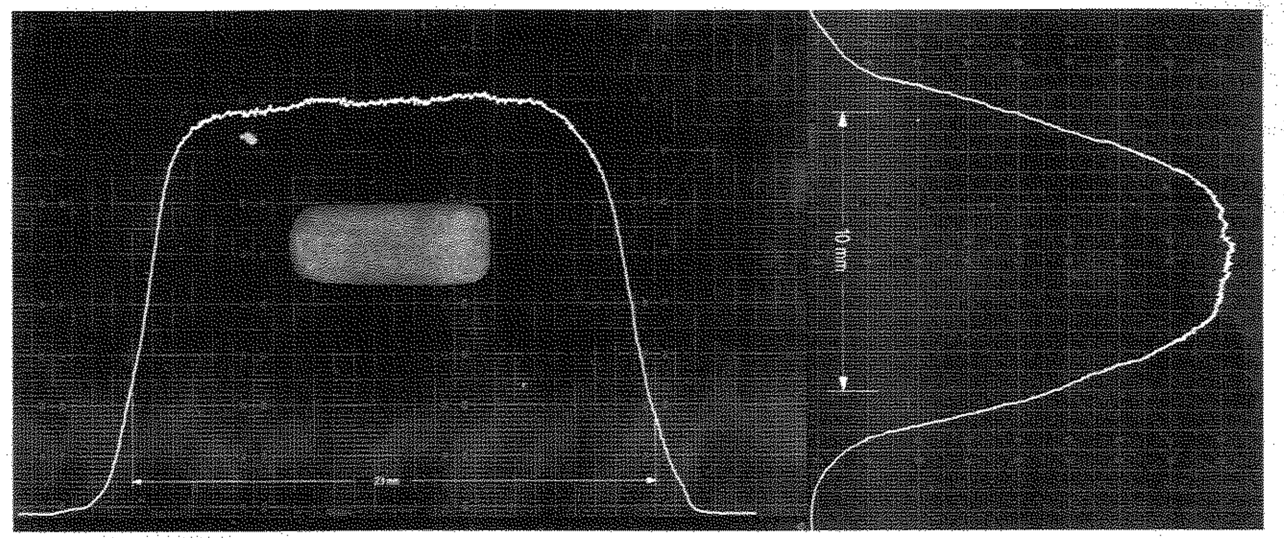
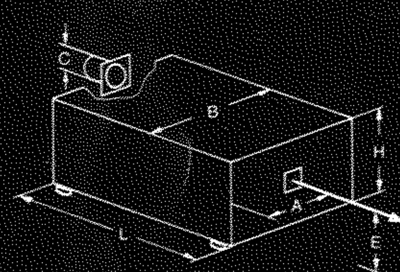
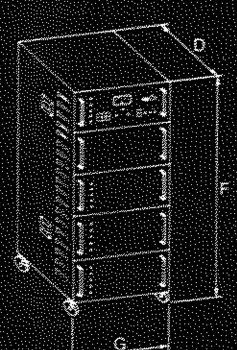


Energy density profile of EMG 103 E/MSC with XeCl (stable resonator). Polaroid pattern (actual size) taken at a distance of 20 cm.

Physical dimensions:



Laser head
L = 130 cm (100 series without ILC)
L = 150 cm (100 series with ILC)
L = 170 cm (200 series without ILC)
L = 190 cm (200 series with ILC)
B = 71 cm (100 series)
B = 86 cm (200 series)
H = 40 – 44 cm, adjustable
E = 23 – 27 cm, adjustable
C = 15 cm
A = 35 cm
Weight:
205 kg (100 series)
290 kg (200 series)



Power supply
D = 66 cm
G = 51 cm
F = 66 cm (100 series and 201)
F = 101 cm (202, 203 and 204)
Weight
110 kg (100 series and 201)
150 kg (202)
190 kg (203 and 204)

Vacuum pump
23 x 24 x 53 cm, 23 kg

ILC (optional)
Computer: 50 x 50 x 15 cm, 15 kg
Energy monitor: 16 x 20 x 40 cm, 5 kg

Power requirements
380 V, 3 phase, 50 Hz (standard version)
208 V, 3 phase, 60 Hz (US version)
208 V, 3 phase, 50 Hz (special version)
EMG 100 series: 4.5 kVA
EMG 201 MSC: 4.5 kVA
EMG 202 MSC: 7 kVA
EMG 203 and 204 MSC: 10 kVA

Water cooling
EMG 100 MSC series: 4 liters per minute
EMG 200 MSC series: 10 liters per minute

DANGER

VISIBLE AND INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION

Max. average power:	120 W
Max. output energy:	0.5 J/pulse
Pulse duration:	4 to 90 ns
Wavelength:	157 to 700 nm

EMG 101 MSC/EMG 102 MSC/
EMG 103 MSC/EMG 104 MSC/
EMG 201 MSC/EMG 202 MSC/
EMG 203 MSC/EMG 204 MSC
CLASS IV LASER PRODUCT

This product complies with DHEW Performance Radiation Standards 21 CFR Chapter I, Subchapter J
LAMBDA PHYSIK reserves the right to make any change at any time without further notice in order to provide the best product possible.

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Excimer Lasers
with Magnetic Switch Control
EMG 100 MSC Series
EMG 200 MSC Series

LAMBDA PHYSIK
LASERTECHNIK

Historical Background

Since the first thyratron-switched excimer laser became commercially available in 1977 (Lambda Physik, EMG 500), excimer laser technology has dramatically improved: automatic synchronization between preionization and the main discharge became possible by using a single thyratron for HV switching. This resulted in lower amplitude fluctuations (<5 %) as well as higher repetition rates (>100 Hz) (Lambda Physik, EMG 100 series). Subsequently Lambda Physik was the first to develop high-energy, thyratron-switched excimer lasers (EMG 200 series) as well as tunable oscillator/amplifier systems (EMG 150 series).

Gas-lifetime and HV-component lifetimes continued to be a severe problem. Then, by 1982, Lambda Physik introduced the first "gas-processor" for excimer lasers which automatically purifies the gas. The processor makes window cleaning procedures unnecessary and yields gas-lifetimes exceeding 10^7 shots (Lambda Physik "E-series"). The lifetime of the most expensive parts of an excimer laser namely the electrodes and thyratrons, was however, still limited to 10^7 shots.

In 1983, Lambda Physik accomplished another major breakthrough in excimer laser technology: by using oil-cooled thyratrons and a **M**agnetic **S**witch **C**ontrol **(MSC)** for transferring the electrical energy economically into the active gas medium, the lifetimes of the thyratron, the electrodes and even the gaseous medium have been raised by more than an order of magnitude (Lambda Physik "MSC-series").

Currently, the MSC-series is supplied with a switch-mode.

Finally, the MSC-series is available with a microprocessor system, which automatically stabilizes the output power for more than 10^7 shots (**I**ntelligent **L**aser **C**ontrol **ILC**).

Introduction to Excimer Laser Switching Techniques

The "heart" of any excimer laser is its electrical discharge circuit, including thyratron and electrodes (cf. page 4). In conventional excimer laser technology, the discharge circuit, as indicated in (a), is used (preionization is excluded for simplicity): after charging the storage capacitors C_1 with the high-voltage power supply HVPS, the full energy is transferred through the thyratron switch, (after applying a trigger pulse to its grid), to the "peaking capacitors" C_2 and, thus, to the electrodes. In order to increase the lifetime of all HV-components, especially that of the thyratron, it is necessary to avoid at all cost any current reversal (cf. Fig. 1). A complete elimination of current reversal can only be achieved by **M**agnetic **S**witch **C**ontrol.

Contrary to other standard or magnetically assisted switch techniques (cf. page 4 part a, b), **MSC** allows the **optimum adaption** of the thyratron to other HV-components.

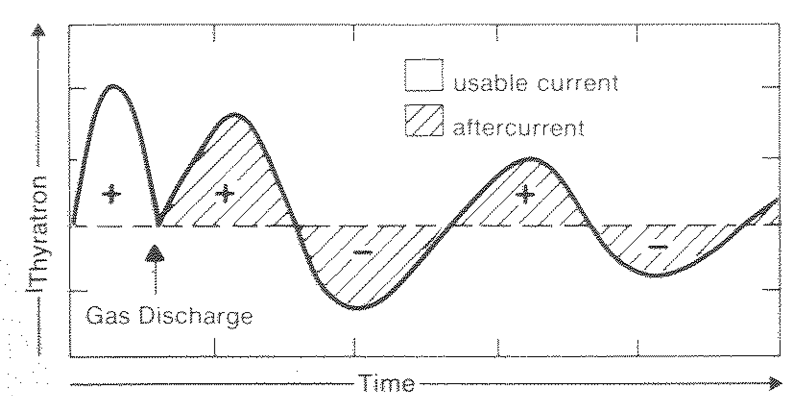
Thus, the electrical input energy is converted most efficiently into optical output energy.

In other words, electrical energy is only transferred to the active gas molecules **when it is actually required.**

Consequently not only the total effiency but also the gas lifetime is greatly increased.

In addition, the **M**agnetic **S**witch **C**ontrol **(MSC)** (cf. page 4 part c) from Lambda Physik also includes circuits for voltage enhancement and current pulse compression, which reduce the action of the thyratron to a simple trigger: peak voltage as well as current increase dI/dt, are signifanctly reduced.

Figure 1



Advantages of the Lambda Physik MSC-Series

- 2 years component warranty on the thyratron, capacitor and MSC-switch
- E-series gas processor incorporated – extended window cleaning intervals
- New electrode assembly – uniform beam and low amplitude fluctuation as a **standard** feature.
- Microprocessor-controlled power stabilization available (ILC)

Breakthrough in Component Lifetime

The MSC-technique from Lambda Physik offers several improvements for the excimer laser discharge circuit (cf. Table 2).

The most important ones being:

→ complete elimination of thyratron current reversal

→ reduction of thyratron current increase $dI_{Thyratron}/dt$ by more than one order of magnitude to about 5×10^{10} A/sec

→ reduction of thyratron operating voltage and peak current to ≈20 KV and only a few KA, respectively

The combination of all these features leads to a drastical improvement of the lifetime of all HV-components (cf. Table 2).

The lifetime of the complete electrode assembly is mainly limited by the electrode surface material and the specific type of preionization set-up: Since sparks are normally used for preionization, the material used for the preionization electrodes can be sputtered into other regions of the laser head. This not only reduces the lifetime of the preionization electrodes, but also generates impurities inside the laser head, reduces the halogen gas concentration due to the formation of organometallic complexes (especially with the fluorines), leads to instabilities in the main discharge itself and, thus, also reduces the thyratron lifetime.

In both the EMG 100-series '84 and the MSC-series, the sputtering process mentioned above is reduced to a minimum: first, the preionization is spatially decoupled from the main electrodes thereby avoiding sparks on the main electrode surfaces. Thus, the main electrodes need not be fully made from a nickle, a material which exhibits poor heat transfer characteristics and mechanical instabilities. Secondly, the preionization is now more symmetric offering a very uniform discharge and concomitantly a very uniform laser beam.

In this manner, the lifetime of the electrodes has been increased by more than one order of magnitude.

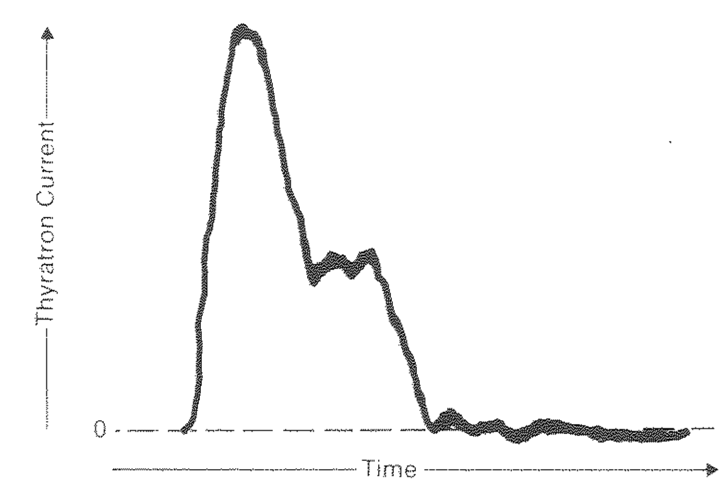
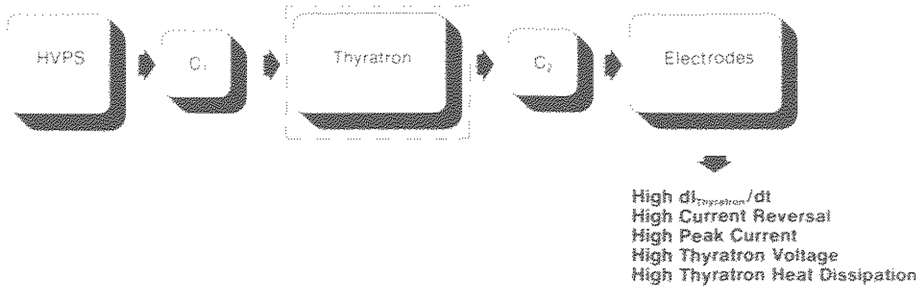
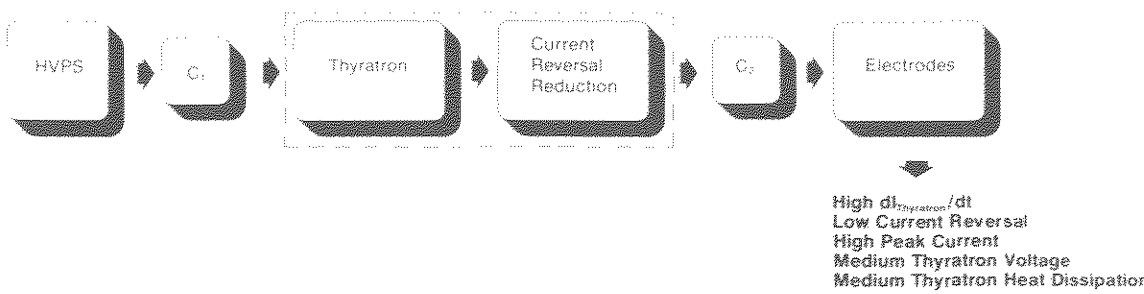


Figure 2a

Standard: Thyratron Switch (a)



Improved: Magnetic Assist (b)



State-of-the-art: Lambda Physik MSC (c)

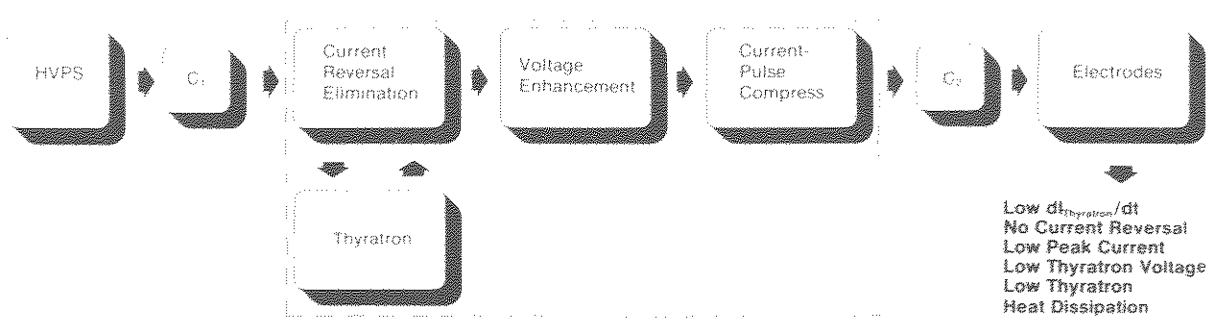


Table 2: Excimer Laser Discharge Circuit Data (MSC-Series)

	Lambda Physik EMG 103 MSC – KrF	Lambda Physik EMG 203 MSC – XeCl
Electrical Av. Power Fed Into Power Supply[2]	4.5 KW	10 KW
Average Laser Ouput Power	45 W	100 W
Repetition Rate	200 Hz	250 Hz
Typical Thyratron Operating Voltage	24 KV	23 KV
Thyratron Switching Losses	<1%	<1%
Thyratron Peak Current	5 KA	6 KA
Thyratron Peak Power	8 MW	9 MW
Thyratron Current Reversal	zero	zero
Pulse Compression	yes	yes
Current Increase $\frac{dI_{Thyratron}}{dt}$	44 KA/µs	60 KA/µs
Power Supply Design	Resonant Charging[1]	Resonant Charging[1]
Gas Cleaning System (Processor)	yes	yes
Oil-cooled Thyratron And MSC-Circuit	yes	yes

1) Switch Mode Power Supply (charge-on-demand) included in ILC-option
2) Including power for gas fan motor, gas processor, lamps etc.

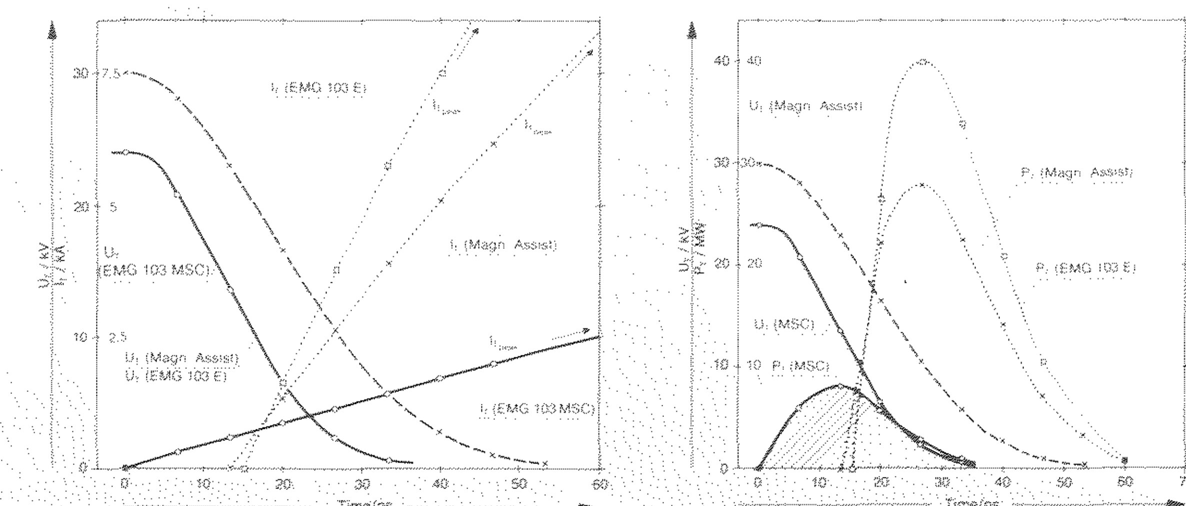
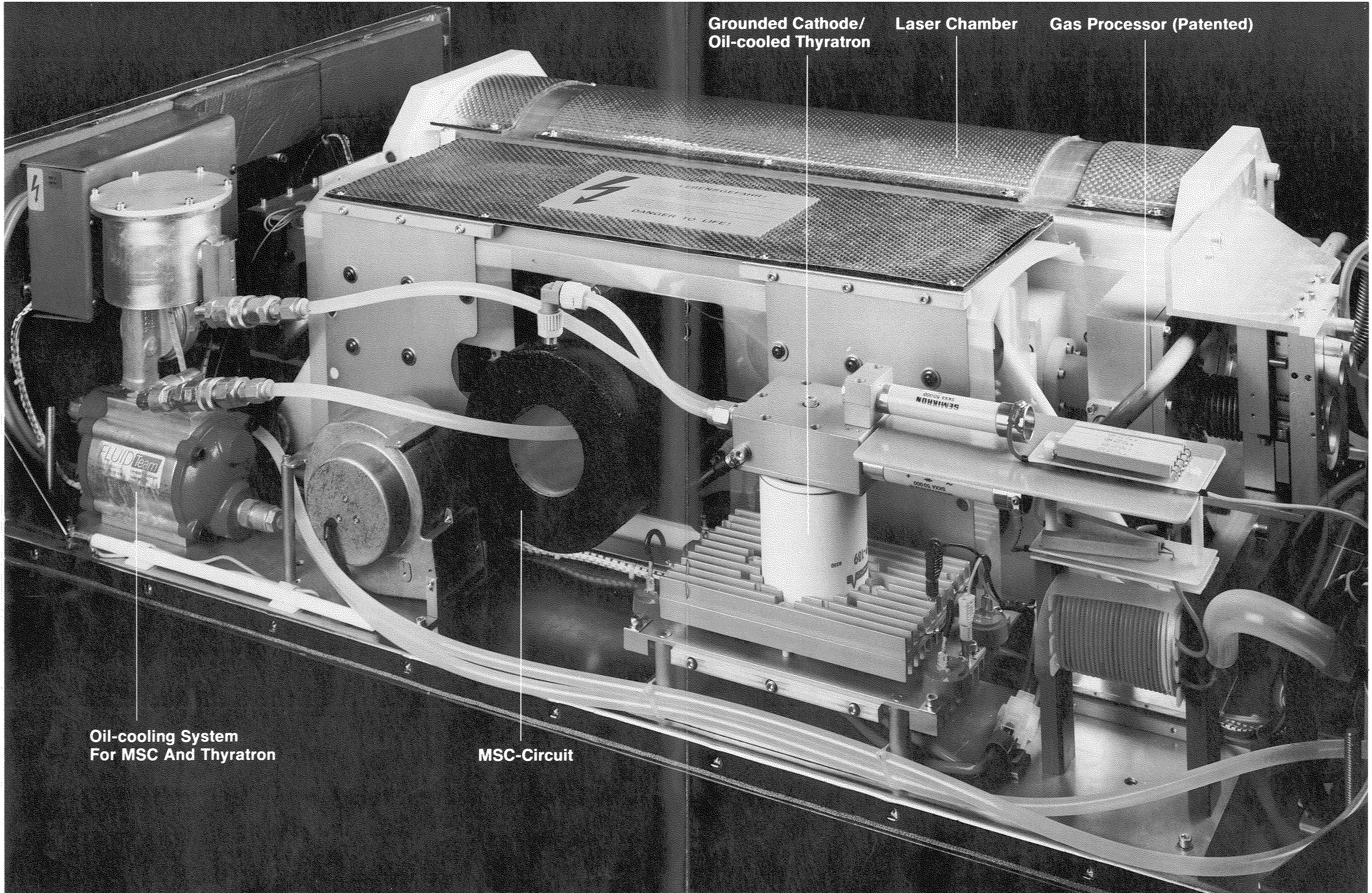


Fig. 2 b:
Thyratron switching characteristics of standard excimer lasers (e.g. EMG 103 E), magnetically assisted excimer lasers and excimer lasers with magnetic switch control (e.g. EMG 103 MSC). The thyratron lifetime is determined by **(I)** thyratron operating voltage $\int U_{Tmax}$ which should be as low as possible **(II)** thyratron switching losses $\int P_T dt$ which are extremely small with the MSC **(III)** thyratron peak current $I_{T\,peak}$ which is lowest with MSC **(IV)** thyratron current reversal which is zero with MSC and **(V)** dI/dt which is extremely low with the MSC.



Grounded Cathode/
Oil-cooled Thyratron
Laser Chamber
Gas Processor (Patented)
DANGER TO LIFE!
SEMIKRON
Oil-cooling System
For MSC And Thyratron
MSC-Circuit

Breakthrough in Stability

Until now, the average power of commercial excimer lasers was limited to 10 W, typically. With the new highly efficient EMG 103 MSC and 203 MSC it can be as high as 40 W and 100 W, respectively (cf. Fig. 4).

In addition, because of the aerodynamically optimized Lambda Physik gas circulation system, the average power is still increasing even at high repetition rates (cf. Fig. 4).

With other words, the Lambda Physik MSC-series and EMG 100-series '84 are excimer lasers which actually reach their maximum average power at maximum repetition rate which, in most cases, is only power supply limited.

This is dissimilar to other conventional excimer lasers, for which the pulse rate for maximum average power is typically 100 Hz, and thus only half of the maximum pulse rate. With those conventional excimer lasers, large (>10 %) pulse-to-pulse amplitude fluctuations are observed at high (>100 Hz) repetition rates. Thanks to the advanced MSC-technique in combination with the new electrode assembly, these problems also have been overcome by Lambda Physik: pulse-to-pulse amplitude fluctuations are only of a few percent even at maximum repetition rates (cf. Fig. 3).

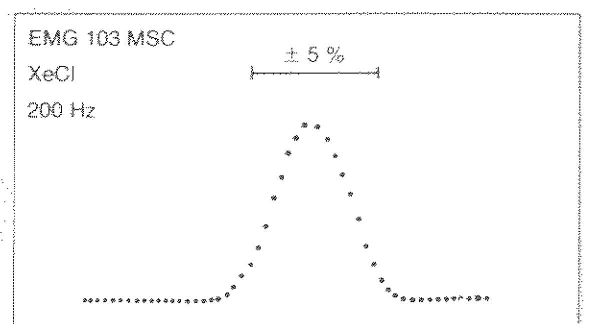


Figure 3: Pulse-to-pulse Amplitude Fluctuation of EMG 103 MSC at Maximum Repetition Rate.

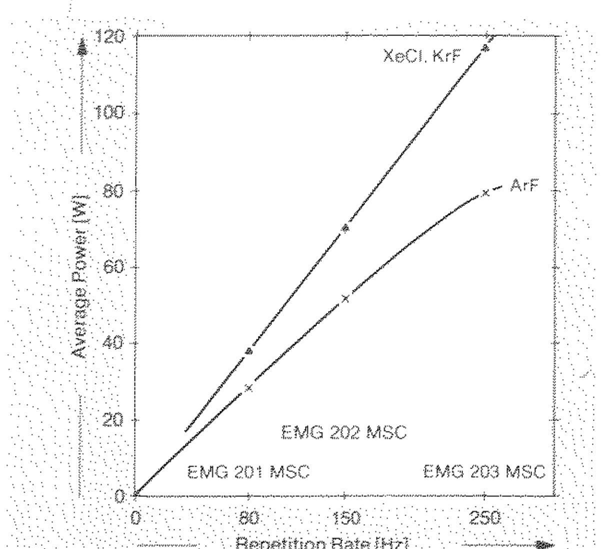


Figure 4: Linearity of Output Power vs. Repetition Rate (MSC-Series).

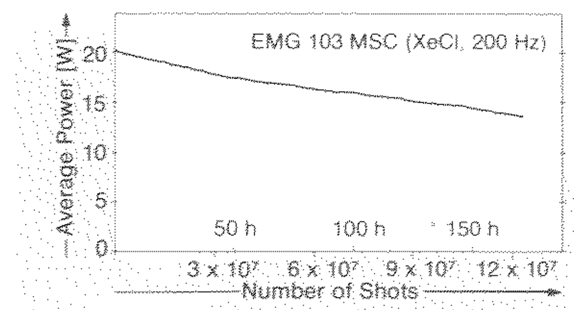


Figure 5: Long-term Output Power Stability of EMG 103 MSC Measured at September 16, 1983 at Lambda Physik Under Optimum Operating Conditions. Specified Power Stability is 2×10^7 Shots to 12.5 W/200 Hz/Continuous Operation/Without ILC.

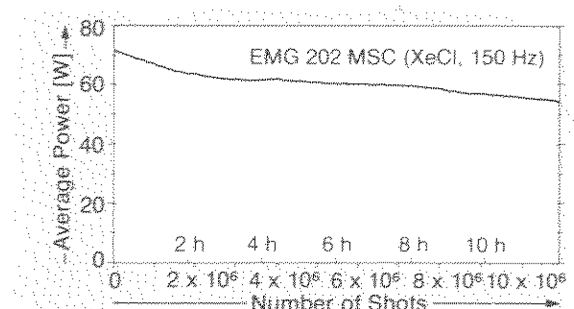


Figure 6: Long-term Output Power Stability of EMG 202 MSC Measured at Lambda Physik. Specified Power Stability is 10^7 Shots to 30 W/150 Hz/Continuous Operation/Without ILC.

In the EMG 103 MSC/203 MSC models, Lambda Physik uses an advanced preionization technique. And the combination of the new MSC technique with our worldwide patented gas processor (E-series) results not only in considerably longer component lifetime, but also yields a significant improvement in long term stability (cf. Fig. 5, 6). For example, using the standard EMG 103 MSC excimer laser, our engineers set a new world-record for gas lifetime: on September 16, 1983, after 110,000,000 shots continuous operation with a single XeCl gas fill, the laser was still delivering 75 % of its specified average power. Such long-term stability and gas lifetime have never been achieved before by any other scientific or commercial laser. This demonstration is only one proof of the inventive technology created by Lambda Physik.

Automatic Power Stabilisation by ILC

With other conventional excimer lasers one has to deal with a continuous decrease in power during operation. The main reasons are window contamination (this problem had been solved by Lambda Physik with its worldwide patented E-version gas processor), generation of organometallic gaseous impurities (which may absorb the laser wavelength) and a change of the concentration of halogen molecules due to photochemical surface-processes (if the laser is well-passivated this problem is of less importance). But, only a few gaseous impurities can be "trapped" by cooling-down the gas mixture externally.

Thus, in order to get stable output power, one has to replace (partially) the contaminated gas by fresh mixture – at least for the most critical ArF- und KrF-operation.

Consequently, Lambda Physik developed a microprocessor-controlled power stabilization (**ILC** = **I**ntelligent **L**aser **C**ontrol), which includes a fully automatic feedback loop and HV-regulation (switch mode HVPS required). E.g., Lambda Physik engineers could stabilize the power for one full working day even at the most critical ArF-excimer line.

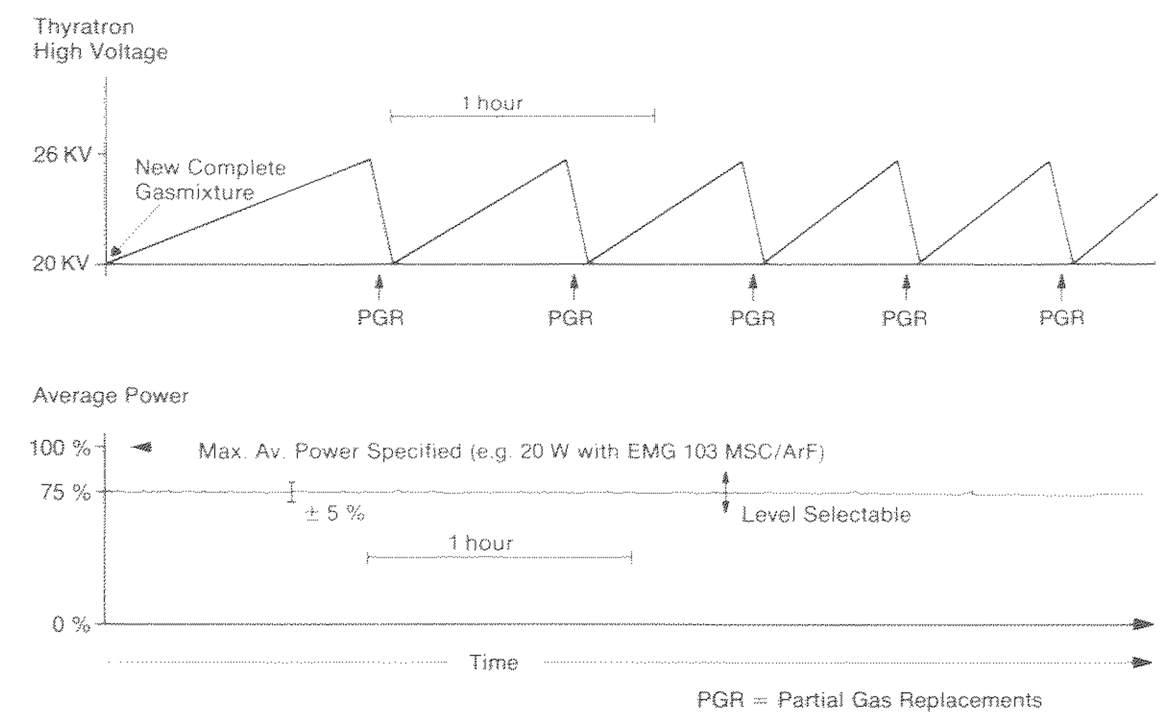


Figure 7: Typical Operating Condition of ILC.

The theoretical calculation of operational costs is in good accordance with performance available from commercial excimer lasers.

E.g., with the EMG 103 MSC operating at ArF, KrF or XeF using ILC, the running costs are below 1 $/Wh when stabilized at about 75 %.

For completeness it should be noted, that the operation of the XeCl-gas can be as economic (although Xe is more expensive) because the "gas lifetime" is significantly longer with XeCl and automatic gas replacements are to be done very rarely.

The maximum time for which the power can be stabilized is limited by the window cleaning intervals ($1 - 2 \times 10^7$ shots), by the halogen gas & dust filter replacement intervalls ($2 - 10 \times 10^7$ shots), by the volume of the gas bottles used ($1 - 10 \times 10^7$ shots) and, finally, by electrode degradation (after some 10^8 shots) which cannot be avoided, in principle.

E.g., one set of large gas bottles may last for about 100 complete new ArF-fillings (each at $ 2) and, thus, for more than 20 hours (>10^7 shots) under active power stabilization at a level of 15 W.

The ILC active power stabilization is mostly recommended for the ArF-, KrF- and XeF-line which exhibit short gas lifetimes.

Contrary to other commercial excimer power stabilization systems, the ILC regulates (cf. Fig. 8) the high voltage **and** replaces the active gas medium partially during operation **without** the need of pure F_2 and **without** any complex cooling-trap configuration, the power being stabilized all the time.

A typical operation condition will be as follows: before starting the laser after some standby-time, the user may simply push a button ("FILL") and the microprocessor will automatically initiate a complete new gasmixture. This procedure (taking about 3 min) may be a daily one for the Fluorines (because of gaseous impurities accumulated) whereas for XeCl (308 nm) it will be needed every week or month only.

Then, the laser operation may be started and the ILC slowly increases the HV to maintain the power. After some time, further increase of HV will not be reasonable anylonger (e.g. because of power supply limitation) and a partial gas replacement (PGR) will be initiated by the microprocessor automatically without involving the user. During this gas replacement period, the HV is reset to a lower value and, after all, the same cycle starts again.

Because of some gas kinetics, the interval between two sequential partial gas replacements are becoming shorter in time and, after all, those intervals keep constant according to a dynamic equilibrium reached.

The power level, at which the laser will be stabilized, can be selected by the microprocessor.

Contrary to other commercial systems which are stabilized at a 90 % level (percentage referring to the maximum average power specified) Lambda Physik recommends to stabilize at 75 % in order to minimize gas consumption and to reduce the costs/photon (cf. Fig. 9).

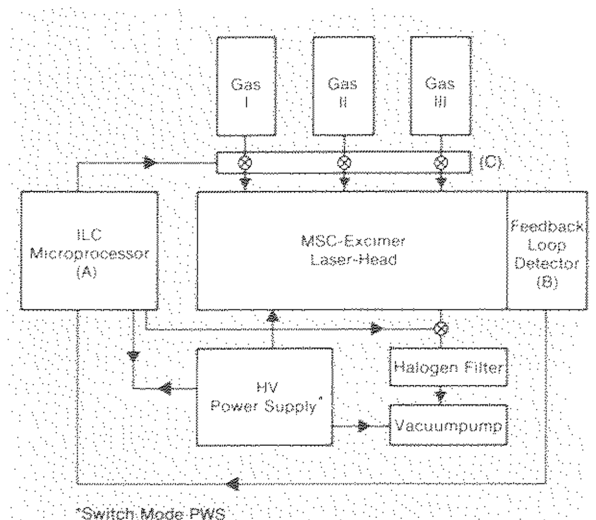


Figure 8: Lambda Physik ILC-Active Power Stabilization (schematic).

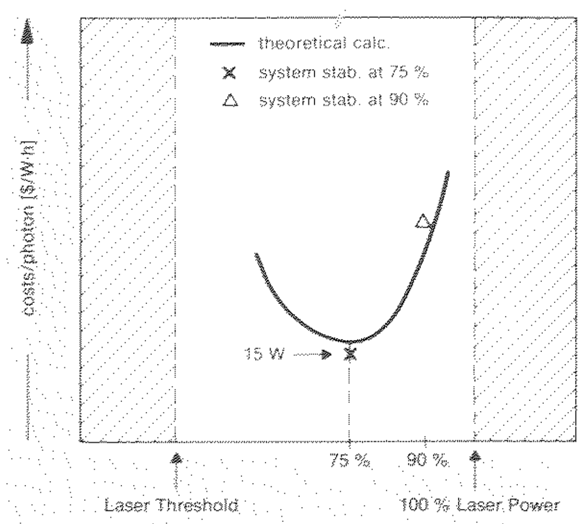
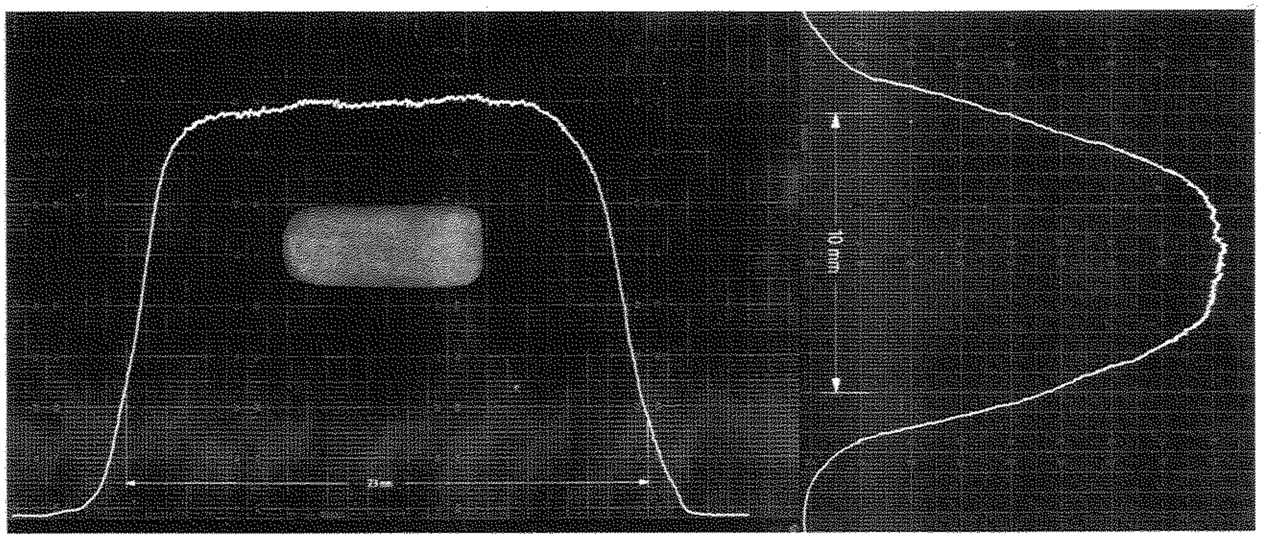


Figure 9: Gas Consumption of Power-Stabilized Excimer Lasers.

Specifications for EMG 100 MSC series and EMG 200 MSC series

Laser medium	F_2	ArF	KrCl	KrF	XeCl	N_2	XeF	
Wavelength	157	193	222	248	308	337	351	(nm)
Pulse energy								
EMG 101 – 103 MSC	5	200	35	250	150	5	80	(mJ)
EMG 104 MSC	n.m.	30	n.m.	50	40	n.m.	10	(mJ)
EMG 201 – 203 MSC	6	300	125	400	400	8	200	(mJ)
EMG 204 MSC	n.m.	175	n.m.	300	200	n.m.	n.m.	(mJ)
Average power								
EMG 101 MSC	0.03	5	1.1	12	6.5	0.2	4	(W)
EMG 102 MSC	0.03	10	2.2	23	13	0.5	8	(W)
EMG 103 MSC	0.03	20	4.5	45	25	1	15	(W)
EMG 104 MSC	n.m.	10	n.m.	25	20	n.m.	n.m.	(W)
EMG 201 MSC	0.05	24	2.5	32	32	0.3	12	(W)
EMG 202 MSC	0.05	40	4.8	60	60	0.6	22	(W)
EMG 203 MSC	0.05	60	4.8	100	100	0.6	35	(W)
EMG 204 MSC	n.m.	40	n.m.	100	75	n.m.	n.m.	(W)
Maximum pulse rate								
EMG 101 MSC	10	50	50	50	50	50	50	(Hz)
EMG 102 MSC	10	100	100	100	100	100	100	(Hz)
EMG 103 MSC	10	200	200	200	200	200	200	(Hz)
EMG 104 MSC	n.m.	400	n.m.	500	500	n.m.	n.m.	(Hz)
EMG 201 MSC	10	80	80	80	80	80	80	(Hz)
EMG 202 MSC	10	150	150	150	150	150	150	(Hz)
EMG 203 MSC	10	250	150	250	250	150	250	(Hz)
EMG 204 MSC	n.m.	400	n.m.	500	500	n.m.	n.m.	(Hz)
Pulse width (typ.)								
EMG 101 – 103 MSC	n.m.	17	10	23	17	4	20	(ns)
EMG 201 – 203 MSC	19	23	21	34	28	7	30	(ns)
Pulse to pulse stability								
EMG 101 – 103 MSC	20	6	10	4	3	1	6	(±%)
EMG 201 – 203 MSC	20	6	10	4	3	1	6	(±%)
EMG 104 and 204 MSC	n.m.	10	n.m.	8	6	n.m.	n.m.	(±%)
Number of shots to 50% of specified power (without ILC)								
EMG 101 – 104 MSC	n.m.	4E5	2E5	2E6	2E7	1E7	4E6	
EMG 201 – 204 MSC	n.m.	4E5	1E6	1E6	1E7	1E7	2E6	
Beam dimensions (typ.)								
EMG 101 – 103 MSC and 201 – 203 MSC: hor. 22 mm, vert. 6 to 10 mm								
EMG 104 MSC and 204 MSC: hor. 18 mm, vert. 5 to 10 mm								



Energy density profile of EMG 103 E/MSC with XeCl (stable resonator). Polaroid pattern (actual size) taken at a distance of 20 cm.

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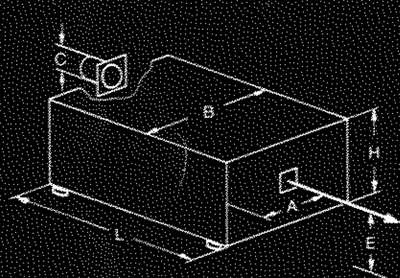

Laser head
L = 130 cm (100 series without ILC)
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A = 35 cm
Weight:
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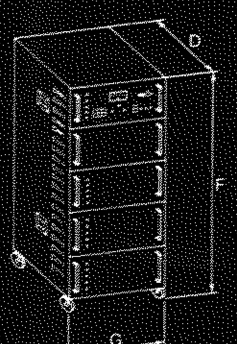
290 kg (200 series)



Power supply
D = 66 cm
G = 51 cm
F = 66 cm (100 series and 201)
F = 101 cm (202, 203 and 204)
Weight
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150 kg (202)
190 kg (203 and 204)

Vacuum pump
23 x 24 x 53 cm, 23 kg

ILC (optional)
Computer: 50 x 50 x 15 cm, 15 kg
Energy monitor: 16 x 20 x 40 cm, 5 kg

Power requirements
380 V, 3 phase, 50 Hz (standard version)
208 V, 3 phase, 60 Hz (US version)
208 V, 3 phase, 50 Hz (special version)
EMG 100 series: 4.5 kVA
EMG 201 MSC: 4.5 kVA
EMG 202 MSC: 7 kVA
EMG 203 and 204 MSC: 10 kVA

Water cooling
EMG 100 MSC series: 4 liters per minute
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DANGER

VISIBLE AND INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION

Max. average power: 120 W
Max. output energy: 0.5 J/pulse
Pulse duration: 4 to 90 ns
Wavelength: 157 to 700 nm
EMG 101 MSC/EMG 102 MSC/
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EMG 201 MSC/EMG 202 MSC/
EMG 203 MSC/EMG 204 MSC
CLASS IV LASER PRODUCT

This product complies with DHEW Performance Radiation Standards 21 CFR Chapter I, Subchapter J
LAMBDA PHYSIK reserves the right to make any change at any time without further notice in order to provide the best product possible.

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