ARIEL: SCIENCE, MISSION & COMMUNITY 2020 CONFERENCE

ARIEL Telescope Assembly Design Overview

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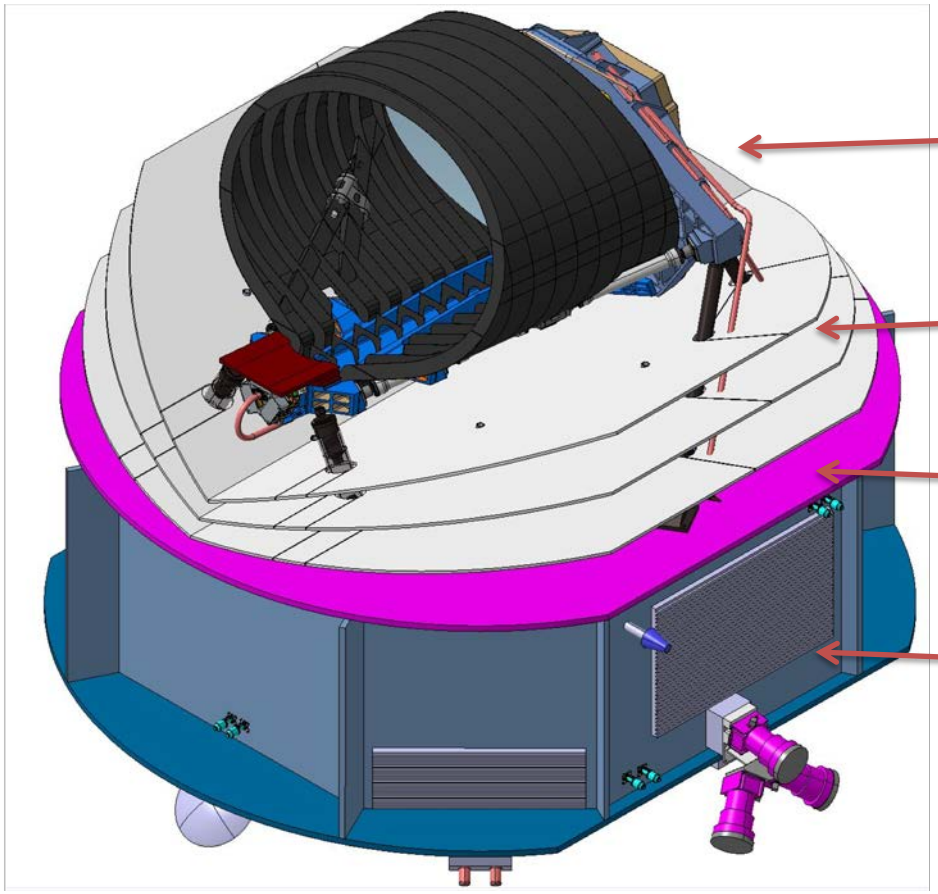
On the behalf of the ARIEL Team

ARIEL Architecture



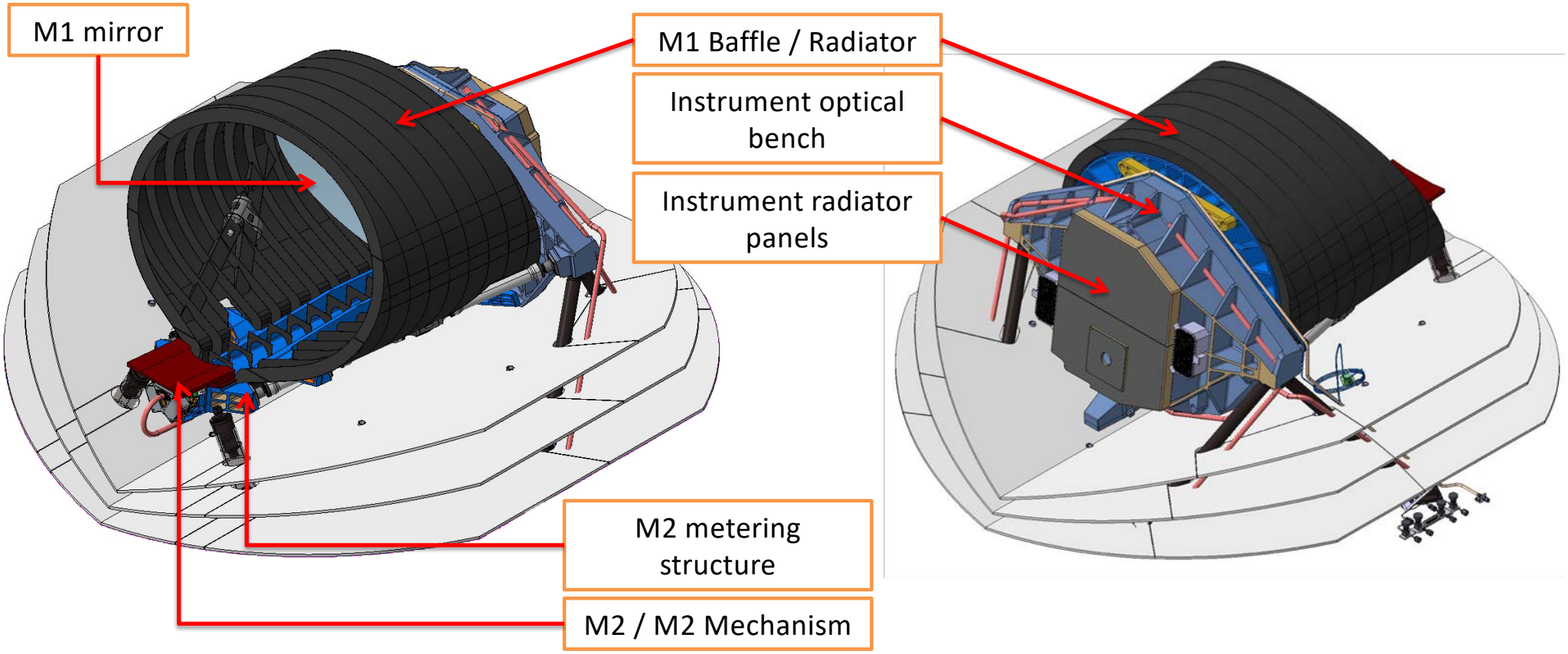
Telescope Assembly

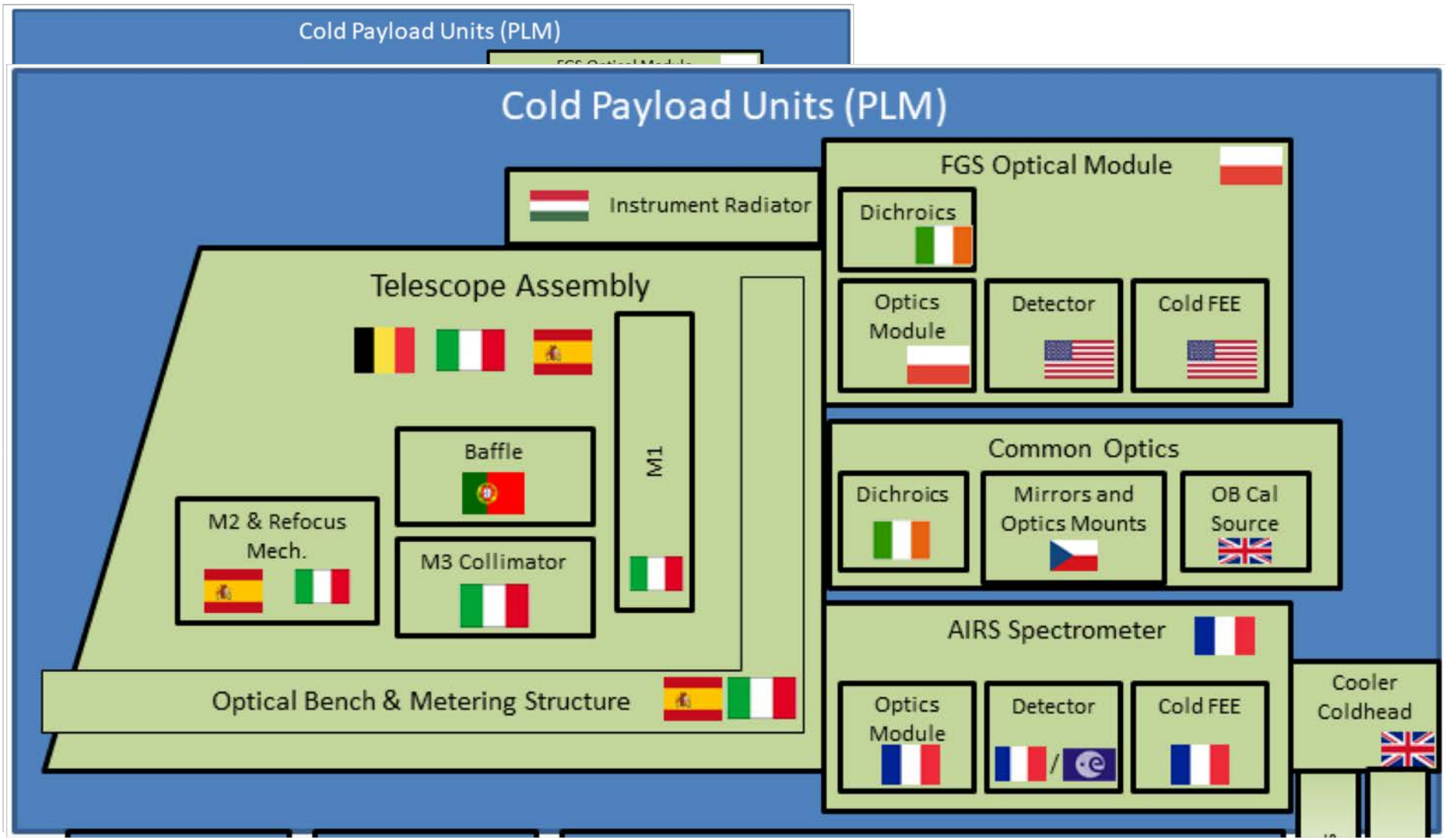
V-grooves thermal radiators

Platform

Service Vehicle Module

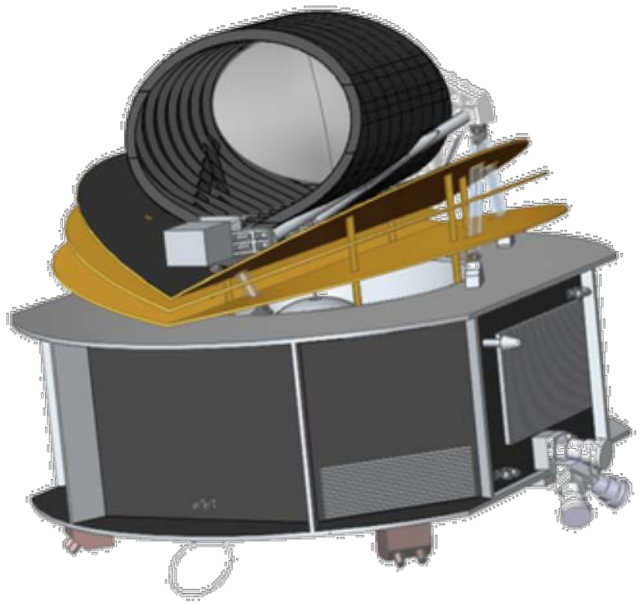
The Telescope Assembly



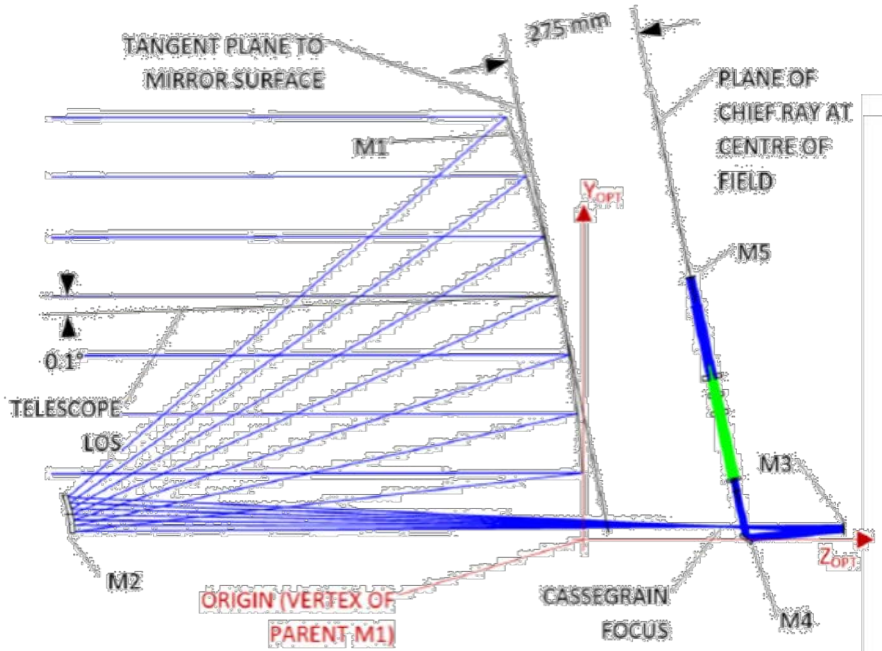

Cold Payload Units (PLM)
Cold Payload Units (PLM)
Instrument Radiator
Telescope Assembly
Baffle
M1
M2 & Refocus Mech.
M3 Collimator
Optical Bench & Metering Structure
FGS Optical Module
Dichroics
Optics Module
Detector
Cold FEE
Common Optics
Dichroics
Mirrors and Optics Mounts
OB Cal Source
AIRS Spectrometer
Optics Module
Detector
Cold FEE
Cooler Coldhead

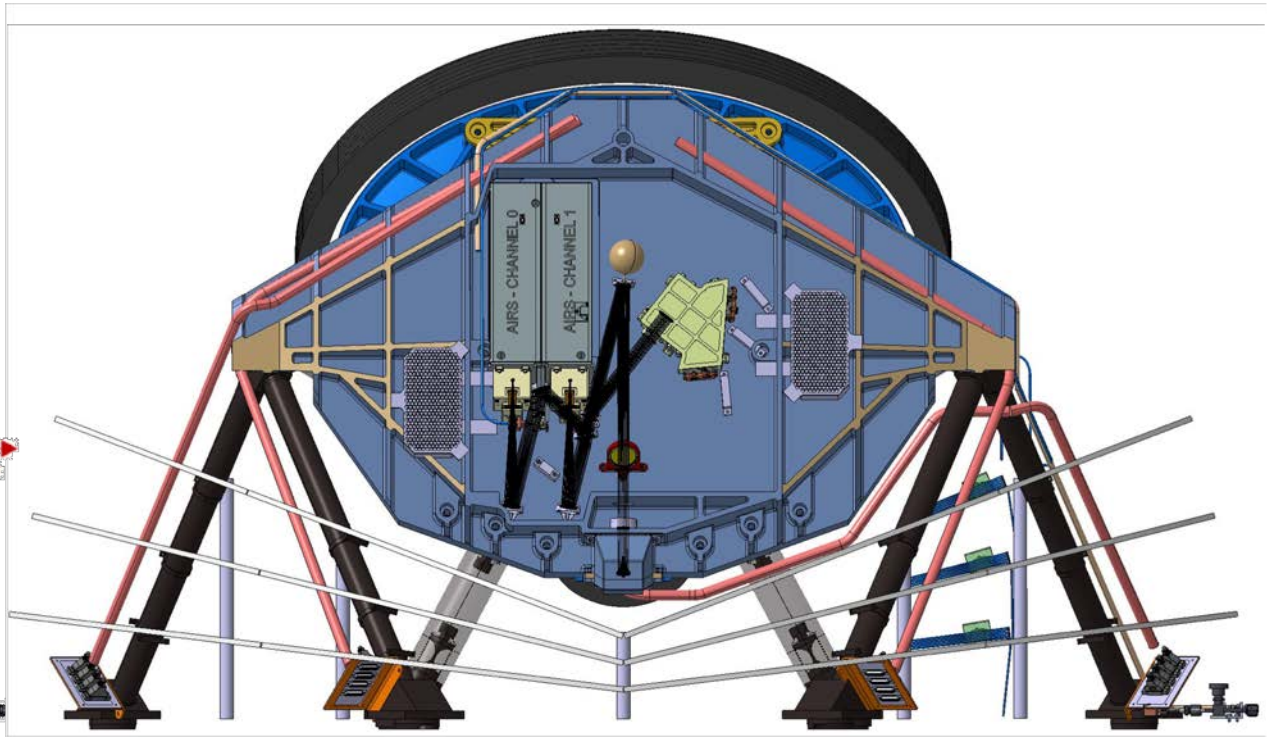
Telescope main parameters

Parameter	Value
Size	1110 x 730 mm
Collecting area	> 0.6 m^2
FoV	30" with diffraction limited performance 41" with optical quality TBD allowing FGS centroiding 50" unvignetted
Wavelength range	0.5 – 8 micron
Throughput	Minimum > 0.78 Average > 0.82
WFE	Diffraction limited ≤ 3 μm (220 nm RMS)
M1 WFE	< 200 nm RMS
M1 Roughness	< 10 nm RMS
Exit pupil (beam size)	20.0 x 13.3 mm

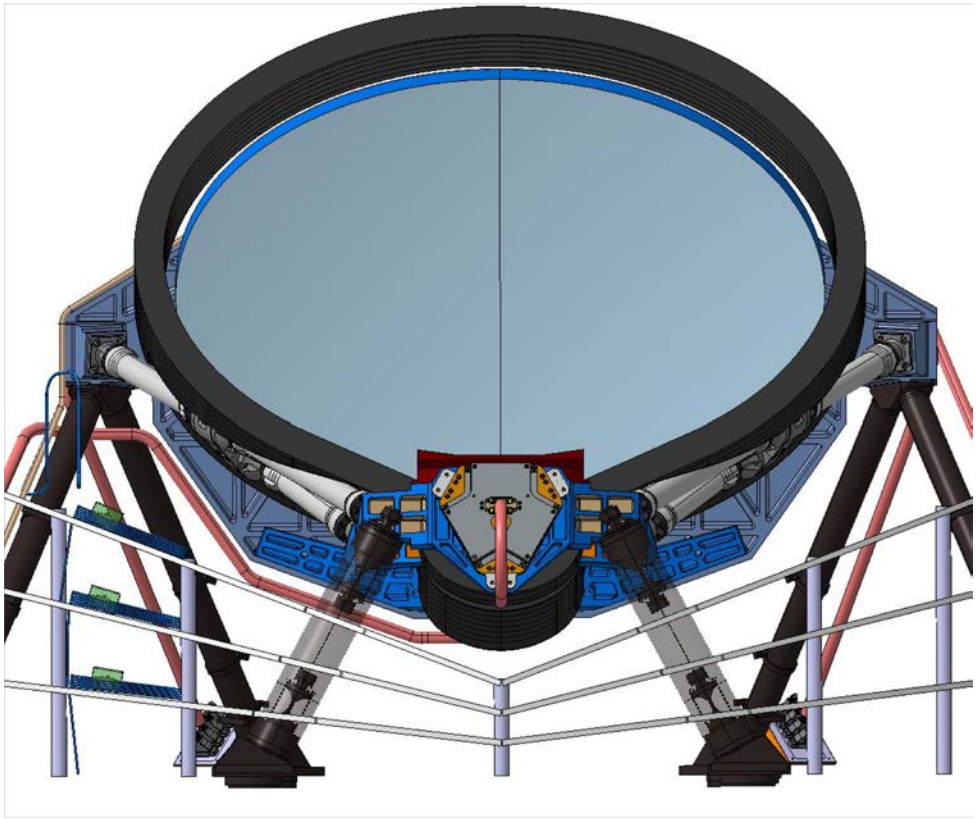


Afocal telescope: optical design





Large area aluminum mirror



- Cryogenic operating temperature @ 55 K
- Fully aluminum structure
- M1. M2, M3, M4 are silver-coated aluminum mirrors
- Large area aluminum mirror is proposed for the first time, i.e. technological innovation

Pathfinder Telescope Mirror program

"Cryotesting of ARIEL M1 mirror and coating process qualification for de-risking ARIEL schedule".

This activity shall verify the opto-mechanical stability and optical quality of the ARIEL pathfinder M1 mirror (full scale pathfinder 1.1 x 0.7m elliptical mirror) (referred to as PTM M1 mirror) at cryogenic temperature and qualify the baselined mirror coating process.

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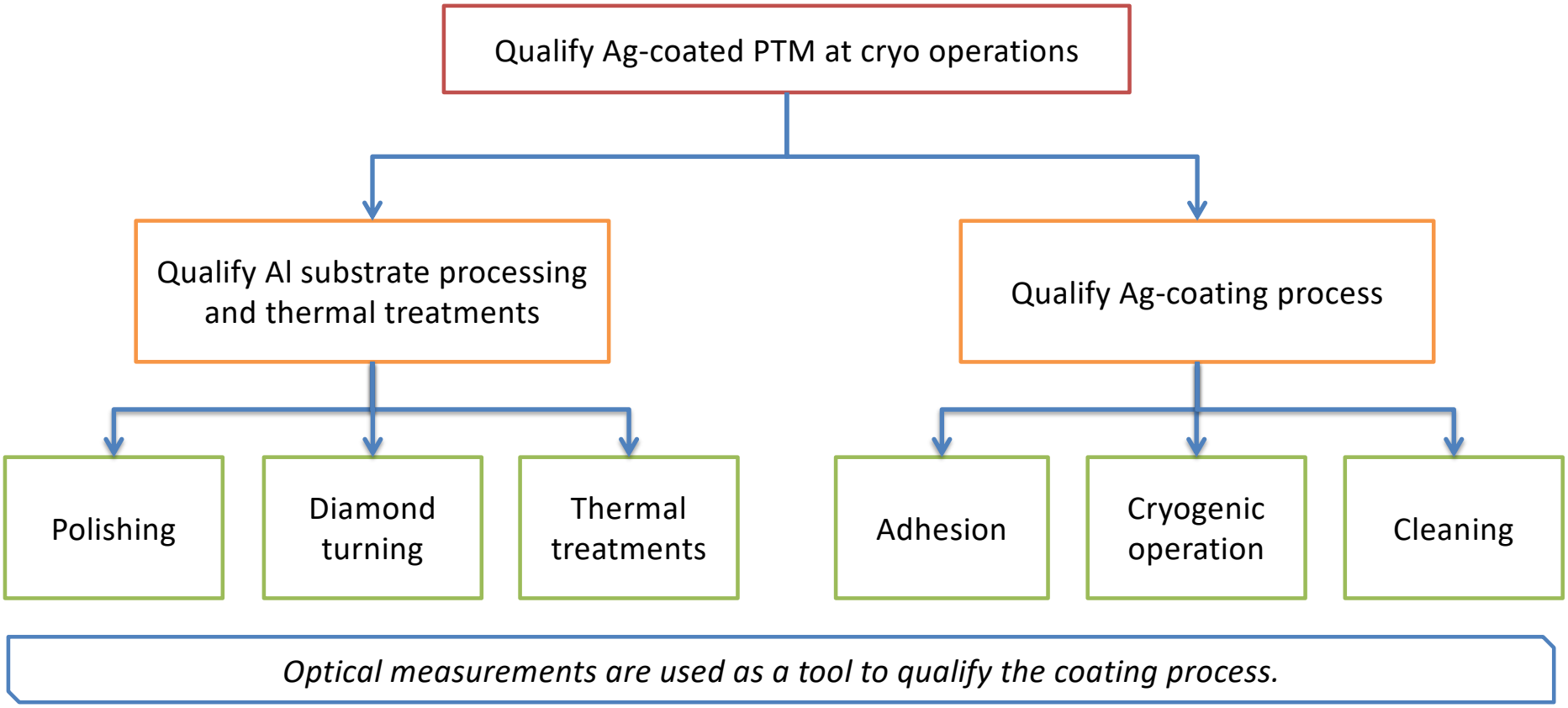
ESA-ARIEL-EST-PL-SOW-003
Cryotesting of ARIEL M1 mirror and coating process qualification for de-risking ARIEL schedule
Date 03/07/2018 Issue 1 Rev 0

Target



Optical measurements are used as a tool to qualify the coating process.

Substrates: Samples

Coated 2.5 cm flat mirror.

Material: Al 6061-T651 laminated

Al 6061-T651 extruded

RSA 6061-T651

Available for coating qualification.

Requirements as per PTM.

Produced by Media Lario, Italy

Substrates: Models

Uncoated 15 cm flat mirror.

Material: Al 6061-T651

4 models available:

LTU1 has been used to optimize the optical surface polishing process.

Requirements as per PTM.

2614-011-01/02/03 has been used to optimize the substrate stabilization by thermal treatments.

Requirement: surface quality useful just for metrology.

Produced by Media Lario, Italy

Substrates: PTM

Lightweighted PTM produced at the end of the ARIEL phase A.

The PTM mirror is a full-scale pathfinder mirror (1.1 x 0.7m elliptical mirror).

Material: Al 6061-T651

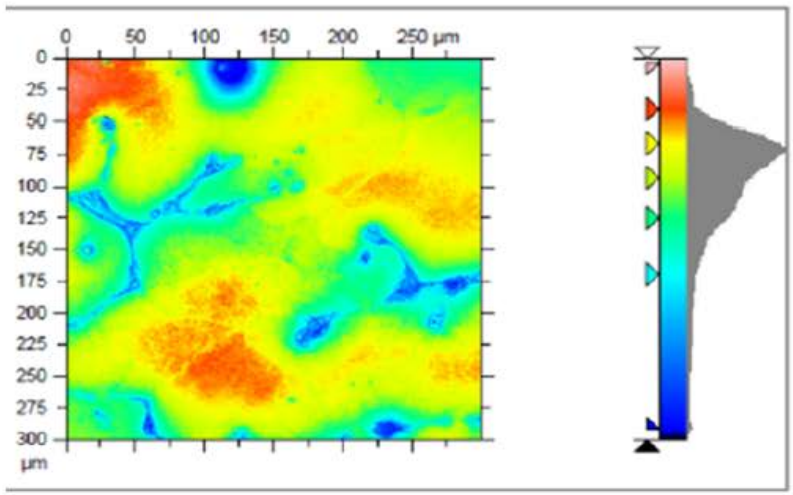
Requirements:

- Spherical
- Surface Error RMS ≤ 100 nm
- Roughness RMS ≤ 10 nm

Produced by Media Lario, Italy

Al 6061 T651 : surface roughness

Laminated



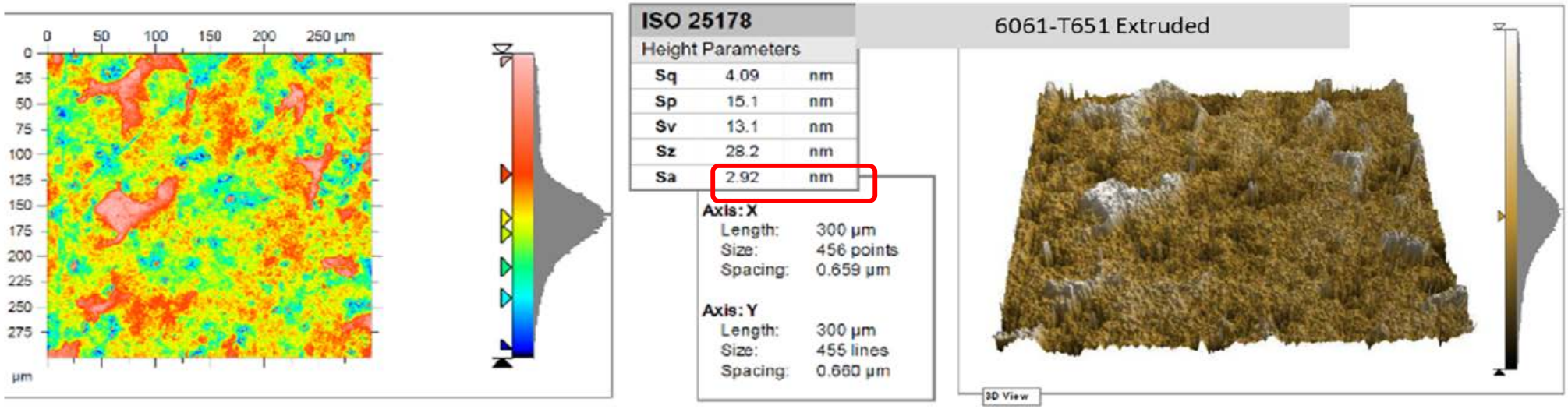
ISO 25178		
Height Parameters		
Sq	21.0	nm
Sp	48.2	nm
Sv	99.3	nm
Sz	148	nm
Sa	[illegible]	nm

Axis: X
Length: 300 µm
Size: 911 points
Spacing: 0.330 µm

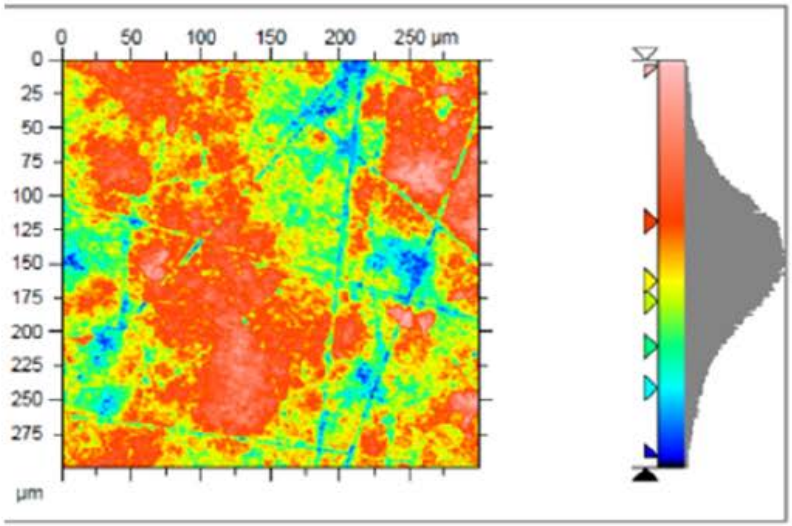
Axis: Y
Length: 300 µm
Size: 910 lines
Spacing: 0.330 µm

Al 6061 T651 : surface roughness

Extruded



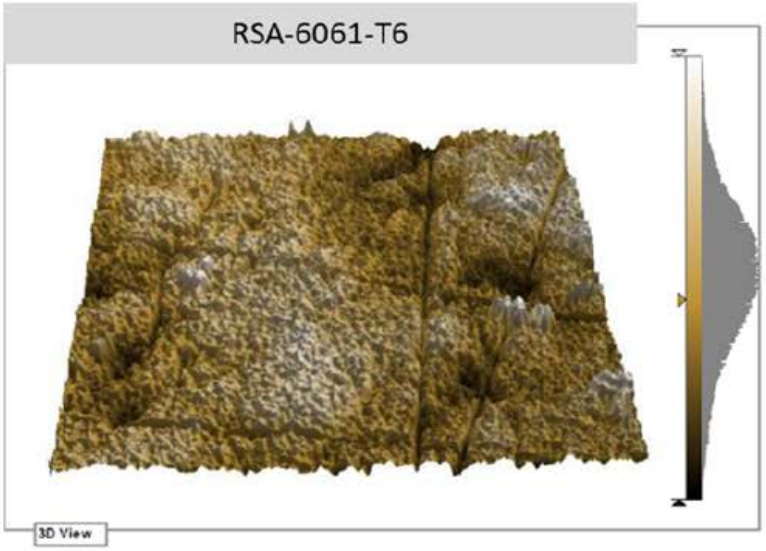
Al RSA-6061 T6: surface roughness



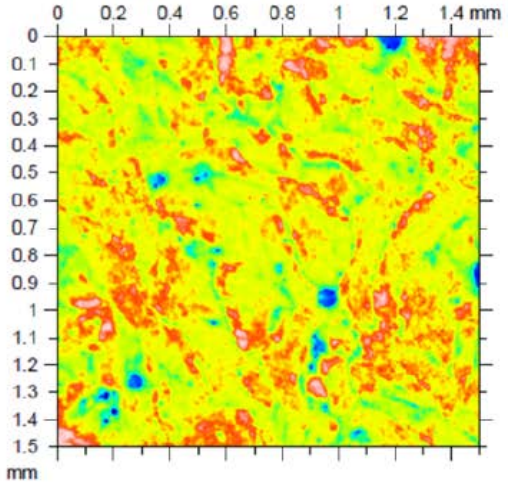
ISO 25178		
Height Parameters		
Sq	2.81	nm
Sp	8.85	nm
Sv	9.04	nm
Sz	17.9	nm
Sa	2.23	nm

Axis: X
Length: 300 µm
Size: 456 points
Spacing: 0.659 µm

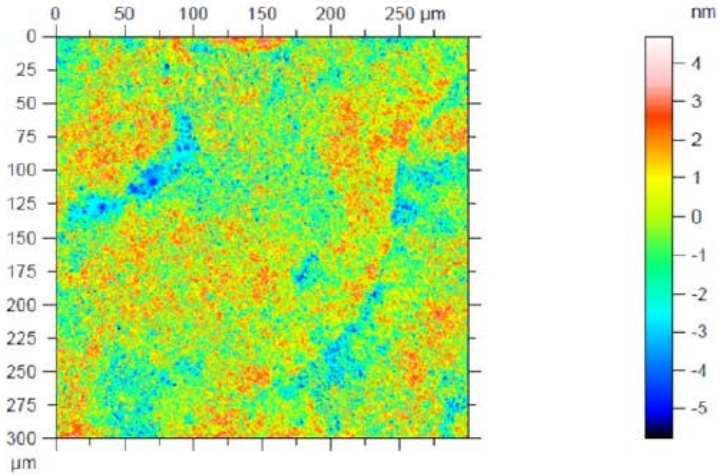
Axis: Y
Length: 300 µm
Size: 455 lines
Spacing: 0.660 µm



Al RSA905: surface roughness



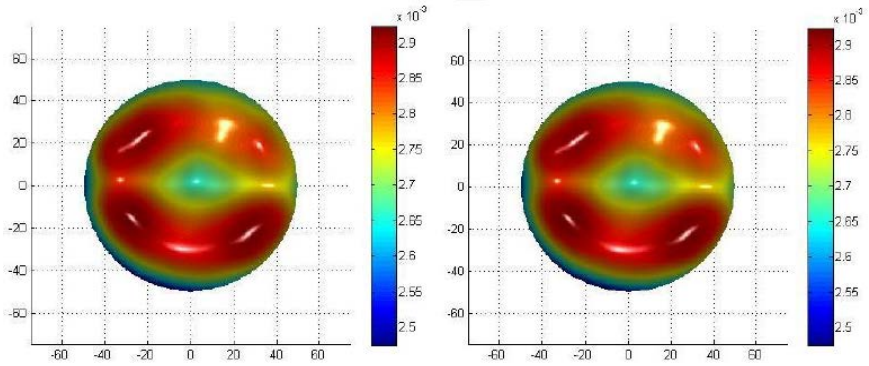
CCI 10x: 2.1 nm RMS



CCI 50x: 1.7 nm RMS

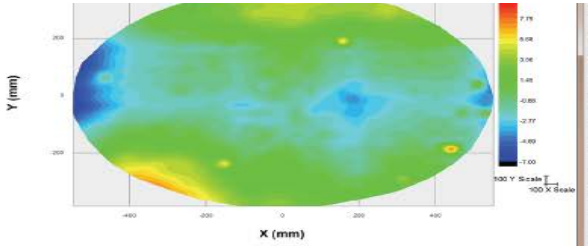
Thermal treatments results

Thermal treatments results

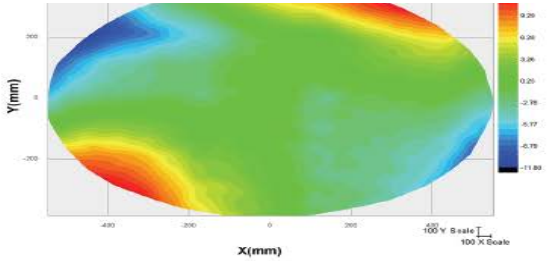


	Pre HT5 RMS	Post HT5 RMS
S/No2	nm 77	nm 76

Thermal treatments of the PTM

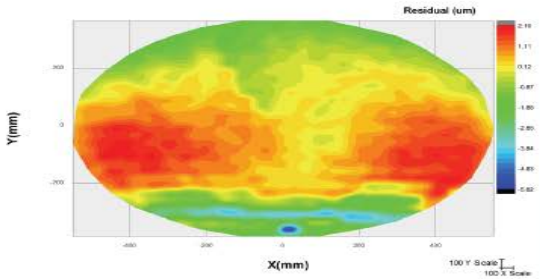


Best fit radius	2402.9334
shift x (mm)	0.0199849
shift y (mm)	-0.0481417
shift z (mm)	-2456.3974
Figure error	
rms full surface(um)	2.4087492
PTV full surface(um)	16.442893
rms opt. surface(um)	2.4087492
PTV opt. surface(um)	16.442893
min value (um)	-6.5434656
max value(um)	9.8994278
Slope error	
Mean S.E.(mrad)	0.0000002
RMS S.E.(mrad)	0.0387089
Max Abs S.E.(mrad)	0.4177892
OK	



Best fit radius	2402.815
shift x (mm)	-0.0687077
shift y (mm)	-0.0042375
shift z (mm)	-2456.2807
Figure error	
rms full surface(um)	4.3859055
PTV full surface(um)	24.062994
rms opt. surface(um)	4.3859055
PTV opt. surface(um)	24.062994
min value (um)	-11.787854
max value(um)	12.27514
Slope error	
Mean S.E.(mrad)	0.0003252
RMS S.E.(mrad)	0.0323549
Max Abs S.E.(mrad)	0.0922140
OK	

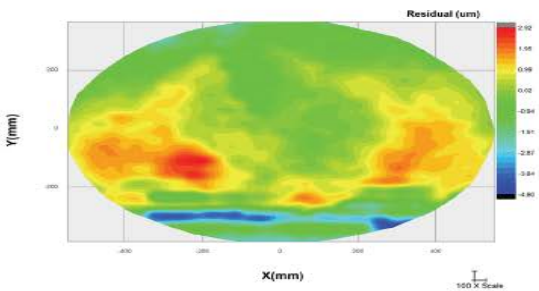
20190926_Residuals Ariel post DT mis 01



Pre-Analysis options

Optimization parameters	
Best fit radius	2402.922
shift x (mm)	-0.0282029
shift y (mm)	-0.0734976
shift z (mm)	-2456.3473
Figure error	
rms full surface(um)	1.2307996
PTV full surface(um)	7.9028237
rms opt. surface(um)	1.2307996
PTV opt. surface(um)	7.9028237
min value (um)	-5.8171047
max value(um)	2.085719
Slope error	
Mean S.E.(mrad)	-0.0000810
RMS S.E.(mrad)	0.0230664

20191022 ResidualsAriel post HT_mis01



Pre-Analysis options

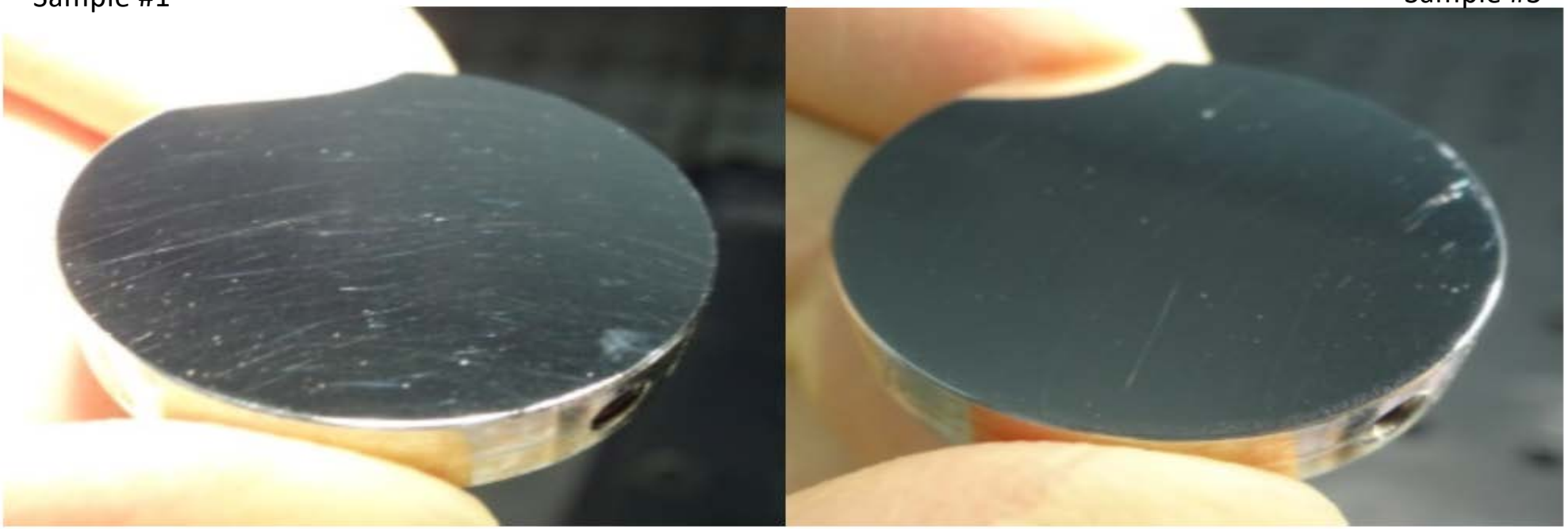
Optimization parameters	
Best fit radius	2402.8751
shift x (mm)	-0.0084127
shift y (mm)	-0.0678848
shift z (mm)	-2456.3031
Figure error	
rms full surface(um)	1.1988508
PTV full surface(um)	7.6882735
rms opt. surface(um)	1.1988508
PTV opt. surface(um)	7.6882735
min value (um)	-4.7841834
max value(um)	2.9040901
Slope error	

Cryotests on coated samples

Before cryo-cycles

Sample #1

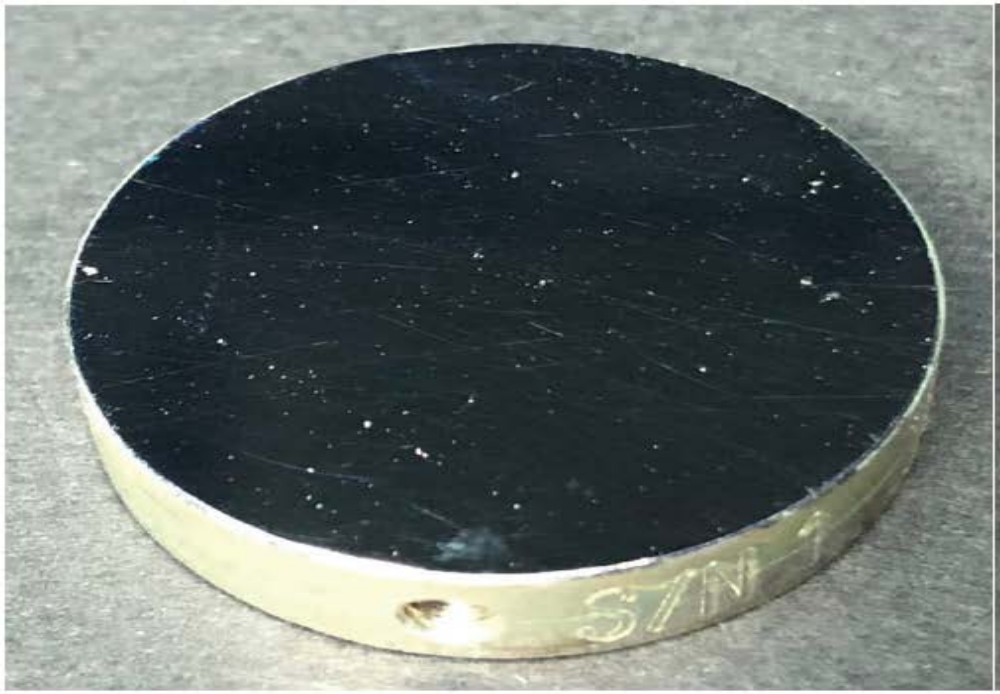
Sample #3



Cryotests on coated samples

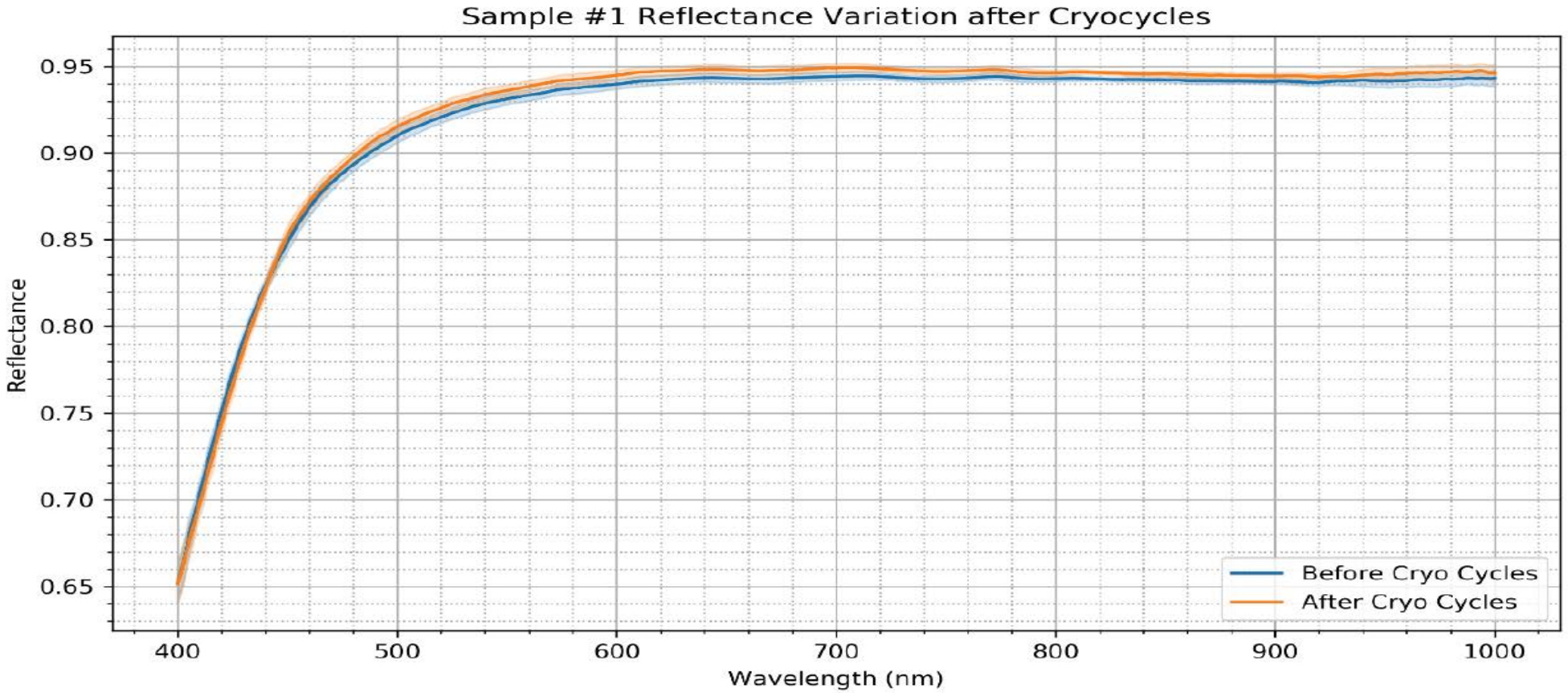
After cryo-cycles

Sample #1

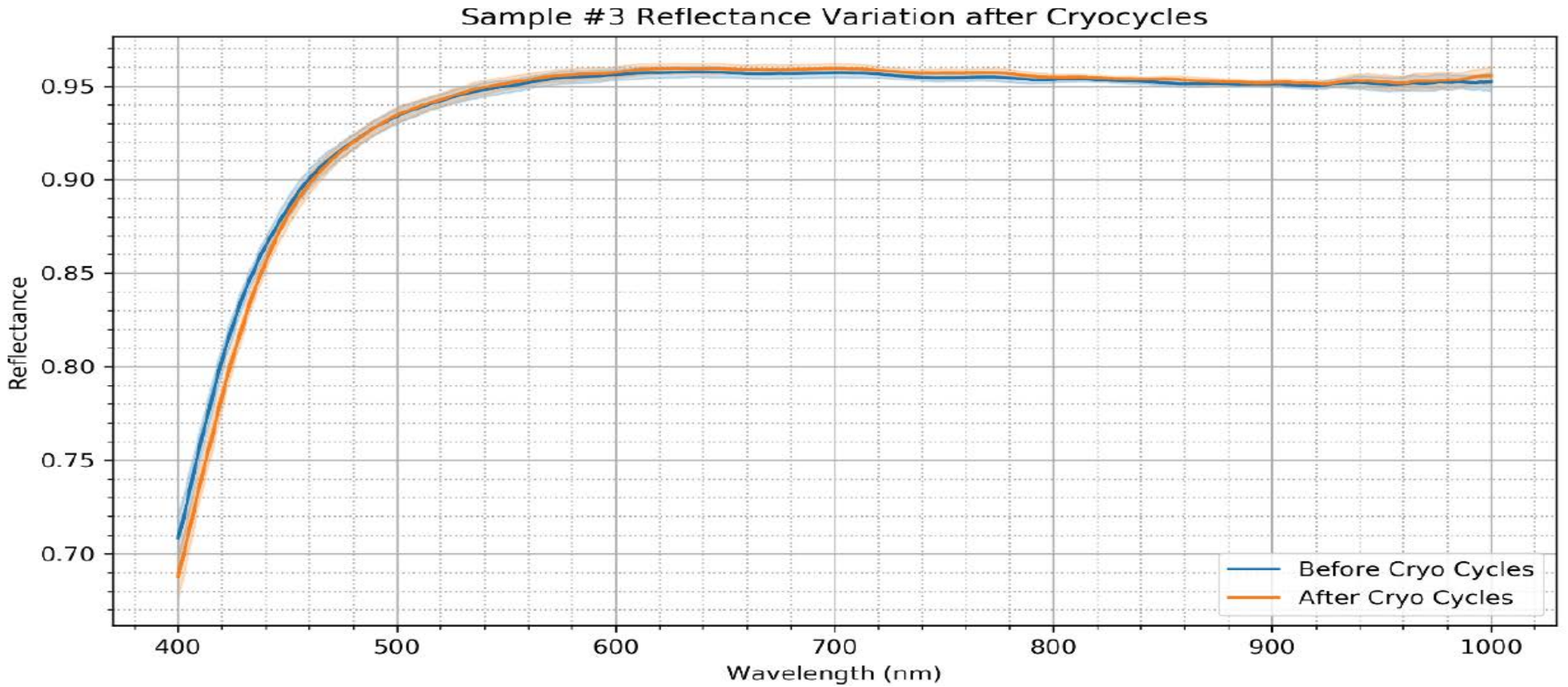


Sample #3

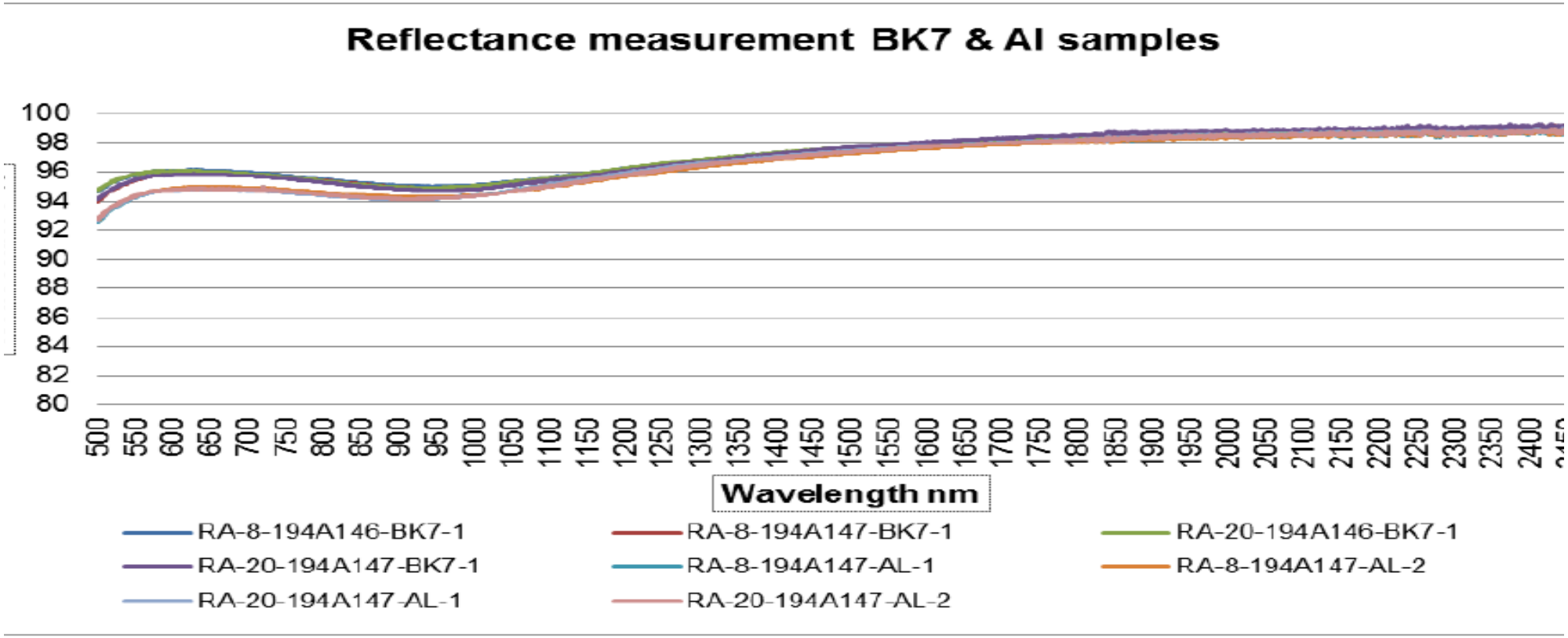
Performance



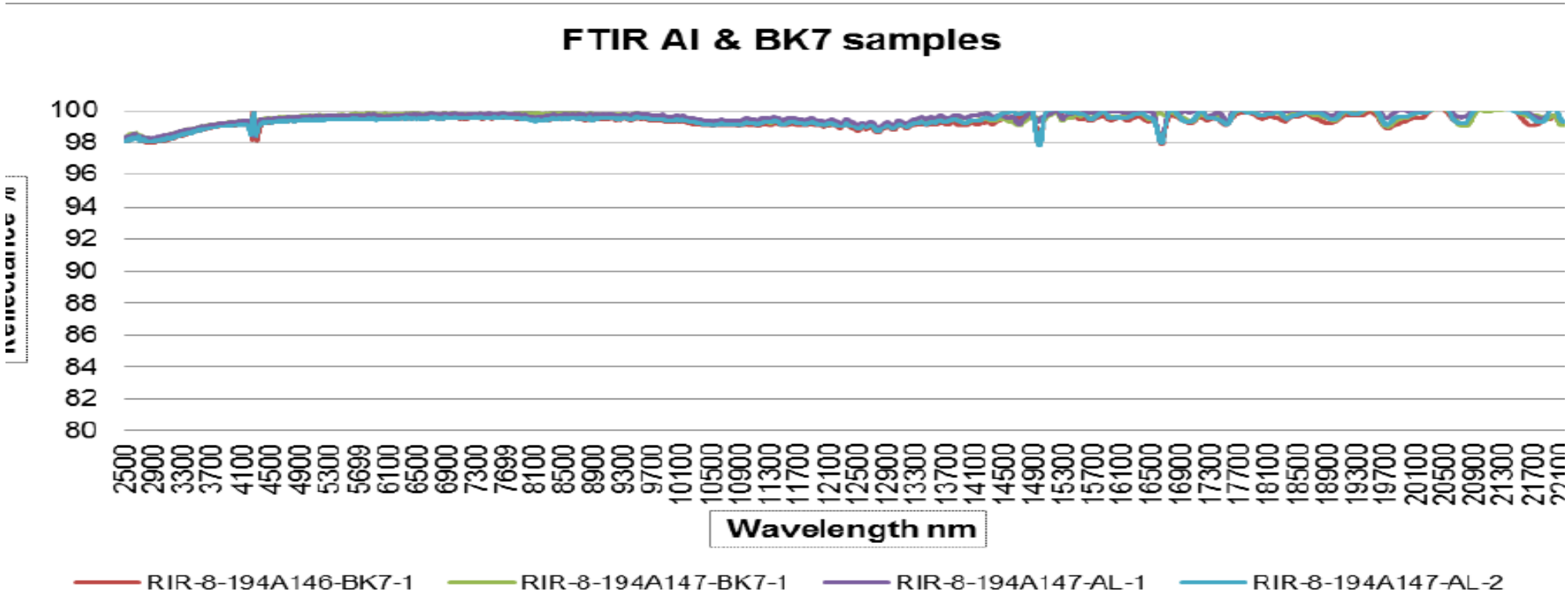
Performance



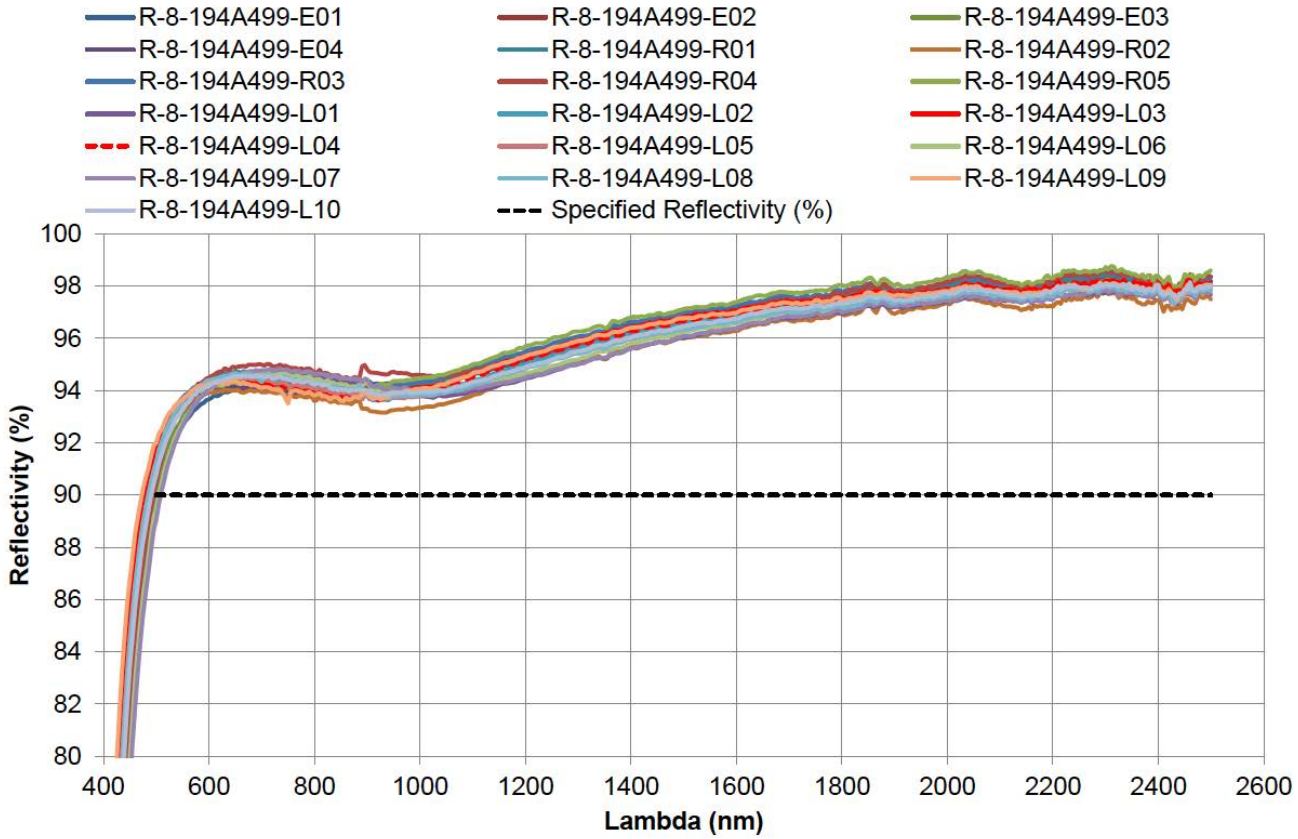
Absolute reflectance



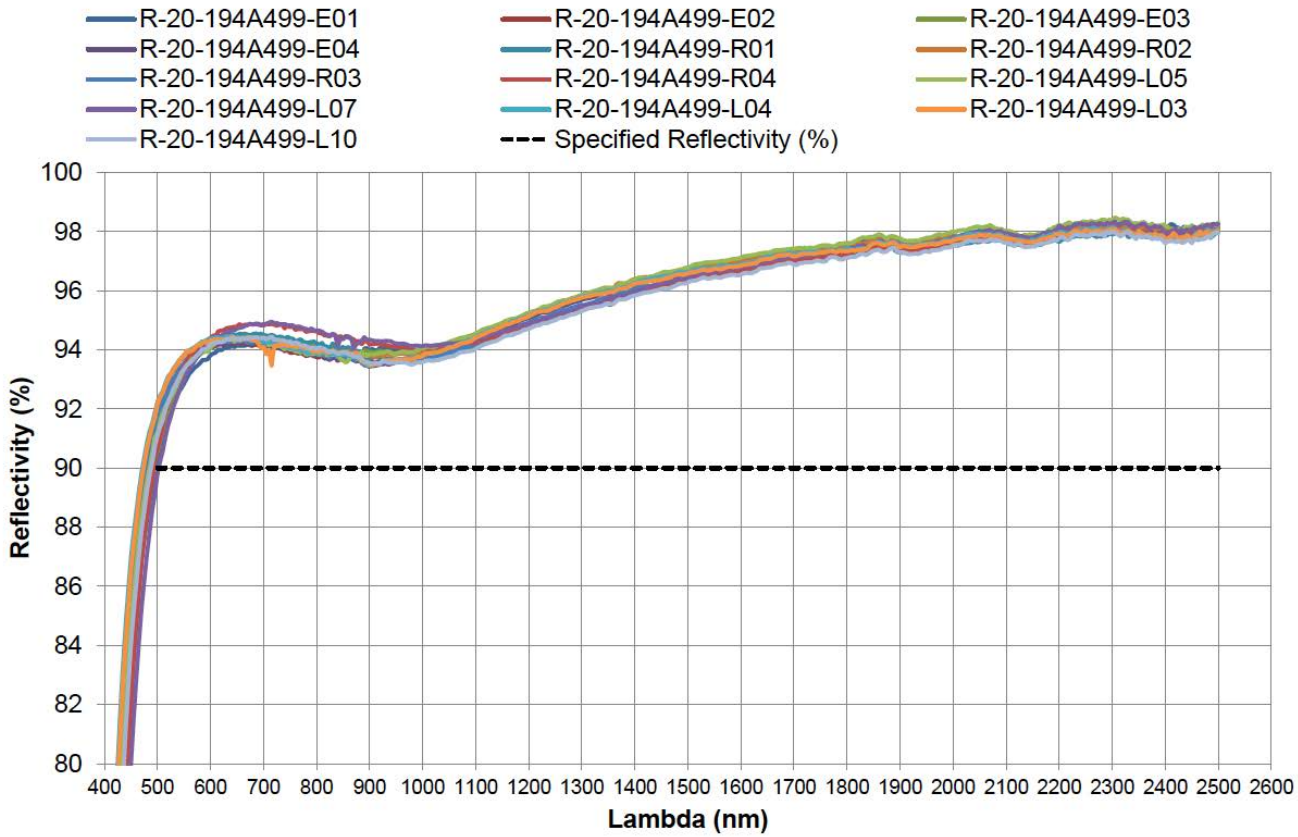
Absolute reflectance



Reflectivity @ 8° AOI

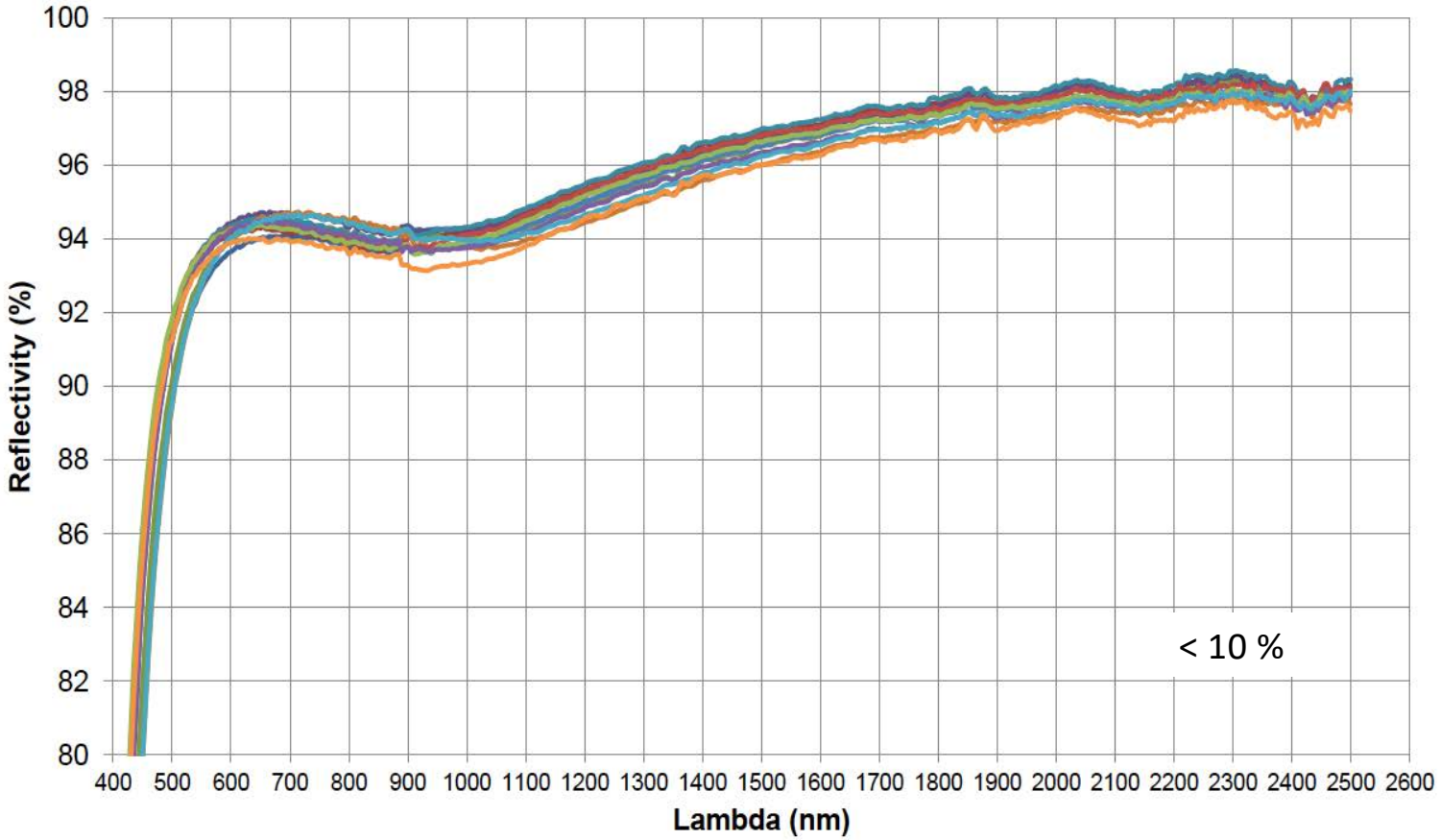


Reflectivity @ 20° AOI

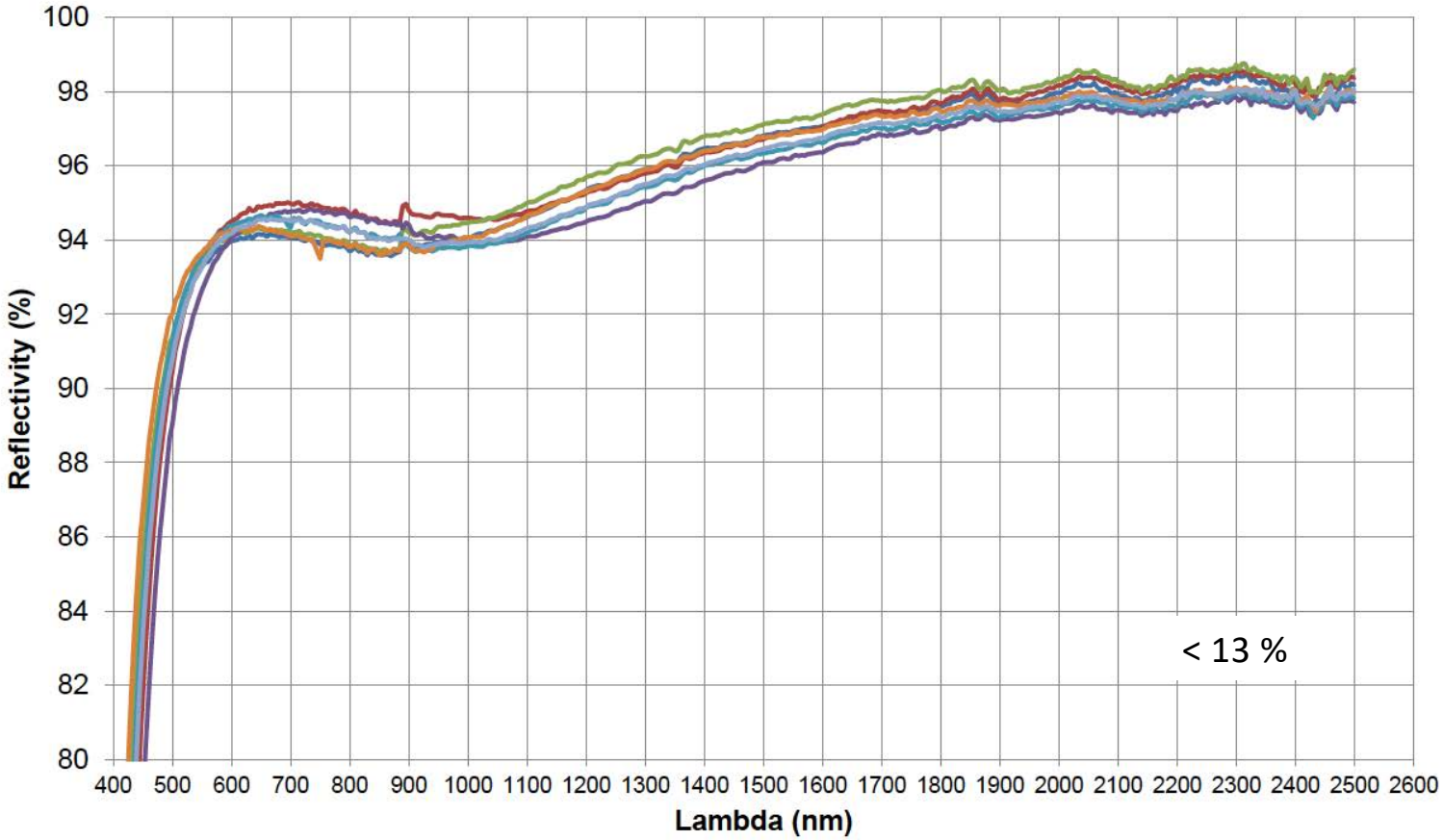


GSE: specimen holder

Uniformity (x axis)



Uniformity (y axis)



PTM ready for coating

- WFE 230 nm
- Roughness 19 nm rms

- Coating process @ CILAS on Jan 28th, 2020

- Cryotest qualification @ CSL in Febrary 2020

Conclusions

- ARIEL Telescope Assembly has a standard afocal off-axis configuration for IR telescopes
- Fully aluminum structure and optical elements have been selected (Al6061 T651)
- The large area aluminum M1 introduces an innovation. The PTM program has been supported by ESA as derisking activity in order to achieve TRL = 6.
- The program is not completed yet. The end is scheduled March 2020.
- Some important results have been achieved:
  - Substrates processing and polishing of M1 is feasible at the ARIEL requirements level
  - The recipe optimized for thermal stabilization of aluminum substrates works on large size aluminum mirrors
  - Protected Silver coating of smaller aluminum mirrors is not damaged by cryo-cycling
  - Reflectivity is compliant with the ARIEL requirements