Robust liquid metal collector mirror for EUV and soft X-ray plasma sources

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New Lambda

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Overview

- Motivation
- First Prototypes (Cone + Flat)
- Current Prototypes (Cylinder + Ellipsoid)
- Zemax Modelling
- Focused EUV – First Results
- Lifetime Monitoring
- Planned Work

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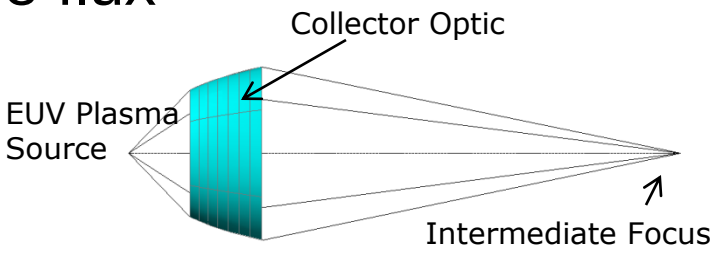
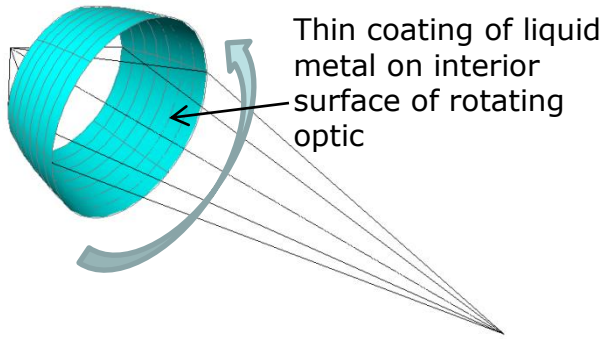
Motivation

- EUV Sources for Metrology
  - Simple collector ⇒ ~10^4 more flux
  - Requires atomically flat mirror
  - Sn Plasma debris + fast ions
    - Lifetime issues



- Liquid metal coated mirror
  - Sn based alloy
  - Relatively long lifetime
  - No debris mitigation



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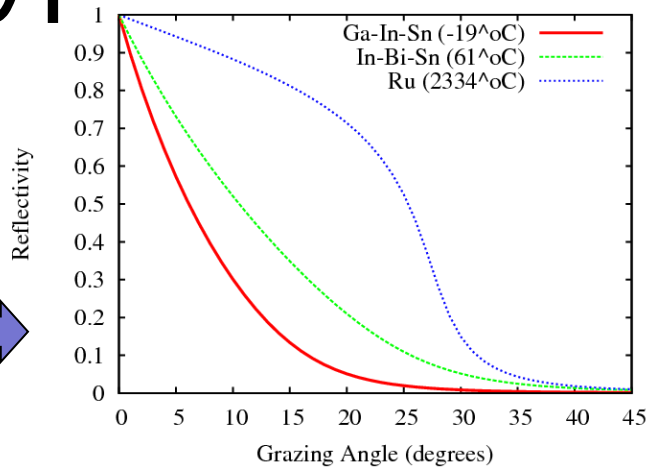
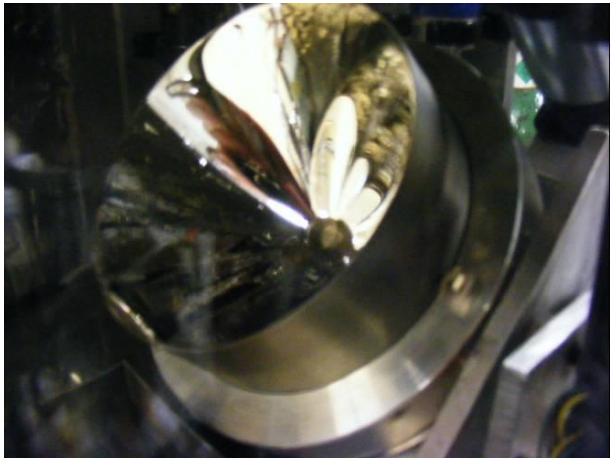
First Prototypes

- Established coating mechanism on rotating optic
  - GaInSn alloy ; Melting pt -19ºC
  - Theoretical R v θ at 13.5 nm (92eV)
    (from http://henke.lbl.gov/optical_constants/mirror2.html)





Cone: Dia: 100mm

Plane: Dia: 100mm

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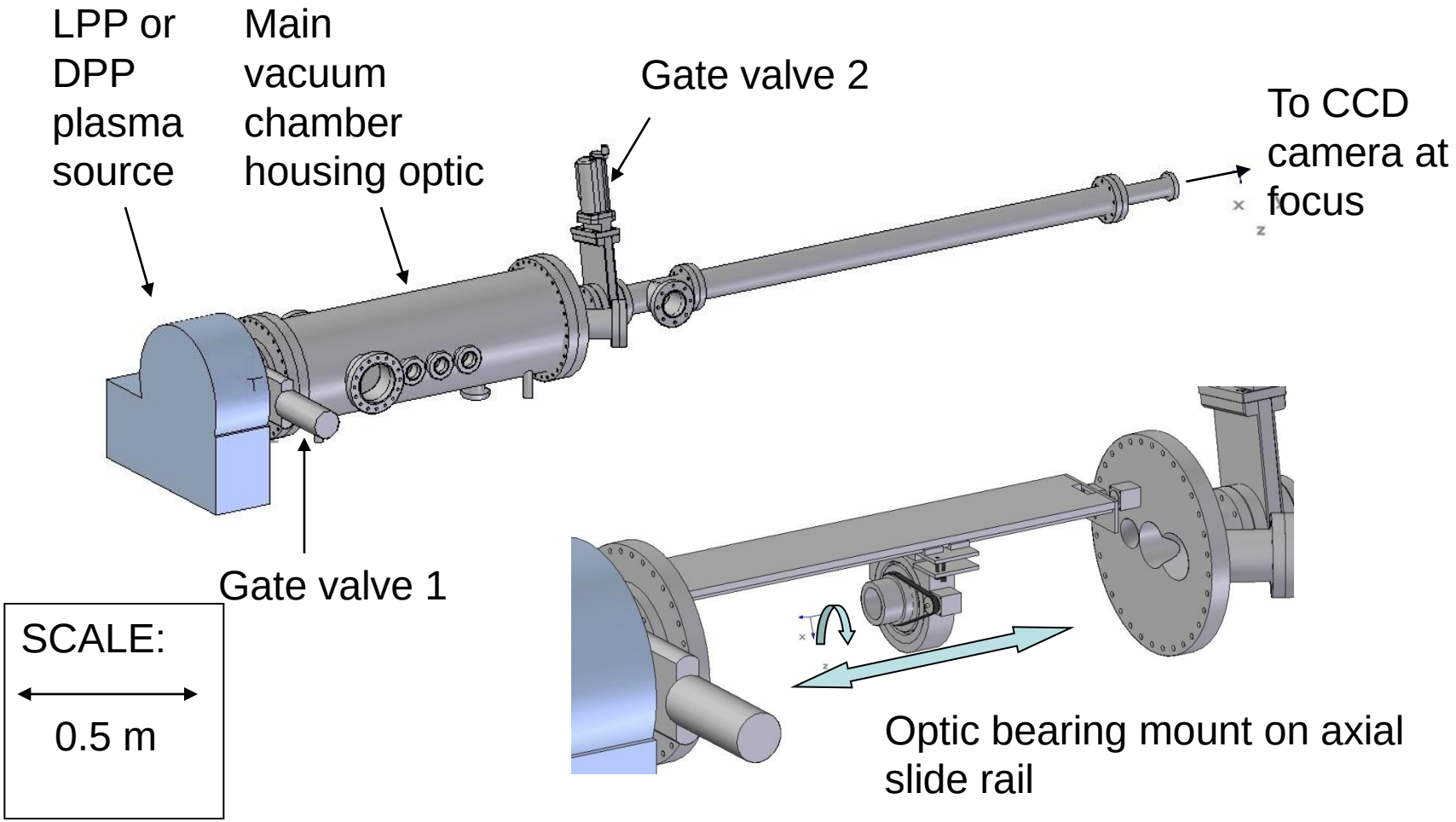
Focusing EUV: Exp. Design



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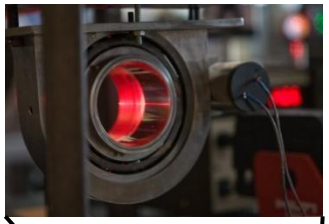
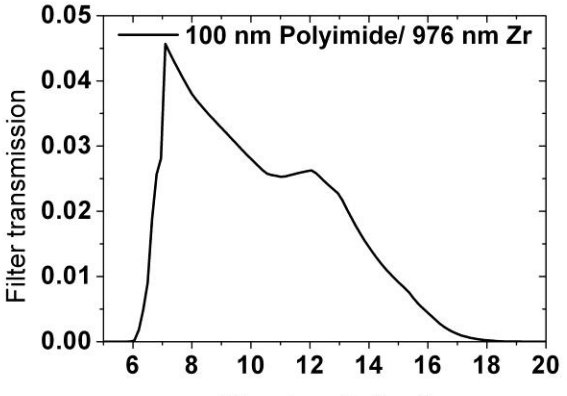
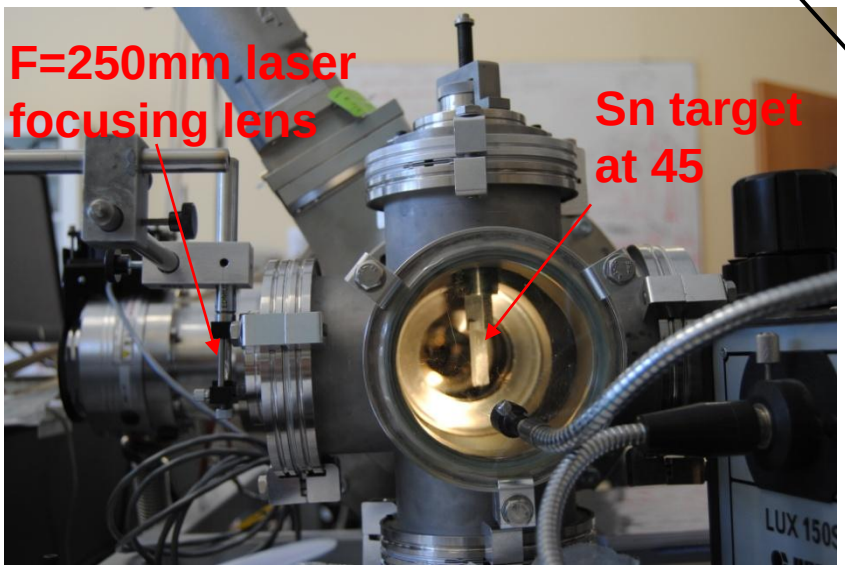
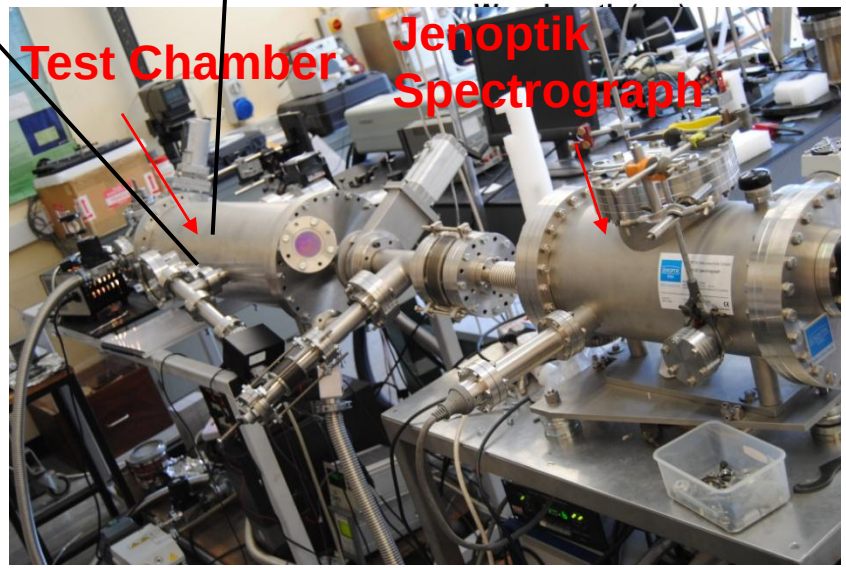
EUV Testing: Initial Setup

- Sn LPP source
- Optic: Cylinder shell 80 mm x 55 mm (LxDia)
- 100 nm Poly/976 nm Zr EUV filter
- CCD camera: Princeton Instruments PI-SX, 1024x1024, 13 µm pixels.









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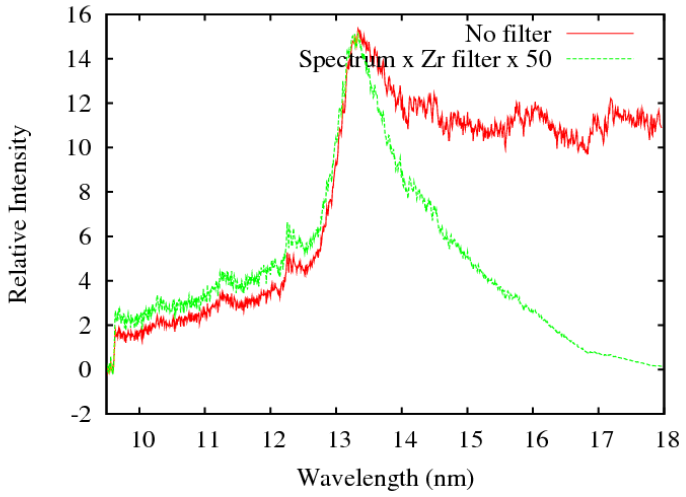
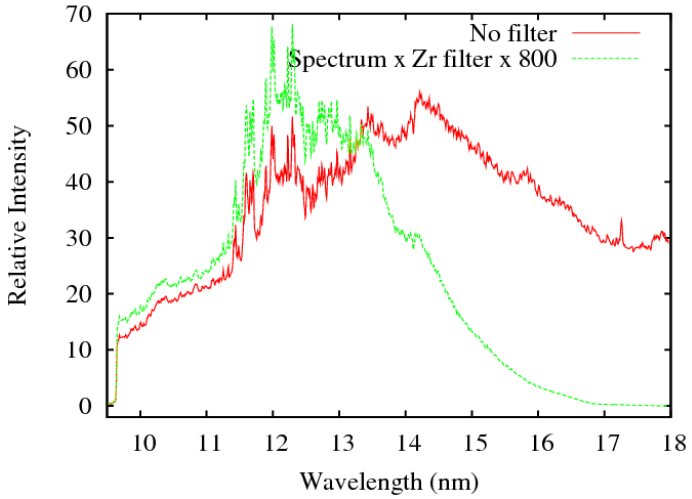
Source Spectra

- Jenoptik Espec grazing incidence spectrograph

Pure Sn Spectrum
$\Phi \sim 3x10^{10}$ Wcm^{-2}



Liquid target Spectrum (GaInSn)
$\Phi \sim 3x10^{11}$ Wcm^{-2}



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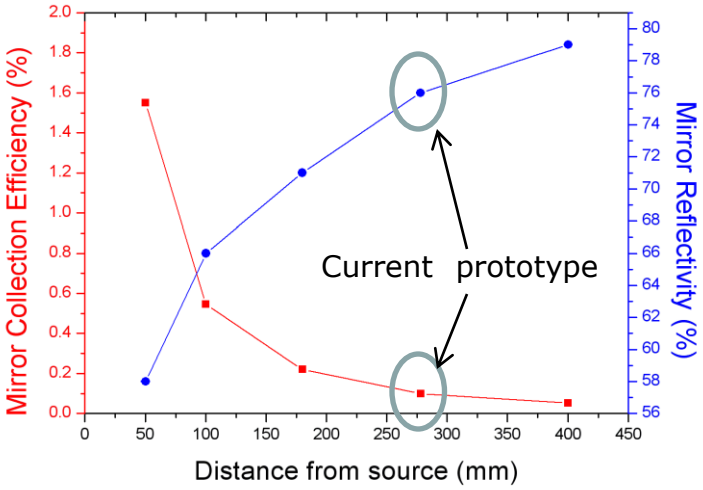
Zemax Modelling

- Cylinder + Ellipsoid performance modelled
- Optimization of Ellipsoid for typical DPP source



	Present Collector	Optimized Collector I	Optimized Collector II
In-band Power at source (W)	11.2	11.2	11.2
Source radius or FWHM (mm)	0.345	0.345	0.345
Source to mirror distance (mm)	278	200	25
Magnification	13.6	3.2	2.6
Average Reflectivity (%)	78	67	18
Power Density at Image (mW/mm^2)	0.4	14.4	151.9
Power Density No Collector (mW/mm^2)	0.0002	0.0024	0.029

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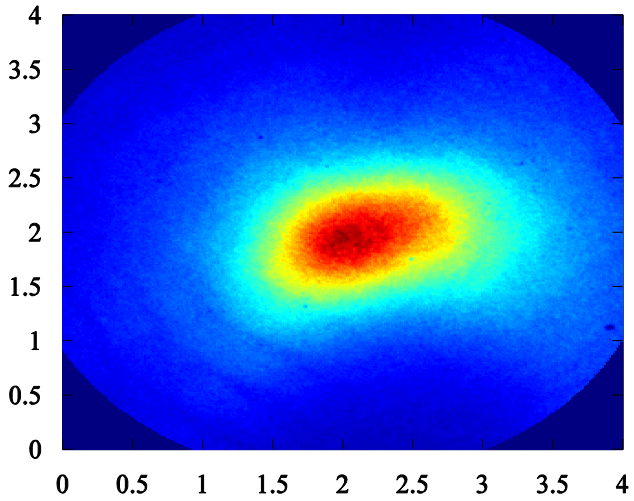
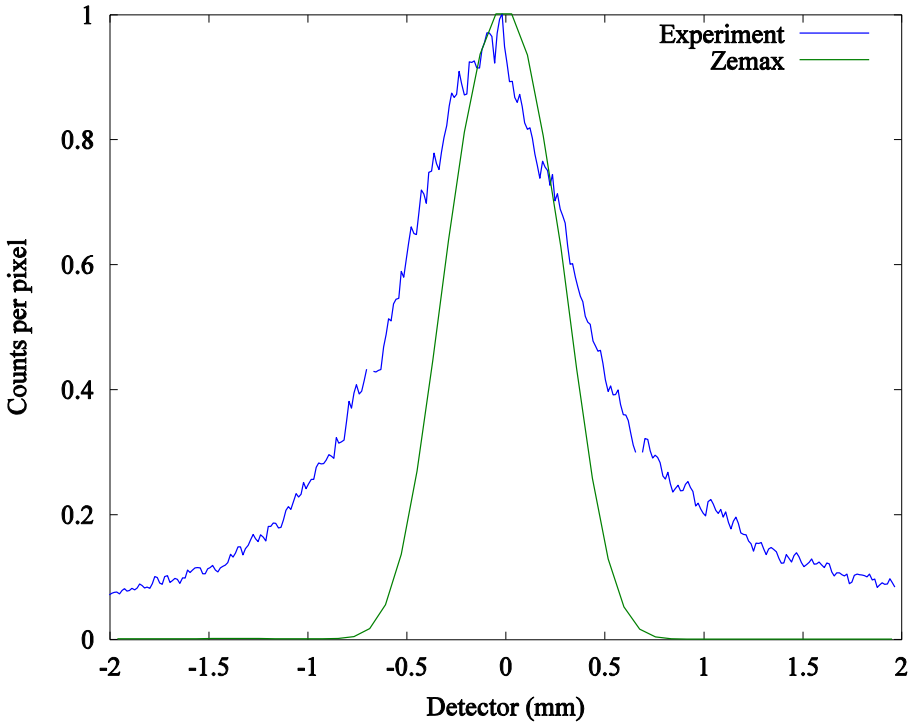
Focused EUV – First Results

- Ellipsoid Section





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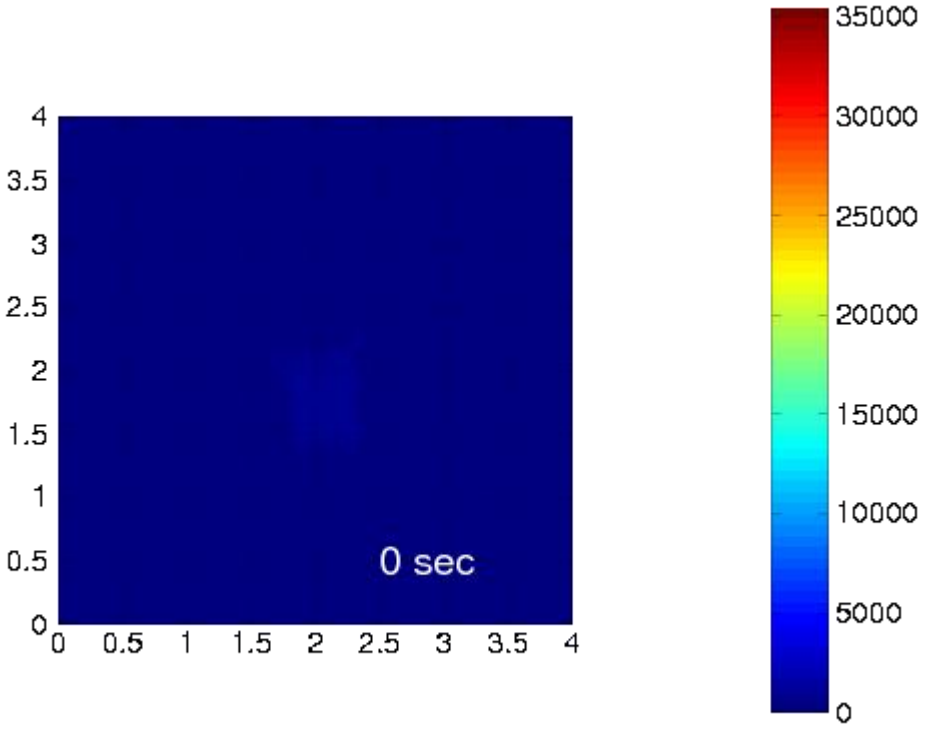
Mirror Start-up



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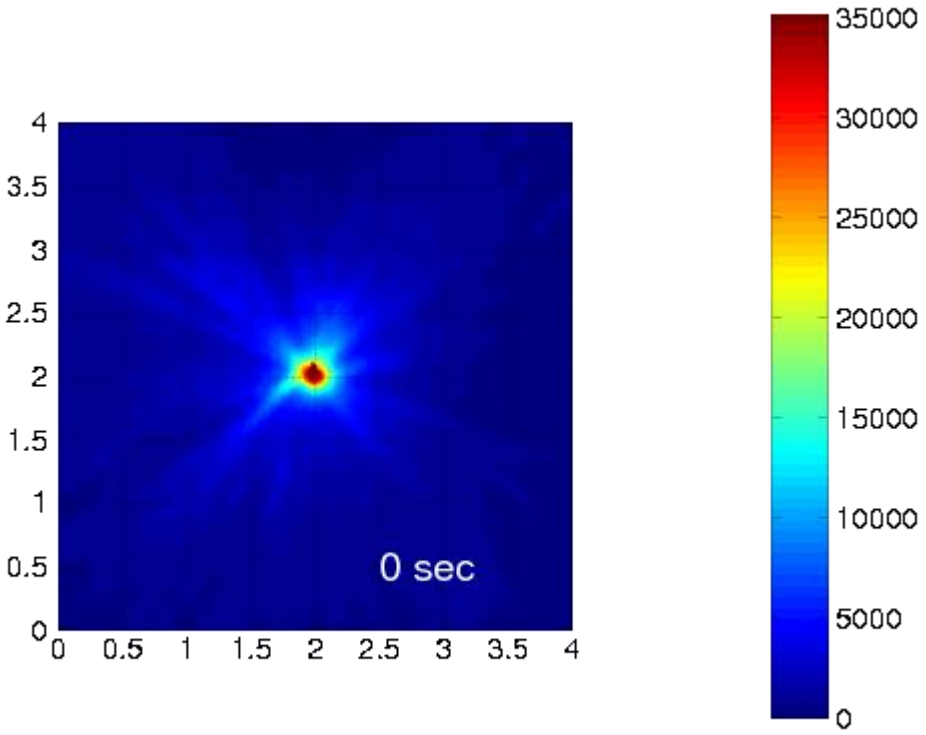
Mirror Running



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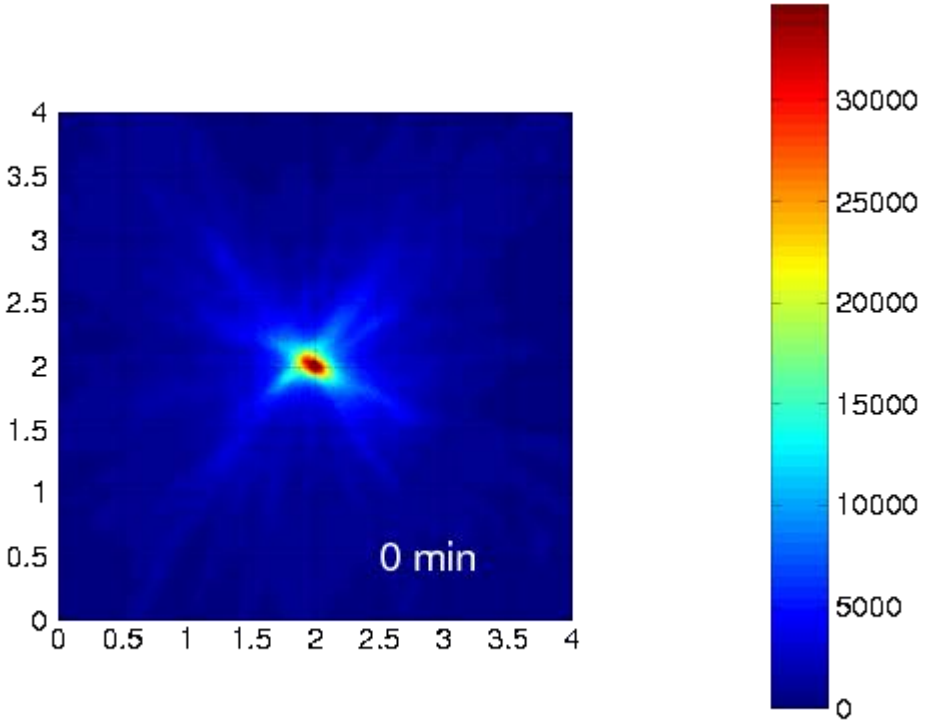
Mirror Stopping



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Lifetime Testing

- 20 W LPP Plasma
- Plasma to mirror distance = 200 mm

# Pulses (x1000)	# EUV Photons collected	Image fwhm (μm)
0	3.08 x 10^6	290
200	2.78 x 10^6	299
400	3.11 x 10^6	292
600	3.01 x 10^6	302
800	3.05 x 10^6	286

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Ongoing Work

- Characterise EUV Source
- Optically characterise ellipsoid figure error
- Zemax – Application specific optimum mirror shapes
- Long term operation in front of commercial DPP or LPP source

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