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)
  - H = 86 cm (200 series)
  - H = 40 - 44 cm, adjustable
  - D = 23 - 27 cm, adjustable
  - C = 15 cm
  - T = 20 cm

- Weight:
  - 290 kg (100 series)
  - 390 kg (200 series)

- Power supply:
  - Q = 66 cm
  - Q = 51 cm
  - R = 66 cm (100 series and 201)
  - R = 97 cm (202, 203 and 204)

- Vacuum tank:
  - 25 x 24 x 15 cm, 23 kg
  - ILC (optional)
  - Computer: 50 x 50 x 15 cm, 15 kg
  - Energy monitor: 15 x 20 x 40 cm, 5 kg

- Power requirements:
  - 230 V, 3 phase, 50 Hz (standard version)
  - 220 V, 3 phase, 60 Hz (US version)
  - EMG 100 series: 4.5 kW
  - EMG 101 MSC: 4.6 kW
  - EMG 200 MSC: 7 kW
  - EMG 200 and 204 MSC: 10 kW

**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 50 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 DHHS Performance Standards 21 CFR Chapter I. For further information, please contact LAMBDA PHYSIK.

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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Historical Background

Since the first thyatron-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 thyatron for HV switching. This resulted in lower amplitude fluctuations (<5%) as well as higher repetition rates (>100 kHz) (Lambda Physik, EMG 100 series). Subsequently Lambda Physik was the first to develop high-energy thyatron-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 1980, 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 10^4 shots (Lambda Physik ‘EMG’ E-series). The lifetime of the most expensive parts of an excimer laser namely the electrodes and thyatrons, was however, still limited to 10^3 shots. In 1983, Lambda Physik accomplished another major breakthrough in excimer laser technology by using oil-cooled thyatrons and a Magnetic Switch Control (MSC) for transferring the electrical energy economically into the active gas medium, the lifetimes of the thyatron, 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 purifies the gas. The processor makes window cleaning procedures unnecessary and yields gas-lifetimes exceeding 10^4 shots (Lambda Physik Intelligent Laser Control ILC).

Introduction to Excimer Laser Switching

The ‘heart’ of any excimer laser is its electrical discharge circuit, including thyatron 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_G, with the high-voltage power supply HVPS, the full energy is transferred through the thyatron switch, (after applying a trigger pulse to it’s grid), to the ‘peaking capacitance’ C_P and, thus, to the electrodes. In order to increase the lifetime of all HV-components, especially that of the thyatron, 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 Magnetic Switch Control.

Contrary to other standard or magnetically assisted switch techniques (cf. page 4 part a. b), MSC allows the optimum adaption of the thyatron 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 efficiency but also the gas lifetime is greatly increased. In addition, the Magnetic Switch Control (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 thyatron to a simple trigger: peak voltage as well as current increase dI/dt, are significantly reduced.

Figure 1

Advantages of the Lambda Physik MSC-Series

- 2 years component warranty on the thyatron, 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 thyatron current reversal
- reduction of thyatron current increase dI_0/dt by more than one order of magnitude to about 5 x 10^8 A/sec
- reduction of thyatron operating voltage and peak current to ~25 kV and only a few kA, respectively
- The combination of all these features leads to a drastic improvement of the lifetime of all HV-components (cf. Table 2).
- The lifetime of the complete electrode assembly 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

[Image 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)

<table>
<thead>
<tr>
<th>Lambda Physik EMG 103 MSC - KrF</th>
<th>Lambda Physik EMG 203 MSC - XeCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Avg. Power Fed Into Power Supply (1)</td>
<td>4.5 KW</td>
</tr>
<tr>
<td>Average Laser Output Power</td>
<td>45 W</td>
</tr>
<tr>
<td>Repetition Rate</td>
<td>200 Hz</td>
</tr>
<tr>
<td>Typical Thyratron Operating Voltage</td>
<td>24 KV</td>
</tr>
<tr>
<td>Thyratron Switching Losses</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Thyratron Peak Current</td>
<td>5 KA</td>
</tr>
<tr>
<td>Thyratron Peak Power</td>
<td>8 MW</td>
</tr>
<tr>
<td>Thyratron Current Reversal</td>
<td>zero</td>
</tr>
<tr>
<td>Pulse Compression</td>
<td>yes</td>
</tr>
<tr>
<td>Current Increase</td>
<td>44 KA/μs</td>
</tr>
<tr>
<td>Power Supply Design</td>
<td>Resonant Charging (1)</td>
</tr>
<tr>
<td>Gas Cleaning System (Processor)</td>
<td>yes</td>
</tr>
<tr>
<td>Oil-cooled Thyratron And MSC-Circuit</td>
<td>yes</td>
</tr>
</tbody>
</table>

1) Switch-mode Power Supply (charging capacitors) included in U.S.-option
2) including power for gas flow meter, gas pressure transducer, lamps, etc.

Fig. 2b: Thyratron switching characteristics of standard excimer lasers (e.g. EMG 103 C), 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 $V_{op}$ which should be as low as possible (ii) thyratron switching losses $P_{sw}$ which are extremely small with the MSC (iii) thyratron peak current $I_{peak}$ which is lowest with MSC (iv) thyratron current reversal which is zero with MSC and (v) $dt/dt$ which is extremely low with the MSC.
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).

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) contaminated gas by fresh mixture – at least for the most critical ArF- and KrF-operation.

Consequently, Lambda Physik developed a microprocessor-controlled power stabilisation (ILC = Intelligent Laser Control), which includes a fully automatic feedback loop and HP-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.

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 XeCl using ILC, the running costs are below 1.5/W 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 x 10^8 shots), by the halogen gas & dust filter replacement intervals (2 – 10 x 10^8 shots), by the volume of the gas bottles used (1 – 16 x 10^8 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-filings (each at §2) and, thus, for more than 20 hours (>10^8 shots) under automatic active power stabilization at a level of 15 W.

The ILC active power stabilization is mostly recommended for the ArF-, KrF- and XeCl-line which exhibit short gas lifetimes.
Contrary to other commercial excimer power stabilization systems, the ILC regulates (cf. Fig. 9) the high voltage and replaces the active gas medium partially during operation without the need of pure F2 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 gas mixture. This procedure (taking about 3 min) may be a daily one for the Fluornes (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 anymore (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/photons (cf. Fig. 9).

---

**Specifications for EMG 100 MSC series and EMG 200 MSC series**

<table>
<thead>
<tr>
<th>Laser medium</th>
<th>F2</th>
<th>ArF</th>
<th>KrCl</th>
<th>KrF</th>
<th>XeCl</th>
<th>XeF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>157</td>
<td>193</td>
<td>222</td>
<td>248</td>
<td>308</td>
<td>337</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>351</td>
</tr>
</tbody>
</table>

**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 | 23 (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 | 250 | 200  | 200 | 200 (Hz) |
| EMG 104 MSC       | n.m. | 400 | n.m.| 500 | 500  | n.m.| n.m.  |
| 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 | 250 | 250 | 250  | 250 | 250 (Hz) |
| EMG 204 MSC       | n.m. | 400 | n.m.| 500 | 500  | n.m.| n.m.  |

**Pulse width (typ.)**

| EMG 101 – 103 MSC | 17  | 10  | 23  | 17  | 4    | 28  | 28 (ns) |
| EMG 201 – 203 MSC | 19  | 23  | 21  | 34  | 28   | 7   | 32 (ns) |

**Pulse to pulse stability**

| EMG 101 – 103 MSC | 6   | 10  | 4   | 3   | 1    | 6   | (± %) |
| EMG 201 – 203 MSC | 6   | 10  | 4   | 3   | 1    | 6   | (± %) |

**Number of shots to 50% of specified power (without ILC)**

| EMG 101 – 103 MSC | 4E5 | 2E5 | 2E7 | 1E7 | 4E6 |
| EMG 201 – 204 MSC | n.m.| 4E5 | 1E6 | 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.

**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)

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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