G4 Pulsed Fibre Laser Product Manual

Installation Guide and User Manual

The document covers the G4 Laser modules detailed in the table below

Product Code	Laser Module Description	
SP-010P-A-RM-S-A-X	G4 10W, RM series (air cooled)	Single moded products
SP-020P-X-HS-S-A-X	G4 20W, HS series (air or water cooled)	
SP-030P-A-HS-S-A-X	G4 30W, HS series (air cooled)	
SP-012P-A-HS-L-A-X	G4 12W, HS series (air cooled)	Low moded products
SP-020P-A-RM-L-A-X	G4 20W, RM series (air cooled)	
SP-020P-X-HS-L-X-X	G4 20W, HS series (air or water cooled)	
SP-025P-A-RM-H-B-X	G4 25W, RM series (air cooled)	High moded products
SP-030P-A-HS-H-X-X	G4 30W, HS series (air cooled)	
SP-040P-X-HS-H-X-X	G4 40W, HS series (air or water cooled)	

Preface

Definition of Symbols and Terms

This symbol is to alert the user to the danger to exposure of hazardous invisible Laser radiation

This symbol is to emphasize important information regarding installation points or operating procedures

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 or practices that could lead to minor personal injury or product damage.

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

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 component for incorporation.

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.

WARNING: 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:

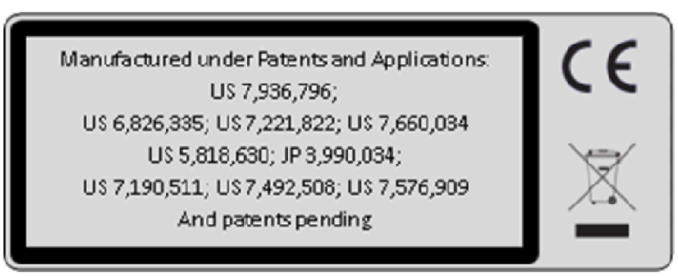
- **will invalidate the warranty**
- **may result in patent infringement**

Laser Integrators are not authorized to modify the specification of the Product.

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 Safety, Compliance and Installation

This section details all health and safety issues regarding the safe installation, operation and maintenance of the Laser module as described in this product manual. Information regarding Laser Safety, Electrical and Mechanical Safety and EMC Compliance is included.

1.1 Laser Hazard Information

DANGER: The Fiber Laser Modules described in this Product Manual carry a Class 4 Laser rating and emit invisible Laser radiation in the region of 1030 -1200 nm with a rated average output power of up to 40 W.

The products contain embedded Laser devices that emit invisible radiation in the region of 900 - 1000 nm with a total output power of up to 70 W for the rated output power of the Laser modules: this radiation is not accessible to the user unless the protective housing is opened.

The Laser may emit significantly higher powers under a single fault condition (<60 W 1030 – 1200 nm; <100 W 900 – 1000 nm).

AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.

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

DANGER: The (optional) internal visible pilot Laser carries a Class 3R Laser rating and emits visible Laser radiation in the region of 630 - 670 nm with an average output power of up to 1 mW.

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

AVOID DIRECT EYE EXPOSURE.

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

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

1.2 Protective Eyewear

Based on the product specification detailed in this manual, the following optical density rating is advised for protective eyewear:

- **DR L6 in the wavelength range of 900-1050 nm (to EN 207)**
- **DR L7 in the wavelength range of 1050-1200 nm (to EN 207)**
- **R1 to EN208 for wavelength 400-700 nm (for visible Lasers)**

The optional internal visible alignment Laser (630nm – 680nm) incorporated in this product carries a Class 3R Laser rating. It is advised that the user **AVOIDS DIRECT EYE EXPOSURE.**

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. The user must complete a documented risk assessment and provide any required personal protection equipment (PPE) before operation of the Laser.

It is recommended that Glass based protective eye wear be used due to the relatively high Peak Powers associated with IR output of the Pulsed Lasers, especially when used in a Laser laboratory prior to fully validated and Eye Safe Installation.

1.3 Compliance

CAUTION: - If the Laser is used in a manner not specified by the manufacturer, the protections incorporated may be impaired and the warranty will be void.

The product is specifically designed as an OEM Laser device 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 IEC/EN 60825-1 and 21 CFR 1040.10 under the Radiation Control for Health and Safety Act of 1968.

It is the responsibility of the equipment manufacturer who integrates the G4 Laser module into a system to meet all of the regulatory requirements for their final system. Nonetheless, the G4 module has been labelled to facilitate the Laser integrator's system compliance with regulatory requirements.

The product is CE marked and is compliant with the requirements of the EMC Directive 2004/108/EC if used and installed according to the recommendations in this document. The Laser module and its cables have been designed as a product for incorporation into equipments that operate in industrial or light industrial environments against the following standards (see section 1.5):

- EN 61010-1:2001 Safety requirements for electrical equipment for measurement, control and laboratory use - Part 1: General requirements
- EN 61000-6-1:2007 Electromagnetic compatibility (EMC) - Part 6.2: Generic standards - Immunity for residential, commercial and light-industrial environments
- EN 61000-6-2:2007 Electromagnetic compatibility (EMC) - Part 6.2: Generic standards -Immunity for industrial environments
- EN 61000-6-3:2007 Electromagnetic compatibility (EMC) - Part 6.3: Generic standards –Emission standard for residential, commercial and light-industrial environments
- EN 61000-6-4:2006 Electromagnetic compatibility (EMC) - Part 6.4: Generic standards - Emission standard for industrial environments.

1.4 Laser Safety on Installation

This product is a Class 4 OEM Laser product specifically designed 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 60825-1:2007.

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 protective housing which prevents human access to Laser radiation in excess of the Accessible Emission Limit (AEL) for Class 1 (see section 4.2 detailed in IEC/EN 60825-1).
- The beam delivery cable is not Class 1 under a worst case single fault, no cable break or fibre break detection is offered on this product. The integrator must either include the beam delivery cable inside the Class 1 enclosure with the Pulsed Laser Aperture or undertake suitable measures to ensure that under reasonable and foreseeable use, the cable is suitably positioned to prevent it from becoming damaged or mishandled.
- The beam delivery cable has not been designed for robotic applications. The Laser must not be designed into systems where the Beam Delivery Cable will be subject to high levels of acceleration, torsion and twist, or combination thereof. If this is a requirement for the integration please contact SPI to discuss the application in more detail.
- Provision of a remote interlock connector which, when open-circuited, prevents access to Laser radiation in excess of Class 1M (section 4.4 detailed in IEC/EN 60825-1).
- Provision of a manual reset function to enable resumption of accessible Class 4 Laser radiation emission after interruption of emission caused by use of the remote interlock connector or an interruption of longer than 5s of electrical mains power (section 4.5 detailed in IEC/EN 60825-1).
- Provision of a key-operated master control. The key should be removable and the Laser radiation shall not be accessible when the key is removed (section 4.6 detailed in IEC/EN 60825-1).
- 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 (section 4.7 detailed in IEC/EN 60825-1).
- Provision of a beam stop or attenuator is permanently attached to prevent access to Laser radiation in excess of Class 1M (section 4.8 detailed in IEC/EN 60825-1).
- If the Laser module has the optional internal, visible Pilot Laser, it is vital that the Laser integrator ensures 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.

  Be aware that the visible Pilot Laser carries a Class 3R eye safety rating and as such SPI recommends use of suitable safety goggles as detailed in section 1.2.

  If the enclosure in which the Laser is mounted is opened, the interlock must interrupt the IR but not necessarily the Pilot Laser, under this condition the enclosure is classed as a 3R Laser Product and should be labeled so.

  i.e. for the Laser to be considered Class3R, the selection of the Pilot Laser must **physically** interrupt the 24V Laser Diode Supply, to prevent any IR emission under a single fault condition (see section 5.1). The pilot Laser operates from the 24V logic supply so will still function. See section10.3 for the pin allocation for the diode and logic 24V power supplies.

  It is the Integrators responsibility to provide the engineering requirements to meet section 4.0 of IEC/EN 60825-1. Review this section for guidance on compliance.

"Laser integrator" in this context is meant to include any person that integrates the Laser into their equipment, or any person who uses the Laser in the form as supplied by SPI.

1.5 Laser Safety under Ethernet Control

It is possible for multiple users to connect to and control a G4 Laser simultaneously via the Ethernet port. The Laser will respond to each command in the order in which it is received and does not differentiate between commands sent from different sources.

Care should be taken especially when controlling the Laser remotely across a network as another user could be working with the Laser.

It is the Integrators responsibility to ensure that any remote connectivity to the Laser cannot inadvertently allow the Laser IR to be enabled during the Integration process when, IR, Pilot Laser and interlock systems are being installed.

We recommend that any user intending to control the Laser via Ethernet, remotely across a network should first check that the Laser is installed in an interlocked, Class 1 enclosure.

1.6 EMC and Electrical Safety Compliance

This is a Laser component product for incorporation, having a requirement for a current-controlled power supply for incorporation within a Finished Laser System. It is a low-voltage, DC-powered sub-assembly and, as such, it is the responsibility of the Laser integrator to meet all of the regulatory requirements for the full system.

SPI recommends the use of a power supply incorporating reinforced (double) insulation rated to a withstand voltage level of 3 kV AC. Alternative electrical power supply configurations are possible. For the Laser product integration in an industrial environment, the selected power supply should be compatible with the intended environment and additional screening may be required to meet the applicable EMC standards. Suitable signal cables of length less than 3 meter should be used.

The electrical connections on the Laser module require electrostatic protection due to the active electronics inside the module. The operator is advised to wear ESD (Electro-Static Device) to provide protection to the unit when handling.

The table below details the EMC test results for the G4 Laser module when tested as a standalone unit as a guide to Laser integrators own system design and testing.

Standard	**Specifics**	**G4**
EN61000-6-1:2007	Immunity/Light industrial /Conducted	Pass
EN61000-6-1:2007	Immunity/Light industrial/Radiated	Pass
EN61000-6-2:2005	Immunity/Industrial/Conducted **Note 1**	Pass **(Note 4)**
EN61000-6-2:2005	Immunity/Industrial/Radiated **Note 1**	Pass **(Note 3,4)**
EN61000-6-3:2007	Emissions Light industrial (Class B) **Note 1**	Pass **(Note 2)**
EN61000-6-4:2007	Emissions Industrial (Class A)	Pass
FCC Part 15	Emissions (Class A)	Pass
IEC 61000-4-2	ESD 4kV Contact Discharge	Pass
IEC 61000-4-2	ESD 8kV Air Discharge	Pass
Note 1:- Most stringent Criteria		
Note 2:- Pass with Ferrites detailed on the G4 Accessory sheet.		
Note 3:- Pass with Shielded Diode and Logic PSU cable accessory. With standard, unshielded cable G4 passed at <7V/m.		
Note 4 Tests were carried out using a shielded 5m Cat5e RJ45 STP patch lead.		

1.6.1 SCSI Signals - Suggested EMC Circuitry

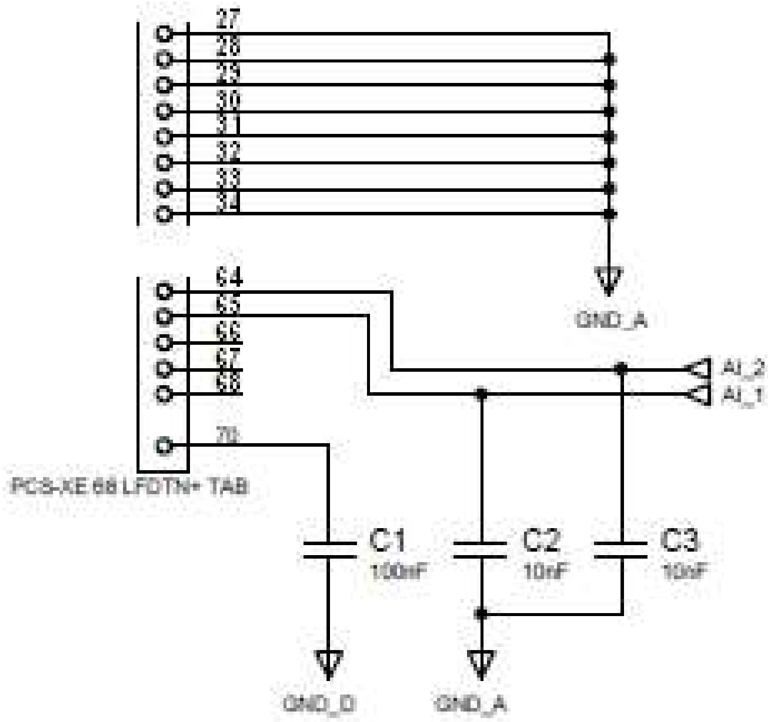


Figure 1. **SCSI Signal Suggested EMC Circuitry**

The inclusion of capacitors C1, C2 and C3 in the Laser integrator's driver circuitry is recommended to increase the current capacity of the Analog Ground line from a trace to a power plane (Pins 27 – 34 inclusive on the I/O connector (SCSI)).

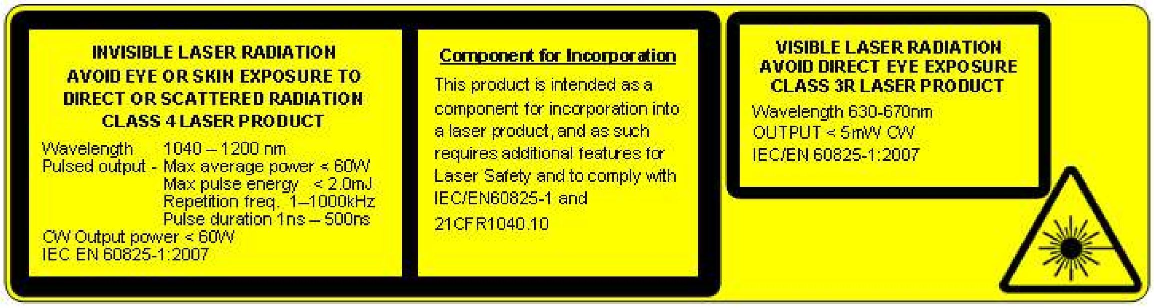
1.7 RoHS Directive Compliance

This product is RoHS compliant in accordance with Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

1.8 WEEE Directive Compliance

	This logo is incorporated in SPI's Laser module labeling. It 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.

1.9 Laser Safety and Compliance Labelling

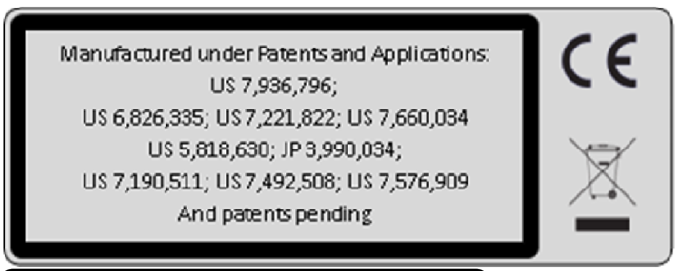


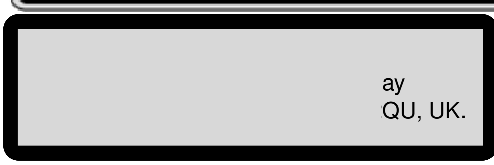
Laser safety warning label incorporating the elements required by IEC/EN 60825-1:2007, specifically

- *Laser warning triangle*
- *Component for Incorporation Labelling.*
- *Laser product classification label*
- *Maximum optical output parameters of the Laser*

Note: this example is used on products where the optional, internal pilot Laser is fitted.

Laser Aperture label, attached to the ILLK.

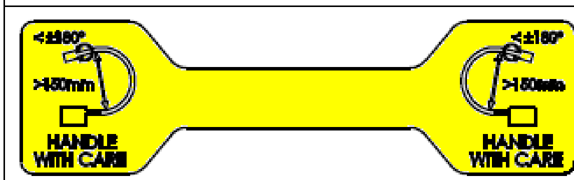




They meet requirements for Patent marking, CE Marking and of the WEEE directive

Serial number and order code. Please quote these numbers when contacting G4 Product Support

Indicates location of earth stud



Specifies optical cable bend diameter

1.10 Location of Labels

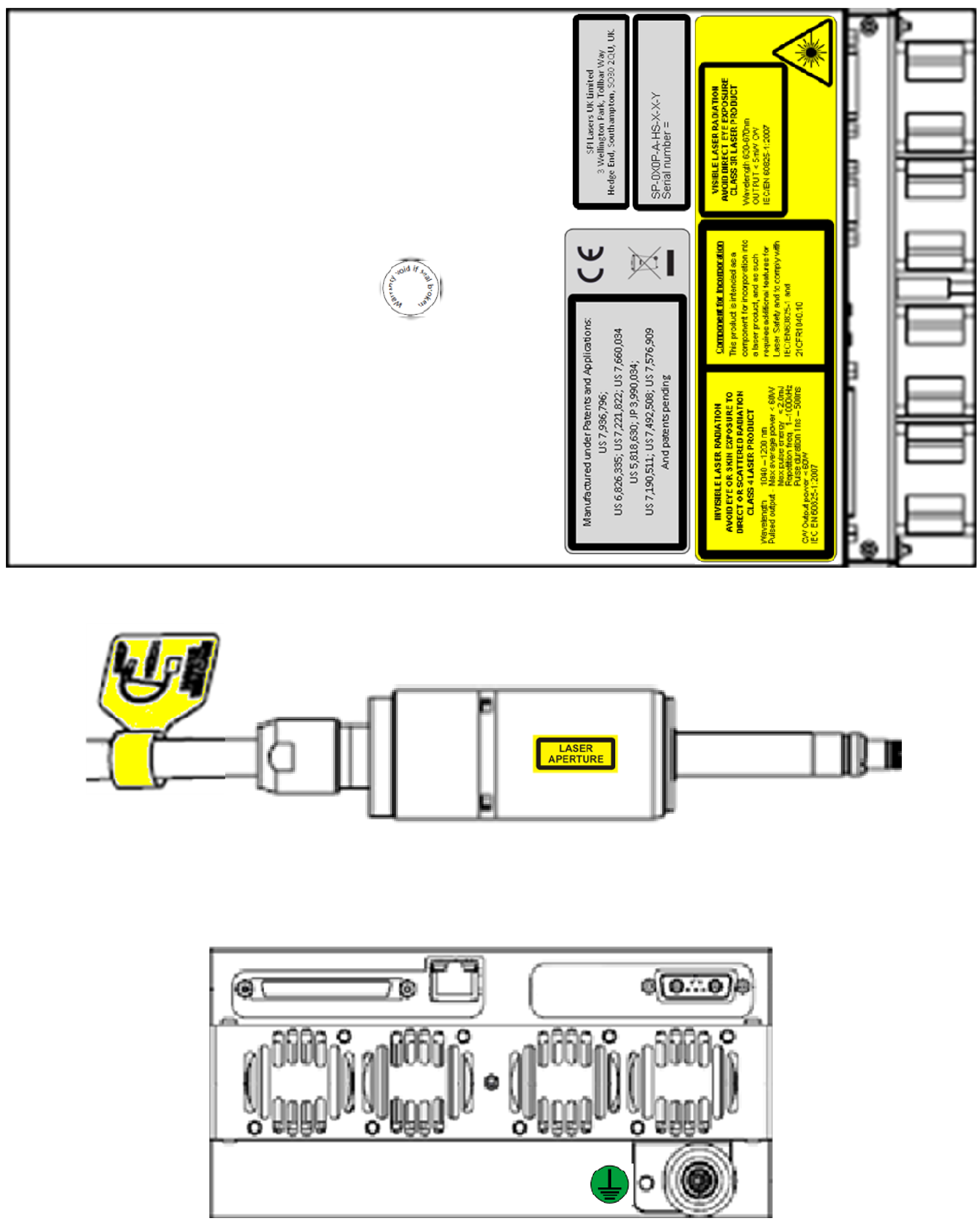


Figure 2. **Label Positioning on the Laser Module**

2 Product Tour

The G4 Laser module is a pulsed fibre MOPA Laser that builds on the successful SPI G3 series Lasers. These products are designed to offer high levels of efficiency and reliability for OEM system integrators requiring pulsed Laser sources traditionally serviced with Q-switched, diode pumped, solid-state Lasers.

2.1 Key Physical Features

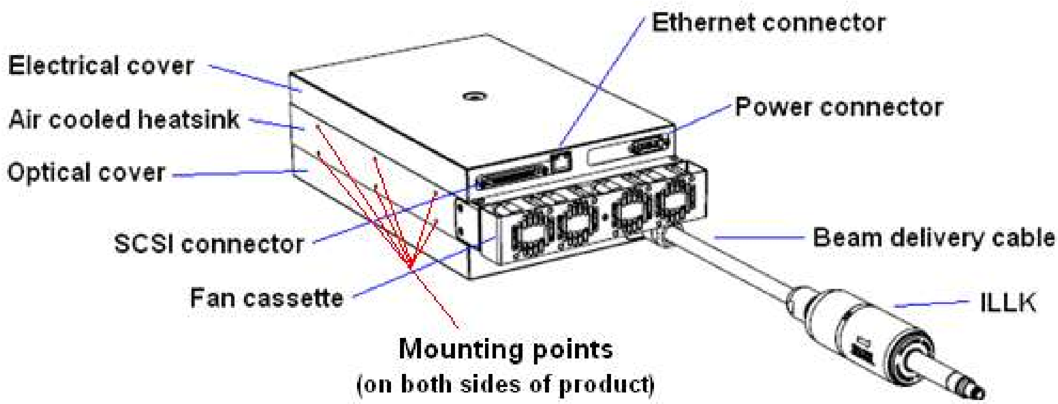


Figure 3. **Laser Module Illustration**

2.2 Integrated Cooling

The G4 product platform has integrated cooling: all variants are available with an integrated air-cooled heat-sink and temperature controlled fans; selected product variants will also be offered with a water-cooled heat-sink (see section 2.5 for available variants).

Figure 4. **Air Cooled G4 Laser module (top); Water Cooled Laser module (bottom)**

2.3 Functional Features

The G4 fiber Laser platform uses SPI's innovative PulseTune technology that offers the OEM integrator highly flexible control over pulse width and peak power. This facilitates deployment of a single OEM solution in multiple applications. See section 2.5 for available variants.

DC-powered, with an integral controller the G4 OEM fibre Laser module has been specifically designed to work with the most widely-used scan card interfaces.

2.3.1 RM Series

The RM series offers entry level models which have a single, pre-set waveform to cover the main Laser marking application space. The user can select repetition rates up to 200 kHz.

- Entry level products with limited pulse options - A single pulse waveform is available
- Repetition rates to 200kHz
- Extended range of flexible interfaces (full hardware or software control, Ethernet).

2.3.2 HS Series

The HS series offers full PulseTune functionality; the HS model enables repetition rates up to 1MHz for a variety of different pulse widths whilst maximizing the pulse peak power.

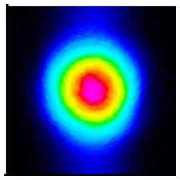
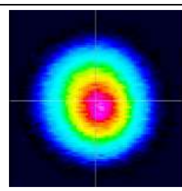
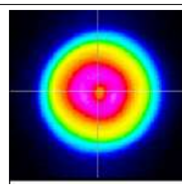
- 25 user selectable PulseTune waveforms
- Continuous wave operation with the facility to modulate the beam.
- Repetition rates to 1 MHz
- Extended range of flexible interfaces (full hardware or software control, Ethernet).

2.3.3 RM – HS Delta Summary

		RM	HS
PulseTune Waveforms		1	25
CW operation		No	Yes
Pulse Repetition Frequency (PRF) range (kHz)		1 - 200	1 - 1000
Pulse width range (ns)	L-type	200	9 - 200
	S-type	170	15 – 220
	H-type	250	9 – 250 (40W) 9 – 200 (30W)
RS 232		Yes	Yes
Ethernet		Yes	Yes
Field Diagnostics and Serviceability		Yes	Yes

2.4 Beam M^2 Options

The table below shows the available fibre types offered on the G4 platform, in terms of the associated M^2 of the output beam. See section 2.5 for available variants.

Beam quality	**Beam profile**	**Minimum M^2 value**	**Maximum M^2 value**
S – type			1.3
L – type		1.6	2
H – type		2.5	3.5

2.5 G4 Product Variants

SPI's G4 Pulsed Fiber Laser Products are ordered and delivered against the following order code structure:

SP-XXXP-X-XX-X-X-X

AVERAGE POWER

COOLING OPTION

PERFORMANCE SERIES

INTERNAL ALIGNMENT LASER

OPTICAL CABLE LENGTH OPTIONS

FIBER MODE OPTIONS

Average Power	
010	10W rated power
012	12W rated power
020	20W rated power
025	25W rated power
030	30W rated power
040	40W rated power

Cooling Options					
		20W S type	**20W HS L type**	**40W**	**Others**
A	Air	All products are available with integrated air cooling (heat sink and fans)			
W	Water	•	•	•	

Performance Series	
HS	Full functionality with PulseTune waveforms and flexible control interfaces
RM	Basic specification with a single waveform and basic interfaces

Fiber Mode Options	
S	Single moded fiber $M^2 \leq 1.3$
L	Low moded fiber $1.6 \leq M^2 \leq 2$
H	High moded fiber $2.6 \leq M^2 \leq 3.7$

Optical Cable Length Options						
		S and L types	**20W HS-L type**	**25W**	**30W**	**40W**
A	**2m**	•	•			
B	**3m**		•	•	•	•
C	**5m**				•	•

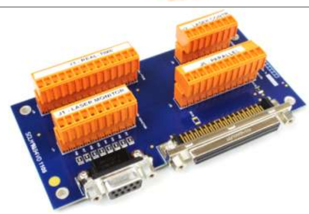
Alignment Laser Options	
N	No internal pilot Laser
Y	Internal pilot Laser

Allowed combinations		Performance Series	
		HS	**RM**
Beam quality	**S type** $M^2 \leq 1.3$	20W, 30W	10W
	L type $1.6 \leq M^2 \leq 2.0$	12W, 20W	20W
	H type $2.5 \leq M^2 \leq 3.5$	30W, 40W	25W

Collimators (F30, F50, F75 & F100) are available to order as separate accessories – no configuration is required. See section 11.3 for more information.

2.6 G4 Accessories

The following accessories are available for the G4 Product family.

Type			Part #	Description
Flanged Collimators		F30	PT-P00577	
		F50	PT-P00553	
		F75	PT-P00554	
		F100	PT-P00555	
Cylindrical Collimators		F30	PT-P00614	
		F50	PT-P00615	
		F75	PT-P00616	
		F100	PT-P00617	
I/O Control Cables			PT-E01261	This is a 1m 68-way SCSI III male to male screened cable with M2.5 screw locks. It is used to provide connectivity for RS-232 communications and hardware control and fault reporting. G4 Lasers ship with this cable as standard. This is available as a replacement part.
Standard DC power cable			PT-E01590	This power cable is 1.1m in length Two pairs of conductors allow easy connection to the diode and logic power supplies of a G4 module. G4 Lasers ship with this cable as standard. This is also available as a replacement part.
Screened DC Power cable			PT-E01651	Power cable for use to meet the tighter radiated immunity requirements of BS61000-6-2:2007 for industrial environments. (length = 1.1m, cable diameter = 10.1mm) (Without this G4, stand alone, meets EN61000-6-1:2007 immunity standard for light industrial requirements).
G4 break-out board			PT-E01628	This part allows the user to separately access the individual interfaces implemented via the 68 way SCSI cable. Use with the IO control cable. Note: no serial cable provided with this part. If required please also order part number PT-E00746.
Ferrites			PT-K00123	For use with G4 SCSI and power cables to meet the tighter emissions requirements of BS61000-6-3:2007 for residential, commercial and light-industrial environments. (Without these G4, stand alone, meets EN61000-6-4:2007 emissions standard for industrial requirements).
Protective Gaiter			PT-M03592	To provide a seal between ILLK and BEC (shown with ILLK and Flanged collimator)

2.7 G4 Software Tools

To support the user in controlling the G4 Laser module in their equipment SPI provide the following SW tools for the modules Ethernet and RS-232 interfaces.

	Part #
G4 Graphical User Interface for Ethernet control of the Laser	PT-S00095
G4 GUI manual	SM-S00263
G3/G4 Terminal Application for RS-232 control of the Laser	PT-S00103
Manual for G3/G4 terminal application	SM-S00319

3 Getting Started

3.1 Unpacking and Handling the Laser

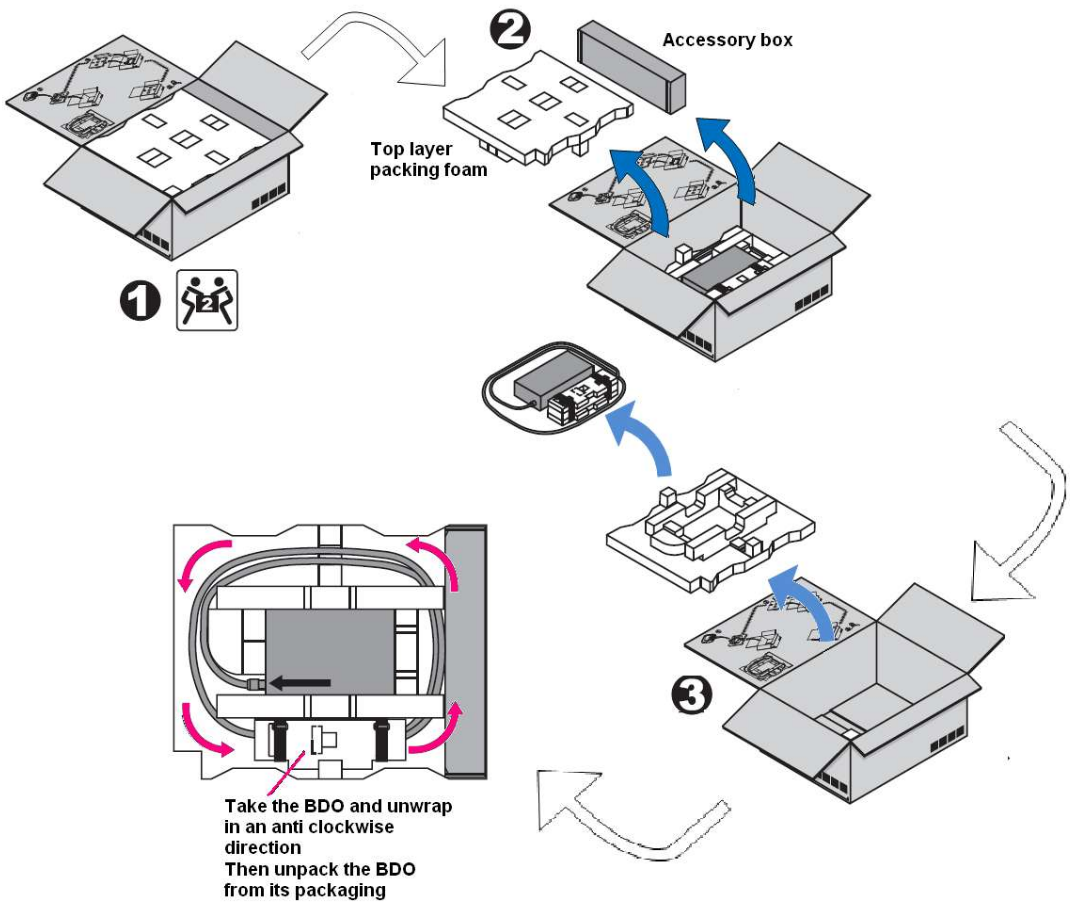


Figure 5. **Unpacking the Laser**

When unpacking the G4 Laser module from the shipping carton you should:

- Remove the documentation and foam spacer from the top of the Laser module
- Remove the box containing the accessories
- Carefully remove the Laser module from the packaging using both hands taking care to avoid any tight cable bends, or trapping the cable under the Laser module.
- Locate the BDO (optical connector). To uncoil the beam delivery cable, unwind it from the free end whilst taking care not to knock the optical connector.

CAUTION: Be careful to not drop optical connector or knock it against a hard surface since it contains precision optics that can be damaged by mishandling.

3.2 Receiving and Inspection

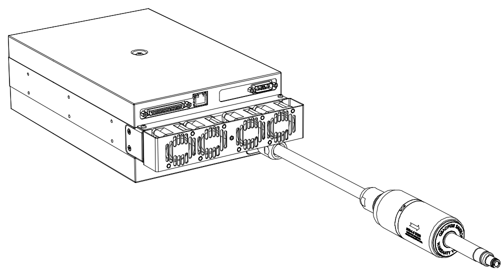
Before installing or operating the Laser Module, you should:

- Inspect the shipping container for damage
- Inspect the G4 Laser module for signs of damage
- Inspect the ILLK optic and cable for any signs of damage
- Confirm that the shipping carton contains all items on the shipping inventory list including any accessories order as separate line items

Retain all packaging materials until the Laser module has been inspected for completeness and damage, and you have checked the operating performance. If anything is missing or defective, see section 19 for contact details.

3.3 Delivered Product

The product will be shipped with the options defined by the appropriate fields of the product order code as defined in section 2.5.



All G4 Laser modules will be shipped with the following accessories as standard:

1	DC power supply cable	PT-E01590	
2	SCSI control cable	PT-E01261	
3	Customer CD		Contains Manual, Ethernet graphical user interface and RS-232 terminal application

Any accessories required (see section 2.6) must be ordered as separate line items.

They will be shipped inside the associated Laser module packaging

4 Principles of Operation

4.1 System Overview

A functional block diagram of the G4 Laser is shown below. It is a DC-powered module based around a dual-stage Yb GTWave^{TM} fibre amplifier system with an optical seed pulse generated by a single-mode semi-conductor (master-oscillator) Laser diode.

The GTWave^{TM} amplifiers are pumped by multi-mode 9xx nm Laser diodes. The fibre-optic beam delivery cable is terminated with an ILLK connector which has a divergent beam. A range of optional beam expanding collimator (BEC) accessories are available to provide a collimated output beam.

The module incorporates

- Diode driver electronics for the seed Laser diode.
- The pre-amplifier pump Laser diodes.
- The power-amplifier pump Laser diodes.

The main control electronics provides synchronization of the semi-conductor pump Laser diodes according to parameters set by the user. The hardware and software control interfaces give the user the capability to achieve a wide range of parametric characteristics.

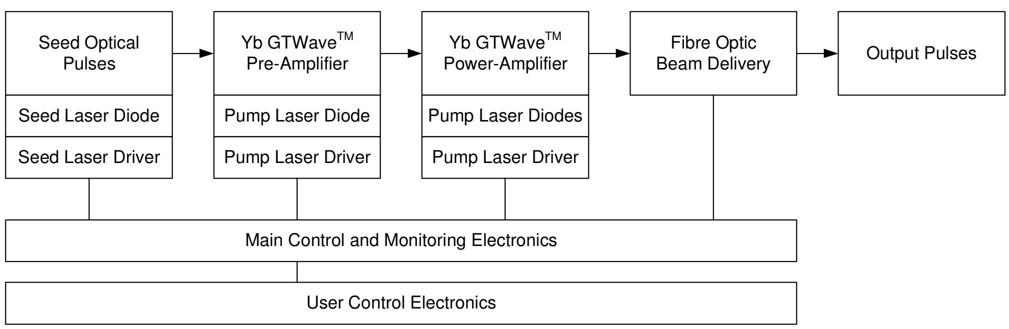


Figure 6. **G4 Laser Module Functional Block Diagram**

4.2 PulseTune Waveforms

The HS series Laser modules incorporate pre-programmed waveforms, The RM series has a single, waveform defined. A waveform defines:

- an electrical impulse to the seed Laser diode
- a default 'switching frequency', PRF_0, selected to give maximum peak power

The parameters of the waveforms for the different variants are tabulated in sections 14.2 and 14.3. See section 15 for samples of the waveform temporal profiles.

4.2.1 Pulse Repetition Frequency (PRF) Range

The G4 Laser can be operated with any pulse repetition rate regardless of the waveform selected without any damage being caused.

- At pulse repetition frequencies below PRF_0 the Laser diodes are modulated to prevent damaging, high-energy pulses. The average power therefore drops linearly as the frequency decreases below PRF_0. This allows effective pulsing from 1 kHz to PRF_{MAX} for the Laser variant.

  On the rising edge of the pulse trigger (internal or external) with the Laser enabled and Laser_Emission_Gate signal active the Laser module enters the ACTIVE state and the pump Laser diodes are driven as defined by the active current set point. After a period of $1/PRF_0$ has elapsed the Laser module returns to the SIMMER state. The pump Laser diodes are then driven as defined by the simmer current set point. This lower level works to maintain the energy in the fibre spools ready for the next pulse trigger and prevents excessive energy being pumped into the fibre.

- At pulse repetition frequencies above PRF_0: the average power of the Laser is maintained whilst pulse energy and peak power decrease with increasing pulse repetition frequencies.

  As previously, on the rising edge of the pulse trigger the Laser module enters the ACTIVE state and the pump Laser diodes are driven as defined by the active current set point. However, given the pulse rate the next pulse trigger occurs before the $1/PRF_0$ period has elapsed. As the full active period has not completed the energy built up in the spools is less and so the resulting pulse has lower energy and peak power than in the case where $PRF \leq PRF_0$. As the PRF increases the energy available for each pulse decreases as $E_{max} \times \frac{PRF}{PRF_0}$.

These two cases are illustrated in the timing diagram shown in Figure 8.

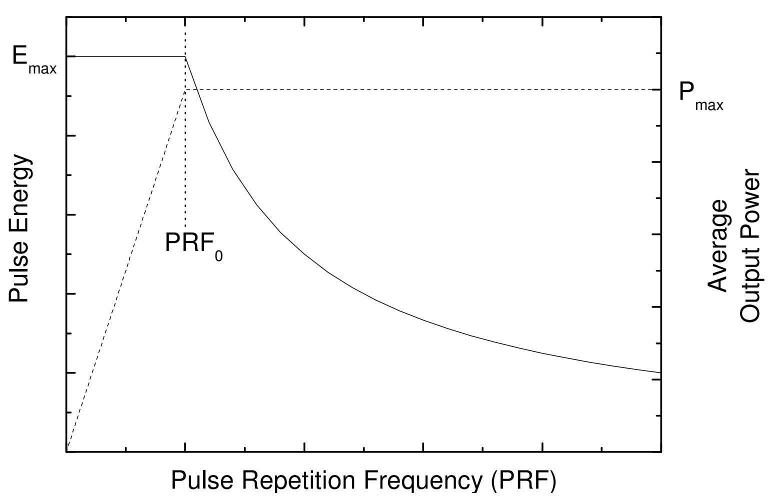


Figure 7. **Average Power and Pulse Energy vs Pulse Repetition Frequency**

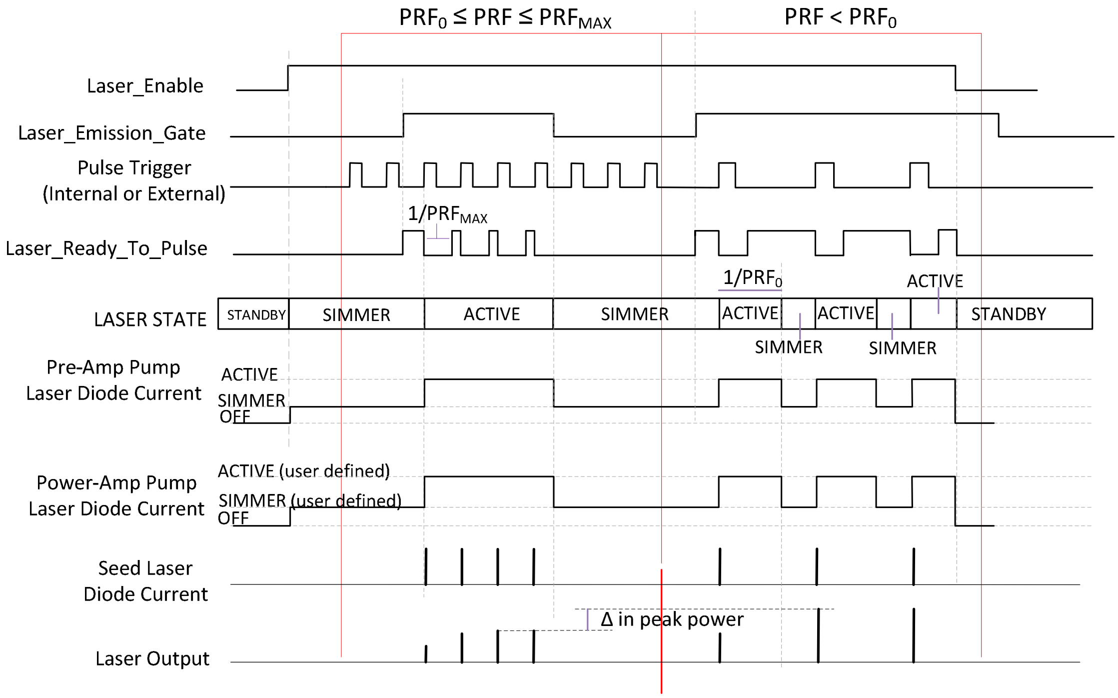


Figure 8. **Timing Diagram for PRF > PRF$_0$ and PRF < PRF$_0$**

4.3 Active Current Effects

G4 Lasers also allow the user to control the active current of the power amplifier pump diodes.

The active current set-point defines the level at which the power-amplifier Laser diodes operate when the Laser is the ACTIVE state.

This setting acts as an approximately linear scaling factor to the Laser's maximum rated average power in both pulsed and CW modes of operation.

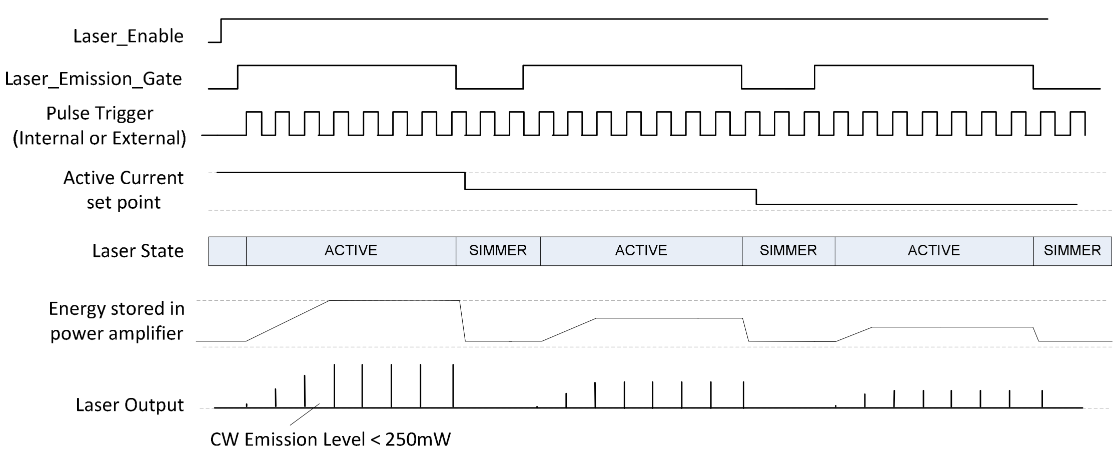


Figure 9. **Effect of Active Current on Optical Output**

4.4 Simmer and Pumping Scheme

4.4.1 Simmer Scheme

G4 Lasers have a facility for the user to control the simmer current of the power amplifier. This is available when using Interface Control Modes 0, 1, 4 and 5. (Note: RM does not support mode 4).

The simmer current is a low-level current set-point at which the power-amplifier Laser diodes operate at when the Laser is the SIMMER state (i.e. between pulses). The effect of the simmer current is to 'pre-charge' the power amplifier to a certain level so that there is energy in the power amplifier fibre for the first few pulses from the pre-amplifier to extract After a few pulses, the energy in the power-amplifier will be determined by the power-amplifier Active-state Current Set-Point. The simmer current set point affects the shape the rising edge of the CW mode optical output.

The maximum simmer current is factory-set to give optimised rise-time characteristics for an output at rated power with pulse rates = PRF_0 for the waveform selected.

For operation with pulse energies lower than the maximum (i.e. at lower-than-rated average power, or with pulse rates > PRF_0 at rated power) then the power-amplifier simmer current set point should be decreased using the power-amp simmer current line or the appropriate RS-232 or Ethernet commands until the desired rise-time characteristics are achieved.

Under normal, pulsed mode operation when the Laser is enabled it will enter the SIMMER state for a minimum of 10ms to ensure that there is sufficient energy in the power amplifier for the first pulse.

4.4.1.1 Emission in the SIMMER state

Operation of the Laser with the simmer current set point levels set above their threshold levels when the Laser is in the SIMMER state the emission will result in continuous-wave emission, levels defined in the table below

Laser Type	Max CW emission in SIMMER state (mW)
S and L type	250
H type	330

To prevent Laser emission, put the Laser into STAND-BY state by making the Laser_Enable line LOW in hardware mode, or with the command 'SC 0' in software interface mode.

There is a trade-off between the level of Laser emission in the SIMMER state and the energy in the 1st pulse: lower set point levels result in less energy and slower rise-times but less emission in the SIMMER state.

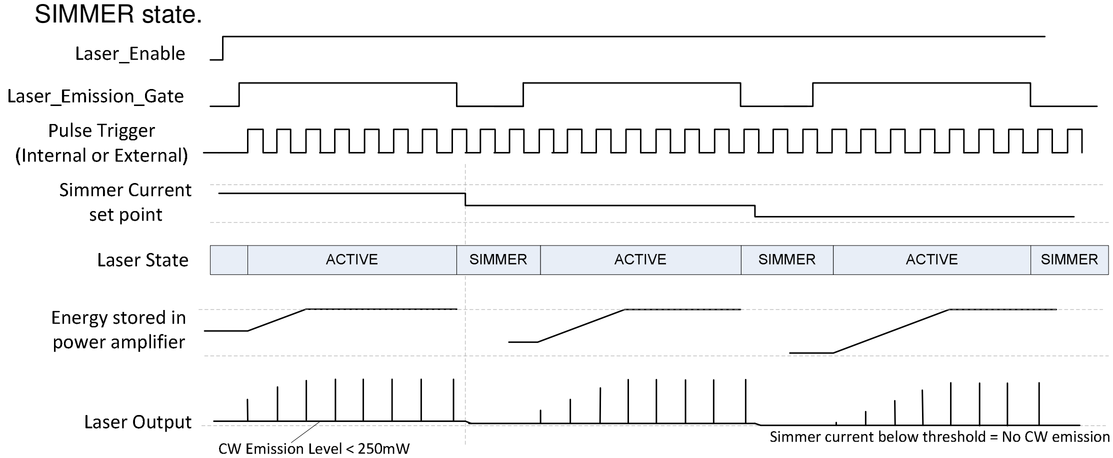


Figure 10. **Effect of Simmer Current on Optical Output**

4.4.2 Pumping Scheme

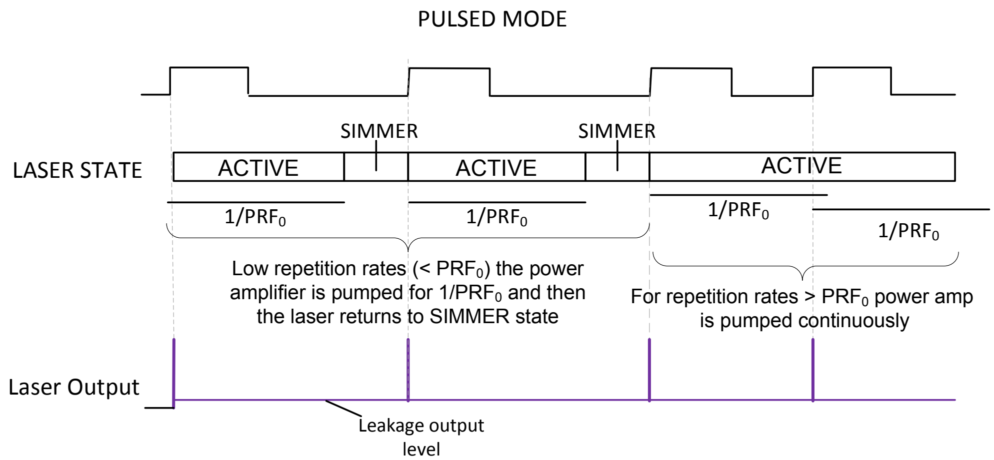


Figure 11. **Standard Pumping Scheme**

The rising edge of Pulse trigger (internal or external) transitions the Laser into the ACTIVE state, enabling an IR pulse to be emitted. At the same time the power amplifier is charged to replenish the energy stored in the fibre for a period of 1/PRF$_0$ (associated with the selected waveform).

For high repetition rates (> PRF$_0$) the power amplifier is constantly pumped.

For low repetition rates (< PRF$_0$) the Laser returns to the SIMMER state once the 1/PRF$_0$ interval has elapsed. In the SIMMER state there is a small amount of leakage output power. However, for repetition rates reasonably close to PRF$_0$ this leakage amount is fairly small and has a minimal effect on the following Laser pulse energy.

4.5 Laser State Definition

4.5.1 Laser State Diagram

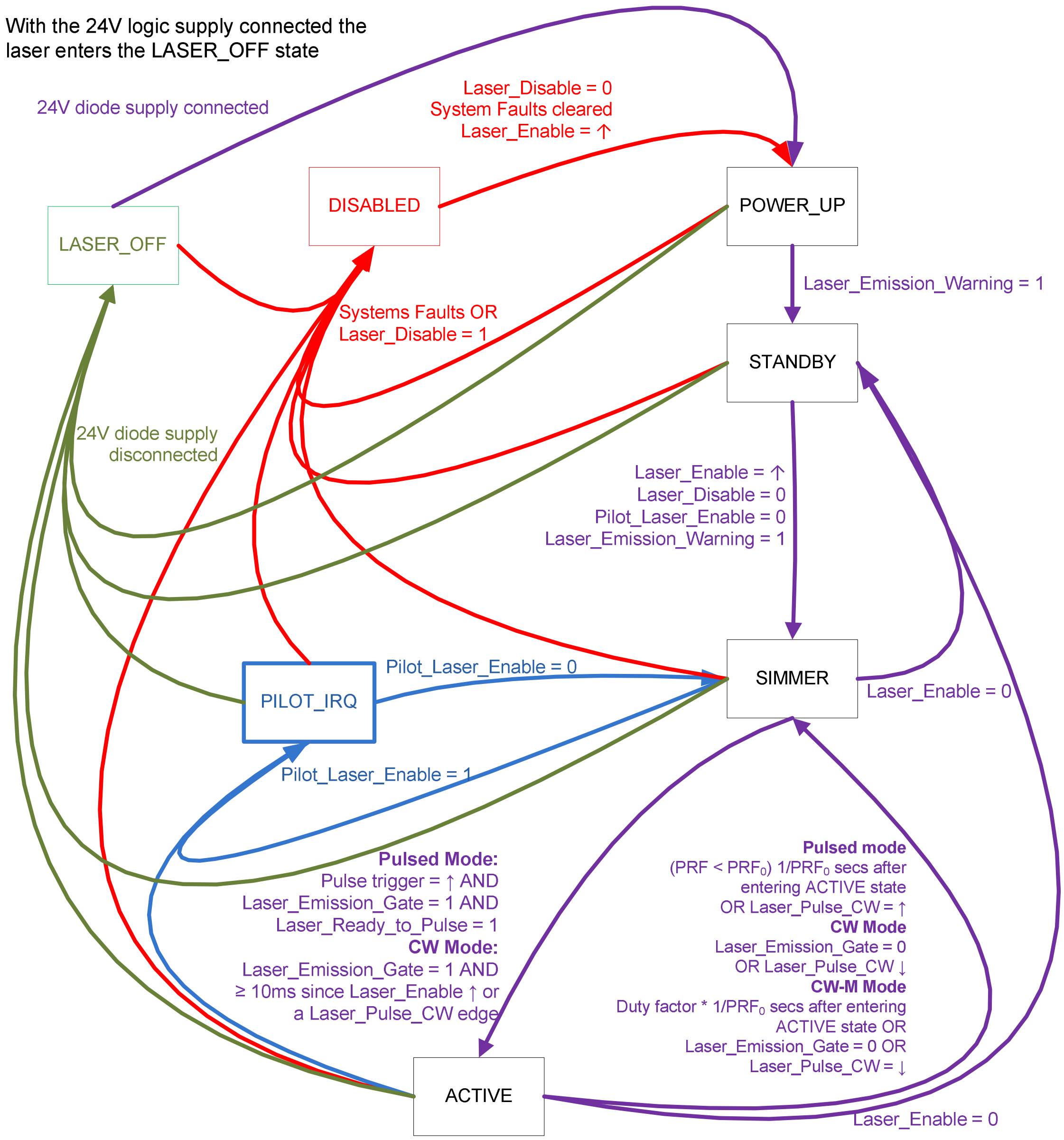


Figure 12. **G4 Laser State Diagram**

Laser State	Description
DISABLED	A fault or interlock event has occurred and the internal power supplies are disabled
LASER_OFF	No 24V diode supply is connected
POWER_UP	Internal 24V diode supply is powering up
STANDBY	Internal power supplies are on but the Laser is not enabled
SIMMER	The Laser can emit power depending on the simmer current set point –section 4.4.1
ACTIVE	The Laser is emitting pulses or CW IR output according to the specified settings
PILOT__IRQ	IR Laser output interrupted, visible pilot Laser active

4.5.2 Laser State Functionality and Signal States

	DISABLED	LASER_OFF	POWER_UP	STANDBY	SIMMER	ACTIVE	PILOT_IRQ
Functionality							
Logic internal power supplies	ON	ON	ON	ON	ON	ON	ON
Diode internal power supply	OFF	OFF	Turning on	ON	ON	ON	ON
Laser pump diodes	OFF	OFF	OFF	OFF	ON	ON	OFF
Pilot Laser	(1)	(1)	(1)	(1)	OFF	OFF	ON
Switching between hardware and software control allowed	NO	YES	YES	YES	NO	NO	NO
Signals							
External 24V diode supply	X	0V	24V	24V	24V	24V	24V
Laser_Emission_Warning	L	L	L	H	H	H	H
Laser_Is_On signal	L	L	L	L	H	H	L
Laser_Deactivated (active low)	L	H	H	H	H	H	H
IR Laser emission	NO	NO	NO	NO	YES (simmer level)	YES (active level)	NO

X = don't care

(1) Pilot Laser can be operation in these states depending on Pilot_Laser_Enable signal and whether interlock strategy interrupts the logic power supply needed to operate the pilot Laser (section5).

4.6 Laser Controls and Settings Overview

The table below indicates the settings that can be controlled by the user for each variant series

Name	Description	HS	RM
Pulsed mode	Pulsed Laser output from 1kHz to 1MHz - high peak powers/pulse energies	●	
	Pulsed Laser output from 1kHz to 200kHz - high peak powers/pulse energies		●
CW mode	Continuous Laser output. Output power range 0W – max Laser rated power	●	
Modulated CW mode	Modulated CW output with variable duty cycle. Average output power = CW output power * duty factor %	●	
Waveform selection	The G4 Laser contains a number of pre-defined pulse waveforms that allow a degree of control over the optical output pulse characteristic. Each waveform defines the electrical impulse sent to the seed Laser diode The RM variants have a single pre-defined waveform – no user selection. The HS variants incorporate 32 user selectable waveforms. These allow a wide range of processing parameters (pulse energy, peak power, pulse width) for any given average output power and pulse rate. For example shorter pulses at high pulse rates allow higher peak powers.	●	
Pulse Repetition Rate	Each waveform has a default pulse rate (PRF_0) which is the minimum frequency that gives maximum average power (defined by the active current set point). For $PRF < PRF_0$ the Laser diodes are modulated to prevent damaging pulses with excessive energy. For $PRF > PRF_0$ pulse energies & peak powers decrease so that the average power does not exceed the active current set point level	●	●
Active Current	Sets the current set-point for the power-amplifier pump Laser diodes when the Laser is in ACTIVE state (i.e. for a period of $1/PRF_0$ from the start of a pulse). Controls the average output power impacting pulse energy & peak power	●	●
Simmer Current	Sets a low level current set-point for the power-amplifier Laser diodes in the SIMMER state (i.e. before entering active state and between pulses when $PRF < PRF_0$ and after $1/PRF_0$ seconds have elapsed). Pre-charges the power amplifier for the first few pulses of a new pulse train. There is a trade off between • High simmer = High 1st pulse energy, higher CW emission between pulses • Low simmer = Lower 1st pulse energy but low CW emission	●	●
Pilot Laser (factory fitted option)	Enabling the internal pilot Laser interrupts the IR Laser output. Pilot Laser brightness is factory set. S**ee section 1.4 - Laser safety requirements of EN 60825**	○	○
Laser Enable	A rising edge of the Laser_Enable input or setting STATUS_WORD bit 0 attempts to enable the Laser. This resets any latched fault condition where the fault is no longer active; re-enables the internal power supplies and enables the Laser diode drivers.	●	●
Laser_Emission_Gate	Allows/prevents emission from the Laser by gating internal or external pulse triggers	●	●
Laser Disable	Used to stop all Laser emission. It disables the internal DC-DC power supplies and electronically interrupts the 24V diode power supply line input to the internal power supplies. Active tasks are stopped & requests for Laser emission are ignored.	●	●

4.6.1 Laser Hardware and Software Control Overview

The G4 Pulsed Laser Module can be controlled either by hardware signals or software commands. Software commands can be issued via either Ethernet or RS-232 interfaces. The details of the specific commands and signals are covered in later sections of this document.

	Software control	**Hardware control**
Pulsed mode	STATUS_WORD bit 3 controls selection of these modes. STATUS_WORD bit 1 must then be set again for the Laser to switch mode.	The Laser_Pulse_CW digital I/O selects between these modes.
CW mode		
Modulated CW mode	STATUS_WORD bit 3 must be set. The duty factor, burst length & pulse rate registers of the selected waveform define the CW modulation STATUS_WORD bit 1 must be set again for changes to take effect.	The continuous wave output can be modulated using the Laser_Emission_Gate signal.
Waveform selection	Command to select waveform. STATUS_WORD bit 1 must then be set again for changes to take effect	The waveform selected can be switched on-the-fly using the 8 bit parallel digital input, DI_7 : DI_0
Pulse Repetition Rate	Both the pulse rate and pulse burst length can be set for each waveform. STATUS_WORD bit 1 must then be set again for changes to these values to take effect. Setting this bit starts the internal pulse generator with the programmed parameters. The pulse clock is synchronized by the rising edge of a signal on the Laser_Emission_Gate input.	Under hardware control the rising edge of the Pulse_Trigger digital input signal is used to initiate a pulse. The external signal source has control. The Laser does not know the pulse repetition rate or the intended pulse burst length.
Active Current	Command to set active current set point, takes immediate effect.	Analog input signal, AI_1 (0 – 10V).
Simmer Current	Command to set active current set point, takes immediate effect.	Analog input signal, AI_2 (0 – 10V).
Pilot Laser (factory fitted option)	Setting 'Pilot Laser Enable' (STATUS_WORD bit 8) immediately enables the pilot Laser (if fitted) & interrupts the IR Laser. Clearing the 'Pilot Laser Enable' bit disables the pilot Laser and the IR Laser will revert to its previous state.	Pilot_Laser_Enable digital input signal turns on the red alignment laser and interrupts IR Laser if this option is installed.
Laser_Enable	STATUS_WORD bit 0 is set	Laser_Enable external digital input signal
Laser_Emission_Gate	This external digital input signal is used to gate the internal pulse generator	This external digital input signal is used to gate the external pulse trigger signal
Laser_Disable	This digital input is used to as an emergency stop. It stops any Laser emission and disables the internal diode power supply.	

4.6.2 Laser Module Status Reporting

4.6.2.1 Hardware Status Signals

Digital Output	Status	RM	HS
Laser_Is_On	A rising edge of the Laser_Enable input or setting of STATUS_WORD bit 0 attempts to enable the Laser and set this signal to its active state. If there are fault conditions or alarms or if there is no 24V Laser diode supply the Laser_Is_On signal will remain inactive. When active this signal indicates that the Laser diodes are operational.	•	•
Laser_Ready_To_Pulse	This signal indicates that the Laser will respond to a pulse trigger (internal or external) and will output an optical pulse. The signal is set by the Laser_Emission_Gate signal going active It is goes inactive by any of the following events • Laser_Emission_Gate goes inactive. • Laser fires pulses – inactive for 1/PRF_{max} when until Laser is ready to fire the next pulse. • A Laser task is completed or aborted. • An alarm or Laser is disabled by Laser_Disable.		•
Laser_Has_Pulsed	This signal goes active for >600ns when an optical pulse is detected by an internal monitor photodiode.		•
PRF_Sync_Out	This signal will only go active under the following conditions • Pulse_Trigger input is receiving a pulse train within the specified frequency limits and the Laser_Emission_Gate signal is active OR • The Laser is in software mode and the internal pulse generator is active. Laser_Emission_Gate signal is active. The rising edge of this output signal is synchronized with the active pulse trigger (internal or external) and is active for ~400 ns.		•
Task_Active	A Laser task has been started and is being executed. The signal will remain active until • The task is successfully completed. • The Laser is put into the STANDBY state by Laser_Enable signal going low or clearing STATUS_WORD bit 0 by software command. • There is an alarm condition that stops the task. • The Laser is disabled by the Laser_Disable signal.		•
Laser_Emission_Warning	This signal is active when the Laser power supplies are operational.	•	•
Laser_Deactivated	The signal goes active when • The Laser_Disable input goes active. • A system fault is active. The output remains active until the condition is removed and the Laser is then reset by either a rising edge on the Laser_Enable signal or by clearing then setting STATUS_WORD bit 0.	•	•
Monitor	This signal remains active while any of the following conditions persist • A temperature sensor is outside the turn on limits. • The pilot Laser is enabled. • A condition is detected that has caused the Laser to be disabled. • Laser is approaching alarm condition. See section 7.	•	•
Alarm	This signal is active when an alarm has occurred. See section 7.	•	•

4.6.2.2 Software Status bits

	STATUS_WORD BIT	Fault
'Laser Is On'	0	A rising edge of the Laser_Enable input or setting of STATUS_WORD bit 0 attempts to enable the Laser and set this bit to its active state. If there are fault conditions or alarms or if there is no 24V Laser diode supply the 'Laser Is On' bit will remain inactive. When active this bit indicates that the Laser diodes are operational.
'Laser Emission Warning'	11	This bit is active when the Laser power supplies are operational.
'Laser Deactivated'	10	The bit is active when the Laser state = DISABLED i.e. when • The Laser_Disable input goes active. • A system fault is active. The output remains active until the condition is removed and the Laser is then reset by a rising edge on the Laser_Enable signal or by clearing then setting STATUS_WORD bit 0.
Internal pulse generator active	1	Automatically cleared when the programmed number of pulses is completed, when the Laser is disabled or there is an alarm condition.

4.7 Continuous Wave (CW) Operation (HS series only)

This mode can be accessed under either hardware control (digital input Laser_Pulse_CW = 1) or software commands (setting STATUS_WORD bit 3). Under software control the internal pulse repetition rate of the active waveform must be set < 100Hz for un-modulated CW output. Under hardware control the Pulse_Trigger signal is ignored.

The active current set point can be used to vary the average Laser output power between 0W and the Laser's maximum rated average output power.

While Laser_Emission_Gate remains active the output duration is determined by the user programmed value pulse burst length and the PRF_0 for the active waveform under RS-232 control. Setting pulse burst length register to 0 guarantees CW emission while Laser_Emission_Gate signal is high.

The external pulse trigger is ignored and waveform selection and pulse burst length register value are ignored under HW or Ethernet control.

Maximum rate at which Laser_Emission_Gate can be toggled to switch the CW output is 1MHz.

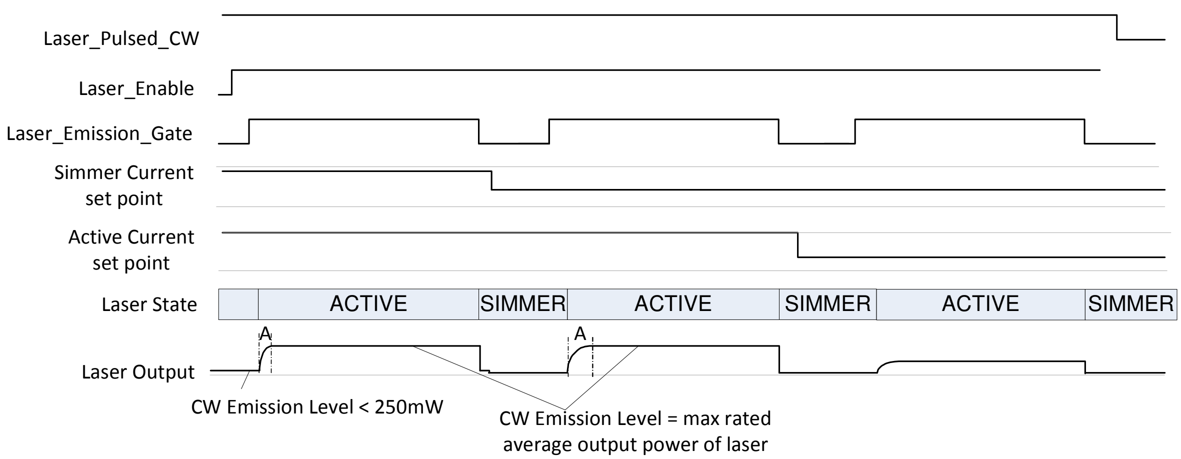


Figure 13. **Continuous Wave (CW) Operation**

The simmer level affects the CW emission in the SIMMER state and the shape of the ramp on the rising edge of the optical output with time A in the order 100 – 200 us.

The active current level determines the CW output power. 10V on AI_1 or setting the active power level to 1000 sets the CW output to the maximum rated average power of the Laser.

4.8 Modulated Continuous Wave (CW-M) operation

Modulated continuous wave (CW-M) operation is only available under software control on HS series G4 variants.

The registers associated with the selected waveform are used to control the modulation of the continuous wave output.

Pulse rate	Sets the modulation frequency (100 Hz – 100 kHz)
Duty Factor	Defines the mark : space ratio of the modulation (e.g. programming 750 defines the mark **:** space ratio as 75:25. Setting this to the maximum value gives a CW output with no modulation
Pulse Burst Length	defines the number of modulation cycles

In the modulation spaces, when the Laser is in the SIMMER state, there is some CW emission but this is less than when the Laser is in pulsed mode.

The average output power = Laser's max. rated average power x mark-space ratio

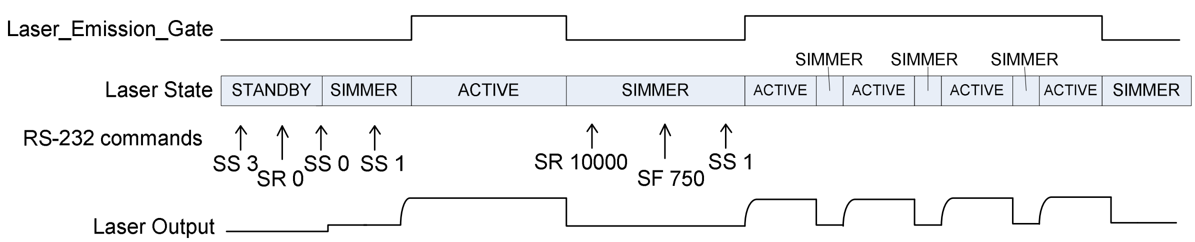


Figure 14. **Modulated Continuous Wave (CW-M) Operation**

4.9 Laser Power Sequencing

When connecting the power supplies the user must connect the ground first and then the 24V power line. When disconnecting the power supplies disconnect the 24V power line first and then the ground. This approach allows a current return path.

See Figure 22 and Figure 23 for details of switching the power supplies.

The 24V DC logic supply should be connected first. This will power up the internal logic supply and ensure the Laser is in a known, controlled state = LASER_OFF.

The 24V DC diode supply can then be connected. Providing the following conditions are true this will initiate powering up of the internal diode power supply and transition the Laser to the POWER_UP state.

- Laser_Disable = 0
- No system faults are active

The internal diode power supply typically takes 250ms to come up. After this time is elapsed a rising edge on the Laser_Enable signal (or clearing then setting the 'Laser Is On' bit (STATUS_WORD bit 0) to put the Laser into the SIMMER state.

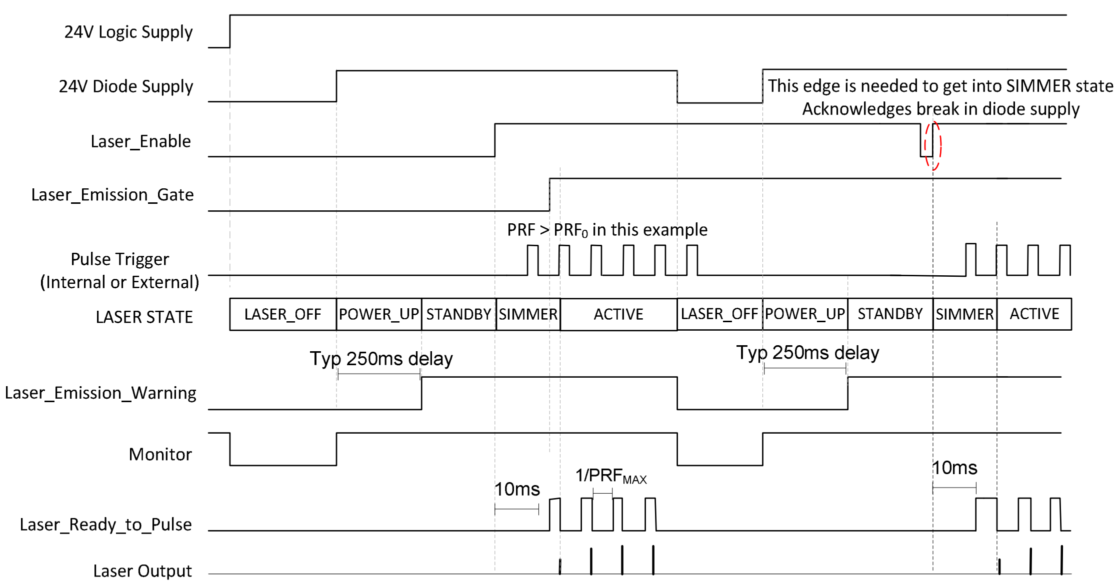


Figure 15. **Power Up Sequence – Examples 1**

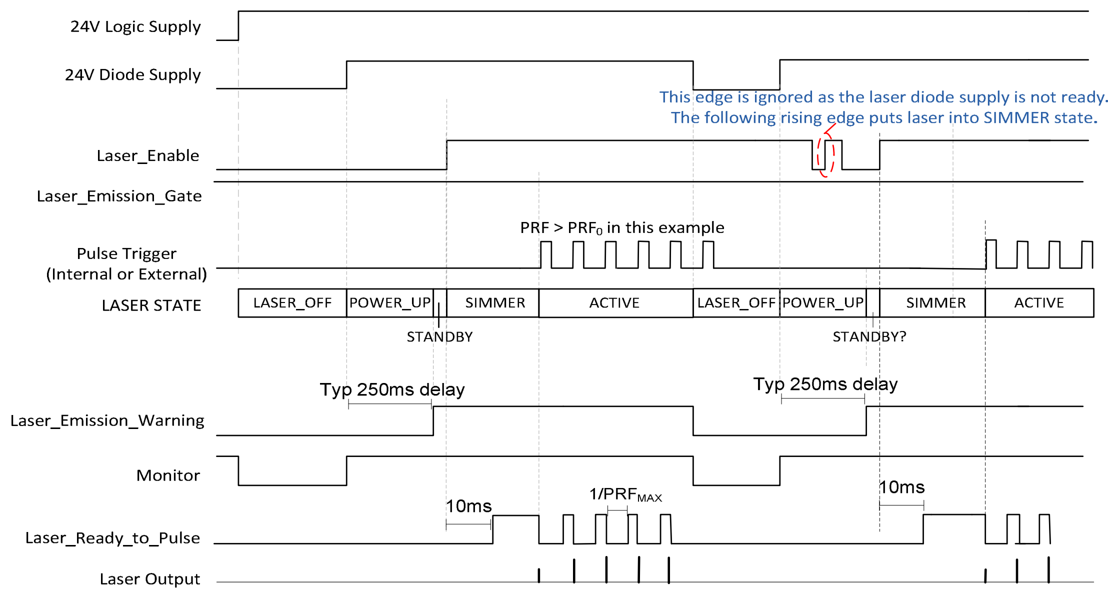


Figure 16. **Power Up Sequence – Examples 2**

4.10 Pilot Laser Operation – Factory Fitted Option

The pilot Laser can be enabled by setting the digital input Pilot_Laser_Enable signal HIGH or by setting the 'Pilot Laser Enable' bit (STATUS_WORD bit 8). Both methods act to

- Interrupt the IR Laser if it is active, cancelling any active task.
- Switch on the pilot Laser.
- Prevent the IR Laser from being started while pilot Laser is enabled.

Disabling the pilot Laser (Pilot_Laser_Enable = 0 or 'Pilot Laser Enable' bit = 0) switches off the pilot Laser then allows the Laser to return to an operational state

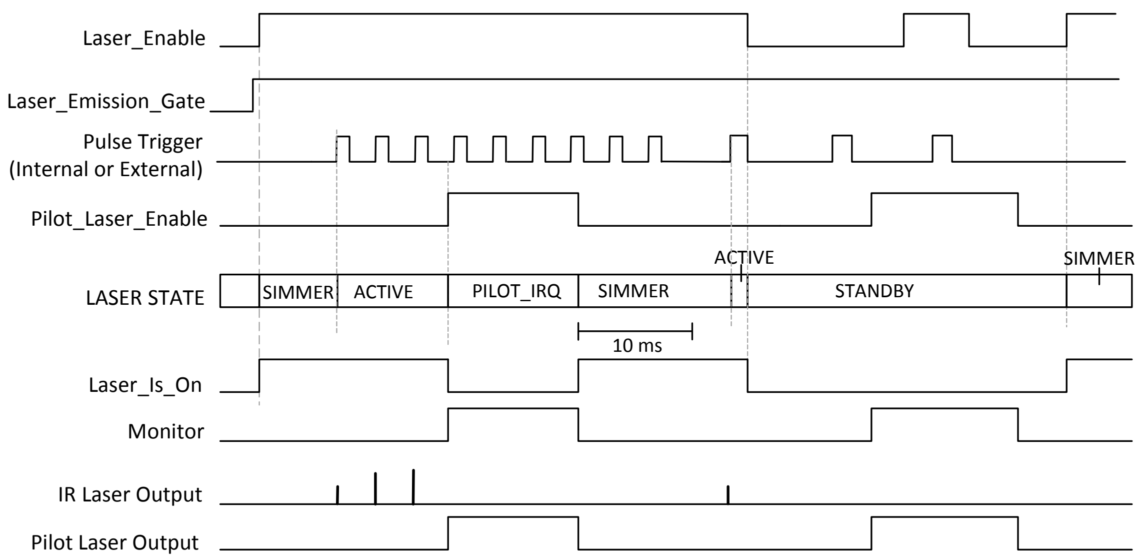


Figure 17. **Visible Pilot Laser Operation – with 24V diode supply connected**

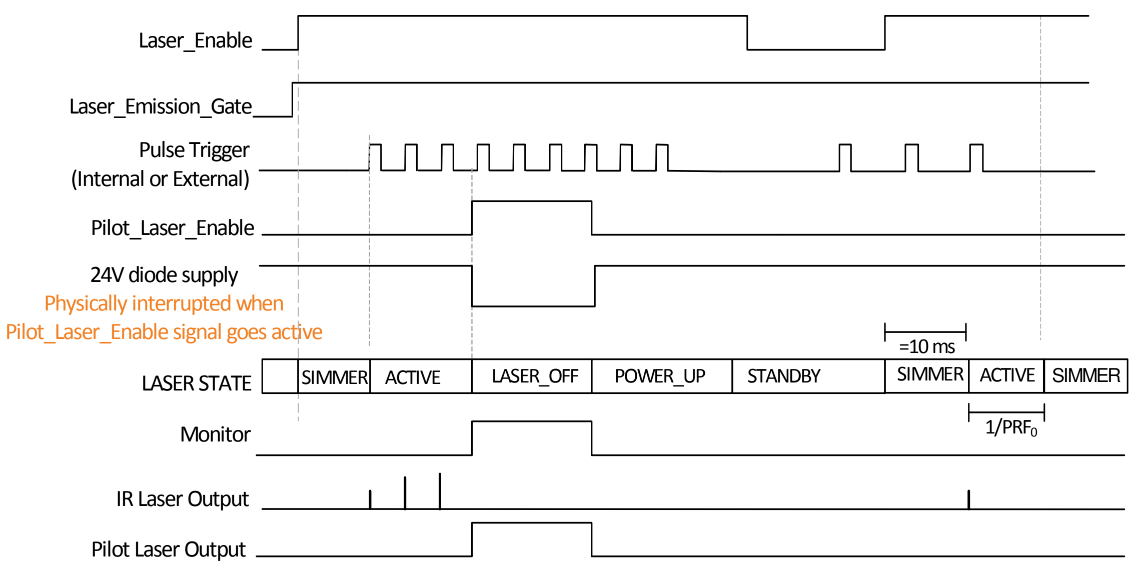


Figure 18. **Visible Pilot Laser Operation – with 24V diode supply disconnected**

4.11 Switching between Pulsed and CW operation

4.11.1 Hardware Control Using Laser_Pulse_CW digital input

If the Laser_Is_On signal is active (SIMMER or ACTIVE states) and the Laser_Pulse_CW signal transitions

- from HIGH to LOW (i.e. from CW to Pulsed mode) the Laser returns to the SIMMER state for 10ms and will then respond to the rising edges of Pulse_Trigger input signal as normal.
- from LOW to HIGH (i.e. from Pulsed to CW mode) the Laser transitions to the SIMMER state for 10 ms to allow pump diode current set up and settling time. The Laser will then transition to the ACTIVE state and start continuous wave emission.

Changing the Laser_Pulse_CW signal in other states sets the mode of operation when the Laser enters the SIMMER or ACTIVE states.

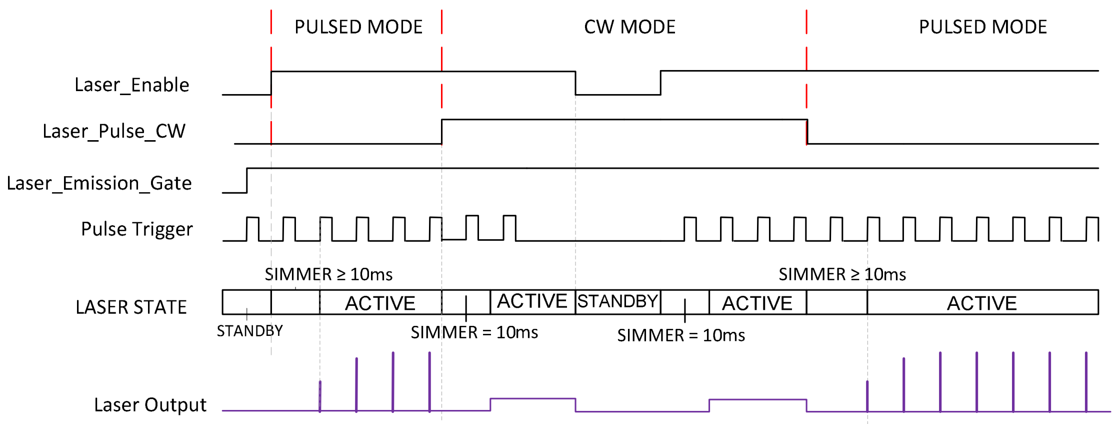


Figure 19. **Switching Between Pulsed and CW modes Under Hardware Control**

4.11.2 Software control – STATUS_WORD Bit 3

Instead of using Laser_Pulse_CW signal, the 'Laser Pulse CW' bit (STATUS_WORD bit 3) can be set or cleared using the appropriate Ethernet (0x1A) or RS-232 (SC 3, SS 3) commands. For changes to this bit to take effect the 'Start Pulses' bit (STATUS_WORD bit 1) must be set using the appropriate software command.

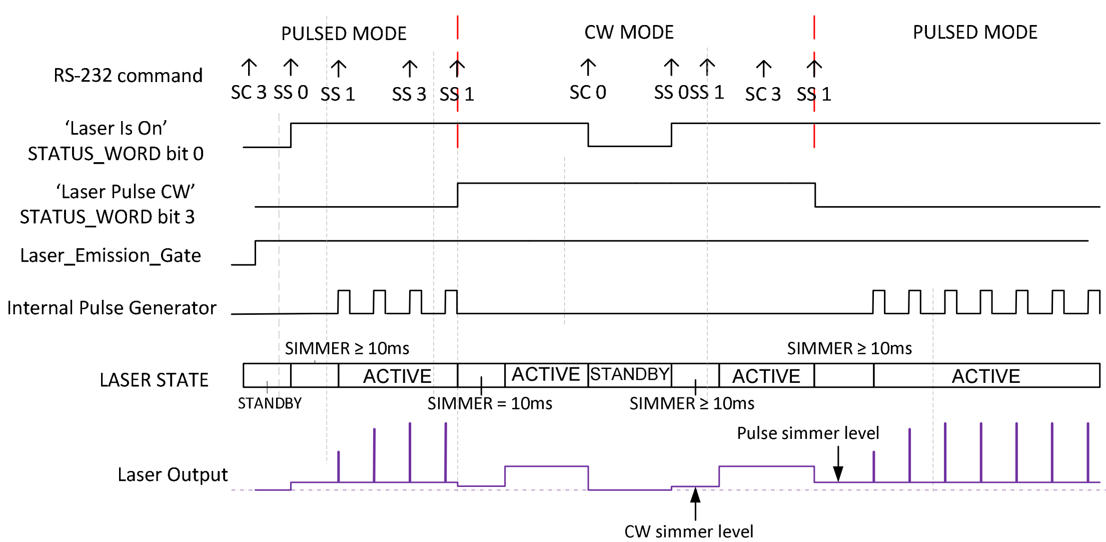


Figure 20. **Switching Between Pulsed and CW modes Under Software Control**

4.12 Pulse to Pulse Waveform Switching

4.12.1 Hardware Control of Waveform Switching

The waveform selected by the DI_7:DI_0 can be changed for each pulse trigger signal. Note, the pumping for each pulse is based on the waveform selection latched by the previous external Pulse_Trigger rising edge. In this way pulse energy can be varied pulse by pulse by changing the waveform and hence both pulse duration and peak power.

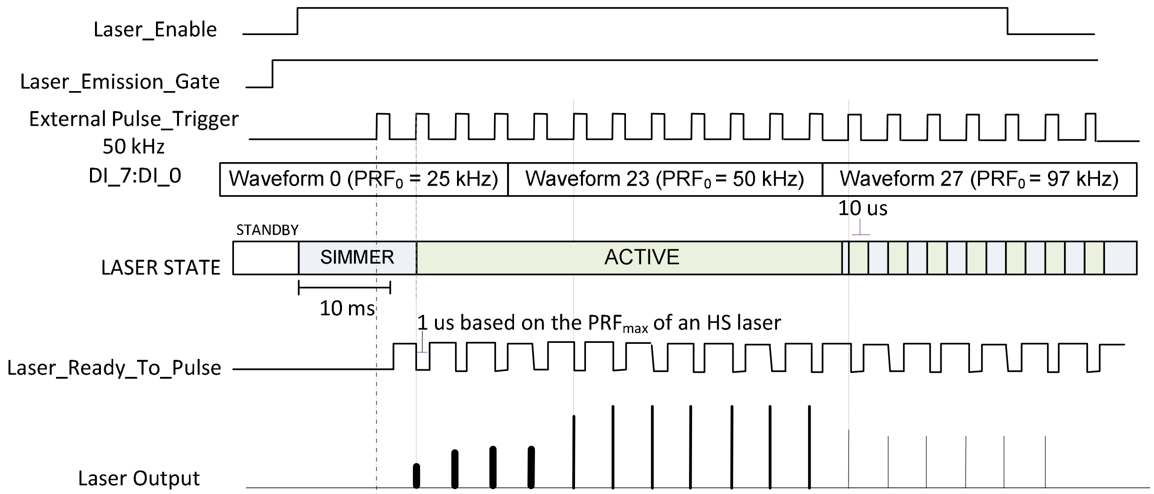


Figure 21. **Hardware Control of Waveform Switching**

4.12.2 Software Control of Waveform Switching

The following example shows how to configure the parameters associated with waveform 0 and waveform 1 for continuous operation of waveform 0 at 30 kHz, and then a one-second burst of waveform 1 at 75 kHz with a fast change over.

[Configure parameters associated with waveform number 0]

SW 0	[select waveform number 0]
SF 500	[set pump duty factor to 500 for CWM operation]
SL 0	[set pulse burst length to 0 for continuous pulsing]
SR 30000	[set pulse rate to 30 kHz]

[Configure parameters associated with waveform number 1]

SW 1	[select waveform number 1]
SF 200	[set pump duty factor to 200 for CWM operation]
SL 75000	[set pulse burst length to 75000]
SR 75000	[set pulse rate to 75 kHz]

[Select waveform number 0 and start task]

SW 0	[select waveform number 0]
SS 1	[start task]

(Operation will continue until stopped by user, or new task started)

[Select waveform number 1 and start task]

SW 1	[select waveform number 1]
SS 1	[start task and go into 'ACTIVE' state]

(Operation will cease after 75000 pulses have been triggered- 1 second)

The speed of waveform switching is determined by the RS-232 baud rate and the speed at which the 'select waveform' and 'start task' software commands are issued.

5 Safety and Interlocking

5.1 Laser Integrator's Interlock Implementation Options

This Laser module does not incorporate the interlock requirements for a final Laser system as identified by EN 60825-1 and CFR 1040.10. It is the responsibility of the system integrator to interface the Laser module to suitable interlock circuitry in the final equipment. If required, please contact SPI for guidance on the requirements for incorporating this product to achieve full compliance.

Three main actions can be taken to shut the Laser down. In order, as listed below, they provide increasing levels of security:

Least secure	Force Laser_Enable signal low
	Force Laser_Disable input signal high
Most secure	Remove power to the 'Diode Supply' +/- lines

The following table specifies the results of these actions and the monitor line status that indicates whether the action has been successful.

Action	Effect	Acknowledgements
Laser_Enable = 0	• Disables pre-amplifier diode driver. • Disables power-amplifier diode driver . • Disables Seed Laser diode driver. LASER STATE = STANDBY Note: that there is no time delay between switching the Laser_Enable input to a high state and Laser emission if other control lines leave the Laser in an operational state.	Laser_Is_On = 0 Note: Laser_Emission_Warning = 1 as under a single fault condition the Laser could emit radiation.
Laser_Disable = 1	• Forces a shut-down of the internal diode power supply of the Laser (logic power supply is unaffected). • Laser_Disable = 1 is latched until a rising edge occurs on Laser_Enable. LASER STATE = DISABLED	Laser_Is_On = 0 Laser_Deactivated = 0 (active) Laser_Emission_Warning = 0
Remove 24V Diode Supply +/-	• No further energy is delivered to the Laser Module. • The diode supply needs to be restored followed by a rising edge on Laser_Enable. LASER STATE = LASER_OFF	Monitor = 0 Alarm code 93 is asserted 99 E-STOP Fault

In the event of normal operation (i.e. no failure of internal electronic circuitry) a forced shut-down using the Laser_Disable input will stop Laser emission.

To absolutely guarantee that no light is emitted from the Laser, the Laser Diode power supply input to the Laser should be electronically interrupted. Two alternative methods of implementing this are:-

1. The addition of a single / dual interlocked contactor(s) series connected to interrupt the AC supply line of the 24V Laser Diode Power Supply Source – (preferred method)

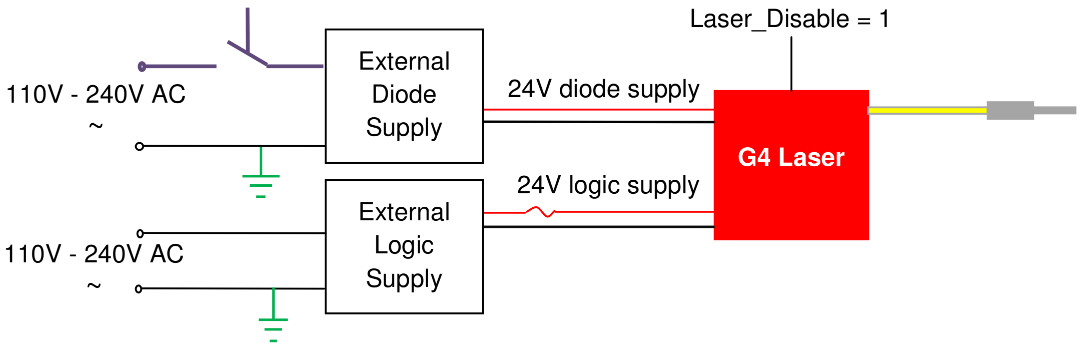


Figure 22. **Interlocking the Laser Diode AC Supply**

2. The addition of a single / dual interlocked contactor(s) series connected in the Positive +24V Output conductor of the +24V Laser Diode Power Supply Source – (alternative method).

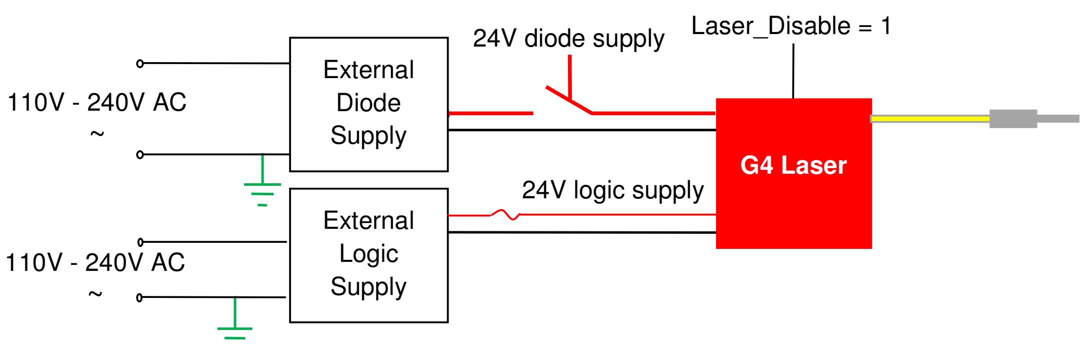


Figure 23. **Interlocking the 24V Laser Diode Supply**

Note: We do not recommend switching the 0V Laser Diode Power Supply Conductor

We recommend that the 24V Logic Supply to the Laser module remains permanently connected to the 24V Logic Supply Power source. The Pilot Laser (if this option is fitted) operates from the logic supply so will remain operational. See sections 1.2 and 1.4.

5.2 Resetting the Laser after a Forced Shut-Down

To reset the Laser after a forced shut-down event, the following action should be taken:

1) Reconnect 24V diode supply
2) Set Laser_Disable = 0
3) Set Laser_Enable = 0
4) Set Laser_Enable = 1
   Laser transitions from DISABLED state to POWER_UP state where internal diode supply switches on and settles (~250ns).
   Laser then enters STANDBY state and normal operation can resume.

6 Control Interface Mode Options

G4 Lasers offer the option of controlling the Laser via hardware signals or software commands via the RS-232 and Ethernet interfaces. Hardware interface mode is the factory default setting.

STATUS_WORD bits 9 and 4 determine the Laser control interface mode.

	STATUS_WORD Bit 9	**STATUS_WORD Bit 4**
Hardware mode (default)	**1**	**1**
Software mode with external current control	**0**	**1**
Software mode	**0**	**0**

The table below shows a summary of control methods for the primary functions in the different control interface modes. The following sub-sections described these modes in more detail.

Function	**Hardware Mode**	**Software mode with external current control**	**Software mode**
Laser Enable	Laser_Enable	'Laser Enable' command - STATUS_WORD bit 0 Or Laser_Enable signal	
Pulse Triggering	Pulse_Trigger	Internal pulse generator	
Waveform selection	DI_0 – DI_7	'Select Waveform' Command	
Pulse/CW select	Laser_Pulse_CW	'Laser Pulse CW' command - (STATUS_WORD bit 3) Or Laser_Pulse_CW signal	
Power Control	AI_1		'Active Current' command
Simmer Control	AI_2		'Simmer Current' Command

6.1 Hardware Control Interface Mode

The user can use the following external input signals to control the Laser.

<table>
<tr><th>Signal name</th><th colspan="9">Description</th></tr>
<tr><td>Laser_Pulse_CW</td><td colspan="9">The digital I/O selects between Pulsed and CW modes.
A rising edge on Laser_Enable signal is required to activate a change on this signal</td></tr>
<tr><td rowspan="12">DI_7 : DI_0</td><td colspan="9">The waveform selected can be switched on-the-fly using this 8 bit parallel digital input.</td></tr>
<tr><td>DI_7</td><td>DI_6</td><td>DI_5</td><td>DI_4</td><td>DI_3</td><td>DI_2</td><td>DI_1</td><td>DI_0</td><td>Waveform</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>2</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>:</td><td>:</td><td>:</td><td>:</td><td>:</td><td>:</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>29</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>30</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>31</td></tr>
<tr><td>X</td><td>X</td><td>1</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td rowspan="3">None
Error flagged</td></tr>
<tr><td>X</td><td>1</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>1</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Pulse_Trigger</td><td colspan="9">Under hardware control the rising edge of this digital input signal is used to initiate a pulse.
The external signal source has control. The Laser does not know the pulse repetition rate or pulse burst length..</td></tr>
<tr><td>AI_1</td><td colspan="9">Analog input signal, (0 – 10V) controls the active current.</td></tr>
<tr><td>AI_2</td><td colspan="9">Analog input signal, (0 – 10V) controls the simmer current.</td></tr>
<tr><td>Pilot_Laser_Enable</td><td colspan="9">Pilot_Laser_Enable = 1 interrupts the IR Laser (if in SIMMER or ACTIVE states) and turns on the Pilot Laser if this factory fitted option is installed.</td></tr>
<tr><td>Laser_Enable</td><td colspan="9">Laser_Enable external digital input signal.</td></tr>
<tr><td>Laser_Emission_Gate</td><td colspan="9">This external digital input signal is used to gate the external pulse trigger signal.</td></tr>
<tr><td>Laser_Disable</td><td colspan="9">This digital input is used to stop any Laser emission and disables the Laser diode power supply.</td></tr>
</table>

6.1.1 Hardware Control Interface Timing Diagram

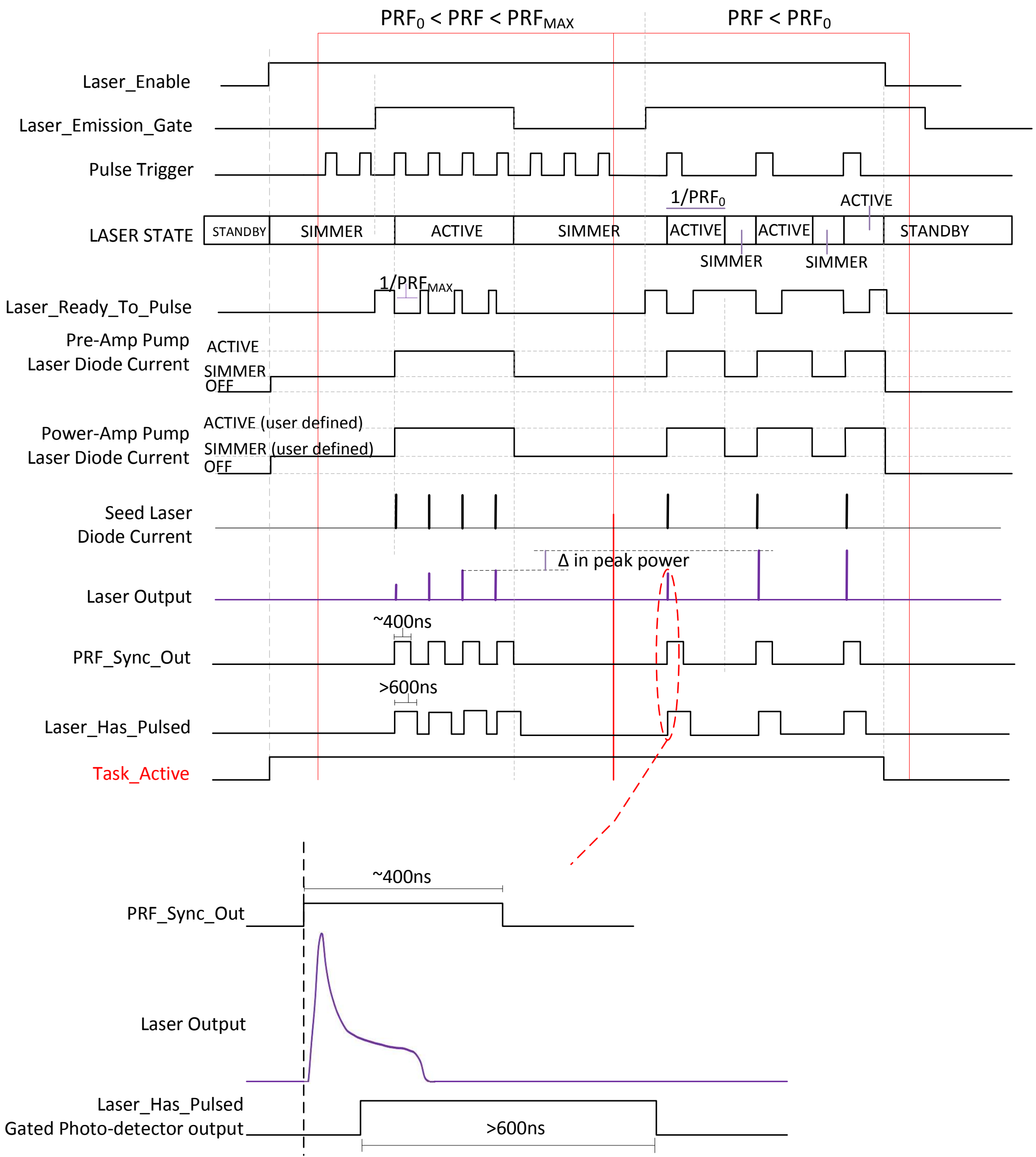


Figure 24. **Hardware Control Interface Timing Diagram**

6.2 Software Control Interface mode

<table>
<tr><td colspan="2"></td><td>Effect</td></tr>
<tr><td>STATUS_WORD Register</td><td>Bit</td><td></td></tr>
<tr><td>‘Interface Mode’</td><td>9</td><td>1 = hardware control mode.
0 = software control mode.
(Note: Laser_Enable signal must be LOW when changing this bit).</td></tr>
<tr><td>‘Pilot Laser Enable’</td><td>8</td><td>1 = Enable pilot Laser.
0 = Disable pilot Laser.</td></tr>
<tr><td>Current set point source</td><td>4</td><td>Use in software control mode to select current set point sources.
0 = software based current control.
1 = external analog current control.
(Note: Laser_Enable signal must be LOW when changing this bit).</td></tr>
<tr><td>‘Laser Pulse CW’</td><td>3</td><td>1 = CW / CW-M mode.
0 = pulsed mode.
STATUS_WORD bit 1 must be set for any change to this bit to take effect</td></tr>
<tr><td>‘Start Pulses’</td><td>1</td><td>1 = Task start - internal pulse generator is started and causes the commands in section 9.4.5 to take effect.
Pulses are gated by the Laser_Emission_Gate signal.</td></tr>
<tr><td>‘Laser Is On’</td><td>0</td><td>1 = Attempts to enable Laser.
Successful if - no fault conditions, alarms & 24V diode supply present.
0 = Disables the Laser and returns it to the STANDBY state.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>‘Select waveform’</td><td colspan="2">Valid values - 0 to 31. See section 14.3 for waveform reference tables.
STATUS_WORD bit 1 must be set again for changes to take effect.</td></tr>
<tr><td>Waveform registers</td><td colspan="2">Each pre-programmed waveform has the following associated registers
STATUS_WORD bit 1 must be set after changes for new values to take effect.</td></tr>
<tr><td>‘Pulse burst length’</td><td colspan="2">Defines the number of pulses to be executed, assuming Laser_Emission_Gate remains high. Continuous pulsing if this value is set to 0.
Valid value range = 0 – 1000000.
If Laser_Emission_Gate goes LOW the internal pulse generator is stopped at the current count. On re-enabling Laser_Emission_Gate the pulse generator continues from the value it had reached.</td></tr>
<tr><td>‘Pulse rate register’</td><td colspan="2">Determines the pulse repetition rate (PRF). The pulse clock is synchronized by the rising edge the Laser_Emission_Gate input signal.
<table>
<tr><td></td><td>Series</td><td>Valid Value Range</td><td>Frequency range</td></tr>
<tr><td></td><td>HS</td><td>0 – 1000000</td><td>0 Hz – 1 MHz</td></tr>
<tr><td></td><td>RM</td><td>0 – 200000</td><td>0 Hz – 200 kHz</td></tr>
</table>
1kHz < PRF < PRF_{MAX} pulsed operation
0 Hz < PRF < 100 Hz CW operation (HS only)
100 Hz < PRF < 100 kHz CW-M operation (HS only)</td></tr>
<tr><td>‘Duty factor’</td><td colspan="2">Used to define the duty factor of the CW modulation
Valid value range = 0 – 1000
e.g. Duty factor = 750 => mark: space ratio = 75:25.</td></tr>
</table>

	Effect
Active Current	See section 6.2.1
Simmer Current	
'Pilot Laser ' (factory fitted option)	Setting 'Pilot Laser Enable' (STATUS_WORD bit 8) immediately enables the pilot Laser (if fitted) & interrupts the IR Laser if in SIMMER or ACTIVE states Clearing the 'Pilot Laser Enable' bit disables the pilot Laser and the IR Laser will revert to its previous state.
External Input Signals	
Laser_Emission_Gate	This external digital input signal is used to gate the internal pulse generator.
Laser_Disable	This digital input is used to stop any Laser emission.
Laser_Enable	These hardware signals are functional in software control mode and can be used instead of the STATUS_WORD bits. See section 6.1 for their functionality.
Pilot_Laser_Enable	
Laser_Pulse_CW	

Both RS_232 and Ethernet interfaces can be used to control the Laser in Software Interface mode. Both interfaces can be active simultaneously, for example the RS-232 interface could be used to control the Laser and the Ethernet interface used for monitoring and diagnostic purposes.

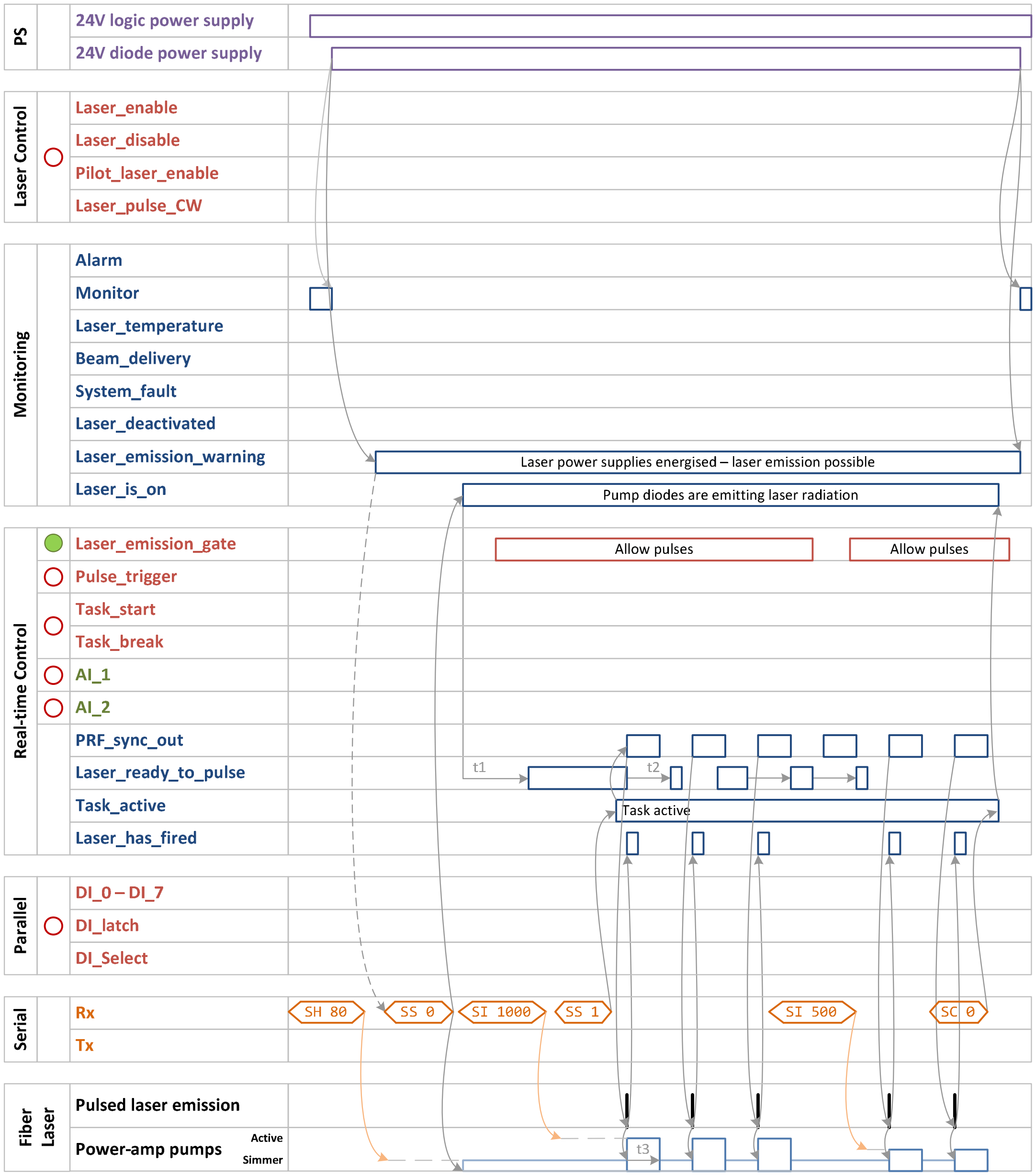
See sections 17 and 18 for the respective detailed command sets that control the following bit and register values.

6.2.1 Software Interface Mode Current Control Options

Whilst operating in software interface mode, the user can choose whether the current to the power-amplifier pump diodes is controlled by analogue voltage inputs or software commands. STATUS_WORD bit 4, 'External Current Control Mode', is used to determine the current control source.

'External Current Control Mode' (STATUS_WORD bit 4)	Simmer current source	Active current source
0	Current set points are specified by value set via RS-232 or Ethernet commands.	
1	AI_2	AI_1

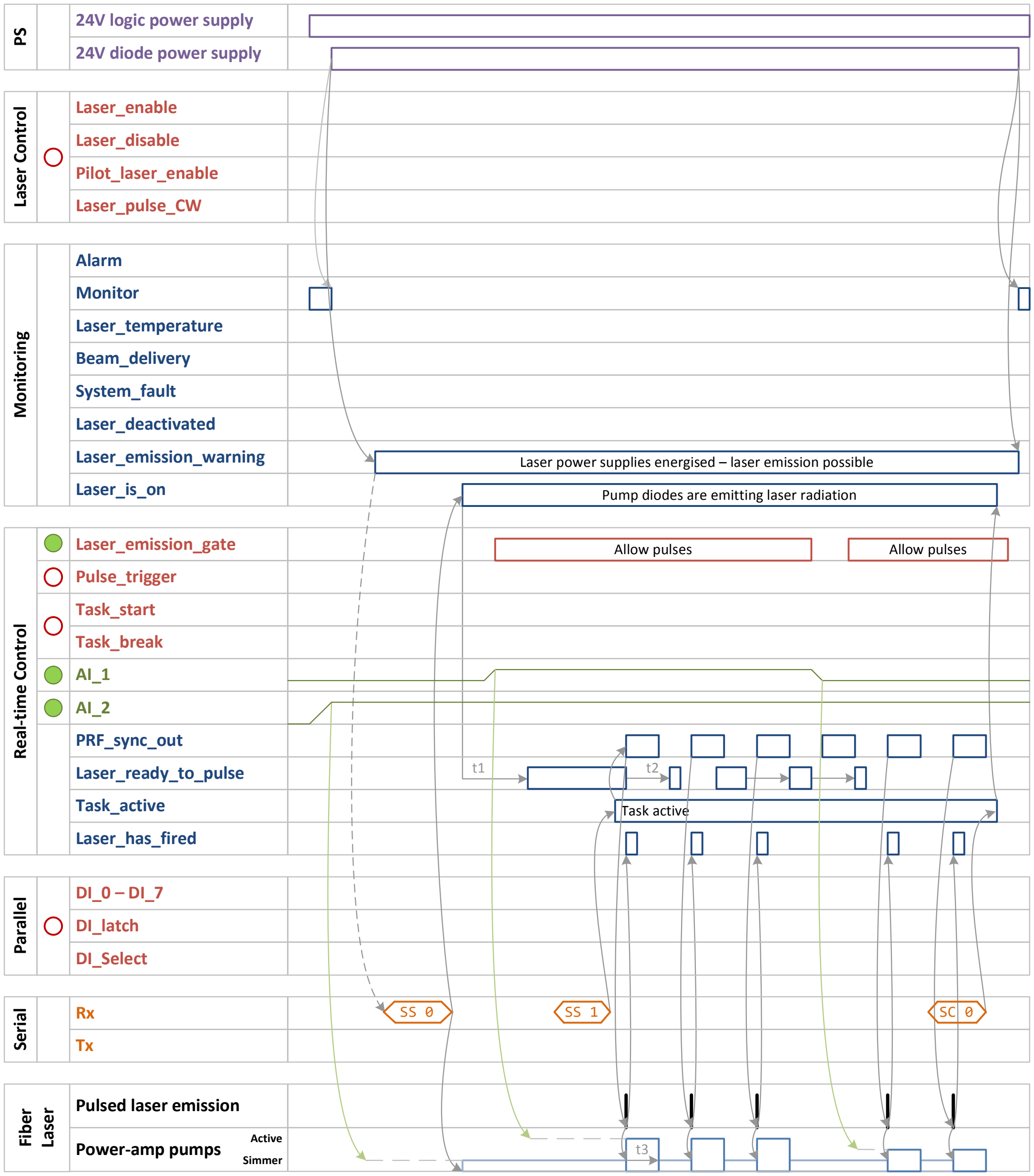
6.2.2 Timing Diagram for Software Mode – SW Current Control



t1 = 10ms
t2 = 1 / max_pulse_rate
t3 = 1/ PRF0

Figure 25. **Software Control Timing Diagram (SW Current Control)**

6.2.3 Timing Diagrams for Software Mode – Analogue Current Control



t1 = 10ms
t2 = 1 / max_pulse_rate
t3 = 1/ PRF0

Figure 26. **Software Control Timing Diagram (HW Current Control)**

6.3 Changing Laser Control Interface Mode

6.3.1 Enabling Software Interface Mode from Hardware Interface Mode

To enable Software Interface mode when in hardware mode

- The Laser must be in the STANDBY, OFF or POWER_UP states with the Laser_Enable digital input signal = LOW.
- STATUS_WORD bit 9, 'Interface Mode' should then be cleared (= 0) to enable Software Interface mode using the appropriate RS-232 or Ethernet command.
- Set STATUS_WORD bit 4 if external control of the simmer and active current set points is required, or check this bit is cleared if software control is desired. If this bit is changed then the user will to set bit 1 of the STATUS_WORD for this change to take effect.

6.3.2 Enabling Hardware Mode from Software Mode

To enable Hardware interface mode when in software mode

- Clear the 'Laser Is On' bit (STATUS_WORD bit 0) to return the Laser to the STANDBY state
- Set STATUS_WORD bit 9 to enable Hardware Interface mode.
- Connect the desired voltages on the AI_1 and AI_2 analog inputs to reflect the desired active and simmer current set points.

6.3.3 Reset and power off / on effects

Hardware interface mode is the default factory setting.

When the Laser is powered down the current Laser interface mode is stored into non-volatile memory. This setting is restored when the Laser is next powered up.

7 Laser Module Fault Reporting

7.1 Alarm Signals and STATUS_WORD bits

Output Signal	**Fault**	**STATUS WORD bit**
Alarm	This signal is active when an alarm has occurred (section 7).	15
System_Fault	If this signal is active it indicates that the Laser may require servicing (see section 7). This signal is active when a condition is detected that indicates a fault in the Laser system that is not associated with environmental conditions.	14
Beam_Delivery	This signal is active if • The optical connector is outside of specified operating temperature range. • The value measured by the optical connector temperature sensing circuit is such that it indicates a sensor fault or a fault in the optical cable.	13
Laser_Temperature	This signal is active if • The measured Laser temperature is outside the operating limits. • There is a fault in the Laser temperature sensor.	12

These signals and bits remain active while the alarm or fault persists. They are reset after removing the alarm or fault condition by:

- a Laser_Enable signal rising edge OR
- clearing then setting 'Laser Is On' bit (STATUS_WORD bit 0).This returns the Laser to STANDBY state.

The Monitor digital output warns of approaching alarm conditions (e.g. the temperature sensor(s) are outside the turn on limits). See section 8.4.1.

7.2 Software Commands

The QA (RS-232 see section 17.2.1) or 0x50 (Ethernet see section 18.3.1) commands read the codes of all asserted alarms from the alarm buffer. The alarm conditions all assert the 'Alarm Flag' bit of the STATUS_WORD (bit 15) and the Alarm digital output (Control I/O pin 2).

The presence of an alarm can also be determined by using the RS-232 STATUS_WORD commands, GS or QS. The responses that indicate an Alarm are tabulated below.

RS-232	**Response indicating Alarm has been raised**
GS (section 17.1.7)	Any number 11 –15
QS (section 17.2.7)	2049 ≤ Value ≤ 65535

7.3 Alarm Codes

ALARM CODE	DESCRIPTION	STATUS_WORD bit			
		15	14	13	12
40 - 65 67 – 79 81 – 92 94, 96-98 ≥ 100	System faults – internal Laser fault.	1	1		
66	Beam delivery temperature alarm (1).	1		1	
80	Base plate temperature alarm.	1			1
93	Power supply alarm. When supply is restored the Laser returns to the STANDBY state.	1			
95	Fan alarm. The Laser continues to operate if one fan stalls. The fan noise increases as the remaining 3 fans increase their speed to compensate. Is cleared by cycling the power supply, and only if the fault has also been cleared.	1			
99	Emergency stop alarm. Triggered by the Laser_Disable signal.	1			

(1) The beam delivery temperature sensor is only fitted on 30W and 40W products.

7.4 Temperature Alarms

All products have a Laser base plate temperature sensor. The 30W and 40W products also have a temperature sensor in the BDO.

Inclusion of the BDO temperature sensor in the 30W and 40W products ensures a minimum level of isolation is provided on the output of the Laser (the isolation decreases as the temperature increases) and ensures that the BDO surface is safe to handle.

The lower power Lasers (10 - 25W) radiate sufficient heat from the ILLK surface that they do not need this sensor.

The table below gives the Laser base plate and BDO (30W and 40W products) temperature sensor limits of the Laser module.

Limit	Temp	Laser Behaviour
Min system fault temperature	-20	Below this temperature a system fault is flagged
Min Turn off temperature	0	Below this temperature the Laser will turn off
Min turn on temperature	5	Below this temperature the Laser will not turn on
Max turn on temperature	50	Above this temperature the Laser will not turn on
Max turn off temperature	55	Above this temperature the Laser will turn off
Max system fault temperature	85	Above this temperature a system fault is flagged

The diagram below shows the system fault, alarm and monitor STATUS_WORD bits and signals.

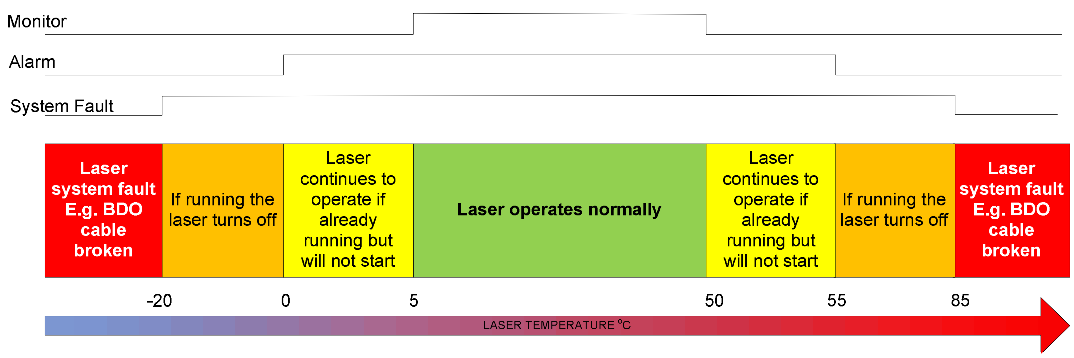


Figure 27. **Temperature Faults, Alarms and Monitor Conditions**

8 Laser Hardware Signal Reference

8.1 Laser Control Group Signal Reference

These signals will affect the Lasers operation whether it is in hardware or software control mode.

8.1.1 Laser_Enable

Signal Names:	**Laser_Enable_H**	**Laser_Enable_L**
I/O Pins:	7	41
BoB Pins:	J2:1	J2:2
Prerequisites:	• **Laser_Disable** is inactive.	
Active Signal:	• Clears alarm flags if the alarm condition no longer persists. • Re-enables the internal Laser power-supplies, if the **Laser_Deactived** signal was active and the deactivating condition no longer persists. • Requests the Laser to enter SIMMER state and enables the pump Laser diodes.	
Inactive Signal:	• Returns the Laser into STANDBY state. • Stops current flowing through the pump Laser diodes.	
Acknowledgement:	• **Laser_Is_On** becomes active	

8.1.2 Laser_Disable

Signal Names:	**Laser_Disable_H**	**Laser_Disable_L**
I/O Pins:	15	49
BoB Pins:	J2:3	J2:2
Active Signal:	• Disables the internal Laser power supplies and electronically interrupts the 24V_diode_supply on the input to the Laser power supplies. • Stops any active tasks. • Prevents any requests for Laser emission being acted upon.	
Inactive Signal:	• Allows the Laser to be re-enabled using **Laser_Enable.** • Does not remove the acknowledgements of the active signal.	
Acknowledgement:	• **Laser_Emission_Warning** becomes inactive. • **Laser_Is_On** becomes inactive. • **Monitor** becomes active. • **Alarm** becomes active.	

8.1.3 Pilot_Laser_Enable

Signal Names:	**Pilot_Laser_Enable_H**	**Pilot_Laser_Enable_L**
I/O Pins:	6	40
BoB Pins:	J2:5	J2:6
Active Signal:	• Switches on the internal pilot Laser, if installed. • Interrupts the IR Laser if it was active and prevents IR Laser being started from STANDBY state. • Stops any active task.	
Inactive Signal:	• Switches off the internal pilot Laser. • Allows the main Laser to return to an operational state. • Allows the **Laser_Is_On** signal to return to an active state. • Allows the **Monitor** signal to become inactive.	
Acknowledgement:	• **Monitor** becomes active.	

8.1.4 Laser_Pulse_CW

Signal Names:	**Laser_Pulse_CW_H**	**Laser_Pulse_CW_L**
I/O Pins:	21	55
BoB Pins:	J2:7	J2:8
Prerequisites:	• Laser is in hardware mode (bit 9 of STATUS_WORD is set).	
Active Signal:	• Specifies that the Laser is started in CW mode, if the feature is installed, the next time that **Laser_Enable** becomes active.	
Inactive Signal:	• Specifies that the Laser is started in pulsed mode the next time that **Laser_Enable** becomes active.	
Acknowledgement:	None	

8.2 Real-Time Interface Group Signal Reference

8.2.1 Laser_Emission_Gate

Signal Names:	**Laser_Emission_Gate_H**	**Laser_Emission_Gate_L**
I/O Pins:	5	39
BoB Pins:	J3:2	J3:1
Active Signal:	• Allows the Laser to respond to internal or external pulse triggers from SIMMER state. • Allows **Laser_Ready_To_Pulse** to become active once 10ms simmer period has elapsed.	
Inactive Signal:	• Prevents the Laser from responding to internal or external pulse triggers. • Sets **Laser_Ready_To_Pulse** inactive.	
Acknowledgement:	• **Laser_Ready_To_Pulse** becoming inactive. • An active pulse on the output **Laser_Has_Pulsed.**	

8.2.2 Pulse_Trigger

Signal Names:	**Pulse_Trigger_H**	**Pulse_Trigger_L**
I/O Pins:	13	47
BoB Pins:	J3:3	J3:1
Prerequisites:	• Laser is in hardware mode (bit 9 of STATUS_WORD is set). • Laser is in pulsed mode. • **Laser_Ready_To_Pulse** is active. • **Laser_Emission_Gate** is active.	
Rising Edge:	• Laser triggered to emit an optical pulse.	
Acknowledgement:	• An active pulse on the output **PRF_Sync_Out.** • **Laser_Ready_To_Pulse** becoming inactive. • An active pulse on the output **Laser_Has_Pulsed.**	

8.2.3 AI_1

I/O Pin:	65
BoB Pin:	J3:7
Prerequisites:	Laser is in hardware mode (bit 9 of STATUS_WORD is set) or bit 4 of STATUS_WORD is set in software mode.
Control Level:	The input voltage to this signal controls the power-amplifier pump Laser diode active state current • 0V = no current. • 10V = maximum current.

8.2.4 AI_2

I/O Pin:	64
BoB Pin:	J3:8
Prerequisites:	Laser is in hardware mode (bit 9 of STATUS_WORD is set) or bit 4 of STATUS_WORD is set in software mode.
Control Level:	The input voltage to this signal controls the power-amplifier pump Laser diode simmer current. • 0V = no current. • 10V = maximum current.

8.2.5 PRF_Sync_Out

I/O Pin:	22
BoB Pin:	J3:10
Prerequisites:	• **Laser_Emission_Gate** input is active. • **Pulse_Trigger** input is receiving a pulse train within range and the Laser is in hardware mode, or the Laser is in software mode.
Rising Edge:	The rising-edge of the output signals is synchronised with the internal pulse frequency clock. The signal has duration of approximately 400 ns.

8.2.6 Laser_Ready_To_Pulse

I/O Pin:	35
BoB Pin:	J3:11
Active Signal:	• The Laser will respond to a pulse trigger (internal or external) request and will generate an optical pulse.
Inactive Signal	• Laser emission is locked because **Laser_Emission_Gate** is inactive • The Laser has just fired a pulse; until such time that the Laser is ready to fire another pulse (i.e. $1/PRF_{max}$). • A Laser task is completed, or aborted. • There is an alarm condition that stops the Laser. • The Laser is disabled by the **Laser_Disable** signal becoming active.

8.2.7 GND_A

I/O Pin:	27:34
BoB Pin:	J3:6

8.2.8 Task_Active

I/O Pin:	1
BoB Pin:	J3:12
Active Signal:	• A Laser task is has been started and is being executed. Conditions for a task to start in HW and SW modes. No faults present, Laser was/is in SIMMER state, Laser_Emission_Gate active.
Inactive Signal	• The task is successfully completed. • There is an alarm condition that stops the task. • The Laser is disabled by the **Laser_Disable** signal becoming active.

8.2.9 Laser_Has_Pulsed

I/O Pin:	2
BoB Pin:	J3:13
Active Signal: (pulsed mode)	• An optical pulse is detected by an internal monitor photodiode. • The output remains active for a minimum of 600ns.
Active Signal: (CW mode)	• The output is active when an internal monitor photodiode detects optical radiation

8.3 Parallel Interface Group Signal Reference

8.3.1 DI_0 ... DI_7

The G4 Laser contains a number of pre-programmed pulse waveforms that allow the user a degree of control over the optical output pulse characteristics. The waveforms are pre-programmed in the controller and each waveform has an associated minimum pulse rate at which maximum rated power may be achieved. Pulse rates below these values are allowed, but the average output power will be reduced as the controller will modulate the amplifier pump Laser diodes in order to avoid damage to the Laser. See section 14 for descriptions of the waveforms for each variant.

Signal Names:	**DI_0**	**DI_1**	**DI_2**	**DI_3**	**DI_4**	**DI_5**	**DI_6**	**DI_7**
I/O Pin:	17	18	19	20	51	52	53	54
BoB Pin:	J6:2	J6:3	J6:4	J6:5	J6:6	J6:7	J6:8	J6:9
Prerequisites:	Laser is in hardware mode (bit 9 of STATUS_WORD is set)							
Active Signal:	• The state of **DI_0** – **DI_7** at the time when a pulse is triggered is used to specify the waveform for the pulse. • Active signal = bit set. • **DI_0** = LSB • **DI_7** = MSB							

8.4 Monitoring Group Signals

8.4.1 Monitor

I/O Pin:	3
BoB Pin:	J1:2
Active Signal (LOW)	• A temperature sensor is outside the turn-on limits. • The pilot Laser is enabled. • A condition is detected that has led to switching off the Laser.
Notes:	The output remains active for as long as the condition persists.

8.4.2 Alarm

I/O Pin:	9
BoB Pin:	J1:3
STATUS_WORD bit:	15
Active Signal (LOW)	• A condition has occurred that has switched-off the Laser.
Notes:	The output remains active until the alarm condition is removed and the Laser is reset by the **Laser_Enable** signal.

8.4.3 Laser_Temperature

I/O Pin:	8
BoB Pin:	J1:4
STATUS_WORD bit:	12
Active Signal (LOW)	• The measured Laser temperature is outside limits. • The value measured by the Laser temperature sensing circuit is such that it indicates a sensor fault.

8.4.4 Beam_Delivery

I/O Pin:	11
BoB Pin:	J1:5
STATUS_WORD bit:	13
Active Signal (LOW)	• The optical connector temperature is outside limits. • The value measured by the optical connector temperature sensing circuit is such that it indicates a sensor fault or a fault in the optical cable.

8.4.5 System_Fault

I/O Pin:	10
BoB Pin:	J1:6
STATUS_WORD bit:	15
Active Signal (LOW)	• A condition is detected that indicates a fault in the Laser system that is not associated with environmental conditions.
Notes:	If this signal is active it indicates that the Laser may require service.

8.4.6 Laser_Deactivated

I/O Pin:	12
BoB Pin:	J1:7
STATUS_WORD bit:	10
Active Signal (LOW)	• The Laser_Disable input is activated. • A System fault is active (see section 7).
Notes:	The output remains active until the condition is removed and the Laser is reset by the Laser_Enable signal.

8.4.7 Laser_Emission_Warning

I/O Pin:	16
BoB Pin:	J1:8
STATUS_WORD bit:	11
Active Signal (HIGH)	• The internal Laser power supplies are operational.

8.4.8 Laser_Is_On

I/O Pin:	14
BoB Pin:	J1:9
Active Signal (HIGH)	• The pump diode Lasers are commanded to be operational. • There is >1A of current flowing through the pre-amplifier pump Laser diode.

9 Software Commands and Controls

9.1 Control and Status Command Summary

Parametric set-point values, or modes that can be specified by the user can be read and written

	RS-232		Ethernet	
Description	Command	Section	Command	Section
Set RS-232 Baud rate	SB nnnnnn	17.1.1	0x10	18.1.1
Get RS-232 Baud rate	GB		0x11	18.1.2
Set Power amplifier simmer current set point	SH 0 - 100	17.1.3	0x1C	18.1.7
Set Power amplifier active current set point	SI 0 – 1000	17.1.4		
Get Power amplifier simmer current set point	GH	17.1.3	0x1D	18.1.8
Get Power amplifier active current set point	GI	17.1.4		
Pulse Generator Commands				
Set pulse waveform (*)	SW 0 - 31	17.1.8	0x20	18.2.1
Get pulse waveform (*)	GW		0x21	18.2.2
Set pulse repetition frequency (Hz) (*)	SR 0 - 1000000	17.1.6	0x22	18.2.3
Get pulse repetition frequency (Hz) (*)	GR		0x23	18.2.4
Set pulse burst length (0 = continuous) (*)	SL 0 - 1000000	17.1.5	0x24	18.2.5
Get pulse burst length (0 = continuous) (*)	GL		0x25	18.2.6
Set CW mode modulation duty factor	SF 0 - 1000	17.1.2	0x26	18.2.7
Get CW mode modulation duty factor	GF		0x27	18.2.8
Set all pulse generator parameters	No equivalent RS-232 commands		0x2C	18.2.9
Get all pulse generator parameters for waveform			0x2D	18.2.10
STATUS_WORD commands				
Set Laser enable – STATUS_WORD(0)	SS 0	17.1.7	00x1A	18.1.5
Clear Laser enable – STATUS_WORD(0)	SC 0			
Set Pulsed or CW mode – STATUS_WORD(3)	SS 3			
Clear Pulsed or CW mode – STATUS_WORD(3)	SC 3			
Set Pilot Laser Enable – STATUS_WORD(8)	SS 8			
Clear Pilot Laser Enable – STATUS_WORD(8)	SC 8			
Set Start Pulses – STATUS_WORD(1)	SS 1		0x2F	18.2.11
Set current control source – STATUS_WORD(4)	SS 4		0x14	18.1.3
Clear current control source – STATUS_WORD(4)	SC 4			
Set current control source – STATUS_WORD(9)	SS 9			
Clear current control source – STATUS_WORD(9)	SC 9			
Get active bits in STATUS_WORD	GS		No identical command	
Get Laser interface control mode			0x15	18.1.4
Get Laser control signals	GS 0 – 2 or QS	17.2.7	0x1B	18.1.6

(*) these commands require that the Laser is re-enabled to affect the change.

9.2 Monitoring Commands

Parameters that are actually measured values of a monitor signal from the Laser Module (e.g. temperature, or current) can only be queried and not set.

	RS-232		Ethernet	
Description	Command	Section	Command	Section
Query active alarm codes	QA	17.2.1	0x50	18.3.1
Query monitoring group signal status	QD	17.2.2		
Query Laser temperature	QT	17.2.5	0x51	18.3.2
Query beam delivery temperature	QU	17.2.6		
Query actual diode currents (mA)	QI	17.2.4	0x52	18.3.3
Query power supply voltages	No equivalent RS-232 commands		0x53	18.3.4
Query user interface			0x54	18.3.5
Query operating hours	QH	17.2.3	0x55	18.3.6
Query STATUS_WORD	QS	17.2.7	No identical command	

9.3 General Diagnostic Commands

	RS-232		Ethernet	
Description	Command	Section	Command	Section
Read part number	RPN	17.3.1	0x63	18.4.3
Read serial number	RSN	17.3.2	0x62	18.4.2
Query Laser variant	QV*	17.2.8	0x64	18.4.4
Set Laser into diagnosis state	No equivalent RS-232 commands		0x60	18.4.1
Get Laser feature description			0x65	18.4.5

* Frequent, repeated use of the QV command can cause the internal RS-232 buffer to overflow due to its long response argument. This can lock the RS-232 communications interface, requiring a power off to reset the interface. **Therefore, we recommend that this command should not be incorporated in an automated polling loop.**

9.4 The STATUS_WORD and Modes of Operation

bit	Signal	Type	Levels	QS Bit Mask Value
15	**Alarm**	Read-only	1 = alarm condition detected. 0 = no alarm condition detected.	32768
14	**System_Fault**		1 = system fault detected. 0 = no system fault detected.	16384
13	**Beam_Delivery**		1 = beam delivery alarm or monitor detected. 0 = no beam delivery alarm or monitor detected.	8192
12	**Laser_Temperature**		1 = temperature alarm or monitor detected. 0 = no temperature alarm or monitor detected.	4096
11	**'Laser Emission Warning'**		1 = Laser power supplies are both in range. 0 = one or more Laser power supplies are not in range.	2048
10	**'Laser Deactivated'**		1 = Laser has been deactivated. 0 = Laser has not been deactivated.	1024
9	Interface mode (**)	Read/write	1 = hardware mode. 0 = software mode.	512
8	**'Pilot Laser Enable'**		1 = enable pilot Laser / pilot Laser is enabled. 0 = disable pilot Laser / pilot Laser is not enabled.	256
7	(Reserved)		0	128
6	(Reserved)		1	64
5	(Reserved)		1	32
4	External current control mode		1 = external (AI_1, AI_2). 0 = internal (serial control).	16
3	**'Laser Pulse CW' (*)**		1 = cw/m mode selected. 0 = pulsed mode selected.	8
2	(Reserved)		0	4
1	Start Pulses		1 = start internal pulse generator with programmed parameters (*).	N/A
0	**'Laser Is On'**		1= enable Laser / Laser_Is_On. 0 = Laser is not on.	1

(*) pulses are always gated by the Laser_Emission_Gate input signal.

(**)stored in non-volatile memory and is remembered by the Laser after turning the Laser power off

9.4.1 Interface Mode (STATUS_WORD bit 9)

9.4.1.1 Hardware Interface mode (STATUS_WORD bit 9 = 1) –default

If Software Interface mode is enabled, ‘Laser Is On’ (STATUS_WORD bit 0) must first be made cleared. The STATUS_WORD bit 9 can then be set to enable Hardware Interface mode.

In hardware interface mode, the user must use the digital/analogue lines on the Control I/O connector to control Waveform selection, power-amp simmer / active-state current set-points, and must use the Pulse Trigger input.

9.4.1.2 Software Interface mode (STATUS_WORD bit 9 = 0)

In order to enable Software Interface mode, the Laser_Enable input must be LOW. STATUS_WORD bit 9 should then be cleared to enable Software Interface mode.

In software interface mode, pulses are triggered by the internal pulse generator, and pulse characteristics (pulse rate, waveform, pulsed/CW mode) are set with the appropriate software commands. It is not possible to trigger pulses directly using the External Pulse Trigger in Software Interface mode, but the pulse clock is synchronized by the rising edge of a signal on the Laser_Emission_Gate input.

9.4.2 External Current Control Mode (STATUS_WORD bit 4)

The ‘External Current Control’ bit allows the current to the power-amplifier pump diodes to be controlled by analogue voltage inputs whilst operating in software interface mode. The state of the External Current Control mode can be specified by setting/clearing bit 4 of the STATUS_WORD.

- **Cleared:** Current set points are specified by software commands
- **Set:** Current set points are specified by the voltages on the analogue inputs AI_1 and AI_2

9.4.3 Pulsed and CW / CWM Mode Select (STATUS_WORD bit 3)

There are two Laser modes that can be set using bit 3 of the STATUS_WORD in software control mode: PULSED and CWM (CW/Modulated). The internal frequency generator is used to generate suitable sequencing signals at the specified frequency in order to provide a train of pulses, or a modulated CW operation

Pulsed Mode (STATUS_WORD bit 3 = 0)

$PRF_0 \leq PRF \leq 1000000$	Pump Laser diodes are continuously enabled and pulses are triggered at the programmed pulse repetition frequency, PRF.
$1000 \leq PRF \leq PRF_0$	Pump Laser diodes are modulated at the programmed pulse repetition frequency, PRF.

CWM Mode (STATUS_WORD bit 3 = 1)

$0 \leq PRF < 100$	Pump Laser diodes are permanently enabled (i.e. this regime is enabled by the user entering a value of pulse repetition frequency lower than 100).
$100 \leq PRF \leq 100000$	Pump Laser diodes are modulated at the specified pulse repetition frequency (PRF). The duty factor is as specified by a software command.

9.4.4 'Laser Is On' (STATUS_WORD bit 0)

A rising-edge on the Laser_Enable input, or using a command to set STATUS_WORD bit 1 attempt to enable the Laser. If there are fault conditions, alarms, or if the 24V Laser diode supply is not present, then these attempts will fail to set the Laser_Is_On bit.

If the 'Laser Is On' bit IS set, the controller

- o enables the Laser diode driver circuits.
- o sets the diode currents to the programmed or analog simmer levels.
- o allows the active-state current set-point levels to be set.

9.4.5 Start Pulses (STATUS_WORD bit 1)

The 'Start Pulses' bit is used to start the pulse generator in software interface mode. The output of the Laser is gated by the Laser_Emission_Gate. It is necessary to set the 'Start Pulse' bit in order for changes to the following pulse parameters to take effect:

- Pump Duty Factor (SF/GF).
- Pulse Rate (SR/GR).
- Pulse Burst Length (SL/GL).
- Pulse Waveform (SW/GW).
- Pulsed/CWM mode select (SS 3, SC 3).
- External Current Control Mode (SS 4, SC 4).

9.4.6 'Pilot Laser Enable' (STATUS_WORD bit 8)

Asserting the 'Pilot Laser Enable' bit will enable the red alignment Laser diode, if one is present. Enabling the pilot Laser will disable IR output except for the visible alignment beam. The pilot Laser can be enabled at any point there is power to the logic board of the Laser. The control line can be set regardless of whether the SPI Laser Module connected has the pilot Laser option installed or not. Clearing the 'Pilot Laser Enable' bit disables the pilot Laser and the IR Laser will revert to its previous operating state.

9.5 User-selectable Pulse Waveforms

9.5.1 Selecting Pulse Waveforms

The G4 Laser contains a number of pre-programmed pulse waveforms that allow the user a degree of control over the optical output pulse characteristics. The waveforms are pre-programmed in the controller and are selectable using the 'SW' command. Each waveform has an associated minimum pulse rate at which maximum rated power may be achieved. Pulse rates below these values are allowed, but the average output power will be reduced as the controller will modulate the amplifier pump Laser diodes in order to avoid damage to the Laser. See section 14 & 15 for descriptions of the waveforms for each variant.

9.5.2 The Waveform Data Structure

Each waveform stored in the controller has an associated data structure that defines the pulse waveform shape and includes the following parameters that are accessible to the user in software control mode:

parameter	type	minimum	maximum	SET command	GET command
Pump Duty Factor (*)	Integer (U16)	0	1000	SF	GF
Pulse Burst Length	Integer (U32)	0	1000000	SL	GL
Pulse Rate	Integer (U32)	0	500000	SR	GR

(*) affects CW mode operation only

The values of these parameters are stored in volatile memory (i.e. they return to default values when the controller is reset) for each waveform. Parameters associated with a certain waveform are set using the **SF**/**SL**/**SR** commands after selecting the waveform using the **SW x** command;

10 Electrical Interface Specification

WARNING: Connecting the Laser module to non-isolated (active) power supplies and with unspecified control-line states could lead to uncontrolled Laser emission with the associated risk of personal exposure to hazardous radiation and product damage.

10.1 Location of Connectors

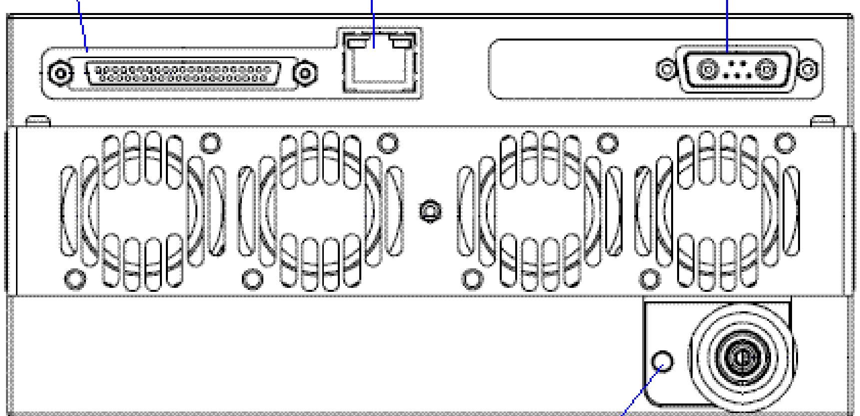
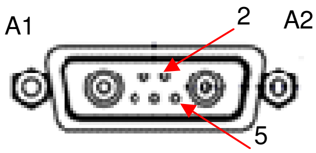


Figure 28. **Connector Locations**

10.2 Earth Bonding

The integrator must comply with 61010-1:2010, section 6.5.2 in the connection of the Protective Bonding fixing point. The G4 bonding fixing point is an M5 threaded hole and requires a fixing torque of 2Nm. The bonding point on the Laser is for 'earth' connection to the chassis in which the Laser in mounted. It should not be connected to the 0V of the Diode 24V PSU or the Logic 24V PSUs.

10.3 Power Connector



pin	Signal name	Level	Action
A1	**Diode Power Supply +**	+22 to +26V	Power supply for pump Laser diodes
A2	**Diode Power Supply -**	0V	
1, 3, 4	reserved		
2	**Logic Power Supply +**	+22 to +26V	Power supply for logic board and RAL
5	**Logic Power Supply -**	0V	

G4 Laser Modules are supplied with a power supply cable with 2 pairs of conductors to allow easy connection to the required power supplies (PT-E01590). Alternatively a shielded cable is available as a G4 accessory (PT-E01651). SPI recommends that the Laser integrator implements the fuse shown below in their equipment to protect the logic supply to the G4 Laser module.

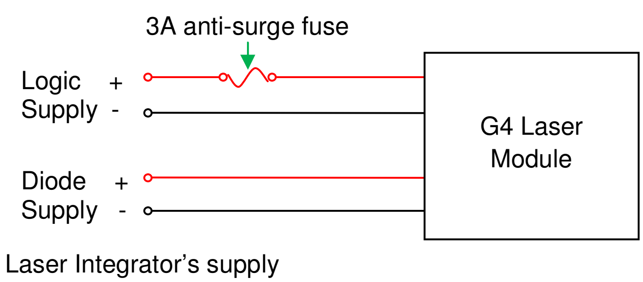
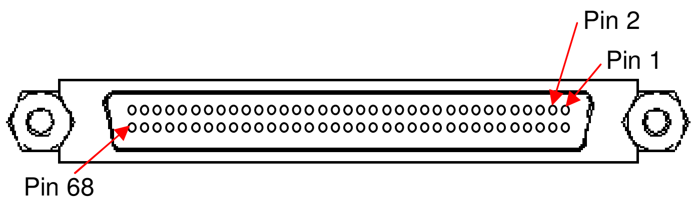


Figure 29. **Logic Supply Protection Circuit**

10.4 Power Supply Requirement

Parameter	Condition	10W	12W	20W	30W	40W
Output Voltage	Continuously rated	24V DC (22 – 26 V)				
Diode Power supply	Continuously rated	200 W			300 W	
Logic Power supply	Continuously rated	50 W				
Minimum load		No minimum load				
Voltage Accuracy	of set (specified) voltage	<1%				
Ripple and noise	using EIAJ test method & 20MHz bandwidth	<1% pk-pk				
Hold up	100% rated output power	>16 ms				
Turn on overshoot	cold start no load	<5%				
Load regulation	0-100% load change	<0.5%				
Line regulation	Assuming ± 10% input change	<0.2%				
Voltage Isolation	input-output (reinforced)	≥3 kV AC RMS				
Voltage Isolation	output-ground (operational)	≥500 V AC RMS				

10.5 Laser I/O Connector (SCSI)



signal group	signal name		pin			signal name	signal group
real-time	**Laser_Ready_To_Pulse**	DO	35	1	DO	**Task_Active**	real-time
real-time	**GND_D**	↓	36	2	DO	**Laser_Has_Pulsed**	real-time
monitoring	**GND_D**	↓	37	3	DO	**Monitor**	monitoring
real-time	N/C	DI	38	4	DI	First_Pulse_Equalization	real-time
real-time	**Laser_Emission_Gate_l**	↓	39	5	DI	**Laser_Emission_Gate_h**	real-time
Laser control	**Pilot_Laser_Enable_l**	↓	40	6	DI	**Pilot_Laser_Enable_h**	Laser control
Laser control	**Laser_Enable_l**	↓	41	7	DI	**Laser_Enable_h**	Laser control
monitoring	**GND_D**	↓	42	8	DO	**Laser_Temperature**	monitoring
monitoring	**GND_D**	↓	43	9	DO	**Alarm**	monitoring
monitoring	**GND_D**	↓	44	10	DO	**System_Fault**	monitoring
monitoring	**GND_D**	↓	45	11	DO	**Beam_Delivery**	monitoring
monitoring	**GND_D**	↓	46	12	DO	**Laser_Deactivated**	monitoring
real-time	**Pulse_Trigger_l**	↓	47	13	DI	**Pulse_Trigger_h**	real-time
monitoring	**GND_D**	↓	48	14	DO	**Laser_Is_On**	monitoring
Laser control	**Laser_Disable_l**	↓	49	15	DI	**Laser_Disable_h**	Laser control
monitoring	**GND_D**	↓	50	16	DO	**Laser_Emission_Warning**	monitoring
parallel	**DI_4**	DI	51	17	DI	**DI_0**	parallel
parallel	**DI_5**	DI	52	18	DI	**DI_1**	parallel
parallel	**DI_6**	DI	53	19	DI	**DI_2**	parallel
parallel	**DI_7**	DI	54	20	DI	**DI_3**	parallel
Laser control	**Laser_Pulse_CW_l**	↓	55	21	DI	**Laser_Pulse_CW_h**	Laser control
real-time	**GND_D**	↓	56	22	DO	**PRF_Sync_Out**	real-time
parallel	DI_Select	DI	57	23	DI	DI_Latch	parallel
parallel	GND_D	↓	58	24		N/C	
RS-232	**GND_D**	↓	59	25	→	**RS232_Tx**	RS-232
RS-232	**GND_D**	↓	60	26	←	**RS232_Rx**	RS-232
	N/C		61	27	↓	**GND_A**	
	N/C		62	28	↓	**GND_A**	
	N/C		63	29	↓	**GND_A**	
real-time	**AI_2**	AI	64	30	↓	**GND_A**	real-time
real-time	**AI_1**	AI	65	31	↓	**GND_A**	real-time
	N/C		66	32	↓	**GND_A**	
	N/C		67	33	↓	**GND_A**	
	N/C		68	34	↓	**GND_A**	

- **Available on all models**
- **Not available on RM models**
- **Future use**

Figure 30. **SCSI Connector Pin Allocations**

10.6 Electrical Signal Descriptions

The hardware control signals are shown in the table below, (see section 8 for functional descriptions).

<table>
<tr><th></th><th>Signal Name</th><th>Type Direction</th><th>Active Level</th><th>Opto-coupled</th><th>Transition Time</th><th>Comments</th></tr>
<tr><td rowspan="8">Laser Control</td><td>Laser_Enable_H</td><td rowspan="8">Digital IN</td><td rowspan="8">High</td><td rowspan="8">Yes</td><td rowspan="8">~ 3 us</td><td rowspan="8">V_{IL} = 0V, V_{IH} = 5V
I_{IN} = 2 mA</td></tr>
<tr><td>Laser_Enable_L</td></tr>
<tr><td>Laser_Disable_H</td></tr>
<tr><td>Laser_Disable_L</td></tr>
<tr><td>Pilot_Laser_Enable_H</td></tr>
<tr><td>Pilot_Laser_Enable_L</td></tr>
<tr><td>Laser_Pulse_CW_H</td></tr>
<tr><td>Laser_Pulse_CW_L</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td rowspan="8">Monitoring</td><td>Monitor</td><td rowspan="8">Digital OUT</td><td rowspan="6">Low</td><td rowspan="8">Yes</td><td rowspan="8">~ 3 us</td><td rowspan="8">Open-collector
Recommend 4.7kΩ pull up with a 5V source, i.e. I_{OL} ~1mA.
Absolute max rated current 40 mA</td></tr>
<tr><td>Alarm</td></tr>
<tr><td>Laser Temperature</td></tr>
<tr><td>Beam_Delivery</td></tr>
<tr><td>System_Fault</td></tr>
<tr><td>Laser_Deactivated</td></tr>
<tr><td>Laser_Emission_Warning</td><td rowspan="2">High</td></tr>
<tr><td>Laser_Is_On</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td rowspan="9">Real-time Control</td><td>Laser_Emission_Gate</td><td rowspan="3">Digital IN</td><td rowspan="3">High</td><td rowspan="3">Yes</td><td rowspan="3">~100 ns</td><td rowspan="3">V_{IL} = 0V, V_{IH} = 5V
I_{IN} = 10 mA.</td></tr>
<tr><td>Pulse_Trigger(1)</td></tr>
<tr><td>First_Pulse_Equalization</td></tr>
<tr><td>AI_1</td><td rowspan="2">Analog IN</td><td rowspan="2">n/a</td><td rowspan="2">No</td><td rowspan="2">BW = 100kHz</td><td rowspan="2">0 – 10V
Over voltage protection clips inputs up to 30V to 10V max
Inputs enter a 4kΩ potential divider so voltage supply must be low impedance.</td></tr>
<tr><td>AI_2</td></tr>
<tr><td>Laser_Ready_To_Pulse</td><td rowspan="4">Digital OUT</td><td rowspan="4">High</td><td rowspan="4">Yes</td><td rowspan="4">~100ns</td><td rowspan="4">Open-collector
Recommend 680Ω pull up with a 5V source, i.e. I_{OL} ~8mA.
Pull up range 330Ω - 4kΩ,
Absolute max rated current 40 mA</td></tr>
<tr><td>Task_Active</td></tr>
<tr><td>Laser_Has_Pulsed</td></tr>
<tr><td>PRF_Sync_Out</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td rowspan="3">Parallel I/F</td><td>DI_0 – DI_7</td><td rowspan="3">Digital IN</td><td>N/A</td><td rowspan="3">Yes</td><td rowspan="3">~100ns</td><td rowspan="3">V_{IL} = 0V, V_{IH} = 5V
I_{IN} = 10 mA</td></tr>
<tr><td>DI_Latch</td><td>↑</td></tr>
<tr><td>DI_Select</td><td>high</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td rowspan="2">RS-232</td><td>RS232_TX</td><td>OUT</td><td rowspan="2">N/A</td><td>No</td><td rowspan="2">See section 16.1</td><td rowspan="2"></td></tr>
<tr><td>RS232_RX</td><td>IN</td><td>No</td></tr>
</table>

(1) Minimum active pulse width > 250ns

- **Signals available on all models**
- **Signals not available on RM models**
- **Future use**

10.7 I/O Interface Circuitry

The I/O circuits below are replicated for each of the identified 68 way I/O Connector Pins or pairs of pins.

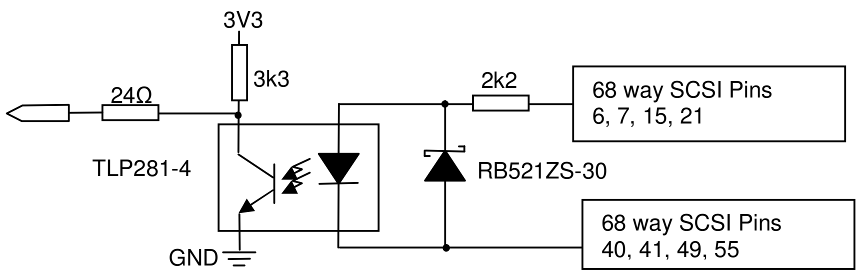


Figure 31. **Laser Control Digital Input**

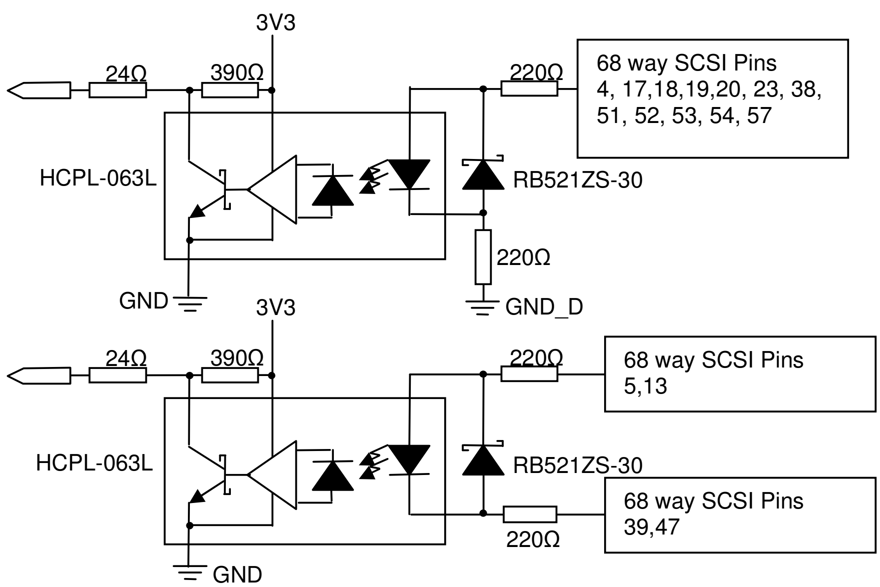


Figure 32. **Parallel Interface and Real Time Digital Inputs**

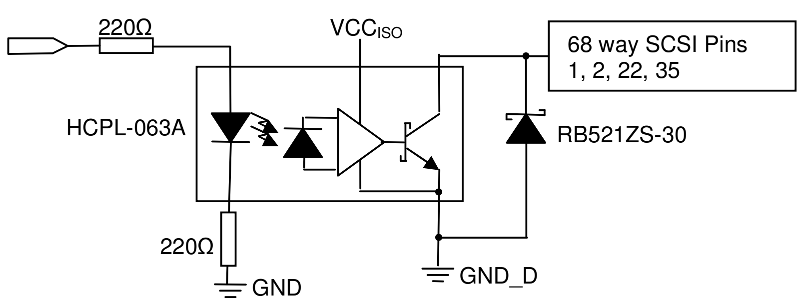


Figure 33. **Real Time Digital Outputs**

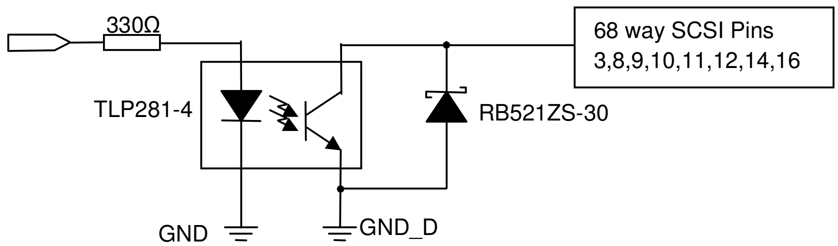


Figure 34. **Monitor Signal Digital Outputs**

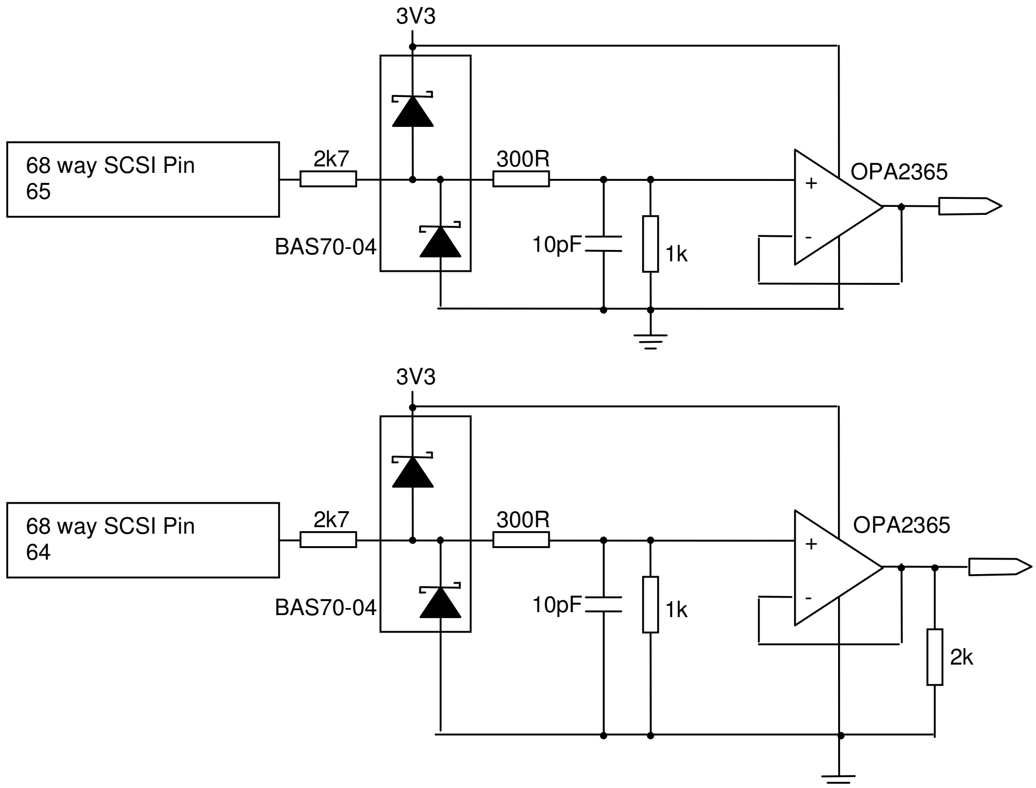


Figure 35. **Analog Input Circuitry**

10.8 Break-Out Board

The SPI G4 Break-out Board accessory (PT-E01628) provides an easy way to connect signals to different Laser control devices, such as scan cards. The table below shows how the signal groups are each associated with one connector on the G4 break-out board.

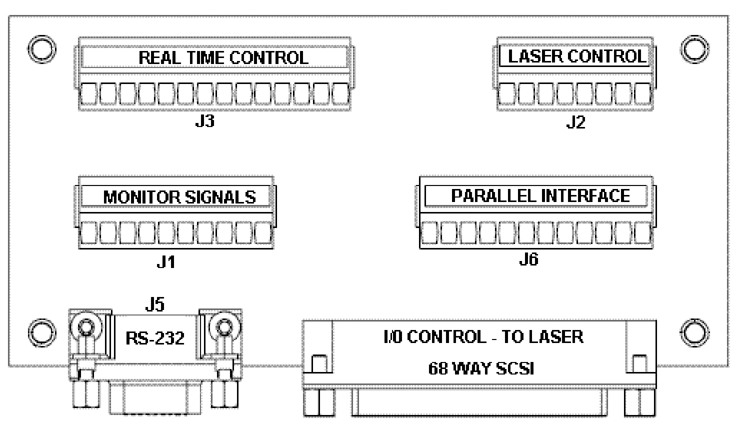
	Signal Name		Pin
Laser Control	Laser_Enable_H	J2	1
	Laser_Enable_L		2
	Laser_Disable_H		3
	Laser_Digital_L		4
	Pilot_Laser_Enable_H		5
	Pilot_Laser_Enable_L		6
	Laser_Pulse_CW_H		7
	Laser_Pulse_CW_L		8

	Signal Name		Pin
Monitoring	GND_D	J1	1
	Monitor		2
	Alarm		3
	Laser Temperature		4
	Beam_Delivery		5
	System_Fault		6
	Laser_Deactivated		7
	Laser_Emission_Warning		8
	Laser_Is_On		9
	VCC		10

Real-time Control Signals	GND_D	J3	1
	Laser_Emission_Gate		2
	Pulse_Trigger		3
	Task_Start		4
	Task_Break		5
	GND_A		6
	AI_1		7
	AI_2		8
	GND_D		9
	PRF_Sync_Out		10
	Laser_Ready_To_Pulse		11
	Task_Active		12
	Laser_Has_Pulsed		13
	VCC_5V		14

Parallel Interface Signals	GND_D	J6	1
	DI_0		2
	DI_1		3
	DI_2		4
	DI_3		5
	DI_4		6
	DI_5		7
	DI_6		8
	DI_7		9
	DI_Latch		10
	DI_Select		11
	N/C		12

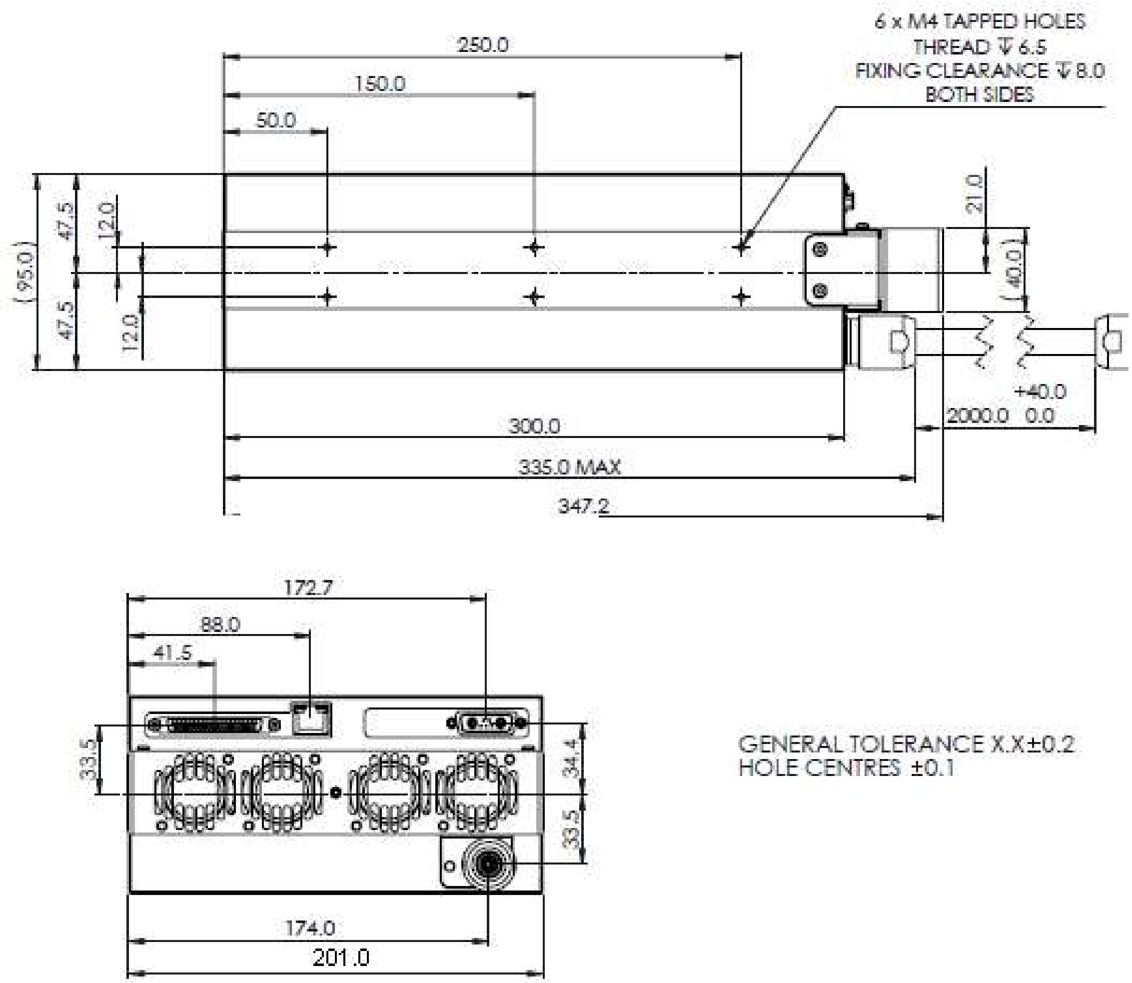
RS-232 Signals	N/C	J5	1
	RS232_TX		2
	RS232_RX		3
	N/C		4
	GND_D		5
	N/C		6
			7
			8
			9



11 Mechanical Specification

11.1 Laser Modules

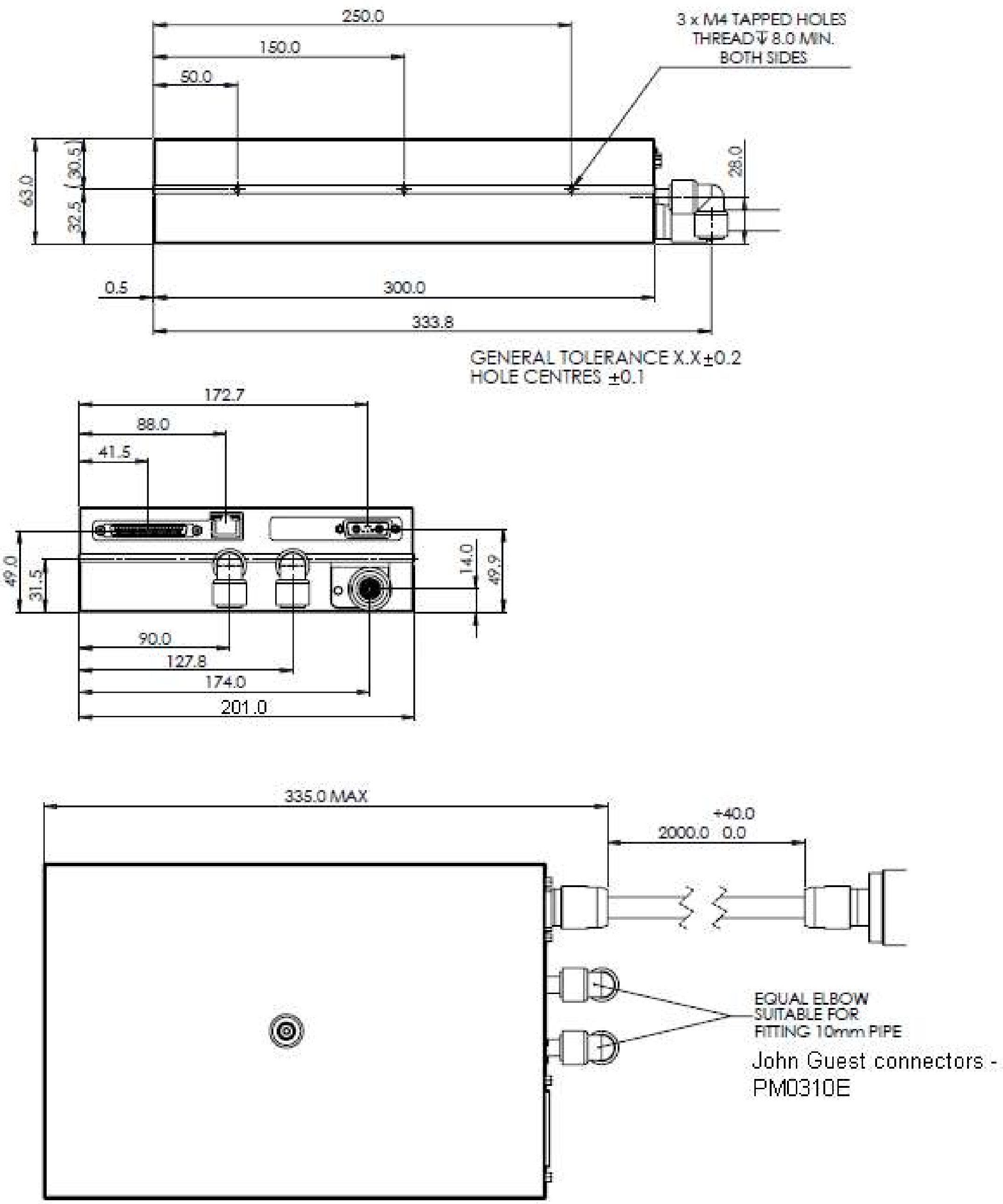
11.1.1 Air-cooled G4 10W – 40W Mechanical Drawings



Note: Max height of this G4 Module = 96.5 mm (including paint, the surface finish and labeling)
SPI recommend that Laser integrators allow suitable clearance on the overall height of the Laser to avoid damage/scratching upon installation/removal.

Figure 36. **Air Cooled G4 10W – 40W Mechanical Drawing**

11.1.2 Water-cooled G4 10W – 40W Mechanical Drawing



Note: Max height of this G4 Module = 64.5 mm (including paint, the surface finish and labeling) SPI recommend that Laser integrators allow suitable clearance on the overall height of the Laser to avoid damage/scratching upon installation/removal.

Figure 37. **Water Cooled G4 10W – 40W Mechanical Drawing**

11.1.3 G4 Laser Module Weights

Air-cooled 10 - 40W Modules (2m optical cable)	**10.4 kg**	Excludes packaging, BECs, cables etc
Water-cooled 10 - 40W Modules (2m optical cable)	**6.7 kg**	

11.2 Beam Delivery Optic – ILLK

11.2.1 ILLK Mechanical Drawing

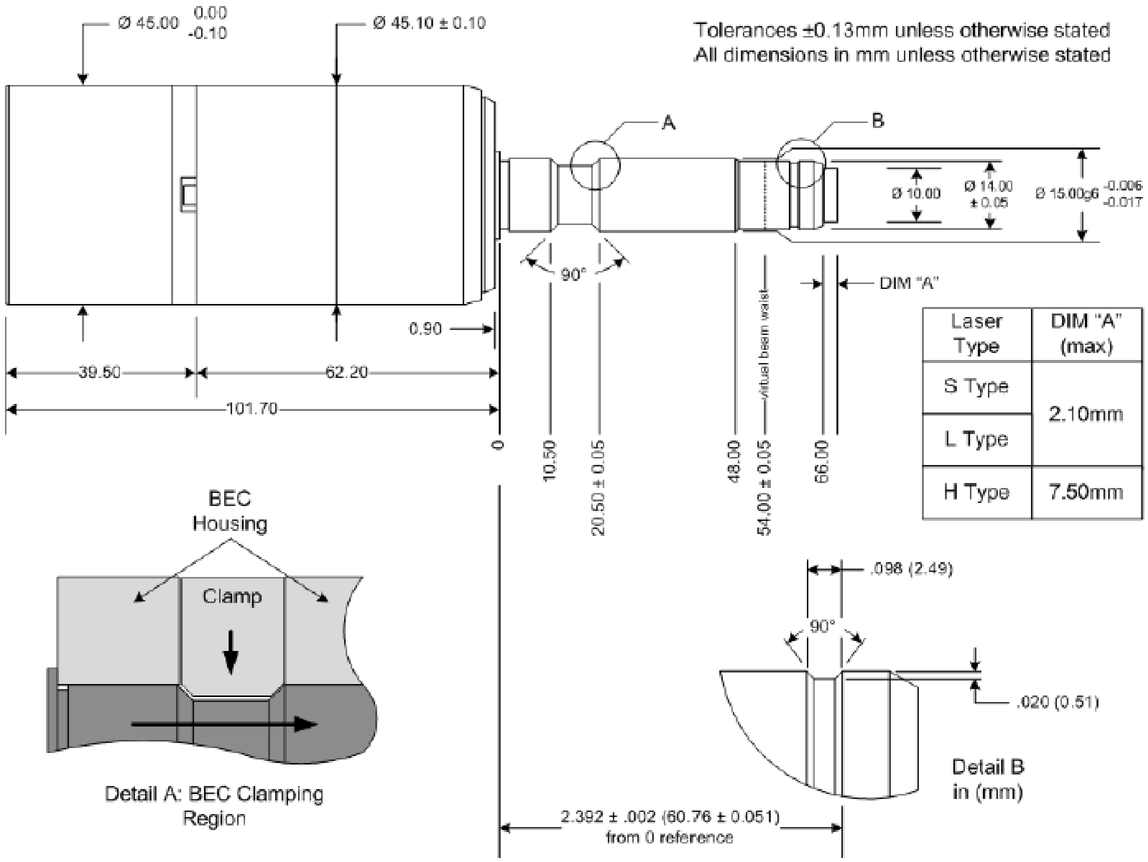


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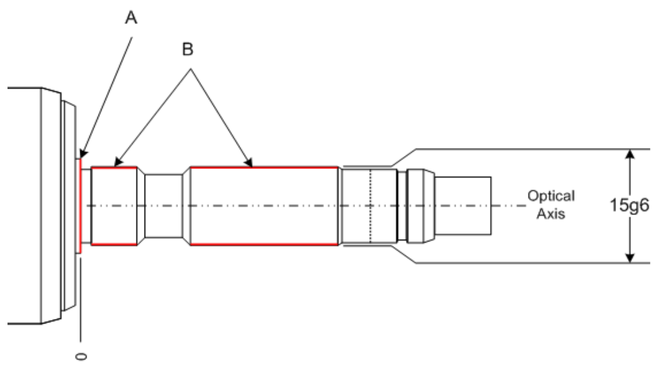
Figure 38. **ILLK Mechanical Drawing**

11.2.2 ILLK Weight

	Weight (kg)
ILLK (stand alone)	0.77
ILLK with 2m cable	0.86

11.2.3 ILLK Critical Reference Planes



A: the (virtual) waist reference plane. Any subsequent optical system that relies on source beam waist location and beam divergence (e.g. collimating lens) must be referenced to this surface

B: the 15g6 dimension (15mm diameter with g6 shaft tolerance) from which the ILLK optical axis, beam pointing error and lateral offset are specified. Alignment of any subsequent optical system (e.g. beam collimator) must be with respect to this surface.

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Figure 39. **ILLK Critical Reference Planes**

11.3 Beam Expanding Collimators (BECs)

11.3.1 BEC Mechanical Drawings

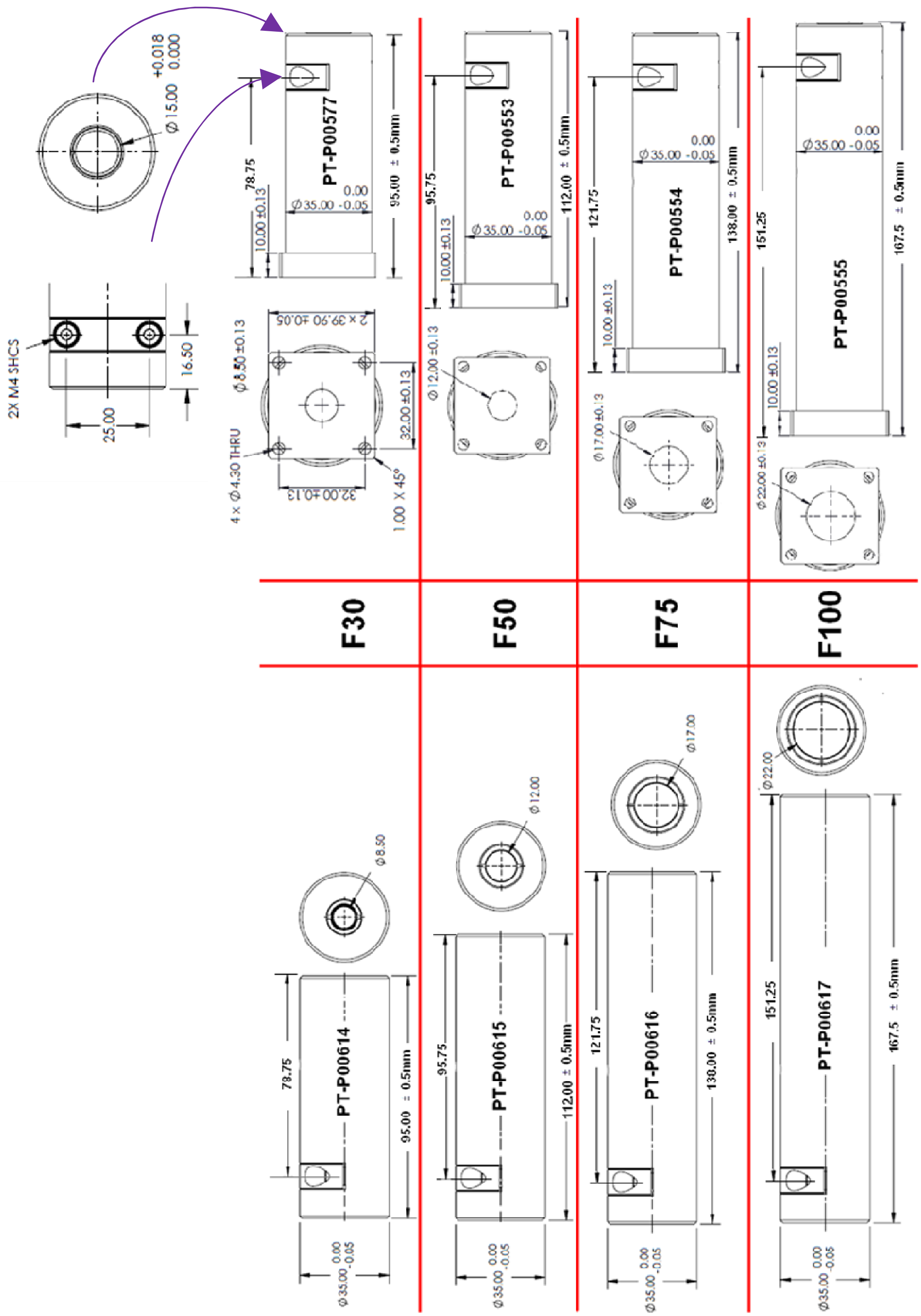


Figure 40. **G4 Beam Expanding Collimators – Mechanical Drawings**

11.3.2 BEC Weight Information

		Weight (kg)
Cylindrical	F30	0.23
	F50	0.25
	F75	0.30
	F100	0.32
With flange	F30	0.25
	F50	0.27
	F75	0.32
	F100	0.34

11.4 Break-Out Board (PT-E01628)

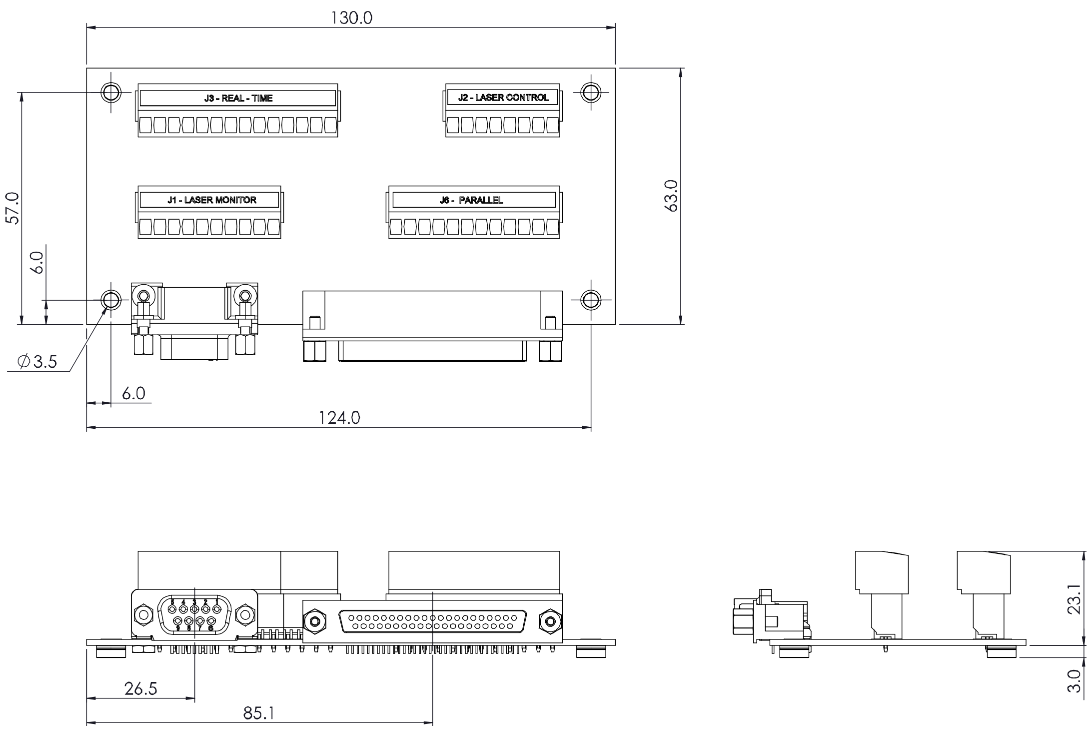


Figure 41. **Break Out Board Mechanical Drawing**

12 Installation and Operating Environmental Requirements

12.1 G4 Air Cooled Products

12.1.1 Operating and Storage Conditions

Parameter	Units	Value	
		Min	Max
Operating Temperature – 10W – 30 W	℃	0	45
Operating Temperature – 40W	℃	0	40
Storage temperature range	℃	-10	60
Relative Humidity(non condensing) (Operating & Storage)	%	5	95
Warm-up time (Thermal Equilibrium)	minutes		<15

12.1.2 Cooling Requirements for Air Cooled Lasers

For air cooled models, the Laser is 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.
- **Note**, there is no IP (Dust and water) rating for this assembly. The Laser integrator must provide suitable air filtering to prevent dust build up in the heat-sink/fan assembly

Figure 42. **Direction of Air Flow (Air cooled products only)**

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.

12.2 G4 Water Cooled Products

12.2.1 Operating and Storage Conditions

Parameter	Units	Value	
		Min	Max
Operating Temperature - Ambient Air Temperature.	℃	15	35
Cooling Water Temperature Specification.	℃	18	32
Storage Temperature Range.	℃	5 (-10 if blown through)	+60
Relative Humidity – Non-condensing (Operating and Storage).	%	5	95
Warm-up time (Thermal Equilibrium).	min		<15

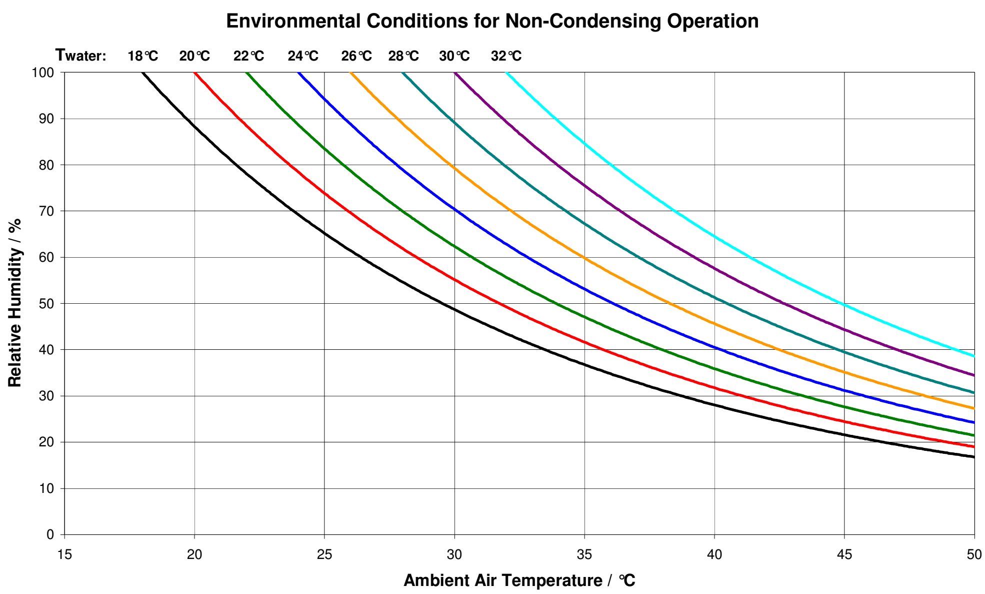


Figure 43. **Environmental Conditions for Non-Condensing Operation**

12.2.2 Cooling Requirements for Water Cooled Lasers

CAUTION: To avoid corrosion to the cooling circuit components the use of de-ionized 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℃ then it is recommended that an appropriate anti-freeze additive such as ethylene glycol is used to prevent frost damage to the Laser. It is also recommended that anti-fungal inhibitor is added to the water supply. Please contact SPI for further advice.

Any cooling water should not electrochemically react with the internal copper pipes.

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.

12.2.3 External Chiller Unit Requirements (water cooled variants)

CAUTION: Ensure a suitable external pressure release valve is installed when connecting the Laser to an external chiller or factory water supply. This should comply with ISO4126-1 (or equivalent) and be rated to protect the Laser against a flow or differential water pressure in excess of that specified in the table below

Parameter	**Units**	**20W**	**40W**
Cooling capacity (@20℃ set-point)[1,2]	W	200W	300W
Minimum flow rate	l/m	TBD	TBD
Cooling water temperature	℃	18 – 32°C	
Maximum input (flow) pressure	bar	8	
Pressure drop between flow and return	bar	2	
Connections at Laser	-	10mm John Guest Speedfit (PM0310E)	
Use of de-ionised water	-	Not permitted	

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

2 It is important that the Laser is always operated in a non-condensing environment, i.e. above the dew point. Refer to section 12.2.1 for a chart showing the relationship between relative humidity, ambient air temperature and cooling water temperature for non-condensing operation.

12.2.4 Connection to Laser (for water cooled variants only)

To connect Laser to a chiller unit or factory water supply, use water fittings and hose specified to operate under the conditions listed in table of section 12.2.3. The flow and return pipes are reversible for G4 water-cooled products.

The G4 Laser modules do not contain flow or return valves and control of the water flow must be regulated by the Laser system into which it is integrated.

The Laser must be filled and primed BEFORE the being switched on. To do this:

- Remove the flow and return bungs supplied with the Laser module.
- Connect the chiller to the Laser and open any flow valve open.
- Switch on the chiller unit –the water level is likely to drop below the lower limit.
- Switch off the chiller and top up the water level before operating the Laser for the first time.

12.2.5 Water Cooler: Disconnection from the Laser

If the Fibre Laser is to be placed in storage once the chiller unit has been disconnected, the system must be disconnected from the chiller unit and drained of all coolant. When the Laser has been completely drained remove the hoses and fittings.

CAUTION: The Fibre Laser must be drained of all coolant and the flow and return bungs fitted prior to shipment.

If the Laser is shipped without the cooling water bungs fitted then any residual coolant can escape during transit and cause permanent damage.

12.3 Noise Measurements - G4 Air cooled Variants

CAUTION: The Laser integrator should ensure there system housing mitigates the risk of obstruction to the G4 fans that could potentially cause one of the fans to stall

The measurements were carried out under as follows:

- Made using a GA213 sound pressure meter held 1m from the air intake and outlet of the product which are the two noisiest areas around the product. See section 12.1.2 for air flow.
- Carried out in a non-anechoic environment – noise floor = 34 dBA so these results are worse than might be expected when made in an anechoic chamber.

The graph below shows the results of these noise measurements

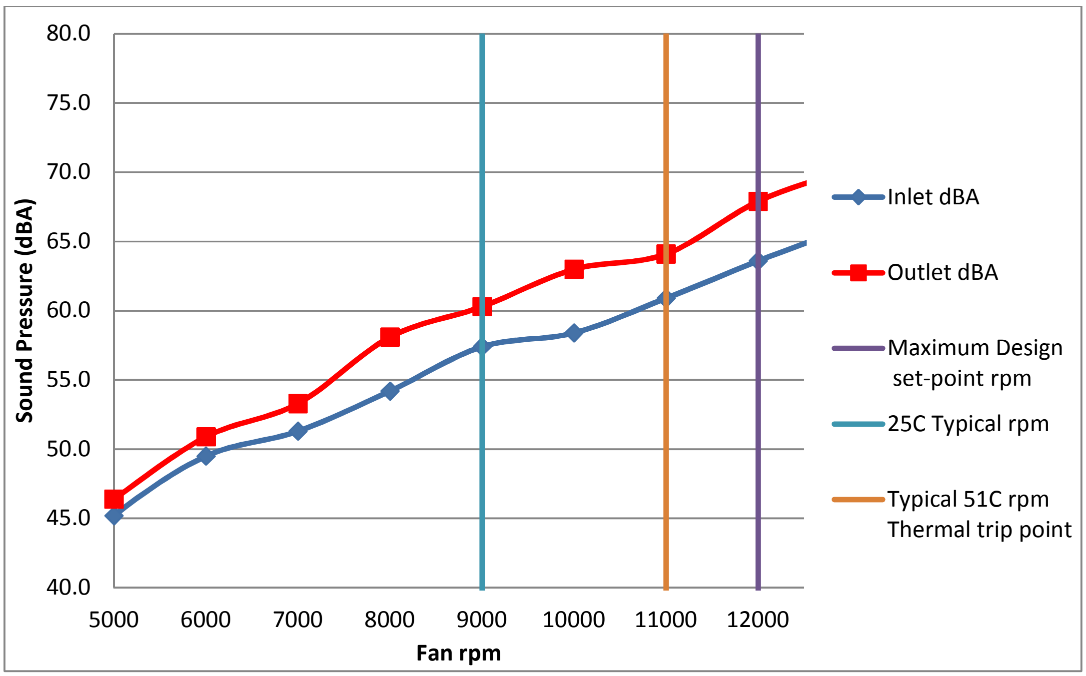


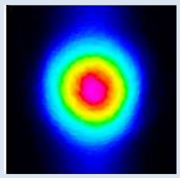
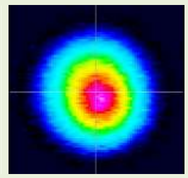
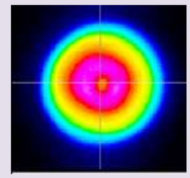
Figure 44. **Fan Noise Measurements – Air Cooled Variants**

The table below summarizes key metrics for a Laser running at maximum rated power in thermal equilibrium and quotes the worst case measurements at the air outlet.

	Fan speed (rpm)	**Noise Level (dBA)**
At 25°C ambient operating temperature	9000	60.0
The temperature alarm will typically interrupt Laser operation with when base plate temperature = 51°C	11000	64.1
The fan speed is limited such that under normal conditions (all 4 fans working) the fan speed cannot exceed 12000rpm	12000	67.9
If one fan stalls the speed of the others is increased to compensate to a maximum of 16800 rpm	16800	77.2

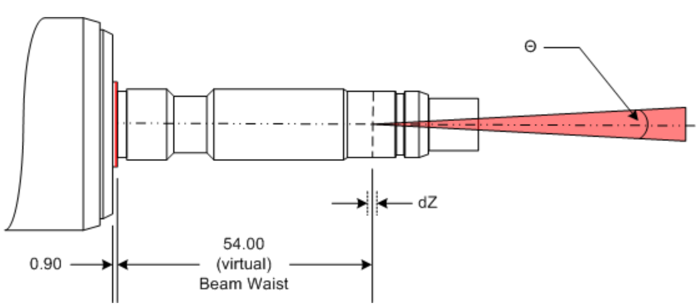
13 Laser Optical Specifications

13.1 Optical Specification Overview

	S type			L type			H type		
Beam Profile									
Power	10W	20W	30W	12W	20W		25W	30W	40W
M²	**≤ 1.3**			**1.6 – 2.0**			**2.5 – 3.5**		
Series	RM	HS	HS	HS	RM	HS	RM	HS	HS
Beam delivery cable length	2m			2m	2m	3m	3m	3m or 5m	
Average power (W)	10	20	30	12	20		25	30	38
Peak power (kW)	6	7	9	9	12	7.5	20	15	20
Pulse Energy (mJ)	0.5	0.57	0.66	0.6	0.8		1.25	1.0	1.25
PRF_0 for max pulse energy (kHz)	20	35	45	20	25		20	30	30

13.2 Reference Plane A Optical Specifications

See section 11.2.3 for definition of reference plane A.



(virtual) Beam Waist Location, dZ:	
Laser Type	All
Value	±50µm
Full Angle divergence, Θ:	
Laser Type	All types
Value	100 – 120 mrad

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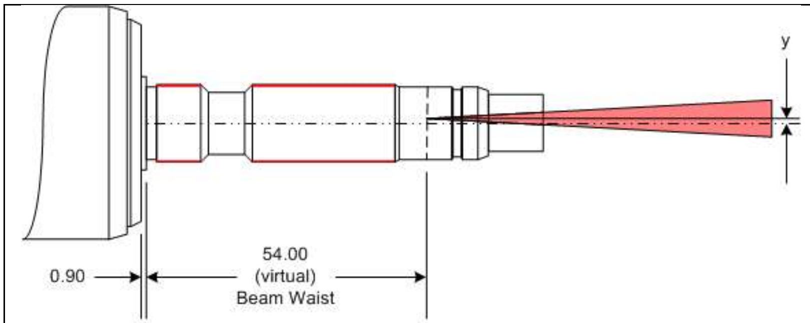
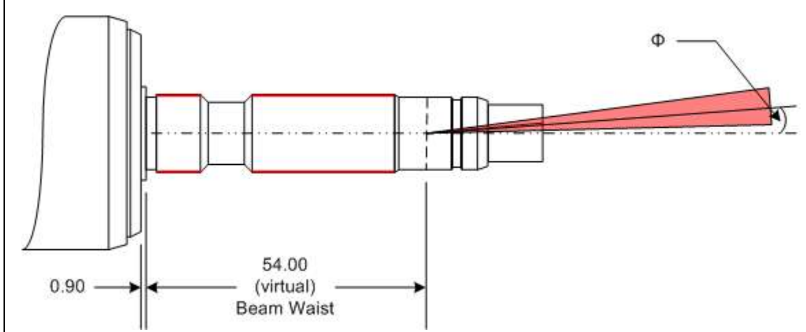
Figure 45. **Reference Plane A Beam Pointing and Offset Errors**

13.3 Reference Plane B Optical Specifications

See section 11.2.3 for definition of reference plane B.



Beam Offset, y:	
Laser Type	All
Value	<±0.1mm



Beam Pointing, ϕ:	
Laser Type	All
Value	<±10mrad

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Figure 46. **Reference Plane B Beam Pointing and Offset Errors**

13.4 Beam Expanding Collimator (BEC) Selection

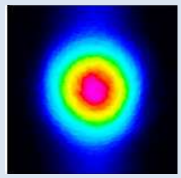
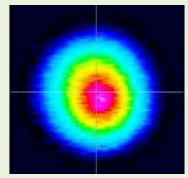
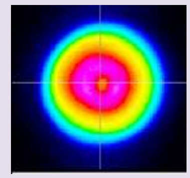
SPI offer a range of beam expanding collimators for use with G4 Laser modules. The table below details the optical characteristics of the BEC output. For the accessory part numbers see section 2.6.

Options		**F30**	**F50**	**F75**	**F100**
Nominal beam diameter mm		3	5.5	8	11
Divergence (mrad) typ. ± 10%	M2 ≤ 1.3	0.52	0.31	0.21	0.16
	1.6 ≤ M2 ≤ 2.0	0.87	0.52	0.35	0.26
	2.5 ≤ M2 ≤ 3.5	1.61	0.96	0.64	0.48
Pointing Error (mrad)		≤ 6.0	≤ 3.6	≤ 2.4	≤ 1.8

Design wavelength = 1064nm

14 G4 Waveform Reference

14.1 Pulse Repetition Rate Ranges

	S type			L type			H type		
Beam Profile									
Power	10W	20W	30W	12W	20W		25W	30W	40W
M²	**≤ 1.3**			**1.6 – 2.0**			**2.5 – 3.5**		
Series	RM	HS	HS	HS	RM	HS	RM	HS	HS
Beam delivery cable length	2m			2m	2m	3m	3m	3m or 5m	
Average power (W)	10	20	30W	12	20		25	30	38
Peak power (kW)	6	7	9	9	12	7.5	20	15	20
Pulse Energy (mJ)	0.5	0.57	0.66	0.6	0.8		1.25	1.0	1.25
PRF_0 for max pulse energy (kHz)	20	35	45	20	25		20	30	30

14.2 Fixed Waveform - RM Variants

G4 RM Variants have a single pre-defined waveform - users may vary the pulse characteristics solely by varying the pulse repetition frequency.

	Approx. Electrical Duration (ns)	**PRF_0 (kHz)**	**E_{MAX} (mJ)**	**Full Power Range (kHz)**		**Output Power Stability**
				Min	**Max**	
10W S type	170	20	0.5	20	200	3%
20W L type	200	25	0.8	25	200	5%
25W H type	250	20	1.33	20	200	2%

14.3 Waveform Reference Tables - HS variants

G4 HS Variants have a variety of pre-defined waveforms. Users can select different waveforms which, in combination with their chosen pulse repetition rate, can be used to optimize the pulse characteristics and processing speed for their target application. See section 15 for waveform examples.

Waveform Number	Approx. Electrical Duration (ns)	12W L type		20W L type		30W H type		Approx. Electrical Duration (ns)	40W H type		Approx. Electrical Duration (ns)	20W S type		30W S type	
		PRF_0 (kHz)	E_{MAX} (mJ)	PRF_0 (kHz)	E_{MAX} (mJ)	PRF_0 (kHz)	E_{MAX} (mJ)		PRF_0 (kHz)	E_{MAX} (mJ)		PRF_0 (kHz)	E_{MAX} (mJ)	PRF_0 (kHz)	E_{MAX} (mJ)
0	200	20	0.6	25	0.8	30	1.0	250	30	1.33	220	35	0.57	45	0.67
1	65	50	0.24	65	0.31	75	0.4	130	47	0.85	120	55	0.36	70	0.43
2	30	100	0.12	125	0.16	150	0.2	60	76	0.53	55	90	0.22	115	0.26
3	15	200	0.06	250	0.08	300	0.1	30	145	0.28	25	170	0.12	220	0.14
4	12	300	0.04	375	0.053	450	0.067	20	230	0.17	18	270	0.074	350	0.09
5	9	400	0.03	500	0.04	500	0.06	9	250	0.16	15	290	0.068	375	0.08
6 – 10	Duplicate of waveform 5														
11	200	20	0.6	25	0.8	30	1.0	250	30	1.33	220	35	0.57	45	0.67
12	190	20.8	0.58	26	0.77	31	0.97	230	32	1.25	205	37	0.54	48	0.63
13	180	21.6	0.56	27	0.74	32	0.94	220	34	1.18	200	39	0.51	50	0.60
14	170	22.4	0.54	28	0.71	33	0.91	200	38	1.05	190	44	0.45	57	0.53
15	160	23.2	0.52	29	0.69	34	0.88	170	41	0.98	160	48	0.42	62	0.48
16	150	24.4	0.49	30.5	0.66	36	0.83	150	43.5	0.92	140	51	0.39	66	0.45
17	140	25.6	0.47	32	0.63	38	0.79	130	47	0.85	120	55	0.36	71	0.42
18	130	26.8	0.45	33.5	0.6	40	0.75	110	51	0.78	100	60	0.33	77	0.39
19	120	28.4	0.42	35.5	0.56	42.5	0.71	100	54	0.74	95	63	0.32	81	0.37
20	110	30.4	0.4	38	0.53	45.5	0.66	90	58	0.69	85	68	0.29	87	0.34
21	100	32.8	0.37	41	0.49	49	0.61	80	62	0.65	75	72	0.28	93	0.32
22	90	36	0.33	45	0.44	54	0.56	70	69	0.58	65	80	0.25	103	0.29
23	80	40	0.3	50	0.4	60	0.5	60	76	0.53	55	90	0.22	116	0.26
24	70	45.6	0.26	57	0.35	68	0.44	50	89	0.45	45	105	0.19	135	0.22
25	60	52.8	0.23	66	0.3	79	0.38	40	108	0.37	35	125	0.16	160	0.19
26	50	62.4	0.19	78	0.26	93	0.32	30	145	0.28	25	170	0.12	220	0.14
27	40	77.6	0.15	97	0.21	116	0.26	20	230	0.17	18	270	0.074	350	0.09
28	30	108	0.11	135	0.15	162	0.19	9	250	0.16	15	290	0.068	375	0.08
29	20	200	0.06	250	0.08	300	0.1	Duplicate of waveform 28							
30 - 63	Duplicate of waveform 29														

15 Waveform Examples

The examples in this section demonstrate the general relationships between pulse shape, pulse width, pulse energy, waveform PRF_0, pulse repetition rate, average power and peak power. Please refer to the appropriate extended data sheet if you require information specific to a particular G4 variant.

15.1 12W Optical Pulse Shape Examples

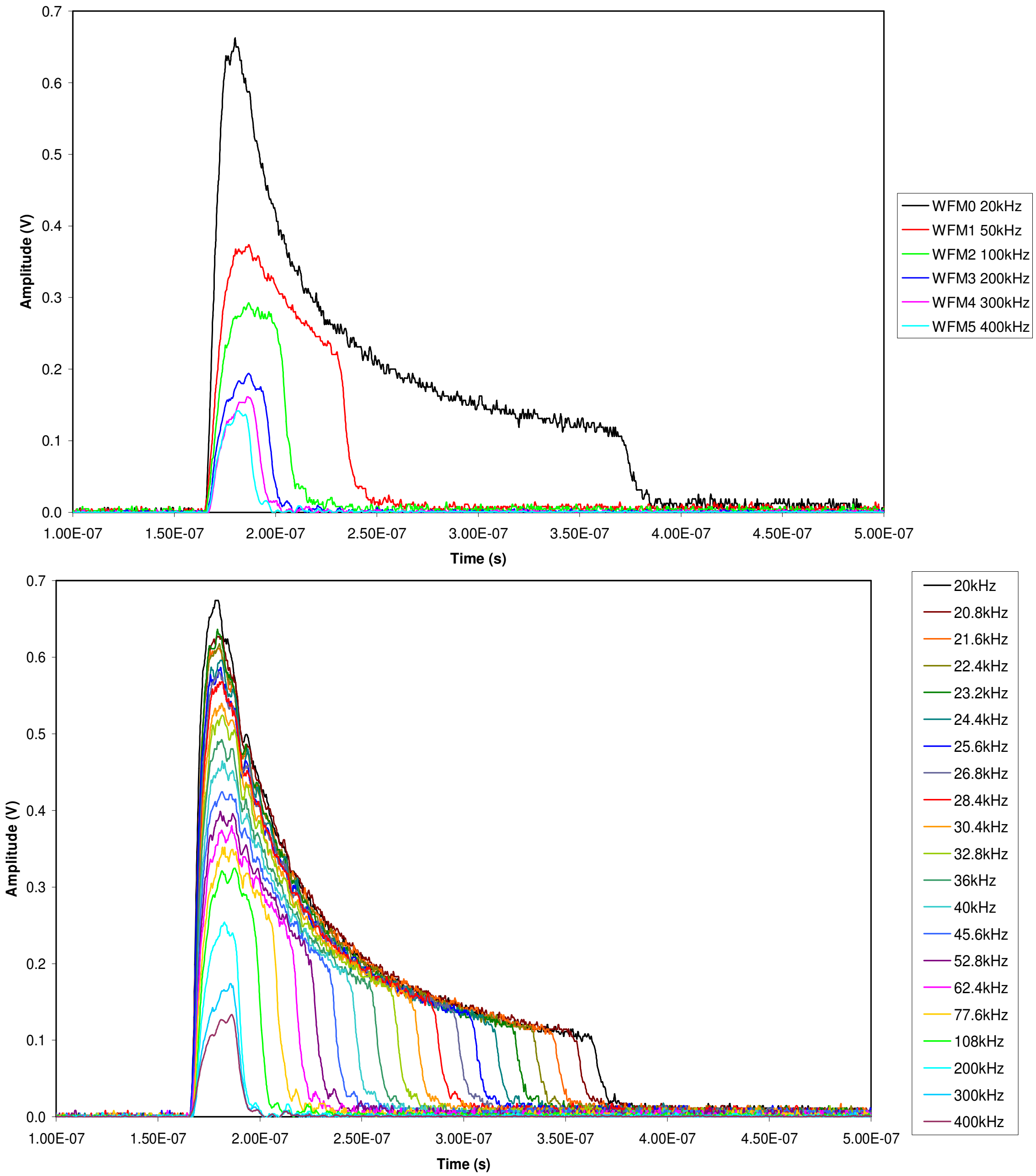
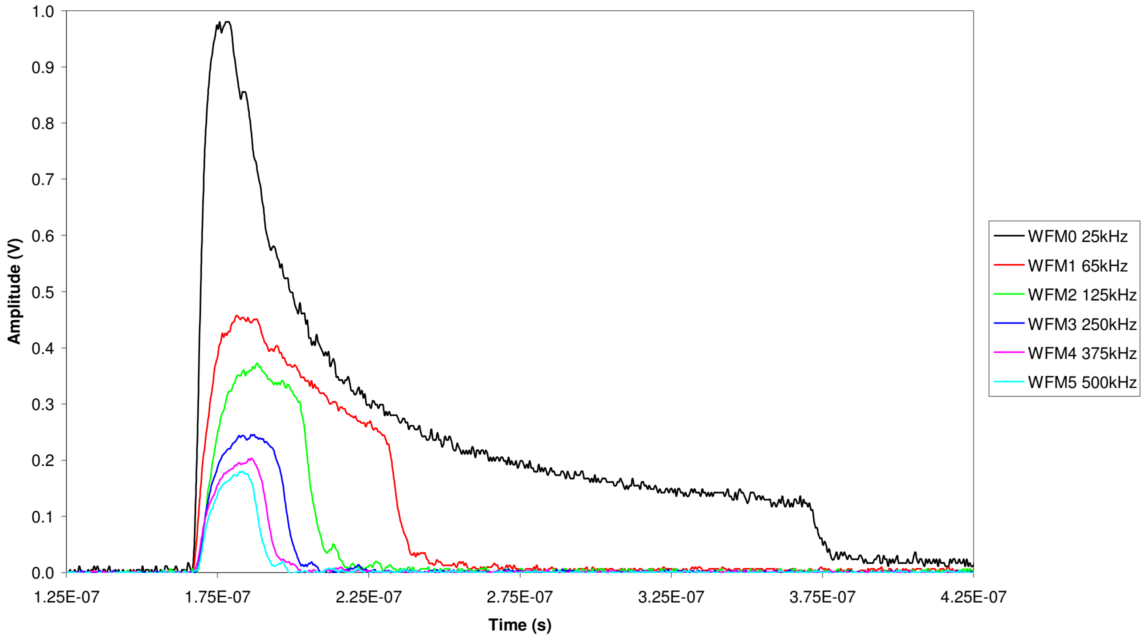


Figure 47. **Example Pulse Shapes from a 12W Pulsed Laser Module**
(top) Waveforms 0 – 5 at PRF_0 for each waveform
bottom) Waveforms 11 – 29 at PRF_0 for each waveform

15.2 20W L-type Optical Pulse Shape Examples



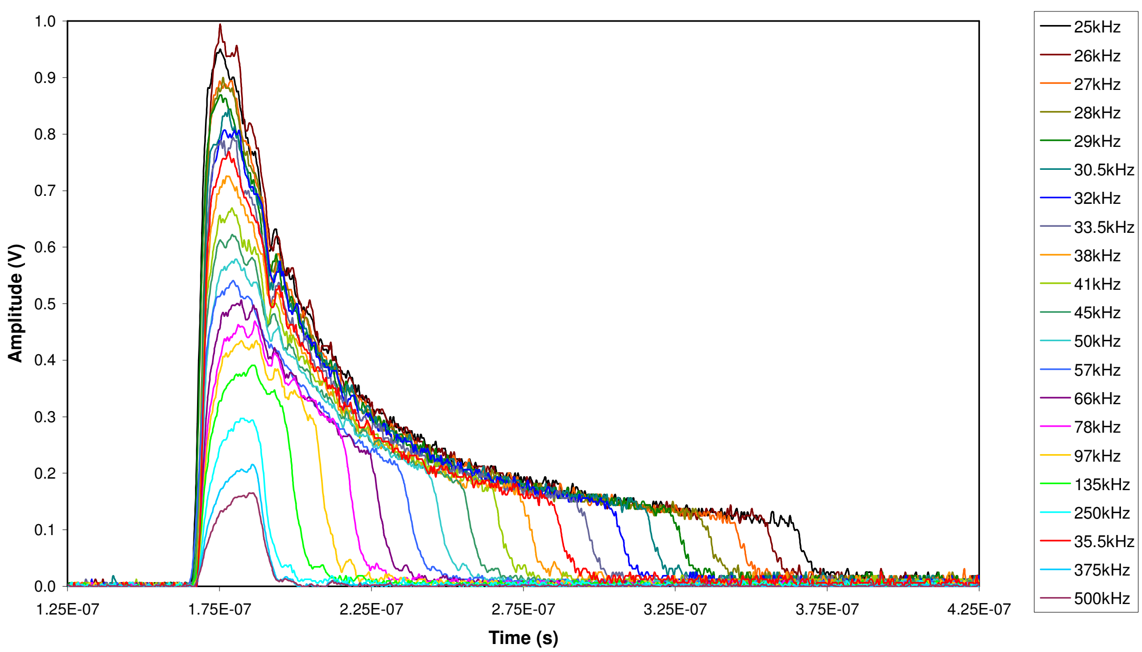


Figure 48. **Example Pulse Shapes from a 20W Pulsed Laser Module**
(*top*) waveforms 0 – 5 at PRF$_0$ for each waveform
(*bottom*) waveforms 11 – 29 at PRF$_0$ for each waveform

15.3 20W L type - Average Power vs. PRF

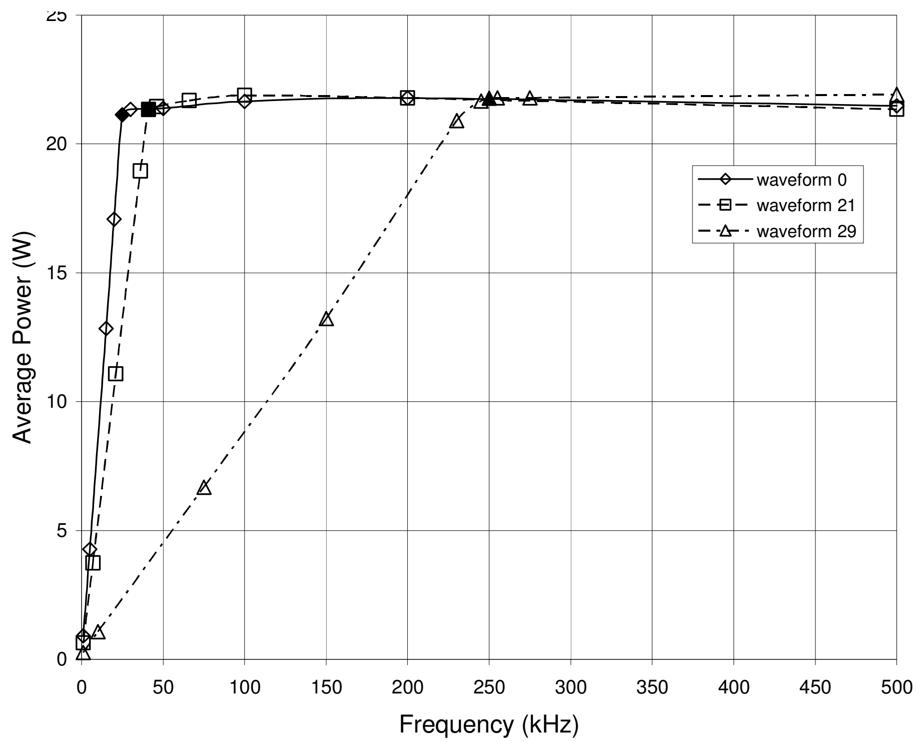


Figure 49. **Example Average Power vs. PRF (solid points indicate PRF_0)**
Waveform 0: PRF_0 = 25 kHz,
Waveform 21: PRF_0 = 41 kHz,
Waveform 29: PRF_0 = 250 kHz

15.4 20W L type FWHM Pulse Width vs. PRF

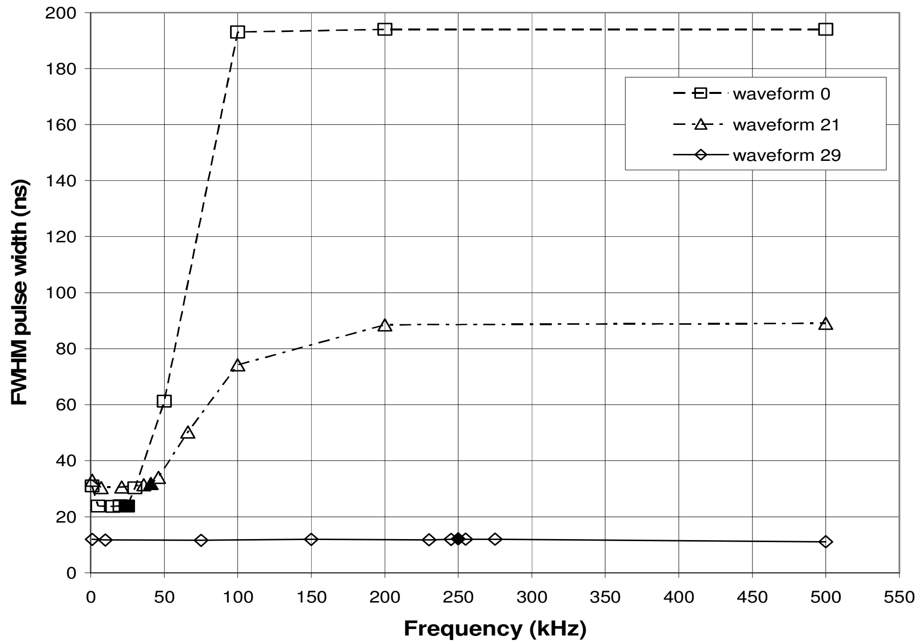


Figure 50. **Example Pulse Width vs. PRF for Maximum Current (solid points indicate PRF_0). Note: for pulse rates < PRF_0 average power is reduced**

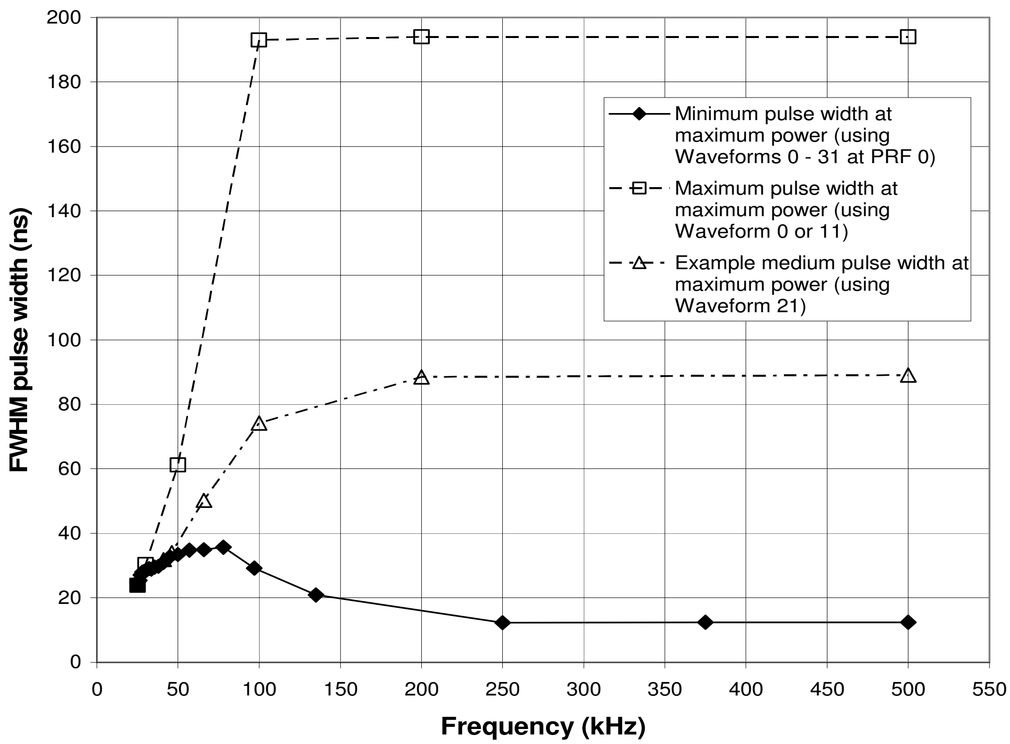


Figure 51. **Example Range of Achievable FWHM Pulse Width vs. PRF**
at Maximum Output Power using Waveforms at, or above their Specified PRF_0 Frequency
(Solid Points Indicate PRF_0)

Note: This Graph Does Not Show Operation at Pulse Rates < PRF_0 for any Waveform.

15.5 20W Laser Module Peak Power vs. PRF

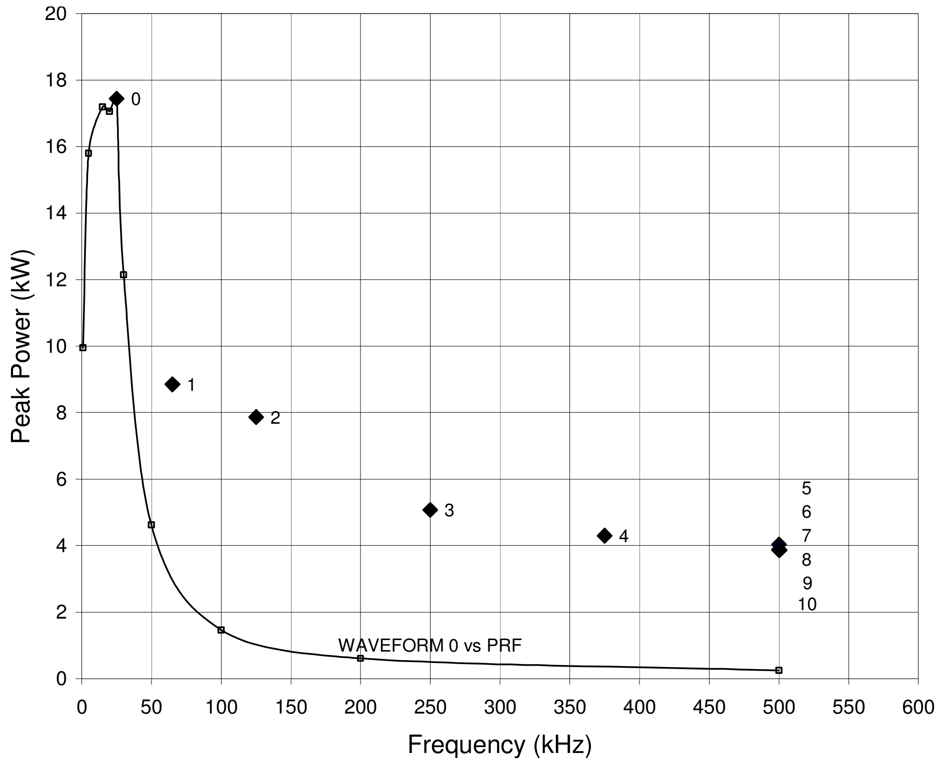


Figure 52. **Example of Peak Power vs. PRF with Waveforms 0 – 10**
(Solid Points Indicate PRF_0)

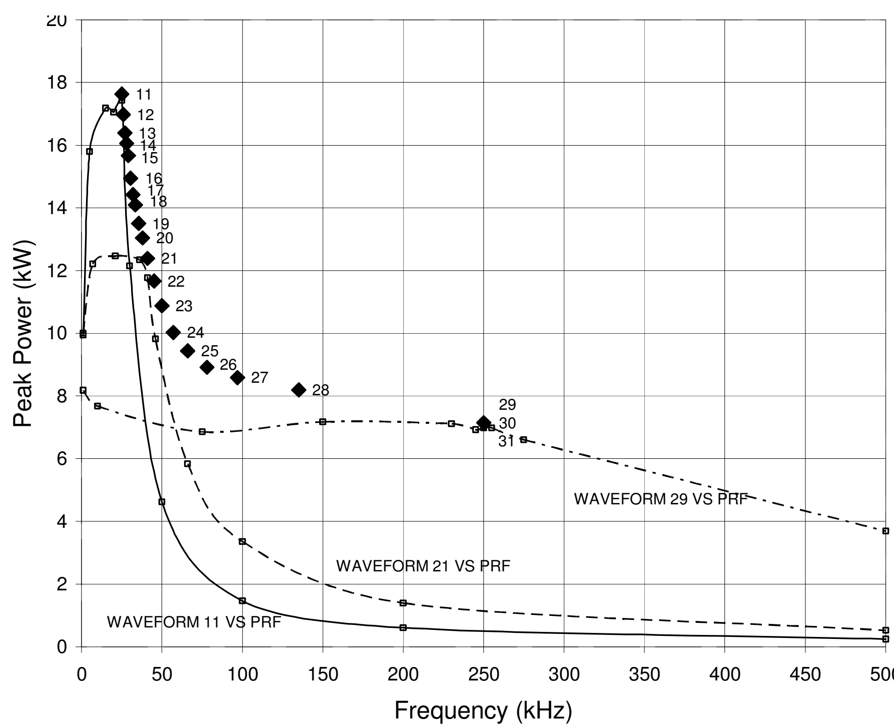


Figure 53. **Example of Peak Power vs. PRF with Waveforms 11 – 31**
(solid points indicate PRF0)

16 Serial Control Interface Protocols

16.1 RS-232 Communications Interface

Control Signals:	**RS232_Rx** **RS232_Tx**
Isolation:	Galvanic isolation
Baud Rates:	9600 19200 38400 57600 **115200 (default)**
Start Bits:	Not settable
Data Bits:	8
Stop Bits:	1
Parity:	None
Flow Control:	None
Termination Characters:	\r\n

This is a simplex interface (it can either transmit or receive but not simultaneously). Consequently the user must take care to allow time for the Lasers RS-232 interface to respond to commands before issuing the next command. This is especially the case for commands

- with a long response argument (such as QV)
- where the response argument is variable (such as QA)

16.2 Ethernet Communications

16.2.1 Command Packets sent to Laser

Ethernet communication requires the data to be structured using a specific packet format.

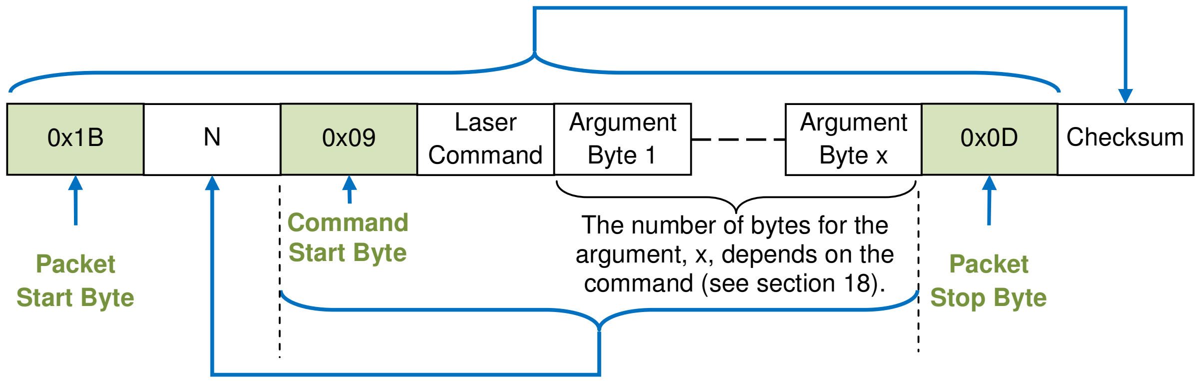


Figure 54. **Ethernet Transmit Packet Structure**

The data sent to the Laser consists of the following:

- Fixed bytes (packet start byte = 0x1B, packet stop byte = 0x0D, Command start byte = 0x09)
- Byte containing the number of command bytes, N
- The Laser command number
- The command argument bytes

Byte No	Value	Description	
1	0x1B	Packet Start byte, always = 0x1B.	
2	N	Number of command bytes (includes the fixed value byte, 0x09) N = **x** + 2, where x is the number of argument bytes for the chosen command.	
3	0x09	Command start byte, always = 0x09	
4	C	Laser Command number	
5	X1	Send Argument byte 1	The number of argument bytes, **x**, depends on the command being sent to the Laser (see section 18)
6	X2	Send Argument byte 2	
7	X3	Send Argument byte 3	
8	0x0D	Packet Stop byte, always = 0x0D	
9	CS	Check sum byte	

Constructing the packet

- Start with the command number and the argument bytes to be sent.
- Calculate N = 2 + number of argument bytes. (In this example the value would be 5).
- Assemble the packet, inserting the packet start and stop bytes and the command start byte.
- Calculate the checksum by performing unsigned, integer addition of all of the bytes in the packet. (In this case the sum of bytes 1 through 8 inclusive). Ignore any overflow bits.
- Append the checksum byte to the end of the packet.

16.2.2 Response Packet received from the Laser

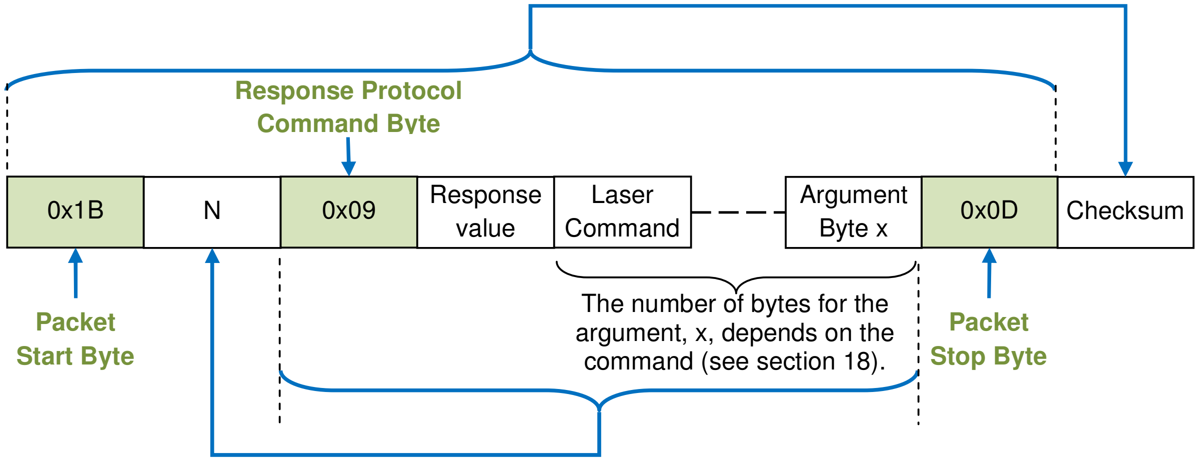


Figure 55. **Ethernet Response Packet Structure**

Byte No	Value	Description	
1	0x1B	Packet Start byte, always 0x1B	
2	N	Number of bytes in this command	
3	0x09	Response Protocol Command Byte (normally = 0x09, protocol error = 0x00)	
4	R	Response value	
5	C	Laser Command number	
6	X1	Data byte 1	The number of data bytes, **y**, depends on the command being responded to (see section18)
7	X2	Data byte 2	
8	0x0D	Packet Stop Byte, always = 0x0D	
9	CS	Check sum of bytes 1 through 8 (in this case) Calculated as the unsigned sum of the bytes from Packet Start Byte to Packet Stop byte inclusive. Any overflow bits are ignored.	

On receipt of a response packet from the Laser the following steps are recommended

Validate Packet - When the response is received the user can check the validity of the packet by comparing the check sum bytes against the sum of bytes 1 through to (and including) the packet stop byte. The values of the Packet Start and Stop Bytes and the Response Protocol Command Byte should be checked against the expected values.

Response check -

Response Protocol Command Byte (Byte 3)	R value (Byte 4)	Meaning
0x09	0	Command transferred to Laser correctly
0x00 Indicates Ethernet protocol error	0	Command not supported (did not send Command start byte = 0x09)
	1	Unused
	2	Unknown command
	3	Command Packet Stop Byte ≠0x0D
	4	Checksum error
	5	Payload too long
	6	Timeout (only part of transmitted command received)

Command check - If Response Protocol Command byte = 0x09 (byte 3) and R = 0 (byte 4) then look at byte the Laser command byte, C (byte 5).

- C should equal the command byte in the packet sent to the Laser. If so, refer to command descriptions in section 18 for the specific meaning of the response bytes relating to that command.
- If the value C = 0 then there is a problem with the command. If this is the case then data byte X1 will indicate the error

Data Byte X1 Value	Description
0	Command not recognized
2	Number of data bytes too small
3	Number of data bytes too large

16.2.3 Worked examples

16.2.3.1 Set RS-232 baud rate to 9600.

The packet sent to the Laser is:

Byte No	Value	Description
1	0x1B	Packet Start byte
2	0x06	Number of bytes in this command
3	0x09	Command Start Byte
4	0x10	Laser Command number (see section 18.1.1)
5	0x00	Argument byte 1
6	0x00	Argument byte 2
7	0x25	Argument byte 3
8	0x80	Argument byte 4
9	0x0D	Packet Stop Byte
10	0xEC	Check sum of bytes 1 through 9

Laser responds with

Byte No	Value	Description
1	0x1B	Start byte
2	0x04	Number of bytes in this command
3	0x09	Response Protocol Command Byte
4	0x00	Response byte = protocol command 0x09 was received successfully by the Laser
5	0x10	Laser Command number associated with this response
6	0x00	Response to Laser command = command accepted
7	0x0D	Packet stop byte
8	0x45	Check sum of bytes 1 through 7

16.2.3.2 Error example – Incorrect Command Start Byte

The packet sent to the Laser is:

Byte No	**Value**	**Description**
1	0x1B	Packet Start byte
2	0x06	Number of bytes in this command
3	**0x19**	Command Start Byte (should be 0x09 but 0x19 sent instead)
4	0x10	Laser Command number (see section 18.1.1)
5	0x00	Argument byte 1
6	0x00	Argument byte 2
7	0x25	Argument byte 3
8	0x80	Argument byte 4
9	0x0D	Packet Stop Byte
10	0xFC	Check sum of bytes 1 through 9

Laser responds with

Byte No	**Value**	**Description**
1	0x1B	Start byte
2	0x02	Number of bytes in this command
3	0x00	Response Protocol Command Byte = 0x00 indicating an error
4	0x00	Response byte = expected command start byte 0x09 was not received by the Laser
5	0x0D	Packet stop byte
6	0x2A	Check sum of bytes 1 through 5

16.2.3.3 Error example – Incorrect Packet Stop Byte

The packet sent to the Laser is:

Byte No	**Value**	**Description**
1	0x1B	Packet Start byte
2	0x06	Number of bytes in this command
3	0x09	Command Start Byte
4	0x10	Laser Command number
5	0x00	Argument byte 1
6	0x00	Argument byte 2
7	0x25	Argument byte 3
8	0x80	Argument byte 4
9	**0x0E**	Packet Stop Byte – incorrect – should be 0x0D
10	0xED	Check sum of bytes 1 through 9

Laser responds with

Byte No	**Value**	**Description**
1	0x1B	Start byte
2	0x02	Number of bytes in this command
3	0x00	Response Protocol Command Byte (≠ 0x09 but = 0x00 indicating an error)
4	0x03	Ethernet protocol error 3 = wrong packet stop byte
5	0x0D	Packet stop byte
6	0x2D	Check sum of bytes 1 through 5

16.2.3.4 Error example – Invalid Laser Command

The packet sent to the Laser is:

Byte No	Value	Description
1	0x1B	Packet Start byte
2	0x03	Number of bytes in this command
3	0x09	Command Start Byte
4	**0xF3**	Laser Command number (not a valid Laser command)
5	0x00	Argument byte 1
6	0x0D	Packet Stop Byte
7	0x27	Check sum of bytes 1 through 6 (=0x127 – this is truncated to 27)

Laser responds with

Byte No	Value	Description
1	0x1B	Start byte
2	0x04	Number of bytes in this command
3	0x09	Response Protocol Command Byte
4	0x00	Response byte = command 0x09 was received successfully by the Laser
5	0x00	Laser Command number
6	0x00	X1 = 0, command not recognized
7	0x0D	Packet stop byte
8	0x35	Check sum of bytes 1 through 7

17 RS-232 Command Reference

17.1 Set/Get Command Reference

17.1.1 Set/Get Baud Rate

Command:	SB nnnnnn	GB
Returns:		nnnnnn
Range:	9600, 19200, 38400, 57600, 115200	
Actions:	Sets / gets the baud rate used for RS-232 communication.	

17.1.2 Set/Get Pump Duty Factor

Command:	SF nnnn	GF
Returns:		nnnnnn
Range:	0 to 1000	
Actions:	Sets / gets the pump modulation duty factor when the Laser is in CWM mode.	
Notes:	Change is implemented when SS 1 is called to start pulses.	

17.1.3 Set/Get Power-amp Simmer Current Set Point

Command:	SH nnn	GH
Returns:		nnn
Range:	0 to 100	
Actions:	Sets/gets the power-amp simmer current set point when the Laser is in software mode.	

17.1.4 Set/Get Power-amp Active State Current Set Point

Command:	SI nnnn	GI
Returns:		nnnn
Range:	0 to 1000	
Actions:	Sets/gets the power-amp active state current set point when the Laser is in software mode.	

17.1.5 Set/Get Pulse Burst Length

Command:	SL nnnnnnn	GL
Returns:		nnnnnnn
Range:	0 to 1000000 [0 = continuous pulsing]	
Actions:	Sets/gets the number of pulses to be emitted when Laser_Emission_Gate input = HIGH.	
Notes:	Change is implemented when SS 1 is called to start pulses.	

17.1.6 Set/Get PRF

Command:	SR nnnnnnn	GR
Returns:		nnnnnnn
Range:	1000 to 1000000 (pulsed mode) 100 to 100000 (CWM mode)	
Actions:	Sets/gets the specified pulse rate (Hz) when the Laser is operating in internal trigger mode.	
Notes:	Change is implemented when SS 1 is called to start pulses.	

17.1.7 Set/Clear/Get STATUS_WORD Bits

Command:	SS n	SC n	GS
Returns:			n, n, n ...
Range:	0 to 9		
Actions:	Sets/Clears the specified bit of the STATUS_WORD Gets the asserted bits of the STATUS_WORD		

17.1.8 Set/Get Pulse Waveform

Command:	SW nn	GW
Returns:		nn
Range:	0 to 31	
Actions:	Sets/gets the specified pulse waveform for use in software mode.	
Notes:	Change is implemented when SS 1 is called to start pulses.	

17.2 Query Command Reference

17.2.1 Query Alarms

Command:	QA
Returns:	nn, nn, nn… Nothing if there are no active alarms.
Range:	nn = 0 to 99 representing active error codes.
Actions:	Returns the alarm codes of any active alarms as specified in section 7.3.

17.2.2 Query Monitoring Group Signal States

<table>
<tr><td>Command:</td><td colspan="10">QD</td></tr>
<tr><td rowspan="3">Returns:</td><td colspan="8">bbbbbbbb</td><td rowspan="3">Bit #</td><td rowspan="3">0 Monitor
1 Alarm
2 Laser_Temperature
3 Beam_Delivery
4 System_Fault
5 Laser_Deactivated
6 Laser_Emission_Warning
7 Laser_Is_On</td></tr>
<tr><td colspan="8">Bit #</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>Range:</td><td colspan="10">0000000 to 11111111</td></tr>
<tr><td>Actions:</td><td colspan="10">Queries the state of the Monitoring group output lines.</td></tr>
</table>

17.2.3 Query Operating Hours

Command:	QH
Returns:	nnnnnn
Range:	0 to 999999 representing active error codes
Actions:	Returns the operating hours for the Laser (time for which the 24V_logic supply has been applied).

17.2.4 Query Actual Diode Currents

Command:	QI
Returns:	nnnnn, nnnnn
Range:	nnnn = 0 to 20000
Actions:	Returns the pump diode current of the pump Laser diode driver stages (mA).

17.2.5 Query Laser Temperature

Command:	QT
Returns:	nn.n
Range:	0 to 85.0
Actions:	Returns the measured temperature of the Laser module (℃).

17.2.6 Query Beam Delivery Temperature

Command:	QU
Returns:	nn.n
Range:	0 to 85.0
Actions:	Returns the measured temperature of the ILLK beam delivery module (℃).

17.2.7 Query STATUS_WORD Value

Command:	QS
Returns:	nnnnnn
Range:	0 to 65535
Actions:	Returns the current value of the STATUS_WORD as a 16-bit integer.

17.2.8 Query Vendor Info

Command:	QV
Returns:	FPGAHWRev:x.x.x NIOS-IIFWRev:x.x.x StellarisFWRevx.x.x.x StellarisIPConfig:xxx.xxx.xxx.xx DHCPDRIVERfwrEV:xx.x
Range:	x.x.x specifies the versions
Actions:	Returns information regarding the Laser.

This command should not be incorporated in an automated polling loop due to its long response argument. We cannot envisage any scenario where this restriction will cause the Laser integrator problems.

Frequent, repeated use of the QV command on G4 can cause the internal RS-232 buffer to overflow and lock the RS-232 communications interface. A power off is then needed to reset the interface.

17.3 Read Command Reference

17.3.1 Read Part Number

Command:	RPN
Returns:	XX-XXXP-X-XX-X-X-X(XX)
Actions:	• Returns the part number of the Laser.

17.3.2 Read Serial Number

Command:	RSN
Returns:	nnnnnn
Actions:	• Returns the serial number of the Laser.

17.4 Example Control Code

17.4.1 Poll STATUS_WORD

The following example illustrates how the STATUS_WORD should be queried and used to determine if any Alarm Flags are raised.

```
[query the STATUS_WORD as a 16-bit integer]

QS

[get value returned by QS]
[convert string returned by QS to integer variable]

[check if alarm bits are set]
        if (STATUS_WORD AND 2^15)  [there is an alarm flag raised]
        if (STATUS_WORD AND 2^11)  [the interlock circuit is open]
        if (STATUS_WORD AND 2^12)  [there is a temperature alarm]
        if (STATUS_WORD AND 2^13)  [there is a beam delivery alarm]
        if (STATUS_WORD AND 2^14)  [there is a system alarm]

[deal with alarms]
```

17.4.2 Query Alarm Buffer

The following example illustrates how to Query Alarm Buffer to determine which Alarm Codes are asserted.

```
[query alarm buffer]

QA

[parse response from QA to determine asserted alarm codes]
[compare returned alarm codes with alarm code table]
[deal with alarm condition]
```

17.4.3 Turn the Laser On and Off

The following example shows how to start Laser emission.

```
[turn on Laser step-by-step]
SS 0          [enable 'Laser Is On' bit and go into 'SIMMER' state]
SS 1          [start pulses and go into 'ACTIVE' state]

[turn the Laser off]
SC 0          [disable 'Laser Is On' bit and enter 'STAND-BY' state]
```

17.4.4 General Parametric Monitoring

The following example illustrates the queries that should be used for general parametric monitoring of the Laser.

QT	[query Laser temperature]
QU	[query ILLK beam delivery module temperature]

[check that temperature stability is sufficient and that the temperature is not approaching a turn-off limit]

17.4.5 Start Pulses and Vary Power Amplifier Current

The following example illustrates how to control the power-amplifier active state current during an active task.

[set power-amplifier active-state current to 0% and start task]

SI 0	[set power-amplifier current to 0%]
SS 1	[start pulses]

[wait for a while]

SI 250	[set power-amplifier current to 25%]

[wait for a while]

SI 500	[set power-amplifier current to 50%]

17.4.6 Change Pulse Rate

The following example illustrates how to change pulse rate 'on-the-fly'..

[set initial pulse rate, specify continuous pulsing and start task]

SS 0	[put the Laser into SIMMER state]
SL 0	[set pulse burst length to 0, for continuous pulsing]
SR 50000	[set pulse rate to 50 kHz]
SS 1	[start pulses and go into 'ACTIVE' state]

[wait a while]

SR 200000	[set pulse rate to 200 kHz]
SS 1	[trigger Start Pulses bit to update settings]

17.4.7 Changing Pulse Rates and Stand-by Current Settings

The following example illustrates how parameters may be changed to give different output characteristics.

[set up for fast-rise time]

SC 0 [put Laser into 'STAND-BY' state]
SW 0 [select waveform 0]

[specify parameters and start task]

SH 100 [set power-amplifier stand-by current to 100%]
SI 800 [set power-amplifier active-state current to 80%]
SR 20000 [set pulse rate to 20 kHz]
SS 0 [enable LASER READY bit and go into 'SIMMER' state]
SS 1 [start pulses and go into 'ACTIVE' state]

[stop Laser, specify new parameters, and start task (note: power-amplifier stand-by current is lowered because new characteristics will result in lower pulse energy)]

SH 50 [set power-amplifier stand-by current to 50%]
SI 600 [set power-amplifier active-state current to 60%]
SR 40000 [set pulse rate to 40 kHz]
SS 1 [start pulses and go into 'ACTIVE' state]

17.4.8 Set Parameters for Waveforms 0 and 1 and make Fast Switch

The following example shows how to configure the parameters associated with waveform 0 and waveform 1 for continuous operation of waveform 0 at 30 kHz, and then a one-second burst of waveform 1 at 75 kHz with a fast change over.

[configure parameters associated with waveform number 0]

SW 0 [select waveform number 0]
SF 500 [set pump duty factor to 500 for CWM operation]
SL 0 [set pulse burst length to 0 for continuous pulsing]
SR 30000 [set pulse rate to 30 kHz]

[configure parameters associated with waveform number 1]

SW 1 [select waveform number 1]
SF 200 [set pump duty factor to 200 for CWM operation]
SL 75000 [set pulse burst length to 75000]
SR 75000 [set pulse rate to 75 kHz]

[select waveform number 0 and start task]

SW 0 [select waveform number 0]
SS 1 [start pulses]
(operation will continue until stopped by user, or new task started)

[select waveform number 1 and start task]

SW 1 [select waveform number 1]
SS 1 [start pulses and go into 'ACTIVE' state]
(operation will cease after 75000 pulses have been triggered- 1 second)

17.5 RS-232 Command Syntax / Execution Error Codes

RESPONSE	ERROR CODE	DESCRIPTION
	8-9	Password errors
E8	8	Incorrect password
E9	9	Insufficient privilege
	10-19	Command errors
E10	10	Syntax error: command not recognised
E11	11	‘Set’ method not available for this command
E12	12	‘Get’ method not available for this command
E13	13	Parameter error: too many characters
E14	14	Parameter error: not a number
E15	15	Unsupported command in this Laser
E16	16	Command not available (e.g. password protected)
E17	17	Too few parameters
E18	18	Too many parameters
	20-49	Execution errors
E20	20	Parameter out of range
E21	21	Command not executed because an alarm is active
E22	22	Command not executed because of beam delivery alarm(1)
E23	23	Command not executed because of temperature alarm
E24	24	Command not executed because power supplies were not ready
E25	25	Command not executed because Laser is not ready
E26	26	Command not executed because it is not available in the active Laser mode
E27	27	Command not executed because Laser_Enable input signal is active (high)
E28	28	Command not executed – bit is already set
E29	29	Command not executed – bit is already set
E30	30	Command could not be executed because Laser is enabled
E31	31	Command could not be executed because Laser is not enabled
E32	32	Command could not be executed because hardware control mode is enabled
E33	33	Command could not be executed because hardware control mode is not enabled
E34	34	Command could not be executed because pilot Laser is enabled
	35-39	Reserved for future use

(1) Only on 30W and 40W Lasers which have a BDO temperature sensor

18 Ethernet Command Reference

It is possible for multiple users to connect to and control a G4 Laser simultaneously via the Ethernet port. The Laser will respond to each command in the order in which it is received and does not differentiate between commands sent from different sources.

Care should be taken especially when controlling the Laser remotely across a network as another user could be working with the Laser.

It is the Integrators responsibility to ensure that any remote connectivity to the Laser cannot inadvertently allow the Laser IR to be enabled during the Integration process when, IR, Pilot Laser and interlock systems are being installed.

We recommend that any user intending to control the Laser via Ethernet, remotely across a network should first check that the Laser is installed in an interlocked, Class 1 enclosure.

18.1 Interface Control Command Reference

Commands - 0x10 - 0x1F

18.1.1 0x10: Set RS-232 Baud Rate

Command Byte	**0x10**		**RS232 Version:**	SB nnnnnn	
Actions:	Sets the baud rate used for RS-232 communication.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	1	Uint 32	9600, 19200, 38400, 57600, 115200 (0x2580, 0x4B00, 0x9600, 0xE100, 0x01C200)	RS-232 baud rate	
Receive Arguments	1	Byte	0x0?	Response byte	
	Byte	**Value**	**Meaning**		
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)		
	2	0x0?	Arg 1: data byte 2		
	3	0x??	Arg 1: data byte 3		
	4	0x?0	Arg 1: data byte 4 (LSB)		
Received data bytes	1	0x00	Command accepted		
		0x01	Value passed not valid		
		0x02	Internal error		

18.1.2 0x11: Get RS-232 Baud Rate

Command Byte	**0x11**		**RS232 Version:**	GB	
Actions:	Gets the baud rate used for RS-232 communication.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	none				
Receive Arguments	1	Byte	9600, 19200, 38400, 57600, 115200 (0x2580, 0x4B00, 0x9600,0xE100, 0x01C200)	RS-232 baud rate	
	Byte	**Value**	**Meaning**		
Received data bytes	1	0x00	Arg 1: data byte 1 (MSB)		
	2	0x0?	Arg 1: data byte 2		
	3	0x??	Arg 1: data byte 3		
	4	0x?0	Arg 1: data byte 4 (LSB)		

18.1.3 0x14: Set Laser control interface mode

Command Byte	**0x14**			**RS232 Version:**	SS 9, SC 9, SS4, SC 4
Actions:	Sets the Laser control interface mode.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	1	Uchar	0 - 7	Laser Control Interface Mode	
Receive Arguments	1	Byte	0x0?	Response byte	
	2	Uchar	0 - 7	Current Control Interface mode	
	Byte	**Value**	**Meaning**		
Send Data Bytes	1	0x0?	Arg 1: data byte 1, valid values 0 - 6		
Received data bytes	1	0x00	Mode changed		
		0x01	Mode not changed		
		0x02	Internal error		
	2	0x0?	Current mode value		

Valid send arguments

Laser Control Interface mode byte	'Interface Mode' STATUS_WORD bit 9	'External Current Control Mode' STATUS_WORD bit 4
0x05	1	1
0x01	0	1
0x00	0	0

18.1.4 0x15: Get Laser control interface mode

Command Byte	**0x15**			**RS232 Version:**	GS 9, GS 4, part of QS
Actions:	Gets the Laser control interface mode.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	none				
Receive Arguments	1	Uchar	0 - 7	Active control interface mode value	
	Byte	**Value**	**Meaning**		
Received data bytes	1	0x0?	Arg 1: data byte 1 (MSB)		

Receive byte meanings

Laser Control Interface mode byte	'Interface Mode' STATUS_WORD bit 9	'External Current Control Mode' STATUS_WORD bit 4
0x05	1	1
0x01	0	1
0x00	0	0

18.1.5 0x1A: Set Laser control signals

Command Byte	**0x1A**	**RS232 Version:**		SS 0, SC 0 SS 3, SC 3 SS 8, SC8
Actions:	Sets state of Laser control signals.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	1	Uint 16	LSB: 0-2	LSB: State of signal bits Bit 0 = Laser enable (STATUS_WORD bit 0) Bit 1= Pilot Laser enable (STATUS_WORD bit 8) Bit 2 = CW pulse(STATUS_WORD bit 3)
Receive Arguments	1	Byte	0x0?	Response byte
	Byte	**Value**	**Meaning**	
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x0?	Arg 1: data byte 2 (LSB)	
Received data bytes	1	0x00	Requested bit settings accepted	
		0x01	Requested bit settings not accepted	

18.1.6 0x1B: Get Laser control signals

Command Byte	**0x1B**	**RS232 Version:**		
Actions:	Gets the state of Laser control signals			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Byte	LSB: 0-2	LSB: State of signal bits Bit 0 = Laser enable (STATUS_WORD bit 0) Bit 1 = Pilot Laser enable (STATUS_WORD bit 8) Bit 2 = CW pulse(STATUS_WORD bit 3)
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x0?	Arg 1: data byte 1	

18.1.7 0x1C: Set analogue current set point

Command Byte	**0x1C**			**RS232 Version:**	SI, SH
Actions:	Sets the values of the active or simmer current set points.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	1	Uint 16	0 - 1	Defines which point to set 0 = active current 1 = simmer current	
	2	Uint 16	0 – 1000 (100)	0 = no current, 1000 = maximum active current (e.g. 800 ≡ 8V on analog input) 100 = maximum simmer current (e.g. 20 ≡ 2V on analog input)	
Receive Arguments	1	Byte	0x0?	Response byte	

	Byte	**Value**	**Meaning**
Send Data Bytes	1	0x??	Arg 1: data byte 1 (MSB)
	2	0x??	Arg 1: data byte 2 (LSB)
	3	0x??	Arg 2: data byte 1 (MSB)
	4	0x??	Arg 2: data byte 2 (LSB)
Received data bytes	1	0	Set Point set correctly
		1	Set point requested does not exist
		2	Set point too large
		3	Set point too small
		4	Current set points under hardware control

18.1.8 0x1D: Get analogue signals

Command Byte	**0x1D**			**RS232 Version:**	GI,GH
Actions:	Gets the values of the active or simmer current set points.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	1	Uint 16	0 - 1	Defines which point to get 0 = active current 1 = simmer current	
Receive Arguments	1	Byte	0x00		
	2	Byte	0x0?	Response byte	
	3	Uint 16	0-4095	Value of specified current set point	

	Byte	**Value**	**Meaning**
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)
	2	0x0?	Arg 1: data byte 2 (LSB)
Received data bytes	1	0x00	
	2	0	Level read correctly
		1	Set point requested does not exist
	3	0x00	Arg 1: data byte 1 (MSB)
	4	0x??	Arg 1: data byte 2 (LSB)

18.2 Pulse Generator Command Reference

18.2.1 0x20: Set pulse waveform

Command Byte	**0x20**		**RS232 Version:**		SW nn
Actions:	Selects the pulse waveform.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	1	Uint 16	0 - 63	Select pulse waveform	
Receive Arguments	1	Byte	0x0?	Response byte	
	Byte	**Value**	**Meaning**		
Send Data Bytes	1	0x00	None		
	2	0x??	Arg 1: data byte		
Received data bytes	1	0	Pulse wave form selected OK		
		1	Wave form number does not exist or in hardware mode		

18.2.2 0x21: Get pulse waveform

Command Byte	**0x21**		**RS232 Version:**		GW
Actions:	Gets the index of selected pulse waveform and its PRF_0.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	none				
Receive Arguments	1	Uint 16	0 - 63	Selected pulse waveform	
	2	Uint 32	0 - 1000000	PRF_0 of selected waveform	
	Byte	**Value**	**Meaning**		
Send Data Bytes	1	0x00	None		
	2	0x??	Arg 1: data byte		
Received data bytes	1	0x00	None		
	2	0x??	Arg 1: data byte		
	3	0x00	Arg 2: data byte 1 (MSB)		
	4	0x0?	Arg 2: data byte 2		
	5	0x??	Arg 2: data byte 3		
	6	0x??	Arg 2: data byte 4 (LSB)		

18.2.3 0x22: Set Pulse Rate

Command Byte	**0x22**		**RS232 Version:**	SR nnnnnnn
Actions:	Selects the pulse rate of the currently selected waveform.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	1	Uint 32	Depends on Laser settings • 1000 – 1000000 • 0 - 99 • 100- 100000	Pulse rate • Pulsed mode • CW mode • CW-M Mode
Receive Arguments	1	Byte	0x0?	Response byte
	Byte	**Value**	**Meaning**	
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x0?	Arg 1: data byte 2	
	3	0x??	Arg 1: data byte 3	
	4	0x??	Arg 1: data bye 4 (LSB)	
Received data bytes	1	0	Pulse rate set correctly	
		1	Pulse rate too slow for active mode	
		2	Pulse rate too fast for active mode	
		3	Not under software control	

18.2.4 0x23: Get pulse rate

Command Byte	**0x23**		**RS232 Version:**	GR
Actions:	Gets the pulse rate of the currently specified waveform.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 32	0 - 1000000	PRF_0 of selected waveform
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x0?	Arg 1: data byte 2	
	3	0x??	Arg 1: data byte 3	
	4	0x??	Arg 1: data byte 4 (LSB)	

18.2.5 0x24: Set pulse burst length

Command Byte	**0x24**		**RS232 Version:**	SL nnnnnnn	
Actions:	Sets the pulse burst length (number of pulses) of the currently selected waveform.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	1	Uint 32	0-100000	Pulse burst length (0 = continuous pulsing)	
Receive Arguments	1	Byte	0x0?	Response byte	
	Byte	**Value**	**Meaning**		
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)		
	2	0x0?	Arg 1: data byte 2		
	3	0x??	Arg 1: data byte 3		
	4	0x??	Arg 1: data bye 4 (LSB)		
Received data bytes	1	0	Burst count rate set correctly		
		1	Burst count too big		

18.2.6 0x25: Get pulse burst length

Command Byte	**0x25**		**RS232 Version:**	GL	
Actions:	Gets the pulse burst length (number of pulses) of the currently selected waveform.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	none				
Receive Arguments	1	Uint 32	0 - 1000000	Pulse burst length of selected waveform	
	Byte	**Value**	**Meaning**		
Received data bytes	1	0x00	Arg 1: data byte 1 (MSB)		
	2	0x0?	Arg 1: data byte 2		
	3	0x??	Arg 1: data byte 3		
	4	0x??	Arg 1: data byte 4 (LSB)		

18.2.7 0x26: Set pump duty factor

Command Byte	**0x26**		**RS232 Version:**	SF nnnn
Actions:	Sets the pump modulation duty factor for the currently-selected waveform in CW mode.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	1	UInt 16	0 - 1000	Pump modulation duty factor 0 = 0%, 1000 = 100%
Receive Arguments	1	Byte	0x0?	Response byte
	Byte	**Value**	**Meaning**	
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 2 (LSB)	
Received data bytes	1	0	Duty factor set correctly	
		1	Duty factor too big	
		2	Not under software control	

18.2.8 0x27: Get pump duty factor

Command Byte	**0x27**		**RS232 Version:**	GF
Actions:	Gets the pump modulation duty factor for the currently-selected waveform in CW mode.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 16	0 - 1000	Pump modulation duty factor 0 = 0%, 1000 = 100%
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 2 (LSB)	

18.2.9 0x2C: Set all pulse generator parameters

Command Byte	**0x2C**		**RS232 Version:**		SW SR SL SF
Actions:	Sets all the pulse generator parameters for the specified waveform.				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	1	Uint 16	0 - 63	Pulse waveform	
	2	Uint 32	0 - 1000000	Pulse rate	
	3	Uint 32	0 - 1000000	Pulse burst length	
	4	Uint 16	0-1000	Pump duty factor	
Receive Arguments	1	Byte	0x0?	Response byte	
	Byte	**Value**	**Meaning**		
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)		
	2	0x??	Arg 1: data byte 2 (LSB)		
	3	0x00	Arg 2: data byte 1 (MSB)		
	4	0x0?	Arg 2: data byte 2		
	5	0x??	Arg 2: data byte 3		
	6	0x??	Arg 2: data byte 4 (LSB)		
	7	0x00	Arg 3: data byte 1 (MSB)		
	8	0x0?	Arg 3: data byte 2		
	9	0x??	Arg 3: data byte 3		
	10	0x??	Arg 3: data byte 4 (LSB)		
	11	0x00	Arg 4: data byte 1 (MSB)		
	12	0x??	Arg 4: data byte 2 (LSB)		
Received data bytes	1	0	Pulse parameters set correctly		
		1	Pulse waveform number too big		
		2	Pulse specified rate too big		
		3	Pulse burst count too big		
		4	Duty factor too big		

18.2.10 0x2D: Get all pulse generator parameters

Command Byte	**0x2D**		**RS232 Version:**	GW, GR, GL, GF
Actions:	Gets all the pulse generator parameters for the specified waveform.			

	Arg	Type	Valid values	Meaning
Send Arguments	1	Uint 16	0-63, 32768	0-63: waveform 32768: currently-selected waveform
Receive Arguments	1	UInt 16	0, 1	Response word
	2	Uint 16	0 - 63	Pulse waveform
	3	Uint 32	0 - 1000000	PRF_0
	4	Uint 32	0 - 1000000	Pulse rate
	5	Uint 32	0 - 1000000	Pulse burst length
	6	Uint 16	0-1000	Pump duty factor

	Byte	Value	Meaning
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)
	2	0x??	Arg 1: data byte 2 (LSB)
Received data bytes	1	0x00	None
	2	0x00	Pulse parameters read correctly
		0x01	Pulse waveform number not supported
	3	0x00	Arg 1: data byte 1 (MSB)
	4	0x??	Arg 1: data byte 2 (LSB)
	5	0x00	Arg 2: data byte 1 (MSB)
	6	0x0?	Arg 2: data byte 2
	7	0x??	Arg 2: data byte 3
	8	0x??	Arg 2: data byte 4 (LSB)
	19	0x00	Arg 3: data byte 1 (MSB)
	10	0x0?	Arg 3: data byte 2
	11	0x??	Arg 3: data byte 3
	12	0x??	Arg 3: data byte 4 (LSB)
	13	0x00	Arg 4: data byte 1 (MSB)
	14	0x0?	Arg 4: data byte 2
	15	0x??	Arg 4: data byte 3
	16	0x??	Arg 4: data byte 4 (LSB)
	17	0x00	Arg 5: data byte 1 (MSB)
	18	0x??	Arg 5: data byte 2 (LSB)

18.2.11 0x2F: Restart Pulse Generator

Command Byte	**0x2F**	**RS232 Version:**		SW SS 1
Actions:	Restarts the pulse generator with latest parameter settings.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	1	Uint 16	0-63, 32768	0-63: waveform 32768: currently-selected waveform
Receive Arguments	1	Byte	0, 1	Response byte
	Byte	**Value**	**Meaning**	
Send Data Bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 2 (LSB)	
Received data bytes	1	0x00	Pulse generator restarted correctly.	
		0x01	Pulse waveform number not supported	
		0x02	Not under software control	
		0x03	Laser not enabled	

18.3 Monitoring Command Reference

18.3.1 0x50: Query status lines and alarms

Command Byte	**0x50**		**RS232 Version:**	QD, QA
Actions:	Queries the Laser status lines and any active alarms.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 16		Bits indicating status lines • Bit 11: Task active (1) or task inactive (0) • Bit 10: CW mode (1) or pulse mode (0) • Bit 9: Pilot Laser is on • Bit 8: Laser is enabled • Bit 7: Laser is on - • Bit 6: Laser emission - Driver PSU • Bit 5: Laser disabled - Class 1, 2 or 3 latched alarm. • Bit 4: System fault - Class 1 latched alarm • Bit 3: Beam Delivery - BDO Temperature • Bit 2: Laser body temperature • Bit 1: Alarm - Class 1 or 2 latched alarm • Bit 0: Monitor - Temperature Monitor (both Laser body and BDO) or class 3 alarm
	2 - n	Uint 16	0 - 255	Active alarm codes - see section 7.3 for code definitions Number of bytes returned depends on number of active alarms.
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x0?	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 1 (LSB)	
	3	0x??	Arg 2: data byte 2 (MSB)	
	4	0x??	Arg 2: data byte 2 (LSB)	
	n-1	0x??	Arg n: data byte n (MSB)	
	n	0x??	Arg n: data byte n (LSB)	

18.3.2 0x51: Query Laser temperatures

Command Byte	**0x51**		**RS232 Version:**	QT, QU
Actions:	Queries the Laser and beam delivery optic temperatures.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 16	25300 - 35800	Laser temperature (K/100) (-20 to +85C)
	2	Uint 16	25300 - 35800	Beam delivery temperature (K/100) (-20 to +85C)
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 2 (LSB)	
	3	0x00	Arg 2: data byte 1 (MSB)	
	4	0x??	Arg 2: data byte 2 (LSB)	

18.3.3 0x52: Query Laser currents

Command Byte	**0x52**		**RS232 Version:**	QI
Actions:	Queries the pre-amplifier and power amplifier diode currents.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	UInt 16	0 - 15000	Pre-amplifier diode current (mA)
	2	UInt 16	0 - 15000	Power-amplifier diode current (mA)
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x00	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 2 (LSB)	
	3	0x00	Arg 2: data byte 1 (MSB)	
	4	0x??	Arg 2: data byte 2 (LSB)	

18.3.4 0x53: Query power supply voltages

Command Byte	**0x53**		**RS232 Version:**	
Actions:	Queries the Laser input voltages.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 16	0 – 65535	Logic power supply 0 = 0V, 24000 = 24V
	2	Uint 16	0 – 65535	Diode power supply 0 = 0V, 24000 = 24V
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x??	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 2 (LSB)	
	3	0x??	Arg 2: data byte 1 (MSB)	
	4	0x??	Arg 2: data byte 2 (LSB)	

18.3.5 0x54: Query hardware interface

Command Byte	**0x54**	**RS232 Version:**		
Actions:	Queries the state of the hardware interface.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 16	0 – 511	**Digital output signals** Bits 9-15: reserved Bit 8: Task_Active (active high) Bit 7: Laser_Is_On (active high) Bit 6: Laser_Emission_Warning (active high) Bit 5: Laser_Deactivated (active low) Bit 4: system alarm (active low) Bit 3: Beam_Delivery (active low) Bit 2: Laser_Temperature (active low) Bit 1: alarm (active low) Bit 0: monitor (active low)
	2	Uint 16	0 – 8191	**Digital input signals** Bits 13-15: reserved Bit 12: Laser_Emission_Gate Bit 11: Laser_Disable Bit 10: Laser_Pulse_CW Bit 9: Pilot_Laser_Enable Bit 8: Laser_Enable Bit 7: D7 … Bit 0: D0 Waveform selection
	3	Uint 16	0 – 10000	Active Analogue input 1 (mV)
	4	Uint 16	0 – 10000	Simmer Analogue input 2 (mV)

	Byte	**Value**	**Meaning**
Received data bytes	1	0x0?	Arg 1: data byte 1 (MSB)
	2	0x??	Arg 1: data byte 2 (LSB)
	3	0x??	Arg 2: data byte 1 (MSB)
	4	0x??	Arg 2: data byte 2 (LSB)
	5	0x??	Arg 3: data byte 1 (MSB)
	6	0x??	Arg 3: data byte 2 (LSB)
	7	0x??	Arg 4: data byte 1 (MSB)
	8	0x??	Arg 4: data byte 2 (LSB)

18.3.6 0x55: Query operating hours

Command Byte	**0x55**	**RS232 Version:**	QH
Actions:	Queries the Laser’s operating hours (24V logic supply connected time).		

	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 32	0 – nnnnnn	Operating hours

	Byte	**Value**	**Meaning**
Received data bytes	1	0x??	Arg 1: data byte 1 (MSB)
	2	0x??	Arg 1: data byte 2
	3	0x??	Arg 1: data byte 3
	4	0x??	Arg 1: data byte 4 (LSB)

18.4 Diagnostics Command Reference

18.4.1 0x60: Set Laser into diagnosis state

Command Byte	**0x60**		**RS232 Version:**	

Actions:	Sets the Laser into a default state by calling the following sequence:
	• Set Laser control mode: 0
	• Set pulsed/cw: Pulsed
	• Set Pilot Laser: off
	• Set Waveform: 0
	  o Set Pulse rate: PRF_0 of waveform 0
	  o Set Pulse burst length: 0
	  o Set Pump duty factor: 500
	• Set Simmer current (SH): 0
	• Set Active current (SI): 1000
	• Set ‘Laser Is On’ = 0			

	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Byte	0, 1	Response byte
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x00	Default state set correctly.	
		0x01	Default state not set	
		0x02	Internal error	

18.4.2 0x62: Get Laser serial number

Command Byte	**0x62**		**RS232 Version:**	
Actions:	Gets the Laser’s serial number.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 32	0 – nnnnnnn	Laser serial number
	Byte	**Value**	**Meaning**	
Received data bytes	1	0x??	Arg 1: data byte 1 (MSB)	
	2	0x??	Arg 1: data byte 2	
	3	0x??	Arg 1: data byte 3	
	4	0x??	Arg 1: data byte 4 (LSB)	

18.4.3 0x63: Get Laser part number

Command Byte	**0x63**		**RS232 Version:**		
Actions:	Gets the Laser's part number – SP-XXXP-X-XX-X-X-X(XX)				
	Arg	**Type**	**Valid values**	**Meaning**	
Send Arguments	none				
Receive Arguments	1	Char	A-Z, 0-9, -, ()	Laser part number string (max 32 char's)	

	Byte	**Value**	**Meaning**
Received data bytes	1	0x??	Char 1 = S
	2	0x??	Char 2 = P
	3	0x??	Char 3 = -
	4	0x??	Char 4 = 0
	5	0x??	Char 5 = 1, 2, 3, 4
	6	0x??	Char 6 = 0, 2, 5
	7	0x??	Char 7 = P
	8	0x??	Char 8 = -
	9	0x??	Char 9 = A, W
	10	0x??	Char 10 = -
	11	0x??	Char 11 = H, R
	12	0x??	Char 12 = S, M
	13	0x??	Char 13 = -
	14	0x??	Char 14 = L. S, H
	15	0x??	Char 15 = -
	16	0x??	Char 16 = A, B, C
	17	0x??	Char 17 = -
	18	0x??	Char 18 = Y, N
	19	0x??	Char 19 = (
	20	0x??	Char 20 = 0 - 9
	21	0x??	Char 21 = 0 - 9
	22	0x??	Char 22 =)
	23 - 32	0x00	Char 23 - 32

18.4.4 0x64: Get Laser firmware details

Command Byte	**0x64**	**RS232 Version:**		
Actions:	Gets the Laser's version details.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	UInt 16		FPGA Hardware Revision
	2	UInt 16		FPGA Hardware Release
	3	UInt 16		FPGA Firmware Revision
	4	UInt 16		FPGA Firmware Release
	5	UInit 32		Stellaris Firmware Version
	6	UInt 16		Driver Firmware
	Byte	**Value**	**Meaning**	
Received data bytes	**Byte**	**Value**	**Meaning**	
	1	0x??	Arg 1: FPGA Hardware Rev Major	
	2	0x??	Arg 1: FPGA Hardware Rev Minor	
	3	0x??	Arg 2: FPGA Hardware Release	
	4	0x??	Arg 2: 0x00	
	5	0x??	Arg 3: FPGA Firmware Rev Major	
	6	0x??	Arg 3: FPGA Firmware Rev Minor	
	7	0x??	Arg 4: FPGA Firmware Release	
	8	0x??	Arg 4: 0x00	
	9	0x??	Arg 5: Stellaris Firmware Version Major	
	10	0x??	Arg 5: Stellaris Firmware Version Mid 1	
	11	0x??	Arg 5: Stellaris Firmware Version Mid 2	
	12	0x??	Arg 5: Stellaris Firmware Version Minor	
	13	0x??	Arg 6: Driver Firmware MSB	
	14	0x??	Arg 6: Driver Firmware LSB	
	15 - 20	0x00	Reserved	
	22	0x??	Char 22 =)	
	23 - 32	0x00	Char 23 - 32	

18.4.5 0x65: Get Laser description

Command Byte	**0x65**		**RS232 Version:**	
Actions:	Gets a description of the installed features of the Laser.			
	Arg	**Type**	**Valid values**	**Meaning**
Send Arguments	none			
Receive Arguments	1	Uint 16	0 - 500	Rated power level (W)
	2	Uint 16	0 - 1000	Maximum pulse rate (kHz)
	3	Uint 16	0 - 1250	Rated energy (uJ)
	4	Uint 32	0 - 65535	Bits relating to installed features Bits 16-31: reserved Bits 8-15: number of waveforms Bits 4 – 7: reserved Bit 3: water-cooling Bit 2: air-cooling Bit 1: pilot Laser Bit 0: CW mode

	Byte	**Value**	**Meaning**
Received Data Bytes	1	0x0?	Arg 1: data byte 1 (MSB)
	2	0x??	Arg 1: data byte 2 (LSB)
	3	0x0?	Arg 2: data byte 1 (MSB)
	4	0x??	Arg 2: data byte 2 (LSB)
	5	0x0?	Arg 3: data byte 1 (MSB)
	6	0x??	Arg 3: data byte 2 (LSB)
	7	0x00	Arg 4: data byte 1 (MSB)
	8	0x00	Arg 4: data byte 2
	9	0x??	Arg 4: data byte 3
	10	0x0?	Arg 4: data byte 4 (LSB)

18.5 Ethernet Error Codes

Each command has its own error response defined in the sections above.

19 Technical Support & Customer Service

19.1 Warranty Information

SPI Lasers UK Ltd. (hereinafter referred to as SPI) 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 use.**

19.2 Product Support

In the unlikely event that the Compact Laser Module does not function normally and that it requires attention, contact SPI for advice on further on-site fault diagnosis and/or module return.

If the module 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 module 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 module. If part or all of the original packaging is unavailable, please contact SPI Lasers 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 module repair at SPI.

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

19.2.1 SPI Product Support and Customer Service Contacts

Product Support
productsupport@spiLasers.com
Tel: +44 (0)1489 779696 - Option 2

Customer Services
customersupport@spiLasers.com
Tel: +44 (0)1489 779696 - Option 5

Company Web Site
www.spiLasers.com

Or contact your local distributor.

19.2.2 SPI Sales and Customer Service Contacts

US Corporate Office
SPI Lasers LLC
4000 Burton Drive, Santa Clara,
CA 95054, USA
Tel: +1(408) 454-1169
Fax: +1(408) 454-1161

UK Head Office
SPI Lasers UK Limited
6 Wellington Park, Tollbar Way, Hedge End,
Southampton, SO30 2QU, UK
Tel: +44 (0)1489 779696
Fax: +44 (0)1489 779698

19.2.3 SPI Distributors

Please refer to website in case of updates:
http://www.spiLasers.com/Sales_and_Customer_Services/Distributors.aspx