INTERFACING MANUAL

COMPex*Pro*® (RoHS)

LASER CONTROL SOFTWARE LCS V2.29

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1 INTRODUCTION

This Interfacing Manual is part of the instruction manual for the COMPex*Pro*® excimer laser device. The instruction manual is designed to familiarize the user with the COMPex*Pro* excimer laser device and its designated use. It contains important information on how to install, operate and service the laser device safely, properly and most efficiently. Observing these instructions helps to avoid danger, reduce repair costs and downtimes and increase the reliability and lifetime of the laser device.

The COMPex*Pro* excimer laser device is intended for use as a subsystem within a laser system (laser assembly or laser unit as defined in ISO 11145). Consequently, the instruction manual is to be used in conjunction with other instruction manuals that describe the complete system or further system elements. In addition, it is to be supplemented by the respective national rules and regulations for accident prevention and environmental protection.

The instruction manual for the COMPex*Pro* laser device is subdivided into the following self-contained manuals:

– User Manual

– Service Manual

– Interfacing Manual

– Site Preparation Manual.

Each manual has been prepared for a specific target audience and will be made available to this audience by Coherent, their authorized representative or the laser unit manufacturer (system integrator).

1.1 The Interfacing Manual

This manual describes the interfaces, message formats and commands required for communication with the COMPex*Pro* controller. This information is required when preparing a program to operate the laser device from an external (remote) computer control system.

The LCS laser control software (version 2.29) is based on a source software that is used with various excimer laser device configurations. Therefore, some commands available in the software may not specifically apply for the COMPex*Pro* laser device and are, consequently, not described in this manual.

For further information about the software control structure or hand-held keypad controlled laser operation, please refer to the separate User Manual.

1.1.1 Intended Audience

The Interfacing Manual is intended for all persons that are to prepare the installation of the COMPex*Pro* laser device, integrate the laser device into a laser processing system or prepare a program to operate the laser device from an external (remote) control system.

1.1.2 Availability and Use

The Interfacing Manual should be made available to all persons that are assigned with the installation or integration of the COMPex*Pro* laser device and particularly persons that are to prepare a communication link with the laser device.

1.1.3 Numbering of Chapters, Pages and Instructions

The pages of this manual are numbered continuously. The page number appears in the lower outside corner of every page.

The chapters are numbered continuously. The name of the chapter appears in the upper outside corner of every even page. Each chapter ends with an even page number. Consequently, certain even pages at the ends of chapters will be intentionally left blank.

Each step within a procedure is sequentially numbered. Each procedure starts with the step number one.

1.1.4 Typographic Conventions

The button description <ENTER> is used to describe the keyboard button marked or referred to as ENTER, ↵, RETURN, CR or CARRIAGE RETURN.

Commands to be entered through a keyboard are written in non-proportional lower-case letters.

– Example: Type `cd lambda`.

Programming commands for remote communication to be used literally are written in upper-case letters.

– Example: OPMODE=

Placeholders in commands or messages are written in italic letters.

– Example: OPMODE=*operating mode*
  A permitted command is to be used instead of the words operating mode.

Examples are written in non-proportional, upper-case letters to simulate the appearance of monitor displays or printer output.

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1.1.5 Trademarks

The trademarks used in this manual are the properties of their respective owners and are used for identification purposes only:

– Coherent and the Coherent Logo are registered trademarks of Coherent Inc., USA

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– SERTO is a registered trademark of Gressel AG, Switzerland

– Shockwatch is a registered trademark of Media Recovery Inc., USA

In the following sections of this manual, no mention is made of patents, trademark rights or other proprietary rights which may attach to certain words. The absence of such mention, however, in no way implies that the words in question are exempt from such rights.

1.1.6 Cited Standards

Unless otherwise stated, all technical standards cited in this manual relate to the latest version of the standard that is applicable at the date of the publication of this manual.

In many cases, cited international standards (ISO and IEC standards) have been adopted wholly or in part by national or regional standards authorities and are often known locally under the appropriate local designation. For instance, IEC 60825-1 (Safety of Laser Products) has been adopted by the European Committee for Standardization as EN 60825-1 and, in turn, by various national standards authorities as, for example, DIN EN 60825 (Germany) and BS EN 60825 (United Kingdom). The exact content, number and revision date of a national standard may, however, vary from that of the corresponding international standard. For further information, please contact the publisher of the respective national standard.

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1.2 Safety

1.2.1 Laser Safety Classification

IEC-60825-1, FDA 21 CFR 1040.10 and 1040.11 and ANSI Z-136.1 indicate the requirements and procedures that are to be followed to ensure the safe use of laser products. These standards and regulations classify each laser product according to the potential hazards arising in its use. In each case, the Laser Class indicates the accessible emission limit (AEL), i.e. the maximum emission level that humans can access.

The lowest Laser Class is Class 1 and the highest is Class 4:

– Class 1 laser products are laser products that are safe under reasonably foreseeable conditions of operation.

– Class 4 laser products are laser products that permit human access to emission levels that represent an acute hazard to the eyes and skin from direct and scattered radiation.

Within this classification, the COMPex*Pro*, as a stand-alone laser device, is a Class 4 laser product. It must, consequently, be regarded as a potential hazard to the human operator.

The laser beam must also be regarded as a potential fire hazard.

1.2.2 Safety Information

The Safety Chapter of the separate User Manual describes the physical hazards related to the excimer laser device, the means of protection against these hazards and the safety features incorporated in the design of the laser device. This chapter must be read by all persons entrusted with any sort of work on the laser device.

Never start to work on or with the laser device unless you have read and fully understood the information in the Safety Chapter!

1.2.3 Signal Words and Symbols in this Manual

The COMPex*Pro* documentation may contain sections in which particular hazards are defined or special attention is drawn to particular conditions. These sections are indicated with signal words in accordance with ANSI Z-535.2-2002 and ISO 3864-2:2004 and safety symbols (pictorial hazard alerts) in accordance with ANSI Z-535.3-2002 and ISO 7010:2003.

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1.2.3.1 Signal Words

Four signal words are used in the COMPex*Pro* documentation: DANGER, WARNING, CAUTION and NOTICE.

In this document, only the signal word “NOTICE” may be used. This indicates that there is the risk of property damage:

NOTICE
Addresses practices not related to personal injury.

1.2.3.2 Symbols

The signal words **DANGER**, **WARNING**, and **CAUTION** are always emphasized with a safety symbol that indicates a special hazard, regardless of the hazard level. As only the signal word “NOTICE” may occur in this manual, no safety symbols are used.

1.3 Laser Terminology

ISO 11145 (“Optics and Optical Instruments - Lasers and Laser Related Equipment - Vocabulary and Symbols”) contains a list of laser terminology (for more information, see the User Manual):

– Laser
  Consists of an amplifying medium capable of emitting coherent radiation with wavelengths up to 1 mm by means of stimulated emission.

– Laser Device
  A laser, where the radiation is generated, together with essential additional facilities that are necessary to operate the laser, e.g. cooling, power and gas supply.

To prevent misunderstandings, the COMPex*Pro* documentation strictly differentiates between “laser” and “laser device”. Thus “start laser device” means that the power is off and shall be turned on. To “start the laser” means to switch on the laser beam and start laser operation.

1.4 Conversion Table

Listed below are the units of measure used in this manual and their equivalents according to the SI standard:

1 meter (m)	=	39.37 inches (in)
1 meter (m)	=	3.28 feet (ft)
1 centimeter (cm)	=	0.3937 inch (in)
1 bar	=	100,000 Pascal (Pa)
100,000 Pascal (Pa)	=	14.50 pounds force per square inch (lbf/in^2)

1.5 Feedback Regarding Documentation

If you have any comments regarding the documentation provided to you, please contact us.

When you contact us, please provide us with:

– the document code,

– the date of issue,

– the page number, section number and, where applicable, the procedure step number,

– a description of any errors,

– a proposal for improvements.

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2 CONTROL STRUCTURE

The COMPex*Pro* (see Figure 1, A) is controlled through a central laser control board (C) that directly communicates with the system's various controllable modules and components (B) such as the HV power supply, energy monitor, trigger board, solenoid valves and ventilators. Depending on the address, communication occurs through 24 V control signals or optically through fiber optic lightwave guides.

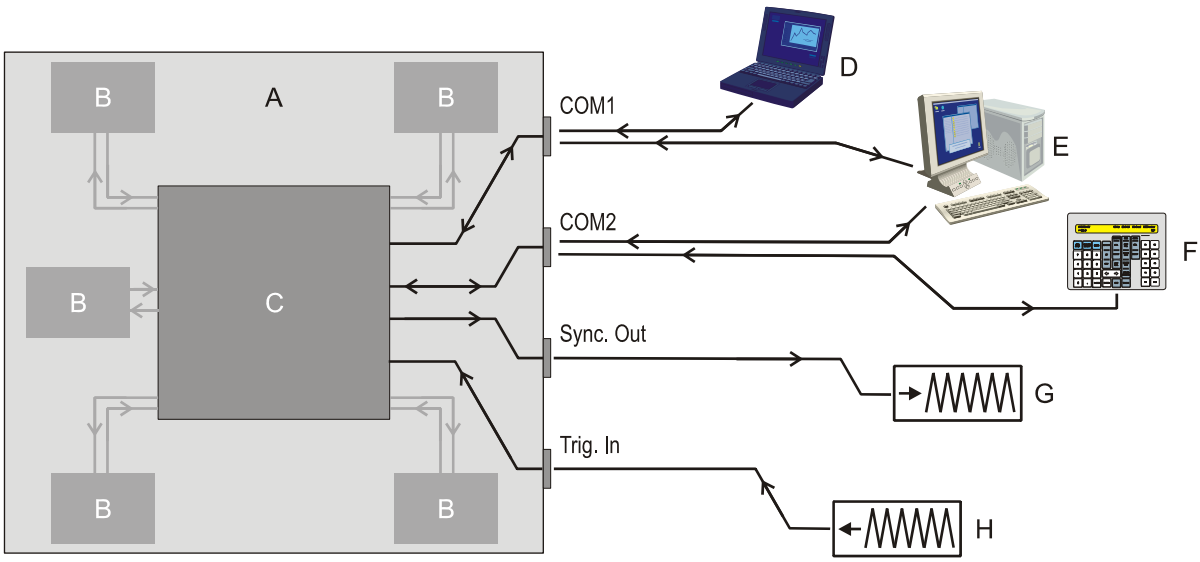

Figure 1: *External interfaces and control structure*

Key to Figure 1

A	Laser device	E	Computer control system
B	Controlled module/ component	F	Handheld keypad
C	Laser control board (LCB)	G	Synchronization device
D	Diagnostics computer	H	Trigger generator

The user interface to the LCB (C) is either the handheld keypad (F) or a remote computer control system (E). Two serial interface (RS232) ports are provided so that two user interface devices can be connected at the same time. To prevent the input of conflicting commands, one of the ports (COM1) can be deactivated by the user. Alternatively, this port can be switched by the user to allow the connection of a diagnostics computer (D) or a control system designed for an earlier version of the laser device (backward compatibility).

In addition to the serial interfaces, the laser device is equipped with dedicated ports that allow trigger signals from an external trigger generator (H) to be input and synchronization pulses to be output to an external device (G) that synchronizes the laser pulses with other operating sequences.

Serial Interfaces

All operating modes and laser parameters are set and/or requested through either of the serial interfaces. The laser device requests a special handshake with the user or the control program in the following cases:

– PGR request
  Partial gas replacement (PGR) requests are indicated by status code 104. When a request occurs, the user has to activate the HI/PGR mode (see Section 4.3.2.6 on page 27) so that the gas action can be performed. If the gas action is not carried out within a predefined timeout period, a corresponding interlock will be activated and laser operation is stopped.

– Interlocks and warnings
  A list of possible laser status codes is indicated in Section 4.3.3 on page 35. If an interlock or warning occurs, solve the problem (see “Basic Troubleshooting” in the User Manual) and clear the message by sending the opmode OFF (see Section 4.3.2.1 on page 24).

Handheld Keypad

The handheld keypad is a dedicated control device that is supplied as standard with the laser device. It communicates with the laser device through the corresponding serial interface port.

For more information about controlling the laser device through the hand-held keypad, please refer to the laser device’s User Manual.

External Triggering

The external trigger (Trig. In) port is only active in one of the external triggering modes, i.e. when the laser device expects external signals. The signals received through the Ext. Trigger port can either be trigger signals for externally triggered laser operation or gate signals for operation in the internal gated trigger mode (for more information, see Section 4.4.4 on page 45).

Synchronization Pulses

Synchronization pulses (Sync. Out) are generated when the system controller recognizes a trigger signal, regardless of whether the signal is internally or externally generated. These pulse signals inform an external device that a trigger signal has been received. This enables the triggering of the laser device to be synchronized with external operating sequences.

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Software Communication

The structure of the COMPex*Pro* laser control software and communication between the various modules is shown in Figure 2.

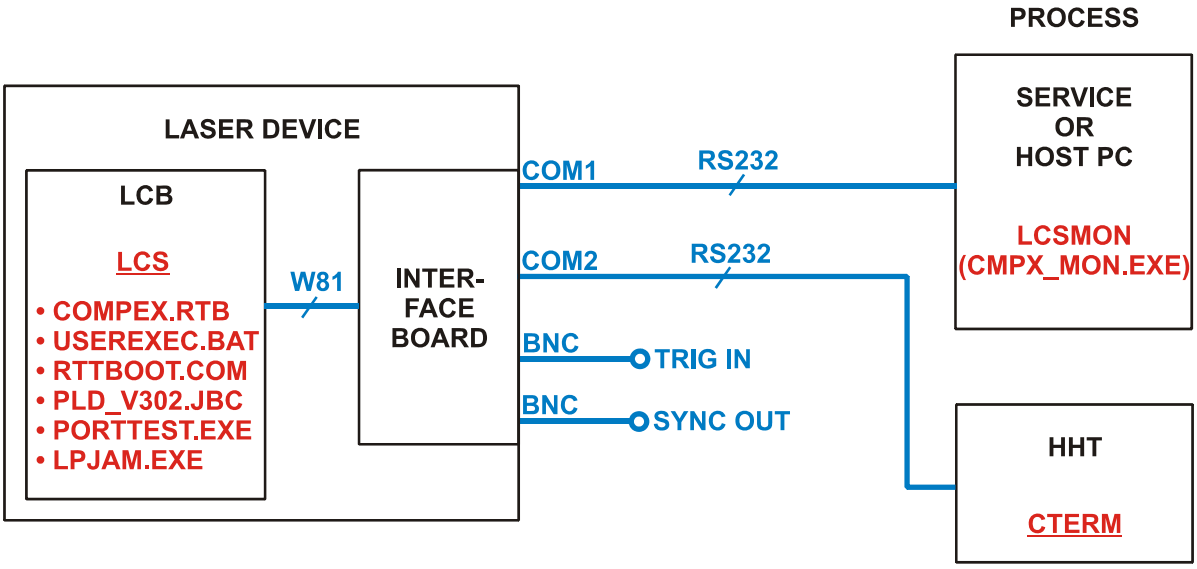

Figure 2: *Software communication*

- The LCS software consists of various modules that control all operations of the laser device:
  - COMPEX.RTB is the primary laser control program.
  - USEREXEC.BAT and RTTBOOT.COM are execution and boot programs for the primary laser control program.
  - PLD_V302.JBC is the configuration file for the PLD (programmable logic device). The PLD controls access to the periphery devices in the laser device such as pumps and fans.
  - PORTTEST.EXE and LPJAM.EXE are setup and service tools.

  The LCS software is stored on the LCB on a flash drive. Necessary software upgrades can be carried out by authorized Coherent field service engineers.
- The CTERM software controls the operation of the hand-held keypad that is supplied as standard with the laser device. This software is stored on an EPROM in the hand-held keypad.
- LCSMON (CMPX_MON.EXE) is a service software package that is exclusively available to authorized Coherent service engineers. It is installed on an external computer (usually a laptop PC) that has to be connected to COM1 on the laser device. LCSMON enables operations such as debugging and modification of operating parameters in the LCS software modules.
- The host PC software is the software written by the customer or system integrator that allows the laser device to be operated through a remote computer control system. The syntax and necessary laser control commands to write this software are

described in Section 4 of this manual. If the host PC software was orginally written for an earlier Coherent or Lambda Physik excimer laser device (backward compatibility), take into account the fundamental changes that affect interaction with the external software described in Section 6 of this manual.

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3 INTERFACE SPECIFICATIONS

3.1 Location of Connections

The connections for all signal and control lines are located on the connector panel which is situated on the connection side of the laser device. The exact location of the connector panel is indicated in Figure 3, A.

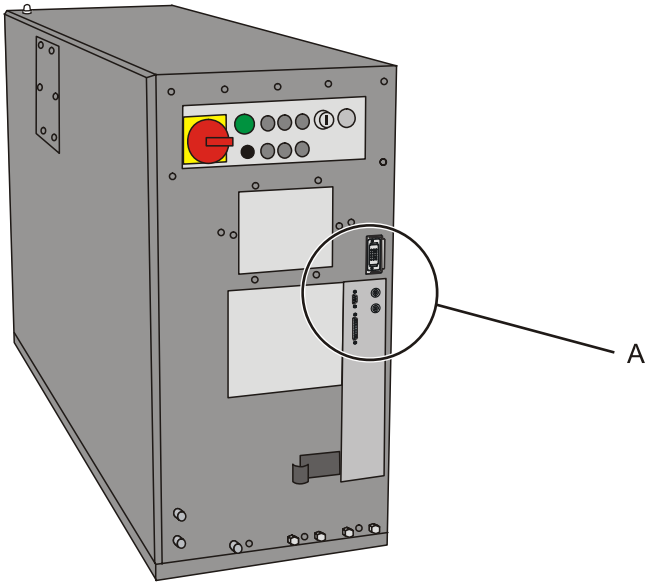

Figure 3: *Location of signal and control line connector panel*

The location of the respective connections on the connector panel is indicated in Section 3.2.

3.2 Overview of Connections

Figure 4 shows the layout of the connections on the connector panel.

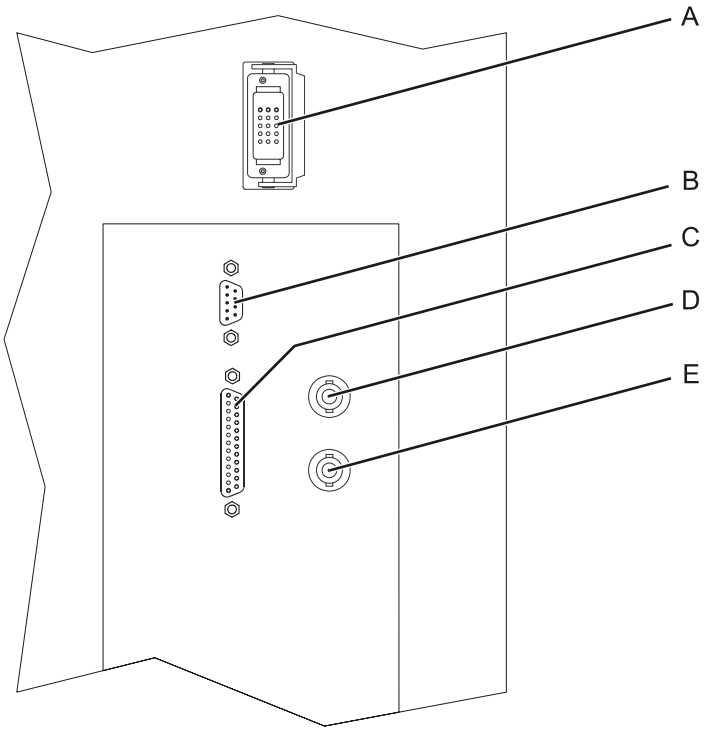

Figure 4: *Layout of connector panel*

The table below contains a key to Figure 4 and provides an overview of the configuration of the control and signal connections. The gender of the connector (where indicated) relates to the chassis part on the laser device and not the connector on the cable. The cables have to be provided with the corresponding plugs.

Pos.	Designation	Type	Purpose	Further information
A	Remote	15 pin Harting, female	Safety connections (category 3 remote interlock, external laser radiation warning lamp, external gas error etc.)	Section 3.5
B	COM 1	9 pin sub D, male	Serial interface for input/output of operating modes and parameters	Section 3.3.1
C	COM 2 (TERMINAL)	25 pin sub D, female	Serial interface (handheld keypad configuration) for input/output of operating modes and parameters	Section 3.3.2
D	SYNC. OUT	BNC	Output of synchronization signal	Section 3.4.2
E	TRIG. IN	BNC	Input of external trigger signal	Section 3.4.1

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3.3 Serial Interfaces

The laser device is equipped with two RS232 serial interfaces, designated as COM 1 and COM 2. Both ports enable operating modes (opmodes) and parameters to be set or read and status codes to be read.

All signals are compatible to standard RS232 levels: +5 to +15V for SPACE and -5 to -15V for MARK.

Communication Protocol

Baud rate	9600 bps
Number of data bits	8
Number of start bits	1
Number of stop bits	1
Parity	none
Handshake	none
Message format	uppercase and lowercase ASCII characters using clear text full word commands

Communication Syntax

Both ports use an identical communication syntax. The communication syntax is described in Chapter 4 on page 19.

3.3.1 COM 1

COM 1 can be switched by the user through a pushbutton on the handheld keypad to enable the connection of one of the following:

– a diagnostics computer,

– an external computer control system (remote computer) that uses the current protocol (see Section 4 on page 19),

–a control system designed for an earlier version of the COMPex, COMPex*Pro* or LPX series laser device (backward compatibility). With this setting, not all commands offered by the current laser control software will be supported. In addition, as the status code table has changed, status codes sent by the laser device may not be recognized or correctly interpreted by the external control system. A list of the currently applicable status codes is contained in Section 4.3.3 on page 35.

Alternatively, this port can be deactivated by the user to prevent the input of conflicting commands.

For further information about switching the COM 1 port, please refer to the separate User Manual

Specifications

Device	9 pin Sub-D
Type	RS232C
Gender	male
Galvanic isolation	TBS
Locking size	4-40 UNC

Pin Assignment

Signal	Pin	Type	Purpose
RxD	2	Input	Receive RS 232 data
TxD	3	Output	Transmit RS 232 data
GND	5	Output	RS232 ground
n.c.	1, 4, 6 to 9		not connected

3.3.2 COM 2 (Terminal)

COM 2 is configured for the connection of the handheld keypad that is supplied as standard with the laser device. If required, an external control computer (remote computer) can be connected to this terminal instead of the handheld keypad. This computer has to use the same protocol as the handheld keypad (see Section 4 on page 19).

Specifications

Device	25 pin Sub-D
Type	RS232C
Gender	female
Galvanic isolation	TBS
Locking size	4-40 UNC

Pin Assignment

Signal	Pin	Type	Purpose
RxD	3	Input	Receive RS 232 data
TxD	2	Output	Transmit RS 232 data
GND	7	Output	RS232 ground
15 V	9	Output	+15 V DC
n.c.	1, 4 to 6 and 10 to 25		not connected

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3.4 Synchronization Signals

3.4.1 Trigger In

The laser can be triggered from an external source (trigger generator). This source is to be connected to the TRIG. IN socket.

Specifications

Port on laser device	Trig. In
Device	BNC, galvanic isolation through optocoupler
Signal level	3.3 VDC to 5 VDC, TTL
Pulse duration	10 ms to 100 ms
Trigger edge	positive slope
Delay ext. trigger to light pulse:[a]	
- without COD	2 ms
- 50 / 110 with COD	9500 ms
- 102 with COD	12500 ms
- 201 / 205 with COD	18000 ms
Delay, drift	< 200 ns
Jitter ext. trigger to light pulse	< ± 10 ns (pulse-to-pulse)

a. For further information, see Section 3.4.3 on page 16

3.4.2 Sync. Out

The Sync. Out signal informs external devices that a trigger signal has just been sent to the discharge capacitors..

Specifications

Port on laser device	Sync. Out
Device	BNC, galvanic isolation through optocoupler
Signal level	3.3 VDC to 5 VDC, TTL
Pulse duration	50 ms
Delay sync. out to light pulse[a]	0.5 ms

a. For further information, see Section 3.4.3 on page 16

3.4.3 Timing Diagrams

The diagrams in this section indicate the time delay between:

– the trigger-in signal (signal A in each diagram),

– the laser light pulse (B) and

– the sync out. signal (C).

There is a fundamental difference in delay times for laser operation with and without charge on demand (COD).

Operation With COD

In the COD mode, capacitor charging is specifically triggered by the demand for a laser pulse rather than occurring automatically after the previous discharge. This maximizes the lifetime of the components in the high voltage (HV) circuit and prevents the laser firing a light pulse without receiving a trigger pulse (self-firing). The trade-off of COD is a long delay between the trigger-in signal and the laser light pulse. The exact length of this delay differs depending on the version of the laser device (see Figures 5 to 7).

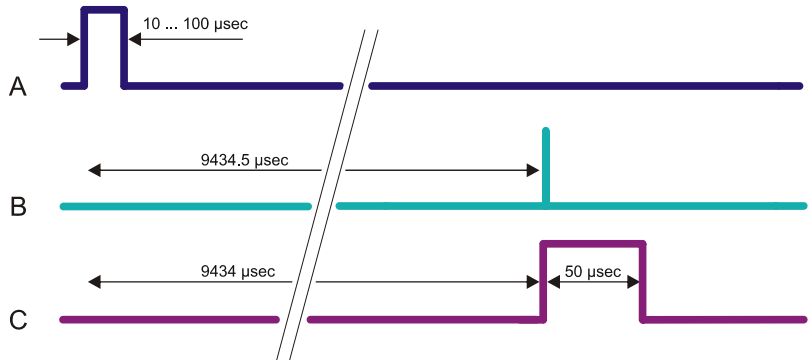

Figure 5: *Delay, COMPex*$\mathcal{Pro}$ *50 and 110 with COD*

In the case of the COMPex$\mathcal{Pro}$ 110, there is an exception to the delay times indicated in Figure 5. Interacting parameters such as the signal-to-light delay and the maximum permissible HV are normally set to enable operation at the maximum permissible repetition rate (100 Hz). However, when operating in the HV constant mode at repetition rates below 10 Hz, the HV setpoint can be increased to a value above the usually applicable maximum. To compensate for the necessary additional capacitor charging time, the signal-to-light delay is automatically increased to the value specified for the COMPex$\mathcal{Pro}$ 102 (see Figure 6).

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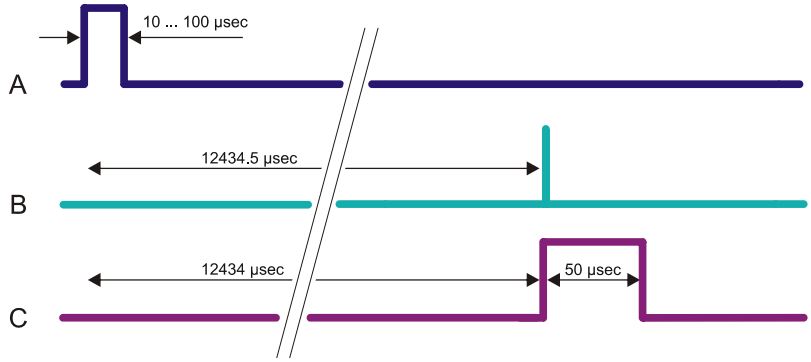

Figure 6: *Delay, COMPex$\mathcal{P}ro$ 102 with COD*

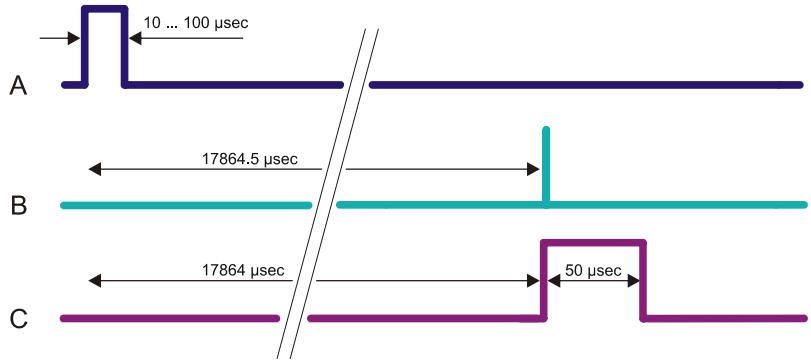

Figure 7: *Delay, COMPex$\mathcal{P}ro$ 200 Series with COD*

If the delay is unacceptable for the effective coordination of the laser with other operations, COD can be switched off through a dedicated software command.

Operation Without COD

Without COD (see Figure 8), the delay is the same for all versions of the laser device.

Figure 8: *Delay, all versions without COD*

3.5 Remote Connector

The remote connector enables the laser device to be connected to external safety circuits that, for instance, disable the laser until a protective door is closed, indicate that laser radiation is being emitted or indicate an external halogen leak.

Specifications

Port on laser device	Remote
Device	15 pin connector
Type	Harting HAN 15D
Gender	female

Pin Assignment and Connections

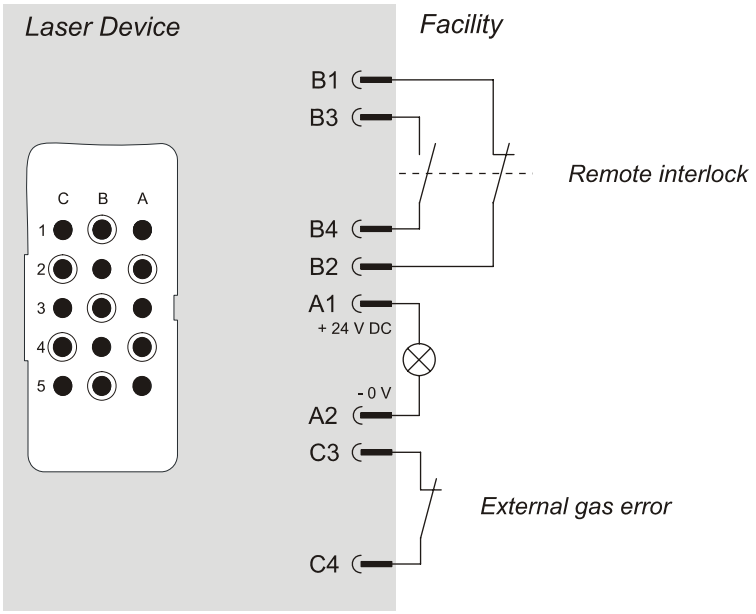

Figure 9: *Remote connector pin assignment and connections*

Signal	Pins	Type	Purpose	Specifications
Laser radiation warning lamp	A1 + A2	Output	External warning lamp that lights when laser radiation is being emitted	24 V DC
Remote interlock	B1 + B2	Input	EN 954-1 safety category 3 connection. B3 and B4 have to be open and B1 and B2 have to be closed to enable the emission of laser radiation	Potential-free contacts
	B3 + B4	Input		
External gas error	C3 + C4	Input	Contact has to be closed if there is no external gas error (e.g. leak)	

4 REMOTE COMMUNICATION

The serial interface is used to set and request all operating modes and parameters and to indicate the laser status. Activities requiring a handshake wit h the user or the remote controller, like PGRs, indication of interlocks and warnings as well as maintenance activities, are also handled via this interface.

4.1 Communication Syntax

All commands are case insensitive text commands. Each command is terminated with the <CR> (Carriage Return) character.

Two fundamental types of commands are used:

– Setting commands:
  are used to set laser operating modes or values of configurables.

– Polling commands:
  are used to request the current laser status or configurable setting.

The laser confirms commands, returns requested parameter settings or sends an error code as a reply message.

Setting Commands

Command syntax:	*name*=*setting*<CR>
Reply syntax:	*reply code*<CR>
Example:	The command OPMODE=OFF<CR> has to be sent to the system controller to switch off the laser. To indicate that the command is permitted and has been accepted, the system controller re-sends 0<CR>

Polling Commands

Command syntax: *name?*<CR>

The syntax of the reply will depend on whether an operating mode (see Section 4.3 on page 22) or operating parameter (see Section 4.4.2 on page 39) is being polled:

Reply syntax for operating modes:	OPMODE=*setting,status*<CR> or OPMODE=*setting,status,status*<CR> or *reply code*<CR>
Reply syntax for operating parameters:	*name=setting*<CR> or *name=setting,setting*<CR> or *reply code*<CR>
Example:	The command `OPMODE?<CR>` has to be sent to the system controller to request the current operating mode. If the laser is ready for operation but at present switched off, the system controller will re-send `OPMODE=OFF,0<CR>`. If the reply `2<CR>` is received, the entered polling command is unknown to the system controller and, consequently, cannot be processed.

Syntax Description

name	The name OPMODE (to indicate an operating mode) or one of the parameter names listed in Section 4.4 on page 37. The name occurs both in setting and polling commands.
setting	A word or numerical value that defines an operating mode or parameter setting. With numerical values, the character X in the descriptions in this chapter indicates each permitted place in the value (i.e. each digit between 0 and 9). Less positions or leading zeros are permitted. If the value has to be within a permitted range of values, this range is indicated in the respective command description. When a numerical value is to contain a special character (e.g. colon or decimal point), this is also indicated in the respective command description. Where more than one word or numerical value is required, the information separator is a comma.
reply code	One of the reply codes listed in Section 4.2 on page 21.
status	One of the status codes listed in Section 4.3.3 on page 35.

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=	Equals sign. This is always written between the name and setting in both setting commands and replies to polling commands.
?	Question mark. This is always written at the end of a polling command.
,	Comma. This is written as information separator when a setting consists of more than one word or numerical value.
<CR>	Carriage Return character. This is always inserted after each polling command, setting command or reply to terminate the command. The insertion of this character is assumed in the command syntax descriptions in the remainder of this chapter.

Do not insert a blank before or after an equals sign, question mark, comma or CR character. If a blank is required within a command, this is indicated in the syntax of the individual command description.

4.2 Reply Codes

The respective meaning of the possible reply codes together with any necessary corrective action is listed in the table below. The reply codes apply to both laser operating modes and laser parameter commands.

No.	Description	Action
0	Command/parameter accepted	—
1	Command/parameter not accepted in current mode	Change operating mode and send the command/ parameter again
2	Command/parameter unknown	Send correct command/ parameter name
3	Parameter value out of range or input/output error	Send any value inside valid range

One of the above reply codes will always be sent as response to a setting command.

No reply code is sent when a valid polling command is received. In this case, acceptance of the command is indicated by the reply to the polling command. The reply code 2 will be sent as response to an invalid command.

The means of clearing by changing the operating mode indicates that a valid opmode command has to be sent. Take into account that not all operating mode transitions are possible (see Section 4.3.1.).

4.3 Laser Operating Mode Commands

The operating modes of the COMPex*Pro* are changed and called through OPMODE commands (abbreviation for “OPerating MODE“). In most cases, a change of operating mode will not influence the settings of the parameters.

Operating modes are changed by the “`OPMODE=`” command.

The current operating mode can be requested through the polling command “`OPMODE?`”. The reply contains the operating mode, followed by one or more status codes (see Section 4.3.3 on page 35).

4.3.1 Overview of Operating Modes

The available operating modes are listed alphabetically in the following table. The access “r” (read) indicates operating modes that will be received from the laser controller after sending the `OPMODE?` polling command. The access “s” (send) indicates commands that are to be sent to the laser controller to enter the corresponding operating mode.

OPMODE=	Access	Meaning / Function	Accepted	Description
CONT	s	Continue the flushing procedure with a leak test	FLUSHING CONT active	Section 4.3.2.14
ENERGY CAL	r/s	Routine for calibrating the energy monitor	always	Section 4.3.2.18
ENERGY CAL CONT	r	Calibration value ready	-	
FLUSH <xy> LINE	r/s	Evacuate the <xy> gas line for two seconds	OFF mode only[a]	Section 4.3.2.15
FLUSHING	r/s	Evacuate the laser tube and fill it with an inert gas to enable the optics to be exchanged	OFF mode only[a]	Section 4.3.2.13
FLUSHING CONT	r	Flushing action waiting for `OPMODE=CONT` after window exchange	-	
FLUSHING LEAKTEST	r	Leak test being performed during a flushing action	-	
HI	r/s	Inject gas into the laser tube (HI, RI)	always	Section 4.3.2.4
HI/PGR	s	Execute a requested gas action	gas action request exists	Section 4.3.2.6
LL OFF	s	Deactivate the low light function	always	Section 4.3.2.17
MANUAL FILL INERT	r/s	Fill the laser tube for 10 seconds with inert gas	OFF mode only[a]	Section 4.3.2.12

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OPMODE=	Access	Meaning / Function	Accepted	Description
NEW FILL	s	Evacuate the laser tube and fill it with fresh laser gas	OFF mode only[a]	Section 4.3.2.7
NEW FILL,EVAC	r	New fill in progress, gas evacuation phase	-	
NEW FILL,FILL	r	New fill in progress, new gas fill phase	-	
OFF	r/s	Switch the laser off	always	Section 4.3.2.1
OFF,WAIT	r	Laser is switching to the ON state	-	
ON	r/s	Switch the laser on to run with the currently active operating parameters	OFF mode[b]	Section 4.3.2.2
PASSIVATION FILL	r/s	Evacuate the laser tube and fill it with a gas mixture for tube re-passivation (Halogen / Buffer)	OFF mode only[a]	Section 4.3.2.8
PGR	r/s	Exchange part of the laser gas (PGR, macro PGR)	always[c]	Section 4.3.2.5
PURGE <xy> LINE	r/s	Evacuate the <xy> gas line for 5 seconds and fill it with inert gas	OFF mode only[a]	Section 4.3.2.16
PURGE RESERVOIR	r/s	Evacuate the laser tube and fill it with inert gas for purging	OFF mode only[a]	Section 4.3.2.9
SAFETY FILL	r/s	Fill the laser tube with inert gas in case of a leak	OFF mode only[a]	Section 4.3.2.10
SKIP	s	Interrupt the warm-up phase	always[d]	Section 4.3.2.3
TRANSPORT FILL	r/s	Evacuate the laser tube and fill it with buffer gas (Neon) for transport	OFF mode only[a]	Section 4.3.2.11

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a. Ignored if any other gas action is already in progress
b. Ignored if an interlock condition is pending or a gas action is in progress
c. If OPMODE=ON is active, pulse triggering is switched off for the duration of the action
d. Ignored if the laser is not in the warm up period

4.3.2 Description of Operating Modes

This chapter describes the various operating modes as well as the commands that are to be used to change the mode and poll the current status.

4.3.2.1 OPMOFE=OFF

Syntax:

Setting:	OPMODE=OFF
Polling:	OPMODE?
Reply:	OPMODE=OFF,aa OPMODE=OFF,WAIT,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)
WAIT	During laser start-up: the laser waits for power supply standby and the gas circulation fan to start (duration: approx. 5 seconds)

In this mode the laser device is switched on and the laser controller is active. The high voltage power supply and pulse triggering is off. No gas action is in progress.

OPMODE=OFF is activated:

– automatically after switching on the laser device,

– from OPMODE=ON, when OPMODE=OFF is sent to switch off the laser,

– automatically after an interlock.

When OPMODE=OFF is active, laser operation can be started and maintenance actions can be executed.

4.3.2.2 OPMODE=ON

Syntax:

Setting:	OPMODE=ON
Polling:	OPMODE?
Reply:	OPMODE=ON,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

In this mode the laser is switched on. Light pulses will be generated and emitted according to the currently active laser parameters.

OPMODE=ON will be accepted in any mode. It will, however, be ignored if an interlock condition is pending or a gas action is in progress.

4.3.2.3 OPMODE=SKIP

Syntax:

Setting:	OPMODE=SKIP

After initially switching on the laser device (mains on), the laser enters a warm-up period that normally has to elapse before laser emission can be started. OPMODE=SKIP terminates the warm-up period. If, however, the warm-up period is skipped, the laser will not optimally perform (missing pulses or no pulses!).

4.3.2.4 OPMODE=HI

Syntax:

Setting:	OPMODE=HI
Polling:	OPMODE?
Reply:	OPMODE=HI,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

In this mode a HI (*H*alogen *I*njection), RI (*R*are *I*njection) or MHI (*m*acro *H*alogen *I*njection) is carried out to refreshen the laser gas. The partial pressure of the gas to be injected is indicated in the gas menu. OPMODE=HI will be accepted in any mode. The command will, however, not be executed if an interlock inhibits gas actions.

4.3.2.5 OPMODE=PGR

Syntax:

Setting:	OPMODE=PGR
Polling:	OPMODE?
Reply:	OPMODE=PGR,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

The software LCS 2.29 does not support this operating mode!

In this mode a PGR (*P*artial *G*as *R*eplacement) is carried out to refreshen the laser gas. A portion of the gas in the laser tube is replaced by fresh gas. The partial pressure of the gases to be filled is indicated in the gas menu.

OPMODE=PGR will be accepted in any mode. The command will, however, not be executed if an interlock inhibits gas actions.
If OPMODE=ON is active, triggering will be suspended and the HV power supply will be switched off before starting the PGR. When the PGR has been completed, the HV power supply will be switched on again and triggering will resume.

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4.3.2.6 OPMODE=HI/PGR

Syntax:

Setting: OPMODE=HI/PGR

The software LCS 2.29 does not support this operating mode!

This mode will execute the required gas action (PGR or macro PGR) when the corresponding gas action request is received (the currently active operating mode is appended by status code 104). The gas action request occurs according to the algorithms specified in the laser control software.

Depending on the laser control software setting, gas actions will either be carried out automatically or a request for a gas action will be output:

– If the HI/PGR entry is set to AUTO, the required gas action will be carried out automatically and immediately. The user does not have to send OPMODE=HI/PGR. This choice may, however, cause unwanted interruptions in automated laser processing sequences as no laser pulses can be triggered when the PGR or macro PGR is in progress.

– If the HI/PGR entry is set to REQUEST (default setting), the user can choose the exact timing of the gas action. OPMODE=HI/PGR has to be sent within a specified period of time of the request to perform the required gas action (status code 104). When the setting command is not sent within the specified period, the “PGR request timeout” interlock is triggered (OPMODE=OFF,63). The default setting for the maximum period that can elapse between the HI/PGR request and the command to trigger the HI/PGR is 10 minutes. This period can be amended by changing the corresponding setting in the gas action table. Alternatively, the “HI/PGR request timeout” interlock can be completely deactivated by setting the “PGR action” parameter in the gas setting table to DISABLE. In this case, the laser will only perform remotely triggered PGRs.

OPMODE=HI/PGR will only be accepted if a PGR request or macro PGR request is present. If OPMODE=ON is active, sending OPMODE=HI/PGR will suspend triggering and switch off the HV power supply before starting the PGR or macro PGR. When the PGR or macro PGR has been completed, the HV power supply will be switched on again and triggering will resume.

4.3.2.7 OPMODE=NEW FILL

Syntax:

Setting:	OPMODE=NEW FILL
Polling:	OPMODE?
Reply:	OPMODE=NEW FILL,EVAC,aa OPMODE=NEW FILL,FILL,aa

Syntax Description:

EVAC	Laser tube is being evacuated
FILL	Laser tube is being filled with fresh gas
aa	Status code (see Section 4.3.3 on page 35)

In this mode the laser tube is evacuated and filled with fresh laser gases.

OPMODE=NEW FILL is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

4.3.2.8 OPMODE=PASSIVATION FILL

This function fills the laser tube with up to ten times the usual concentration of halogen gas. For safety reasons, only authorized and correspondingly trained service personnel shall have access to this function (please refer to the Service Manual for further information).

Syntax:

Setting:	OPMODE=PASSIVATION FILL
Polling:	OPMODE?
Reply:	OPMODE=PASSIVATION FILL,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

In this mode the laser tube is evacuated and filled with halogen and buffer gas so that the tube can be re-passivated.

OPMODE=PASSIVATION FILL is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

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4.3.2.9 OPMODE=PURGE RESERVOIR

Syntax:

Setting:	OPMODE=PURGE RESERVOIR
Polling:	OPMODE?
Reply:	OPMODE=PURGE RESERVOIR,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

In this mode the laser tube is evacuated and filled (purged) with inert gas.

OPMODE=PURGE RESERVOIR is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

4.3.2.10 OPMODE=SAFETY FILL

Syntax:

Setting:	OPMODE=SAFETY FILL
Polling:	OPMODE?
Reply:	OPMODE=SAFETY FILL,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

This mode is started automatically by the laser controller when the permissible period for the evacuation of the laser tube is exceeded (30 mbar is not reached within 11.5 minutes). The laser tube is filled to 1050 mbar with the gas connected to the ”Buffer“ connection (Neon).

4.3.2.11 OPMODE=TRANSPORT FILL

Syntax:

Setting:	OPMODE=TRANSPORT FILL
Polling:	OPMODE?
Reply:	OPMODE=TRANSPORT FILL,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

In this mode the laser tube is evacuated and filled for transport or storage to 1050 mbar with the gas connected to the ”Buffer“ connection (Neon). If no gas is connected to the ”Buffer“ connection, the laser tube will be automatically filled with the gas connected to the “Inert” connection.

OPMODE=TRANSPORT FILL is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

4.3.2.12 OPMODE=MANUAL FILL INERT

Syntax:

Setting:	OPMODE=MANUAL FILL INERT
Polling:	OPMODE?
Reply:	OPMODE=MANUAL FILL INERT, aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)

In this mode inert gas will be filled into the laser tube for 10 seconds. This is only possible up to a tube pressure of 3000 mbar.

OPMODE=MANUAL FILL INERT is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

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4.3.2.13 OPMODE=FLUSHING

Syntax:

Setting:	OPMODE=FLUSHING
Polling:	OPMODE?
Reply:	OPMODE=FLUSHING,aa OPMODE=FLUSHING CONT,aa OPMODE=FLUSHING LEAKTEST,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)
CONT	The flushing routine has been stopped to allow the optics to be exchanged. The routine is continued by sending OPMODE=CONT (see Section 4.3.2.14)
LEAKTEST	Leak test being performed after exchanging the windows

This routine is required to exchange the tube optics. The laser tube is evacuated and filled to 1050 mbar with inert gas. After exchanging the optics, a leak test is carried out and the laser tube is then filled with fresh laser gas.

OPMODE=FLUSHING is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

4.3.2.14 OPMODE=CONT

Syntax:

Setting:	OPMODE=CONT

The flushing routine automatically stops whenever user intervention is required (see Section 4.3.2.13). OPMODE=CONT continues the flushing routine after exchanging the optics and successfully completing the leak test. OPMODE=CONT is only accepted when OPMODE=FLUSHING CONT is active.

4.3.2.15 OPMODE=FLUSH <XY> LINE

Syntax:

Setting:	OPMODE=FLUSH <XY> LINE
Polling:	OPMODE?
Reply:	OPMODE=FLUSH <XY> LINE,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)
<XY>	Name of a gas line (BUFFER, HALOGEN, INERT or RARE)

In this mode the selected gas line will be evacuated for two seconds.

OPMODE=FLUSH <XY> LINE is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

Example: Evacuating the halogen gas line

```
OPMODE=FLUSH HALOGEN LINE<CR>
OPMODE?<CR>
OPMODE=FLUSH HALOGEN LINE,0<CR>
```

4.3.2.16 OPMODE=PURGE <XY> LINE

Syntax:

Setting:	OPMODE=PURGE <XY> LINE
Polling:	OPMODE?
Reply:	PURGE <XY> LINE,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)
<XY>	Name of a gas line (BUFFER, HALOGEN, INERT or RARE)

In this mode the selected gas line will be evacuated for five seconds and then filled for two seconds with inert gas.

OPMODE=PURGE <XY> LINE is only accepted when OPMODE=OFF is active. It will be ignored if any other gas action is already in progress.

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Example: Purging the halogen gas line

```
OPMODE=PURGE HALOGEN LINE<CR>
OPMODE?<CR>
OPMODE=PURGE HALOGEN LINE,0<CR>
```

4.3.2.17 OPMODE=LL OFF

Syntax:

Setting:	OPMODE=LL OFF

This mode deactivates the Low Light function. When the Low Light function is active (default choice), laser operation is interrupted when more than 30% of laser pulses are missing within a 10 second period. The Low Light OFF function (OPMODE=LL OFF) will not interrupt laser operation when there are missing pulses and should, therefore, only be used for diagnostic purposes.

OPMODE=LL OFF is a one shot command. After setting LL OFF, the Low Light function will be deactivated for the next laser operation started through OPMODE=ON. When this laser operation is terminated through OPMODE=OFF, OPMODE=LL OFF will be automatically cancelled. The Low Light function (default choice) will be automatically active for the following laser operation started through OPMODE=ON.

4.3.2.18 OPMODE=ENERGY CAL

Syntax:

Setting:	OPMODE=ENERGY CAL
Polling:	OPMODE?
Reply:	OPMODE=ENERGY CAL,aa OPMODE=ENERGY CAL CONT,aa

Syntax Description:

aa	Status code (see Section 4.3.3 on page 35)
CONT	The routine waits for the input of a reference energy through the command ”EGY=“ (see Section 4.4.3.2) or „EGY SET=“ (see Section 4.4.3.3)

This mode controls the internal energy monitor calibration routine.

The functional sequence of the routine when controlling the laser device through an external PC is indicated in Figure 10. The steps are indicated in the rectangles, the necessary commands are written in capital letters next to the corresponding steps.

OPMODE=ENERGY CAL will be accepted in any mode. It will, however, be ignored if an interlock condition is pending or a gas action is in progress.

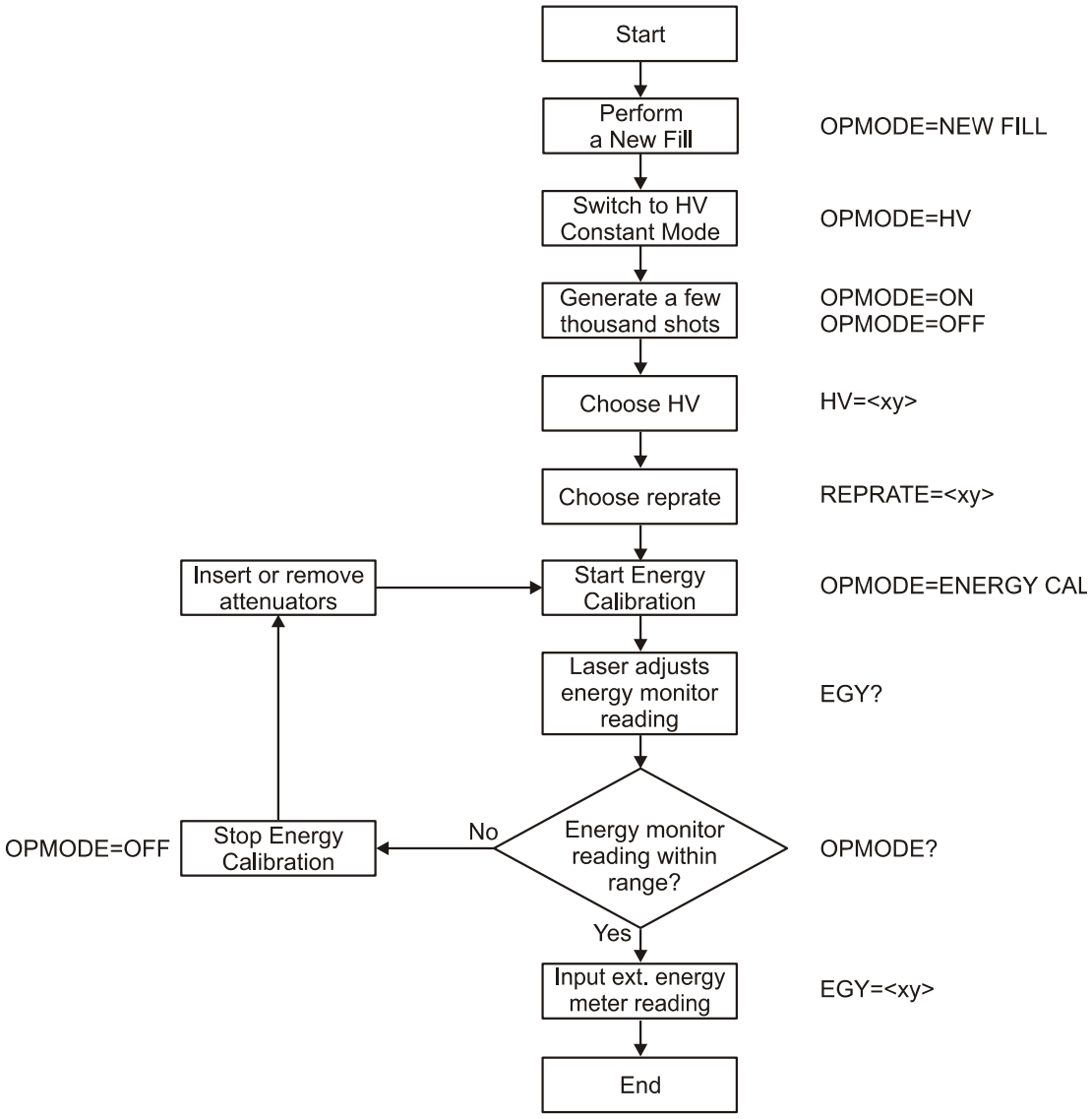

Figure 10: *Calibrating the energy monitor*

4.3.3 Status Codes

One or more of the status codes indicated in this section will always be sent as attachment to an operating mode returned to the OPMODE? polling command. Status codes are values with up to three digits.

The table below lists the available status codes. Depending on the configuration of the laser device, some of the listed codes may not apply. Missing status code numbers are reserved for other laser devices or future use.

Interlocks will only be cleared when sending a valid operating mode, e.g. OFF. Warnings will automatically be cleared when the checked parameter is within its limit or the corresponding signal is detected.

Status Code	Type[a]	Meaning
0	--	No message, warning or interlock active
2	Interlock (sw)	Preset energy too high
6	Interlock (sw)	Tube pressure out of range
10	Interlock (hw)	Tube temperature too high
11	Interlock (hw)	Ventilation motor failed
16	Interlock (hw)	Remote interlock switch is open
18	Interlock (hw)	HV power supply error
21	Warning	Thyratron warm-up
23	Warning	No gas flow
25	Warning	Preset energy too low
26	Interlock (sw)	Low light
27	Interlock (sw)	No gas flow
30	Interlock (sw)	Configuration error detected (no valid set of parameters can be loaded from FRAM)
31	Interlock (sw)	Reboot required (after tube temperature or pulser temperature interlock)
32	Warning	No vacuum (set time period to evacuate laser tube to set point pressure exceeded)
42	Interlock (hw)	Service panel (cover 1) open
46	Interlock (hw)	Liquid leak detected
49	Interlock (hw)	HV power supply temperature too high
51	Warning	Internal gas purifier error
54	Interlock (sw)	No external trigger signal detected (time out, set time between two successive external trigger pulses exceeded)
62	Interlock (sw)	Halogen filter exchange required (halogen filter filling capacity has been exceeded)
63	Interlock (sw)	HI/PGR request time out[b]
64	Warning	Tube temperature too high
69	Warning	Check safety relay

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Status Code	Type[a]	Meaning
89	Warning	Preset energy too high
95	Interlock (sw)	Max. power (calculated power exceeds max. power parameter)
103	Warning	Halogen filter exchange required soon
104	Warning	HI/PGR request (the gas action algorithm indicates that a gas action is required)[b]
106	Interlock (hw)	Pulser temperature too high
120	Interlock (hw)	Front mirror access panel (cover 2) open
121	Interlock (hw)	Rear mirror access panel (cover 3) open
122	Interlock (hw)	Safety control module off
123	Warning	Tube pressure too high
124	Warning	Tube pressure too low
125	Interlock (sw)	Tube temperature too high
126	Warning	Leak test failed
127	Interlock (sw)	Communication time out (no communication through serial interface within set time period)
128	Interlock (sw)	Tube pressure sensor failed (reading outside of the parameter range)
130	Interlock (sw)	Tube temperature sensor failed (reading outside of the parameter range)
131	Warning	HV power supply temperature
157	Interlock (sw)	Gas action time out (gas action not completed within set time period)
182	Interlock (sw)	Gas mismatch (gas mixture does not correspond with current menu or tube flushing, transport fill, safety fill or passivation fill has been carried out)
220	Interlock (sw)	Watchdog error (fatal error)
221	Interlock (sw)	External gas failure
223	Warning	Tube pressure max.
224	Interlock (sw)	Tube pressure max.

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a. hw = hardware, sw = software
b. LCS version 2.29 does not support HIs/PGRs

Status After Warnings and Interlocks:

A *Warning* generally indicates a condition that will cause an interlock if no corrective measures are taken. The status of the currently active operating mode is not changed.

A *Software Interlock* will always change the operating mode to OPMODE=OFF. In most cases, started gas actions will be aborted.

A *Hardware Interlock* will always change the operating mode to OPMODE=OFF. In most cases, the HV power supply will also be shut down and started gas actions will be aborted.

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4.4 Parameter Commands

To set or change laser operating parameters, parameter commands are used.

Parameter settings are changed by the "*name*=" command (with *name* as the parameter name). The available parameter setting commands are listed in the overview in Section 4.4.1. Each command is described in more detail in the corresponding section indicated in the right column of the table.

The current parameter setting can be requested at any time through the polling command "*name*?". The reply contains the parameter name, followed by one or more settings. The available parameter setting commands are listed in the overview in Section 4.4.2. Each command is described in more detail in the corresponding section indicated in the right column of the table.

4.4.1 Overview of Setting Commands

Command Name	Command Setting	Unit	Further Information
BSTPAUSE=	XXXXX	ms	Section 4.4.4.4
BSTPULSES=	XXXXX	pulses	Section 4.4.4.3
BUFFER=	XXXX	mbar	Section 4.4.5.2
COD=	ON	-	Section 4.4.6.1
	OFF	-	
COUNTER=	RESET	-	Section 4.4.7.1
COUNTER E3=	RESET	-	Section 4.4.7.2
COUNTERMAINT.=	RESET	-	Section 4.4.7.3
COUNTS=	XXXXXXX	pulses	Section 4.4.4.7
EGY=	XX.XX	mJ	Section 4.4.3.2
EGYSET=	XX.XX	mJ	Section 4.4.3.3
FANCTRL=	ON	-	Section 4.4.6.2
	OFF	-	
FILTER=	XX	1/10 second	Section 4.4.8.1
FILTERCONTAMINATION=	RESET	-	Section 4.4.8.2
HALOGEN=	XXXX	mbar	Section 4.4.5.3
HV=	XX.XX	kV	Section 4.4.3.4
INERT=	XXXX	mbar	Section 4.4.5.4

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Command Name	Command Setting	Unit	Further Information
MENU=	RESET	-	Section 4.4.5.1
	X	-	
MODE=	EGY NGR	-	Section 4.4.3.1
	EGY PGR	-	
	EGYBURST NGR	-	
	EGYBURST PGR	-	
	HV NGR	-	
	HV PGR	-	
RARE=	XXXX	mbar	Section 4.4.5.5
REPRATE=	XXX	Hz	Section 4.4.4.2
SEQBST=	XXXXX	bursts	Section 4.4.4.5
SEQPAUSE=	XXXXX	ms	Section 4.4.4.6
SYSDATE=	XX.XX.XX	-	Section 4.4.9.1
SYSTIME=	XX:XX:XX	-	Section 4.4.9.2
TEMP CONTROL	ON	-	Section 4.4.6.3
	OFF	-	
TIMEOUT	ON	-	Section 4.4.6.4
	OFF	-	
TRIGGER=	EXT	-	Section 4.4.4.1
	EXT COUNTS	-	
	INT	-	
	INTB	-	
	INT COUNTS	-	
	INTG	-	

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Except for HV=XX.XX, parameter setting commands are accepted in all operating modes and with any other parameter active. HV=XX.XX is only accepted if MODE=HV NGR or MODE=HV PGR is active.

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4.4.2 Overview of Polling Commands

Polling Command	Possible Replies	Unit	Further Information
BSTPAUSE?	BSTPAUSE=XXXXX	ms	Section 4.4.4.4
BSTPULSES?	BSTPULSES=XXXXX	pulses	Section 4.4.4.3
BUFFER?	BUFFER=XXXX	mbar	Section 4.4.5.2
COD?	COD=ON	-	Section 4.4.6.1
	COD=OFF	-	
COUNTER?	COUNTER=XXXXXXXXX	pulses	Section 4.4.7.1
COUNTER E3?	COUNTER=XXXXXXXXX	10^3 pulses	Section 4.4.7.2
COUNTERMAINT.?	COUNTERMAINT=XXXXXXXXX	pulses	Section 4.4.7.3
COUNTER NEW FILL?	COUNTER NEW FILL=XXXXXXXXX	pulses	Section 4.4.7.8
COUNTER TOTAL?	COUNTER TOTAL=XXXXXXXXX	pulses	Section 4.4.7.4
COUNTER TOTAL E3?	COUNTER TOTAL E3=XXXXXXXXX	10^3 pulses	Section 4.4.7.5
COUNT NEW FILL?	COUNT NEW FILL=XXXXXXXXX	pulses	Section 4.4.7.8
COUNTS?	COUNTS=XXXXXXX	pulses	Section 4.4.4.7
EGY?	EGY=XX.XX	mJ	Section 4.4.3.2
EGYSET?	EGYSET=XX.XX	mJ	Section 4.4.3.3
FANCTRL?	FANCTRL=ON	-	Section 4.4.6.2
	FANCTRL=OFF	-	
FILTER?	FILTER=XX	1/10 second	Section 4.4.8.1
FILTERCONTAMINATION?	FILTERCONTAMINATION=XXX	%	Section 4.4.8.2
HALOGEN?	HALOGEN=XXXX	mbar	Section 4.4.5.3
HICOUNT?	HICOUNT=XXXXX	actions	Section 4.4.7.6
HV?	HV=XX.XX	kV	Section 4.4.3.4
ID	ID=L,text,XX.XX,XX.XX,text	-	Section 4.4.9.3
INERT?	INERT=XXXX	mbar	Section 4.4.5.4
INTERLOCK?	INTERLOCK=NONE	-	Section 4.4.8.3
	INTERLOCK=XXX	-	
MAINTENANCE?	MAINTENANCE=X	-	Section 4.4.8.4
MENU?	MENU=X,text	-	Section 4.4.5.1

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Polling Command	Possible Replies	Unit	Further Information
MODE?	MODE=EGY NGR	-	Section 4.4.3.1
	MODE=EGY PGR	-	
	MODE=EGYBURST NGR	-	
	MODE=EGYBURST PGR	-	
	MODE=HV NGR	-	
	MODE=HV PGR	-	
NF COUNT?	COUNTER NEW FILL=XXXXXXXXX	pulses	Section 4.4.7.8
OPMODE?	See Section 4.3 on page 22		
PGR COUNT?	PGR COUNT=XXXXX	actions	Section 4.4.7.7
PRESSURE?	PRESSURE=XXXX	mbar	Section 4.4.8.6
RARE?	RARE=XXXX	mbar	Section 4.4.5.5
RESERVOIR TEMP?	RESERVOIR TEMP=XX.X	°C	Section 4.4.8.5
REPRATE?	REPRATE=XXX	Hz	Section 4.4.4.2
SEQBST?	SEQBST=XXXXX	bursts	Section 4.4.4.5
SEQPAUSE?	SEQPAUSE=XXXXX	ms	Section 4.4.4.6
SERIALNUMBER?	SERIALNUMBER=text	-	Section 4.4.9.4
SYSDATE?	SYSDATE=XX.XX.XX	-	Section 4.4.9.1
SYSTIME?	SYSTIME=XX:XX:XX	-	Section 4.4.9.2
TEMP CONTROL?	TEMP CONTROL=ON	-	Section 4.4.6.3
	TEMP CONTROL=OFF	-	
TIME?	TIME=0	-	Section 4.4.8.7
	TIME=XXX	secs.	
TIMEOUT?	TIMEOUT=ON	-	Section 4.4.6.4
	TIMEOUT=OFF	-	
TOTAL COUNTER?	TOTAL COUNTER=XXXXXXXXX	pulses	Section 4.4.7.4
TRIGGER?	TRIGGER=EXT	-	Section 4.4.4.1
	TRIGGER=EXT COUNTS		
	TRIGGER=INT	-	
	TRIGGER=INTB	-	
	TRIGGER=INT COUNTS	-	
	TRIGGER=INTG	-	
TUBETEMP?	TUBE TEMP=XX.X	°C	Section 4.4.8.5
TYPEOFLASER?	TYPEOFLASER=text	-	Section 4.4.9.5
VERSION?	VERSION=X.XX	-	Section 4.4.9.6

(Sheet 2 of 2)

All polling commands are accepted at all times.

4.4.3 Energy Management Parameters

For additional information about fundamental energy management of the excimer laser device, please refer to the “Fundamentals” chapter of the User Manual.

4.4.3.1 MODE

Syntax:

Setting:	MODE=*mode*
Polling:	MODE?
Reply:	MODE=*mode*

Syntax Description:

mode	EGY NGR, EGY PGR, EGYBURST NGR, EGYBURST PGR, HV NGR or HV PGR

This parameter specifies the laser running mode:

– EGY NGR indicates laser operation in the constant energy mode without gas actions (constant *E*ner*GY*, *N*o *G*as *R*eplacements).

  When MODE=EGY NGR is active, the laser runs at the pulse output energy specified through the parameter EGY (see Section 4.4.3.2). To compensate for the deterioration in the excimer laser gas, the HV is continuously increased. When the HV has reached a given level, a message appears indicating that the gas in the laser tube requires replacing.

– EGY PGR indicates laser operation in the constant energy mode with gas actions (constant *E*ner*GY*, *P*artial *G*as *R*eplacements).

  When MODE=EGY PGR is active, the laser runs at the pulse output energy specified through the parameter EGY (see Section 4.4.3.2). To compensate for the deterioration in the excimer laser gas, the HV is continuously increased. When the HV reaches a preset replacement value, the gas in the laser tube is replenished and the HV value is correspondingly reduced.

  The gas replenishment action (Halogen Injection, macro Halogen Injection, Rare Injection, Partial Gas Replacement or Macro Partial Gas Replacement) occurs according to the gas replenishment algorithms defined in the laser control software. Depending on the HI/PGR entry in the configuration file, the gas replenishment action will either occur immediately (AUTO setting) or the laser control software will request that the gas action is performed within a preset time period (REQUEST setting). In case of a request, the command OPMODE=HI/PGR will cause the gas action to be performed (see Section 4.3.2.6 on page 27).

– EGYBURST NGR indicates operation in the energy burst mode without gas replenishment actions (constant *E*ner*GY BURST*, *N*o *G*as *R*eplacements). This function is only available if the laser device is equipped with the optional POWERLOK function.

  The energy burst mode without gas actions operates similarly to the constant energy mode without gas actions (see EGY NGR above). Additionally, the optional POWERLOK function is activated to minimize power overshoots at the beginning of each burst of laser pulses.

– EGYBURST PGR indicates operation in the energy burst mode with gas replenishment actions (constant *E*ner*GY BURST*, *P*artial *G*as *R*eplacements).This function is only available if the laser device is equipped with the optional POWERLOK function.

  The energy burst mode with gas actions operates similarly to the constant energy mode with gas actions (see EGY PGR above). Additionally, the optional POWERLOK function is activated to minimize power overshoots at the beginning of each burst of laser pulses.

– HV NGR indicates laser operation in the constant high voltage (HV) mode without gas actions (constant *HV*, *N*o *G*as *R*eplacements).

  When MODE=HV NGR is active, the high voltage remains constant at the value specified through the parameter HV (see Section 4.4.3.4). In the constant HV mode the pulse energy will decrease as the excimer laser gas deteriorates. When the energy has dropped to a given level, a message appears indicating that the gas in the laser tube requires replacing.

– HV PGR indicates laser operation in the constant high voltage (HV) mode with gas actions (constant *HV*, *P*artial *G*as *R*eplacements).

  When MODE=HV PGR is active, the high voltage remains constant at the value specified through the parameter HV (see Section 4.4.3.4). In the constant HV mode the pulse energy will decrease as the excimer laser gas deteriorates. To compensate for the decreases in energy, pulse counter controlled and/or timer controlled gas actions are performed.

  The gas replenishment action (Halogen Injection, macro Halogen Injection, Rare Injection, Partial Gas Replacement or Macro Partial Gas Replacement) occurs according to the gas replenishment algorithms defined in the laser control software. Depending on the HI/PGR entry in the configuration file, the gas replenishment action will either occur immediately (AUTO setting) or the laser control software will request that the gas action is performed within a preset time period (REQUEST setting). In case of a request, the command OPMODE=HI/PGR will cause the gas action to be performed (see Section 4.3.2.6 on page 27).

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4.4.3.2 EGY

Syntax:

Setting:	EGY=XXX.XX
Polling:	EGY?
Reply:	EGY=XXX.XX

Syntax Description:

Variable	decimal, max. 3 places before and 2 places after decimal point
Unit	mJ
Range	*For energy set point*: ≥ 0.1 × [max. energy set point] ≤ [max. energy set point] *For calibration value*: ≥ 0.2 × [max. energy set point] ≤ 2 × [max. energy set point]
Increment	0.01 mJ

The exact function and meaning of this parameter depends on the currently active operating mode:

– In all modes except OPMODE=ENERGY CAL, the setting command EGY=XXX.XX specifies the pulse energy set point, i.e. the energy of each pulse at which the laser is to be stabilized. The value defined through EGY=XXX.XX is effective in conjunction with the energy constant modes (MODE=EGY NGR or MODE=EGY PGR) and burst modes (MODE=EGYBURST NGR or MODE=EGYBURST PGR).

– In OPMODE=ON, the polling command reply EGY=XXX.XX indicates the current average energy value.

– In OPMODE=OFF, the polling command reply EGY=XXX.XX indicates the current energy set point for the constant energy mode.

– In OPMODE=ENERGY CAL, the setting command EGY=XXX.XX specifies the energy value for calibration. If the value is accepted (within range), the laser switches to OPMODE=OFF and the calibration value is saved.

– In OPMODE=ENERGY CAL, the polling command reply EGY=XXX.XX indicates the raw average value of the energy sensor.

4.4.3.3 EGYSET

Syntax:

Setting:	EGYSET=XXX.XX
Polling:	EGYSET?
Reply:	EGYSET=XXX.XX

Syntax Description:

Variable	decimal, max. 3 places before and 2 places after decimal point
Unit	mJ
Range	≥ 0.1 × [max. energy set point] ≤ [max. energy set point]
Increment	0.01 mJ

This parameter indicates the pulse energy set point, i.e. the energy of each pulse at which the laser is to be stabilized. It is similar to EGY except that the function of EGYSET does not change according to the currently active operating mode.

4.4.3.4 HV

Syntax:

Setting:	HV=XX.XX
Polling:	HV?
Reply:	HV=XX.XX

Syntax Description:

Variable	decimal, max. 2 places before and after decimal point
Unit	kV
Range	≥ [HV minimum] for HV constant mode ≤ [HV maximum] for HV constant mode
Increment	0.01 kV

This parameter specifies the charging voltage (HV power supply module). The setting command HV=XX.XX is only effective in conjunction with the HV constant modes (MODE=HV NGR or MODE=HV PGR).

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4.4.4 Pulse Trigger Parameters

For additional information about the fundamental laser triggering modes, please refer to the “Fundamentals” chapter of the User Manual.

4.4.4.1 TRIGGER

Syntax:

Setting:	TRIGGER=*mode*
Polling:	TRIGGER?
Reply:	TRIGGER=*mode*

Syntax Description:

mode	name of one of the triggering modes: EXT, EXT COUNTS, INT, INTB, INT COUNTS, INTG

This parameter specifies the trigger source and mode. For additional information about the fundamental laser triggering modes, please refer to the “Fundamentals” chapter of the User Manual.

– EXT indicates external triggering, i.e. the laser pulses are triggered from an external trigger generator connected to the trigger interface on the laser device.

– INT indicates internal triggering, i.e. the laser pulses are triggered by the laser device’s internal trigger generator at the repetition rate specified through the parameter REPRATE (see Section 4.5.2.5).

  The internal trigger generator will trigger a series of pulses without a break. If bursts of pulses are required, activate either

  – TRIGGER=INTB and set the burst generator through the dedicated burst generator functions or
  – TRIGGER=EXT and use an external trigger generator.

– INTG indicates internal gated triggering, i.e. the laser pulses are triggered by the laser device’s internal trigger generator at the repetition rate specified through the parameter REPRATE (see Section 4.4.4.2) when a gate signal is received through the external trigger socket on the laser device.

– INTB indicates triggering with the internal burst generator according to a predefined burst pattern (see Figure 11).

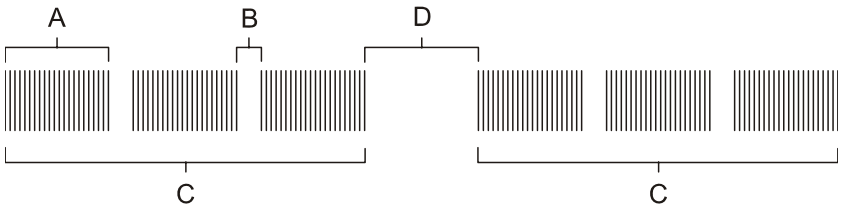

Figure 11: *Burst pattern*

Key to Figure 11:

A	Burst length in pulses	B	Burst pause in milliseconds
C	Sequence length in bursts	D	Sequence pause in milliseconds

Before sending TRIGGER=INTB to start internal triggering in the burst mode, always check and, where necessary, change the repetition rate (see Section 4.4.4.2) and set the burst pattern through the following functions:

- BSTPULSES (see Section 4.4.4.3)
- BSTPAUSE (see Section 4.4.4.4)
- SEQBST (see Section 4.4.4.5)
- SEQPAUSE (see Section 4.4.4.6)

– EXT COUNTS indicates external triggering of the amount of trigger pulses set through the command COUNTS=XXXXXXX (see Section 4.4.4.7).

– INT COUNTS indicates internal triggering of the amount of trigger pulses set through the command COUNTS=XXXXXXX (see Section 4.4.4.7).

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4.4.4.2 REPRATE

Syntax:

Setting:	REPRATE=XXX
Polling:	REPRATE?
Reply:	REPRATE=XXX

Syntax Description:

Variable	integer, max. 3 places
Unit	Hz
Range	≥ 1 ≤ 200
Increment	1 Hz

This parameter indicates the repetition rate (rep. rate) at which the laser is running with internal triggering.

When TRIGGER=INT is active, REPRATE=XXX will become active immediately. When TRIGGER=EXT is active, REPRATE=XXX will become immediately active when TRIGGER=INT is next activated.

4.4.4.3 BSTPULSES

Syntax:

Setting:	BSTPULSES=XXXXX
Polling:	BSTPULSES?
Reply:	BSTPULSES=XXXXX

Syntax Description:

Variable	integer, max. 5 places
Unit	pulses
Range	≥ 1 ≤ 10000
Increment	1 pulse

This parameter indicates the amount of laser pulses in a burst (see Figure 11, A on page 46). The rate at which the pulses are emitted is set through REPRATE (see Section 4.4.4.2). The break between the pauses is set through BSTPAUSE (see Section 4.4.4.4).

The BSTPULSES value will become active when TRIGGER=INTB (see Section 4.4.4.1) is activated.

4.4.4.4 BSTPAUSE

Syntax:

Setting:	BSTPAUSE=XXXXX
Polling:	BSTPAUSE?
Reply:	BSTPAUSE=XXXXX

Syntax Description:

Variable	integer, max. 5 places
Unit	milliseconds
Range	≥ 1 ≤ 10000
Increment	1 millisecond

This parameter indicates the length of the break between two bursts of laser pulses (see Figure 11, B on page 46). The amount and frequency of the laser pulses in the burst is defined through BSTPULSES (see Section 4.4.4.3) and REPRATE (see Section 4.4.4.2).

The BSTPAUSE value will become active when TRIGGER=INTB (see Section 4.4.4.1) is activated.

If one of the energy burst modes (EGYBURST NGR, EGYBURST PGR; see Section 4.4.3.1) is active, the optional POWERLOK algorithm may be activated to minimize the inherent power overshoot at the beginning of the each burst.

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4.4.4.5 SEQBST

Syntax:

Setting:	SEQBST=XXXXX
Polling:	SEQBST?
Reply:	SEQBST=XXXXX

Syntax Description:

Variable	integer, max. 5 places
Unit	bursts
Range	≥ 1 ≤ 10000
Increment	1 burst

This parameter indicates the amount of pulse bursts in a sequence of bursts (see Figure 11, C on page 46). The burst is defined through BSTPULSES (see Section 4.4.4.3), REPRATE (Section 4.4.4.2) and BSTPAUSE (Section 4.4.4.4).

The SEQBST value will become active when TRIGGER=INTB (see Section 4.4.4.1) is activated.

4.4.4.6 SEQPAUSE

Syntax:

Setting:	SEQPAUSE=XXXXX
Polling:	SEQPAUSE?
Reply:	SEQPAUSE=XXXXX

Syntax Description:

Variable	integer, max. 5 places
Unit	milliseconds
Range	≥ 1 ≤ 10000
Increment	1 millisecond

This parameter indicates the length of the break between two sequences of pulse bursts (see Figure 11, D on page 46). The amount of pulse bursts in a sequence is defined through SEQBST (see Section 4.4.4.5).

The SEQPAUSE value will become active when TRIGGER=INTB (see Section 4.4.4.1) is activated.

4.4.4.7 COUNTS

Syntax:

Setting:	COUNTS=XXXXXXX
Polling:	COUNTS?
Reply:	COUNTS=XXXXXXX

Syntax Description:

Variable	integer, max. 7 places
Unit	pulses
Range	≥ 1 ≤ 1000000
Increment	1 pulse

This parameter indicates the value of the reload counter for countdown triggering of the laser.

Countdown triggering is only available when one of the commands TRIGGER=EXT COUNTS or TRIGGER=INT COUNTS is active. COUNTS=XXXXXXX sets the laser to generate a preset number of laser pulses. Trigger pulses will only be accepted until the indicated amount of counts is reached. Following this, the laser will switch to OPMODE=OFF and COUNTS will be reloaded. When OPMODE=ON is reselected, the set number of pulses will be triggered again.

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4.4.5 Gas Parameters

4.4.5.1 MENU

Syntax:

Setting:	MENU=X or MENU=RESET
Polling:	MENU?
Reply:	MENU=X,text

Syntax Description:

Variable	integer, 1 place
Unit	–
Range	≥ 1 ≤ 6
Increment	1
text	text string indicating gas type and gas supply mode

This parameter selects the required gas menu. This menu contains the pressure set points for the individual gases that are to be filled into the laser tube. The six gas menus are factory set according to the version of the laser device (F or Cl) and, consequently, the gas mixtures that the laser can be operated with. The gas menu has to be changed when, for instance, the gas supply mode is changed from single gases to a premix gas. Generally, the menus 1 to 3 are for single gases and the menus 4 to 6 are for premix gases. The F-version has single gas and premix gas menus for ArF, KrF and XeF (six menus). The Cl-version has single gas and premix gas menus for XeCl (two menus).

The reply MENU=X,TTT indicates the currently selected gas menu. The value in front of the comma is the gas menu number and the string after the comma is a description of the gas menu. For example, `MENU=2,KrF Single` indicates gas menu number 2 for Krypton fluoride operation (248 nm) supplied from single gas cylinders.

If the partial gas pressures have been changed (see Sections 4.4.5.2 to 4.4.5.5), the command MENU=RESET resets the gas pressure set points to the factory settings.

4.4.5.2 BUFFER

Syntax:

Setting:	BUFFER=XXXX
Polling:	BUFFER?
Reply:	BUFFER=XXXX

Syntax Description:

Variable	integer, max. 4 places
Unit	mbar
Range	≥ [min. set point buffer] ≥ [min. total pressure] – ([set point halogen] + [set point rare] + [set point inert]) ≤ [max set point buffer] ≤ [max total pressure] – ([set point halogen] + [set point rare] + [set point inert])
Increment	1 mbar

This parameter indicates the set point in the currently active gas menu for the gas connected to the buffer line.

4.4.5.3 HALOGEN

Syntax:

Setting:	HALOGEN=XXXX
Polling:	HALOGEN?
Reply:	HALOGEN=XXXX

Syntax Description:

Variable	integer, max. 4 places
Unit	mbar
Range	≥ [min. set point halogen] ≥ [min. total pressure] – ([set point buffer] + [set point rare] + [set point inert]) ≤ [max set point halogen] ≤ [max total pressure] – ([set point buffer] + [set point rare] + [set point inert])
Increment	1 mbar

This parameter indicates the set point in the currently active gas menu for the gas connected to the halogen line.

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4.4.5.4 INERT

Syntax:

Setting:	INERT=XXXX
Polling:	INERT?
Reply:	INERT=XXXX

Syntax Description:

Variable	integer, max. 4 places
Unit	mbar
Range	≥ [min. set point inert] ≥ [min. total pressure] – ([set point buffer] + [set point halogen] + [set point rare]) ≤ [max set point inert] ≤ [max total pressure] – ([set point buffer] + [set point halogen] + [set point rare])
Increment	1 mbar

This parameter indicates the set point in the currently active gas menu for the gas connected to the inert line.

4.4.5.5 RARE

Syntax:

Setting:	RARE=XXXX
Polling:	RARE?
Reply:	RARE=XXXX

Syntax Description:

Variable	integer, max. 4 places
Unit	mbar
Range	≥ [min. set point rare] ≥ [min. total pressure] – ([set point buffer] + [set point halogen] + [set point inert]) ≤ [max set point rare] ≤ [max total pressure] – ([set point buffer] + [set point halogen] + [set point inert])
Increment	1 mbar

This parameter indicates the set point in the currently active gas menu for the gas connected to the rare line.

4.4.6 Miscellaneous Switching Commands

4.4.6.1 COD

Syntax:

Setting:	COD=XXX
Polling:	COD?
Reply:	COD=XXX

Syntax Description:

Variable	ON or OFF

This parameter defines the status of the Charge on demand (COD) function.

– ON indicates that the COD function is active.

  COD=ON is a setting command or reply to the polling command COD? Capacitor charging is specifically triggered by the demand for a laser pulse. In other words, as long as there is no pulse trigger signal, the HV is switched off and the capacitors remain uncharged. When a laser pulse is needed, a trigger signal enables the power supply to charge the storage capacitors. When the storage capacitors have been charged, the thyratron is triggered, the laser emits a single pulse and the HV is switched off again. This prevents laser pulses being emitted without the input of a trigger signal (self-firing).

  When the laser is operating in the COD mode, the delay between the trigger signal and the laser pulse is significantly increased (see Section 3.4.3 on page 16). With certain laser device versions, this delay will vary depending on the currently active running mode and repetition rate.

  To prevent malfunctioning, a COD status change (e.g. COD=OFF to COD=ON) will only be accepted when OPMODE=OFF is active.

– OFF indicates that the COD function is inactive.

  The capacitors are automatically charged after the previous discharge. Without COD, the delay between the trigger pulse and laser pulse is minimized. There is, however, an increased risk of self-firing.

  To prevent malfunctioning, a COD status change (e.g. COD=ON to COD=OFF) will only be accepted when OPMODE=OFF is active.

4.4.6.2 FANCTRL

Syntax:

Setting:	FANCTRL=XXX
Polling:	FANCTRL?
Reply:	FANCTRL=XXX

Syntax Description:

Variable	ON or OFF

This parameter defines the status of the gas circulation fan when OPMODE=OFF is active.

– ON indicates that the gas circulation fan is to stay on when OPMODE=OFF is active.

– OFF indicates that the gas circulation fan is to be switched off when OPMODE=OFF is active.

4.4.6.3 TEMP CONTROL

Syntax:

Setting:	TEMP CONTROL=XXX
Polling:	TEMP CONTROL?
Reply:	TEMP CONTROL=XXX

Syntax Description:

Variable	ON or OFF

This function only applies if the laser device is equipped with the automatic temperature regulation option. It defines the status of the tube temperature measurement function.

– ON indicates that the tube temperature measurement function is enabled. TEMP CONTROL=ON is the default choice when the laser device is initially powered up.

– OFF indicates that the tube temperature measurement function is disabled.

4.4.6.4 TIMEOUT

Syntax:

Setting:	TIMEOUT=XXX
Polling:	TIMEOUT?
Reply:	TIMEOUT=XXX

Syntax Description:

Variable	ON or OFF

This parameter defines the status of the serial interface time out function.

– ON indicates that the serial interface time out function is active. This monitors the flow of data through the serial interface to detect any interruptions in the communication between the laser device and handheld keypad or remote control computer system. If no communication occurs through the serial interface for a specific period of time, an interlock (status code 127) will shut down the laser.

  When TIMEOUT=ON is active, there should be continuous communication through the RS232 interface. Where necessary, program the remote computer system with continuous requests to ensure that communication with the laser device is not interrupted resulting in the laser device being unexpectedly switched off.

– OFF indicates that the serial interface time out function is not active. TIMEOUT=OFF is the default choice when the laser device is initially powered up.

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4.4.7 Counters

To allow scheduled gas actions and maintenance activities to be effectively coordinated with fabrication cycles, various counters and timers are incorporated into the laser control software. These either count a number of pulses or events or count a period of time to or from a particular event. One of the pulse counters is user-resettable.

4.4.7.1 COUNTER

Syntax:

Setting:	COUNTER=RESET
Polling:	COUNTER?
Reply:	COUNTER=XXXXXXXXX

Syntax Description:

Variable	integer, max. 9 places
Unit	pulses
Range	0 to 2^{32}
Increment	1 pulse

This parameter indicates the momentary reading of the user-resettable pulse counter. This counts the number of individual pulses that have been emitted since the counter was last reset through COUNTER=RESET.

4.4.7.2 COUNTER E3

Syntax:

Setting:	–
Polling:	COUNTER E3?
Reply:	COUNTER E3=XXXXXXXXX

Syntax Description:

Variable	integer, max. 9 places
Unit	10^3 pulses
Range	0 to 2^{32}
Increment	10^3 pulses

This parameter has the same purpose and syntax as COUNTER except that it counts 10^3 pulses. Due to the limitation of the counters to 2^{32} (4,294,967,296) pulses, higher readings will not be correctly indicated. COUNTER E3 enlarges the number of countable pulses but reduces accuracy as it is not possible to break-down the reading to one individual pulse. COUNTER E3 is reset together with COUNTER.

4.4.7.3 COUNTERMAINT.

Syntax:

Setting:	COUNTERMAINT.=RESET
Polling:	COUNTERMAINT.?
Reply:	COUNTERMAINT.=XXXXXXXXX

Syntax Description:

Variable	integer, max. 9 places
Unit	pulses
Range	0 to 2^{32}
Increment	1 pulse

This parameter indicates the momentary reading of the maintenance counter. This counts the number of individual pulses that have been emitted since the counter was last reset through COUNTERMAINT.=RESET.

4.4.7.4 COUNTER TOTAL

Syntax:

Setting:	–
Polling:	COUNTER TOTAL?
Reply:	COUNTER TOTAL=XXXXXXXXX

Syntax Description:

Variable	integer, max. 9 places
Unit	pulses
Range	0 to 2^{32}
Increment	1 pulse

This parameter indicates the momentary reading of the non-resettable pulse counter. This counter counts the number of individual pulses that have been emitted since the laser was initially commissioned.

The polling command TOTAL COUNTER? has same purpose and reply syntax as COUNTER TOTAL?

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4.4.7.5 COUNTER TOTAL E3

Syntax:

Setting:	–
Polling:	COUNTER TOTAL E3?
Reply:	COUNTER TOTAL E3=XXXXXXXXX

Syntax Description:

Variable	integer, max. 9 places
Unit	10^3 pulses
Range	0 to 2^{32}
Increment	10^3 pulses

This parameter has the same purpose and syntax as COUNTER TOTAL except that it counts 10^3 pulses. Due to the limitation of the counters to 2^{32} (4,294,967,296) pulses, higher readings will not be correctly indicated. COUNTER TOTAL E3 enlarges the number of countable pulses but reduces accuracy as it is not possible to break-down the reading to one individual pulse.

4.4.7.6 HICOUNT

Syntax:

Setting:	–
Polling:	HICOUNT?
Reply:	HICOUNT=XXXXXXXXX

Syntax Description:

Variable	integer, max. 5 places
Unit	HI / RI actions
Range	0 to 2^{32}
Increment	1 HI or RI

This parameter indicates the reading of a counter that counts the number of HI and RI actions that have been carried out since the last new fill. This counter is automatically reset to zero by the laser control software when OPMODE=NEW FILL is received.

4.4.7.7 PGR COUNT

Syntax:

Setting:	–
Polling:	PGR COUNT?
Reply:	PGR COUNT=XXXXXXXXX

Syntax Description:

Variable	integer, max. 5 places
Unit	Macro HI / PGR / Macro PGR actions
Range	0 to 2^{32}
Increment	1 Macro HI, PGR or Macro PGR

This parameter indicates the reading of a counter that counts the number of macro gas actions (Macro HIs, PGRs and Macro PGRs) that have been carried out since the last new fill. This counter is automatically reset to zero by the laser control software when OPMODE=NEW FILL is received.

4.4.7.8 COUNTER NEW FILL

Syntax:

Setting:	–
Polling:	COUNTER NEW FILL?
Reply:	COUNTER NEW FILL=XXXXXXXXX

Syntax Description:

Variable	integer, max. 9 places
Unit	pulses
Range	0 to 2^{32}
Increment	1 pulse

This parameter indicates the reading of a counter that counts the number of individual pulses that have been emitted since the excimer laser gas in the laser tube was last exchanged. This counter is automatically reset to zero by the laser control software when OPMODE=NEW FILL is received.

The polling commands COUNT NEW FILL? and NF COUNT? have the same purpose and reply syntax as COUNTER NEW FILL?

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4.4.8 System Status Parameters

4.4.8.1 FILTER

Syntax:

Setting:	FILTER=XX
Polling:	FILTER?
Reply:	FILTER=XX

Syntax Description:

Variable	integer, max. 2 places
Unit	1/10 second
Range	00 and ≥ 01 ≤ 99
Increment	1/10 second

This parameter indicates the time period during which the average energy is to be calculated. For instance, FILTER=50 indicates that the average energy is to be calculated over a period of 5 seconds. The default is FILTER=10 (1 second). If no filter is required, FILTER=00 has to be set.

4.4.8.2 FILTERCONTAMINATION

Syntax:

Setting:	FILTERCONTAMINATION=RESET
Polling:	FILTERCONTAMINATION?
Reply:	FILTERCONTAMINATION=XXX

Syntax Description:

Variable	integer, max. 3 places
Unit	%
Range	≥ 0 ≤ 100
Increment	1 %

This parameter indicates the filling level of the halogen filter. The setting command FILTERCONTAMINATION=RESET resets the halogen filter saturation indicator to 0.

4.4.8.3 INTERLOCK

Syntax:

Setting:	–
Polling:	INTERLOCK?
Reply:	INTERLOCK=NONE or INTERLOCK=XXX[,XXX,...]

Syntax Description:

Variable	integer, max. 3 places
Unit	–
Range	see Section 4.3.3 on page 35

This parameter indicates the codes of the currently active interlocks. If more than one interlock is active, the individual codes are separated by a comma. The meaning of each code is indicated in Section 4.3.3.

If no interlocks are active, the reply INTERLOCK=NONE is returned.

4.4.8.4 MAINTENANCE

Syntax:

Setting:	–
Polling:	MAINTENANCE?
Reply:	MAINTENANCE=X[,X,...]

Syntax Description:

Variable	integer, max. 1 place
Unit	–
Range	0 to 4

This parameter indicates the currently active maintenance status code(s). If more than one maintenance status code is active, the individual codes are separated by a comma.

The individual maintenance status codes have the following meaning:

0	No maintenance action required
1	New fill required
2	Maintenance action required
3	Halogen filter contamination counter exceeds 80 %
4	HI/PGR request active

Example:
The reply `MAINTENANCE=1,3` indicates that the halogen filter contamination exceeds 80% and a new fill is required.

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4.4.8.5 TUBETEMP

Syntax:

Setting:	–
Polling:	TUBETEMP?
Reply:	TUBETEMP=XX.X

Syntax Description:

Variable	decimal, max. 1 place after decimal point
Unit	°C
Increment	0.1 °C

This parameter indicates the temperature of the excimer laser gas in the laser tube.

The polling command RESERVOIR TEMP? has same purpose and reply syntax as TUBETEMP?

4.4.8.6 PRESSURE

Syntax:

Setting:	–
Polling:	PRESSURE?
Reply:	PRESSURE=XXXX

Syntax Description:

Variable	integer, max. 4 places
Unit	mbar
Increment	1 mbar

This parameter indicates the pressure of the excimer laser gas in the laser tube.

4.4.8.7 TIME

Syntax:

Setting:	–
Polling:	TIME?
Reply:	TIME=XXX or TIME=0

Syntax Description:

Variable	integer, max. 3 places
Unit	seconds
Decrement	1 second

This parameter indicates the remaining time period of the flushing leak test (see Section 4.3.2.13 on page 31). If the command TIME? is sent when the flushing leak test is not in progress, the reply TIME=0 is returned.

4.4.9 General Information

4.4.9.1 SYSDATE

Syntax:

Setting:	SYSDATE=dd.mm.yy
Polling:	SYSDATE?
Reply:	SYSDATE=dd.mm.yy

Syntax Description:

Variable	3 x integer with 2 places each, separated by a dot

This parameter indicates the system date setting. This setting will be displayed on the hand-held keypad and entered into system logbook files written by the laser device's controller.

4.4.9.2 SYSTIME

Syntax:

Setting:	SYSTIME=hh:mm:ss
Polling:	SYSTIME?
Reply:	SYSTIME=hh:mm:ss

Syntax Description:

Variable	3 x integer with 2 places each, separated by a colon

This parameter indicates the system time setting. This setting will be displayed on the hand-held keypad and entered into system logbook files written by the laser device's controller.

4.4.9.3 ID

Syntax:

Setting:	–
Polling:	ID?
Reply:	ID=L,text,XX.XX,XX.XX,text

Syntax Description:

Variable	text string in four main blocks, separated by commas

This parameter describes the laser device.

The first text block (L,text) is a plain language description of the laser device. This is followed by the software version of the laser control software (XX.XX) and the version of the PLD (programmable logical devcice) software (XX.XX). The last text block indicates the serial number of the laser device.

4.4.9.4 SERIALNUMBER

Syntax:

Setting:	–
Polling:	SERIALNUMBER?
Reply:	SERIALNUMBER=text

Syntax Description:

Variable	text string

This parameter indicates the serial number of the laser device. The currently applicable serial number format is GEP.XXXXXXX.XXXXX. (three letter code, followed by seven digit device part number and a five digit running number).

4.4.9.5 TYPEOFLASER

Syntax:

Setting:	–
Polling:	TYPEOFLASER?
Reply:	TYPEOFLASER=text

Syntax Description:

Variable	text string

This parameter indicates the model of the laser device.

4.4.9.6 VERSION

Syntax:

Setting:	–
Polling:	VERSION?
Reply:	VERSION=X.XX

Syntax Description:

Variable	decimal, 2 places after decimal point

This parameter indicates the version number of the laser control software. The string is always written with two decimal places.

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5 OPERATING ROUTINES

This section provides examples for remote commands which are to be sent to check or perform routines such as

– Laser device start-up (Section 5.1)

– Laser operation (Section 5.2)

– Laser maintenance and upkeep (Section 5.3)

5.1 Laser Device Start-Up

After switching on the laser device, the controller waits for the thyratron to warm up, the power supply to enter the standby mode and the gas circulation fan to start. During this period (approx. 8 minutes) laser operation is inhibited.

⇨ OPMODE?
⇦ OPMODE=OFF,WAIT,0

When the gas circulation fan is running and the HV power supply is ready to operate, the WAIT message disappears.

⇨ OPMODE?
⇦ OPMODE=OFF,0

Laser operation should not be started until the gas in the laser tube has reached operating temperature. For a feedback of the temperature in the laser tube, the temperature value can be requested in a loop and displayed for the user:

⇨ TUBETEMP?
⇦ TUBETEMP=38.2

After initially powering up the laser device, the fan control mode is active. This means that once the laser gas has been warmed-up, the gas circulation fan is switched off and only switched on again in order to maintain the gas at the operating temperature. If the gas circulation fan is to remain permanently switched off in the OFF mode, the parameter FANCTRL=OFF has to be set.

5.2 Laser Operation

5.2.1 Set Laser Operating Parameters

For production sequences, the laser device can be operated with internal or external triggering.

In the following example, the laser is to be set for internal triggering at a repetition rate of 10 Hz and operation in the energy constant mode with a pulse energy of 10 mJ.

1. Set the operating parameters.

⇨ TRIGGER=INT
⇦ 0

⇨ MODE=EGY PGR
⇦ 0

⇨ REPRATE=10
⇦ 0

⇨ EGY=10.00
⇦ 0

2. The current settings can be polled using the following commands:

⇨ TRIGGER?
⇦ TRIGGER=INT

⇨ MODE?
⇦ MODE=EGY PGR

⇨ REPRATE?
⇦ REPRATE=10

⇨ EGY?
⇦ EGY=10.00

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5.2.2 Start and Stop Laser

1. Set the Opmode to ON to start laser operation:

⇨ OPMODE=ON
⇦ 0

The HV power supply module and gas circulation fan are switched on and the trigger mode is set. The laser then enters the On state: laser pulses are generated with the preset parameters:

⇨ OPMODE?
⇦ OPMODE=ON,0

2. Check the operating parameters (see step 2 on page 68) and change if necessary (see step 1 on page 68).
3. After finishing the work, the laser is to be set to the OFF mode:

⇨ OPMODE=OFF
⇦ 0

5.2.3 Start Internal Burst Operation

The laser is to emit a sequence of 20 bursts of 300 pulses each at a repetition rate of 10 Hz. Between each burst there is to be a pause of half a second. The pause between each sequence of bursts is to be two seconds.

1. Make sure that the laser is in the OFF mode.

⇨ OPMODE?
⇦ OPMODE=OFF

2. Set the repetition rate and internal burst generator

⇨ REPRATE=10
⇦ 0

⇨ BSTPULSES=300
⇦ 0

⇨ BSTPAUSE=500
⇦ 0

⇨ SEQBST=20
⇦ 0

⇨ SEQPAUSE=2000
⇦ 0

3. Change the trigger mode to internal burst.

⇨ TRIGGER=INTB
⇦ 0

4. Start laser operation in the internal burst mode.

⇨ OPMODE=ON
⇦ 0

Laser operation will start with the set burst pattern in the currently active running mode. It will continue according to the burst pattern until OPMODE=OFF is sent.

5.2.4 External Countdown Operation

The laser is to emit 2500 pulses at specific positions on a workpiece with a repetition rate and burst pattern defined by an external trigger generator.

1. Make sure that the laser is in the OFF mode.

⇨ OPMODE?
⇦ OPMODE=OFF

2. Set the trigger mode and pulse counter.

⇨ TRIGGER=EXT COUNTS
⇦ 0

⇨ COUNTS=2500
⇦ 0

3. Move the workpiece to the first position and start laser operation.

⇨ OPMODE=ON
⇦ 0

2500 pulses will be emitted in the currently active running mode according to the pulse pattern set by the external trigger generator.

4. After making sure that the laser is OFF, move the workpiece to the next position.

⇨ OPMODE?
⇦ OPMODE=OFF

5. Start laser operation.

⇨ OPMODE=ON
⇦ 0

6. Repeat steps 4 and 5 until all positions have been processed.

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5.3 Laser Maintenance and Upkeep

5.3.1 New Fill

After a series of gas actions have been performed (see Section 5.3 on page 71), a New Fill is to be performed to completely exchange the exhausted gas in the laser tube with fresh gas.

The gas lifetime is monitored by an internal new fill maintenance counter. When this indicates that a new fill is required, the maintenance status code 1 is indicated. This status code is called through the MAINTENANCE? polling command:

⇨ MAINTENANCE?
⇦ MAINTENANCE=1

To determine the number of pulses that have been fired since a new fill was last carried out, use one of the new fill counter functions (see Section 4.4.7.8 on page 60).

At the end of the gas lifetime, the HV power supply may not be able to be adjusted to a value that provides the preset beam energy output. In this case, the “Preset energy too high” warning will be generated,e.g.

⇨ OPMODE?
⇦ OPMODE=ON,0

changes to

⇨ OPMODE?
⇦ OPMODE=ON,89

After 8 minutes warning time, the laser is switched off with the “Preset energy too high” interlock. The status code changes:

⇨ OPMODE?
⇦ OPMODE=OFF,2

Performing a New Fill

1. If the laser is not in the OFF mode, stop laser operation by switching to the OFF mode:

⇨ OPMODE=OFF
⇦ 0

⇨ OPMODE?
⇦ OPMODE=OFF,0

2. Set the Opmode to NEW FILL to start the New Fill:

⇨ OPMODE=NEW FILL
⇦ 0

⇨ OPMODE?
⇦ OPMODE=NEW FILL,0

If OPMODE=NEW FILL,23 or OPMODE=OFF,27 is returned, there is insufficient or no gas flow. In this case, check that the gas cylinder valves are open and that the pressure regulators in the external gas lines are correctly set.

3. When the New Fill has been completed, the Opmode changes automatically to OFF:

⇨ OPMODE?
⇦ OPMODE=OFF,0

4. Restart laser operation (see Section 5.2 on page 68).

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6 APPENDIX

This chapter is primarily intended for system integrators and other users that have previously worked with earlier (pre RoHS) versions of the COMPex and COMPex*Pro* laser device. This information will simplify the integration of the latest version of the laser device in an existing system environment.

6.1 Primary Design Changes

The table in this section outlines the primary differences in design and operation between the RoHS compliant (so-called “green”) versions of the COMPex*Pro* and the earlier, pre-RoHS (so-called “brown”) versions of COMPex*Pro* and COMPex laser devices.

Feature / Item	Pre-RoHS	RoHS Compatible	Comments
Remote socket	4 pin round socket Single channel remote interlock and lamp connection	15 pin Harting HAN15D socket Two channel, category 3 remote interlock with lamp connection and input for external signal	See Section 3.5 for further information
Interlocked panels	Service panel	Service panel Front and rear mirror access panels	See User Manual for further information
Effect of remote interlock	HV power supply disabled	HV power supply disabled and halogen solenoid valve closed	See User Manual for further information
System control	Communication interface (CI) and serial FOL data ring	Laser control board (LCB) as central controller.	See Section 2 for further information
Serial interface	25 pin sub D	9 pin sub D (COM1) and 25 pin sub D (COM2).	See Section 3.3 for further information
Software version	COMPex version 4.8 or below	LCS version 2.29	To enable communication with external programs written for Pre-RoHS laser devices, COM1 can be switched to OLD through the hand-held keypad (see User Manual)
Status codes	Approx. 30 in the range between 0 and 44	Approx. 50 in the range between 0 and 254	The new set of status codes will be used even when COM1 is set to OLD. The external control program will have to be correspondingly amended (see Section 6.2)

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Feature / Item	Pre-RoHS	RoHS Compatible	Comments
Reply codes	None sent	0, 1, 2 or 3 sent	See Section 4.2 for further information
Polling command replies	Syntax of reply: *setting*:*status*	Syntax of reply: *name=setting,status*	When COM1 is set to OLD, the syntax of the reply will be correspondingly converted. The value of the reply will not be converted. For instance, if previous software versions returned an integer and the latest version returns a decimal value, the decimal value will *not* be converted to an integer!
Burst generator	Only external through TRIG IN socket.	Internal through dedicated software commands. External through TRIG IN socket.	The internal trigger generator commands are not available through COM1 when OLD has been selected
Charge On Demand (COD)	COD activated through dedicated software command. Repetition rates above 50 Hz are not accepted	Active as the default choice. Repetition rates up to the max. permissible for the laser device (i.e. 100 Hz for certain models) are accepted. COD can be deactivated through a dedicated software command	See Section 3.4.3 for further information
Vacuum pump and halogen filter	Outboard	Internal	No change in the fundamental function and control. Increased operational safety and reduced footprint.
Halogen source	Optionally available	Not available	Device discontinued

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6.2 Status Code Comparisons

As indicated in Section 6.1, the laser control software will always output the new status codes listed in Section 4.3.3, even if COM1 has been set to OLD. Due to fundamental differences in design between the RoHS-compliant and pre-RoHS versions of the laser device, a number of the current status codes were previously unknown. In addition, other status codes that were previously required are no longer needed.

To avoid runtime errors, the external control software will have to be amended to take into account the changes in the status codes.

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6.2.1 New to Old

The following table provides a cross reference between the new set of status codes (RoHS compliant laser devices) and the corresponding code or nearest equivalent in the old set of status codes (pre-RoHS laser devices).

Status Code .		Description	Comments
New	Old		
0	0	No message, warning or interlock active	New code corresponds with old
2	2	Preset energy too high (interlock)	Status code 2 (interlock) now follows on from status code 89 (warning) if no action is taken
6	27	Tube pressure out of range (interlock)	Equivalent to “wrong tube pressure”
10	1	Tube temperature too high	Internal hardware interlock switch
11	1	Ventilation motor failed	Internal hardware interlock switch
16	1	Remote interlock switch is open	External hardware interlock switch
18	1	HV power supply error	Internal hardware interlock switch
21	21	Thyratron warm-up	New code corresponds with old
23	3	No gas flow (warning)	Code 23 (warning) will change to code 27 (interlock) if no action is taken
25	40	Preset energy too low	New and old status codes have different numbers, but a similar meaning
26	26	Low light	New code corresponds with old
27	3	No gas flow (interlock)	This status follows on from status code 23 (warning) if no action is taken
30	29	Configuration error detected (no valid set of parameters can be loaded from FRAM)	Equivalent to “Memory Check Malfunction”
31	-	Reboot required (after tube temperature or pulser temperature interlock)	No equivalent
32	9	No vacuum (set time period to evacuate laser tube to set point pressure exceeded)	New and old status codes have different numbers, but a similar meaning
42	1	Service panel (cover 1) open	Cover hardware interlock switch
46	1	Liquid leak detected	Internal hardware interlock switch
49	1	HV power supply temperature too high	Internal hardware interlock switch
51	-	Internal gas purifier error	No equivalent
54	-	No external trigger signal detected (time out, set time between two successive external trigger pulses exceeded)	No equivalent
62	-	Halogen filter exchange required (halogen filter filling capacity has been exceeded)	No equivalent
63	-	HI/PGR request time out	No equivalent
64	-	Tube temperature too high	No equivalent

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Status Code .		Description	Comments
New	Old		
69	-	Check safety relay	No equivalent
89	2	Preset energy too high (warning)	Code 89 (warning) will change to code 2 (interlock) if no action is taken
95	-	Max. power (calculated power exceeds max. power parameter)	No equivalent
103	-	Halogen filter exchange required soon	No equivalent
104	-	HI/PGR request (the automated gas action algorithm indicates that a PGR or macro PGR is required)	No equivalent
120	1	Front mirror access panel (cover 2) open	Cover hardware interlock switch
121	1	Rear mirror access panel (cover 3) open	Cover hardware interlock switch
122	1	Safety control module off	Internal hardware interlock switch
123	27	Tube pressure too high (warning)	Equivalent to “wrong tube pressure”
124	27	Tube pressure too low (warning)	Equivalent to “wrong tube pressure”
125	-	Tube temperature too high	No equivalent
126	30	Leak test failed	New and old status codes have different numbers, but a similar meaning
127	31	Communication time out (no communication through serial interface within set time period or communication corrupted)	New and old status codes have different numbers, but a similar meaning
128	-	Tube pressure sensor failed (reading outside of the parameter range)	No equivalent
130	-	Tube temperature sensor failed (reading outside of the parameter range)	No equivalent
131	-	HV power supply temperature	No equivalent
157	-	Gas action time out (gas action not completed within set time period)	No equivalent
182	-	Gas mismatch (gas mixture does not correspond with current menu or tube flushing, transport fill, safety fill or passivation fill has been carried out)	No direct equivalent Old code 8 indicates that the gas needs changing because no further increase in energy is possible
220	4	Watchdog error (fatal error)	New and old status codes have different numbers, but a similar meaning
221	-	External gas failure	No equivalent
223	-	Tube pressure max.	No equivalent
224	-	Tube pressure max.	No equivalent

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6.2.2 Old to New

The following table provides a cross reference between the old set of status codes (pre-RoHS laser devices) and the corresponding code or nearest equivalent in the new set of status codes (RoHS compliant laser devices).

Status Code		Description	Comments
Old	New		
0	0	No message, warning or interlock active	Old code corresponds with new
1	various	Interlock (group signal)	No direct equivalent. With RoHS compatible devices, dedicated interlock status codes indicate the exact reason for an interlock (see Section 4.3.3 on page 35). Previously, the *Interlock?* polling command had to be used to determine the reason for the interlock
2	89 2	Preset energy too high	Condition is now first indicated by a warning (89). If no action is taken, this is followed by an interlock (2)
03	-	Duty cycle exceeded	Not required. Customer-specific function
3	23 27	No gas flow	Condition is now first indicated by a warning (23). If no action is taken, this is followed by an interlock (27)
4	220	Watchdog activated	Old and new status codes have different numbers, but a similar meaning
5	-	Fatal error in FOL data ring	Not required. RoHS compatible laser device has no FOL data ring!
6	-	Polling: at least one laser module does not reply	Not required. RoHS compatible laser device has different control concept
7	-	Energy calibration error	Not required. The revised energy monitor in the RoHS compatible laser device does not need gain adjustment during the calibration procedure
8	various	New gas fill needed	No direct equivalent. The need for a new fill is indicated by the following new codes: 2, 6, 89, 123, 223 (depending on the exact reason for the new fill)
9	32	No vacuum	Old and new status codes have different numbers, but a similar meaning
10	-	Halogen source: low pressure	Not required. Halogen source not available for RoHS compatible devices
11	-	Halogen source: no capacity left	Not required. Halogen source not available for RoHS compatible devices
12	-	Halogen source: error temperature measurement	Not required. Halogen source not available for RoHS compatible devices

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Status Code		Description	Comments
Old	New		
13	-	Halogen source: fluorine valve not open	Not required. Halogen source not available for RoHS compatible devices
21	21	Thyratron warm-up	Old code corresponds with new
26	26	Low light	Old code corresponds with new
27	6	Wrong pressure	Equivalent to “Tube pressure out of range”
29	30	Memory check malfunction	Equivalent to “Configuration error detected”
30	126	Laser tube leak after optics exchange	Old and new status codes have different numbers, but a similar meaning
31	127	Timeout	Old and new status codes have different numbers, but a similar meaning
33	-	Halogen source: halogen pressure too high	Not required. Halogen source not available for RoHS compatible devices
34	-	Halogen source: HI in preperation	Not required. Halogen source not available for RoHS compatible devices
35	-	Halogen source: function not available	Not required. Halogen source not available for RoHS compatible devices
36	-	Charge on demand is switched on	Not required. COD is now the default choice. The COD status (ON or OFF) can be determined through the polling command COD?
37	-	Warning! Repetition rate for COD < 50 Hz	Not required. Repetition rate limit for COD no longer applies
39	-	Inert valve closed	No equivalent command. With RoHS compatible devices, a reply code will indicate that the command to open the inert valve was not accepted. As a workaround when COM1 is set to OLD, send the polling command OPMODE? The reply OFF will indicate that the inert valve is closed
40	25	Preset energy too low	Old and new status codes have different numbers, but a similar meaning
41		Entered energy value too high	No equivalent command. With RoHS compatible devices, a reply code will indicate that the energy value entered is too high. As a workaround when COM1 is set to OLD, send the polling command EGY? when OPMODE=OFF is active. The last sent energy setpoint should be returned as a reply.

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6.3 Filter Command Parameter

The FILTER command parameter has been changed from a pulse-related value to a time-related value. Previously, the value specified the amount of pulses required to calculate the average beam energy. Now the value indicates the period during which the average energy is to be calculated in 1/10 seconds. In other words, FILTER=50 indicates that the average energy is to be calculated over a period of 5 seconds. The default is FILTER=10 (1 second).

6.4 HV Running Modes

The LCS software for RoHS-compliant laser devices has the running modes EGY NGR, EGY PGR, HV NGR, and HV PGR. The COMPex software version 4.8 or below (for pre-RoHS laser devices) has the running modes EGY NGR, EGY PGR and HV. If COM1 has been set to OLD and MODE=HV is sent, the software will assume the last active gas replacement mode (PGR or NGR). In other words, if EGY NGR is active and MODE=HV is sent, HV NGR will be activated and if EGY PGR was previously active, HV PGR will be activated.

The currently active running mode will always be returned together the gas replacement mode when the polling command MODE? is sent.

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