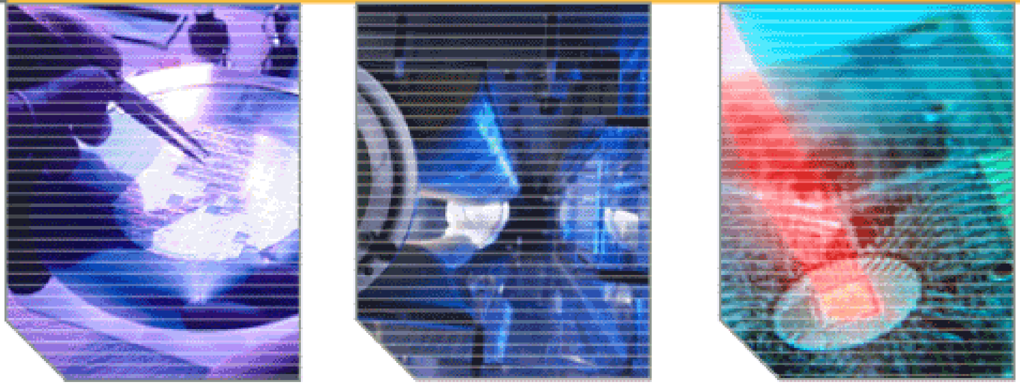
LPP EUV Source Development for HVM



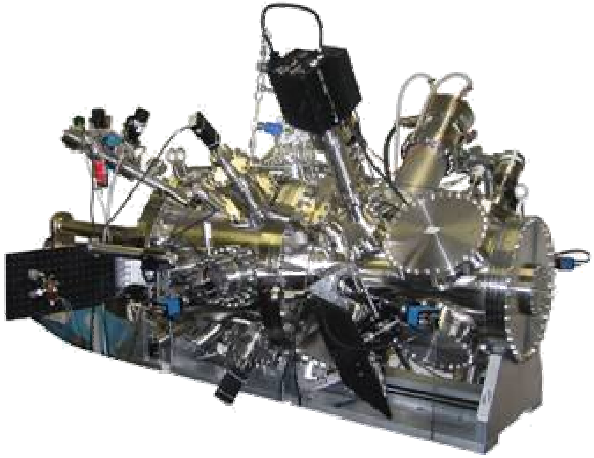
EUVL Symposium, Barcelona Spain, October 17 2006

David C. Brandt*, Igor V. Fomenkov, Norbert R. Böwering, Alex I. Ershov, William N. Partlo, David W. Myers
Oleh V. Khodykin, Alexander N. Bykanov, Jerzy R. Hoffman, Ernesto L. Vargas, Juan Chavez, Rodney Simmons, Georgiy O. Vaschenko

Contents

Introduction

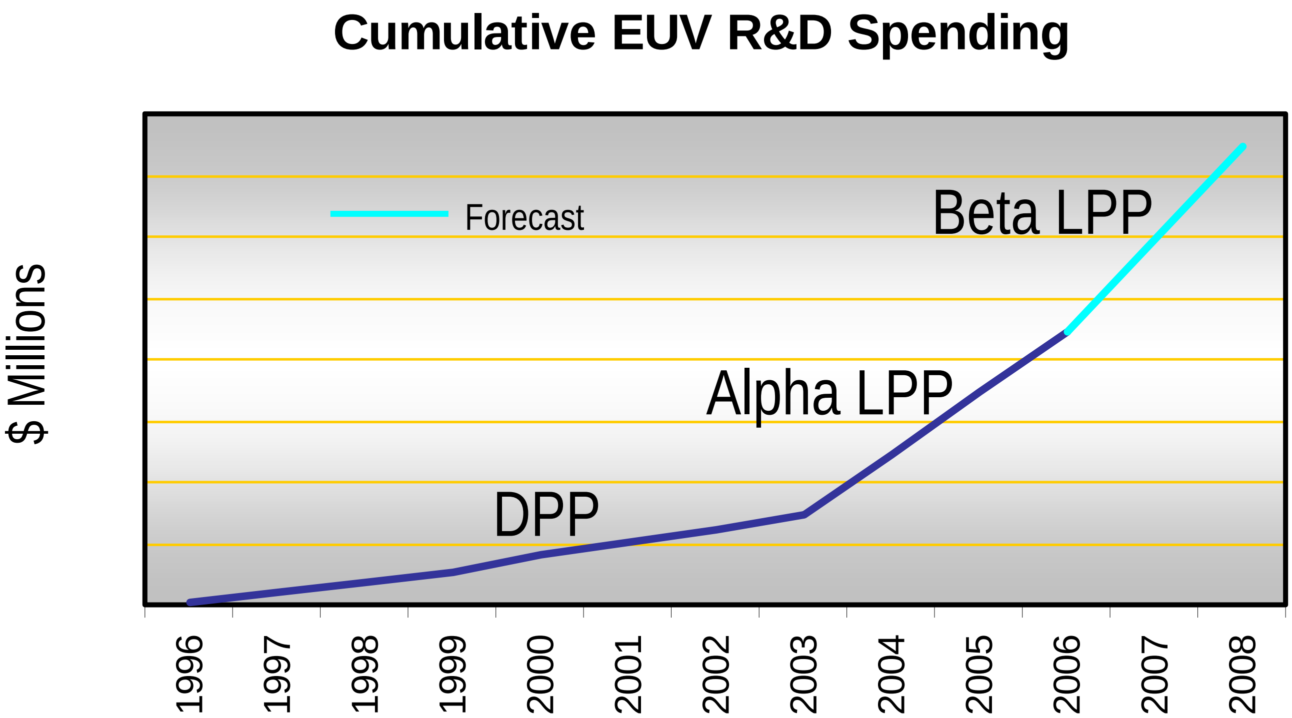
Fully Integrated LPP Development System is Operational with High Power CO_2 Laser and Sn Droplets



Development Focus Disciplines

- High Power Laser
- High Reflectivity Collectors
- Liquid Sn Droplet Generation
- Debris Mitigation
- Collector Lifetime
- Vacuum Technology
- Beam Transport and Focusing
- Droplet Targeting Control
- Plasma Metrology
- IF Metrology
- System Control and Interface

Product Development is Expected to Require a $100M Investment

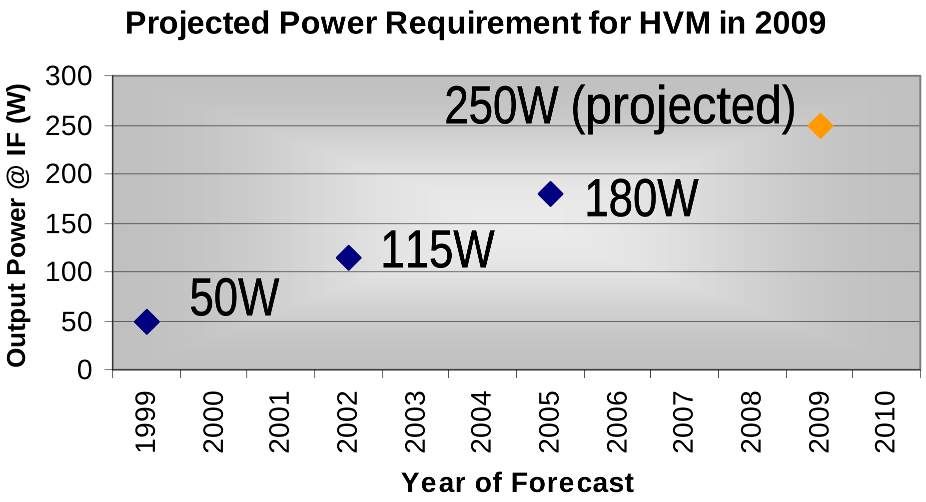


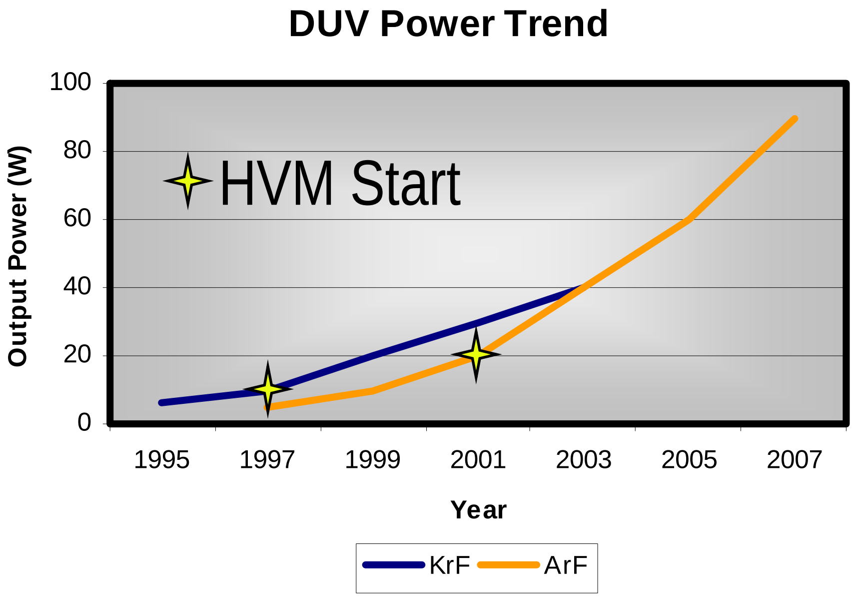
- Revenues generated from sales of today's 193i, 193d, and 248nm sources provides R&D investment for next generation EUV sources

Source Power Requirement Continues to Increase

- The projected HVM source power requirement continues to increase
  - Resist sensitivity
  - Process latitude
  - Spectral Purity Filter
  - Degradation of transmission
  - 450mm wafers

- DUV Experience
  - Power increases with each system generation
  - HVM is only the beginning

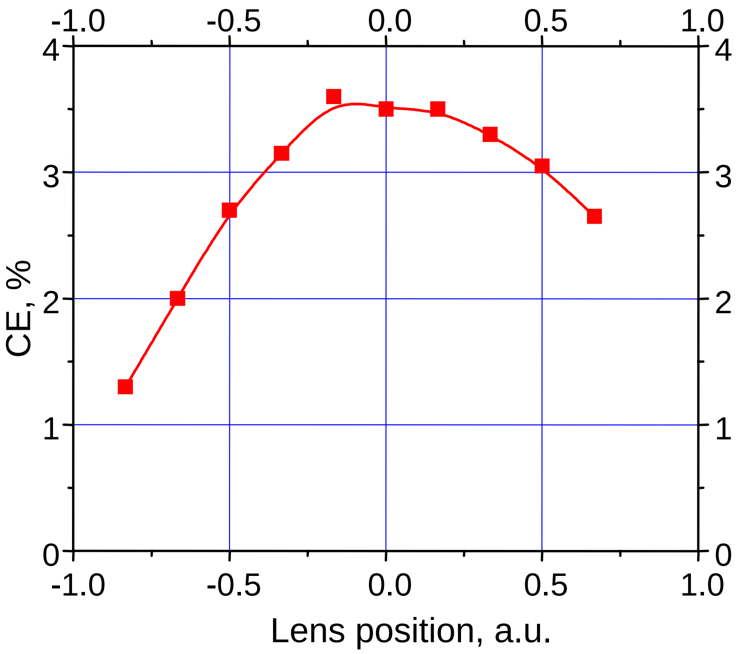




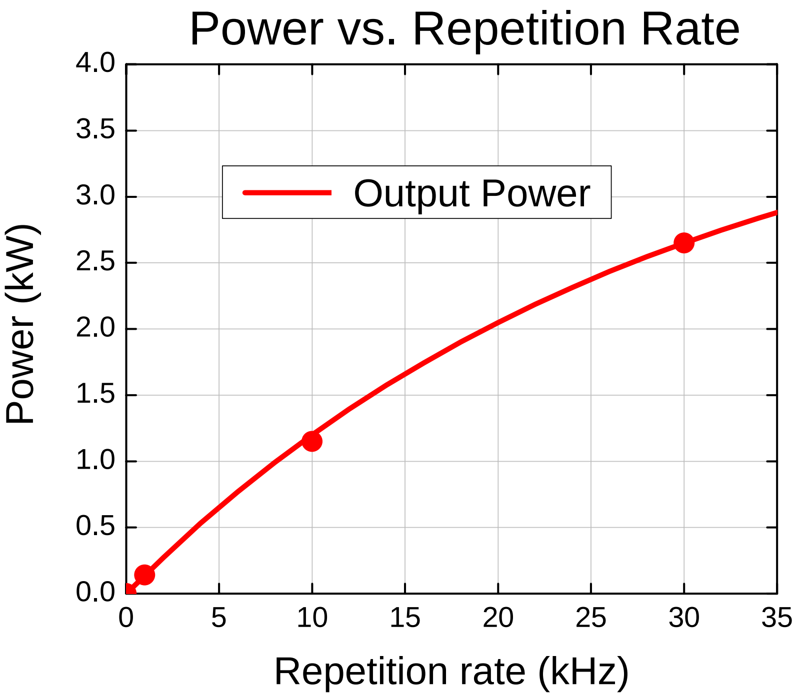
Recent Development Results

High Power Pulsed CO2 Laser Operation and High CE with Sn have been Successfully Validated

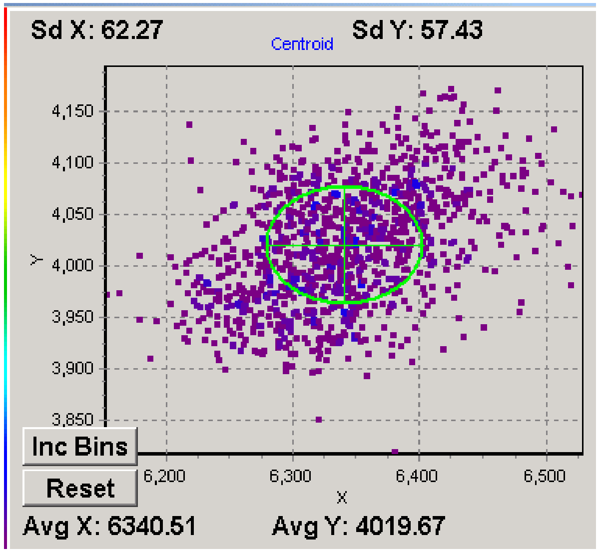
CE of CO_2 on Sn droplets



CO_2 Laser Performance



Measurements of CO_2 Beam Quality and Stability

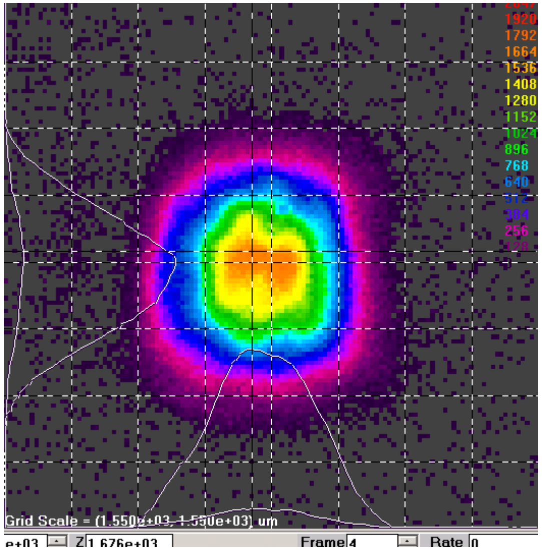

Sd X: 62.27

Sd Y: 57.43

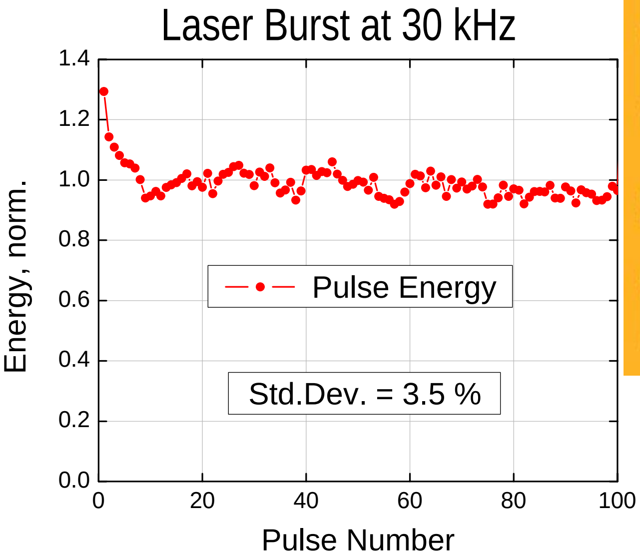
Avg X: 6340.51

Avg Y: 4019.67

Pointing Stability <10μrad


Grid Scale = (1.550e+03, 1.550e+03) um

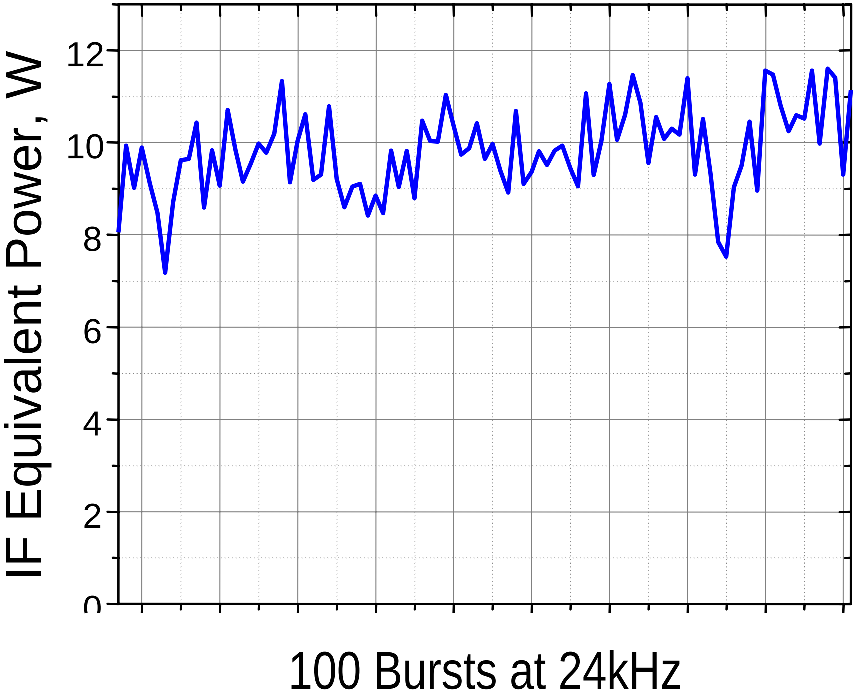
Beam Quality; $M^2<2.0$

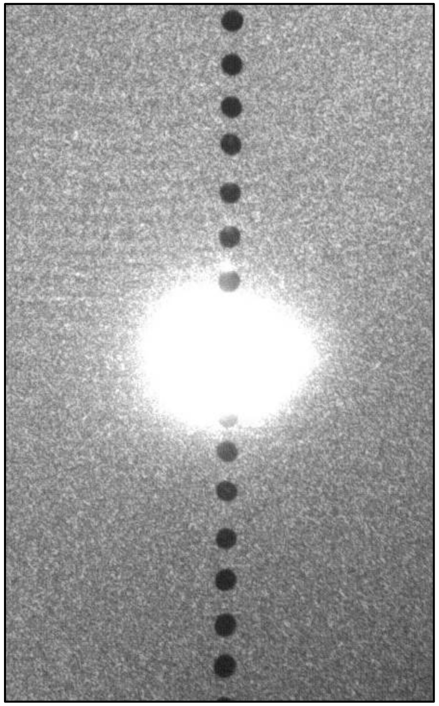


Energy Stability = 3.5%

The CO_2 Beam has High Beam Quality, Good Focusing Properties, and Stable Pulse-to-Pulse Energy

EUV Power at Intermediate Focus

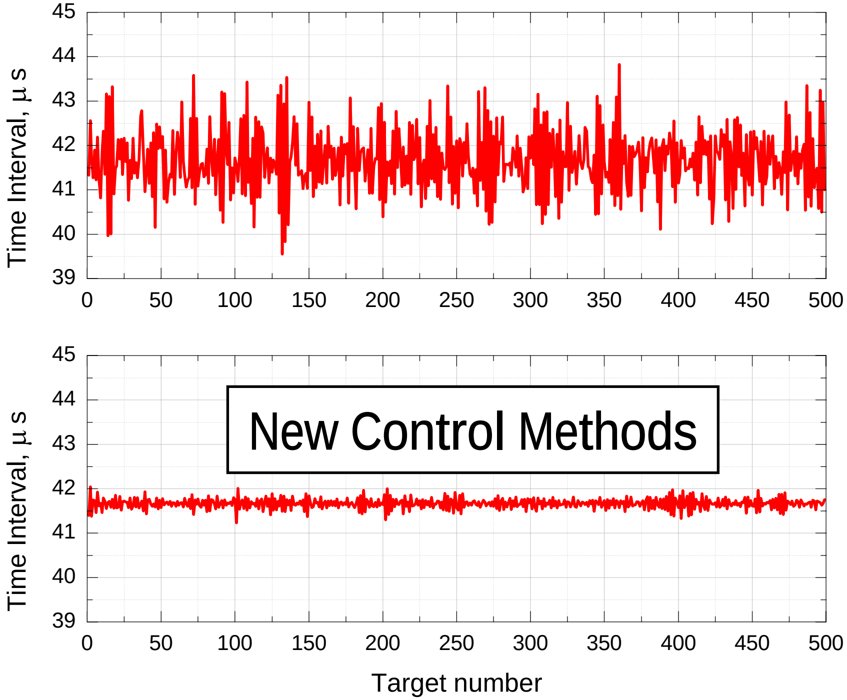




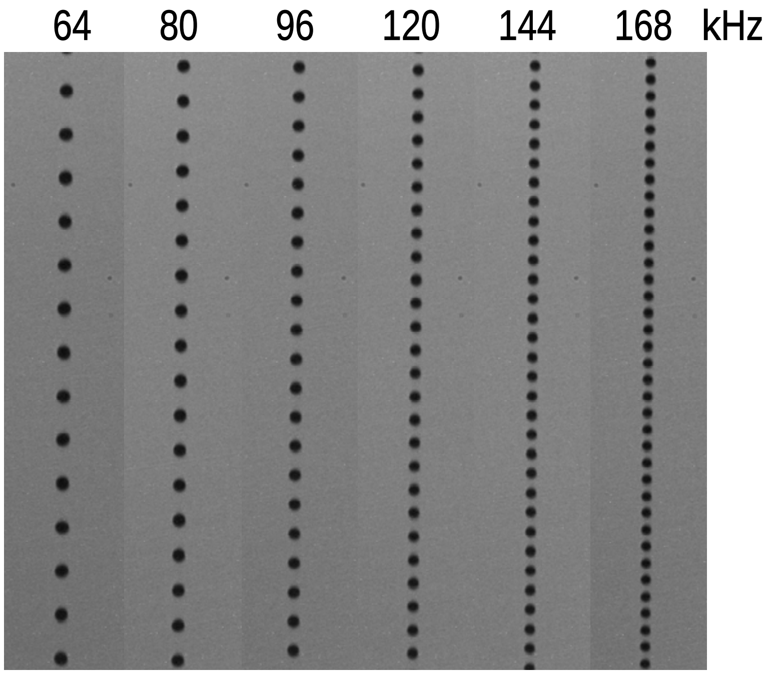
10W Achieved during High Rep Rate Burst Mode Operation

- 24,000 Hz, 50 Pulses/Burst, Sn Droplets at 48,000 Hz, 10.6 μm (CO_2) Laser
- IF Equivalency assumptions: 50% reflectivity, 5sr, 90% transmission

Stable High Repetition Rate Droplet Capability

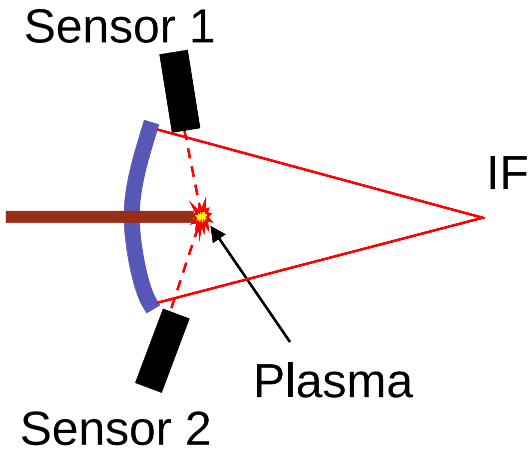


Stability of Sn Droplet Spacing

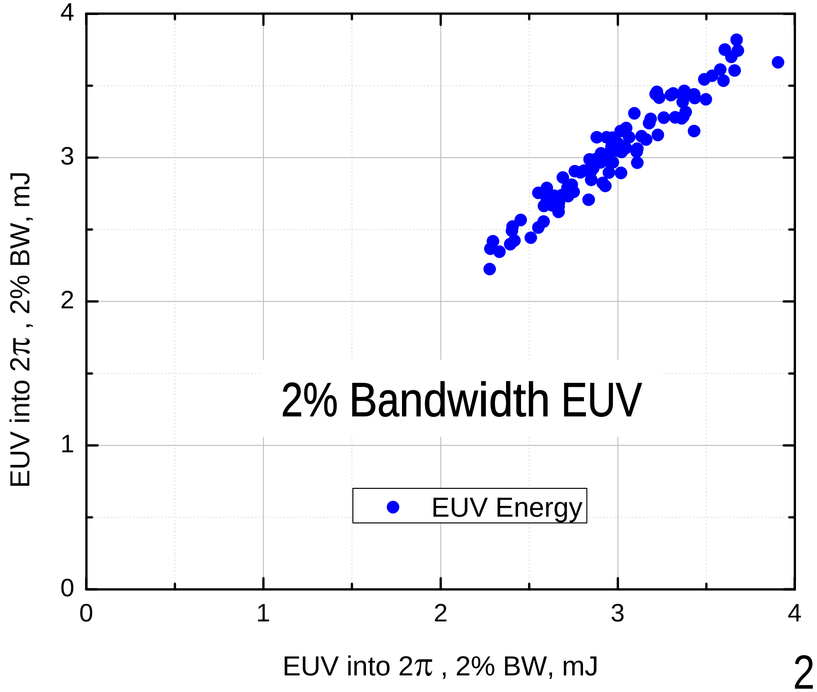


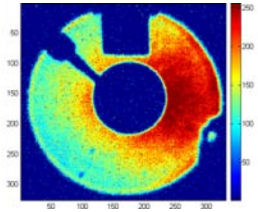
Sn Droplets at High Repetition Rates

Angular Uniformity of CO_2 / Sn EUV Radiation



Signals from 2 off axis 60° detectors 180° apart



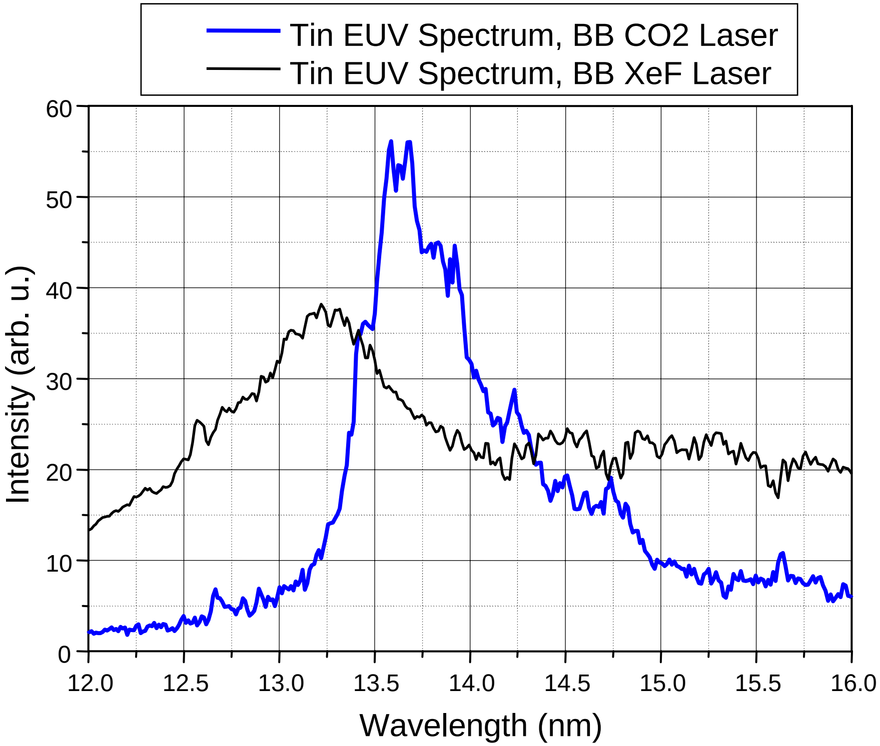


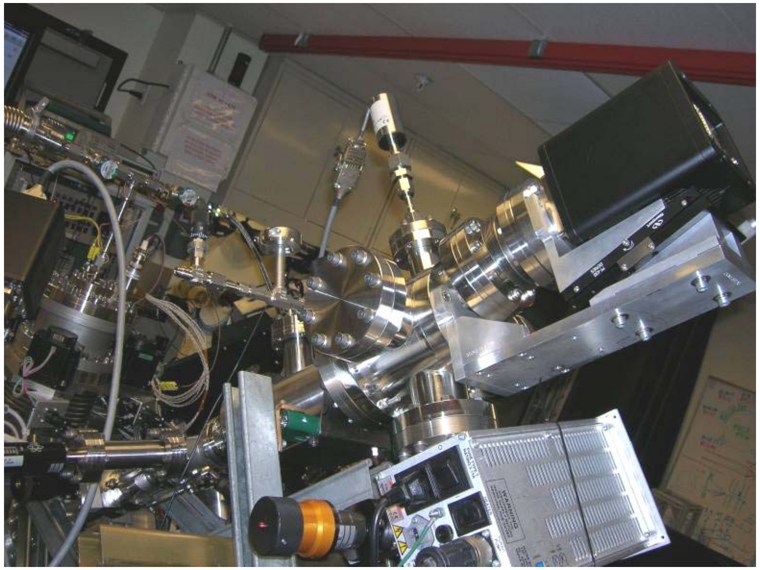
2D Angular Distribution measurement (XeF/Sn) [Ref: SPIE 6151-26, 2006]

Angular Uniformity (~5%)

Uniform Radiation up to 80° (~5sr)

CO_2 / Sn LPP Spectrum Measured with Grazing Incidence Spectrometer





Spectrometer

CO_2 / Sn EUV Spectrum is Narrower, has Higher Intensity, and is Peaked closer to 13.5 than XeF / Sn

EUV Source Size for CO_2 / Sn LPP

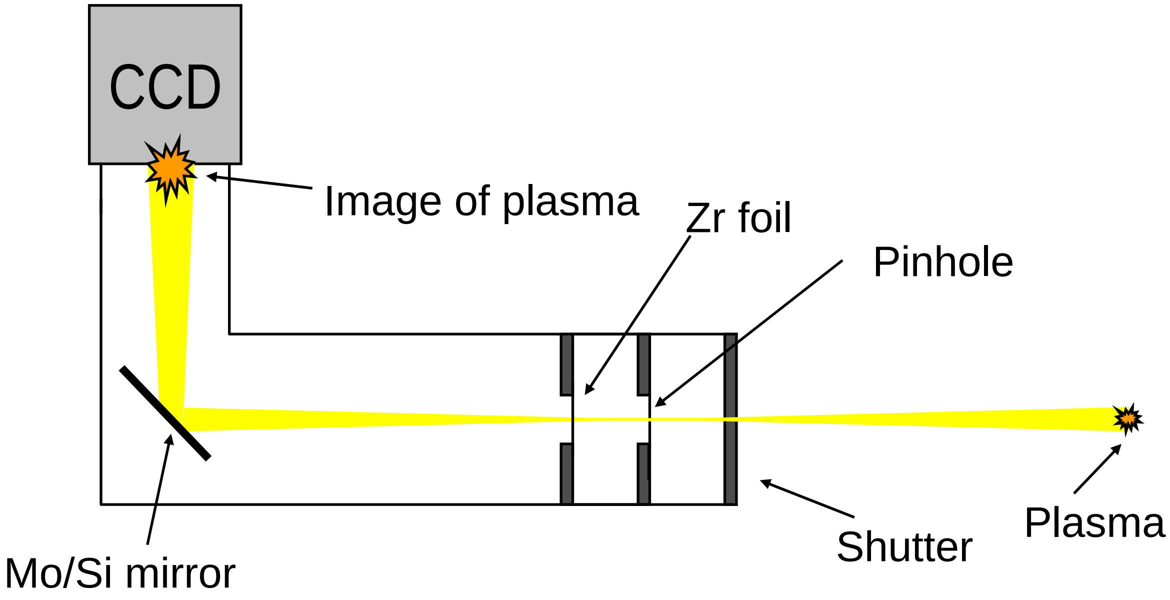

CCD

Image of plasma

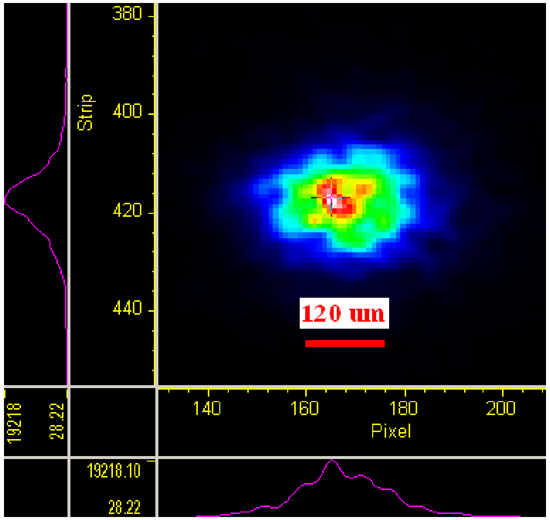
Zr foil

Pinhole

Mo/Si mirror

Shutter

Plasma



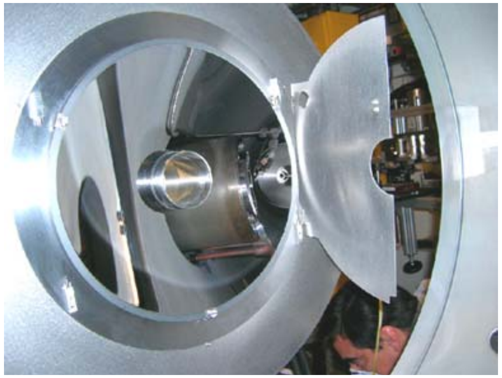
- EUV source size of CO_2 / Sn LPP is ~120 μm in diameter
  - In-band EUV pinhole camera used to collect images of plasma at 60° angle
  - LPP source size is advantageous for scanner optics
  - Etendue ~ 0.1 mm^2sr

Normal Incidence Collector

Large NI Collector Manufacturing Infrastructure Developed and Validated using 320mm Sub-Aperture Substrate

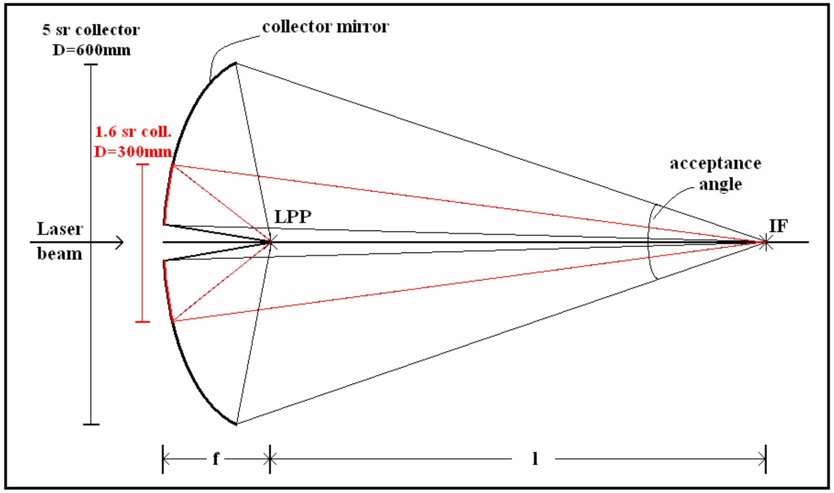
Grinding

Polishing

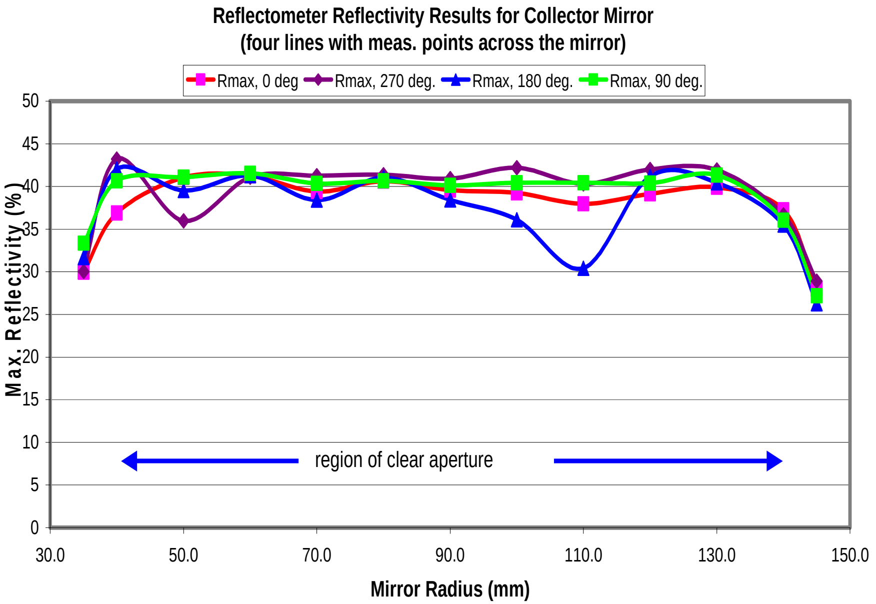


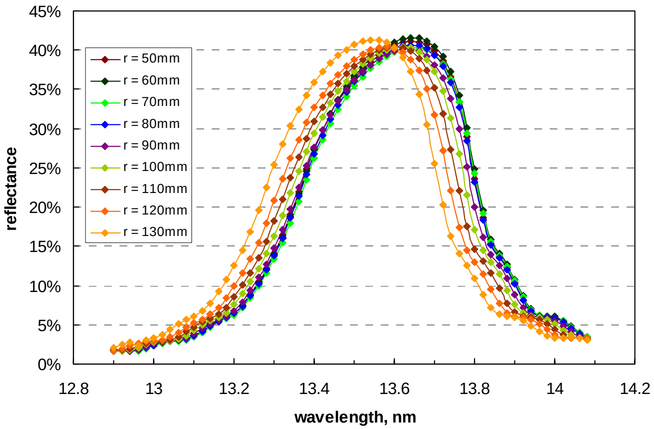
ML Coating

- A sub-aperture shell with 1.6 sr collection solid angle and 320 mm optical surface was implemented to represent the final 5 sr collector configuration.
- 320mm mirror coated by deposition tool compatible with 5 sr collector
- High temperature graded multi-layer coating



Pre-Exposure EUV Reflectivity of Collector Mirror


Reflectometer Reflectivity Results for Collector Mirror
(four lines with meas. points across the mirror)



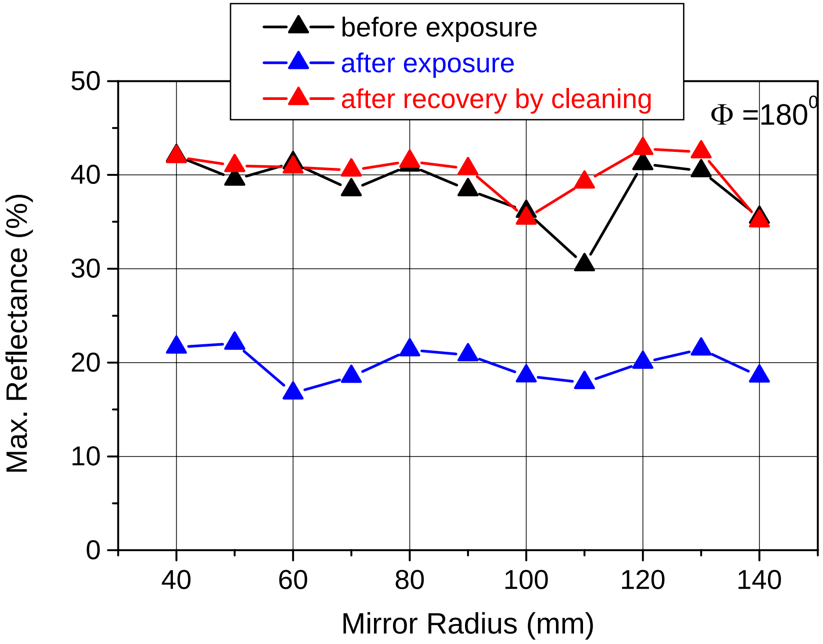
Reflectivity vs. wavelength

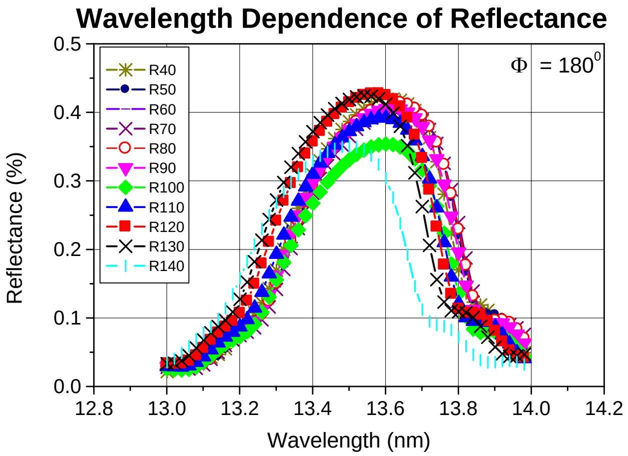
- 41% peak reflectivity measured on mirror within clear aperture
- Peak reflectivity 54% was observed on a Si witness plate
- Reduction of reflectivity is due to residual substrate surface roughness

Ref: SPIE 6151-131, 2006

Post-Exposure EUV Reflectivity of Collector Mirror

Reflectance for measurement points across the mirror radius





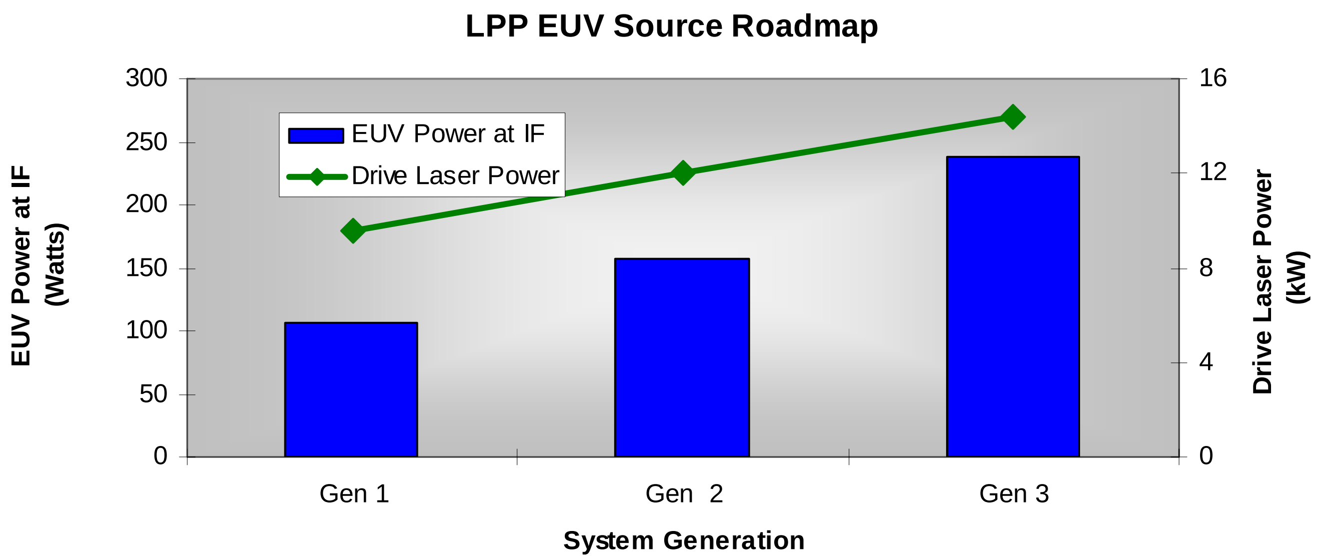
- The collector was exposed over an eight month period with frequent temperature cycling and venting.
- The reflectivity decrease from exposure was recovered by cleaning after use.
- The wavelength dependence of reflectivity curves did not change substantially during use.

Summary

Source Performance Roadmap to HVM and Beyond

LPP EUV Source Performance Roadmap				
	Current	**Gen 1**	**Gen 2**	**Gen 3**
Laser power (kW)	**3.0**	**9.6**	**12.0**	**14.4**
In-band CE	1.5%	3.5%	4.0%	4.5%
Geometric collection effy (sr)	5	5	5	5.5
Collector average reflectivity	50%	50%	50%	50%
Optical transmission	90%	90%	90%	90%
Total power at IF (W)	**15**	**110**	**155**	**230**

🟩 - Equivalency assumptions



Summary

- Cymer is committed to commercializing an HVM EUV light source for the 32nm node in 2009
- Cymer is uniquely positioned to ensure that current lithography source business drives investment in next generation EUV sources
- Laser Produced Plasma (LPP) technology is the most viable HVM EUV source solution and our chosen technology path
- High conversion efficiency is the key to cost effective solutions
- High power high repetition rate CO_2 laser technology has been validated and is operational at the 3kW level
- Current performance on our LPP development system is 30-45W at plasma or 10-15W equivalent at IF

Acknowledgements

- University of Illinois – Urbana Champaign
  Martin J. Neumann, Brian E. Jurczyk, David N. Ruzic
- Fraunhofer Institut f. Angewandte Optik und Feinmechanik
  Sergiy Yulin, Nicolas Benoit, Torsten Feigl, Norbert Kaiser
- Lawrence Berkeley National Laboratory
  Eric Gullikson, Franklin Dollar
- University of Central Florida
  Martin Richardson
- SEMATECH
  Vivek Bakshi

Please see our poster
21-SO-98
“LPP Source System
Development Results”

CYMER®

INSIST on CYMER™