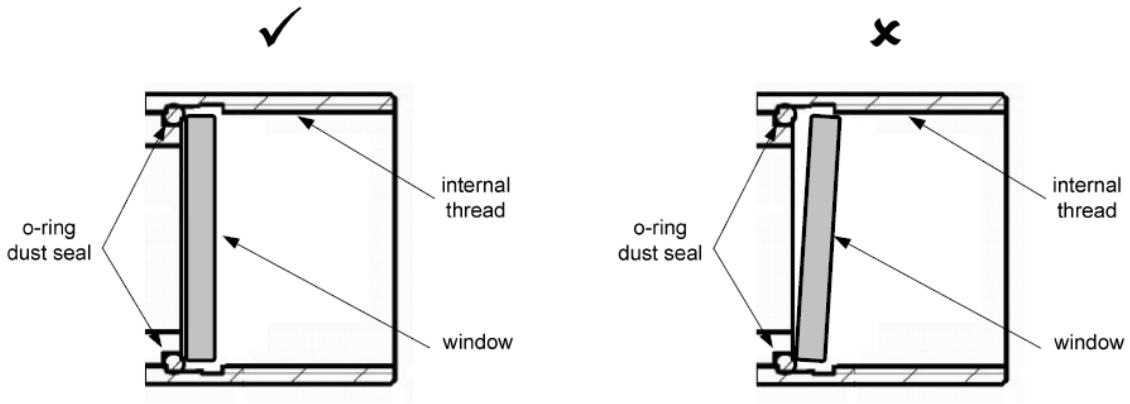


Figure 12.1.6: Correct Window Location

12.1.7 Removing the LLK-Q Protective Window

WARNING: Isolate all electrical supplies to the laser to ensure that inadvertent operation of the laser cannot take place.

- Removal of the protective window should be conducted in a clean environment to reduce the possibility of dust particles being deposited onto the exposed quartz block surface.
- Prepare the replacement window assembly and keep it in the dust free packaging; the optic is factory inspected and therefore should not require cleaning. If the window does need cleaning then please refer to the Window Cleaning section in this document.
- Holding the LLK-Q connector facing downwards towards the floor use the window removal tool to break the seal on the window assembly (Figure 12.1.7).
- Slowly unscrew the window assembly (anti-clockwise) and remove completely from the BDO. Take care not to touch the exposed quartz block beam expander.
- Inspect the exposed quartz block for further contamination or damage. If any debris or dust particles are present blow away with clean air as described.

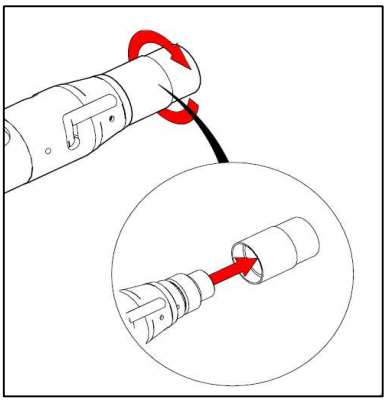


Figure 12.1.7 (i) : Removing the LLK-Q Window Assembly

- If the quartz block requires further cleaning then always use soft lens cleaning paper specifically designed for cleaning optical surfaces and Isopropyl Alcohol (IPA or isopropanol).

Figure 12.1.7 (ii): Lens Cleaning Paper

1 Place a sheet of lens cleaning paper on top of the quartz block.

Figure 12.1.7 (iii): Placing lens cleaning paper on top of the quartz block

2 Drip a single drop of Isopropyl Alcohol on the lens paper above the quartz block.

Figure 12.1.7 (iv): Wetting the lens paper

3 Drag the lens paper across the surface of the quartz block until the surface is completely dry.

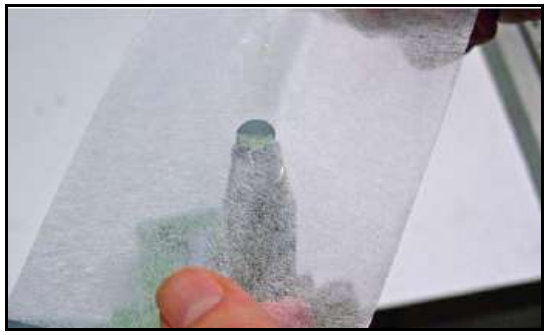


Figure 12.1.7 (v): Cleaning the quartz block

4 Visually inspect the quartz block for cleanliness using a strong light and inspect the surface at a slight angle to improve visibility. Carefully replace the protective window as described in section 12.1.8.

12.1.8 Replacing the LLK-Q Protective Window

CAUTION: The thread of the replacement window does not require any form of thread locking compound for re-assembly into the housing. Using such compounds may result in optical damage or failure.

- Refer to figure 12.1.8 below; the replacement window assembly (1) is packaged within items 2, 5 and 6.
- Ensure you are wearing finger cots or gloves to protect the surface of the window.
- Remove item 5 from the packaging facing down to ensure no particles can enter the inside of the window assembly.
- The replacement window assembly (1) should be held by items 2 & 6. Carefully place the replacement window assembly onto the LLK-Q connector taking care not to make contact with the quartz block.
- Whilst maintaining hold of both the LLK-Q connector and the window assembly turn the whole assembly slowly upright.
- Screw the replacement window assembly clockwise for a few threads only at this stage.
- Remove the window assembly holder (2 & 6); turn the holder around and refit such that item 6 (the tool) now locates on top of the new window assembly.
- Screw the window into position using the tool; be careful not to over tighten.
- Inspect the window face for dust particles and blow clean if necessary as described using the clean air can or clean filtered compressed air.
- If the laser is not to be operated at this time then replace the protective cap.

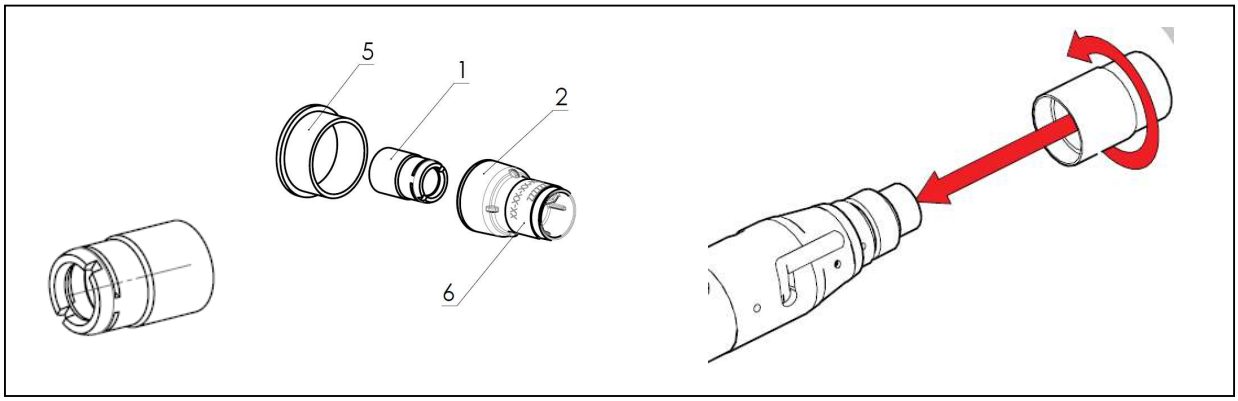


Figure 12.1.8: LLK-Q Window Assembly and Packaging

12.1.9 Cleaning the QBH Connector Quartz Block

WARNING: Isolate all electrical supplies to the laser to ensure that inadvertent operation of the laser cannot take place.

1. Remove the protective plastic cap. This is used only to protect the QBH connector from contamination and damage during shipment and storage.

2. Carefully unscrew and remove the protection tube.

Figure 12.1.9(i): Removing the QBH Protection Cap and Protection Tube

3. Always store the protection cap with the open end facing down in order to avoid contaminants falling inside the cap.

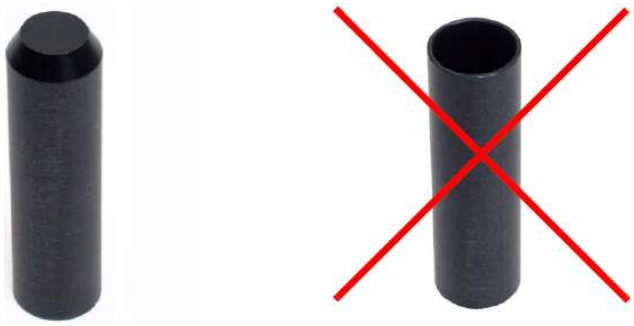


Figure 12.1.9(ii): Always store the protection cap with the open end facing down

4. To clean the quartz block always use soft lens cleaning paper specifically designed for cleaning optical surfaces and Isopropyl Alcohol (IPA or isopropanol).

Figure 12.1.9(iii): Lens Cleaning Paper

5. Place a sheet of lens cleaning paper on top of the quartz block.

Figure 12.1.9(iv): Placing lens cleaning paper on top of the quartz block

6. Drip a single drop of Isopropyl Alcohol on the lens paper above the quartz block.

Figure 12.1.9(v): Wetting the lens paper

7. Drag the lens paper across the surface of the quartz block until the surface is completely dry.

Figure 12.1.9(vi): Cleaning the quartz block

8. Visually inspect the quartz block for cleanliness using a strong light and inspect the surface at a slight angle to improve visibility. Carefully replace the protection tube.

Figure 12.1.9(vii): Replace the protection tube

12.2 General Cleaning

Occasionally, the outside of the laser until may require cleaning to assure full and clear visibility of status LEDs and warning labels and to ensure that the ventilation grille does not become obstructed. Before cleaning, disconnect the laser from the power supply. Clean only with a clean damp cloth and if any labels become displaced contact SPI immediately for a replacement.

WARNING: Do not operate the laser if any of the hazard warning labels are missing or damaged such that they cannot be read properly.

CAUTION: Electrical Hazard. If water comes into contact with any of the electrical connectors, allow the unit to dry completely before commissioning. If water is allowed to enter the system enclosure, do not use the laser and consult SPI immediately.

12.3 Safety Related Control Circuitry

There are no user serviceable components within the safety related circuitry (refer to section 4.4), however it is advised that correct operation of the safety circuit is confirmed on a regular basis.

In order to confirm correct operation of the safety circuit the laser should be armed and then one of the two safety circuits should be opened (refer to section 4.4). When either or both of the circuits are open then the laser must not remain in the armed condition. Repeat this check for the second safety circuit.

If this check fails then contact SPI for advice.

13.0 Customer Service

In the unlikely event that the Fibre Laser requires attention outside the scope of the maintenance requirements as detailed in Section 12.0, contact SPI for advice on further on-site fault diagnosis and/or unit return.

If the unit is to be returned to SPI, ensure that all relevant return documentation is in place before shipment. Details of documentation requirements and copies can be obtained where required from SPI.

Pack the unit in the original packaging and include all original accessories and documentation as detailed in the original inventory. It is advised that the correct and original packaging is used to prevent transit damage to the unit. If part or whole is unavailable, contact SPI for replacement items. Please take time to complete all return documentation. This can be obtained from SPI and accurate details, diagnosis and comments in the documentation can help reduce turn around time for unit repair at SPI.

On request, SPI will supply a report detailing faults found and repairs carried out necessary to return the unit to full operational specification.

CAUTION: The Fibre Laser and the water cooled Beam Delivery Connector (LLK-Q or QBH where fitted) must both be drained of all coolant and the flow and return bungs (plugs) fitted prior to shipment (refer to section 5.5).

If the laser is shipped without the cooling water bungs fitted then any residual coolant will escape during transit and cause permanent damage to the system.

13.1 Contact Information

US Corporate Office	UK Head Office and Manufacturing Facility
SPI Lasers LLC 4000 Burton Drive, Suite 1 Santa Clara CA 95054 USA Tel: +1 408 454 1169	SPI Lasers UK Limited 6 Wellington Park Tollbar Way, Hedge End Southampton SO30 2QU, UK Tel: +44 (0)1489 779696
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Customer Services customerservices@spilasers.com Tel: +44 (0)1489 779696 – Option 5 **Product Support** productsupport@spilasers.com Tel: +44 (0)1489 779696 – Option 2	**Company Web Site** www.spilasers.com Or contact your local distributor.

Table 13.1: Contact Information