Collector development with IR suppression and EUVL optics refurbishment at RIT

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Outline

- Background
- Collector development
  - Machining and figuring
  - Infrared rejection
  - Smoothing layer
  - Reflectivity results
- Optics refurbishment
  - Wet Etching
  - Ion Beam Etching
- Conclusion

L3 INTEGRATED OPTICAL SYSTEMS

NIST National Institute of Standards and Technology

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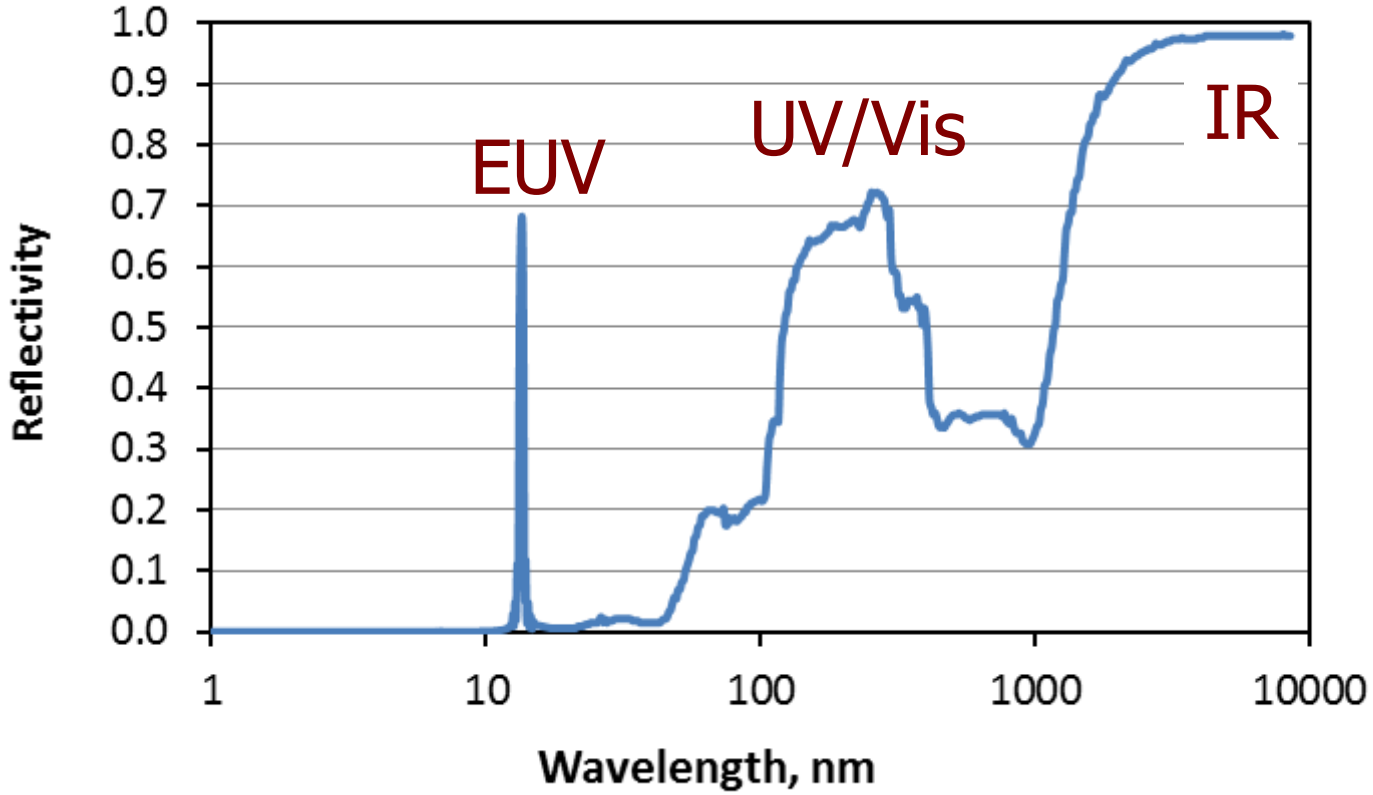
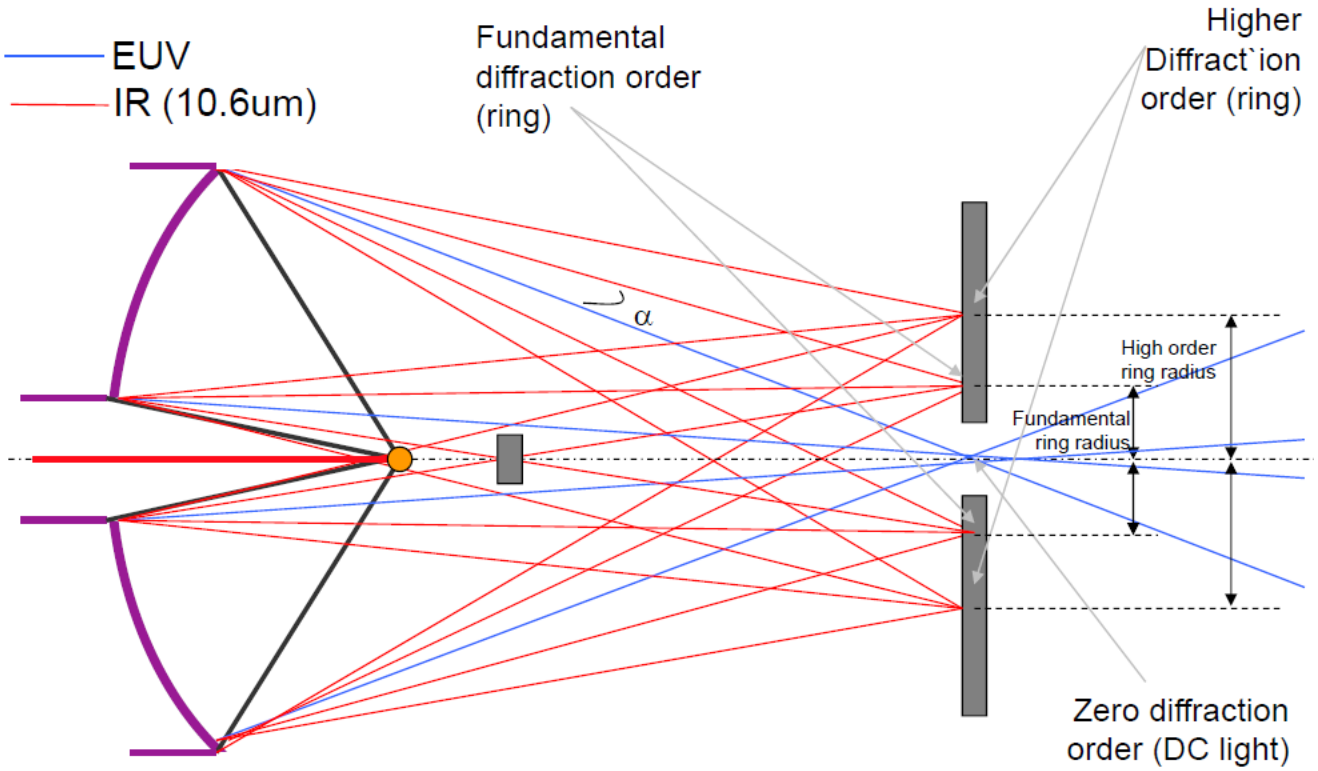
Background

- LPP sources generate 10.6μm IR radiation
- Mo/Si ML optics reflect IR radiation through IF



Infra-Red Rejection Collector (IRRC)

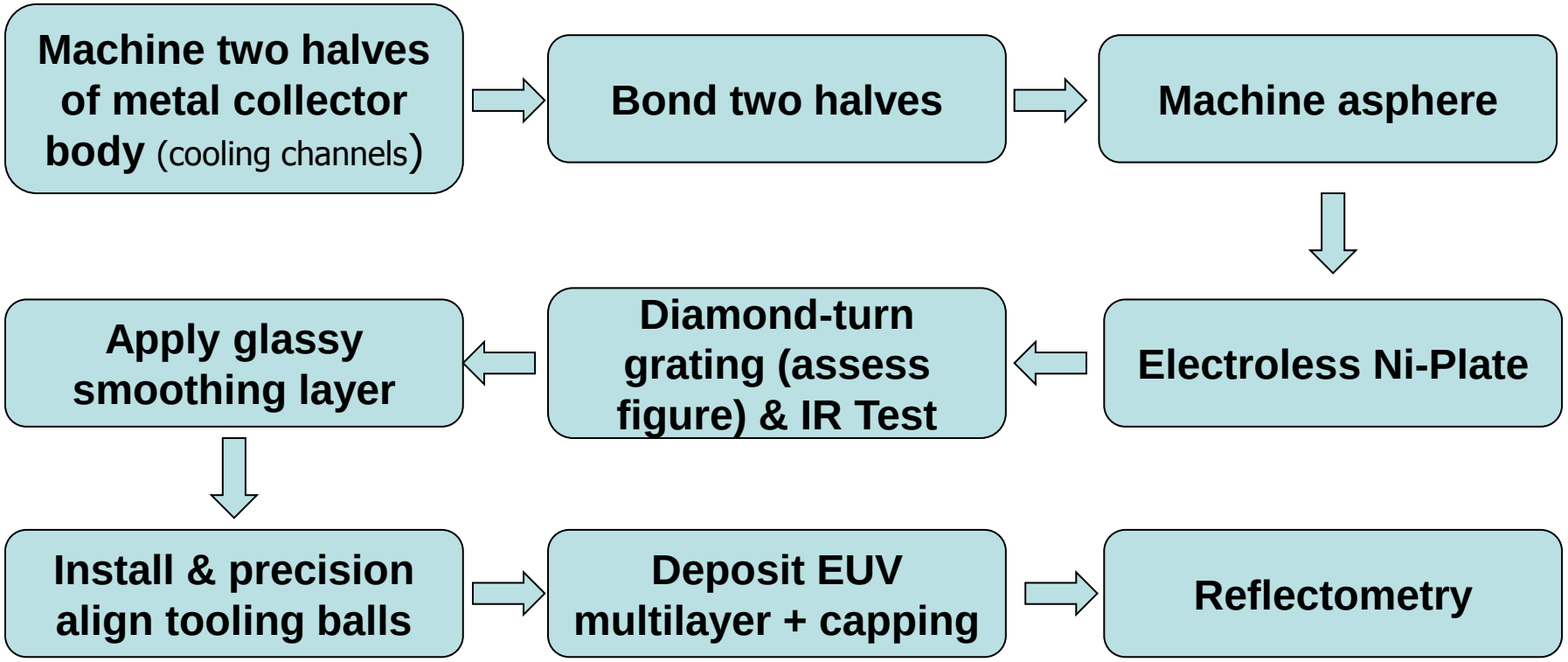
- Ellipsoidal collector with NA ≳ 0.22 surface with multilayer to focus 13.5nm
- Turned grating directly on optical surface to diffract 10.6μm (IR) away from IF aperture



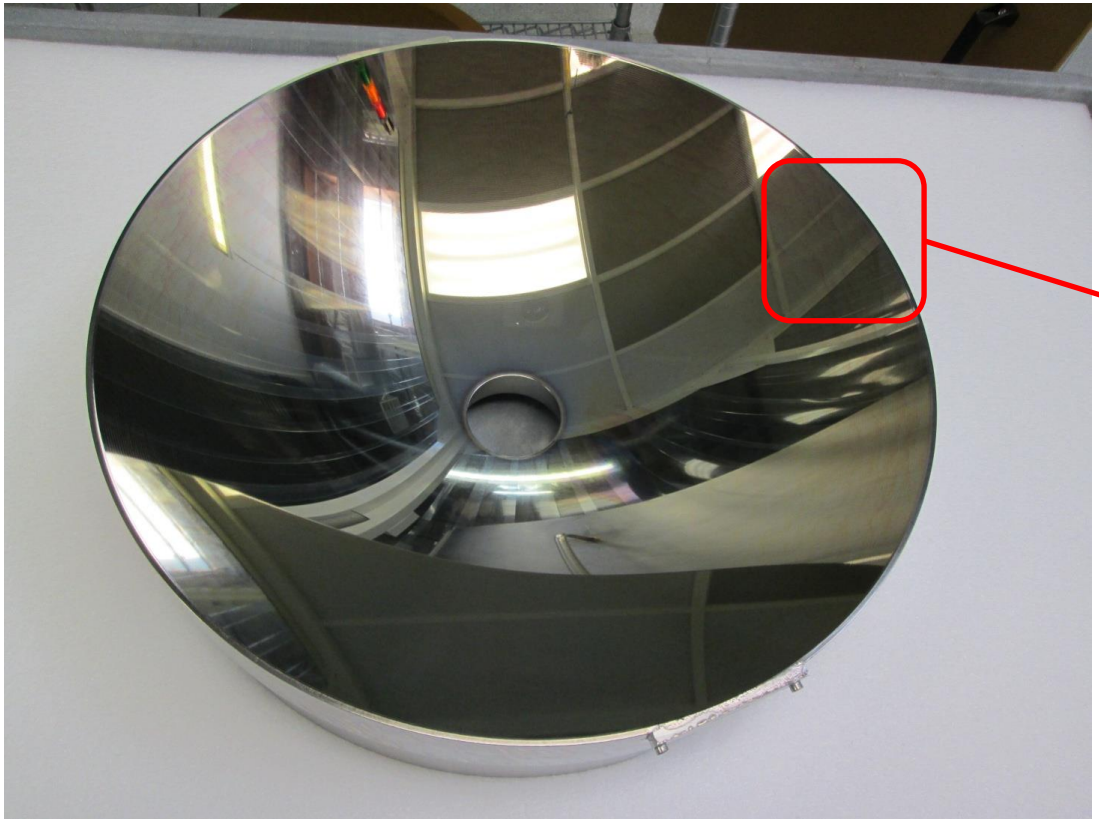
$$\alpha = \arcsin(m\frac{\lambda}{\Lambda})$$

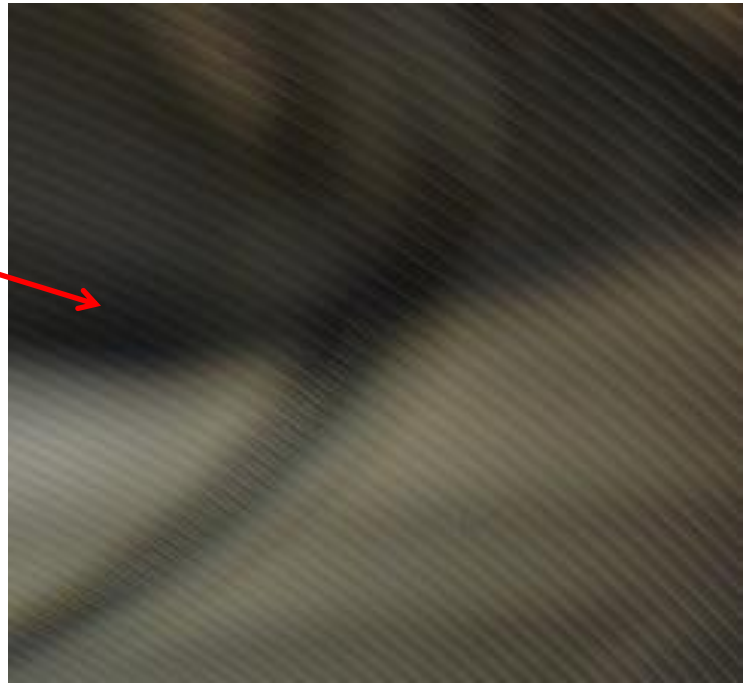
$$\delta r = L \cdot \tan(\arcsin(m\frac{\lambda}{\Lambda}))$$

Process Flow



Demonstration Collector: ellipsoidal ~410mm dia (NA ≳ 0.22)

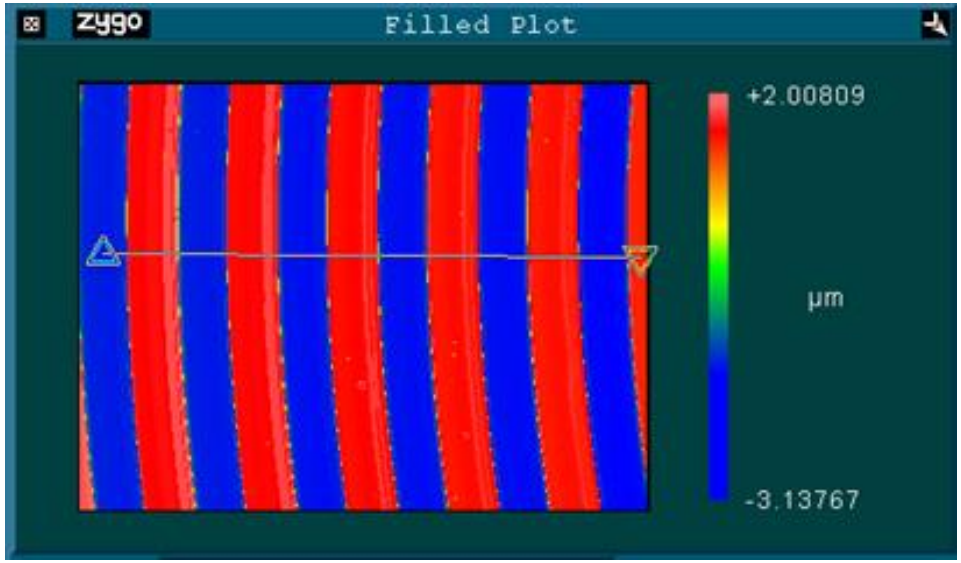


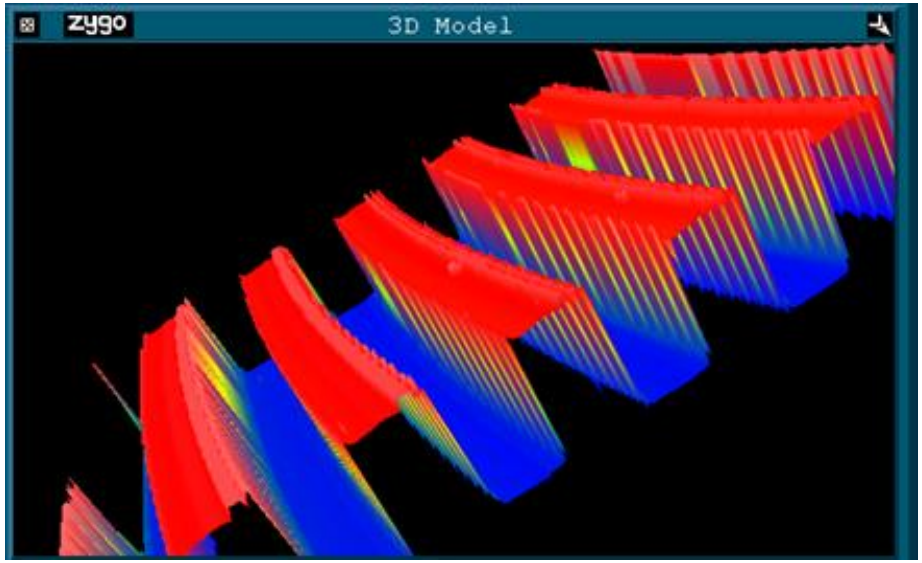


Grating structure

Zygo interferometer images

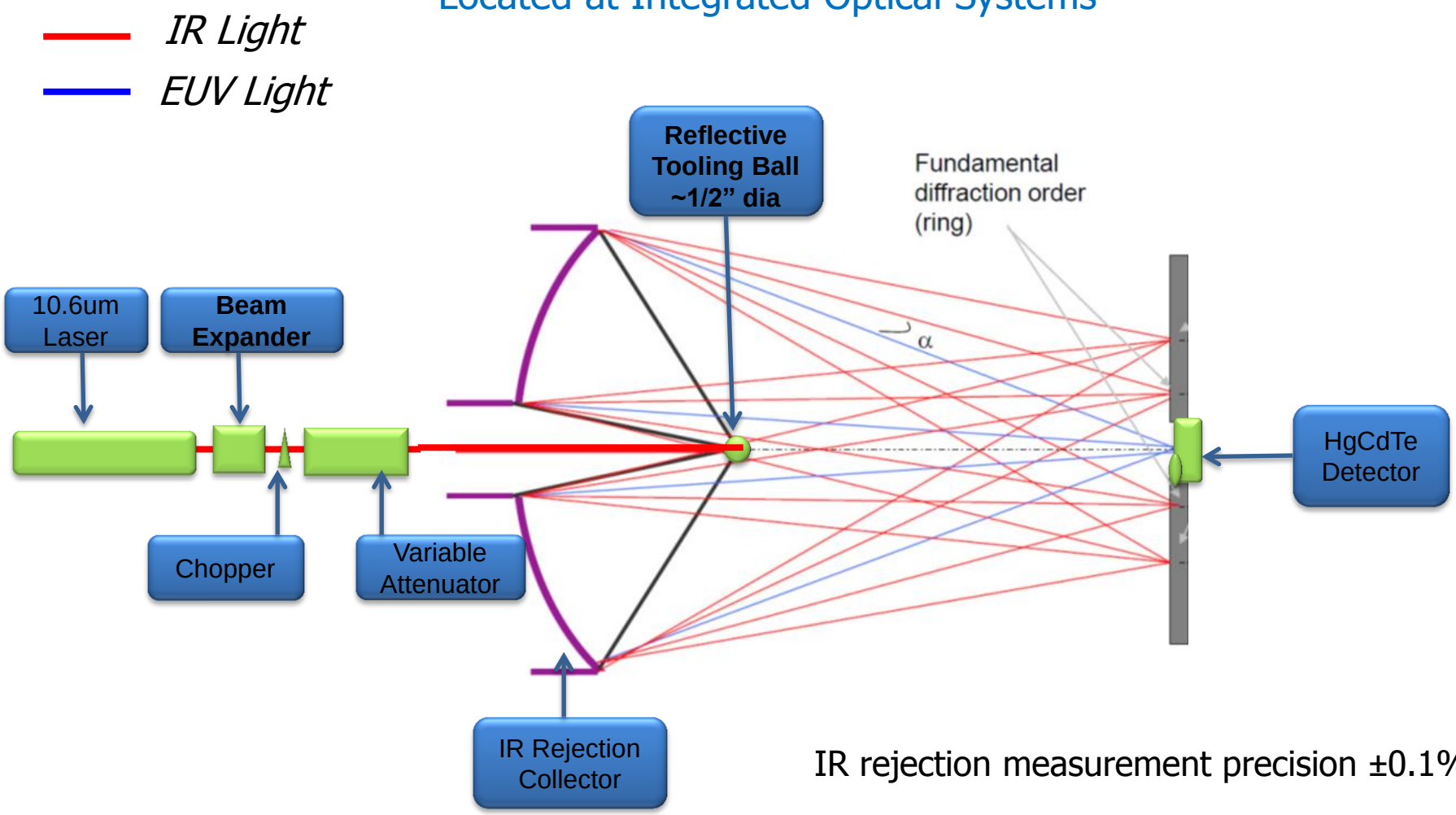
- Grooves contoured to the elliptical surface & are central-symmetric rings
- Groove pitch & depth vary with distance from collector center to account for changing angle of incidence





IR Rejection Stand

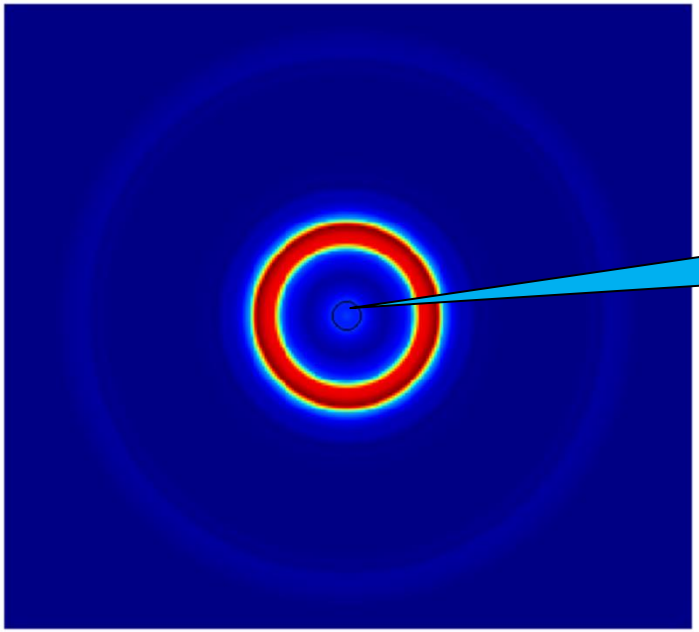
Located at Integrated Optical Systems



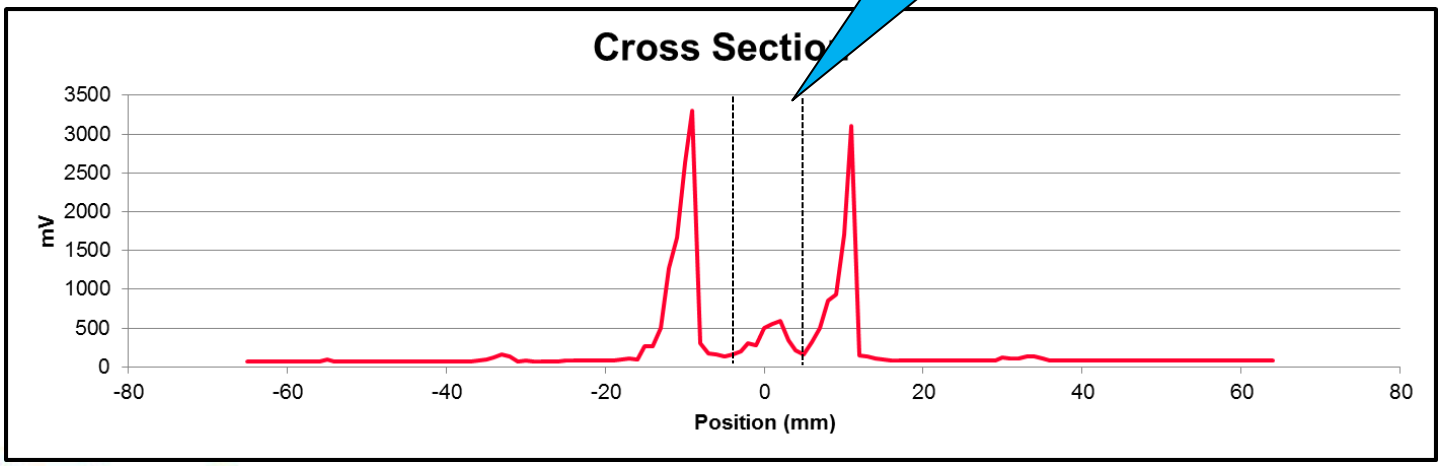
IR rejection measurement precision ±0.1%

IR suppression result

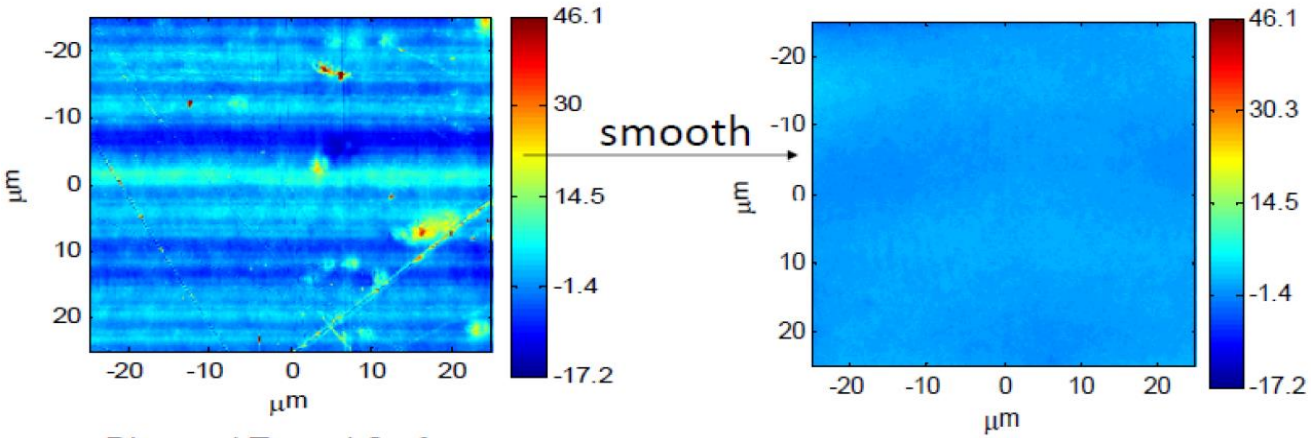
125X IR Suppression on Demo collector



Fraction of light in IF aperture is 0.8% ± 0.1% of total IR radiation



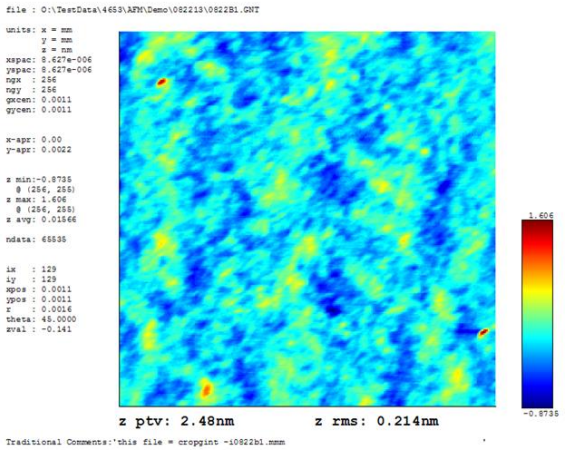
Smoothing after diamond turning



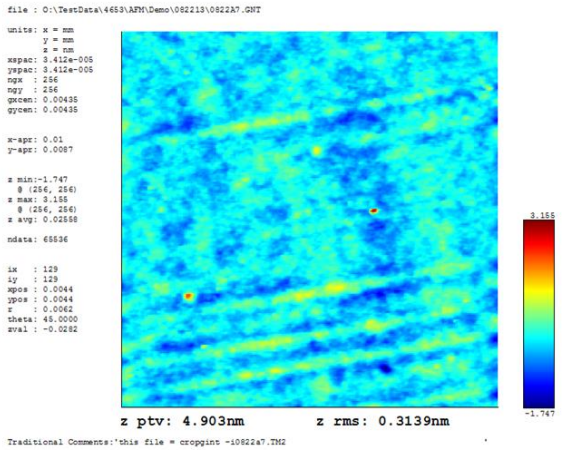
Diamond Turned Surface
50Å rms typical

Smoothed Diamond
Turned Surface

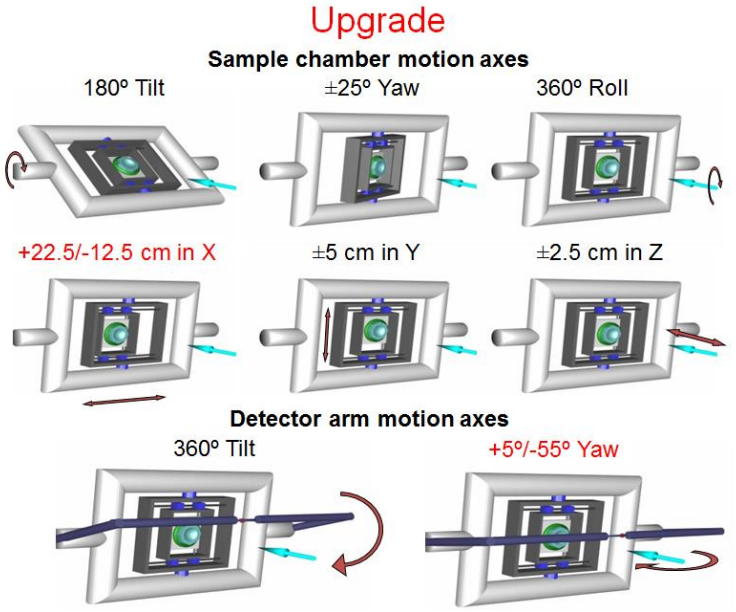
0.14 – 0.29nm rms over 2.2μm



0.29 – 0.39nm rms over 8.7μm



EUV Reflectometry at NIST



Sample Chamber

- Samples up to 45 cm diameter, 40 kg mass.
- Six axes sample motion, three axes detector motion.
- UV spot size: 1mm x 1mm (FWHM)
- Can be fitted with external end-stations for assembled instrument calibration.

Monochromator

- VLS grating:
  - 600 mm^{-1}, 7 nm - 35 nm
- Wavelength Uncertainty: 0.01 nm
- High throughput (P_{EUV} > 1 μW)
- Fixed exit slit
- Reflectivity uncertainty: Rp ~0.25% near 13.5 nm

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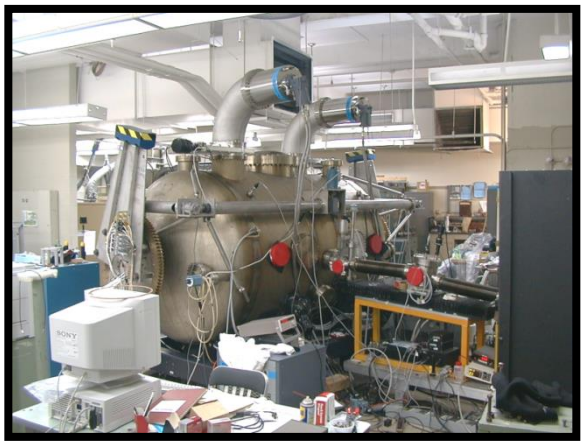
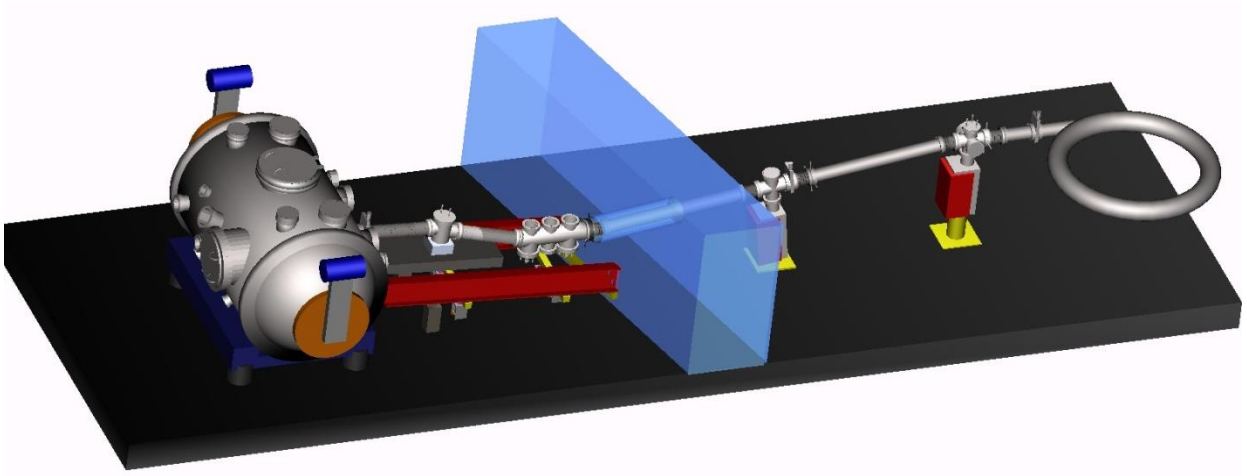
NIST upgraded to handle 45cm collectors



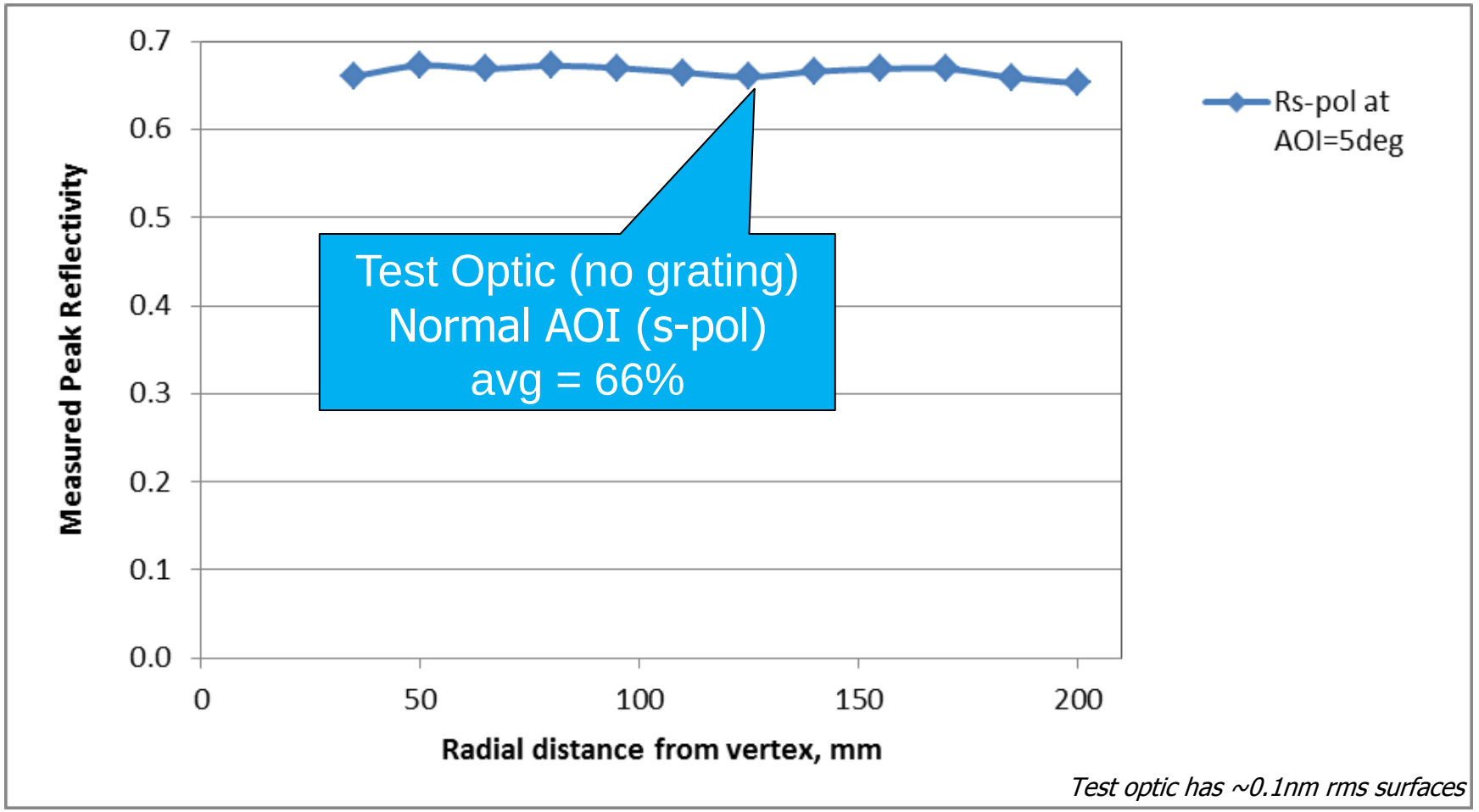


Goniometer can't be tilted far enough to make all measurements. Two angles should be set to add up to the incidence angle. It allows making measurements that simulate un-polarized light by setting reflection plane to 45^{o} from vertical, thus converting this into un-polarized light (as from a plasma source) measurement.

A Zemax model was developed to predict the performance of the optic at various angles and positions. This model was used to place the optic and detector and to confirm alignment of the optic.

Performance at Normal AOI

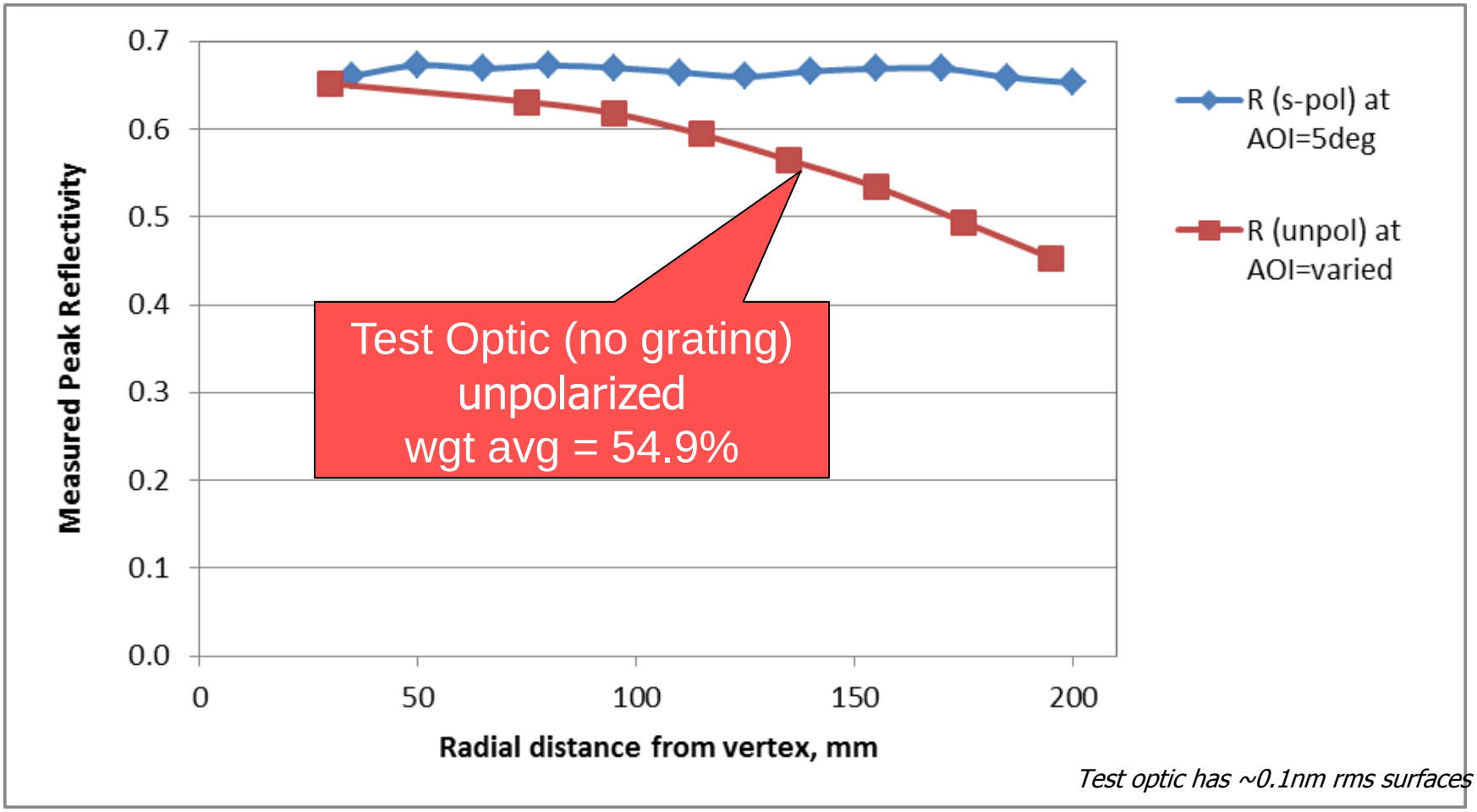
5º



Test optic has ~0.1nm rms surfaces

Performance at Design AOI

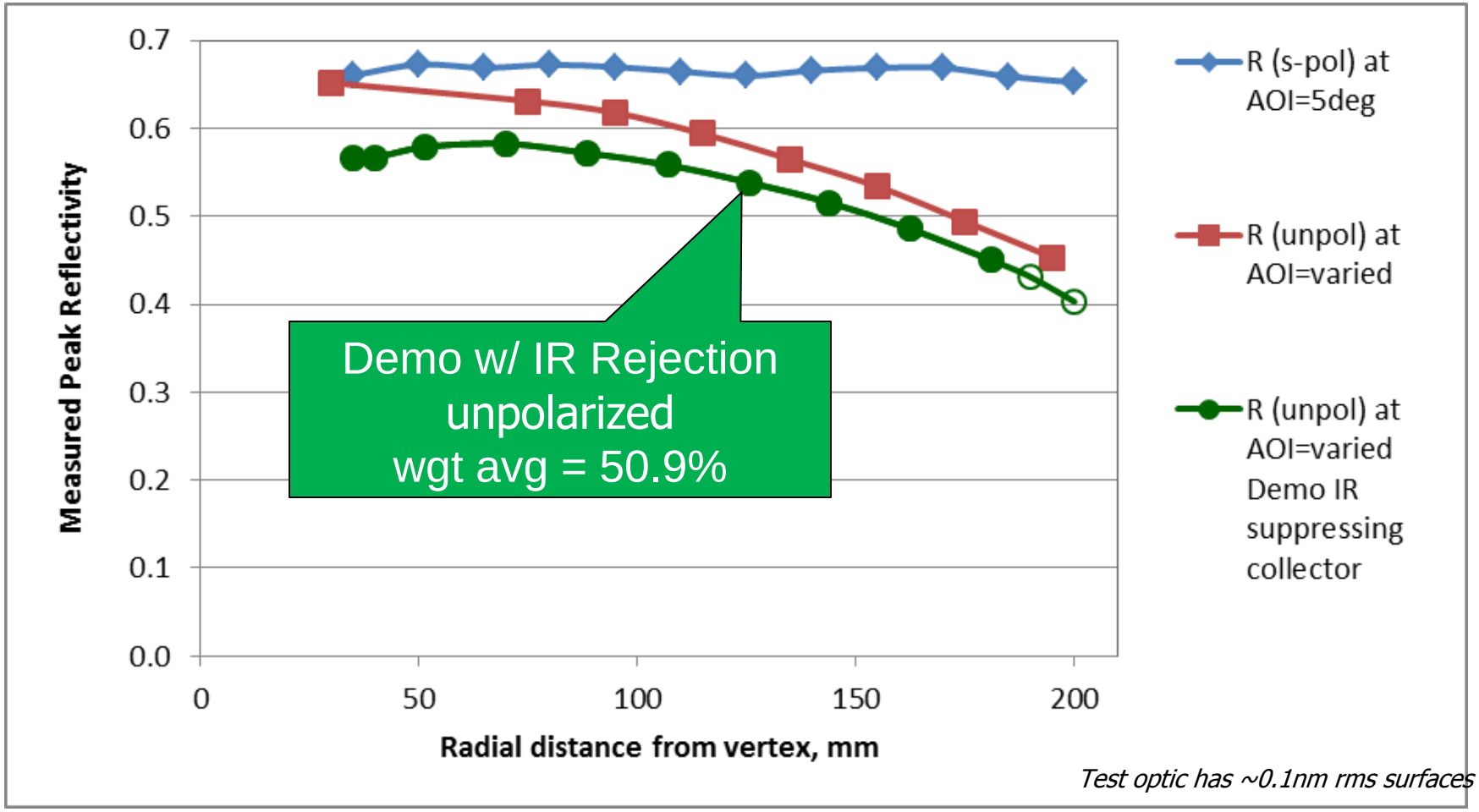
~5º to ~35º



Test optic has ~0.1nm rms surfaces

Performance at Design AOI

~5º to ~35º



Test optic has ~0.1nm rms surfaces

Refurbishment

Refurbishment

Illumination optics

Coating:
Cap(~2nm)/(Mo/Si /Si

Collector optics

Coating:
Cap/(Mo/Si)/(smoothing)/Grating/Ni/Al

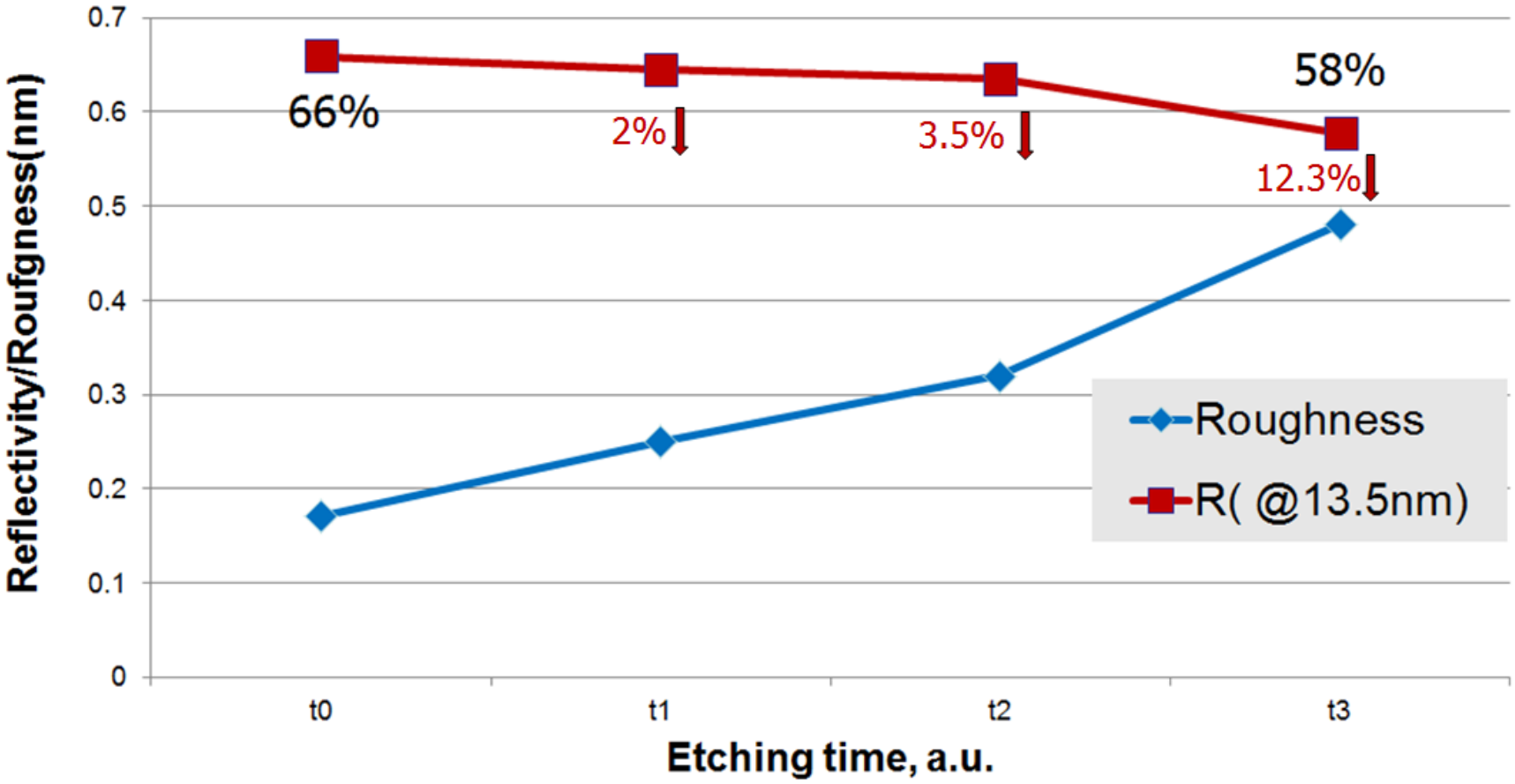
Current paper's subject

Technologies under test

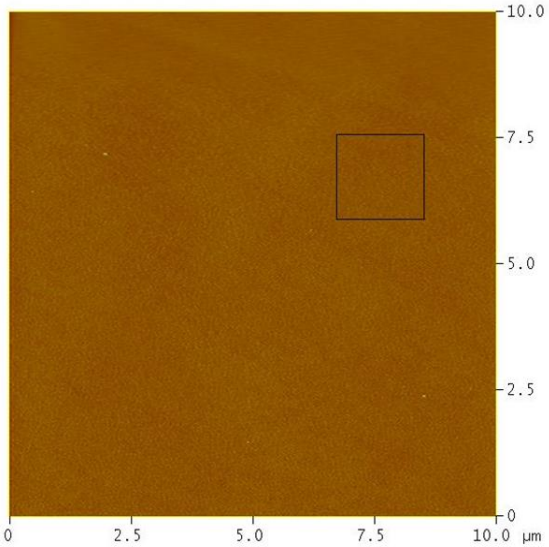
- Wet selective etching
- Reactive Ion Etching
- Ion beam etching

Mo/Si on Si substrate

Roughness and EUV reflectivity of Mo/Si multilayers deposited on Si substrates



Buffer layer and surface roughness



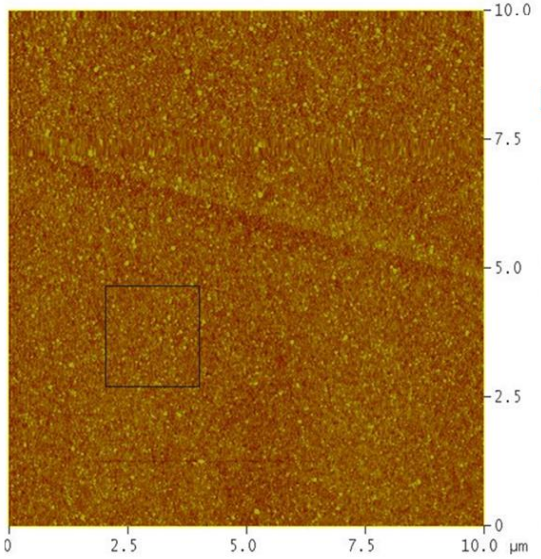
Uncoated wafer

Image Statistics

Img. Rms (Rq)	0.141 nm
Img. Ra	0.108 nm
Img. Rmax	5.312 nm

Box Statistics

Rms (Rq)	0.126 nm
Mean roughness (Ra)	0.101 nm
Max height (Rmax)	0.964 nm
Max peak ht (Rp)	
Av max ht (Rpm)	
Max depth (Rv)	
Av max depth (Rvm)	
Box x dimension	1.800 µm
Box y dimension	1.683 µm



After 40x(Mo/Si) removal, Buffer #1

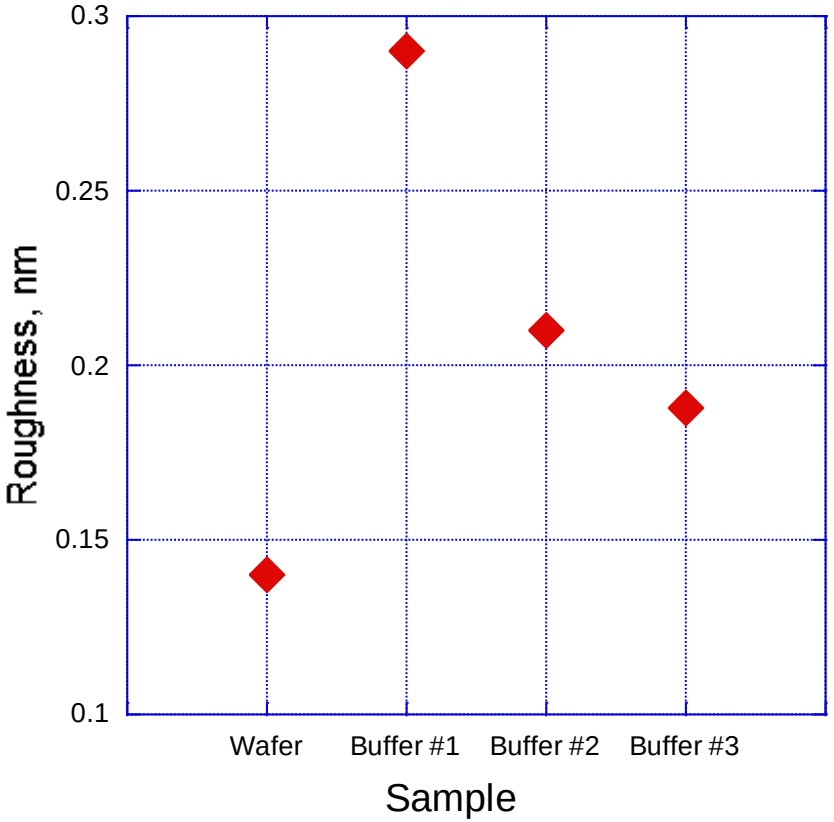
Image Statistics

Img. Rms (Rq)	0.290 nm
Img. Ra	0.206 nm
Img. Rmax	12.992 nm

Box Statistics

Rms (Rq)	0.270 nm
Mean roughness (Ra)	0.198 nm
Max height (Rmax)	2.744 nm
Max peak ht (Rp)	
Av max ht (Rpm)	
Max depth (Rv)	
Av max depth (Rvm)	
Box x dimension	1.977 µm
Box y dimension	1.957 µm

Surface roughness after ML removal



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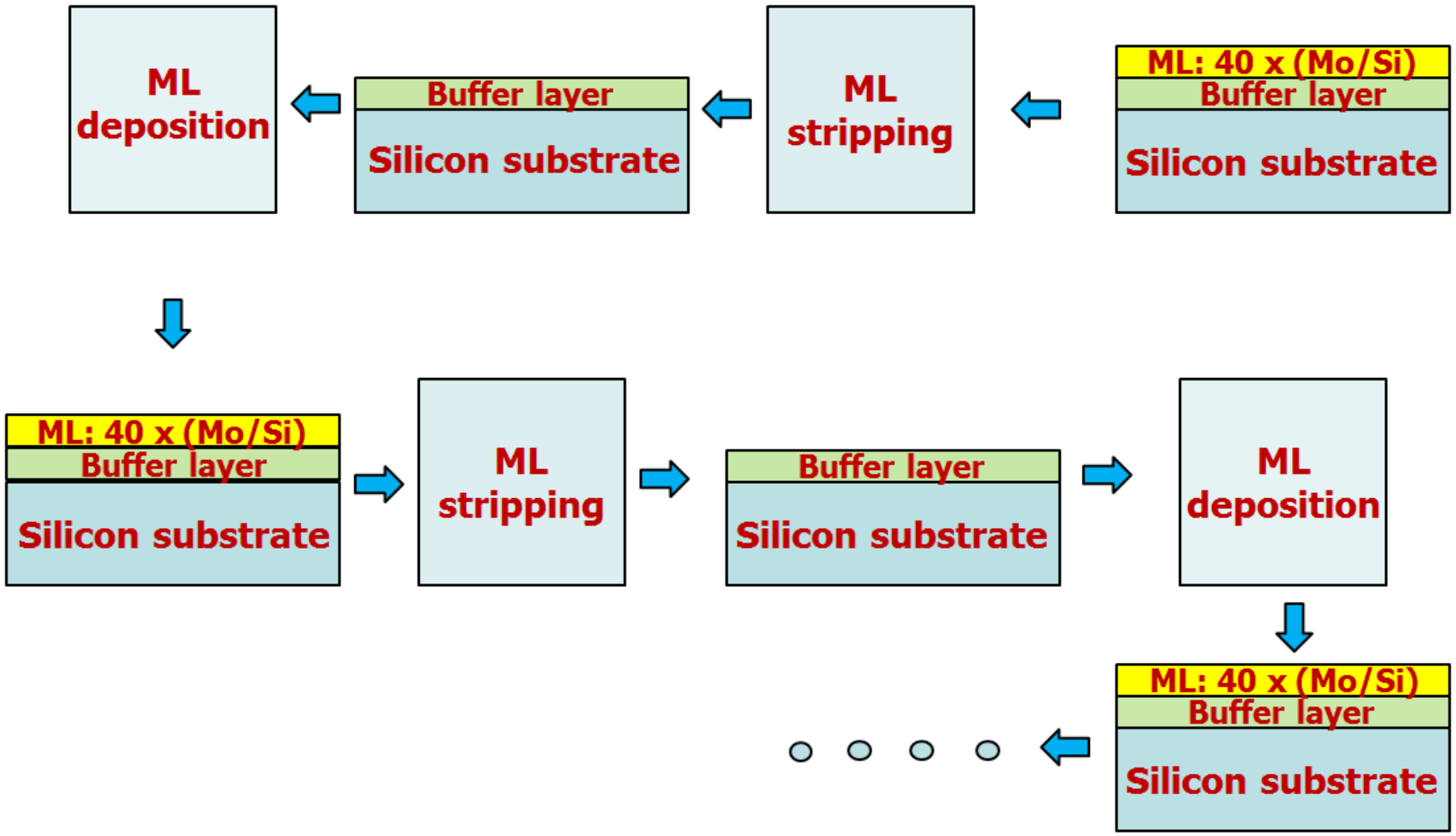
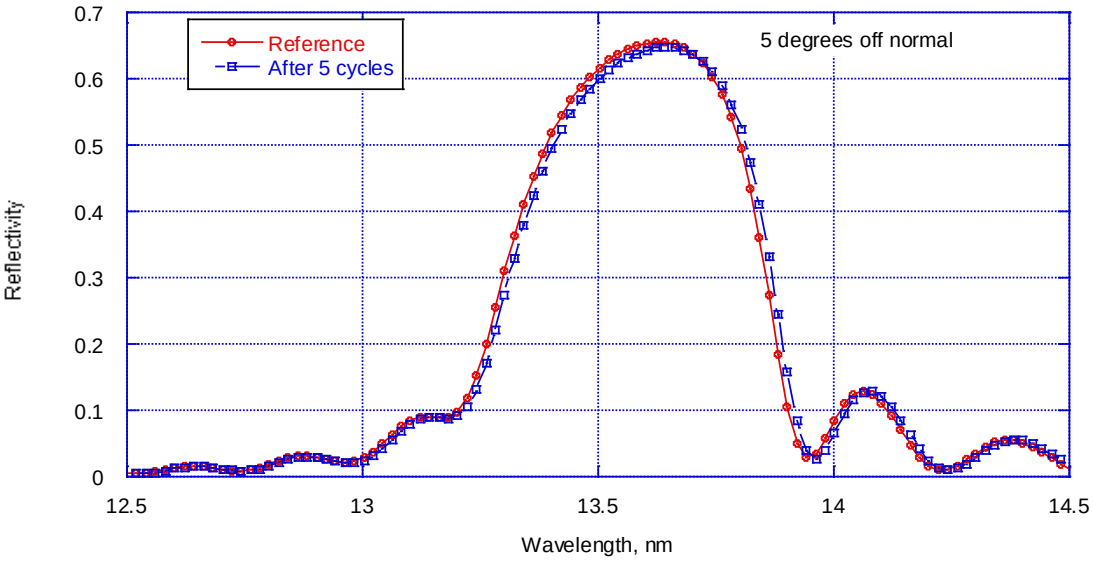
Multi cycles refurbishment



5 refurbishment cycles result

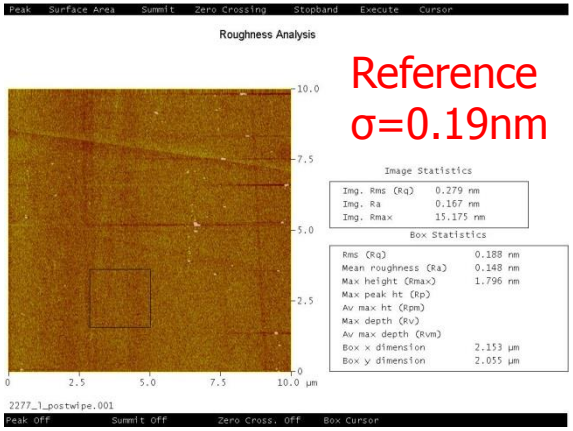
EUV reflectivity

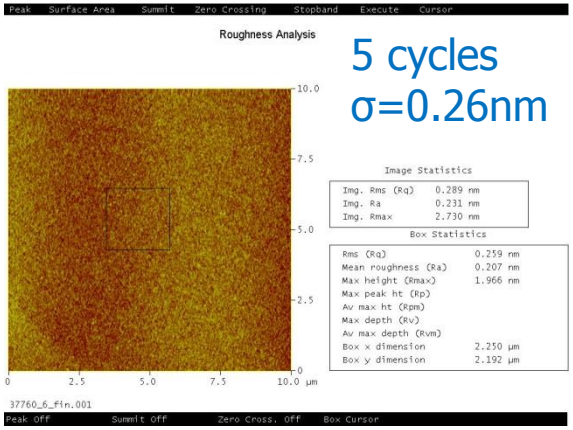


R(reference)=65.6%

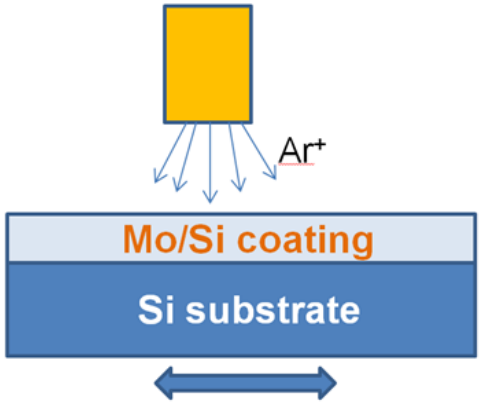
R(5 cycles)=64.8%

Surface roughness





Ion Beam Etching



V_{beam}~1.2kV
I_{beam} ~ 50mA
T_{etch} - variable

Large loss of EUV reflectivity due to Ar ions implantation into multilayer structure during the etching

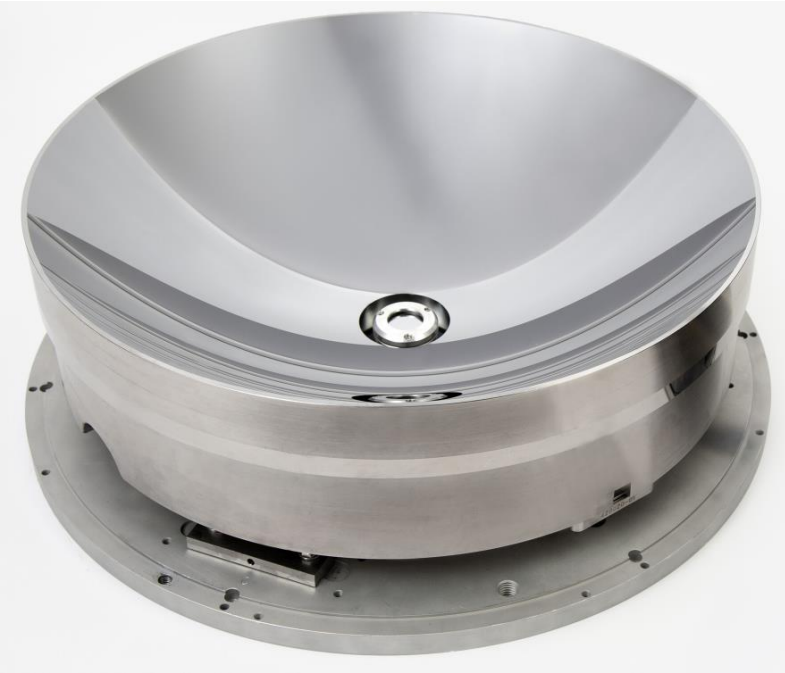
No#	Number of removed periods	Suface roughness after etching, Å	R(avg)	λ(avg), nm	fwhm(avg), nm	% Loss
1	0 (original)	1.5	0.632	13.490	0.486	0.0
2	3	6.8	0.574	13.428	0.477	9.2
3	6	4	0.570	13.425	0.473	9.7
4	9	6	0.559	13.375	0.470	11.5
5	15	14	0.588	13.463	0.486	7.0
6	20	4.7	0.593	13.405	0.483	6.2

Original structure had 80 periods

Conclusion

Collector:

- Demo collector: ~410mm, NA ≳ 0.22
- IR Suppression (grating): 125X
- Area-weighted EUV Rp: 50.9%
- HVM-ready facility for 750mm optics (Jan-2014)



Refurbishment:

- No Buffer layer: reflectivity loss ~1% - 2% per cycle
- With a buffer layer: reflectivity loss 1.2% after 5 refurbishment cycles
- Removing multilayer top layers by Ion beam etching resulted in a large (6%-12%) loss in EUV reflectivity

Acknowledgement

- **RIT**

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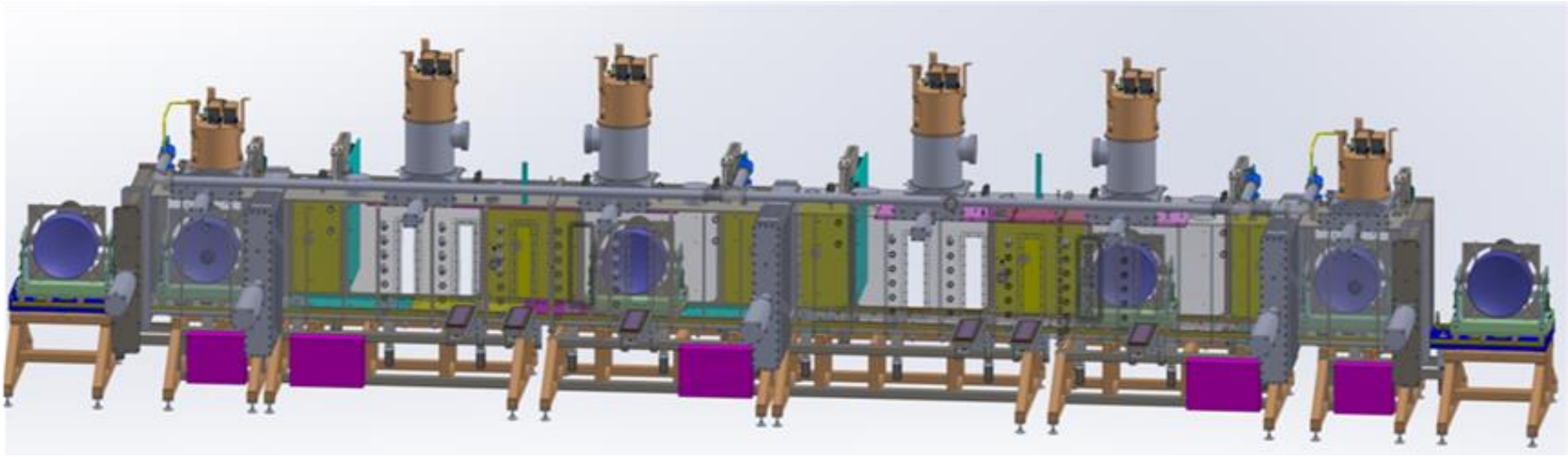
- **CXRO**

  E. Gullikson

Thank You



HVM (9-target) Inline Deposition System for 750mm Optics
— to be installed January 2014 —