High Power Solid State Diode Pumped Laser for Laser Produced Plasma (LPP) EUV Sources

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EUV Source Workshop Santa Clara, 23 February 2003

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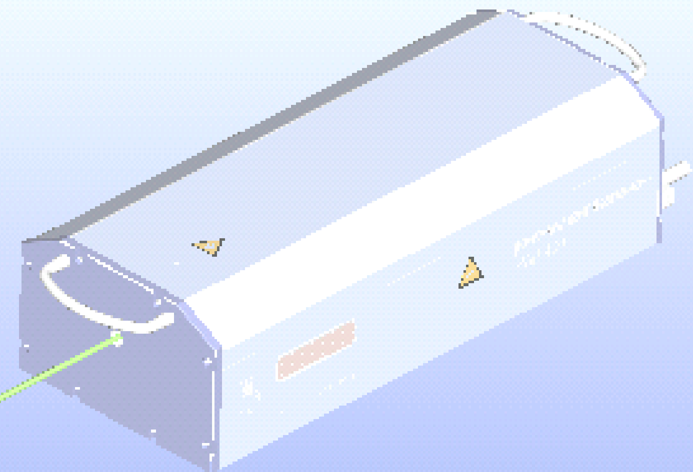
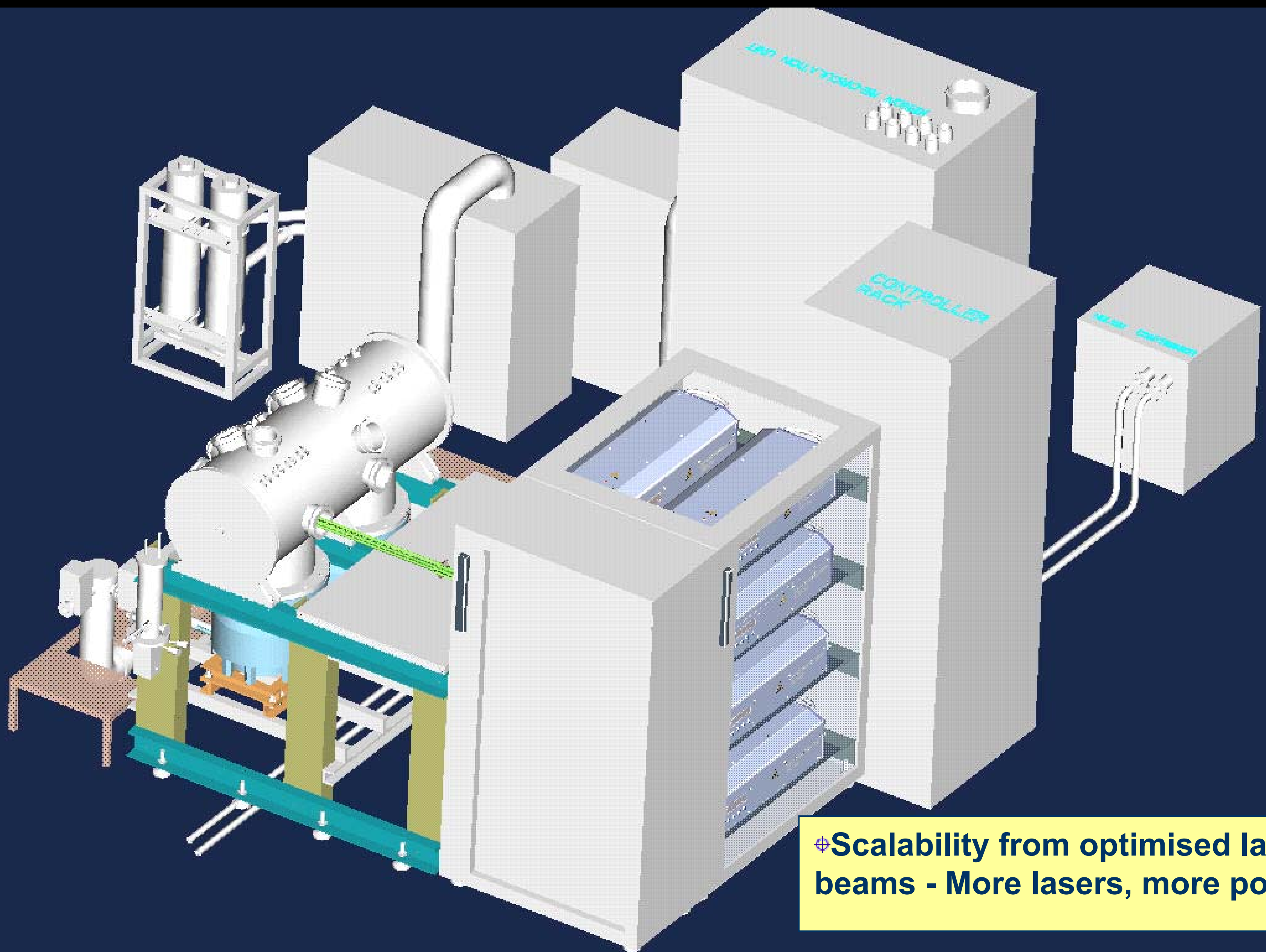
BOC EDWARDS

Presentation Outline

- EUV system
- Xe-target, Xe-recycling and contamination control
- Source characterisation
- EUV source development roadmap
- Summary

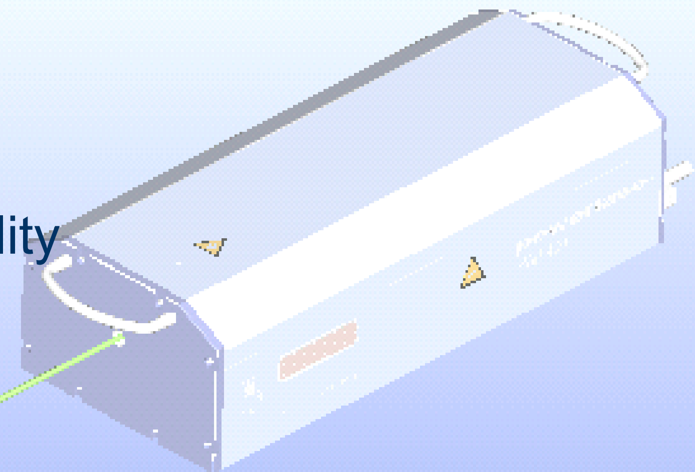




- **Scalability from optimised laser beams - More lasers, more power**

Starlase AO & EO Lasers

- High energy conversion efficiency
- High power
- High repetition rate
- Spatial stability
- High pulse to pulse energy stability
- AO Pulse duration 35ns
- EO Pulse duration 9ns



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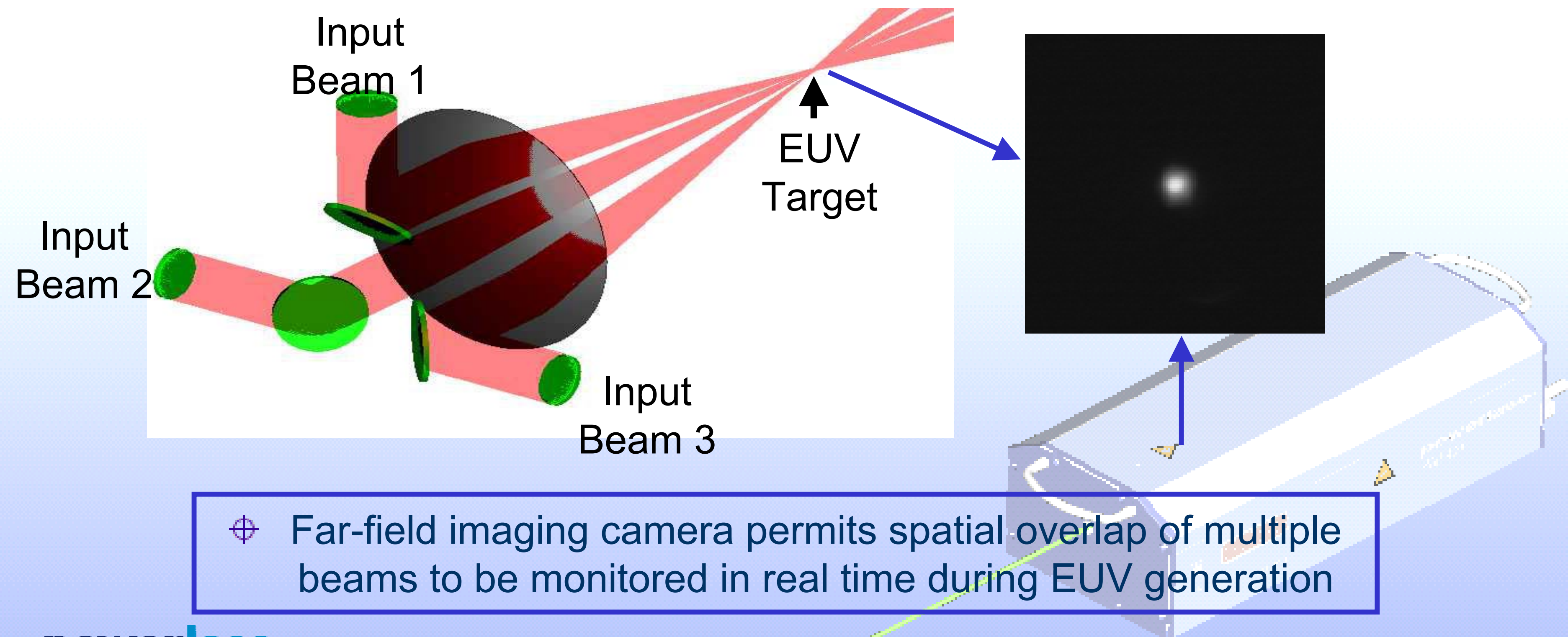
Spatial Multiplexing

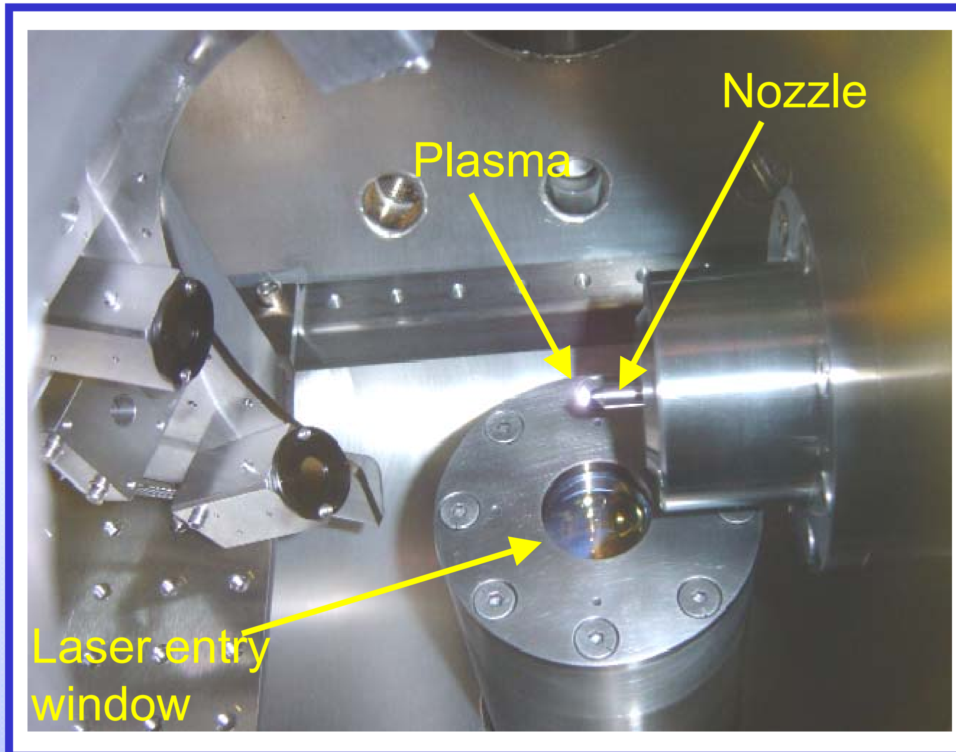
- Beams spatially combined using specially designed optics
- Using a single lens for focussing

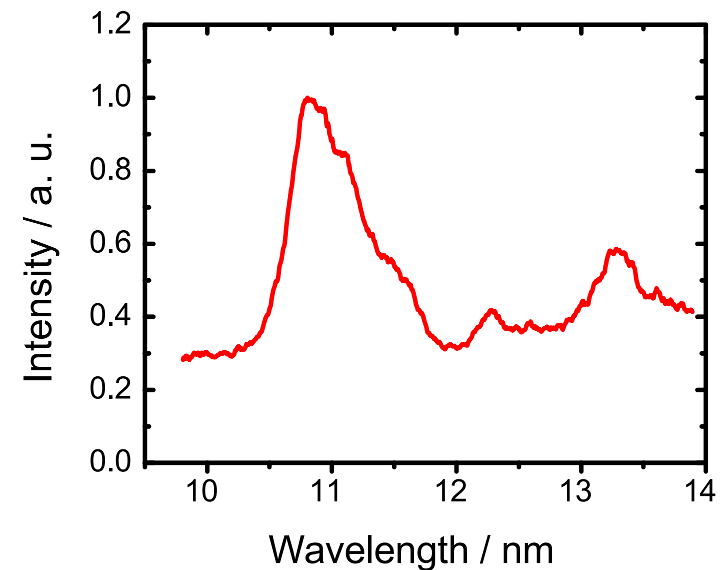


- Far-field imaging camera permits spatial overlap of multiple beams to be monitored in real time during EUV generation

Xe-Target

- High density xenon gas cluster target
- 50 Bar gas pressure behind the nozzle
- Optimisation of the nozzle design is ongoing
- High vacuum pumping minimises absorption of EUV in background gas





TGS spectrum of Xe plasma

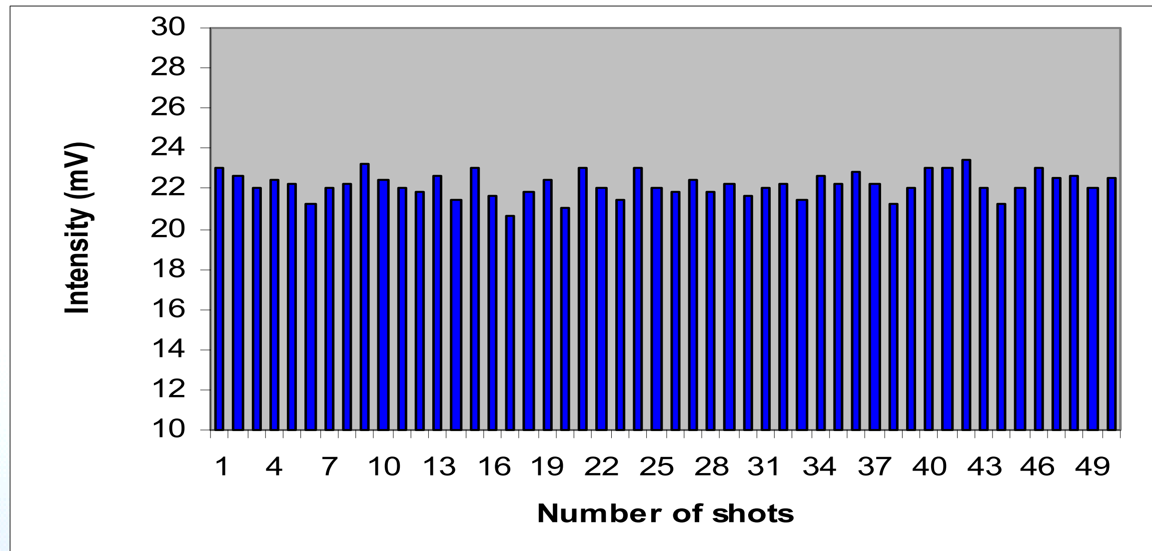
Xe-Recycling and Contamination Control

- The Xe gas is compressed, recycled and purified continuously
- Extremely low Xe consumption

RGA is monitoring the presence of hydrocarbons and water which have detrimental effect on the MLM :

- Water level ~10^{-9} mbar as partial pressure
- Hydrocarbon level was measured ~10^{-11} mbar
  as partial pressure
- These are within the specifications of EUVL system suppliers.

In-band EUV Pulse to Pulse Stability using the FC2



CE of 0.5%/2π sr/2% at distance >1.5 mm from the nozzle measured with FC2
(higher conversion efficiency has been demonstrated)

<3% pulse to pulse repeatability

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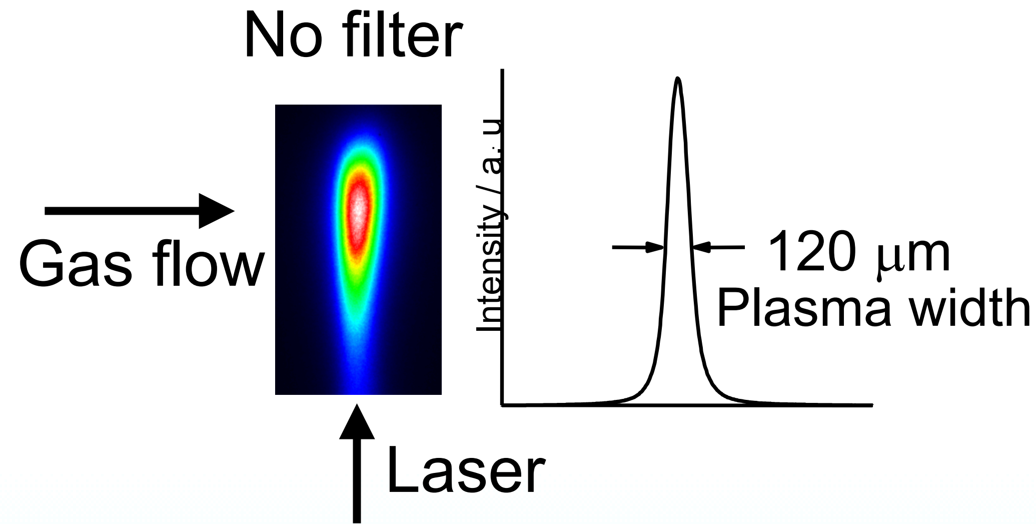
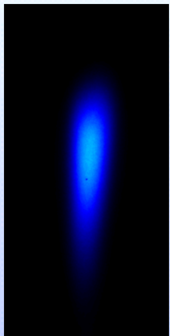
Source Size Measurements

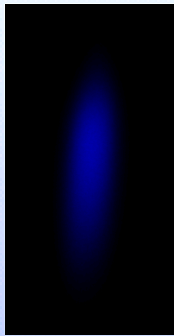


- Pinhole size of 50 μm
- Magnification of 4
- Filters of 200 nm thickness
- Princeton Instruments SX-1024 Soft x-ray back illuminated CCD Camera

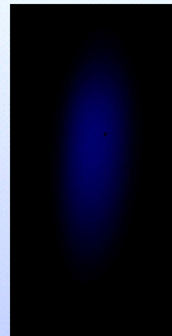
Zr filter



Si filter



Al filter



- Source size was measured in different wavelength bands
- 5-20 nm band shows strong emission consistent with out-band measurement

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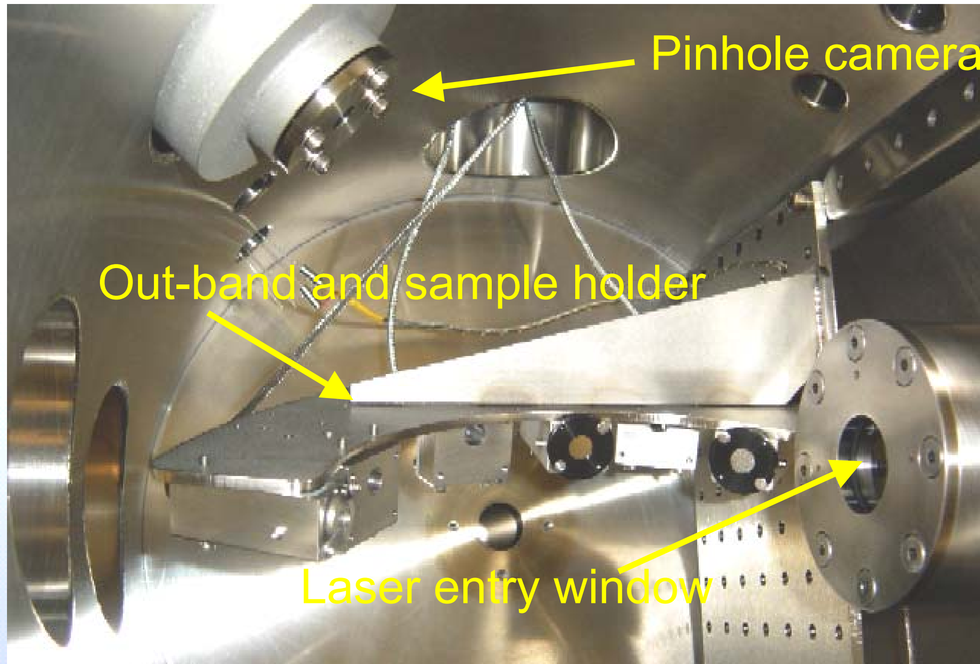
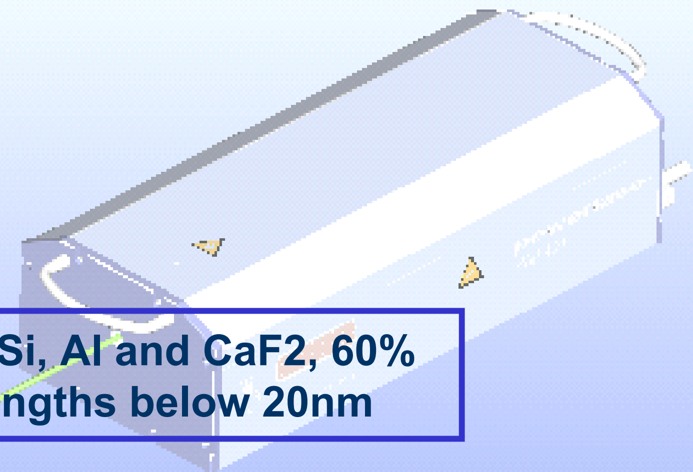
Out-band Radiation Measurements and Source-induced Debris Characterisation



Reflectivity of the MLM was measured after 10^7 shots to be more than 90% of its original reflectivity
The witness plate was placed at 110 mm from the source



Using different type of filters such as Zr, Si, Al and CaF2, 60% of total radiation was emitted in wavelengths below 20nm

EUV Source Performance Roadmap

Metrics	Sep-02	Sep-03	Mar-04	Mar-05	Mar-06	Mar-07
Central Wavelengths (nm)	13.5	13.5	13.5	13.5	13.5	13.5
Demonstrated collectable EUV power in a 2% spectral bandwidth (W)	1	15	40	55	100	150
Available collection solid angle (sr)	2π	2π	2π	2π	2π	2π
Source emission area (mm^2)	0.008	0.017	0.025	0.05	0.05	0.05
Etendue ($mm^2 sr$)	0.05	0.11	0.16	0.3	0.3	0.3
Demonstrated maximum repetition rate (kHz)	3.5	10	10	10	12	12
Demonstrated steady state repetition rate (kHz)	3.5	10	10	10	12	12
Dissipated total power in source region (at steady state)(kW)	0.450	5	8	10	17	20
Source-facing condenser life time (# of pulses to 10% reflectance loss)	10^7	10^8	10^{11}	10^{11}	10^{11}	10^{11}
Pulse to pulse spatial stability (μm 3σ)	<15	<10	<10	<10	<10	<10
Pulse to pulse intensity stability (3σ)	9%	<9%	5%	5%	5%	5%
Pulse to pulse angular stability (3σ)	TBD	TBD	TBD	TBD	TBD	TBD
Pulse to pulse pointing stability	TBD	TBD	TBD	TBD	TBD	TBD
Key risk area	Nozzle	Mirror lifetime				

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Powerlase facility

Laser development,
Product applications development,
Manufacturing

Summary:

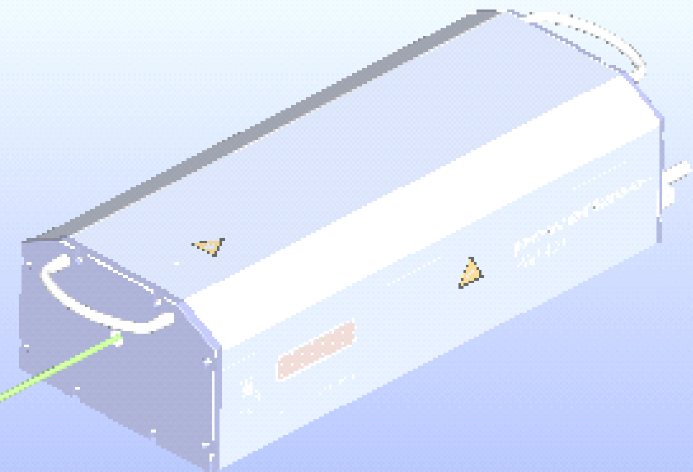
- Developed laser drivers for LPP sources
- Scalability with multiple laser beams was demonstrated
- Recyclable Xe gas target with minimal hydrocarbon and water content
- Excellent pulse to pulse energy stability
- Out-band contamination and source induced debris was characterised
- Clear source roadmap to production level EUV source

Acknowledgements

Samir Ellwi[1], Andrew Comley[1], Ian Henderson[1], Mike Mason[1], Mark Middleton[1], Duncan Parsons-Karavassilis[1], Jo Greenwood[2], Julian Dean[2]

[1]Powerlase Ltd (Lasers and application)

[2]BOC Edwards (Vacuum and Xenon recycling)



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