Lame Dichroïque
Large Bande, Grande Dimension
Et Très Bonne Uniformité

18 Octobre 2022

C.Michel pour la plateforme LMA-IP2I

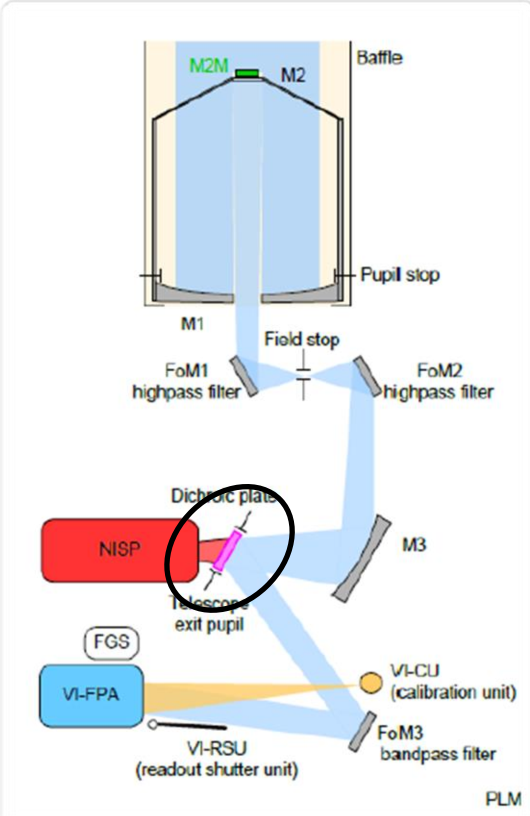
Outlines

1. Purpose of this R&T project
2. Dichroic coating design
3. Deposition process optimization
4. Pathfinder production
5. Environmental testing

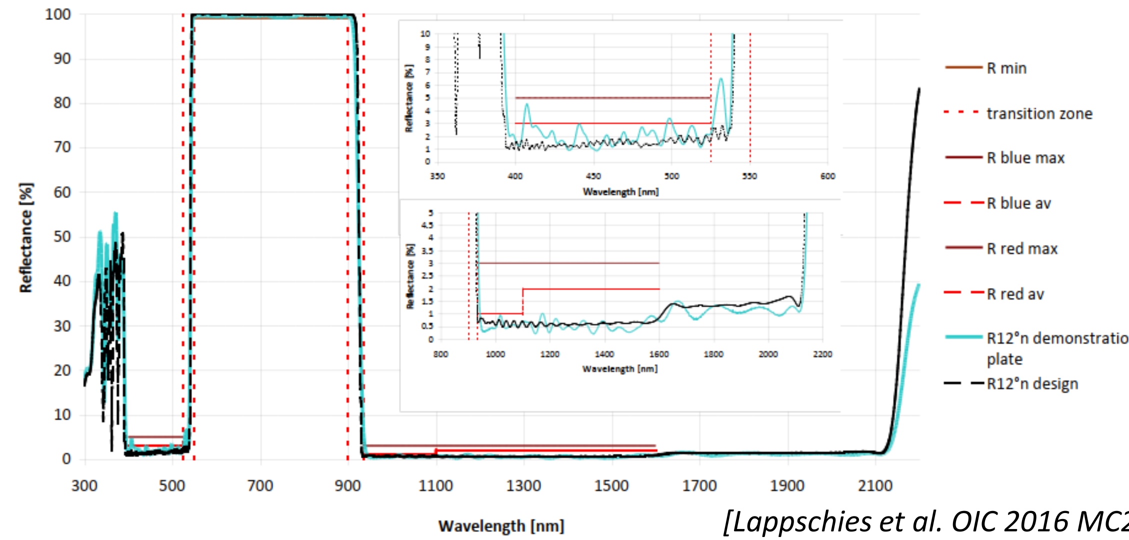
Purpose of this R&T project

Starting point : the Euclid's dichroic plate

[Courtesy ADS, https://www.euclid-ec.org/?page_id=2639]

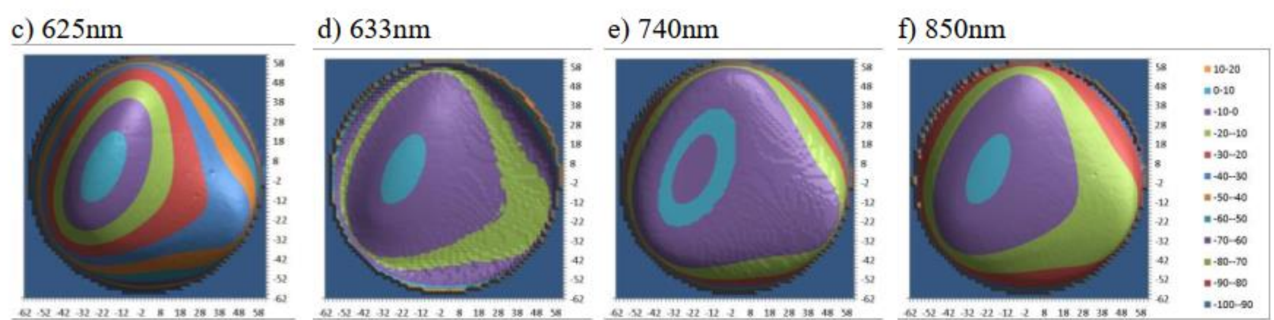


Dichroic manufactured by Optics Balzer Jena.
Outstanding optical performances !
Fully compliant to the specs.



[Lappschies et al. OIC 2016 MC2]

But it was recently highlighted a **chromatic WFE** incompatible with the needs of the mission.



[Lappschies et al. OIC 2016 MC2]

And so ?

Is LMA able to handle such issue ?

Can we mitigate/avoid this effect ?

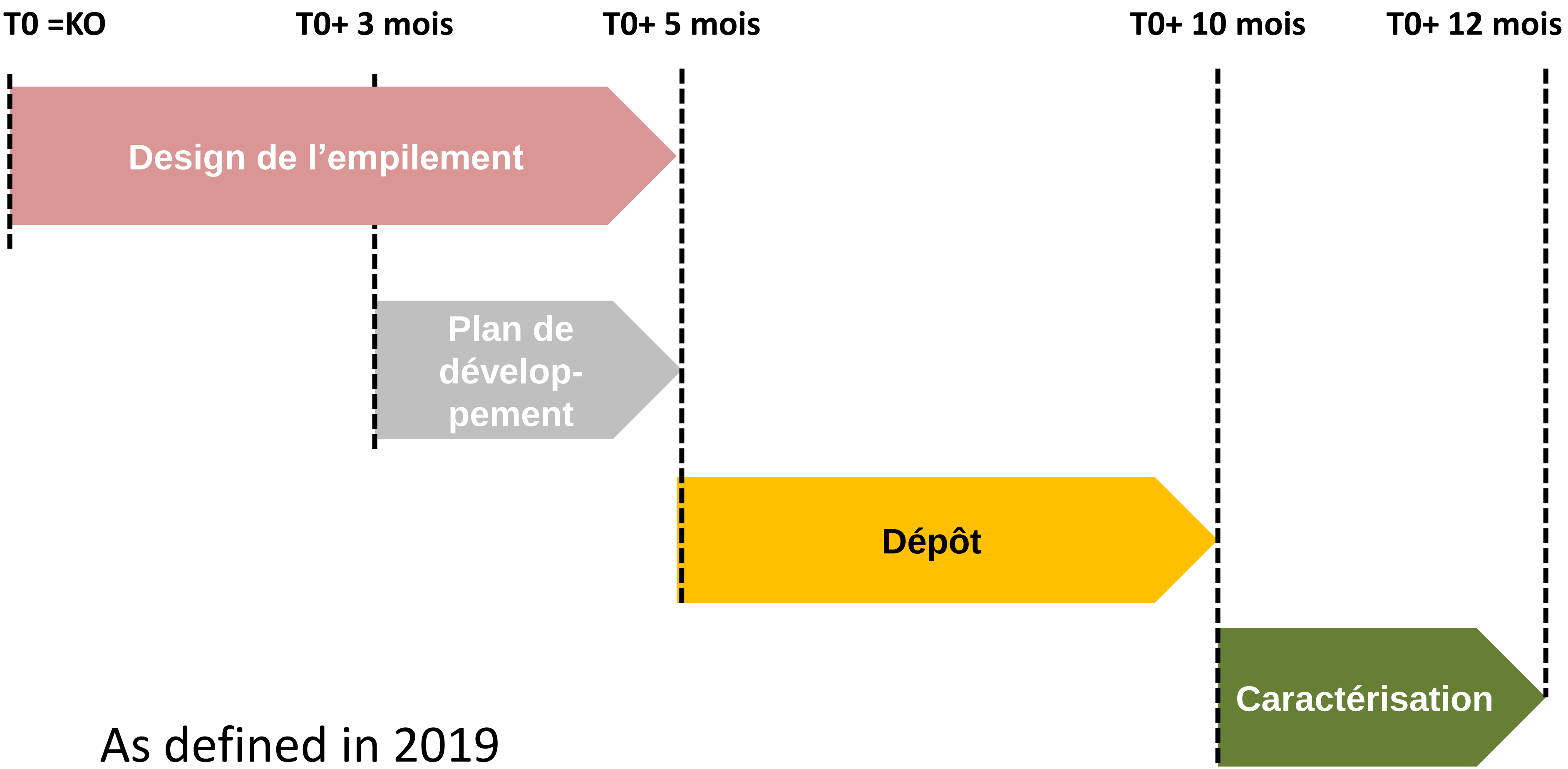
Is there any solution to improve the performances for future components ?

LMA has a long standing experience in the development and the realisation of high performances optics.

Goal : explore our capabilities in order to **produce a twice larger dichroic** plate with limited chromatic aberrations.

A demanding and challenging project !

Planning



As defined in 2019

Planning

T0 =KO | T0+ 3 mois | T0+ 12 mois | T0+ 19 mois | T0+ 24 mois

Design de l'empilement

Plan de dévelop-pement

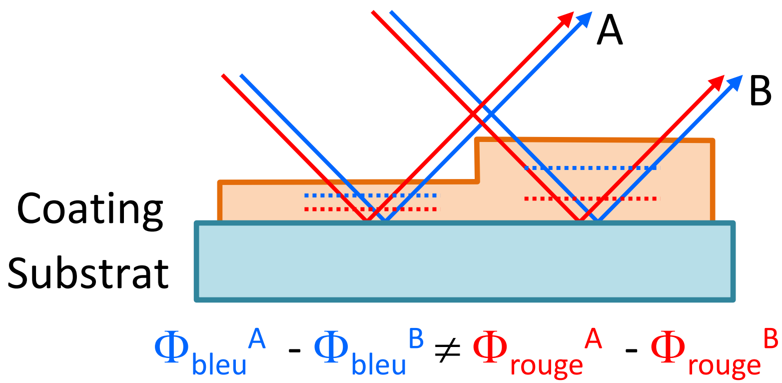
Dépôt

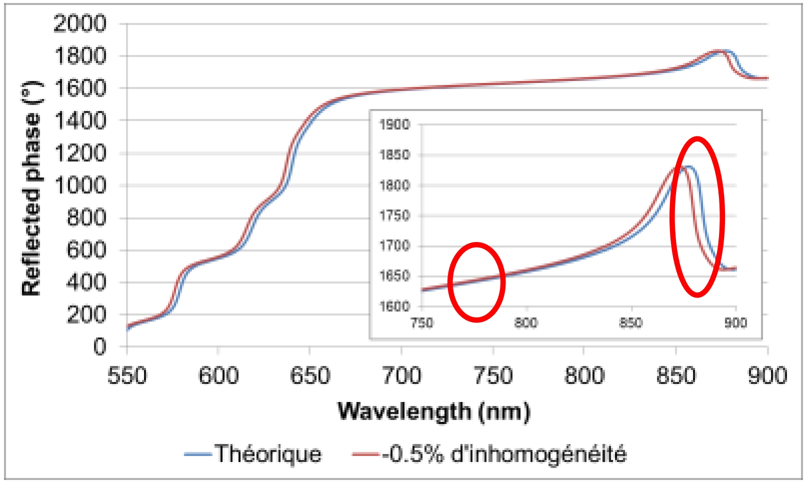
Caractérisation

1 year delay …

Dichroic coating design

A matter of phase-shift …





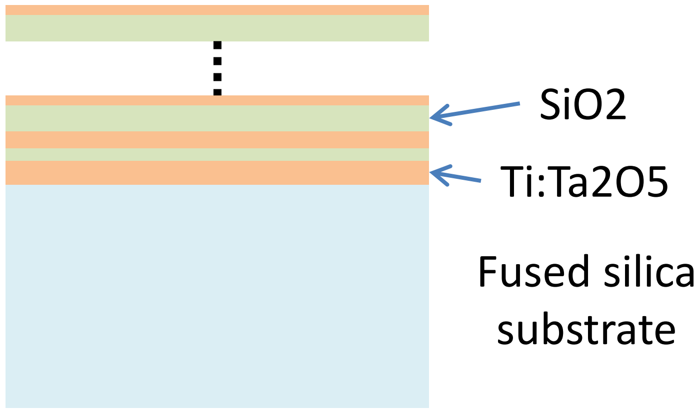
The WFE behavior according to the wavelengh arises from two factors :

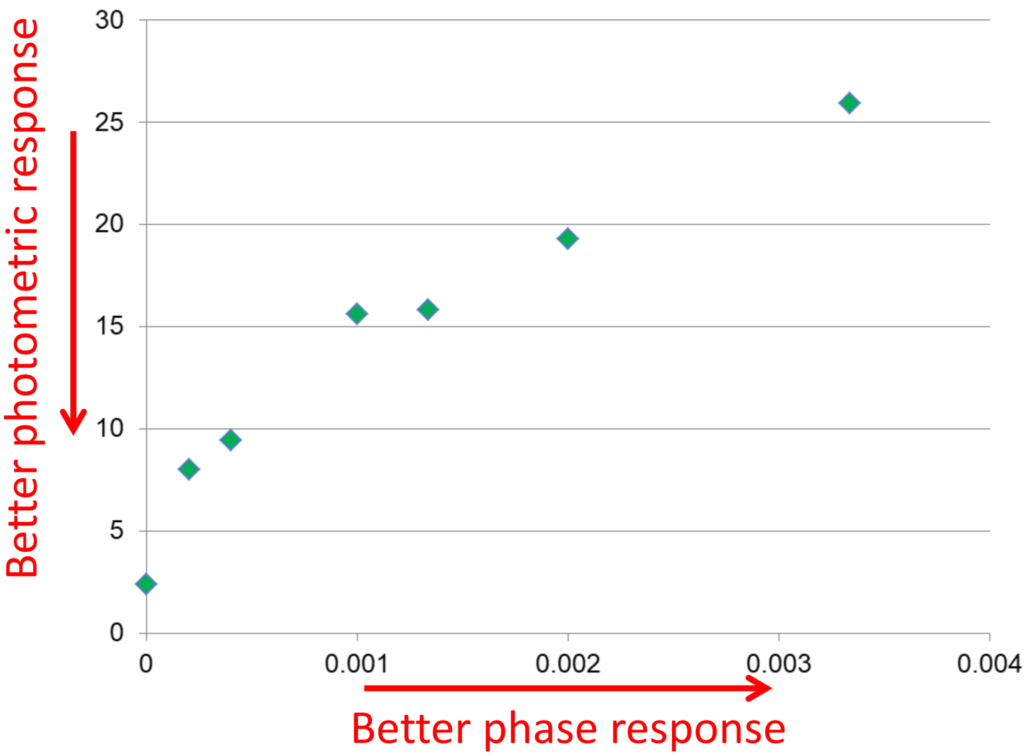
- Thickness uniformity
- $\frac{\partial^2 \phi}{\partial \lambda^2} \neq 0$ (more convenient to consider the Group Delay Dispersion $\frac{\partial^2 \phi}{\partial \omega^2}$)

Improvements can be achieved with a coating with a **high thickness uniformity** and/or a **« smoother » phase-shift function** !

Tricky to comply with the specs

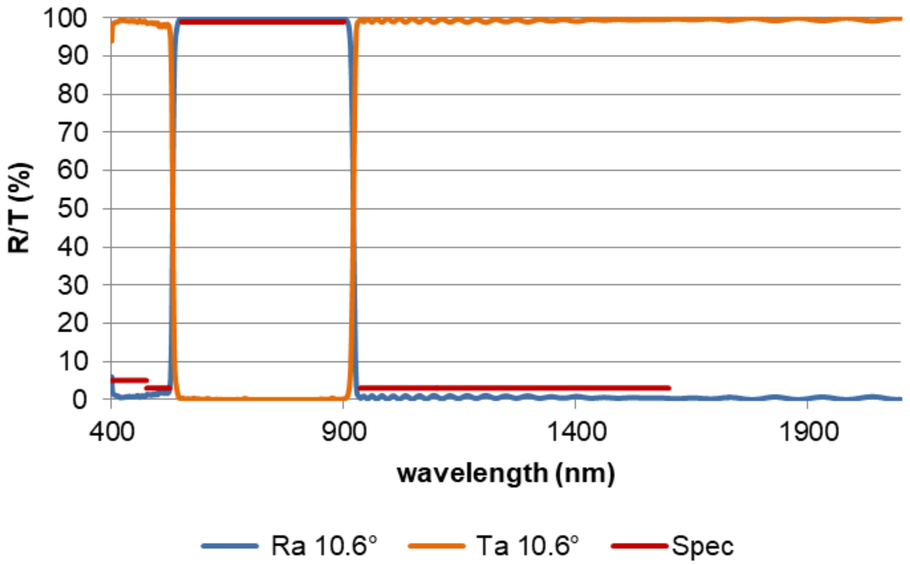
Method : optimization of the thin-film stack in order to meet the photometric (R/T) and phase requirements.
Parameters : number of layers and their thickness.

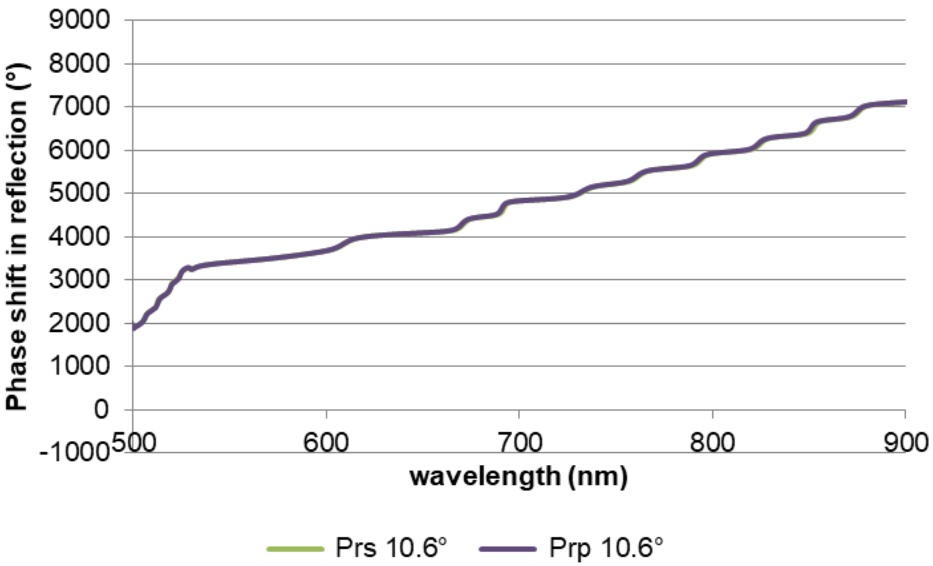




There is a correlation between the phase and the photometric performances.

Nominal performances





The selected design has 100 layers

Total coating thickness ~10µm : **40% higher than the thickest coating** produced so far.

Deposition process optimization

Description

Coating in the Grand Coater (GC) :

- Vacuum Chamber 2.4 x 2.4 x 2.2 m^3
- Pumping Units : 10^{-7} Torr in 1h
- Ion Beam Sputtering
- Max coating diameter ~ 1m
- Thick. Uniformity < +/-0.1% over Ø200mm
- Quartz microbalance monitoring
- ISO3

The manufacturing of a dichroic plate consists of 5 steps :

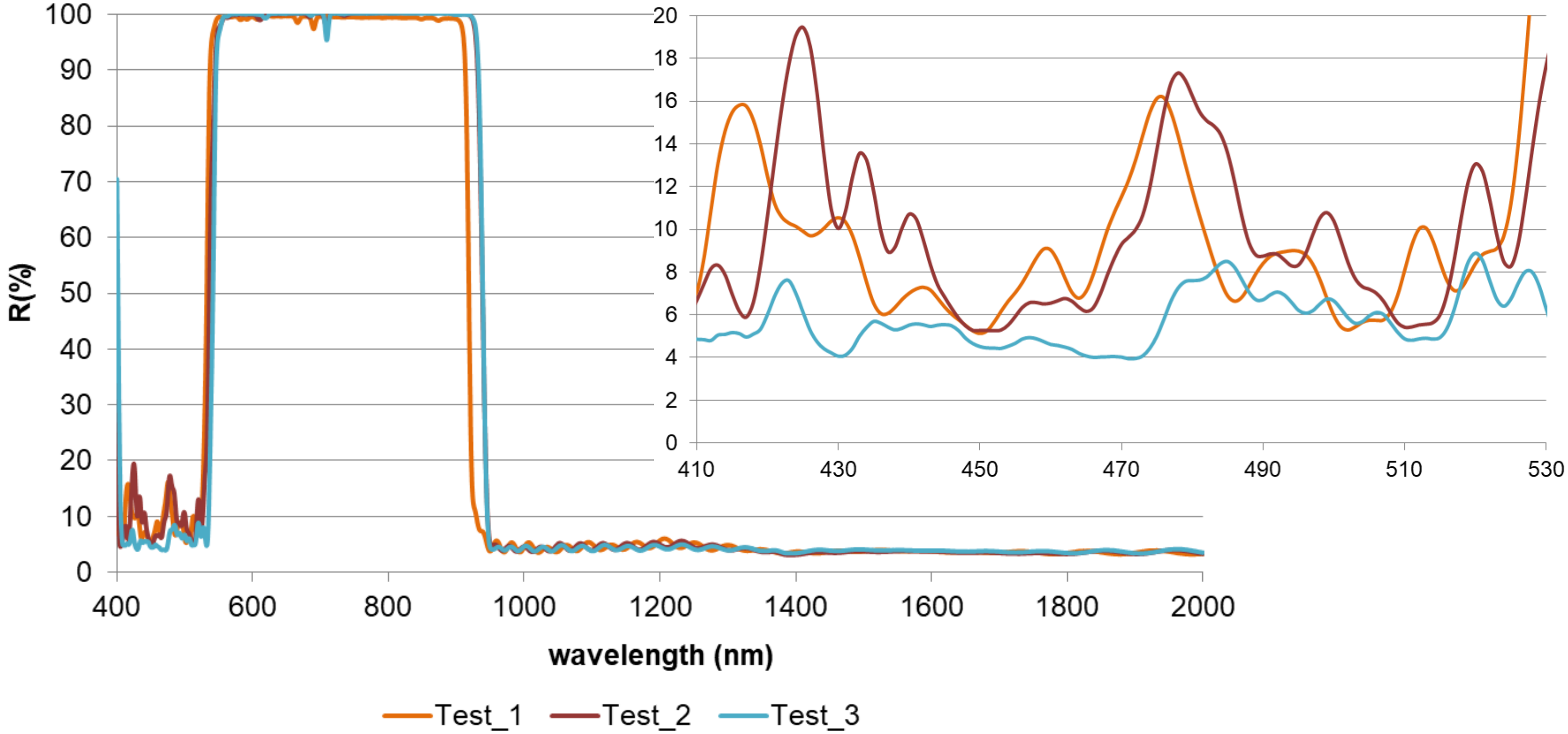
1. Calibration of the quartz microbalances for each material
2. Quartz microbalance fine-tuning with a thin multilayer stack
3. Dichroic coating deposition
4. Post-deposition annealing
5. Characterization

Steps 1 to 3 represent ~100h of deposition.

During this cycle the **stability** and the **repetability** of the process **are mandatory** otherwise the calibrations are useless.

The longer cycle carried out with the Grand Coater so far : **a careful check was required**.

Optimiation through a trial-error process



We ran 3 test depositions in order to check the **repetability**, the **accuracy**, the **behaviour** of the coating machine during such **long runs**.

Improvement of the process btw Test_2 and Test-3 : **reduction of the peaks** < 540nm by 10% (abs.)

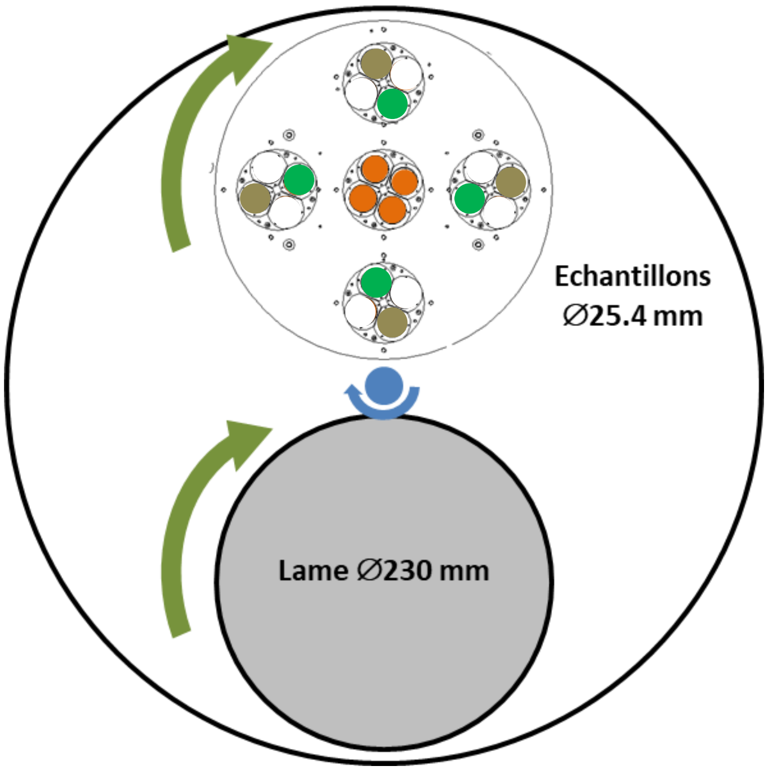
Test_2 and Test_3 are both redshifted about 1.5% but corrective action is straightforward (aim a shorter central wavelength)

Pathfinder production

Deposition procedure used for Tests.

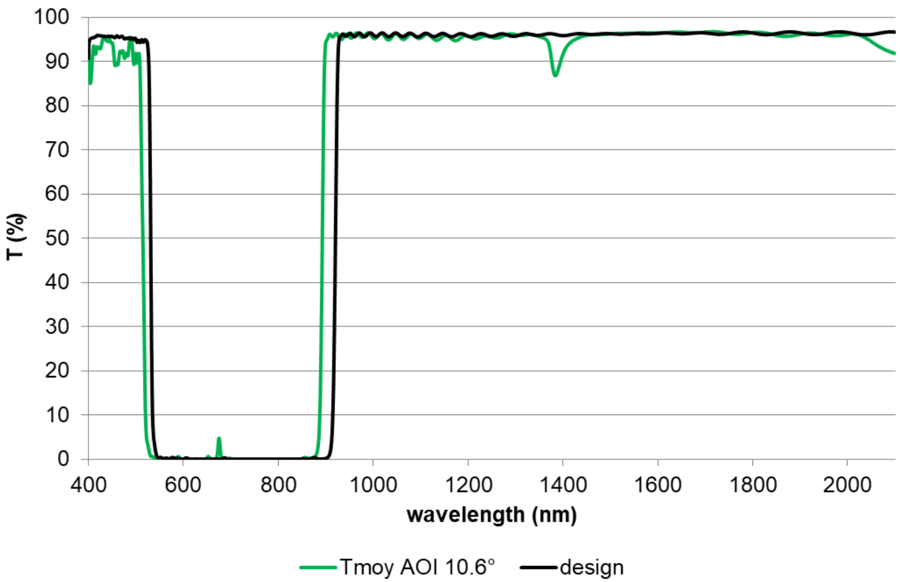
Substrates:

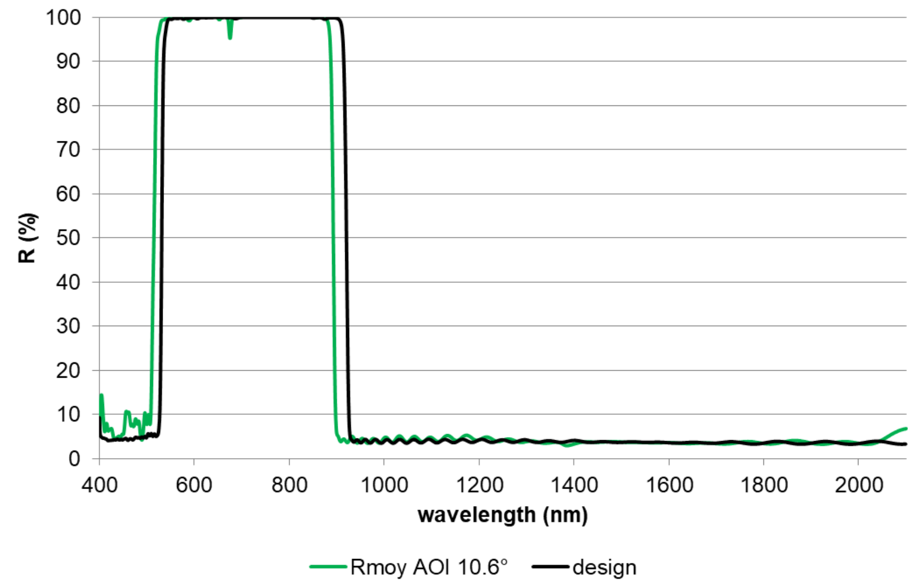
- Ø230mm and 55mm thick
- 12x Ø1'' witness samples (for environmental testing)



Dichroic coating

Optical response at 10.6° AoI (Ø1'' witness sample)



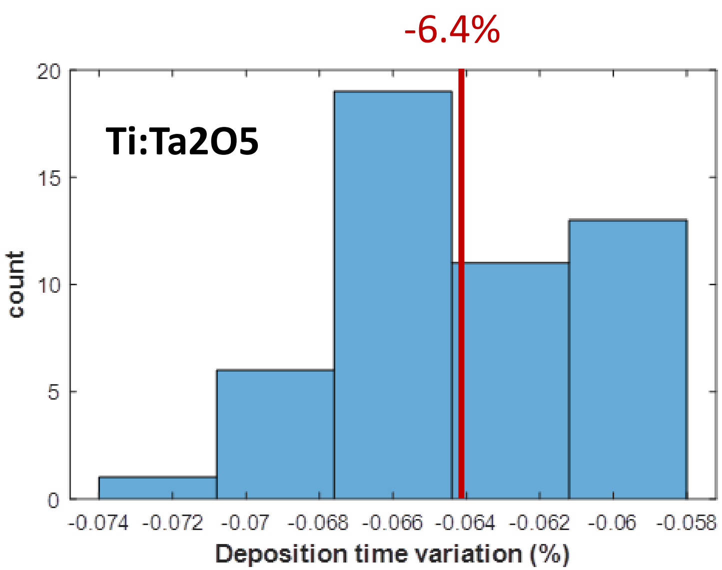


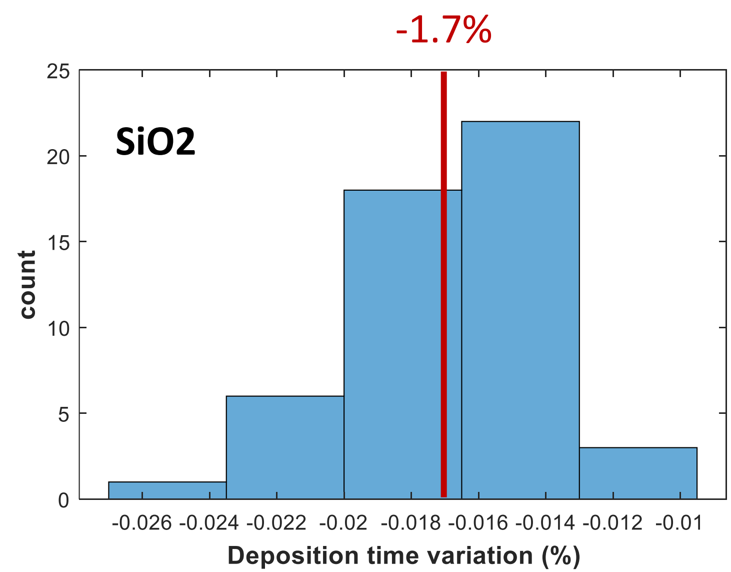
1. The filter edges are steep according to the design
2. The reflection band is blueshifted ~3%
3. Peaks <540nm are higher than Test_3
4. Leak in the reflection band (R~95%)

Postmortem analysis

Test_2 and Test_3 were both redshifted by 1.5% => considered as a bias.
The correction has been 3 times higher than expected (?!)

Comparisation of the deposition durations btw Test_3 and Pathfinder:



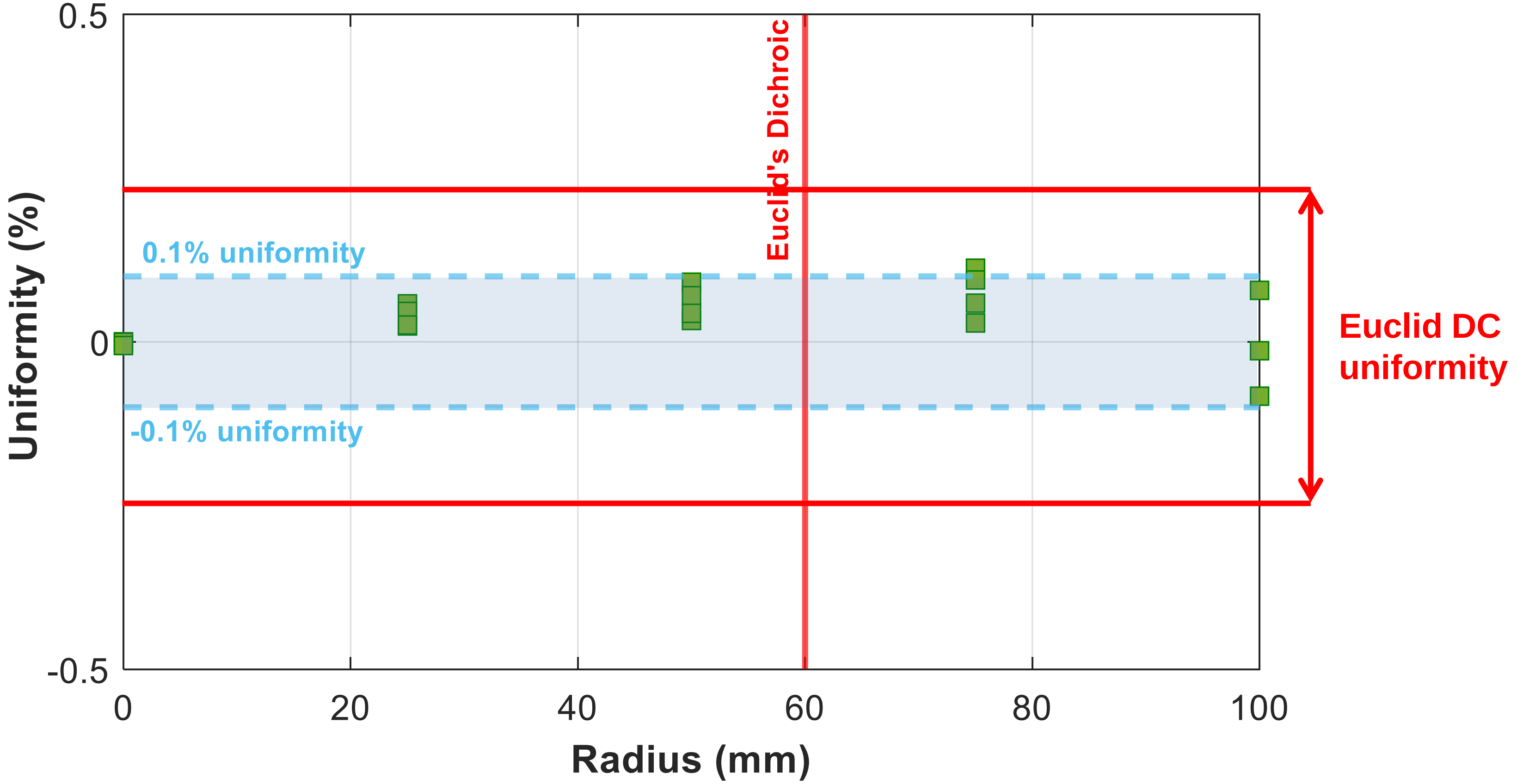


Mean time variation :

- SiO2 results are consistent with the correction of the bias (1.5%).
- Ti:Ta2O5 results are ~4 times higher than expected.

Why ? Actually we do not know. We suspect the erosion of the sputtering target that was near the end of life.

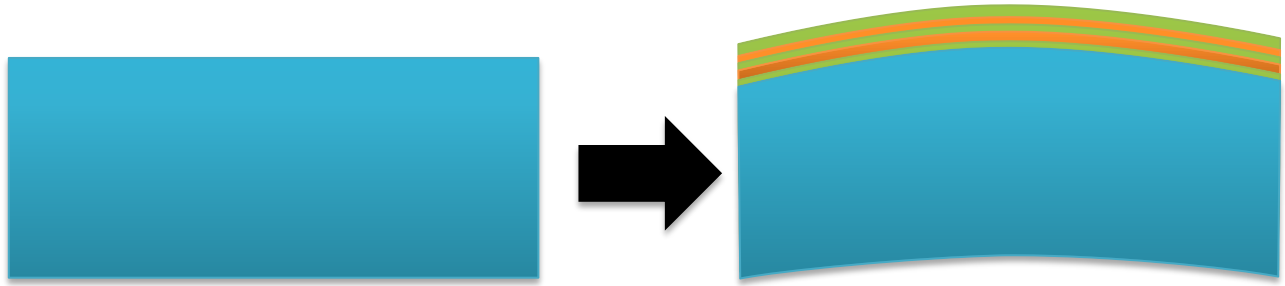
Thickness uniformity



Thickness uniformity **is <u>+/-0.1% PtV</u>** <u>over Ø200mm</u>

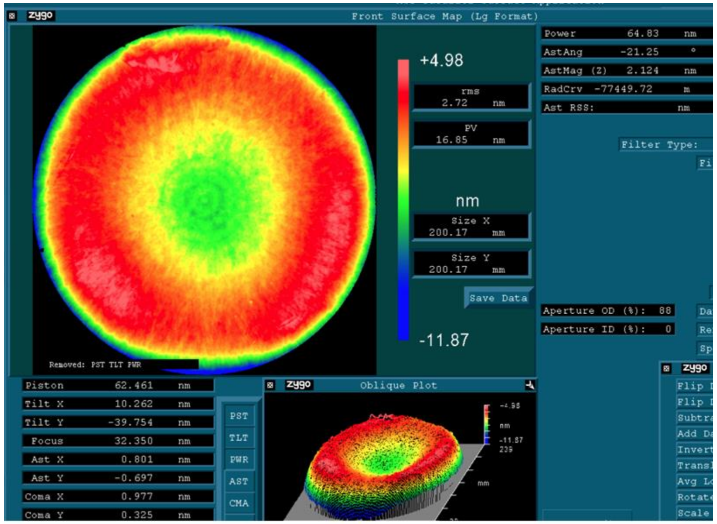
WFE

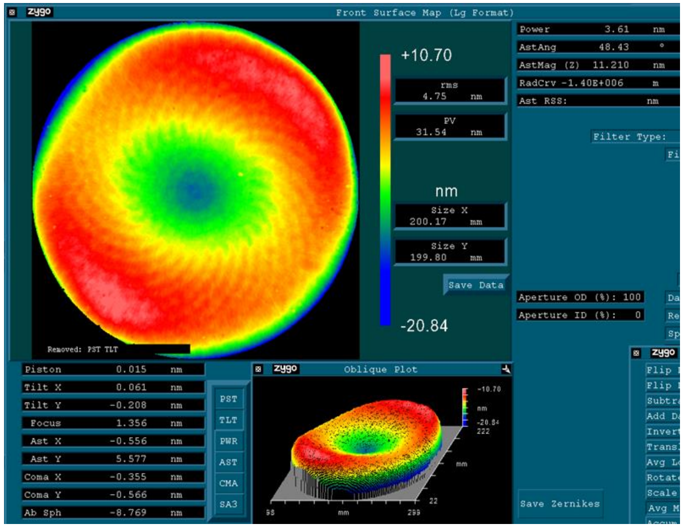
Substrate | Dichroic coating



RoC=-77.4 km
2.7nm RMS – 16.9 PtV

RoC = 1400 km
4.8 nm RMS – 31.5nm PtV





WFE **fully compliant** to the 10nm rms requirement

Environmental testing

Tests matrix

ESSAIS	RESULTATS
Inspection visuelle	
Mesure spectrale	C
Chaleur humide	C
Inspection visuelle	
Mesure spectrale	C
Cyc. Therm. sous vide	C
Inspection visuelle	
Mesure spectrale	C
Cyclage thermique à pression amb. sous N2	C
Inspection visuelle	
Mesure spectrale	C
Mes. sp. cryo	C
Test d'adhérence	C
Inspection visuelle	
Test d'abrasion	C
Inspection visuelle	
Test de nettoyabilité	C
Inspection visuelle	
Nett. Sév. (2 faces)	C
Inspection visuelle	
Mesure spectrale	C
Nettoyage LMA	C
Inspection visuelle	C
Mesure spectrale	C

Summary

Pathfinder :

- Ø230mm, 55mm thick
- 2.7nm RMS – 16.9 PtV

Fabrication according to the optimized procedure worked out for Test_3:

1. The filter edges are steep according to the design
2. The reflection band is blueshifted ~3%
3. Peaks <540nm are higher than Test_3
4. Leak in the reflection band (R~95%)

Ti:Ta2O5 layer seems to be underdeposited. Because of sputtering erosion ? Quartz cristal aging ?

Thickness uniformity +/-0.1% over Ø200mm

WFE compliant to the spec. <10nm rms (w/o focus) : 8.5 nm RMS – 40nm PtV.

The samples keep their optical, mechanical and cosmetic properties despite the environmental testing.

That’s it !

Thank you for your attention.