Detailed analysis of the optical scheme for the EXULITE LLP source

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Abstract :

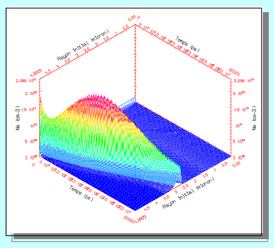
Within the EXULITE consortium, we drive the development of a EUV power source for lithography following an innovative approach based on laser produced plasma (LPP).
Our original concept* has been recently proposed at the Sematech EUV source workshop 2000. We use many identical, simple and compact laser modules, having a pure power oscillator design, which are spatially and temporally synchronized. This approach presents several advantages to the classical MOPA approach, particularly in terms of strongly reduced Cost-of-Ownership and increased reliability.
We developed a 500 W laser oscillator with a good beam quality ($M^2 \approx 10$). The repetition rate can be varied from 10 to 30 kHz and the pulse width ranges from 35 to 75 ns.
In order to reach the desired peak power on the xenon target ($5.\ 10^{11}$ W/cm²), we designed a special focusing system to concentrate the light of 10 laser beams on a 50 µm spot.
A feedback loop avoids any long term drift due to thermal effects and a special system allows pulse-to-pulse energy control.
Finally, we present a novel specific multi-element EUV collector. Ray-tracing calculations show that it will reach the requested specifications for useful power at the second focus.

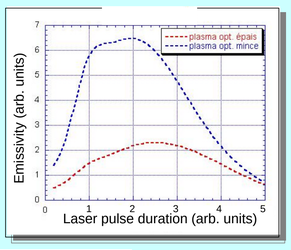
* European patent **EP1320913** : *High peak power laser device and application to the generation of light in the extreme ultraviolet*

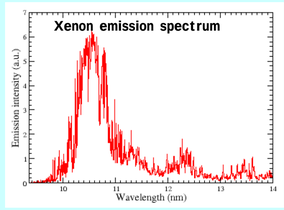
Theoretic work:

Numerical simulations are performed at CEA that aims at:
- optimisation of the laser plasma coupling (peak intensity, pulse duration, pulse shape, target geometry)
- improved comprehension of the atomic physics (Xe, Sn)
- optimisation of the plasma EUV emissivity (plasma temperature, density)

Several numerical codes are available at CEA#:
- Hydrodynamic codes (Auguste et al.)
- Atomic physics codes (Blenski et al.)



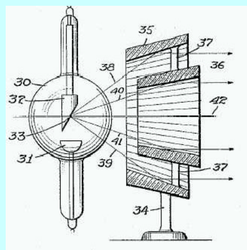


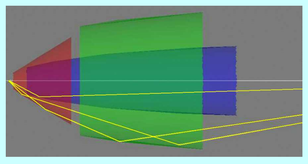


CEA is member of the Sematech Atomic physics data workgroup

EUV collection :

The optimized collector configuration corresponds to a method and an apparatus patented in 1932.
The collector optical design has been made using a commercial ray-tracing optical software.
The source dimensions, the angular emission, the reflectivity of the collector depending on the material and on the incidence angle are integrated to the design.
The results obtained with this simulation are presented below: they exceed current alpha tool requirements.





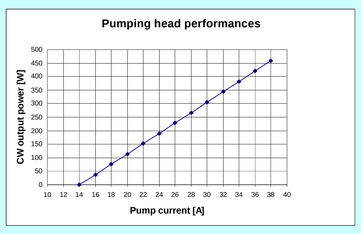
	Alpha Tool requirement	collector 1	collector 2	Collector 3
Ideal geometrical collection efficiency* η	28%	36%	40%	80%
Mean reflection R	65%	61%	67,5%	46%
Transmission: ηR	18%	22%	27%	37%

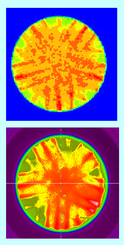
* Geometrical collection efficiency is the collection solid angle divided by 2π

5 kW Laser system development :

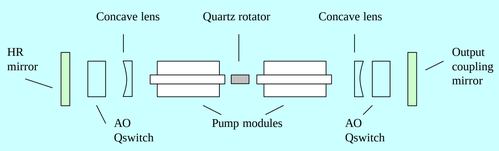
10 high-power, diode-pumped 500 W laser oscillators are combined to obtain a 5 kW laser system. This approach is very attractive for LPP EUV sources due to :

- High efficiency, high rep rate,
- High spatial and temporal stability,
- Low Cost of Ownership, compactness, robustness,
- Excellent reliability.



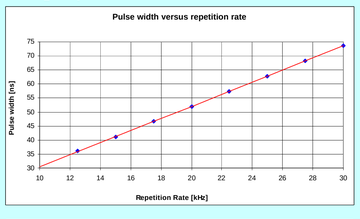


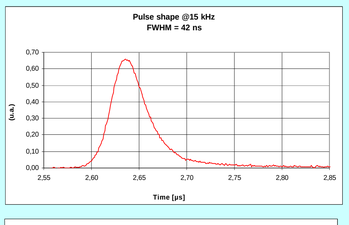
Thalès Pump module : Unique homogeneous pumping scheme, 40% optical-optical efficiency, 17% electr.-optical efficiency

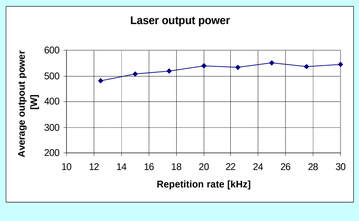


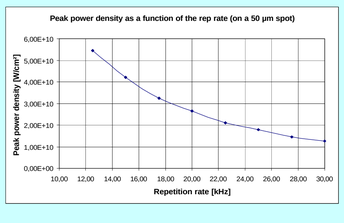
Cavity design

Laser performances :



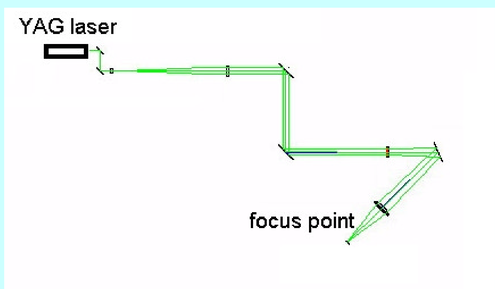






Wavelength	1064 nm
Output power	> 500 W
Beam quality (M^2)	< 13
Jitter	3 ns RMS
Plug efficiency	7 %

Beam transport and focusing scheme:



Goal:
- to focus 10 beams on a 50µm diameter spot
- 5 µm stability for each beam

Definition of a multibeam transport and focusing scheme:
- adjustable pupil transport
- far and near field control
- several focusing solutions studied.
- high precision focusing elements chosen for:
  - high focusing quality
  - intrinsic stable fixing.
  - low sensitivity to thermal effects generated by UV and EUV radiation.
- tolerance analysis
- precise alignment system will be implemented

Manufacturing of focusing elements:

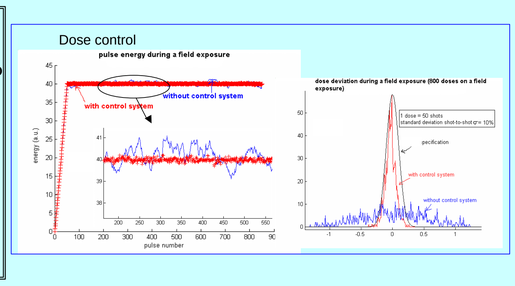
Key points : - high precision on optical surfaces
- tight mechanical tolerances

Experimental validation with high power, high rep rate Nd:YAG beam

- practical tackling and partial validation of future beam transport and focusing
- focusing on a 32 µm diameter spot

Dose control and energy stability :

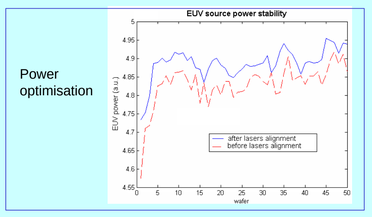
Requirements :
-Dose stability s = 0.1 %
-Min. rep-rate = 10 kHz
-Number of pulses in the slit = 50



Instabilities come from the lasers, the xenon jet or the structure vibrations, are short- or long-term perturbations ➡ 2 systems needed.

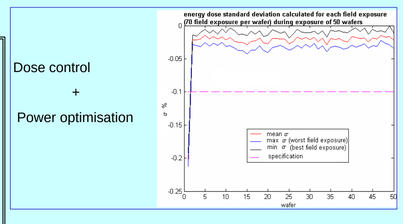
The power optimisation is carried out in few second periods during wafer replacement.
The dose control system works at the laser rep.rate (10-15 kHz)

Power optimisation



➡ The control systems thus do not disturb the normal operation process.
On the contrary, they allow reduced shutdown time of the EUV source.

Dose control + Power optimisation



Conclusion :

Through specific experiments and calculation, the concept of using multiple diode-pumped, power oscillators to generate EUV radiation has been validated.
Some critical points such as focusing the laser beams on a 50 µm spot and controlling the dose applied to the wafer were carefully investigated .
The laser module is still being optimized and higher output power and better beam quality are expected soon.
The whole optical system will be implemented with two 500-W-lasers on the target chamber by the end of 2003.
As a next step, a complete system with 5 kW laser power will be set up during the year 2004.

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