Overview of High Efficiency EUV Source Generated by Laser-Produced-Plasma

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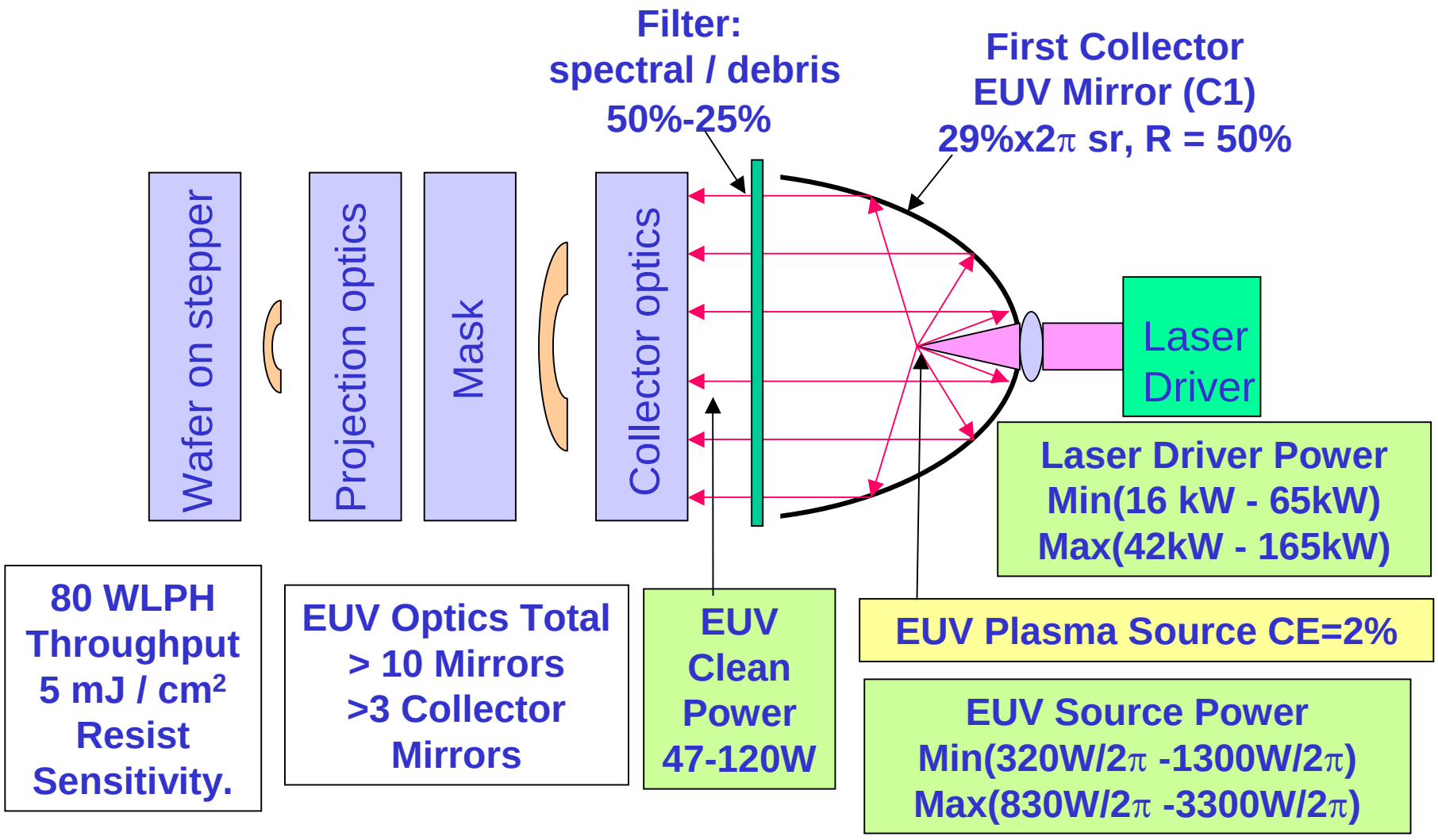
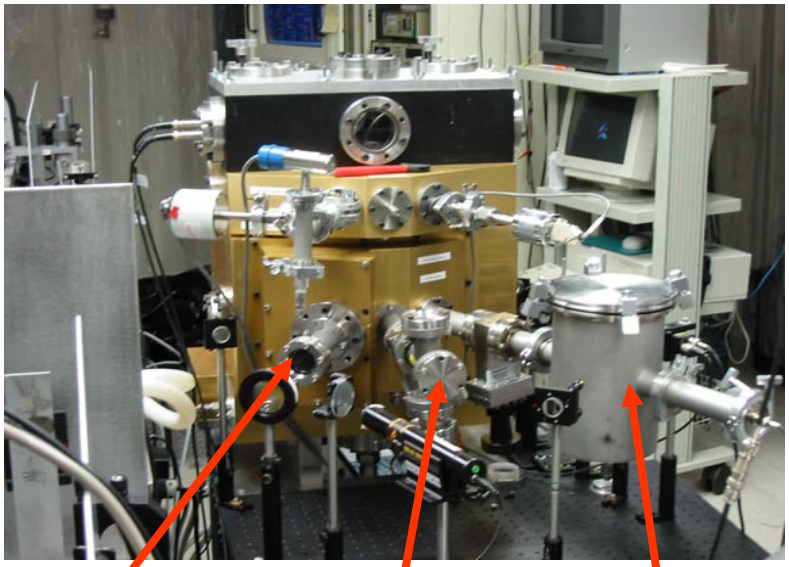
Implications on EUV Source Power: EUVL Workshop (3/3/02)



TRW / CEO and JMAR Collaborating on Advanced Targets

JMAR EUV Generator at TRW



- **JMAR's proprietary Tin-based target has been tested with a TRW / CEO laser**
- **Successful initial tests up to 265 W input power at 500 Hz — nine times prior incident laser powers. Brief operation at 650 W, 2500 Hz.**
- **Preliminary, max CE measurement is 1.3% / 2π/ 2%BW@13.5nm before optimizing focus and timing.**
- **Condensable target will require more debris mitigation than xenon target**
- **Planning cross-calibration by using JMAR, TRW, and Flying Circus detectors**

This approach is less mature than the TRW / CEO xenon target. Further development could allow its introduction in later product generations as a higher power upgrade.

In-Band Power Measurements: Joint Experiment

- **1.6W power normalized into 2π sr 2% of BW @ 13.5nm**
- **Maximum efficiency 1.3%/ 2π/ 2% BW @ 13.5nm**
- **source size: ~ 50 μm (laser focus diameter)**
- **source power stability: ~ 50%**
- **hours of operation: ~ 3 hours in 45 min runs**
- **spectral power distribution of emission: published Tin spectrum in J. App. Phys. 79, 225 (1996). Laser intensity on target ~ 1.4×10^{12} W/cm^2.**

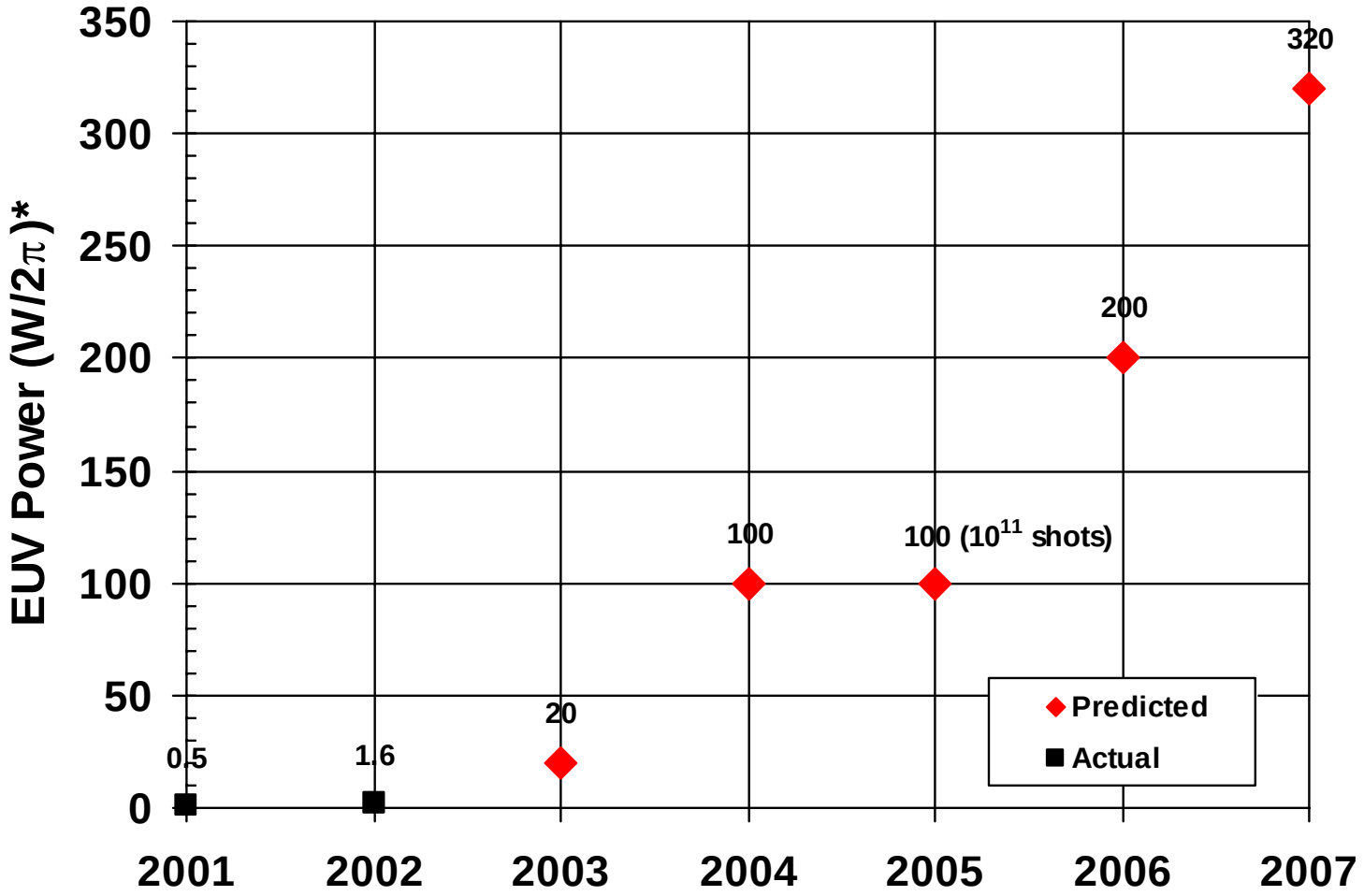
Debris Characterization, Mitigation Results. Joint Experiment

- Target Debris: Tin ions in the forward direction and Tin particulates at the back of target.
- Reflectance loss rate: none observed at ~ 40cm from plasma over ~ 1 h operation at 500 Hz. Preliminary data.
- Deposition rate of contaminants. N/A
- Debris mitigation methods:
  - micro-target with small mass
  - Ambient gas in chamber:1 torr He, with modest flow.
  - debris angular distribution: debris mainly at back of target in a 20^0 cone along laser direction, also in two lobes at $\pm 75^0$ from laser axis.
  - E&B fields: not yet used
- Very little tin vapor emitted in the forward direction (towards laser). Laser input window at 40 cm from plasma clean after hours of operation. More detailed measurements required.

Thermal load at peak operating power

- thermal load in EUV generator at peak operating power will be the laser power 5 - 16 kW,
- effectiveness of heat removal approaches
  - — Helium gas cooling
  - — Chamber and condenser cooling
- impact on components
  - Condenser: may require metal substrate.
  - debris mitigation components, gas curtain, E-field electrodes should be unaffected. EUV pellicle need be heat resistant.
  - Target insertion mechanism is at 1-5cm from plasma

EUV Source Plan



* **No filters**

**** 1.6 W in 2002 with TRW laser**

EUV Source Development Roadmap

EUV Source Performance Roadmap					Funding	Dependent		
	Mar-01	Mar-02	Sep-02	Mar-03	Mar-04	Mar-05	Mar-06	Mar-07
Central Wavelength (nm)	13.5nm	13.5nm	13.5nm	13.5nm	13.5nm	13.5nm	13.5nm	13.5nm
Demonstrated collectable EUV power in a 2% spectral bandwidth in the region between13-14nm (W) *	0.5W/2π	0.5W/2π	1.6W/2π with TRW laser(+)	4W/2π	20W/2π	100W/2π	200W/2π if needed	>200W/2π if needed
Available collection solid angle (sr)	>2π	>2π	>2π	>2π	>2π	>2π	>2π	>2π
Source emission area (mm^2)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Etendue (mm2str)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Demonstrated maximum repetition rate (kHz)	0.3	0.3	0.5-2.5+	5	5	5 or >5 if needed	5 or >5 if needed	5 or >5 if needed
Demonstrated steady state repetition rate (kHz)	0.3	0.3	0.5-2.5+	5	5	5 or >5 if needed	5 or >5 if needed	5 or >5 if needed
Dissipated total power in source region (at steady state) (kW)	0.03	0.03	0.3-0.6+	0.2	1	5	10	>10
Source-facing condenser lifetime (# of pulses to 10% reflectance loss)	2E8**	2E8**	>E6 estimate	2E8 @ 4 W	2E9 @ June-03	2.00E+10	2.00E+11	2.00E+11
Pulse to pulse spatial stability (μm 3s)	~20μm	~20μm	~20μm	~20μm	~20μm	~20μm	~20μm	~20μm
Pulse to pulse intensity stability (3s)	~50%	~50%	~50%	10%	5%	2%	<2%	<2%
Pulse to pulse angular stability (3s)	uniform	uniform	uniform	uniform	uniform	uniform	uniform	uniform
Pulse to pulse pointing stability (3s)	uniform	uniform	uniform	uniform	uniform	uniform	uniform	uniform
Key risk areas	Debris	Debris	Debris	Debris	Debris	Debris	Debris	Debris
Critial component lifetime	C1mirror	C1mirror	C1mirror	C1mirror	C1mirror	C1mirror	C1mirror	C1mirror

* No filters, ** Similar target, (+) Joint TRW/CEO and JMAR experiment

Activities for Development

- Top 3 issues for LPP technology development
  - Issue 1: ≥ 5 kW CW DPSS laser development
  - Issue 2: Conversion efficiency of ≥ 2% 2p/ 2%BW@13.5nm
  - Issue 3: Debris mitigation for 1year life of C1

- Topics for Precompetitive research/development
  - Topic 1: Debris/heat mitigation
  - Topic 2: C1 mirror (geometry/collection angle).
  - Topic 3: Metrology standard.

Acknowledgements

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