L A S E R
TruPulse nano

TRUMPF

Pulsed Fiber Laser

Control and Interface Manual

Firmware V8

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 TRUMPF Laser UK Limited.

PRODUCT The definition of “Product” as used herein means the item that was procured from TRUMPF Laser 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 TRUMPF Laser UK Limited, 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.

Virtual patent marking

TruPulse nano lasers are protected by patents and patent applications including those listed in the virtual patent marking notice, which can be found at **www.trumpf.com/s/patents**. This website address can also be found on the following label, which is applied to all TruPulse nano laser products.

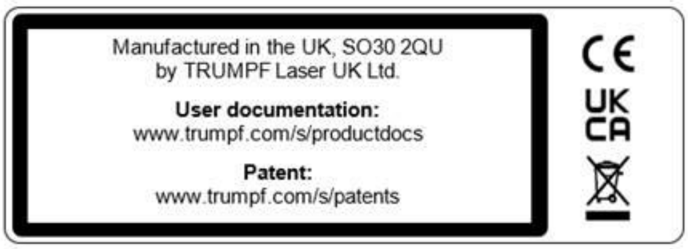


Table of Contents

1 Introduction

1.1 How it Works

1.1.1 TruPulse nano System Overview

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

The GTWave™ 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 is 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.

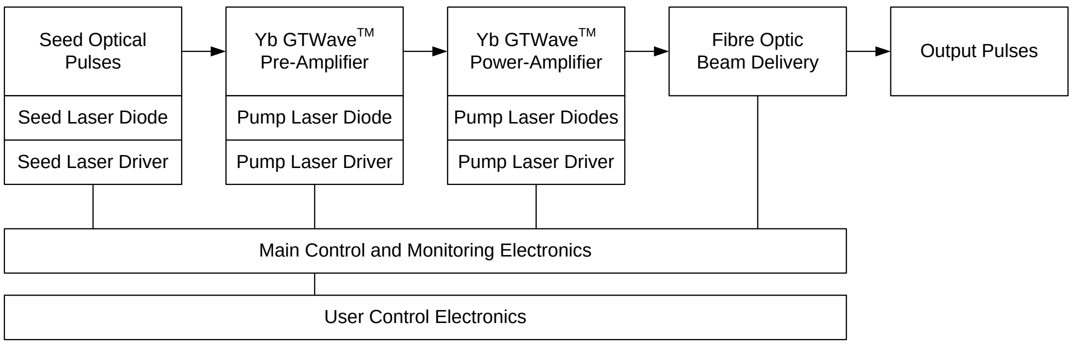


Figure 1. TruPulse nano Laser Module Functional Block Diagram

1.1.2 Power Control

TruPulse nano Lasers allow the user to control the Laser's average power by controlling the active current of the power amplifier pump diodes. The active state current set-point defines the level at which the power-amplifier Laser diodes operate when the Laser is the ACTIVE state.

This setting provides approximately linear control of Laser's average power in both pulsed and CW modes of operation.

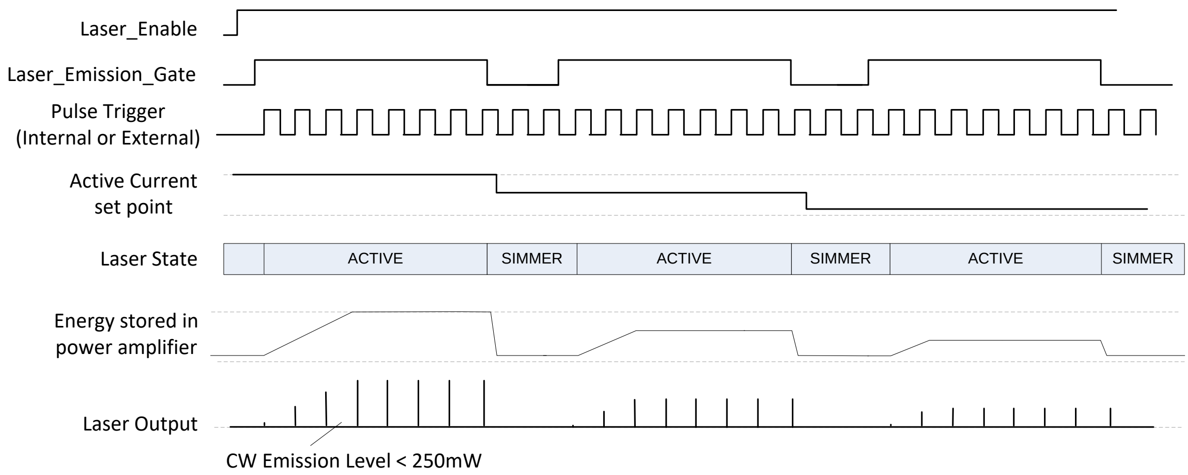


Figure 2. Effect of Active Current on Optical Output

1.1.3 Waveforms

TruPulse nano Laser modules incorporate pre-programmed waveforms. A waveform defines:

- an electrical impulse to the seed Laser diode
- a maximum pulse repetition frequency at which the waveform can be triggered (PRF_{max})
- a default 'switching frequency', PRF_0, selected to give maximum peak power

Refer to the Product Safety and Integration Manual for details of the waveforms programmed in a certain laser type.

1.1.3.1 Pulse Repetition Frequency (PRF) Range

The TruPulse nano 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 approximately linearly as the frequency decreases below PRF_0. This allows effective pulsing from 1 kHz to PRF_{max} for all waveforms.

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 the PRF increases the energy available for each pulse decreases as $E_{max} \times \frac{PRF_0}{PRF}$.

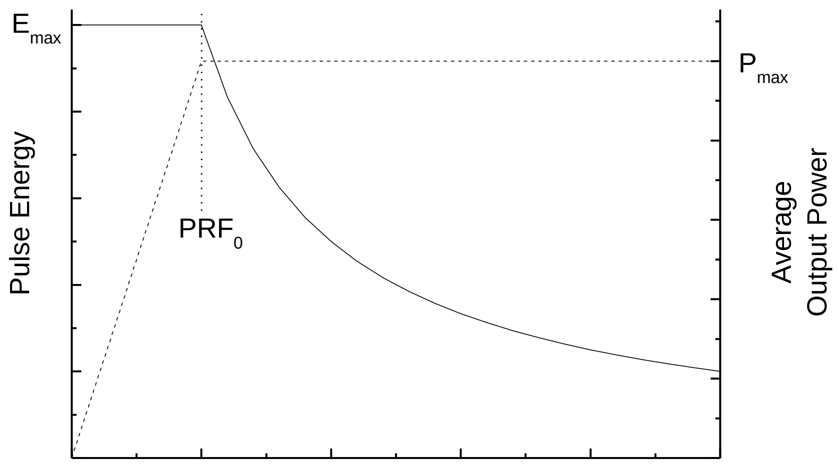


Figure 3. Average Power and Pulse Energy vs Pulse Repetition Frequency

1.1.4 First Pulse Equalisation

With a pulsed fibre MOPA it is necessary to ‘pre-charge’ the fibre power-amplifier with energy in order to avoid a slow ramp-up of pulse energies at the beginning of a pulse burst. This is referred to as ‘first-pulse equalisation’. The TruPulse nano lasers operating v8 firmware offer laser control modes with two methods of first-pulse equalisation:

- Simmer pumping
- Just-in-time pumping

First-Pulse Equalisation method	**Description**	**Firmware version**	**laser control modes**	**Reference Section**
Simmer pumping	A low-level current is supplied to the pump laser diodes when the laser is enabled and the pumps are not fully operational (i.e. before pulses, and in between pulses as low pulse rates). This ensures that the amplifiers are ‘charged’ for subsequent pulse trains. The level of simmer current is controlled by the analogue input **AI_2**, or by serial commands according to the laser mode selected.	>6.0.0	0,1, 4, 5	1.7
Just-in-time pumping	This approach aims to achieve the required stored energy in the power amplifier just before a pulse is triggered, thereby minimising CW leakage. A ‘start’ pulse is required on the **First_Pulse_Equalisation** signal after **Laser_Emission_Gate** goes high. This quickly ‘charges’ amplifiers to the required level. The laser makes calculation of the current level and duration required for just-in-time pumping to achieve first-pulse equalisation. User-control of the **First_Pulse_Equalisation** signal duration can achieve a softer turn-on characteristic if required.	>8.0.0	2, 3, 6, 7	1.8

1.2 Signal Names

1.2.1 Tables of Signal Names

1.2.1.1 Laser Control Signals

Signal name	Description	Type	RS232	E'Net
Laser_Enable	Attempts to enable the laser. Resets any latched fault condition where the fault is no longer active; re-enables the internal power supplies and enables the Laser diode drivers.	dig_in	SS 0 SC 0	0x1A
Laser_Pulse_CW	switches the laser between pulsed and CW output	dig_in	SS 3 SC 3	
Pilot_Laser_enable	enables the factory-fitted optional pilot laser and interrupts IR output	dig_in	SS 8 SC 8	
Laser_Disable	stops any laser emission and disables internal power supplies	dig_in	none	none

1.2.1.2 Real-time Control Signals

Signal name	Description	Type	RS232	E'Net
Laser_Emission_Gate	allows or prevents emission of pulses (in pulsed mode) or CW emission (in CW mode)	dig_in	none	none
Pulse_Trigger	rising edge triggers pulse generation in control modes where the internal pulse generator is not used (serial command equivalent starts internal pulse generator)	dig_in	SS 1	0x2F
First_Pulse_Equalisation	specifies the duration of start-of-vector pumping for first-pulse equalisation in control modes employing just-in-time pumping	dig_in	none	none
AI_1	Active state current: specifies the power-amplifier pump laser diode current	Analog in	SI	0x1C
AI_2	Simmer current: specifies the power-amplifier pump laser diode current to control first-pulse characteristics in control modes employing simmer current	Analog in	SH	
PRF_Sync_Out	reference output for the internal pulse generator, and the synchronisation of an external pulse trigger request against the system clock	dig_out	none	none
Laser_Ready_To_Pulse	indicates that the laser is ready to respond to a pulse trigger request	dig_out	none	none
Task_Active	indicates that a task (such as a pulse burst) has been started and is currently active	dig_out	none	none
Laser_Has_pulsed	indicates that a pulse has been generated within the laser	dig_out	none	none

1.2.1.3 Parallel Interface Signals

Signal name	Description	Type	RS232	E'Net
DI_0 – DI7	selects pulse waveform	dig_in	SW GW	0x20

1.2.1.4 Monitoring Signals

Signal name	Description	Type	RS232	E'Net
Monitor	indicates that: 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	dig_out	`GS` `QS`	`0x51`
Alarm	indicates that an alarm condition is present	dig_out		
Laser_Temperature	specifies that a monitor or alarm condition is associated with the temperature of the laser chassis	dig_out		
Beam_Delivery	specifies that a monitor or alarm condition is associated with the beam delivery cable or ILLK	dig_out		
System_Fault	specifies that a monitor or alarm condition is associated with a fault in the system that may require service	dig_out		
Laser_Deactivated	indicates that the laser has been disabled using the **Laser_Disable** control	dig_out		
Laser_Emission_Warning	indicates that the internal laser power supplies are energised sufficiently that laser emission may occur	dig_out		
Laser_Is_On	indicates that the pump laser diodes are operational	dig_out		

1.2.2 Reference Sections for Signals

signal type	section	page
hardware signals	2.5	39
RS-232 command	3	55
Ethernet command	4	68

1.3 Laser States

1.3.1 Laser State Definition

Laser State	Description
DISABLED	A fault or interlock event has occurred and the internal power supplies have been disabled
LASER_OFF	No 24V diode supply is connected
POWER_UP	Internal diode supplies are powering up
STANDBY	Internal power supplies are on but the Laser is not enabled
SIMMER	The Laser is emitting IR power depending on the simmer current set point
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

1.3.2 Laser State Table

	DISABLED	**LASER_OFF**	**POWER_UP**	**STANDBY**	**SIMMER**	**ACTIVE**	**PILOT_IRQ**
Signals							
External 24V diode supplies	Don't care	0V	**24V**	**24V**	**24V**	**24V**	**24V**
Laser_Emission_Warning	L	L	L	**H**	**H**	**H**	**H**
Laser_Is_On	L	L	L	L	**H**	**H**	L
Laser_Deactivated (active low)	**L**	H	H	H	H	H	H
Functionality							
Logic internal power supplies	ON	ON	ON	ON	ON	ON	ON
Diode internal power supply	OFF	OFF	Turning on	ON	ON	ON	ON
Switching between control interface modes allowed	NO	YES	YES	YES	NO	NO	NO
Pump laser diodes	OFF	OFF	OFF	OFF	ON	ON	OFF
Pilot Laser	(1)	(1)	(1)	(1)	OFF	OFF	ON
IR Laser emission	NO	NO	NO	NO	YES (leakage level)	YES (active level)	NO

(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.

1.3.3 Laser State Diagram– Laser modes 0, 1, 4, 5

This section details the Laser states when using laser modes 0, 1, 4, 5 which employ simmer current for first-pulse equalisation. Please refer to section 1.3.4 if using laser modes 2, 3, 6, 7.

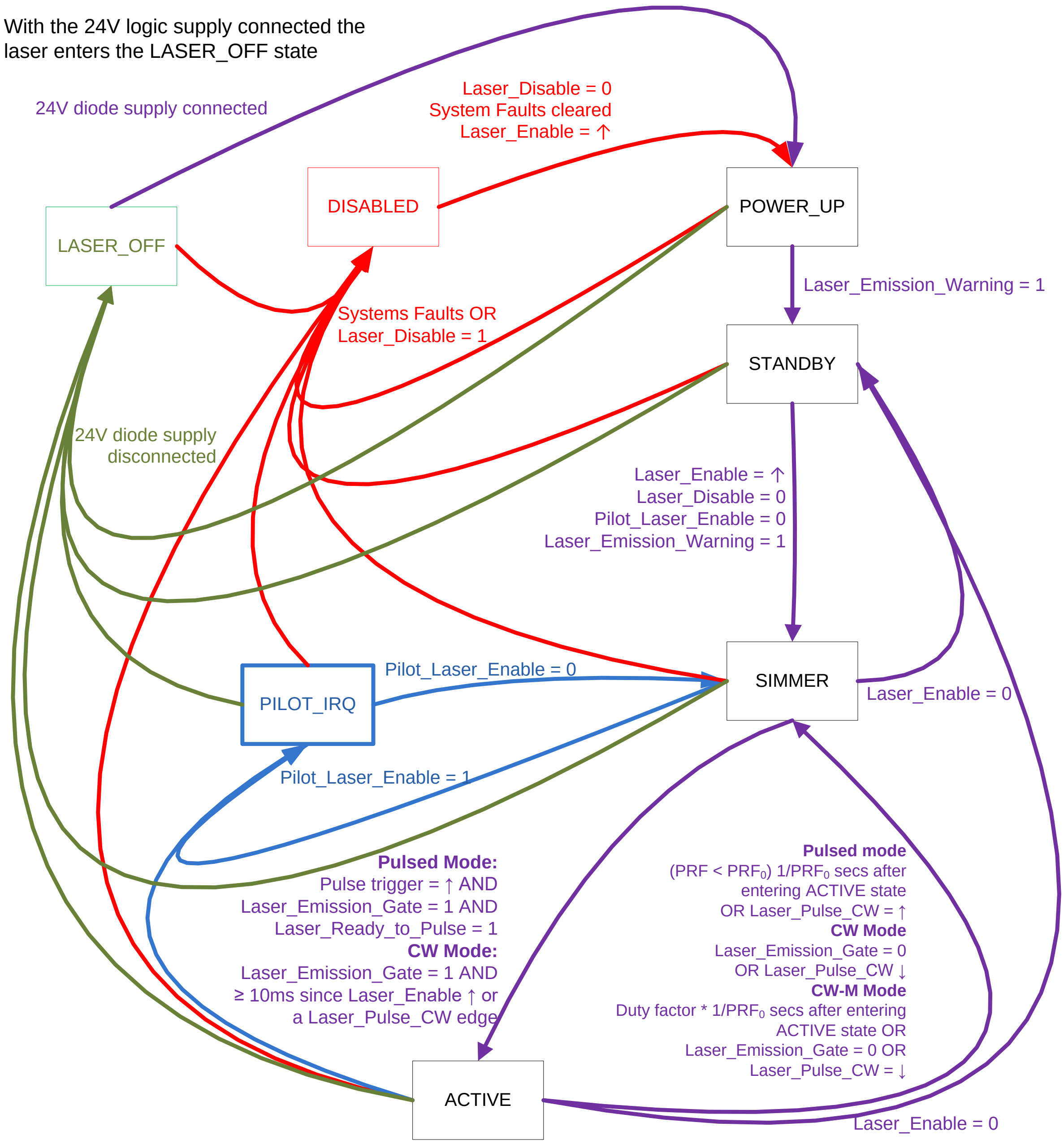


Figure 4. TruPulse nano Laser State Diagram – Standard Simmer and Pumping Scheme

1.3.4 Laser State Diagram – Laser modes 2, 3, 6, 7

This section details the laser states when using laser control modes 2, 3, 6 or 7 which employ just-in-time pumping for first-pulse equalisation. CW and CW-M operation is the same as for standard pumping scheme.

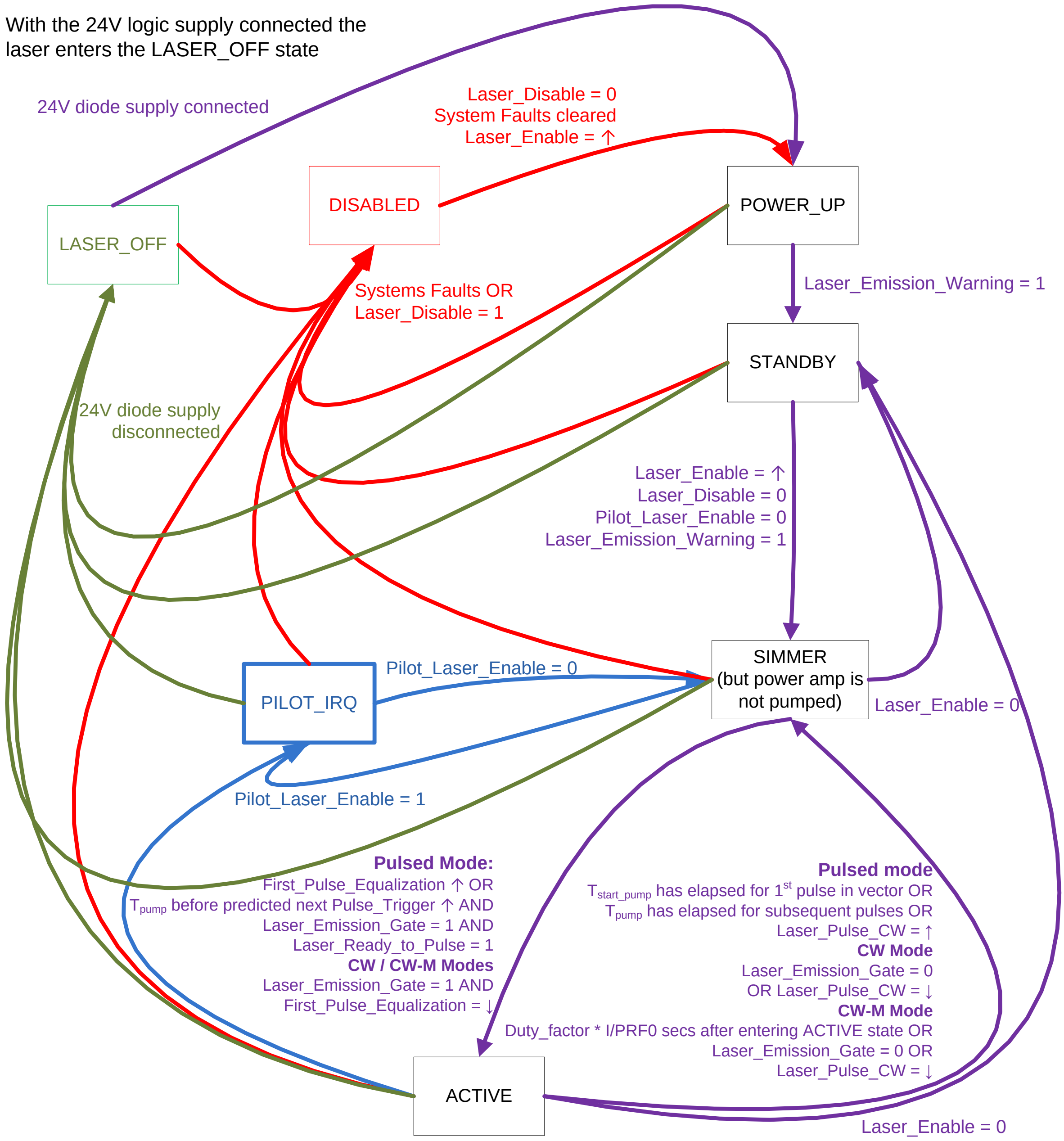


Figure 5. Laser State Diagram –Alternative Simmer and Pumping Scheme

1.4 Control Modes

1.4.1 Laser Control Modes

The TruPulse nano lasers offer eight control modes to suit a wide range of integration equipment and processes. The table below indicates whether various controls are set with serial commands or hardware lines in the eight laser control modes.

<table>
<tr><th rowspan="2">Control</th><th colspan="8">Laser Control Mode</th></tr>
<tr><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5
(default)</th><th>6</th><th>7</th></tr>
<tr><td>General Laser Control</td><td colspan="4">Serial cmd</td><td colspan="3">Laser_Enable
Laser_Pulse_CW
Pilot_Laser_Enable</td><td>Serial cmd</td></tr>
<tr><td>Pulse Triggering (1)</td><td colspan="3">Internal pulse gen.</td><td colspan="5">Pulse_Trigger</td></tr>
<tr><td>Active State Current Control (2)</td><td>Serial cmd</td><td>AI_1</td><td colspan="2">Serial cmd</td><td colspan="3">AI_1</td><td>Serial cmd</td></tr>
<tr><td>First-Pulse Equalisation Method (3)</td><td colspan="2">simmer</td><td colspan="2">just-in-time pumping</td><td colspan="2">simmer</td><td colspan="2">just-in-time pumping</td></tr>
<tr><td>First-pulse Equalisation Control</td><td>Serial cmd</td><td>AI_2</td><td colspan="2">FPE</td><td>Serial cmd</td><td>AI_2</td><td colspan="2">FPE</td></tr>
<tr><td>Waveform selection</td><td colspan="3">Serial cmd</td><td>DI_0 – DI-5</td><td>Serial cmd</td><td colspan="2">DI_0 – DI_5</td><td>Serial cmd</td></tr>
<tr><td>Legacy SPI Lasers redENERGY G3 compatibility</td><td>yes</td><td>yes</td><td colspan="3">N/A</td><td>yes</td><td colspan="2">N/A</td></tr>
</table>

(1) Indicated by bit 9 of RS-232 status word
(2) Indicated by bit 4 of RS-232 status word
(3) Indicated by bit 7 of RS-232 status word

1.4.2 Changing Laser Control Modes

To change Interface Control Mode

- the Laser must be in the STANDBY, LASER_OFF or POWER_UP states
- the **Laser_Enable** digital input signal = LOW and ‘Laser Is On’ bit (STATUS_WORD bit 0) must be cleared
- Use the RS-232 command ‘`SM`’ (see section 3.3.2) or Ethernet Command `0x14` (see section 4.3.3) to change the Interface control mode.

Any interface control mode can be selected irrespective of the current interface control mode. The Laser must then be enabled for the new interface control mode to take effect.

Interface Control Mode 5 is the default factory setting (= G3 hardware mode which was also factory default setting).

1.4.3 Reset and power off / on effects

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

1.4.4 Accessing Legacy Control Modes with SPI Lasers redENERGY G3 Syntax

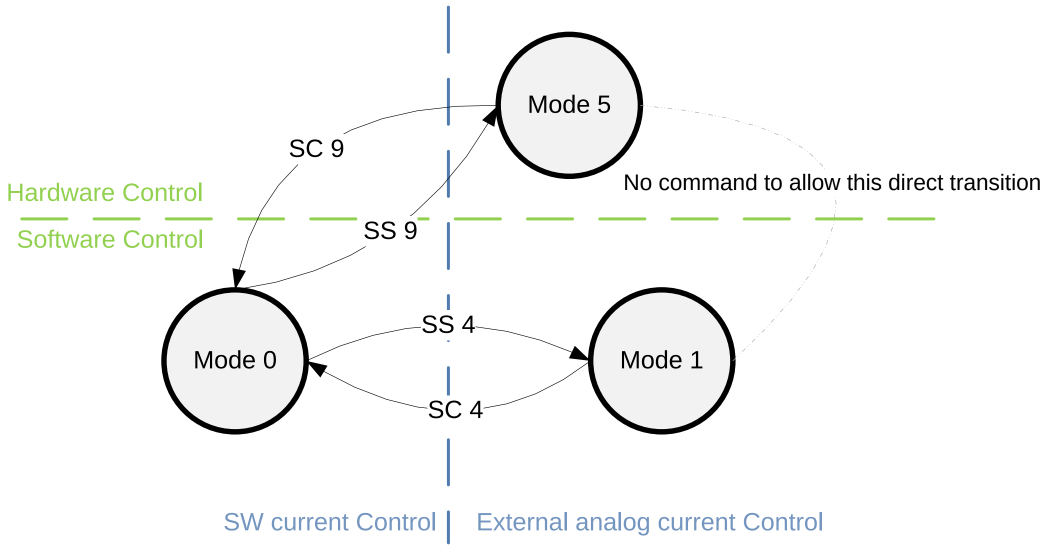


Figure 6. G3 Legacy Commands Impact on TruPulse nano Interface Control Modes

Note that an error will occur if G3 legacy commands (`SS 9`, `SC 9`, `SS 4` and `SC4`) are used when the Laser is set to one of the TruPulse nano specific interface control modes (2, 3, 4, 6 and 7) as these modes are beyond the scope of G3 legacy support.

Also note that there is no direct transition from HW mode to or from SW mode with external current control so the order of commands is important.

1.5 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.

1.5.1 24V Logic Supply

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.

1.5.2 24V Diode Supply

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 the **Laser_Emission_Warning** signal has become active, a rising edge on the **Laser_Enable** signal, or clearing, then setting, the 'Laser Is On' bit (STATUS_WORD bit 0) will put the Laser into the SIMMER state.

1.5.3 Power-Up Sequence Examples

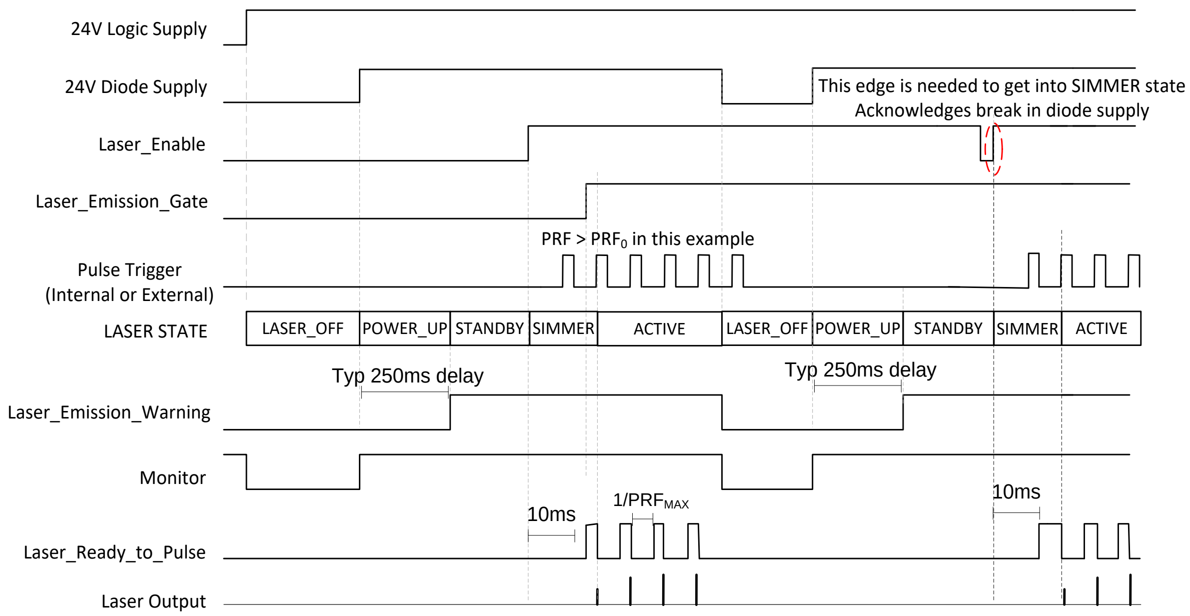


Figure 7. Power Up Sequence – Example 1

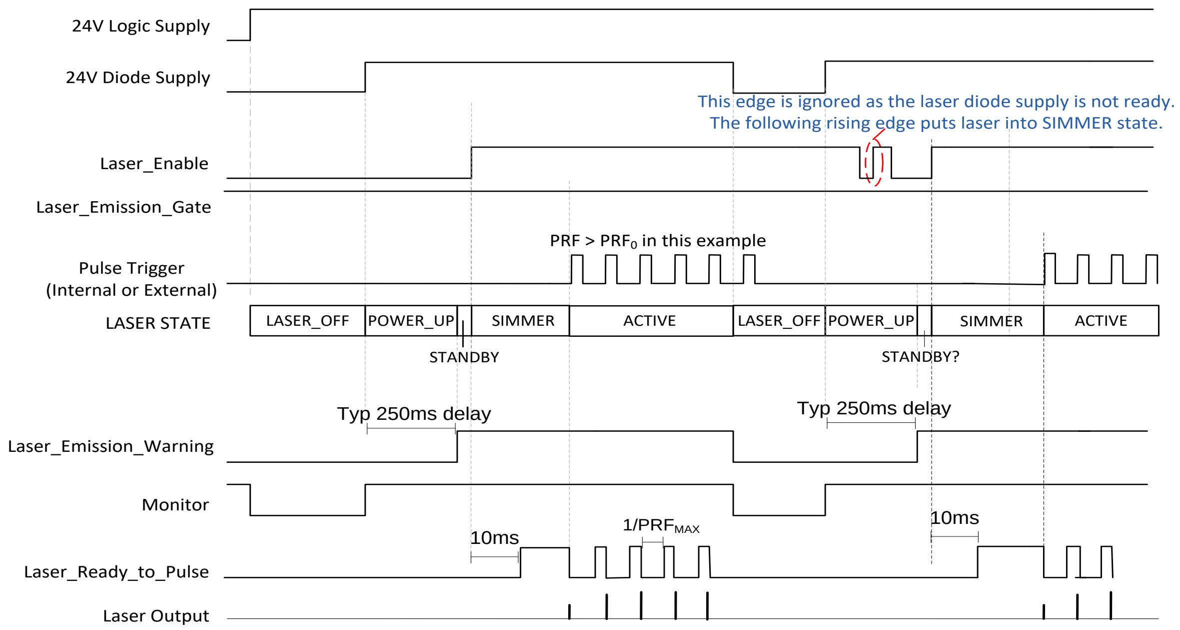


Figure 8. Power Up Sequence – Example 2

1.6 Pilot Laser Operation

The factory-fitted optional pilot laser can be enabled by:

- setting the digital input **Pilot_Laser_Enable** signal HIGH
- 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.

1.6.1 Pilot Laser Operation in Laser Modes Employing Simmer

The timing diagram below shows the Pilot Laser operation for the standard simmer and pumping scheme. If the Pilot Laser is enabled the Laser's IR output is immediately interrupted. When the Pilot Laser is disabled the Laser returns to the SIMMER state for at least 10 ms if the Laser's IR operation was interrupted. If the Laser was not in the ACTIVE or SIMMER states then it returns to the state it was in prior to enabling of the Pilot Laser.

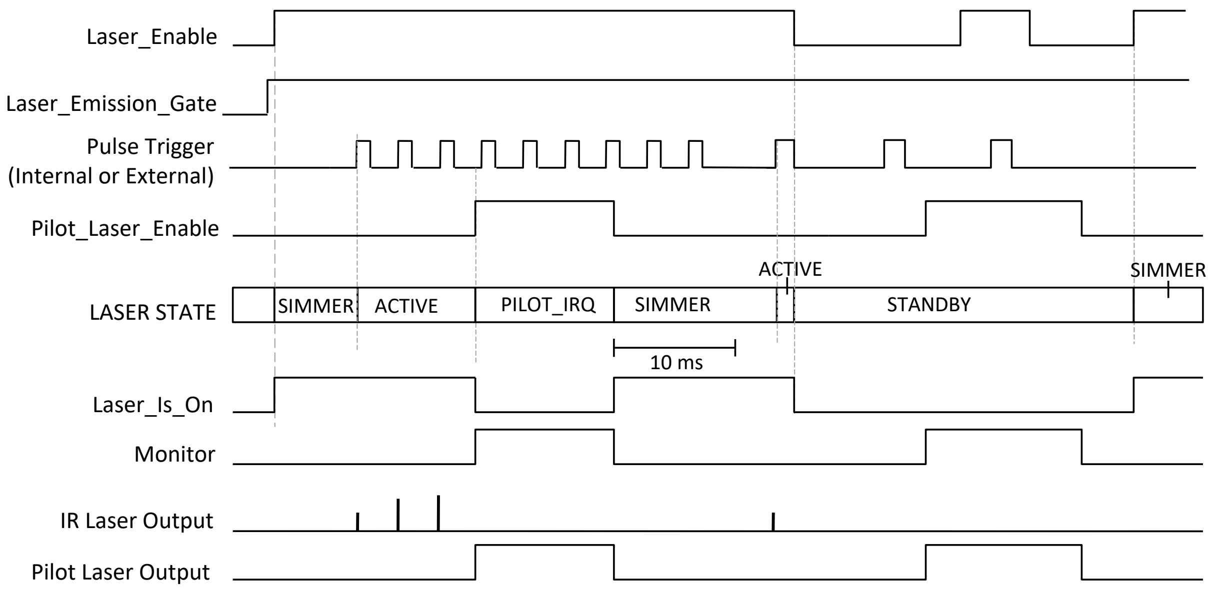


Figure 9. Visible Pilot Laser Operation – Interface Control Modes 0, 1, 4 and 5

1.6.2 Pilot Laser Operation in Laser Modes Employing Just-in-time Pumping

Behaviour with the alternative simmer and pumping scheme is similar. When the pilot laser is disabled, if the Laser's IR was interrupted, it also returns to the SIMMER state but a pulse on the **First_Pulse_Equalization** signal is required to reinitiate IR output.

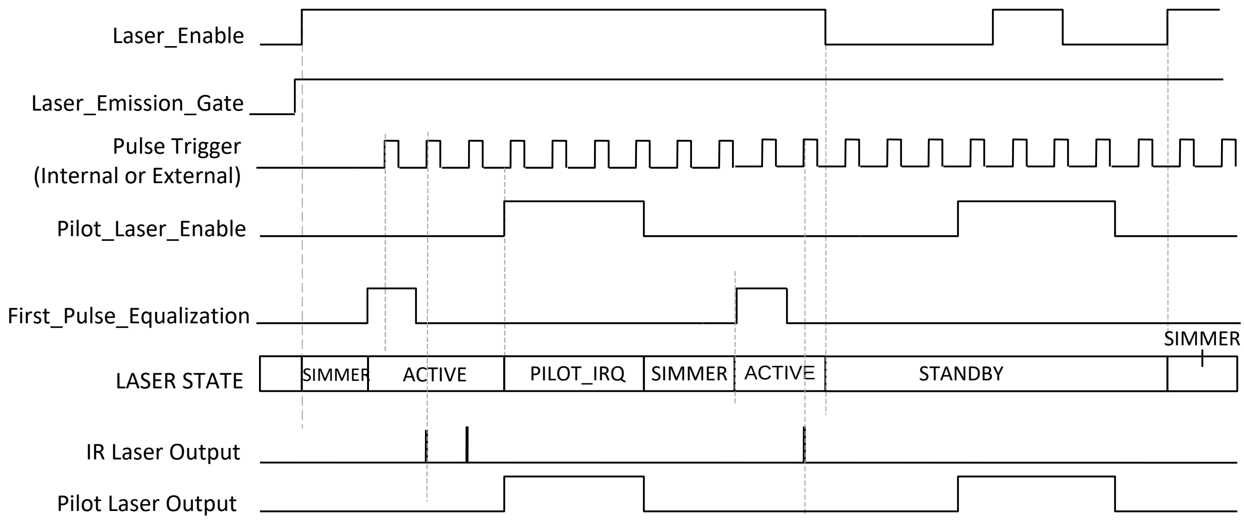


Figure 10. Visible Pilot Laser Operation – Interface Control Modes 2, 3, 6 and 7

1.6.3 Pilot Laser Operation with 24V Diode Power Supply Disabled

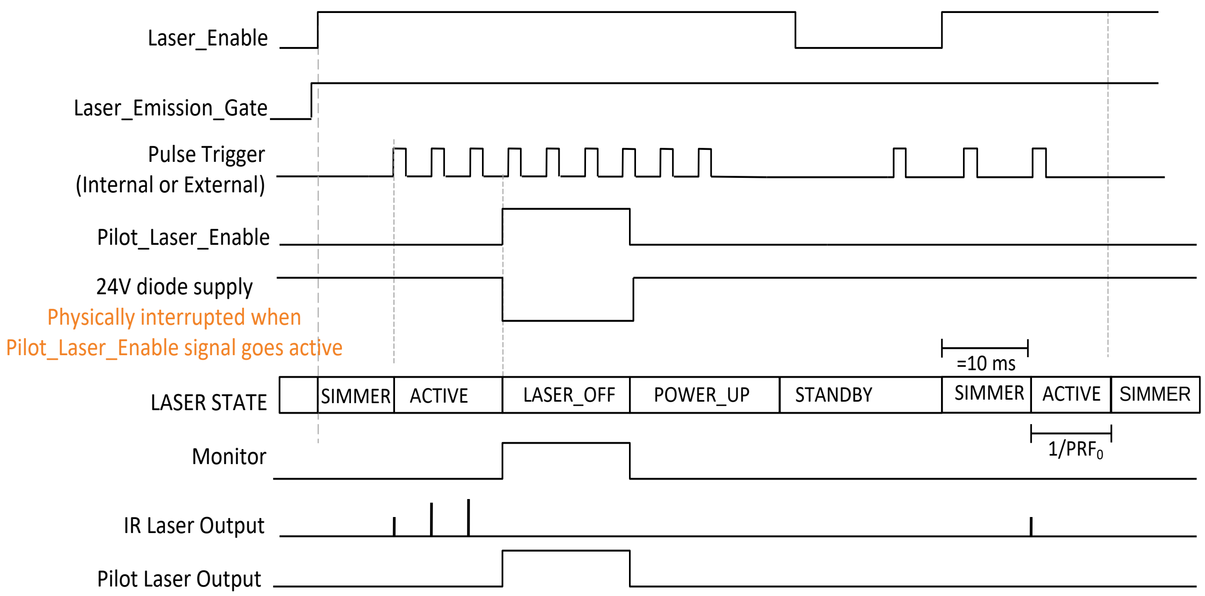


Figure 11. Visible Pilot Laser Operation – with 24V diode supply disconnected

1.7 Laser Modes using Simmer Pumping for First-Pulse Equalisation

1.7.1 Description of Laser Modes 0, 1, 4, 5

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. when **Laser_Emission_Gate** is low, or after 1/PRF0 from the last pulse). The effect of the simmer current is to 'pre-charge' the power amplifier 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, output pulse will be determined by the Active-state Current Set-Point. The simmer current set point affects the shape the rising edge of the CW mode optical output.

Operation of the Laser with high simmer current set point will result in a low-level continuous-wave emission when the laser is in SIMMER state. The level of emission is defined in the product specification. To prevent Laser emission, put the Laser into STAND-BY state (**Laser_Enable** line LOW under hardware control; '`SC 0`' under software control) . 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.

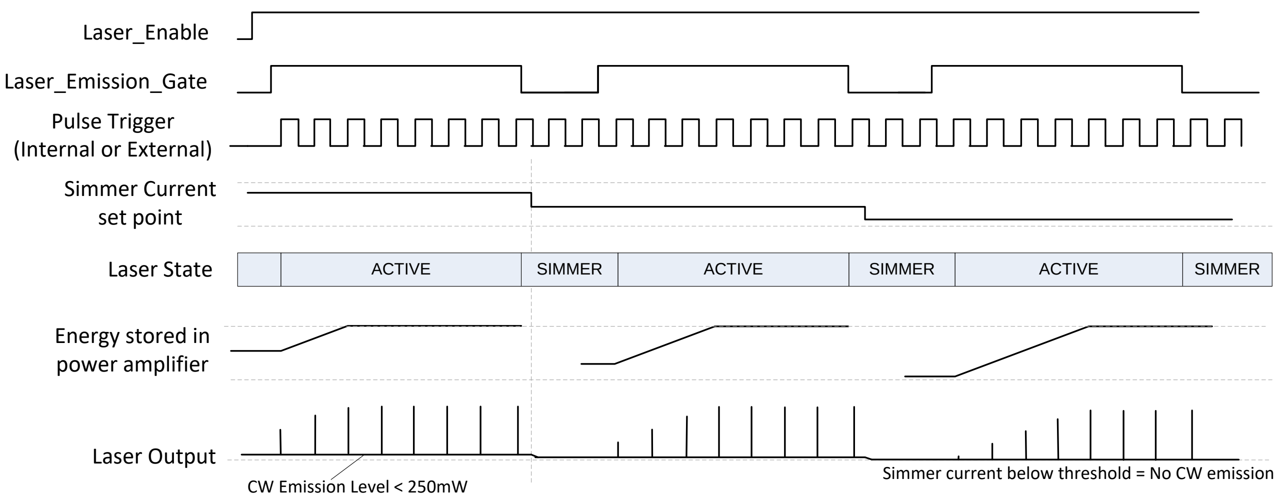


Figure 12. Effect of Simmer Current on Optical Output

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

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) the power-amplifier simmer current set point should be decreased until the desired rise-time characteristics are achieved.

1.7.2 Operation with Pulse Rates Below PRF0

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 an interval of $1/PRF_0$ for the active waveform has elapsed.

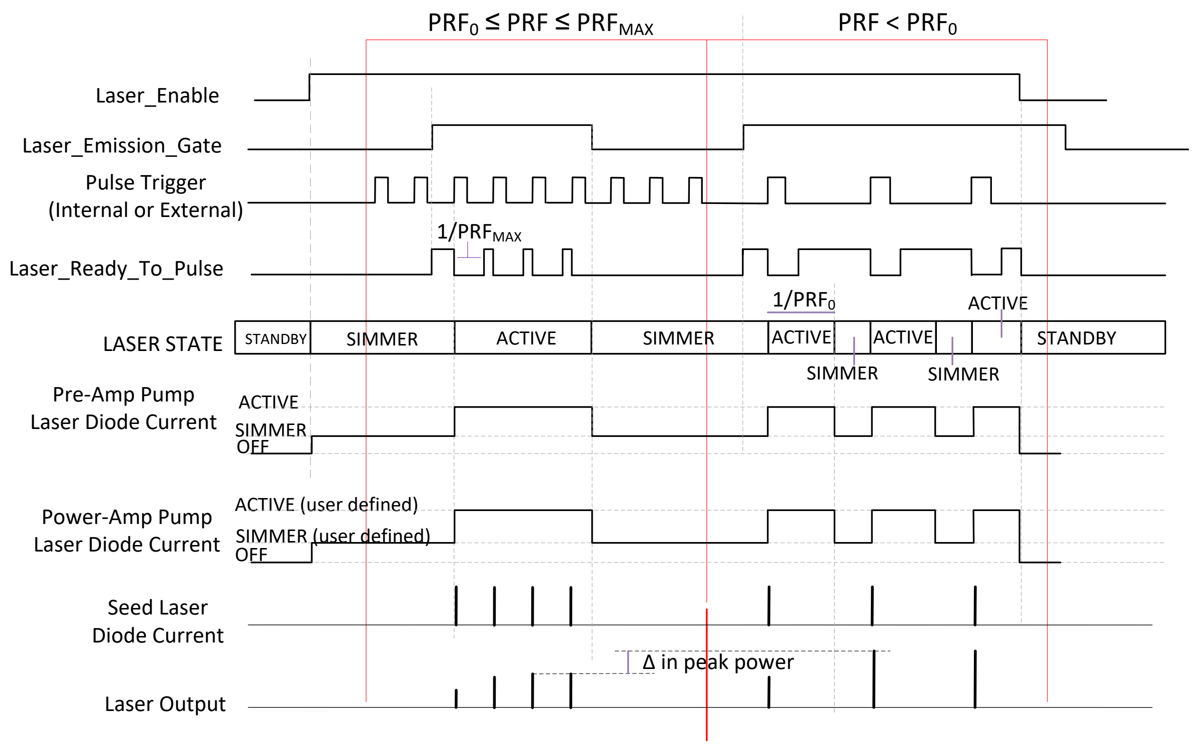


Figure 13. Timing Diagram for PRF > PRF_0 and PRF < PRF_0

1.8 Laser Modes using Just-in-time Pumping for First-Pulse Equalisation

1.8.1 Description of Laser Modes 2, 3, 6, 7

When control modes 2, 3, 6 or 7 are selected, the first-pulse equalisation of the laser is controlled by :

- the duration of the **First_Pulse_Equalization** signal for the first pulse in the vector/job
- by using the preceding measured pulse interval and the PRF_0 of the selected waveform to predict when to start pumping for the next pulse
- The active current set point.

This feature pre-charges the power amplifier in order to get a good first-pulse characteristic without the CW emission that is seen with the constant, low level simmer approach.

The time T_{start_pump} in the figure below, is the minimum duration of the following:

- The duration of the high time of the **First_Pulse_Equalization** signal. This allows the user to tune the first pulse energy
- A maximum internal limit that prevents excessive energy build-up in the power amplifier. Therefore, T_{start_pump} may be < T_{FPE}.
- An internally calculated value related to the time for which the **Laser_Emission_Gate** signal is low. This counteracts the decay in stored energy due to leakage from the power amplifier when it is not being pumped while preventing the power amplifier being over charged if this interval is relatively short.

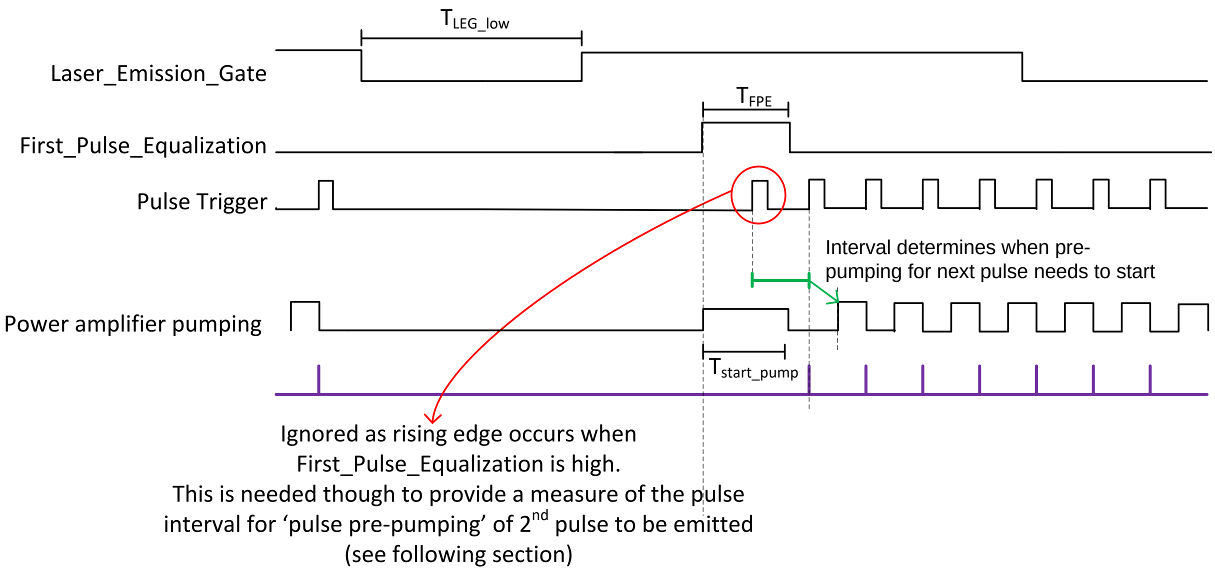


Figure 14. First pulse equalisation with Just-in-time pumping modes

1.8.2 First_Pulse_Equalisation Signal

The **First_Pulse_Equalisation** signal should be 150us, but may be reduced if a softer turn-on characteristic is required (which may be desirable for pulse rates >> PRF0).

It is envisaged that the 'First Pulse Kill' (FPK) signal available on many scan cards could be used to drive the **First_Pulse_Equalisation** signal on the TruPulse nano Laser module to provide this feature at the start of each vector. This FPK signal can typically have a user defined duration allowing the user to tune the first pulse energy. Please refer to your scan card reference manual for details of programming this 'First Pulse Kill' signal.

1.8.3 Operation with Pulse Rates Below PRF0

With the just-in-time pumping scheme, the Laser estimates when the next pulse will occur based on the interval between the previous two pulses. It then calculates when it needs to start pumping so that the power amplifier is fully 're-charged' just in time for the next predicted pulse as shown in the diagram below. This means that there is no leakage time between the power amplifier becoming fully charged and the pulse occurring. Also, immediately following a pulse (when the Laser is in the 'SIMMER' state) the power amplifier is not fully charged so the leakage output is reduced. This can have a benefit when marking sensitive materials.

These control modes will give the best results when the interval between pulse trigger rising edges is constant or varies by < 5% and the Laser is being used at low repetition rates.

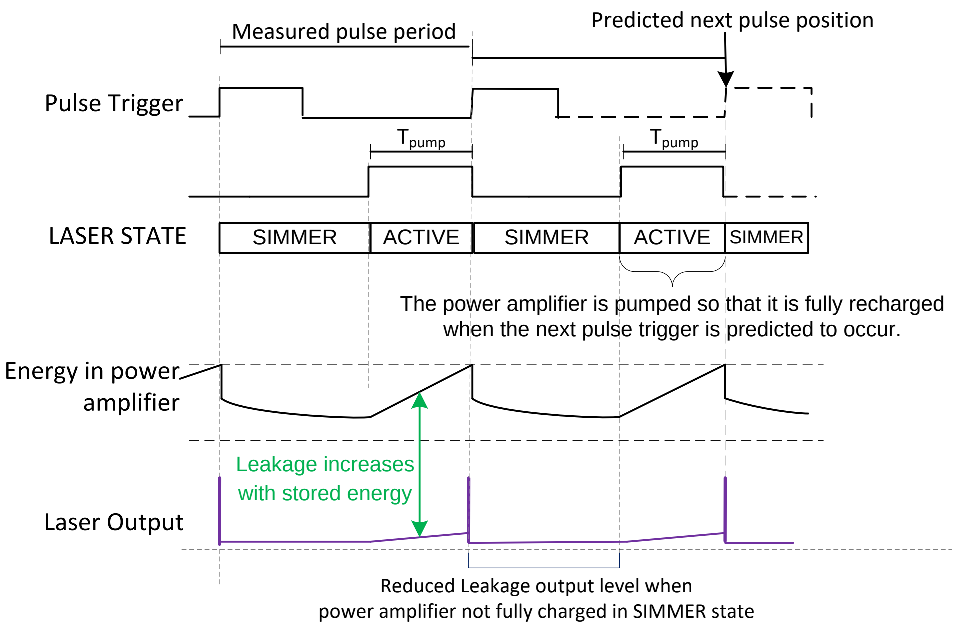


Figure 15. Pulse 'Pre-pumping' Scheme

1.9 Waveform Selection

1.9.1 On-the-fly Waveform Selection (laser modes 3, 5, 6)

The waveform selected by the **DI_7**:**DI_0** can be changed for each pulse trigger signal. However, bear in mind that the pumping for each pulse is based on the waveform selection latched by the previous external **Pulse_Trigger** rising edge.

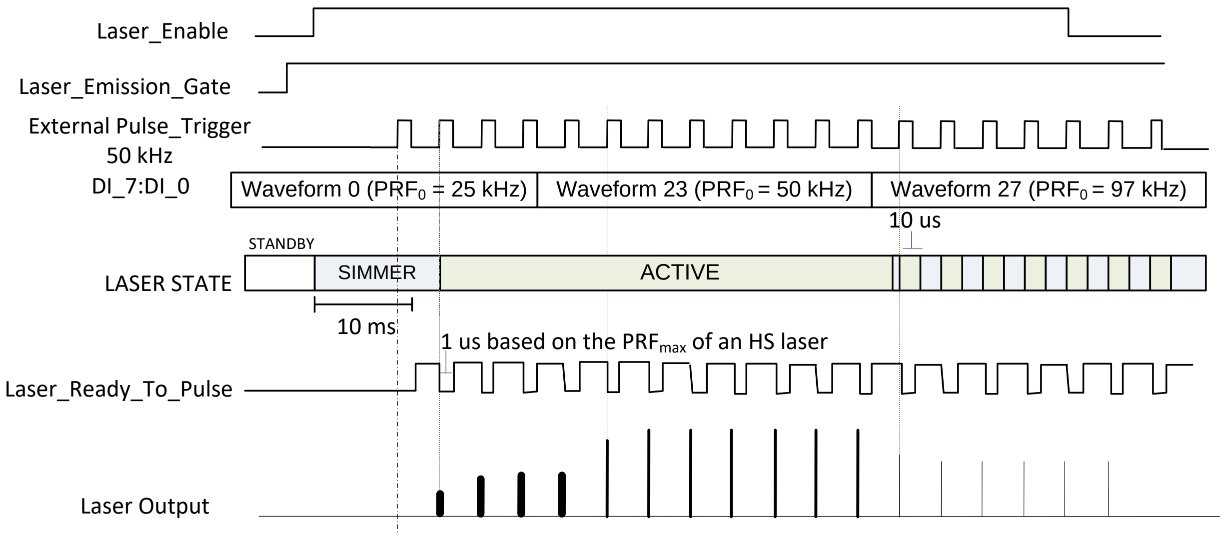


Figure 16. Example on-the-fly waveform selection

In this way pulse energy can be varied pulse by pulse by changing the waveform and hence both pulse duration and peak power.

1.9.2 Software Selection of Waveform (laser modes 0, 1, 2, 4, 7)

1.9.2.1 Internal Pulse Generator - Parameters for each Waveform

Each waveform has an associated data structure that defines the pulse waveform shape and includes the following parameters that can be set to control internal pulse:

				RS-232		Ethernet	
parameter	**Type**	**minimum**	**maximum**	**SET cmd**	**GET cmd**	**SET cmd**	**GET cmd**
Pulse Rate	Integer (U32)	0	500000	`SR`	`GR`	`0x22`	`0x23`
Pulse Burst Length	Integer (U32)	0	1000000	`SL`	`GL`	`0x24`	`0x25`
Pump Duty Factor (*)	Integer (U16)	0	1000	`SF`	`GF`	`0x26`	`0x27`

(*) affects CW mode operation only – used to modulate the CW output

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. Refer to sections 3.4 and 4.4 for more detail on RS-232 and Ethernet command syntax respectively.

1.9.2.2 Examples

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.

1.10 Continuous Wave (CW) Operation (model specific)

Continuous-Wave emisison 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 CW output power between 0W and the Laser's maximum rated average output power. Applying 10V to **AI_1**, or setting the active power level to 1000 (`SI 1000`) sets the CW output to the maximum rated average power of the Laser. The maximum rate at which **Laser_Emission_Gate** can be toggled to switch the CW output is 1MHz.

1.10.1 CW Operation in Modes with Simmer (0, 1, 4, 5)

CW operation is active while **Laser_Enable** and **Laser_Emission_Gate** are high.

The simmer level affects

- the CW emission in the SIMMER state (< 250mW) in interface control modes 0, 1, 4 and 5
- the shape of the ramp on the rising edge of the optical output (time A in the order 100 – 200 us).

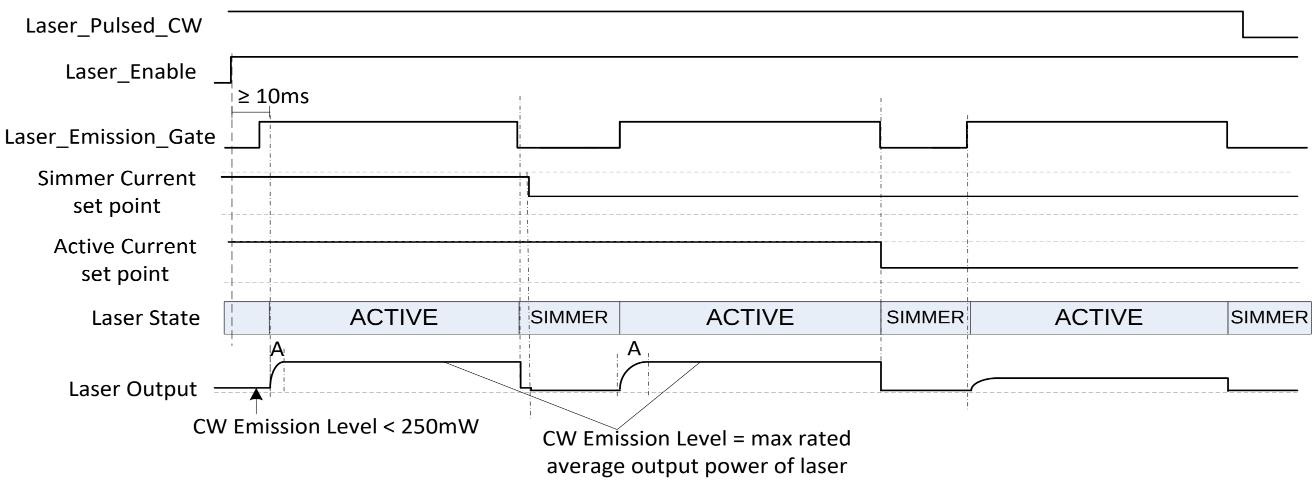


Figure 17. Continuous Wave (CW) Operation in Interface Control Modes 0,1,4, 5

1.10.2 CW Operation in Modes with Just-in-Time pumping (2, 3, 6, 7)

If the Laser is enabled and **Laser_Emission_Gate** is active the **First_Pulse_Equalization** signal (FPE) can be used to initiate CW emission. CW emission starts on the falling edge of FPE signal. CW emission stops when **Laser_Emission_Gate** signal goes low (inactive) or if Pulsed Mode is enabled.

The duration of the FPE pulse and the simmer current set point have no effect on the CW output. Consequently, the CW mode output in interface control modes 2, 3 and 6 ramps more slowly than in the other modes as the power amplifier is not pre-charged on entering the ACTIVE state (cf. Simmer current set point = 0 in standard pumping scheme)..

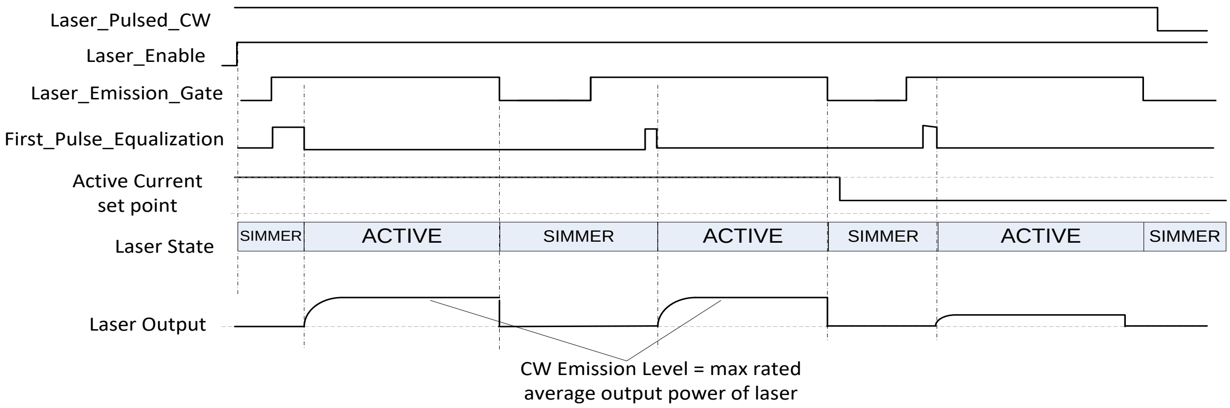


Figure 18. Continuous Wave (CW) Operation in Interface Control Modes 2, 3, 6 & 7

1.11 Modulated Continuous-Wave (CW-M) operation

Modulated continuous wave (CW-M) operation is only available when the pulse triggering is under software control on HS series, i.e. in interface control modes 0, 1 and 2.

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 – 200 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 in interface control modes 0 and 1 there is some CW emission but this is less than when the Laser is in pulsed mode. In interface control mode 2 the **First_Pulse_Equalization** signal also needs to be provided each time **Laser_Emission_Gate** goes active.

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

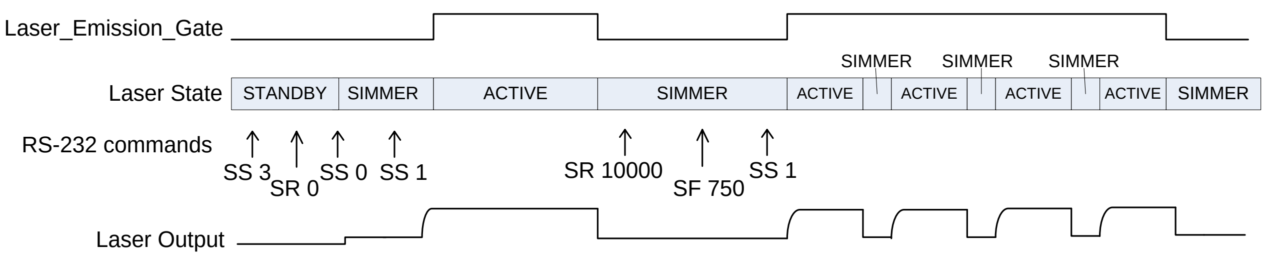


Figure 19. CW-M Operation (Interface Control Modes 0 and 1)

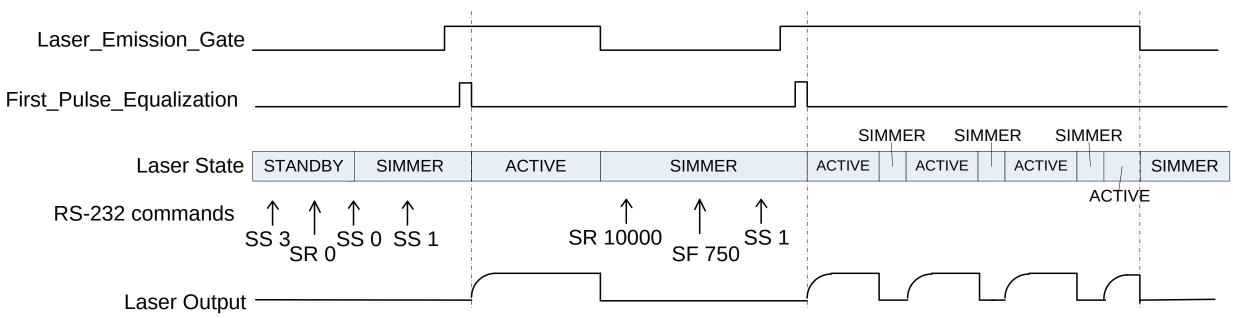


Figure 20. CW-M Operation (Interface Control Mode 2)

1.12 Switching between Pulsed & CW operation

1.12.1 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.
  - Laser modes 0, 1, 4, 5– stays in SIMMER for 10ms and will then respond to the rising edges of **Pulse_Trigger** input signal as normal.
  - Laser modes 2, 3, 6, 7– waits for a **First_Pulse_Equalization** (FPE) signal rising edge. Responds to pulse trigger signals as normal after FPE falling edge. FPE duration affects the power profile of the first few pulses. Simmer current set point has no effect.
- from LOW to HIGH (i.e. from Pulsed to CW mode) the Laser transitions to the SIMMER state.
  - Laser modes 0, 1, 4, 5 – stays in SIMMER for 10ms. The Laser will then transition to the ACTIVE state and start continuous wave emission.
  - Laser modes 2, 3, 6, 7– waits for a **First_Pulse_Equalization** signal falling edge. FPE duration and simmer current set point have no effect.

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

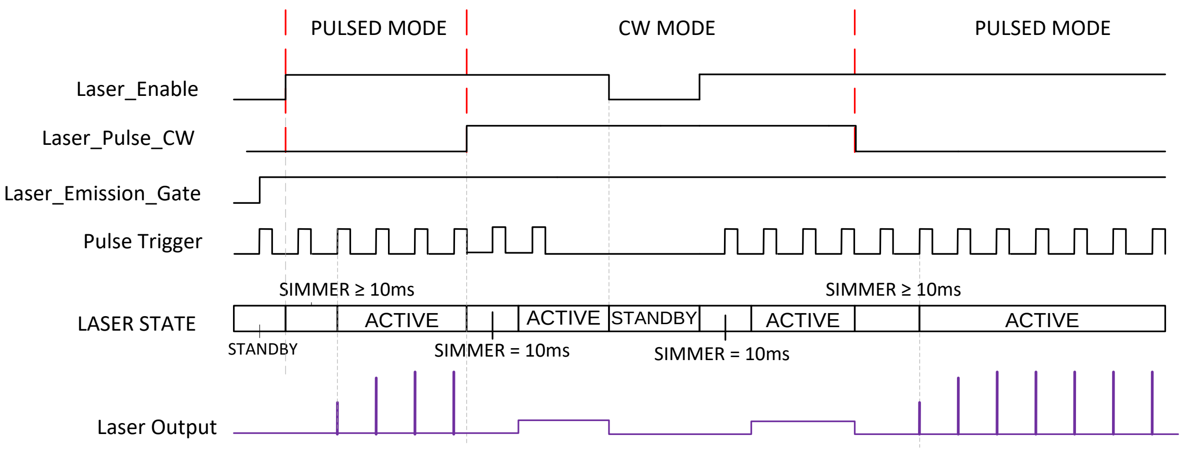


Figure 21. Switching between Pulsed and CW modes – Interface Control Modes 4 and 5

1.12.2 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.

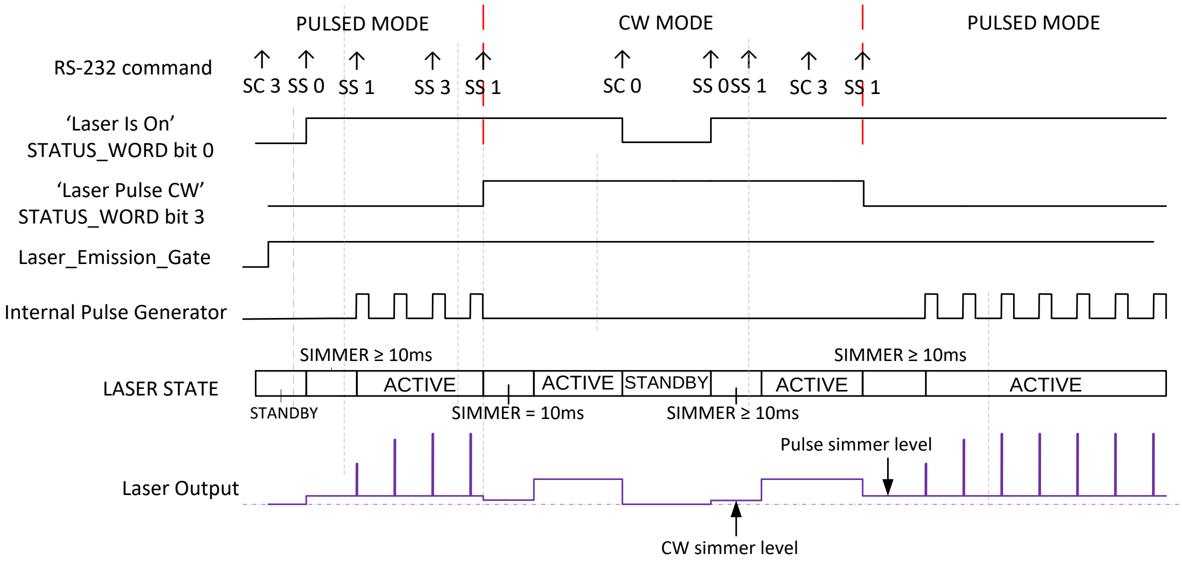


Figure 22. Switching between Pulsed and CW modes – Interface Control Modes 0 and 1.

1.13 Serial Interfaces Commands and Controls

1.13.1 Laser Control and Status Command Summary

	RS-232		Ethernet	
Interface control commands	Command	Section	Command	Section
Set RS-232 Baud rate	SB nnnnnn	3.3.1	0x10	4.3.1
Get RS-232 Baud rate	GB		0x11	4.3.2
Set Laser Interface Control Mode	SM 0 - 7	3.3.2	0x14	4.3.3
Get Laser Interface Control Mode	GM		0x15	4.3.4
Set Laser enable – STATUS_WORD(0)	SS 0	3.3.3	0x1A	4.3.5
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			
Get STATUS_WORD bits	GS 0 - 8		No identical command	
Get Laser control signals	GS 0 – 2 or QS		0x1B	4.3.6
Set Power amplifier simmer current set point	SH 0 – 100	3.3.4	0x1C	4.3.7
Set Power amplifier active current set point	SI 0 – 1000	3.3.5		
Get Power amplifier simmer current set point	GH	3.3.4	0x1D	4.3.8
Get Power amplifier active current set point	GI	3.3.5		
SPI Lasers redENERGY G3 legacy commands				
Set / clear current control source – STATUS_WORD(4)	SS 4 / SC 4	3.3.3	No identical command	
Set / clear current control source – STATUS_WORD(9)	SS 9 / SC 9			

(*) these commands require that the internal pulse generator is re-enabled to effect the change.

1.13.2 Pulse Generator Commands

	RS-232		Ethernet	
Description	Command	Section	Command	Section
Set pulse waveform (*)	SW 0 – 31	3.4.1	0x20	4.4.1
Get pulse waveform (*)	GW		0x21	4.4.2
Set pulse repetition frequency (Hz) (*)	SR 0 - 1000000	3.4.2	0x22	4.4.3
Get pulse repetition frequency (Hz) (*)	GR		0x23	4.4.4
Set pulse burst length (0 = continuous) (*)	SL 0 - 1000000	3.4.3	0x24	4.4.5
Get pulse burst length (0 = continuous) (*)	GL		0x25	4.4.6
Set CW mode modulation duty factor	SF 0 - 1000	3.4.4	0x26	4.4.7
Get CW mode modulation duty factor	GF		0x27	4.4.8
Set all pulse generator parameters	No equivalent RS-232 commands		0x2C	4.4.9
Get all pulse generator parameters for waveform			0x2D	4.4.10
Set Start Pulses – STATUS_WORD(1)	SS 1	3.3.3	0x2F	4.4.11

1.13.3 Monitoring Commands

	RS-232		Ethernet	
Description	Command	Section	Command	Section
Query active alarm codes	QA	3.5.1	0x50	4.5.1
Query monitoring group signal status	QD	3.5.2		
Query laser temperature	QT	3.5.3	0x51	4.5.2
Query beam delivery temperature	QU	3.5.4		
Query actual diode currents (mA)	QI	3.5.5	0x52	4.5.3
Query power supply voltages	No equivalent RS-232 commands		0x53	4.5.4
Query user interface			0x54	4.5.5
Query operating hours	QH	3.5.6	0x55	4.5.6
Query measured PRF	QR	3.5.7	0x56	4.5.7
Query extended diode currents (mA)	QJ	3.5.8	0x57	4.5.8
Query STATUS_WORD value	QS	3.5.9	No identical command	

1.13.4 General Diagnostic Commands

	RS-232		Ethernet	
Description	Command	Section	Command	Section
Read serial number	RSN	3.6.1	0x62	4.6.2
Read part number	RPN	3.6.2	0x63	4.6.3
Query Laser variant	QV	3.6.3	0x64	4.6.4
Set Laser into diagnosis state	No equivalent RS-232 commands		0x60	4.6.1
Get Laser feature description			0x65	4.6.5

2 Electrical Interface Specification

2.1 Safety Warning

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.

2.2 Location of Connectors

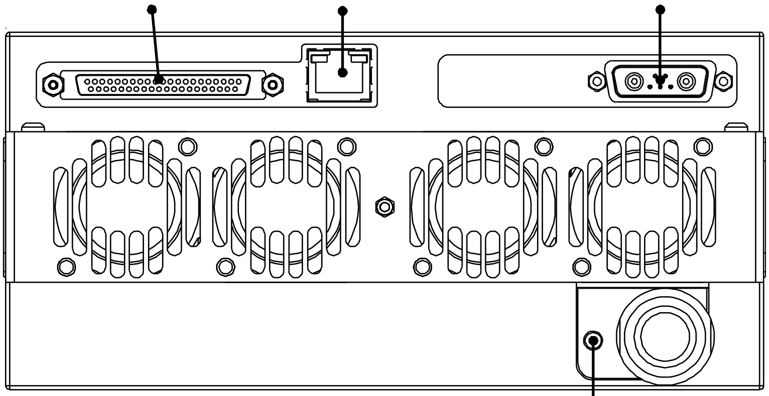


Figure 23. Connector Locations

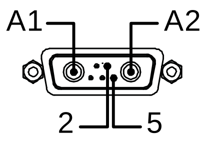
2.3 Earth Bonding

The integrator must comply with 61010-1:2010, section 6.5.2 in the connection of the Protective Bonding fixing point. The TruPulse nano 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.

2.4 Power Connector

2.4.1 Power Connector Pin-Out

Shown for lasers that require 24 VDC supply. For 36 VDC models refer to integration manual.



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 (+ Pilot Laser if fitted)
5	**Logic Power Supply -**	0V	

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

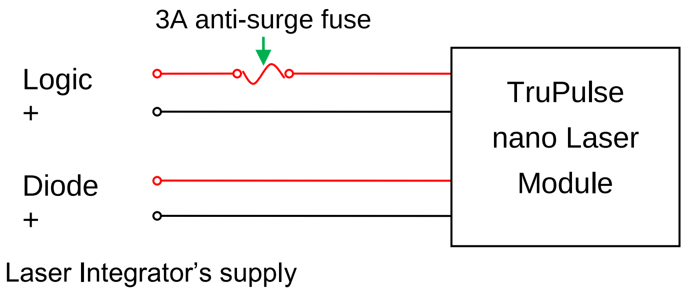


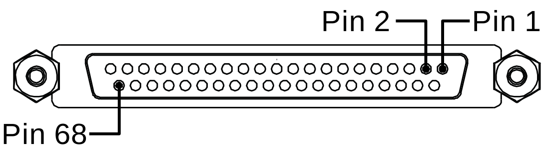
Figure 24. Logic Supply Protection Circuit

2.4.2 Power Supply Requirement

Parameter	Condition	Value
Output Voltage	Continuously rated	24V DC (22 – 26 V) See product specification for required current
Logic Power supply	Continuously rated	50 W
Minimum load		No minimum load
Ripple and noise	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

2.5 Laser I/O Connector

2.5.1 Laser I/O Connector Pin-out



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
	N/C		38	4	DI	First_Pulse_Equalisation	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	

- Not available on RM models
- Future use

Figure 25. Laser IO Connector Pin Allocations

2.5.2 I/O Connector Signal Descriptions

	Signal Name	Type Direction	Active Level	Opto-coupled	Transition Time	Comments
Laser Control (section 2.8)	Laser_Enable_H	Digital IN	High	Yes	~ 3 us	V_{IL} = 0V, V_{IH} = 5V I_{IN} = 2 mA
	Laser_Enable_L					
	Laser_Disable_H					
	Laser_Disable_L					
	Pilot_Laser_Enable_H					
	Pilot_Laser_Enable_L					
	Laser_Pulse_CW_H					
	Laser_Pulse_CW_L					
Real-time Control (section 2.9)	Laser_Emission_Gate	Digital IN	High	Yes	~100 ns	V_{IL} = 0V, V_{IH} = 5V I_{IN} = 10 mA.
	Pulse_Trigger(1)					
	First_Pulse_Equalisation					
	AI_1	Analog IN	n/a	No	BW = 100kHz	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.
	AI_2					
	Laser_Ready_To_Pulse	Digital OUT	High	Yes	~100ns	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
	Task_Active					
	Laser_Has_Pulsed					
	PRF_Sync_Out					
Parallel I/F (section 2.10)	DI_0 – DI_7	Digital IN	N/A	Yes	~100ns	V_{IL} = 0V, V_{IH} = 5V I_{IN} = 10 mA
	DI_Latch		↑			
	DI_Select		high			
Monitoring (section 2.11)	Monitor	Digital OUT	Low	Yes	~ 3 us	Open-collector Recommend 4.7kΩ pull up with a 5V source, i.e. I_{OL} ~1mA. Absolute max rated current 40 mA
	Alarm					
	Laser Temperature					
	Beam_Delivery					
	System_Fault					
	Laser_Deactivated					
	Laser_Emission_Warning		High			
	Laser_Is_On					
RS-232 (section 3.1)	RS232_TX	OUT	N/A	No		
	RS232_RX	IN		No		

(1) Minimum active pulse width > 250ns

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

2.5.3 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.

2.5.3.1 Digital Inputs

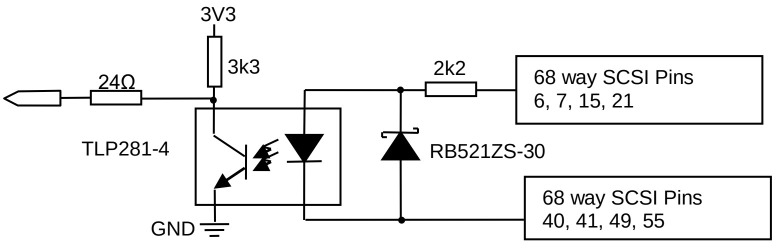


Figure 26. Laser Control Digital Inputs

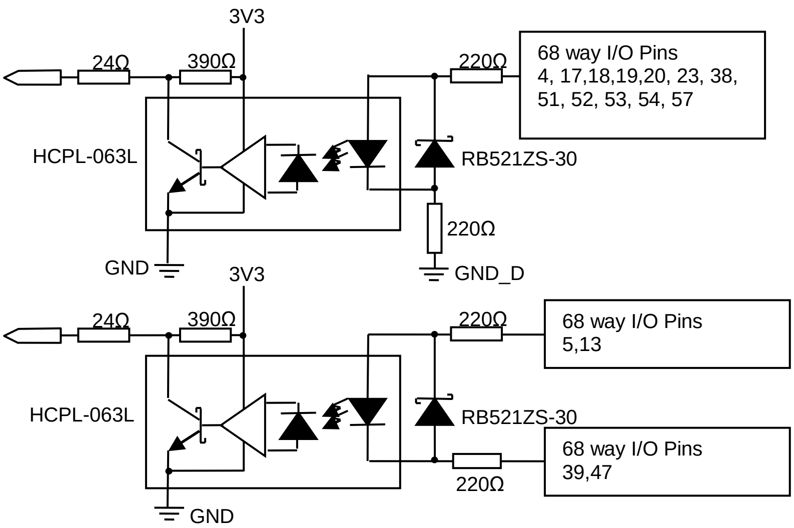


Figure 27. Parallel Interface and Real Time Digital Inputs

2.5.3.2 Digital Outputs

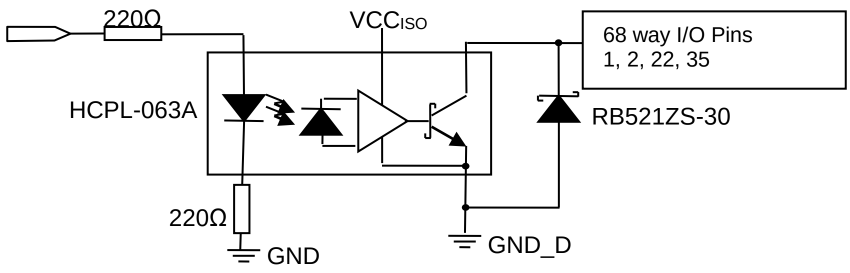


Figure 28. Real Time Digital Outputs

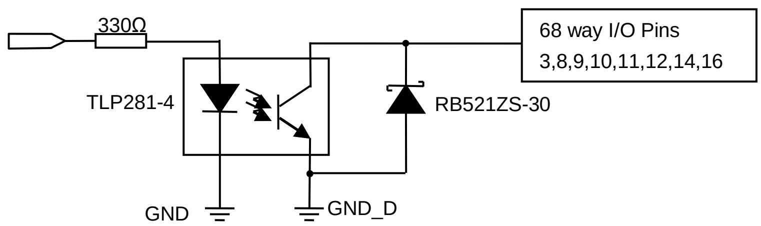


Figure 29. Monitor Signal Digital Outputs

2.5.3.3 Analogue Inputs

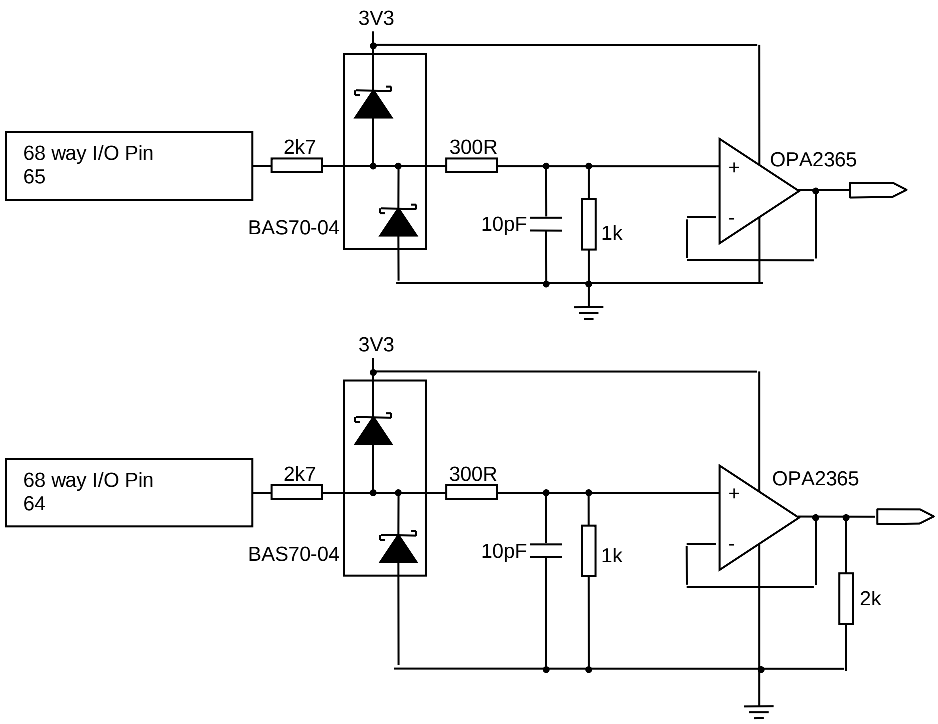


Figure 30. Analog Input Circuitry

2.6 Break-Out Board

The TruPulse nano 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 TruPulse nano break-out board.

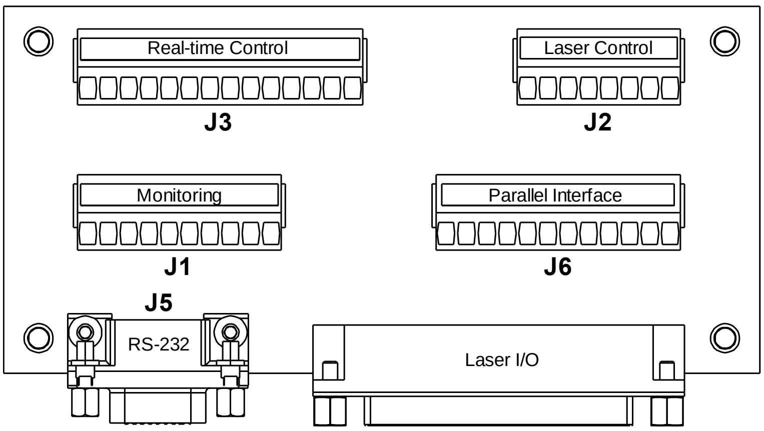
	Signal Name		Pin
Laser Control	Laser_Enable_H	J2	1
	Laser_Enable_L		2
	Laser_Disable_H		3
	Laser_Disable_L		4
	Pilot_Laser_Enable_H		5
	Pilot_Laser_Enable_L		6
	Laser_Pulse_CW_H		7
	Laser_Pulse_CW_L		8

Real-time Control Signals	GND_D	J3	1
	Laser_Emission_Gate		2
	Pulse_Trigger		3
	First_Pulse_Equalization		4
	N/C		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

	Signal Name		Pin
Parallel Interface Signals (not RM)	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
	VCC		12

Monitoring Signals	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

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



2.7 Safety and Interlocking

2.7.1 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 TRUMPF Laser UK 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:

Method 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)

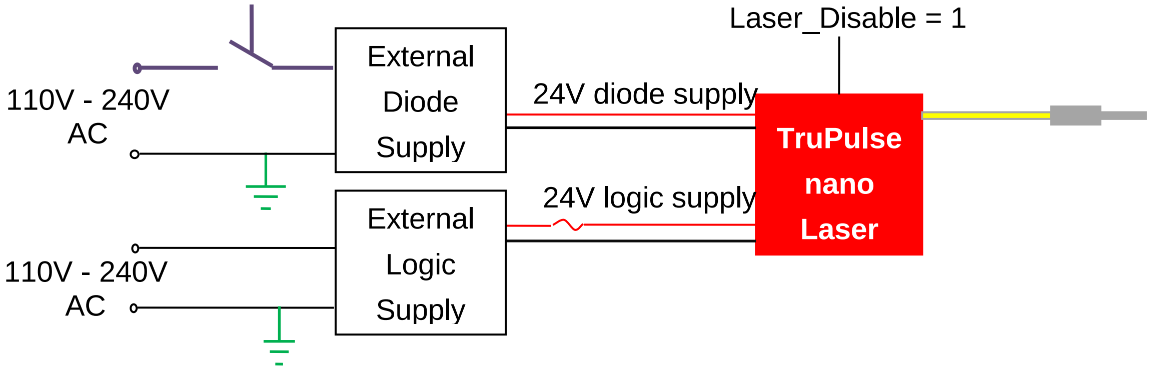


Figure 31. Interlocking the Laser Diode AC Supply

Method 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).

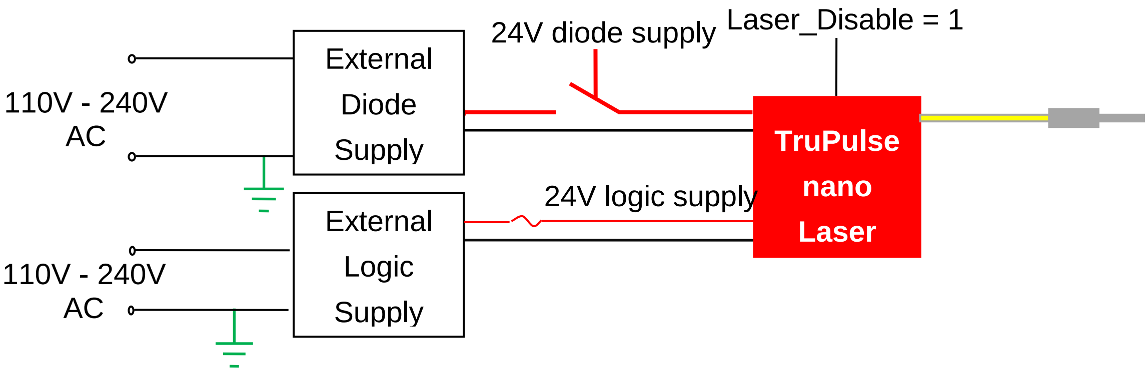


Figure 32. Interlocking the 24V Laser Diode Supply

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.

2.7.2 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

The Laser transitions from DISABLED state to POWER_UP state where internal diode supply switches on and settles (~250 ms). The Laser then enters STANDBY state and normal operation can resume.

2.8 Laser Control Group Signal Reference

These signals will affect the Lasers operation regardless of the interface control mode. It should be noted that in interface control modes 0, 1, 2, 3 and 7 software commands can also be used to enable the Laser, control the Pilot Laser and select between pulsed and CW modes.

2.8.1 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	

2.8.2 Laser_Disable

Signal Names:	**Laser_Disable_H**	**Laser_Disable_L**
I/O Pins:	15	49
BoB Pins:	J2:3	J2:4
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	

2.8.3 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	

2.8.4 Laser_Pulse_CW (HS Only)

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	

2.9 Real-Time Interface Group Signal Reference

2.9.1 GND_D

I/O Pin:	36, 37, 42 – 46, 48, 50, 56, 58
BoB Pin:	J3:1, J3:9

2.9.2 Laser_Emission_Gate

Signal Names:	**Laser_Emission_Gate_H**	**Laser_Emission_Gate_L**
I/O Pins:	5	39
BoB Pins:	J3:2	J3:1 (GND_D)
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 • required for Laser emission in all interface control modes	
Inactive Signal:	• prevents the Laser from responding to internal or external pulse triggers • sets **Laser_Ready_To_Pulse** inactive	
Acknowledgement:	• **Laser_Ready_To_Pulse** becomes active	

2.9.3 Pulse_Trigger

Signal Names:	**Pulse_Trigger_H**	**Pulse_Trigger_L**
I/O Pins:	13	47
BoB Pins:	J3:3	J3:1 (GND_D)
Prerequisites:	• Laser is in interface control mode 3, 4, 5, 6 or 7 • 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**	

2.9.4 First_Pulse_Equalization

I/O Pin:	4
BoB Pin:	J3:4
Prerequisites:	• Laser is in Interface Control Mode 2, 3, 6 or 7 (i.e. one of the just-in-time pumping modes)
Control Level:	• Rising edge: resets and starts the pulse counter and sets **Task_Active** high. • High level: external **Pulse_Trigger** input is blocked but the pulse trigger interval is measured between any pulses that occur so that a value is available for pulse pre-pumping as soon as first 'real' pulse occurs • Falling edge: synchronises the internal frequency generator if in use and allows the **Laser_Ready_To_Pulse** signal to become active. Pulses can then be triggered.

2.9.5 GND_A

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

2.9.6 AI_1

I/O Pin:	65
BoB Pin:	J3:7
Prerequisites:	Laser is in Interface Control Mode 1, 4, 5 or 6 (i.e. active current is set by analogue input).
Control Level:	The input voltage to this signal controls the power-amplifier pump laser diode active state current • 0V = no current • 10V = maximum current

2.9.7 AI_2

I/O Pin:	64
BoB Pin:	J3:8
Prerequisites:	Laser is in Interface Control Mode 1 or 5 (i.e. simmer current is set by analogue input - simmer pumping scheme only).
Control Level:	The input voltage to this signal controls the power-amplifier pump Laser diode simmer current • 0V = no current • 10V = maximum current

2.9.8 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 in interface control modes with external pulse triggering, 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 a duration of approximately 400 ns

2.9.9 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

2.9.10 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

2.9.11 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

2.10 Parallel Interface Group Signal Reference

2.10.1 DI_0 ... DI_7 – User Selectable pulse waveforms

The TruPulse nano 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 Product Specification 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 Interface Control Mode 3, 5 or 6							
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							

2.11 Monitoring Group Signals

2.11.1 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.

2.11.2 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.

2.11.3 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

2.11.4 Beam_Delivery

I/O Pin:	11
BoB Pin:	J1:5
STATUS_WORD bit:	13
Prerequisites:	This is only relevant on lasers with average powers >= 30W. For lower power lasers, this signal duplicates **Laser_Temperature**
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

2.11.5 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.

2.11.6 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
Notes:	The output remains active until the condition is removed and the Laser is reset by the **Laser_Enable** signal.

2.11.7 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

2.11.8 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

3 RS-232 Command Reference

3.1 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`)

3.2 RS-232 Command Syntax / Execution Error Codes

RESPONSE	ERROR CODE	DESCRIPTION
E5	5	Illegal character
E6	6	Too few characters
	7-9	Password errors
E7	7	Illegal password character
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 – parameter under hardware control
E33	33	Command could not be executed – parameter under software control
E34	34	Command could not be executed because pilot Laser is enabled
E34	35	Command could not be executed because pulse repetition rate is out of range
	36-39	Reserved for future use

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

3.3 Laser Control Command Reference

3.3.1 Set/Get Baud Rate

Command:	SB nnnnnn	GB
Returns:	nothing, if parameter in range	nnnnnn
Range:	9600, 19200, 38400, 57600, 115200	
Actions:	Sets / gets the baud rate used for RS-232 communication	

3.3.2 Set/Get Laser Interface Control Mode

Command:	SM n	GM
Returns:	nothing, if parameter in range	n
Range:	n = 0 – 7	
Actions:	Sets / gets the Laser interface control mode	

3.3.3 Set/Clear/Get STATUS_WORD Bits

Command:	SS n	SC n	GS
Returns:	nothing, if parameter in range		n, n, n
Range:	0 – 9 (only bits 0, 1, 3. 4, 8 and 9 can be set or cleared)		
Actions:	Sets/Clears the specified bit of the STATUS_WORD Gets the asserted bits of the STATUS_WORD		

3.3.4 Set/Get Power-amp Simmer Current Set Point

Command:	SH nnn	GH
Returns:	nothing, if parameter in range	nnn
Range:	0 to 100	
Actions:	Sets/gets the power-amp simmer current set point when under software control	

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

Command:	SI nnnn	GI
Returns:	nothing, if parameter in range	nnnn
Range:	0 to 1000	
Actions:	Sets/gets the power-amp active state current set point when under software control	

3.4 Pulse Generator Command Reference

3.4.1 Set/Get Pulse Waveform

Command:	`SW nn`	`GW`
Returns:	nothing, if parameter in range	`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	

3.4.2 Set/Get PRF

Command:	`SR nnnnnnn`	`GR`
Returns:	nothing, if parameter in range	`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 with an internal pulse trigger	
Notes:	Change is implemented when `SS 1` is called to start pulses	

3.4.3 Set/Get Pulse Burst Length

Command:	`SL nnnnnnn`	`GL`
Returns:	nothing, if parameter in range	`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	

3.4.4 Set/Get Pump Duty Factor

Command:	`SF nnnn`	`GF`
Returns:	nothing, if parameter in range	`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	

3.5 Monitoring Command Reference

3.5.1 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 3.7.

3.5.2 Query Monitoring Group Signal States

<table>
<tr><td>Command:</td><td colspan="10"><code>QD</code></td></tr>
<tr><td rowspan="3">Returns:</td><td colspan="8"><code>bbbbbbbb</code></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>

3.5.3 Query Laser Temperature

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

3.5.4 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 (°C)

3.5.5 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)

3.5.6 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)

3.5.7 Query Measured PRF

Command:	QR
Returns:	nnnnnnn
Range:	0 to 1000000
Actions:	Returns the measured repetition rate in Hz of the external pulse trigger signal (rising edge to rising edge).

3.5.8 Query Extended Diode Currents

Command:	QJ
Returns:	nnnnn, nnnnn, nnnnn, (nnnnn)
Range:	nnnn = 0 to 20000
Actions:	Returns the pump diode current of the pump Laser diode driver stages (mA) in high-power lasers

3.5.9 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

3.6 Diagnostics Command Reference

3.6.1 Read Serial Number

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

3.6.2 Read Part Number

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

3.6.3 Query Vendor Info

Command:	`QV`

Returns:	`FPGA HW Rev: 8.x.x`
	`NIOS-II FW Rev: 8.x.x`
	`Stellaris FW Rev: 0.0.x.x`
	`IP Config: xxx.xxx.xxx.xxx DHCP`
	`Driver FW Rev: x.x`
	
	Note: '`DCHP`' may be replaced with '`STATIC`' depending on the IP configuration

Range:	x.x.x specifies the versions etc
Actions:	• Returns information regarding the Laser

3.6.4 RS-232 Status word definition

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	**‘External Pulse Trigger’** Legacy support for SPI Lasers redENERGY G3 interface modes (**)	Read/ write	1 = external **Pulse_Trigger** selected 0 = Internal pulse generator selected Backwards compatibility with the G3 hardware and software modes has been preserved - see section **Error! Reference source not found.**	512
8	**‘Pilot Laser Enable’**		1 = enable pilot Laser / pilot Laser is enabled 0 = disable pilot Laser / pilot Laser is not enabled	256
7	**First-pulse equalisation method**	Read	1 = Just-in-time pumping 0 = simmer pumping	128
6	(Reserved)		1	64
5	(Reserved)		1	32
4	**External active current control** Legacy support for External current control	Read/ write	1 = External analog active current control 0 = internal current control Backwards compatibility with the G3 hardware and software modes has been preserved - see section **Error! Reference source not found.**	16
3	**‘Laser Pulse CW’ (*)**		1 = CW/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 Enable ‘ / ‘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

3.7 RS-232 Alarm Codes

ALARM CODE	DESCRIPTION	STATUS_WORD bit			
		15	14	13	12
40 - 49	System fault: diode driver current	1	1		
50 - 53	System fault: seed laser	1	1		
≥ 100	System fault: internal laser fault	1	1		
65	System fault: beam delivery temperature sensor fault (1)	1	1	1	
82	System fault: base plate temperature sensor fault	1	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. Only cleared by cycling the power supply.	1			
99	Emergency stop alarm Triggered by the **Laser_Disable** signal	1			

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

3.8 Example Control Code

3.8.1 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]
```

3.8.2 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]
```

3.8.3 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]
```

3.8.4 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]
```

3.8.5 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%]
```

3.8.6 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]
```

3.8.7 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]
```

3.8.8 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]
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]
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)
```

4 Ethernet Command Reference

4.1 Ethernet Control Safety Warning

It is possible for multiple users to connect to and control a TruPulse nano 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 Ethernet controllers.

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.

4.2 Ethernet Communications Protocol

4.2.1 Command Packets sent to Laser

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

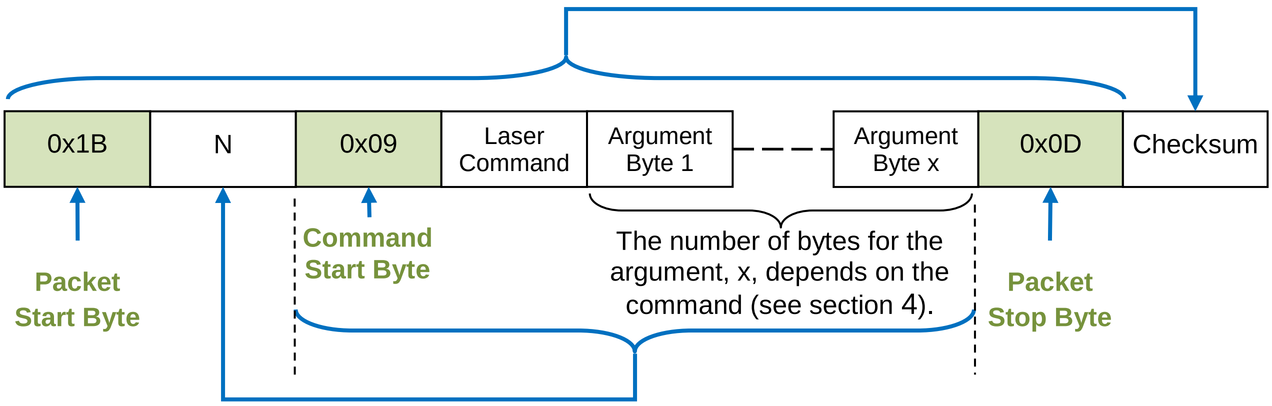


Figure 33. Ethernet Transmit Packet Structure

The data sent to the Laser (via TCP communication port 58174) 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 4)
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 - 8 inclusive). Ignore any overflow bits.
- Append the checksum byte to the end of the packet.

4.2.2 Response Packet received from the Laser

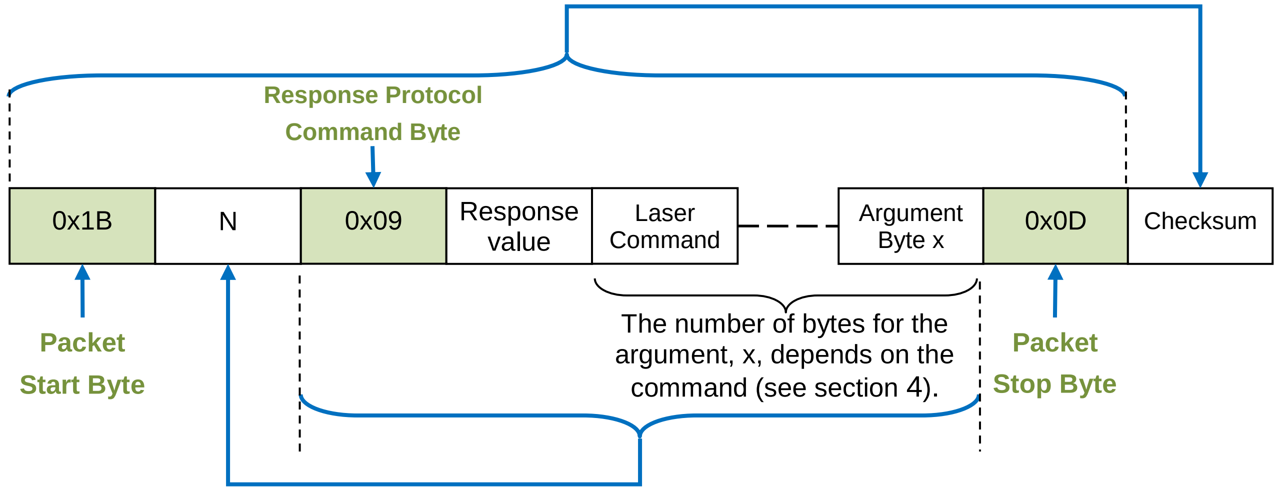


Figure 34. Ethernet Response Packet Structure

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 section 4)
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 unsigned 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 4 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

4.2.3 Ethernet Error Codes

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

4.2.4 Worked examples

4.2.4.1 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 4.3.1)
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

4.2.4.2 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 4.3.1)
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

4.2.4.3 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	**0x0D**	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

4.2.4.4 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

4.3 Interface Control Command Reference (0x1.)

4.3.1 0x10: Set RS-232 Baud Rate

Command Byte	0x10	RS232 Version:	SB
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

4.3.2 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)

4.3.3 0x14: Set Laser interface control mode

Command Byte	`0x14`	**RS232 Version:**	`SM`
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
Received data bytes	1	0x00	Mode changed
		0x01	Mode not changed
		0x02	Internal error
	2	0x0?	Current mode value

4.3.4 0x15: Get Laser interface control mode

Command Byte	`0x15`	**RS232 Version:**	`GM`
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) value corresponds to Laser interface control mode

4.3.5 0x1A: Set Laser control signals

Command Byte	`0x1A`	**RS232 Version:**	`SS 0`, `SC 0`
			`SS 3`, `SC 3`
			`SS 8`, `SC 8`

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

4.3.6 0x1B: Get Laser control signals

Command Byte	`0x1B`	**RS232 Version:**	`GS 0 – 2` or `QS`
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

4.3.7 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	Laser is in an inappropriate interface control mode

4.3.8 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)

4.4 Pulse Generator Command Reference (0x2.)

4.4.1 0x20: Set pulse waveform

Command Byte	`0x20`	**RS232 Version:**	`SW`
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
		2	Laser is in an inappropriate interface control mode

4.4.2 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)

4.4.3 0x22: Set Pulse Rate

Command Byte	`0x22`	**RS232 Version:**	`SR`
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	In inappropriate interface control mode

4.4.4 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)

4.4.5 0x24: Set pulse burst length

Command Byte	`0x24`	**RS232 Version:**	`SL`
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

4.4.6 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)

4.4.7 0x26: Set pump duty factor

Command Byte	`0x26`	**RS232 Version:**	`SF`
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	In inappropriate interface control mode

4.4.8 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)

4.4.9 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

4.4.10 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)

4.4.11 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	Laser is in an inappropriate interface control mode
		0x03	Laser not enabled

4.5 Monitoring Command Reference (0x5.)

4.5.1 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 3.7 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)

4.5.2 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)

4.5.3 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)

4.5.4 0x53: Query power supply voltages

Command Byte	`0x53`	**RS232 Version:**	
Actions:	Queries the Laser input voltages – returns value in mV		

	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)

4.5.5 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)

4.5.6 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)

4.5.7 0x56: Query External Pulse Trigger Repetition Rate

Command Byte	`0x55`	**RS232 Version:**	`QR`
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 – 1000000	External pulse trigger repetition rate in Hz

	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)

4.5.8 0x57: Query Extended Laser currents

Command Byte	`0x57`	**RS232 Version:**	`QJ`
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)
	3	UInt 16	0 - 15000	Power-amplifier diode current (mA)
	4	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)
	5	0x??	Arg 3: data byte 2 (LSB)
	6	0x??	Arg 3: data byte 2 (LSB)
	7	0x??	Arg 4: data byte 2 (LSB)
	8	0x??	Arg 4: data byte 2 (LSB)

4.6 Diagnostics Command Reference (0x6.)

4.6.1 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
	    ○ Set Pulse rate: PRF_0 of waveform 0
	    ○ Set Pulse burst length: 0
	    ○ Set Pump duty factor: 500
	• Set Simmer current (`SH`): 0
	• Set Active current (`SI`): 1000
	• Set **Laser_Enable** = 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

4.6.2 0x62: Get Laser serial number

Command Byte	0x62	**RS232 Version:**	RSN
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)

4.6.3 0x63: Get Laser part number

Command Byte	0x63	**RS232 Version:**	RPN
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

4.6.4 0x64: Get Laser firmware details

Command Byte	`0x64`	**RS232 Version:**	`QV`
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

4.6.5 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)

5 Technical Support & Customer Service

5.1 Warranty Information

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

TRUMPF Laser UK Limited expressly warrants the equipment it manufactures as set forth in the standard Terms and Conditions of sale. **TRUMPF Laser UK Limited makes no other warranties, expressed or implied, including and without limitation, warranties as to merchantability of fitness for use.**

5.2 Product Support

In the unlikely event that a TruPulse nano laser does not function normally and that it requires attention, contact TRUMPF Laser UK Limited for advice on further on-site fault diagnosis and/or module return.

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

Pack the laser 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. Please contact TRUMPF Laser UK Limited for replacement packaging items if some, or all, or the original packaging is missing. Please take time to complete all return documentation. This can be obtained from TRUMPF Laser UK Limited and accurate details, diagnosis and comments in the documentation can help reduce turnaround time for repair at TRUMPF Laser UK Limited.

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

5.2.1 TRUMPF Laser UK Product Support Contacts

Product Support
service.tgbl@trumpf.com
Tel: +44 (0)1489 779696 - Option 2

Order management
orders_laser@trumpf.com
Tel: +44 (0)1489 779696 - Option 5

Product documentation
www.trumpf.com/s/productdocs

Company Web Site
www.trumpf.com

Or contact your local distributor.