

# High Power Astron EUV Source

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## Universal Efficiency for 13.5nm Generation in Xenon: Thermal Limits

Laser-produced xenon plasma converts 0.5 - 1.0% of absorbed laser light into 2% band at 13.5nm, (2 sr)

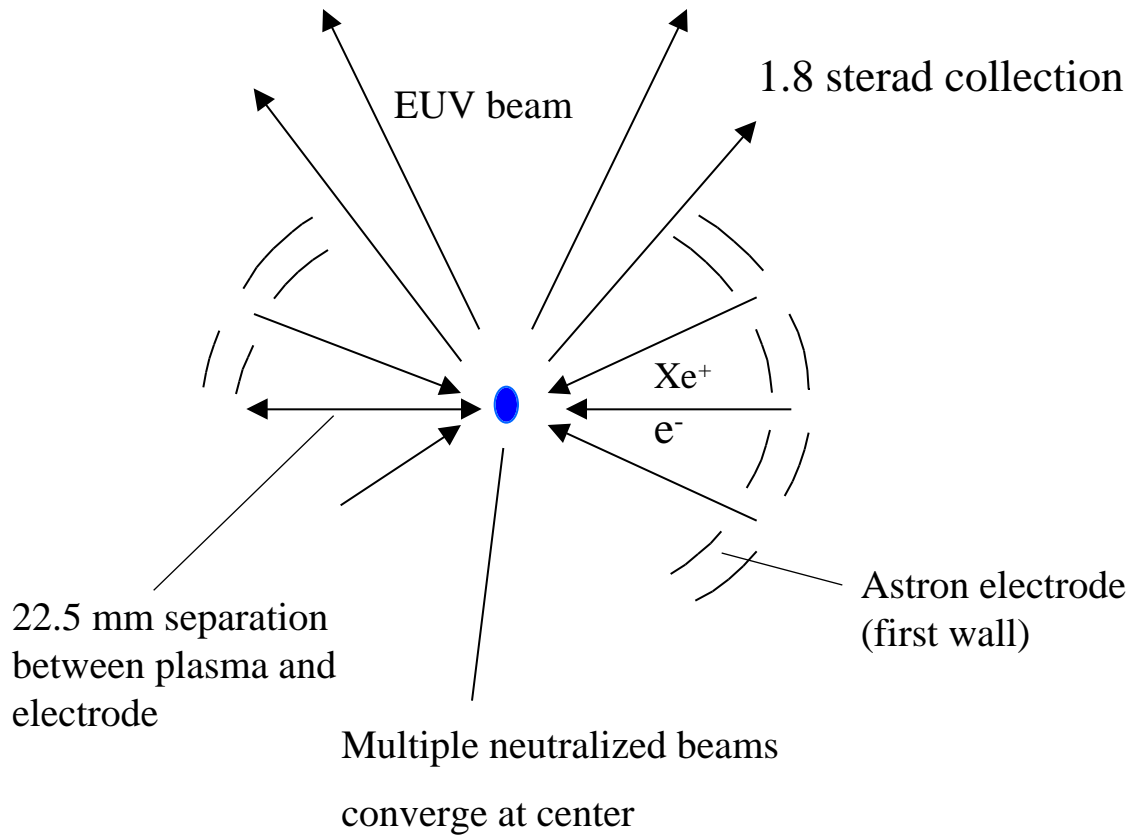
Discharge-produced plasmas have at least 0.5% efficiency from stored energy into 2% band at 13.5nm, (2 sr)

**86W** in 1.8sr (before first collector optic) implies a plasma power of 30-60kW

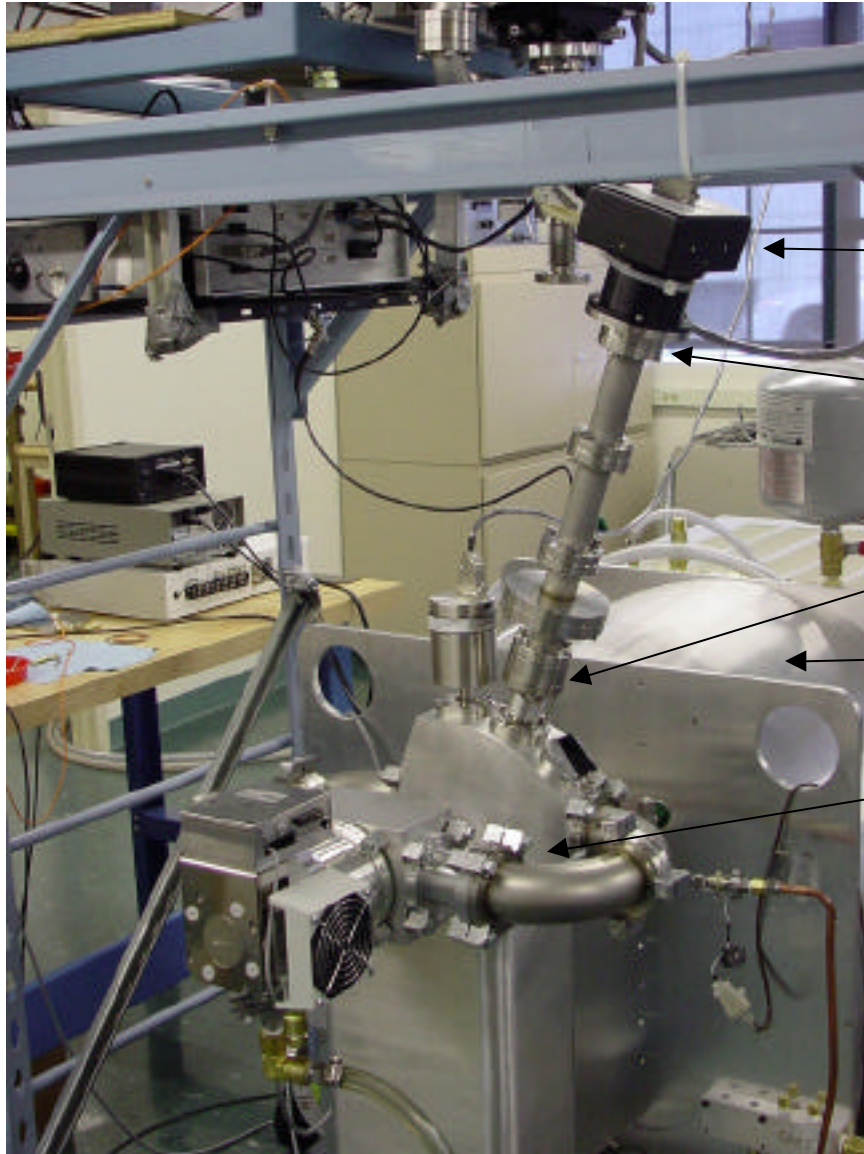
BUT heat load from 30-60kW plasma is significant.  $< 500\text{Wcm}^{-2}$  on first wall implies **wall should be 20 - 30mm from plasma.**

The **Astron** discharge geometry has been developed by PLEX to solve this problem. It has currently 0.5% efficiency and 22.5mm distance to nearest wall: It can extend to full industrial EUV power with only  $500\text{Wcm}^{-2}$  heat load.

**Astron plasma has generated 13.5nm at 0.5% efficiency, NOT optimized**



**Optimized 13.5nm efficiency is projected to be >0.6% in 2% BW into  $2\pi$**



CCD camera

Zr filter

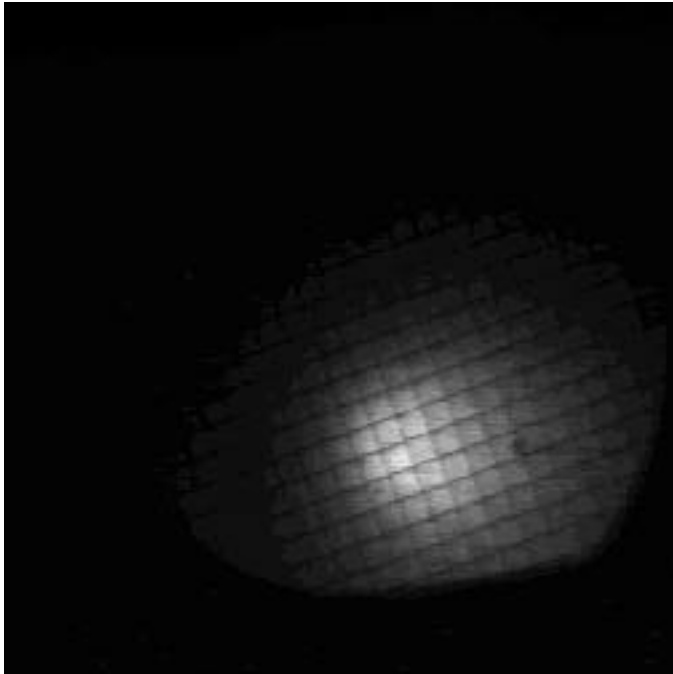
pinhole

20J, 1000Hz modulator

Astron plasma device

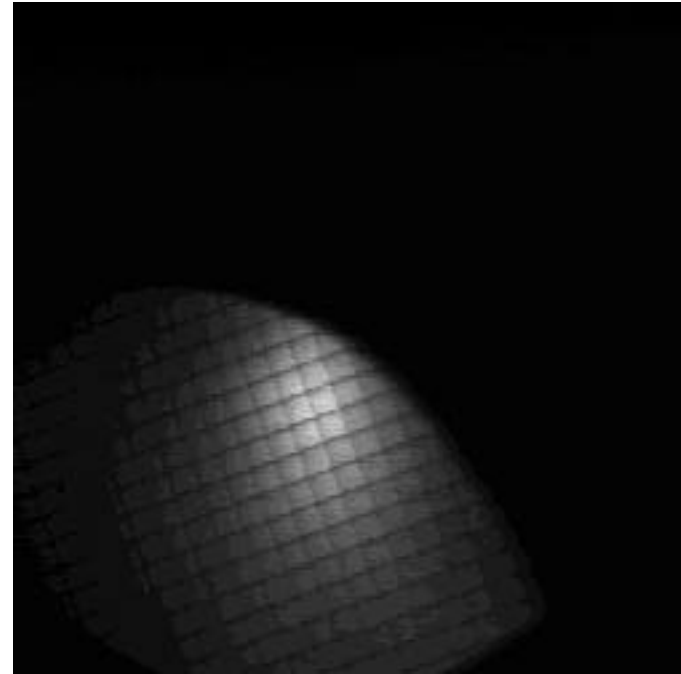
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## EUV Imagery of Astron Plasma



axial image

FWHM dia  $1.3 \pm 0.3$ mm



20deg image

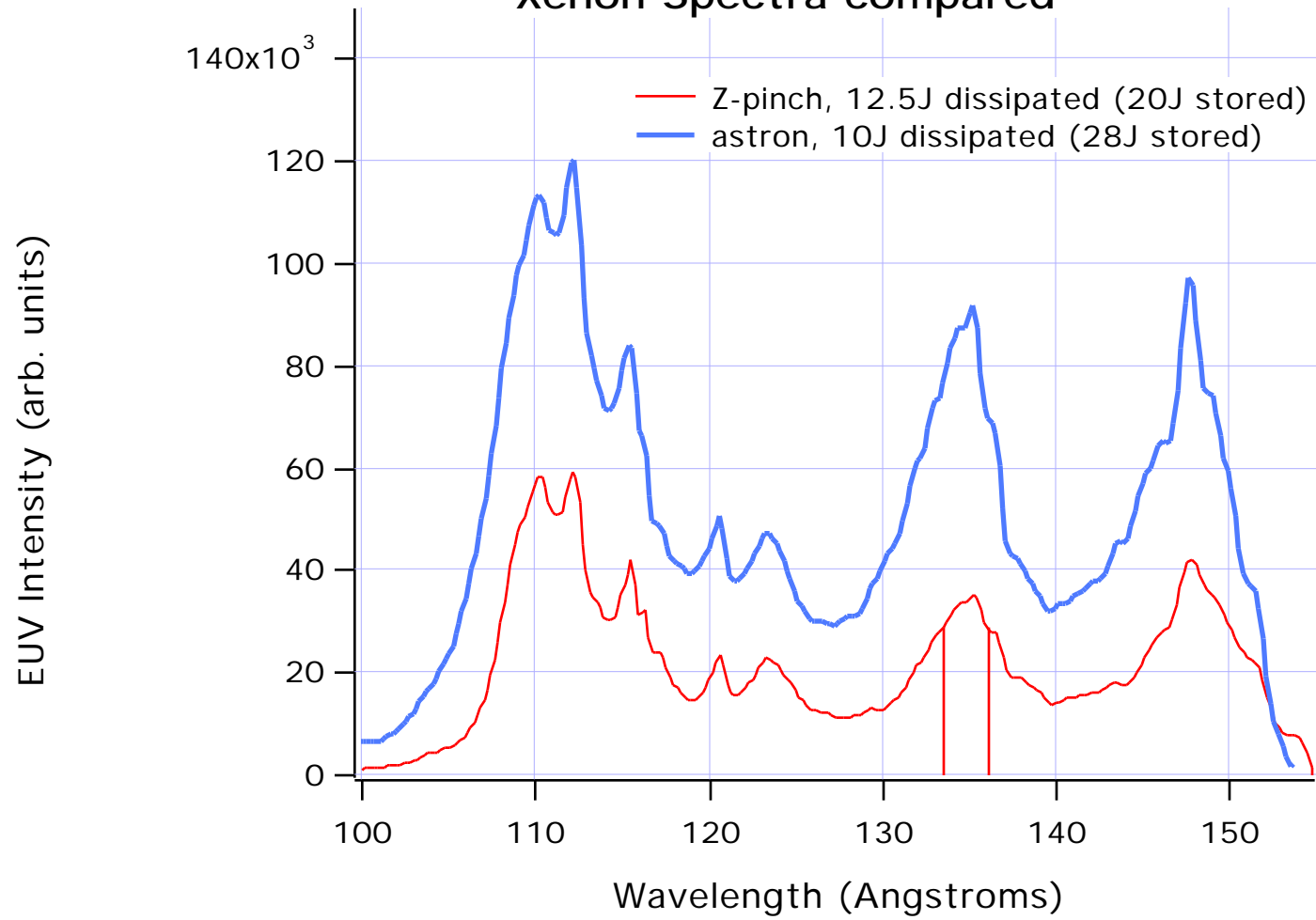
Apparent FWHM 1.7mm x 1.3mm

Single pulse 7-17nm images thru 2100Å Zr filter, 50µm pinhole

Positional stability  $< 0.4$ mm (centroid)

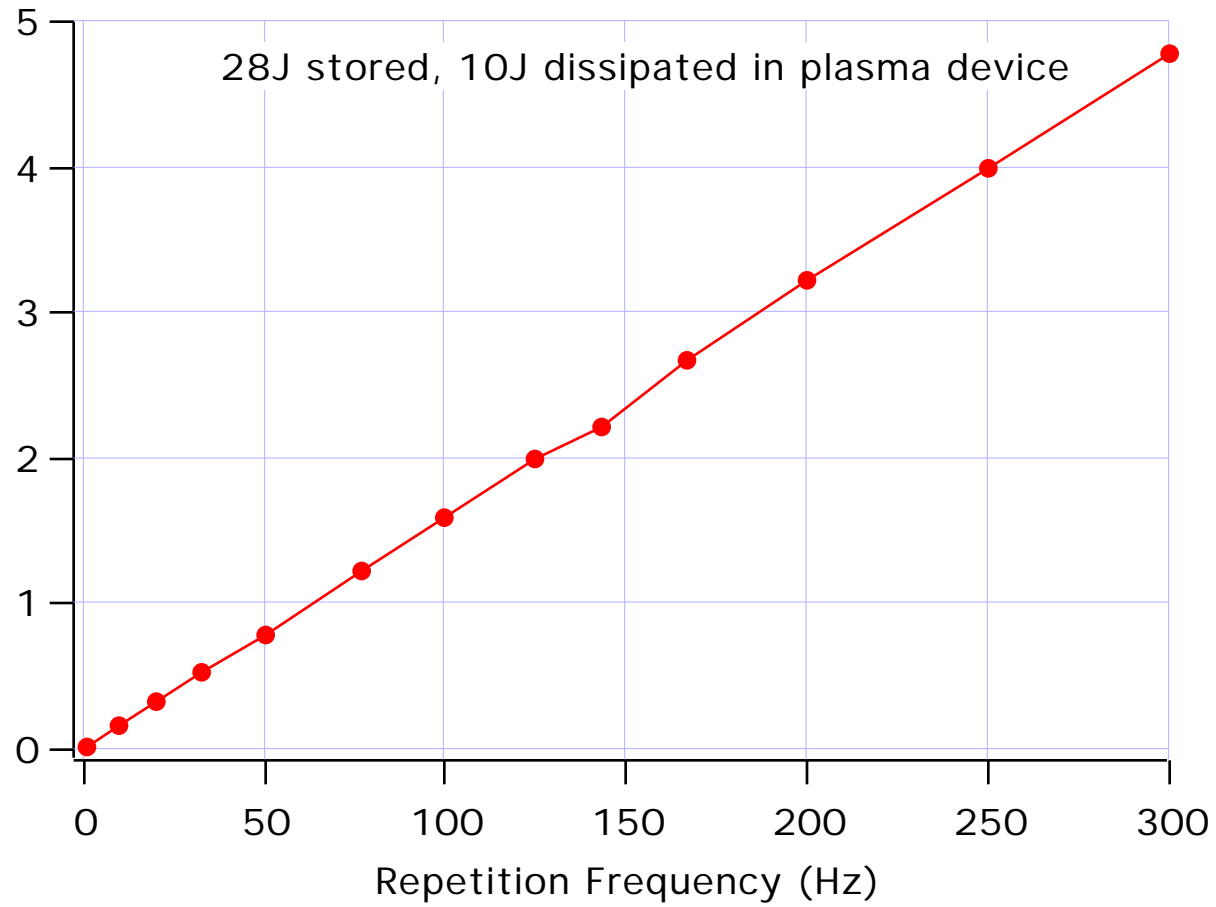
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### Xenon Spectra compared



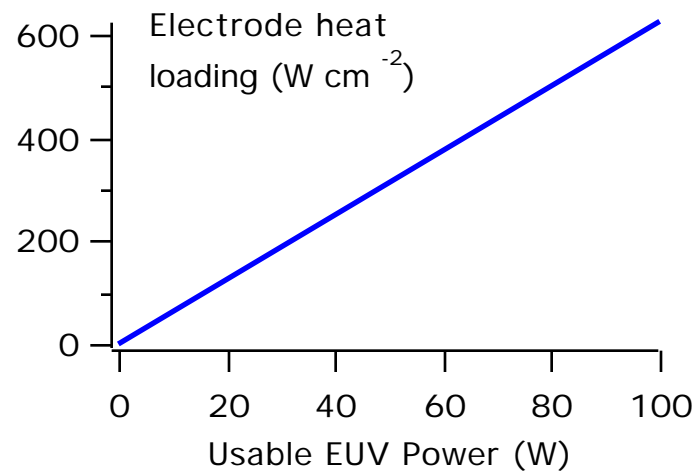
# Experimental Power Scaling

13.5nm Power (W) in 2% BW into 2 sterad



## Astron Electrode Heat Load Scaling (with xenon)

	Present	Future
Efficiency	0.5%	>0.6%
Plasma to First Wall (mm)	22.5	25
Electrode Area (cm <sup>2</sup> )	30	50
Repetition Rate (Hz)	300	6,000
Usable EUV (clean, 2%BW, 2sr)	4W	80W
Electrical Input (to plasma)	3.0kW	<60kW
Peak Electrode Heat Load (W cm <sup>-2</sup> )	30 (est)	<500



## **Near Term Astron Development:**

DARPA research contract began 9-01 with milestones:

12-01

Plasma size measured in EUV at angles 0°, 20°, 40°,  
13.5nm efficiency optimized, 10kHz modulator designed

3-02

Life test to  $10^7$  pulses at 500Hz (6W usable), burst test to 1,000Hz,  
Ellipsoidal condenser cleanliness test completed

6-02

Designs completed for 2kHz, 20W continuous operation

9-02

Life test at 1,000Hz, 10W to  $10^8$  pulses, with condenser

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## Conclusions

The industrial EUV source power will be attained by the astron

Its cost of ownership should be similar to excimer lasers

It will have <60kW “wallplug” power consumption using xenon  
(and possibly much less using lithium)

It has <500Wcm<sup>-2</sup> projected heat load on plasma-facing parts

It has stability and cleanliness

It is expected to have industrial reliability and life