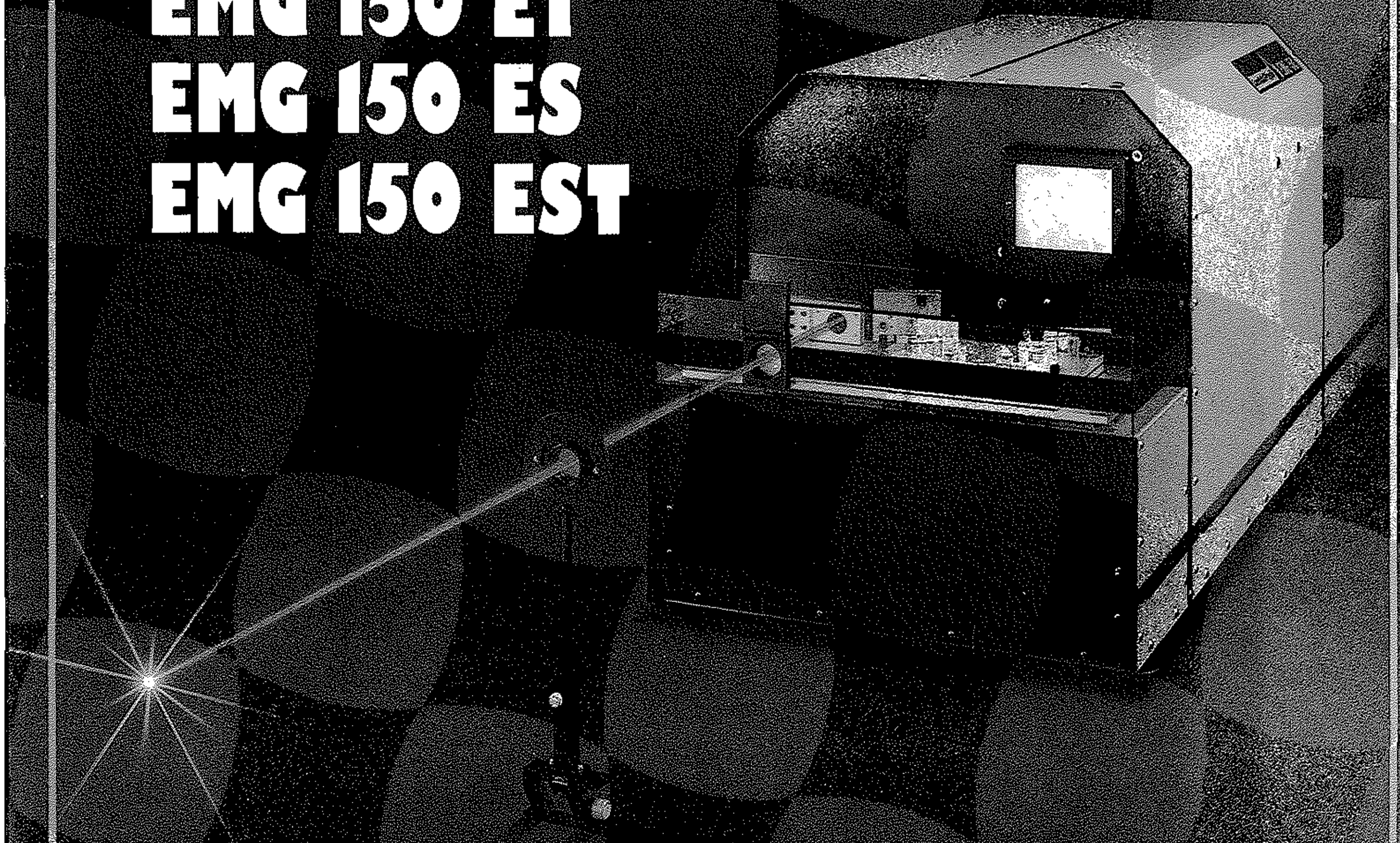
Lambda Physik

The Tunable Excimer Lasers

EMG 150 E
EMG 150 ET
EMG 150 ES
EMG 150 EST



EMG 150 Series

Introduction

Commercial excimer lasers have experienced a tremendous development in the past four years. For a variety of applications, like frequency conversion, chemical vapor deposition, nonlinear spectroscopy etc., however, the spectral or spatial brightness of the excimer laser radiation was not yet sufficient.

By nature, most of the laser transitions are bound-free, and thus the emitted wavelength is broadband (0.5 nm). In addition, the divergence is rather large (>1 mrad) because of the high gain (0.15/cm) of the laser gas. Consequently, researchers were often forced to use frequency-tripled or quadrupled Nd:YAG systems, even though the power of such systems was limited.

Injection locking

This situation changed drastically, when Lambda Physik in 1982 as the first company introduced a commercially available excimer laser system, based on injection locking. These devices, the EMG 150 E and EMG 150 ET, met high-performance values thought impossible only a few years ago. **Although the maximum spectral brightness achieved by the EMG 150 ET is unmatched by any other commercial system,** now after two year's experience with injection locking, Lambda Phyik is pleased to offer a system with output energy and spectral brightness increased by more than a factor of 2 while maintaining the high quality of the beam with respect to homogeneity, narrow bandwidth, and divergence.

Principle of the EMG 150 series

Each EMG 150 consists of two separate laser heads, a common thyratron switch and a switch mode power supply.

An oscillator (Fig. 1, A) working with stable* resonator optics (1) delivers a signal with nearly diffraction-limited beam, controlled by apertures (2). Tunability and narrow bandwidth are provided by a set of prisms (3) in case of the "T"-version. The oscillator signal is injected into the amplifier (Fig. 1, B) with unstable** resonator optics (4), forcing the amplifier to run in the desired cavity mode. The extremly high precision needed for timing the two sections is attained by using only one switching element (thyratron). This advanced concept is realized in the EMG 150 series.

* mirrors with flat surfaces
** mirrors with curved surfaces

Line narrowing

This is achieved by a set of prisms in case of EMG 150 ET/EMG 150 EST. (Optional for EMG 150 E/ EMG 150 ES).

There are a lot of reasons to use prisms as line-narrowing element:

1. It is most user-friendly as the system can be tuned by simply tilting the oscillator's rear mirror manually or by means of the EMG 155 step motor drive (requires FL 512). No complicated synchronization for a set of etalons is necessary. (In case of extreme requirements additionally inserting **one** etalon will render narrowest line-width).
2. The set of prisms can be used for all **four** wavelengths. There is no need to buy expensive tuning elements such as gratings or etalons.
3. Even radiation of moderate power density can be sufficient to destroy etalon coatings because of the highly increased fluence inisde the etalon. By use of prisms, this problem is avoided. Even inserting an etalon into this system, the user runs no risk, as the beam is enlarged by the prisms by a factor of 30, decreasing the power density by the same amount. No damage has to be suspected.

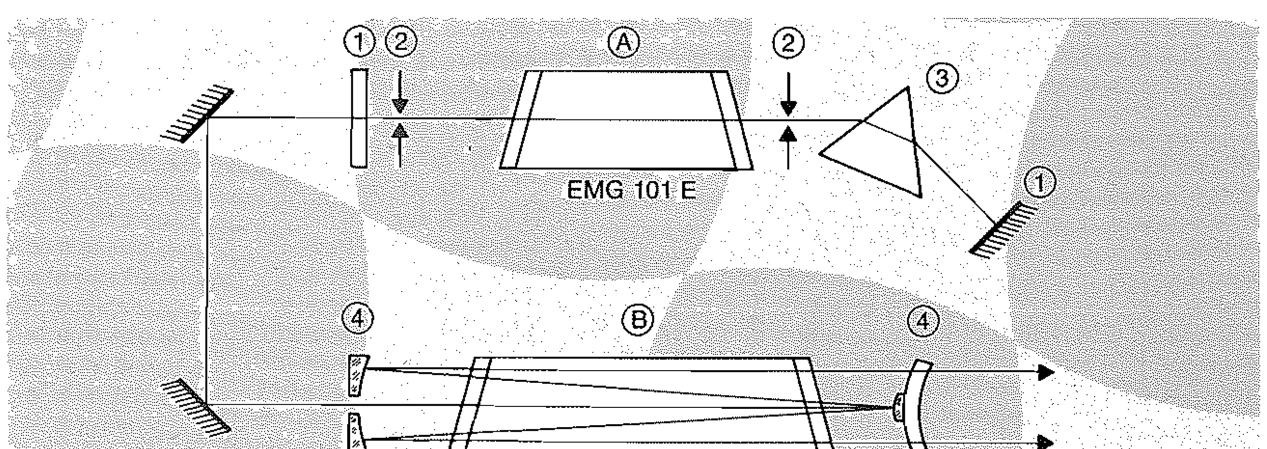


Fig. 1

Line to line tuning

XeCl and XeF exhibit line-spectra, due to their weakly bound lower state. Therefore continuous tuning is not possible, but the spectral intensity can be enhanced considerably by tuning to one of the lines.

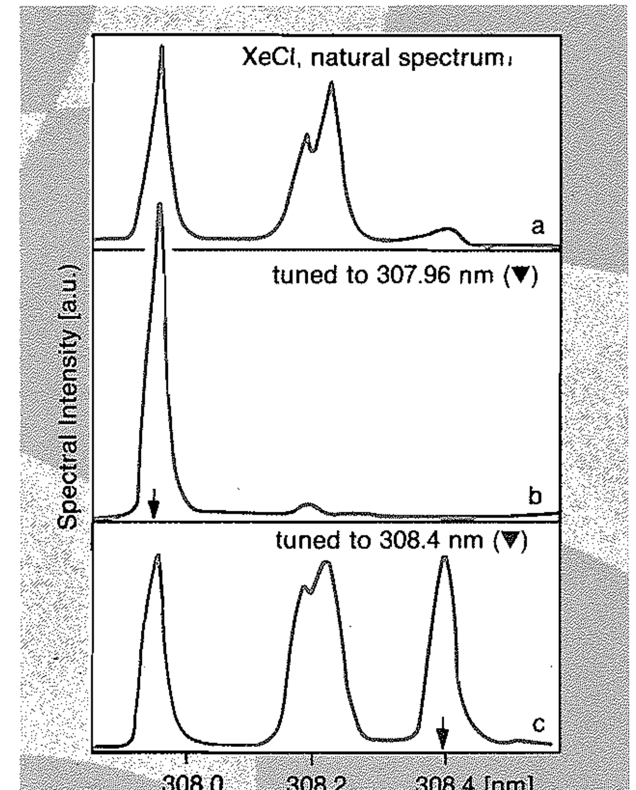


Fig. 6

Fig. 6a shows the natural spectrum of XeCl (without line narrowing element). It is demonstrated by Fig. 6b, that one of the two prominent lines can be enhanced, suppressing the rest of the spectrum. In Fig. 6c the oscillator is tuned to a weak line. Although the prominent lines are present, the spectral intensity at the tuning position (marked by an arrow) is considerably increased.

Spectral brigthness

This number is crucial for quite a lot of experiments in physical, chemical or biological area. It is defined (see Fig. 7) by peakpower (W) in terms of pulse-energy and duration, beam area (cm²), full angle of divergence (sr) and bandwidth (cm^{-1}). The highest spectral brightness, at present available from excimer lasers, is supplied by the EMG 150 EST working with KrF (248 nm). Half of the peakpoker (33 MW) is contained within 4×10^{-8} sr. With a beam area of 3.3 cm² and a bandwidth of less than 0.5 cm^{-1}, the spectral brightness is SB = 2.5×10^{14} W/cm² * sr * cm^{-1}. Compared to a conventional excimer laser without unstable resonator, this means an increase by more than 4 orders of magnitude.

Spectral Brightness

$$SB = \frac{P}{A \cdot \Omega \cdot \Delta\nu}$$

P	=	peak power	[W]
A	=	beam area	[cm²]
Ω	=	divergence	[sr]
$\Delta\nu$	=	bandwidth	[cm^{-1}]

EMG 150 EST, KrF

$$SB = 2.5 \cdot 10^{14} \frac{W}{cm^2 \cdot sr \cdot cm^{-1}}$$

Fig. 7

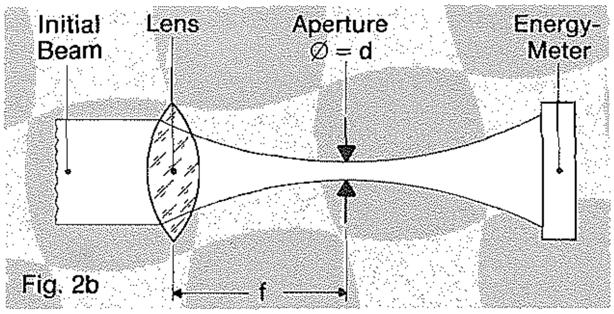


Fig. 2b

Then the maximum divergence Θ of that part of the initial beam which passes the aperture is given by $\Theta = d/f$. This value is an upper limit and valid for both, the horizontal and the vertical direction. For measurements of this kind, curves like those of Fig. 2a unavoidably have to touch the abscissa asymptotically, as the area of the aperture decreases with Θ^2. Curves touching the ordinate axis asymptotically indicate that the measurement has been performed either in only one direction or incorrectly.

Narrow bandwidth

Nearly all the energy from the ordinary free-running amplifier can be locked to the narrow-band oscillator signal injected into the amplifier cavity. Curve 1 of Fig. 3 shows the KrF-spectrum of a free running excimer laser, curve 2 the narrowed line.

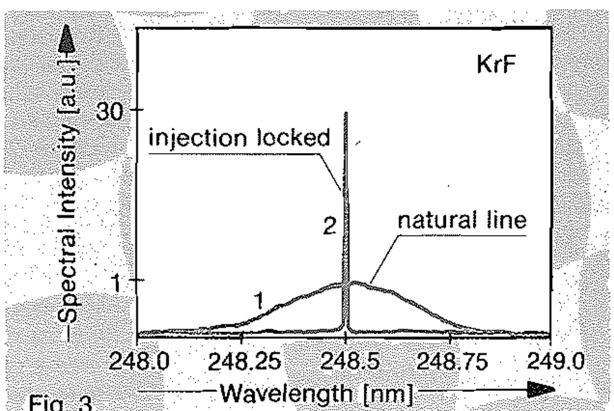


Fig. 3

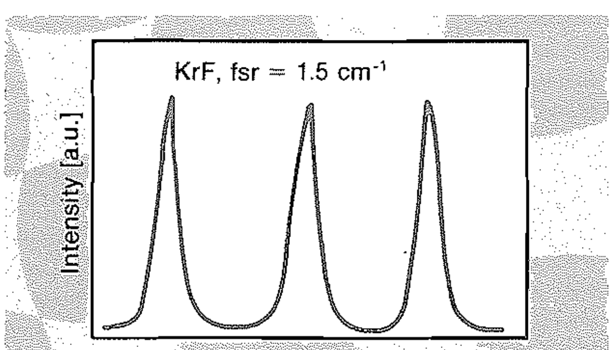


Fig. 4a

The linewidth obtainable from Fig. 3 is due to the resolution of the spectrometer. For closer measurement, Fabry-Perot fringes from the narrowed KrF-line are shwon in Fig. 4a (free spectral range 1.5 cm^{-1}, finesse better than 10). The achieved linewidth is about 0.3 cm^{-1}.

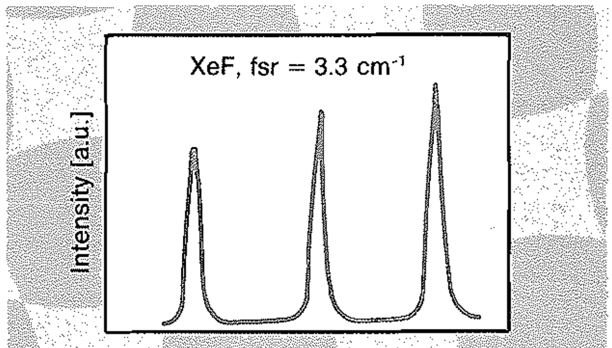


Fig. 4b

Fig. 4b shows a Fabry-Perot scan of the XeF line (free spectral range 3.3 cm^{-1}, finesse better than 10). The achieved linewidth is by far less than 1.4 cm^{-1}, calculated theoretically from the set of prisms, because the EMG 150 ET/EMG 150 EST was tuned to a very narrow natural line (cf. "Line to line tuning" below).

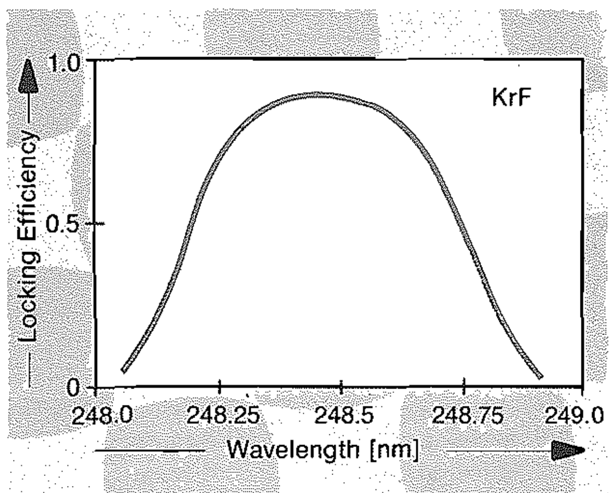


Fig. 5

Locking efficiency and tuning range

The locking efficiency is a measure for that part of the amplifier output, which exhibits the narrow bandwidth of the oscillator signal. Clearly, the locking efficiency depends on the tuning position with respect to the center of the gain profile. In case of ArF (193 nm) and KrF (248 nm), continuous tuning over a range of more than 0.3 nm is possible. In Fig. 5 the locking efficiency is given as a function of the wavelength for KrF.

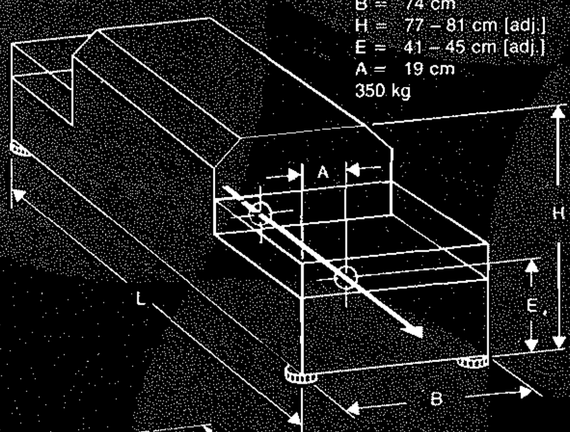
Specifications

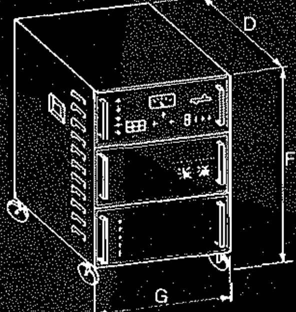
		EMG 150 E				EMG 150 ES			
Laser medium		ArF	KrF	XeCl	XeF	ArF	KrF	XeCl	XeF
Wavelength	[nm]	193	248	308	351	193	248	308	351
Pulse energy max.									
C-version	[mJ]	100	250	150	60	150	500	400	150
F-version	[mJ]	130	350	–	80	250	750	–	200
Av. power max.									
C-Version	[W]	1	5	3	1	1	4	3	1
F-version	[W]	1.3	7	–	1.5	2	7	–	1.5
Rep. rate	[pps]	0.1 – 25*				0.1 – 10			
Beam shape									
vertical	[mm]	25	25	25	25	30	30	30	30
horizontal	[mm]	5	8	10	5	9	11	10	7
Pulse width, FWHM, typ.	[ns]	11	20	18	19	12	25	22	22
Divergence, full angle	[mrad]	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.3
Shots to 50 % of specified power at max. rep. rate		10^4	$2x10^5$	10^6	10^5	10^4	$2x10^5$	10^6	10^5
additional		**EMG 150 ET**				**EMG 150 EST**			
Bandwidth, FWHM	[nm]	0.01	0.003	0.01	0.01	0.01	0.003	0.01	0.01
Tuning range	[nm]	0.3	0.3	line to line tuning		0.3	0.3	line to line tuning	
Locking efficiency		> 0.5	> 0.8	> 0.8	> 0.8	> 0.5	> 0.7	> 0.7	> 0.7
Pulse energy max in "two-lasers-mode"									
"Oscillator head"	[mJ]	120	170	120	60	120	170	120	60
"Amplifier head C"	[mJ]	140	200	150	60	200	500	400	150
"Amplifier head F"	[mJ]	180	250	–	80	300	700	–	200

*on request improved systems with higher rep. rate.

Physical dimensions:

Laser head
L = 180 cm
B = 74 cm
H = 77 – 81 cm [adj.]
E = 41 – 45 cm [adj.]
A = 19 cm
350 kg





Power supply
D = 63 cm, G = 50 cm,
F = 65,5 cm

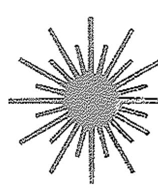
Vacuum pump
ca. 23 x 24 x 53 cm, 23 kg

Power requirements
380 V (208 V) 3phase
3.5 kVA

Water cooling
2 – 4 l/min

DANGER

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



Max Average Power:	10 W
Output:	1 J/pulse
Duration:	5 to 20 ns
Wavelength:	157 to 353 nm

CLASS IV LASER PRODUCT

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