Broadband Reflective Coating Process for Large FUVOIR Mirrors

NASA SBIR Phase II contract No. NNX14CG39P
Technical Monitor: Dr. Manuel Quijada (JPL)

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FUVOIR Coating Performance Objectives

Table 1- Performance Objectives

Metric	SBIR Goal
Reflectance (90-nm to 110-nm)	>60%
Reflectance (110-nm to 200-nm)	> 85%
Reflectance (200-nm – 2500-nm)	> 90%
Surface Roughness	<5 A RMS
Coating Stress	< 85 MPa
Humidity	95% RH, 50 C, 24 hour
Moderate Abrasion	20 rub, 5 psi, cheese cloth
Thermal Cycling	-80 + 50 C (ten cycles)
Adhesion	ASTM Tape Test

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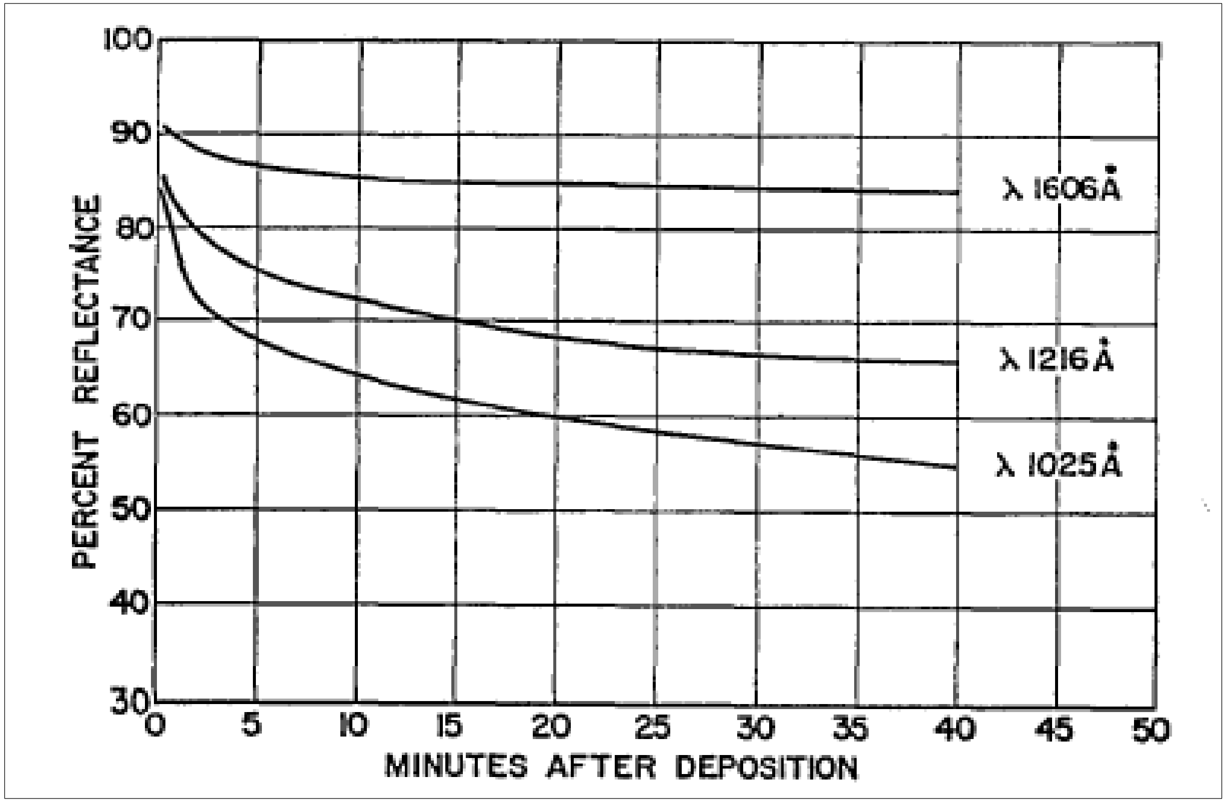
“There is nothing new except what has been forgotten”

-Marie Antoinette

Oxidation of aluminum film in 5x10^-7 torr vacuum



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FUSE: Lessons learned for future FUV missions

- FUSE: SiC coatings 905 A – 1,105 A, Al:LiF 987 A – 1,187 A.
- LiF-coated mirrors were exposed to 30%- 50% RH for less than 5-days during ground storage yet the mirrors degraded prior to launch from 70% reflectance to 55% reflectance
- Time required to degrade un-oxidized bare aluminum in the vacuum of space
  - A 3 months to 2 years in low earth orbit (to drop to 35%, which is approximately the reflectance of SiC)
  - 20-years or more in higher orbit (L2) (provided outgassing from spacecraft doesn't kill the reflectivity)
- Al/MgF2 reflectance ~15% 90-nm to 100-nm

Summary: Types of Contamination

- Oxygen
  - Contaminates bare aluminum
    - Ground storage
    - In the vacuum of space, spacecraft outgassing, (LEO worse)
- Water
  - Humidity during ground storage
  - Outgassing from spacecraft
- Organic
  - Ground storage
  - Outgassing from spacecraft (UV exposure from sun in space makes this worse)

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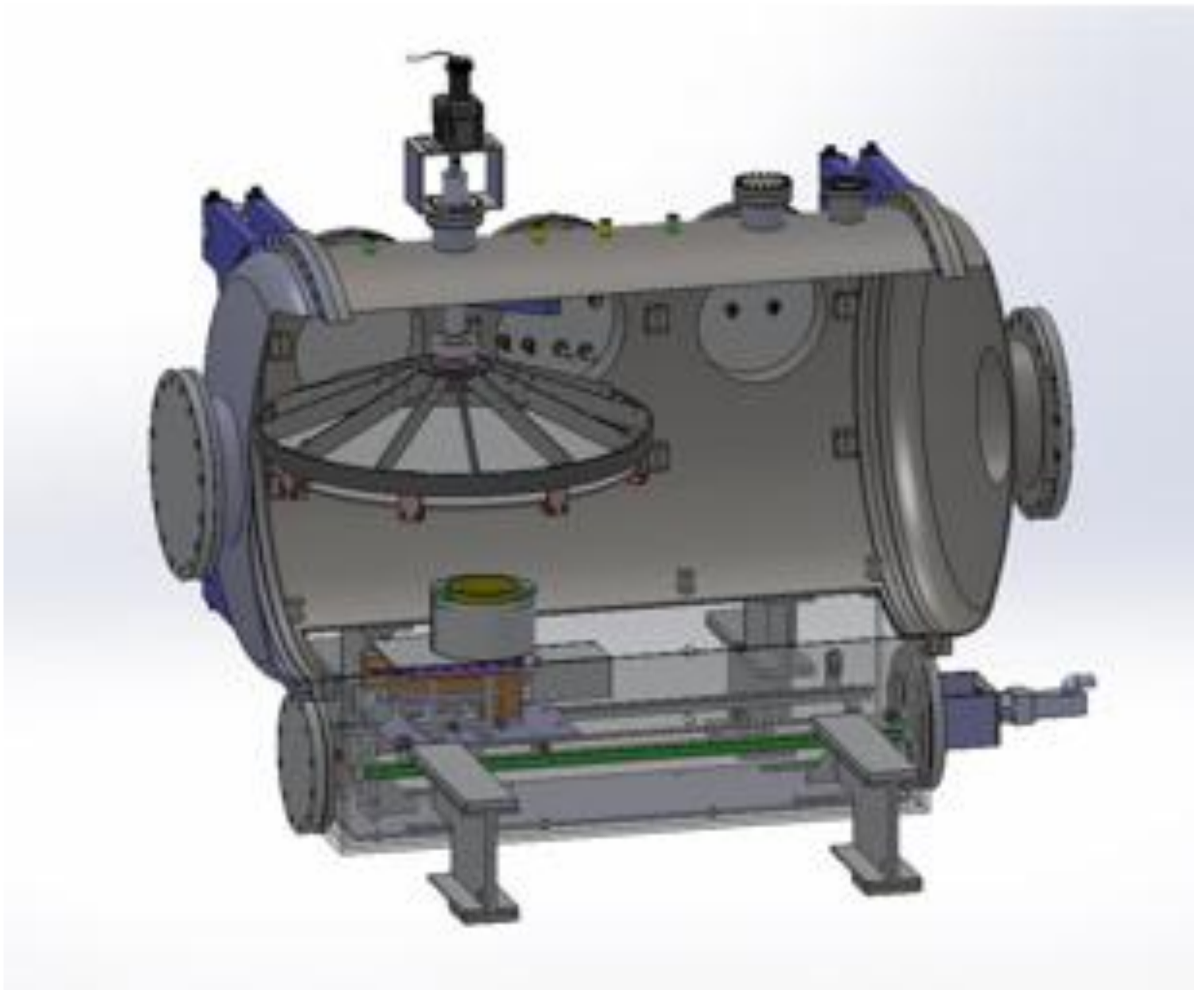
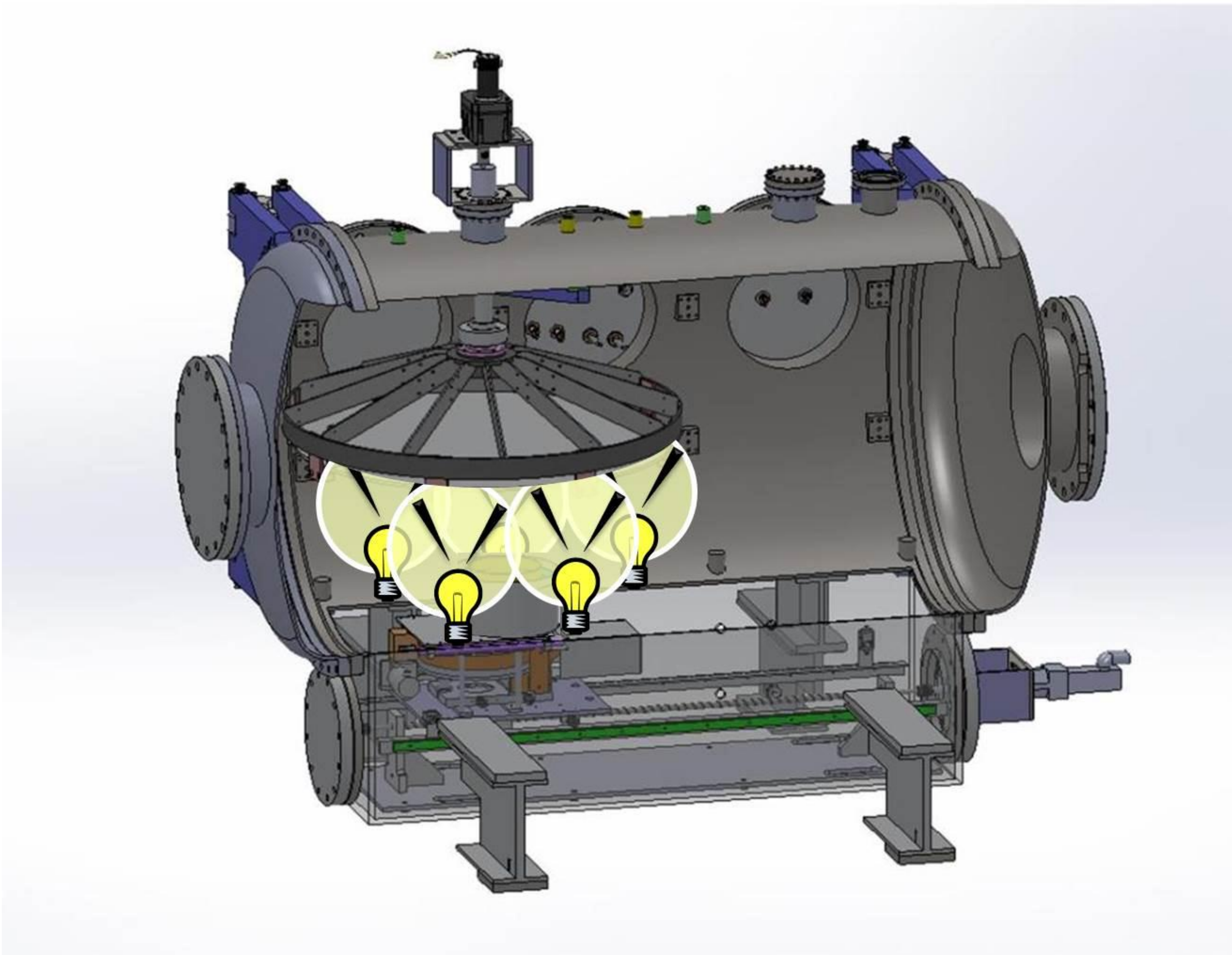
What things will we need to coat large mirrors with Manuel's 3-step process?

- A technique to heat a surface to ~250 C and apply a coating, without heating the entire mirror assembly <u>(may not need this step if Sn over-coat idea works)</u>
- A method to apply very thin layers (2-nm) uniformly over large areas
- A way to protect the sensitive fluoride layers from humidity during ground storage (apply Sn and remove in space by heating; 230 C melt temperature)

Use ZeCoat's moving source technology to apply a very thin layer, quickly over a large mirror



Radiant heating during metal-fluoride deposition heats aluminum coating to 250 C before entire mirror assembly gets hot



Tin (Sn) as a protective cover for LiF or Al?

449.5°F (231.9°C)

Tin, Melting point

For bare aluminum in space facing sun
$\alpha/\varepsilon \sim 0.07/0.03 = 2.33$
Temperature = 217 C

Tin

Chemical Element

Tin is a chemical element with symbol Sn and atomic number 50. It is a main group metal in group 14 of the periodic table. Wikipedia

Symbol: Sn

Electron configuration: Kr 4d10 5s2 5p2

Melting point: 449.5°F (231.9°C)

Atomic number: 50

Electrons per shell: 2, 8, 18, 18, 4

Discovered: 3500 BC

Atomic mass: 118.71 u

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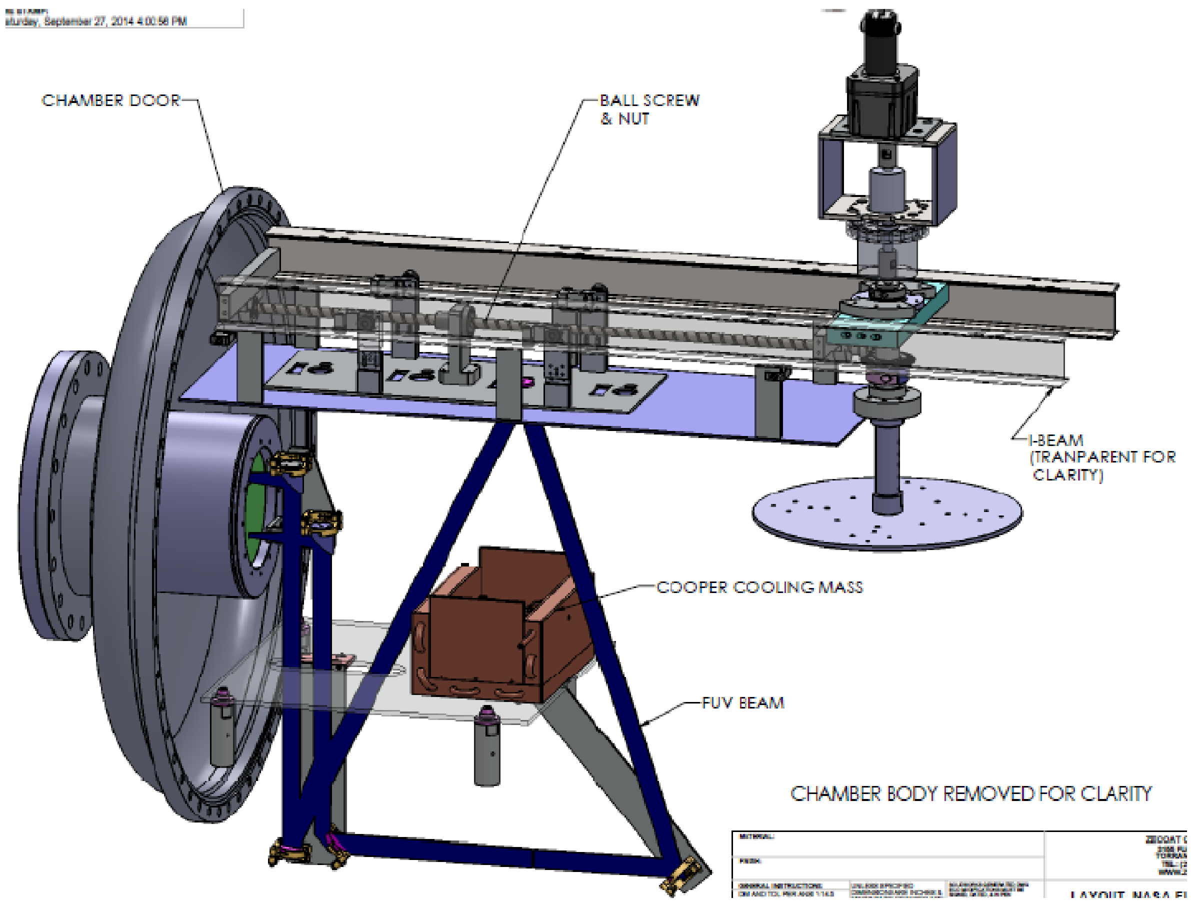
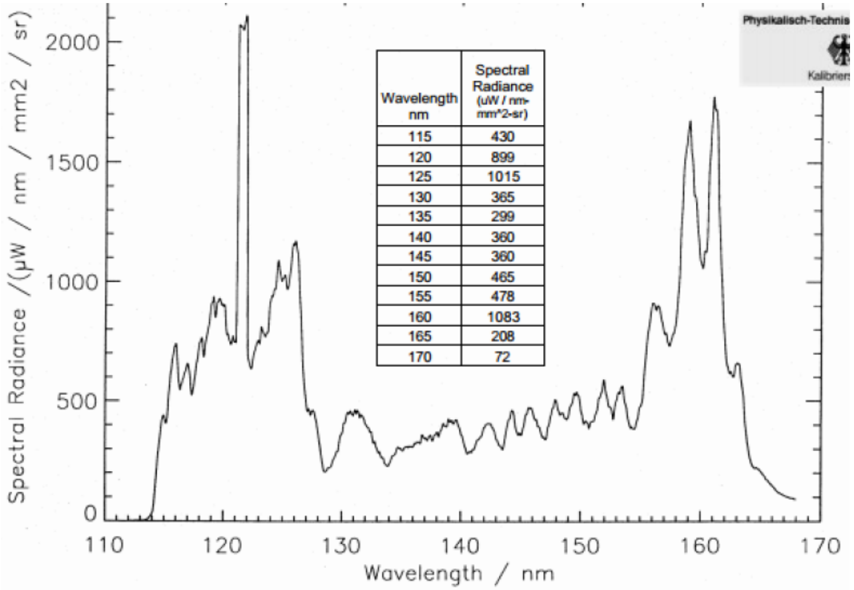
FUV Deposition and Monitoring Set-Up



Deuterium lamp and PMT



Wavelength nm	Spectral Radiance (uW / nm-mm^2-sr)
115	430
120	899
125	1015
130	365
135	299
140	360
145	360
150	465
155	478
160	1083
165	208
170	72

PHOTOMULTIPLIER TUBE R1081

Figure 1: Typical Spectral Response

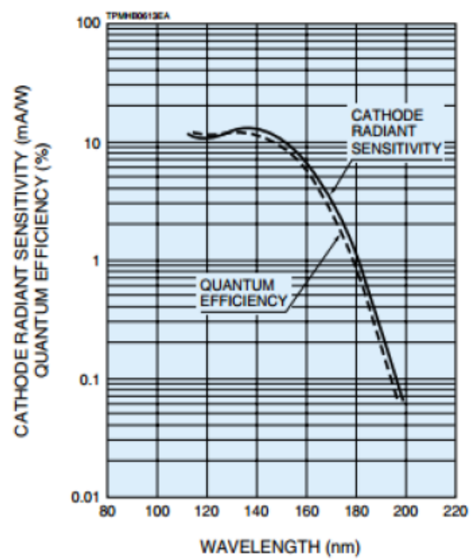
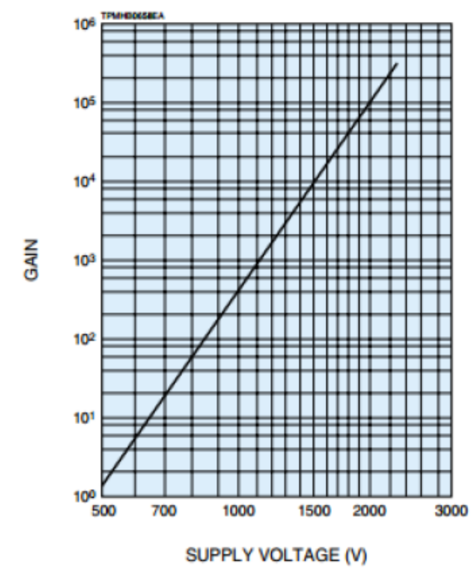
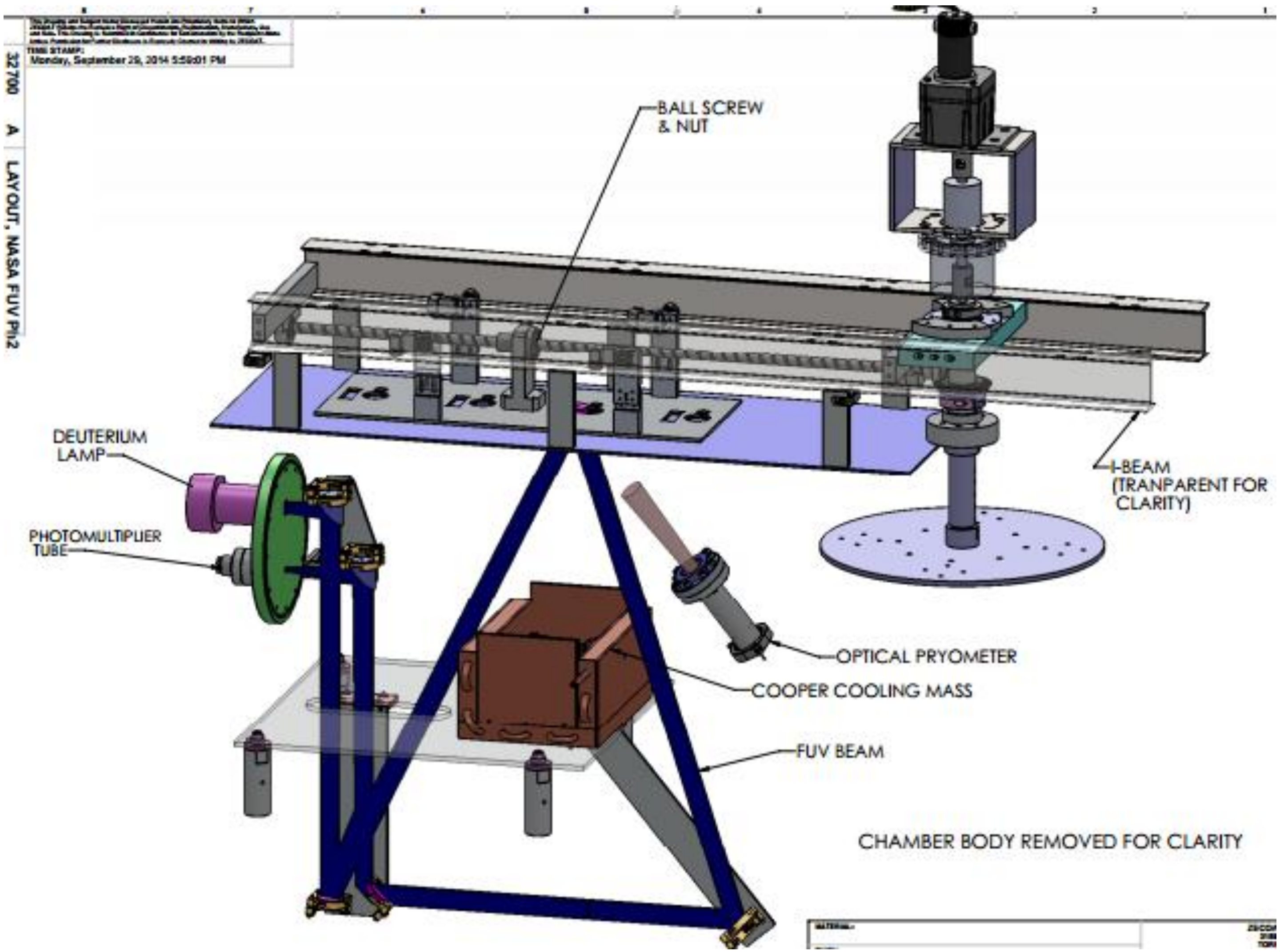


Figure 2: Typical Gain Characteristics

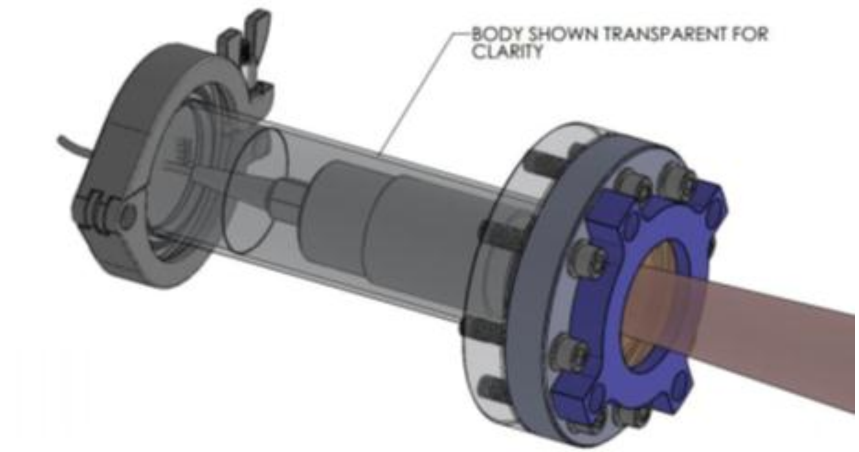


Upward view looking at sample holder and quartz crystal monitor

FUV coating set-up with moving substrate holder

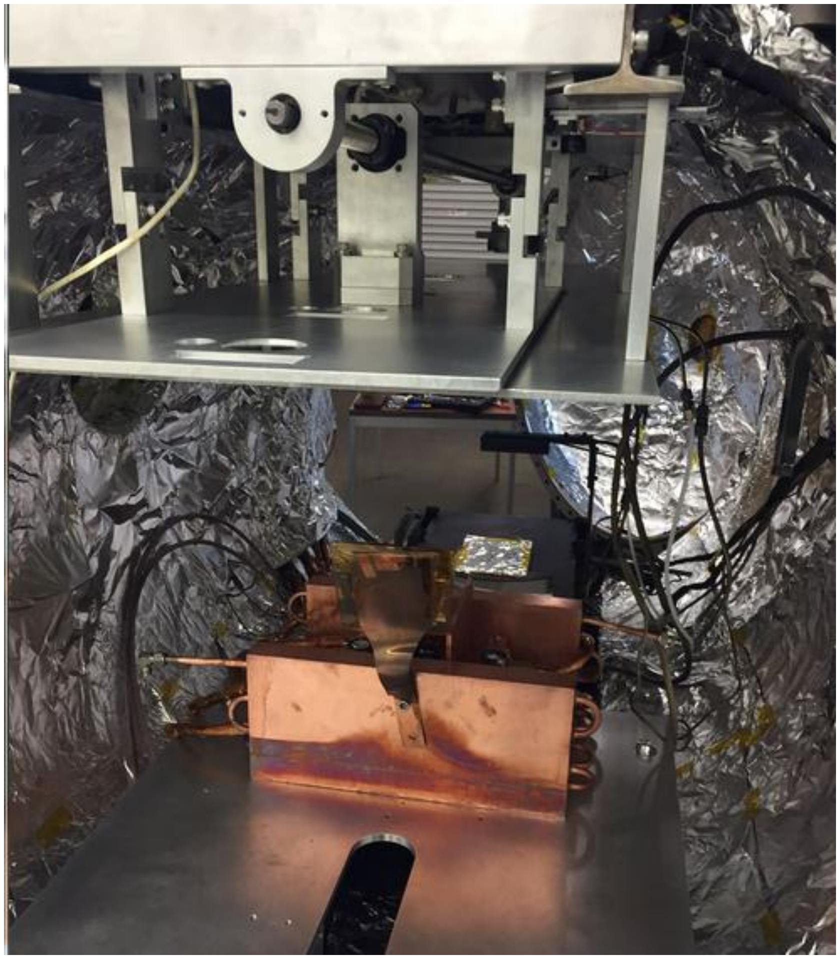


Pyrometer (8-14 μ) canister with zinc selenide window



1-2 micron pyrometer can look through glass window into vacuum chamber

Resistive (3) source heat-sink



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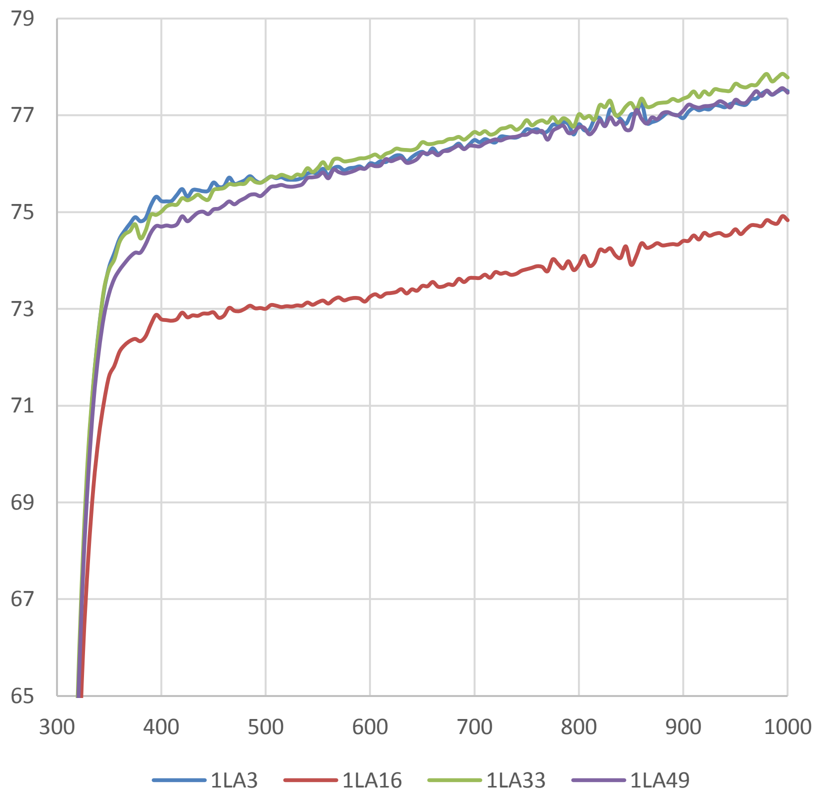
Phase I Challenges

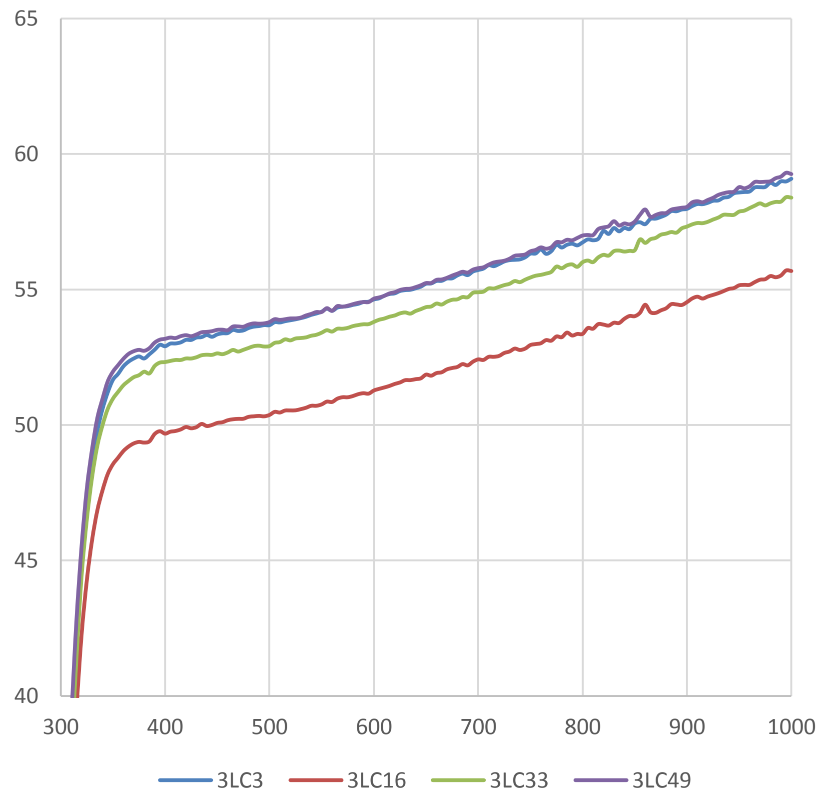
- Demonstrating uniform, 1-nm coating over large area
- Demonstrating complete removal of Sn from Surface
- Measuring temperature of coated aluminum surface
  - Pyrometer very sensitive to stray light in chamber

Transmission (%) vs Wavelength (nm) measured at (4) radial positions

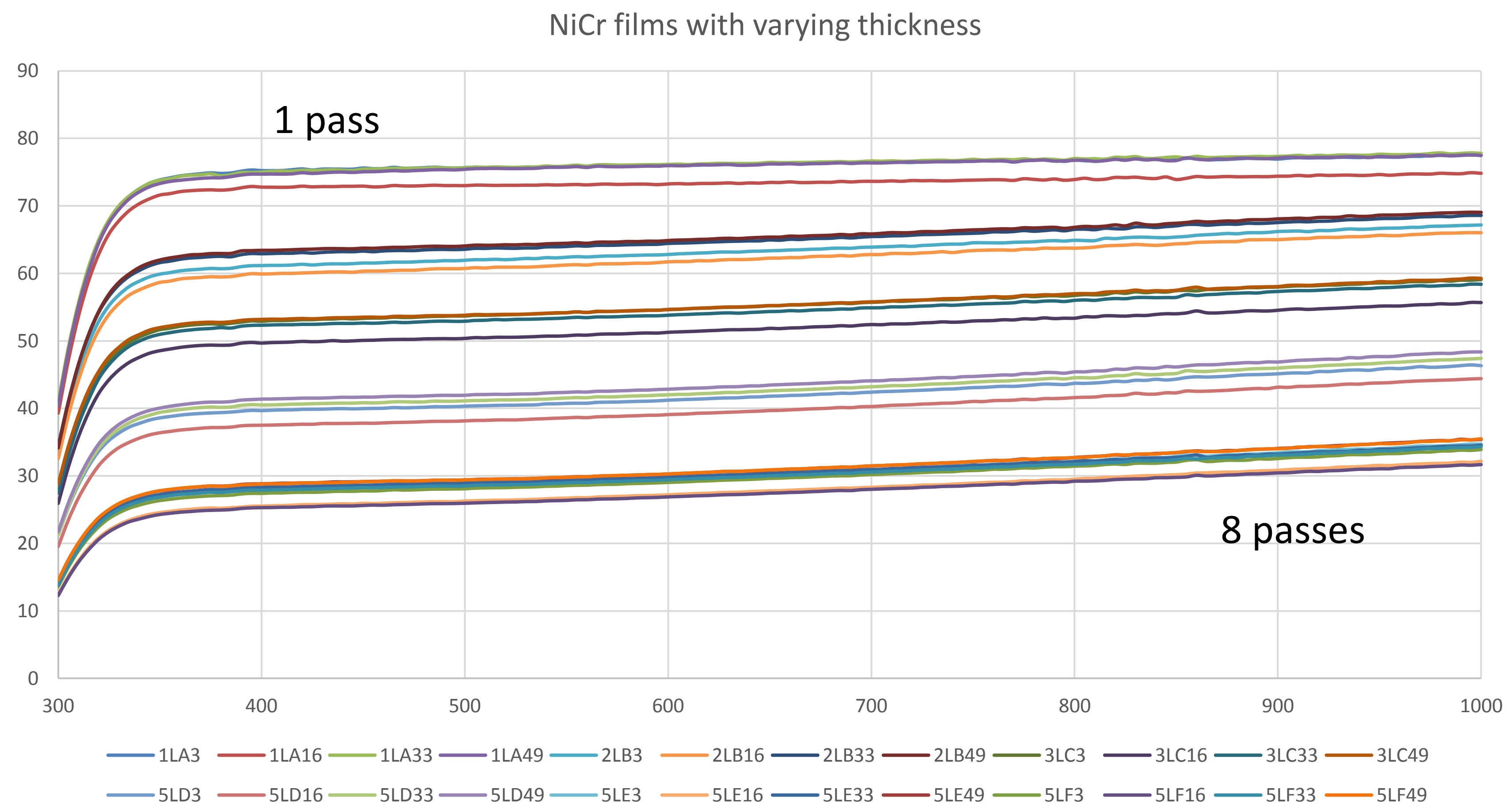
NiCr 1 pass



NiCr 3 passes



Phase I results (coating uniformity over large area using motion control evap. system)



Conversion of transmission data to layer thickness using optical constants n,k

Average thickness (nm)

		(nm)						
	Layers	1	2	3	5	6	8	8
	3	1.51	3.01	4.25	6.90	8.18	10.38	10.67
Radial	16	1.80	3.17	4.83	7.43	8.85	11.41	11.56
Position (cm)	33	1.49	2.80	4.38	6.70	8.17	10.38	10.51
	49	1.52	2.74	4.22	6.50	7.88	10.16	10.16

Average thickness per layer (nm)

		(nm)							
	Layers	1	2	3	5	6	8	8	Avg
	3	1.51	1.51	1.42	1.38	1.36	1.30	1.33	1.40
Radial	16	1.80	1.59	1.61	1.49	1.48	1.43	1.45	1.55
Position (cm)	33	1.49	1.40	1.46	1.34	1.36	1.30	1.30	1.38
	49	1.52	1.37	1.41	1.30	1.31	1.27	1.27	1.35
	Avg	1.58	1.46	1.47	1.38	1.38	1.32	1.34	1.42

To be discussed in final report….

- Sn removal experiments (reflectance before and after removal)
- Surface heating experiments (ability to produce crystalline fluorides by heating surface and producing large temperature gradient between the front and back of the mirror)

QUESTIONS?