Low-Stress Silicon Cladding for Surface Finishing Large UVOIR Mirrors NASA

SBIR Phase II contract No. NNX14CP14

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Introduction

- In this presentation, I will discuss the status of our Phase II silicon cladding development effort, which is based on ion-assisted, physical evaporation (PV)
- The coating area is currently 1.2-meter in diameter and we are considering options for demonstrating coating a larger area (2-meter +)
- Future large telescopes may be monolithic (4-meters or larger), or comprised of many smaller segments (~1.5-m).

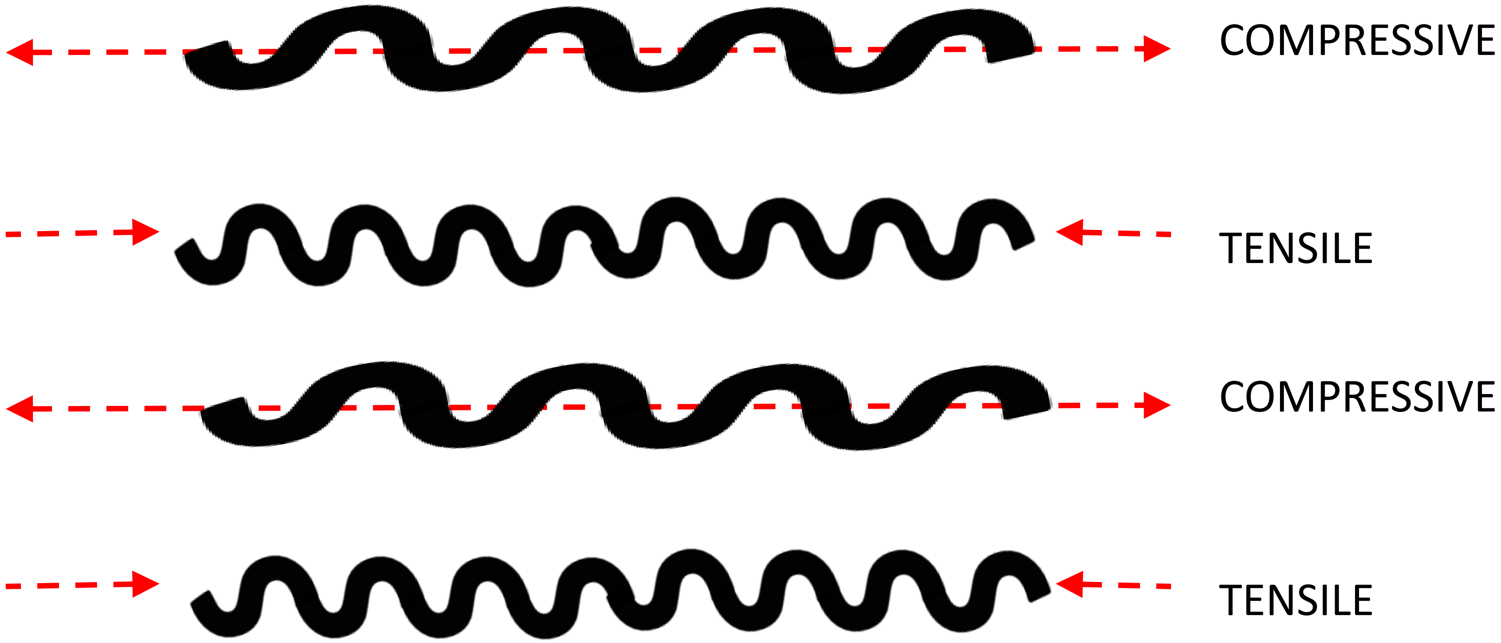
What is Silicon Cladding?

- Silicon cladding is a material applied on the surface of a SiC mirror substrate, to provide a better surface to polish and to reduce figuring time
- A 10 to 100-micron silicon layer is typically applied on top of the SiC
- Why Silicon? Good material to diamond turn or polish, and the CTE is very close to SiC

Research Goals

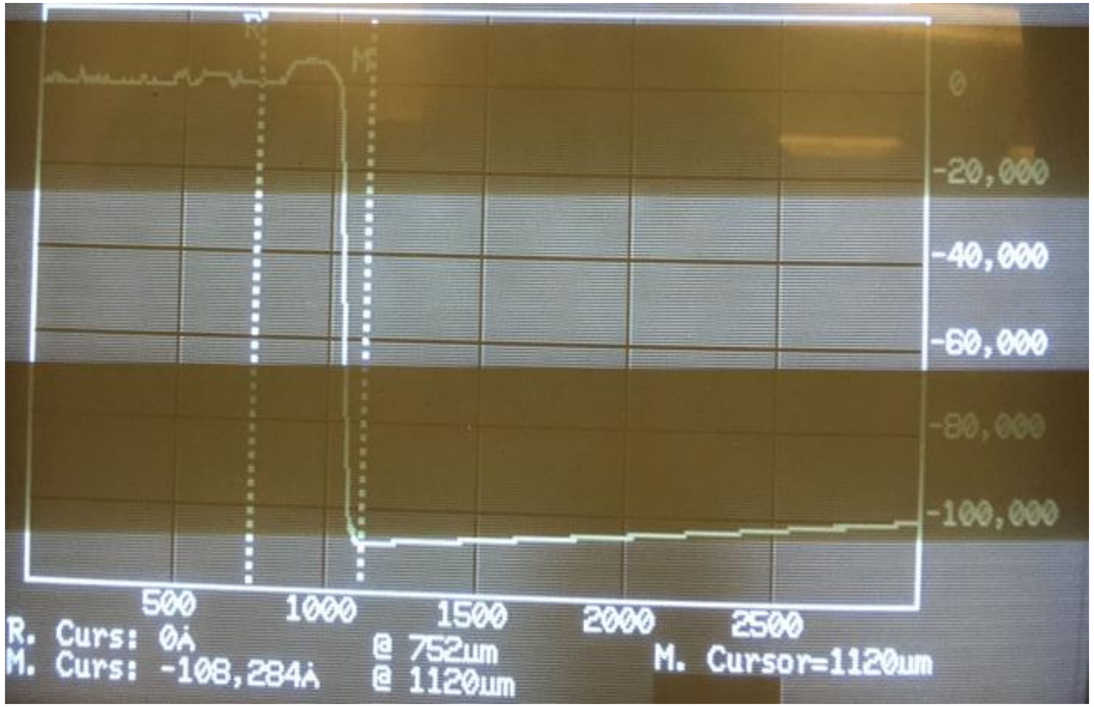
- Create a viable cladding production process for large mirrors
- Create a process that is scalable to ANY size vacuum chamber
- Create a "turn-key" technology suitable for licensing to silicon carbide mirror manufacturers
  - ZeCoat 2nd source supplier
  - ZeCoat R&D

ZeCoat's Si cladding process is based on periodically alternating the sign of the coating stress to yield a near-zero net coating stress. IAD silicon has compressive stress and non-IAD silicon has natural tensile stress

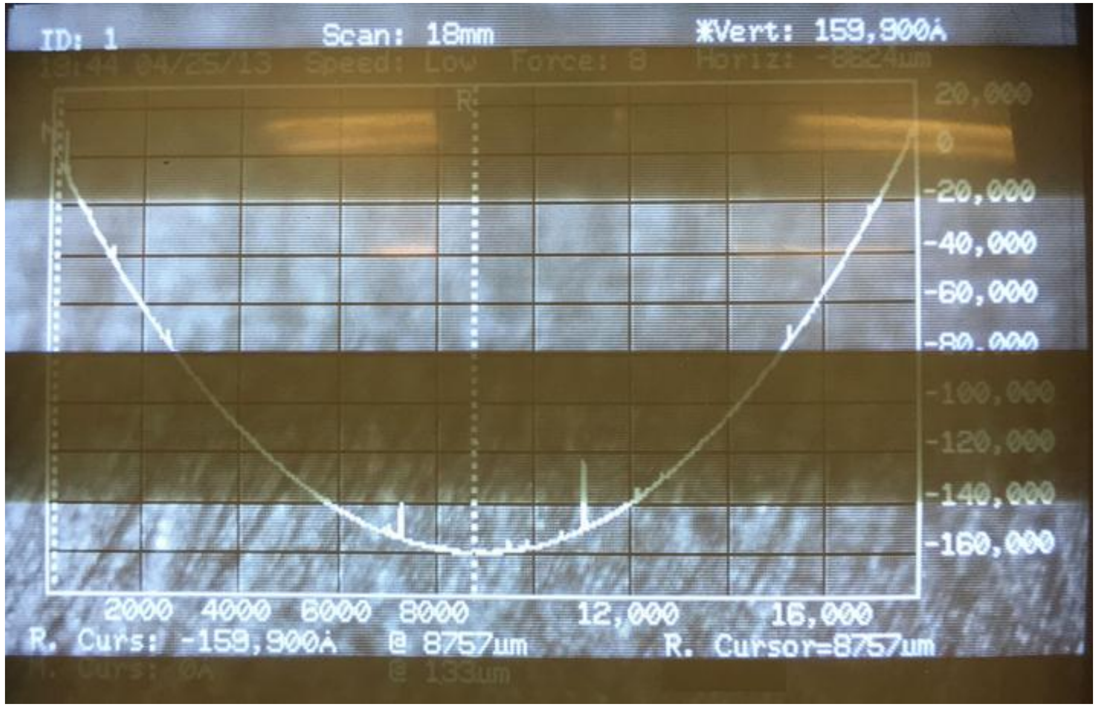


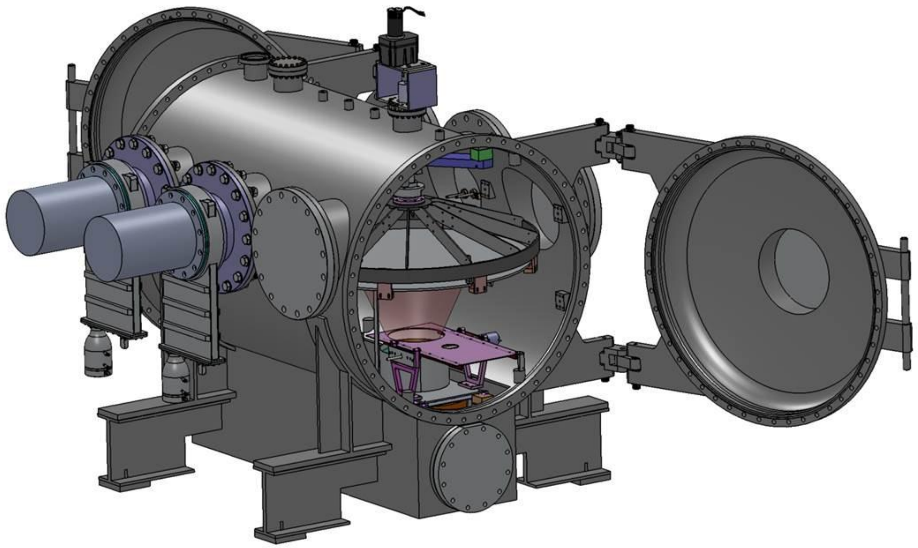
Calculating Stress (goal is less than 85 MPa)

Profilometry measurement shows ~11 microns of Si



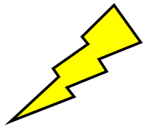
1 inch diameter, 20-mil fused silica disc bent 16-microns = ~60 MPa (tensile)





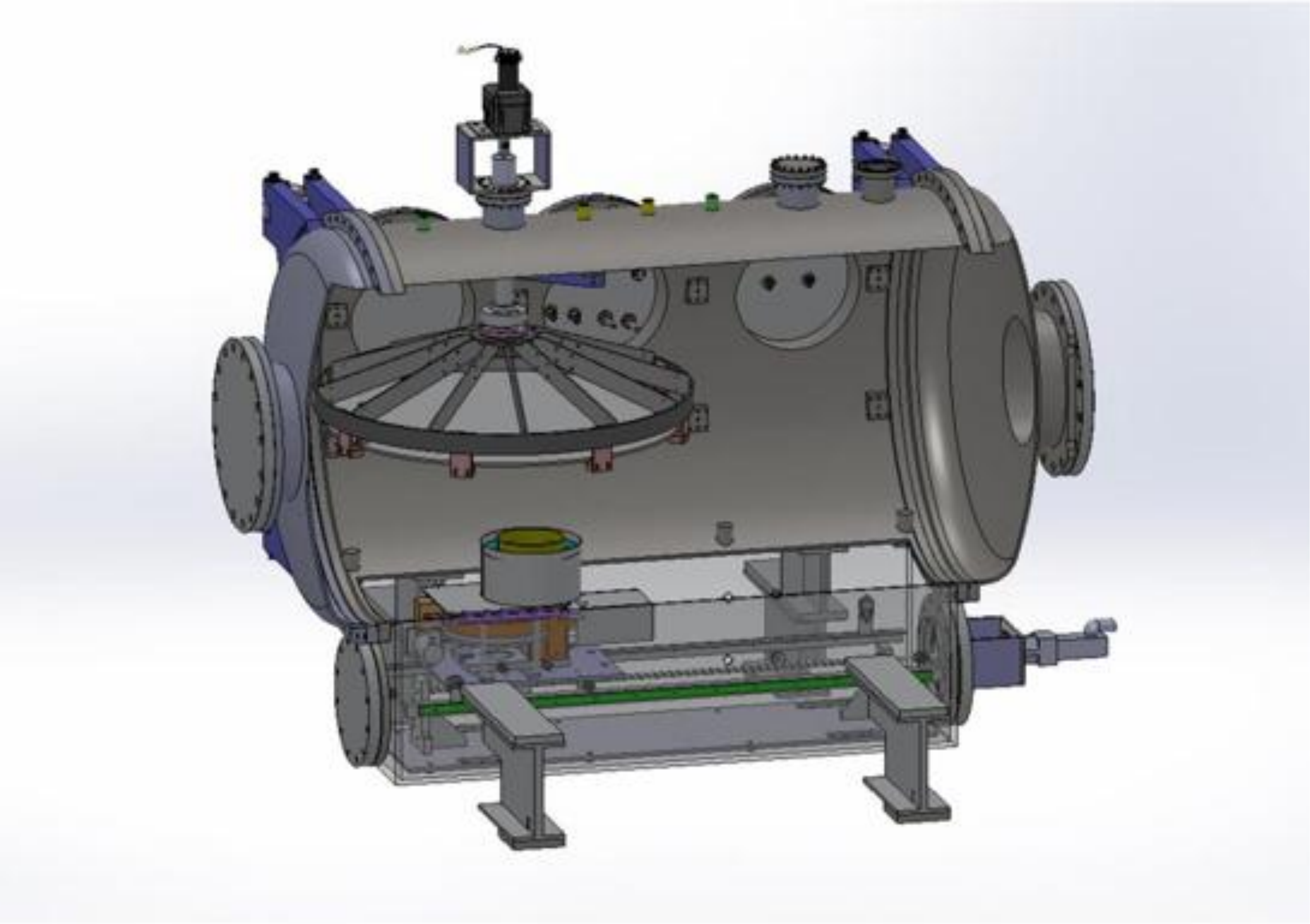
ZeCoat's 1.2-m vacuum coating chamber was completed in March, 2013 and utilizes an ion-assisted e-beam evaporation system

Phase I & II Challenges

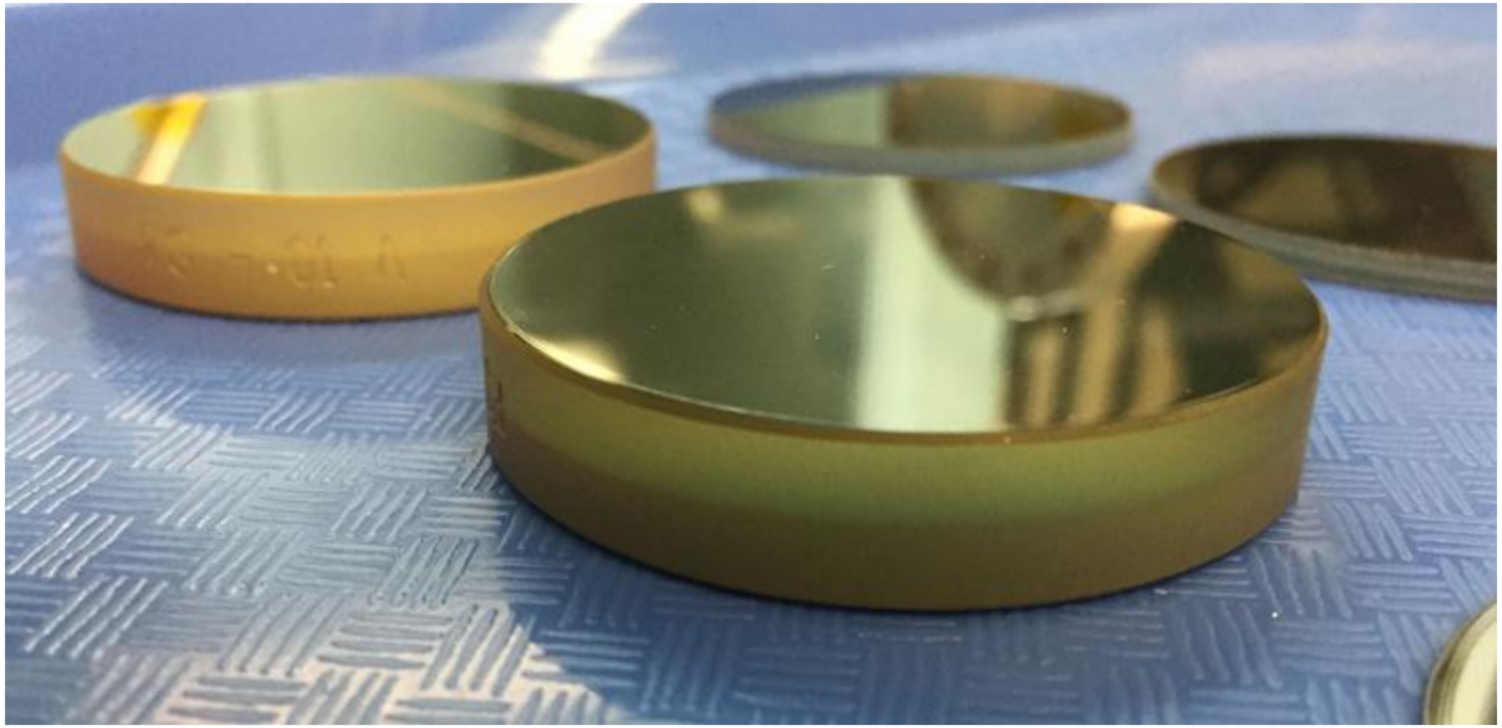
- Surface defects
  - A spitting event is when molten silicon explodes from the evaporation crucible potentially damaging the silicon clad surface.
    - Pre-conditioning
    - Excessive evaporation rates, e-beam “digging”
  - Dust; opening and closing the chamber many times during the process to replenish materials, etc.
- Arcing 
  - Arcs associated with ebeam evaporation (high voltage discharges within the chamber) cause many problems

Overcoming Arcing Problems

- Designed and installed new shielding over the electron emitter assembly
- New shielding over ceramic insulators
- Ground wires far from high-voltage lines
- Installed relays between the computer system and process sensors within the chamber, to isolate the computer from arcing interference
- Wrote new motion control software to detect false signals due to arcing and reset the computer system seamlessly



Silicon Polishing Tests



Polishing Results Phase I and Phase 2 (1^{st} Q)

Scan length 1024 microns						
						goal < 5
Project	**ID**	**Substrate**	**Evap. Rate**	**Si Thickness (µ)**	**PTV (A)**	**RMS (A)**
Phase I	1a	SiC (rough)	3x	20	16	2.8
Phase I	1b	SiC (rough)	3x	20	236	21.5
Phase I	1c	SiC (rough)	3x	20	460	36.7
Phase I	2a	SiC (rough)	3x	20	137	21.4
Phase I	2b	SiC (rough)	3x	20	84.2	10.8
Phase I	2c	SiC (rough)	3x	20	314.1	24.4
Phase II	SN1	Fused Silica (polished)	1x	4	9.2	1.4
Phase II	SN3	Fused Silica (polished)	1x	11	23.3	3.2

Surface Roughness Profile
Silicon Coated Sic Sub #1 B
Processed
RMS 21.53 angstroms
P-V 236.78 angstroms
Points 1024 microns

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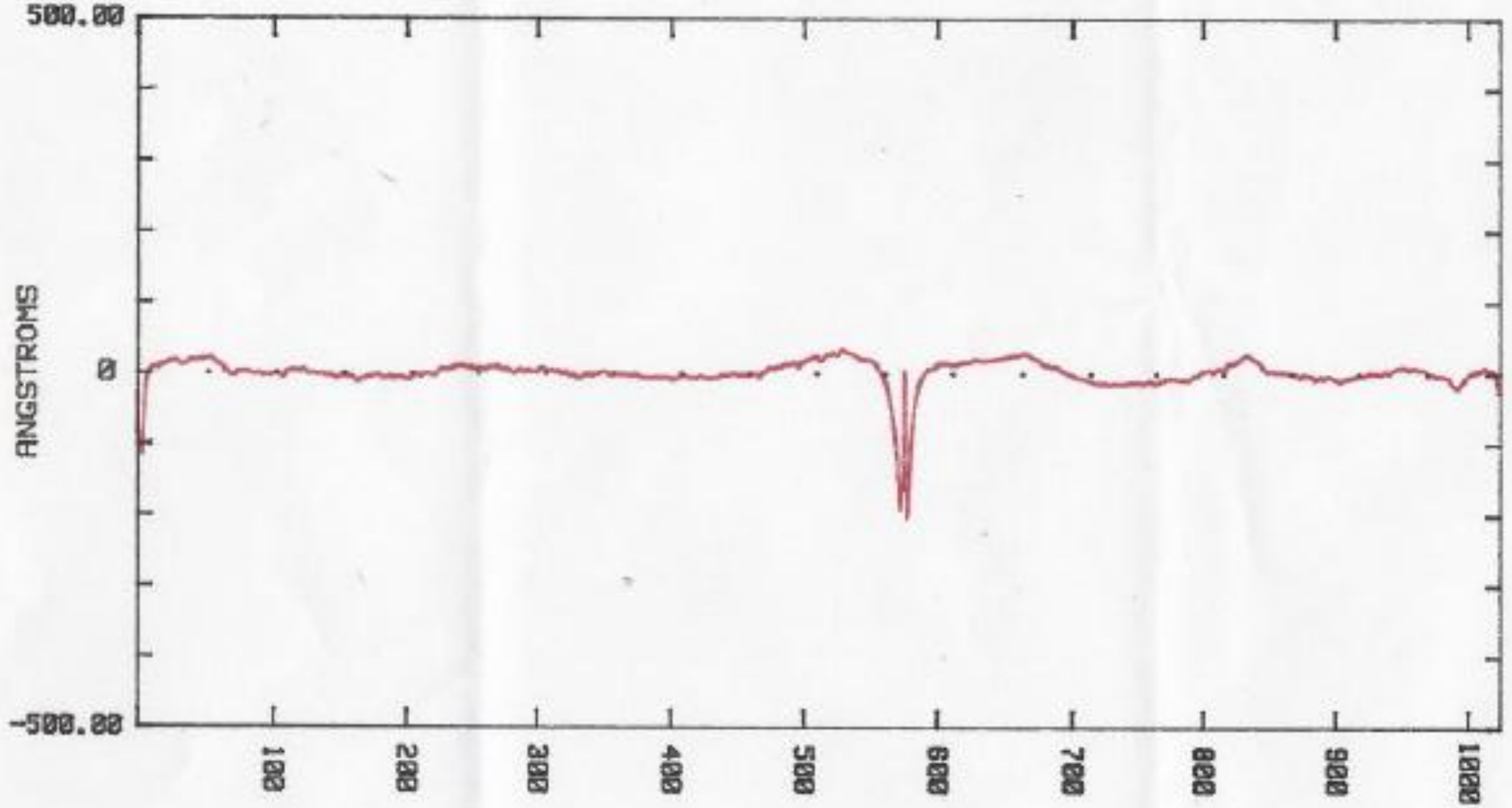

Surface Roughness Profile
Silicon Coated Sic Sub #1 C
Processed
RMS 36.65 angstroms
P-V 459.52 angstroms
Points 1024 microns

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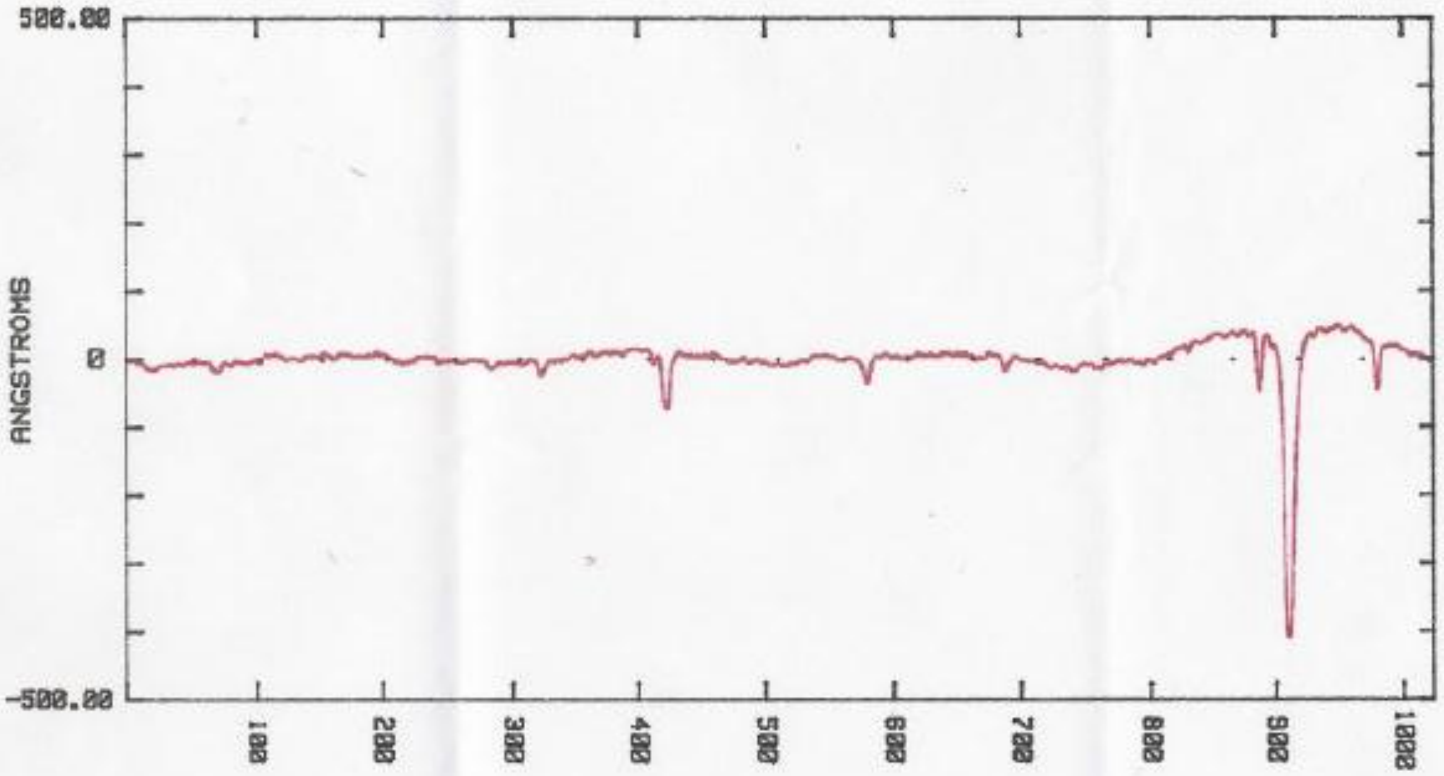

Surface Roughness Profile
FS-03
Processed

RMS	3.24	angstroms
P-V	23.32	angstroms
Points	1024	microns

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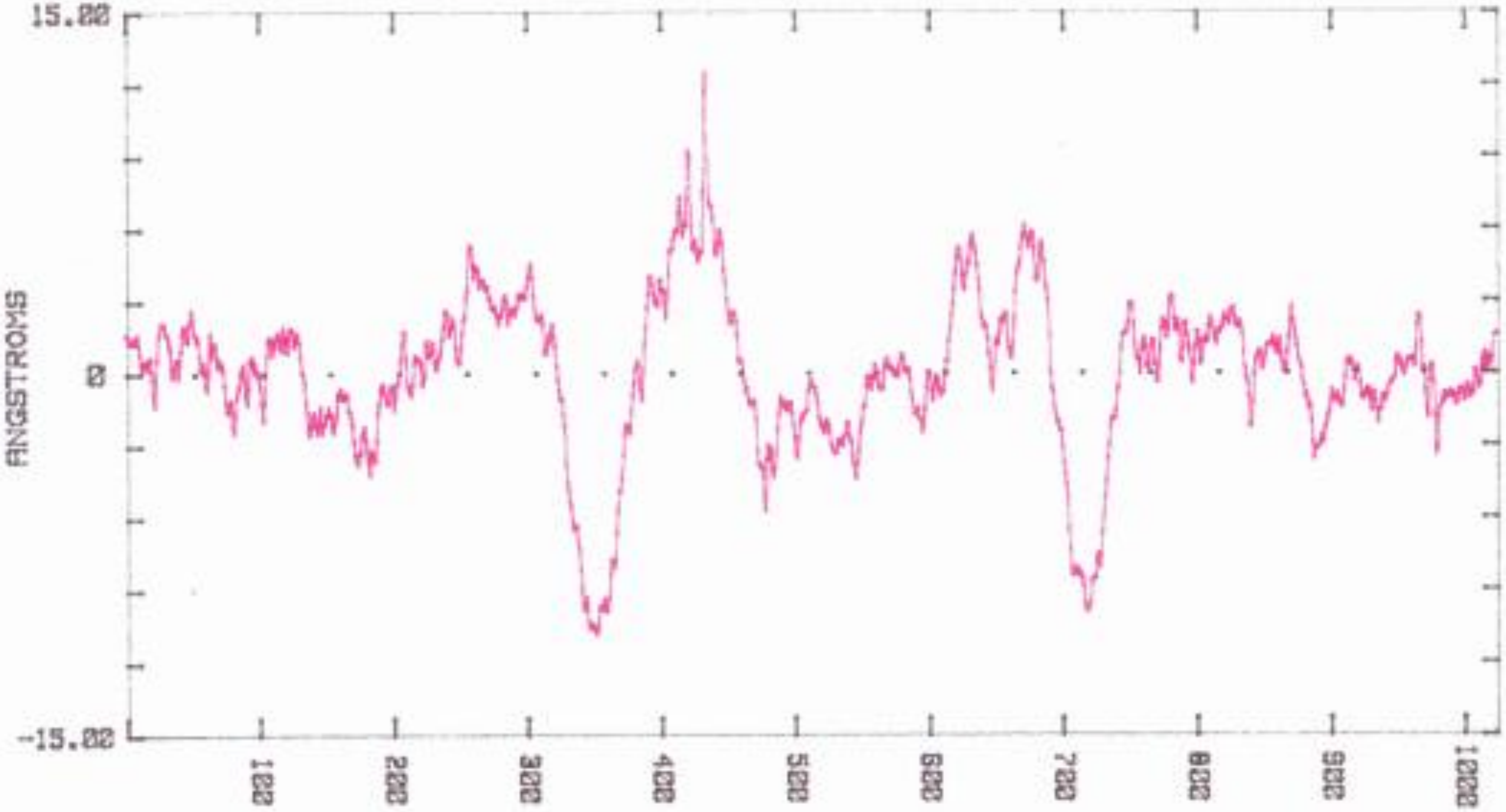

Surface Roughness Profile

FS-01

Processed

RMS	1.36	angstroms
P-V	9.19	angstroms
Points	1024	microns

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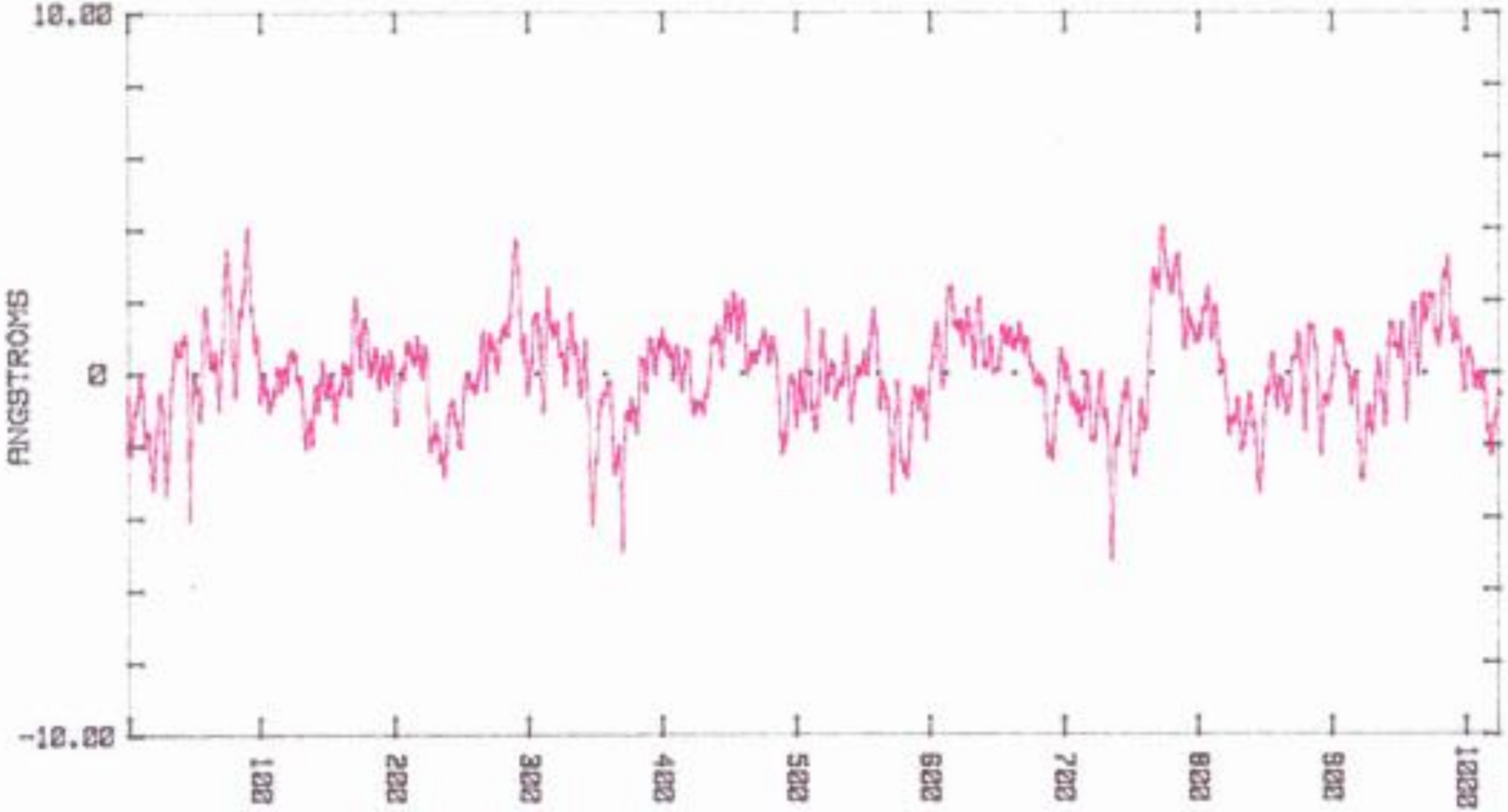

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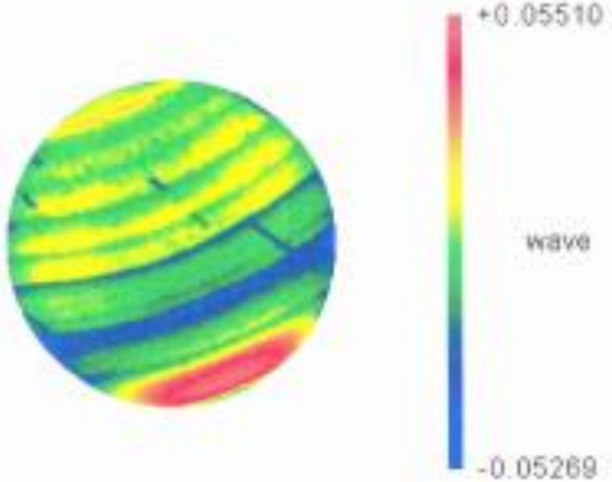

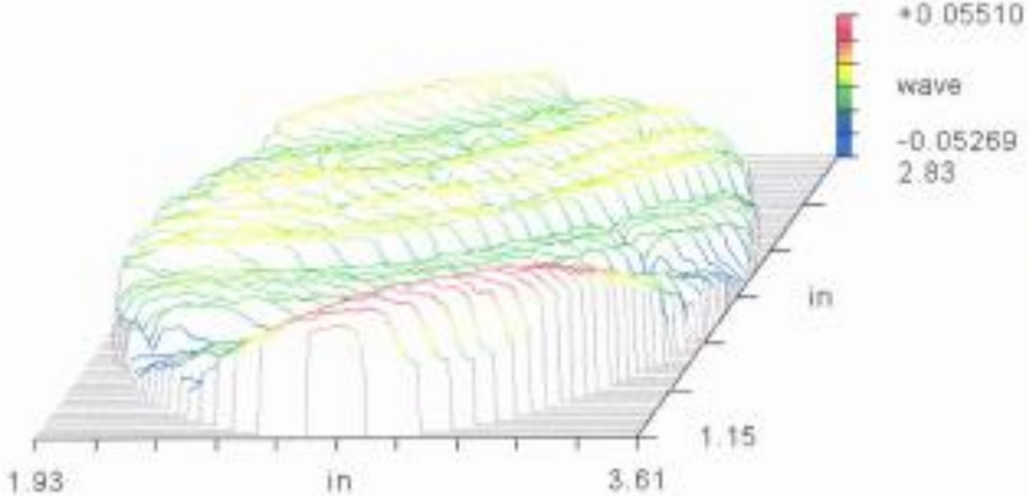

PV	0.1078 wave
rms	0.0160 wave
Power	0.0083 wave
Removed:	PST TLT
Data Points	31177
Rad	-43535.7 m
Auto Aperture:	Off
Aperture OD (%):	90
Trim Filter:	Off
Trim Mode:	Outside
Trim Quantity:	0
Filter:	Off
Filter Window Size:	3
Filter Type:	Average

Desc:	2.0 Si Coated FS Sub
S/N:	FS-03
Inspector:	K. Chavez
Wavelength-In:	632.8 nm
Wavelength-Out:	632.8 nm
Refractive Index of Material:	1.500
AGC:	On
Light Level:	185
AGC Mode:	Normal Reflectivity
Acquisition Mode:	Phase
Phase Resolution:	High
Phase Avg:	4
Intens Avg:	4
Camera Res:	640x480 25 Hz

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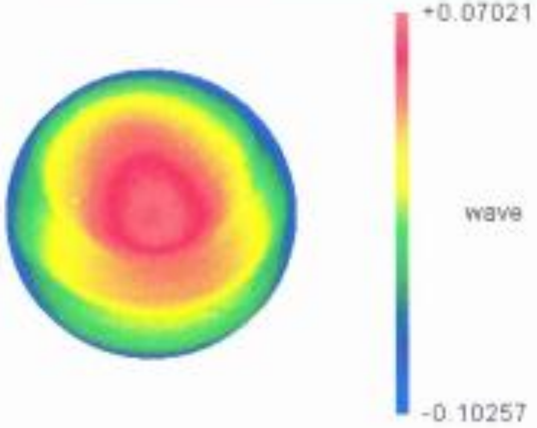
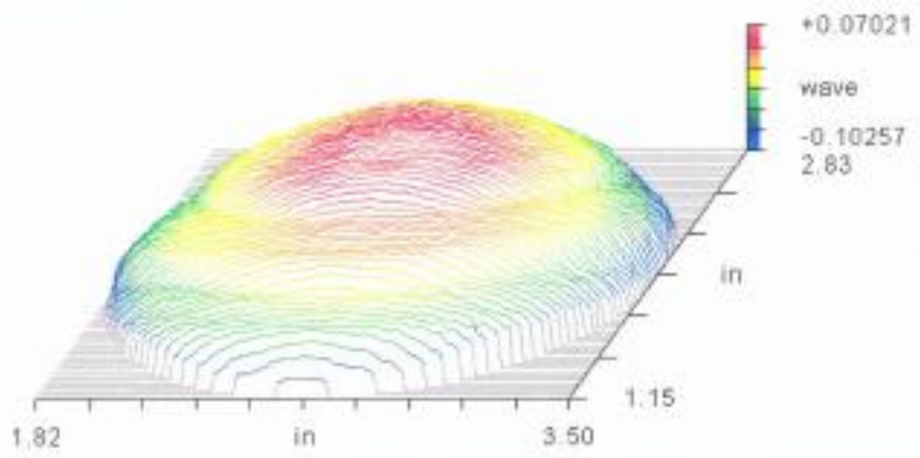
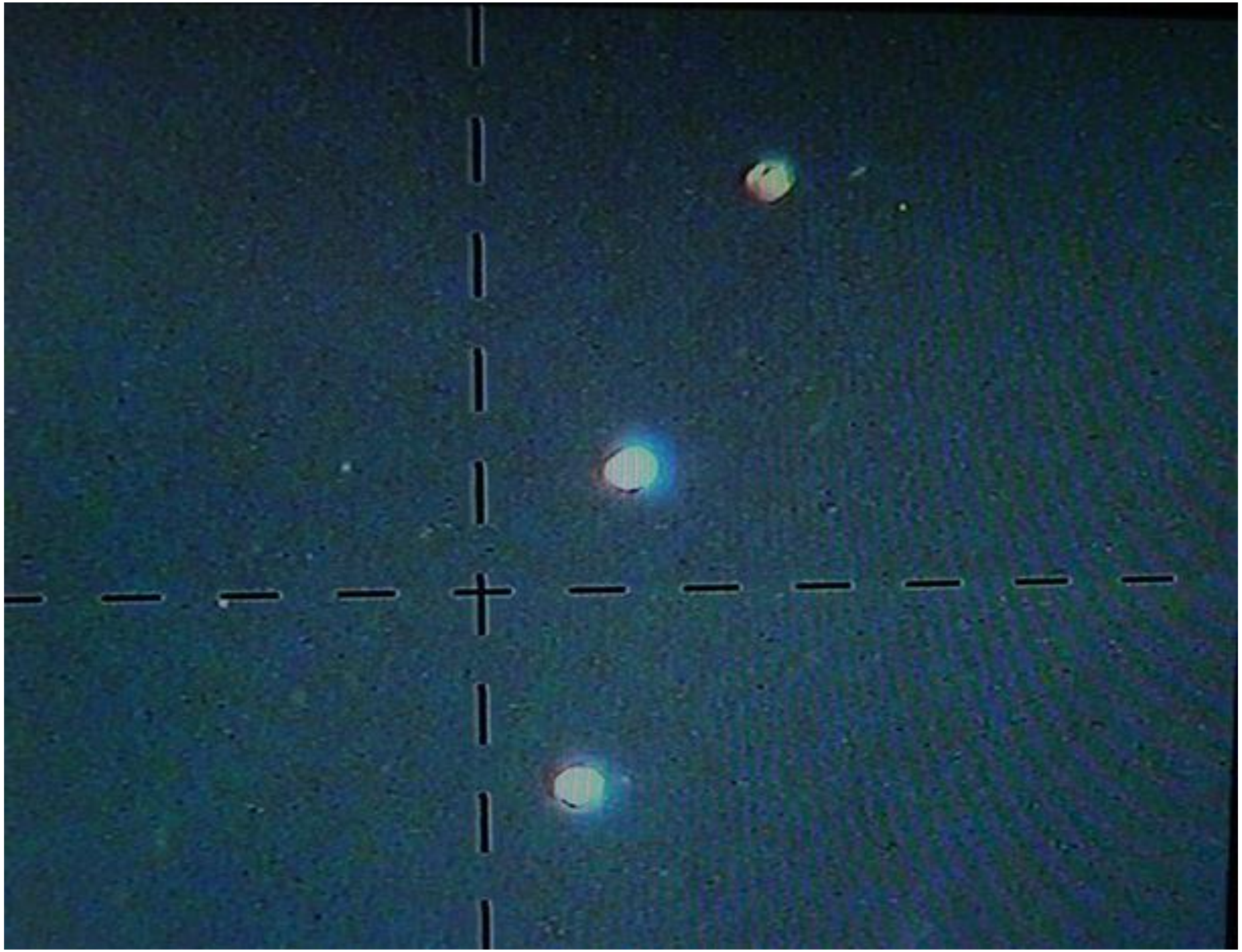
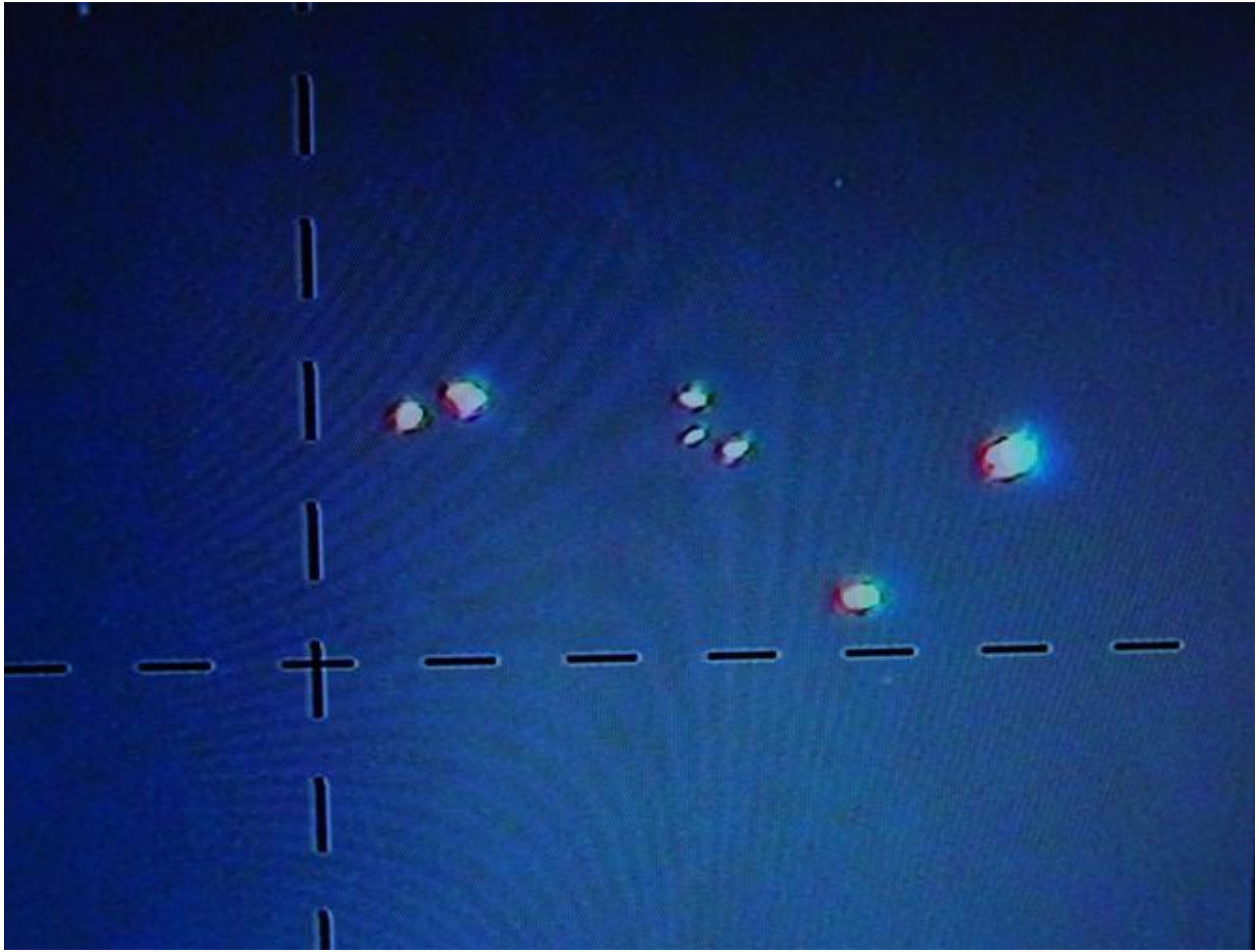




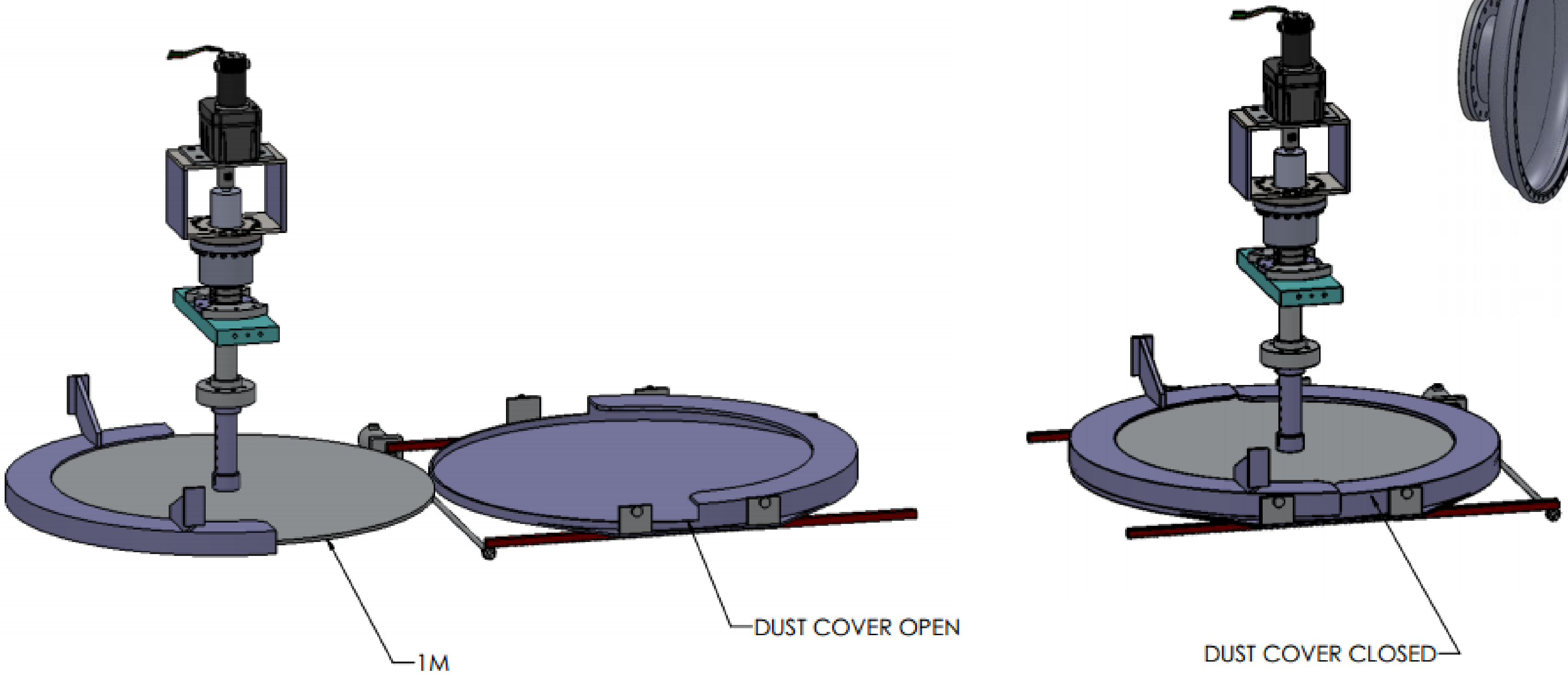
PV 0.1728 wave	Data Points 31177	Auto Aperture: Off	Trim Filter: Off
rms 0.0383 wave	Rad 2807.4 m	Aperture OD (%): 90	Trim Mode: Outside
Power -0.1290 wave			Trim Quantity: 0
Removed: PST TLT	Filter: Off	Filter Window Size: 3	
	Filter Type: Average		

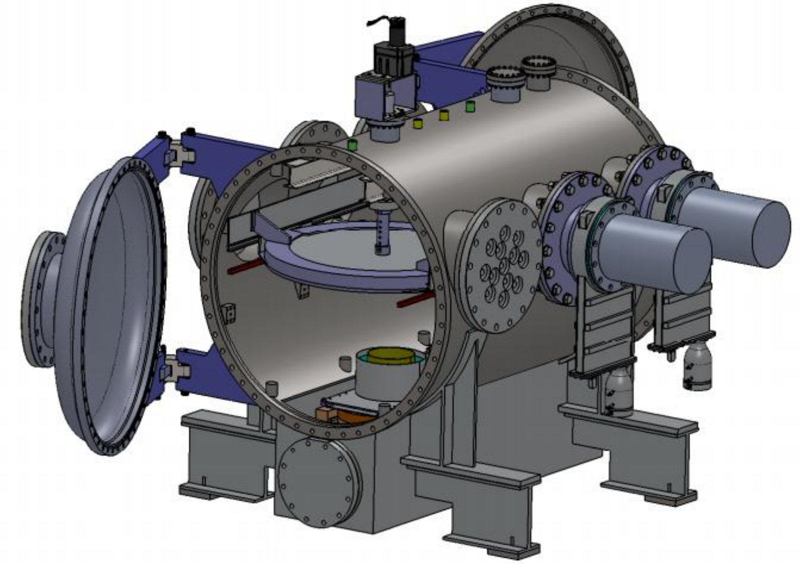
Desc: 2.0 Si Coated FS Sub	AGC: On	Light Level: 185
S/N: FS-01	AGC Mode: Normal Reflectivity	
Inspector: K. Chavez	Acquisition Mode: Phase	
Wavelength-In: 632.8 nm	Phase Resolution: High	
Wavelength-Out: 632.8 nm	Phase Avg: 4	Intens Avg: 4
Refractive Index of Material: 1.500	Camera Res: 640x480 25 Hz	
Substrate System Error: Off	Discon Action: Filter	
System Error File: 12InTFlat.dat	Discon Filter: 0	
	Interferometer Scale Factor: 0.500	
Inst: Mark GPI Id 0 SN 004157	Date: Tue Nov 11 14:38:44 2014	





Motorized Dust Cover Inside Vacuum Chamber





Alternatives to heating with an electron beam? Possible advantages (higher rates?, reduced surface defects?)

Thermal resistive Ta source (1800 C)

Inductive heating

Resistive graphite heating (3000 C)

Other things to investigate?

- Cold-cathode neutralization of the ion gun?
  - Process duration is currently limited because of required ion gun maintenance (neutralization filament replacement)
- More automation
  - Rate control
  - Automate ion gun turning on off
  - Crucible changes (heat up and cool down)
- How to remove the silicon for re-work?
  - Chemical removal
  - Micro-gritblasting

Questions?