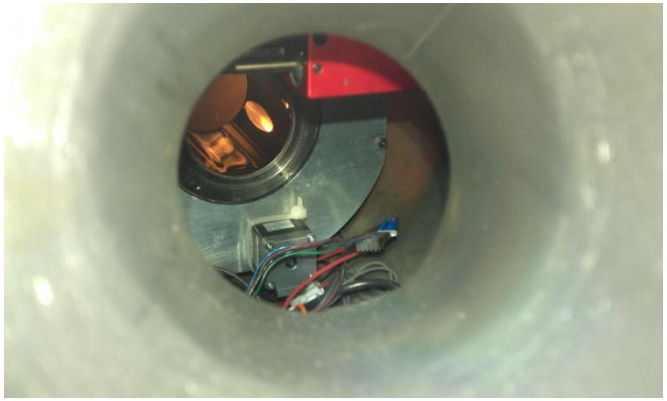
Progress on Liquid-Metal Collector Mirrors as Robust Plasma-Facing EUV & Soft X-ray Optics.

Kenneth Fahy, Fergal O'Reilly, Enda Scally, Padraig Dunne & Paul Sheridan



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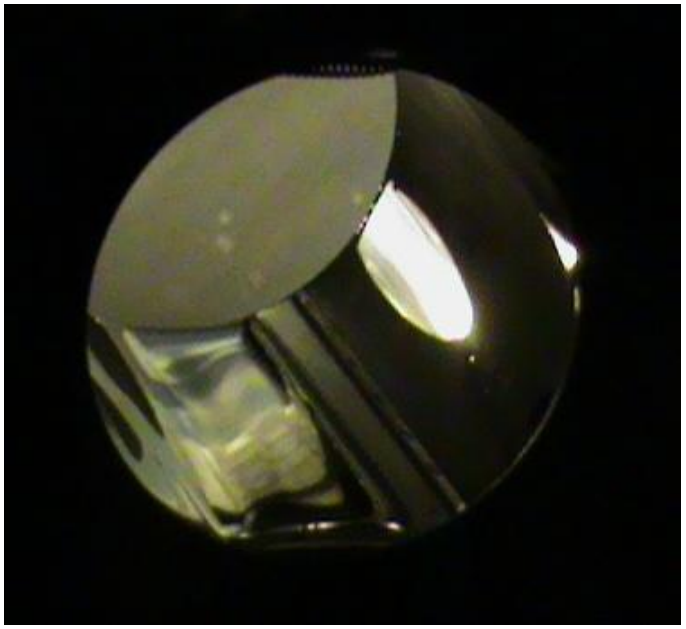
Outline

- Motivation
- The liquid metal mirrors
- Experimental setup
- The EUV sources
- Experiment & results:
  - EUV & optical
- NewLambda Technologies
- Conclusions



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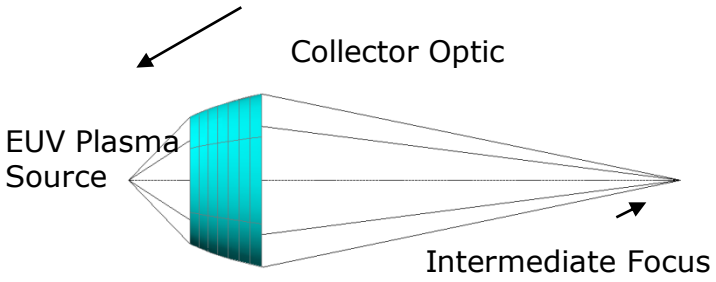
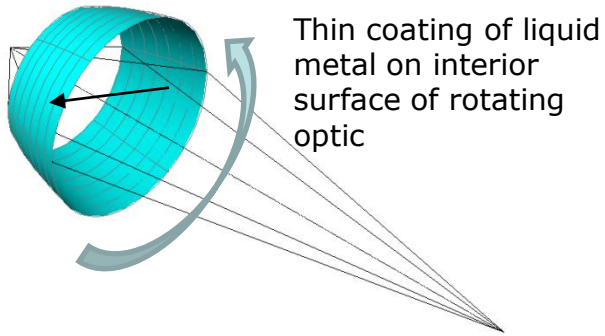
Motivation

- EUV Sources for Metrology
  - Simple collector
  - Requires atomically flat mirror
  - Sn Plasma debris + fast ions
    - Lifetime issues



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



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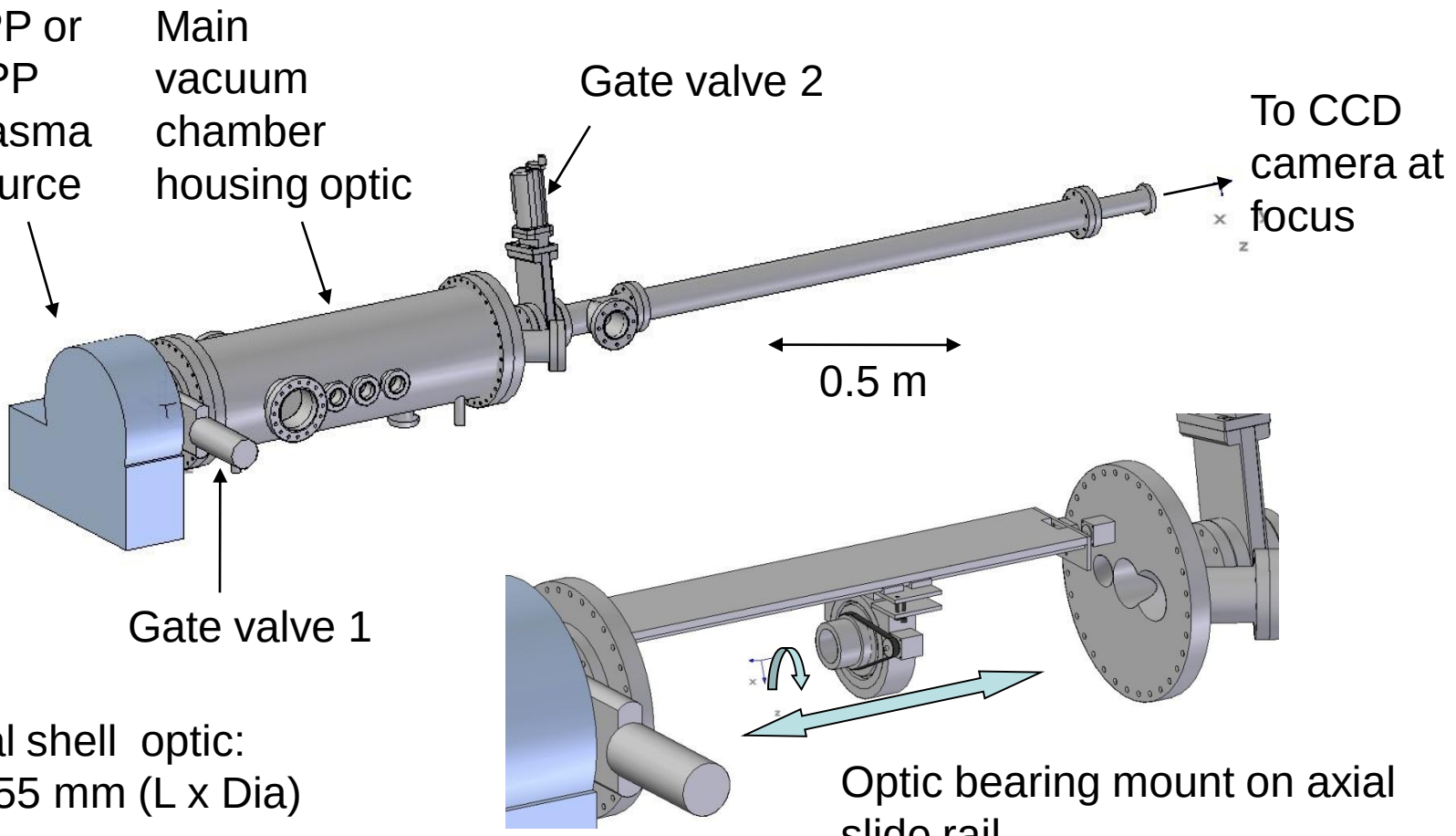
Experimental Setup



Cylindrical shell optic:
80 mm x 55 mm (L x Dia)

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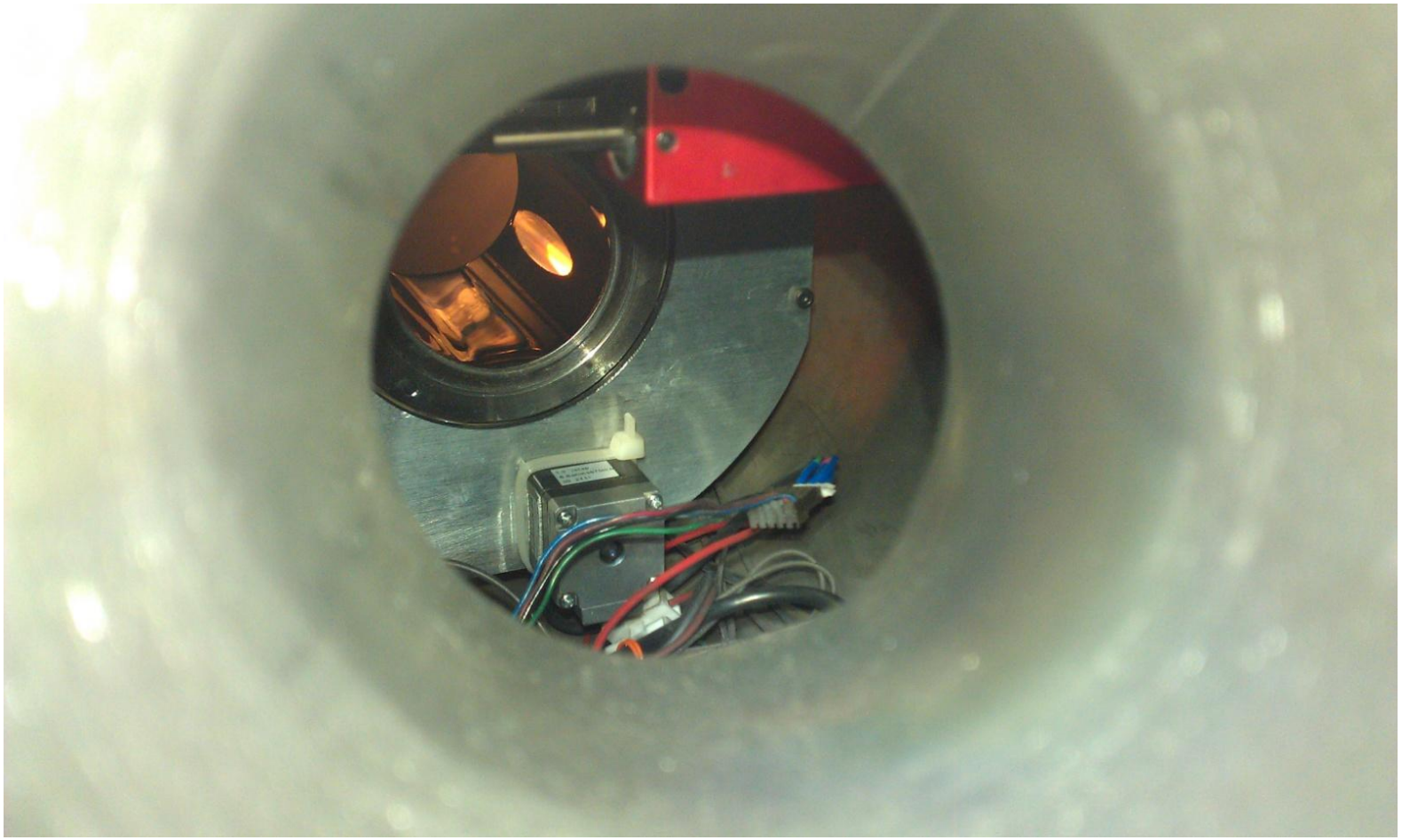
The Cylindrical Mirror



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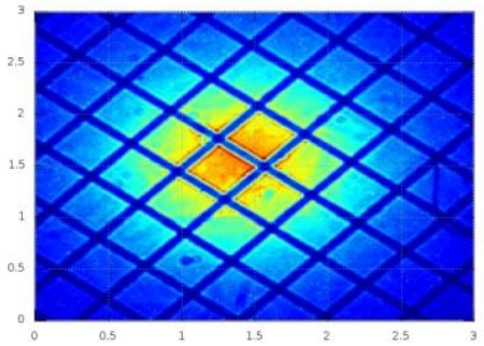
EUV Sources

- #1 Xe, Ar DPP Bruker 200 W
- 100 Hz
- Size 300 - 500 µm



- #2 GaInSn LPP
- 50 Hz, 25 W Nd:YAG laser
- Size ~ 60 µm

- #3 Sn DPP ISAN 200 W
- 10 Hz, 50 Hz.
- Size < 500 µm

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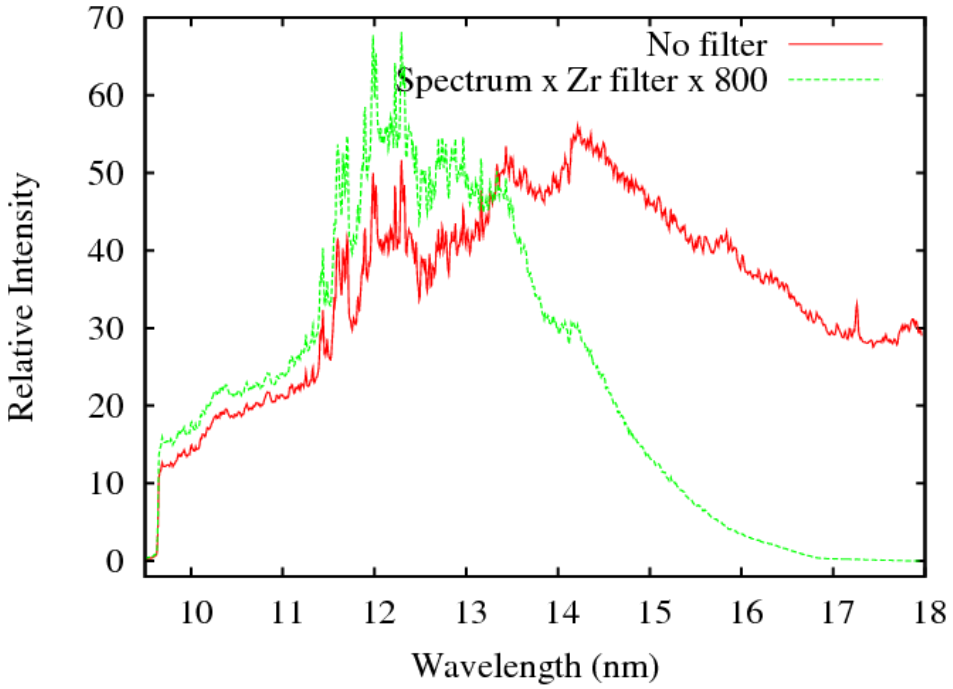
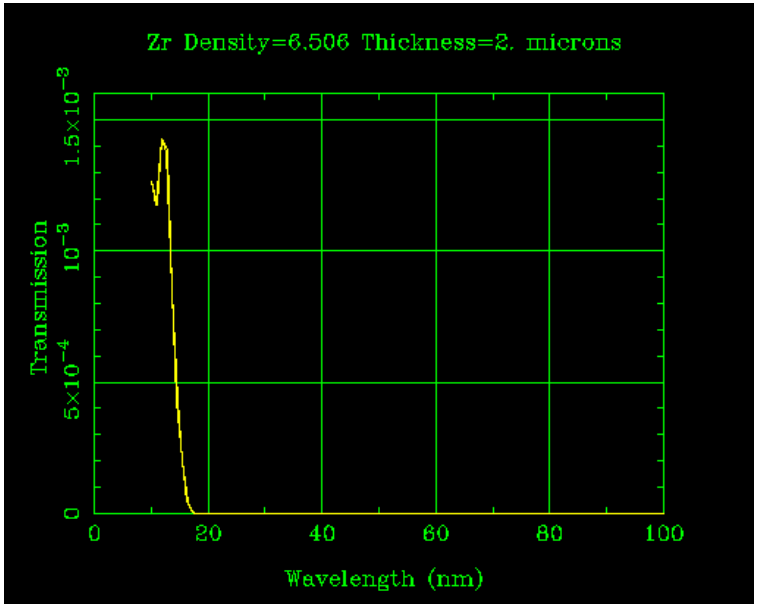
EUV Spectrum - GaInSn





Source: CXRO

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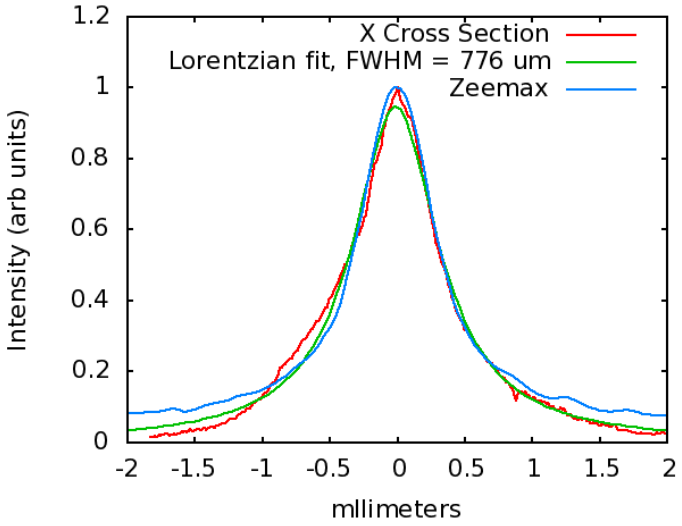
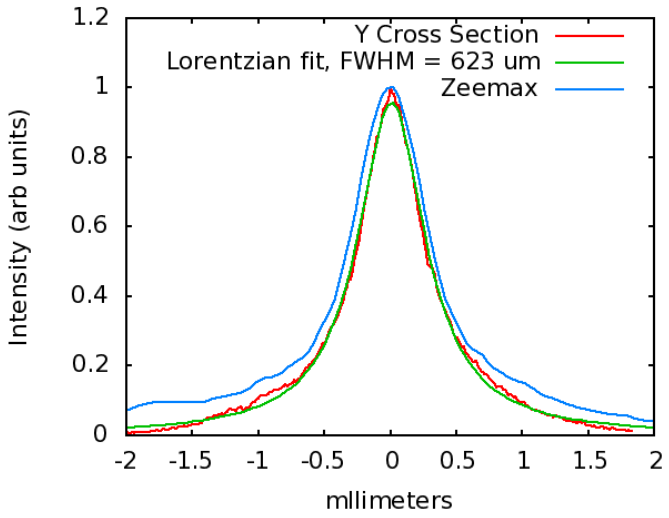
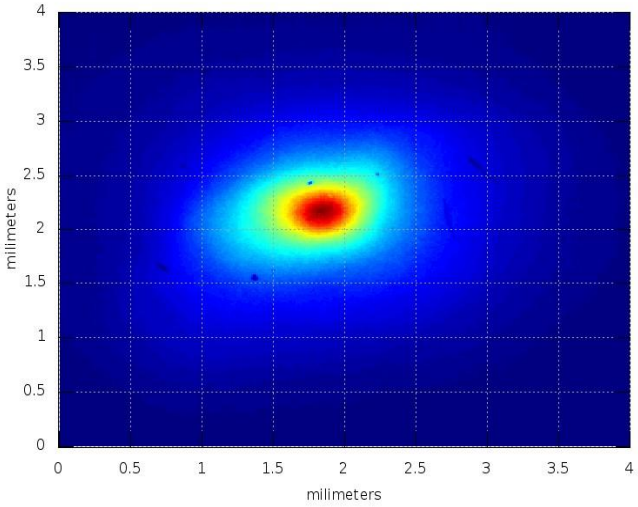
EUV Test Data - DPP

- Bruker DPP source, Xe, 8 kV, 1.28 J, ω_{mirror} < 2 r.p.m





Single shot CCD image



- *$FWHM_x$ = 776 µm, $FWHM_y$ = 623 µm*
- *Zemax DPP source model*
  - *Lorentzian pinch, FWHM = 420 µm*

- *Asymmetry due to liquid pool – Zemax predicted*

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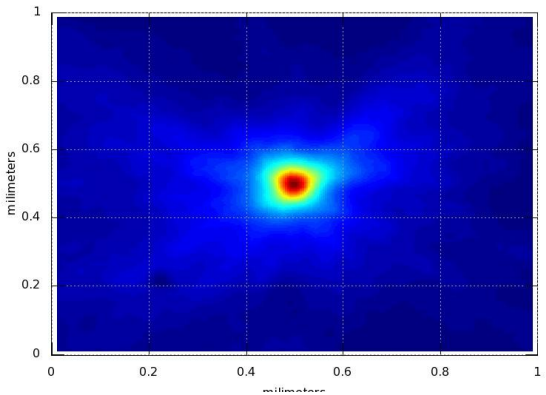
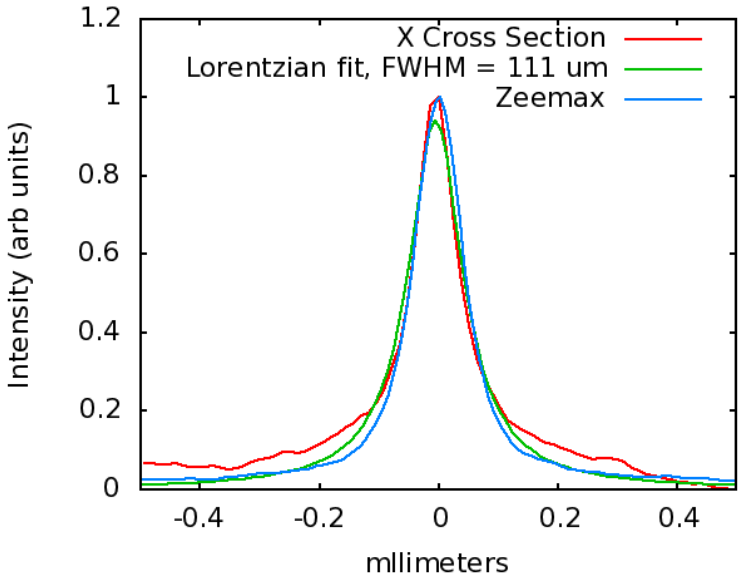
EUV Test Data - LPP

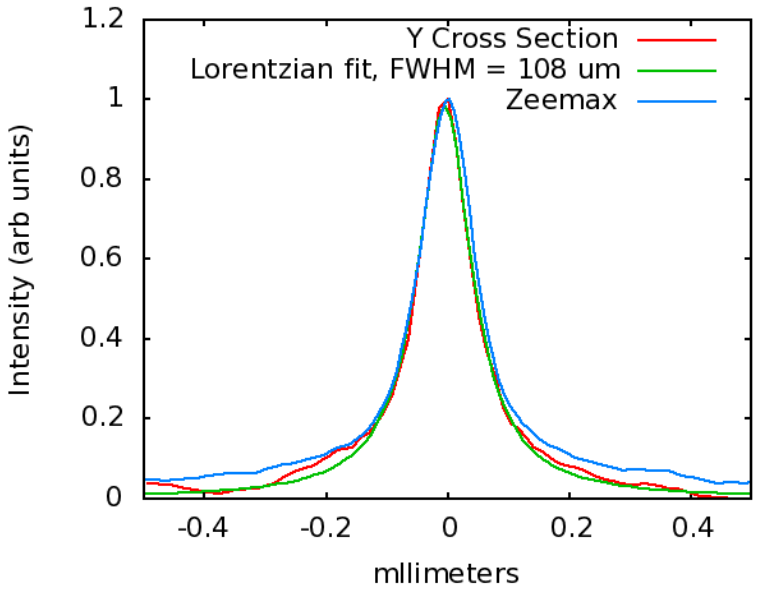
- GaInSn LPP source
- ~50 mJ on target

- Plasma size ~60 µm (Zemax)

Single shot CCD image, Zr filter 2 µm







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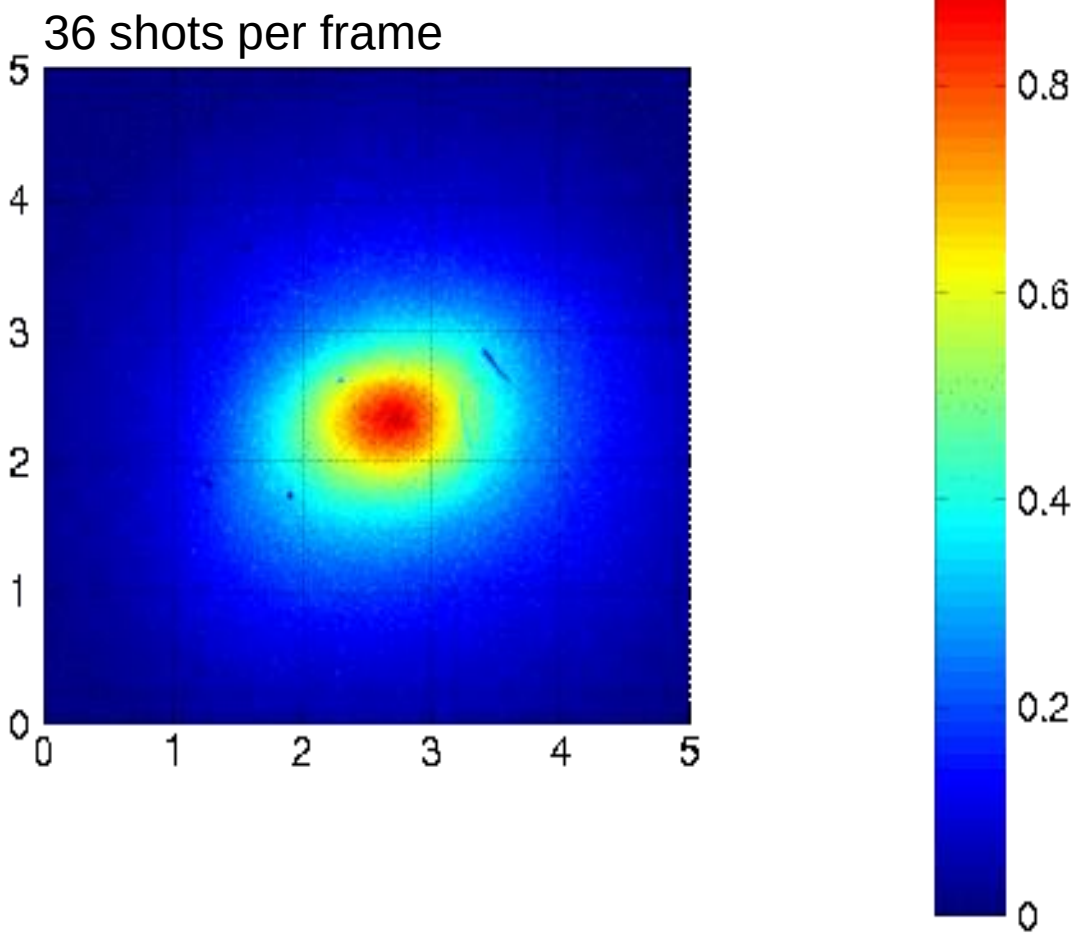
EUV Test Data - DPP

- Rotating mirror (ω< 2 r.p.m), Bruker DPP



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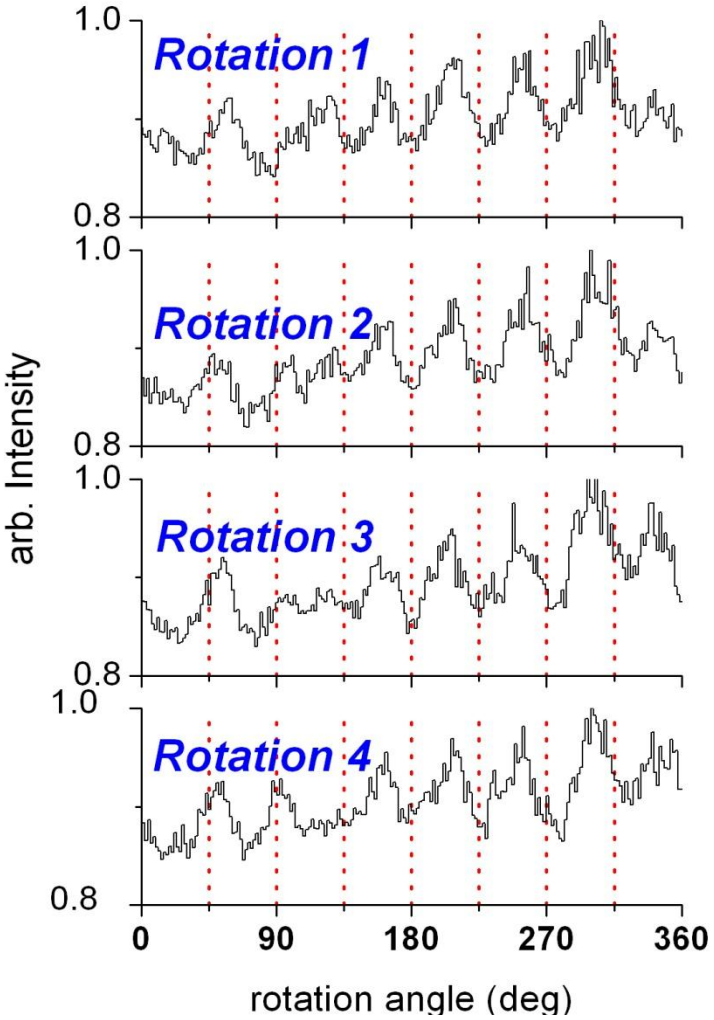
Test data – Visible

- Focused spot intensity V rotation angle
- Source FWHM = 350 µm
- ω_{mirror}< 2 r.p.m
- CCD 34 f.p.s

- Fluctuations regular and repeatable over many rotations » bearing wobble

- spatial stability at focus, ± 100 µm

- Higher accuracy commercial bearings available (± 5 µm stability at focus)



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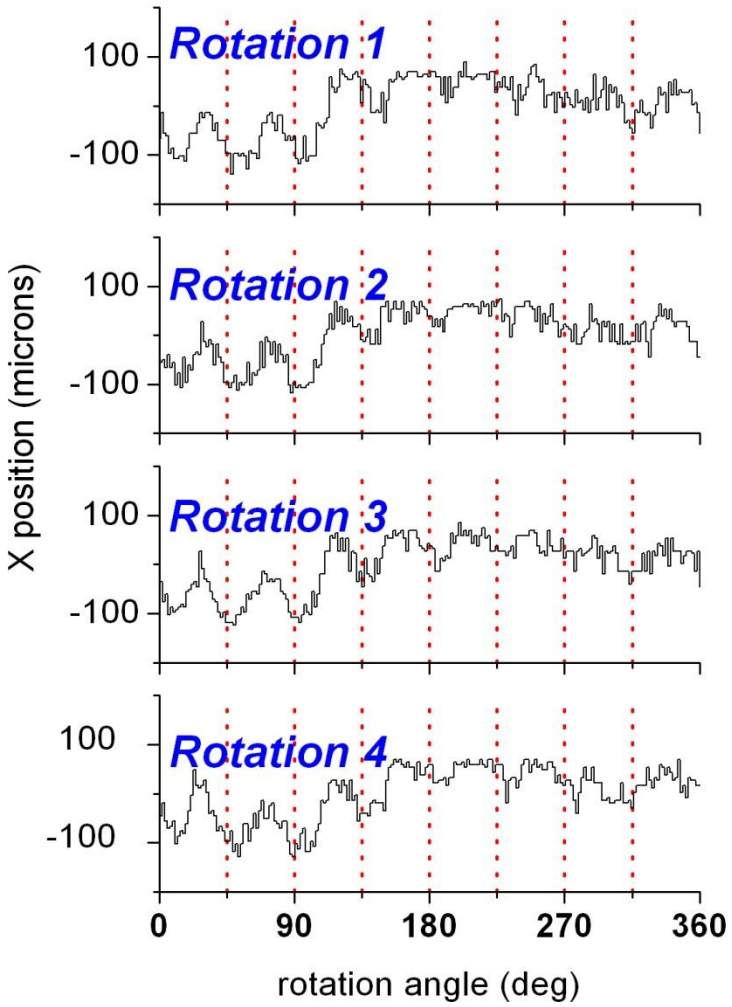

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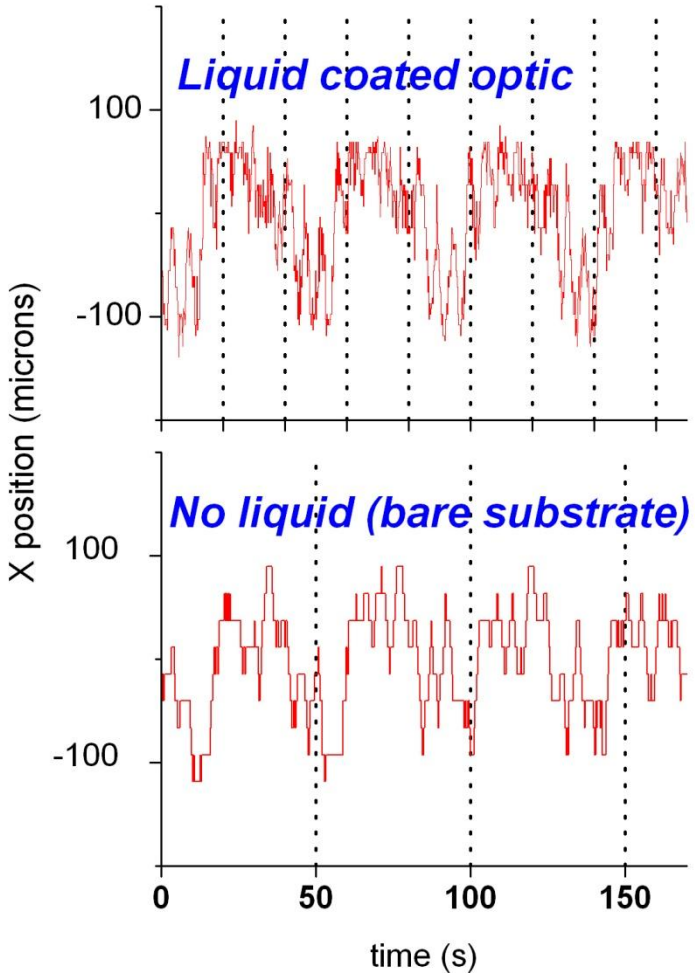
Test data – Visible

- Variations independent of liquid
- $\omega_{mirror} < 2$ r.p.m
- 34 f.p.s (coated)
- 9.7 f.p.s (uncoated)



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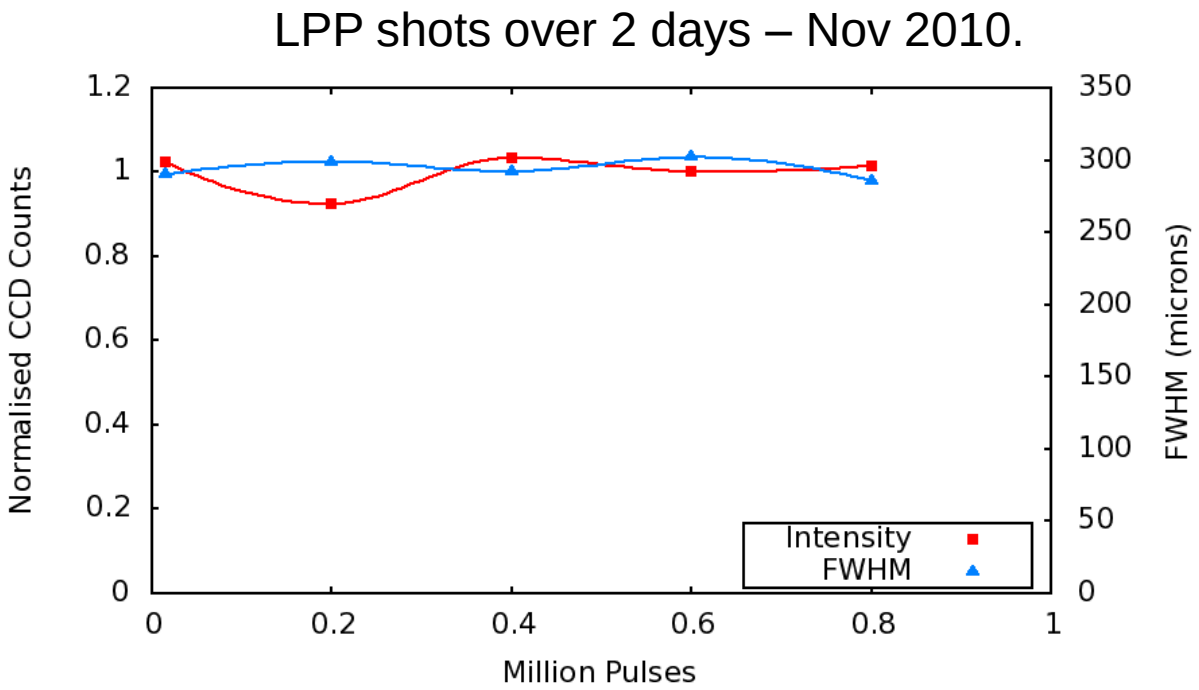
Lifetime Data



Recent activity:

- 20 million DPP shots
- Vented many times + 3 months continuous use
- Exposed to Ar, Xe, Sn & Gallinstan
- Laser irradiation of mirror surface 500mJ, 9 ns, Nd:YAG
- No obvious decrease in performance

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NewLambda Technologies Ltd.

- UCD Spin Out Company
  - located on UCD campus

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Fergal O' Reilly, PhD (CSO)

Paul Sheridan, PhD (CFO)

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Plan – next 6 months

- Improve image stability to ± 5 µm
    - commercial bearings available

- EUV focusing from liquid coated ellipsoids
    - electroformed or diamond turned

- Image smaller & brighter sources
- Measure brightness – EUV photodiode
- Expose optic to harsh plasmas

- Engage with engineering partner to develop products
- First product prototype Sept 2011

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Thank You for Listening

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