USER MANUAL

OPTex

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1 INTRODUCTION

This chapter outlines:

– the purpose as well as the necessary availability and use of the instruction manual,

– the persons, for whom the instruction manual is intended,

– how the instruction manual is organized,

– the use of signal words and safety signs in the instruction manual,

– the contents of each chapter.

1.1 About this Manual

1.1.1 Purpose, Availability and Use

This instruction manual is intended to familiarize the user with the OPTex and its designated use.

The instruction manual contains important information to installing and operate the OPTex 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 OPTex.

The instruction manual must always be available wherever the OPTex is in use.

The instruction manual must be read and applied by any person in charge of carrying out work with and on the OPTex, e.g.:

– operation including setting up, troubleshooting in the course of work, removal of production waste, care and disposal of consumables.

– maintenance (servicing, inspection, repair) and/or

– transport.

The instruction manual is to be supplemented by the respective national rules and regulations for accident prevention and environmental protection.

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1.1.2 Intended Audience

This manual is intended for:

– Operators, who have completed the OPTex Basic Operations course. An operator operates the OPTex excimer laser in normal day-to-day operations.

– Process engineers, who have completed the OPTex Advanced Operations course. A process engineer prepares jobs for production and other purposes and monitors production quantity and quality.

– Any reader who wishes to acquire general knowledge of the OPTex excimer laser.

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, the name of the main section appears in the upper outside corner of the corresponding odd 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.

1.2 Safety

1.2.1 Laser Safety Classification

Lasers and laser systems are classified according to their relative hazards. These classifications are found in the American National Standards for the Safe Use of Lasers (ANSI Z 136.1-1986), FDA 21 CFR 1040.10 and 1040.11 and IEC-825.
Within this classification, the OPTex excimer laser is a class IV (high power) laser. It must be regarded as a potential hazard to the human operator. When connected to a correspondingly configured beam guidance system, the OPTex becomes a class I laser device.
The laser beam must also be regarded as a potential fire hazard.

1.2.2 Safety Information

Chapter 3 (Safety) describes the physical hazards related to the laser device, the means of protection against these hazards and the safety features incorporated in the design of the laser device.

The Safety Chapter must be read by all persons entrusted with any sort of work on the OPTex excimer laser device.

Never start to follow the procedures detailed in this manual unless you have read and fully understood the information given in the Safety Chapter.

1.2.3 Signal Words and Symbols in this Manual

Contained within this manual are sections in which particular hazards are defined or special attention is drawn to particular conditions. These are indicated with signal words in accordance with ANSI Z-535.2-1991 and safety symbols (pictorial hazard alerts) in accordance with ANSI Z535.3-1991. The signal words are defined in section 1.2.3.1 of this manual and the safety symbols in section 1.2.3.2.

1.2.3.1 Signal Words

Four signal words are used in this manual: DANGER, WARNING, CAUTION and NOTE. The signal words DANGER**,** WARNING and CAUTION designate the degree or level of hazard:

DANGER
Indicates an <u>imminently</u> hazardous situation which, if not avoided, will result in <u>death or serious injury</u>.

WARNING
Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

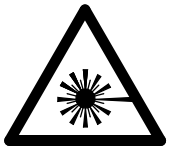
CAUTION
Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It is also used to alert against unsafe practices that may result in property damage.

Use of the signal word ”NOTE”:

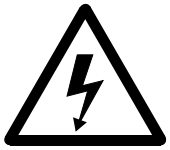
NOTE
Used to define sections, where particular attention should be paid to ensure efficient operation or servicing of the laser device.

1.2.3.2 Symbols

The signal words **DANGER**, **WARNING**, and **CAUTION** are always emphasized with a safety symbol. These safety symbols are used to indicate special hazards. They are used regardless of the hazard level:



This symbol is combined with one of the signal words **DANGER**, **WARNING** or **CAUTION** to indicate a hazardous situation caused by laser radiation.



This symbol is combined with one of the signal words **DANGER**, **WARNING** or **CAUTION** to indicate a hazardous situation caused by electricity.

This symbol is combined with one of the signal words **DANGER**, **WARNING** or **CAUTION** to indicate a hazardous situation caused by toxic substances.

This symbol is combined with one of the signal words **DANGER**, **WARNING** or **CAUTION** to indicate a hazardous situation caused by flammable substances.

This symbol is combined with one of the signal words **DANGER**, **WARNING** or **CAUTION** to indicate a hazardous situation caused by circumstances other than those described above.

1.3 Overview of Chapters

- **Chapter 1** (this chapter).
- **Chapter 2** provides the reader with a short overview of system elements and a description of different subsystems. It introduces fundamental operational concepts, such as running modes, as well as familiarizing the reader with organization and function of the system.
- **Chapter 3** explains safety and provides an overview of safety signs and identification labels. Described are the main physical hazards as well as personal and constructional precautions. **It is essential that you read this chapter before performing any task on the OPTex.**
- **Chapter 4** describes the specifications, installation requirements, conditions of transport and operation and the accessories delivered with the OPTex.
- **Chapter 5** describes the installation of the OPTex.
- **Chapter 6** describes the laser control and service software and its application in the operation of the OPTex.
- **Chapter 7** contains instructions on how to start and operate the OPTex.
- **Chapter 8** describes fundamental maintenance routines, which can be performed by instructed operators.
- **Chapter 9** explains what action the operator can take when errors occur and how to trace errors.
- **Chapter 10** gives an overview of wiring diagrams and schematics.
- The last pages of this manual include a list of figures and a index.

1.4 Conversion Tables

1.4.1 Measurements

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 square meter (m^2)	=	1,550 square inches (in^2)
1 square meter (m^2)	=	10.76 square feet (ft^2)
1 cubic meter (m^3)	=	35.31 cubic feet (ft^3)
1 liter (l)	=	0.264 US gallons (gal)
1 kilogram (kg)	=	2.20 US pounds (lbs)
1 bar	=	100,000 Pascal (Pa)
100,000 Pascal (Pa)	=	14.50 pounds force per square inch (lbf/in^2)

1.4.2 Temperatures

The temperatures in this manual are primarily indicated in degrees celsius (° C).

To convert °C to °F; multiply by 9, divide by 5 and add 32.

To convert °F to °C; subtract 32, multiply by 5, divide by 9.

As a guide, we have converted below some temperature values from °C to °F:

-10 °C	=	14 °F
0 °C	=	32 °F
5 °C	=	41 °F
16 °C	=	61 °F
20 °C	=	68 °F
38 °C	=	100 °F
100 °C	=	212 °F

1.5 Patents and Trademarks

1.5.1 Patents

Lambda Physik GmbH is owner of the following patents:

Germany: P 32 12 928.9	“Entladungsgepumpter Laser”
US Patent # 4,534,034	“Discharge-pumped laser”
Germany: P 33 35 690.4	“Vorrichtung zum Erzeugen von Hochleistungs-Hochspannungsimpulsen hoher Wiederholfrequenz”
Germany: P 38 17145.7	“Elektrode für gepulste Gaslaser und ihre Verwendung”
Germany: G 88 17 197.3	“Elektrode für gepulste Gaslaser”
US Patent # 4,860,300	“Electrode for pulsed gas lasers”
Germany: P 37 14 503.7	“Steuerschaltung für einen gepulsten Gaslaser und Verfahren zum Initialisieren der Steuerschaltung”
US Patent #4,916,707	“Control circuit for a pulsed gas laser”
US Patent # 4,993,042	“Device for mounting a window on a gas discharge laser”
US Patent # 4,980,894	“Ignitor for the preionization of a gas discharge laser”
US Patent # 4,951,295	“Preionization means for a gas discharge laser”
Germany: G 8906 627.8	“Vorrichtung zum Reinigen von Lasergas”
Germany: P 40 03 841.6-09	“Laserresonator”
US Patent #5,220,574	“Excimer laser with hydrogen chloride and method for producing hydrogen chloride for an excimer laser”
Japan 1 991 984	“Excimer laser with hydrogen chloride and method for producing hydrogen chloride for an excimer laser”
Germany: P 42 06 803.7-09	“Verfahren zum Nachfüllen von Halogengas in das Gasreservoir eines Excimerlasers”
US Patent # 5,396,514	“Excimer laser comprising a gas reservoir and a collecting receptacle and a method of refilling the gas reservoir of the laser”
Germany: G 92 08 936.4	“Laserresonator”

Germany: P 42 33 634.1	“Elektroden für die Entladungseinheit eines Excimerlasers”
US Patent # 5,347,532	“Laser having at least one anode and one cathode for preionization and/or discharge”
Japan: Hei 5-262 989/93	“Laser having at least one anode and one cathode for preionization and/or discharge”
US Patent # 4,977,573	“Excimer laser output control device”
US Patent # 4,611,270	“Method and means of controlling the output of a pulsed laser”
Germany: P 43 35 079.8-33	“Elektroden in einer Fluor enthaltenden Entladungseinheit eines gepulsten Gasentladungslasers”
Germany: G 93 20 768.9	“Elektroden in einer Fluor enthaltenden Entladungseinheit eines gepulsten Gasentladungslasers”
Germany: G 94 01 808.1	“Vorrichtung zum Regeln der Temperatur von Lasergas, insbesondere eines Excimerlasers”
Germany: 295 20 820.1	“Laserröhre für halogenhaltige Gasentladungslaser”
US Patent # 4,611,327	“Gas transport laser system”
US Patent # 4,549,091	“Electrical excitation circuit for gas laser”
US Patent # 4,393,505	“Gas discharge laser having a buffer gas of neon”
US Patent # 4,340,968	“Rare gas hydrogen-halide excimer laser with hydrogen additive”
Germany P 44 00 345.5	“Vorrichtung für die Reinigung von Lasergas”

1.5.2 Trademarks

LAMBDA PHYSIK	is a registered trademark of Lambda Physik AG
	the Lambda Physik logo is a registered trademark of Lambda Physik AG
OPTex	is a trademark of Lambda Physik AG
NovaTube	is a registered trademark of Lambda Physik AG
Gyrolok	is a registered trademark of Hoke Inc., NJ, USA
Microsoft, MS, Windows, Windows 95 and Windows NT	are registered trademarks of Microsoft Corporation in USA and other countries
IBM	is a registered trademark of International Business Machines, Inc.

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1.6 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

Feedback Address

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2 LASER DEVICE FUNDAMENTALS

This chapter briefly describes the most important features, functions, and subassemblies of a Lambda Physik excimer laser. This background information will ease your understanding of the information contained in the subsequent chapters.

The information in this chapter does not enable you to operate or service the OPTex excimer laser.

Never switch on or attempt to operate or service the OPTex before reading, understanding and fully familiarizing yourself with Chapter 3 of this manual (Safety)!

2.1 Excimer Laser

Excimer lasers take their name from the *exci* ted state di*mer*s from which lasing occurs. The most important excimers are rare gas halides such as Argon Fluoride (ArF), Krypton Fluoride (KrF), Xenon Chloride (XeCl) and Xenon Fluoride (XeF). These produce intense UV light (*U* ltra *V* iolet) on distinct spectral lines between 157nm and 351nm.

2.1.1 The NovaTube® Innovation

All Lambda Physik excimer lasers use the NovaTube® technology. The NovaTube® has been conceived to virtually eliminate the effects of corrosion and contamination. To ensure strict adherence to these design objectives, all laser tube components are assembled in a clean-room. Optimized electrode materials combined with an improved preionization scheme minimizes electrode erosion. These major improvements in laser tube technology lead to an increased laser tube lifetime.

2.2 Laser Terminology According to ISO 11145

ISO 11145 (“Optics and Optical Instruments - Lasers and Laser Related Equipment - Vocabulary and Symbols”) contains a list of laser terminology.

To prevent misunderstandings, this manual strictly differentiates between “laser” and “laser device” (see Figure 1). 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 lasing.

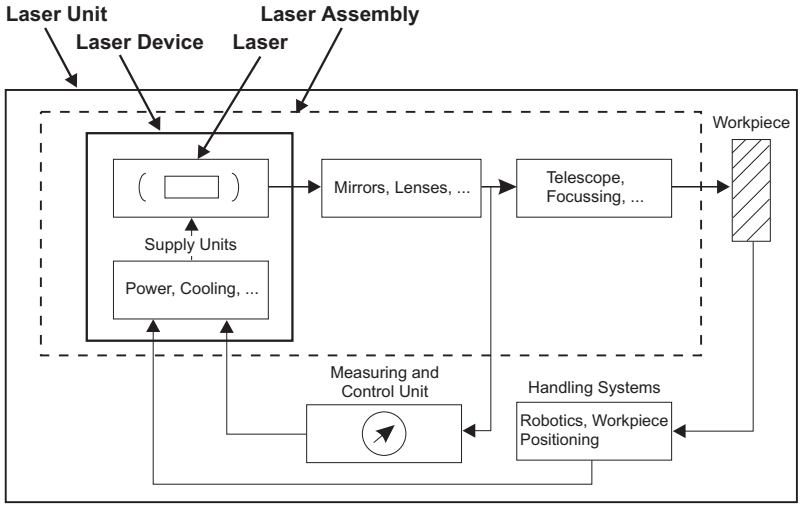

Figure 1: *Laser components according to ISO 11145*

Definitions:

Laser	Lasers consist 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 (e.g. cooling, power and gas supply) that are necessary to operate the laser.
Laser Assembly	Laser device together with specific, normally optical, mechanical and/or electrical system components for beam handling and forming.
Laser Unit	One ore more laser assemblies together with handling, measurement and control systems.

2.3 Fundamental Design of the OPTex

The OPTex is provided with all required power supply and control units. One-phase mains power supply with protective earth as well as Premix and Inert gas supply are sufficient for safely and ease operation. Only a few modules are to be checked and serviced within determined periods. The maintenance schedule is shown in Section 8.3 on page 109.

The OPTex is the most compact Lambda Physik excimer laser device. To ensure fail-safe operation and ease-of-service, the laser device housing is divided into two separate chambers containing the internal components; designated as the tube chamber and the electronics chamber.

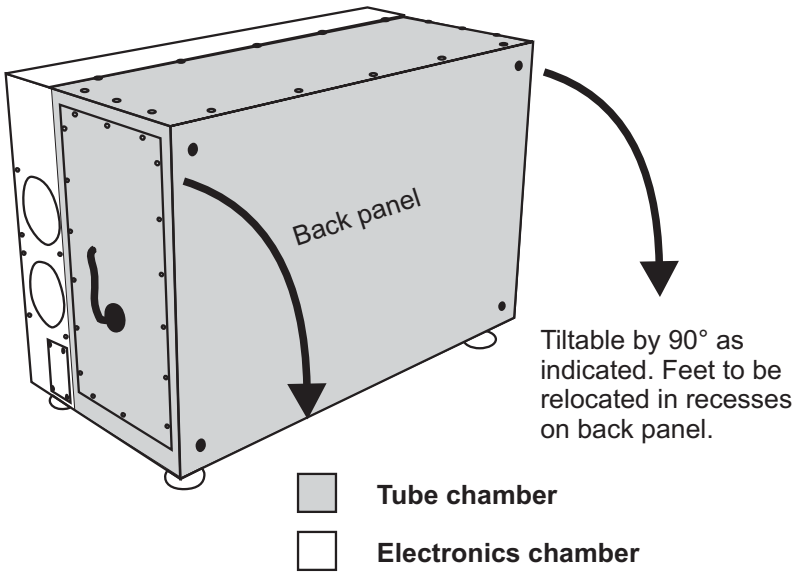

Figure 2: *Fundamental design of the OPTex*

To enable space at the installation site to be optimally utilized, the laser device can be installed on its back or on its bottom panel: recesses for the feet are provided in both panels.

The installation position (upright or flat) and the beam exit side are set at the factory. In this manual, we assume that the laser device is to be installed on its bottom panel (upright position). The beam is to exit from the aperture on the right-hand side (shown in Figure 2 and in Figure 3 on page 14). The gas and power connections are situated on the left-hand side (see Figure 4 on page 15).

2.4 Overview of the OPTex

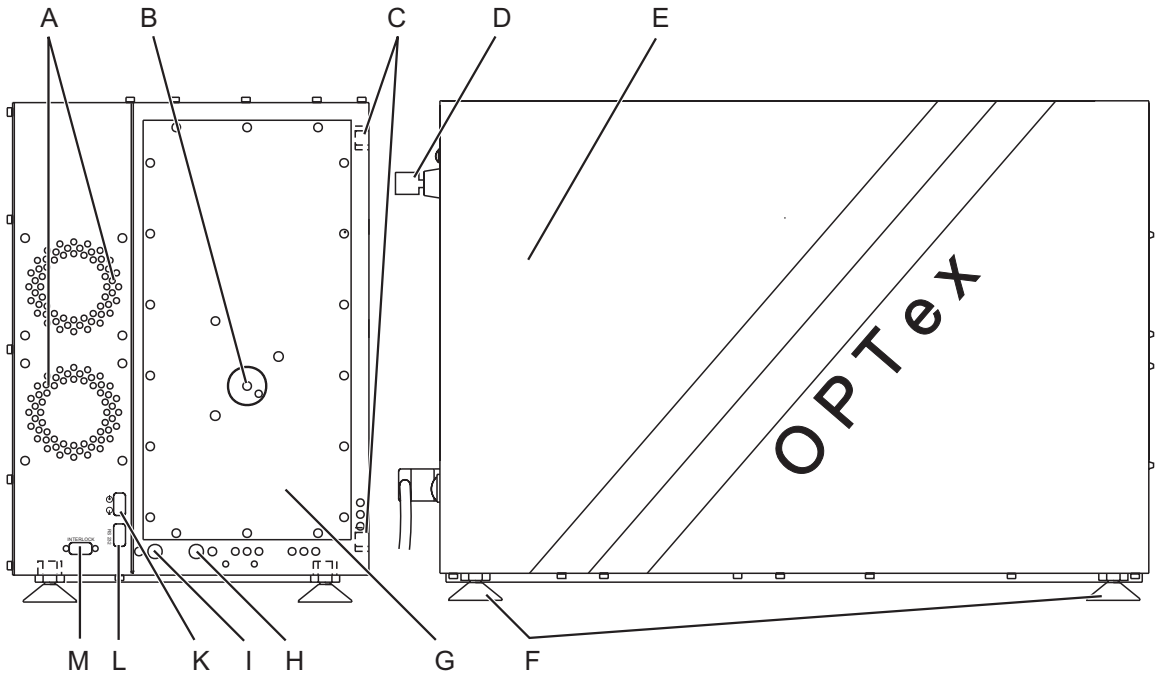

Figure 3: *Right side and front of the OPTex*

Key to Figure 3:

A	Exhaust electronics chamber
B	Beam exit aperture (for F_2 version with beam guidance system connector)
C	Recesses for feet (alternative)
D	Key switch
E	Front service panel
F	Height adjustable feet
G	Right-hand service panel
H	Gas connection valve, Inert (alternative)
I	Gas connection valve, Premix (alternative)
K	Trigger in / Pre trigger out connector (alternative)
L	Optical RS232 connector (alternative)
M	Interlock connector (alternative)

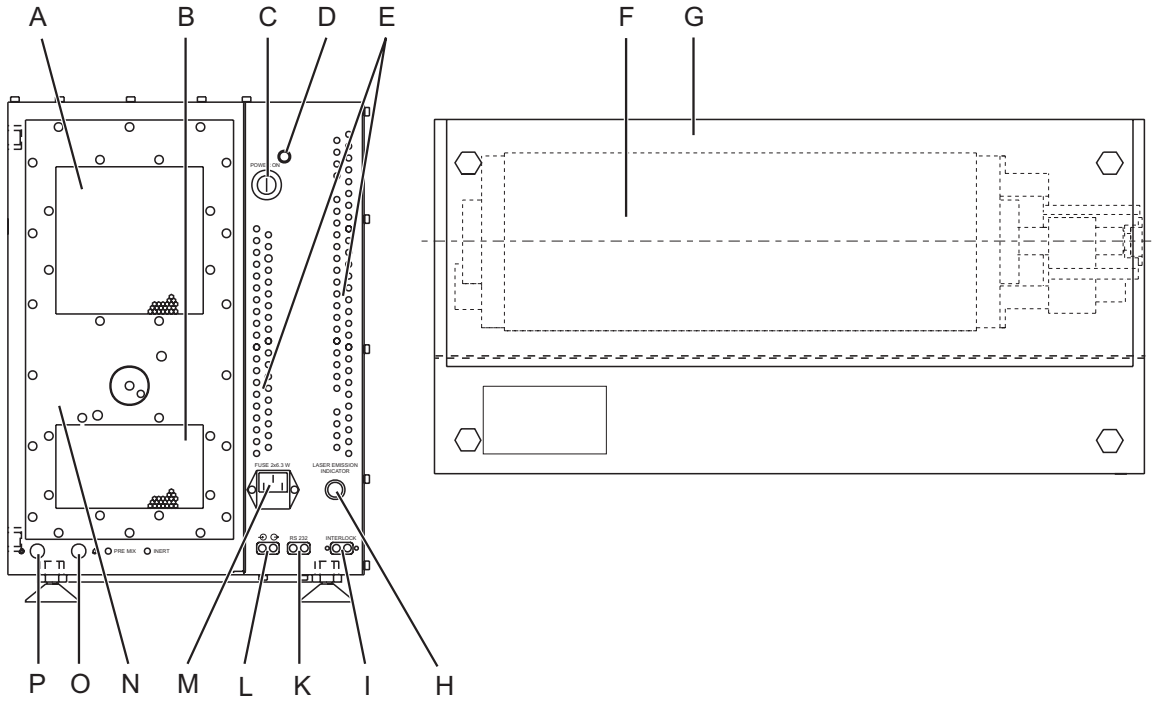

Figure 4: *Left side and top of the OPTex*

Key to Figure 4:

A	Exhaust tube chamber
B	Air intake tube chamber
C	Key switch
D	Power ON light
E	Air intake electronics chamber
F	Laser tube
G	Top service panel
H	Laser radiation warning lamp
I	Interlock connector
K	Optical RS232 connector
L	Trigger in / Pre trigger out connector
M	Mains socket with main fuses
N	Left-hand service panel
O	Gas connection valve, Inert
P	Gas connection valve, Premix

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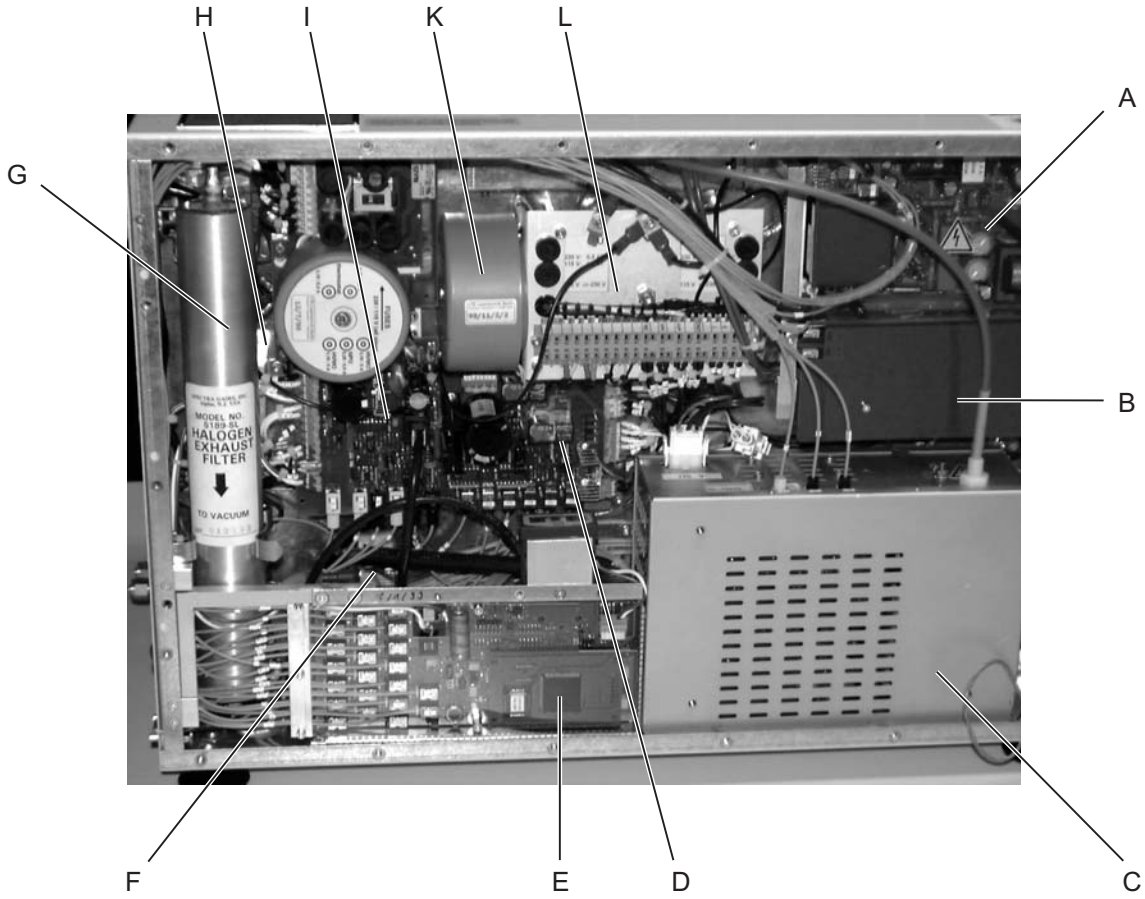

Figure 5: *Electronics chamber (with service panel removed)*

Key to Figure 5:

A	Trigger board
B	Thyratron supply board
C	High voltage power supply module
D	Gas supply unit
E	Laser control unit
F	Vacuum pump
G	Halogen filter
H	Mains filter
I	Mains power supply unit
K	Transformer
L	Power distribution unit

2.5 Laser Control

The OPTex is controlled through an integral control device, known as the laser control unit (CLS). This communicates with decentralized submodules that perform dedicated functions (e.g. laser pulse triggering).

Communication between the laser control unit and the decentralized modules occurs through fiber optic light waveguides (FOLs). As the FOLs do not pick up or transmit electromagnetic interference (EMI), they provide a secure noise-free communication link. This is of considerable importance as the fast high voltage (HV) discharges required with excimer lasers create a high level of EMI.

The laser control software is stored on a flash prom mounted on the laser control unit. This is interfaced to the operator through either the optical RS232 in case of an OEM subassembly or through an operating panel simulated on an PC (the software is provided). In the following description “PC” also means Laptop.

Figure 6: *OPTex controlled through a Laptop*

The OEM device’s controller unit or the existing PC is connected to the laser control unit in the laser device through an optical RS232 interface. To convert the electrical signals emitted by the PC into the optical signals required by the laser control unit and vice-versa, a RS232 optical interface adapter is connected to a serial port on the PC. This adapter is supplied as standard when operation through a PC is specified.

2.6 Laser Tube

The NovaTube® can be considered as the motor of the laser. Figure 7 shows a cross section of the longitudinally symmetrical laser tube.

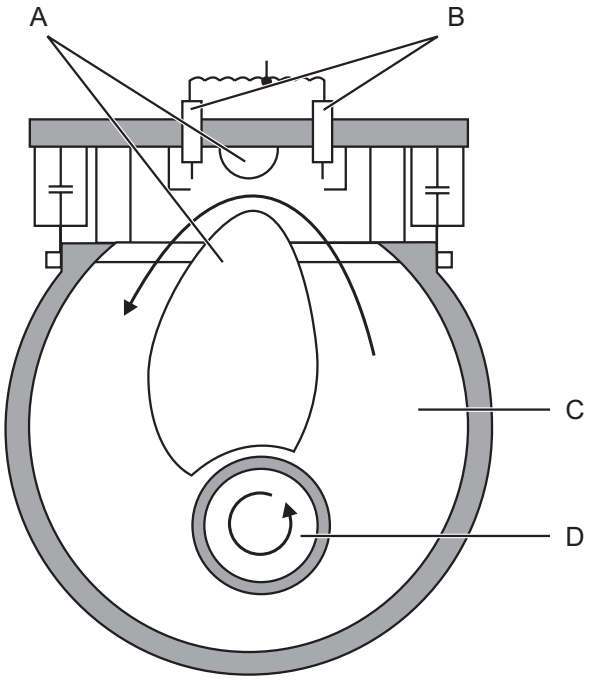

Figure 7: *Cross section of the laser tube*

The laser tube (C) is the reservoir for the laser gas. The materials chosen allow the problem-free use of excimer gas mixtures. The material surfaces become coated with a layer of halogen metal complex. This process, resulting from a reaction between halogen (laser gas) and metal (material within tube), is called passivation. Passivation renders the material surfaces within the tube chemically inert to halogen.

A repetition of this process, known as re-passivation, is always required

– if the surface passivation has been damaged as a result of air entering the laser tube

– (with multigas version only) if a change from a Fluorine to a Chloride gas mixture is necessary

– when the laser device or laser tube has been transported or stored for longer periods.

A high voltage discharge between the electrodes (A) transfers the energy to the excimer gas mixture (e. g. fluorine or krypton premix). In order to obtain a controlled, spark-free discharge, the laser gas has to be preionized, i. e. a sufficiently high density of free charged molecules has to be created between the electrodes. This is achieved with preionization pins (B) arranged along the main electrodes. The result is a homogeneous preionization of the laser gas. The switching of preionization and main discharge in series ensures a perfect synchronization between preionization and main discharge.

After the high-voltage discharge, thermal inhomogenities in the laser gas arise in the discharge area. Therefore, the gas volume in the discharge area has to be completely exchanged between two laser pulses. A transverse circulation fan (D) positioned within the laser tube causes the gas volume between the main electrodes to be completely replaced between two successive laser pulses. The circulation fan is driven externally via a magnetic coupling by a single-phase motor.

The energy efficiency of the excimer laser is to the order of 2%, i. e. the main part of the energy supplied has to be carried away in the form of heat. The gas heated up by the discharge is recooled to the correct operating temperature (approx. 40 °C or 104 °F) using environmental air.

The maintenance operations required during the lifetime of the NovaTube® are new gas fills and the exchange of the windows. To minimize downtimes, the windows should be stored as premounted units.

2.7 Thyratron

The laser uses a simple hydrogen thyratron, a thermionic tube. It is used as an active switch to discharge the storage capacitors. The anode of the thyratron is connected to the charging voltage. The cathode is connected to ground. Between these two main electrodes is the control grid, which initiates the discharge (switching) of the thyratron.

As is also the case with conventional thermionic tubes, the cathode structure has to be heated in order to ensure sufficient emission of starting electrons. If the electron emission after a longer operating period is no longer sufficient to initiate switching of the thyratron, this can be corrected during the thyratron lifetime by increasing the heating power of the cathode. Hydrogen is necessary to provide a fast current increase and a high current intensity. However, as hydrogen is continually lost due to diffusion and metal erosion, the concentration of hydrogen has to be continually renewed. For this purpose, there is a reservoir structure (palladium) in the tube, in which a large quantity of hydrogen is stored. By heating the reservoir, hydrogen is released from the reservoir into the main thyratron. It should be noted, however, that too much hydrogen reduces the hold-off voltage between the electrodes of the thyratron to such a level that unwanted switching of the thyratron will take place even without the trigger pulse. On the other hand, if the partial hydrogen pressure in the thyratron is too low, the laser is unable to pulse. This is because there is no discharge in the thyratron due to a lack of charged particles.

The values for the two heating voltages, UH for the cathode heating and UR for the hydrogen reservoir voltage, are critical to the correct operation of the tube. The voltages are stabilized in a broad input voltage range in order to be unaffected by voltage fluctuations in the supply line (spikes). These values have to be altered during the total life of the thyratron to ensure proper switching of the tube.

2.8 Energy Monitor

An energy monitor (where fitted) continually determines the beam energy by sliding averaging of each of 16 pulses. The transient effect takes less than 100 pulses. The energy monitor converts the determined value into a digital value, for transmission through an FOL link to the laser control unit.

As the energy monitor does not supply absolute measured values, it has to be calibrated by means of a calibrated energy meter or power meter. Apart from the additional energy and power detector, no further measures are necessary. The necessary calibration procedure is described in the maintenance section (Chapter 8).

2.9 Operating Modes

The pulse energy (output energy) of an excimer laser is dependent upon the charging voltage (high voltage) and condition (age) of the excimer laser gas.

If the pulse energy (E) is considered as a function of the charging voltage (U), the result is approximately the function shown in Figure 8.

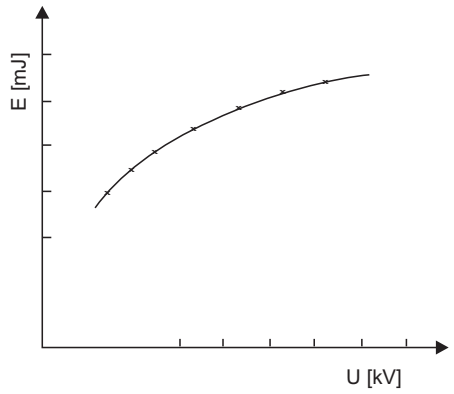

Figure 8: *Pulse energy as a function of charging voltage*

As excimer laser gases age, the pulse energy obtained from a given charging voltage will decrease.

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The laser can, therefore, run either in the Energy Constant mode (EGY CONST) or in the High Voltage Constant mode (HV CONST).

– If the Energy Constant mode is selected, the laser control continuously adjusts the high voltage to achieve laser operation at a preset energy level (see Figure 9).

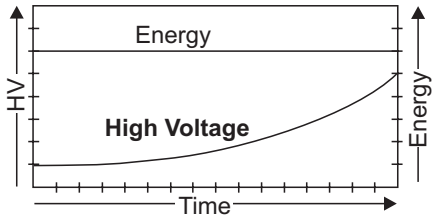


Figure 9: *Voltage increase in the Energy Constant mode*

– If the High Voltage Constant mode is selected, the pulse energy decreases with time as excimer laser gases have a limited lifetime (see Figure 10).

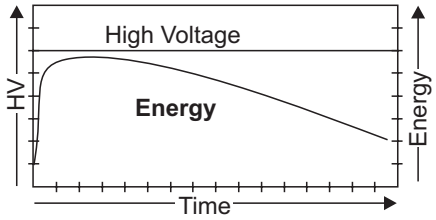


Figure 10: *Energy decrease in the HV Constant mode*

Most applications require the energy constant mode, whereas the high voltage constant mode is primarily used for diagnostic purposes.

NOTE
The energy constant mode is only available if an energy monitor is installed.

2.10 Safety Systems of the OPTex

The laser device is provided with three safety circuits. Watch dogs are monitoring laser operation. In case of faults they are not reset automatically; laser operation will be interrupted and the warm-up period will start again.

Faults are detected by hard- and software and classified into two groups. The error messages are stored in the flagbytes of the laser control software or indicated by the user shell WINLAC (see Section 6.1.3.3 on page 85). Pop-up text fields are giving some information about potential reasons for these error messages.

Statical Errors

The error message “STATICAL ERROR” appears in case of the following conditions or failures

– Remote (external safety) interlock,

– cover interlocks tube chamber or exceeding tube temperature,

– cover interlock electronics chamber or exceeding temperature in the electronics chamber.

These signals are interrupting laser operation. All power supply lines with more than 42 V DC and the mains supply line (except the housing circulation power supply) are interrupted, the triggering is blocked.

Laser operation can be restarted when the cause of the error has been rectified.

Operation Errors

The error message “OPERATION ERROR” qualifies the deviation of laser operation parameters from limiting values concerning

– data transfer and processing

– HV charging time and HV value,

– leak rate,

– HV module temperature,

– Thyratron power supply,

– Overpressure in the laser tube (more than 4.5 or 4.1 bar).

These “Operation Errors” are stopping laser operation. After rectifying the error the laser device has to be switched off by turning the key switch and then on before laser operation can be restarted.

NOTE
In case of overpressure in the laser tube the solenoid valves of the valve assembly are closed automatically.

2.10.1 Safety Interlock

The Remote interlock circuit is supplied with 20 mA by an own power supply unit. Interruption of the power supply line leads to an interlock message.

2.10.2 Electronics Chamber

Closed housing and laser tube temperature are monitored by one circuit and indicated by a common error message. For determined service procedures the safety interlock has to be bridged by the interlock defeaters.

Air cooling is adequate to laser operation only with closed front panel.

2.10.3 Tube Chamber

The laser device can operate only with closed housing of the tube chamber. Interlock switches on the right, left and top service panel and a temperature sensor near the laser tube are monitoring the operation status. Interlock and temperature errors are indicated by a common error light.

When the tube chamber is open, all power supply lines with ≥ 42 V DC and the mains supply line (≥ 100 V AC) are interrupted. For determined service procedures the safety interlocks are to be bridged.

The tube temperature is monitored by hardware components. If the tube temperature exceeds 48 °C, an error message is generated, if it reaches 60 °C, the current laser operation is interrupted automatically. In case of this interruption, the laser tube has to cool down to the optimal operating temperature (40°C) before restarting any laser operation. Depending on the environmental temperature this may take approx. 30 minutes.

3 SAFETY

Never switch on or attempt to operate or service the OPTex before reading, understanding and fully familiarizing yourself with the contents of this chapter.

This chapter is divided into three sections:

– General Safety Aspects, which explains aspects relating to the safe operation of the laser device.

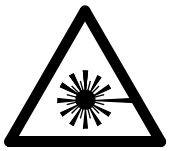
– Special Safety Aspects, which outlines the risks specific to working procedures with and on this laser device.

– Overview of safety-relevant labels, which shows the design of and describes the safety labels.

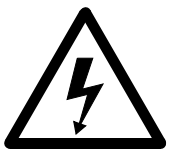
3.1 General Safety Aspects

3.1.1 Basic Operation and Designated Use

The OPTex laser device has been built in accordance with state-of-the-art standards and the recognized safety rules. Nevertheless, its use may constitute a risk to life and limb of the user or of third parties or cause damage to other material property.



WARNING
Potential eye and skin burns!
Only use the laser in accordance with its designated use. Safety interlocks are only to be defeated by authorized personnel.



WARNING
Electrical hazard!
Safety interlocks are only to be defeated by authorized personnel.

WARNING!
Toxic hazards!
The gas system of an excimer laser contains a mixture of halogen gases (fluorine or hydrogen chloride). Inhalation of, or skin contact with, halogen gases should be avoided.

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The OPTex must only be used in technically perfect condition and in accordance with its designated use and the instructions set out in this manual, and only by safety conscious persons who are fully aware of the risks involved in operating the laser device. Any functional disorders, especially those affecting the safety of the laser device, should therefore be rectified immediately.

The OPTex is primarily designed for use in low duty-cycle operation in medical and scientific applications. Using the laser device for purposes other than those mentioned above is considered contrary to its designated use. The manufacturer/supplier cannot be held liable for any damage resulting from such use. The risk of such misuse lies entirely with the user.

Operating the OPTex within the limits of its designated use also involves observing the instructions set out in this manual and complying with the inspection and maintenance directives.

3.1.2 Organizational Measures

In accordance with the valid national regulations for prevention of accidents (in Germany: VBG 93, In the USA: ANSI Z 136.1) a responsible person should be designated as the Laser Safety Officer (LSO) with the responsibility to effect the knowledgeable evaluation of laser hazards and to monitor and enforce their control.

The instruction manual must always be at hand at the place of use of the OPTex laser device.

In addition to the operating instructions, observe and instruct the user in all other generally applicable legal and other mandatory regulations relevant to accident prevention and environmental protection.

These compulsory regulations may also deal with the handling of hazardous substances and the issuing and/or wearing of personal protective equipment.

WARNING
Risk of serious injury through incorrect operation!
Personnel entrusted with work on the OPTex must have read the instruction manual and in particular the safety instructions before beginning work. Reading the instructions after work has begun is too late.

The necessity of reading the instruction manual applies especially to persons working only occasionally on the OPTex, e.g. during setting up, service or maintenance.

Use protective equipment, e. g. protective eyewear, wherever required by the circumstances or by law.

Ensure that all safety-relevant labels are attached to the laser device in accordance with the label location diagrams in Section 3.4.1 on page 48 and local regulations. Make sure that these labels are always complete and perfectly legible. If any labels are missing, immediately inform Lambda Physik.

In the event of safety relevant modifications or changes in the behaviour of the OPTex during operation, stop the laser device immediately and report the malfunction to the competent authority/ person (e.g. Lambda Physik Service).

Never make any modifications, additions or conversions which might affect safety without the suppliers approval. This also applies to the installation and adjustment of safety devices and valves.

Spare parts must comply with the technical requirements specified by the manufacturer. Spare parts from original equipment manufacturers can be relied upon to do so.

Never modify the software of programmable control systems.

Adhere to prescribed intervals or those specified in the instruction manual for routine checks and inspections.

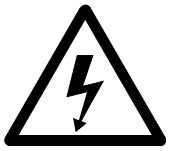
For the execution of maintenance work, tools and workshop equipment adapted to the task on hand are absolutely indispensable.

3.1.3 Selection and Qualification of Personnel - Basic Responsibilities

Make sure that only authorized personnel works on or with the OPTex laser device. Statutory minimum age limits must be observed.

Employ only trained or instructed staff and set out clearly the individual responsibilities of the personnel for operation, set up, maintenance and repair.

Do not allow persons to be trained or instructed or persons taking part in a general training course to work on or with the OPTex laser device without being permanently supervised by an experienced person.



WARNING
Potential electrical hazards!
Work on the electrical system and equipment of the OPTex laser device must be carried out only by a skilled electrician or by instructed persons under the supervision and guidance of a skilled electrician and in accordance with electrical engineering rules and regulations.

WARNING
Toxic hazards!
Work on gas fuelled equipment may be carried out by specially trained personnel only.

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3.1.4 Safety Instructions Governing Specific Operational Phases

Take the necessary precautions to ensure that the OPTex is used only when in a safe and reliable state.

Operate the laser device only if all protective and safety oriented devices, such as removable safety devices, emergency shut off equipment and exhausters, are in place and fully functional.

In the event of malfunctions, stop the laser device immediately and lock it. Have any defects rectified immediately.

Before starting the OPTex laser device ensure that nobody is at risk.

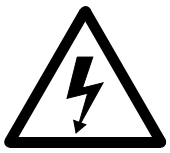
Never switch off or remove suction and ventilation devices when the laser device is in operation.

Observe the adjusting, maintenance and inspection activities and intervals set out in the instruction manual, including information on the replacement of parts and equipment. These activities may be executed by skilled personnel only.

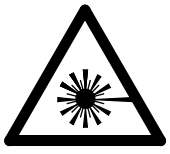
Brief operating personnel before beginning special operations and maintenance work, and appoint a person to supervise the activities.

In any work concerning the operation, conversion or adjustment of the OPTex and its safety oriented devices or any work related to maintenance, inspection and repair, always observe the start up and shut down procedures set out in the instruction manual and the information on maintenance work.

Ensure that the maintenance area is adequately secured.



WARNING
Potential electrical hazards!
If the laser device is completely shut down for maintenance and repair work, it must be secured against inadvertent starting. Ensure that the electrical system is locked-out and tagged-out prior to servicing by locking the key switch of the laser device and tagging appropriate warning signs.



WARNING
Potential eye and skin burns!
If the laser device is completely shut down for maintenance and repair work, it must be secured against inadvertent starting. Ensure that the radiation system is locked-out and tagged-out prior to servicing by locking the key switch of the laser device and tagging appropriate warning signs.

CAUTION
Risk of gas leaks!
Switching off the laser device automatically closes the solenoid valves in the laser device's gas circuit. This interrupts the gas flow in the laser device, but does not evacuate the circuits in the laser device. Also, operating pressure remains in the external gas supply lines. For additional safety, close the corresponding external gas shut-off valves when locking out the laser device.

Always tighten any screwed connections that have been loosened during maintenance and repair.

Any safety devices removed for set up, maintenance or repair purposes must be refitted and checked immediately upon completion of the maintenance and repair work.

Ensure that all consumables and replacement parts are disposed of safely, with minimum environmental impact and in accordance with the valid national and local regulations for waste disposal.

3.2 Specific Safety Aspects

Specific safety aspects are:

– the physical hazards related to the system

– the protection of the operators or users of the system against these hazards

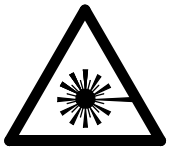
– the constructive protective measures against these hazards.

Lasers and laser systems are classified according to their relative hazards. These classifications can be found in the American National Standard for the Safe Use of Lasers (ANSI Z 136.1-1968), FDA 21 CFR 1040.10 and 1040.11, IEC-825 and in the European Standard EN 60625.
Within this classification, the OPTex is a **Class IV (high power) laser device** when operated with open covers during servicing conditions, and must therefore be regarded as a potential hazard to the human operator.
The laser beam must also be regarded as a potential fire hazard.

A Class IV laser system is not enclosed and therefore requires several safety precautions. Class IV is the most powerful (and potentially hazardous) category of lasers. Direct and scattered radiation from Class IV products are considered acute hazards to the eyes and skin. Precautions include eye and skin protection, remote interlocks and warning labels.

NOTE
The OPTex is a class IV laser device. However, when connected to an OEM device or with housing closed, it becomes a Class I laser device.

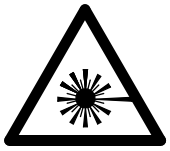
A Class I laser device is defined as a laser system which is supplied with a special enclosure which does not allow access to hazardous levels of laser light during normal operation. This class of laser does not require special precautions for eye safety during normal operations as long as the protective enclosure is in place.



WARNING
Risk of serious injury!
A Class I laser system becomes a Class IV when the enclosure is open.
The laser itself is a class IV device.

3.2.1 Physical Hazards

3.2.1.1 Ultra-Violet Light



WARNING
The laser beam is very dangerous to the eyes and skin!
The following are hazardous,
1. Direct radiation-light as it leaves the laser.
2. Reflected radiation-light which has hit a surface and bounced off.
3. Diffuse radiation-light, which has hit a surface, bounced off, and scattered.

Laser radiation is emitted as a narrow beam of almost parallel rays, the intensity of which will remain high even at some distance of the laser. Although the radiation is nonionizing, damage can still occur to living tissue, if exposed for to long, as a result of heat produced during radiation absorption.

The radiation of an excimer laser lies outside the visible range. Possible wavelengths of the high intensity ultraviolet radiation are 157 nm, 193 nm, 248 nm, 308 nm or 351 nm.

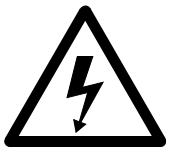
Operating the laser at 157 nm causes additional spontaneous and stimulated emission of radiation in the range of 635 nm to 755 nm (visible red).

In general, the maximum permissible radiation exposure for the skin is several times greater than for the eye. Safety measures with regard to the radiation hazard are therefore mainly based on dangers for the eye.

A potential chemical hazard originates from interaction between the laser beam and an obstruction. The high irradiance could result in the liberation of hazardous fumes and gases. In addition, the heat generated is sufficient to ignite many materials.

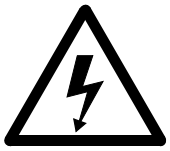
Not only is the direct laser beam hazardous, but unchecked reflections of laser light also constitute a potential hazard. This risk is excluded if the laser beam is contained within a protective enclosure. Protective measures must be taken, therefore, when personnel are working in an open beam situation (use of beam shielding and beam dump).

3.2.1.2 High Voltage / Electric Energy



WARNING
Electrical hazards!
High voltages exceeding the Safety Extra Low Voltage levels (SELV) of 42 VAC or 60 VDC introduce the potential hazard of electric shock and might cause serious injuries by passing electricity through the body.

High voltages of up to 14 kV are generated in the OPTex laser device. As the equipment is provided with a protective housing, accidental contact with current-carrying conductors during normal operation is impossible. However, if an appropriate protective cover is removed, potentially lethal hazards exist in spite of the existence of the housing interlocks. With a protective cover removed, there is the risk of an electric shock whenever the mains supply is connected and the high voltage capacitors are charged. The capacitors in the laser device hold some of joules at peaking voltages of up to 30 kV.



WARNING
Risk of electrocution!
Personnel should never open the laser device before the main power supply cable has been disconnected and the high voltage capacitors are completely discharged.

An electrical safety overview is given in Section 3.2.2.2 of this chapter (page 38), but reference should also be made to Section 3.2.3 (page 42) for an overall description of the system safeguards.

In addition to the above mentioned hazards, the HV switch used (thyratron) generates ionizing radiation.

Radiation limit: 0.2 mSievert/h at 10cm distance

3.2.1.3 Halogen Gases

WARNING!
Toxic hazards!
The gas system of an excimer laser contains a mixture of up to 5 % Fluorine gas or 0.5 % Hydrogen Chloride. Inhalation of, or skin contact with, halogen gases should be avoided.

Halogen gases can cause severe chemical and thermal burns and in sufficient concentrations can cause death due to respiratory damage and pulmonary edema.

It is essential, therefore, that local safety regulations concerning the emission of chemical vapors must be strictly observed along with the recommendations made in this chapter and throughout this manual. Depending upon the wavelength in which the laser is to be operated, the halogen is either Fluorine or Hydrogen Chloride.

– Fluorine is in the form of a premix gas, ratio ≤ 5 % Fluorine in premix, and diluted further with other gases in the laser. Fluorine is characterized by an extremely stinging smell in very low concentrations (0.1ppm).
– Hydrogen Chloride (HCl) is in the form of a premix gas, ratio < 0.5 % HCl in premix.

Both gases are still present in sufficient quantities in the gas supply to cause serious injury if not correctly handled and used.

The attention of the user is drawn, therefore, to the following maximum permitted exposure limits for Fluorine and Hydrogen Chloride. The permitted periods of time in respect of these limits will depend on local safety regulations.

The MAK (maximum acceptable concentration level) values according to the German publication:

"Technische Regel des Ausschuß für Gefahrstoffe des Bundesministeriums für Arbeit und Soziales (TRGS 900)"

and the PEL (permissible exposure limit) set by the American government agency

Occupational Safety and Health Administration (OSHA)

are as follows:

F_2 limit:	0.1 ppm (0.2 mg/m^3)
HCL limit:	5.0 ppm (7.5 mg/m^3)

NOTE
Refer to the International Chemical Safety Cards for Fluorine (ICSC: 0046) or Hydrogen Chloride (ICSC: 0163), respectively, for more precise health hazard information.

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The possibility of over-pressure of the gas mixture containing fluorine or hydrogen chlorine creates potential hazards with the risk of leakage from the laser tube and gas pipes. Under normal operating conditions the overpressure is less than 2.4 bar (3.4 bar abs.), respectively 2.0 bar (3.0 bar abs.) for the F_2 version of the OPTex laser device. In the event of a leak occurring, the release of halogen gas constitutes the greatest hazard.

To remain even in a worst case under the MAK-value of 0.1 ppm for Fluorine, non-ventilated rooms must have an air volume of at least 100 m^3. For the installation in smaller rooms a sufficient air suction is necessary.

Further potential chemical hazards exist due to the formation of hydrofluoric acid if fluorine gas comes into contact with water.

Hydrofluoric acid can also be formed in the halogen filters used in the system due to Fluorine coming into contact with the hygroscopic components of the filter.

3.2.1.4 Ozone

The formation of ozone due to the interaction of ultra-violet light (in particular at 193 nm) with oxygen, and high voltage discharge, constitutes a potential hazard.

The MAK (maximum acceptable concentration level) value according to the German publication

"Technische Regel (TRGS 900) des Ausschuß für Gefahrstoffe des Bundesministeriums für Arbeit und Soziales"

and the PEL (permissible exposure limit) set by the American government agency

Occupational Safety and Health Administration (OSHA)

are as follows:

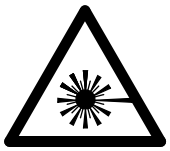
O_3 limit: 0.1 ppm (0.2 mg/m^3)

NOTE
Refer to the International Chemical Safety Card for Ozone (ICSC: 0068) for more precise health hazard information.

3.2.2 Personnel Safety

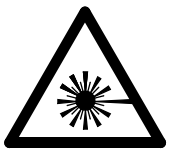
3.2.2.1 Ultra-violet Radiation Safety

An excimer laser emits high intensity pulsed ultraviolet radiation which constitutes a hazard to personnel during periods of operation and servicing. In addition, the F_2 version of the OPTex emits visible red radiation in the range from 635 nm to 755 nm, which represents a particular danger.



WARNING
Risk of serious injury!
A Class I laser system becomes a Class IV when the enclosure is open. The laser itself is a class IV device.

If alignment or maintenance work on Class IV laser equipment is necessary, everyone in the laser area must wear appropriate protective goggles or other appropriate protective eyewear. The mandatory protective goggles provide protection against direct radiation, reflected radiation and standard radiation (normal operating conditions) within the respective wavelength range.

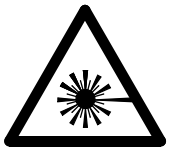


WARNING
Risk of serious injury!
Always wear goggles when there is a chance of exposure to radiation from the laser.
Before putting on the protective goggles, check them for any obvious defects. As the filter in the goggles provides protection for only a narrow band of wavelengths, make sure you are wearing the appropriate goggles for the laser device in question. Check with your Laser Safety Officer or other safety personnel for guidance in selecting the appropriate goggles.

Contact a manufacturer of protective eyewear for information about appropriate protective eyewear. Specifications needed to select appropriate eyewear are: wavelength, power, beam diameter, repetition rate and max. pulse duration.

The ANSI (American National Standards Institute) standard for safe use of lasers requires that protective goggles which block the appropriate laser wavelength should be worn while operating or servicing class IV lasers. The goggles should be clearly labeled with an optical density and the specified wavelength.
To avoid confusion, these goggles should be kept separate from other safety glasses and personal protective equipment. Using the wrong type of goggles is dangerous. It can be worse to have improper eyewear and a false sense of security than to have no eyewear and take precautions based on the absence of protection. Even if you're wearing protective goggles, never looked directly into the beam; intense laser radiation is capable of destroying the protective filter.

Optical Safety Guidelines

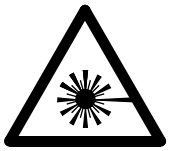


WARNING
Potential eye burns!
Only use the laser in accordance with its designated use. Safety interlocks are only to be defeated by authorized personnel.

The following guidelines describe some of the actions necessary to avoid injury caused by the laser beam. Always follow these guidelines and take additional precautions if necessary.

- When eyewear is necessary, make sure it has the proper optical density for the laser wavelength.
- All other personnel in the vicinity of the laser should also be ordered to wear protective eyewear. Only qualified personnel should be permitted to operate the laser.
- Never intentionally look directly into any laser beam.
- Avoid indirect viewing of direct or reflected laser radiation. Specular reflections (from reflective surfaces) can be as dangerous as the direct laser beam. Do not view the beam through optical instruments unless the optics are designed to filter the laser wavelength.
- Precautions must be taken to ensure that there are no reflecting objects in the path of the laser beam.
- Do not deviate from standard operating procedures when working with class IV laser equipment.
- Use lasers only in approved applications and locations. Take adequate precautions to prevent unauthorized personnel from entering the area where a class IV laser is operating. Do not use lasers around untrained personnel who may injure themselves inadvertently. Ensure that all personnel in the area observed proper safety precautions.
- Do not assume the laser system is aligned. Misaligned optics can cause unintended exposure.
- Report all incidents of exposure to your supervisor.
- Warning signs indicating the laser enclosed area should be clearly displayed with an additional warning light outside the door.
- Local and national regulations governing the safe use of lasers should be adhered to all times.

Skin Safety



WARNING
Potential skin burns!
Direct and reflected laser radiation can burn exposed skin.
Only use the laser in accordance with its designated use. Safety interlocks are only to be defeated by authorized personnel.

- Although the skin can withstand a considerably higher radiation intensity than the eyes, tissue may be burned to a greater or lesser degree, depending on the radiation time and the irradiation intensity.
- Avoid contact between the skin and the beam, or specular reflections of the beam. Reflections of the beam may be as dangerous as the beam itself. Appropriate protective clothing should be worn to protect the skin whenever necessary.

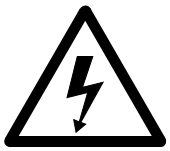
Fire Safety

WARNING
Fire hazards!
Class IV lasers are, by definition, fire hazards.
The laser beam can cause flammable materials to ignite or explode.
Always keep a fire extinguisher in the laser area in case a fire occurs

Because of the high output power from the class IV laser, a wide range of materials can be set on fire. Therefore, when the beam path is open, appropriate fire prevention measures should be taken:

- Combustible materials may be ignited by the laser beam or by electrical components inside the laser system. Flammable items must be isolated from the laser beam and from the laser system.
- Paper (circuit diagrams, leaflets, or even posters on the wall), curtains that are not coated with fire retardant, wooden panels or similar materials can be easily set on fire by direct or reflected laser radiation.
- Only beam stops made of non flammable materials (not asbestos!) should be used.
- Many fluids and solvents (e.g. cleaning agents used for maintenance) are combustible. The intense beam of the laser or a spark from an internal switch can ignite vapors from these materials. Prevent the laser beam from contacting flammable materials used in the laser area.
- Move containers of flammable materials as far from the laser system as possible and shield them from the beam with opaque materials. Under no circumstances should these solutions and vapors be placed in the beam path or near the system.

3.2.2.2 Electrical Safety



WARNING
Electrical hazards!
If the laser device is completely shut down for maintenance and repair work, it must be secured against inadvertent starting. Ensure that the electrical system is locked-out and tagged-out prior to servicing by locking the key switch of the laser device and tagging appropriate warning signs.

High voltages of up to 14 kV are generated within the laser equipment. The following precautions should be observed:

- Local safety regulations must always be strictly complied with.
- Switch off the OPTex immediately with an interlock switch or Emergency Off (EMO) switch in case of an emergency, i.e. to prevent injury or serious material damage, or if trouble occurs in the electrical system (see Section 3.2.3.1 on page 42). Contact after use of the interlock or EMO switch appropriate maintenance personnel (e. g. safety officer).
- Work on the electrical system or equipment may only be carried out by a skilled electrician himself or by specially instructed personnel under the control and supervision of such electrician and in accordance with the applicable electrical engineering rules.
- Fault finding and troubleshooting in high voltage circuits must only be performed by trained personnel.
- Necessary work on live parts and elements must be carried out only in the presence of a second person who can cut off the power supply in case of danger by actuating the emergency shut off or key switch. Secure the working area with a red and white safety chain and a warning sign.
  Use insulated tools only.
- If provided for in the regulations, the power supply to parts of the OPTex laser device on which inspection, maintenance and repair work is to be carried out must be cut off.
- Before starting any work, check the de-energized parts for the presence of power and ground or short circuit them in addition to insulating adjacent live parts and elements.
- Use only original fuses with the specified current rating.
- The electrical equipment of the OPTex laser device is to be inspected and checked at regular intervals. Defects such as loose connections or scorched cables must be rectified immediately.

3.2.2.3 Gas Safety

WARNING!
Toxic hazards!
The gas system of an excimer laser contains a mixture of fluorine or hydrogen chloride gas.
Inhalation of, or skin contact with, halogens should be avoided.

The properties of compressed gases, such as pressure, diffusibility, make the handling of compressed gases hazardous. Laser gas mixtures invariably contain components which are corrosive, toxic and oxidizing. Therefore, extreme care must be taken when handling these mixtures.

As a general guide to safe working practices, the following precautions should be observed when working with gas equipment. Always follow these guidelines and take additional precautions if necessary.

- Gas protective equipment, such as masks, must be available at the entrance to the area where the laser is located.
  Ensure that a protective mask with a protective gas filter, or a complete breathing apparatus set, is placed in a clearly displayed and accessible part of the operating area.
- It is recommended that personnel work in pairs and within sight and sound of each other, although not necessarily in the same working area. Only trained and competent personnel should be permitted to handle premix gas cylinders and regulators.
- Any equipment to be used for halogen gas servicing should be thoroughly cleaned, degreased and dried before use, then treated with increasing concentrations of halogen gas so that any impurities can be burned off without the risk of the equipment catching fire.
- Any equipment that has contained fluorine must be thoroughly purged with helium or argon and evacuated prior to opening or refilling.
- Due to the possibility of over-pressure of the gas mixture containing halogens, potential hazards exist due to the risk of leakage of the laser cavity and gas pipes. The most vulnerable part is the window. Under normal operating conditions the pressure is 3.4 bar (4.4 bar abs.) or, for the F_2 version, 2.8 bar (3.8 bar abs.). The equipment must be used such that the beam exit is not directed at personnel. In the event of a leak occurring, the release of halogen gas constitutes the greatest hazard.
- Avoid repeated bending and excessive vibration of gas piping and equipment as this can result in flaking of the protective halogen film and rupturing of the metal. This could lead to the occurrence of a fluorine metal fire. Flaking of the protective film can also cause dust to foul the valves.
- All areas containing pressurized halogen gas mixtures should be inspected for leaks periodically (weekly).

- All leaks should be repaired immediately, but not while the system contains halogen gases.

  For Fluorine: Ammonia vapor expelled from a squeeze bottle containing ammonium hydroxide may be used to detect leaks at suspected points.
  Filter paper moistened with potassium iodide solution is a very sensitive means of detecting fluorine in concentrations as low as approximately 25 ppm. The potassium iodide paper should be held with the aid of a long tongs or forceps, and will darken and turn black when fluorine is present. Fluorine odor is sufficiently strong to be detectable in very low concentrations (at 0.14 ppm). Fluorine will also fume readily in air.

- Adequate ventilation is essential. See the corresponding “Installation Conditions” manual for the specifications of the required air flow.

WARNING
Toxic hazard!
Ensure that the laser is ventilated into an appropriate exhaust. Make sure that the exhaust of the laser is not connected to the duct system of systems used for the processing of breathing air (e. g. air conditioning or ventilating systems).

- Ozone can be generated by high power ultra-violet radiation (in particular with ArF, at 193 nm). This gas should be removed with a proper air exhaust or by flushing the beam path with Nitrogen or Argon.
- Adequate ventilation is essential. There should be at least 10 air changes per hour when the laser device is installed in a confined space, e.g. housing of additional devices.
- Always wear protective gloves when changing halogen filters as they are hygroscopic and contain oxidizing agents.
- As the premix gas contains halogen, a needle valve or cut-off valve should be installed in the premix gas line. The additional valve is to be located near the gas cylinder to protect the gas line and pressure regulator against corrosion and provide additional gas protection. Do not solely rely on the main gas cylinder valve to provide adequate protection.
- Gas cylinder valves should be closed except while filling the laser, or when running the laser in the constant energy mode (EGY Const.).
- The pressure regulator, situated between the external gas cylinder and the laser, should be checked regularly. The maximum permitted value while cylinders are opened is 5.2 bar (abs).

3.2.2.4 Pressure Safety

Gas pressures of up to 7.5 bar (absolute) are permitted on the valve assembly and up to 5.2 bar (abs.) on the gas inlet.

Gas pressures of up to 4.4 bar (abs.) or, for the F_2 version, 3.8 bar (abs.) are permitted in the laser tube. If pressure rises above that, the laser device is switched off automatically. The following precautions should be observed:

- The laser should only be operated with the housing closed.
- In accordance with the local pressure vessel regulations (in Germany: “Druckbehälterverordnung”), Lambda Physik recommends to have the laser tube checked by a specialist every five years.

3.2.2.5 Seismic Protection

For installations in areas that are susceptible to seismic activity, the end user is responsible for appropriately securing the laser device within their facility or the OEM is responsible if the laser device should be installed within an OEM device, alternatively. For the exact configuration of the protective devices, local regulatory requirements are to be followed and the site vulnerability of the facility or OEM device (e.g. soil conditions and design) is to be taken into account. Provision is to be made for the following:

- Anchors to prevent movement or overturning of the laser device during a seismic event.
- Suitable strain relief devices for all supply lines to control the risks through leakage or escape of gases, liquids and electricity etc. during a seismic event.

Specific information regarding the position of the mounting holes and laser device feet is contained in Section 4.2 on page 52.

3.2.3 Constructive Safety Features

The laser device is equipped with the following constructional safety features:

3.2.3.1 Radiation Safety Features

- Appropriate Class IV label affixed to laser device enclosure (see Section 3.4 of this manual).
- All parts of the laser where laser radiation may possibly escape are marked with the appropriate adhesive danger signs (according to IEC 825).
- Red LASER ON indicator lamp on the left-hand side of the laser device
  When the laser is ready for the emission of radiation or if it is emitting radiation, the LASER ON indicator lamp (see Figure 11, A) is illuminated.

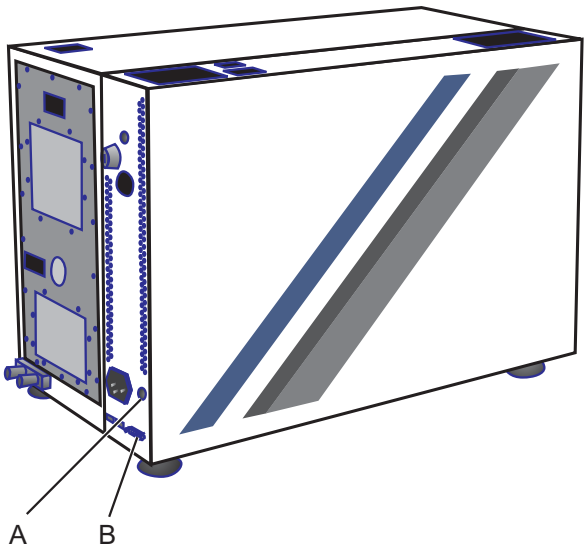


Figure 11: *LASER ON indicator lamp and interlock connector*

- OPTex series lasers are provided with a connector (”Interlock”) on the left-hand side (see Figure 11, B).
  This enables connection to external electrical circuits for a warning light and an interlock or Emergency Off (EMO) switch.
  The external warning light signals that the laser is operating and therefore warns of the risk of laser radiation. The external interlock or EMO switch shuts down the laser, for instance in case of emergency or if a door connected with the switch is opened.

- The beam exit from the laser housing can be closed by a manually operated beam shutter (see Figure 12, A).

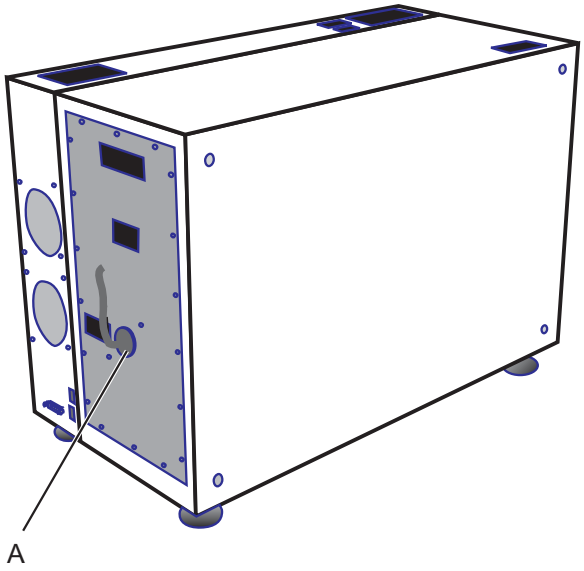


Figure 12: *Shutter on laser device's beam exit*

- All service panels at the laser are equipped with interlock switches which will shut off high voltage (more than 42 VDC and more than 100 VAC) if a panel is opened during laser operation. This stops the laser radiation immediately.

3.2.3.2 Electrical Safety Features

The following safety features protect the user from the potentially lethal hazards associated with high voltage power sources.

- All potentially lethal voltages are contained in fully protected and grounded enclosures. Additionally a chassis cover interlock disables the high voltage power supply when the cover is removed.
- Opening a service panel triggers an interlock switch that shuts off the high voltage and, consequently, the laser radiation.
- For servicing, the capacitors shall be discharged to ground through a safety stick. The safety stick and the discharge connector are located behind the right-hand service panel (beam exit side).
- All AC power wiring is UL-recognized and rated at 1500 V. Black is used for line phases, yellow-green is used for ground and black for neutral.
- Each AC power module has a yellow-green grounding conductor.

- The Power Module shielding encloses the HV parts of the laser to protect the surroundings against ionizing radiation and electromagnetic interference (limits, see Section 3.2.1.2 on page 32). A fully enclosed laser housing shields the surroundings from the ionizing radiation.
- All AC power connectors are labeled for identification. AC power and signal lines are never combined in the same connector.

3.2.3.3 Pressure and Gas Handling Safety Features

The Lambda Physik Excimer Laser incorporates the following pressure and gas handling features:

- The pressure chamber is designed in accordance with the official German pressure vessel regulations, the Druckbehälterverordnung (”Allgemeine Vorschrift, DruckbehV”; edited by the ”Bundesministerium für Arbeit und Soziales”; Germany).
  Every chamber is tested up to 4.5 bar (abs).
- Gas valves are electrically operated.
- The tube housing is fully interlocked.
- All gas fittings are 6 mm Gyrolok.
- A powerful ventilation system causes continuous underpressure in the tube chamber during laser operation. This prevents toxic gas from escaping into the ambient air in case of a leak.
- The exhaust enclosure is designed to ensure ventilation of all components.

3.2.3.4 Fire Safety Features

The fire safety features designed into Lambda lasers eliminate the use of materials which are combustible or produce toxic vapors as well as preventing flames from spreading or burning materials from dripping. The design incorporates the following specific fire safety features:

- Polyvinyl chloride (PVC) is not used.
- No ventilation holes in fire break enclosures are in excess of 5 mm (0.20") in diameter. Hole arrays are used as required.
- Material meeting or exceeding UL 94-V1 is used.

3.2.3.5 Mechanical Safety Features

Mechanical safety design provides protection against any hazards which could cause physical injury or burns. Specific mechanical safety features are listed below:

- Exposed corners are radiused.
- Air fans have grill guards with less than 6.4 mm (0.25 in).
- No high temperature components are accessible to touch.
- The laser center of gravity is centrally located within the enclosure to minimize tipping hazard.
- Threaded holes are provided in the base of the housing to allow suitable seismic anchorage of the laser device.

3.2.3.6 General Safety Features

The OPTex incorporates the following general safety features:

- Key-switch controlled laser operation (see Figure 13, A).
  The laser device can only be switched on with the key-switch. This prevents inadvertent or unauthorized starting of the laser. It cannot be operated with the key in the OFF position and the key cannot be removed in the ON position.

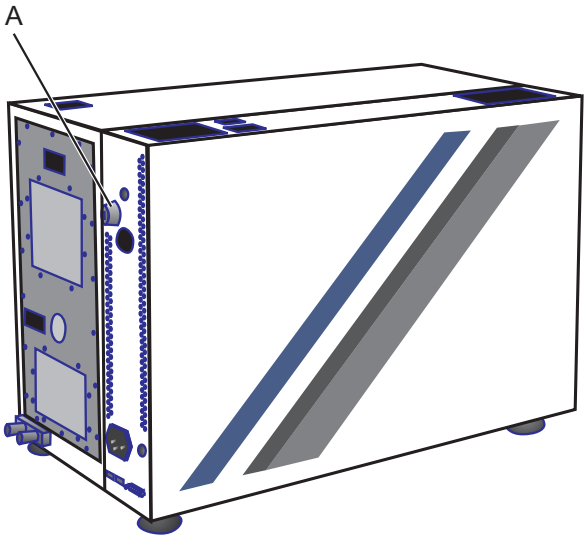


Figure 13: *Key switch*

- No polychlorinated biphenyl (PCB) is used.
- No asbestos is used.

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3.3 Safety Compliance List

The equipment has been tested and found to comply with the limits of the European Council Directives about bringing the laws of the member states into line relating to electromagnetic compatibility (89/336/EEC) and low voltage (73/23/EEC).

The OPTex complies with the following standards:

- EN 50082-1 (electromagnetic immunity)
- EN 50081-1 and EN 55011 (electromagnetic emission and radio disturbances)
- EN 61000-4-2 (electrostatic discharge)
- ENV 50140 and ENV 50141 (radiated susceptibility)
- EN 61000-4-4 (fast transient bursts)
- EN 61010-1 (safety requirements for electrical equipment for measurement, control and laboratory use)
- from the EN 60601 series (safety requirements for medical electrical equipment), if applicable:
  - EN 60601-1 (general requirements for safety)
  - EN 60601-1-4 (collateral standard: programmable electrical medical systems)
  - EN 60601-2-22 (particular requirements for the safety of diagnostic and therapeutic laser equipment).

All laser products from Lambda Physik are also compatible with the European laser safety standard EN 60825.

3.4 Labels

This chapter contains information about the safety-relevant labels attached to the OPTex.

– Section 3.4.1 shows the design of the safety labels and indicates their respective part numbers and physical location on the laser device.

– Section 3.4.2 contains a plain-language description of each safety label. These descriptions are grouped in label part number order.

Ensure that all safety labels are affixed to the laser device in accordance with the Label Location Diagrams in Section 3.4.1 of this chapter.

WARNING
Missing labeling can cause injury!
If warning labeling is missing or incomplete, persons are not made aware of potential exposure to specific hazards. Make sure that all warning labels are affixed to the laser device according to the plans given in this chapter. Do not put the laser device into operation if labeling is incomplete. Immediately replace the missing warning label(s) or inform Lambda Physik.

Each label indicated on the label location diagrams has a part number that provides a cross reference to the description and reproduction of the label that is contained in the second subsection.

NOTE
To simplify the ordering of labels, the appropriate Lamdba Physik part number is indicated together with the label description.

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3.4.1 Label Location Diagrams

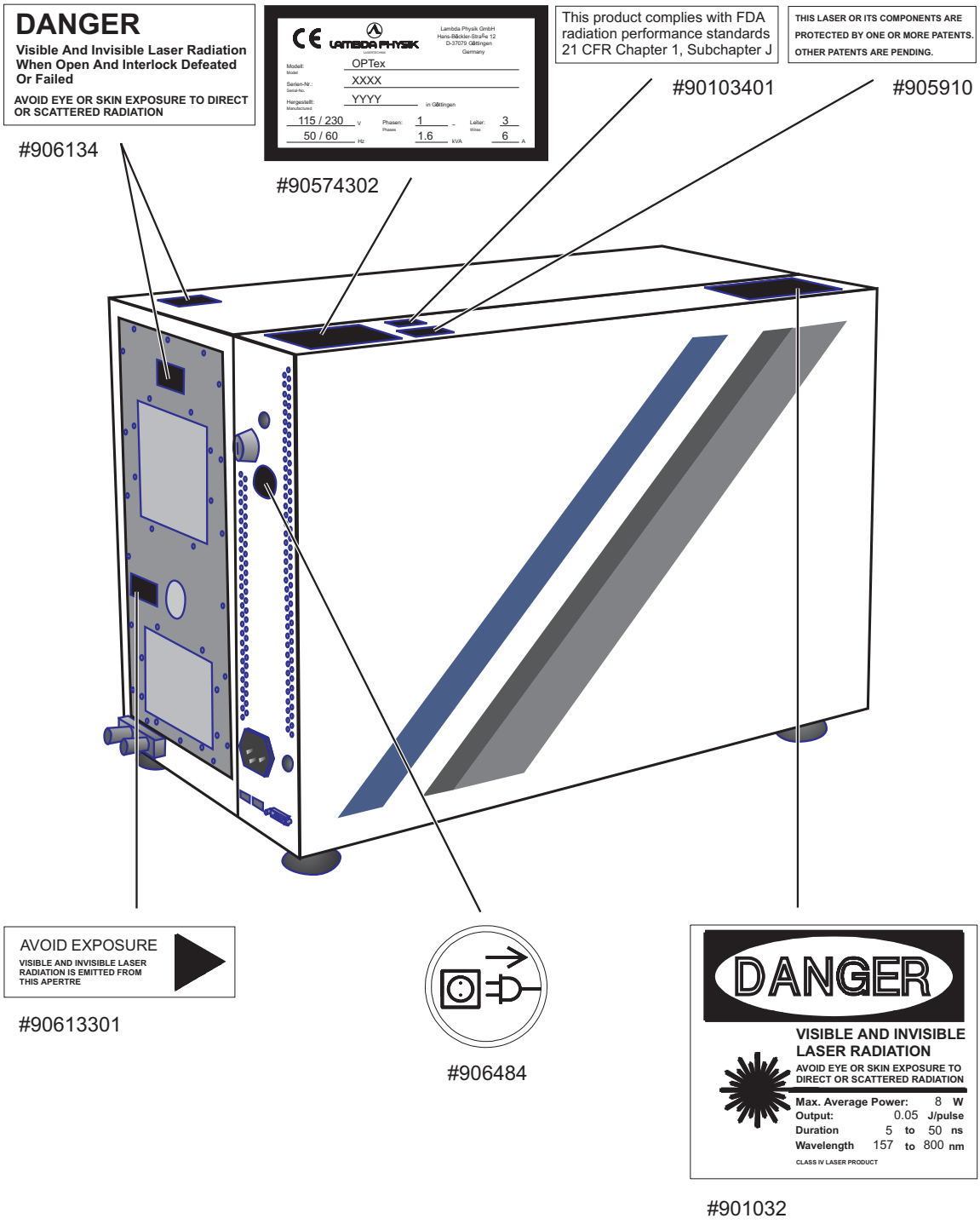

Figure 14: *Labels on front, left and top of the OPTex*

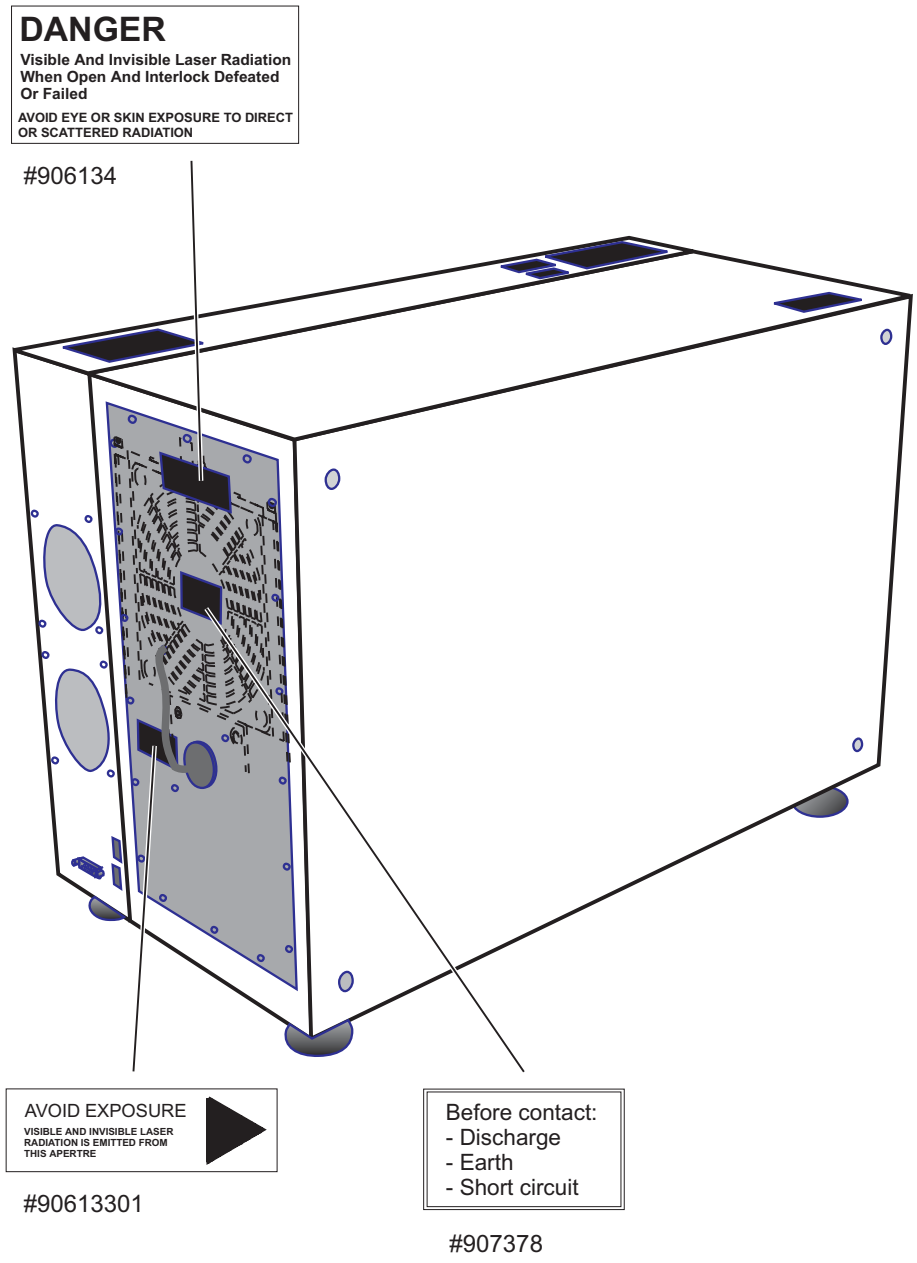

Figure 15: *Labels on rear, right and top of the OPTex*

NOTE
Label #907378 is attached to the protection grill inside the laser device housing.

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3.4.2 Description of the Labels and Safety Labels

LP Part no.:	Description:
# 901032	Safety label in accordance with CDRH. Contains warning of laser radiation as well as data specific to the laser device.
# 90103401	Label guaranteeing that this laser complies with FDA radiation performance standards.
# 90574302	Laser device type plate indicating model, serial number, date and place of manufacture and principal electrical supply data.
# 905910	Label showing that this laser and some of its components are protected by patents.
# 90613301	Beam output safety label informing of the presence of laser radiation when the aperture is open (2 labels).
# 906134	Label warning of the presence of laser radiation when service panels are removed (3 labels).
# 906484	Label indicating that the laser device has to be disconnected from the mains (remove mains plug from mains wall socket) before opening the device.
# 907378	Label indicating that the discharge capacitors have to be grounded (discharged) before removing the protection grill and touching components behind.

4 SPECIFICATIONS AND REQUIREMENTS

To continuously optimize the laser devices, all data contained in this chapter are subjects to changes.

Should information on separate sheets (e.g. laser data sheets) attached to or provided together with this instruction manual contradict the information in this chapter, the information on the separate data sheets has priority.

4.1 Specifications

All indicated data has been measured with an energy monitor and optimized gas mixtures.

Parameter	**F_2**	**ArF**	**KrF**	**XeCl [a]**	**XeF [a]**	**Units**
Wavelength	157	193	248	308	351	nm
CDRH Class.	IV	IV	IV	IV	IV	–
Max. pulse energy [b]	1.5	13	22	10	8	mJ
Max. repetition rate	200	200	200	200	200	Hz
Average power [c]	0.24	2	4	1.8	1.6	W
Pulse duration (nominal)	5 - 10	8	8	8	8	ns, FWHM
Pulse-to-pulse energy stability [d]	< 2	< 2	< 2	< 2	< 2	%
Beam dimensions	7 x 3.5 [e]	7 x 4 [f]	available on request	available on request	available on request	mm^2 (v x h)
Beam divergence [g]	3 x 1	2 x 1				mrad (v x h)

a. all values in column are preliminary and not yet verified through tests, permitted tolerance: -15 %
b. measured at low repetition rate (5 Hz) at 100 % HV, for F_2: includes < 4 % emission of red light
c. measured at max. repetition rate, for F_2: includes < 4 % emission of red light
d. sigma; 100 % HV at 100 Hz
e. typical value, FWHM
f. typical value, FW $1/e^2$ at beam exit
g. FWHM best focus

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4.2 Physical Dimensions

Figure 16 shows an overview of the dimensions and beam exit position of the OPTex laser device. Detailed information is given in Figures 17 and 18 on the following pages.

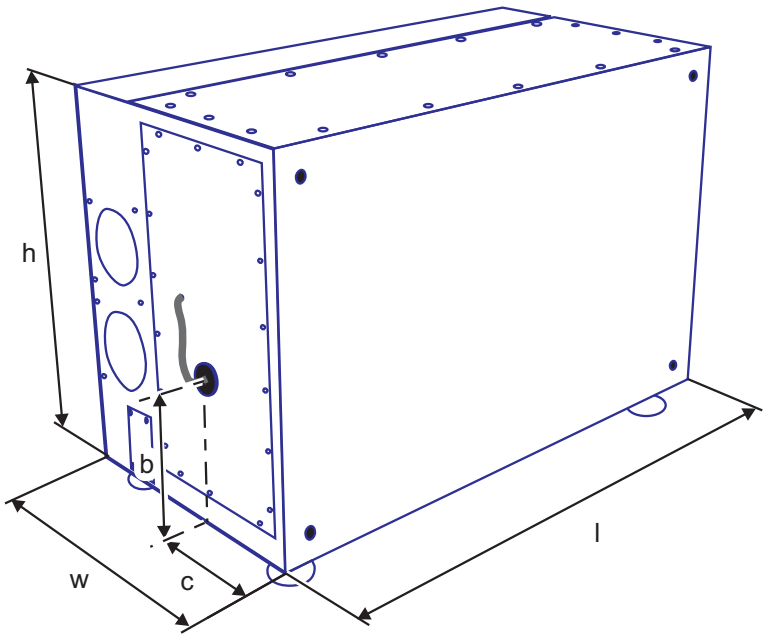

Figure 16: *Dimensions of laser device*

Size [a] (l x h x w)	approx. 600 mm x 400 mm x 300 mm
Weight	60 kg for F_2 version and OPTex2 55 kg for all other versions
Beam exit position	
- vertical (b) [b]	160 mm (± 1 mm)
- horizontal (c)	103 mm (± 1 mm)
Laser device feet	
- height	23 mm (+ 5 mm)
- diameter	45 mm
Distance between feet [c]	
- upright position (l x w)	540 mm x 233 mm
- on side (l x h)	540 mm x 340 mm

a. not including feet, beam guidance system, key switch, earning lamp etc.
b. from lower edge of laser device housing
c. The laser device is tiltable by 90° to the side. In upright position, the bottom side is provided with location holes (M8, see Figure 18).

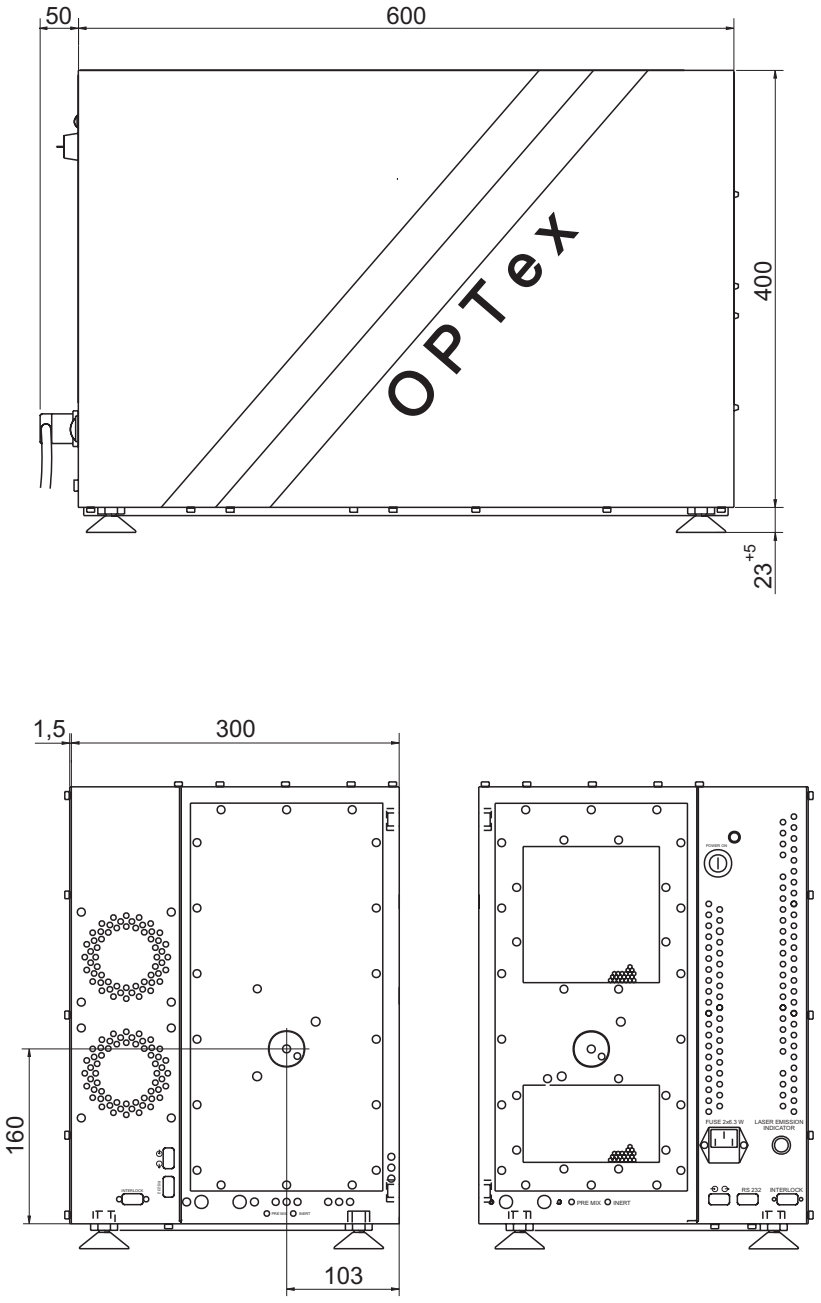

Figure 17: *Front and side views*

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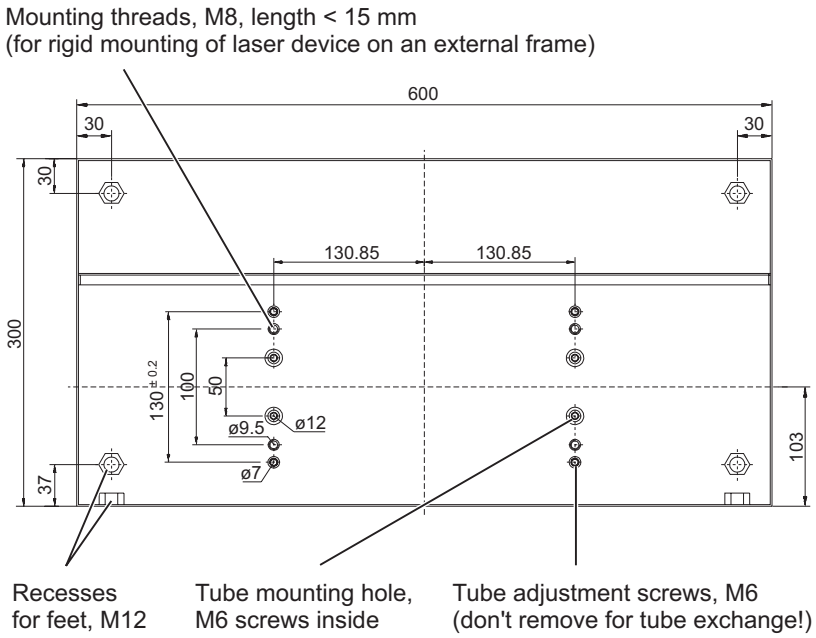

Figure 18: *Bottom view of the OPTex*

4.3 Electrical Power Supply

Input voltage (+ 10 % / -15 %, one phase)	230 VAC
Frequency	50 or 60 Hz
Apparent load	1.5 kVA
nominal current at 230 V	3 A
Fuse rating for each phase	6.3 A
or:	
Input voltage (+ 10 % / -15 %, one phase)	115 VAC
Frequency	50 or 60 Hz
Apparent load	1.5 kVA
nominal current at 115 V	6 A
Fuse rating for each phase	10 A
Type of mains plug	IEC standard

4.4 Remote Control Interlock

The OPTex is provided with a remote interlock socket on the back panel. This enables the laser device to be connected to an external interlock circuit, Emergency Off (EMO) switch or warning light.

The number and location of external interlock switches has to be determined in accordance with safety requirements at the laser installation site. Each installation has a unique configuration.

The necessary plug for the remote interlock circuit is a male 9 pin sub D plug. Pins 1 and 2 serve as power supply for the external laser radiation warning lamp (max. 3 VAC, 50 mA). Pins 3 + 5 serve as connection for the remote interlock circuit.

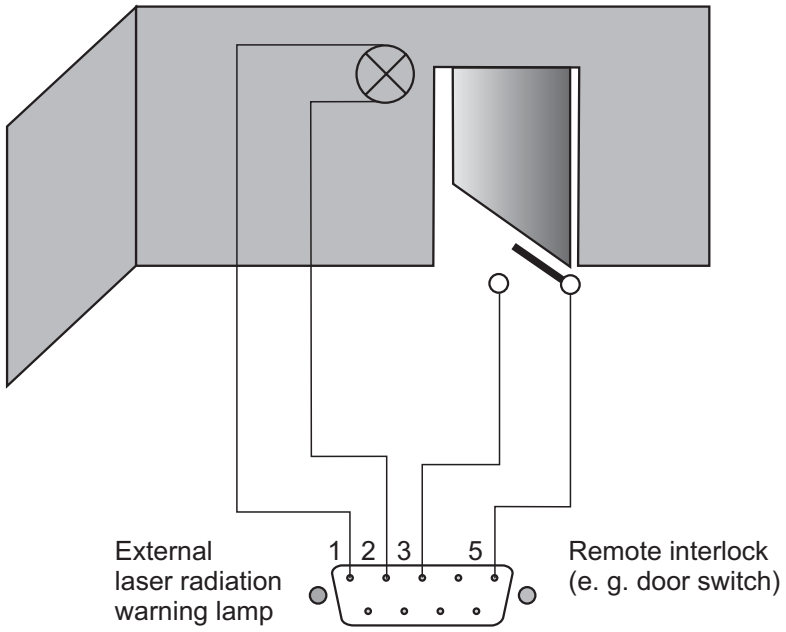

Figure 19: *Remote interlock socket*

To enable laser operation it is necessary to short circuit pin 3 and 5 through a bridge (the appropriate plug is enclosed in your tool case) or an external switch. If not, laser high voltage is disabled immediately with an interlock message.

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4.5 Controller Requirements

An RS 232 optical interface adapter is required to convert the electrical signals from the PC into light signals for the OPTex and vice-versa. This convertor is supplied as standard with laser devices which are to be PC controlled.

Specifications of the convertor:

Connector to PC	25 pin sub-D, male
Connector to laser device	2 pin FOL plug
Length of FOL links	1.5 m (longer on request)
Power supply	max. 7.5 VDC, max. 400 mA

The RS 232 optical interface adapter is to be plugged into a free RS232 serial interface on the PC.

When using a PC to control the OPTex, the minimum requirements for the PC are:

Hardware	IBM compatible 386 or higher 4 MB RAM, 1 MB available hard disk memory Mouse Free 25 pin RS232 serial interface (COM port) Vacant slot in PC housing (for internal mains supply) 3.5” floppy disk drive
Operating system	Windows 3.x, Windows 95 or Windows NT
Options	25 pin to 9 pin interface adapter (when the only free RS232 interface (COM port) is 9 pin) Step down transformer (line voltage to 6 VDC)

As the laser control software runs under Windows® and the mouse is connected to COM1, we recommend plugging the convertor into COM2.

As standard, the convertor draws its current from the PC. For this, a vacant slot is required in the PC. An additional mains socket is, therefore, required near to the PC. As an option, the convertor can draw its current from the mains. A suitable transformer is provided.

4.6 External Trigger In and Pre-Trigger Out

The laser device can be connected to an external trigger generator and/or a device requiring a pre-trigger impulse. To convert electrical signals from external devices to optical signals required by the laser device and vice-versa, use the TWE trigger convertor. The trigger light pulses are transferred to the laser device by using FOL's.

4.6.1 TWE Trigger Converter (Option)

The TWE trigger converter is a battery-operated device, which is optically connected to the dedicated trigger in sockets on the laser device and electrically connected to the external device(s). The specifications of the TWE trigger converter are:

Weight	approx. 150 g
Electrical connectors	BNC/B (50 Ω)
Optical connectors	approx. 1.5 m / HP
Battery	Alkaline, 9 V 9.0 (F22) ≥ 6 months lifetime
Operating temperature	15 to 65 °C

External Trigger In Signal

The external trigger in signal triggers the OPTex from an external trigger generator. The specifications for the electrical input and optical output on the TWE trigger converter are:

Electrical input	
- Voltage	+2 to +5 V
- Impedance	50 Ω
- Pulse width	≥ 300 ps
Optical output	
- Power	50 μW (665 nm)
- Pulse width	≥ 4 μs
- Repetition rate	≤ 200 Hz
- Delay	typ. 30 ns

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Pre-Trigger Out Signal

This signal is a pre-trigger impulse that is sent from the OPTex to an external device. The specifications for the optical input and the electrical output on the TWE trigger converter are:

Optical input

- Power	1 μW (665 nm)
- Repetition rate	≤ 200 Hz
- Delay	typ. 25 ns
- Synchronization	Electrical pre-trigger pulse occurs approx. 100 ns before the laser pulse

Electrical output

- Voltage	≥ +3.5 V
- Impedance	50 Ω
- Pulse width	≥ 1 μs

4.7 Gas Requirements

The active medium in an excimer laser is a mixture of a rare gas, a halogen gas and a buffer gas. This gas mixture is to be supplied to the OPTex from a premix gas cylinder.

The gas mixture needed depends upon the wavelength in which the laser is to be operated:

Gas Mixture	Wavelength
F_2 and He	157 nm
Ar, F_2 and Ne [a]	193 nm
Kr, F_2 and Ne [a]	248 nm
Xe, HCl, H_2 [b] and Ne [a]	308 nm
Xe, He, F_2 and Ne [a]	351 nm

a. Lambda Physik is owner of US Patent #4,393,505. This patent covers the use of neon as a buffer gas to enhance excimer laser performance.
b. Lambda Physik is the exclusive licensee under US Patent #4,340,968. This patent covers the use of hydrogen as an additive to improve Xenon Chloride laser performance.

The OPTex is prepared for operation at a single wavelength. It can, however, be subsequently modified at the factory to operate at a different wavelength.

Ensure that the appropriate gas mixture is available.

In addition to the cylinder of premix gas, a cylinder of inert gas (Helium) is required for flushing.

4.7.1 Gas Lines

The copper pipes (length: 2.4 meters) provided to connect the laser device to the gas supply are only intended for initial commissioning. For the permanently installed laser device, use internally electropolished stainless steel pipes as specified below instead of the copper pipes.

CAUTION
Contaminated gas tubing can pollute the laser tube!
Keep all gas tubing, especially the tubing for premix gases containing halogen, free of dust, humidity, oil or other pollutants.

Gas connections	6 mm Gyrolok®
Max. permitted pressure on the gas inlet	5.2 bar (abs.)
Gas tubing (recommended)	stainless steel (ALT ASTM A 269; material: 1.4404/316L; surface: RA ≤ 0.4) degreased and internally electropolished, 6 mm outer diameter

4.7.2 Pressure Regulators

Pressure regulators are supplied by gas manufacturers. Lambda Physik recommends pressure regulators which are designed to operate within the pressure range of the respective gas. The back pressure has to be 5 bar (70 psi).

The joints for the gas pipes have to be provided with Gyrolok®-fittings for a pipe diameter of 6 mm.

CAUTION
Halogen gas corrodes most metals!
Always use stainless steel pressure regulators with gas mixtures containing halogens.

4.7.3 Gas Cabinets

The risk of leakage from gas cylinders, particularly those containing fluorine and hydrogen chloride gas mixtures is a potential safety hazard. To minimize this hazard, safety gas cabinets are available. Please contact the gas manufacturers for further information.

4.7.4 Gases Required (Premix)

The performance of the excimer laser depends on:

– quality of the gases used

– tightness of the gas installation

– cleanness of the gas equipment.

Gas purity and gas mixture have a decisive influence on:

– pulse energy and pulse-to-pulse stability

– laser power

– gas lifetime.

A halogen filter is placed between the tube and the vacuum pump of the OPTex.

Premix

F_2	0.133 % F_2 in He
ArF	0.106 % F_2 and 3.333 % Ar in Ne
KrF	0.106 % F_2 and 1.515 % Kr in Ne
XeCl	0.114 % HCl, 0.023 % H_2 and 1.061 % Xe in Ne
Purity	99.995 % for F_2/He premix 99.9 % for all other premix gases
Inlet pressure range	4.5 to 5.2 bar (abs.)
Flow	0.05 to 0.5 l/s
Recommended cylinder size	10 l

Helium (inert gas)

Purity	99.995 %
Inlet pressure range	4.5 to 5.2 bar (abs.)
Flow	0.8 to 3.0 l/s
Recommended cylinder size	10 l, 200 bar (2800 psi)

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4.7.5 Optimum Gas Mixtures (Single Gases)

The gas mixtures detailed in this section are current as at the indicated date of release. As the optimum correlation of gases for excimer lasers is continuously being researched, the values in this section are subject to variation.

CAUTION
Risk of tube contamination!
Only use gas cylinders which have at least 5 bar (70 psi) remaining pressure. At lower pressures, impurities can be carried from the gas cylinder walls into the laser tube.

Gas type (wavelength)	Gases	Pressure [%]
F_2 (157 nm)	F_2	0.133
	He	99.867
ArF (193 nm)	F_2	0.106
	Ar	3.333
	Ne	96.561
KrF (248 nm)	F_2	0.106
	Kr	1.515
	Ne	98.379
XeCl (308 nm)	HCl	0.110
	H_2	0.020
	Xe	1.060
	Ne	98.810

4.8 Air Intake and Exhaust

The OPTex has one air intake and one air outlet (exhaust) for each chamber (electronics chamber and laser tube chamber, see Figures 2, 3 and 4 on page 13 ff.).

The intake air for the laser is the ambient air. Under normal operating conditions, the exhaust air does not contain any toxic gases or by-products. Nevertheless, certain failure scenarios may cause the exhaust air from the laser tube chamber to contain a small concentration of halogen gas or ozone and should, therefore, be treated accordingly. Effective protection is guaranteed if the exhaust air is purified or if the optionally available exhaust hose guides the exhaust from the laser tube chamber to an appropriate ventilation system.

WARNING
Toxic hazard!
Lead the exhaust from the laser device into an appropriate ventilation system. Make sure that the exhaust is not connected to the ducting of systems used for the processing of breathing air (e.g. air conditioning or ventilating systems).
Ozone can be generated by high power ultra-violet radiation. Prevent the formation of ozone with a proper air exhaust. Formed ozone gas should be removed by flushing the beam path with Nitrogen.

NOTE
To purge the beam path with Nitrogen from an external gas cylinder, insert and tighten the supplied beam path pipe into the beam shutter thread on beam exit aperture or connect the purge gas line with the purge gas connection tube (F_2 version). Connect the other end of the pipe with the external Nitrogen gas line.

Air flow rate	
- Tube chamber	100 m^3/h
- Electronics chamber	70 m^3/h
Heat transfer to exhaust	< 1 kW
Hose	
- Diameter	160 mm (at tube chamber)
- Length	< 3 m

NOTE
Ensure an adequate supply of cooling air. Especially, prevent the exhaust air from rebounding from surrounding walls and re-entering into the laser device through the air intakes. Location of the laser device within the prescribed maintenance area (see Section 4.10 on page 64) ensures an adequate air cooling.

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4.9 Environmental Conditions

This section indicates the recommended environmental conditions for the transport, storage and operation of the OPTex laser device.

Transport and Storage

Temperature range	–20 to +50 °C
Ambient air pressure	650 to 1070 mbar
Humidity	< 90 % RH (non-condensing conditions)

Operation

Ambient temperature range	+15 to +30 °C for F_2 version +15 to +25 °C for all other versions
Max. temperature gradient	±2 °C/h
Max. pressure gradient	±10 mbar/h
Humidity	< 85 % RH (non-condensing conditions)
Altitude	max. 3000 m above sea level

CAUTION
Impurities in the ambient air can pollute the windows!
Make sure that the ambient air is free of dust, oil, corroding substances and photochemical decompositables or depositable compounds.

For more information, please contact Lambda Physik.

4.10 Space Requirements

The dimensions of the laser device are indicated in Section 4.2 on page 52.

Ensure that the ventilator and exhaust openings are not covered or inhibited.

To enable maintaining and servicing the OPTex from the side (e.g. for servicing the windows), a space of at least 50 cm is required to the left and right of the laser device. Also keep the area above and in front of the laser device free to allow access from the top or front for servicing and repairs.

5 INSTALLATION

This chapter describes the installation of the OPTex laser device. It is to be read:

– prior to initial installation,

– after transportation,

– prior to re-installation after storing the laser device.

CAUTION
Improper installation can cause serious line damage!
All control and signal lines as well as the mains power supply line and gas supply lines must be installed with strain-relief in a cable channel.

5.1 Site Preparation

Purpose

Prepare for the installation of the laser device.

Tools and Materials

- Packing lists
- Cutting pliers
- Sharp knife

Preparation

1. Ensure that the installation site has been prepared and all necessary utilities are available in accordance with the specifications (see Chapter 4 on page 51 ff.).

NOTE
Particularly ensure that the ventilator openings are not covered or obstructed and that the service panels are accessible.

Checking the Delivery

2. Set down the laser device at the installation site.
3. Carefully remove all packaging.
4. Ensure that the shipment is complete and undamaged. The intended contents are listed in the packing list.

NOTE
If any components are missing, immediately inform Lambda Physik.

Damaged Deliveries

If the initial inspection of the delivery indicates mishandling of the laser device during transport, proceed as follows:

- Do not refuse the shipment.
- Make a corresponding notation on the delivery receipt document and inspect for visible signs of damage to the rigid transport packaging.
- If there are visible signs of damage, leave the laser device in the original transport packaging and request immediate inspection from the carrier within three days of delivery.
- Remove the packaging and check for visible signs of damage to the laser device.
- If there is any visible damage to the laser device, immediately contact Lambda Physik for further inspection and rectification.

5.2 Transport Locks

The OPTex is delivered without any transport locks.

5.3 Insert Safety Plug

Purpose

Insert the safety plug to close the interlock circuit. When the interlock circuit is open, the HV supply cannot be switched on.

Tools and Materials

- Female 9 pin sub-D safety plug

NOTE
External devices can be wired into the interlock circuit by being connected to the corresponding pins of a female 9 pin sub-D plug (see Section 4.4 on page 55). When no external devices are required, use the short-circuit plug provided in the service case.

- Corresponding screwdriver for the screws on the short-circuit plug

Inserting the Safety Plug

1. Insert the 9 pin sub-D plug into the interlock socket located on the left-hand side of the laser device.
2. Fasten the screws on the plug.

5.4 Connect Controller

The OPTex can be controlled through an existing PC complying with the specifications in Section 4.5 on page 56.

Installation consists of connecting the PC to the laser device and installing the control software on the PC. Connection to the PC differs depending on whether the fiber optics convertor (converts electrical signals to optical signals and vice-versa) is to be connected to the mains or draw its current from the PC (vacant slot in PC required).

5.4.1 Connecting the PC (PC-Powered Convertor)

Purpose

Establish the data link between the laser device and the PC and connect the fiber optics convertor to the PC power supply (standard).

To enable connection of the fiber optics convertor to the PC power supply, a DC regulator board has to be installed in the PC. This converts the PC's +12 V power supply to 7.5 VDC required by the fiber optics convertor.

Tools and Materials

- PC as specified in Section 4.5 (with free slot).

NOTE
Before opening the PC, consult your PC supplier to ensure that opening the PC or inserting additional boards will not invalidate the warranty. In case of doubt, ask your PC supplier to install the DC regulator board.

- Instruction Manual for the PC
- Appropriate screwdriver for PC housing screws
- Appropriate screwdriver for PC mounting bracket screws
- RS 232 optical interface adapter (supplied)
- DC regulator board with mounting bracket (supplied)
- Y-cable (supplied)
- Set of FOL links (supplied)

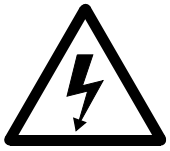
Preparation

1. Disconnect the laser device and PC from mains power supply.

Connecting the PC

2. Set down the PC at the desired location.
   Take into account the length of the FOL links.

NOTE
The FOL links supplied with the laser device have a length of 1.5 m. Longer links can, however, be used providing that each line is in one piece. Intermediate connectors or extension pieces are not to be used as this deteriorates transmission quality. For more information, please contact Lambda Physik.



WARNING
Risk of electric shock!
Always disconnect the PC and any connected devices (e.g. monitor) from the mains supply before opening the housing.

3. Unscrew and open the PC cover.
   For more information, consult the PC's instruction manual.
4. Unscrew and remove the bracket from the vacant slot intend to be used.
5. Insert the DC regulator mounting bracket into the empty slot and tighten the fastening screw.
6. Connect the smaller female plug of an existing Y-power connection cable or of the supplied Y-cable to the DC regulator board.
7. Connect the bigger plug of the Y-cable to the PCs 4-pin power supply socket (12 VDC).

NOTE
The jumpers on the regulator board are already set for 7.5 VDC operation.

8. Close the PC cover and tighten the screws.
9. Insert the RS 232 optical interface adapter into the free serial interface port on the PC (COM2).
10. Insert the cable from the DC regulator board into the power inlet port on the RS 232 optical interface adapter.
11. Insert the FOL links into the socket on the RS 232 optical interface adapter.
12. Insert the FOL links into the optical RS232 socket on the laser device.
13. Reconnect the PC to the mains power supply.

5.4.2 Connecting the PC (Mains-Powered Convertor)

Purpose

Establish the data link between the laser device and the PC and plug the fiber optics convertor into the mains (optional).

Tools and Materials

- PC as specified in Section 4.5
- RS 232 optical interface adapter (supplied)
- Mains lead with integral transformer (optional)
- Set of FOL links (supplied)

Preparation

1. Disconnect the laser device and PC from mains power supply.

Connecting the PC

2. Set down the PC at the desired location.
   Take into account the length of the FOL links.

NOTE
The FOL links supplied with the laser device have a length of 1.5 m. Longer links can, however, be used providing that each line is in one piece. Intermediate connectors or extension pieces are not to be used as this deteriorates transmission quality. For more information, please contact Lambda Physik.

3. Insert the RS 232 optical interface adapter into the free serial interface port on the PC (e.g. COM2).
4. Insert the FOL link into the socket on the RS 232 optical interface adapter.
5. Insert the FOL link into the respective socket on the laser device.
6. Plug the RS 232 optical interface adapter into the mains power supply.
7. Reconnect the PC to the mains power supply.

5.5 Software Installation

Purpose

Install the laser control software on the PC. To simplify installation, an installation file is provided on the software floppy disk. This generates the directory WINLAC as well as the program group and program icon WINLAC. The laser control software can be integrated into other applications using a DLL-interface (for more information, see separate manuals).

The installation software installs the files for energy monitor calibration, maintenance monitoring and service procedures itselfs.

Tools and Materials

- PC as specified in Section 4.5
- ½" laser control software floppy disk (provided)

Preconditions

- PC connected to the laser device (see Section 5.4 on page 67)

Preparation

1. Switch on the PC and allow the operating system (Windows®) to start-up.
2. Ensure that a directory and/or program group called WINLAC does not already exist on your hard disk drive intended to be used.

Installing the Software

3. Insert the control software floppy disk into the PC's disk drive.
4. Select and execute the install.exe file on drive a:.
   For instance, with Windows 95®, you can use the "Execute..." and "Search..." functions.
5. Follow the instructions on the screen.
6. When "INSTALLATION COMPLETE" appears, click "QUIT".
   The program group WINLAC appears on the screen. The laser control software can be started by clicking the icon.
7. Click the "WINLAC" icon.
   The WINLAC screen appears.
8. Select "OPTIONS" from the "SYSTEM" menu.
9. Click the COM port corresponding with the port to which the laser device is connected and confirm the selected port by clicking "OK".

The software is completely installed on the PC. Close the laser control screen and terminate the software by clicking "Exit".

5.6 Connect External Trigger

Purpose

Connect the laser device to an external trigger generator (trigger in socket) and/or device requiring a pre-trigger impulse (trigger out socket).

Tools and Materials

- TWE Trigger Convertor with battery (optional)
- External trigger generator (when required)
- Interconnecting cable(s) for trigger in and/or trigger out, fitted with BNC/B plugs for connection to the TWE Trigger Convertor

Preparation

1. Ensure that the laser device is not connected to the mains power supply.
2. Press the BAT button on the trigger converter to check that a battery is inserted and that the battery is sufficiently charged.

Connecting the External Trigger Device

3. Insert the FOL links into their respective sockets on the laser device (see below).

Trigger In socket Trigger Out socket

4. Connect the trigger in and/or trigger out interconnect(s) into the BNC socket(s) on the trigger generator.
5. Connect the trigger in and/or trigger out interconnect(s) to the respective connection on the external trigger device(s).

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5.7 Connect Power Supply Line

Purpose

Connect the laser device to the mains power supply.

Tools and Materials

- Mains line with appropriate plug for local mains power supply (provided)

Preparation

CAUTION
Incorrect power connection can damage the laser device!
Ensure that the laser device is configured for your local voltage and frequency.

1. Check that the electrical requirements for the laser device indicated on the laser device type plate correspond with your local voltage and frequency. The location of the type plate is shown in Figure 14 on page 48.
2. Ensure that the key switch on the laser device is set to OFF.

Connecting the Mains Power Supply Line

3. Insert the female plug of the mains power supply line into the mains socket located on the left-hand side of the laser device.
4. Insert the mains power supply line into the mains socket of the facility.

5.8 Connect Exhaust Line (Option)

Purpose

Connect the optional exhaust line between the laser device exhaust port and the building ventilation system.

Tools and Materials

- Mounting flange with 4 locating screws
- Exhaust line
- Additional blower (not equipped) for exhaust lines of more than 3 m length
- Appropriate screwdriver or allen key to tighten locating screws
- Connections to the ventilation system
- Appropriate tool(s) for connections to the ventilation system

Preparation

1. Ensure that the proposed exhaust line corresponds with the requirements indicated in Section 4.8 on page 63.

Connecting the Exhaust Line

2. Place the mounting flange onto the exhaust port by aligning the locating holes in the flange with the threaded bore holes on the exhaust side of the laser device.
3. Secure the mounting flange to the laser device by inserting and tightening the four locating screws.
4. Attach the exhaust hose to the mounting flange.
5. Check that the air intake filter is not obstructed.
6. Switch on the laser device according to Section 7.2 on page 90.
7. Check that the exhaust fan and blower are working and sucking air out of the laser device.
8. Switch off the laser device according to Section 7.5 on page 103.

WARNING
Toxic hazard!
Lead the exhaust hose from the laser device to an appropriate ventilation system. Do not connect the exhaust hose to breathing air systems (i. e. air conditioning or ventilating systems).

9. Connect the other end of the exhaust hose to a suitable ventilation (exhaust) system.
10. Check that there are no leaks from any exhaust hose connections.

Any contamination within the laser device will now be directed into the ventilation (exhaust) system.

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5.9 Gas Lines Installation

The exact gas line installation procedure varies according to the configuration of the gas supply.

The laser device is supplied with the necessary excimer laser gases from a premix gas cylinder. To enable flushing, an inert gas (usually helium) is necessary.

5.9.1 Remarks Regarding Gas Line Installation

The quality of the gas line installation greatly influences laser performance. Deficiencies in the gas line installation can cause impurities to enter the system, thereby detrimentally affecting laser operation and output. To ensure optimum laser performance, observe the following instructions:

- Only use the gases specified in Sections 4.7.4 and 4.7.5.
- Only use the materials specified in Section 4.7.1 on page 60. This minimizes the number of points at which impurities may enter the system and surfaces where they may be produced. Never use any material other than stainless steel for tubings or fittings. Other materials are sources of impurities.
- Store gas cylinders in a dry cabinet to avoid corrosion.
- Never expose the halogen line to moisture when it contains halogen or traces of halogen as this will corrode immediately.
- Avoid long and complicated line routings. These can cause impurities to enter the system. Use the shortest possible pipe lengths.
- All fittings used throughout the gas line must be clean, oil-free and leak-proof. Avoid complicated fittings.
- Carefully check for leaks.
- Never use gas lines that have been used for other gases.

5.9.2 Connect Gas Supply Lines

Purpose

Connect the gas supply lines to the laser device.

Tools and Materials

- Appropriate gas cylinder(s) and pressure regulator(s)

NOTE
Use only gas cylinders with a remaining pressure of at least 5 bar (abs.).

- Gas supply lines (pipes)

NOTE
The copper pipes provided for the connection of the laser device to the gas supply are only intended for initial commissioning. For the permanently installed laser device, use stainless steel pipes as specified in Section 4.7.1 on page 60.

- 6 mm Gyrolok® gas connector(s), one for each gas line
- 9/16” wrench (provided)
- Tools for shaping and cutting stainless steel tubing
- Appropriate tools for gas cylinder and pressure regulator connections

Preparation

CAUTION
Gas connectors can be easily damaged.
Always use an appropriate tool to cut stainless steel pipes.
Do not use a saw. Do not use lubricants.

1. Ensure that the appropriate pressure regulators are connected to the gas cylinders.
2. Ensure that the gas supply lines are connected to the pressure regulators.

Connecting the Gas Lines

3. Fit each line with a 6 mm Gyrolok® fitting.
4. Check that all gas supply valves are closed.
5. Remove the blanking plug from the appropriate gas connector on the laser device.

NOTE
Keep the blanking plug in the service case for future use.

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6. Fit the gas line to the appropriate Gyrolok® connector.

CAUTION
Risk of damaging gas lines!
Excessive overtightening will damage the sealing beads and may cause leakage from the system.
Tighten in accordance with the gas fitting manufacturer's instructions.

7. Tighten the Gyrolok® nut using the 9/16" wrench.
8. Repeat steps 5 to 7 to connect the second gas line.
9. Check that all connections are properly matched and sealed tightly.

Finalization

10. Perform a leak test on all newly fitted lines according to Section 8.4.1 on page 110 (premix gas supply line) and Section 8.4.3 on page 114 (inert gas supply line).

5.10 Connect Beam Guidance System (for F_2 Version)

The beam exit of the OPTex laser device is situated at the right side of the laser device, 182 mm (+5 mm adjustable) above the floor and 103 mm measured from the rear of the laser device housing (see Section 4.2 on page 52).

The entire beam path of Class IV lasers (for F_2 lasers including the target area) should be hermetically sealed by an enclosure (beam guidance system) equipped with interlocks to prevent operation of the laser system unless the enclosure is properly secured. The beam path shall, insofar as possible, be free of specularly reflective surfaces and materials which would be combustible if irradiated by the beam.

The OEM should ensure after installation of the beam guidance system that no laser radiation exceeding maximum permitted exposure (MPE) values arises at the connection between the laser device and the beam guidance system. The measurements in accordance with statutory requirements must be carried out by an authorized body.

Purpose

Connect the beam guidance system of the OEM device to the KF-40 flange on the laser device's beam exit (see Figure 20, A).

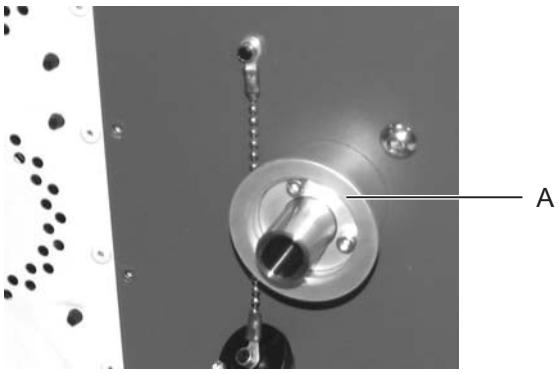

Figure 20: *Beam exit flange*

Tools and Materials

- Purge gas connection tube (provided)
- 2 clamping rings (1 ring provided)

Preconditions

- Beam guidance system equipped with a KF-40 flange on laser device side

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Preparation

1. Equip the purge gas line with a quick-acting connector.

Connecting the Beam Guidance System

2. Connect the purge gas connection tube (see Figure 21, B) with the connection flange on the laser device's right-hand side using the provided clamping ring (A).

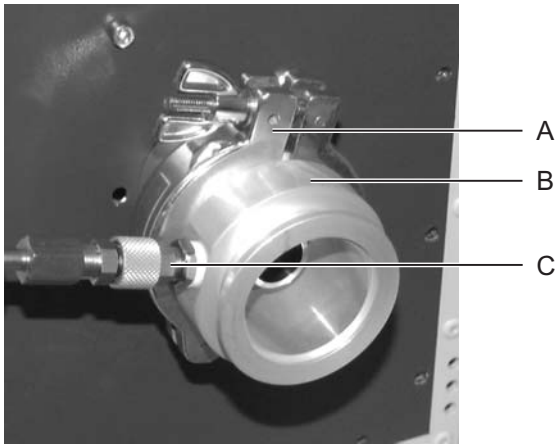

Figure 21: *Purge gas connection tube for beam guidance system*

3. Connect the beam guidance system with the purge gas connection tube using the second clamping ring.
4. Connect the purge gas line (see Figure 21, C) with the purge gas connection tube.

Finalization

5. Evacuate the beam path shielding and, where fitted, refill with purge gas to prepare starting laser operation (see Section 7.2 on page 90).

5.11 New Gas Fill

CAUTION
Risk of damaging the laser tube!
For transportation, the laser tube is filled with helium at a pressure of 1500 mbar. Never attempt to start laser operation with this filling!

Always perform a new gas fill before starting laser operation (see Section 8.5 on page 116).

6 LASER CONTROL

This chapter describes the laser control software simulated on an PC (PC Controller).

The information in this chapter is not sufficient to enable you to fully perform the operation and maintenance procedures initiated through the respective software commands. These procedures are described in the operating and servicing sections of this manual (see Chapters 7 and 8).

6.1 Laser Control Software

NOTE
To enable control through a PC, the laser control software WINLAC (provided on floppy disk) has to be installed on a PC complying with the specifications in Section 4.5. The necessary connections and the software installation procedure are described in Chapter 5.

6.1.1 Start Laser Control Software

Select the program group WINLAC and double click the WINLAC icon. The laser control screen shown in Figure 22 appears.

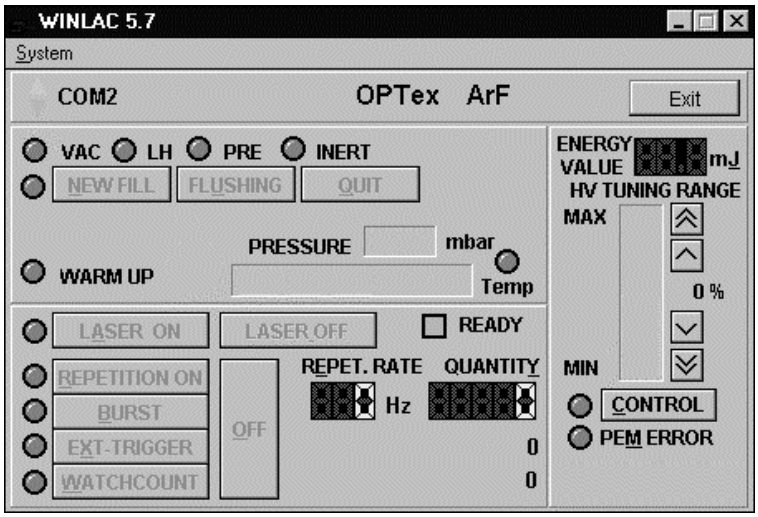

Figure 22: *Laser control screen*

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6.1.2 Exit Laser Control Software

To terminate the laser control software, click EXIT on the WINLAC screen. Only on this way the laser control files are updated.

6.1.3 Laser Control Screen

The laser control screen consists of various buttons, lamps, counters and displays.

The purpose of the buttons is described in Section 6.1.3.1.

The purpose of the counters and displays is described in Section 6.1.3.2.

The purpose of the lamps is described in Section 6.1.3.3.

6.1.3.1 Buttons

All buttons that can be selected at any particular time are highlighted (black colored). In Figure 23 each button is denoted with a letter or letter and digit combination. This denotation serves as a cross reference to the corresponding description in this section.

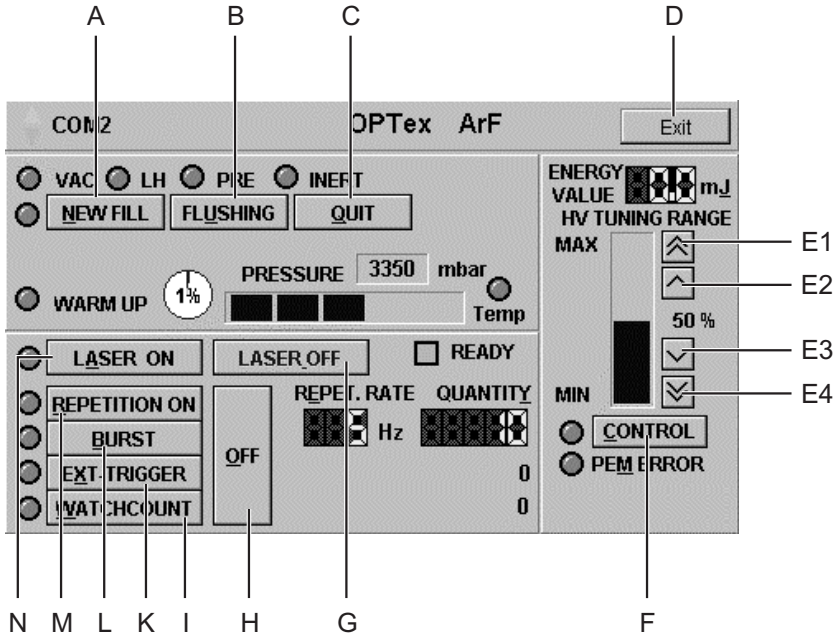

Figure 23: *Buttons on laser control screen*

A **NEW FILL** Starts the new gas fill procedure. The existing gas is pumped out of the laser tube and the laser tube is filled with fresh gas from a premix gas cylinder. The valve currently opened is indicated by the corresponding light on the screen (see Section 6.1.3.3).
Requirements: LASER OFF
Premix gas cylinder with sufficient pressure connected to “PREMIX”

B **FLUSHING** Opens a new window enabling the gas lines or laser tube to be flushed:

FLUSH EXT Evacuates the premix gas supply line and refills with inert gas to enable gas line maintenance (e.g. exchanging the premix gas cylinder).
Requirements: LASER OFF,
Inert gas cylinder with sufficient pressure connected to “INERT”

FLUSH INT Evacuates the laser tube and refills with inert gas to enable windows exchange with leak testing.
Following this, a new gas fill is necessary (see Section 8.5).
Requirements: LASER OFF,
Inert gas cylinder with sufficient pressure connected to “INERT”

FILL INERT Evacuates the laser tube and refills with inert gas up to a pressure of 1500 mbar to enable laser tube transport (transportation fill).
Following this, a new gas fill is necessary (see Section 8.5) to restart laser operation.
Requirements: LASER OFF,
Inert gas cylinder with sufficient pressure connected to “INERT”

EXIT Closes the window without performing a gas action.

C **QUIT** Aborts gas actions.

D **EXIT** Terminates the laser control program.
Requirements: LASER OFF

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E1	**Large HV increment**	Increases the high voltage setting by 10 %. *Requirements*: READY lamp on, Laser in HV Const. mode
E2	**Small HV increment**	Increases the high voltage setting by 1 %. *Requirements*: READY lamp on, Laser in HV Const. mode
E3	**Small HV decrement**	Decreases the high voltage setting by 1 %. *Requirements*: READY lamp on, Laser in HV Const. mode
E4	**Large HV decrement**	Decreases the high voltage setting by 10 %. *Requirements*: READY lamp on, Laser in HV Const. mode
F	**CONTROL**	Toggles between the high voltage constant mode (HV CONST) and the energy constant mode (EGY CONST). When the energy constant mode is active, the red lamp next to the CONTROL button is on. *Requirements*: READY lamp on ***NOTE*** The EGY Const mode is only available with energy monitor!
G	**LASER OFF**	Switches off the HV power supply to disable laser operation. All currently active laser operations (e.g. BURST or REPETITION) are immediately aborted and the repetition rate and quantity are reset. A corresponding signal can be sent by pressing the space bar on the PCs keyboard. *Requirements*: LASER ON, Laser operates (REPETITION ON, BURST or EXT. TRIGGER active)
H	**OFF**	Interrupts the laser operation (REPETITION ON, BURST or EXT. TRIGGER) by switching off the HV power supply. The repetition rate and quantity are not reset. Laser operation can be continued by starting any operation mode. *Requirements*: LASER ON, Laser operates (REPETITION ON, BURST or EXT. TRIGGER active)

I	**WATCHCOUNT**	Activates the high voltage and starts laser operation in accordance with signals received from an external trigger generator for a internally or externally given number of pulses. Laser operation cannot be stopped by all software interrupts! *Requirements*: READY lamp on, LASER ON, External trigger generator connected and correctly set, QUANTITY (number of pulses) set
K	**EXT-TRIGGER**	Activates the high voltage and starts laser operation in accordance with the signals received from an external trigger generator. A laser pulse is emitted whenever a trigger pulse is received. *Requirements*: READY lamp on, LASER ON, External trigger generator connected and correctly set
L	**BURST**	Activates the high voltage and starts laser operation at the preset repetition rate for the preset number (quantity) of pulses. *Requirements*: READY lamp on, LASER ON, REPET RATE and QUANTITY values set
M	**REPETITION ON**	Activates the high voltage and starts laser operation at the preset repetition rate. *Requirements*: READY lamp on, LASER ON, REPET RATE value set
N	**LASER ON**	Enables laser operation. The HV power supply receives current but the storage capacitors are not charged and no laser pulses are emitted. For emission of laser beam pulses, select an operation mode after running a security period of 5 seconds (REPETITION ON, BURST, EXT TRIGGER or WATCHCOUNT). *Requirements*: READY lamp on

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6.1.3.2 Counters and Displays

There are three counters and four displays on the laser control screen (Figure 24). Clicking a counter when the laser is online opens a subsequent menu enabling a new value to be entered.

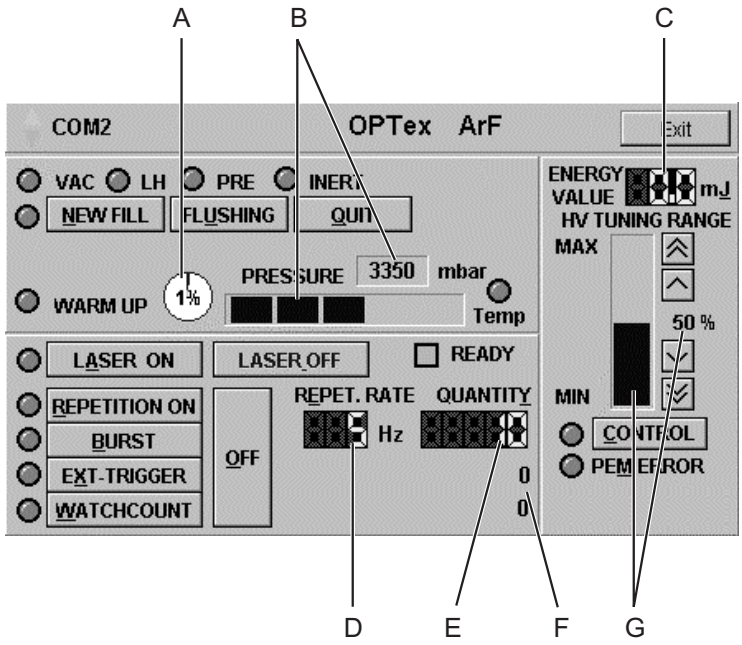

Figure 24: *Counters and displays on laser control screen*

A	**WARMUP**	Percentage indicator indicating the proceeding of the thyratron warm-up period. The warm-up is additionally indicated by the red lamp left from the indicator.
B	**PRESSURE**	Graphical and numerical display indicating the current gas pressure in the laser tube. If the pressure is sufficient for laser operations, the graphical display is blue. If there is insufficient pressure, the graphical display turns red. If there is an overpressure, the graphical display turns yellow.
C	**ENERGY VALUE**	Counter indicating the current pulse energy for laser operations in the EGY Const. mode.
D	**REPET. RATE**	Counter indicating the current repetition rate for internally triggered laser operations.
E	**QUANTITY**	Counter indicating the current amount of laser pulses to be generated in Burst or internally set Watchcount mode.

F Counters — During laser operation, the number (quantity) of pulses are displayed as burst counter (counts down) and user counter (counts up).

G HIGH VOLTAGE — Graphical and numerical display indicating the current high voltage level within the tuning range (in percent) for operations in the HV Const. mode.

6.1.3.3 Lights

In Figure 25 each light is denoted with a letter or letter and digit combination. This denotation serves as a cross reference to the corresponding description in this section.

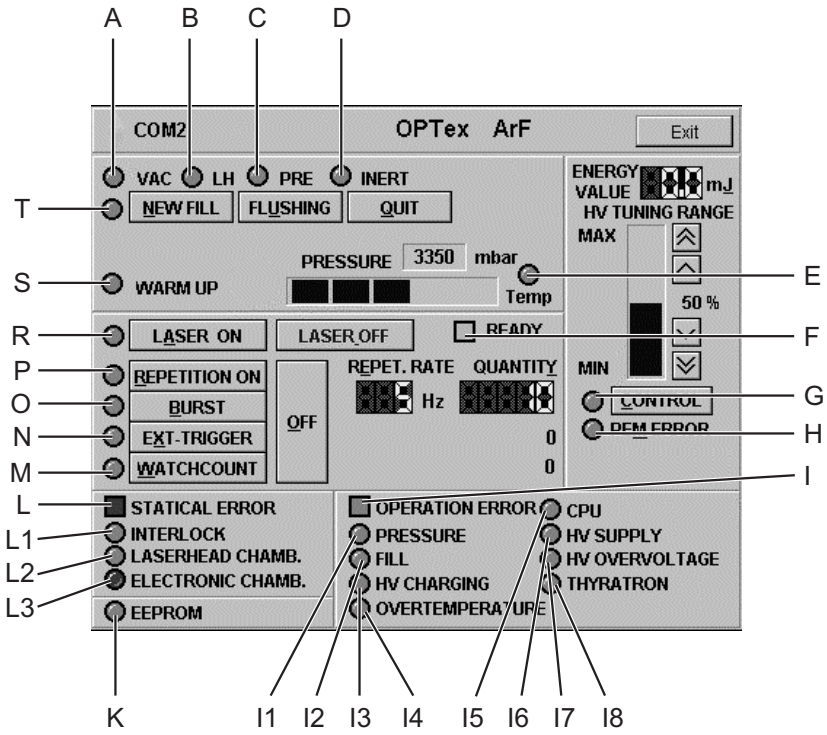

Figure 25: *Lights on laser control screen*

NOTE
The error field (errors I to L) will automatically be opened if an error occurs.

A VAC — The vacuum valve is open and the vacuum pump has been actuated (see gasflow diagram in Figure 62 on page 155).

B LH — Laser tube gas valve is open.

C	**PRE**	The premix gas valve (gas inlet) is open.
D	**INERT**	The inert gas valve (gas inlet) is open.
E	**TEMP**	Warning light for exceeding tube temperature (gas reservoir, more than 48 °C).
F	**READY**	The laser device is ready for operation. High voltage can be switched on.
G	**CONTROL**	The laser is operating in the energy constant (EGY Const.) mode. ***NOTE*** The EGY Const mode is only available with energy monitor!
H	**PEM ERROR**	Fault in the energy monitoring system. The error message vanishes by clicking on the lamp when the cause of the error has been rectified. As long as the error remains, the EGY Const. mode cannot be selected.
I	**OPERATION ERROR**	Flashes red to indicate an error preventing laser operation. After rectifying the error the laser device has to be switched off and then on again before laser operation can be restarted. To ease troubleshooting, one or more of the lights below OPERATION ERROR (I1 to I8) are also red.
I1	**PRESSURE**	Gas pressure in the laser tube is out of the operating range. This indicates a leak or a defective valve or pressure sensor.
I2	**FILL**	Fault in the gas supply line: evacuating or filling time exceeded (time out error).
I3	**HV CHARGING**	Discharge capacitor’s charging time exceeded.
I4	**OVER-TEMPERATURE**	Warning light for exceeding temperature (tube outside, more than 60 °C).
I5	**CPU**	CPU or communication failed.
I6	**HV SUPPLY**	The temperature of the HV power supply unit is too high, the fuse is blown off or the line voltage is too low.
I7	**HV OVERVOLTAGE**	Overvoltage in the HV power supply circuit.
I8	**THYRATRON**	The thyratron is not receiving power or heating circuit failed.
K	**EEPROM**	The lamp flashes if the memory check failed. Laser operating data and status information are saved on the EEPROM approx. every two minutes.

L	**STATICAL ERROR**	Flashes red to indicate an error interrupting laser operation. Laser operation is automatically restarted when the cause of the error has been rectified. To ease troubleshooting, one or more of the lights below STATICAL ERROR (L1 to L3) are also red.
L1	**INTERLOCK**	External safety interlock (remote circuit) is open.
L2	**LASERHEAD CHAMB.**	The right-hand, left-hand or top service panel is open or the tube temperature is too high.
L3	**ELECTRONIC CHAMB.**	The front panel is open or the electronics chamber temperature is too high.
M	**WATCHCOUNT**	The storage capacitors are supplied with high voltage and the laser is operating with external triggering for a predefined number of pulses in a non-interruptable mode.
N	**EXT-TRIGGER**	The storage capacitors are supplied with high voltage and the laser is operating with external triggering. The amount and frequency of pulses are determined by the external trigger generator.
O	**BURST**	The storage capacitors are supplied with high voltage and the laser is operating with internal triggering for a predefined number of pulses.
P	**REPETITION ON**	The storage capacitors are supplied with high voltage and the laser is operating with internal triggering for an indefinite number of pulses.
R	**LASER ON**	Power is applied to the HV power supply unit. Laser operation can be started.
S	**WARM UP**	The laser device is in the warm-up phase or laser tube flushing (FLUSHING INT) is in progress. An indicator to the right of the lamp displays the warm up percentage (see Figure 24 on page 84)
T	**Gas mode**	Indicates that gas actions being performed.

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6.2 Service Software

To ease service operations and troubleshooting, the service software LASTEST (only available for service personnel) can be installed on the external controller. This service software provides additional functions:

The screen for error messages is continuously displayed.

A test mode can be started to check laser functions. In the test mode, the warm-up period can be aborted and gas actions can be canceled.

The gas valve assay can be controlled directly.

The communication between PC and laser device as well as between PC and DLL can be checked.

The data transfer can be interrupted without error message.

6.3 Logbook file

For documentation and diagnosis, a logbook file (“eximer.log”) containing Excel-readable entries is created in the directory “Excimer” by the DLL interface.

Every laser status change is recorded in this logbook file. Under normal operating conditions without status changes the status of the laser device is continuously recorded all 30 minutes. Error codes are noted by date and time and entered together with the laser status.

If the file size reaches 1.4 MB, a new file will be created. We recommend to erase old versions of the logbook file periodically to ensure adequate free memory on the hard disk of the laser controller.

7 OPERATION

This chapter describes the operation of the OPTex.

NOTE
A) Before attempting to operate the OPTex, familiarize yourself with the layout and operation of the laser control interface, as described in Section 6.1 on page 79 ff.
B) Prepare a laser logbook to keep a continuous record of data relating to laser operation. This simplifies routine maintenance scheduling as well as problem location.

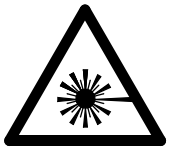
Unless otherwise stated, the descriptions in this section assume that the OPTex is PC controlled.

To ease understanding the information in this section, keep in mind the difference between laser device and laser (see Section 2.2 on page 12).

7.1 Check Beam Path

Purpose

Ensure that the laser beam will be safely guided to the intended target.



WARNING
Risk of serious injury through laser radiation!
Ensure that there are no reflective objects or particles in the path of the laser beam to avoid uncontrolled direct or diffuse reflection of the laser beam.

CAUTION
Risk of fire or release of fumes!
Ensure that there are no materials in the path of the laser beam which may ignite or emit fumes when subject to laser radiation.

NOTE
Utmost safety is provided by completely shielding the beam path (e.g. through a protective enclosure or protective tubes). When the beam path is not to be shielded, keep the beam, wherever possible, in a single plane. Avoid directing the beam at head height.

Tools and Materials

- None

Checking the Beam Path

1. Shielded beam path:
   Ensure that all shields are correctly installed, i.e. there is no risk of unwanted beam emission.
2. Unshielded beam path:
   Ensure that there are no persons, reflective objects or objects in the beam path which can reflect the laser beam, ignite and/or emit fumes.
3. Secure the beam path and vicinity of the beam path against entry of persons.

7.2 Start-Up Laser Device

This chapter describes the procedures required to start-up the OPTex laser device.

7.2.1 Turn On Gas Supply

Purpose

Turn on the excimer laser gases and, where fitted, the purge gas for the beam guidance system to enable laser operation.

WARNING
Health hazard through halogen gas leakage!
To minimize the risk of gas leaks, keep the gas cylinder valves closed except when running the laser in the energy constant mode (EGY Const.) or when performing a new gas fill.

NOTE
The purge gas for the beam guidance system is to be turned on at least 5 minutes before starting laser operation.

Tools and Materials

- Gas cylinders with gases as specified in Section 4.7 on page 59 and with a remaining pressure of at least 5 bar (abs.)

Preconditions

- Gas cylinders for the respective laser gases connected to the corresponding connections on the laser device
- Gas cylinder valves closed

Turning On the Laser Gases

1. Check the pressure gauge (see Figure 26, A) indicating the pressure in the premix gas cylinder to ensure that there is a remaining cylinder pressure of at least 5 bar (abs.).

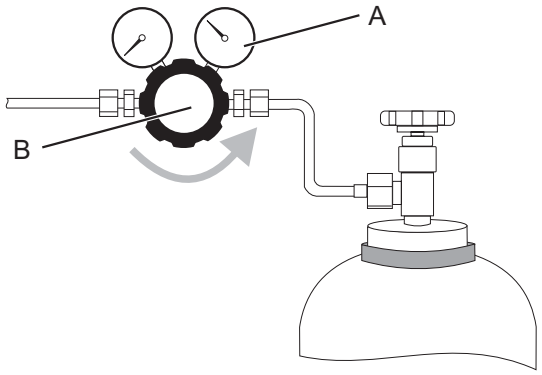


Figure 26: *Checking gas cylinder pressure, closing pressure regulator*

CAUTION
Incorrect operation can damage the pressure regulator!
Never close or attempt to reset the pressure regulator when the gas cylinder valve is open!

2. Turn the valve on the premix pressure regulator (see Figure 26, B) counter-clockwise to its stop, according to the manufacturers instructions, to ensure that the pressure regulator is closed.
3. Open the valve on the premix gas cylinder (see Figure 27, A) by turning counter-clockwise.

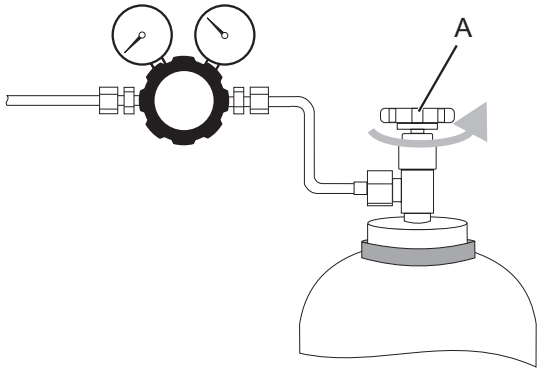


Figure 27: *Opening gas cylinder valve*

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4. Turn the valve on the premix pressure regulator (see Figure 28, A) clockwise, according to the manufacturers instructions, until the pressure gauge (B) indicates the required pressure (see Section 4.7.4 on page 61).

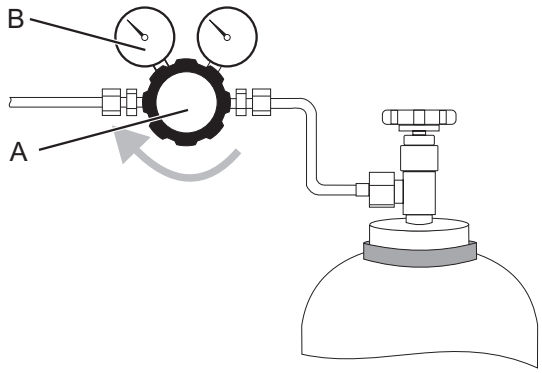


Figure 28: *Setting pressure regulator to required pressure*

5. Repeat steps 1 to 4 to turn on the inert gas.
6. **For F_2 version:**
   Repeat steps 1 to 4 to turn on the purge gas for the beam guidance system.

NOTE
Depending on current configuration, the beam guidance system's vacuum pump is to be switched on instead of turning on the purge gas supply.

7.2.2 Switch On Laser Device and Controller

CAUTION
Incorrect operation can cause damage, downtime and spoilage!
Only authorized and properly instructed personnel are to operate the laser device.

Purpose

Power-up the laser device and PC and start the laser control software to enable laser operation.

Tools and Materials

- Key to key switch
- Protective eyewear suitable for the corresponding laser wavelength

Preconditions

- Beam path checked (see Section 7.1 on page 89)
- Laser device ready to operate

NOTE
All service panels are to be closed. No tags indicating potential hazards (e.g. uncompleted maintenance work) are to be affixed to the laser device.

- Beam guidance system prepared (where fitted)

Switching On the Laser Device

1. Insert the key into the key switch and turn clockwise from the “0” to the “I” setting (see Figure 29, B).
   The POWER ON light (A) comes on. The power circuits in the laser device are enabled.

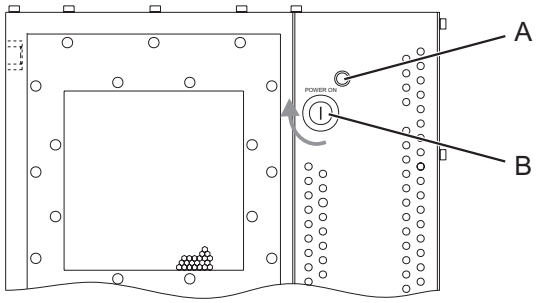


Figure 29: *Enabling power circuits*

Starting the Laser Control Software

2. Switch on the laser control PC and monitor.
3. After Windows has been started, select the program group WINLAC and double click the WINLAC icon.
   The laser control screen appears (see Figure 30). The HV range is set to 50 % of tunable range, the repetition rate to 5Hz.

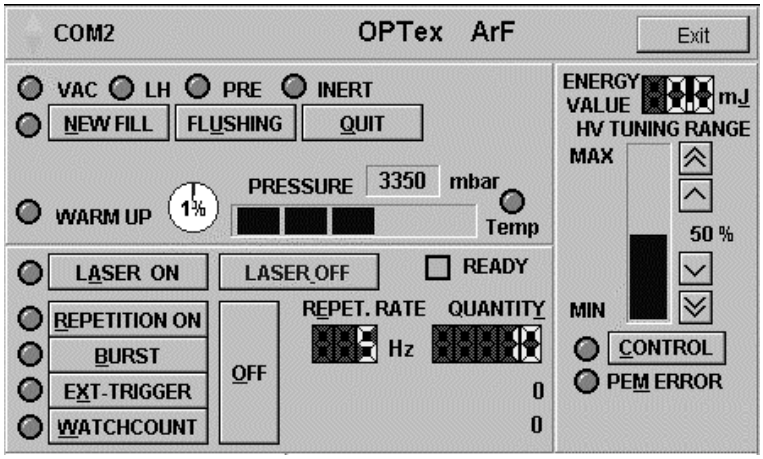


Figure 30: *Laser control screen, warm-up period*

Two colored flashing triangles in the upper left corner of the control screen are indicating the communication between laser controller and PC. If the communication failed, the message “NO CONNECTION” is blinking next to the port number display. When this occurs, select “System” and “Options” from the menu. The Options window appears (see Figure 31). Select the new port by mouse click or using the tabulator key and cursor keys and close the window by clicking “OK” or abort by clicking “CANCEL”.

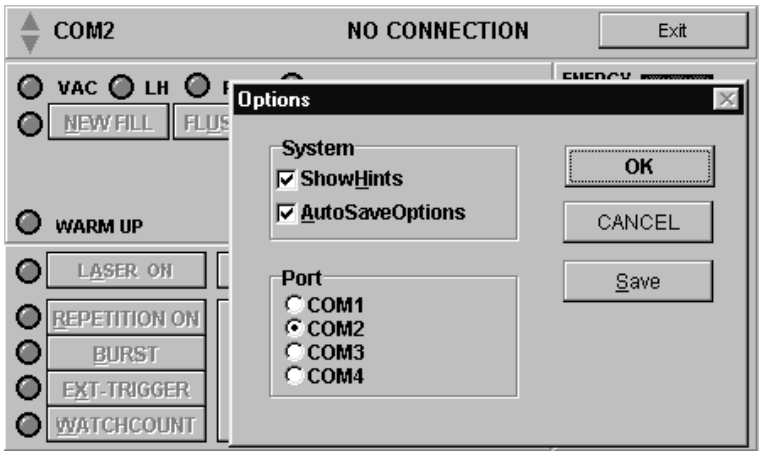
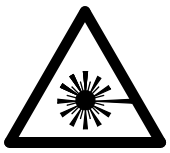


Figure 31: *Laser control screen, options window*



WARNING
Risk of exposure to laser radiation!
Once the laser device has been started, laser standby is established; i.e. laser operation can be started at any time. Never leave the laser device unsecured or unattended in this condition.

NOTE
After switching on the laser device, the thyratron needs approx. 4 min to reach its operating temperature. The warm up period is denoted by the WARM UP lamp and a percentage indicator. Laser operation or actions requiring laser operation cannot be started during this period. Actions not requiring laser operation (e.g. new gas fill) can, however, be performed.

7.3 Methods of Operation

The OPTex excimer laser device can be operated in the operation modes (for emission of laser radiation) or in the gas modes (to perform gas actions like flushing the laser tube and premix line or filling the laser tube with fresh premix gas). In the operation modes, the laser device can be operated with constant energy (EGY Const. mode) or at constant HV values (HV Const. mode). For more information, see also Section 2.9 on page 21).

Generally, all operation modes can be interrupted by clicking “OFF”, “LASER OFF” or “EXIT”. The “OFF” command interrupts laser operation by switching off the HV power supply, but the HV module remains receiving mains power. “LASER OFF” switches off the HV module’s power supply (it takes at least 5 sec. to restart laser operation). Clicking “EXIT” terminates the laser control software.

To restart laser operation without any time delay after interrupting the current operating mode, we recommend to interrupt laser operation by pressing “OFF”.

NOTE
A) When operating in internally triggered modes, the connected external trigger generator must be switched off. In case of non-connected external trigger generator, the interconnecting inputs must be sealed. Otherwise, even low light can trigger laser pulses.
B) The energy constant (EGY Const.) mode is only available if an energy monitor is installed.

7.3.1 Laser Operation Modes

7.3.1.1 Repetition On Mode

Internally triggered laser operation will be started with the selected repetition rate. To change the repetition rate:

1. Click the display “REPET. RATE” (see D in Figure 24 on page 84). A new window appears, showing the current value. The value is marked and the cursor is positioned behind the displayed value (see Figure 32).

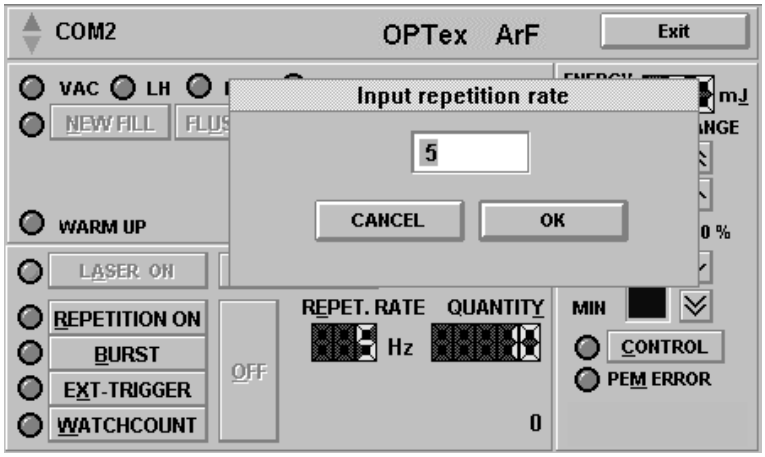


Figure 32: *Setting the repetition rate*

2. Enter the desired value through the numerical keys.
   The value for the repetition rate can be chosen from 1 Hz to 200 Hz in 1 Hz steps.
3. Click “OK” or press ENTER to confirm or click “CANCEL” or press ESC to abort.
   The entered value appears on the display. Entered values above 200 Hz are automatically reduced to 200 Hz.

Start laser operation in accordance with Section 7.4. Laser operation continues until stopped by clicking “OFF” (repetition rate is not reset) or “Laser OFF”.

NOTE
When the repetition rate is changed during operation, the entered value is flushing in the display “REPET. RATE”. The laser operates with the previous repetition rate. Changes don’t become effective until laser operation is stopped by clicking “OFF” and started again.

7.3.1.2 Burst Mode

Internally triggered laser operation will be started for the selected amount of pulses with the current repetition rate. To change repetition rate, see above. To change number of pulses:

1. Click the counter “QUANTITY” (see E in Figure 24 on page 84). A new window appears.
2. Enter the intended number of pulses through the numerical keys. Any value between 1 and 99999 can be entered. In this mode, the laser is able to emit up to 65635 pulses.
3. Click “OK” to confirm. The entered amount of pulses appears on the counter “QUANTITY”. If the input is out of range it is automatically reduced to 65635.

Start laser operation in accordance with Section 7.4.1.

When operating, the numbers (quantity) of pulses are displayed as burst counter (counts down) and user counter (counts up) on laser control screen at the position below the “QUANTITY” counter (see F in Figure 24 on page 84).

The Burst mode can be interrupted by clicking “OFF” (quantity and repetition rate are not reset) or “LASER OFF” (quantity and repetition rate are reset).

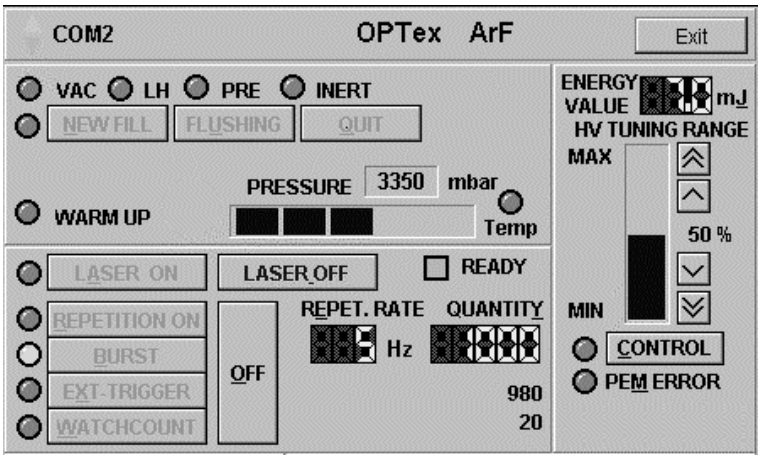


Figure 33: *Burst mode, burst counter and user counter*

7.3.1.3 External Trigger Mode

Externally triggered laser operation will be started with the selected energy value or HV tuning rate. For this operation mode, an external trigger must be connected and correctly set.

Start laser operation in accordance with Section 7.4.1. A laser pulse is emitted whenever a trigger pulse is received.

7.3.1.4 Watch Count Mode

NOTE
When operating in watch count mode, laser operation cannot be stopped by the software interrupt underpressure (< 2.9 bar) or by the command “OFF” until the preset number of pulses has been emitted. HV charging failures (overvoltages or exceeding charging time) are interrupting laser operation immediately.

External trigger mode will be started for a given number of pulses. For setting the number (quantity) of pulses (up to 65635), see “setting quantity” in “Burst mode”.

Start laser operation in accordance with Section 7.4.1. After emission of preset pulses, the control software returns to internal operation mode. Laser operation can be interrupted by stopping the external trigger pulses.

7.3.1.5 Tuning and Operating Ranges

Set High Voltage Values

In the HV Const. mode, the high voltage level can be changed. “MAX” (top of the display) characterizes the highest adjustable high voltage power supply value (100 %), “MIN” the lowest adjustable high voltage power supply value (0 %). After starting laser device, the current level is 50 % of the tunable range.

To change between Energy Constant mode and HV Constant mode (HV CONST), press the “CONTROL” button (see F in Figure 23 on page 80). When the HV Constant mode is selected, the lamp next to the “CONTROL” button is off.

The HV value can also be changed by pressing the buttons for large (10%) or small (1%) increment/decrement (see E1 to E4 in Figure 23 on page 80).

Set Energy Values

In the Energy Constant mode, the average power of the laser beam can be set to a constant value. To select the EGY Const. mode, click the “CONTROL” button. When the EGY Const. mode is active, the lamp next to the “CONTROL” button is on.

Clicking the energy value display selects the window “ENERGY” that enables the energy value to be changed in 0.5 mJ steps by clicking the “+” or “-” buttons (see Figure 34, A). Alternatively, clicking the display on this subsequent window opens a further window enabling the desired value to be directly entered (B). Any value between the minimum and the maximum permissible stabilized energy value can be entered with a precision of 0.1 mJ. After clicking OK to confirm, laser operation can be started with the entered energy value. The new value appears on the display.

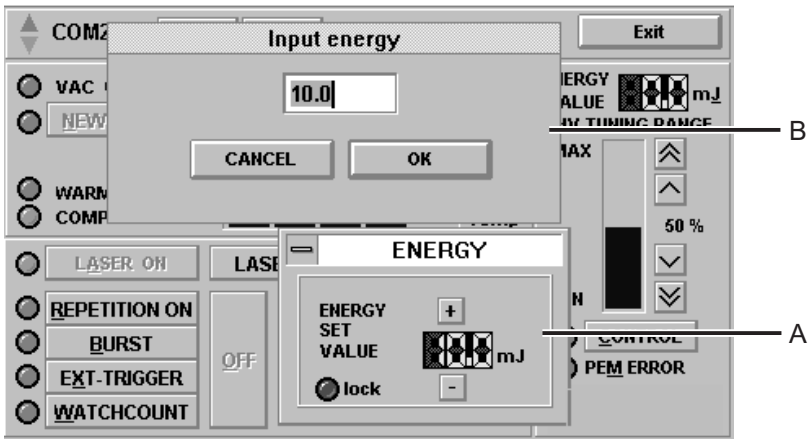


Figure 34: *Setting the energy value for the EGY Const. mode*

NOTE
Exceeding values are automatically reduced to the maximum permissible value. If the input is out of range it will not be accepted (the current value remains). Do not operate the laser with the maximum permissible stabilized energy value over longer periods as this reduces the gas and windows lifetimes.

Laser Tube Pressure and Temperature

The laser device operates with a maximal tube pressure of approx. 3.4 bar (4.4 bar abs.) or 3.0 bar (4.0 bar abs.) for the F_2 version. Displayed operating values lower than 3000 mbar, or 2800 mbar respectively, are indicating a gas leak or fill error. Pressure drops to less than 2600 mbar are activating the safety facilities.

The optimal operating temperature of the laser tube is 40 °C. Temperatures above 48 °C are indicated by the temperature warning light. The safety facilities are activated when the temperatures are considerably exceeded (tube temperature more than 60 °C or thyratron temperature more than 80 °C).

7.3.2 Gas Modes

Maintenance operations such as gas exchange and maintenance of resonator and gaslines are supported by the gas modes. Gas actions are executable even in the warm-up period.

7.3.2.1 New Gas Fill

The static and dynamic lifetime and energy yield of the laser gas is restricted. Gases of insufficient quality are exchanged automatically by clicking the “NEW FILL” button (see A in Figure 23 on page 80). The used gas is pumped out of the laser tube and the tube is refilled with fresh premix gas.

For detailed information, see Section 8.5 on page 116.

7.3.2.2 Flush Premix Gas Supply Line

NOTE
For flushing procedures, the premix gas cylinder is to be closed.

This procedure is always to be performed after installing the laser device and exchanging gas cylinders. It is started by clicking “FLUSH EXT” in the Flushing window (see page 81). The premix gas supply line is pumped out of laser gas and filled with inert gas.

To ensure that the gas line is thoroughly flushed, it is evacuated and refilled twice. At the end of the first cycle, the procedure is interrupted to perform a leak test.

At the end of the procedure, a corresponding message appears. After confirming to exit, the laser device is starting a warm up period again.

For detailed information, see Section 8.4.1 on page 110.

7.3.2.3 Flush Laser Tube

This procedure is to be performed before maintaining the windows (see Section 8.6.1 on page 119) by clicking the “FLUSH INT” button in the Flushing window (see page 81). The laser tube is evacuated and filled with inert gas three times. At the end of the third cycle, a message appears to indicate that the windows can be exchanged. The procedure can be aborted (e.g. before exchanging the windows) by clicking “QUIT”.

Following the laser tube flushing, a new gas fill is necessary.

7.3.2.4 Fill Laser Tube with Inert Gas

This procedure is to be performed before dispatching the laser tube or laser device by clicking the “FILL INERT” button in the Flushing window (see page 81). The laser tube is evacuated and refilled with inert gas (Helium) up to a pressure of 1500 mbar.

Following the laser tube flushing, a new gas fill is necessary before restarting laser operation (see Section 8.5 on page 116).

7.4 Start and Stop Laser Operation

This section describes how to start and stop the laser. For more information about changing operation modes and entering operating parameters, please refer to Section 7.3.

7.4.1 Start Laser Operation

Purpose

Start the laser for designated use. To enable generating the laser beam the high voltage circuit is to be activated.

Tools and Materials

- Protective eyewear suitable for the OPTex laser wavelength

Preconditions

- Beam path checked (see Section 7.1)
- Excimer laser gases and purge gas turned on as required (see Section 7.2.1)
- Laser and PC switched on, laser control software started (see Section 7.2.2)

Preparation

1. Take off your watch, ring or any other jewelry, which could cause reflections that divert the laser beam from the intended path.

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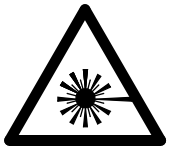
Starting Laser Operation



WARNING
Risk of serious injury through laser radiation!
When laser operation is started, laser radiation is emitted from the beam exit aperture. Strictly adhere to the safety precautions detailed in Chapter 3.

2. **For F_2 version:**
   Ensure that the beam guidance system is prepared for laser operation (depending on current configuration, vacuum pump switched on or purge gas supply turned on).
3. Open the beam shutter (Figure 35, A) by turning the beam dump counter-clockwise and removing it from the beam exit aperture.

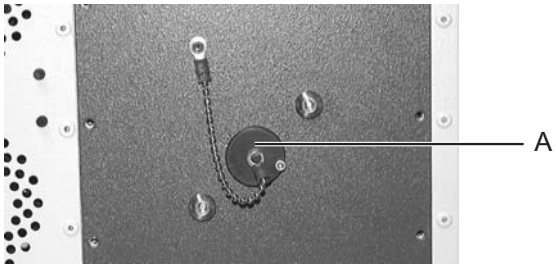


Figure 35: *Beam shutter on laser device*

4. Wait until the warm-up indicator disappears and the “READY” lamp on the laser control screen lights. This indicates that the laser device has warmed-up.

NOTE
The laser cannot be started during the warm-up period. When attempting to start the laser during this period, a warning message appears on the screen.

5. Click “LASER ON” (see N in Figure 23 on page 80).
   The laser radiation indicator light on the laser device flashes. The storage capacitors are supplied with high voltage.
   Laser operation can be started after approx. 5 seconds.
6. Ensure that the repetition rate (REPET. RATE) and number of pulses (QUANTITY) are correctly set (see Section 7.3.1.1 on page 96 and Section 7.3.1.2 on page 97).
7. Ensure that the intended operating mode (EGY Const. or HV Const.) is selected and that the energy or high voltage values are correctly set (see Section 7.3.1.5 on page 98).

NOTE
The CONTROL light on the laser control screen is yellow and the CONTROL button turns to red when the EGY Const. mode is selected.

8. Click REPETITION ON, BURST, EXT-TRIGGER or WATCHCOUNT (see Figure 23 on page 80) to start laser operation. Laser pulses are emitted at the given repetition rate. This can be recognized by an audible clicking.

7.4.2 Stop Laser Operation

Purpose

Switch off the laser and disable the high voltage circuit.

Tools and Materials

- Protective eyewear suitable for the OPTex laser wavelength

Preconditions

- Laser operates (laser radiation being emitted)

Stopping Laser Operation

1. Click OFF on the laser control screen (see H in Figure 23 on page 80) to stop the currently active laser operation and enter stand by mode.
2. Click LASER OFF on the laser control screen (see G in Figure 23 on page 80) or press space bar on keyboard to disable the power supply of the HV module.
   The laser radiation indicator light on the laser device goes out.
3. Close the beam shutter by inserting the beam dump into the beam exit aperture and turning it clockwise until it reaches it's final position.
   The laser standby condition is established, i.e. laser operation can be restarted at any time or the laser device can be switched off.

7.5 Shut-Down Laser Device

This Section describes the procedures required to shut-down the OPTex laser device.

7.5.1 Switch Off Laser Device and Controller

Purpose

Exit the laser control program, switch off laser device and controller and secure the laser device against unauthorized use.

WARNING
Misuse or improper operation can cause serious injury!
To prevent unauthorized persons from starting the laser, always switch off, lock and remove the key from the laser device, when not in service.

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Tools and Materials

- None

Preconditions

- Laser switched off (no laser radiation being emitted)

Exiting the Laser Control Program

1. Click EXIT on the laser control screen (see D in Figure 23 on page 80) to terminate the laser control software.

Switching off Laser Device and Controller

2. Turn the key in the key switch counter-clockwise from the “I” to the “O” setting (see Figure 36, B).
   The POWER ON light (A) goes out.

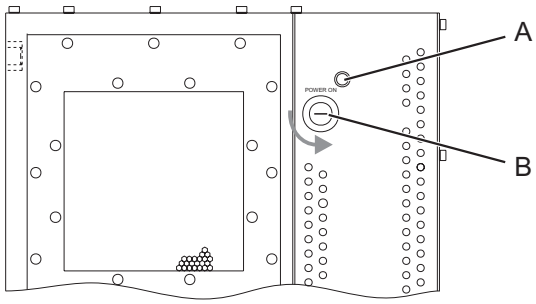

Figure 36: *Disabling power circuits*

3. Remove the key from the key switch and keep in a safe place.
4. Terminate WINDOWS® on the external controller and switch off the controller.
   The procedure varies depending on the WINDOWS® version. For more information, please consult the controller’s user manual.

7.5.2 Turn Off Laser Gases

Purpose

Turn off laser gases when the laser is not to be operated in the energy constant mode, no new fill is to be performed or the laser device is shut-down.

Preconditions

- None

Turning Off Laser Gases

CAUTION
Incorrect operation can cause unnecessary downtime and spoilage! Never close the pressure regulator when the gas cylinder valve is open.

1. Close the valve on the premix gas cylinder (see Figure 37, A) by turning clockwise to its stop.

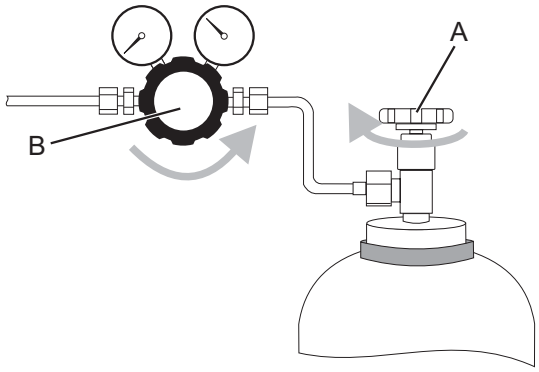

Figure 37: *Turning off gases*

2. Turn the valve on the premix pressure regulator (see Figure 37, B) counter-clockwise to its stop. This ensures that the pressure regulator is closed.
3. Repeat steps 1 and 2 to turn off the inert laser gas supply.
4. **For F_2 version:**
   Repeat steps 1 and 2 to turn off the beam guidance system's purge gas supply.

NOTE
Depending on current configuration, the beam guidance system's vacuum pump is to be switched off instead of turning off the purge gas supply.

The laser device is now fully shut down and secured against unauthorized operation. Restart laser operation according to the procedures described in Sections 7.2 and 7.4.1.

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8 MAINTENANCE

This chapter describes the routine maintenance of the OPTex. Follow the recommended maintenance intervals and procedures to ensure optimum performance.

Unless otherwise stated, the descriptions in this section assume that the OPTex is PC controlled.

WARNING
Risk of serious injury!
Always switch off the laser device when performing maintenance actions.
When performing maintenance actions which require the laser device to be powered-on or require laser operation, ensure that the maintenance area is at all times adequately secured and that no unauthorized persons can access the laser device.
All persons in the maintenance area shall be fully familiar with the applicable safety regulations and requirements.

8.1 Laser Logbook

Prepare a laser logbook to keep a continuous record of data relating to laser operation. This simplifies routine maintenance scheduling as well as problem location.

8.2 Laser Device Design

For fail-safe operation, ease of maintenance and lowest perturbing radiation, the internal components are arranged in two separate chambers (see Section 2.3 on page 13). The partition between these two chambers supports the internal components and is used as cooling surface.

The two chambers of the laser device are cooled separately (see Figures 3 and 4 in Section 2.4 on page 14). The cooling air is guided through apertures and honeycomb filters.

The housing made of galvanized steel sheet ensures an adequate contact-voltage proof and HF-attenuation when completely screwed down. The mains supply line is connected with a mains filter.

Communication between RS 232 optical interface adapter, laser control unit and decentralized modules occurs through fiber optic light waveguides (FOLs). The electrical lines and FOLs are numbered to facilitate the pursuit of signals and the exchange of modules.

Internal solenoid valves are used to fill and evacuate the laser tube. The pressure sensor is located opposite of the gas circulation motor.

For fundamental diagrams of electrical connections and FOL-system, see Chapter 10 on page 155.

8.3 Maintenance Schedule

For proper and safe operation of the OPTex follow the maintenance schedule shown below.

Procedure	Lifetime F_2 version		Lifetime other versions		Other conditions / Comments
	Dynamic	Static	Dynamic	Static	
Flush premix line (Section 8.4.1)	–	–	–	–	before exchanging a premix cylinder, performing a leak test, new gas fill or transportation fill; after several weeks without operating
New gas fill (Section 8.5)	2.0 E+06 pulses	if laser device has been switched off for 1 day	8.0 E+06 pulses	if laser device has been switched off for 5 days	if beam output energy is too low for application; if windows have been cleaned or replaced; if laser device has been transported; if laser tube has been re-passivated
Exchange gas cylinder (Sections 8.4.2 and 8.4.3)	–	–	–	–	if pressure less than 5 bar
Clean windows (Sections 8.6.3 and 8.6.4)	10.0 E+06 pulses	–	not intended		if beam output energy is too low and/or beam profile is poor in spite of a new gas fill
Exchange windows (Section 8.6.1)	50.0 E+06 pulses	–	10.0 E+06 pulses	–	
Exchange halogen filter	every 250 new fills	2 years	every 250 new fills	2 years	
Calibrate energy monitor	not available		5.0 E+06 pulses	3 month	after it has been disassembled; after windows maintenance
Exchange energy monitor	not available		100.0 E+06 pulses	1 year	if calibration failed
Exchange laser tube	available on request		–	5 years (OPTex2 and ArF)	guaranteed lifetime: 500 E+06 pulses or 1 year
Exchange thyratron	available on request		–	5 years (OPTex2 and ArF)	guaranteed lifetime: 3 years
Check vacuum pump	–	3 years	–	3 years	after about 1000 new fills
Clean filter of the aspirating ventilator	–	–	–	–	depending on environmental conditions
Check pressure regulators	–	–	–	–	according to valid national regulations, technical rules and manufacturers data sheet

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8.4 Gas Line Maintenance

To ensure optimum excimer laser performance, the gas lines have to be kept free of leaks and impurities. In addition, potentially hazardous halogen gases have to be flushed from the premix gas line when exchanging the premix gas cylinder. This section describes the procedure to flush the premix gas line as well as how to exchange the gas cylinders.

8.4.1 Flush Premix Gas Line (External Flushing)

Purpose

Evacuate the premix line and fill with inert gas. This is, for example, necessary before exchanging a premix cylinder, before performing a leak test on the premix line or when the laser is not to be used for several weeks.

WARNING
Toxic hazard!
Always thoroughly flush the premix line with inert gas before disconnecting the gas cylinder, disconnecting the gas line or performing a leak test.

Tools and Materials

- Inert gas cylinder with at least 5 bar (abs.) remaining pressure

Preconditions

- Laser device switched on and laser control software started

Preparation

1. Ensure that the gas cylinders are correctly connected.
2. Close the valve on the premix gas cylinder.
3. Close the pressure regulator in the premix gas line.

NOTE
To completely flush the gas line, set the pressure regulator to 5 bar (abs). If the pressure regulator setting is too low, residues of halogen gas could remain in the line between pressure regulator and gas cylinder valve.

4. Set the pressure regulator in the premix gas line to 5 bar (abs). The premix gas line is now open, but no gas will enter from the premix gas cylinder.
5. Close the valve on the inert gas cylinder.
6. Close the pressure regulator in the inert gas line.
7. Open the valve on the inert gas cylinder.
8. Set the pressure regulator in the inert line to 5 bar (abs).

Flushing the Premix Gas Line

9. Click the FLUSH EXT button in the Flushing window of the laser control software.
   The prompt “Please close PREMIX bottle” appears.
10. Ensure that the premix gas cylinder is closed.
11. Click “YES” to continue.
12. The prompt “Please open inert (> 3 bar)” appears.
13. Ensure that the inert gas cylinder is correctly connected and open and that the pressure regulators in the premix and inert lines are set to 5 bar (abs).
14. Click “YES” to continue.
    The message “extern flushing 1" appears. The premix line is evacuated and filled with inert gas. The currently active operation is indicated by the lamps above gas action buttons. At the end of the cycle, the prompt ”Leak test" appears.
15. Immediately close the inert gas cylinder valve.
16. Visually check whether the pressure gauge on the pressure regulator drops within 3 minutes. If there is no sensible drop, continue with step 18.
17. In case of a leak check the gas connections and tighten if necessary. Open the inert gas cylinder valve and continue the flushing procedure by clicking “OK”. If there still is a sensible pressure drop, a detailed leaktest has to be performed. For these service operation, call your authorized and instructed service. After appearing the message “extern flushing finished” continue with step 20.
18. Open the inert gas cylinder valve.
19. Click “OK” to continue the flushing procedure.
    The message “extern flushing 2" appears. The premix line is evacuated and filled with inert a second time. When the cycle is completed, the message ”extern flushing finished" appears.

Finalization

20. Close the pressure regulator in the premix gas line.
21. Close the gas cylinder valve and pressure regulator in the inert gas line.
22. When performing a new gas fill or when exchanging the windows, continue with step 2 (New gas fill, Preparation) on page 116.
23. If necessary, shut-down the laser device and external controller.

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8.4.2 Exchange Premix Gas Cylinder

Purpose

Remove a spent premix gas cylinder and replace with a fresh premix gas cylinder.

A gas cylinder has to be exchanged when

– the remaining pressure in the cylinder is less than 5 bar

– the gas cylinder has expired (see product information provided by the gas supplier).

Tools and Materials

CAUTION
Risk of damaging laser tube!
Never use gas cylinders with a pressure of less than 5 bar (abs.) as impurities that desorb from the gas cylinder walls can contaminate the laser tube and cause loss of passivation.

- Replacement premix gas cylinder as specified in Section 4.7.4 on page 61
- Appropriate wrench for the gas cylinder fittings
- Stainless steel cap to seal gas line
- Liquid leak tester, e.g. SNOOP®
- Ethanol
- Cleaning paper

Preconditions

- Laser device switched on and laser control software started

Preparation

WARNING
Toxic hazard!
Always thoroughly flush gas lines leading to a premix gas cylinder before disconnecting the gas cylinder.

1. Close the gas cylinder valve and pressure regulator in the premix gas line.
2. Open the premix gas cylinder valve.
3. Set the pressure regulator in the premix gas line to 5 bar (abs).
4. Close the gas cylinder valve and the pressure regulator in the inert gas line.
5. Open the valve on the inert gas cylinder.
6. Set the pressure regulator in the inert gas line to 5 bar (abs).

Flushing the Premix Gas Line

7. Perform the flushing procedure described in Section 8.4.1 on page 110 at least twice.

Exchanging the Premix Gas Cylinder

8. Unscrew the corresponding premix gas line connection.

NOTE
Depending on the manufacturers instructions, the pressure regulator may to be exchanged too.

9. Seal the premix line with the stainless steel cap to prevent corrosion.
10. Exchange the premix gas cylinder.
11. Remove the stainless steel cap from the premix line.
12. Screw the line fittings to the pressure regulator.

Leak Testing

13. Ensure that the gas cylinder valve and pressure regulator in the premix gas line are closed.
14. Ensure that the gas cylinder valve in the inert gas line is open and that the pressure regulator is set to 5 bar (abs).
15. Flush the premix gas line by clicking the FLUSH EXT button in the Flushing window of the laser control software. (see Section 8.4.1 on page 110).
16. When the window “LEAKTEST” appears, visually check the pressure gauge on the pressure regulator.
    If there is no pressure drop within 10 minutes, finish the leaktest by clicking “LEAKTEST OK” and continue with step 22.
    If there is a pressure drop, a detailed leaktest using leak tester (e.g. SNOOP®) is to be performed.

CAUTION
Risk of contaminating gas lines!
Do not switch on the vacuum pump when SNOOP® is applied to gas line connectors as this may penetrate the gas lines.

17. Spray SNOOP® on the connectors in the premix gas line.
    If there is a leak, small bubbles will appear within seconds.
18. Tighten any leaky connections.
19. Re-check for leaks.
    If the leak cannot be rectified, call authorized service.
20. Carefully clean the leak tested connectors with cleaning paper.
21. Wipe the leak tested connectors with ethanol and dry with cleaning paper.
22. Close the gas cylinder valve and pressure regulator in the inert gas line.

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Finalization

23. Ensure that the pressure regulator and the gas cylinder valve in the premix line are closed.
24. Open the premix gas cylinder valve.
25. Set the pressure regulator in the premix gas line to 5 bar (abs).
26. Perform a new fill procedure (see Section 8.5 on page 116).
27. If necessary, shut-down the laser device and external controller.

8.4.3 Exchange Inert Gas Cylinder

Purpose

Exchange a spent inert gas cylinder with a fresh gas cylinder.

A gas cylinder has to be exchanged when

– the remaining pressure in the cylinder is less than 5 bar,

– the gas cylinder has expired (see product information provided by the gas supplier).

Tools and Materials

CAUTION
Risk of damaging laser tube!
Never use gas cylinders with a pressure of less than 5 bar (abs.). Impurities that desorb from the gas cylinder walls can contaminate the laser tube and cause loss of passivation.

- Replacement inert gas cylinder as specified in Section 4.7.4 on page 61
- Appropriate wrench for the gas cylinder fittings
- Liquid leak tester, e.g. SNOOP®
- Ethanol
- Cleaning paper

Preconditions

- None

Preparation

1. Close the gas cylinder valve and pressure regulator in the inert gas line.
2. Close the gas cylinder valve and pressure regulator in the premix gas line.

Exchanging the Inert Gas Cylinder

3. Unscrew the connection fittings in the inert gas line.

NOTE
Depending on the manufacturers instructions, the pressure regulator may to be exchanged too.

4. Exchange the inert gas cylinder.
5. Screw the line fittings to the pressure regulator.

Leak Testing

6. Ensure that the gas cylinder valve and pressure regulator in the inert gas line are closed.
7. Open the inert gas cylinder valve.
8. Set the pressure regulator in the inert line to 5 bar (abs).
   The inert gas line is now filled with inert gas at a pressure of 5 bar (abs).
9. Close the gas cylinder valve in the inert gas line.
10. Visually check the pressure gauge on the pressure regulator.
    If there is no pressure drop within 10 minutes, continue with step 16.
    If there is a pressure drop, a detailed leaktest using leak tester (e.g. SNOOP®) has to be performed.

CAUTION
Risk of contaminating gas lines!
Do not switch on the vacuum pump when SNOOP® is applied to gas line connectors as this may penetrate the gas lines.

11. Spray SNOOP® on the connectors in the premix gas line.
    If there is a leak, small bubbles will appear within seconds.
12. Tighten any leaky connections.
13. Re-check for leaks.
    If the leak cannot be rectified, call authorized service.
14. Carefully clean the leak tested connectors with cleaning paper.
15. Wipe the leak tested connectors with ethanol and dry with cleaning paper.
16. Close the gas cylinder valve and pressure regulator in the inert gas line.

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8.5 New Gas Fill

Purpose

Replace gases of insufficient quality in the laser tube with fresh gases.

We recommend a new gas fill when

– the beam energy is too low

– the static or dynamic gas lifetime has been exceeded

– the windows have been cleaned or replaced

– the laser device has been transported

– the laser tube has been re-passivated.

The lifetime and energy yield of the laser gases is heavily dependent upon the conditions under which the laser is operated. We, therefore, recommend to record the frequency of performing new gas fills in the laser logbook. This enables to prepare a specific maintenance schedule.

Take into account, however, that the following situations reduce the lifetime and energy yield of the laser gases:

– the laser tube has just been passivated

– the first fill has been made after several weeks without operation

– the wavelength has been changed

– the windows are contaminated

– the laser is operated at high energy or voltage values

The composition and partial pressures of the gas mixture to be filled is specified in Section 4.7.4 on page 61. Take account of the remaining premix gas pressure!

Tools and Materials

- Premix gas cylinder with a minimum of 10 bar remaining pressure.

Preconditions

- Laser device switched on and laser control program started

Preparation

1. Flush the premix gas line (see Section 8.4.1 on page 110).
2. Open the premix gas cylinder valve.
3. Set the pressure regulator in the premix gas line to 5 bar (abs).

Performing a New Gas Fill

4. Click the NEW FILL button on the laser control screen.
   The prompt “Are you sure” appears.
5. Click “YES” to continue.
6. The prompt “Please open premix” appears.
7. Ensure that the premix gas cylinder valve is open and that the pressure regulator is correctly set.
8. Click “YES” to continue.
9. The new fill procedure is executed automatically.
   When the new fill is complete, the warm-up period starts automatically and the elapsed time is displayed on the screen.
10. Close the gas cylinder valve and the pressure regulator in the premix gas line.

Finalization

11. When exchanging the windows, continue with step 26 on page 125 (Assembling the Laser Device).
12. If necessary, shut-down the laser device and external controller.

8.6 Windows Maintenance

The OPTex laser tube windows are

– the rear mirror (rear window) and

– the output coupler (front window).

Maintenance of the windows consists of the cleaning and/or exchanging the windows.

Cleaning

To enable cleaning, the windows have to be removed.

Cleaning the windows is necessary

– after a specific number of pulses (dependent on gas mixture / wavelength, laser operation at high voltages or energy)

– if the pulse energy is too low

– if the beam profile is poor.

Exchange

Exchange is the removal and disposal of damaged or spent windows and the insertion of new or undamaged windows.

Exchanging the windows is necessary

– if the windows are damaged (e.g. scratched),

– if the windows are unable to be cleaned (e.g. burned-in deposits),

– after a specific number of pulses (dependent on gas mixture / wavelength, laser operation at high voltages or energy).

NOTE
Spare premounts for the windows are optionally available. To maximize uptime, keep a set of ready-to-use windows mounted in spare premounts. This enables contaminated windows to be cleaned at convenience while the laser is running.

8.6.1 Windows Exchange

Purpose

Remove contaminated or damaged windows (rear mirror and output coupler) from the laser device and insert new or clean windows.

Prior to removing the window mounts, the laser tube has to be flushed. With this procedure, the gas mixture is pumped out of the laser tube and the tube is refilled with the gas connected to the inert connection.

Tools and Materials

- Set of allen keys (service box)
- Premounted windows or sealing plates (see Figure 38, in service box)

Figure 38: *Sealing plate*

- Disposable skin-tight plastic gloves
- Cylinder of inert gas with sufficient remaining pressure

NOTE
During the flushing procedure, approx. 25 liters of inert gas at 4bar (abs.) are required. The pressure in the inert gas cylinder is not to drop below 5 bar (abs.) during the flushing procedure.

Preconditions

- Laser device switched on and laser control software started

Preparation

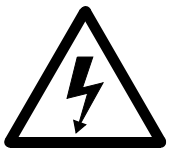
1. Open the valve on the inert gas cylinder.
2. Set the pressure regulator in the inert line to 5 bar (abs).

Open the Laser Device Housing

CAUTION
Risk of damaging the laser tube!
The “FLUSH INT” procedure fills the laser tube with inert gas. Never operate the laser in this condition. Flushing the laser tube is always to be followed by a new gas fill before restarting laser operation.

CAUTION
Incorrect handling can seriously damage the windows!
Never touch the surfaces of the windows. Wear skin-tight plastic gloves when handling the windows.

3. Click the FLUSH INT button on the laser control screen.
   The prompt “Are you sure” appears.
4. Click “YES” to continue.
   The prompt “Please open inert (> 3 bar)” appears.
5. Ensure that the inert gas cylinder is open and that the pressure is correctly set.
6. Click “YES” to continue.
   The flushing procedure, consisting of three automatic cycles, is started. At the end of the third cycle, the message “Please change optics or quit” appears. The procedure is aborted by clicking “QUIT”. Following this, “NEW FILL” must be selected to re-enable laser operation.
7. When “Please change optics or quit” appears, disconnect the beam guidance system and remove the purge gas connection tube by opening the corresponding clamping rings (where fitted, see Section 5.10 on page 77).
8. Use the 3 mm allen key to carefully remove the right-hand and left-hand service panels.



WARNING
Risk of electrocution!
To avoid risk of electrocution, the capacitors must be discharged to ground for each service or maintenance procedure carried out within the tube chamber.

9. To discharge the capacitors, pull the capacitor grounding stick (safety stick) out of the mounting (see Figure 39 on page 121), lead it through the protection grill and plug its metallic side into the discharge connector (see Figure 40).

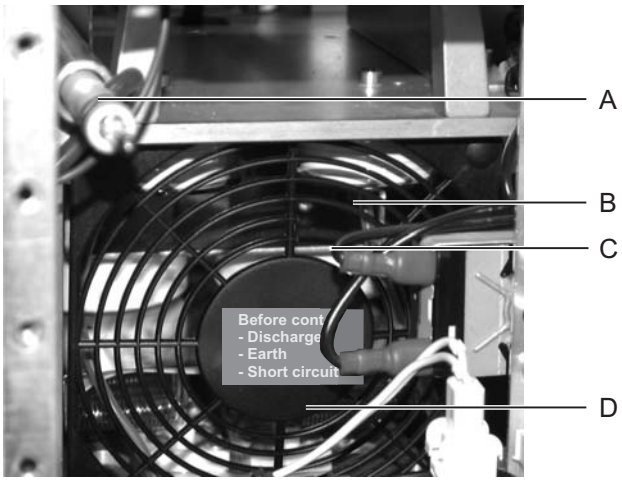


Figure 39: *Safety stick and discharge connector*

Key to Figure 39:

A	Safety stick	B	Discharge connector
C	Safety stick insertion point	D	Protective grid

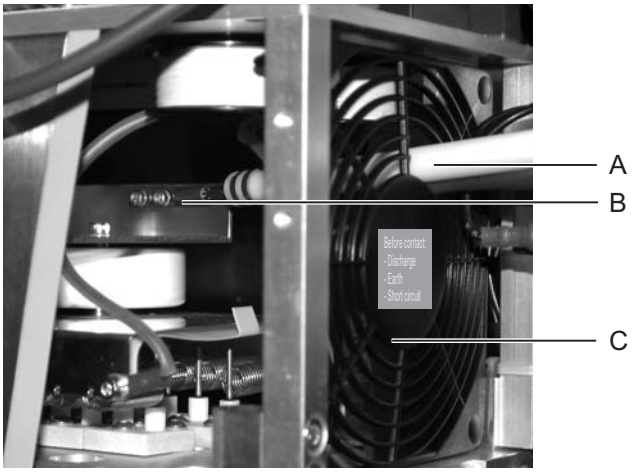


Figure 40: *Discharging the capacitors*

Key to Figure 40:

A	Safety stick	B	Discharge connector
C	Protective grid		

NOTE
The fan is attached to the left-hand service panel. When removing this side panel, take care not to damage the connection.

10. Disconnect the fan connection on the left-hand service panel.
11. Continue with “Removing the Energy Monitor” (step 16 on page 123) if not maintaining a F_2 version of the OPTex.

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Removing the Beam Path Shielding (F_2 version only)

12. Open the clamping ring (see Figure 41, A) to disassemble the beam path shielding.

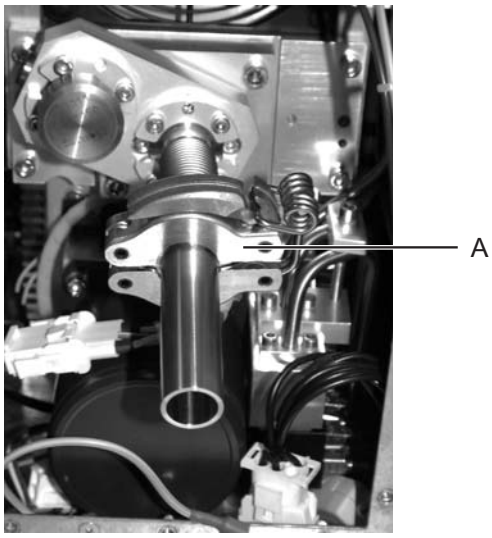

Figure 41: *Clamping ring of the beam path shielding*

13. Remove the beam path tube, centering ring and clamping ring from the flexible tube (see Figure 42).

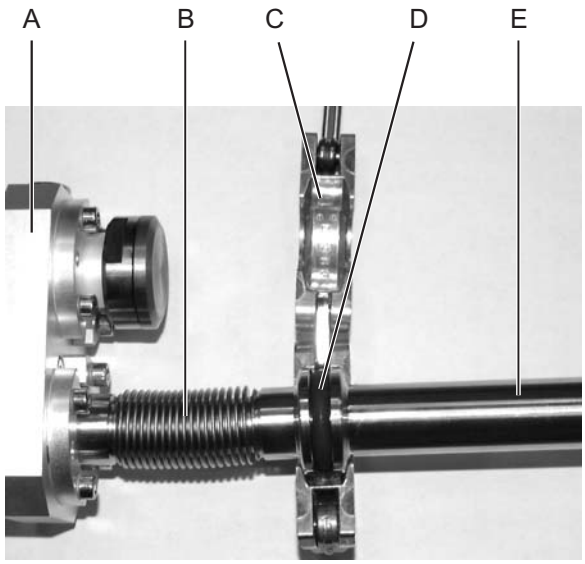

Figure 42: *Beam path shielding accessory*

Key to Figure 42:

A Beam path adapter
B Flexible tube
C Clamping ring
D Centering ring with O-ring
E Beam path tube

14. Loosen and remove the flexible tube from the beam path adapter. The flexible tube is secured through four allen screws (Figure 43).

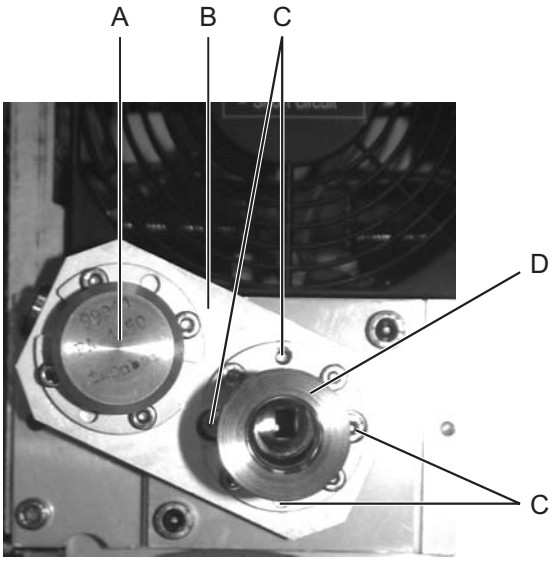

Figure 43: *Beam path adapter*

Key to Figure 43:

A	Pressure reducing valve	B	Beam path adapter
C	Fixing screws	D	Flexible tube

15. Remove the O-ring and contact pressure ring, located between the beam path adapter and the window mount.

Removing the Energy Monitor (where fitted)

16. Disconnect the FOL from the connection on the top of the energy monitor (see Figure 44, A).

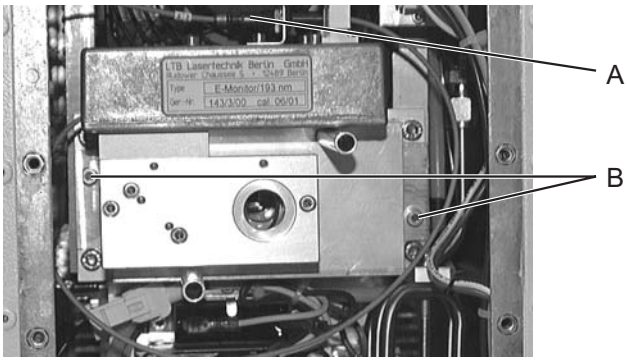

Figure 44: *Removing the energy monitor*

17. Loosen and remove the screws attaching the energy monitor (see Figure 44, B).

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18. Carefully pull the energy monitor out of the locating bores in the laser tube frame and lay it down.

NOTE
The energy monitor is fixed at the front of the laser tube by two locating pins (see Figure 45, B). It is connected to the 24 V DC power supply line and FOL. The power supply line (A) does not need to be disconnected, providing that care is taken not to damage or break the wire and/or links.

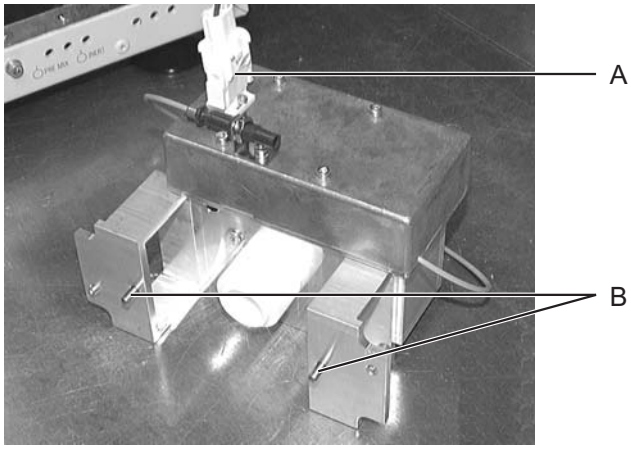

Figure 45: *Energy monitor, rear side*

Exchanging the Window Mounts

CAUTION
Risk of damaging window mount and window!
There is significant overpressure in the laser tube. Press the window mount against the laser tube while loosening. Loosen the holding screws crosswise in even steps.

19. While pressing the window mount (see Figure 46, A) against the laser tube, carefully loosen the four allen screws fixing the window mount (B) and remove the window mount.

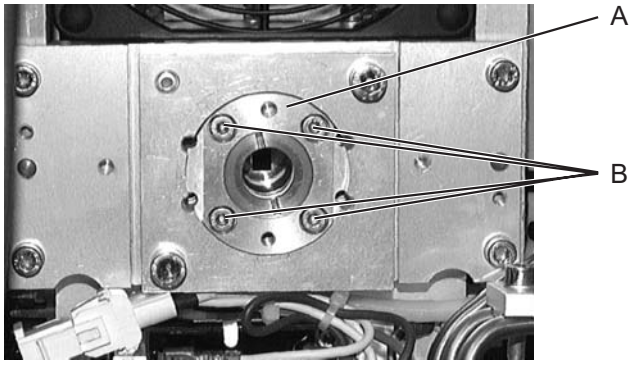

Figure 46: *Exchanging the window mounts*

A short hissing sound, caused by the over pressure in the laser tube, indicates that the tube is now open. The message “optic open” appears on the laser control screen. The inert gas valve opens to compensate for the pressure drop with inert gas. This prevents air from entering. If the laser tube is not closed, this will happen about every two seconds.

20. Immediately mount the sealing plate (see Figure 38 on page 119) or replace pre-mounted windows. For description of disassembling and assembling the window mounts, see Section 8.6.3 on page 132).
21. Carefully tighten the allen screws on the window mount crosswise and in even stages.
    After replacing the window, the laser tube is filled with inert gas up to a pressure of 2000 mbar. The tightness is automatically checked for 5 minutes. In case of a pressure drop of more than 200 mbar a message appears, requesting to check the replaced window. Otherwise (pressure drop less than 200mbar) a message appears indicating the successful exchange. After confirming the message (successful or leakage error) by pressing the ENTER key, the pressure within the laser tube will be reduced to low overpressure. A message appears prompting for a new window exchange or exiting window exchange mode.

CAUTION
Air penetration will damage the laser tube!
Never leave the laser tube open. Always completely exchange one window before starting to exchange the other window.

22. Repeat the steps 19 to 21 to exchange the other window.
23. After completition of the second window exchange, press the ENTER key to confirm the windows exchange mode to be terminated.
    The warm-up routine is started automatically.
24. In case of using pre-mounted windows, continue with step 25, otherwise repeat the internal flushing (steps 3 to 6 on page 120) and the windows exchange (steps 19 to 23 on page 124) to exchange the sealing plates for new or cleaned pre-mounted windows.
25. Perform a new gas fill (see Section 8.5 on page 116).

Assembling the Laser Device

26. Shut-down the laser device.
27. Carefully slide the energy monitor’s locating pins into the appropriate bores on the laser tube (where fitted).
    The white plastics tube is to be fitted into the window mount.
28. Tighten the two holding screws to mount the energy monitor onto the laser tube frame (where fitted).
29. Re-connect the FOL removed in step 16 to the connection on the top of the energy monitor (where fitted).

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30. **For F_2 version only:**
    Insert the contact pressure ring (see Figure 47, B) and O-ring (A) into the right-hand window mount drill hole on the laser tube.
    The O-ring has to point into the direction of the beam path adapter.

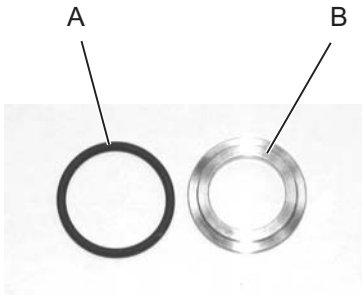


Figure 47: *O-ring and contact pressure ring*

31. **For F_2 version only:**
    Replace and tighten the flexible tube to the beam path adapter (see Figure 43 on page 123).
32. **For F_2 version only:**
    Attach the clamping ring, centering ring and beam path tube to the flexible tube (see Figure 42 on page 122) and close the clamping ring to assemble the beam path shielding.
33. Connect the ventilator connections.
34. Insert and tighten the right-hand and left-hand service panel using the 3 mm allen key.

Finalization

35. Align the windows (see Section 8.6.2).
36. Calibrate the energy monitor (see Section 8.8 on page 143).
37. If necessary, shut-down the laser device and external controller.

8.6.2 Windows Alignment

Purpose

Align the windows using an external adjustment laser beam to ensure an optimum beam energy or beam profile.

Windows alignment is necessary

– after exchanging the windows

– if the pulse energy is too low

– if the beam profile is poor.

Tools and Materials

- 5 mm allen key
- 1/8” allen key

NOTE
Former versions of the OPTex may need a 5 mm allen key.

- Adjustment laser emitting light in the visible spectral range (e.g. He/Ne laser)
- 2 adjustment apertures (see Figure 48)

Figure 48: *Adjustment apertures*

- External power or energy meter with display unit or plain surface (depending on the adjustment demands: beam energy or profile)
- Protective eyewear suitable for the OPTex laser wavelength

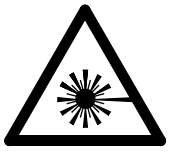
Preconditions

- Laser device switched off
- Window mounts accessable:
  – left-hand and right-hand service panels removed (see page 120),
  – beam path shielding removed (for F_2 version only, see page 122),
  – energy monitor removed (where fitted, see page 123)

Preparation

1. Set the laser device down in front of a smooth surface (e.g. facility wall).
   The beam exit aperture has to point into the direction reflecting from the wall.
2. Position the adjustment laser in front of the beam exit aperture of the laser device.

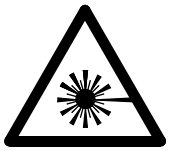
Installing the Adjustment Setup



WARNING
Risk of injury through laser radiation!
When operating the adjustment laser, all safety precautions concerning laser operation are to be strictly enforced (see instruction manual of the adjustment laser device for more information). Never look directly into the alignment laser beam!

3. Switch on the adjustment laser.
4. Fix the adjustment laser device in a horizontal and vertical position ensuring that the adjustment laser beam hits the centre of the beam exit aperture of the OPTex.
5. Turn the adjustment laser device and/or the OPTex until the adjustment laser beam hits the wall.
   The adjustment laser beam should centrically pass both beam exit apertures of the OPTex. The light spot is to be fully visible.
6. Switch off the adjustment laser.
7. Screw the adjustment apertures (see Figure 48) into the window mounts of the OPTex by turning 1 to 2 rotations clockwise.
8. Repeat steps 3 to 5 to install the adjustment setup.
9. Switch off the adjustment laser.
10. Remove the adjustment apertures from the window mounts by turning counter-clockwise.

Rough-adjusting the Windows



WARNING
Risk of injury through laser radiation!
When operating the adjustment laser, all safety precautions concerning laser operation are to be strictly enforced (see instruction manual of the adjustment laser device for more information). Never look directly into the alignment laser beam!

11. Switch on the adjustment laser.
    The adjustment laser beam will be reflected from the front and rear window back to the adjustment laser housing. There should be three light spots visible: the adjustment laser beam (from beam exit, see C in Figure 49) and the reflected light spots from the front (B) and rear (A) window.

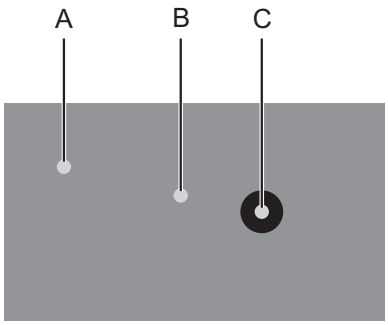


Figure 49: *Light spots on adjustment laser housing*

NOTE
Due to an extreme inclination of the rear window, the laser beam can be additionally reflected within the laser tube. In such cases there will be two light spots from the rear window.

12. Use the 1/8” allen key to turn the rear window alignment screws until the reflected light spot is congruent with the emitted adjustment laser beam.

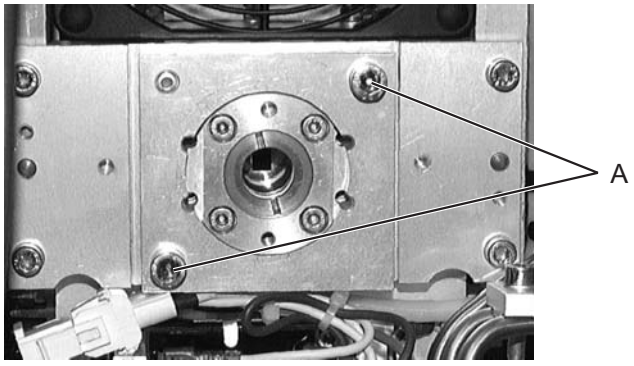


Figure 50: *Window alignment screws*

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13. Use the 1/8” allen key to turn the front window alignment screws until the reflected light spot is congruent with the emitted adjustment laser beam.
14. Switch off the adjustment laser.
15. Replace the energy monitor and/or beam path shielding (where fitted, see page 125).
16. Insert and tighten the right-hand and left-hand service panel using the 3 mm allen key.

Fine-adjusting the Windows

NOTE
In the following description we assume that the laser is to be adjusted for max. beam energy. When adjusting to the best beam profile, the steps are nearly identical to those listed below.

17. Use the 5 mm allen key to loosen and remove the two screws covering the window alignment screws on the laser device’s left-hand or right-hand side (see Figure 51, A).

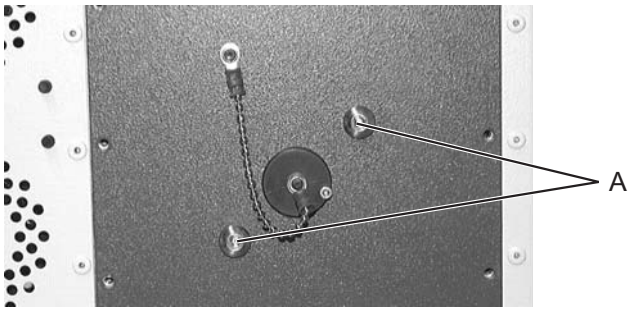
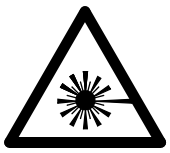


Figure 51: *Window alignment screws covering*

NOTE
Either fine-adjust the front or rear window. Never turn both windows as this may disalign the laser resonator.

18. Remove the mechanical beam shutter from the beam exit port by turning counter-clockwise.
19. Remove the adjustment laser and place the energy or power meter in front of the beam exit of the OPTex.
20. If necessary, connect the display unit to the energy or power meter.
21. Switch on the laser device.
22. Switch on the external controller and start the laser control software.
    Allow the warm-up routine to be performed.
23. Set the operating parameters: set repetition rate to 5 Hz, HV to 100 % in HV Const. mode.



WARNING
Risk of injury through laser radiation!
When operating the laser with an open shutter and/or beam shielding, all safety precautions detailed in Chapter 3 are to be strictly enforced.

24. Start laser operation.
25. Carefully turn the horizontal and vertical alignment screws of the front or rear window until the beam energy is at it's maximum value.

NOTE
Either fine-adjust the front or rear window. Never turn both windows as this may disalign the laser resonator.

26. Stop laser operation.

Finalization

27. Insert and tighten the screws covering the window alignment screws on the laser device's left-hand and right-hand side.
28. Calibrate the energy monitor (see Section 8.8 on page 143).
29. If necessary, shut-down the laser device and external controller.

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8.6.3 Disassembling / Assembling Window Mounts

Purpose

Remove contaminated or damaged windows from the window mounts and insert new or clean windows.

The components of the window mount together with the special tools required for windows exchange are shown in Figure 52..

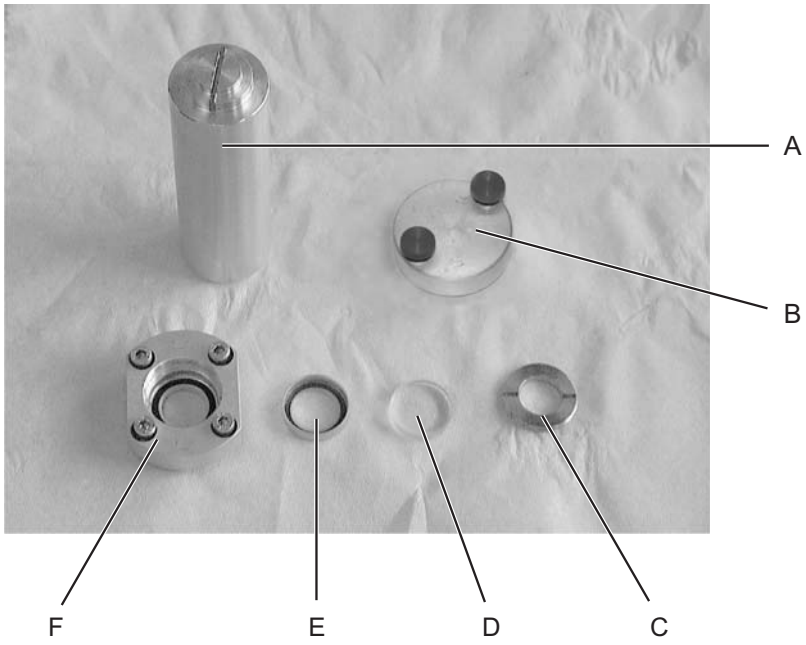

Figure 52: *Window mount components and special tools*

Key to Figure 43:

A	Optics wrench	B	Sealing plate
C	Threaded insert	D	Window
E	Window collar with sealing ring	F	Window mount with O-ring

Tools and Materials

- Window mount with contaminated window
- Optics wrench (special tool in service case)
- Lint-free, cotton-based lens tissue (service case)
- Optics grade Ethanol or Isopropanol
- Disposable skin-tight plastic gloves
- Pencil

Preparation

1. Remove the window mount with the contaminated or damaged window from the laser device and insert a new pre-mounted window or the sealing plate (see Section 8.6.1 on page 119).

Disassembling the Window Mounts

CAUTION
Incorrect handling can seriously damage the windows!
Always wear skin-tight plastic gloves when handling the windows.
Avoid touching the surfaces of the windows.

2. Use the optics wrench to unscrew (counterclockwise) and remove the threaded insert (Figure 53).

Figure 53: *Removing the threaded insert*

3. Remove the window collar with window from the window mount.
4. Take the contaminated or damaged window out of the window collar.

NOTE
A) The coated side of the window is usually marked with a parallel line along the edge that has the coating (see Figure 54).
B) To verify for yourself which side of the window has the coating, hold the window at an angle while looking at reflected light from a fluorescent bulb. The reflected light will have a greenish to pink tint across the entire surface whereas the backside has no tint.

5. Using a pencil, make or enhance the mark indicating the coated surface of an window to be cleaned.
6. Lay a contaminated window aside for cleaning (see Section 8.6.4 on page 136) or dispose of a damaged window.

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Assembling the Window Mounts

7. Remove the O-rings from the window mount.
8. Using lens tissue and a solvent (ethanol, isopropanol), wipe the O-rings until they are clean and free of any debris.
9. Check the O-rings and window mount for damage. Renew the window mount if the O-ring grooves have dents or scratches. Renew the O-rings if there are any indentations or scratches in the O-ring material.

NOTE
A less than perfect O-ring will most certainly cause a leak. If in doubt, replace the O-ring.

10. Insert the O-rings into the window mount.
11. Carefully insert the cleaned or new window with the coated side down into the window collar as shown in Figure 54.

Figure 54: *Inserting the window into the window collar*

12. Insert the window collar top side down into the window mount as shown in Figure 55.
    The coated side of the window points in the same direction as the heads of the allen screws.

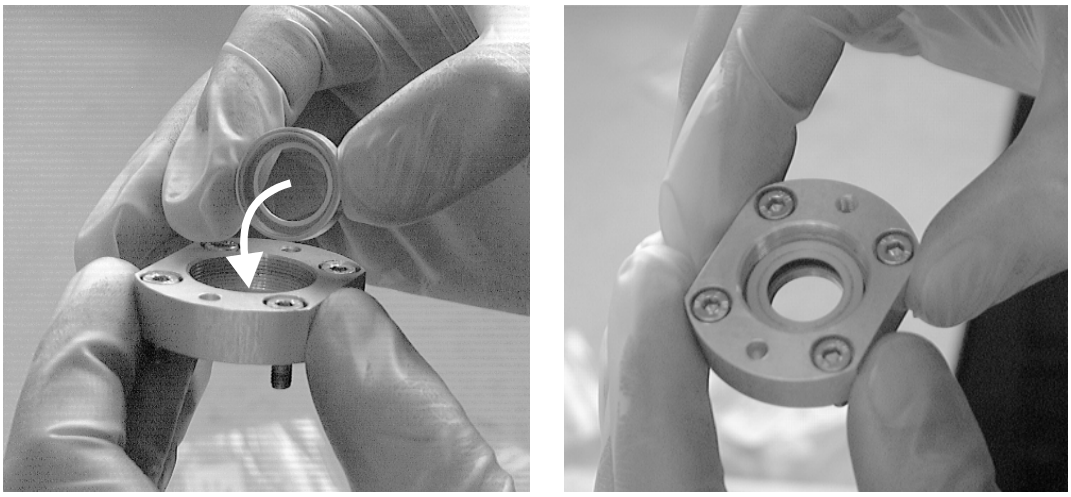

Figure 55: *Inserting the window collar into the window mount*

CAUTION
Risk of damaging the window mount!
Do not overtighten the threaded insert.

13. Insert the threaded insert into the window mount and tighten using the optics wrench (Figure 56).

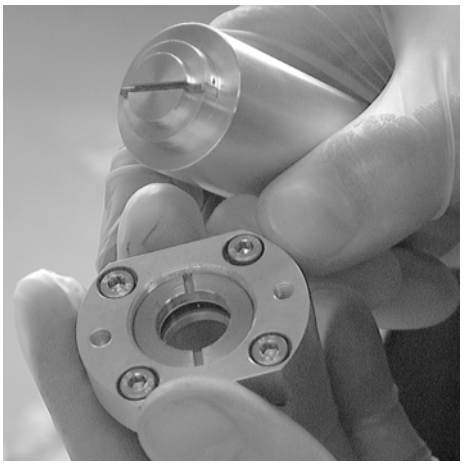

Figure 56: *Inserting the threaded insert*

14. Store the premounted window in a clean and dry place for future use.

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8.6.4 Windows Cleaning

Purpose

Clean contaminated windows.

Tools and Materials

- Glass plate or similar clean, flat and smooth surface for working on
- Lint-free, cotton-based lens tissue
- Pressurized air or inert gas that is particulate and oil-free
- Polishing powder (e.g. vienna chalk from service case)
- Distilled water
- Optics grade Ethanol or Isopropanol
- Disposable skin-tight plastic gloves

Preparation

1. Remove the window from the window mount (see Section 8.6.3 on page 132).
2. Place three layers of lens tissue on a clean, dry and smooth surface (glass plate).

Cleaning the Windows

CAUTION
Incorrect handling can seriously damage the windows!
Always wear skin-tight plastic gloves when handling the windows.
Avoid touching the surfaces of the windows.

NOTE
Any action performed on an window can potentially scratch it. Always begin with the simplest cleaning approach and the one least likely to scratch the window.

3. Remove all dust particles from the window surface with a duster (oil-free compressed air or nitrogen) as these may scratch the surface during the polishing procedure.

Cleaning the Uncoated Side of the Window

4. Lay the window with the **coated side downwards** onto the prepared glass plate.
5. Place a single sheet of lens cleaning paper over the window.
6. Put a few drops of ethanol onto the lens tissue close to one edge of the window (Figure 57).

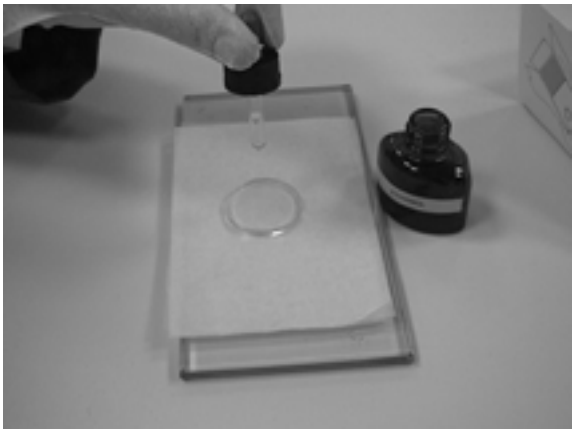

Figure 57: *Window cleaning (1)*

7. While holding the window in place, very gently drag the lens tissue across the surface of the window.

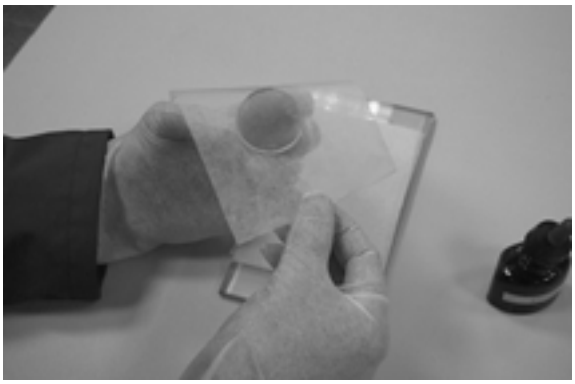

Figure 58: *Window cleaning (2)*

8. If the first cleaning approach did not result in a clean surface, place three fresh sheets of lens cleaning tissue onto the glass plate.
9. Mix 2 teaspoons of distilled water or ethanol with one teaspoon of Vienna Chalk on the uppermost tissue.
10. Holding the window between your index finger and thumb, place the uncoated side of the window onto the Vienna Chalk slurry.

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CAUTION
Risk of damaging the Windows!
Excessive downward pressure can scratch the window surface. Let the weight of the window apply the downward force.

11. While applying a sideways pressure, move the window in a figure-eight movement for 2 to 3 minutes.

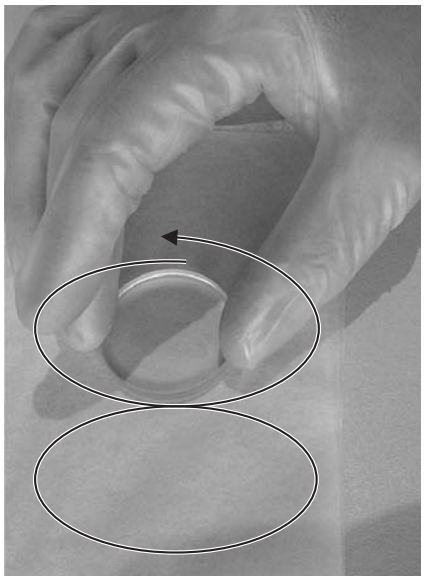

Figure 59: *Cleaning movement*

12. Rinse the window, at first under flowing warm water to take away the chalk and after that under flowing distilled water.
13. Carefully dry the windows using a clean dry lens tissue.
14. Place three layers of fresh lens tissue on the glass plate.
15. Lay the window with the **coated side downwards** onto the prepared glass plate.
16. Place a single sheet of lens cleaning paper over the window.
17. Put a few drops of ethanol onto the lens tissue close to one edge of the window.
18. While holding the window in place, very gently drag the lens tissue across the surface of the window.

NOTE
The window cleaning can be repeated but no more than three times. If dust or spots are still seen, the window must be discarded.

Cleaning the Coated Side of the Window

CAUTION
Risk of damaging the windows!
Only use ethanol to clean the coated side of the window. Use gentle pressure when cleaning the coated side of the window. Never use polishing powder (e.g. Vienna Chalk) to clean the coated side of the window.

19. Place three layers of fresh lens tissue on the glass plate.
20. Lay the window with the **uncoated side downwards** onto the prepared glass plate.
21. Place a single sheet of lens cleaning paper over the window.
22. Put a few drops of ethanol onto the lens tissue close to one edge of the window.
23. While holding the window in place, very gently drag the lens tissue across the surface of the window to clean the coated side.
24. Inspect the window in transmission and grazing incidence for surface spots and dust.

NOTE
The window cleaning can be repeated but no more than three times. If dust or spots are still seen, the window must be discarded.

Finalization

25. Insert the window into the window mount (see Section 8.6.3 on page 132).

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8.7 Halogen Filter Maintenance

Lambda Physik excimer lasers utilize a halogen filter to remove atomic and molecular species of halogen from laser gas mixtures exhausted from the discharge reservoir. Maintenance of the halogen filter consists of the replacement of the filter when full.

NOTE
When the maximum halogen filter filling level is reached a window appears on the laser control screen requesting for filter exchange.

Halogen Filter Storage

Halogen filters must be stored in unopened packaging in accordance with all relevant regulations. The filter shelf-life is indicated on the packaging. Filters shall always be stored in dry rooms in their unopened packaging so that they are protected against damage. Filters with visible signs of damage (e.g. dents) must be disposed of irrespective of the indicated shelf-life.

Halogen Filter Disposal

Used halogen filters may contain an small amount of halogen gas that has not yet reacted. Unused filters as well as filters used in accordance with their intended use must be disposed of in accordance with all relevant local regulations as well as the disposal procedure contained in Section 8.7.2

8.7.1 Halogen Filter Exchange

Purpose

Exchange the halogen filter connected to the vacuum pump.

Tools and Materials

- Halogen filter replacement kit

NOTE
Keep the protective caps provided with the kit for the disposal of the used halogen filter.

- Plastic gloves
- Safety glasses
- Set of wrenches

Preconditions

- Laser device switched on and laser control program started (no laser radiation being emitted)

Preparation

1. Flush the premix line (see Section 8.4.1 on page 110).
2. Switch off the laser device.
3. Remove the front service panel.

Removing the Used Halogen Filter

WARNING
Toxic hazard!
The halogen filter is hygroscopic and contains oxidizing agents. Always wear safety glasses and gloves when changing the halogen filter. Ensure adequate ventilation. Be aware of the hazards described in Section 3.2.1.3.

4. Turn the laser control unit to the left side out of the laser device (see Figure 60, C).

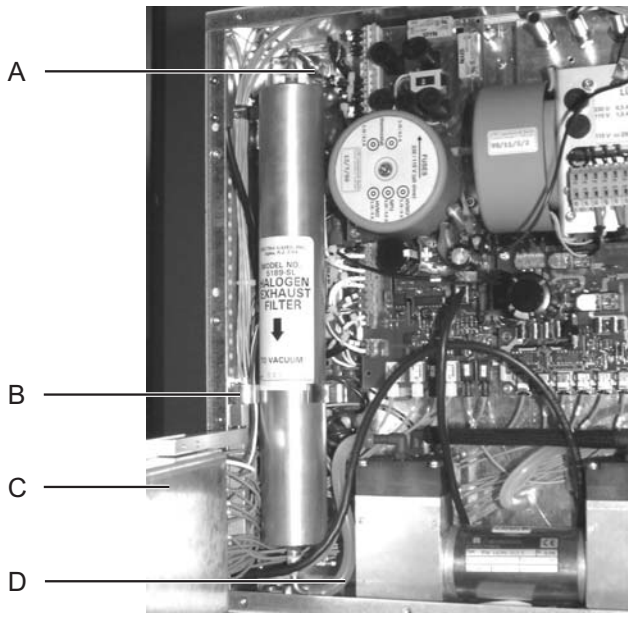

Figure 60: *Halogen filter exchange*

5. Unscrew and remove the nut situated at the top of the halogen filter cartridge (Figure 60, A).
6. Carefully pull the halogen filter towards you so that it is released from the retaining clip (Figure 60, B).

NOTE
A number of FOL links are situated near to the halogen filter. Ensure that they do not become disconnected or damaged when removing the halogen filter.

7. Disconnect the flexible tube from the connection at the bottom of the halogen filter cartridge (Figure 60, D).

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8. Remove the protective caps from the tube ends of the replacement halogen filter.
9. Attach the protective caps to the tube ends of the used filter cartridge.

Inserting the Replacement Halogen Filter

10. Attach the flexible tube to the connection at the bottom of the replacement halogen filter cartridge.
11. Carefully push the halogen filter into the retaining clip until it is correctly located.
12. Tighten the nut at the top of the halogen filter cartridge.
13. Turn the laser control unit into the laser device.
14. Insert and tighten the front service panel.

8.7.2 Halogen Filter Disposal

Purpose

Safely dispose of a used halogen filter cartridge.

NOTE
The used halogen filter must be disposed of in accordance with valid local waste disposal regulations.

Tools and materials

- Plastic gloves
- Plastic bag (e.g. bag that contained the new halogen filter).
- Supplied tie-rap.

Reconditions

- Used halogen filter removed from the laser device and tube ends sealed with protective caps (see Section 8.7.1 on page 140).

Storing the Halogen Filter

WARNING
Toxic hazard!
The used filter may contain a small amount of halogen gas that has not yet reacted. It must be stored for a period in a well ventilated area before final disposal.

1. Store the used halogen filter in a well ventilated area.

Disposing of the Halogen Filter

2. Place the used filter in the delivery bag and close the bag.
3. Dispose of the filter in accordance with local regulations.

8.8 Energy Monitor Calibration

NOTE
The procedure described in this section is not valid for the F_2 version of the OPTex laser device.

The energy monitor is built into the beam output path, within the laser device. It checks:

– if any laser pulses are being emitted

– the energy of the laser pulses.

The energy monitor is to be calibrated:

– if it has been disassembled

– whenever the windows have been maintained.

Factory setted, the energy monitor checks the energy value with an absolutely precision of ± 15 %. This measuring accuracy can be improved by software calibration. Failures caused by different spectral beam properties and contaminations are being corrected at once. Deviations of up to ± 50 % between beam energy and energy monitor measurement can be leveled out by calibration. In case of impossible adjustment, the energy monitor has to be exchanged.

A calibration factor used for energy measurement is denoted in the laser control software. In case of different EPROM-CLS control numbers, the software prompts the operator for calibration.

The true energy value is calculated by multiplication of the beam energy measured through the energy monitor with the calibration factor determined during the calibration procedure.

Purpose

Calibrate the internal energy monitor in accordance with an external power or energy meter. Energy monitor calibration is performed with the help of a dedicated software routine which starts the laser and enables input of a reference power value.

Tools and Materials

- Protective eyewear suitable for the OPTex laser wavelength
- External power or energy meter with display unit

Preconditions

- Laser device switched on and laser control software started (no laser radiation being emitted)

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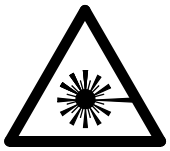
Preparation

NOTE
When the light for PEM ERROR is flashing after starting the laser control software (see Figure 25 on page 85), click the light with the cursor. The error message will be cancelled and the energy monitor is activated again.

1. Perform a new gas fill (see Section 8.5 on page 116) to ensure optimum calibration conditions.
2. Place the energy or power meter in front of the mechanical shutter.
3. If necessary, connect the display unit to the energy or power meter.
4. Open the beam shutter on the beam exit aperture by turning counter-clockwise.

Calibrating the Energy Monitor



WARNING
Risk of injury through laser radiation!
When operating the laser with an open shutter, all safety precautions concerning laser class IV operation detailed in Chapter 3 are to be strictly enforced.

5. Set the operating parameters: set repetition rate to 5 Hz, HV to 100 % in HV Const. mode.
6. Select “System” and “Adjust energy” from the menu bar.
   A new window appears.
7. Click on “Calibration”.
   Laser operation is starting in Burst mode. 150 laser pulses are being emitted. The energy value is measured by the external energy or power meter.
8. Read external energy meter.

NOTE
When using an power meter, the value of the reading (in [W]) has to be converted into mJ. Multiply a W reading by 100 and divide by the repetition rate.

9. Enter the measured beam energy through the numerical keys into the new window (see Figure 61) that automatically appears after 150 pulses have been emitted.

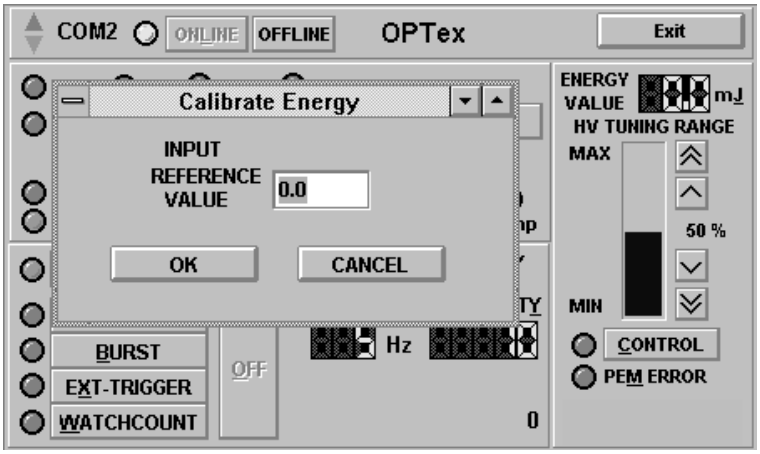


Figure 61: *Energy monitor calibration window*

10. Confirm the entered value and close the adjustment window by clicking “OK”.

Checking the Energy Monitor Calibration

11. Set QUANTITY to at least 100.
    The repetition rate, HV value and HV Const. mode are to remain unchanged.
12. Click on BURST to start laser operation in Burst mode.
13. Measure the beam energy with the external power or energy meter and compare these values with those displayed on the laser control screen. They should differ no more than ± 5 %.
    After emitting the selected number or pulses, laser operation will be stopped automatically.
14. Repeat the calibration procedure if necessary.
15. Terminate the laser control software.

Finalization

16. Insert the beam dump into the beam exit aperture and close the mechanical beam shutter by turning clockwise.
17. If necessary, disconnect the display unit from the energy or power meter.
18. Remove the energy or power meter from the beam path.
19. Close the beam shutter by inserting the beam dump and turning clockwise until it reaches it’s final position.
20. If necessary, shut-down laser device and external controller.

9 TROUBLESHOOTING

This chapter is intended to assist solving common problems with the OPTex. It presupposes that you have read this manual so far, especially the safety instructions in Chapter 3.

WARNING
Risk of serious injury!
Tasks that can only be performed by authorized service personnel can endanger the health and life of untrained person, so do not try to service the OPTex yourself.

Lambda Physik Service

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OEM Service

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9.1 Fuses

The following fine-wire fuses (5x20) are located in the OPTex excimer laser supplied with 230 V AC (50 or 60 Hz):

Quantity	Value	Protection
2	6.300 AT	main fuses (F1)
1	4.000 AT	HV module (F2)
4	3.150 AT	mains power supply board (F1, F2, F4, F5)
1	0.800 AT	power distribution unit (F2)
1	0.400 AT	power distribution unit (F1)
1	0.500 AT	mains power supply board (F3)
1	0.050 AT	HV module (F1)

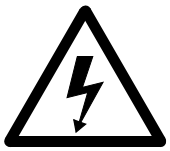
The following fine-wire fuses (5x20) are located in the OPTex excimer laser supplied with 115 V AC (50 or 60 Hz):

Quantity	Value	Protection
2	10.000 AT	main fuses (F1) (BR 195 or 19195 only!)
1	8.000 AT	HV module (F2)
2	6.300 AT	mains power supply board (F4, F5)
2	5.000 AT	mains power supply board (F1, F2)
1	1.600 AT	power distribution unit (F2)
1	0.800 AT	power distribution unit (F1)
1	0.500 AT	mains power supply board (F3)
1	0.100 AT	HV module (F1)

The secondary power supply circuits are secured by the following fuses (230 V and 115 V power supply):

Quantity	Value	Protection
1	1.600 AT	trigger board (ZGP)
1	1.000 AT	gas supply board
1	0.400 AT	power distribution unit (F3)

9.2 Possible Problems and Solutions



WARNING
Risk of electric shock!
Measurements and work on the electrical system and equipment of the system must be carried out only by a skilled electrician or by instructed person under guidance of a skilled electrician and in accordance with electrical engineering rules and regulations. Personnel should never open the power module housing since the danger of electrocution threatens. The energy storage capacitors and the high voltage power supply hold several joules at up to 14 kV.
Work on gas equipment must be carried out by specially trained personnel only.

NOTE
A) For troubleshooting see also Sections 2.10 (Safety Systems) and 6.1.3.3 (Lights).
B) If the laser device automatically enters the warm-up period during laser operation, a watch dog failure occurred. In this case immediately call authorized service.
C) In case of repeatedly occurring error messages call authorized service!

The following tables give some information to ease troubleshooting.

9.2.1 Power-Up Error

Problem	Reason	Solution
Laser device cannot be started, no “POWER ON” light	No power supply	Check mains connection. Check main fuses and replace if necessary. Check fuse of mains power supply unit and replace if necessary.
	Insufficient power supply	The laser device has to be configured for your local voltage and frequency (see type plate). In case of divergences immediately call Lambda Physik.

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9.2.2 Statical Errors

Statical errors (except the warning lamp “Temperature”) are interrupting the laser operation. For troubleshooting or when the cause of the error has been rectified, laser operation can be restarted at once.

Problem	Reason	Solution
Warning lamp “TEMPERATURE”	Tube temperature too high (48 °C)	Allow laser tube to cool down to optimal temperature (40 °C). Check air intake and exhaust to be exposed. Check ventilation fan.
Graphical pressure display turns to red	Insufficient gas pressure in the laser tube	Perform a leak test to check laser tube and gas valves.
	FOL error	Call authorized service.
Error message “INTERLOCK”	External safety circuit open	**CAUTION** The remote interlock circuit can be configured by the customer, the location of the circuit components being dependent on the layout of the system (see Section 4.4). After any remote interlock, the system does not automatically return to operational conditions. Contact appropriate maintenance personnel after having used remote interlock. Don’t restart laser operation until all hazardous situations are eliminated! Check your external remote circuit. Check safety circuit by using the safety plug (service case). For several service operations the safety plug must be inserted into the remote interlock socket. Check the connection.

Problem	Reason	Solution
Error message “LASERHEAD CHAMBER”	One (or more) of the three service panel(s) removed or interlock switch(es) not closed	Check the service panels and interlock switches to be closed.
	Temperature switch near by the thyratron open (80 °C) or tube temperature exceeds 60 °C	Allow laser tube to cool down to optimal temperature (40 °C). Check air intake and exhaust to be exposed. Check ventilation fan.
	If the error message cannot be canceled, thermostat failed	Don’t start laser operation! Call authorized service!
	Mains power supply unit error or FOL error	Call authorized service!
Error message “ELECTRONIC CHAMBER”	Front service panel removed or interlock switch not closed	Check front service panel and interlock switch to be closed.
	Temperature switch on internal partition open (more than 50°C)	Allow laser device to cool down. Check environmental air temperature. Check air intake and exhaust to be exposed. Check ventilation fan.
	Mains power supply unit error or FOL error	Call authorized service!
Error message “PEM ERROR” (Pyroelectric Energy Measurement) [a]	Minimal energy value (2 mJ) remained	Check laser gas fill, perform a new fill if required. Check windows and clear or exchange if necessary.
	Thyratron error	When calibrating energy monitor, click on error message light “PEM ERROR” to activate energy monitor again. If the error message cannot be canceled, call authorized service.
	Triggering, charging cycle and light pulse are not coordinated	Call authorized service to check triggering.

a. The laser device continues laser operation in the HV Const. mode.

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9.2.3 Operation Errors

These errors are stopping the laser operation (“PEM error” only in EGY Const. mode). For troubleshooting, the key switch has to be switched off and on before laser operation can be restarted.

Problem	Reason	Solution
Error message “PRESSURE” and a red colored graphical pressure display	Laser tube gas pressure too low	Leak test the gas supply system, including solenoid valves.
Error message “PRESSURE” and a pressure drop to normal pressure, the graphical pressure display turns to red	If there is no leak, signal error on pressure sensor or laser controller	Call authorized service to check FOL links.
Error message “FILL” after performing a new gas fill	Gas pressure too low	Check the remaining pressure of the premix cylinder. The pressure must not be below 5 bar (abs.). Leak test the premix gas supply line.
	Insufficient underpressure during the new gas fill	Call authorized service to check vacuum pump or valve block.
Error message “HV CHARGING”	Charging time of discharge capacitors exceeded	Perform a new gas fill. If the error message cannot be canceled, call authorized service to check charging circuit.
Error message “HV SUPPLY”	Heat sink of HV module too hot	Check ventilation system (fan, air intake and exhaust). Check operating environmental temperature. Shorten duration of continuous operation.
	HV module fuse blown off or line voltage too low	Call authorized service to check power supply circuits and fuses.
Error message “HV OVERVOLTAGE”	FOL failed	Check FOL connections and switch on laser device again.
	HV module doesn’t receive power or HV module failed	Call authorized service!

Problem	Reason	Solution
Error message “THYRATR.”	Heating circuit of Thyratron cathode and hydrogen generator failed	Check FOL connections and switch on laser device again. Call authorized service to check transformer module fuse (power distribution board) and voltage on heater terminal (6.3 to 6.6 V).
	HV supply failed	Call authorized service!
Error message “CPU”	EPROM or CPU failed	Check EPROM socket and switch on laser device again. If the error message cannot be canceled, call authorized service.

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10 DIAGRAM SCHEMATICS

10.1 Gas Flow Diagram

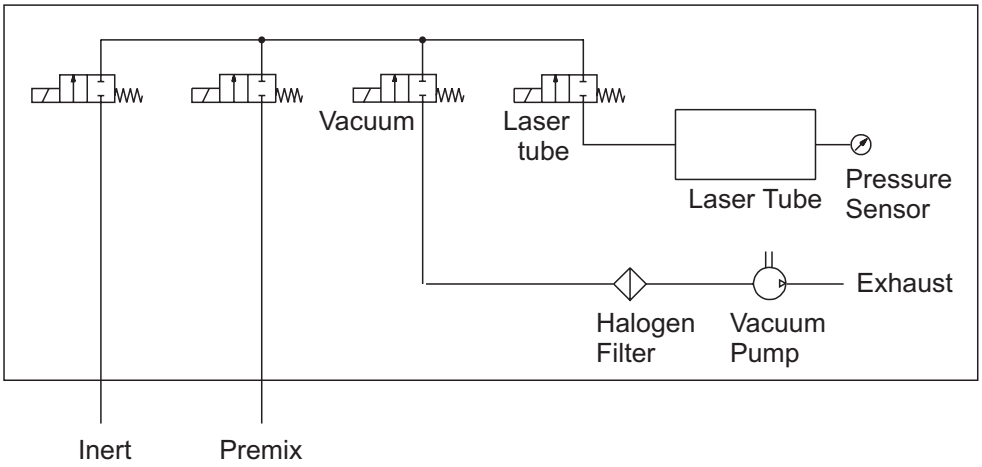

Figure 62: *Gas flow diagram*

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10.2 Electrics Diagram

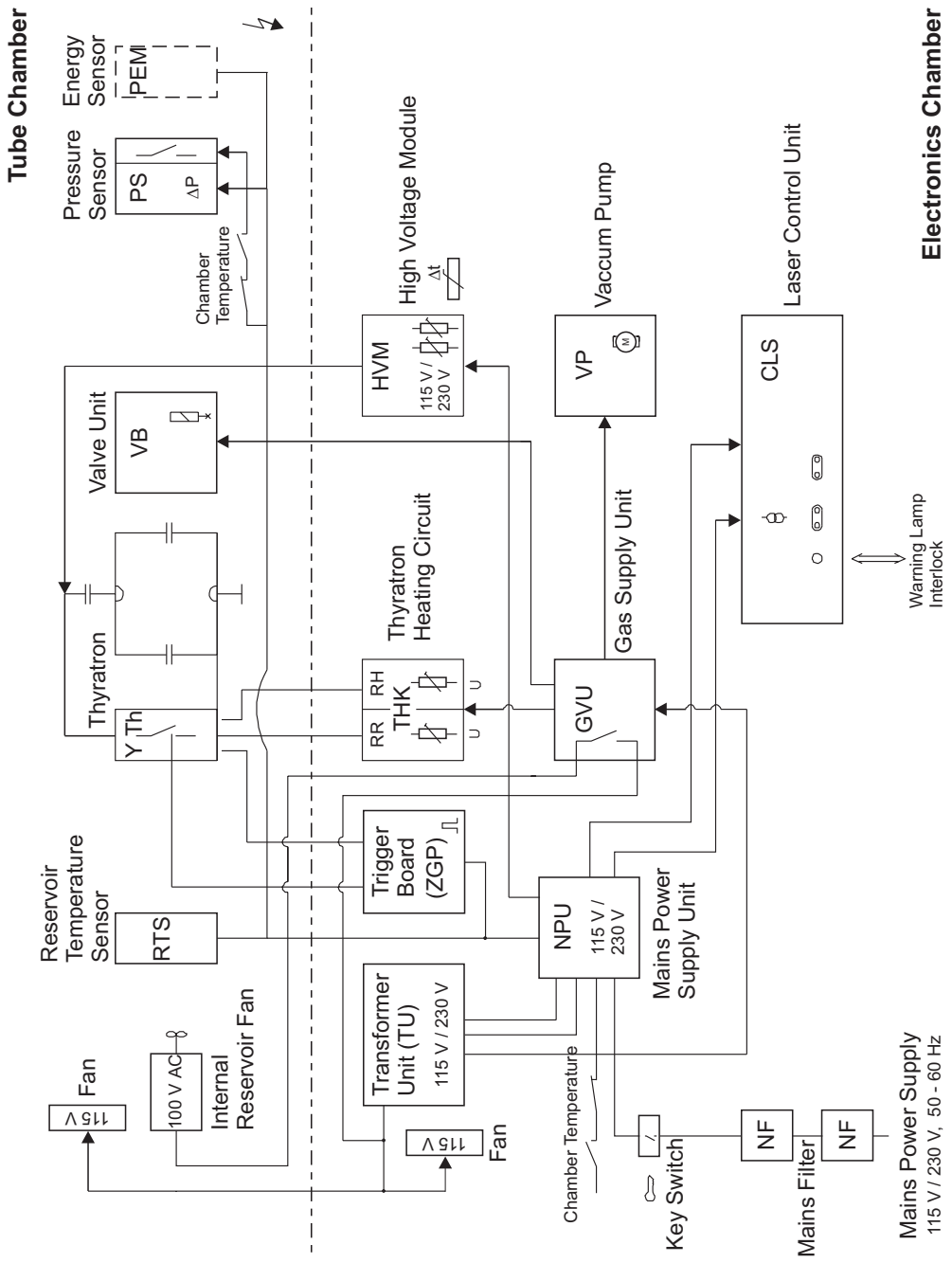
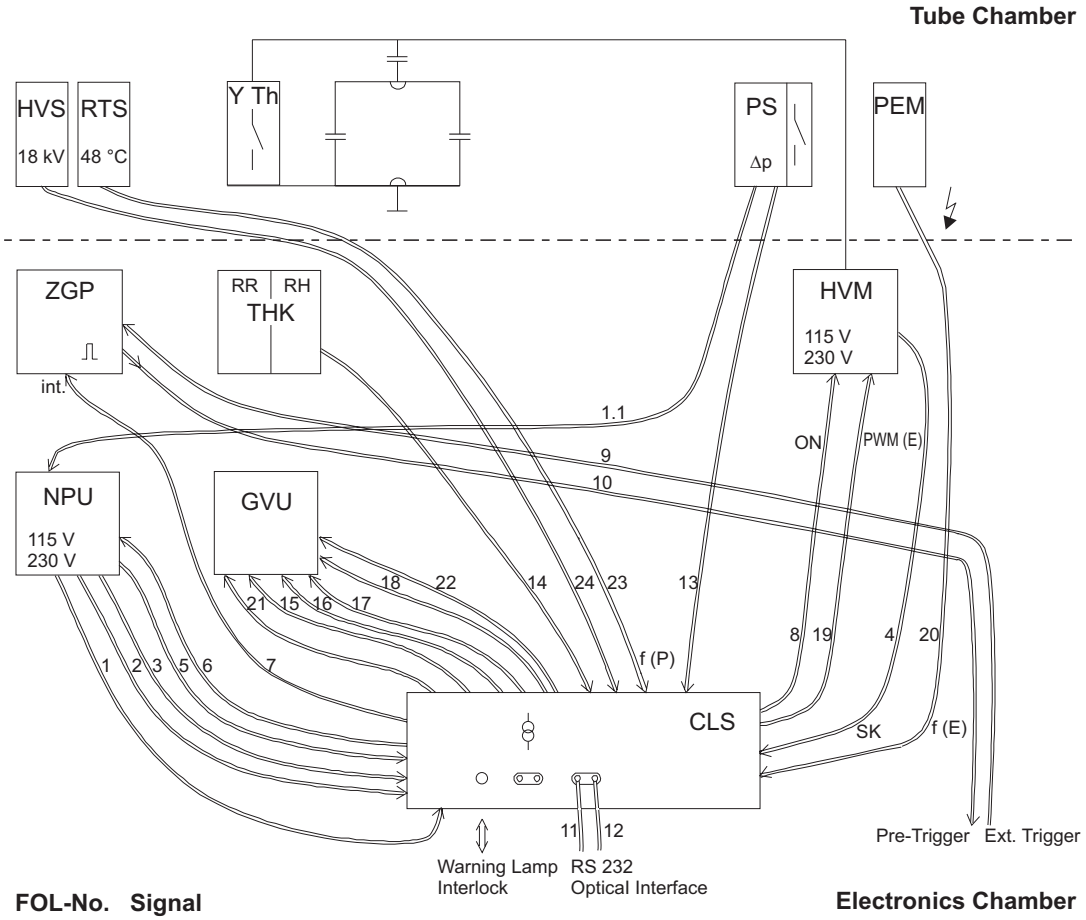


Figure 63: *Functional block diagram electrics*

10.3 Fiber Optic Light Waveguide Diagram



FOL-No.	Signal
1.1	Enclosure/temp. Tube Chamber
1	Enclosure/temp. Tube Chamber to CLS
2	Interlock
3	Enclosure/temperature Electronics Chamber
4	Charge current
5	Warning lamp
6	High Voltage (HV) ON
7	Internal trigger
8	High Voltage module inhibitation
9	External trigger (in)
10	Pre trigger (out)
11	RS 232 TXD
12	RS 232 RXD
13	Gas pressure
14	Thyratron heating circuit supervision
15	Gas supply unit enable
16	Vaccum pump ON
17	Valve "Laserhead" ON
18	Valve "Premix" ON
19	Energy control PWM
20	Energy measurement
21	Valve "Inert" ON
22	Laser gas circulation
23	Reservoir temperature
24	HV too high

Modules:

HVS	HV Sensor
RTS	Reservoir Temperature Sensor
Th	Thyratron
PS	Pressure Sensor
PEM	Energy Sensor
ZGP	Trigger Board
THK	Thyratron Heating Circuit
HVM	High Voltage Module
NPU	Mains Power Supply Unit
GVU	Gas Supply Unit
CLS	Laser Control Unit

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Figure 64: *Functional block diagram FOL connections*

10.4 Safety Circuits Diagram

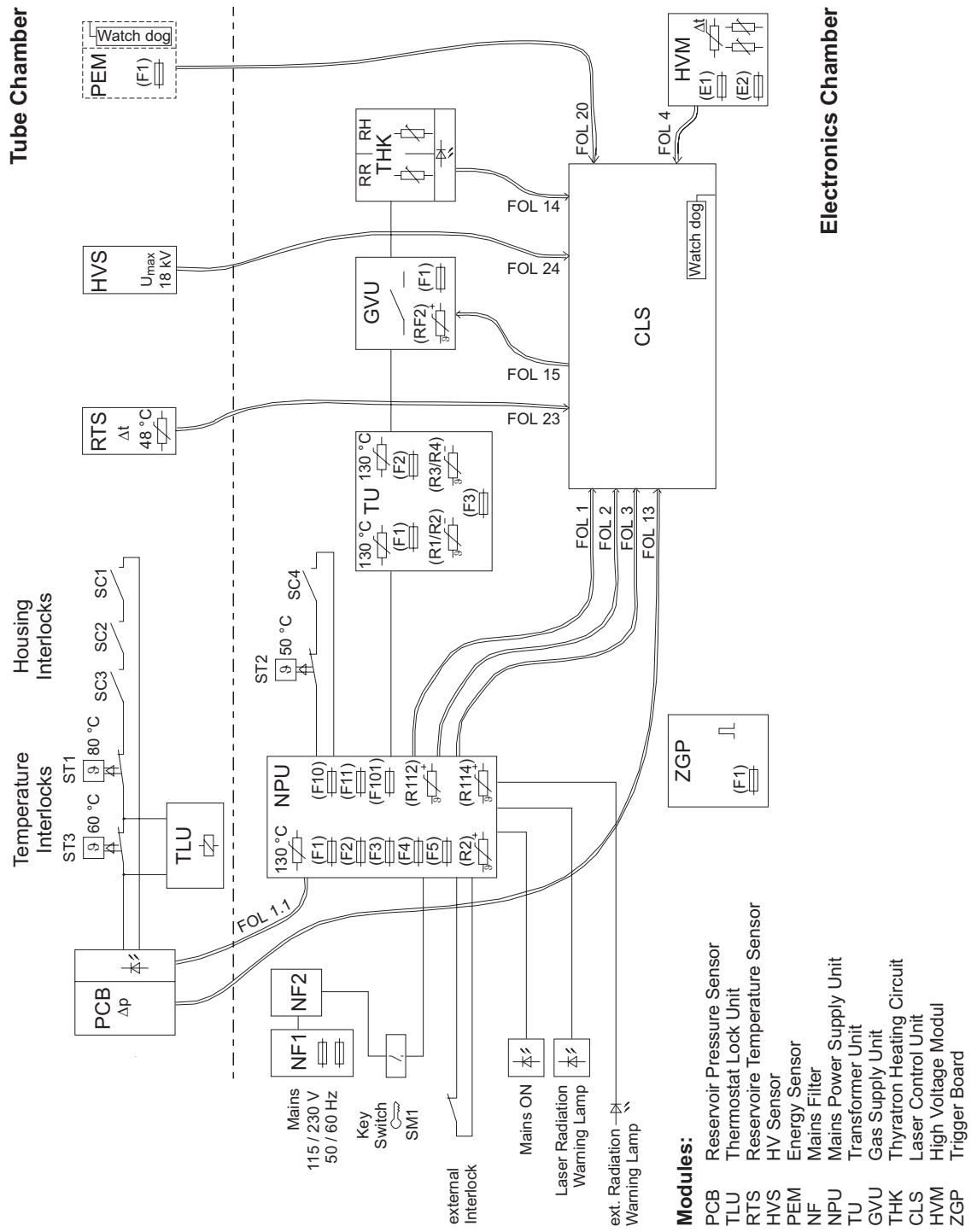

Figure 65: *Functional block diagram safety circuits*

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