Physics of the Cosmos Program

Cosmic Origins Program

Enhanced MgF_2 and LiF Over-coated Al Mirrors for FUV Space Astronomy

By

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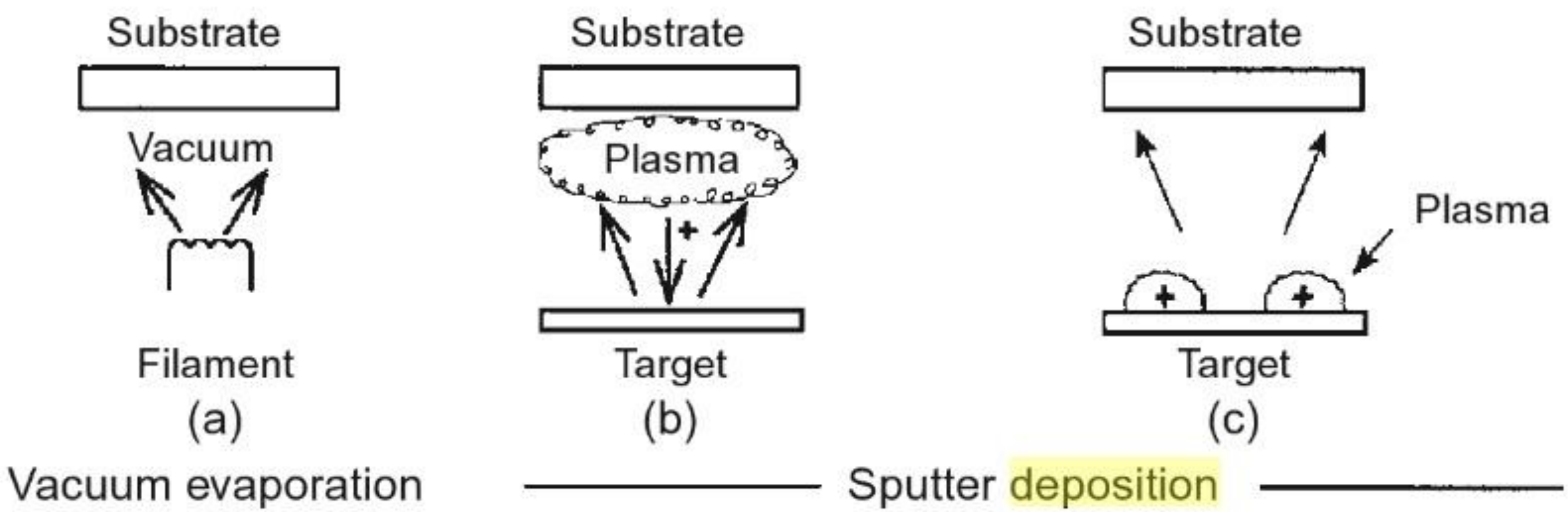
Outlines

- Motivation: The need for better performing coatings in the Far-Ultraviolet (FUV)
- Enhanced UV coating development for the Thermospheric Temperature Imager (TTI)
- More recent research efforts:
  - Preparation of 2-meter coating chambers
  - Study of other low-absorptions dielectric coatings for FUV applications
- Conclusions
- Acknowledgements

Enhanced FUV Coating Applications

- Distant and faint objects are typically searched for in cosmic origin studies:
  - Origin of large scale structure
  - The formation, evolution, and age of galaxies
  - The origin of stellar and planetary systems
- Astronomical observations in the Far Ultraviolet (FUV) spectral region are some of the more challenging
- Very limited option of reflecting coatings to use at FUV wavelengths:
  - Modest reflectivity offered by those coatings
  - Al+MgF_2 [typically 82% at Lyman-alpha, 1216 Å) that are used on reflecting surfaces of FUV instrumentation
- Improved reflective coatings for optics at FUV could yield dramatically more sensitive instruments .
- Permit more instrument design freedom

Optical Coating Deposition Processes



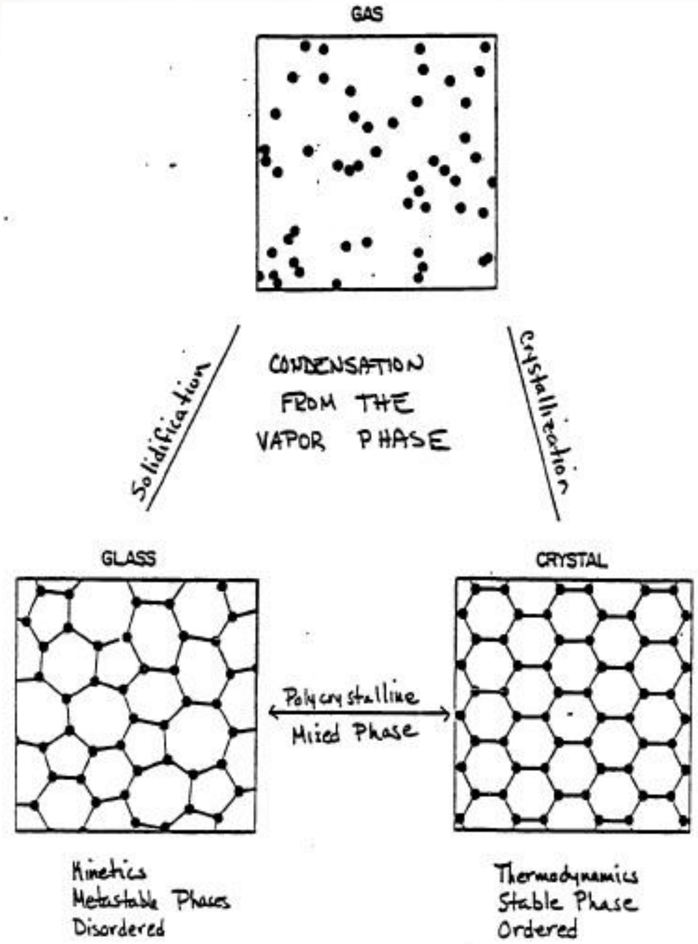
PVD

- Material is heated until it reaches vapor form
- Material is deposited on the substrate where it condenses
- Typical deposition rates are 10-100 Å/Sec.

Sputtering

- Non-thermal evaporation process
- Atoms from a target are ejected by momentum transfer from energetic atom-size particles
- Particles are energized by an ion gun
- Deposition rate are much lower than PVD 1-5 Å/Sec.

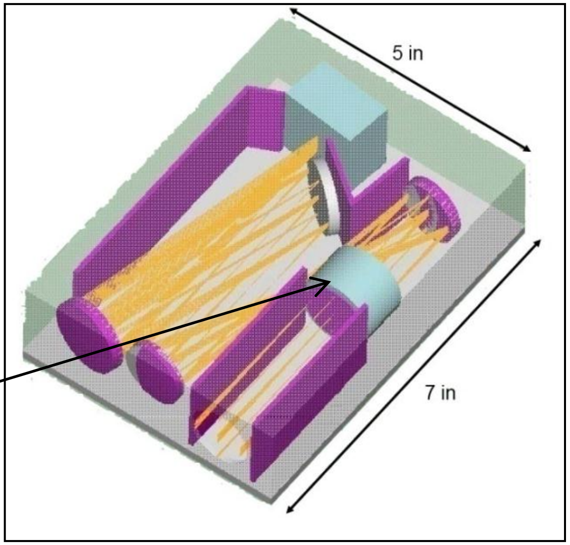
Solidification vs. Crystallization



TTI Mission Concept

TTI Optics

- Imager to provide global-scale remote measurements of thermospheric temperature profile of atomic oxygen at an altitude of 200-400 KM
- Wavelength range: 135.4 to 135.6 nm (0.0004 nm resolution)
- Fabry-perot Etalon cavity:

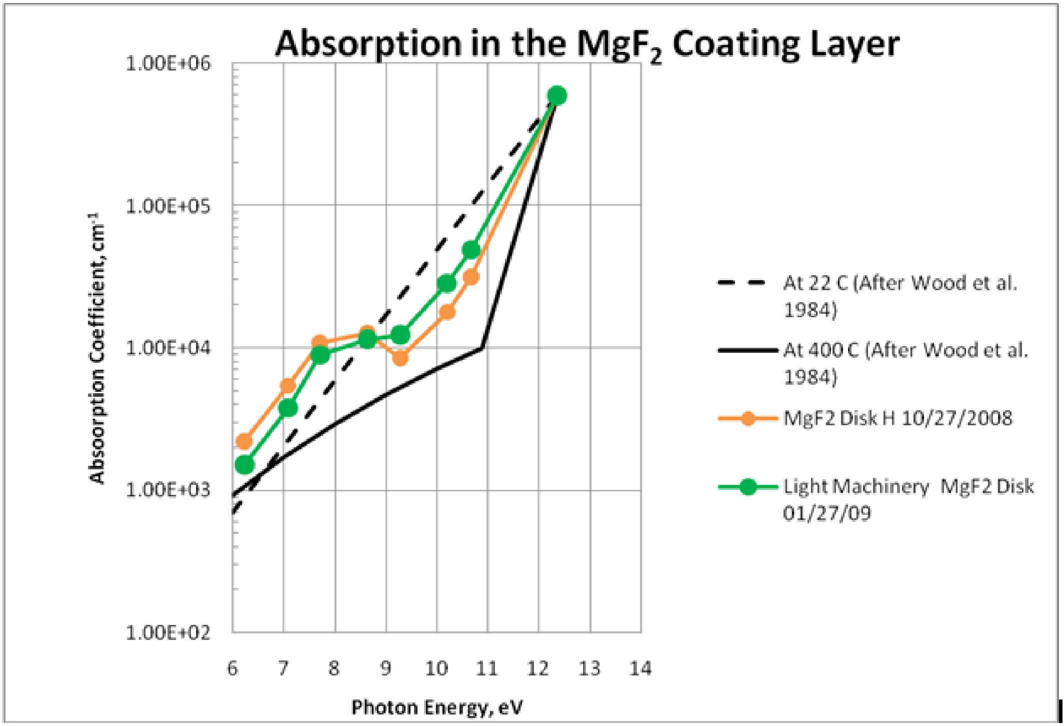


- GSFC effort to develop Al+MgF2 coatings to meet requirements:
  - High reflectance & low absorption

High-Temperature Deposition Al+MgF2

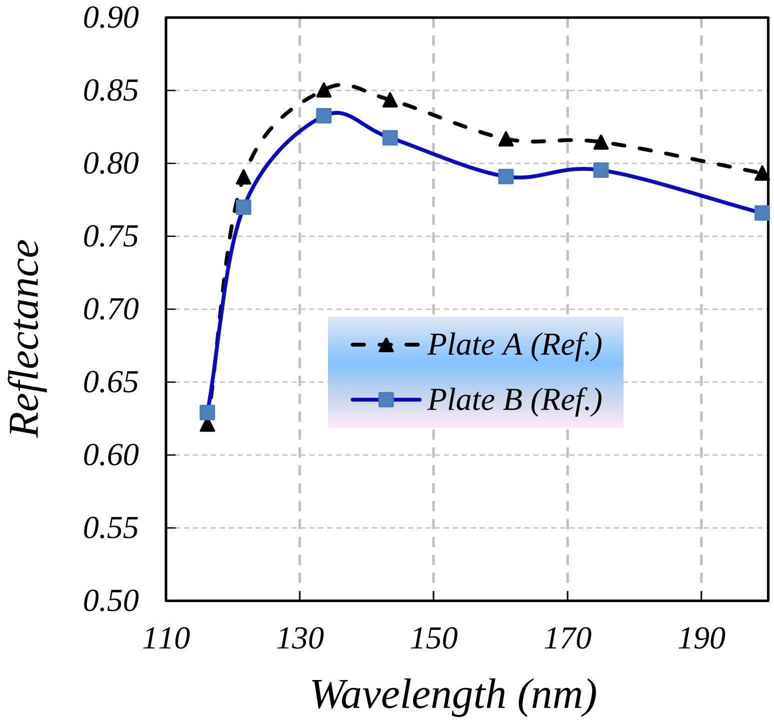
3-step coating process:

- ✓ Al coat the substrate at room temperature to the planned layer thickness
- ✓ As soon as possible after the Al deposition, overcoat the Al layer and substrate at room temperature with a thin 4-5 nm layer of MgF_2 in order to protect the Al from oxidation and contamination.
- ✓ Heat the substrate to maximum temperature and overcoat the thin MgF2 , Al, and substrate with the planned thickness of MgF2.



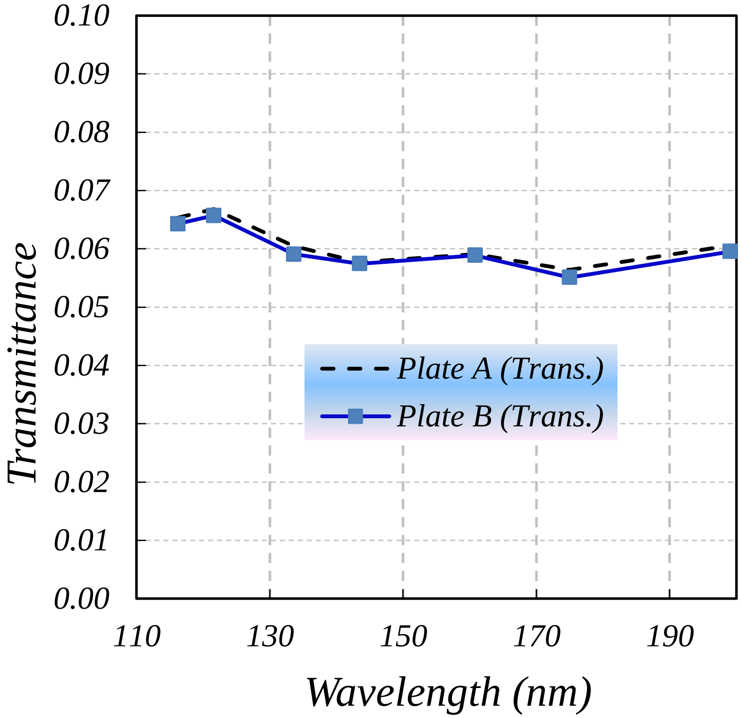
TTI Etalon Plate Performance

Reflectance



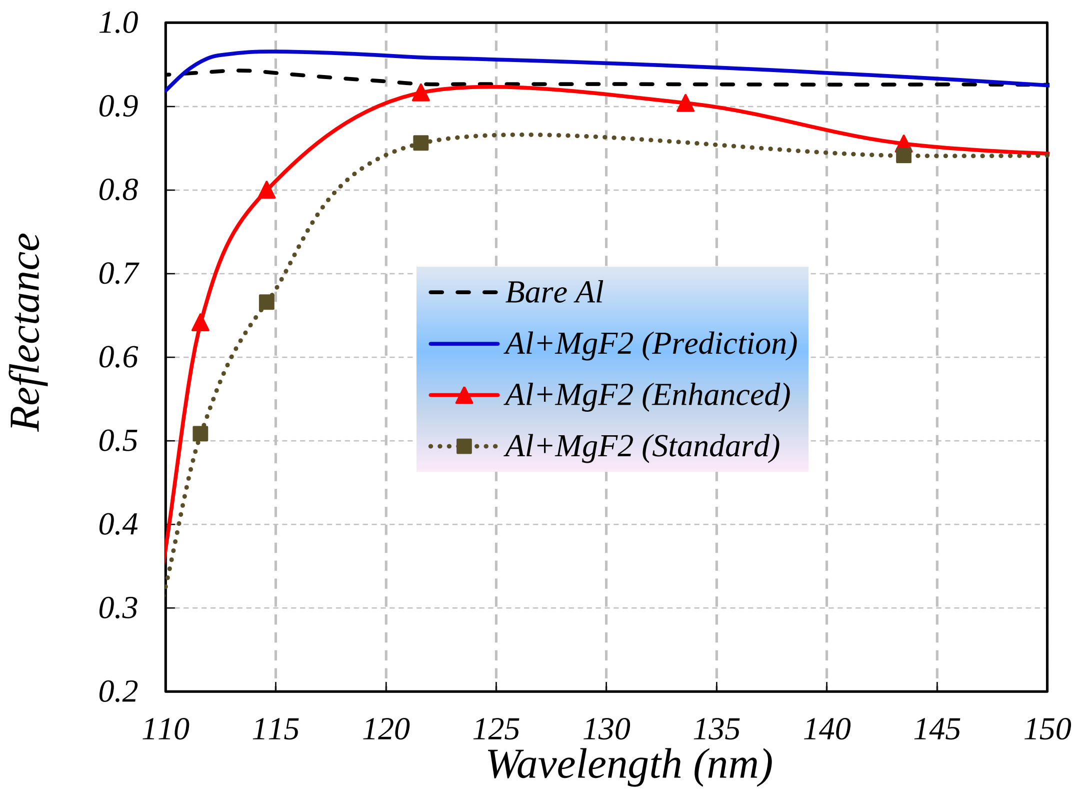
TTI Etalon plate 6a (Thicknesses: Al 277 A; MgF2 300A)

Transmittance



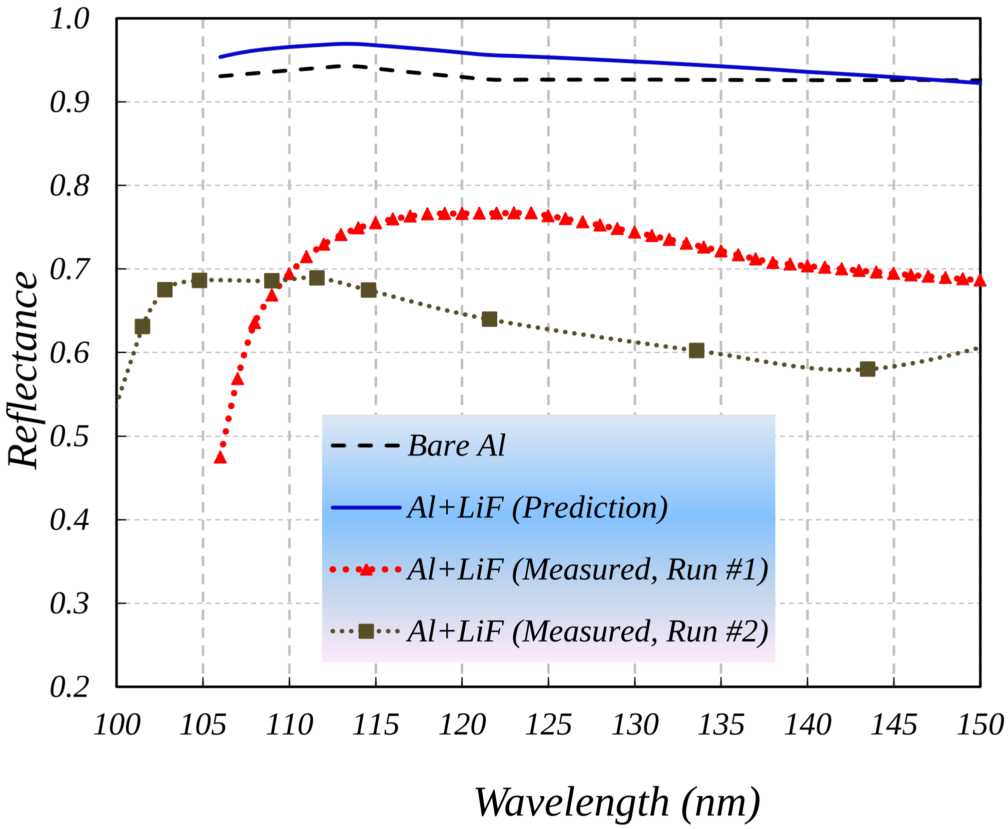
TTI Etalon plate 6b (Thicknesses: Al 278 A; MgF2 310A)

Evaporated Al+MgF2 Mirror Performance



- Predicted vs. measured reflectance of bare Al and Al+MgF_2 reflectance (Al: 50.0 nm; MgF2: 25.0nm)
- Enhanced performance is obtained by heating (~220 ° C) substrate during MgF2 deposition
- Reflectance is > 80% even at 115.0 nm

Evaporated Al+LiF Mirror Performance



- Predicted vs. measured reflectance of bare Al and Al+LiF reflectance
- Enhanced performance is obtained by heating substrate during LiF deposition.

Recent Results 1-meter Chamber

Run AMC1207

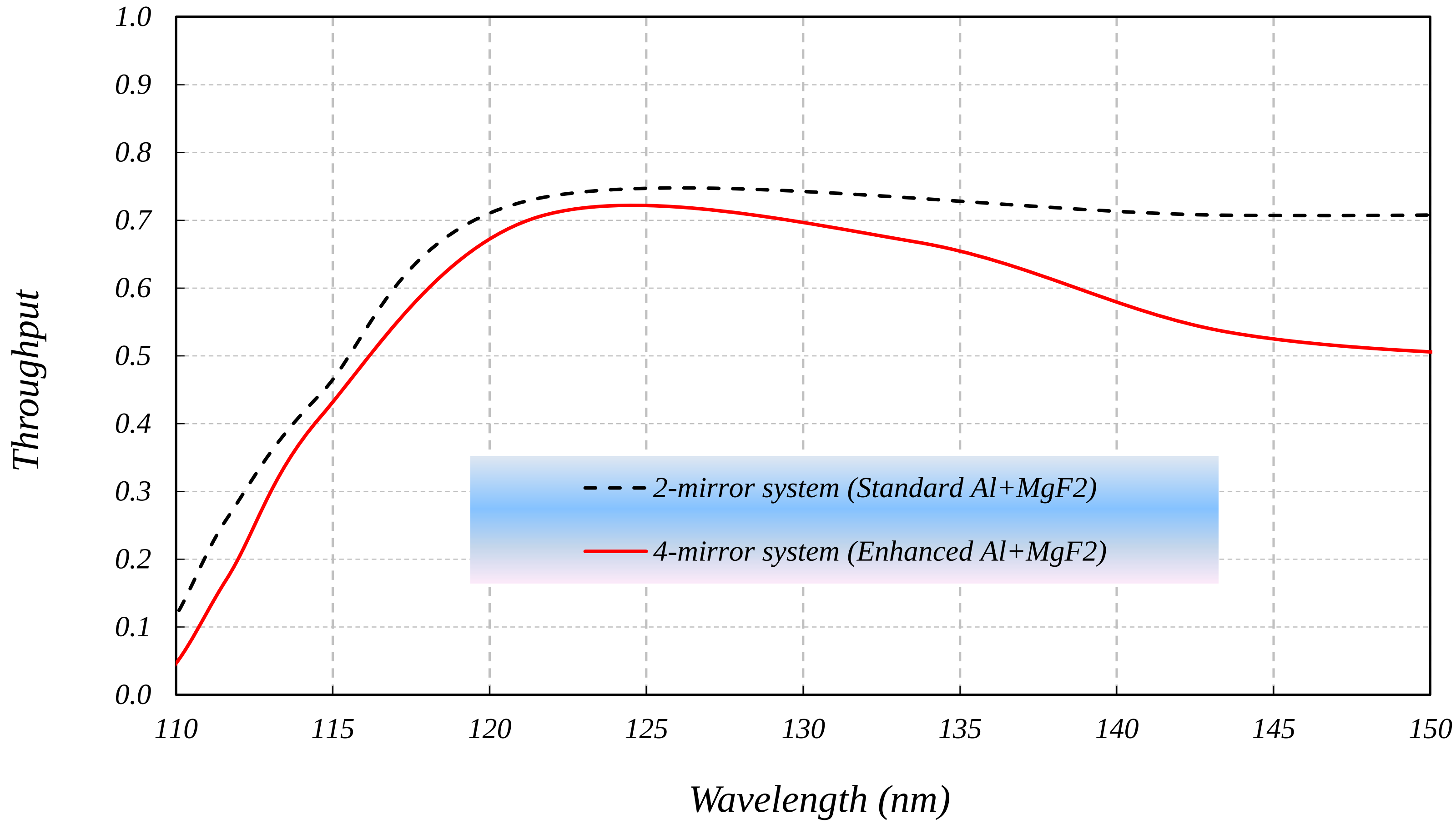
Wavelength (A)	Ref **AMCT0902A**	slide **AMC1207A** center of 14" diam optic	slide **AMC1207B** 8" from center of optic
***1216**	***0.830850419**	***0.863613442**	***0.840455289**
1162	0.62643581	0.655861189	0.741373332
1216	**0.823922691**	**0.863135491**	**0.855357016**
1608	0.845185596	0.881918126	0.818922628

Run AMC1208

Wavelength (A)	Ref **AMCT0902A**	**AMC1208** 3" from center of chamber
***1216**	***0.811149486**	***0.890760365**
1162	0.623358305	0.809512748
1216	**0.814559749**	**0.896448174**
1608	0.815977285	0.843056068

note: * indicates initial measurement

Throughput Performance for 2- and 4-meter Systems



GSFC 2-meter Coating Facility

- Design and fabrication of internal heat shields for 2-meter Chamber.
- Optimized coating parameter for high FUV reflectance of a distribution of slides in center and out to a ~0.5 meter radius.

FIREBALL primary mirror loading

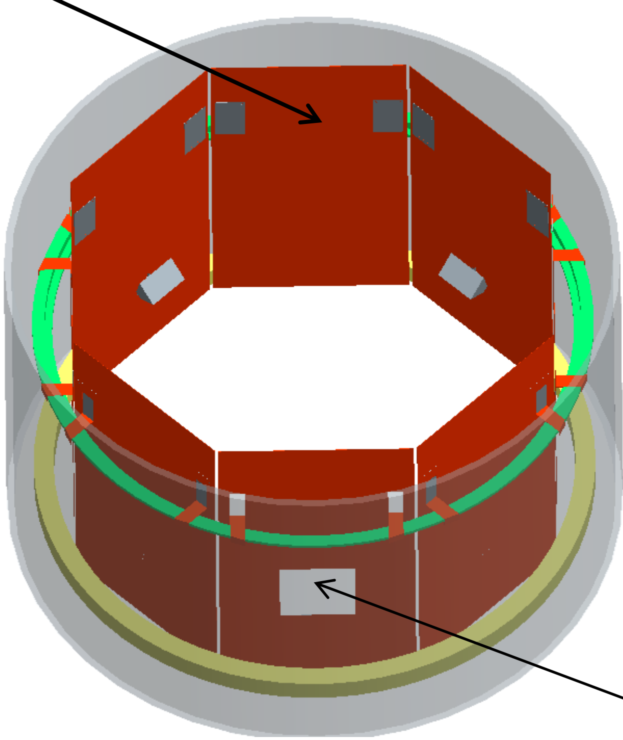
Mirror mounted in 2-meter chamber prior to coating

Missions supported: Astronomical Observatory (OAO) & Ultraviolet Explorer (IUE)
FUSE, HST (COSTAR, GHRS & COS)

2-meter Chamber Heat Panel Concept

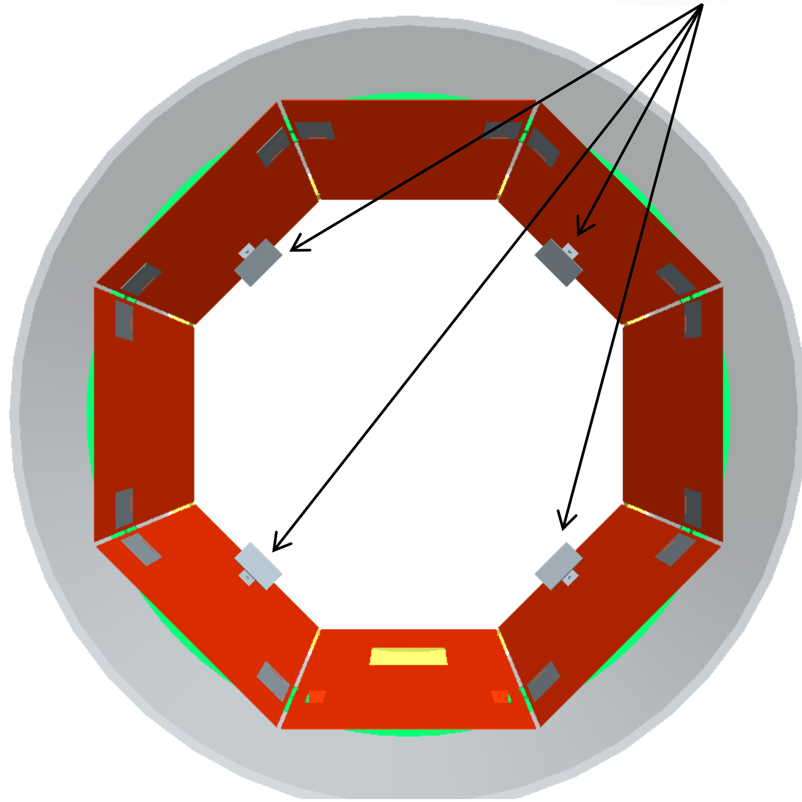
- These wall panels were made out of stainless steel and were designed to easily interface with the existing internal configuration of the chamber.
- We are still in the design phase of the top shields for future installation in the chamber dome.
- We recently test fit the wall panels in the co.

8 PANELS

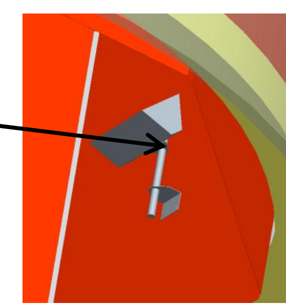


SINGLE VIEWPORT 10" X 10" SQUARE

4X LIGHT MOUNTS

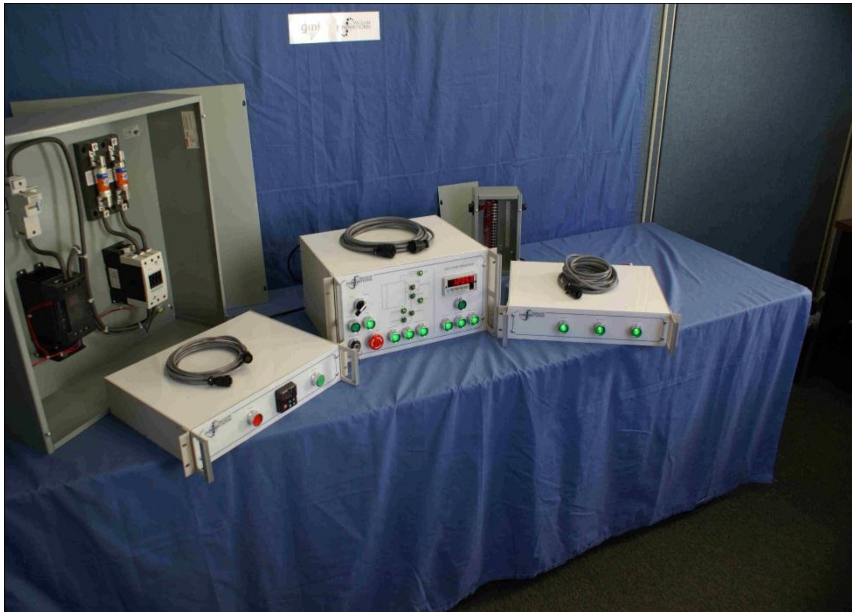


ADJUSTABLE LIGHT MOUNT



Halogen-Quartz Lamp Heater Equipment

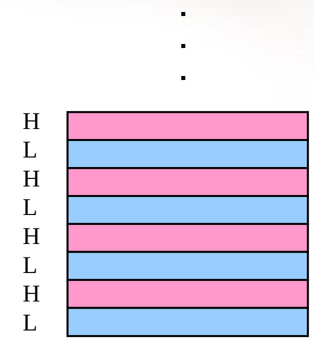
Quartz Lamp Heater Assembly



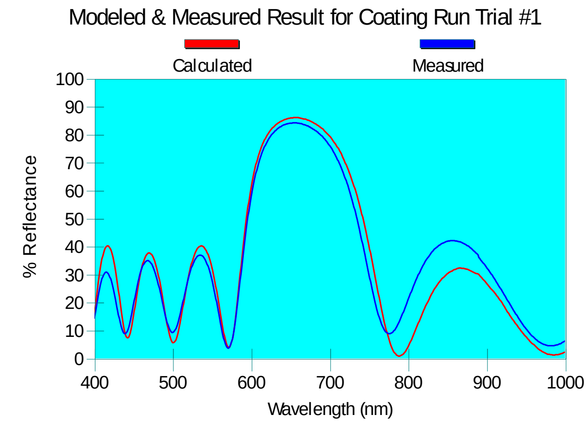
Power Supply System

FUV Reflecting Dielectric Coatings

- **Choose a high-index (H) and low-index (L) pair combination**
- **Form a pair of (H,L) layers with thicknesses equal to a Quarter-Wave Optical thickness at the design wavelength.**
- **Repeat the stack above until desired reflectance is achieved.**



Note: The larger the difference between (n_H-n_L) the better contrast and fewer layers needed to achieve a given R



Options for coating materials:

L: MgF_2 (n~1.38)

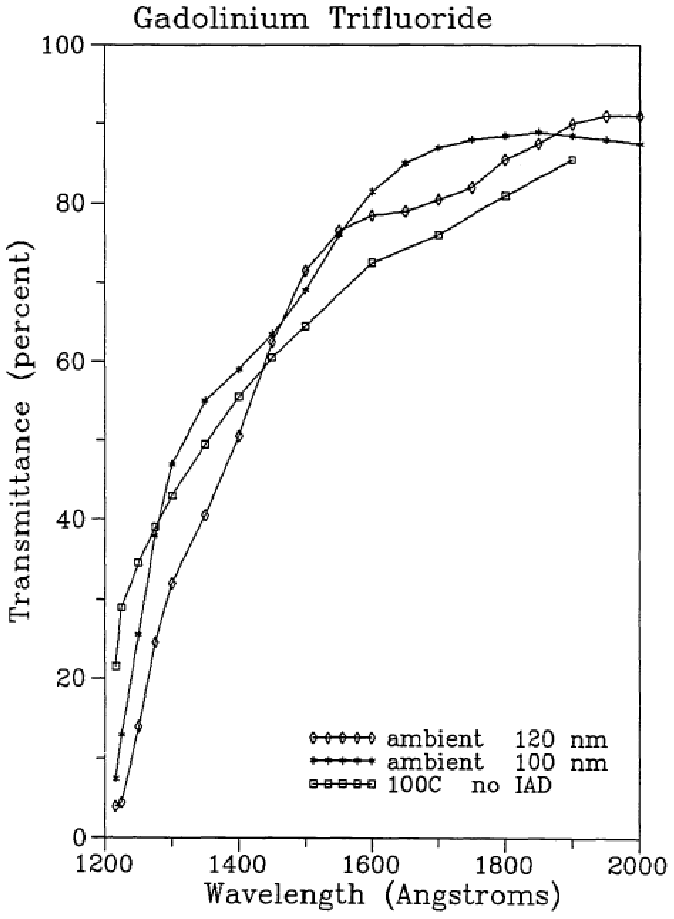
H: ?

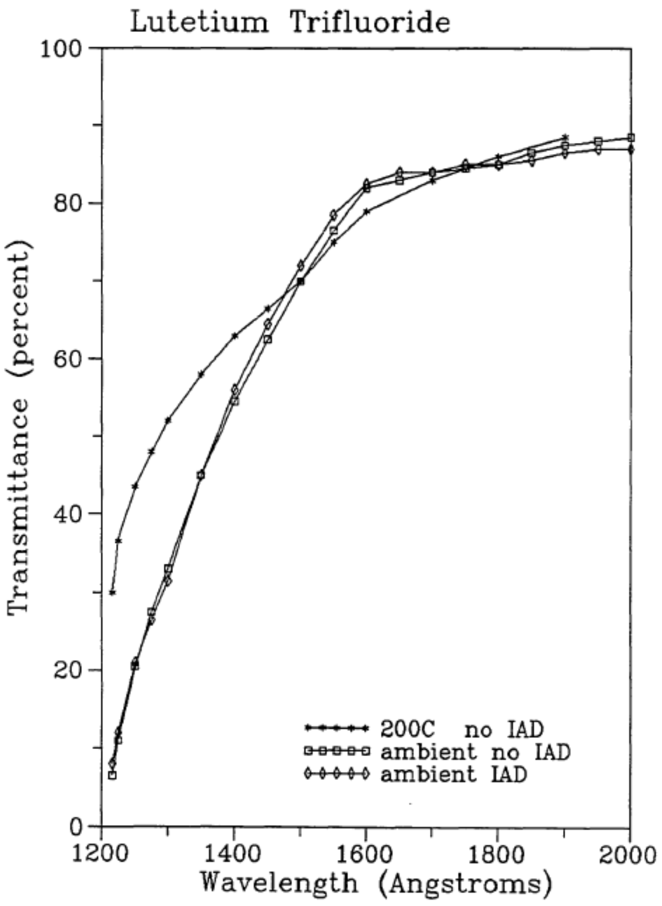
Evaporation Details for Lanthanide Trifluorides

LnF_3	VENDOR & FORM	PURITY	PRICE per gram	BOAT (5 mil canoe)	RATE Å/sec	MELT COMMENTS
PrF_3	Cerac 3-6mm fused $^1/_8$-$^1/_4$" pieces	99.9 vac. dep. grade	$1.60	W (no Mo,Ta)	6	bright green smooth melt large, shiny grains
SmF_3	"	"	$1.62	Mo	6	pale yellow uneven melt small, dull grains
EuF_3	"	"	$16.00	Pt sheet 2 mil (no Mo,Ta)	4	light brown smooth melt large, shiny grains
GdF_3	"	"	$1.70	Mo	6	white, grey uneven melt small, shiny grains
TbF_3	"	"	$7.50	Ta	4	white, grey smooth melt small, shiny grains
DyF_3	"	"	$1.60	Ta	6	dark grey smooth melt small, shiny grains
HoF_3	"	"	$2.30	Ta	6	pink smooth melt large, shiny grains
ErF_3	"	"	$1.90	Ta	6	pink smooth melt large, dull grains
TmF_3	"	"	$18.30	Mo	6	white, grey smooth melt large, dull grains
YbF_3	"	"	$2.40	Mo (no Ta)	3	tan smooth melt large, dull grains
LuF_3	" Aesar crystalline lump	" 99.99 elec.grade low oxy	$37.00 $45.00	Mo Mo	6 6	white whiter smooth melt large, dull grains

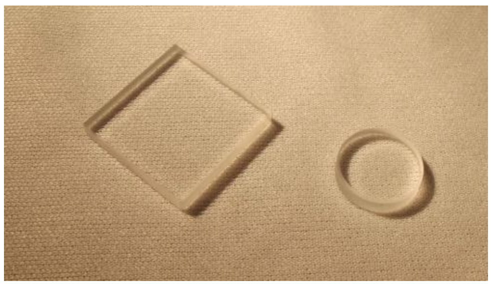
Ref.: Linda Jeanne Lingg, Ph.D. Thesis University of Arizona (1990).

Two FUV Candidate Materials: GdF_3 & LuF_3



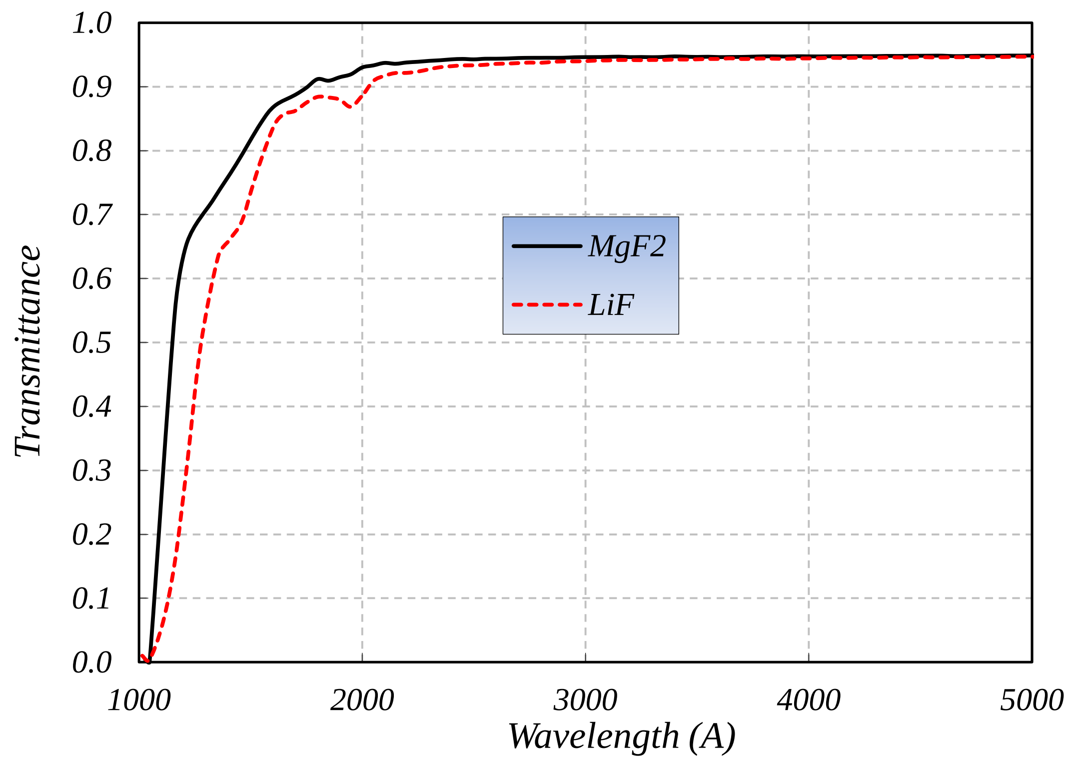


Substrates Characterization

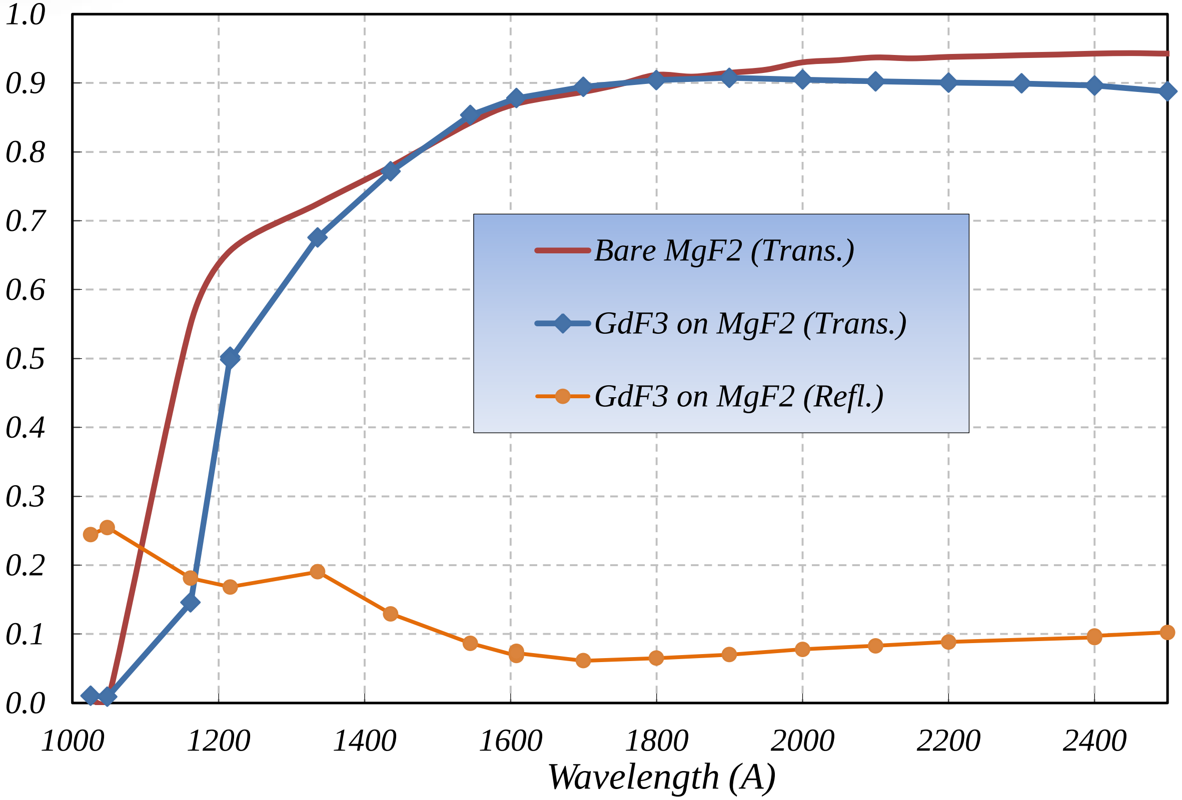


MgF$_2$ & LiF substrates have been procured

Optical Transmission



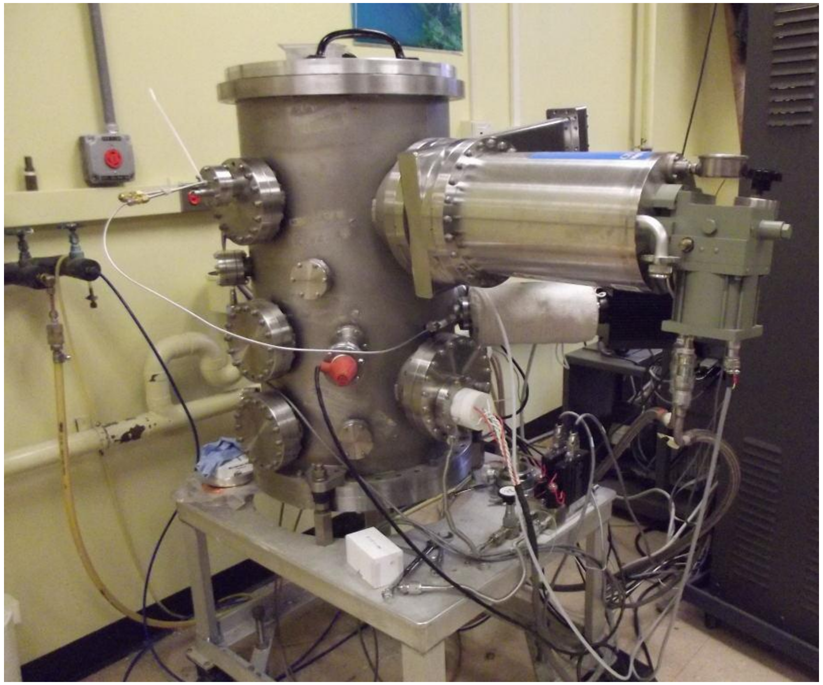
GdF3 Film on MgF2 Substrate



- 430 A GdF_3 film on MgF_2 substrate
- Measured T & R will enable characterization of n & k

Ion Beam Sputtering Coating Chamber

- Upgrade chamber with a two-gas flow controller system.
- Received shipment of Krypton gas cylinder to be used in the ion-beam sputtering deposition of MgF2 and LiF coatings.
- Making preparation to start making test coating runs to “break-in” MgF2 targets.
- Placed order of new magnets to refurbish ion gun in order to increase deposition rate.



Conclusion

- Reported gains in FUV reflectivity of Al+MgF_2 and Al+LiF mirrors by employing a 3-step process during PVD coating deposition of these materials.
- Preparations under way to transfer process to a large 2-meter chamber for allowing coating up to 1 meter diameter optics.
- Characterization of lanthanide trifluoride material candidates to determine their FUV transparency for development of dielectric coatings.
- Advantages of having better performing coatings will add more flexibility to a system design that is certain to improve overall performance.
- Increasing system throughput is a very cost effective way to achieve more science and often is less costly than simply using a larger primary mirror.

Acknowledgements

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John Sigwarth (TTI PI)

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