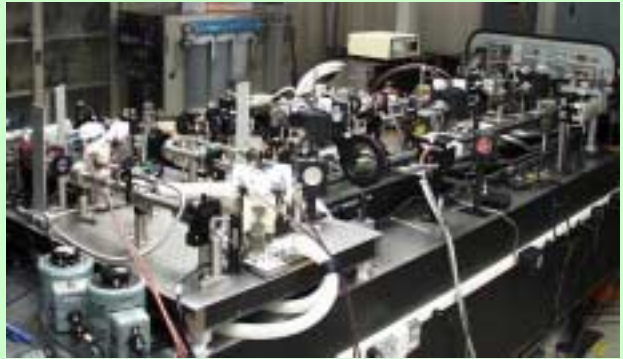


Laser Plasma EUV Source Development

International EUVL Source Workshop

Richard H. Moyer

16-19 October 2000



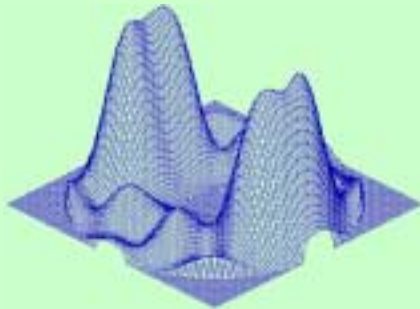
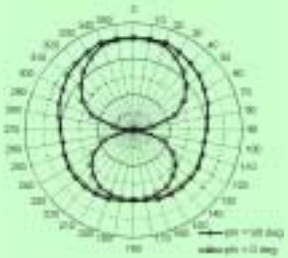
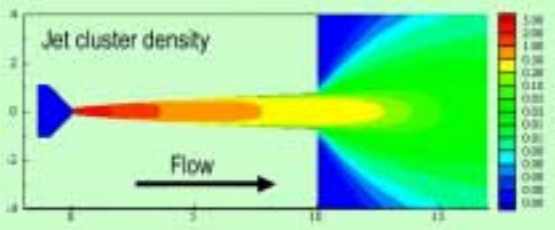
900 W illuminator validating laser designs
Improving laser design, cost-of-ownership, and component availability and performance for transition to production



Comprehensive xenon jet test capability
Measuring source angular distribution, size, shape, stability, repeatability and contamination

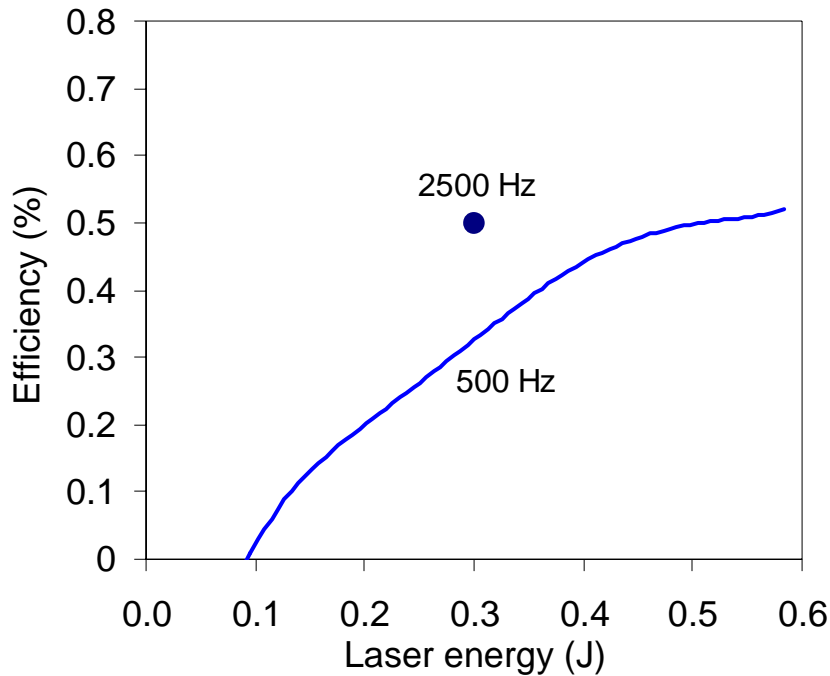
Models optimizing source design

Predicting gas jet profiles and clustering, laser/jet plasma interactions, radiance predictions for EUV optics design



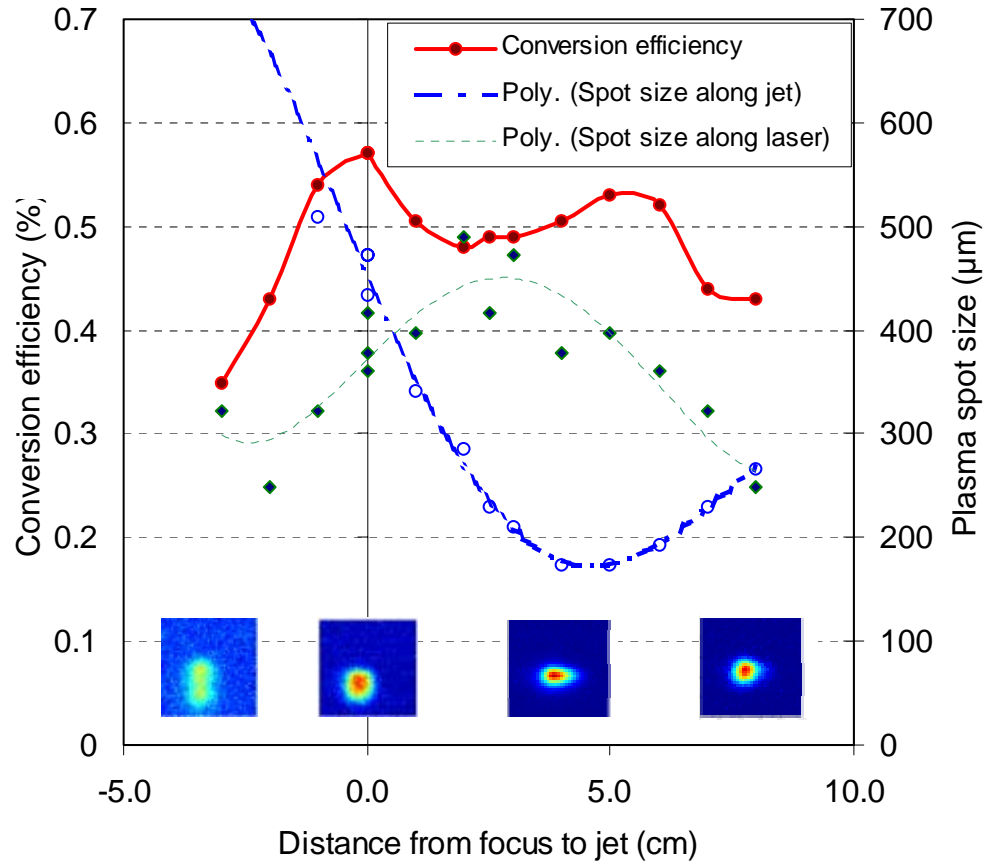
Tests Improving and Characterizing EUV Source

Demonstrated 0.5% peak efficiency
(2.2 eV, 2π ster)

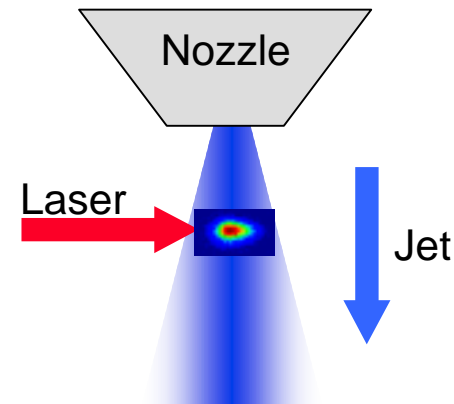


- Improving efficiency and characterizing source for SEMs: angular distribution, size, shape, stability, repeatability, and life
- Improving uniformity and reducing absorption due to gas-phase xenon — potential exists for 3x efficiency increase
- Higher power and pulse rate yielding higher efficiency and uniformity
- Optics life may have strong environmental component — identifying mitigation techniques
- Near-term source will use 1.5 kW laser to yield 5-10 W EUV; scaling both efficiency and laser power boosts EUV to 50-150 W requirement for 80 wafer/hour

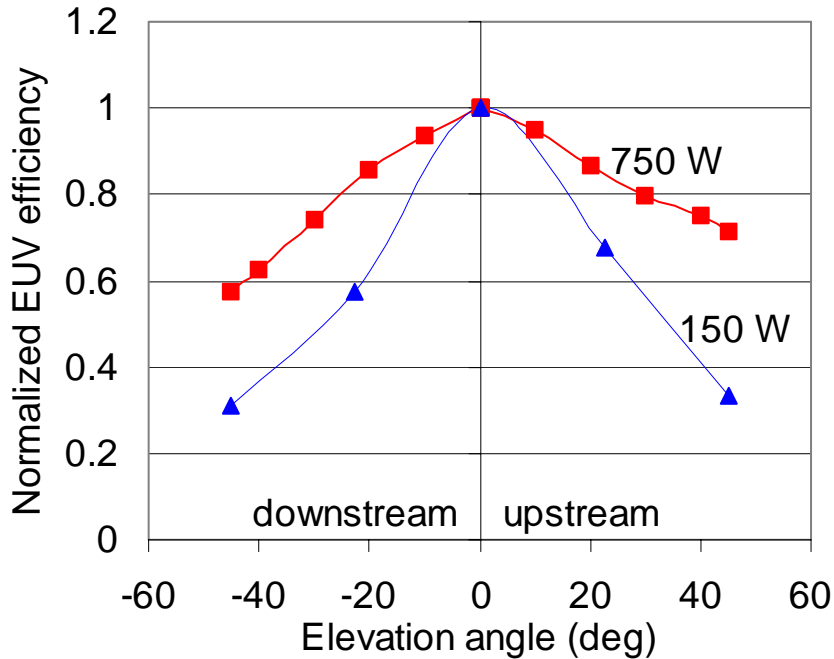
Spot Images Facilitating Condenser Design



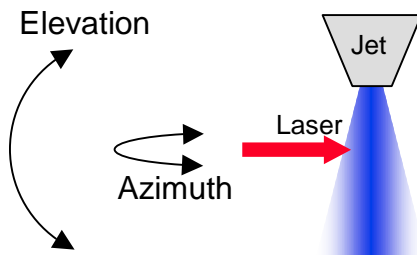
- Condenser design depends on emission size and brightness — small spots and high efficiency desirable
- Typical spot is 400 µm diameter
- Can trade spot size, shape, and efficiency with focus parameters



Angular Distribution Improves at Higher Laser Power



- Reducing EUV-absorbing gaseous xenon is main thrust of jet development
- New nozzles showing improved uniformity at higher power
- Higher power laser may clear xenon from jet, reducing absorption
- Efforts toward isotropic emission have potential for tripling total collected efficiency



Developing Beta Design for EUV Source

- Validating designs with source testing hardware
- Developing technical/market requirements with SEMs
- Improving design cost-of-ownership, component availability and performance
- Planning manufacturing and production



1700 W laser at Sandia



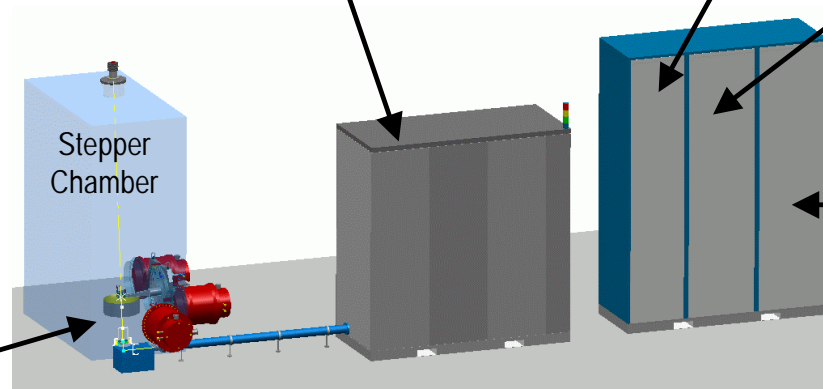
Xenon handling



Chiller



Turbo pumps and jet

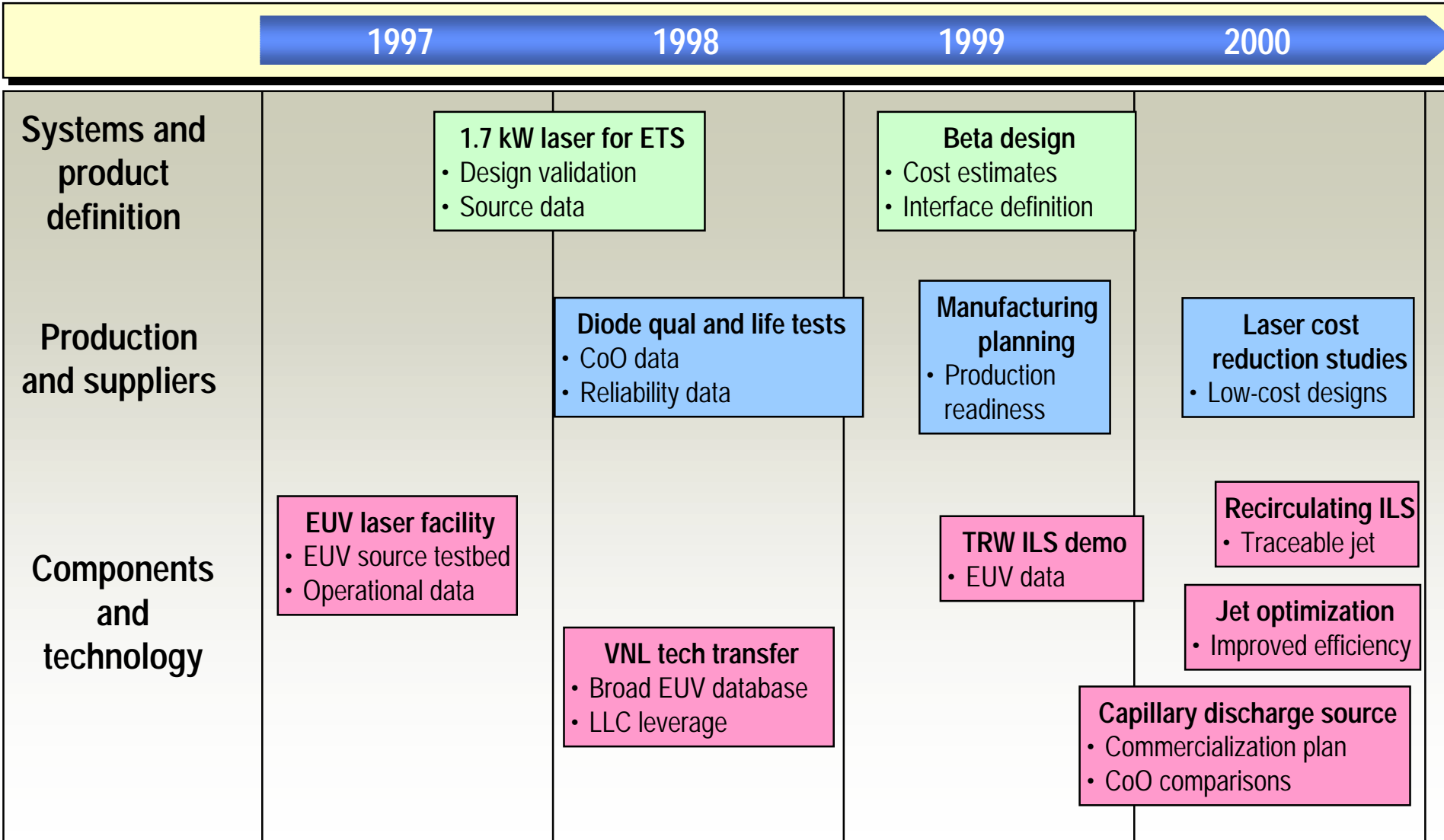


1 x 5 m footprint



Controller and power supplies

Current Program Developing Source Technology



Future Program Develops Source Product

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Source Production *		1	3	3	11	50	100	200	300
Product definition	Development 2-3 W EUV		Productize 10 W EUV		Early Production 25 W EUV		Production 50 W EUV (80 wph)		
	<ul style="list-style-type: none"> • Prototype LPP sources 		<ul style="list-style-type: none"> • Sources for process development 		<ul style="list-style-type: none"> • Sources for stepper integration and pilot plants 		<ul style="list-style-type: none"> • Mass production • Product improvement 		
Production and suppliers	<ul style="list-style-type: none"> • Current TRW facility 		<ul style="list-style-type: none"> • Current TRW facility • Full production investments • Qualify suppliers 		<ul style="list-style-type: none"> • Transition to production facility • Volume production process & logistics • Long-term supplier agreements 		<ul style="list-style-type: none"> • Ramp production capacity • World-wide service network 		
Components and technology	<ul style="list-style-type: none"> • High-power nozzle optimization 		<ul style="list-style-type: none"> • Low-absorption nozzle development • High-power laser 		<ul style="list-style-type: none"> • Low-absorption nozzle optimization • Lower-cost laser development 		<ul style="list-style-type: none"> • Optimize / implement next-generation laser 		

* per LLC forecast

Performance Summary and Forecast



	Now		In 1 year	In 2 years	Ultimo	Requirements for commercial tools
	SNL	TRW				
Demonstrated collectable EUV power in a 2% spectral bandwidth in the region between 13-14 nm (W)	2	1.2	6	26	50	50-150 Watt
Available collection solid angle (ster)	0.5π	0.9π	π	π	π	
Source emission volume dimensions (mm)	0.2-0.4		0.2-0.4	0.2-0.4	0.2-0.4	
Demonstrated maximum repetition rate (kHz)	1.7-6	2.5	2	4.5	6	> 5
Demonstrated steady-state repetition rate (kHz)	1.7-6	2.5	2	4.5	6	
Dissipated total power (e.g. electrical or laser) in source region at steady-state repetition rate (kW)	1.3	0.75	1.5	4.5	4.5 - 9	
Source-facing condenser lifetime (pulses to 10% reflectance loss)	3×10^8		1×10^9	1×10^{10}	$> 10^{11}$	1 year or 1.6×10^{11} pulses
	Environment req'ts TBD					
Pulse-to-pulse spatial stability (3σ variation of EUV emission centroid position) (μm)	50		10	10	10	
Pulse-to-pulse intensity stability (3σ variation of EUV flux)	15%		10%	3%	2%	< 2%
Pulse-to-pulse angular stability (3σ variation of EUV radiant flux at widely separated angular positions)	15%		10%	3%	2%	
Pulse-to-pulse pointing stability (3σ angular variation of principal emission direction [if nonuniform])	TBD		5%	3%	2%	
Key risk areas	Nozzle and diode life					
Critical component lifetime						
Nozzle (hrs)	500		1,000	5,000	5,000	
Laser diodes (hrs)	1,000		2,000	5,000	10,000	

Relax any req't 2x? EUV power reductions will lower capital and operating cost, thermal loading, and contamination