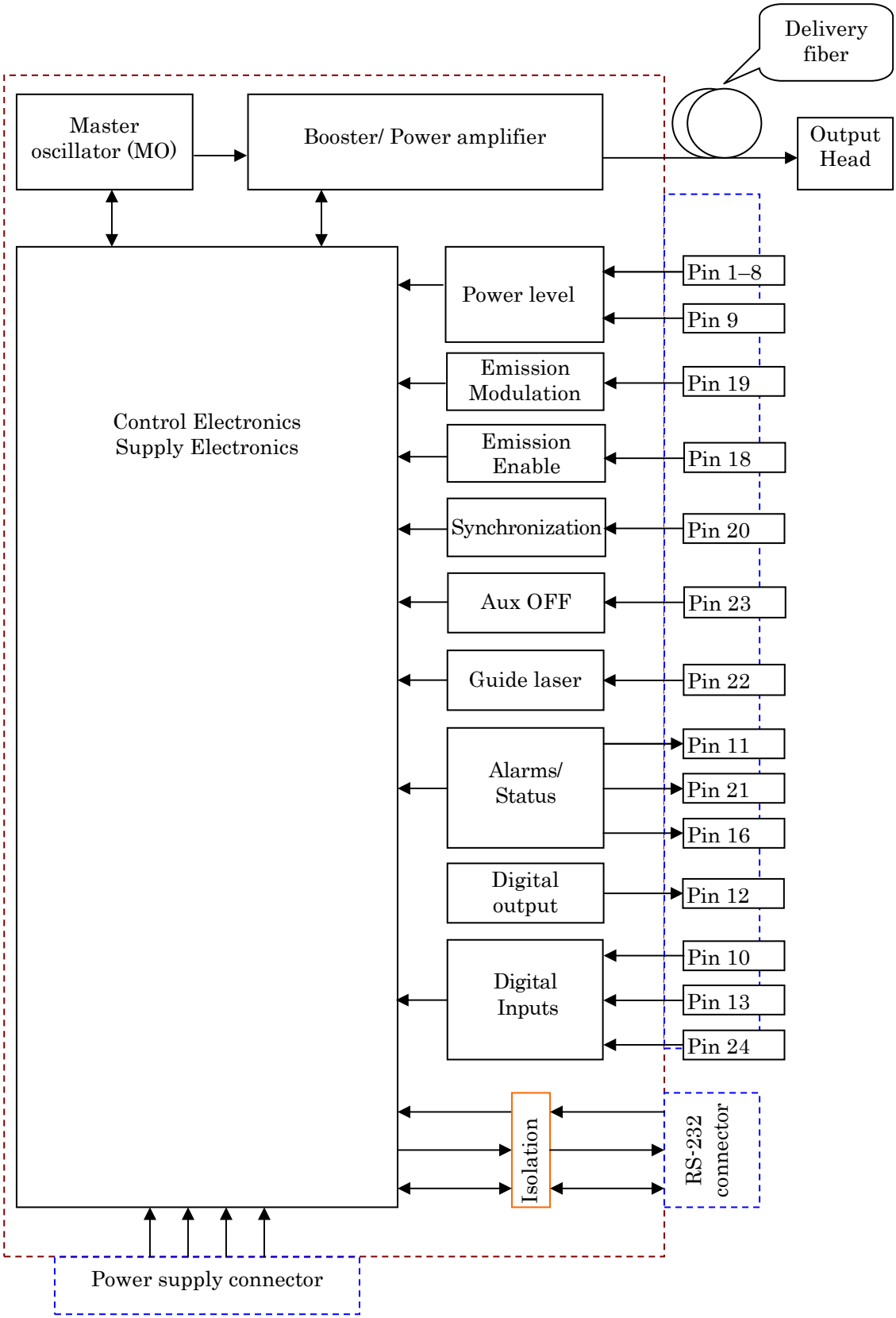
The document describes connection and control basics of pulsed lasers equipped with interface "type E" manufactured by IPG Laser GmbH and its sister companies.

Contents:

Laser Internal Structure.

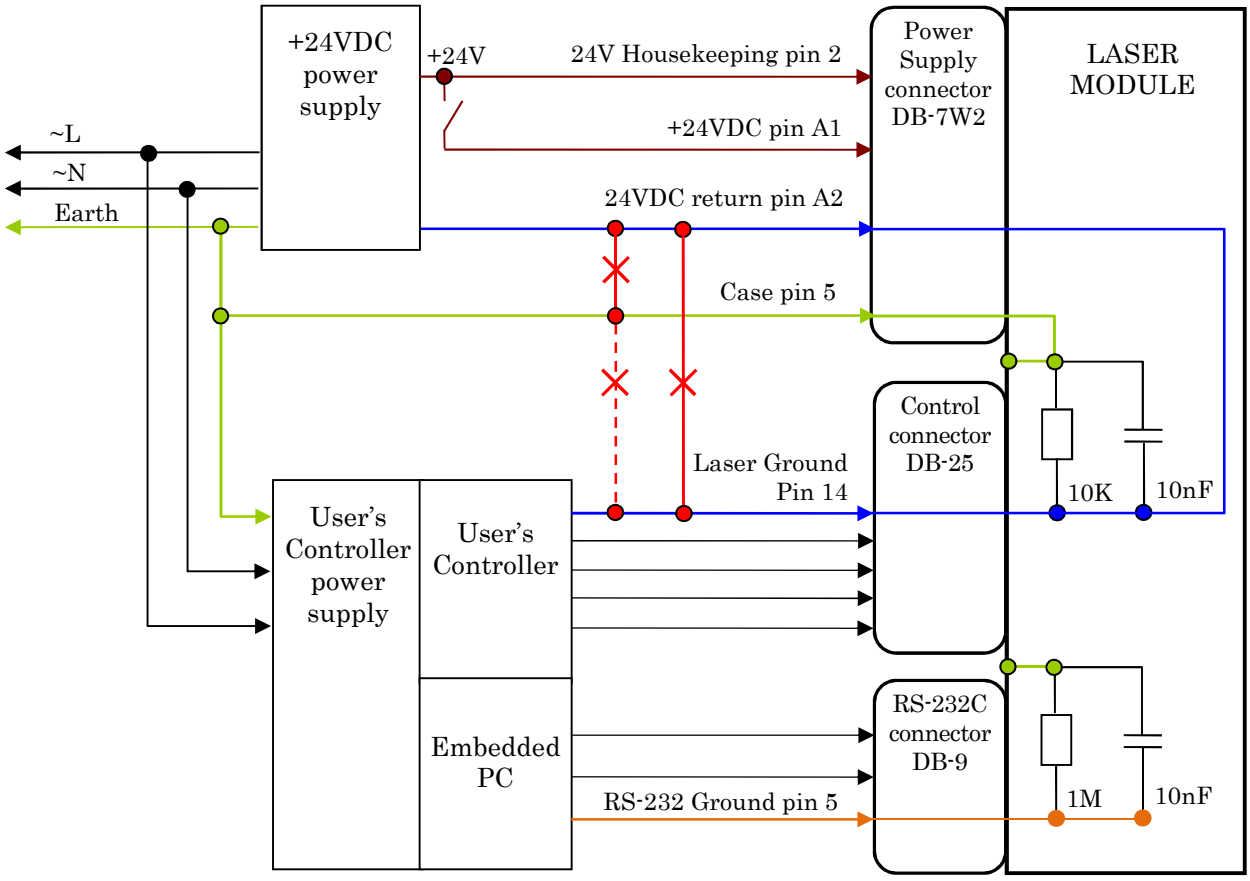


Power supply connector

The power supply connector is the DB-7W2 type plug (male). Pin assignment is shown in the table below.

PIN	Name	Level	Description
A1	+24V Main	+24V DC Supply Voltage	Supply voltage +24V DC ±5%. Must be supplied for the full laser operation. Floating power supply is required.
A2	24V Ret	24V Return Wire (Supply Ground)	Power supply ground. Inside the laser this ground is connected to the laser Ground (pin 14 of DB-25 connector). Floating power supply is required.
1, 3, 4	Reserved		Customer connection is not allowed
2	HK	+24V DC housekeeping	Power supply input for independent electronic board and guide laser operation only. Provides no supply to the pump laser diodes. Operating voltage range is +24VDC ±5%. Voltage should be supplied relative to pin A2. Must be supplied for the laser operation.
5	Case	Earth	Direct electrical connection to the laser housing (module)

Recommended laser connection diagram.



Electrical connection.

1. Main power supply (24VDC) should be capable to permanently supply operating current (refer to the maximum current consumption in the laser specification). Power supply should hold the voltage, measured on the laser DB-7W2 terminals, within a specified range (refer to the laser model specification) both for steady and modulated emission. Supply voltage undershoots and overshoots out of the specified range may lead to a non-stable laser operation and the laser damage. Power supply transient load regulation should be carefully investigated to choose a suitable power supply model.

2. Wires in the cable connecting main power supply and the laser should have an appropriate length and cross section to ensure negligible voltage drop.

3. The main 24V DC supply should have floating outputs. Its return wire should be connected only to the laser 24V return terminal (Pin A2 of DB-7W2). Wrong connections, which may create current loops (shown in the diagram above as the crossed red wires) should be avoided.

4. The main supply line +24V should be connected to +24V DC laser terminal (pin A1 of DB-7W2).

5. Laser Ground (DB-25 pin 14) and laser 24V return are connected inside the laser module. No connections are allowed between these terminals outside of the laser module.

6. The laser is equipped with the housekeeping (HK) supply input- pin 2 of DB-7W2 connector. It should be kept powered for the complete laser operation cycle.

7. For majority of laser models the HK current consumption is less than 0.4 A. For the detailed value refer to the laser specification or a laser series User's guide.

8. For selected laser models wider HK input voltage range may be supplied. Contact the manufacturer for details.

9. Laser warm-up time is calculated from the beginning of supplying a housekeeping voltage. Even if the main +24V supply is disconnected from the DB-7W2 terminal A1, while housekeeping voltage is still available, the main processor of the laser continues operation. The laser supports communication and keeps all settings made for the current session. The warm-up phase ends after 10s after supplying the housekeeping and 0.5s after supplying of main +24V Main. See the diagram in this manual.

10. Inside the module the common ground is connected to the laser housing via 10 kOhm resistor and parallel 10nF capacitor. This network equalizes potential between ground and the laser case.

11. Inside the module the RS-232 ground is connected to the laser housing via 1MOhm resistor and parallel 10nF capacitor. This network equalizes potential between RS-232 ground and the laser case.

12. User controller electronics ground may be connected to the earth by design (dashed red line on the diagram). If there is no such connection, it should not be made intentionally.

Control Connector Pin Assignment, DB-25 plug.

All control pins are TTL compatible, unless otherwise noted in the pin description. For the interface designs level ranges of the TTL standard should be taken into consideration. Some pins can be individually configured for control via RS-232 interface; configuration capability is given in the table.

PIN No.	Name	Description	RS-232 controllable
1-8 (D0-D7)	Power Setting (D0-D7)	8-bit bus, range 0x00..0xFF (hex) or 0..255 (decimal). Least significant bit (lsb) (D0) corresponds to Pin number 1 Most significant bit (msb) (D7) corresponds to pin 8. 00h (0): Minimum output power FFh (255): Maximum output power Disconnected state corresponds to 00h.	full control
9	Latch	Latches power setting into the laser by the rising edge	enable/disable
10	Serial Input	Laser serial data input. Sets data bit to the laser synchronously with SCLK rising edge	full control
12	Serial Output	Laser serial data output. Gets data bit from the laser synchronously with SCLK rising edge	full control
13	Serial Clock	Serial data clocks, 100 kHz maximum	
11,16,21	States	Laser state outputs (see status codes in the table below).	
14	Ground	Ground	
15	5Vout	+5VDC output, max current consumption is 80mA.	
17	5VRG	+5±0.25V DC power supply input for independent operation of the red guide laser, maximum current consumption is 150 mA	
18	EE	Emission Enable (EE) input. HIGH: Emission Enable LOW or disconnected: Emission Disable	full control
19	EM	Emission Modulation (EM) input. HIGH: Emission ON LOW or disconnected: Emission OFF	full control
20	Sync	Pulse Repetition Rate (Synchronization) input	internal trigger generator
22	RG	Guide Laser (red diode) ON/OFF input. HIGH: ON LOW or disconnected OFF	full control
23	AuxOFF	Auxiliary Emission OFF input. HIGH: OK (Normal operation) LOW or disconnected: STOP (Laser automatically switches OFF all optical stages)	enable/disable
24	Serial Enable	Enables serial communications via pins 10, 12, 13 HIGH Enabled. LOW or disconnected Disabled	
25		Reserved, customer connection is not allowed	

Digital Control Interface (DB-25) Description.

The laser is controlled by signals applied to the DB-25 connector. Please refer to the connector interface description table above for pin designation and operating levels.

Pin 1 to 8	Power Setting (D0-D7)

Pin 1 to 8 is the 8 bit bus for the output power setting. Pin 1 is the least significant bit and pin 8 is the most significant bit. Codes in the range 0...255 (0x00...0xFF) should be applied to these pins, which correspond to the power setting of 0...100% of the specified nominal value.

Note 1: optical output power is nearly proportional to the power setting (see specification for the power adjustment range).

Note 2: if the specified laser power adjustment range is limited (typically 10…100%), the optical output power in the unspecified range (here 0…10%) may not correspond to a set value. A power leakage at the zero power setting, as well as a nonlinear response to the power setting, is possible.

Pin 9	Latch

Pin 9 is the "Latch" control line to store power settings (pin1-8) in the laser. The data is stored in the laser by the rising edge of the signal on the pin 9. Data on the pins 1-8 should be stable for 1 µs before and 1 µs after the rising edge on pin 9.

Stability of the data on the Pin 1-9 out of the above mentioned time frames is not required. IPG recommends supplying single positive pulse with duration longer than 2 µs to latch the data into the laser. Time interval between adjacent latching pulses should be longer than 100 µs (latching frequency less than 10 kHz).

Note: The line may be configured to DISABLE state; in this case power setting on pins 1-8 are directly transferred into the laser.

Pin 11, 16, 21 Laser state outputs

Pin 11, 16 and 21 show the following laser states:

State2 Pin 11	State0 Pin 16	State1 Pin 21	Description
LOW	LOW	LOW	**Temperature alarm** Laser temperature is out of the operating temperature range.
HIGH	LOW	LOW	**Power supply alarm** External supply voltage is out of the specified range.
LOW	LOW	HIGH	**Normal operation**
HIGH	LOW	HIGH	**Laser is not ready for emission**
LOW	HIGH	LOW	**Back reflection alarm** Laser automatically switches OFF due to high optical power reflected back to the laser.
HIGH	HIGH	LOW	Reserved
LOW	HIGH	HIGH	**System alarm** Laser protection system detects internal failure.
HIGH	HIGH	HIGH	Reserved

In the case of alarm activation the laser emission will be automatically switched OFF and internal Alarm flag will be set. To continue operation the internal Alarm flag should be reset.

Reset sequence:

The "Reset Sequence" depends on the pins configuration, the table below shows possible configurations and corresponding sequences.

N	EM/EE	Control (use line or RS-232)	Reset sequence
1	EE	line	drop to LOW for at least 2 µs both pins together
	EM	line	
2	EE	RS-232	send RS-232 command "Reset Alarms"
	EM	RS-232	
3	EE	line	drop to LOW pin EE and then send RS-232 command "Reset Alarms"
	EM	RS-232	
4	EM	line	drop to LOW pin EM and then send RS-232 command "Reset Alarms"
	EE	RS-232	

If the reason of alarm condition is removed, alarm outputs (pins 11, 16 and 21) will be recovered to the normal state simultaneously with the reset.

Back reflection alarm: Alarm resets not earlier than in 1 s after activation.

Laser is not ready for emission state: Laser is not ready to emit power. That may be a result of non-correct laser operation control sequence or not correct power supply voltage. The Reset sequence is required to clear this status. The laser could be also not ready during warmup and switching the APD modes. In that case Reset sequence is not required.

If safety discharge monitoring feature is activated, failure of discharge circuit will block laser emission and permanently put laser into 'Laser not ready' state.

Permanent System Alarm: check the Critical Errors counter using RS-232. In case the counter value is increased, contact the factory. Critical error can be cleared only with a reset code received from the factory.

Pin 15	5Vout

Pin 15 provides +5 V DC output with current up to 80 mA that can be used for auxiliary supplying user electronics communicating with the laser DB-25 control interface.

Pin 17	5VRG

Pin 17 is the input for the red guide power supply. The customer may supply +5±0.25V to this pin to operate the guide laser without supplying of +24V Main or HK. The laser electronics, except the guide laser section, is completely off.

Pin 18	EE

Pin 18 is the Emission Enable (EE) signal. The Emission Enable input should be switched ON at least 10ms before switching ON the Emission. After switching ON Emission Enable input, the laser starts to consume more electrical power and emits residual optical power to the output even when EM (pin 19) is LOW. The optical power value (pulsed and CW parts) depends on model and operating mode of the laser. High contrast (HC option) ensures low leakage optical power.

Note: the EE switches ON simultaneously with the rising edge on the pin. If the HIGH level was applied EE before supplying electrical power to PCB, the Reset sequence after the warm-

up is required to start operation.

Pin 19 EM

Pin 19 is the Emission Modulation (EM) control input. Apply HIGH to switch ON the Emission and LOW to switch it OFF. The laser starts to emit optical power within specified delay after setting the pin to the HIGH level and stops to emit within specified delay after setting to the LOW level. Refer to the laser optical specification for the laser average power rise and fall times. Modulation with a period shorter than sum of the rise and fall times (the laser response time) may lead to a non-adequate laser power behavior and optical over/undershoot.

Note 1: The laser may not emit power during 10ms after setting EE to HIGH. Be sure that EE is switched ON at least 10 ms before switching ON EM.

Note: the EM switches ON simultaneously with the rising edge on the pin. If the HIGH level was applied EM before supplying electrical power to PCB, the Reset sequence after the warm-up is required to start operation.

Pin 20 Sync

Pin 20 is the Synchronization input (External Trigger). Pulse train with a repetition rate (PRR) within specified operating range should be applied to the pin (refer to the optical specification for PRR limits). Laser pulses are triggered by the rising edge of the signal. Minimum positive pulse width should be longer than 500 ns. If the PRR over 2 MHz is specified for the laser and needed for operation, internal generator should be used instead of external PRR at Sync input.

Note: In case the PRR supplied being out of the specified range (or no PRR signal is supplied) the laser safety circuit substitutes missing pulses or limits the PRR.

Pin 22 RG

Pin 22 is the guide laser (red diode/ pointer) control line. Apply HIGH to switch the guide laser ON and LOW to switch the guide laser OFF. If the guide laser option is not installed, pin 22 can either be connected to ground (pin14) or left floating.

Note: the laser emission is not allowed simultaneously with the guide laser operation. MO and Booster are blocked internally during the guide laser operation. If the Emission Modulation and/or Emission Enable were set to HIGH level during guide laser operation, the laser will not emit power, and will not start to emit it even after switching OFF the guide laser. It is necessary send Reset sequence to continue operation. Until the reset is done the state "Laser is not ready for emission" will be active on appropriate alarm/status pins.

Pin 23 AuxOFF

Pin 23 is the "Auxiliary stop" input. It should be set to HIGH for normal operation. In case of dropping this pin to LOW state (even for a short period) the laser automatically switches OFF optical stages (similar state when both EE and EM are OFF) independently on other control signals. To recover normal operation the Reset sequence is needed. Pin 23 should be set to HIGH at least 2μs before supplying ON signals to EE and EM pins.

Pin 10, 12, 13, 14 and 24 Synchronous serial interface (SPI-like bus)

These lines of DB-25 connector may be used for laser parameters setting and monitoring using serial communication. Digital interface may be activated or deactivated. Details of using the interface are described in the section **DB-25 Serial Interface Structure and Signals Description**. The interface is designed to control selected laser parameters directly via DB-25 lines. It is recommended for use in case RS-232 configuration interface is too slow or not convenient for operation.

Laser operation using Digital Interface.

1. Remove the protective cap from the laser output optical head and make the appropriate beam termination.

2. Connect the laser module to the control system via DB-25 connector. Drive pins according to the description above.

   Note: IPG USB based remote control may be used to simulate control lines using IPG PC utility.

3. Recommended initial state of control lines:

EE, EM, RG	LOW
AuxOFF	HIGH (stays always HIGH, not shown on diagrams below)
Sync	PRR within specified range

4. Connect power supply sources (housekeeping and main) to the laser.

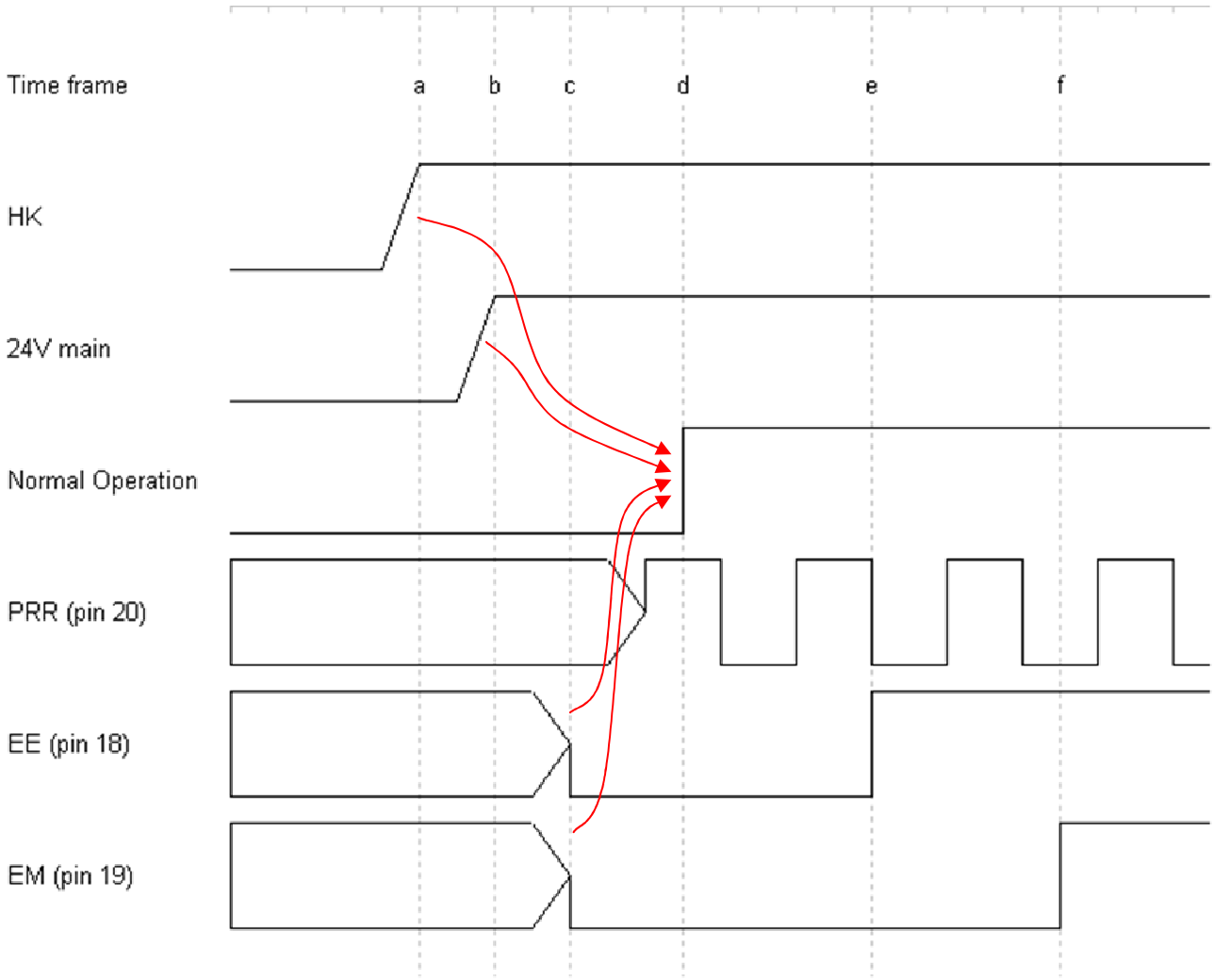
5. In 10 seconds after supplying HK and after 0.5s after supplying +24V Main the warm up phase is complete and the laser is ready for operation.

   Note: HK may be supplied after or before powering lines of the DB-25 interface.

6. Set desired power via D0-D7, latch it using Latch line to store the power settings into the laser.

7. Switch the EE ON applying HIGH to the EE input.

8. Wait for 10 ms, power ON sequence diagram is below.



Timing requirements:

a (HK) to d (Normal Operation status) max 10 s

a (HK) to b (24V main) should zero or positive

b (24V main) to d (Normal Operation status) max 0.5 s

c (EE input) to d (Normal Operation status) max 2 µs

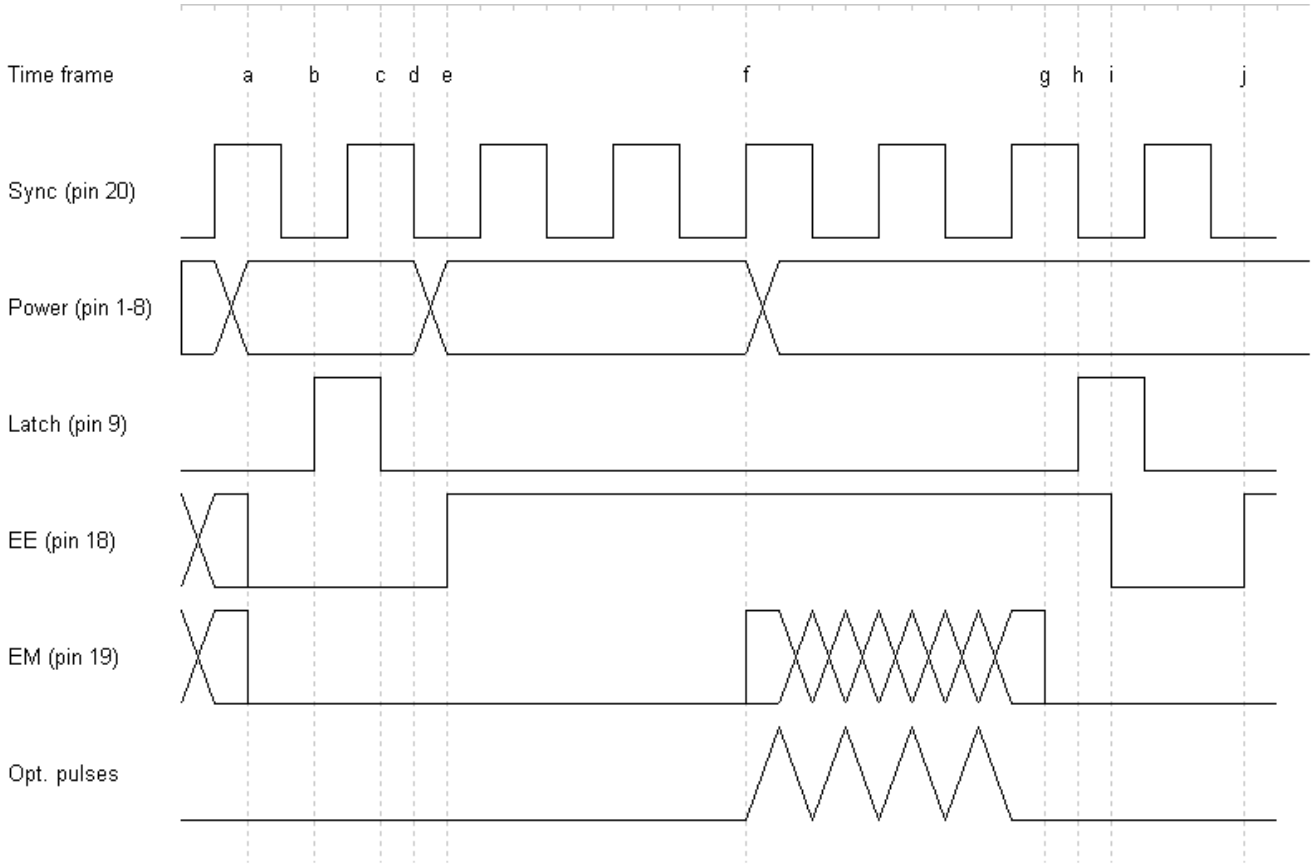
c (EM input) to d (Normal Operation status) max 2 µs

c (EE input) to e (EE input) should be min 2 µs, initialization reset

c (EM input) to e (EM input) should be min 2 µs, initialization reset

c (EM input) to f (EM input) and c (EE input) to e (EE input) overlapping of LOW state should be min 2 µs, initialization reset

9. The Laser is ready for a fast modulation via EM input. Set HIGH and LOW sequence to switch the laser ON and OFF correspondingly. The laser has finite ON/OFF response rise/fall times (refer to the specification for the particular model). The speed of the modulation should not be faster than sum of rise and fall times, otherwise laser optical response may not be as expected. Sequence diagram is shown below.



Timing requirements:

a (D0-D7) to b (Latch) should be min 1µs

b (Latch) to d (D0-D7) should be min 1µs

b (Latch) to c (Latch) should be min 2µs, data are latched with rising edge

e (EE input) to f (EM input) should be >10 ms

b (Latch) to h (Latch) should be min 10µs

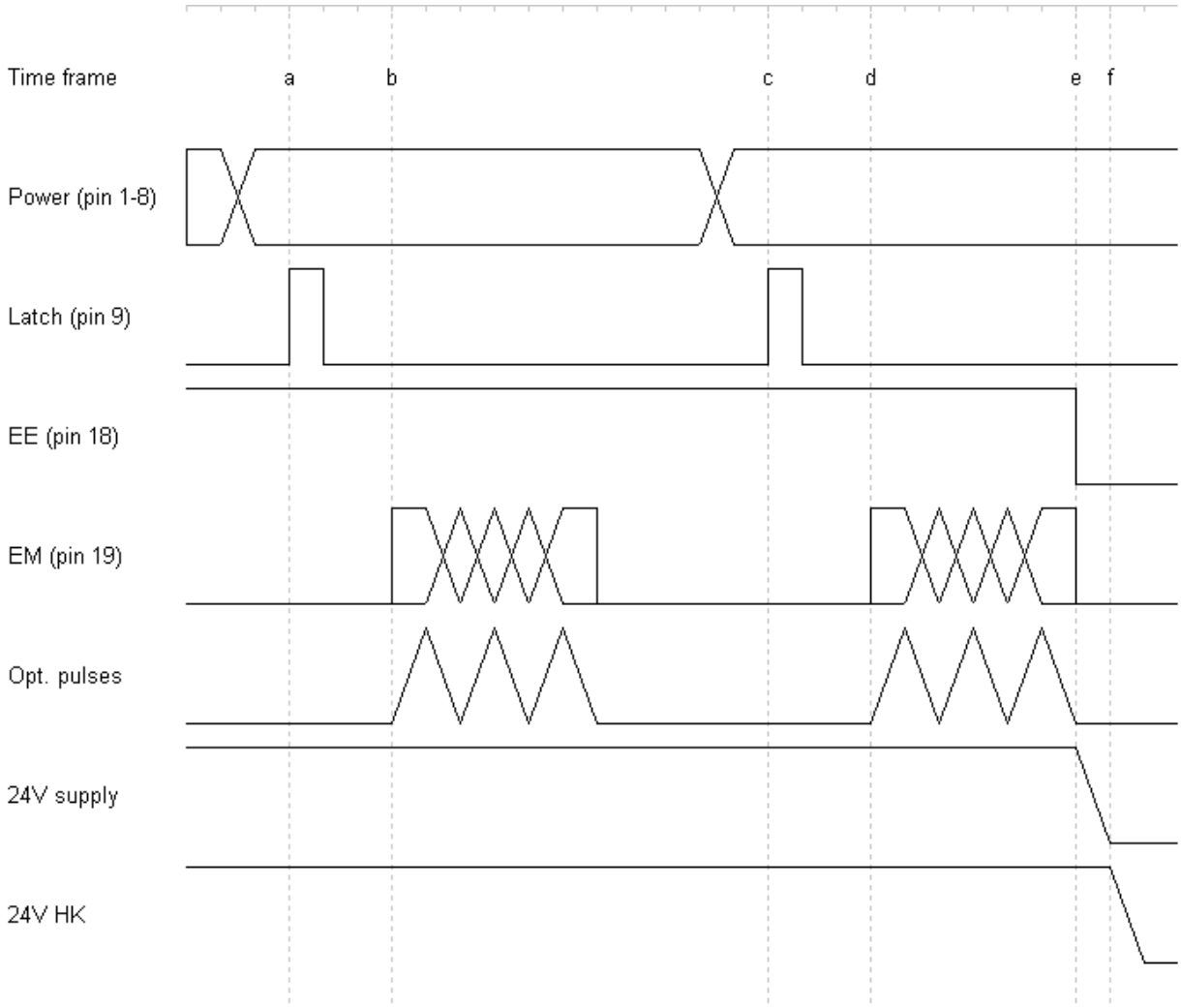
g (EM input) to i (EE input) should be min 1µs

i (EE input) to j (EE input) should be >5ms

10. If the EM OFF time between subsequent ON/OFF batches (jobs) is more than 500 ms, it is recommended to switch OFF EE. It will spare power consumption, avoid unnecessary wear out of the laser and exclude residual MO power at the laser output.

11. After finishing the laser operation, switch OFF the EM and EE.

12. Remove all supply voltages. It is recommended to remove HK together or later that 24V main. Below is a timing diagram for switching OFF sequence and setting the power.



Timing requirements:

a (Latch) to b (EM input) should be min 5 ms for guaranteed transition between any power set levels. Power transitions for smaller steps is faster (step 240< - >200 is faster than 240< - >180)

Switching OFF sequence: set e (EE and EM) to LOW, then switch OFF 24V main power supply

f (HK) should be switched OFF not earlier than e (24V main)

Operation Features.

1. In case PRR at Sync is higher than the maximum allowed PRR, the laser will operate at the maximum specified PRR. If the "master" PRR (Sync line) is lower than the minimum allowed PRR, the laser will operate at the minimum specified PRR.

2. The power setting can be changed during the laser operation by applying updated levels to D0-D7 and writing them into the laser using Latch.

3. If pins EM and EE are LOW, there is no laser radiation at the operating wavelength.

4. If the EE is ON and EM is OFF, there is a residual power at the laser output. The value depends on the laser model and the operating mode.

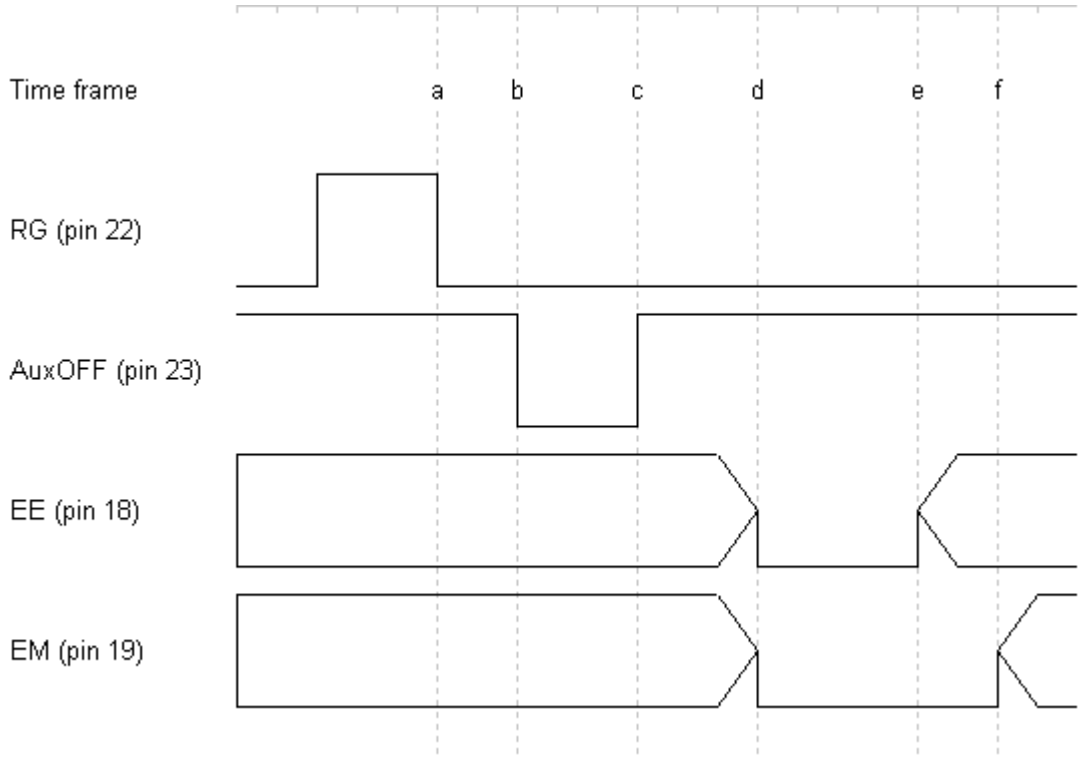
5. If the EE is ON, EM is ON and latched D0-D7 is 0x00 there is a residual power at the laser output. The value depends on the laser model and the operating mode.

6. Make sure that RG is connected to the ground or left floating if the guide laser is not in use. Connection to the HIGH level disables laser emission.

7. The laser automatically switches OFF emission, if the module temperature rises above or drops below specified maximum/minimum operating temperatures (for operating temperature range refer to the laser specification). The internal Alarm flags set and appropriate status signal combination appears on the State0, State1 and State2. The laser does not recover the emission and holds the alarm pins unchanged until the Reset sequence is sent. For devices with a remote Booster (power amplifier), this also relates to the remote head temperature.

8. The laser may have an internal back reflection sensor. It switches emission OFF if the reflected level is potentially dangerous for the laser. The internal Alarm flag is set and the appropriate alarm signal combination appears on the alarm pins 11, 16 and 21. The laser does not recover the emission and holds the alarm pins unchanged until the Reset sequence is sent. Emission is possible in one second after the alarm was emerged.

9. The laser requires reset sequence to clear "alarm" state. See Reset sequence section for sequence description. Below is the diagram for demonstrating reset sequence after the RG and AuxOFF operation.



Timing requirements for reset after the guide laser operation:

a (RG) to e (EE input) should be min 2 µs

a (RG) to f (EE input) should be min 2 µs

d (EE input) to e (EM input) and d (EM input) to f (EM input) LOW state should overlap for min 2 µs

Timing requirements for reset after AuxOFF activation:

c (AuxOFF) to e (EE input) should be min 2 µs

c (AuxOFF) to f (EE input) should be min 2 µs

d (EE input) to e (EM input) and d (EM input) to f (EM input) LOW state should overlap for min 2 µs

Operating modes and options

1. The laser may be equipped with options and control modes, which extend and/or change laser operation. List of installed options may be read by RS-232 interface using appropriate command. Options availability depends on the laser model, refer to the laser specification.

   Below is the list of options.

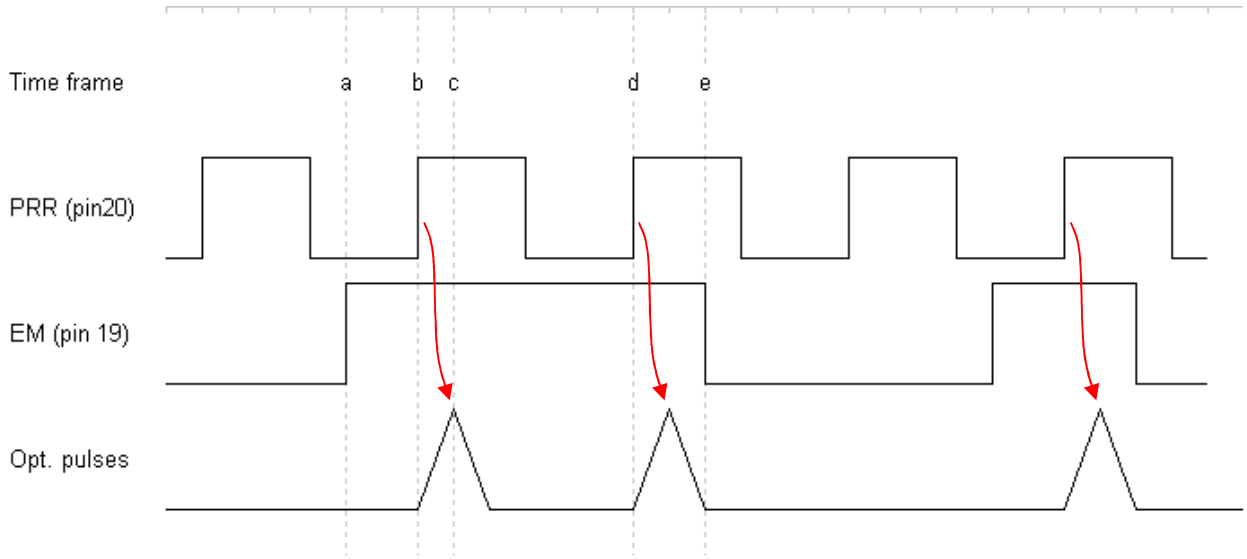
Option/ Mode	Description	Customer configurable
RS-232	RS-232 control interface	no
HC	High Contrast	no
ExtPRR	Extended Pulse Repetition Rate	no
BS1	Bitstream 1 mode	yes
APD	Adjustable Pulse Duration mode	no
Manual Pre-pump	Manual rising time compensation	yes
PRR change	Method of synchronization between laser pulses and external PRR	yes
Guide laser safety	Guide laser power limiting function (fail safe)	yes
Safe emission stop	Main emission stop by monitoring of internal capacitors discharging	yes

2. **"RS-232"** interface allows controlling the laser via RS-232 port. The control lines may be configured for control via RS-232 one independently. Also extended laser monitoring is available through this interface.

3. **"HC"** high contrast option ensures low power leakage if the Emission Modulation signal is LOW and Emission Enable signal is HIGH. For a laser not equipped with this option there is a power leakage at the output, with the value depending on the laser model. If BS1 operating mode is activated, a CW residual power may be emitted in HC mode.

4. **"ExtPRR"** Extended PRR option allows to operate with the PRR lower than nominal (refer to the specification for details). Average power is proportionally reduced while operating at PRR is less than nominal, so that the pulse energy is kept constant.

5. **"BS1"** Bitstream 1 operating mode allows fast emission modulation down to emission of single pulses. Assuming that the laser operates at a constant PRR, the EM signal can be used as a mask. Set EM to HIGH for the pulse emission and LOW to suppress the emission. BS1 option requires pre-pumping to prepare the laser for instant emission. This results in a leakage of a of CW power in case EE is HIGH. An example of a control diagram for BS1 is shown below.



Timing requirements:

a (EM) to b (Sync) should be min 0.5 µs for stable pulse clocking

d (Sync) to e (EM input) should be min 0.5 µs for stable pulse clocking

b (Sync) to c (Optical Pulses) is typically less than 2 µs

6. **"APD"** Adjustable pulse duration option allows user to choose shape and duration of the optical pulse from the preinstalled discrete set. The set of preset optical pulse shapes is defined in the device specification and is calibrated at the factory. Please note that operating parameters of the laser like maximum energy and average power may change with the pulse shape (refer to the device specification for detail). The option can be controlled either via RS-232 or via DB-25 serial interface.

7. **"Manual Prepump"** This option allows to set the emission ON ramping compensation manually instead of factory calibration. Manual ramping compensation may be useful for compensation of galvo speed acceleration. The energy of first pulses after switching ON emission modulation varies by adjusting the prepump value. Higher prepump value corresponds to higher energy of first pulses. The prepump value should be adjusted for each

operating parameters set point: namely the PRR, the power settings and the pulse duration. The prepump maximum value is 10000.

8. **"PRR change"** The option includes set of control options that define how the internal PRR reacts to the external PRR change. Only one of the following options could be activated at a time. Options availability depends on the laser model, refer to the laser specification.

Option/ Mode	Description
Follow PRR	Internal generator continuously follows frequency and phase of the Sync line.
Jump PRR	When PRR at Sync line jumps, laser turns emission OFF for 4 ms and then restarts it again
Sweep PRR	When PRR at Sync line jumps, the laser starts to pull the internal PRR and phase to new PRR

Pulse repetition rate of the optical pulses can be changed during the laser operation by applying different PRR to Sync line. The laser has its own internal frequency generator. Internal generator is a "slave" circuit controlled by "master" pulses applied to the Sync line. If Sync line is disabled, the frequency of the internal generator is set via RS-232 control interface.

Note that PRR change may affect output pulse energy. In that case a transient effect with intermediate energy of optical pulses may take place up to several milliseconds after the PRR stabilization. In case the transient effect is not desired, switch off MO before the PRR change.

Control circuit attempts to synchronize frequency and phase of "slave" optical pulses with "master" pulses at Sync line by an appropriate change of frequency of the internal generator. The internal frequency generator ensures the laser within specified PRR range. Operation of the internal "slave" generator depends on the selected mode..

FollowPRR. The internal generator continuously follows frequency and phase of the Sync line. The slave frequency is still limited to PRR range of the laser.

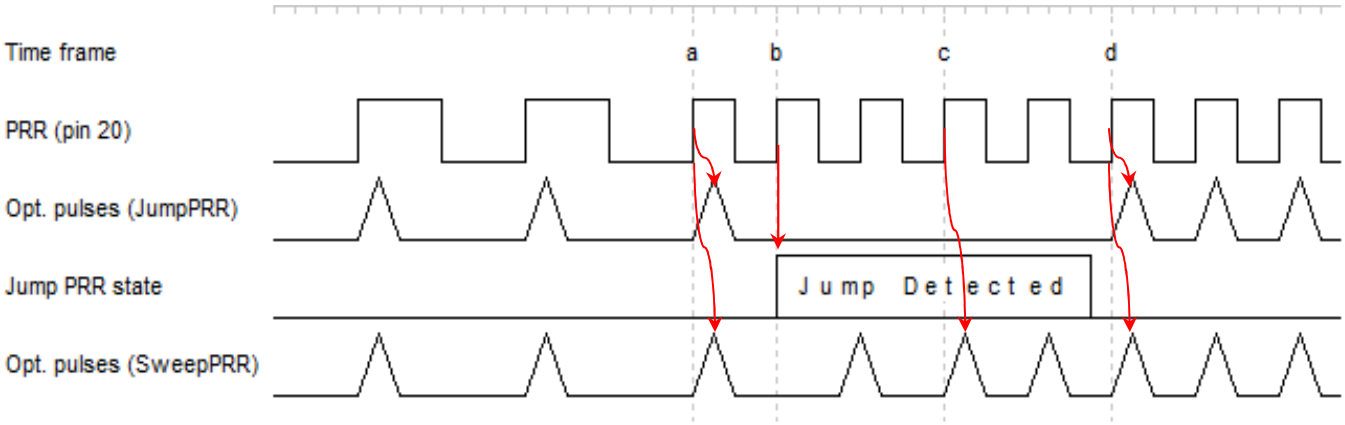
JumpPRR. If the period of the Sync line jumps ones by less than 50 %, compared to the previous period, the internal "slave" generator follows the Sync line. If the period of master pulses is jumped ones by more than 50 % or period of two or more consequent pulses is not stable, a "frequency jump sequence" may be initiated to protect the laser During the "frequency jump sequence", the laser switches off emission for 4 ms (see the

diagram below). During "frequency jump sequence" the "slave" generator adjusts its PRR and phase to new PRR on Sync line. The laser restarts emission automatically. Note that a transient effect in optical pulses may take place over several milliseconds after the stabilization of new PRR on Sync line.

JumpPRR mode is convenient when a synchronization of the laser PRR and phase to external source, e.g. galvo scanner mirror, is required.

SweepPRR. Internal "slave" generator continuously attempts to synchronize PRR and phase to Sync line input. To protect the laser from a fast frequency change, the speed of the internal frequency drift is always limited to approximately 1 octave (2 times) per 1 ms.

This mode avoids interruption of the laser emission (like in Jumps of PRR mode) in case of unstable signal on Sync line.



Laser operation in JumpPRR and SweepPRR modes during Sync line period jump

9. **"Guide laser safety"** The laser contains a circuit for safely limiting the guide laser power to ensure that it does not exceed a specified limit.

   In case of malfunction: the corresponding status bit is set for both activated and not activated option. For activated option commands to switch on the emission of the red guide laser are disabled.

   Note: the option must be activated to enable functionality.

10. **"Safe emission stop"** The laser contains electrical capacitors, which store the energy and may be a source for the laser emission.

The laser incorporates an internal discharge circuit which safely discharges internal capacitors within 200 ms (in case of failure within 400 ms) after disconnecting the main +24V supply line. After 200 ms no laser emission is possible.

The laser allows external discharge of internal capacitors by forced dropping the +24V main supply voltage. In case the +24V line voltage is less than 0.5 V (relative to return wire) no laser emission is possible. The customer is responsible for a discharge circuit design and the voltage monitoring. Time to reach zero emission state with external discharge circuit may be significantly reduced in comparison with built-in 200 ms discharge circuit.

The laser +24V housekeeping line may be always powered, it does not affect to the functionality of safety discharge circuit.

In case of malfunction: the corresponding status bit is set both for activated and not activated option. For the activated option commands to switch on the main emission are disabled and the laser is permanently held in the "Laser is not ready for emission" state.

Note: the option must be activated to enable functionality.

DB-25 Serial Interface Commands Structure and Signals Description

DB-25 serial interface contains 4 signal lines, refer to the pin assignment table.

Use Serial Input (pin 10) to send commands from the control system to the laser and Serial Output (pin 12) to receive a reply from the laser. Seed clock signal to Serial Clock (pin 13) to use the Serial Interface. All command described below should be sent in binary code and most significant bit (msb) should be transmitted first.

User command structure to send to the laser:

0xA5	Command code	Optional Parameter (msb first)

Laser reply structure:

0xA5	0xA5	Optional Parameter (msb first) or 0xA5

0xA5 (A5h) – is a prefix. All subsequent data bits received by the laser Serial Input (pin 10) are recognized according to the command structure described above. Laser sends reply to the Serial Output (pin 12) simultaneously (see timing diagrams below).

A length of a packet to the laser depends of the command code (see the table below)

The second byte of the message to the laser is a command (for example, 0x05). The rest of the message contains parameters (big endian order if more than one byte is transmitted).

Serial Enable signal (pin 24) should be set to HIGH at least 10 µs before transition on serial signal lines and hold HIGH at al least 10 µs after the transition is finished (see diagrams below).

For all commands device returns a sequence starting with the prefix 0xA5.

Reply data are valid with rise of SCLK signal (diagrams time tick "c").

It is recommended to drop EE and EM lines to LOW before using the serial interface.

DB-25 Serial Interface Command Codes

Type	Command	Command code	Parameters or return values	Description/Parameters
Read	Get APD mode max Index	0x05	Binary, one byte	Gets maximum index for APD mode. Integer, range 0…15
Write	Set APD mode Index	0x06	Binary, one byte	Sets APD mode by index
Read	Get APD mode Index	0x07	Binary, one byte	Gets current APD mode by index, which was set by command 0x06 or $69 (RS-232)
Write	Set Prepump	0x10	Binary, two bytes	Sets manual prepump. Integer, range 0…10000
Read	Get Prepump	0x11	Binary, two bytes	Gets manual prepump, which was set by command 0x10 or $64 (RS-232)

The Manual Prepump value is stored in non-volatile EEPROM memory and is used for subsequent operating sessions.

Changing the pulse duration may require several hundred milliseconds. During the command execution the DB-25 status "Laser is not ready for emission" is active.

Note: in case the APD mode index sent by 0x06 command is not supported by the laser, it will be ignored. Refer to the laser specification or the User's guide for a list of the acceptable parameters.

DB-25 Serial Interface Timing diagrams

Below is a sample timing diagrams (diagram 1 Clocks 1 to 16 and diagram 2 Clocks 17 to 24) for setting the APD mode index to 5 using command 0x06.

Command sequence is as follows: 0xA5/0x06/0x05, return sequence is 0xA5/0xA5/0xA5.

Diagram 1

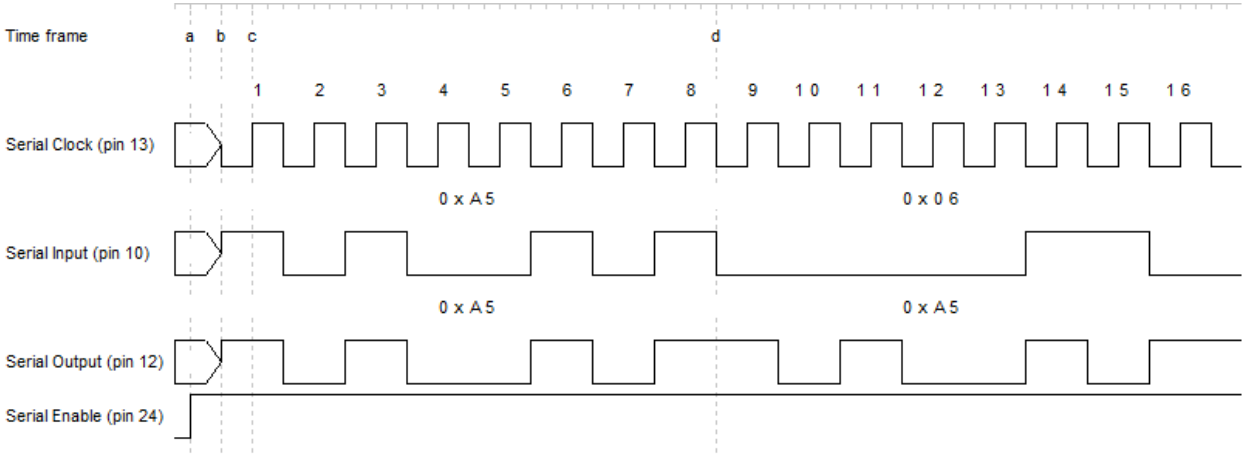
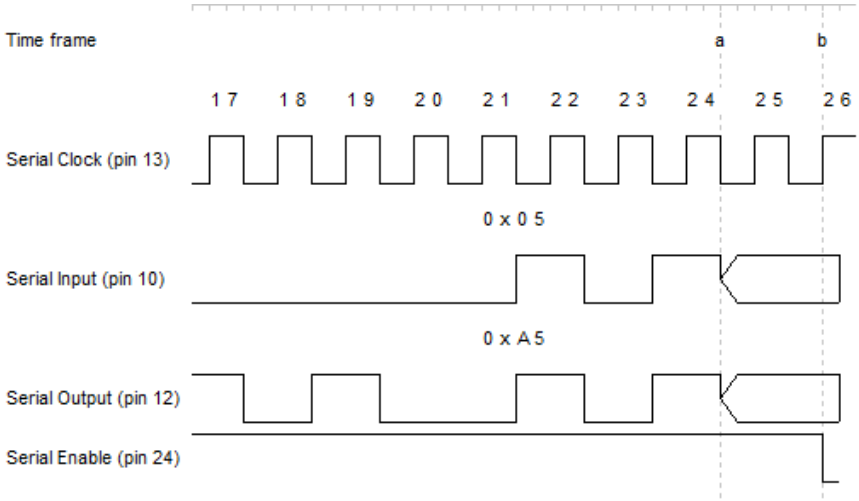


Diagram 2



The command parameter is a binary value of APD mode index.

Below is a sample timing diagrams (diagram 3 Clocks 1 to 16 and diagram 4 Clocks 17 to 24) for reading the APD mode index using command 0x07. Command sequence is 0xA5/0x07, return sequence is 0xA5/0xA5/0x05, which corresponds to APD mode index 5.

Diagram 3

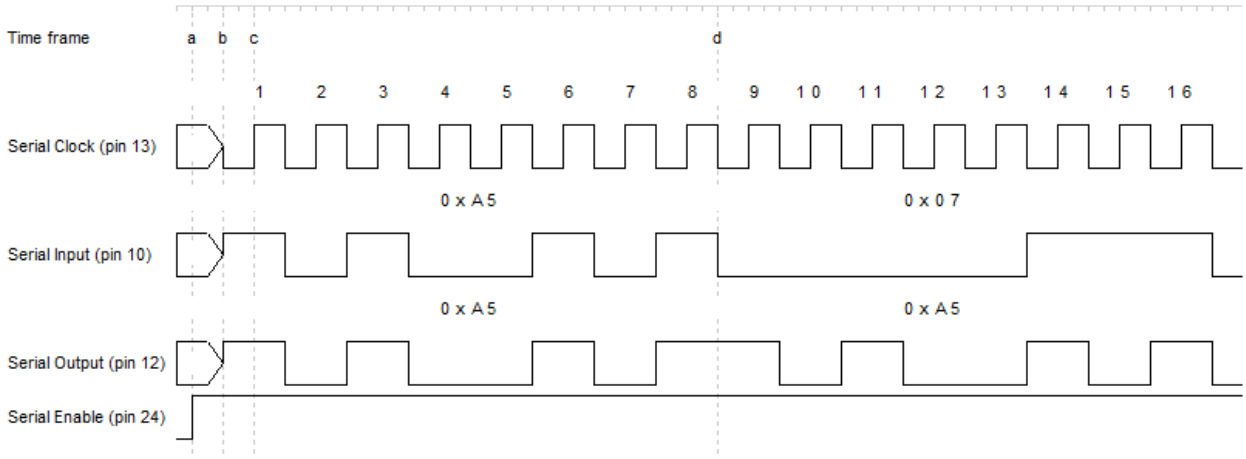
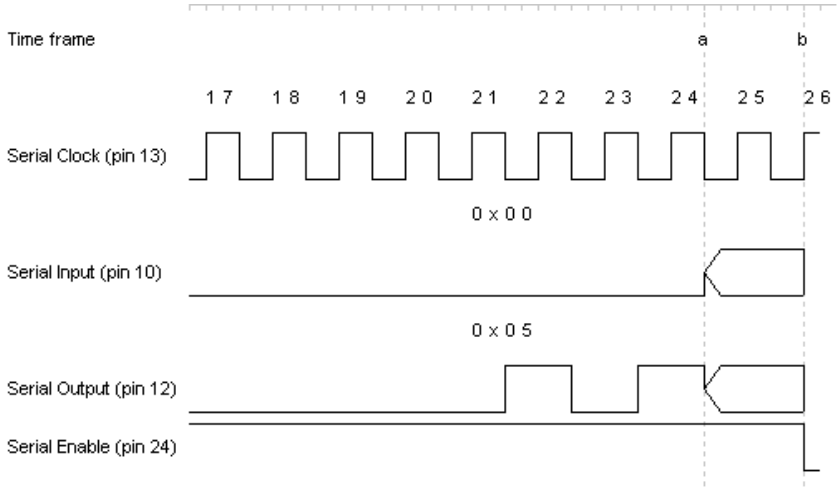


Diagram 4



Below is a sample timing diagrams (diagram 5 Clocks 1 to 16 and diagram 6 Clocks 17 to 32) for reading the Manual Prepump setting using command 0x11. Command sequence is 0xA5/0x11, return sequence is 0xA5/0xA5/0x02/0xEC, which corresponds to the Manual Prepump setting 748.

Diagram 5

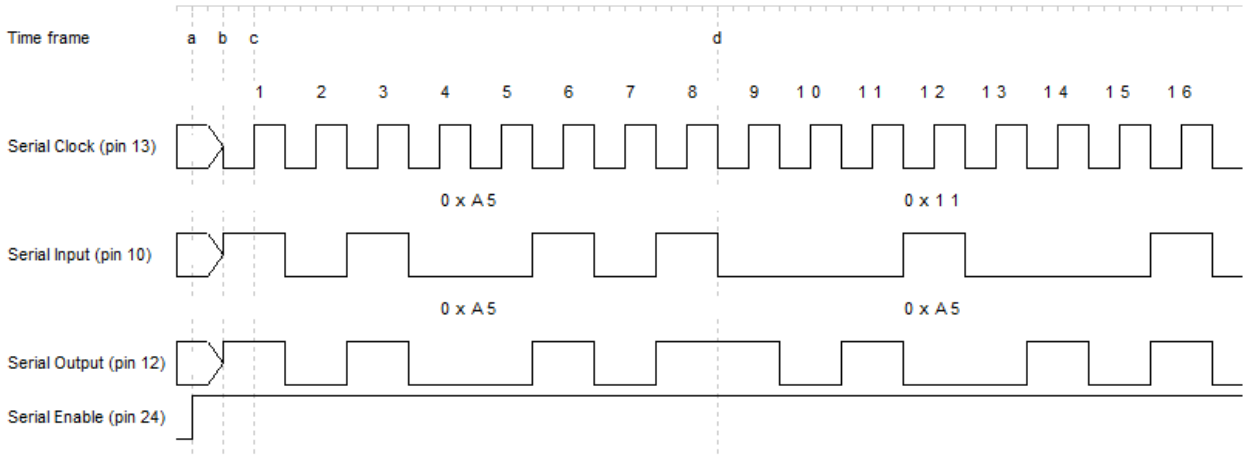
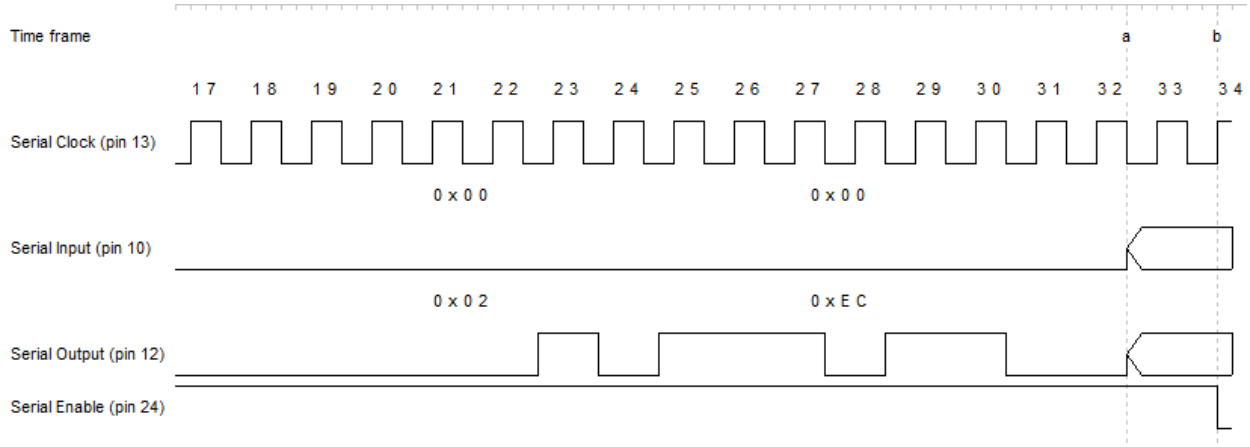


Diagram 6



RS-232 electrical connector

RS-232 connector is the DB-9 type plug (male). The RS-232 interface is galvanically isolated from the internal laser ground and digital interface. This helps to avoid major problems associated with current loops in complex interface interconnections.

Pin assignment is shown in the table below and is standard for communication with a PC COM port. Use crossed RS-232 cable to link the laser and a PC.

PIN No.	Description
1, 4, 6-9	Not connected
2	RxD, receive
3	TxD, transmit
5	Interface ground, galvanically isolated (floating) from the laser internal ground

RS-232 Command Structure Description

1. Initialization of RS-232:

   baud rate: 57600 bits per second

   parity / flow control: none

   start / stop bits: 8 data bits, 1 start bit and 1 stop bit

2. Firmware command structure (ASCII codes for symbols):

$	Command code	; (semicolon)	Optional parameters separated by semicolon	CR symbol (hexadecimal 0x0D)

3. Laser reply structure:

Command code	; (semicolon)	Return values separated by semicolon	CR symbol (hexadecimal 0x0D)

4. The command code is a decimal ASCII representation of a number individual for each command. The list of command numbers is shown in the table below.

5. Command parameter is a text string. If the parameter is a numerical value, it should be converted into a decimal ASCII string.

6. The returned value is also a text string. If the requested value is numerical, the opposite conversion from text string to the numerical value is required.

7. All commands should be terminated by "Carriage Return" symbol, hexadecimal value "0x0D". The RS-232 buffer of the laser receives bytes until the CR symbol occurs. All bytes before this symbol are interpreted as a command. Bytes after CR until next CR will be interpreted as a next command.

8. For all "set" commands device returns as the parameter "Y" if the command was successfully executed and "N" if the command was not executed.

9. For all strings sent to the laser, which were not recognized as valid commands, the laser sends "E" as parameter. In case an option is not applicable for a particular laser the command could answer "E".

10. After switching on electrical power the device RS-232 settings are initialized as following:
    Pulse repetition rate: nominal PRR
    EE and EM are in OFF state
    Set power is zero
    Last saved in EEPROM laser configuration

11. Some of the control signals could be configured for DB-25 control. In that case:
    respective RS-232 control commands will return "N
    respective RS-232 read commands will return an actual parameter value

12. Some of the control signals could be configured for RS-232 control. In that case:
    respective DB-25 lines or DB-25 Serial Interface control commands will be ignored
    respective DB-25 Serial Interface read commands will return an actual parameter value

RS-232 Command Codes.

List of commands for laser monitoring and configuration.

Type	Command	Command code	Parameters or return values	Description/Parameters
Read	Device ID	1	string, up to 64 char	Read device identifier written to the laser in the factory
Read	Device SN	2	string, up to 24 char	Read device serial number
Read	FW revision	3	string, up to 255 char	Read device firmware revision
Read	Vendor	99	string, up to 255 char	Read device vendor written to the laser in the factory
Read	Device Status	4	up to 32 bit integer	Read device status, decimal to binary decoding is required
Read	Device temperature	5	float, 1 digit after point	Read module temperature in degree Celsius
Read	Digital interface Status	10	up to 32 bit integer	Reads digital interface status, decimal to binary decoding is required
Read	Extended Status	11	up to 32 bit integer	Read device extended status, decimal to binary decoding is required
Read	BR Counter	12	up to 32 bit integer	Read back reflection counter
Read	Session BR Counter	13	up to 32 bit integer	Read back reflection counter for the current session. The session starts with supplying voltage to the laser module.
Read	Nominal average Power	14	float, 1 digit after point	Read nominal average power of the laser in [W] Return value is float in [W].
Read	Nominal Pulse Duration	15	float, up to 6 digits after point	Read nominal pulse duration of the laser [ns]
Read	Nominal Pulse Energy	16	float, 2 digit after point	Read nominal pulse energy of the laser [mJ]
Read	Nominal Peak Power	17	float, 1 digit after point	Read nominal peak power of the laser in [kW]. Value is calculated from the nominal energy and the nominal pulse duration.
Read	PRR Range	18	see description	Read pulse repetition rates range. Return value is two floats separated by a semicolon, corresponding to minimum and maximum PRR [kHz].

Type	Command	Command code	Parameters or return values	Description/Parameters
Read	Head Temperature	19	float, 1 digit after point	Read remote head temperature in degree Celsius, if the head is installed
Read	Main Supply Voltage	21	float, 1 digit after point	Read main 24V supply voltage in [V]
Read	24V Housekeeping Voltage	22	float, 1 digit after point	Read 24V housekeeping supply voltage in [V]
Read	Operating Mode	23	32 bit integer	Read active control interface operating mode, decimal to binary decoding is required.
Set	Operating Mode	24	32 bit integer	Set active control interface operating mode, binary to decimal encoding is required. The command parameter is validated before the execution. In case some bits are not correct, the command is not executed. All 32 bits (even unused) should have corrects values. To set correctly all bits, the existing operating mode should be read by the command 24, only necessary bits should be updated and then new value sent to the device.
Read	Installed Options	25	32 bit integer	Read list of installed options and operating modes, decimal to binary decoding is required
Set	Start Operating Mode	26	32 bit integer	Set initial control interface operating mode, binary to decimal encoding is required. This mode becomes active after supplying the laser with electrical power. Value is stored permanently in the laser EEPROM.
Read	Start Operating Mode	27	32 bit integer	Read control interface operating mode, which activates after connecting the laser to the supply voltage. The value is stored permanently in the laser EEPROM, decimal to binary decoding is required
Read	Operating Power [W]	33	float, 2 digit after point	Read back operating power in [W] set by command 32 (in RS-232 mode) or via digital interface (in DB-25 mode), but recalculated into Watts using nominal laser parameters.
Read	Operating Power [%]	34	float, 2 digit after point	Read back operating power in [%] set by command 32 (in RS-232 mode) or via digital interface (in DB-25 mode).
Read	Operating Pulse Energy	36	float, 2 digit after point	Read operating pulse energy in [mJ]. Value is calculated using nominal laser parameters and power settings.
Read	PRR monitor	38	float, 1 digit after point	Read back operating PRR in [kHz] set by command 28 (in RS-232 mode) or applied via Sync input of digital interface (in DB-25 mode)

Type	Command	Command code	Parameters or return values	Description/Parameters
Read	Alarm counters	70	16 bit integer	Read alarm counters. The command contains a parameter which specifies the alarm counter: 1 – 24V main supply 2 – 24V housekeeping supply 3 – System 4 –Temperature 5 –Head Temperature
Read	Module Temperature range	58	float, 1 digit after point	Read operating temperature range. Return value is two floats separated by a semicolon, corresponding to minimum and maximum temperatures in degree Celsius.
Read	Nominal frequency	59	float, 1 digit after point	Read back nominal PRR in [kHz]
Read	Critical error counter	95	16 bit integer	Read critical error counter
Read	Critical error code	96	32 bit integer	Read critical error code
Set	Reset critical error alarms	97	32 bit integer	Reset the critical error. The command contains one parameter, which is a one-time use code generated in IPG factory. In case the correct code is sent to the device, the command is executed with answer "Y" and critical error is cleared.

List of commands for RS-232 control interface.

Type	Command	Command code	Parameters or return values	Description/Parameters	Equivalent DB-25 control line
Set	Set PRR	28	float, 1 digit after point	Set operating pulse repetition rate in [kHz]	Sync
Read	Read PRR	29	float, 1 digit after point	Read back operating pulse repetition rate in [kHz] set by command 28	
Set	Laser Emission ON	30		Switch ON laser emission	EM
Set	Laser Emission OFF	31		Switch OFF laser emission.	
Set	Operating Power	32	float, 1 digit after point	Set operating power in [%]. Range 0…100, resolution 255 levels for the full scale	D0-D7 & Latch
Set	Guide Laser ON	40		Switch ON guide laser	RG
Set	Guide Laser OFF	41		Switch OFF guide laser.	
Set	EE ON	42		Switch ON Emission Enable	EE
Set	EE OFF	43		Switch OFF Emission Enable	
Set	Reset Alarms	50		Reset alarms, see alarms description for details	Reset Sequence

Most of DB-25 connector pins can be individually configured to be controlled by an equivalent RS-232 command. In case the pin is configured to be controlled via DB-25 interface, appropriate RS-232 control command is not executed. Every "ON" command sent by RS-232 is equal to the HIGH state of corresponding control pin and "OFF" command is equivalent to the LOW state. Taking this into consideration, all control logic described for the interface control pins remains unchanged in terms of RS-232 commands.

Note 1: Command $42 "EE ON" cannot activate laser if the status bit "Laser is ready for emission" is not HIGH. In this case the reason of the not ready state (like active state of guide laser, etc.) should be eliminated and reset sequence should be applied to clear "not ready" state.

Note 2: Optical output power is nearly proportional to the set operating power (see specification for the power adjustment range). In case the specified laser power adjustment range is limited (typically 10…100%), the optical output power in the unspecified range (typically 0…10%) may not correspond to a set power value. A power leakage with zero power settings as well as a nonlinear response to set power is possible.

List of commands for Adjustable Pulse Duration (APD) mode.

Type	Command	Command code	Parameters or return values	Description/Parameters
Read	Read the number of APD modes	55	16 bit integer	Read number of APD modes (N)
Read	Read APD mode description	56	Parameter: M Answer: string, up to 128 char	Read a text description of APD mode with index M. Parameter is M is APD mode index, integer, range 0 to N-1. N is number of APD modes read by command $55
Read	Read APD mode index	68	16 bit integer	Read current APD mode index.
Set	Set APD mode index	69	16 bit integer	Set APD mode index.
Set	Save APD mode index	54		Permanently save the APD mode index to EEPROM. Next start the device will be initialized by saved APD mode index.

All commands from the APD mode section are executed only in case the option is installed in the device.

List of commands for Manual Rising Time Compensation (Manual Prepump) mode.

Type	Command	Command code	Parameters or return values	Description/Parameters
Read	Maximum Prepump	63	16 bit integer	Return maximum value of the prepump compensation. The value is always 10000.
Set	Prepump	64	16 bit integer	Set the prepump compensation value. Range is 0…10000
Read	Prepump	65	16 bit integer	Read back value of the prepump compensation set by command $64 or through DB-25 serial interface

Command "$4" "Read device status"- return value interpretation.

Bit	State	Description
0	1 0	Rack reflection Alarm active No BR alarm
1	1 0	Temperature Alarm active. Laser module temperature is out of specified range. No temperature alarm
2	1 0	Temperature Alarm active. Laser remote head temperature is out of specified range. No temperature alarm
3	1 0	System Alarm active No system alarm
4	1 0	+24V main supply Alarm active. Overvoltage or Undervoltage of the main electrical supply occurred during the laser emission. No supply alarm
5	1 0	HK supply Alarm active. Overvoltage or Undervoltage of the 24V housekeeping electrical supply occurred during the laser emission. No supply alarm
6	1 0	Laser is ready for emission Laser is not ready for emission
7	1 0	At least one of the warnings is activated No warning is activated
8-10		Reserved
11	1 0	Malfunction of guide laser safety limiter circuit Guide laser limiter safety circuit operates normally (if activated)
12	1 0	Malfunction of safety discharge circuit Discharge safety circuit operates normally (if activated)
13-31		Reserved

Command "$10" "Read digital interface DB-25 status"- return value interpretation.

Return bits reflect status of the corresponding pins or internal data.
"1" means that pin/data is HIGH, "0" means LOW.

Bit	DB-25 Pin #	DB-25 Control Line	Description of Line/Data
0		Latched D0	D0 latched power setting
1		Latched D1	D1 latched power setting
2		Latched D2	D2 latched power setting
3		Latched D3	D3 latched power setting
4		Latched D4	D4 latched power setting
5		Latched D5	D5 latched power setting
6		Latched D6	D6 latched power setting
7		Latched D7	D7 latched power setting
8	1	D0	D0 power setting
9	2	D1	D1 power setting
10	3	D2	D2 power setting
11	4	D3	D3 power setting
12	5	D4	D4 power setting
13	6	D5	D5 power setting
14	7	D6	D6 power setting
15	8	D7	D7 power setting
16	9	Latch	
17	23	AuxOFF	Auxiliary Emission OFF
18	19	EM	Emission Modulation
19	22	RG	Guide laser control
20	20	Sync	External Synchronization Input
21	18	EE	Emission enable
22	10	Serial Input	
23	13	Serial Clock	
24	16	State0	
25	21	State1	
26	11	State2	
27	12	Serial Output	
28	24	Serial Enable	
29		Reserved	Bit is reserved for future use
30		Reserved	Bit is reserved for future use
31		Reserved	Bit is reserved for future use

Command "$11" "Read device extended status"- return value interpretation.

Bit	State	Description	Message Type
0	1 0	Emergency stop was activated Emergency stop was not activated	Warning
1	1 0	External PRR at Sync line is above specification Not above specification	Warning
2	1 0	External PRR at Sync line is below specification Not below specification	Warning
3		Reserved	
4		Reserved	
5	1 0	Guide laser was activated Guide laser was not activated	Warning
6		Reserved	Warning
7		Reserved	Warning
8	1 0	Laser emission is ON (laser is pumped) Laser emission is OFF (laser is not pumped)	Information
9		Reserved	
10		Reserved	
11	1 0	Laser emission ON command was received by RS-232 Laser emission OFF command was received by RS-232 This bit is valid in RS-232 control mode only	Information
12	1 0	Guide laser ON command was received by RS-232 Guide laser OFF command was received by RS-232 This bit is valid in RS-232 control mode only	Information
13	1 0	24V Main supply voltage is in specified range 24V Main supply voltage is not in specified range	Warning
14	1 0	HK supply voltage is in specified range HK supply voltage is not in specified range	Warning/ Information
15	1 0	Emission Enable is switched ON by RS-232 Emission Enable is switched OFF by RS-232	Warning Information
16-31		Reserved	

Operating modes commands – set/return value interpretation

Command "$23" "Read operation mode"

Command "$27" "Read start operation mode"

Command "$24" "Set operation mode"

Command "$26" "Set start operation mode"

Bit	State	Description	Equivalent DB-25 control line
0	1 0	Power control (D0-D7) by DB-25 Power control (D0-D7) by RS-232	1-8
1		Reserved	
2	1 0	AuxOFF control by DB-25 AuxOFF disabled	23
3	1 0	Guide laser control by DB-25 Guide laser control by RS-232	22
4-6		Reserved	
7	1 0	Emission Modulation control by DB-25 Emission Modulation control by RS-232	19
8	1 0	The laser is in Jump PRR mode Jump PRR mode is inactive	
9		Reserved	
10	1 0	Bitstream 1 (BS1) mode is active (to activate) Not active (to deactivate)	N/A
11		Reserved	
12	1 0	PRR controlled by Sync line in DB-25 Internal trigger generator by RS-232	20
13	1 0	Emission Enable control by DB-25 Emission Enable control by RS-232	18
14	1 0	APD mode is controlled by DB-25 serial interface APD mode is controlled by RS-232	
15	1 0	Automatic latch Latch control by DB-25	9
16-18		Reserved	
19	1 0	The laser is in Sweep PRR mode Sweep PRR mode is inactive	
20	1 0	The laser is in Follow PRR mode Follow PRR mode is inactive	
21	1 0	Manual Prepump mode is active Factory calibrated Prepump is active	
22	1 0	Manual residual is controlled by DB-25 serial interface Manual residual is controlled by RS-232	
23-24		Reserved	
25	1 0	Activation of guide laser safety function Guide laser safety function is not activated	
26	1 0	Activation of discharge circuit safety function Discharge circuit safety function is not activated	
27-31		Reserved	

The bits marked as "Reserved" in the structure above are used for internal laser control purpose and are not allowed to be changed by a customer. To preserve these bits first read the status from the laser and then change only required bits keeping other without modification.

Read options command

Command "$25" "Read installed options and operating modes"- return value interpretation.

Bit	State	Description
0		Reserved
1		Reserved
2		Reserved
3		Reserved
4	1 0	Adjustable pulse duration mode is installed Not installed
5		Reserved
6	1 0	Extended PRR mode is installed Not installed
7		Reserved
8	1 0	Jump PRR mode is installed Not installed
9		Reserved
10	1 0	Bitstream 1 (BS1) option is installed Not installed
11		Reserved
12		Reserved
13		Reserved
14		Reserved
15		Reserved
16	1 0	Guide laser is installed Not installed
17	1 0	HC (high contrast) is installed Not installed
18	1 0	Remote amplifier is installed Not installed
19	1 0	Sweep PRR mode is installed Not installed
20	1 0	Follow PRR mode is installed Not installed
21	1 0	Manual Prepump mode is installed Not installed
22-24		Reserved
25	1 0	Guide laser safety function is installed Not installed
26	1 0	Discharge circuit safety function is installed Not installed
27-31		Reserved