आर्यभट्ट प्रेक्षण विज्ञान शोध संस्थान
ARYABHATTA RESEARCH INSTITUTE OF OBSERVATIONAL SCIENCES
(AN AUTONOMOUS INSTITUTE UNDER DST, GOVT. OF INDIA)

Aluminizing the Primary Mirrors of Telescopes in ARIES

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Outline

➢Introduction to facilities

- Major telescopes
- Coating plants

➢Aluminization of Primary mirrors

- 3.6m Devasthal Optical Telescope (DOT) Primary mirror
- 1.04m Sampurnanad Telescope (ST)Primary mirror

➢In-situ cleaning

- 1.3m Devasthal Fast Optical Telescope (DFOT) Primary mirror
- 3.6m DOT Primary mirror

➢Degradation in Reflectivity of Primary mirrors over the time

Introduction to facilities-Telescopes

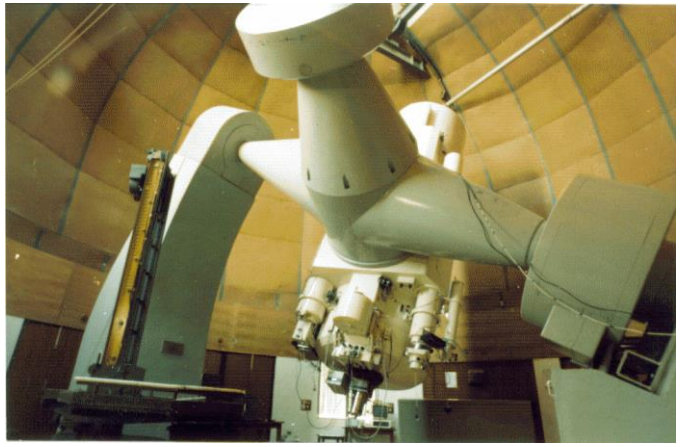
(A). **3.6m DOT**

The 3.6m Devasthal Optical Telescope is a custom-built instrument of great complexity installed at Devasthal in the district of Nainital, India. It was commissioned in the year 2016.
Primary Mechanical Diameter: 3700mm
Clear aperture:3600mm
F/#:9
FOV: 10', 30' with corrector
Pointing accuracy: 2"RMS
Tracking accuracy: 0.1" RMS for 1minute in open loop

(B). **1.3m DFOT**

A modern Ritchey-Chretien Cassegrain 1.3-m diameter Devasthal Fast Optical Telescope (DFOT) has been installed at Devasthal, Nainital by the DFM Engineering Inc. USA in 2010.

The focal length to diameter ratio (focal-ratio) of the overall telescope optics is F/#4 making it a very fast system with a total field view of the sky up to 66 arcmin in diameter. The telescope can be pointed to a celestial object with an accuracy of 10 arcsec rms. The mechanical system provides a tracking accuracy at nearly 0.5 arcsec rms over 10-min without any external guider.



(C). **1.04 ST**

The 1.04 m Sampurnanand Telescope, located at ARIES, Manora Peak, Nainital, is one of the the main observing facility in optical domain. It was installed in 1972 by Carl Zeiss, Germany. The telescope is an RC reflector with a Cassegrain focus and mounted on equatorial 2-pier english mount. The 104-cm, f/13 telescope produce a field of around 45 arcmin with corrector at the cassegrain end. The tracking accuracy is around 7 arcsec/hr (0.1 arcsec/min) without guider and is around 0.7 arcsec/hr with guider.

Introduction to facilities-Coating Plants

• 1.04m Coating Plant

- Aluminium coating unit for the coating of 40 inch mirror was installed in early 1980s at ARIES, Manora peak, Nainital. The chamber was fabricated by Triveni Structurals Limited (TSL), Allahabad in around 1978) is made of mild steel of grade equivalent to IS 2064.
- Principle: Thermal Evaporation
- It uses one Rotary Pump and two diffusion pumps. 40 inch telescope primary mirror is being coated once in two years since early 1990s.

• 3.6m Coating plant

- Aluminium coating unit for the coating of 3.6m mirror was installed in 2014 at Devasthal, ARIES Supplied and installed by Hind high vacuum pvt ltd, Bengaluru.
- Principle: Magnetron Sputtering
- It uses one Rotary Pump, one roots pump and two cryo pumps with two backing pump
- A washing unit was installed near the pant for cleaning the mirror

Aluminization of Primary mirrors-3.6m DOT Primary-M1 Disintegration

We have coated the 3.6m DOT primary for FOUR times since its installation from 2015. 2015,2017,2018,2022

Primary mirror and M1 cell is integrated with:

It is 30 days activity

Pre-preperation: Rehearsal with dummy mirror, M1 pads protection, Readiness of items like distilled water, chemicals, tissues, gloves etc

It includes the following activities.

(A)Disintegration of M1 from the telescope and from its cell after unmounting the radial, axial definers, lateral definer needles, restrainers, aperture stops.

(B)Transportation for M1 from the cell to washing unit.

(C) Removal of old aluminum coating and washing with proper procedure.

(D)Transportation of M1 from the washing unit to coating chamber.

(E)Fresh aluminum coating and reflectivity measurement.

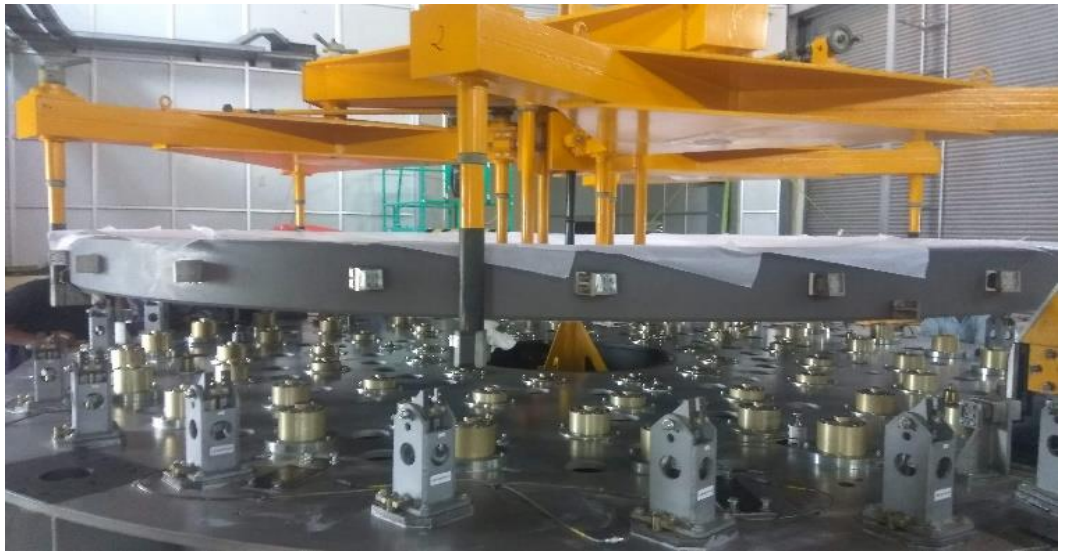
(F)Transportation of M1 from coating chamber to M1 cell

(G) Integration, alignment of M1 with respect to its cell and assembling of radial, axial, lateral definer needles, restrainers, aperture stops.

(H) Checking of actuators, lateral definer, axial definer forces.

Number of items	M1 item	M1 cell item	Action
3	Centering pads	Centering reference	Alignment of M1 wrt cell in a repeatable way
6	Supporting pads	Supporting points	Support M1 mass without any damage
3	Axial fixed points	Axial fixed points	Constraint Z-position, X-tilt and Y-tilt of M1 wrt the cell
69	Active pads	Actuators	Active system

Number of items	M1 item	M1 cell item	Action
3	Lateral fixed points	Lateral fixed points	Constraint X-position, Y-position and Z-tilt of M1 wrt the cell
24	Lateral pads	Lateral support levers	Support M1 mass when the telescope is inclined wrt zenith
10	M1 edge	External restrainers	- Secure M1; - Block M1 for cell transport; - Maintain M1 stop; - Support M1 cover.
3	Internal edge of M1	Internal restrainers	Secure M1



Aluminization of Primary mirrors-3.6m DOT Primary-Removal of old coating

WET MIRROR SURFACE → 5Lit SOAP (1 Jars) +50 Lit RO-WATER

↓

10% SOAP SOLUTION → 10 Lit SOAP (2 Jars) + 100 Lit RO WATER

(1.5m Cotton roll →→ → ↓ Wiper with cotton pads)

RINSE MIRROR SURFACE → 100 Lit RO WATER

↓

ACETONE→ 20 Lit (wipe with Derlin rods)

↓

RINSE MIRROR SURFACE→ 50 Lit D WATER

↓

8%KOH SOLUTION→ 12 Kg. KOH + 150 Lit D WATER (pour & wipe using Derlin rods)

↓

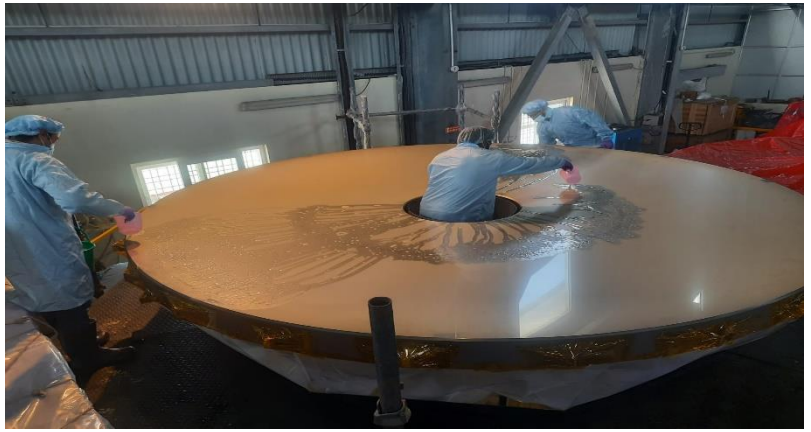
RINSE MIRROR SURFACE → 100 Lit DM WATER (using wiper)

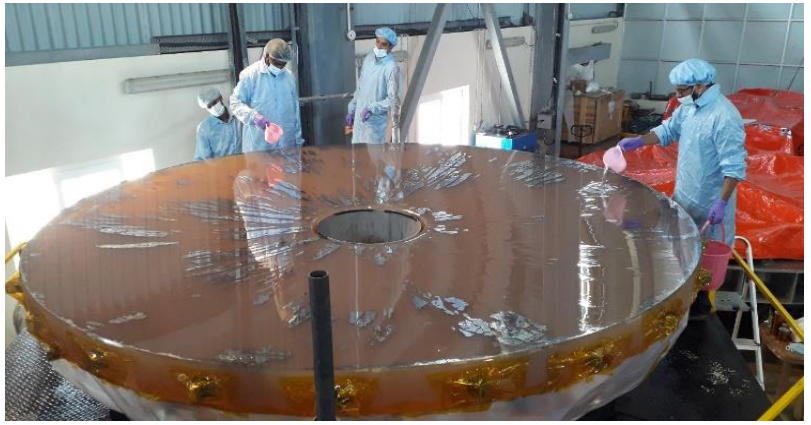
↓

DRY MIRROR SURFACE WITH LINT FREE TOWELS -→ LINT FREE TISSUES→ DRY NITROGEN

↓

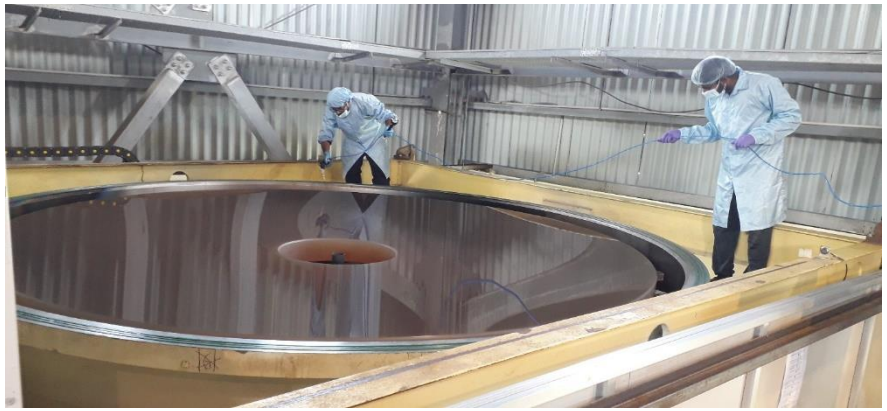
COVER MIRROR SURFACE WITH OPTICAL PAPER

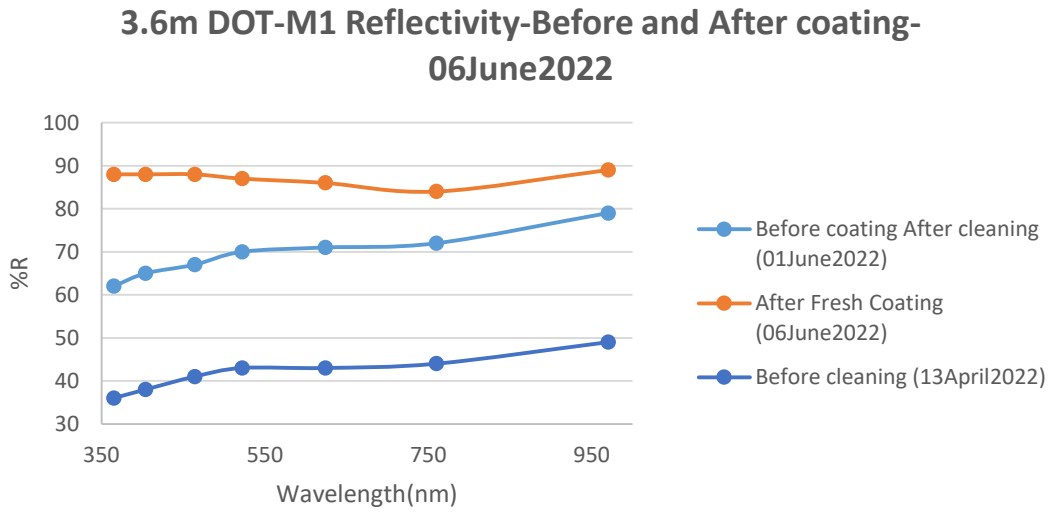




Aluminization of Primary mirrors-3.6m DOT Primary-Recoating

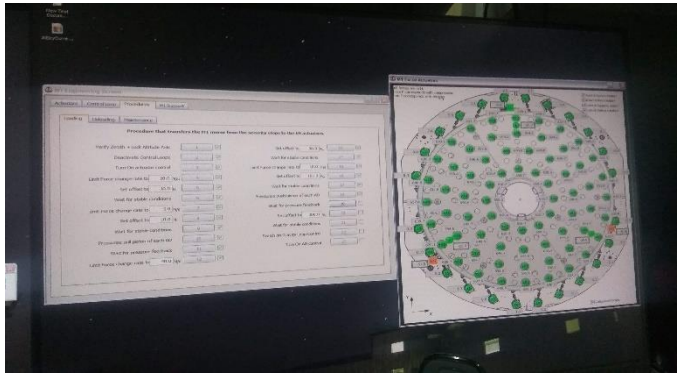
- Transportation of M1 from washing unit to coating chamber
- Aluminizing plant uses magnetron sputtering technique. Initially the chamber is evacuated to vacuum level of 10^{-6} mbar using rotary, roots and cryo pumps. Chamber takes around six hours to achieve $1X10^{-6}$ mbar vacuum level.
- Cryo pumps takes 2 hour 45 minutes to ready (Below 20K temperature)
- Ion beam cleaning is done in rough vacuum in $2X10^{-2}$ mbar conditions, later the sputtering process is done in $1.5X10^{-3}$ mbar vacuum conditions with the help of one cryo pump and 5kW magnetron power (330 V and 15 amps).
- Sputtering for 90 minutes to get around 120nm coating thickness.
- Aluminium purity:99.999%





Aluminization of Primary mirrors-3.6m DOT Primary-M1 integration with cell

- **M1 is moved from coating chamber to M1 cell, Alignment with the cell and Forces verification**
- M1 is mounted on its handling tool;
- M1 is positioned above the cell;
- M1 is moved down at about +5mm wrt its nominal Z-position above the cell;
- The centering references are installed into the cell. Their Z-location is reliable because the centering references have been defined as mounting references during the preliminary integration;
- The cell is moving up of about 5mm until put the three centering references in touch with M1 centering pads, with limited M1 mass transfer (max. 60kg);
- The cell mass is uniformly divided out the 6 cell supports;
- The supporting points of the cell are screwed until contact with the supporting pads of M1. The Z-location of these supporting points is assumed thanks to the preliminary integration;
- M1 mass is transferred onto the supporting points and the centering references of the cell;
- M1 is secured by mounting the restrainers;
- M1 is free from its handling tool which is then removed;
- M1 cover is mounted to secure optical surface;
- The axial fixed points are mounted;
- The needles and the load sensor are connected to M1 lateral support levers;
- The needles of M1 lateral fixed points are installed;
- M1 mass is transferred onto the actuators;
- The centering references and the supporting points are then removed or moved down;
- The M1 mechanical stop is set; M1 is secured into the cell for M1 unit transport.



Aluminization of Primary mirrors-1.04m ST Primary

- It also includes same procedure

(A) Disintegration of M1 from the telescope and from its cell after unmounting the radial and axial weigh assemblies

(B) Transportation for M1 from the cell to washing unit.

(C) Removal of old aluminum coating and washing with proper procedure.

(D)Transportation of M1 from the washing unit to coating chamber.

(E)Fresh aluminum coating and reflectivity measurement.

(F)Transportation of M1 from coating chamber to M1 cell

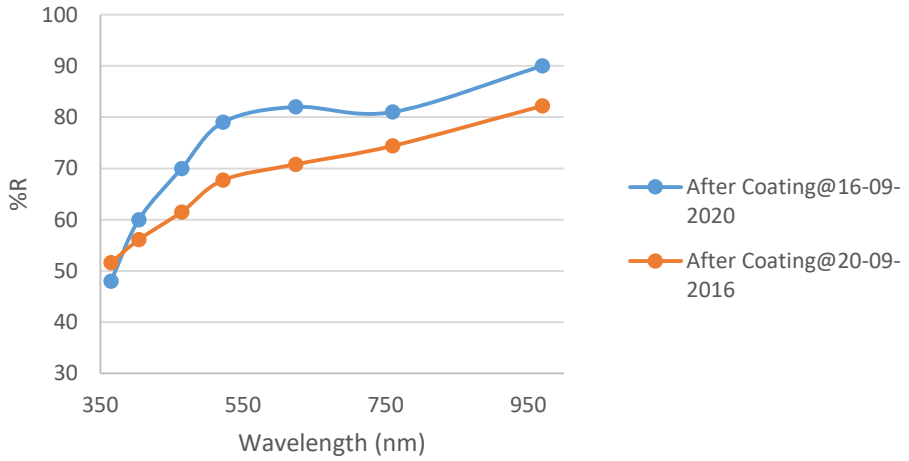
(G) Integration, alignment of M1 with respect to its cell and assembling of radial and axial weigh assemblies

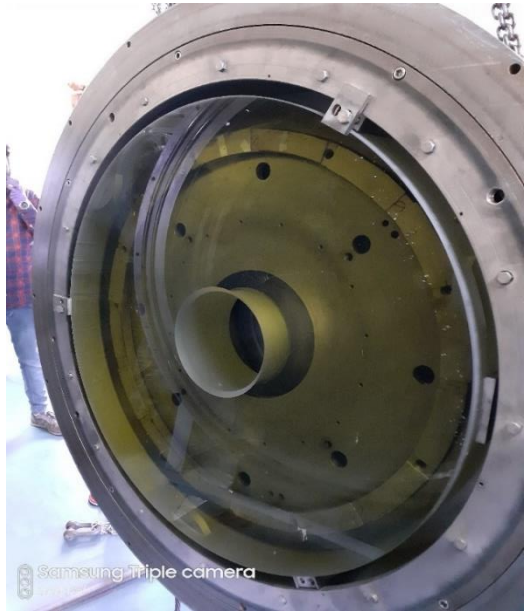
- Completely manual

Aluminization of Primary mirrors-1.04m ST Primary-Recoating

- Same procedure is being used for the removal of old coating and cleaning
- **We have coated the 1.04m ST primary for more than seven times since its installation (1997,2000,2003,2007,2011,2012,2016,2020)**

- Thermal evaporation is a deposition technique that relies on vaporization of source material by heating the material using appropriate methods in vacuum.
- Evacuate the chamber to 10^-5mbar.
- Fire the filaments with high current ~600A.
- Small aluminum targets
- Takes less time to coat
- It is one of the most common and simplest forms of physical vapor deposition.





In-situ Cleaning

- **In-situ CO2 cleaning:**

CO2 snow cleaning is a straightforward surface cleaning process in which a stream of small dry ice particles strike and clean a surface via physical and solvent interactions. There are no chemical reactions or abrasive processes. These interactions remove particles of all sizes, from visible down to 0.03µm, and also remove low levels of organic residues as effectively as solvents. For Performing CO2 cleaning, we need a CO2 cylinder of purity 99.999% with dip tube at 750 psi, a hose to get the CO2 to an on/off valve, and a venturi nozzle.

Humidity dependent.

Effective only in <65% Humidity

Less Effective

Monthly Cleaning.

Performing only on 3.6m DOT Primary mirror

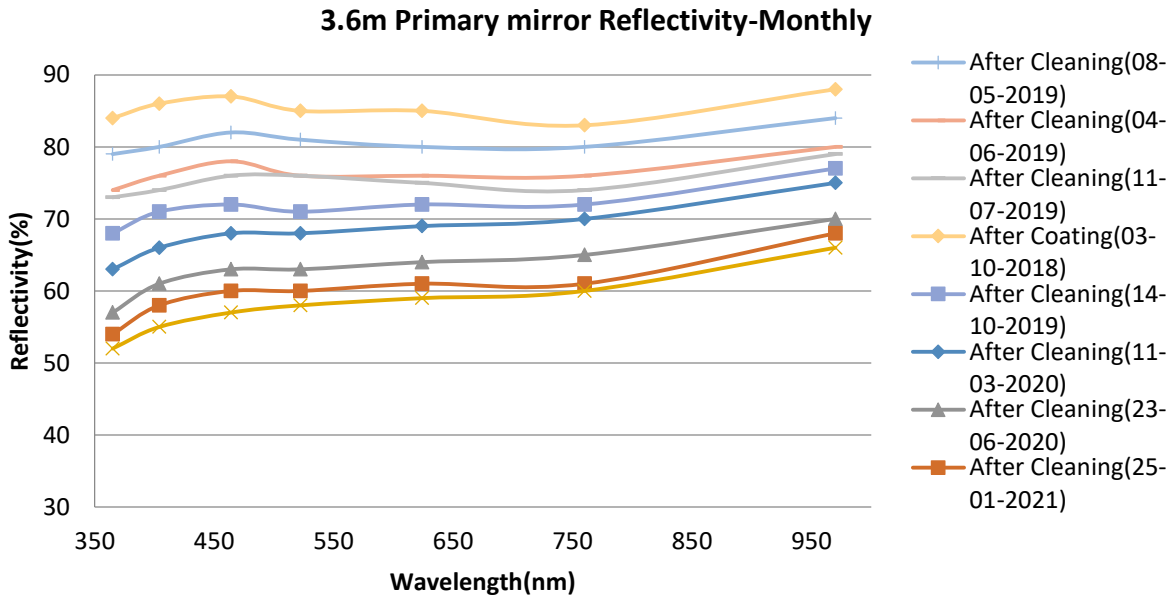
- **In-situ Distilled water cleaning:**

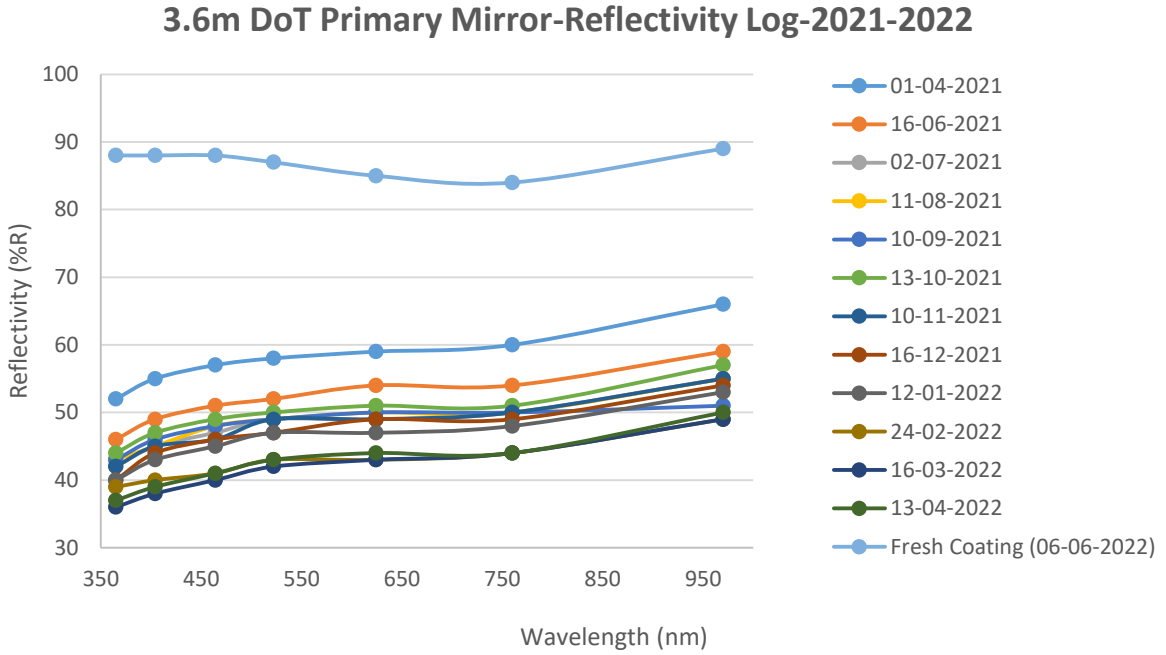
130-cm primary mirror cleaning process is carried out every year in the month of September, just before the observing season starts after the monsoon break. This cleaning is carried out without unmounting the M1 cell. This is a complete in-situ cleaning without disturbing the M1 and its cell. To do this, the primary mirror baffle, corrector assembly and focal plane instrument is dismounted to access the primary mirror surface through central hole. Proper set up is made to protect the radial and axial pads of M1 and the cell before start the cleaning process. Initially wet the M1 surface with 8% neutral soap solution and soak with a cotton pads for some time to loosen the sticky dust. Most of the major dust particles is removed when gently rolling these cotton pads without applying any pressure. Remaining fine dust is removed by dragging the cotton pads on its weight. A thorough cleaning process using distilled water and proper drying without leaving any marks helps to restore the reflectivity values of the primary mirror.

More Effective

Degradation in Reflectivity of Primary mirrors-3.6m DOT Primary Mirror

- There is a considerable degradation of the reflectivity.
- Major factors for degradation are Fine dust, Pollen, Forest fire, High Humidity
- 3.6m DOT Primary Mirror:



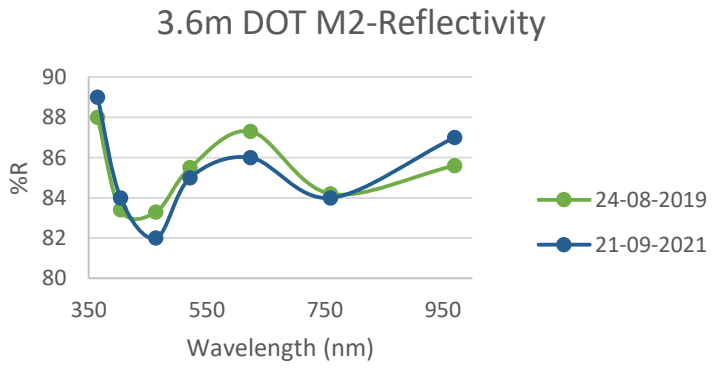


~10-12% per year overall considering above major factors with regular in situ CO2 cleaning.

~3-4% per year if we rule out the dust.

Online weekly log is being maintained on 3.6m DOT webpage.

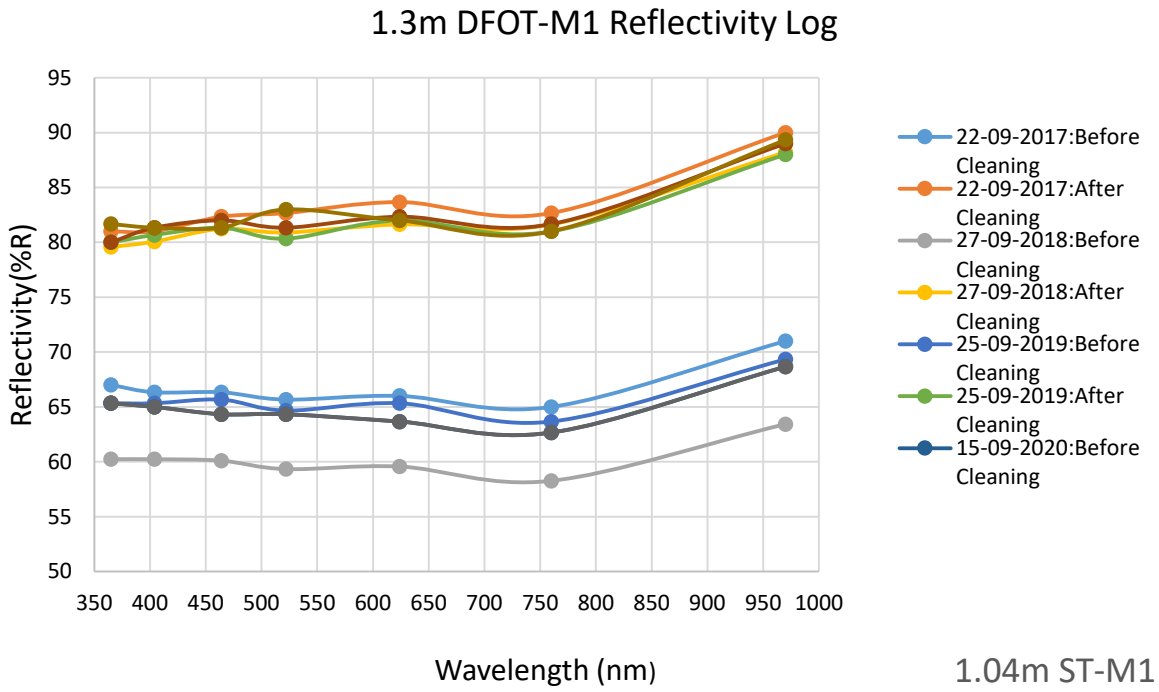
Useful astronomers for %R fitting factors.

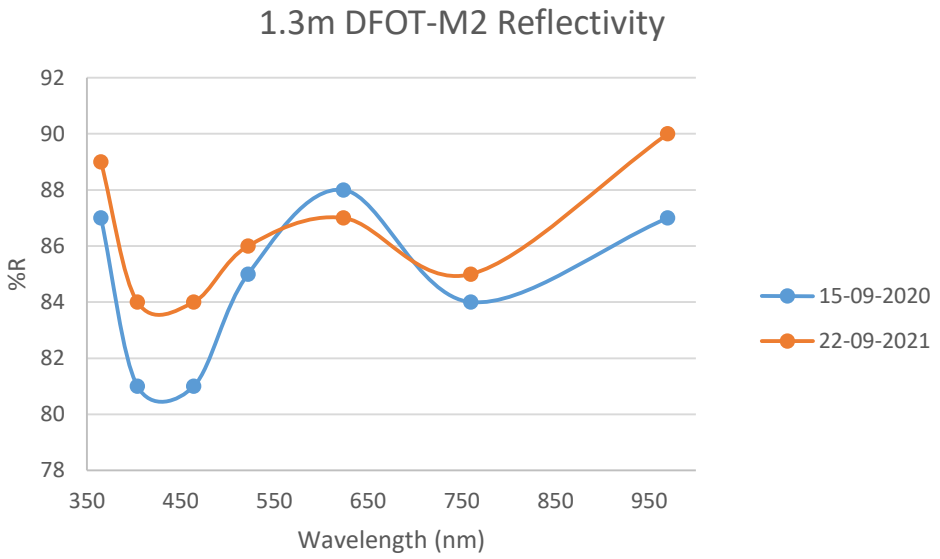


M2 is protective coated

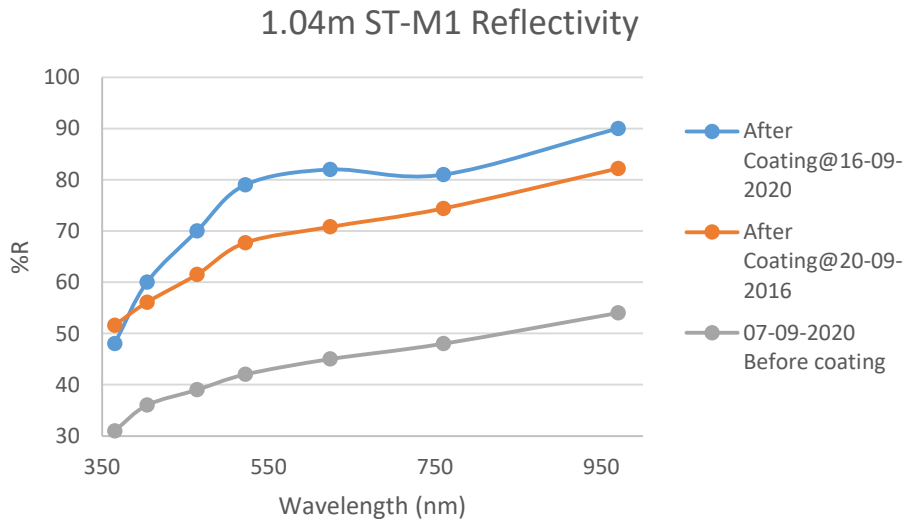
Degradation in Reflectivity of Primary mirrors-1.3m DFOT Primary Mirror

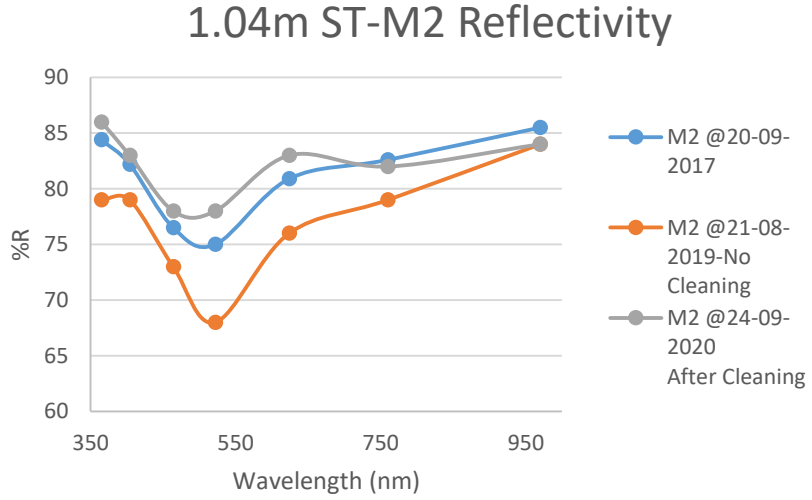
- 1.3m DFOT Primary Mirror:





- 1.04m ST Primary Mirror:



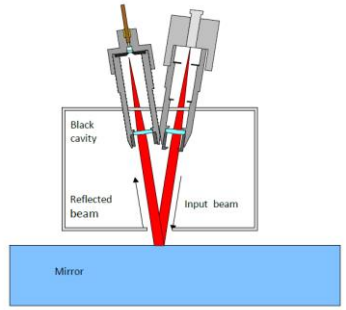


THANK YOU

Reflectometer

- A Reflectometer (CT7) has been procured from **Otto Pregizer Optik, Belgium** in 2017 especially designed to measure the **specular reflectivity** of telescope's coating in 7 wavelength bands. Approximate cost is around 15 lakhs.
- **Accuracy** : 0.2% for R > 50%
- **Repeatability**: 0.01% for R > 50%

Wavelength (nm)	Bandpass (nm)
365	10
411	15
528	30
630	30
750	50
850	50
940	40



Overview:

- CT7 measures optical reflection and scattering at 8° incidence for 365 to 970nm in 7 bands
- The measurement is performed with instrument standing on the measured mirror.
- The results are displayed and stored to non-volatile memory.
- CT7 may be calibrated to user supplied reference targets (“soft” mirror and scattering target values)
- All measurements are time-stamped thanks to the real time clock.
- CT7 is built to protect the measured mirror.
- An USB connection allows for data retrieval to PC.
- All CT7 functions are available from PC and/or from instrument front panel
- CT7 may operate without batteries on the USB power
- The instrument has three power modes: ACTIVE, SLEEP and CHARGE.
- Auto OFF feature protects the batteries against accidental discharge.
- Two parallel Li-Ion cells, 14500-size (~AA)size, power the instrument.
- Charging of AA cells is primarily performed by built-in charger powered from
- USB connector of the PC , thus charge current is limited to 500mA
- Charge is performed only when CT7 is not active
- Mirrors with radius of curvature down to +/- 1000 mm can be measured safely.