COMPexPro RoHS laser system

Product training document, Rev AF

Superior Reliability & Performance

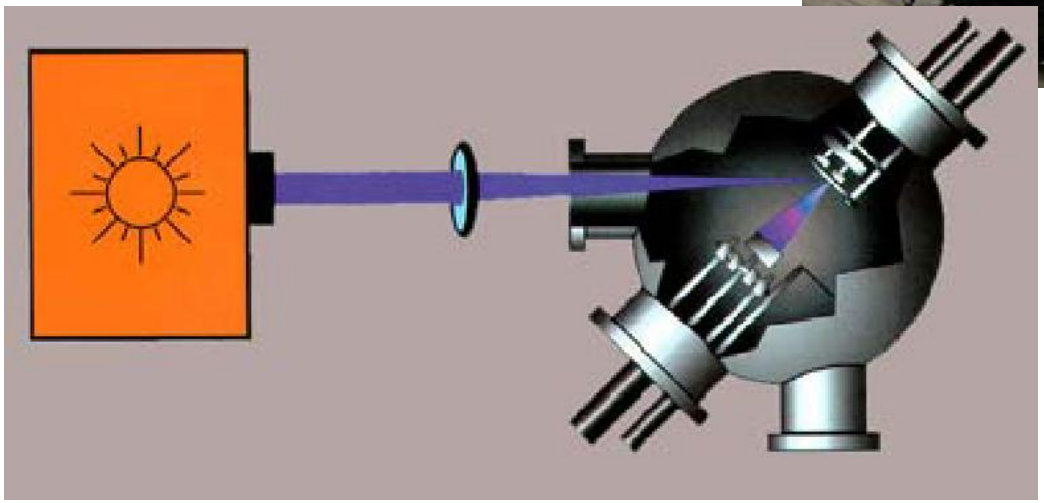
COMPexPro™ (RoHS)

Key Features:

- Energy monitor with output stabilization
- Unique smooth ceramic preionization
- Advanced internal gas purification system
- Single-phase operation
- NovaTube metal-ceramic tube technology
- Magnetic-Assist for extended thyratron lifetime
- Small footprint
- Service access from one side
- Air-cooled versions

Applications 1/3

PLD- Pulsed Laser Deposition



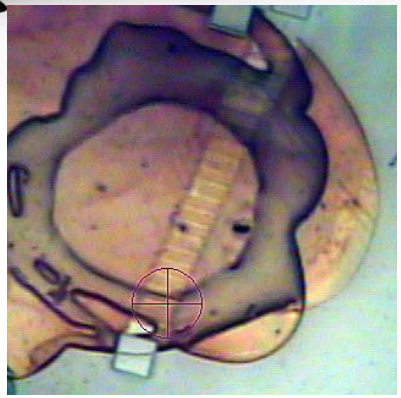
- Typical PLD conditions:
- Pressure: 10-7 to 1 Torr
- Substrate Temp.: 100 to 900°C
- Energy Density: 1-2 J/cm2
- Focus Size: 2 mm2
- Deposition Rate: 0.01 to 1nm/sec

Applications 2/3

GeoLas Pro

(LA-ICPMS)

Typical values:
- pit sizes 5 – 200 µm
- densities 15 – 45 J/cm²
- typ. wavelength 193 nm



VarioLas

(e.g. customized system
for micromanufacturing)

Applications 3/3

Medical Treatments

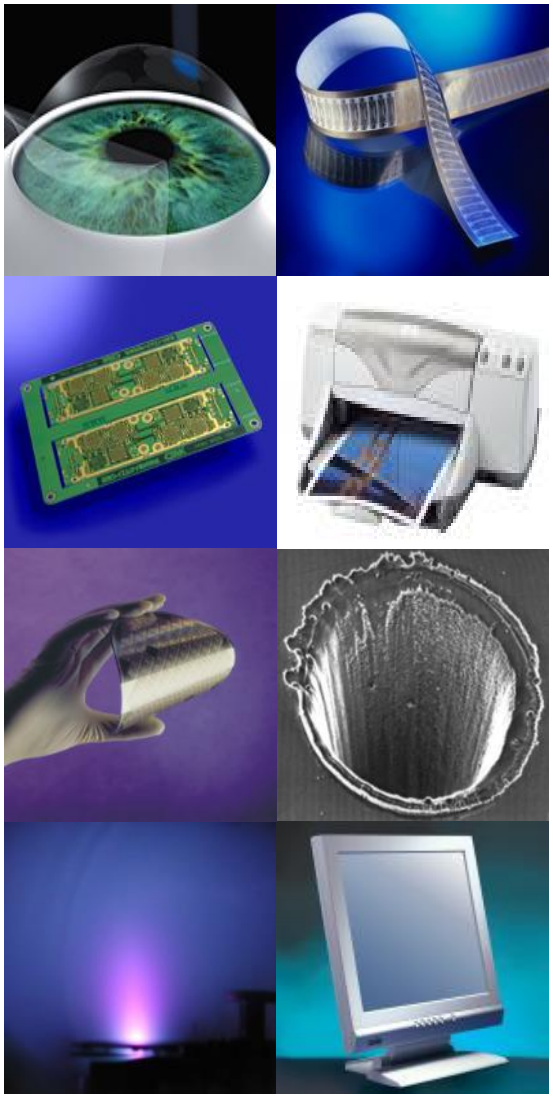
- LASIK, Psoriasis Treatment

Microelectronics

- Lithography
- Mask Production
- Mask / Wafer Inspection
- Stacked- / Microvias
- Si Dicing

Research

- PLD
- LA-ICP-MS
- Scientific Testing & Measurement



Micromashining

- LTPS (ELA)
- Laser Liftoff (LLO)
- Laser Direct Patterning
- Ink Jet Nozzle Drilling
- Glass Marking
- General Marking
- Micro Machining
- One shot ablation
- ITO Patterning
- Glass Cutting
- Circuit Isolation

Definition of „L.A.S.E.R.“

LIGHT

AMPLIFICATION by

STIMULATED

EMISSION of

RADIATION

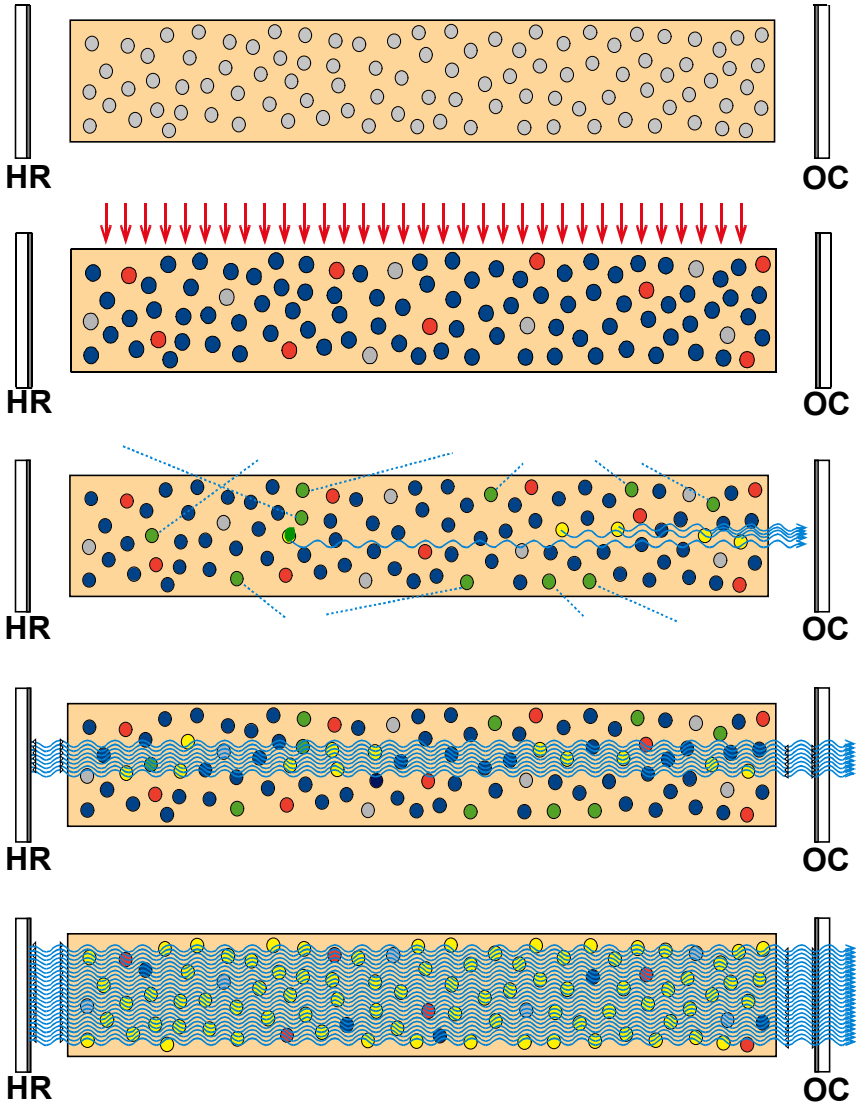
Principle of Stimulation

Legend

- Ground State
- Energy Level 1
- Energy Level 2
- Spontaneous Emission
- Stimulated Emission

HR = totally reflecting mirror

OC = partly reflecting mirror



Laser Gas Kinetics

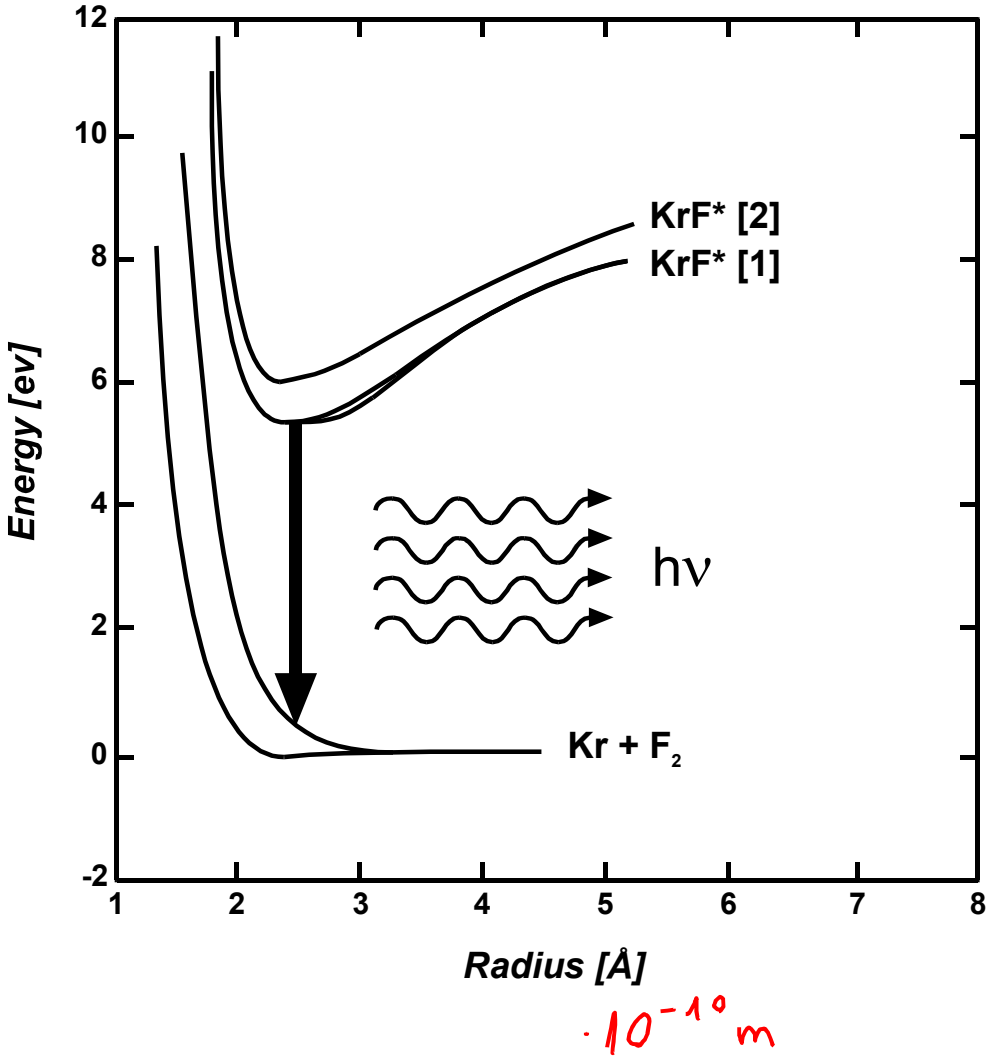
Emission wavelength:

F_2	157 nm
ArF	193 nm
KrF	248 nm
XeCl	308 nm
XeF	351 nm

Laser gas kinetics:

$$e^- + F_2 \rightarrow F^- + F$$
$$e^- + Kr \rightarrow 2\,e^- + Kr^+$$
$$Kr^+ + F^- + Ne \rightarrow KrF^* + Ne$$
$$KrF^* + h\nu \rightarrow Kr + F_2$$

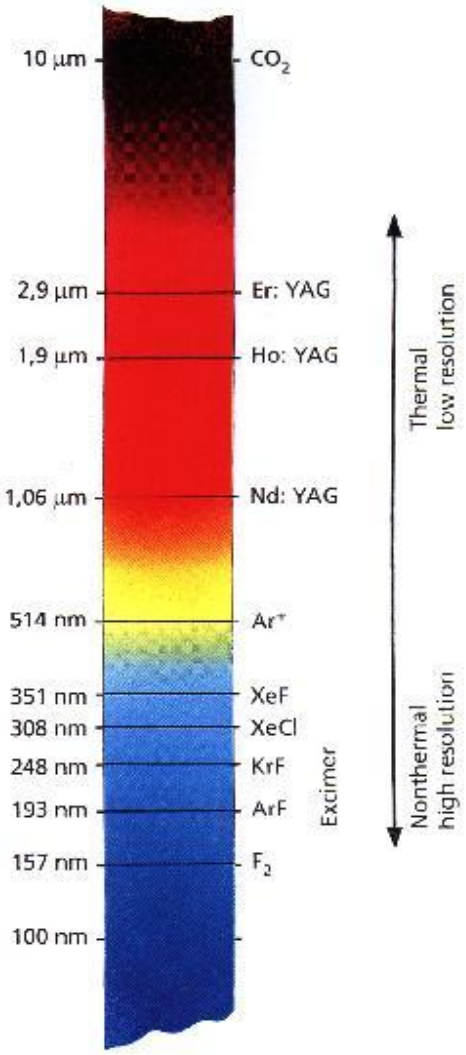
Photon



$\cdot 10^{-10}$ m

Typical Laser Wavelengths

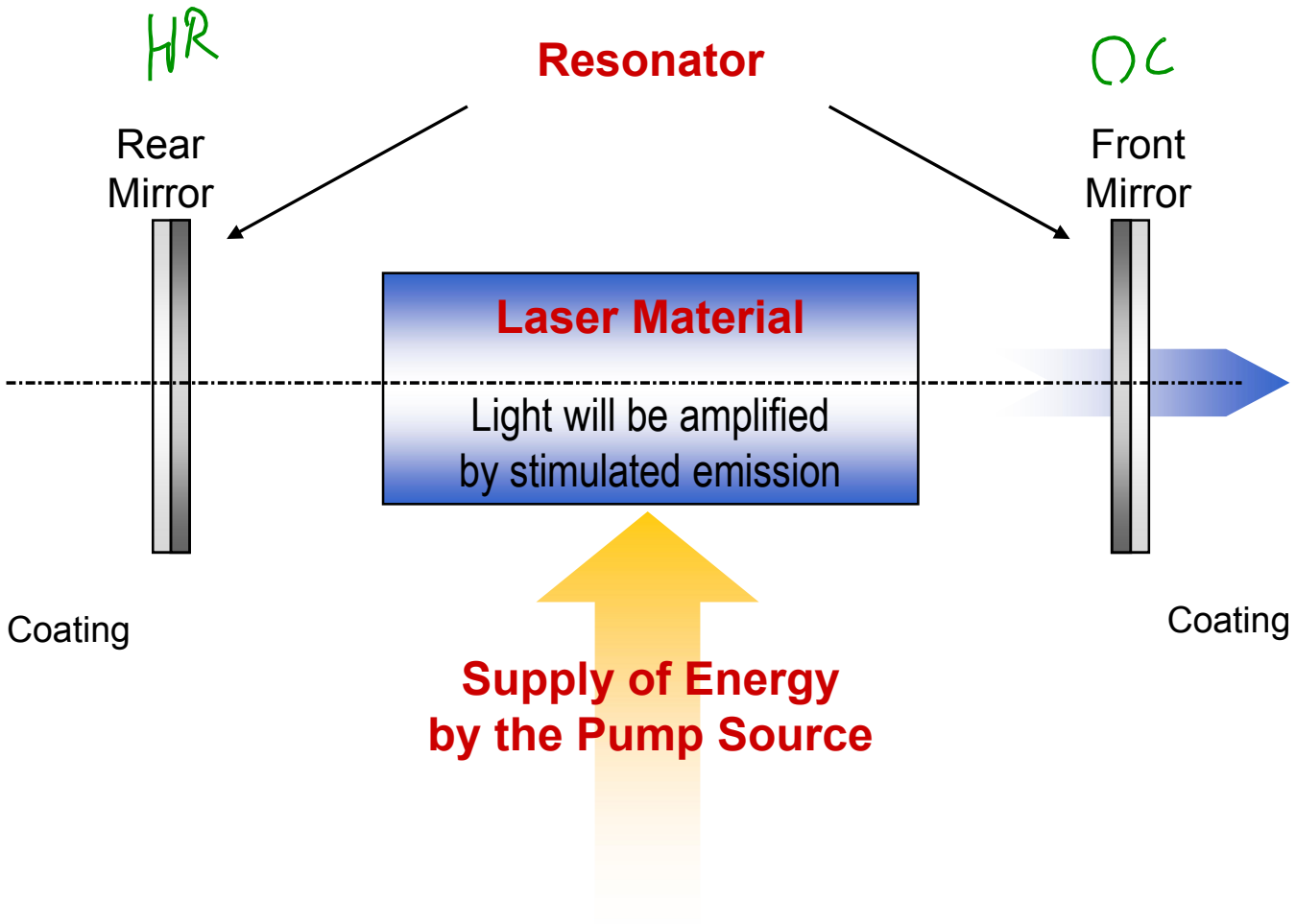
- **10600 nm: CO_2 Laser**
- **1064 nm: Fundamental Nd-YAG Laser**
- **632 nm: Red He-Ne Laser (Continuous Wave)**
- **532 nm: Frequency Doubled Nd-YAG Laser (Continuous Wave or Pulsed Solid-State)**
- **351 nm: XeF (Pulsed Excimer Gas Laser)**
- **308 nm: XeCl (Pulsed Excimer Gas Laser)**
- **248 nm: KrF (Pulsed Excimer Gas Laser)**
- **193 nm: ArF (Pulsed Excimer Gas Laser)**
- **157 nm: F_2 (Pulsed Excimer Gas Laser)**



Conditions for Lasing Action

Active Medium with a Laser Transition	→	**Rare - Halogen Gas Mix**
Pumping with sufficient Energy	→	**Electric Discharge within the Gas between two Electrodes**
Optical Feedback	→	**Rear Mirror and Output Coupler**
Population Inversion ($n_2 > n_1$)	→	**Excited Dimers have no Ground State**

Laser Principles



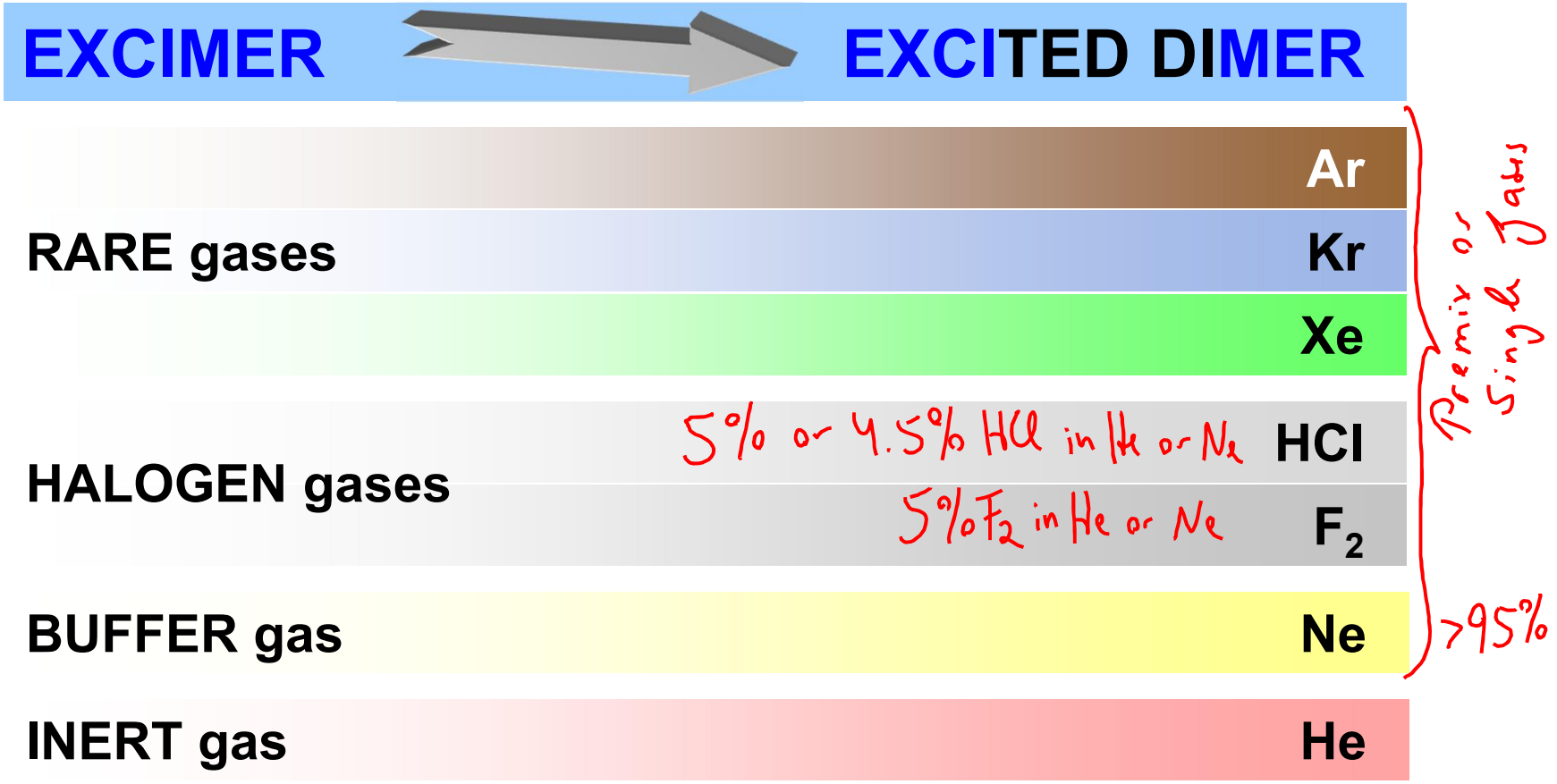
Characteristics of Laser Light

- **Monochromatic light**
- **Low divergence**
- **Coherent light**
- **Light with high intensity**

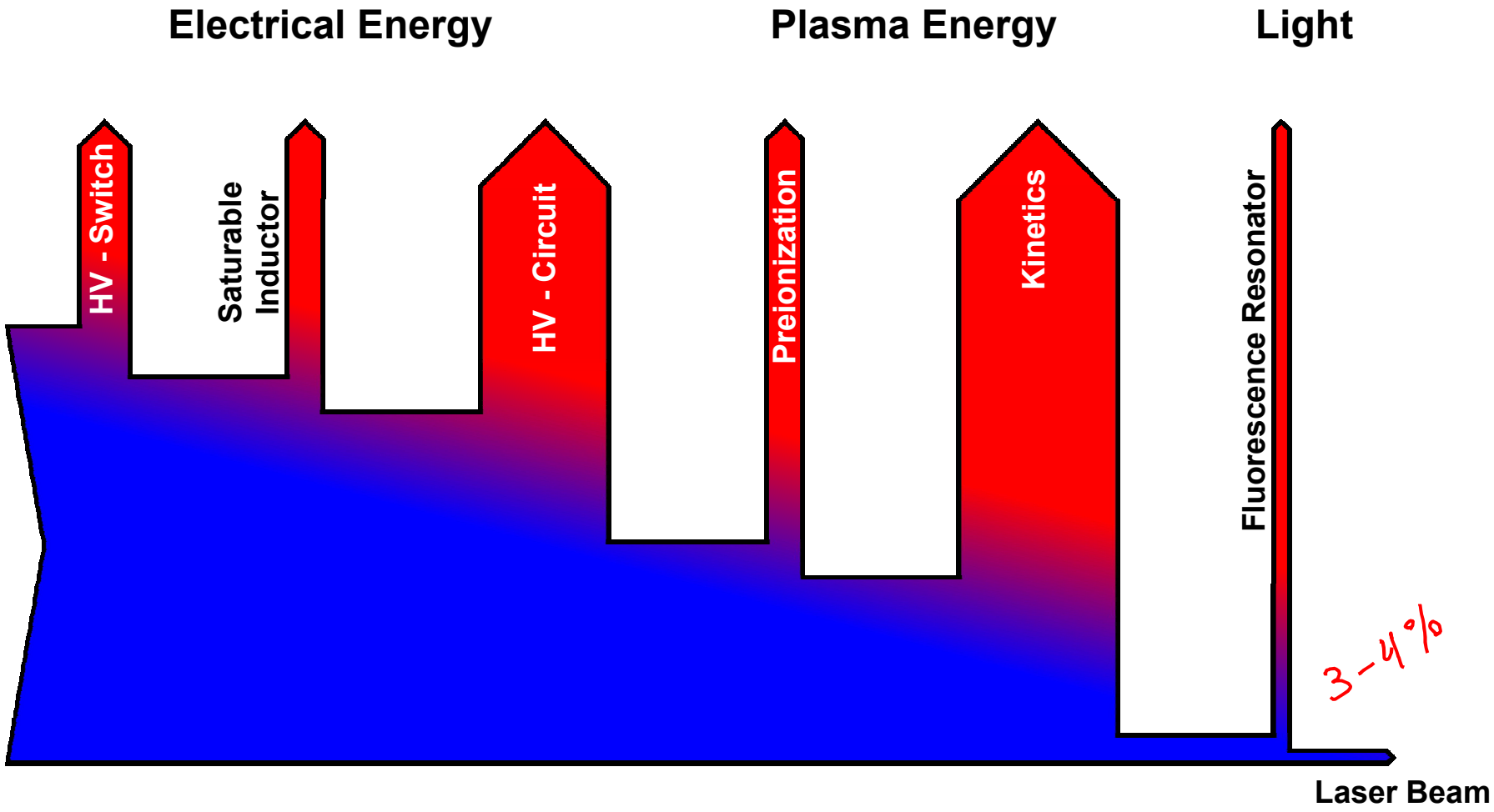
Type of Lasers

- All Solid State Laser
  - Nd:Yag Laser
- Gas Laser
  - **Excimer Laser**
  - HeNe Laser
  - CO_2 Laser
- Liquid Laser
  - Dye Laser
- Semiconductor Laser
  - Diode Laser

Excimer Laser Gases



Excimer Laser - Efficiency



Laser Safety Aspects

Laser radiation

High voltage / current

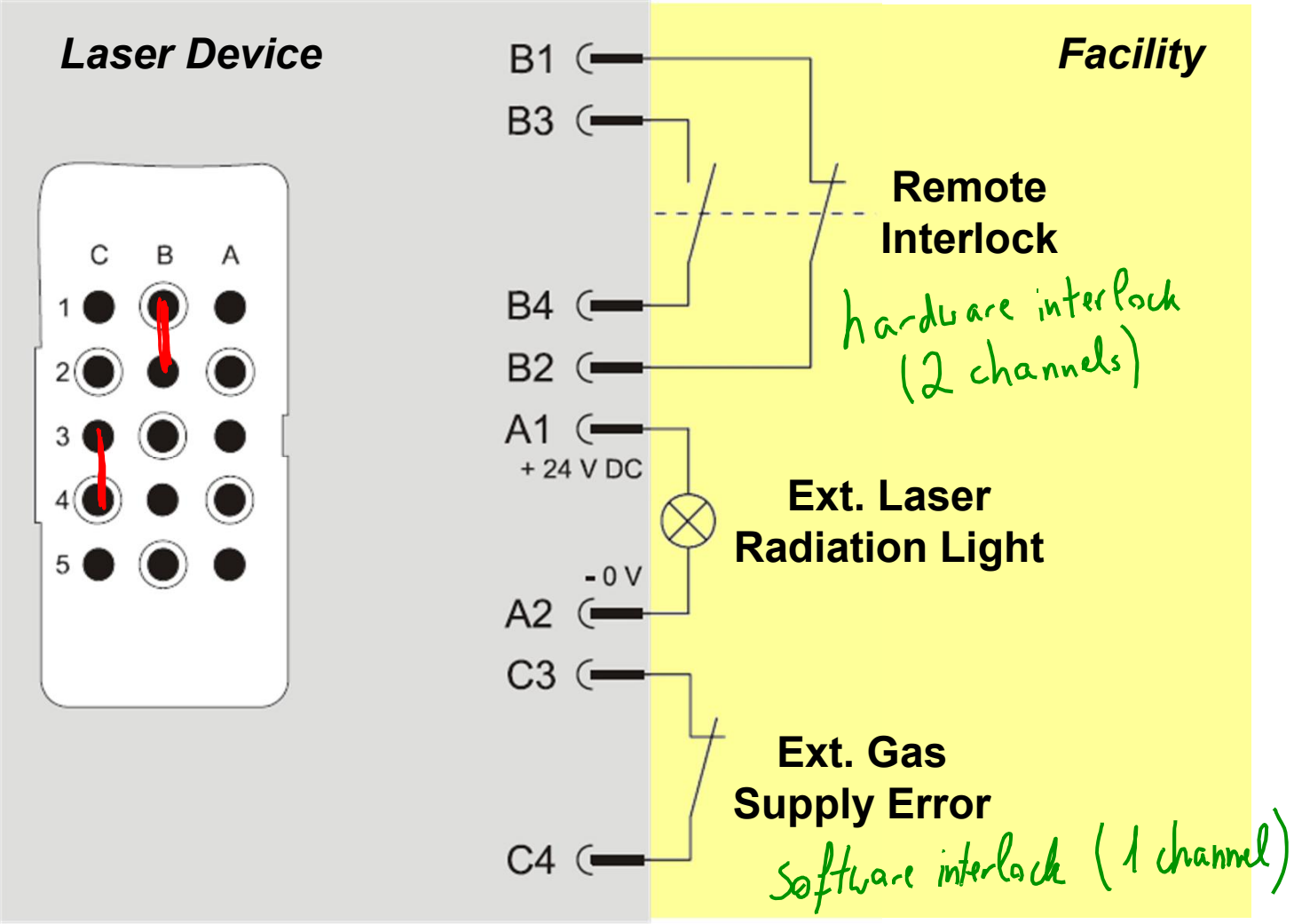
Harmful gases

X-ray radiation

High pressure gas cylinder

Toxic gases

Remote Connector (X21)



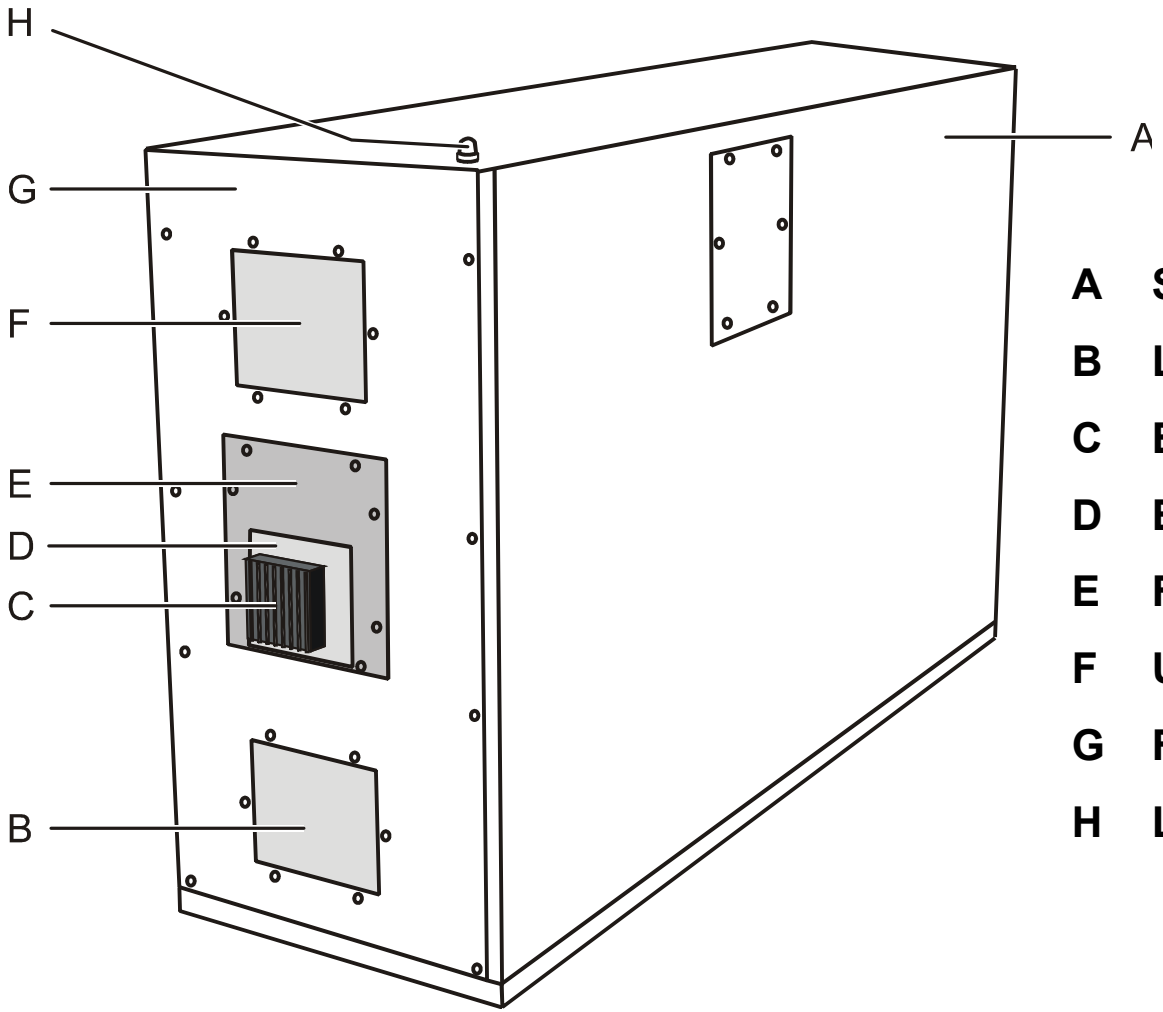
Specification

	Wavelength (nm)	CompexPro 50	CompexPro 102	CompexPro 110	CompexPro 201	CompexPro 205	Braggstar M
Max. Pulse Energy (mJ) ArF up to 10 Hz KrF XeCl XeF	193 248 308 351	100 150 - -	200 400 250 200	200 400 250 200	400 700 500 300	400 700 500 300	- 140 - -
Max. Reprate (Hz)		50	20	100	10	50	100
Average Power (W) @ max. RepRate	193 248 308 351	4 7 - -	4 7 5 4	12 30 16 12	4 5 7 3-5 3	15 30 20 15	- 12 - -
Energy Stability (%) 1sigma		1	1	1	1	1	1
Pulse duration (ns)		20	20	20	25	25	20
Beam Dimension (VxH) (mm)		14x5	24x10	24x10	24x10	24x10	12x4.5
Beam Divergence (VxH) (mrad)		2x1	3x1	3x1	3x1	3x1	0.3x0.2
Spacial Coherence (horizontal) (µm)		-	-	-	-	-	800

Maintenance Schedule

Maintenance action	CompexPro (RoHS)	Comments
New gas fill	5-10-Mill pulses/1-3 days	30min
Clean resonator	15-30 Mill pulses	60min
Thyratron maintenance	After missing discharges or LOW LIGHT	5min
Thyratron exchange	Expected after 500 Mill pulses	60min
Exchange resonator		60min
Exchange tube	Garantied 2year	360min
Exchange beam splitter		30min
Alignment check	After resonator maintenance	30min
Alignment	After tube exchange	60min
Calibration EGY Monitor	After any optic maintenance and external power mismatch	45min
Check halogen filter	Before new fill	10min
Exchange halogen filter	Approx. 100 (XeCl) 300 (KrF) tube evacuation	30min
Exchange gas circulation motor	3 years	60min
Exchange gas cylinder	Remaining pressure less than 20%; static life time expired	30-45min
Housing filter	If soiled	15min

Front View



A **Service Panel (Right Side)**

B **Lower Air Intake**

C **Beam Shutter**

D **Beam Output Frame**

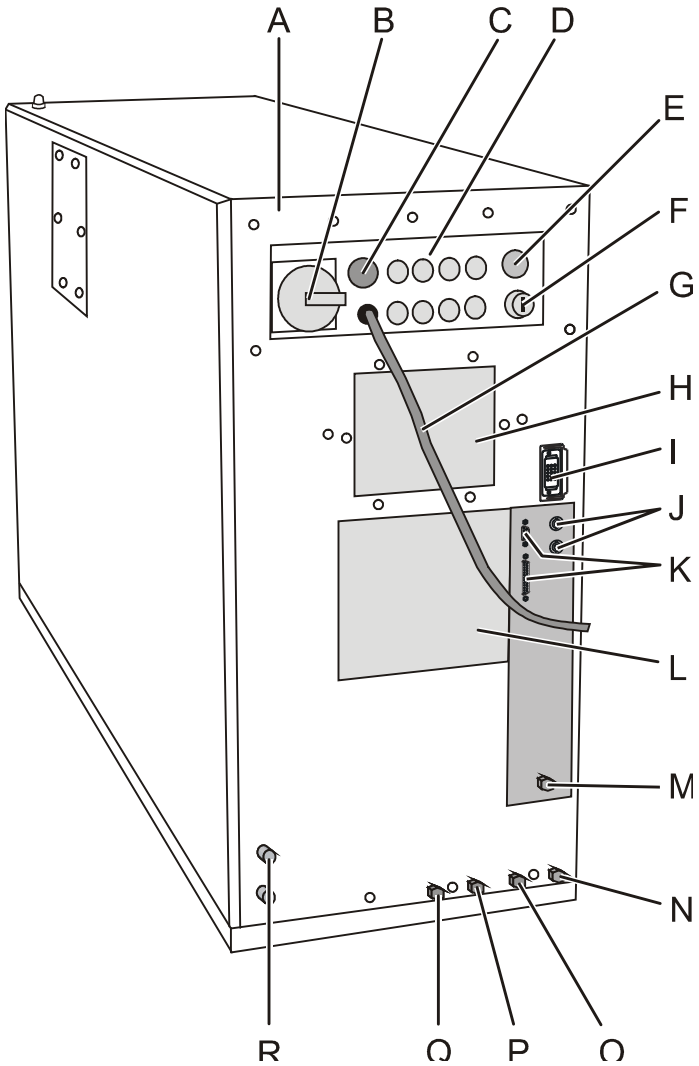
E **Front Mirror Access Panel**

F **Upper Air Intake**

G **Front Side**

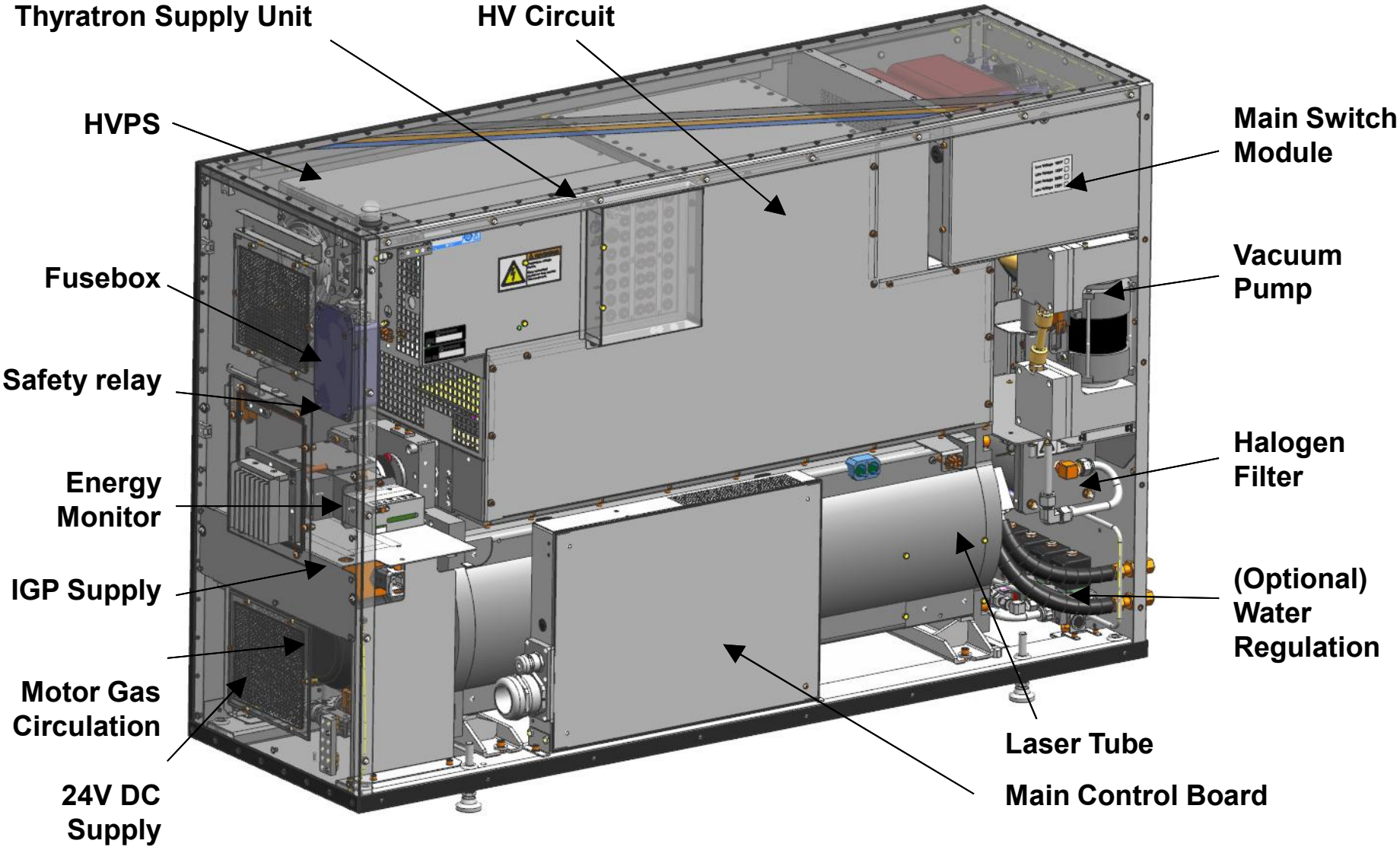
H **Laser Warning Lamp**

Rear View

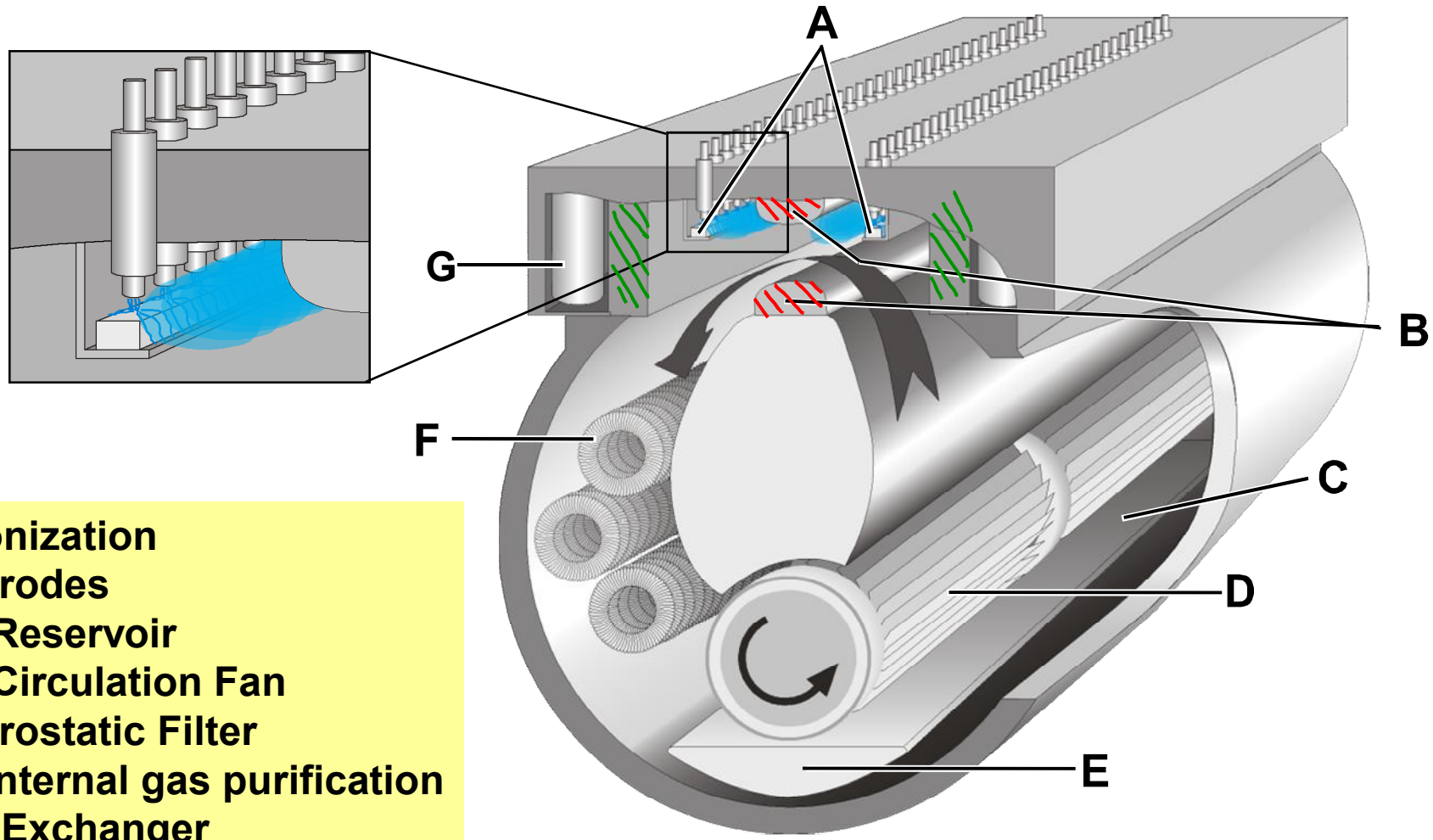


A	**Rear Side**
B	**Mains Switch**
C	**Power On Lamp**
D	**Fuses**
E	**Control Supply Lamp**
F	**Key Switch**
G	**Mains Supply Line**
H	**Exhaust Fan Outlet**
I	**Remote Interlock Connector**
J	**Ext. Trigger / Sync. Out BNC**
K	**RS232 Connectors**
L	**Rear Mirror Access Panel**
M	**Purge Gas Connector**
N	**Buffer Gas Connector**
O	**Rare Gas Connector**
P	**Halogen Gas Connector**
Q	**Inert Gas Connector**
R	**Water Connection Fittings**

COMPexPro (RoHS) Inner System

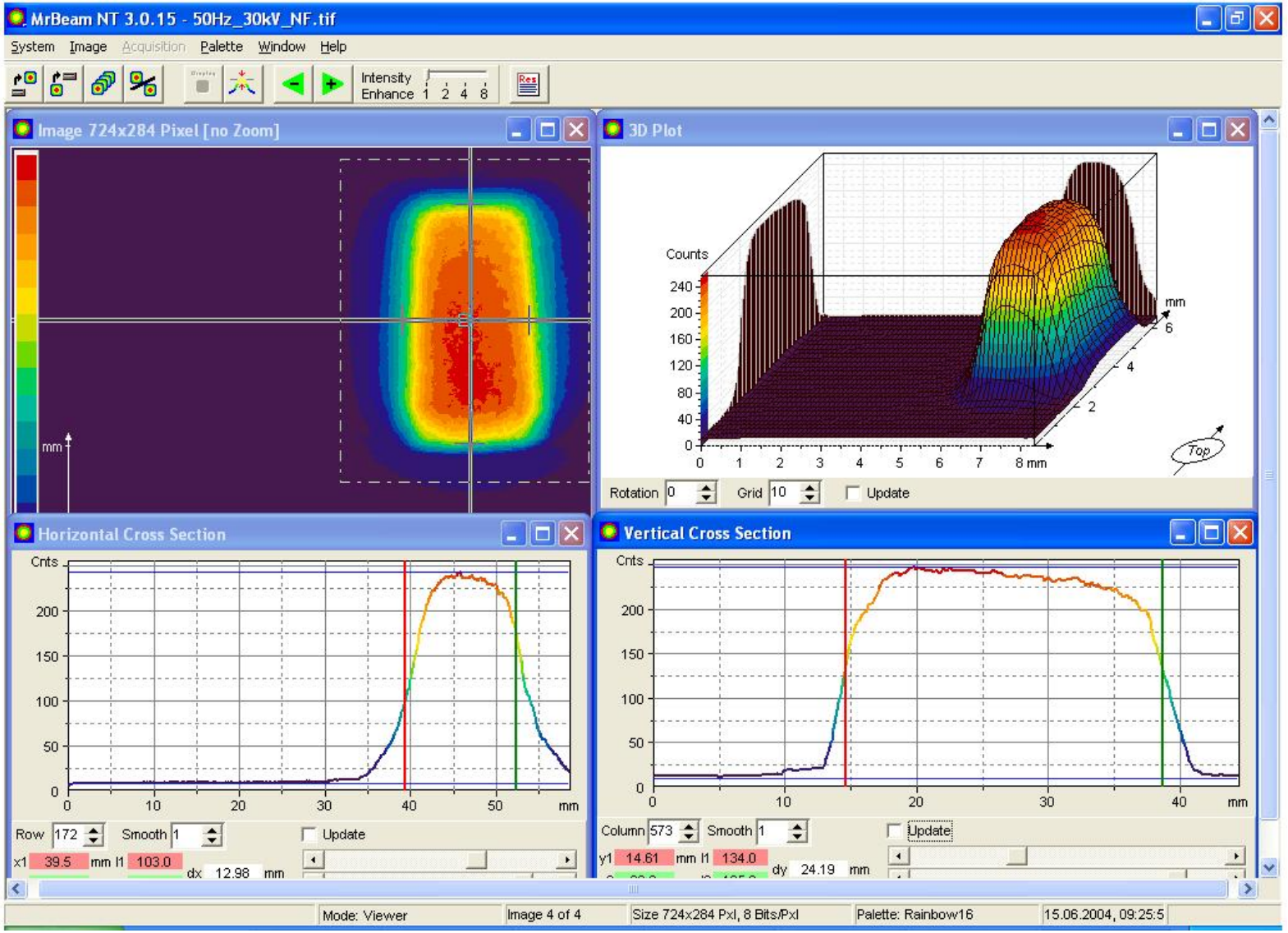


Laser Tube



A Preionization
B Electrodes
C Gas Reservoir
D Gas Circulation Fan
E Electrostatic Filter
IGP internal gas purification
F Heat Exchanger
G Discharge Capacitors

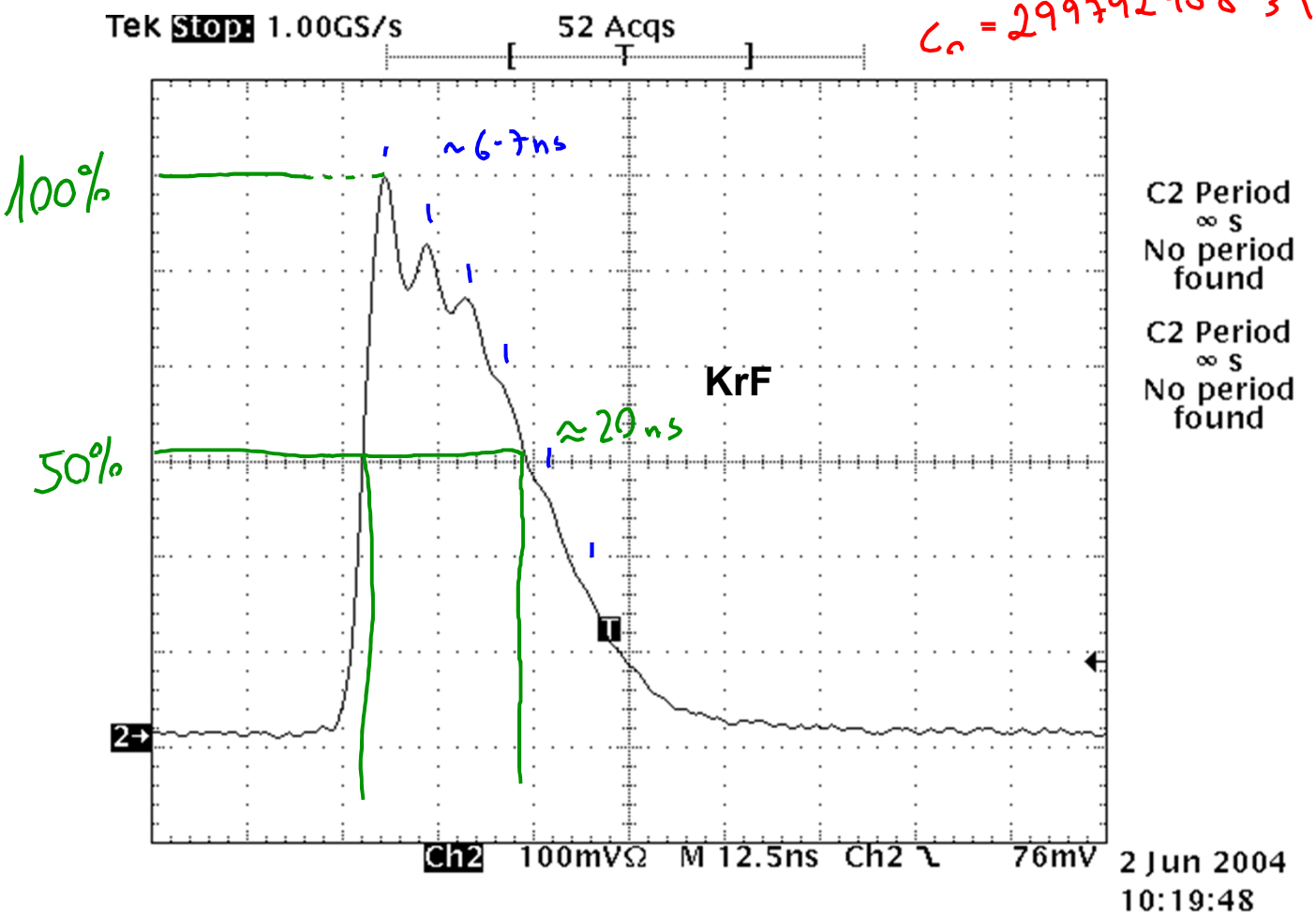
Beam Profile



Pulse Duration

FWHM full width at half maximum

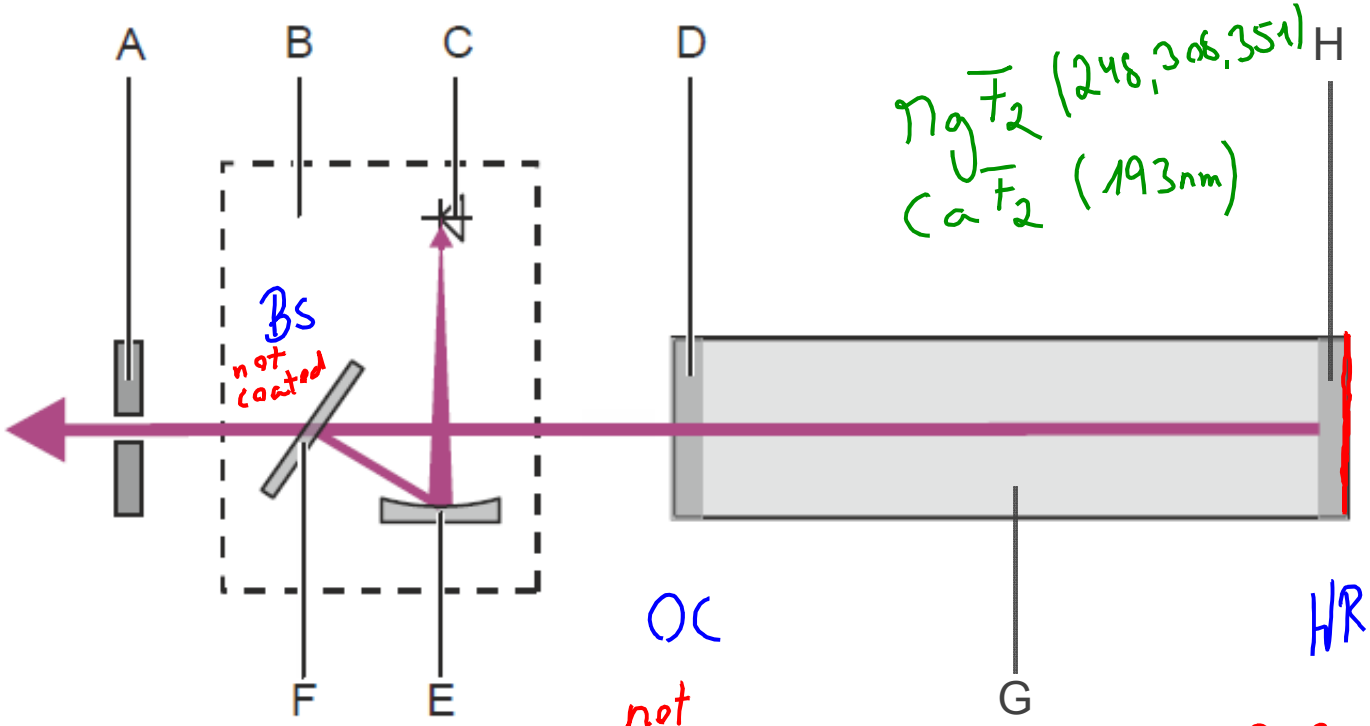
$c_0 = 299792458 \frac{m}{s}$ (speed of light)



Optical Resonator - CompexPro 1/2

internal resonator

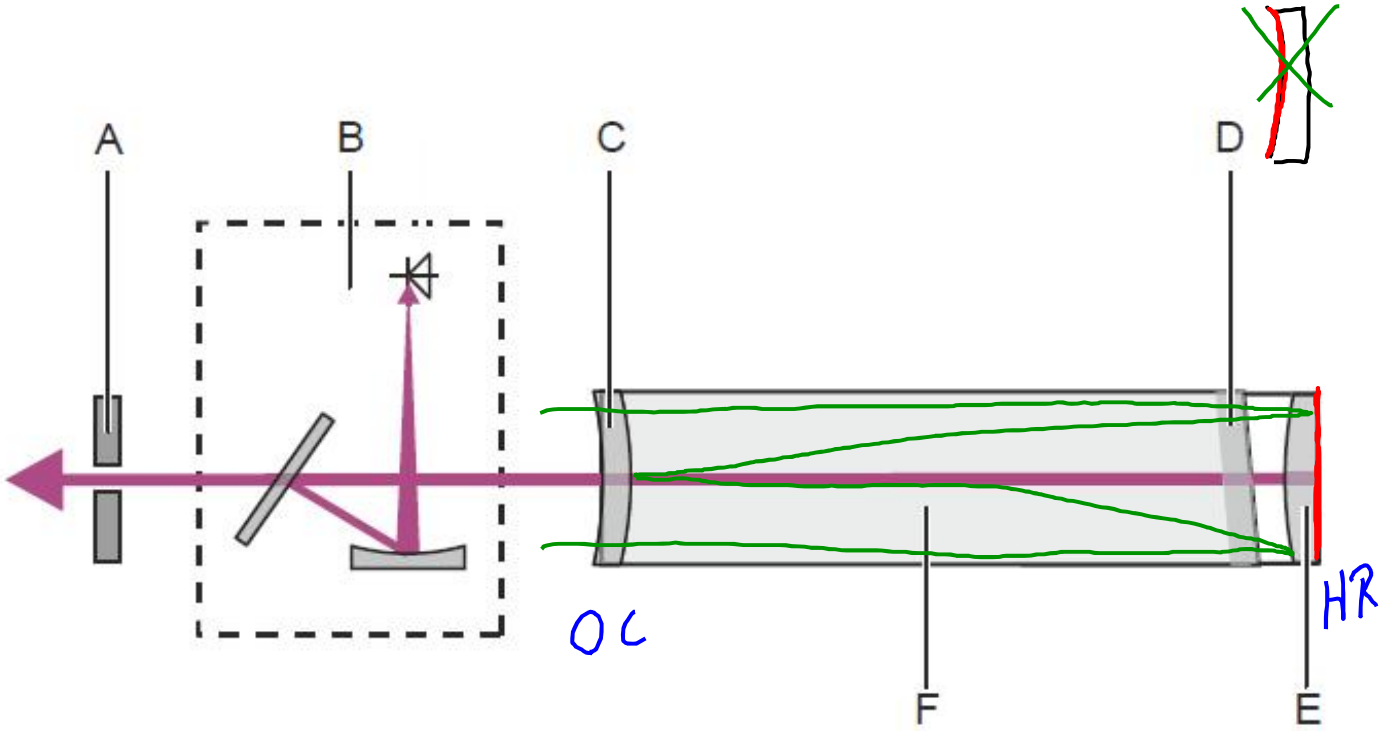
A Beam shutter
B Energy monitor
C UV photodiode
D Output coupler
E Convex mirror
F Beam splitter
H Rear mirror
G Laser tube



Stable Resonator

Optical Resonator – Braggstar-M 2/2

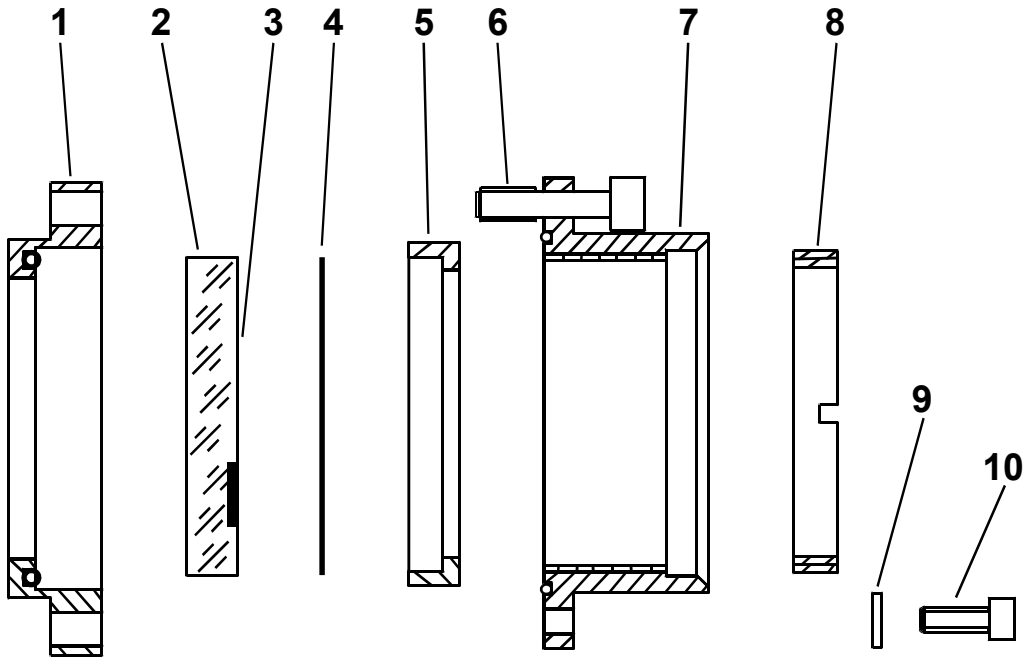
A Beam shutter
B Energy monitor
C Output coupler (miniscus lens)
D Rear Window
E Plano-concave rear mirror
F Laser tube



Unstable Resonator

⊕ smaller divergence
⊕ longer coherence length
⊖ less efficency
⊖ worse homogenity

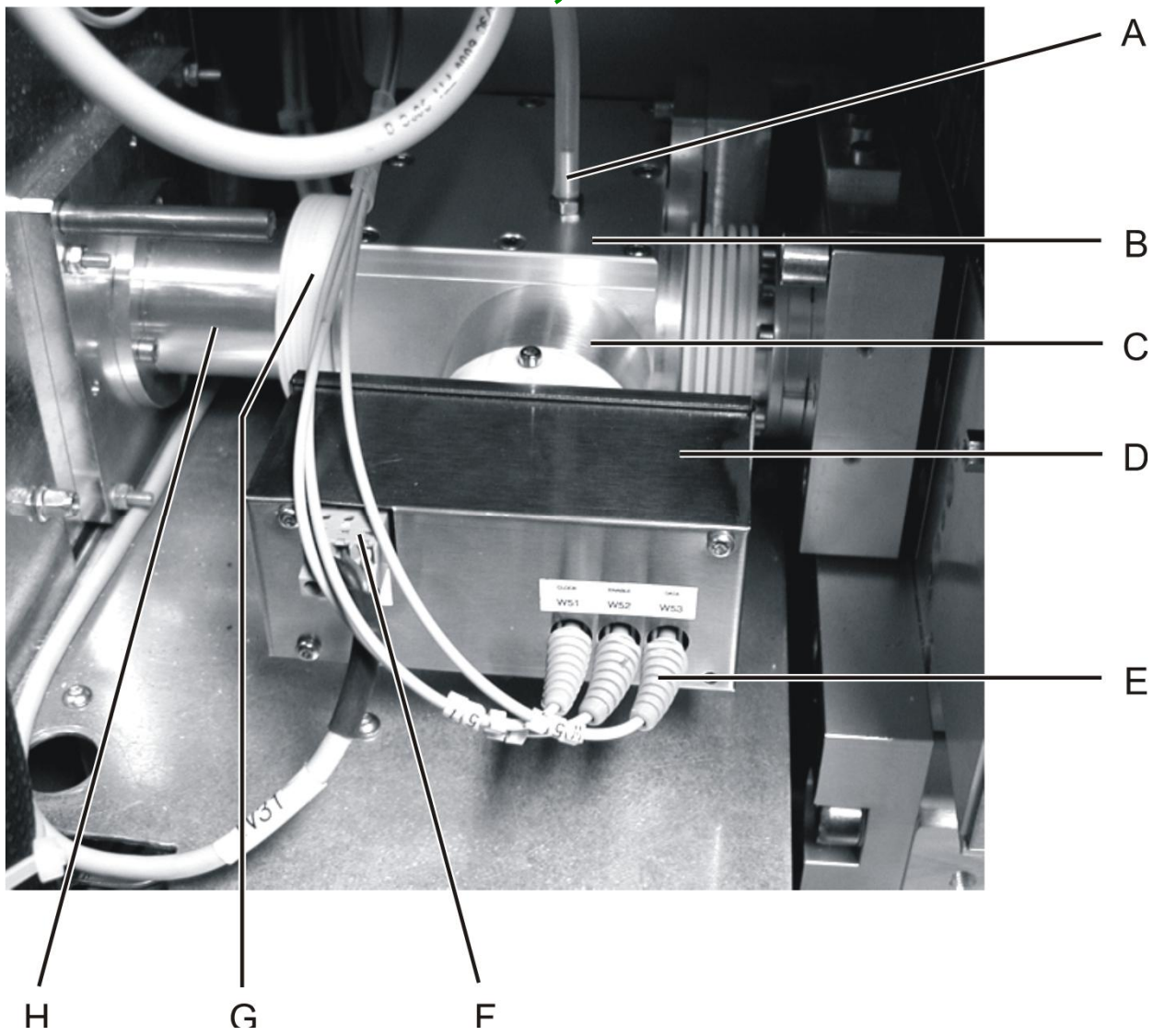
Optic mount



1	Counter optics mount
2	Optic
3	Coating mark
4	Optics spacer
5	Optics collar
6	Fastening screws (captive)
7	Optics mount
8	Pressure insert
9	Washer
10	2.5 mm screw

12 bit Energy Monitor (old version)

$2^{12} = 4096 \quad (0 \ldots 4095)$



A Purge gas connection

B Beam splitter box

C Attenuation tube

D Electronics box

E FOLs

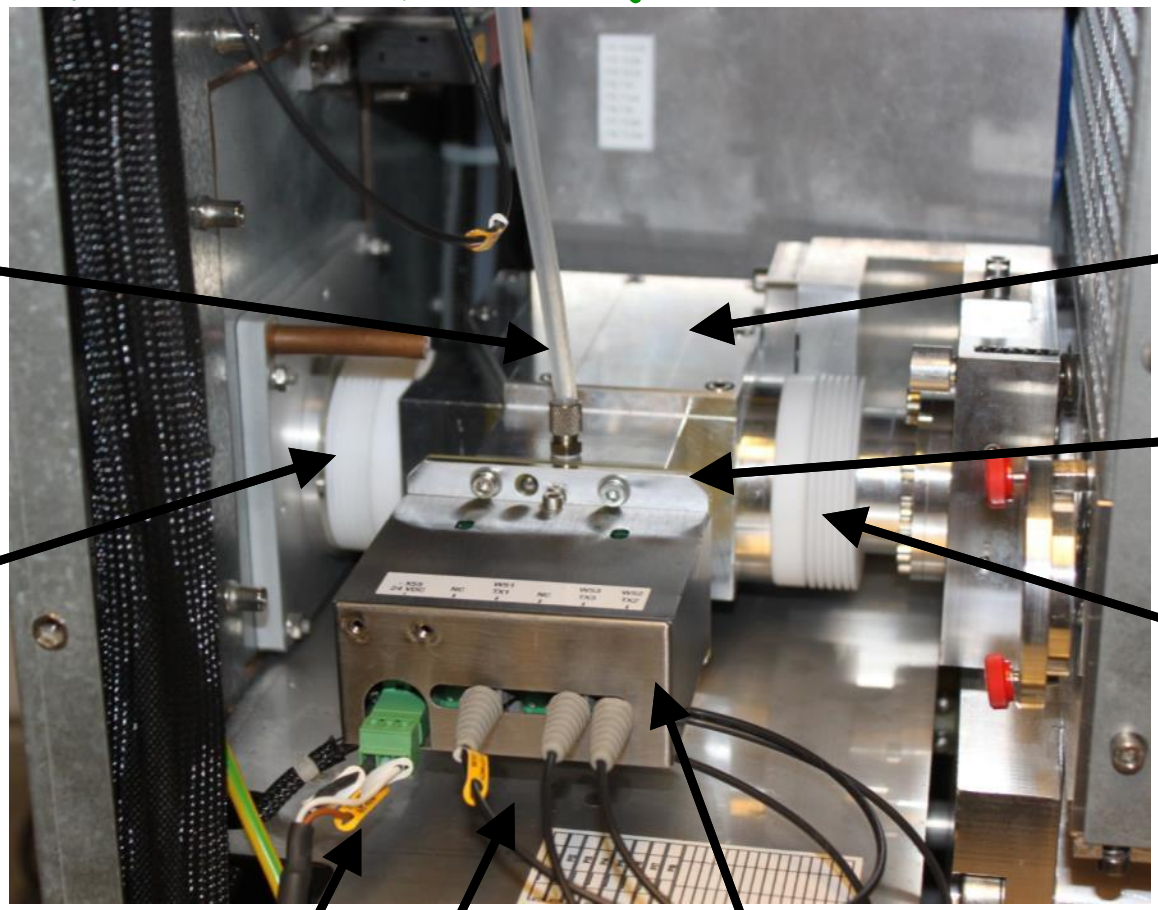
F Electrical connection

G Bellows

H Internal beam delivery tube

16 bit Energy Monitor (standard version)

$2^{16} = 65536$ (0....65535) reading



Purge gas connection

Bellows

Beam splitter box

Attenuation tube

Bellows

Electrical connection

24V

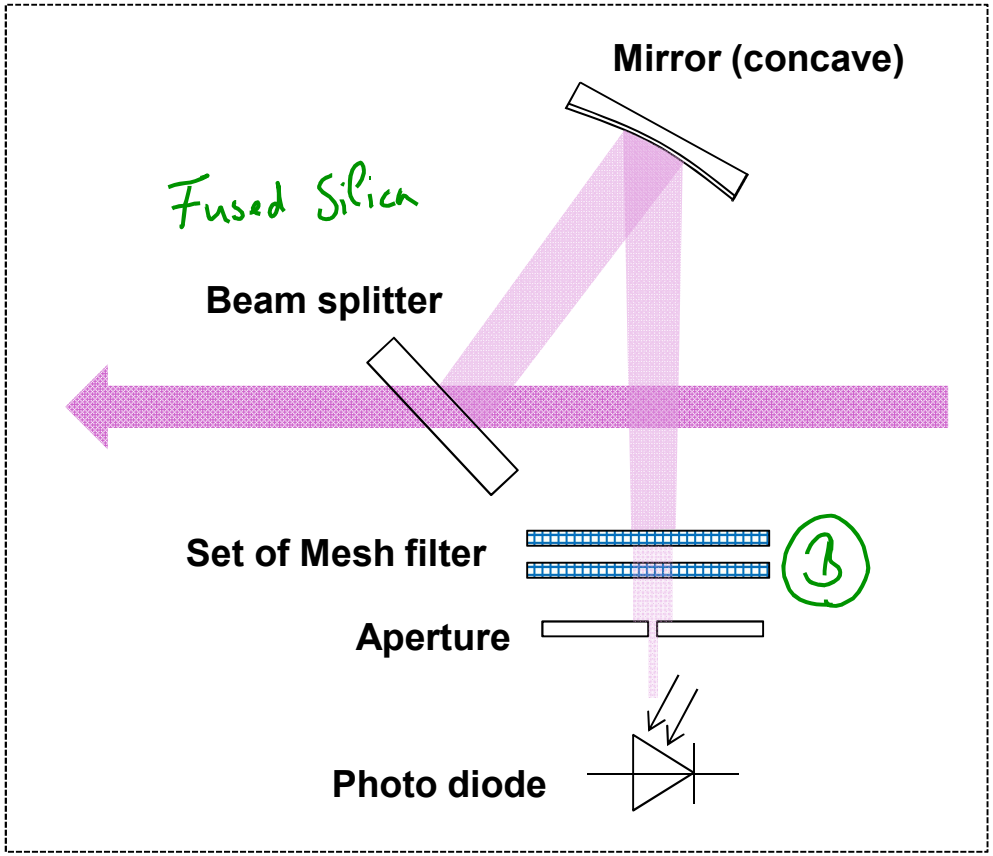
FOLs

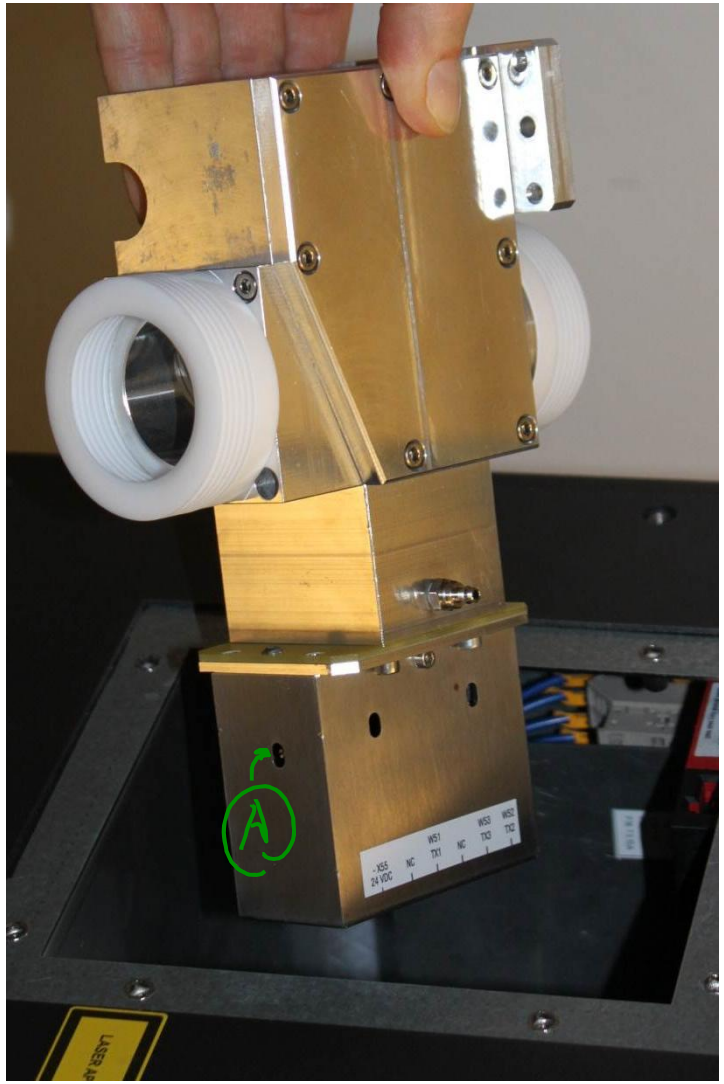
SPI

Electronics box (24V)

Beam Path Energy Monitor (16bit)

Adsorption of 10-15% normal



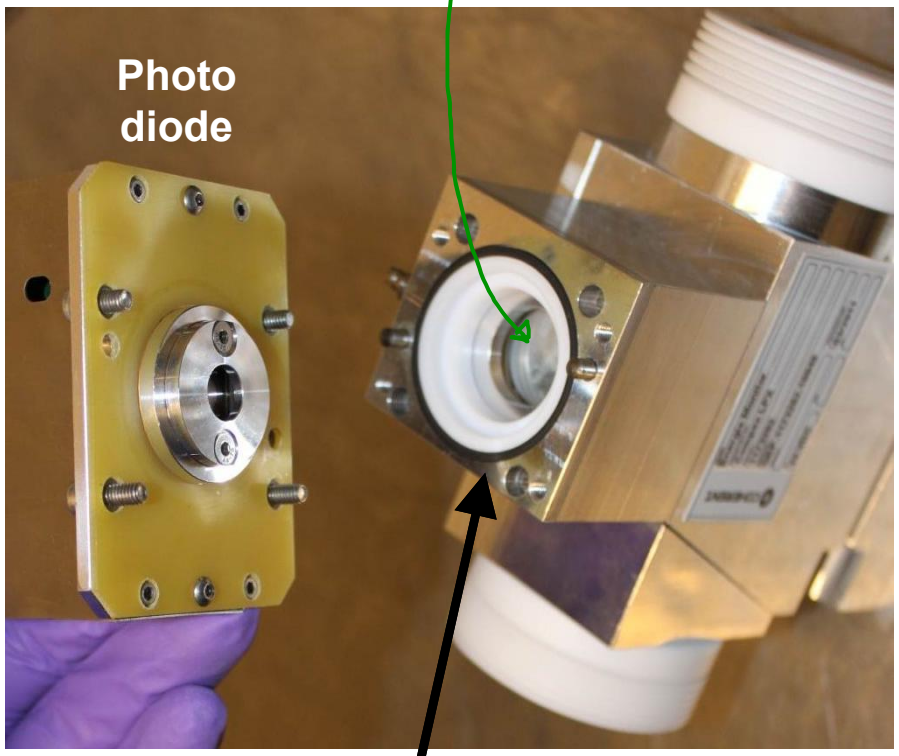


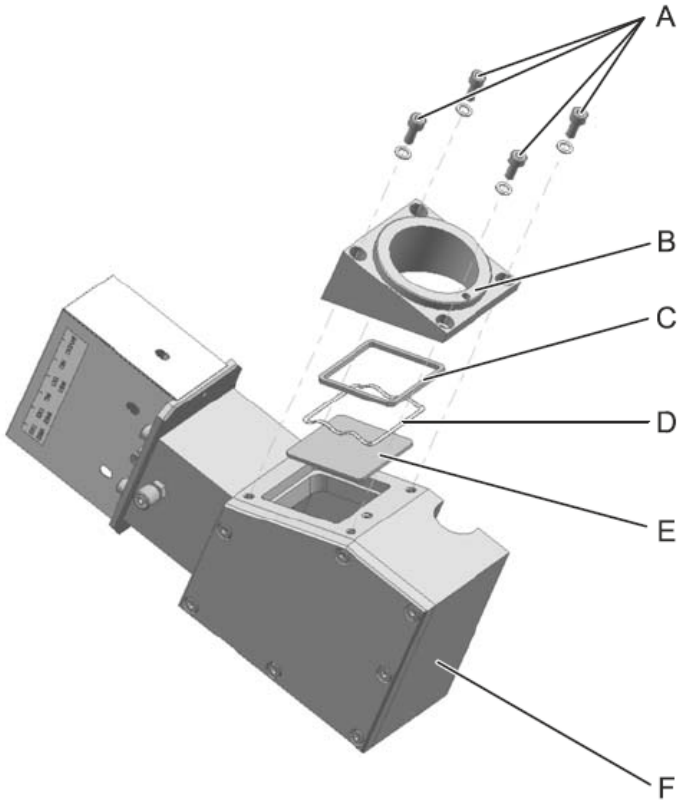
linear Range 25000 - 45000

adapt reading: (A) Potentiometer

(B) Mesh Filter

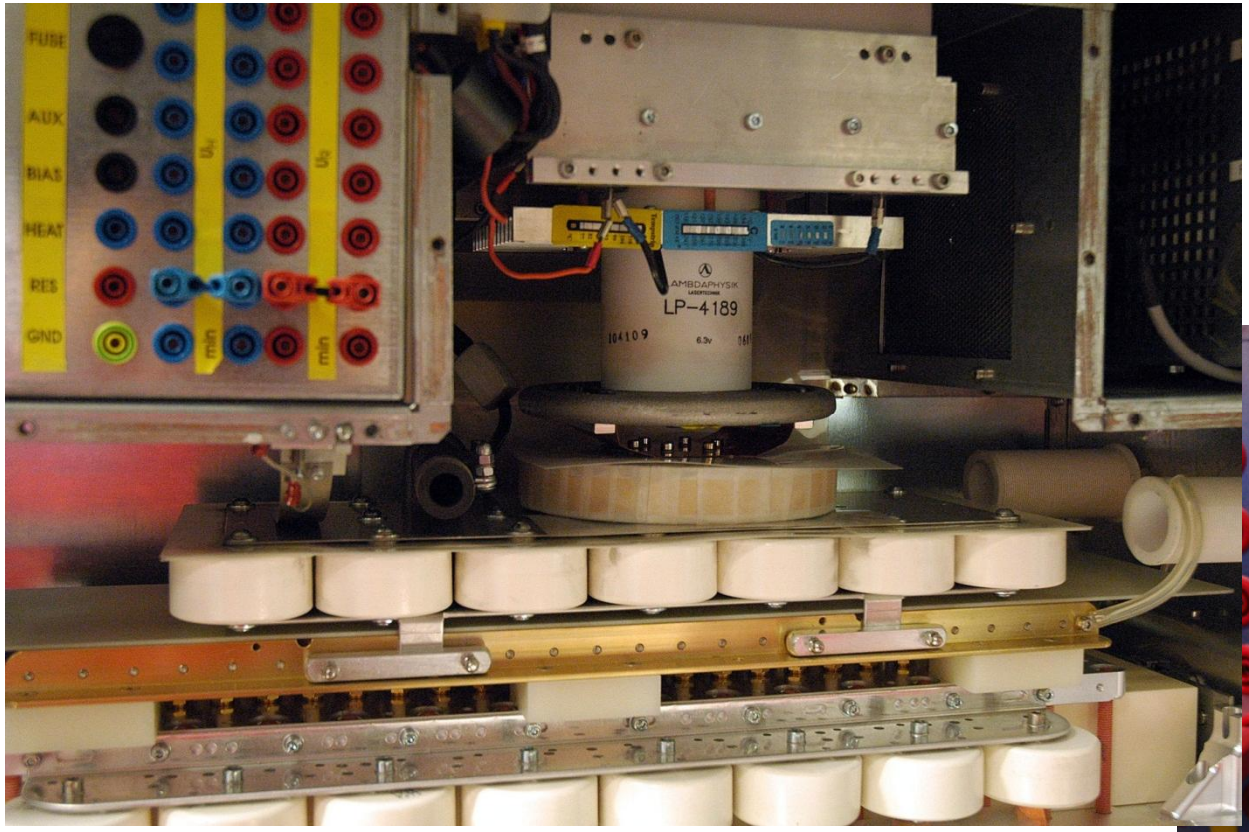
Mechanical design of the Energy Monitor

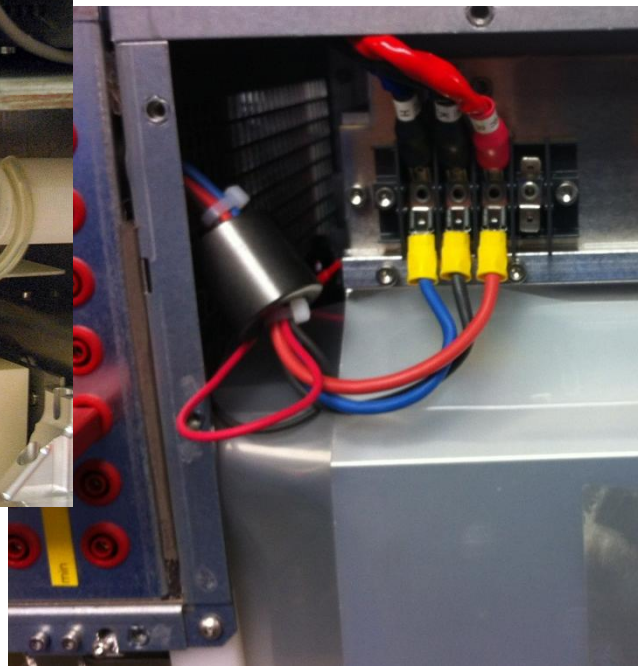




Mechanical design

High Voltage Circuit

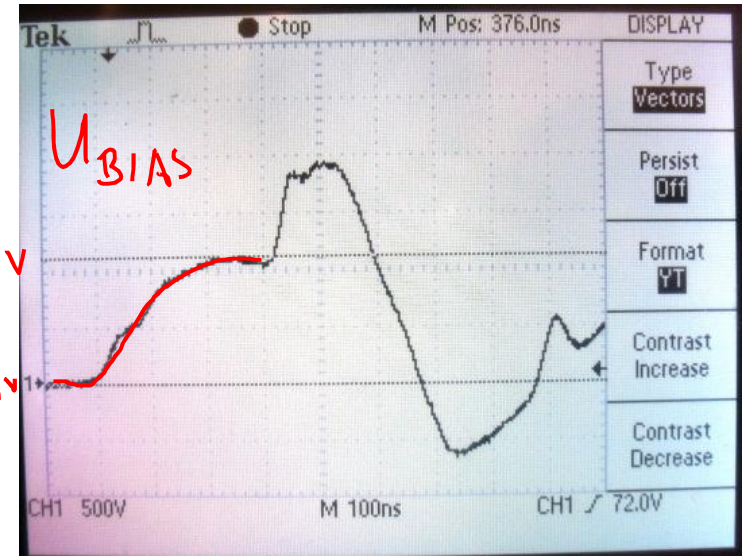




New terminal position

Block Diagram HV Circuit

$E_{el} = \frac{1}{2} \cdot C \cdot U^2$



HV - Trigger

HV - Power Supply

Storage Capacitor

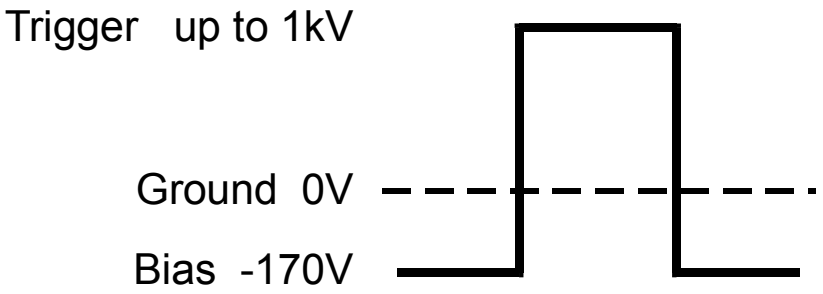
Thyratron

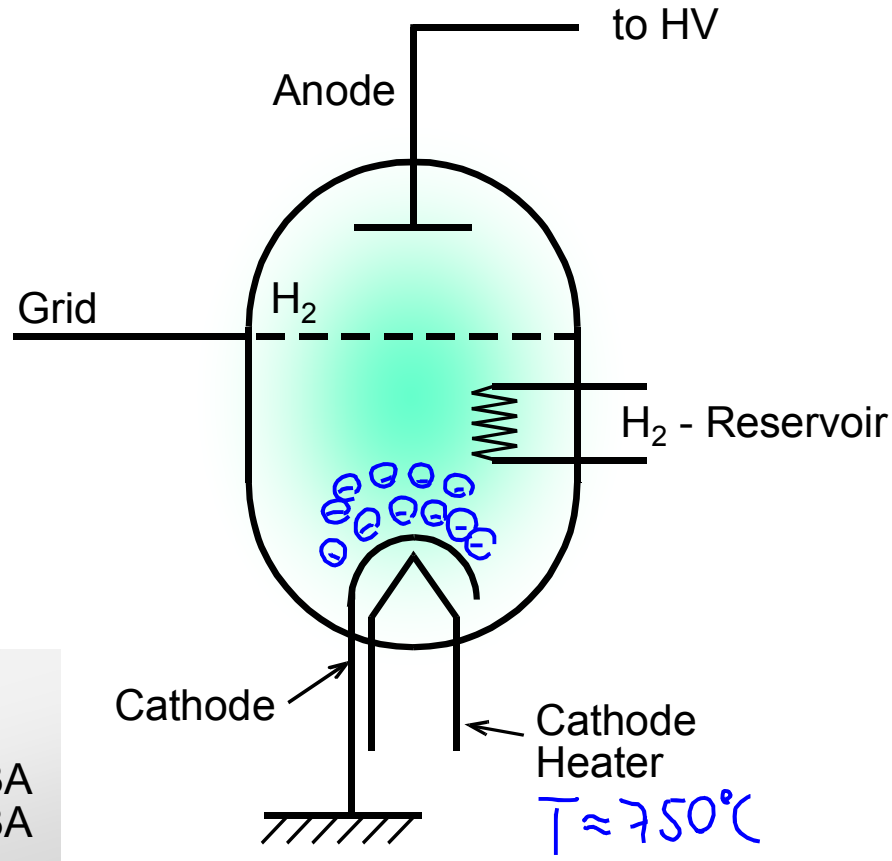
Discharge Unit

HVPS
19 - 30 kV

A ≈ 1 kA

Principle of Thyratron (I)



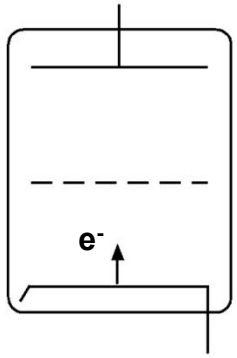


Typical voltages

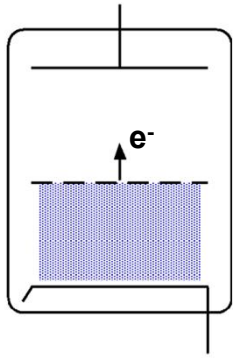
- Cathode Heater: U_H 5 ... 8V; typ.: 6,3V 13A
- Reservoir Heater: U_R 5 ... 8V; typ.: 6,3V 3A

Principle of Thyratron (II)

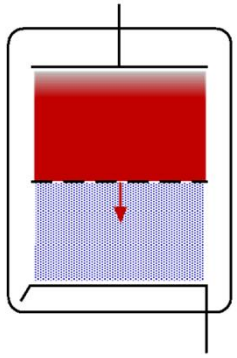
- **Negative bias keeps switch open.**
- **Oxide cathode heated to 750° C.**
- **Positive trigger pulse of sufficient energy forms a plasma in grid-cathode gap.**
- **Plasma propagates through grid and causes breakdown of high voltage region between anode and grid (called switching or commutation).**
- **Further ionization results in complete closure of the switch.**
- **Typical commutation time is 20 ns.**



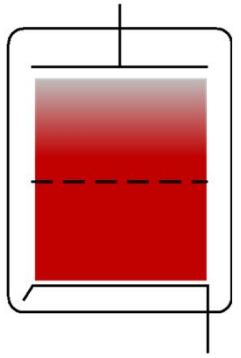
1. Trigger pulse applied to control grid



2. Grid-cathode breakdown



3. Electrons from grid-cathode region create a dense plasma in the grid-anode region. The plasma front propagates toward the cathode via breakdown of gas.



4. Closure

High voltage power supply

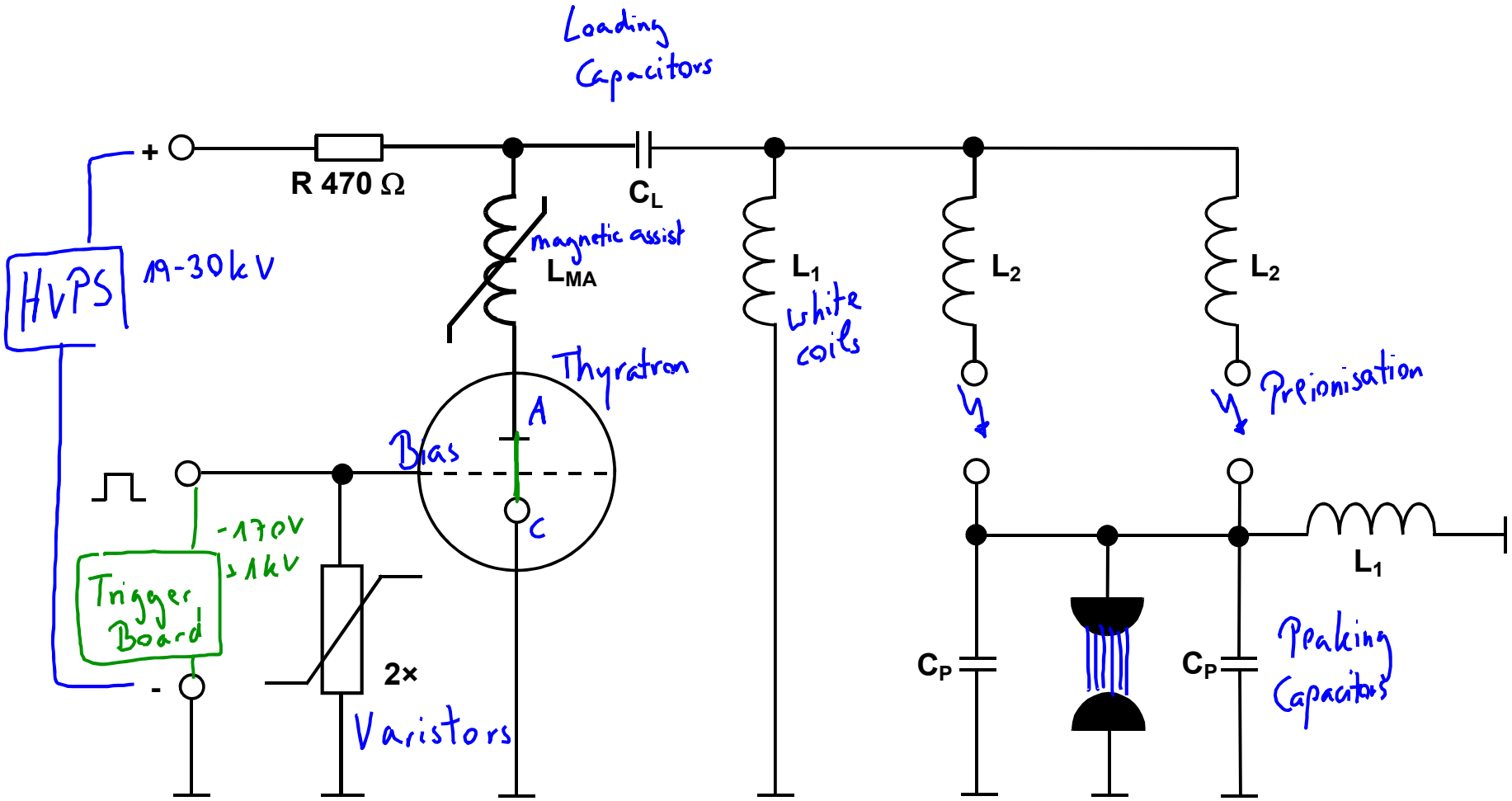
HV PS

Old version:
PU1500+
RoHS only

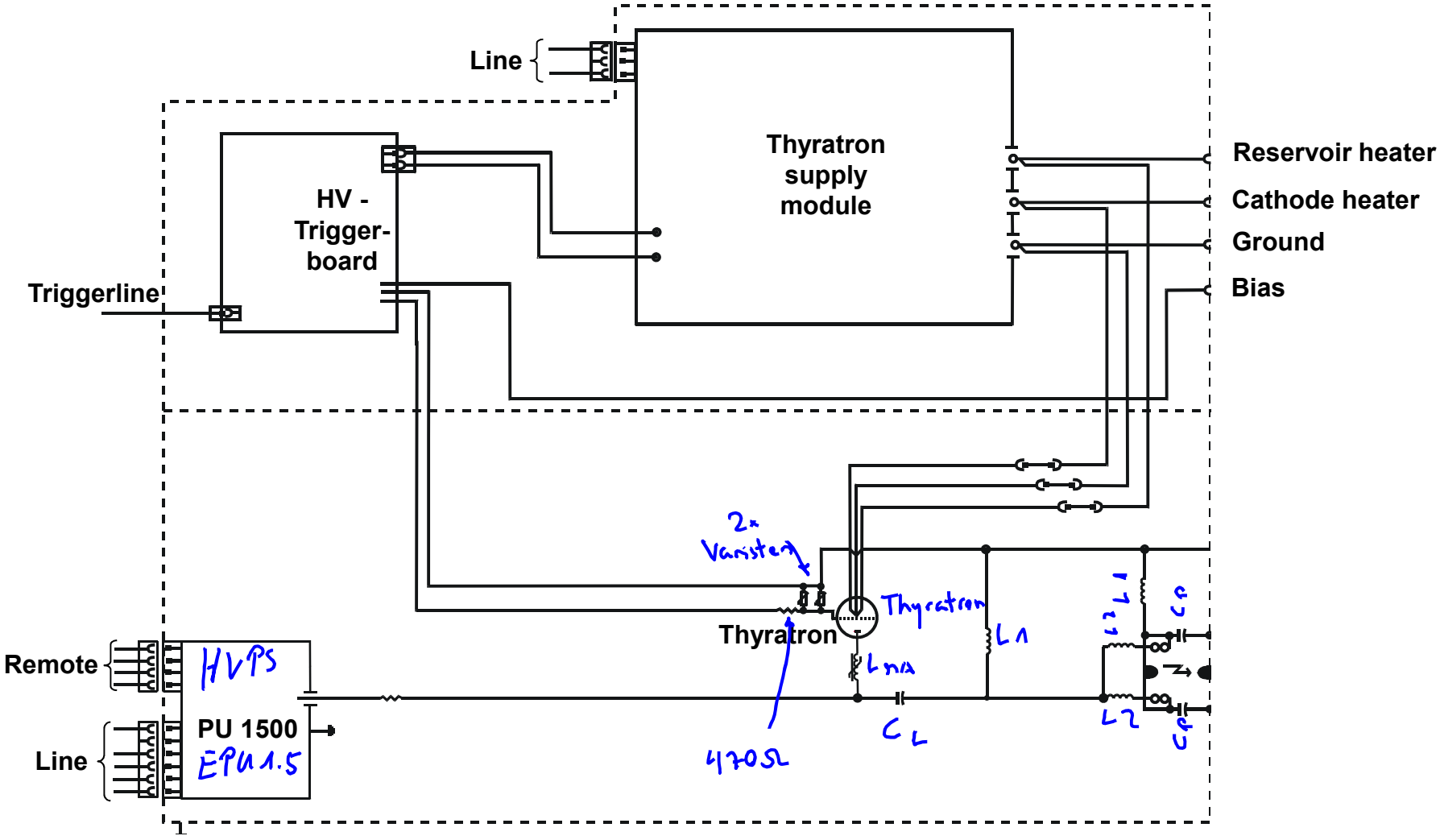
PU 1500
nonRoHS systems

New version:
EPU 1.5
nonRoHS and RoHS

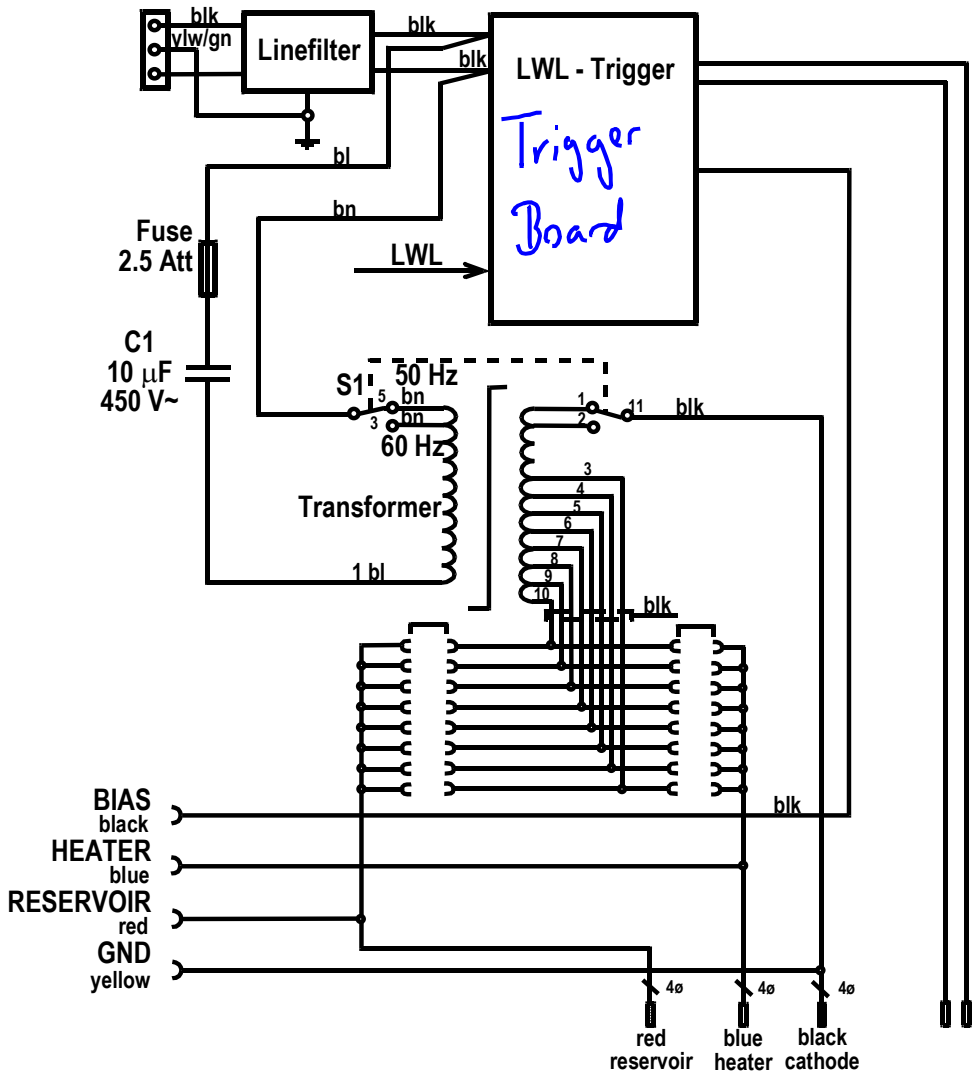
Discharge Unit



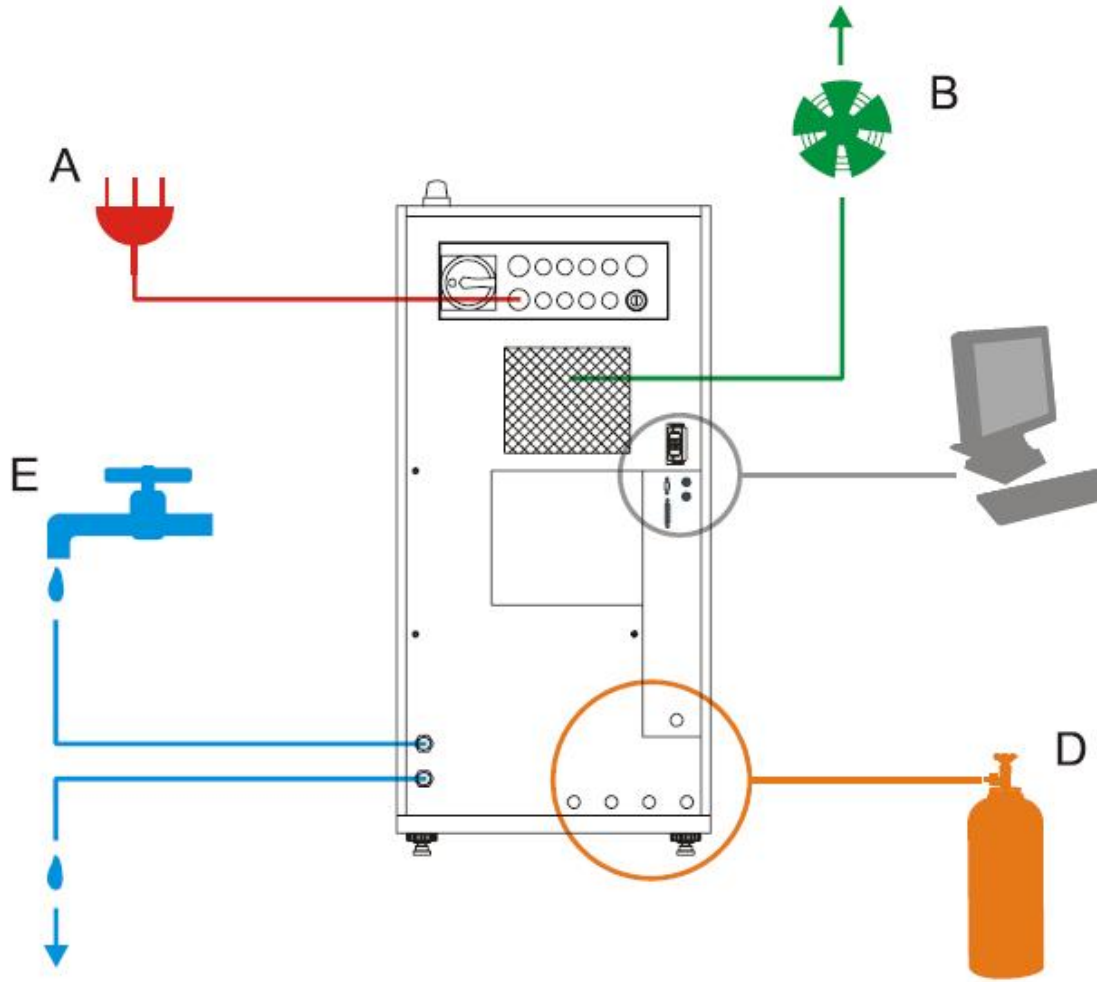
High Voltage Circuit



(Heater Module) Thyratron Supply Module



Utilities and Connections 1/2



A	**Mains power**
B	**Exhaust**
C	**Control and signal lines**
D	**Gases**
E	**Cooling water**

Utilities and Connections 2/2

Premix Gas

Premix gas

Gas mixture	see corresponding table
Purity	Excimer grade
Inlet pressure range	4.4 bar (abs) to 5.2 bar (abs)
Flow rate range	0.05 l/s to 0.5 l/s

Cooling water

Do not use deionized water.

The cooling water specifications are listed below.

Water flow rate	1 l/min to 5 l/min
Water temperature at inlet	10° C to 20° C[a]
Static water pressure	2 bar to 4 bar
Dynamic water pressure drop (in/out)	2 bar to 4 bar
Heat transfer to water	< 1.5 kW
Electrical resistance	10 kΩ/cm to 100 kΩ/cm
Suspended particle size	< 200 µm
Hardness	< 100 ppm Ca
pH range	6.5 to 8

The COMPex*Pro* has an internal mains transformer that enables connection to a local mains electrical supply corresponding with the following specifications:

Nominal voltage	104 VAC / 120 VAC / 208 VAC / 230 VAC
Voltage range	Nominal voltage ± 10%
Frequency	50 Hz / 60 Hz
Wires	2 + PE

Electricity

The internal mains transformer is factory set according to the required local voltage and frequency.

The exhaust specifications are indicated below.

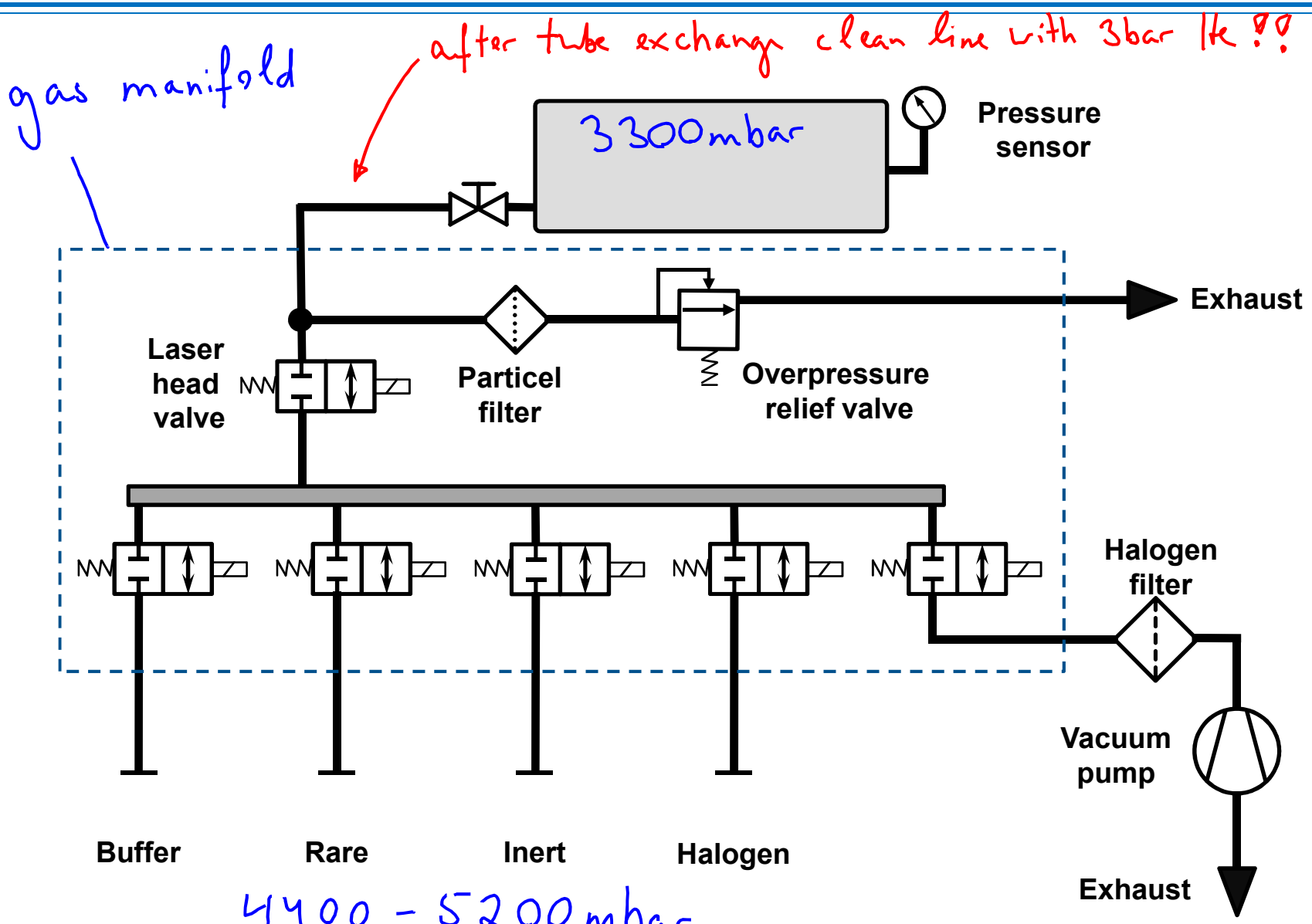
Air flow rate	200 m³/hour to 300 m³/hour
Air intake temperature	15 °C to 25 °C
Heat transfer to air	< 1 kW
Max. exhaust length	4 m (157.5 in)[a]
Exhaust diameter	150 mm (5.9 in)

a. An additional blower is required if the max. length is exceeded

Air cooling

Gas Flow Diagram (with relief valve)

GET. xxxxxx. / xxxx

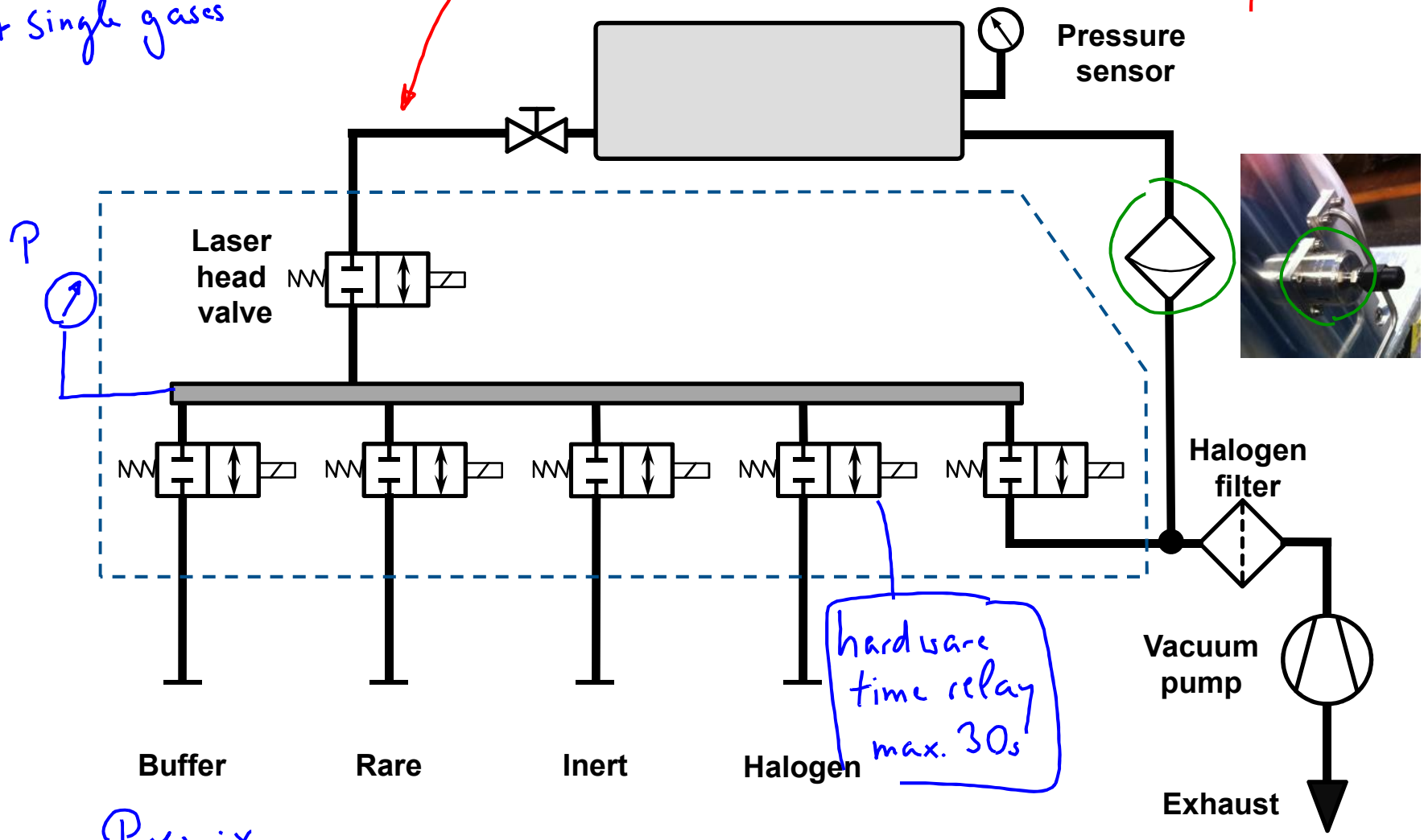


Gas Flow Diagram (with rupture disk) GEP. xxxxxx . 2xxxx

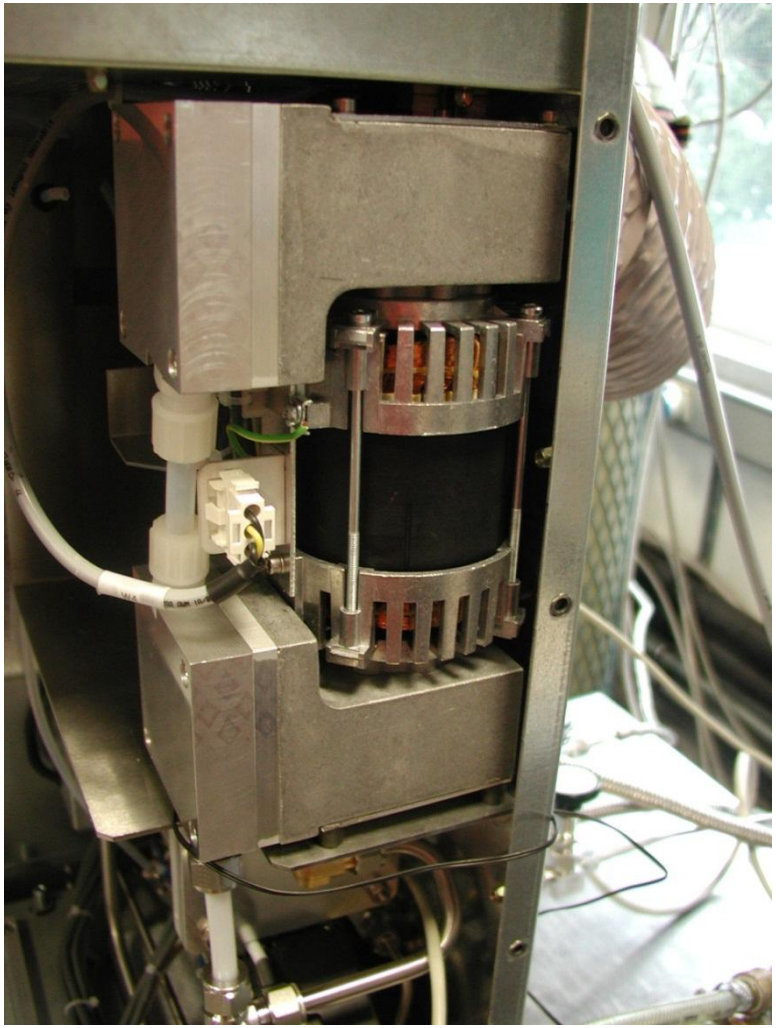
Since beginning 2016

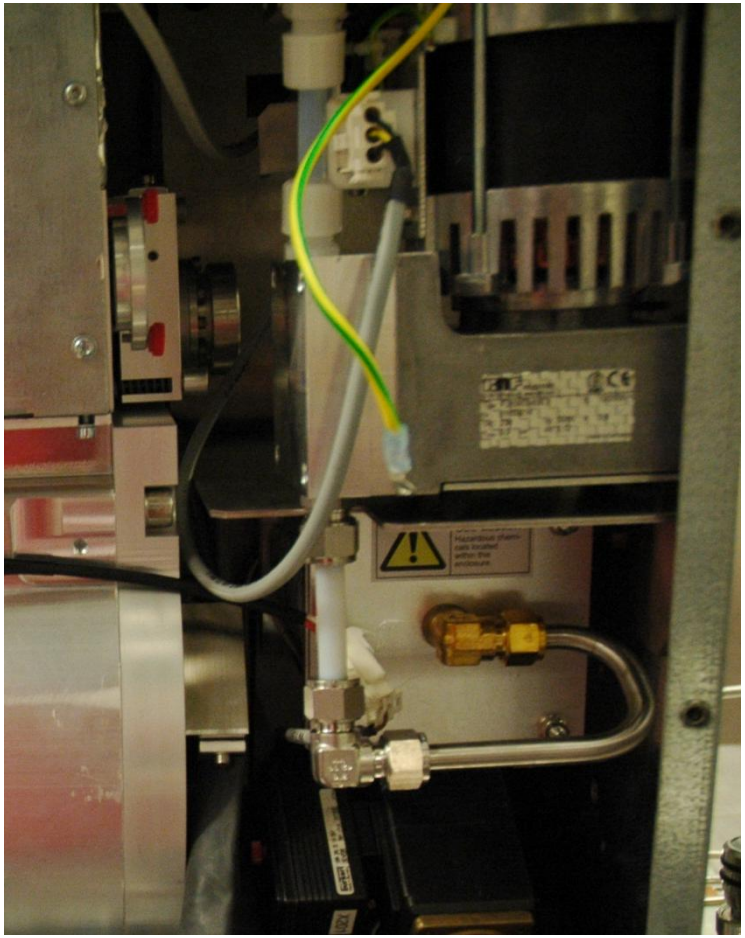
↗ Single gases

after tube exchange clean line with He at full line pressure!

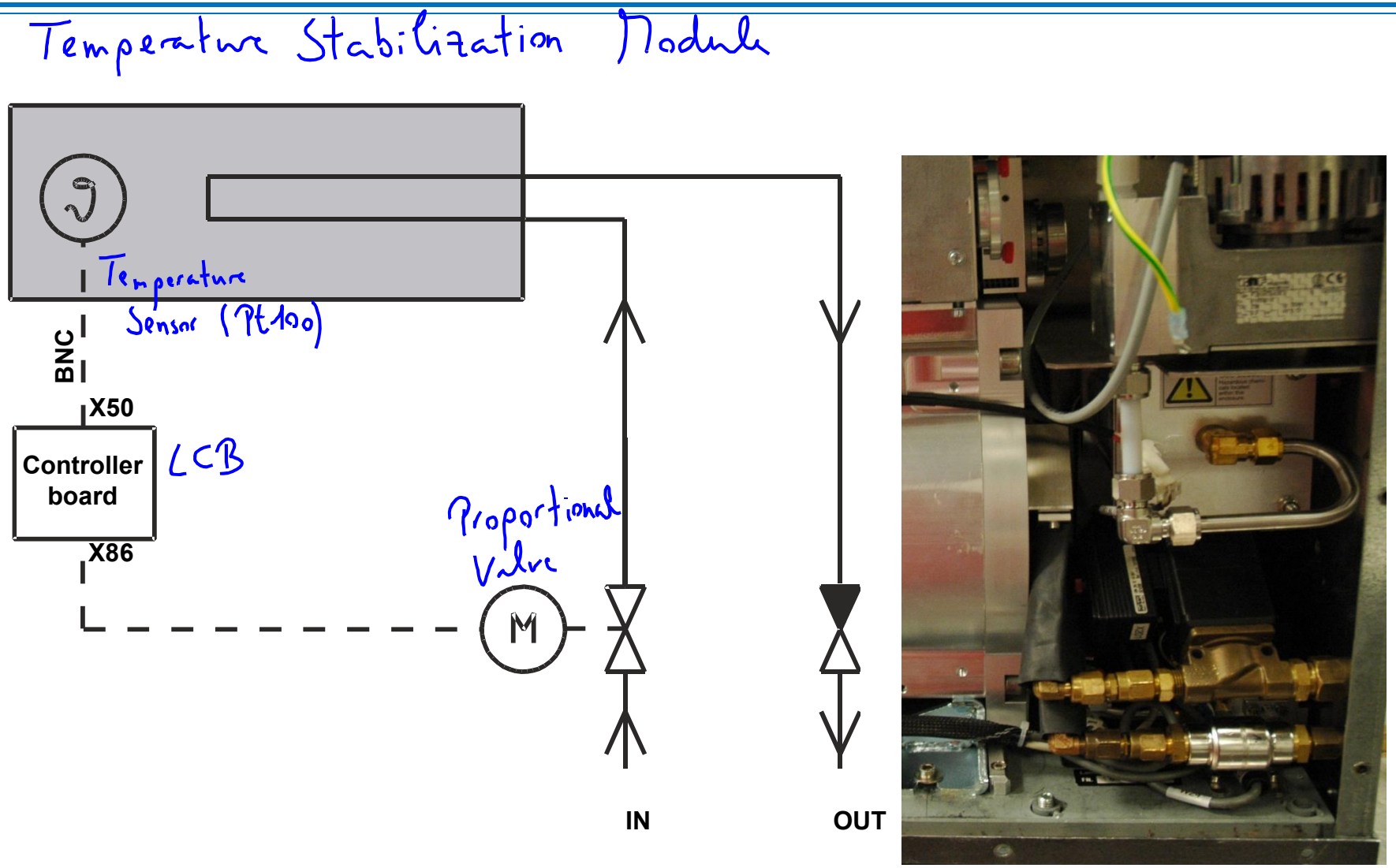


Vacuum pump / Halogen filter



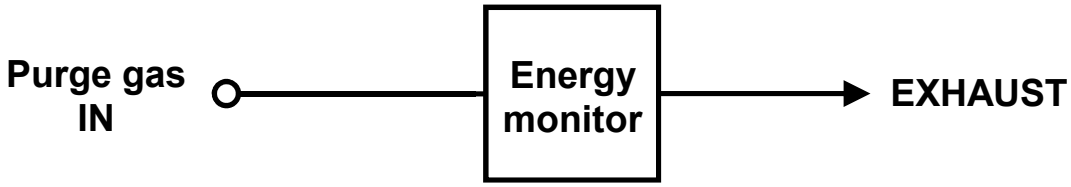


Cooling Water Diagram (optional)



Purge Gas Diagram

N_2 required for ArF (193nm) & formation O_3



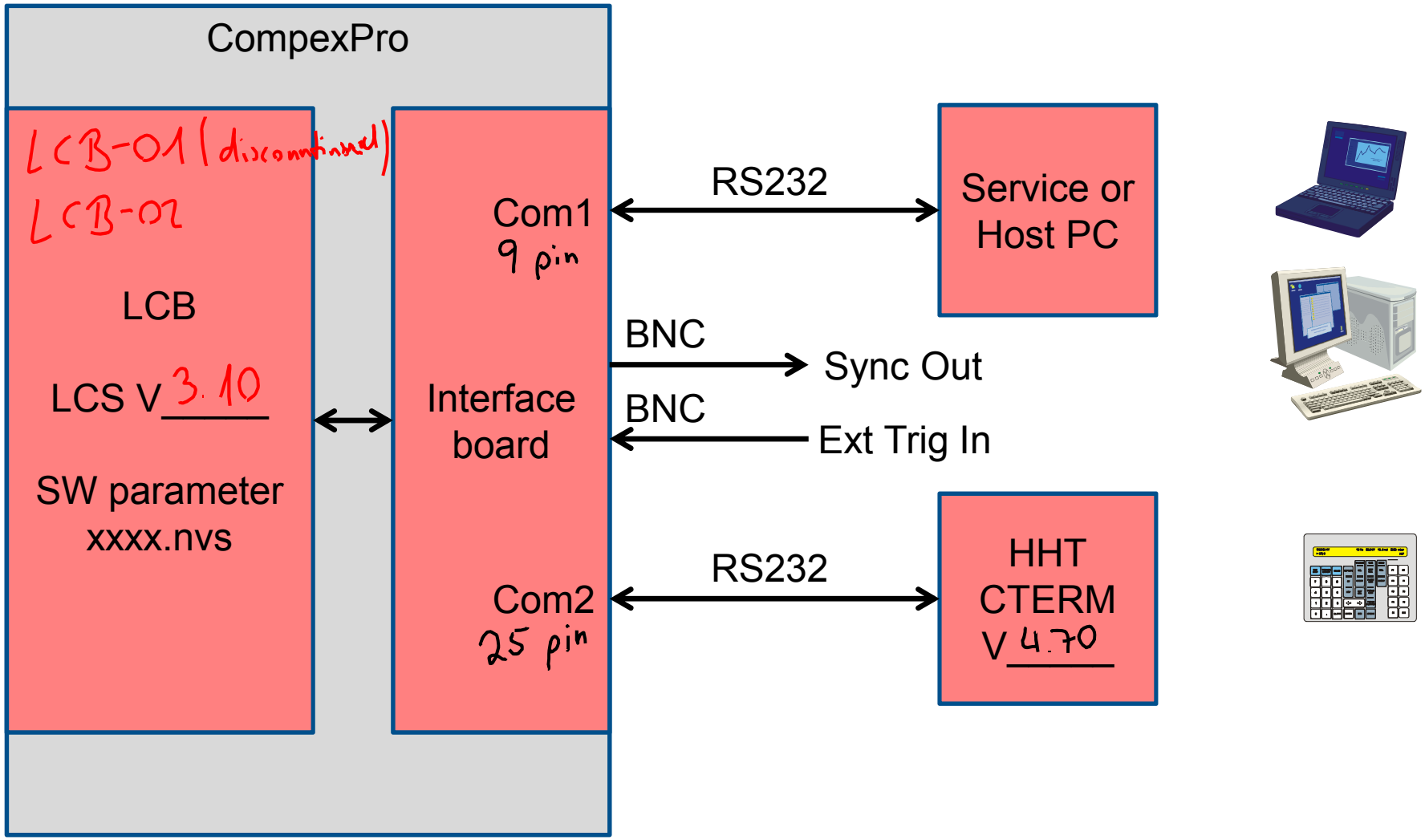
NOTICE
Risk of serious damage to the laser tube!
Nitrogen is only intended for purging the beam path and optics.
Never fill nitrogen into the laser tube or excimer laser gas supply lines.

Nitrogen (N2) is required to purge the beam path and optics when operating the laser device at 193 nm. This prevents the formation of ozone and ensures that the specified performance levels are attained. At other wavelengths, the use of purge gas minimizes contamination and increases optics lifetimes.

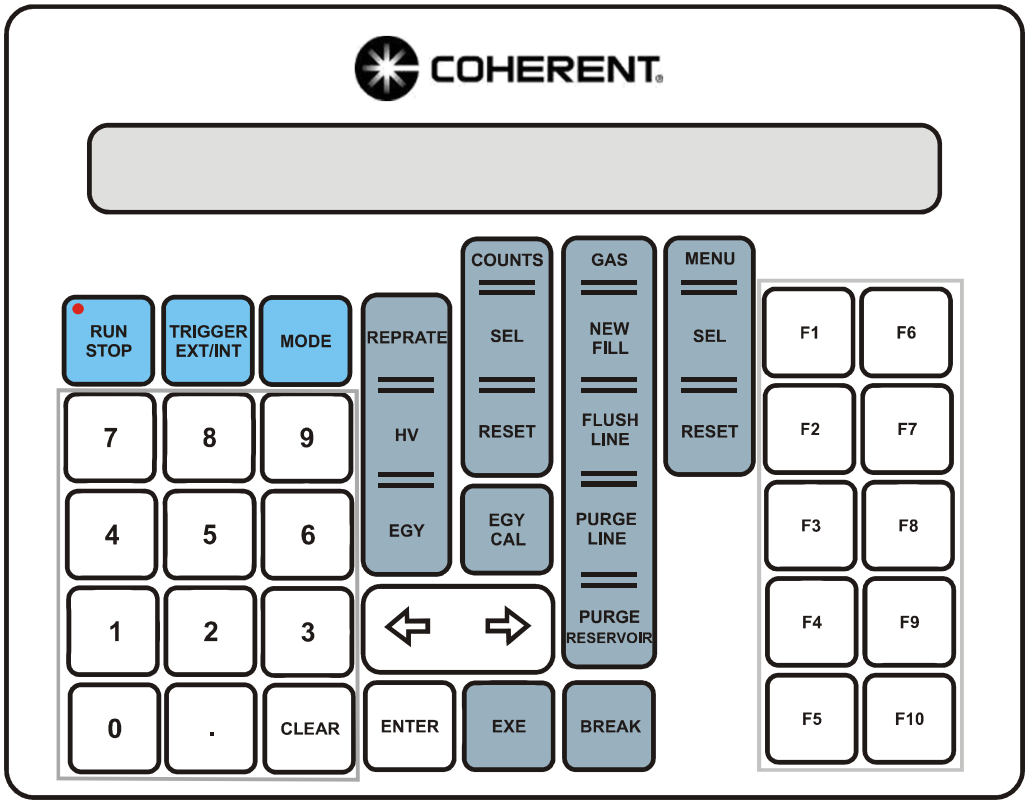
Type of gas	N2
Purity	99.999%
Flow rate range	8 l/min to 12 l/min

Purge gas

CompexPro - Software Communication



HHT - Function Keys



F 1 **Help**

F 2 **Skip Warmup / Low Light Off**
4711

F 3 **Gas Action / PGR Mode**
4711

F 4 **Halogen Filter Filling Ratio**
Reset: 778

F 5 **Temperature Control On/Off**
4711 off: open proportional valve

F 6 **Re-Passivation Fill**
4711 99% F_2 (only single gases)

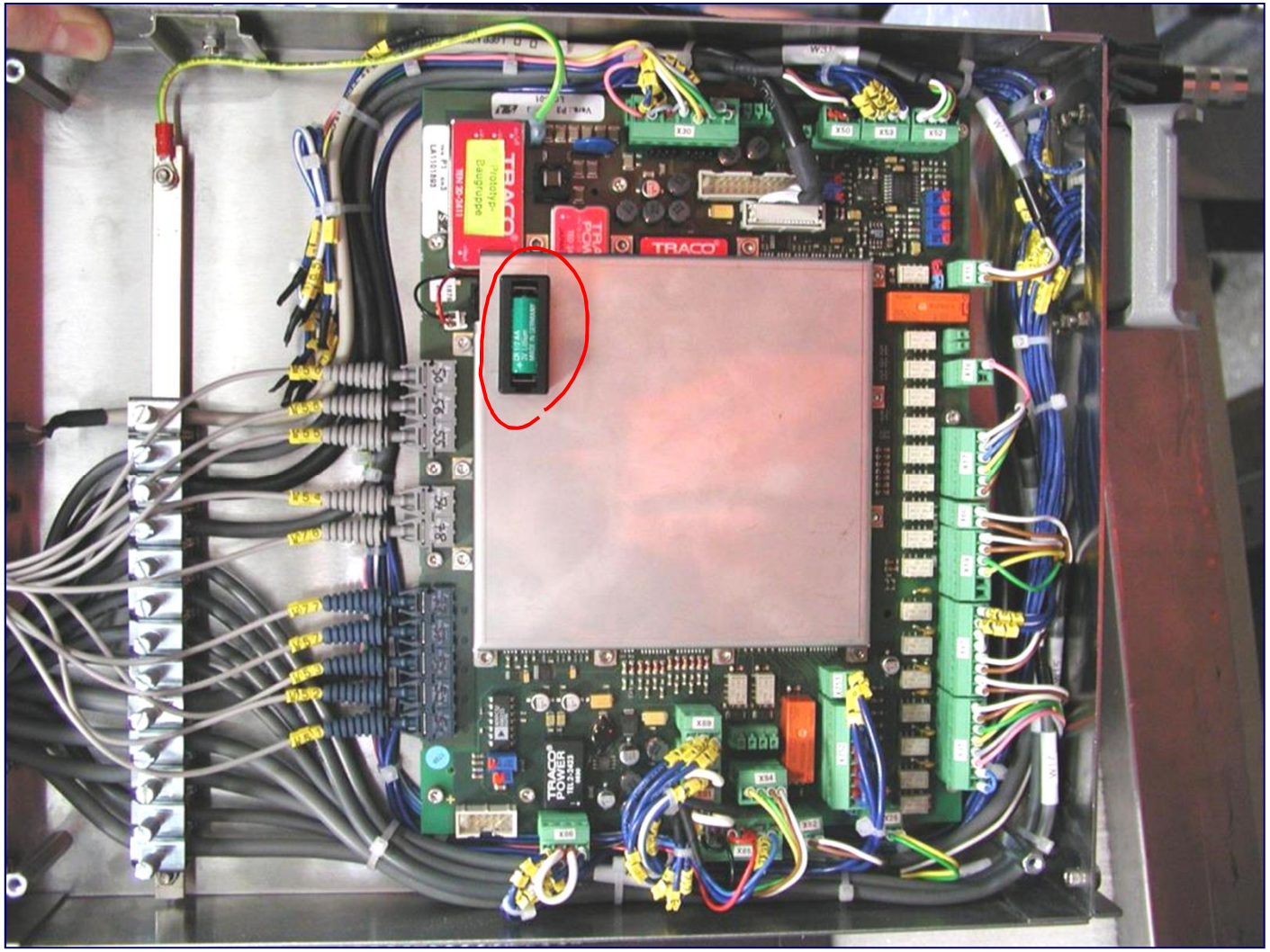
F 7 **Energy Regulation Parameters**

F 8 **Int. Burst Generator Settings**
4 parameters to set sequence

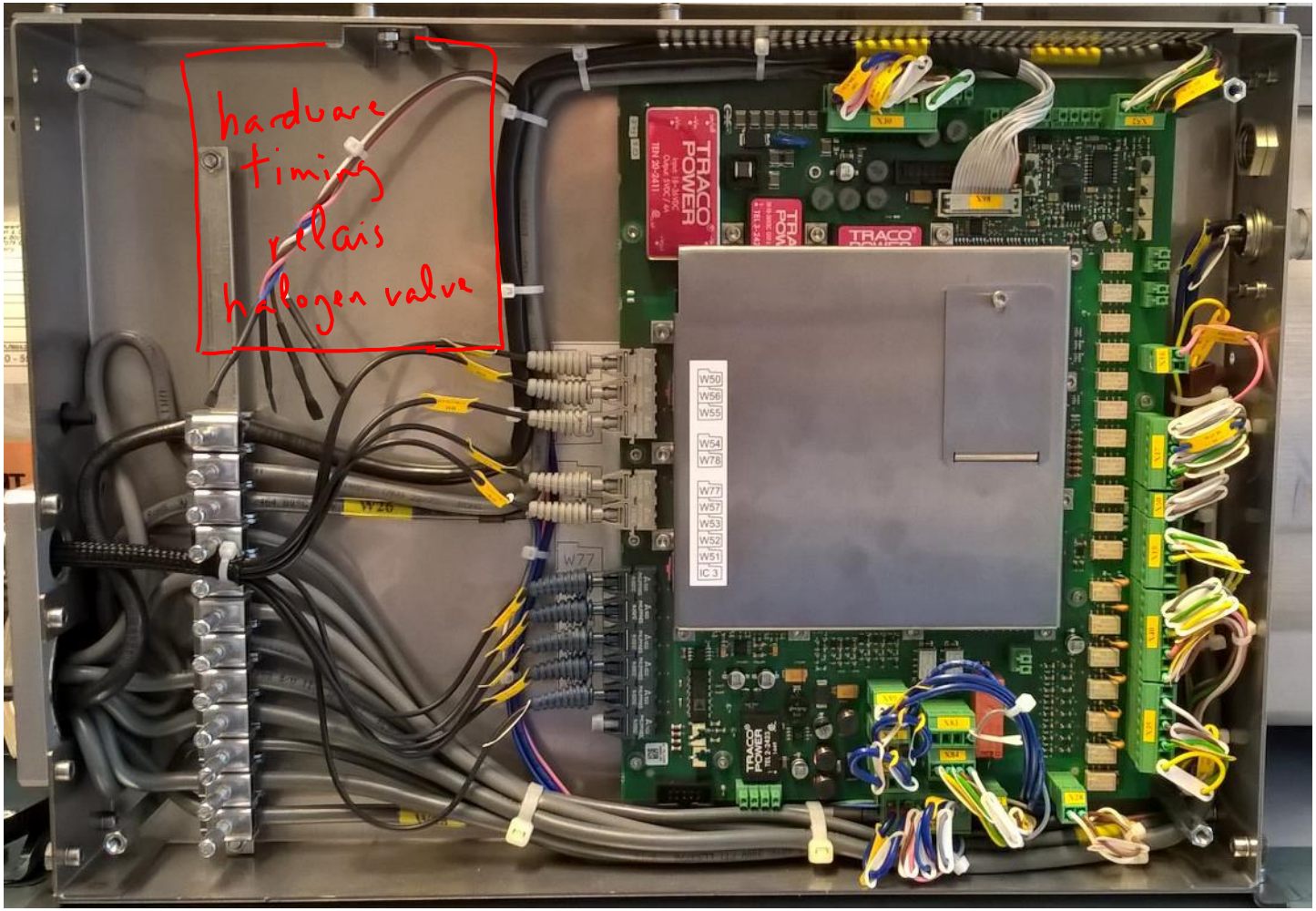
F 9 **Charge on Demand On/Off**
Switch Control HHT ← → Host

F10 **Date, Time / COM1 Mode / Shutdown**

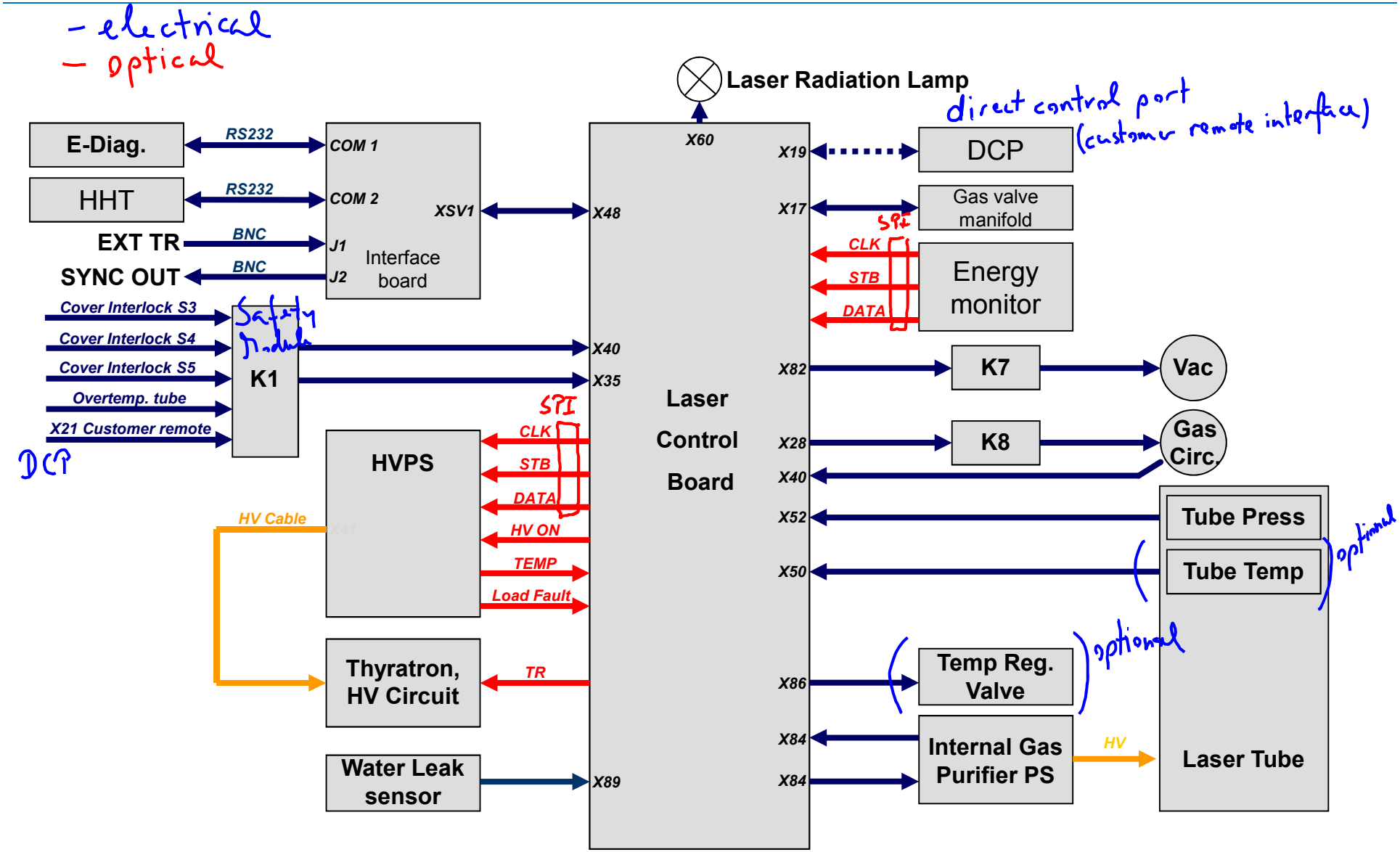
Laser Control Board (LCB-01)



Laser Control Board (LCB-02)



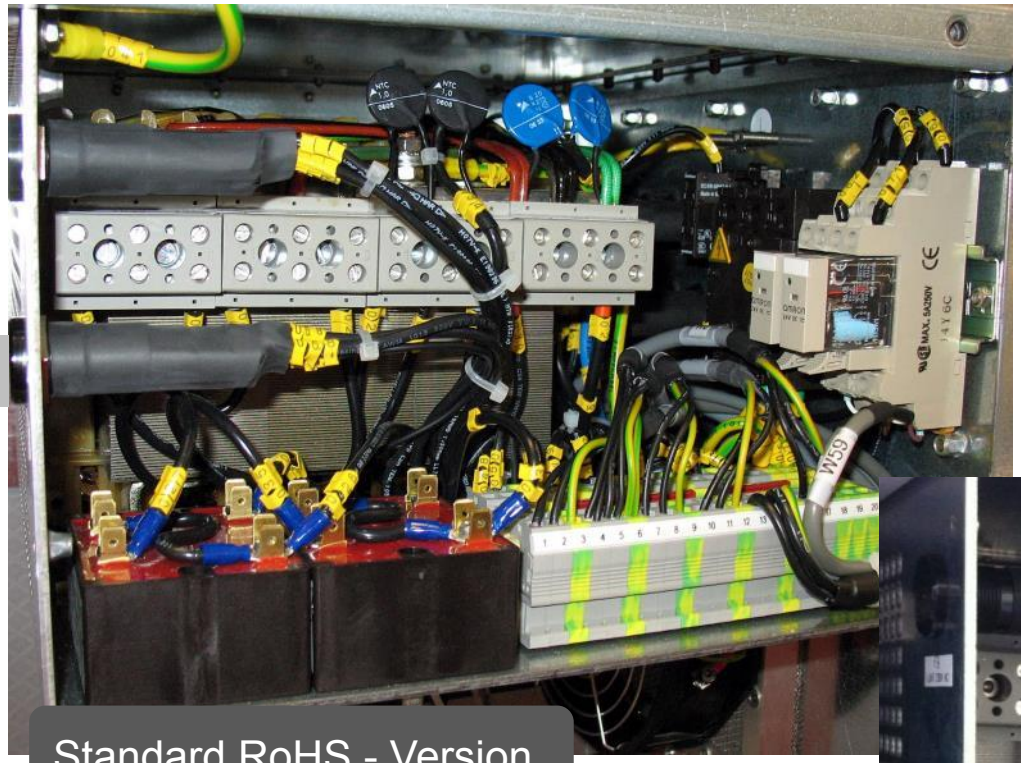
Block Diagram Electrics



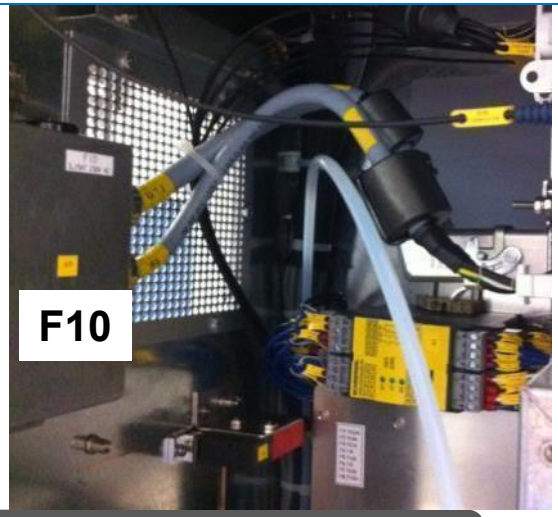
Transformer box

F9

F10

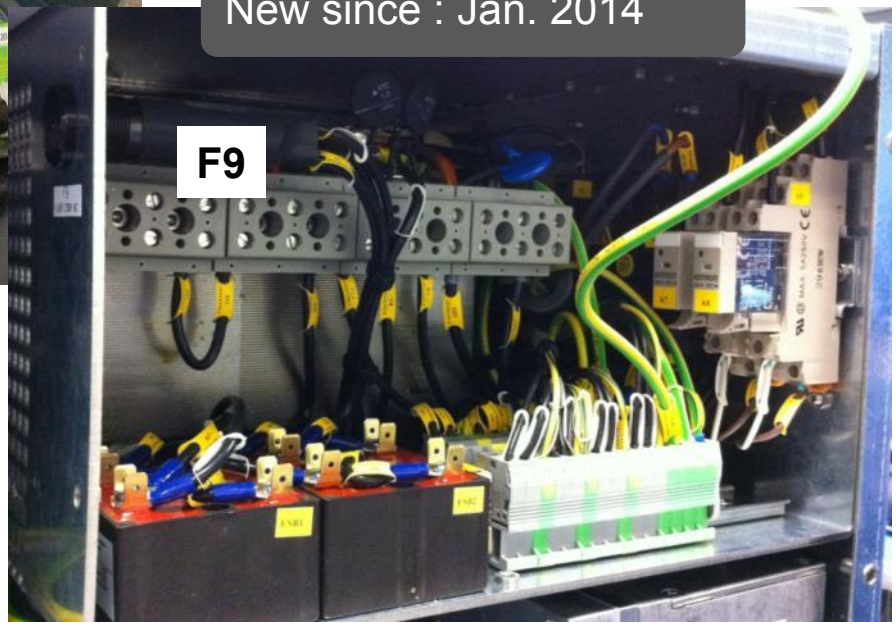


Standard RoHS - Version



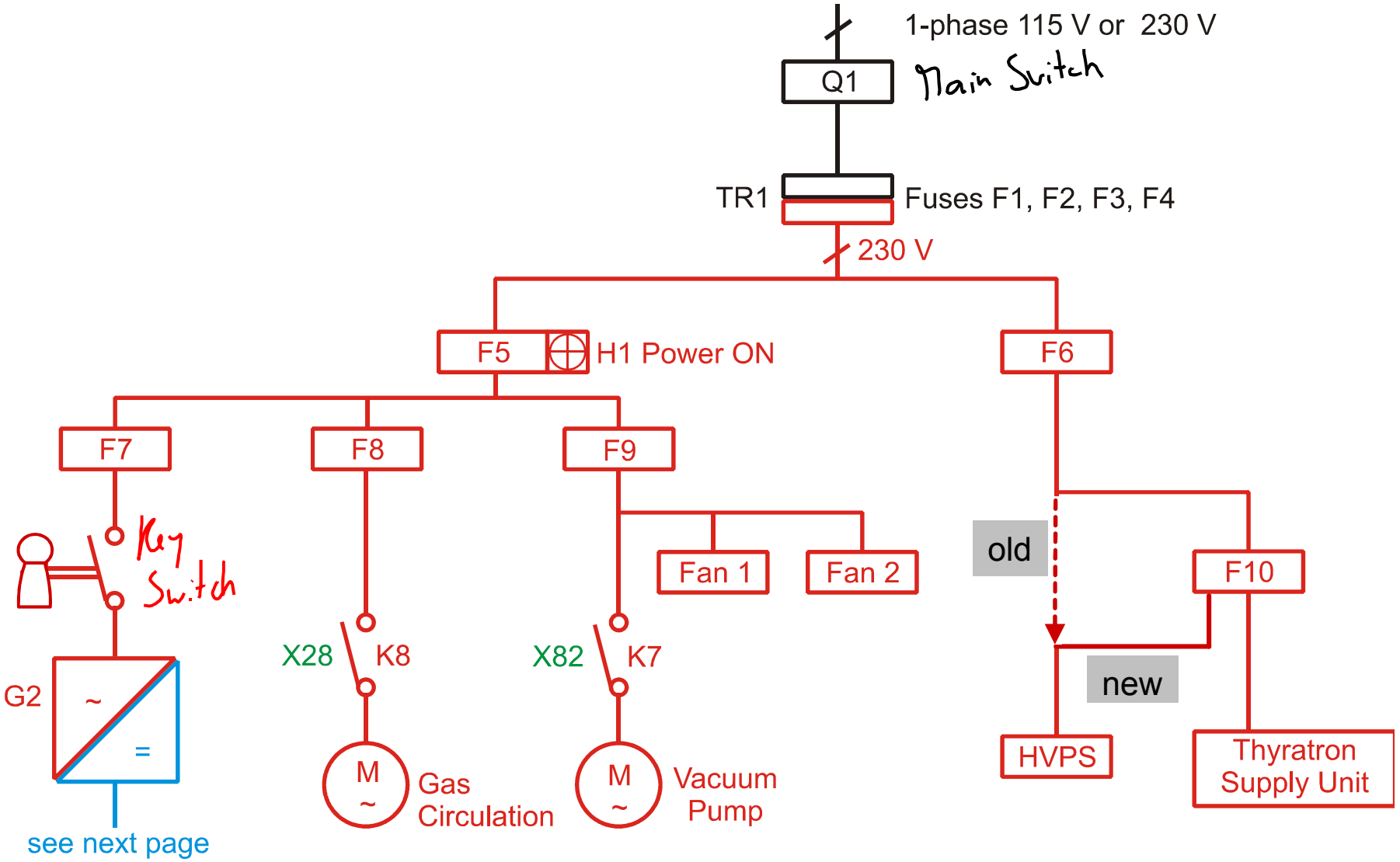
F10

New since : Jan. 2014

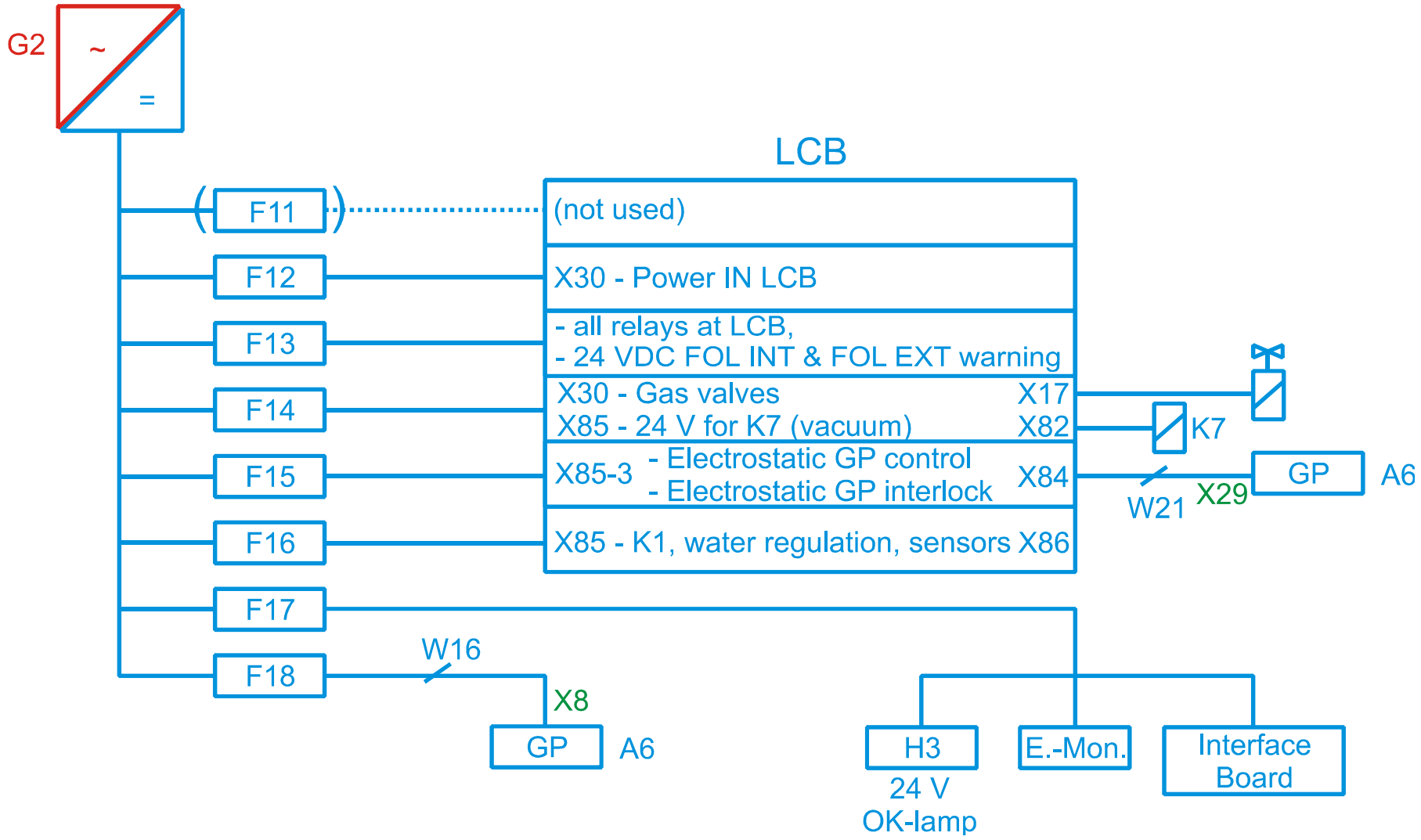


F9

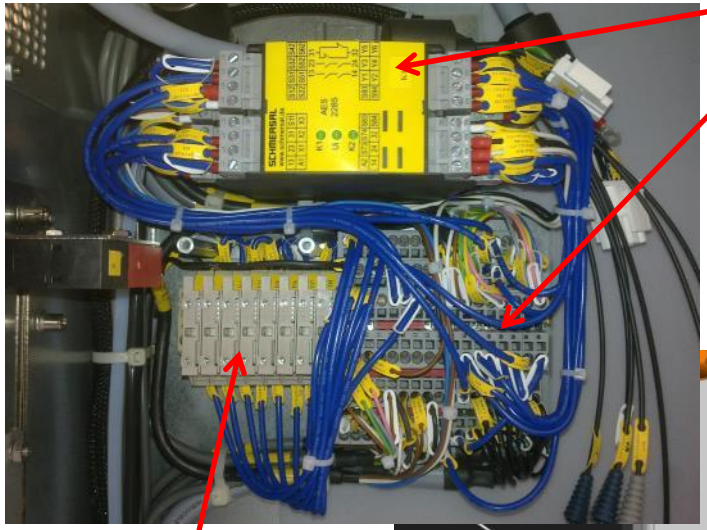
Power Distribution (115/230 V AC)



Power Distribution (24 V DC)



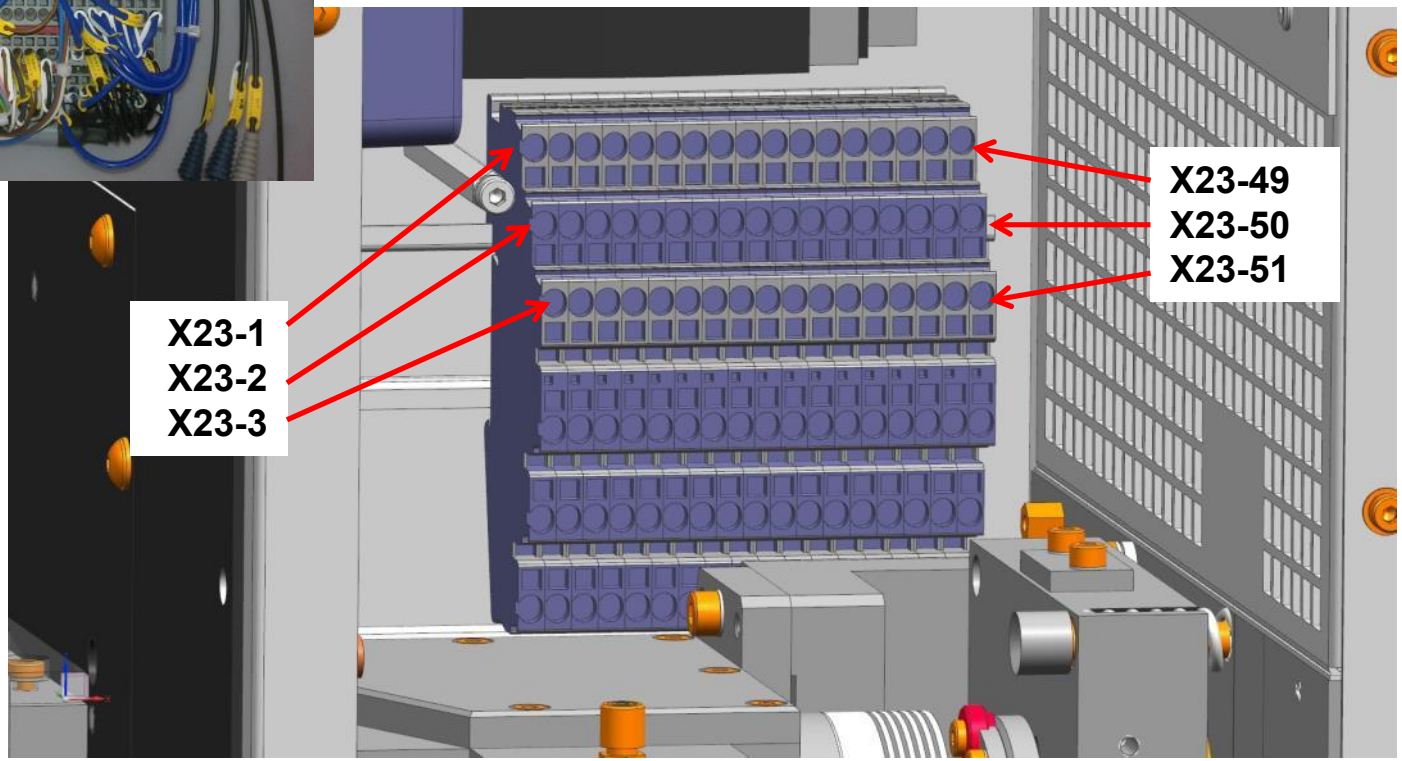
Power Distribution - K1, Fuses & X23



Safety relay K1

Terminal X23

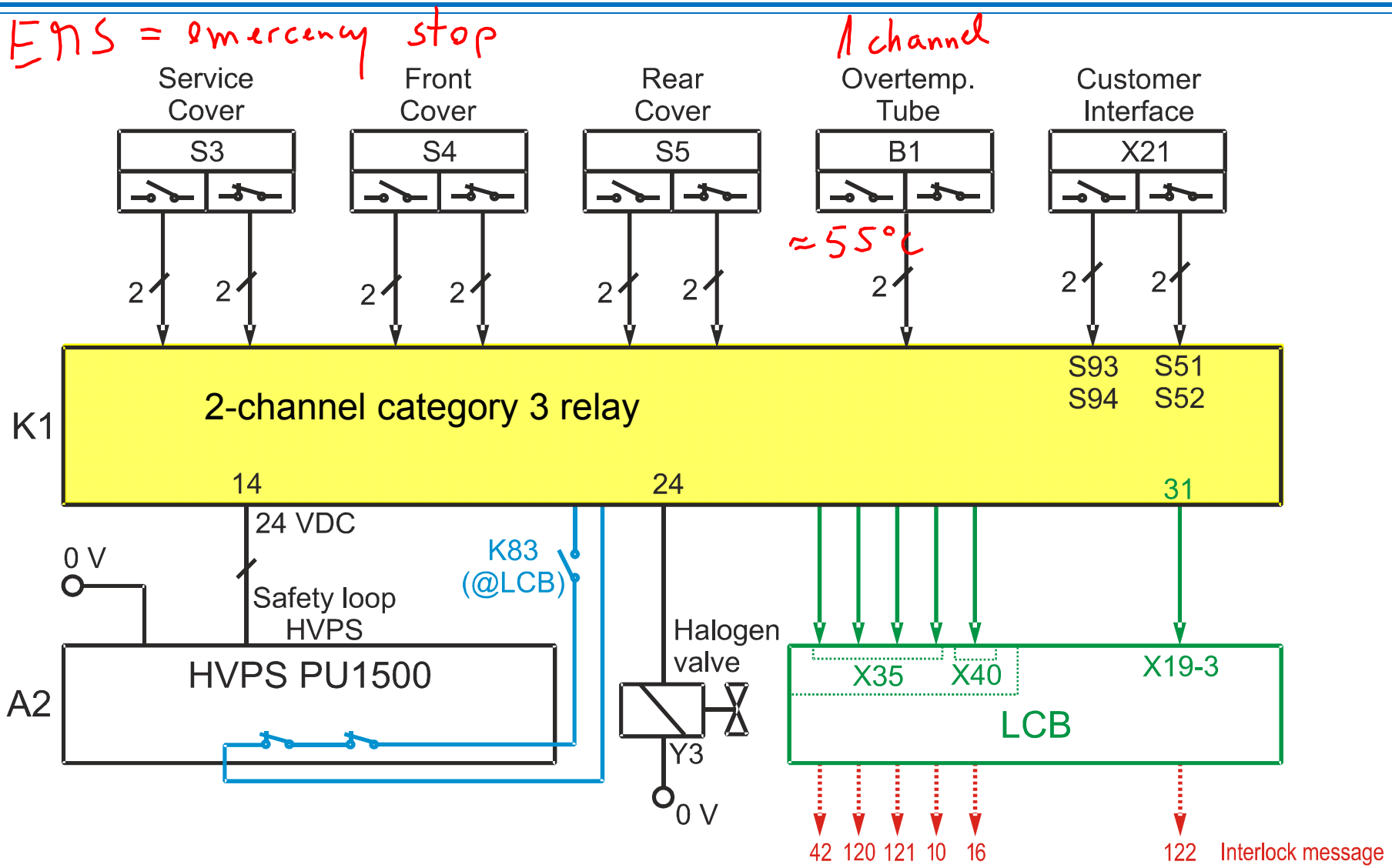
Fuse terminal F11-18



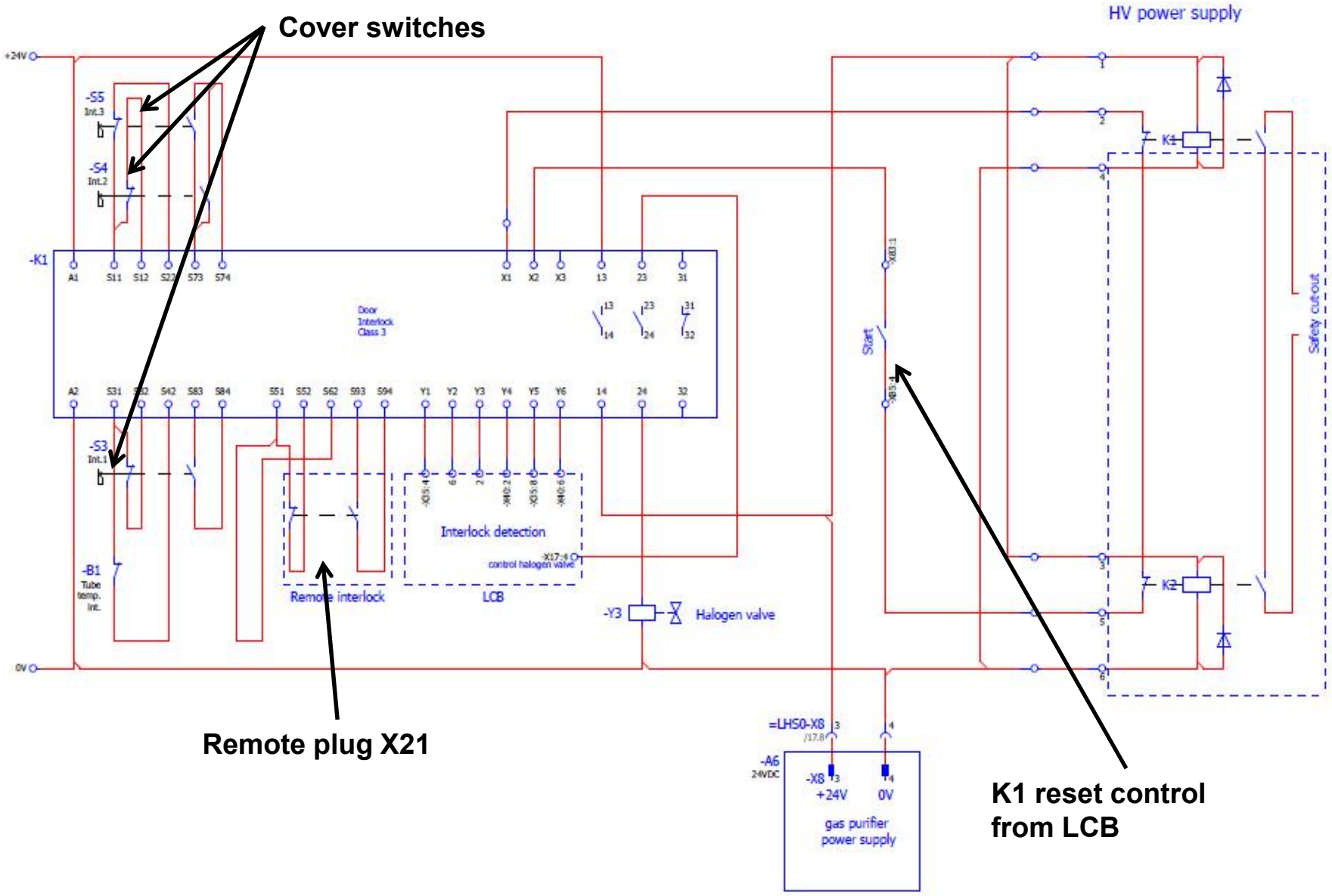
X23-1
X23-2
X23-3

X23-49
X23-50
X23-51

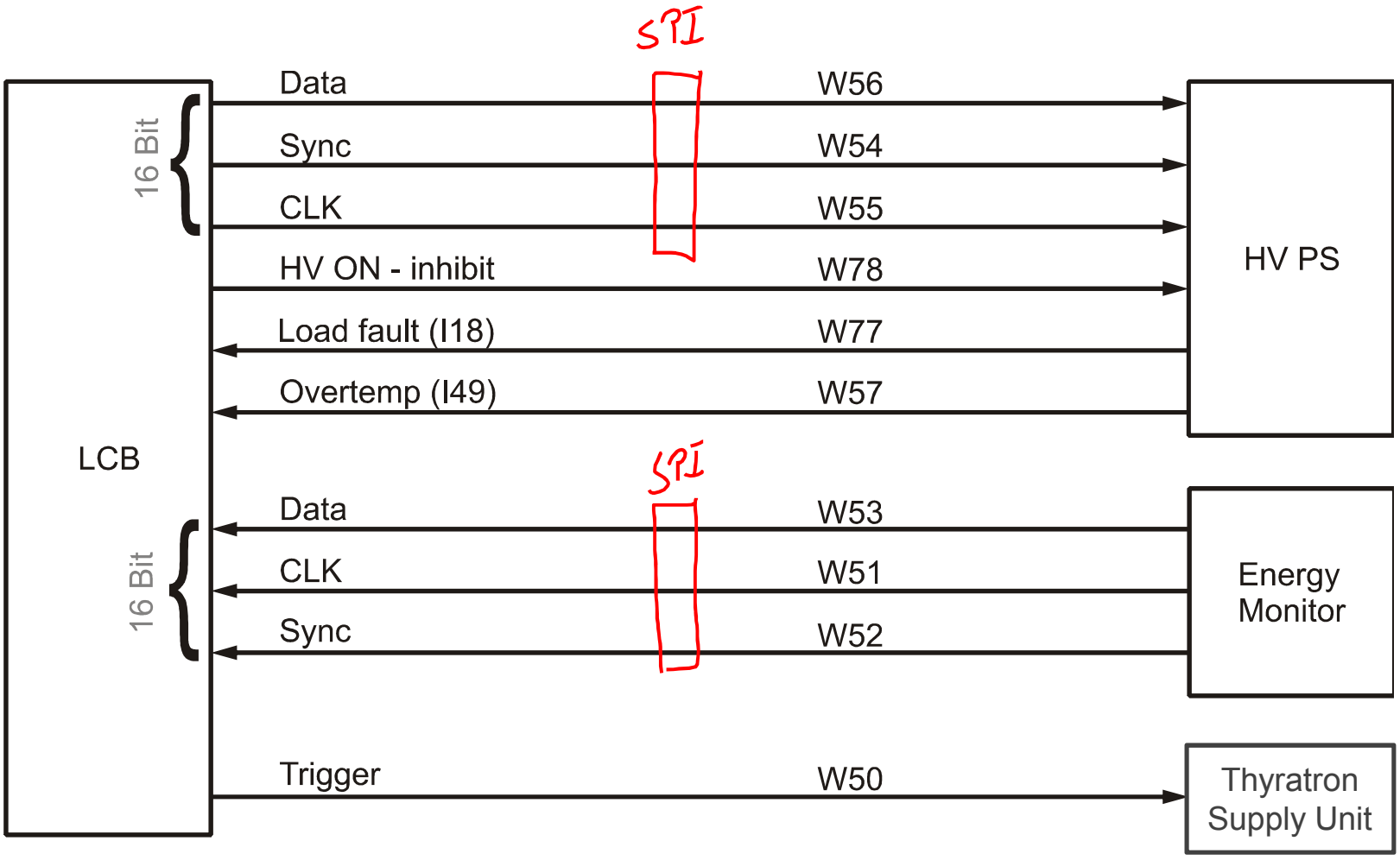
Category III Safety Circuit (Block picture)



Category III Safety Circuit (Schematic)



FOL Connections

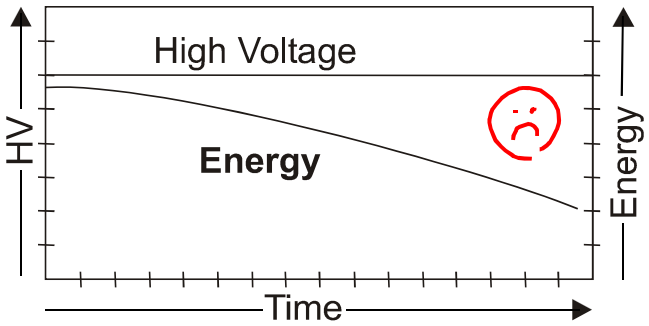


Trigger Modes

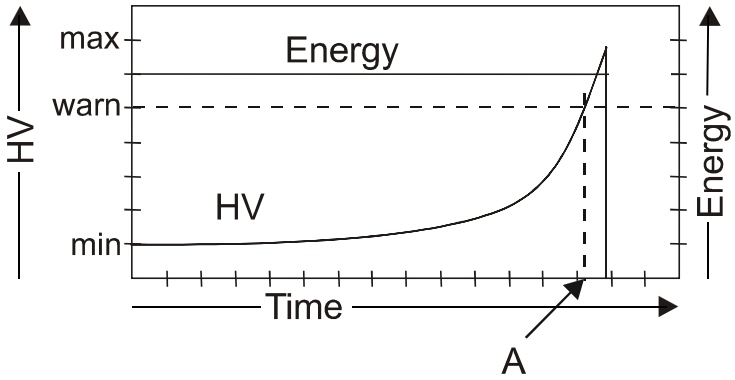
• **INT**	Internal trigger
• **INTG**	Internal trigger with external gate at ext. Trigger in
• **INT COUNTS**	Countdown of preseted counter with internal trigger signal
• **EXT**	External trigger → High Energy Mode? on: HV=30kV 10Hz off HV=26kV 100Hz
• **EXT COUNTS**	Countdown of preseted counter with external trigger signal
• **INTB**	Internal burst generator set parameters F8
• **INTSB**	Internal burst generator with external gate

Gas Actions / Operation Modes

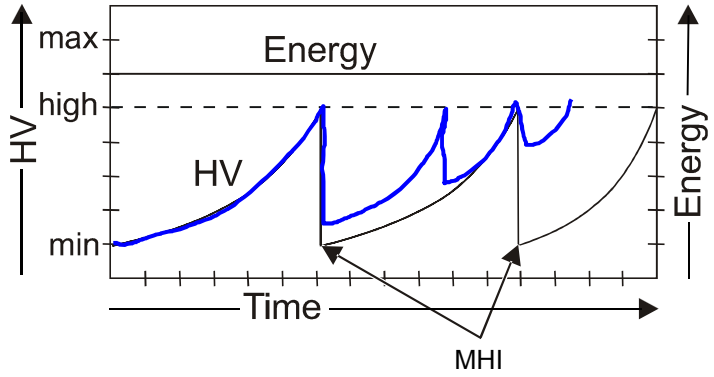
HV Constant Mode (HV Const.)



Energy Constant Mode: No Gas Replacement (NGR)



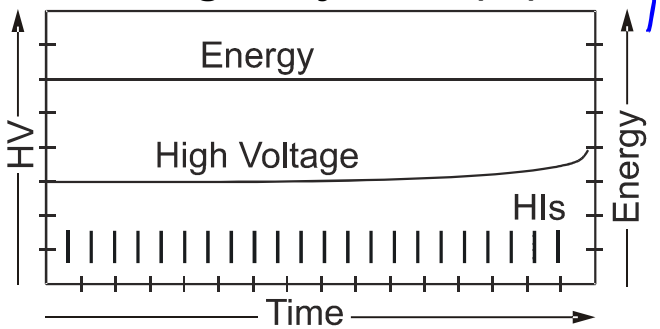
Energy Constant Mode: Macro Halogen Injections (MHI)



Energy Constant Mode: Halogen Injection (HI)

Micro

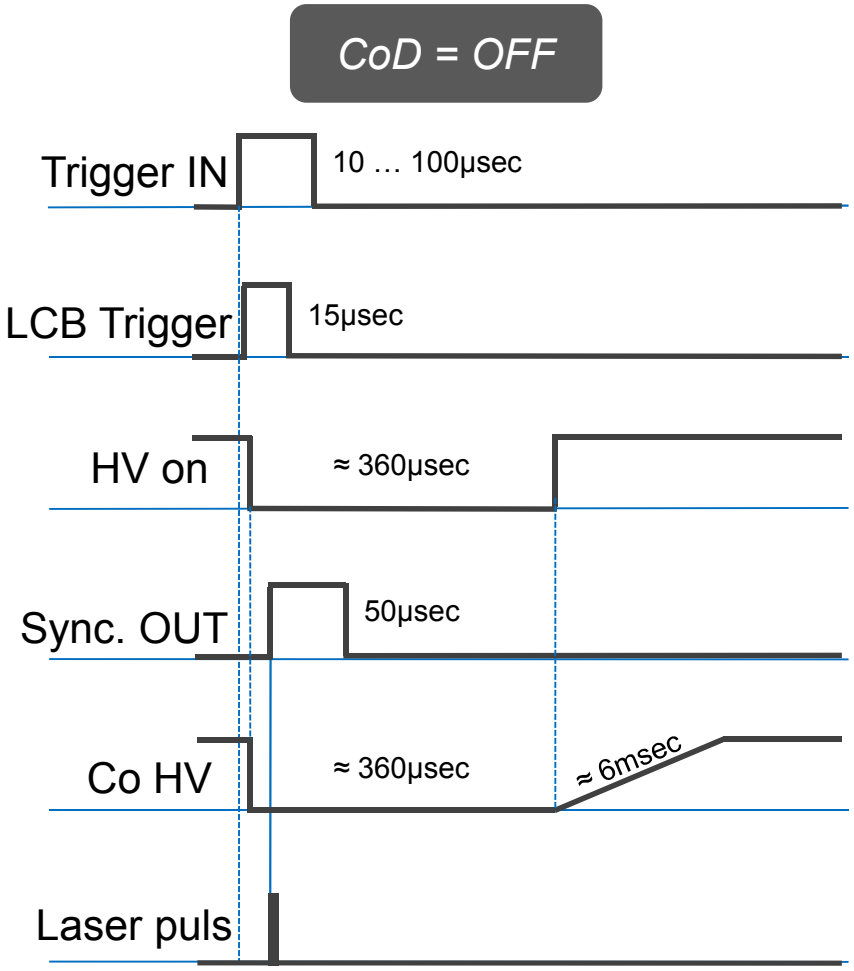
μHI



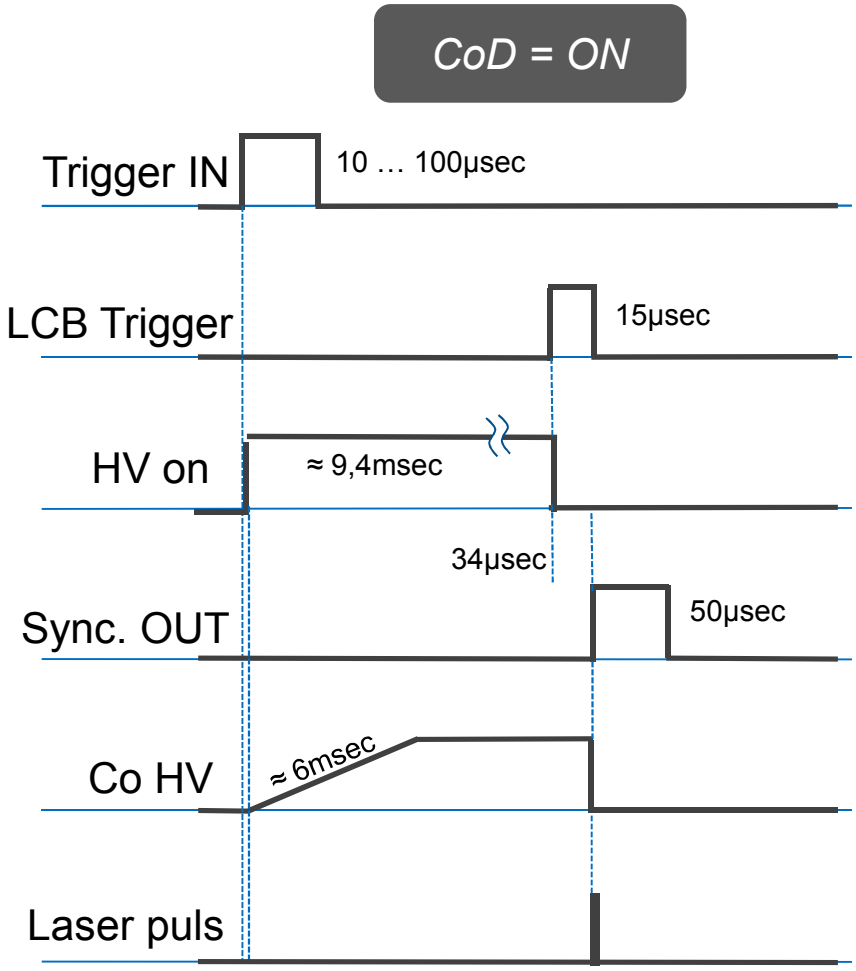
not for COMPexPro

Charge On Demand (COD)

79

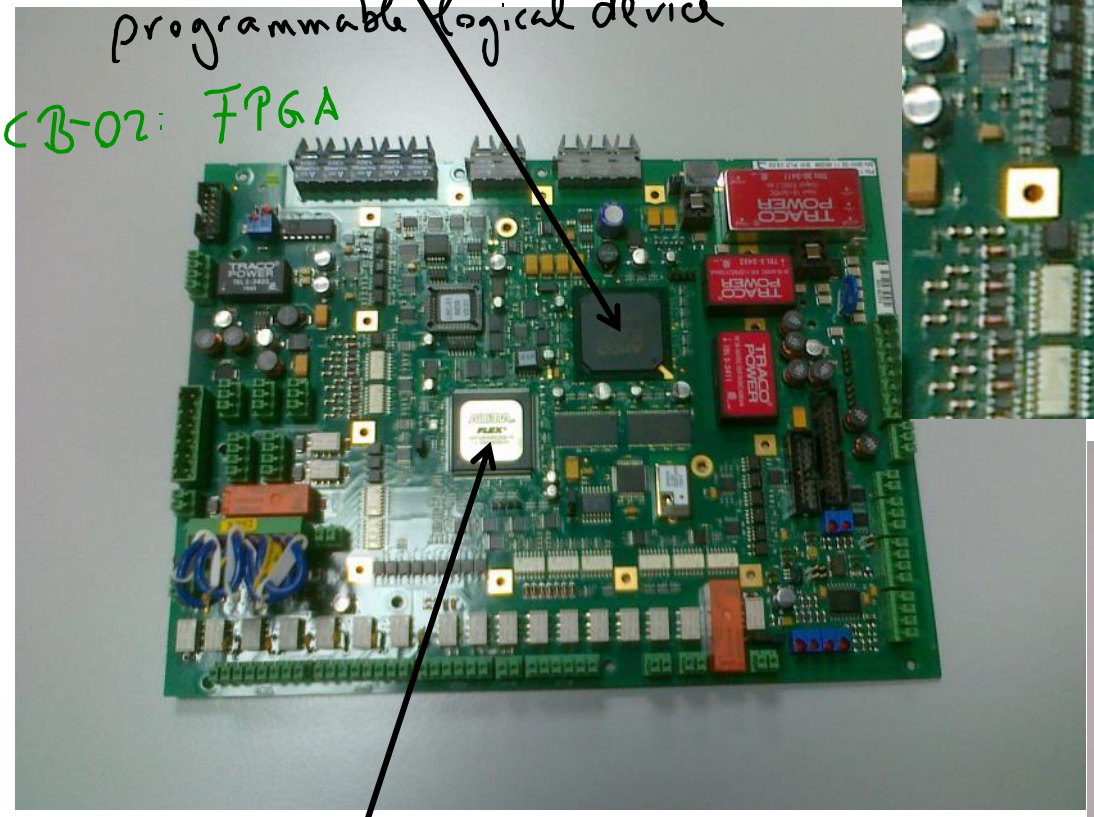


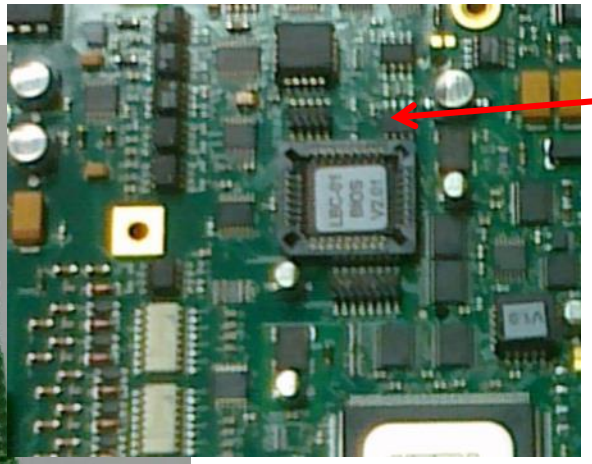
Delay Ext.Trigger -> LP
2.1 µsec

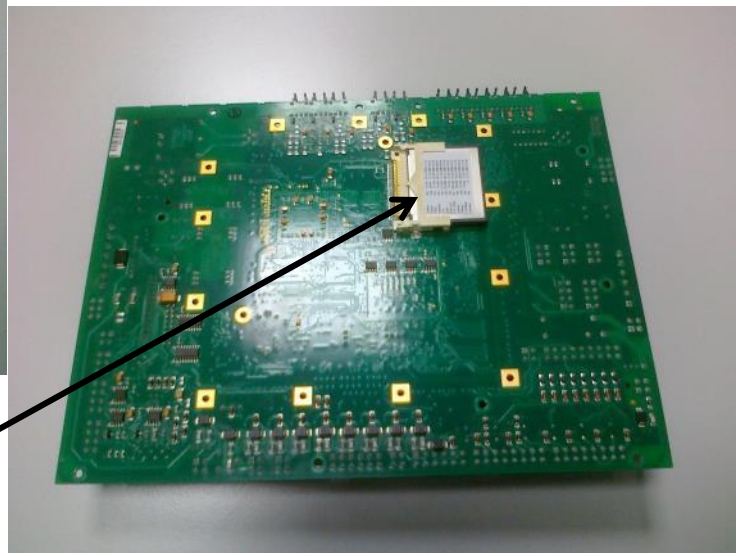


Delay Ext.Trigger -> LP
9.8 msec

LCB - Maintenance (LCB-01)

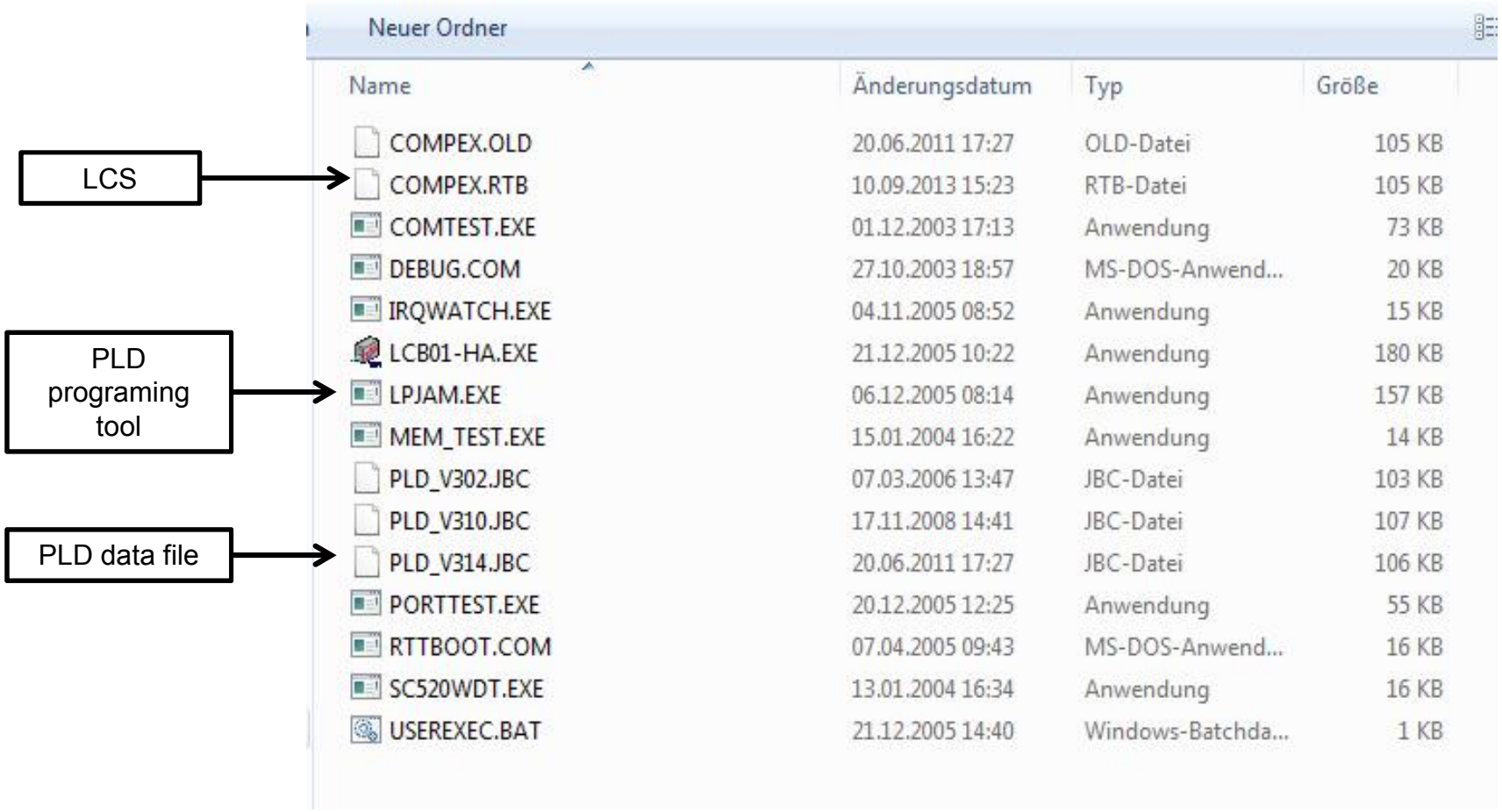




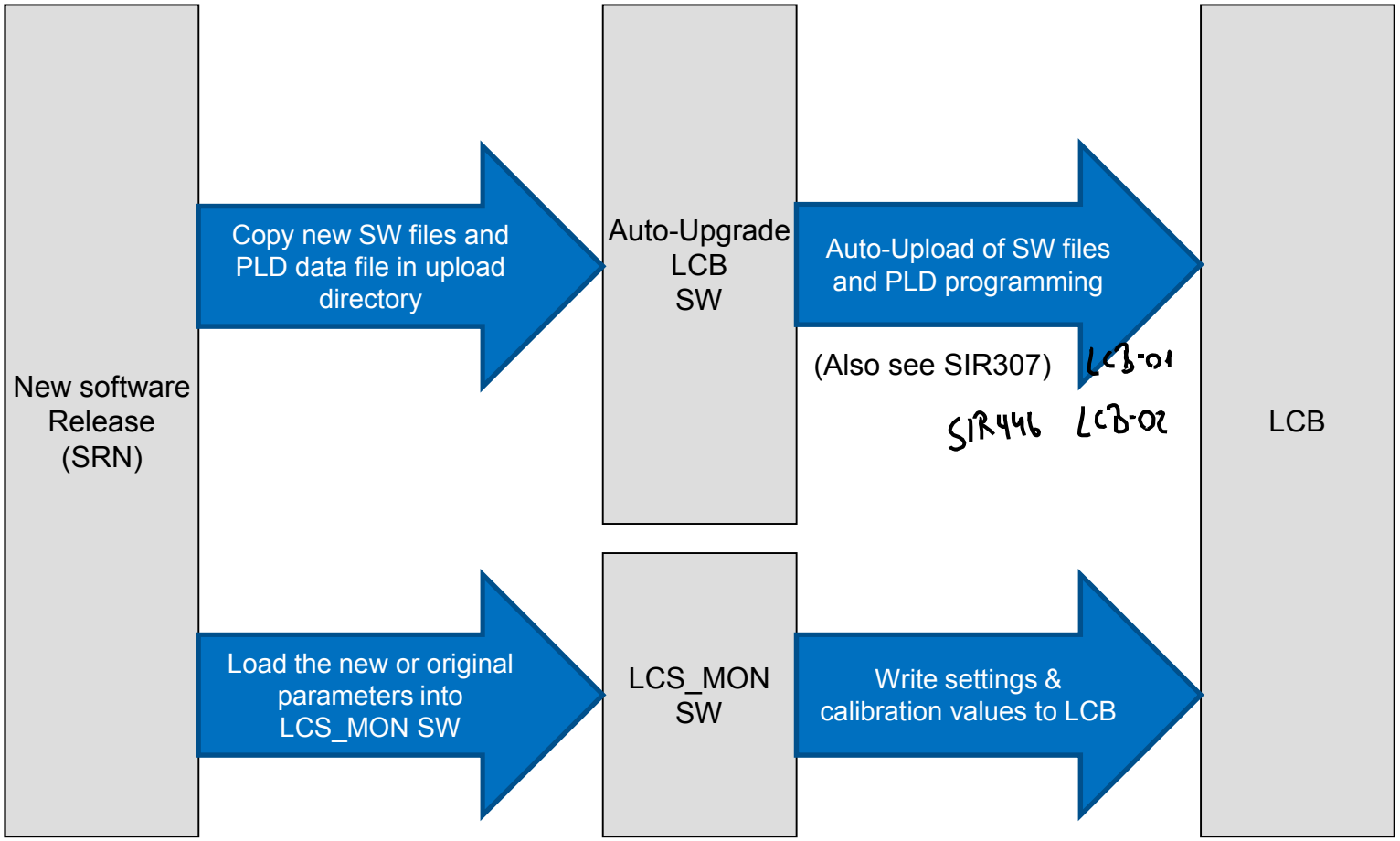


LCB – Software files (LCB-01)

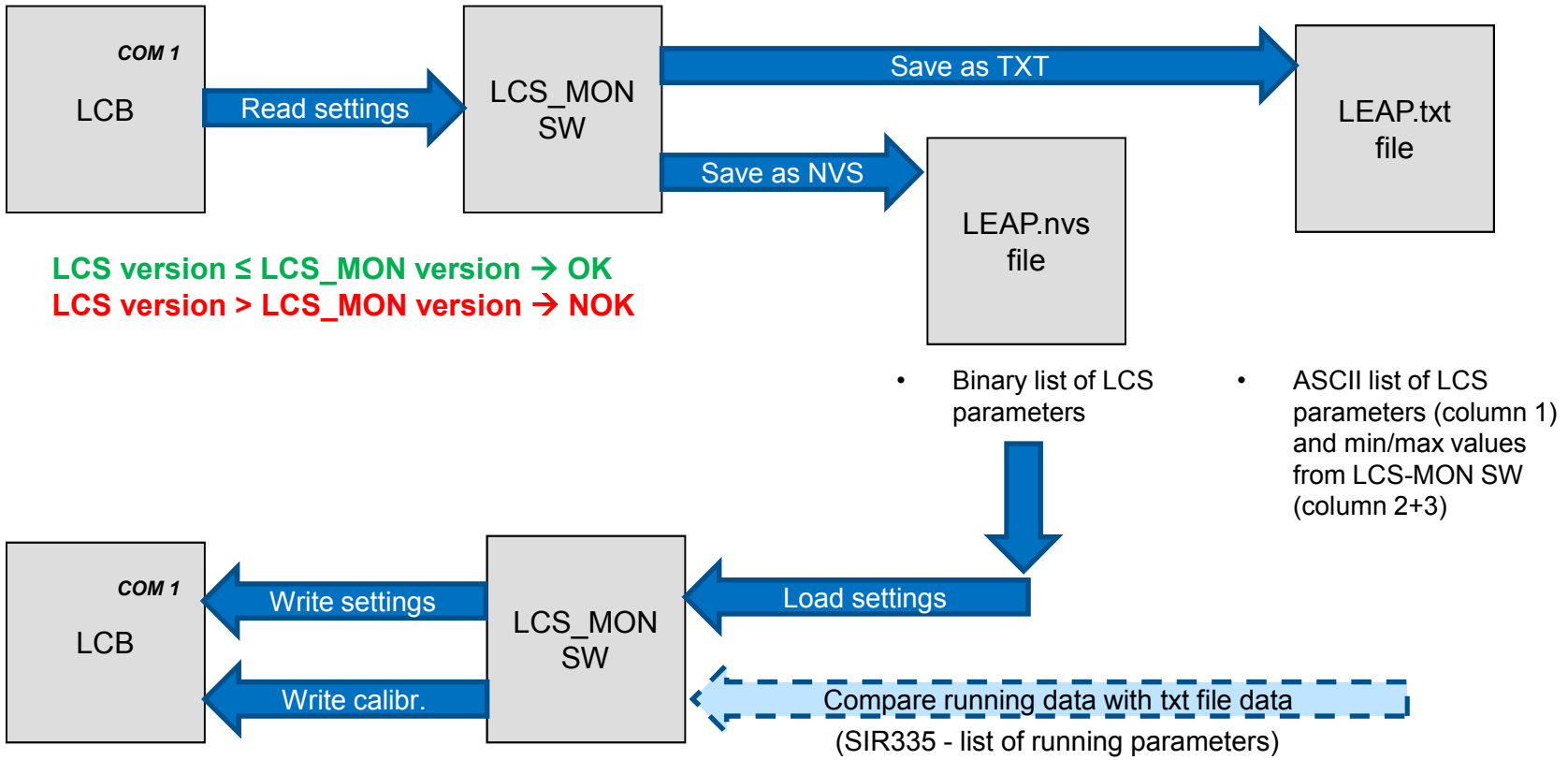
LCS files located at memory card



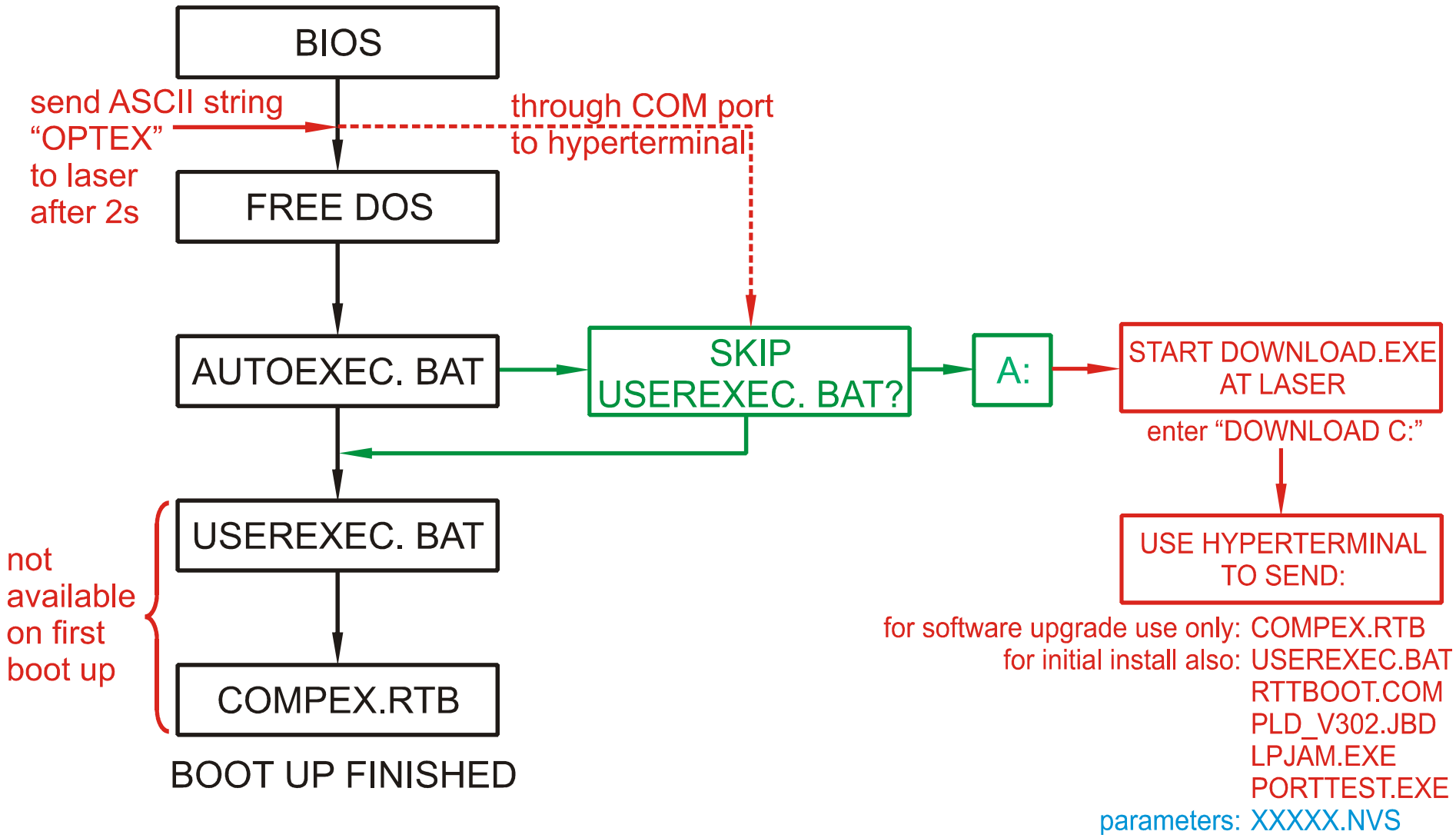
LCB – Software upgrade



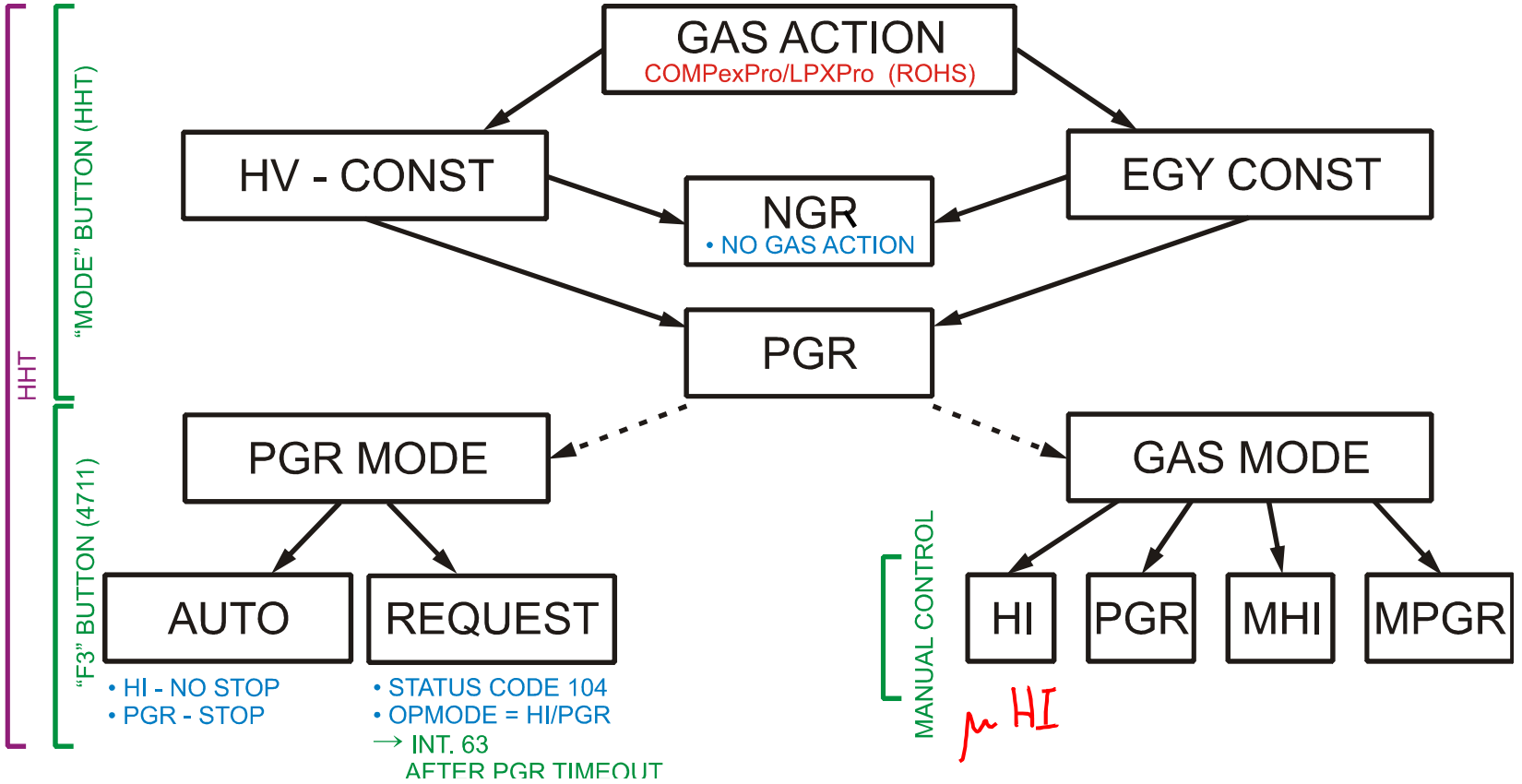
LCB – Software parameter handling/maintenance



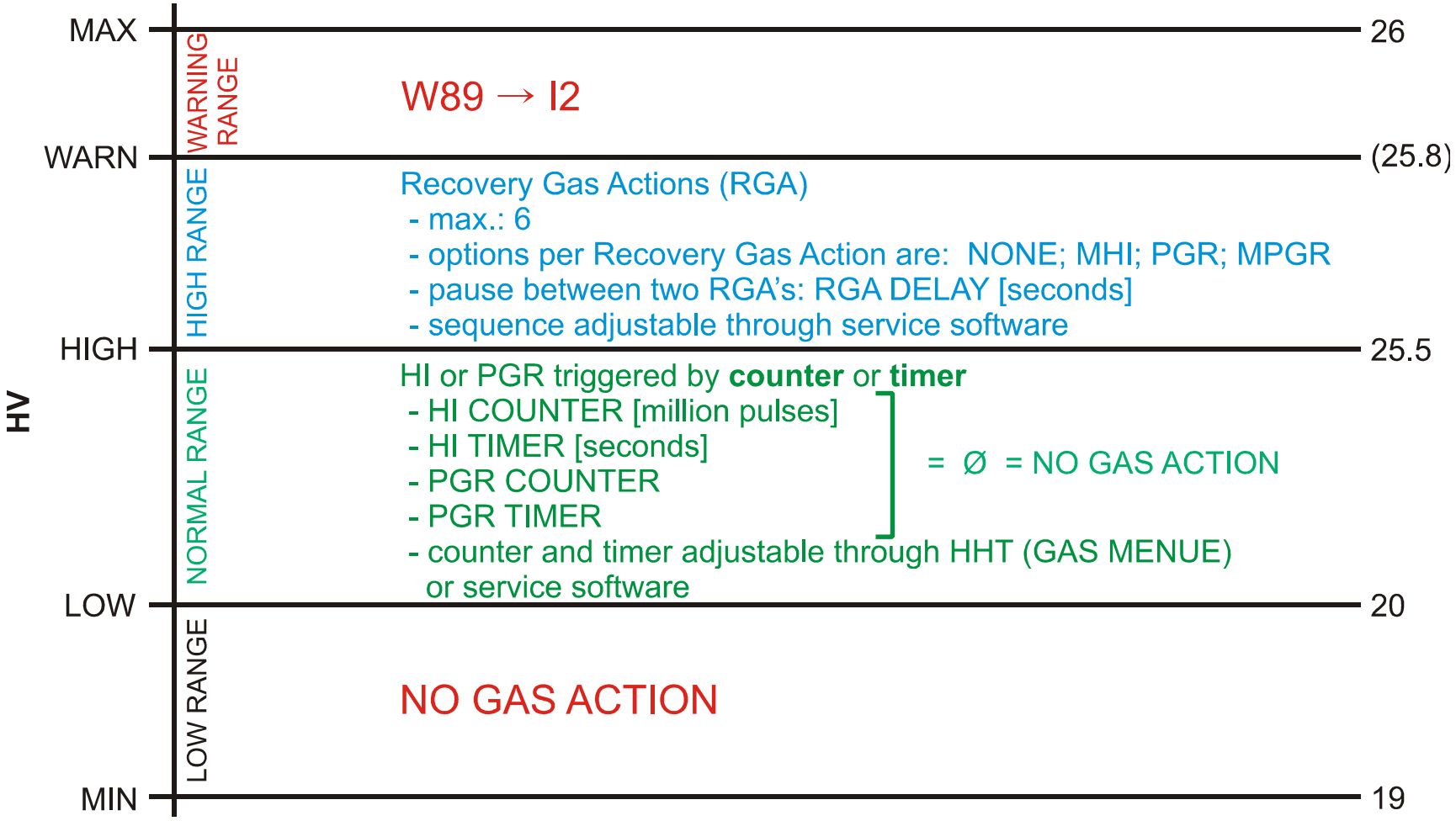
Boot Up LaserControlSoftware (LCS) LCB-01



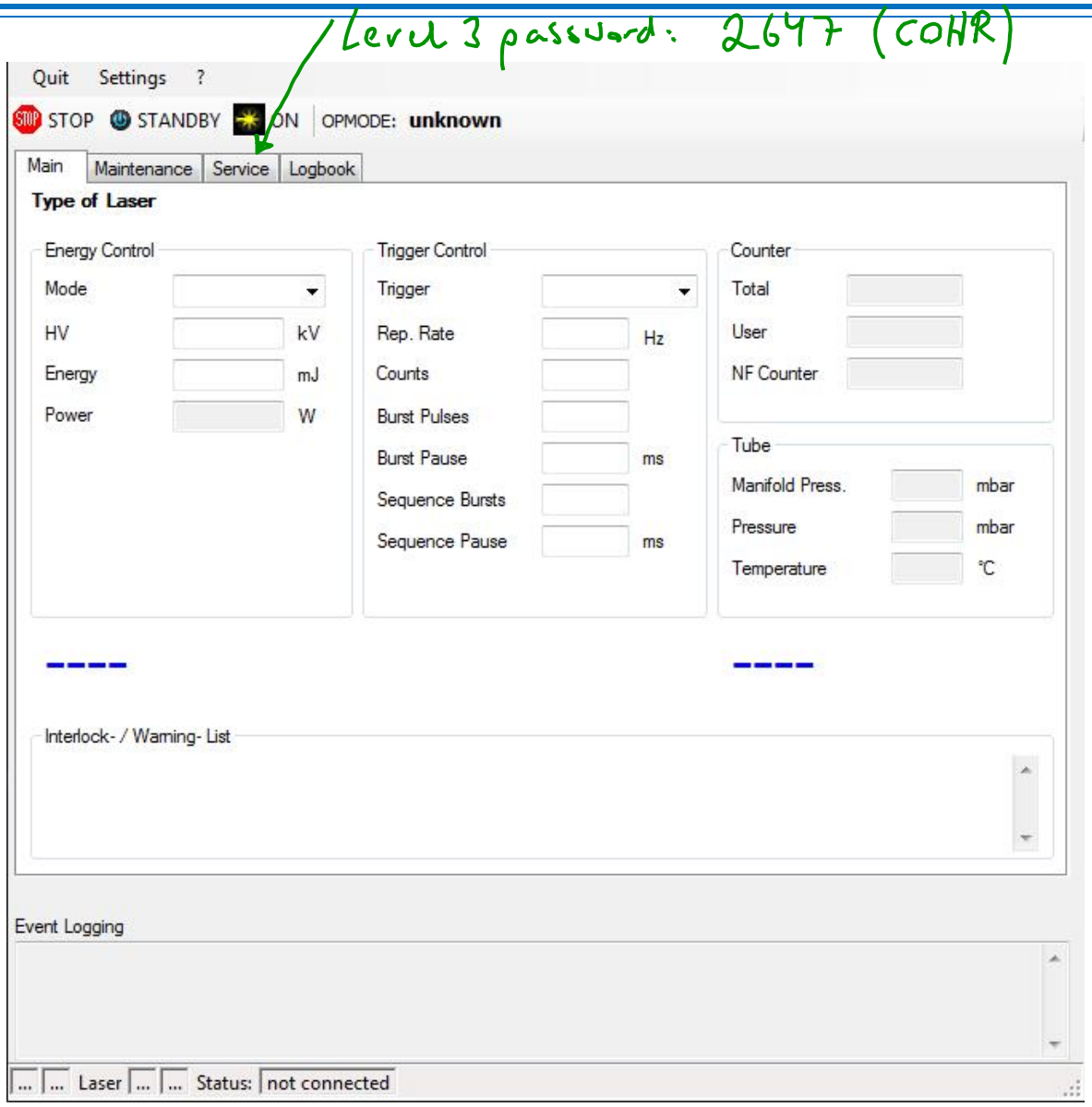
Operation Modes



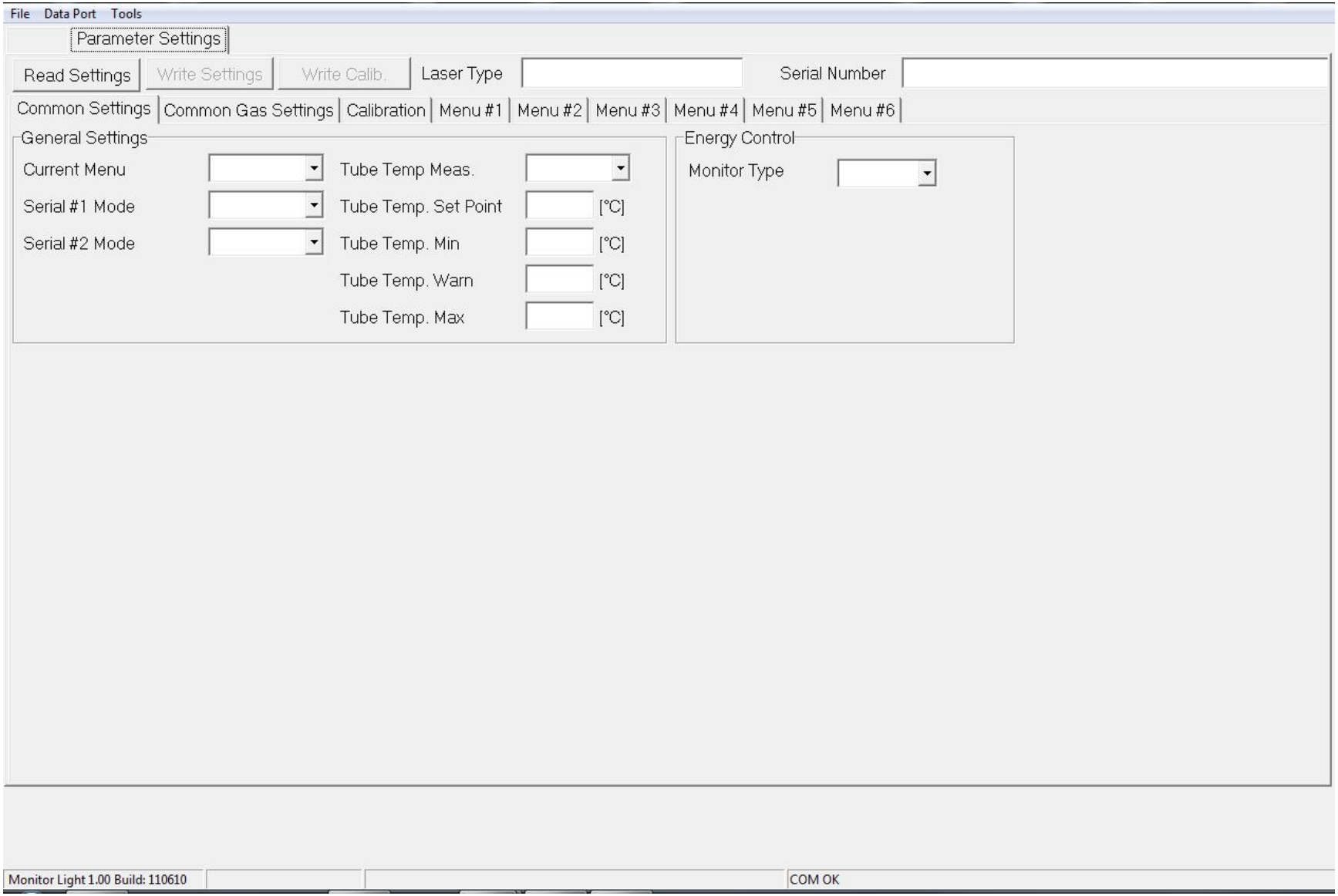
Gas Action Ranges



Software - LasControl



Software – CMPX-Mon-Light



Abbreviation

Abbr.	Comment
LCB	Laser Control Board
LCS	Laser Control Software
HHT	Hand Held Terminal
PGR	Partial Gas Replacement
NGR	No Gas Replacement
HI	Halogen Injection
COD	Charge On Demand
EMS	Emergency Stop
HVPS	High Voltage Power Supply
RoHS	Reduction of Hazardous Substances
FOL	Fiber Optic Line
GCFM	Gas Circulation Fan Motor