9603-46
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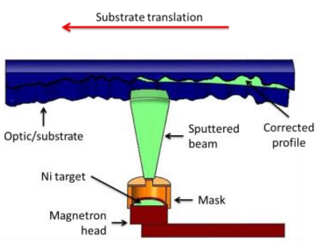
Carolyn Atkins[a], Kiranmayee Kilaru[b], Brian D. Ramsey[b], David M. Broadway[b], Mikhail V. Gubarev[b], Stephen L. O'Dell[b], William W. Zhang[c]

[a] University of Alabama in Huntsville
[b] NASA Marshall Space Flight Center
[c] NASA Goddard Space Flight Center

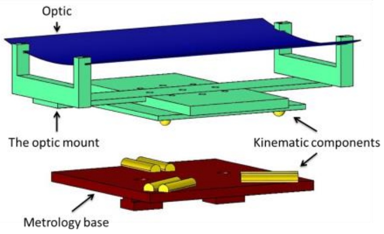
Differential deposition correction of segmented glass x-ray optics

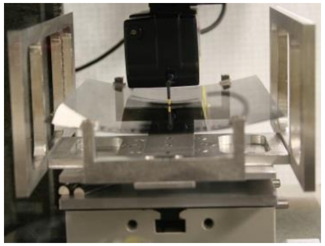
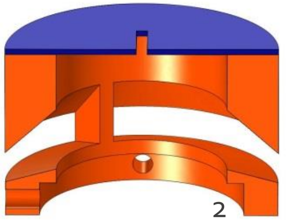
Overview

- Introduction
- Hardware
- Metrology
- Optimisation
- Initial results
- Summary and conclusion





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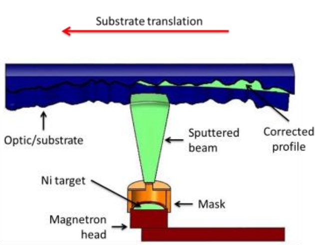
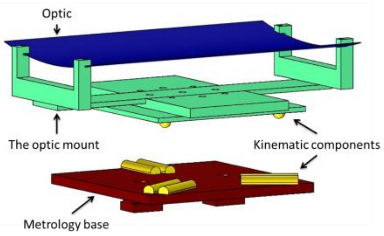
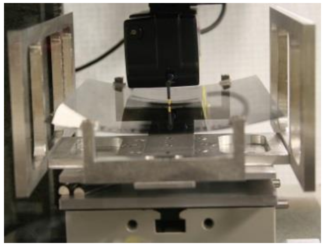
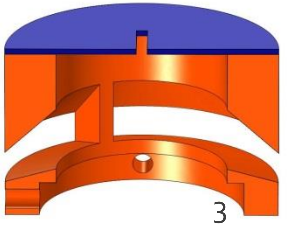
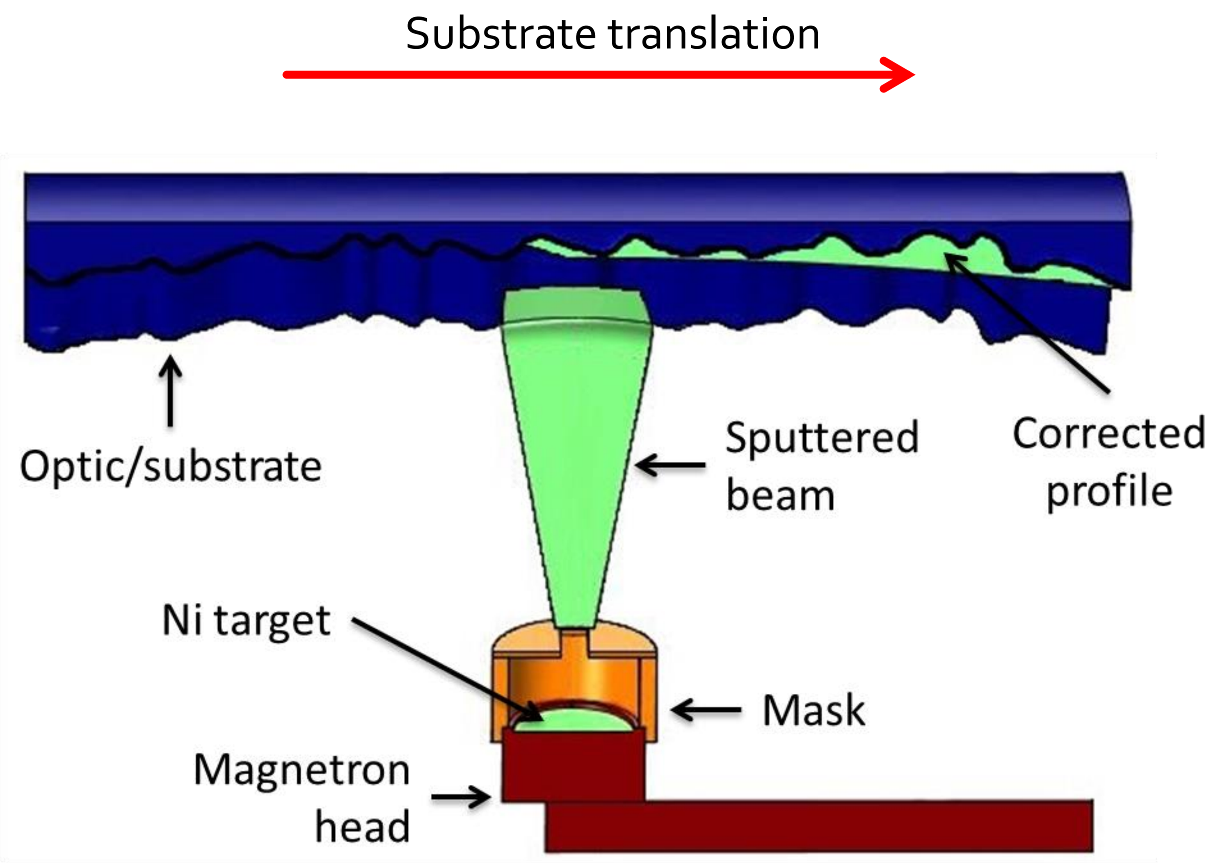








Introduction – differential deposition



Introduction - challenges

SEGMENTED GLASS OPTICS

- Shape – segmented, leading to a less rigid structure.
- Material – borosilicate, lightweight, but easily deformed.
- Mounting – point fixture, where the optics are held at discreet points.

NI-CO REPLICATED OPTICS

- Shape – full shell, rigid structure.
- Material – Ni-Co alloy, heavier but less prone to deformation.
- Mounting – collet fixture, where the optic is held uniformly around its circumference.

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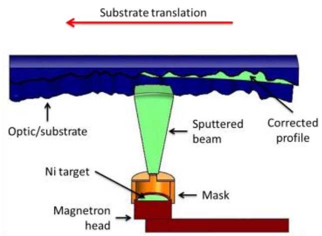
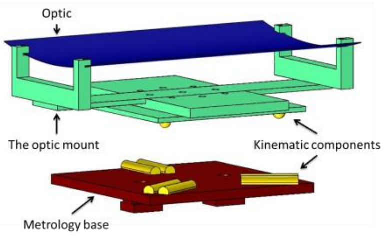
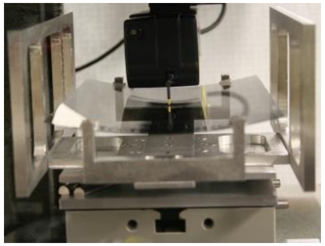
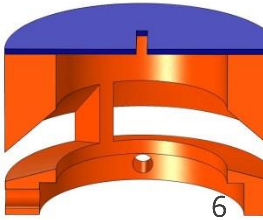




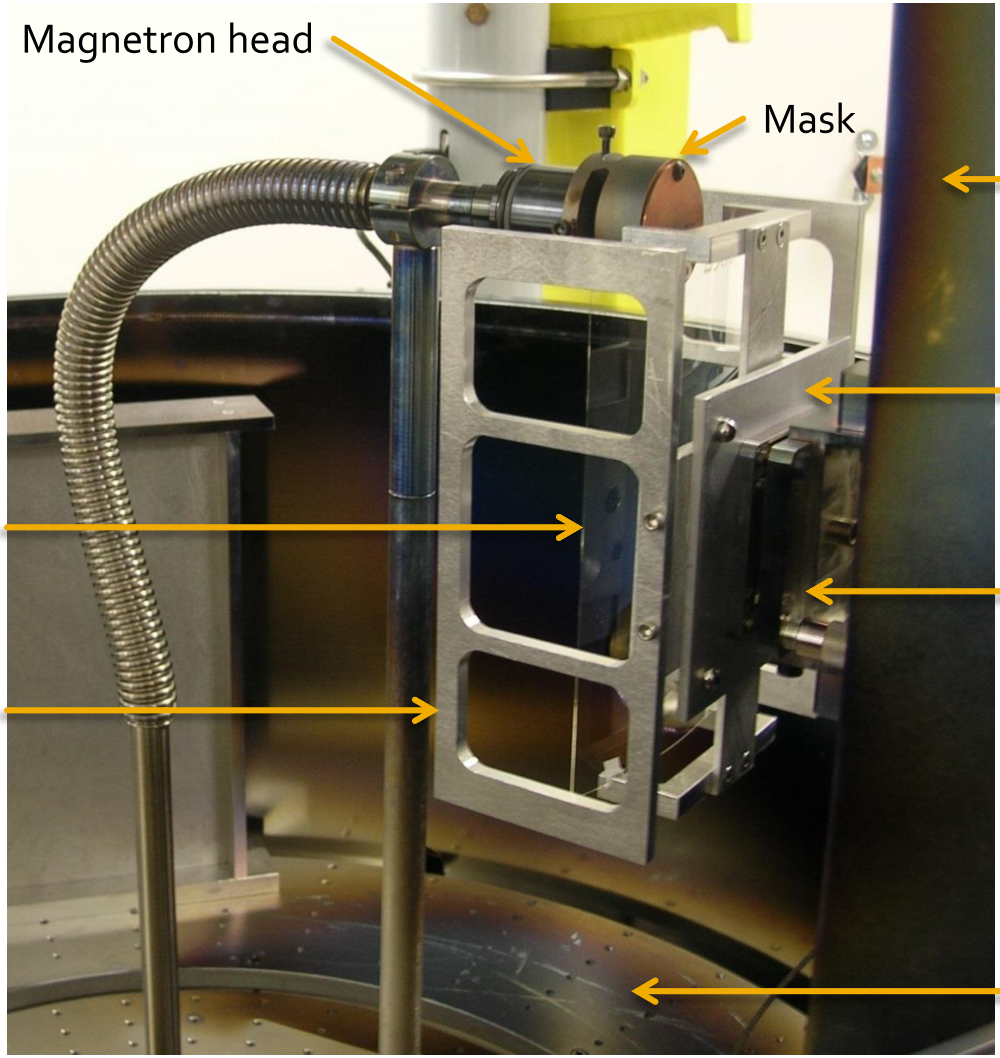



Hardware – vacuum chamber

Specifications

- 1m in diameter, 1.3m in height.
- Vertical translation provided by a portable tower which has a travel of ~680mm in the vertical direction.
- The 360° rotation is provided by an annular platform.
- Optical encoders are used on both the translation and rotation to ensure accurate positioning and feedback.
- A 1 inch DC magnetron is to sputter the material for the differential deposition process.

Hardware – optic and mount



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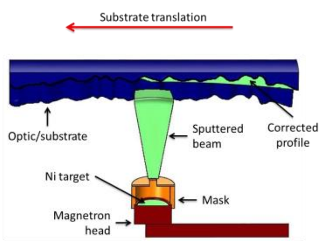
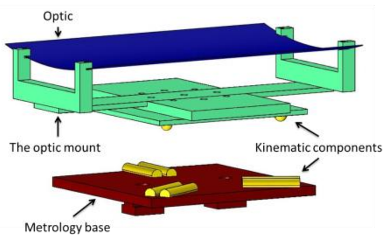
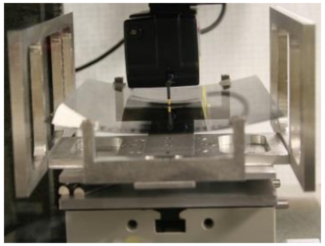
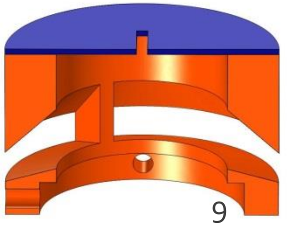
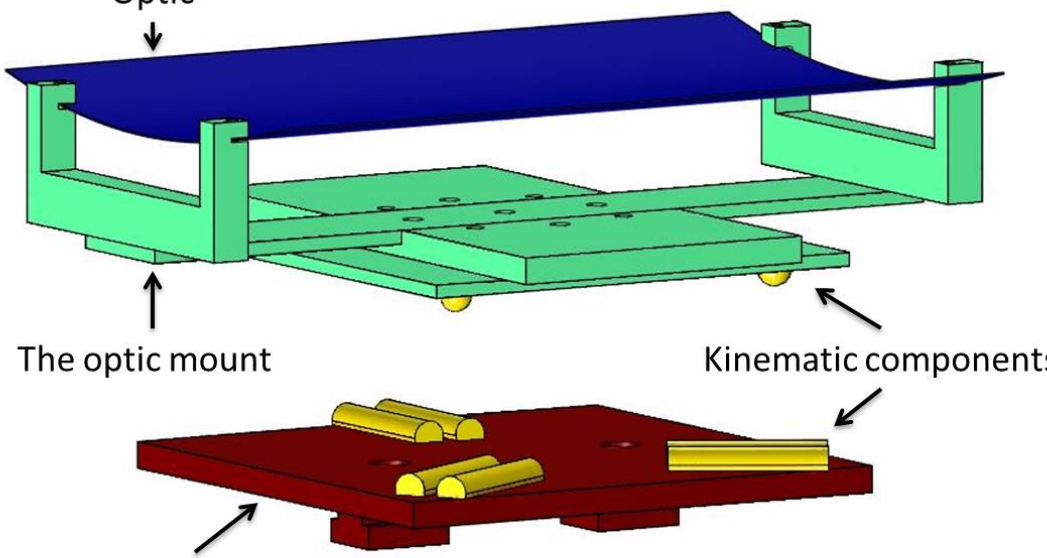




Metrology – optic mount



Due to the requirement for accurate alignment and repeatability a kinematic mount has been developed to ensure accurate positioning of the optic relative to the profiler's stylus between coatings.

The final profile, which is used to define the required correction, is composed of 2 sets of 5 repeat measurements with the optic being repositioned between each set.

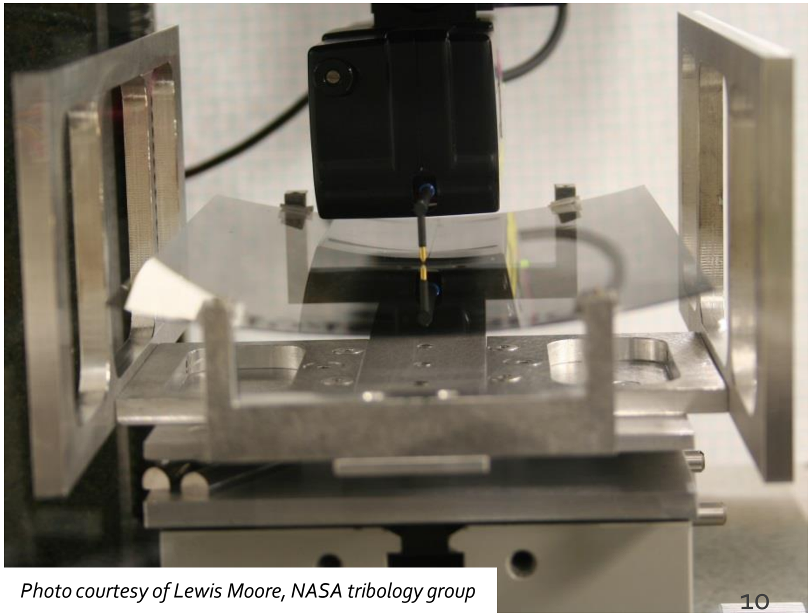


Photo courtesy of Lewis Moore, NASA tribology group

Typically the accuracy of alignment between placements is within 10/20 microns.

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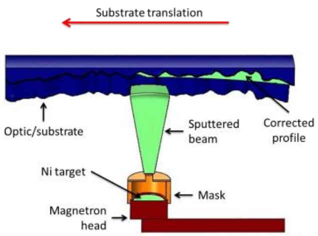
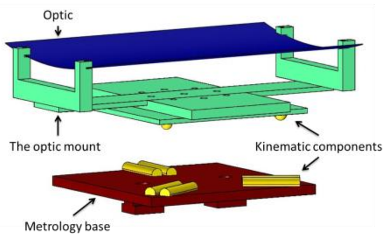
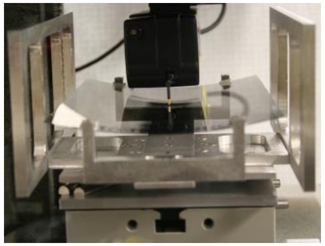
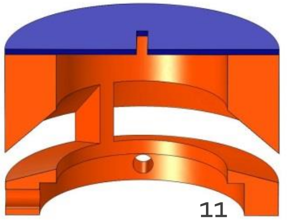




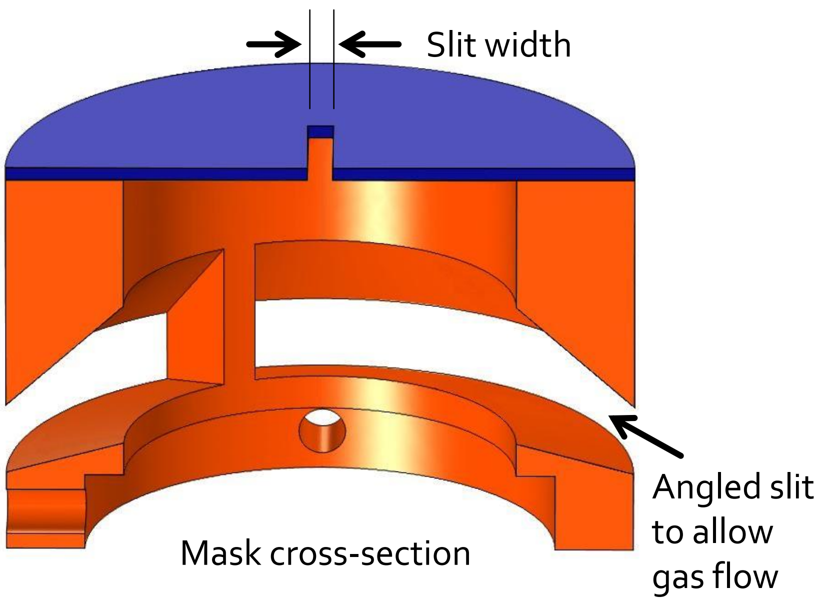



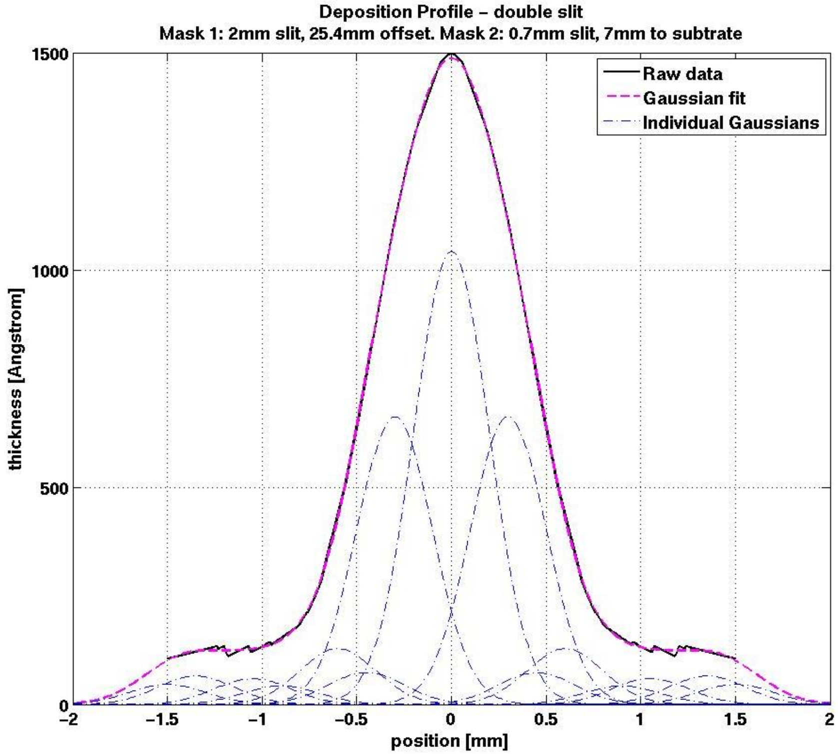



Optimisation – deposition profile

The deposition profile is defined by the width of the slit cut into the mask.

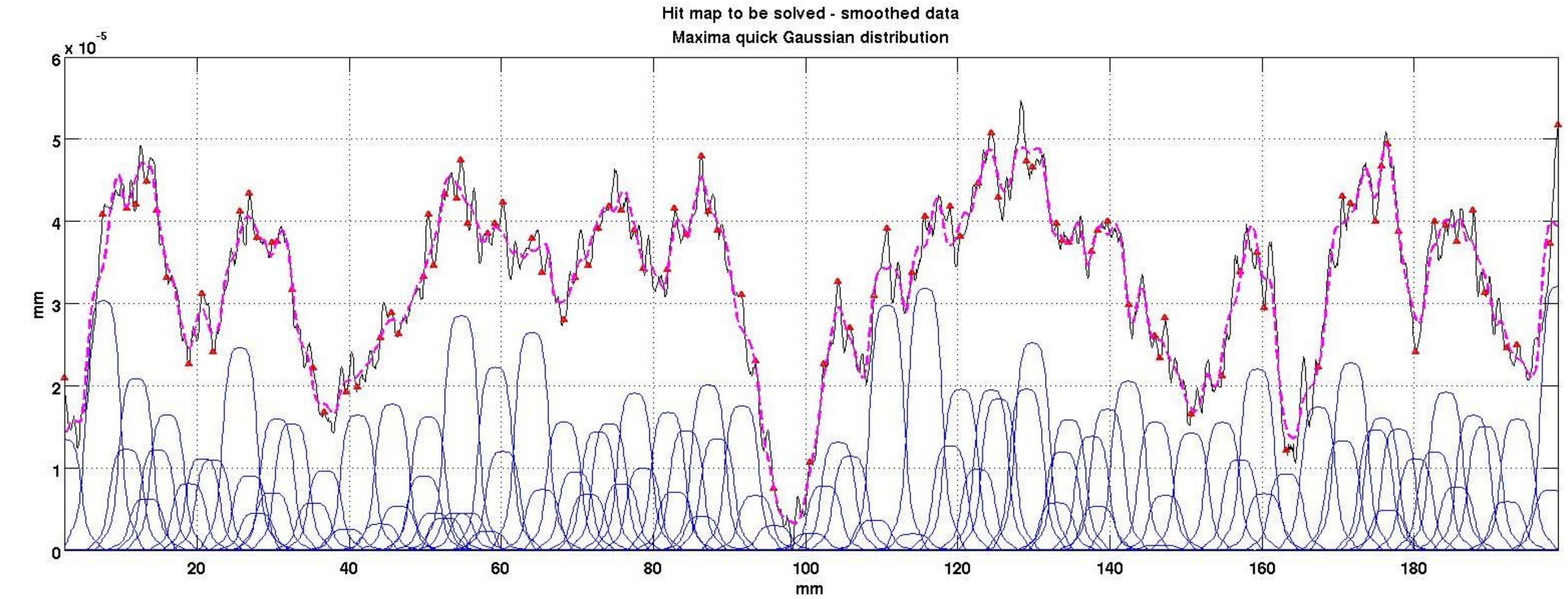
Typical slit widths range from 5mm to 0.5mm depending on the spatial frequency to be corrected.

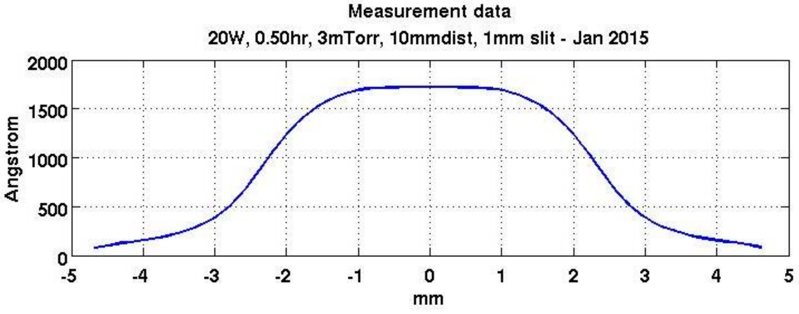




The raw measurement data from a stationary deposition profile is fitted with a number of Gaussians to define a deposition profile function.

Optimisation – surface solution





The deposition functions are located first at the maximas of the peaks and then filled between maximas within a given step size (typically 0.25mm-1mm depending on the width of the deposition function).
Least squares fitting is then used to solve for the metrology data to obtain the 'hitmap'.

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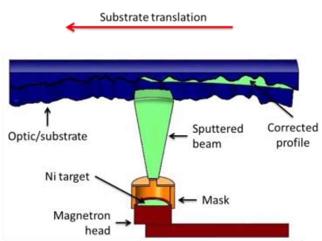
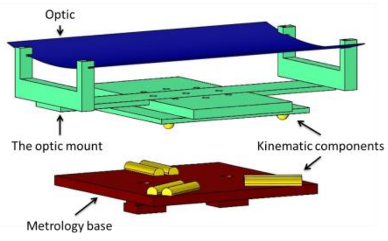
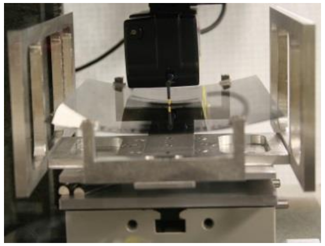
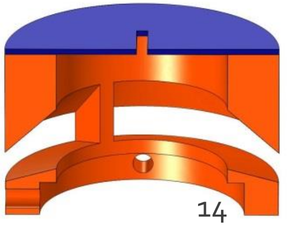


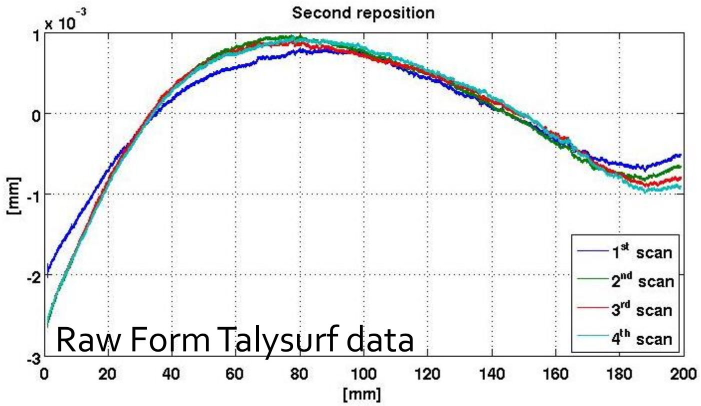


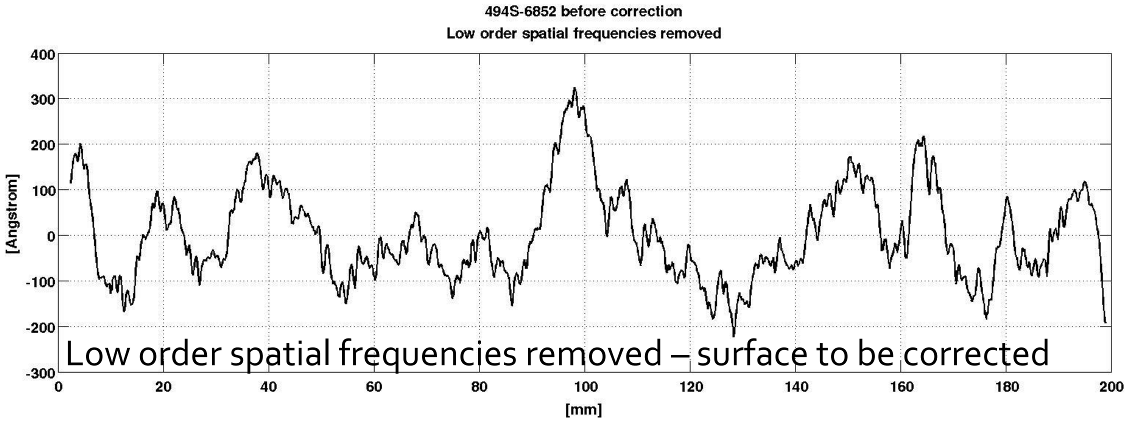




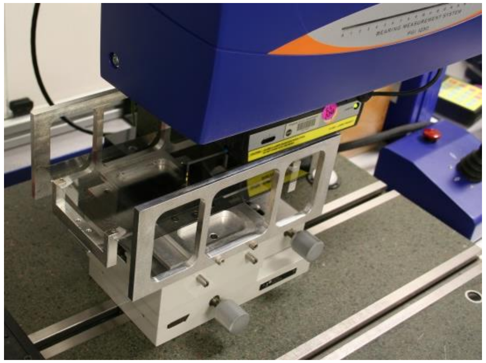
Initial Results - overview

- To date 4 slumped glass optics have been coated via the differential deposition method.
- Different spatial frequencies have been targeted with a variety of deposition functions.
- The low order form of the optic is removed to provide the correction profile.

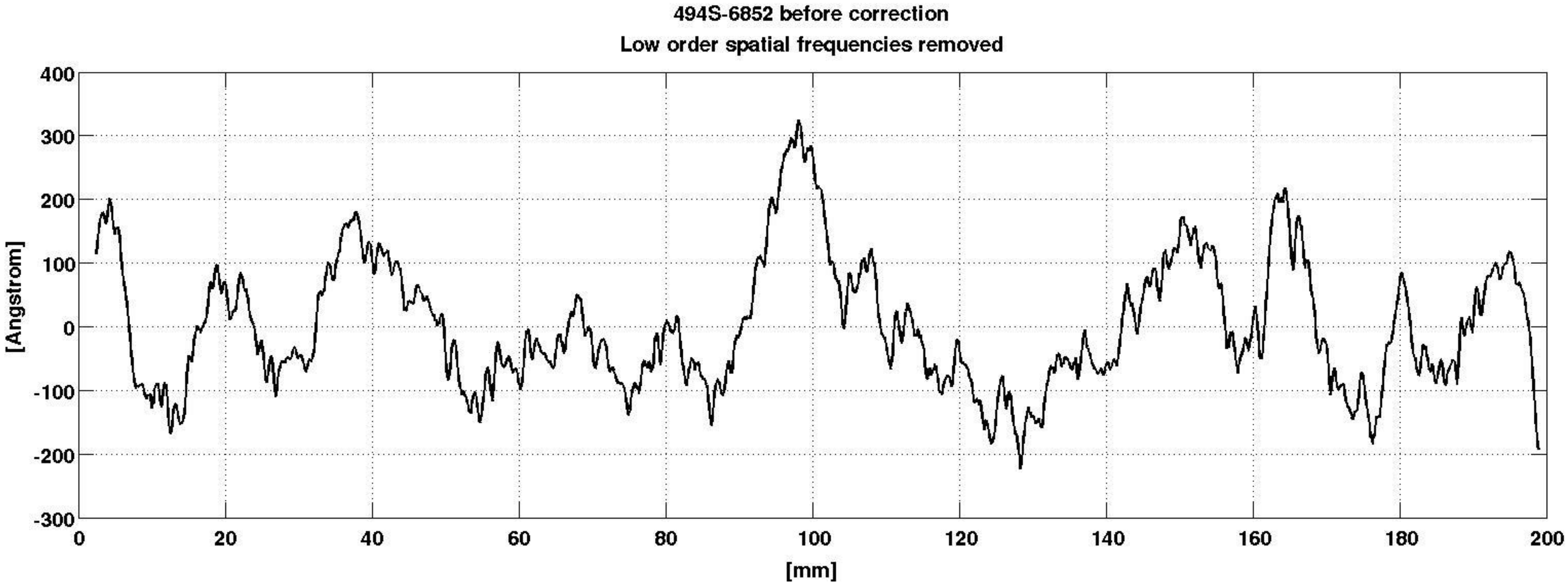


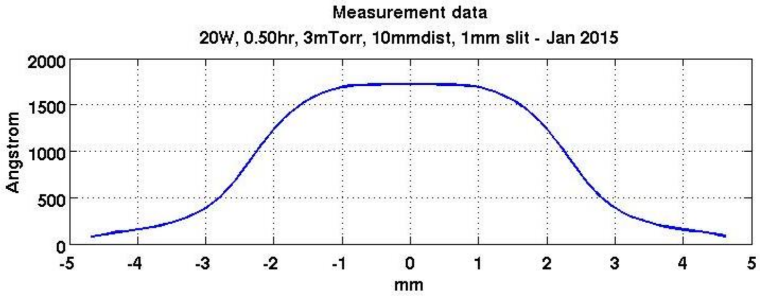


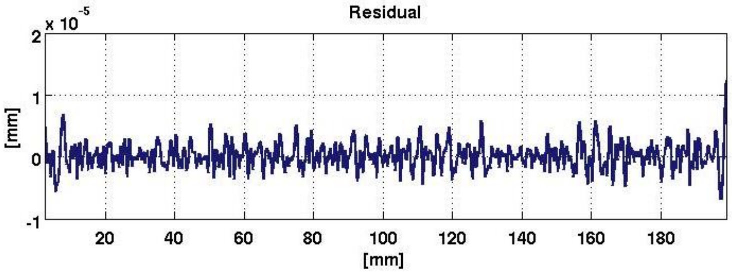
Optic registration	Comments
Optic 1: 494S-6852	Attempted full correction
Optic 2: 489P-2728	3 x Mid frequency correction
Optic 3: 485P-2731	2 x Mid frequency, 1 x High frequency
Optic 4: 485S-2731	2 x Mid frequency corrections



Initial Results – first result

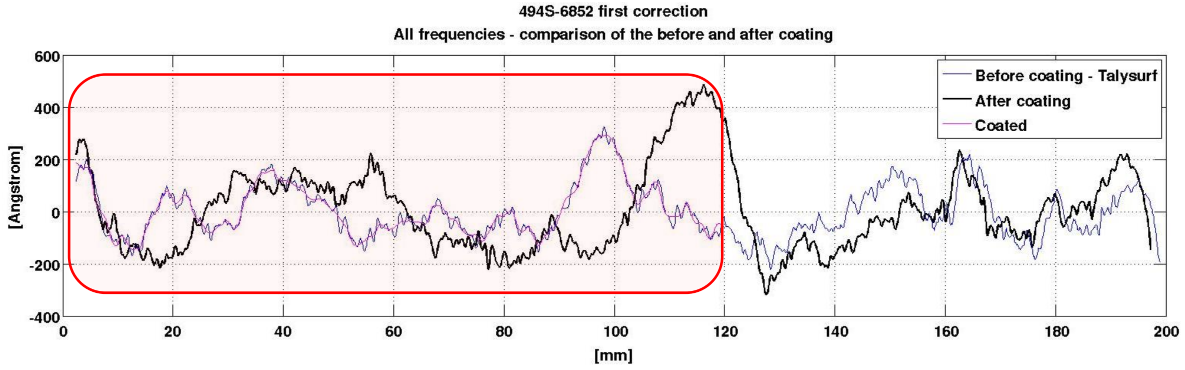


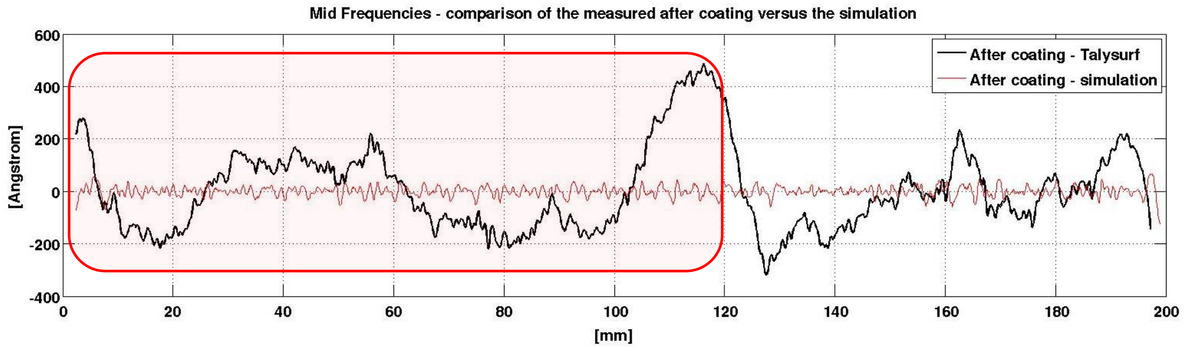




The first optic was corrected using a 1mm slit and targeting all mid frequencies.

Initial Results – first result





The coating only performed up to x = 120mm due to time restrictions.

The after coating profile is clearly worse than the before coating profile and does not resemble the simulation.

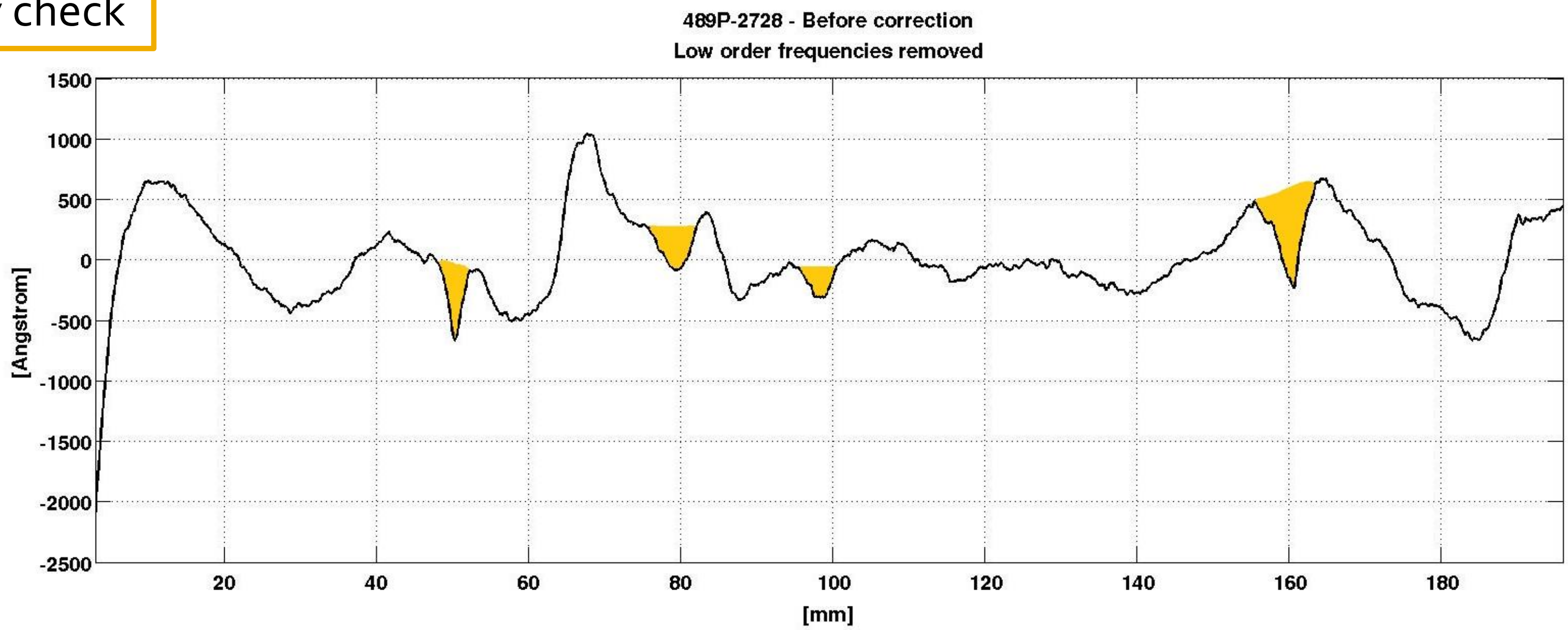
Stress within the deposit was theorised to be the cause.

Lessons learnt

1. A little stress goes a long way, especially compared to the Ni-Co optics, therefore full corrections may not at this point be the way forward.
2. Fiducials on the glass substrate would improve before and after alignment of profiles.

Initial Results – Optic 2 -

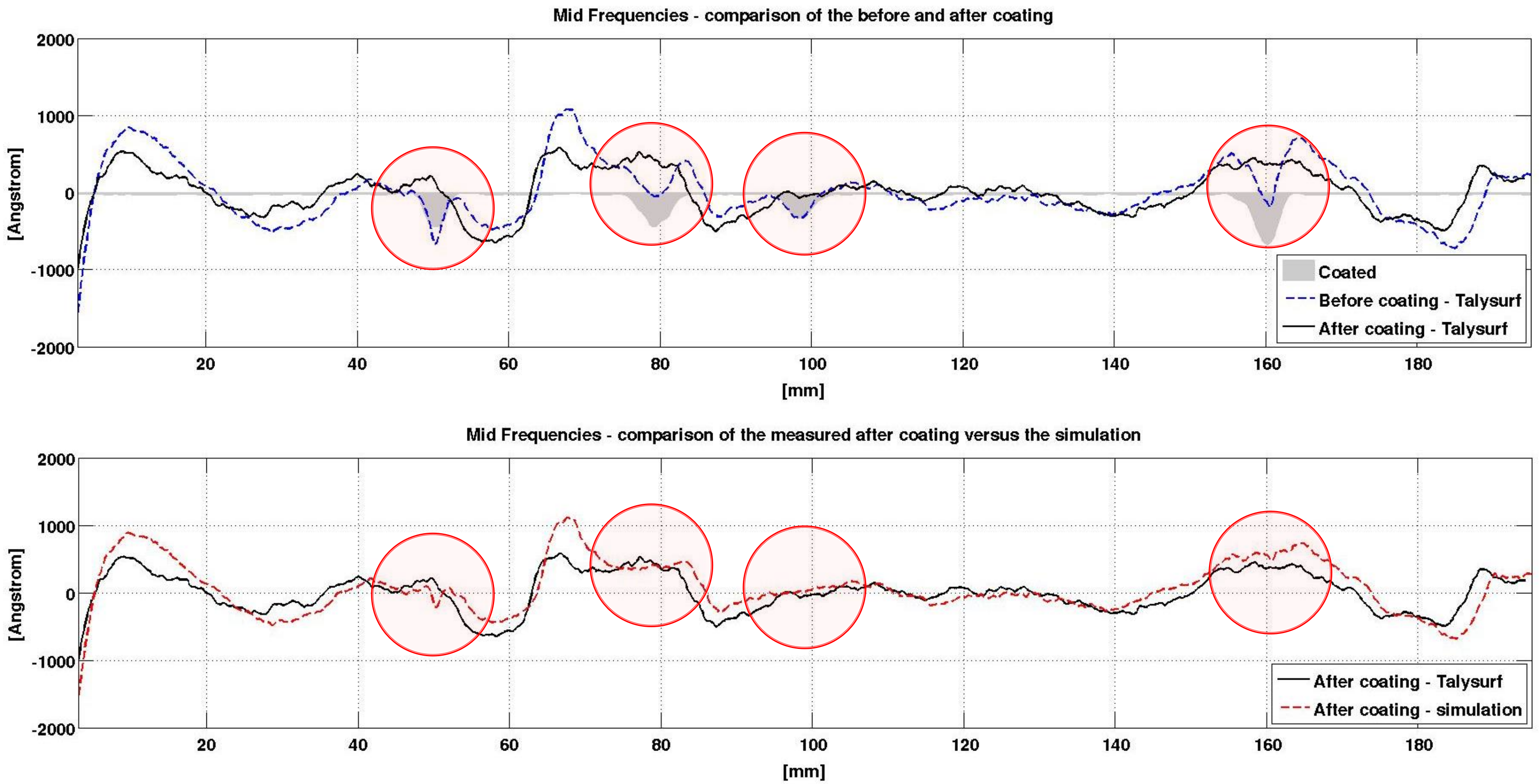
Sanity check



The plan for Optic 2 was to coat 4 distinct troughs in order to confirm the accuracy of the differential deposition method on the slumped glass optics.

4 troughs were selected and targeted for the correction using a 0.5mm slit.

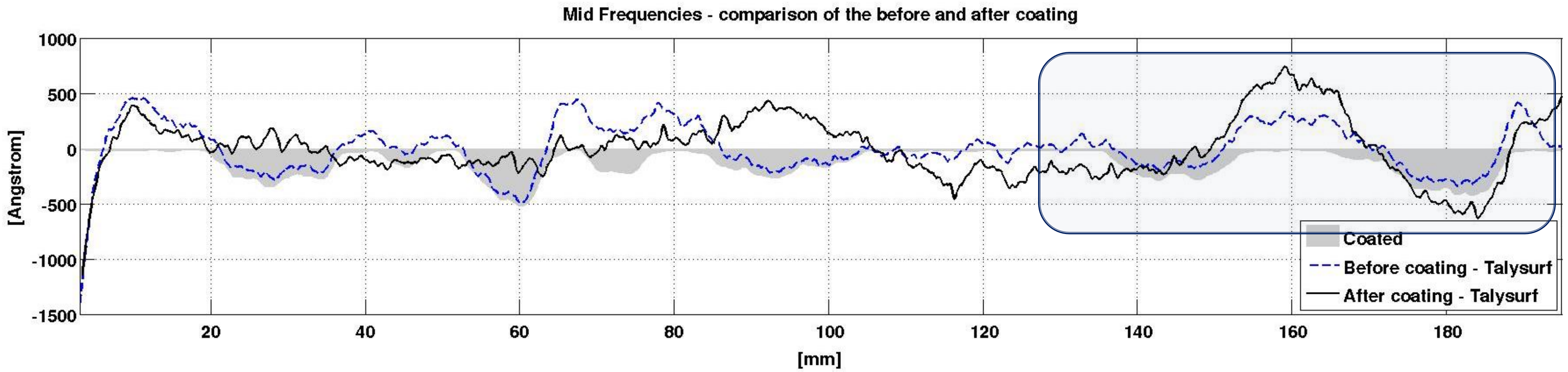
Initial Results – Optic 2, coating 1

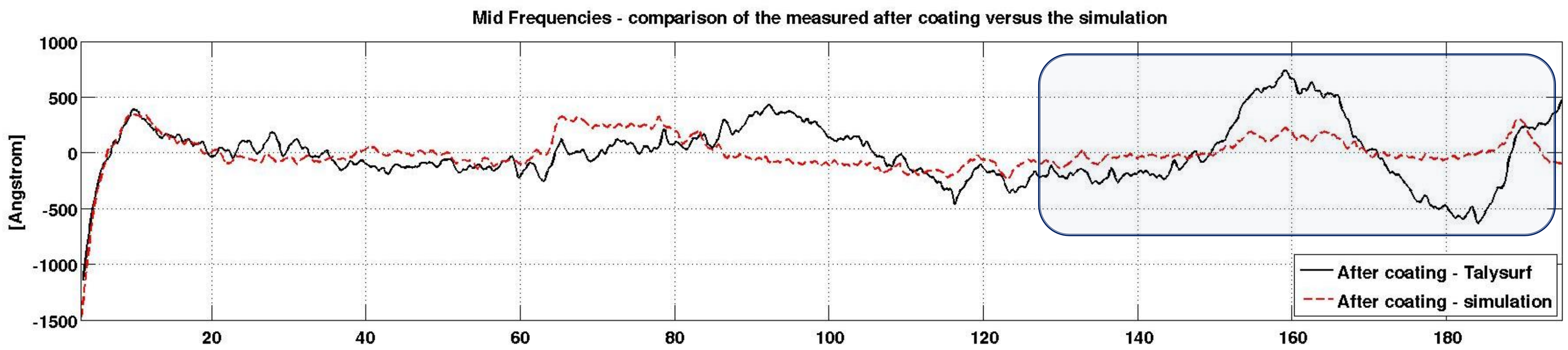


The four troughs were filled accurately using the differential deposition method.

There are some discrepancies when comparing the simulation with the measured data, it is suspected at some of these discrepancies are due to the removal of the kinematic mount from the Form Talysurf stage between coatings.

Initial Results – Optic 2, coating 3





The final coating targeted more areas with the intention to flatten the profile.

The first half of the profile corrected well; however, the second half exhibited a peak and a trough that could not be explained due to the coating. In addition this same artefact was observed in optics 3 and 4.

Initial Results –null correction

Since the null correction had been observed in 3 different optics a few explanations were investigated:

1. **Stress** within the coating? - unlikely as stress would likely affect the entire profile, rather than a localised area, but could stress vary with time? Experimentation suggests that this is not the case.

2. **Mounting**? – is there something about the vertical mount that is causing the bottom of the profile to distort?

3. **Thermal effects**? – it is known that the temperature of the optic and mount does increase during coating. Could a thermal mismatch between the aluminum frame and the glass optic be causing the distortion?

4. A combination of all of the above?

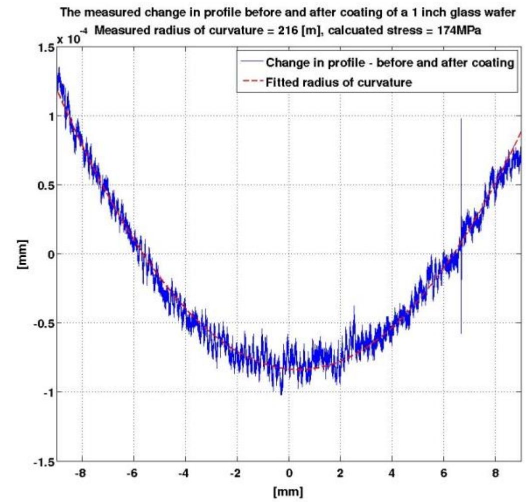
This is current area of investigation.

Initial Results – Stress?

Stress in a thin film can be estimated using Stoney's equation,

$$\sigma_f = \frac{E * h^2}{(6 * (1 - \nu) * roc * t_f)}$$

σ_f = film stress
E = Young's modulus of the substrate
ν = Poisson's ratio of the substrate
roc = measured change in radius of curvature
t_f = film thickness



Borosilicate Glass wafer	Measured stress [MPa]
Wafer 1	119
Wafer 2	175
Wafer 3	172
Wafer 4	248

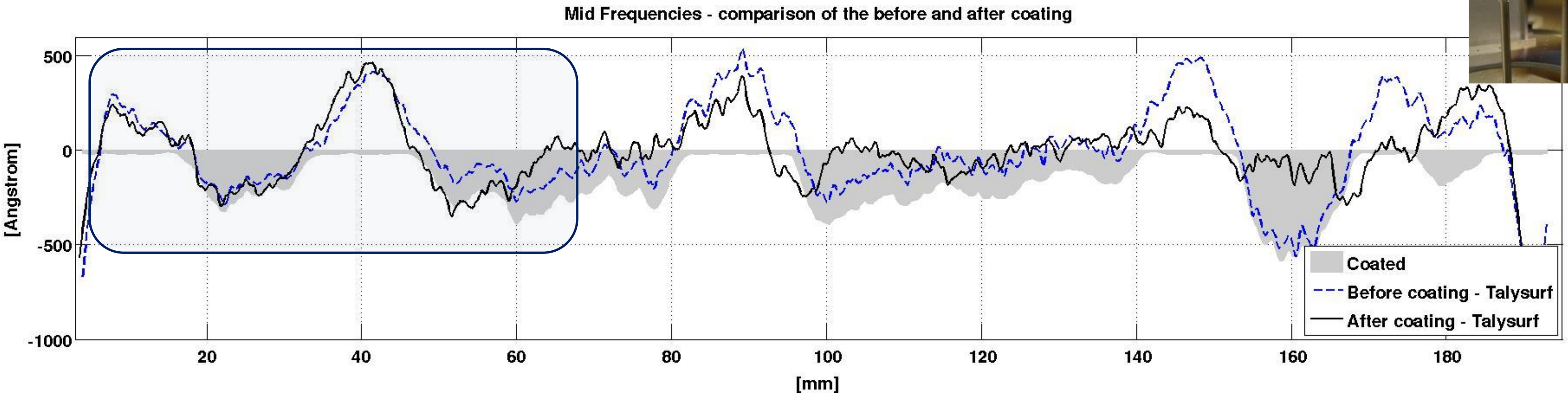
Average measured stress = 179MPa (Tensile)

This is an active area of investigation with several options: -

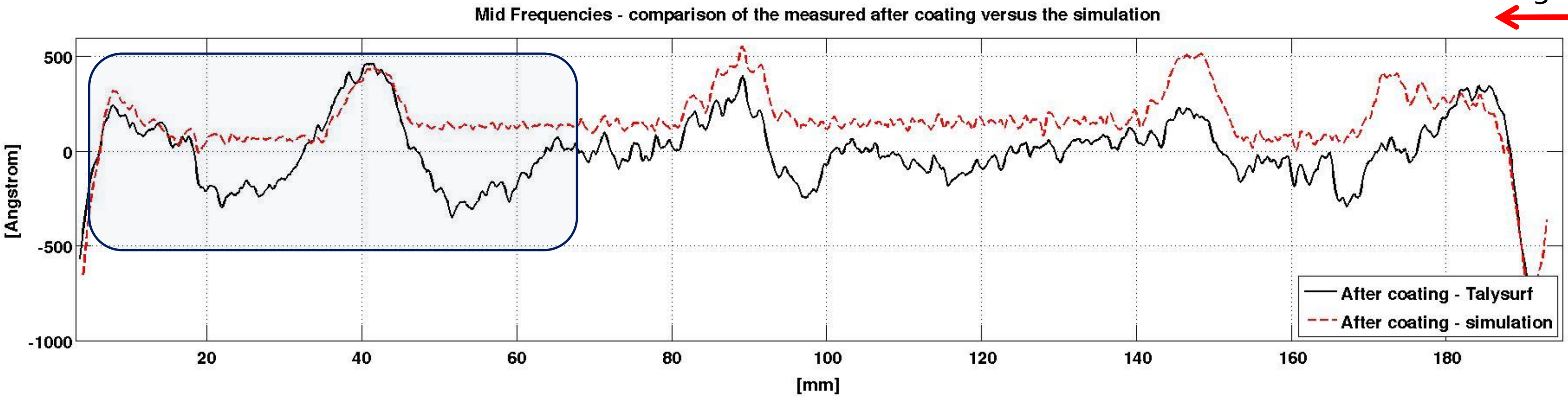
1. Reduce the stress through changing the coating parameters (gas pressure, power etc.)
2. Create an FEA model of the stress to predict its effects.
3. Use the stress to correct the low order spatial frequencies within the surface.

Initial Results – Mounting

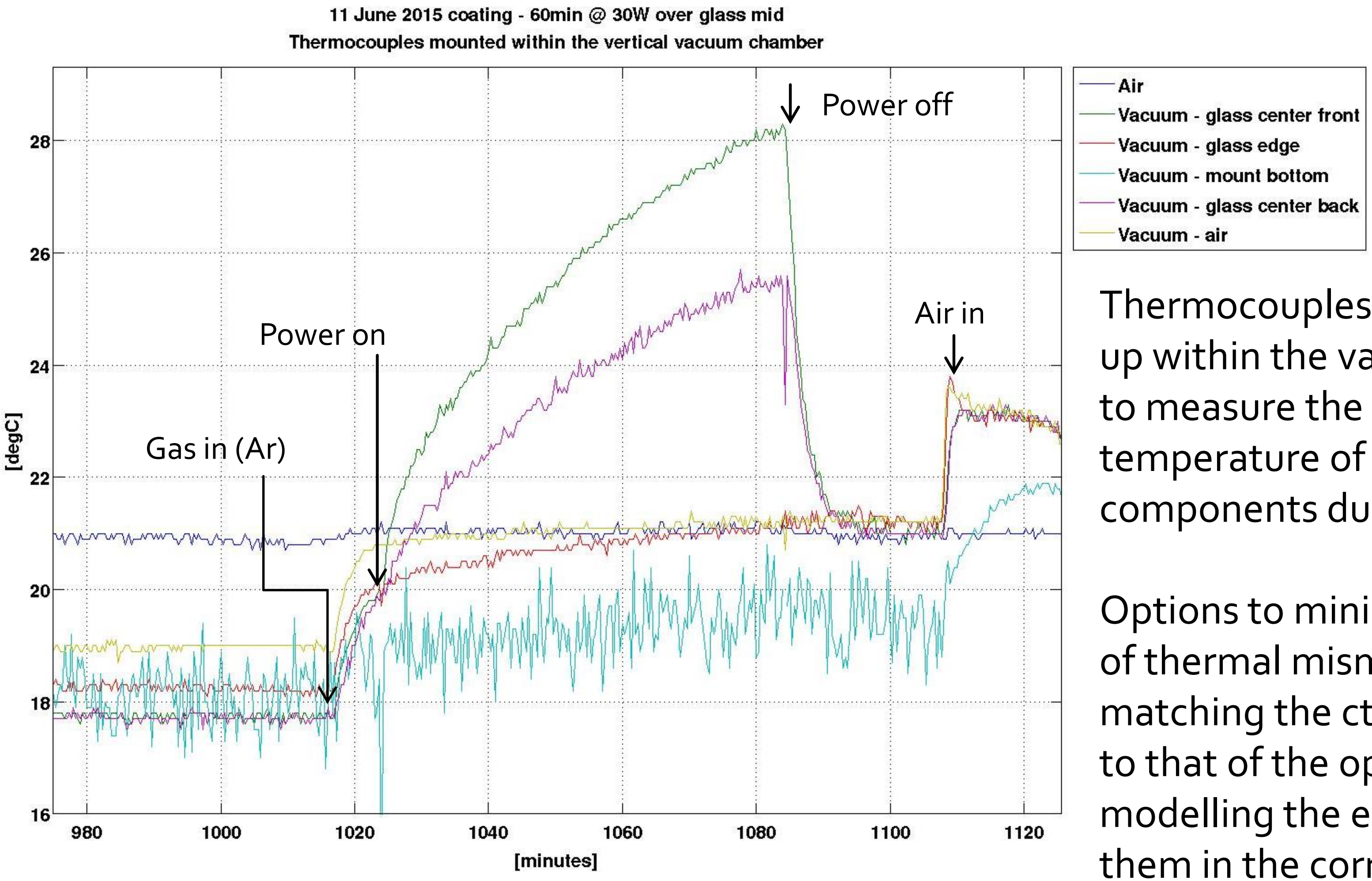
Second, the mount was flipped to reverse the direction of coating to see if there was a mechanical influence. The results indicate that there could be a mechanical effect and this warrants further investigation.



Coating direction



Initial Results - Temperature



Thermocouples have been set up within the vacuum chamber to measure the surface temperature of different components during coating.

Options to minimise the effects of thermal mismatch include: matching the cte of the mount to that of the optic; and modelling the effects to offset them in the correction

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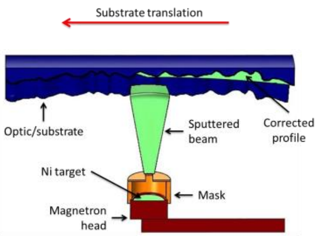
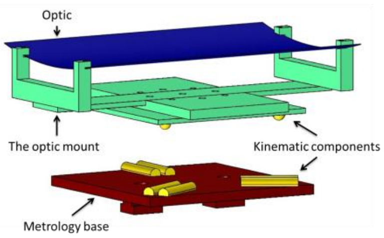
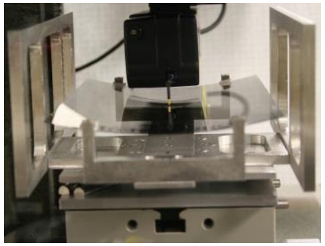
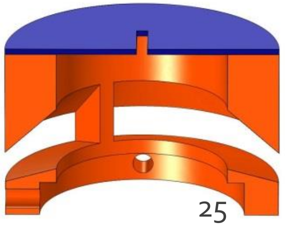








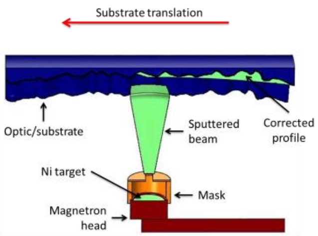
Summary and conclusion

Summary

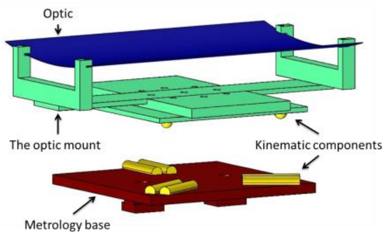
- The vertical chamber for the correction of the slumped glass optics has been presented.
- The difference between the slumped glass and the Ni-Co optics has been identified.
- Initial results have been presented from 6 months of investigation.
- Challenges have been encountered, but direction for future work has also been identified.

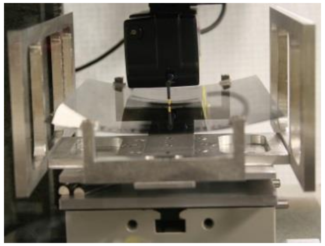
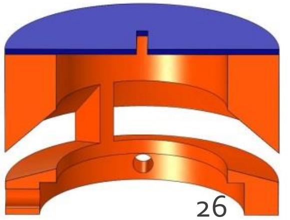
Conclusion

- Slumped glass optics can be corrected to achieve an improvement in resolution through the differential deposition method.
- Factors such as: film stress, mounting mechanics and thermal effects require further investigation.





Acknowledgements

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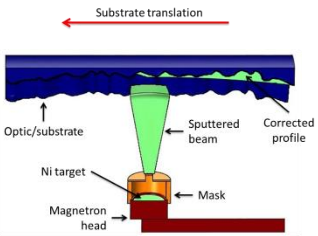
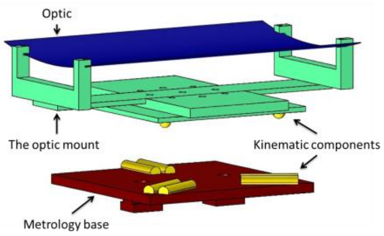
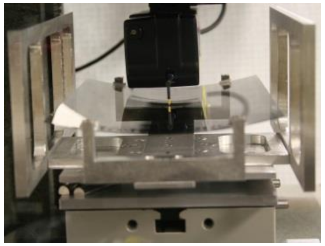
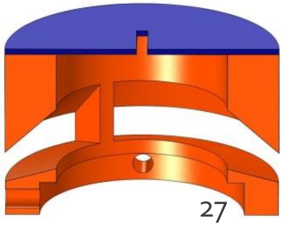
- Chip Moore at the MSFC Tribology Laboratory for use of the metrology equipment.
- Will Zhang at NASA's GSFC for supplying the slumped glass optics for the experiments.
- All those who helped in the construction of the vacuum chambers.
- and the X-ray astronomy group at NASA's MSFC

Thank you for your attention!







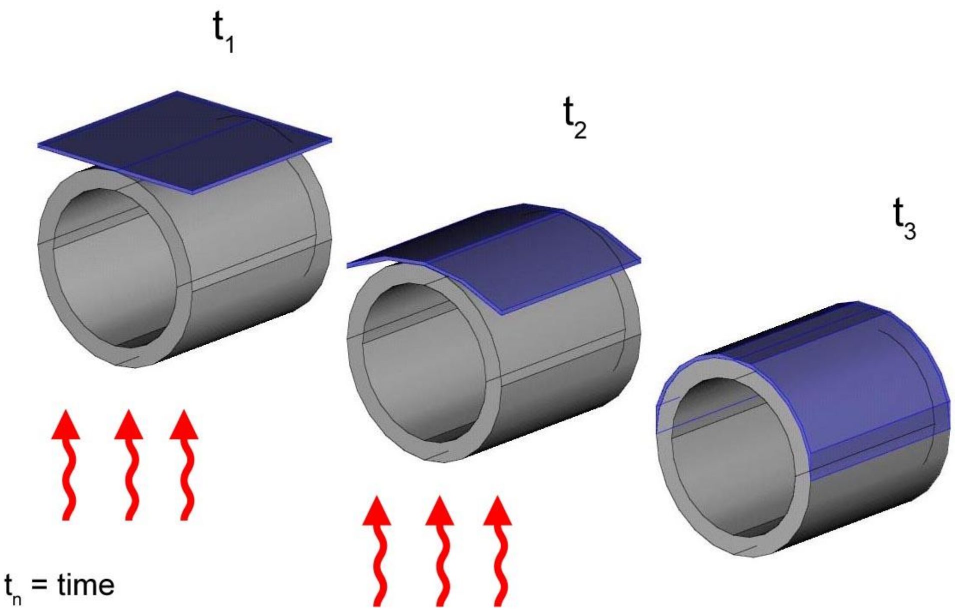


Spare slides

Introduction – segmented glass optics

The slumped glass optics used for differential deposition are those fabricated by NASA's Goddard Space Flight Center (GSFC).

Glass: Schott D263
30° segments, ~200mm long, ~400μm thick.



Metrology – Form Talysurf

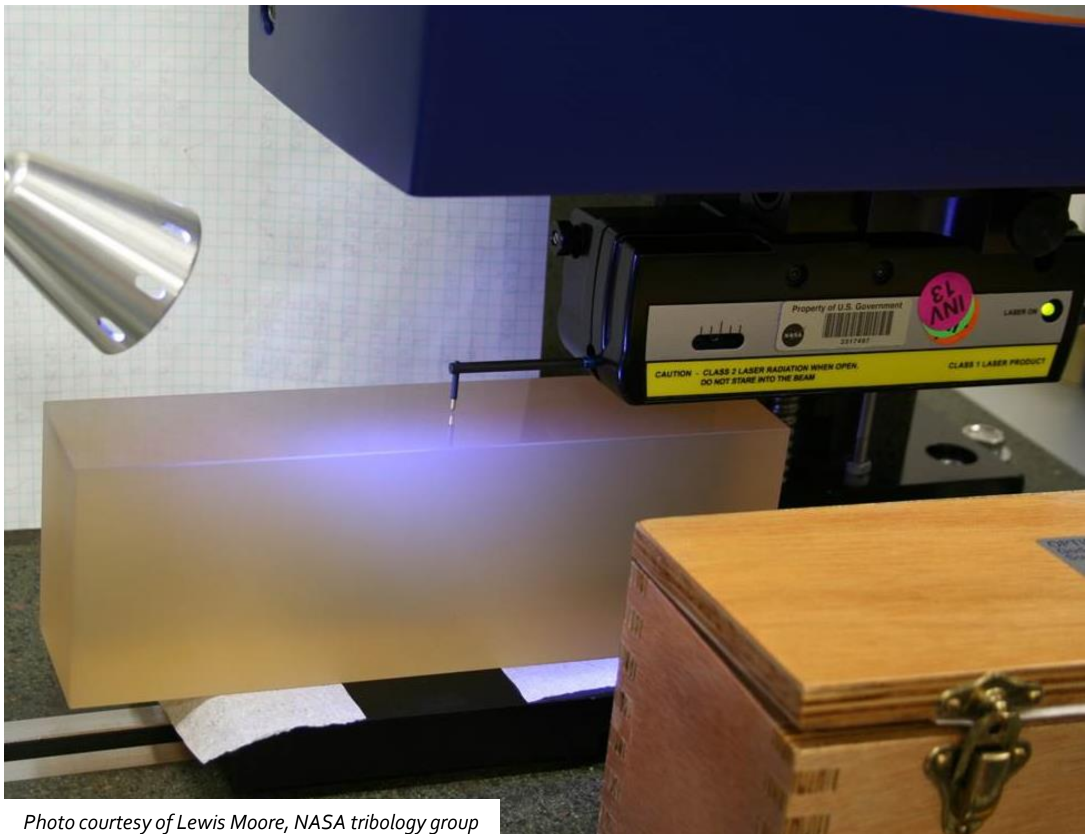


Photo courtesy of Lewis Moore, NASA tribology group

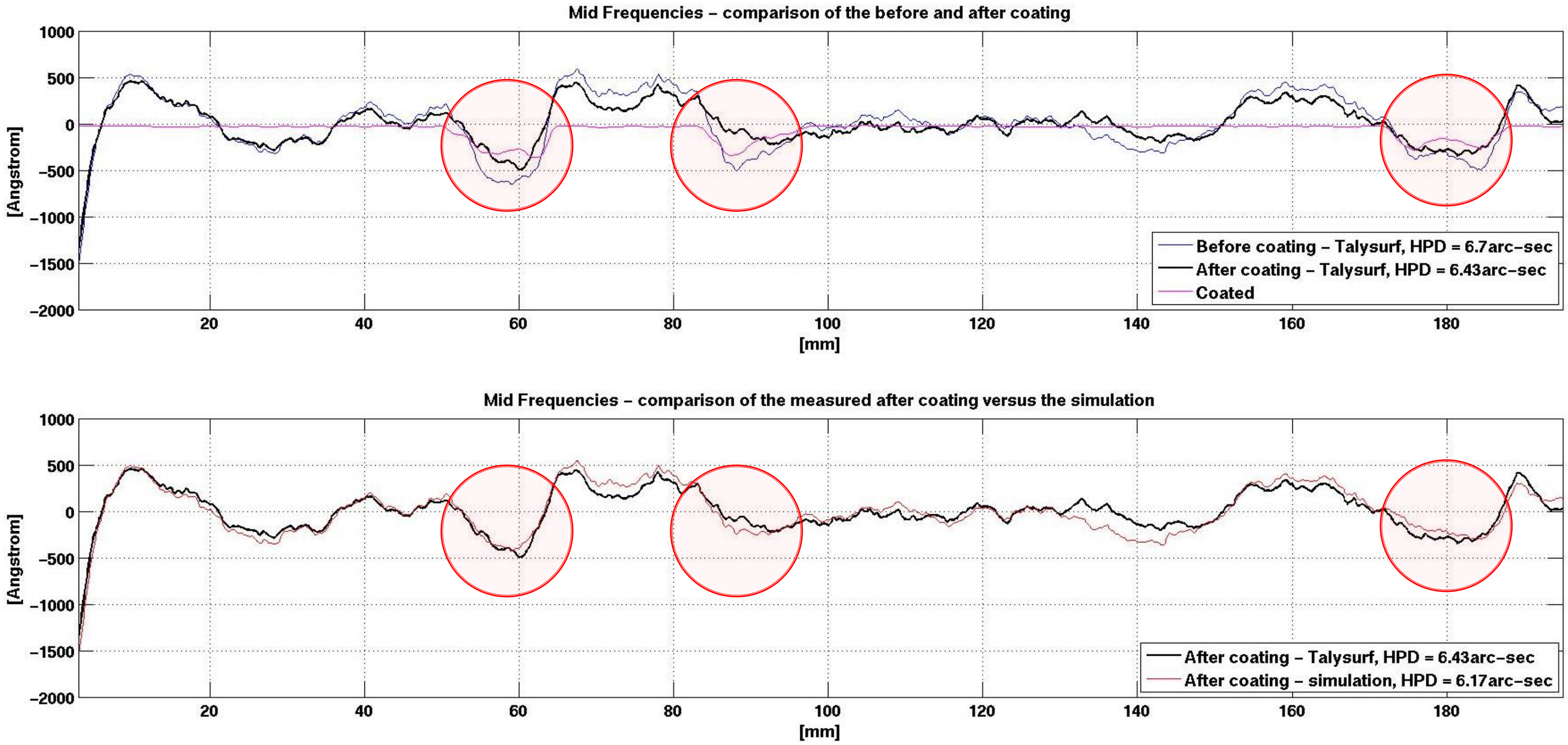
A Taylor Hobson Form Talysurf is used for axial line profile measurements of the slumped glass optics.

A 2µm diamond tip is used to gain 0.8nm resolution in the measurements

The Form Talysurf has a measurement range of 200mm which is the approximate length of the optics

Calibration data is used to correct for distortions inherent within the profiler

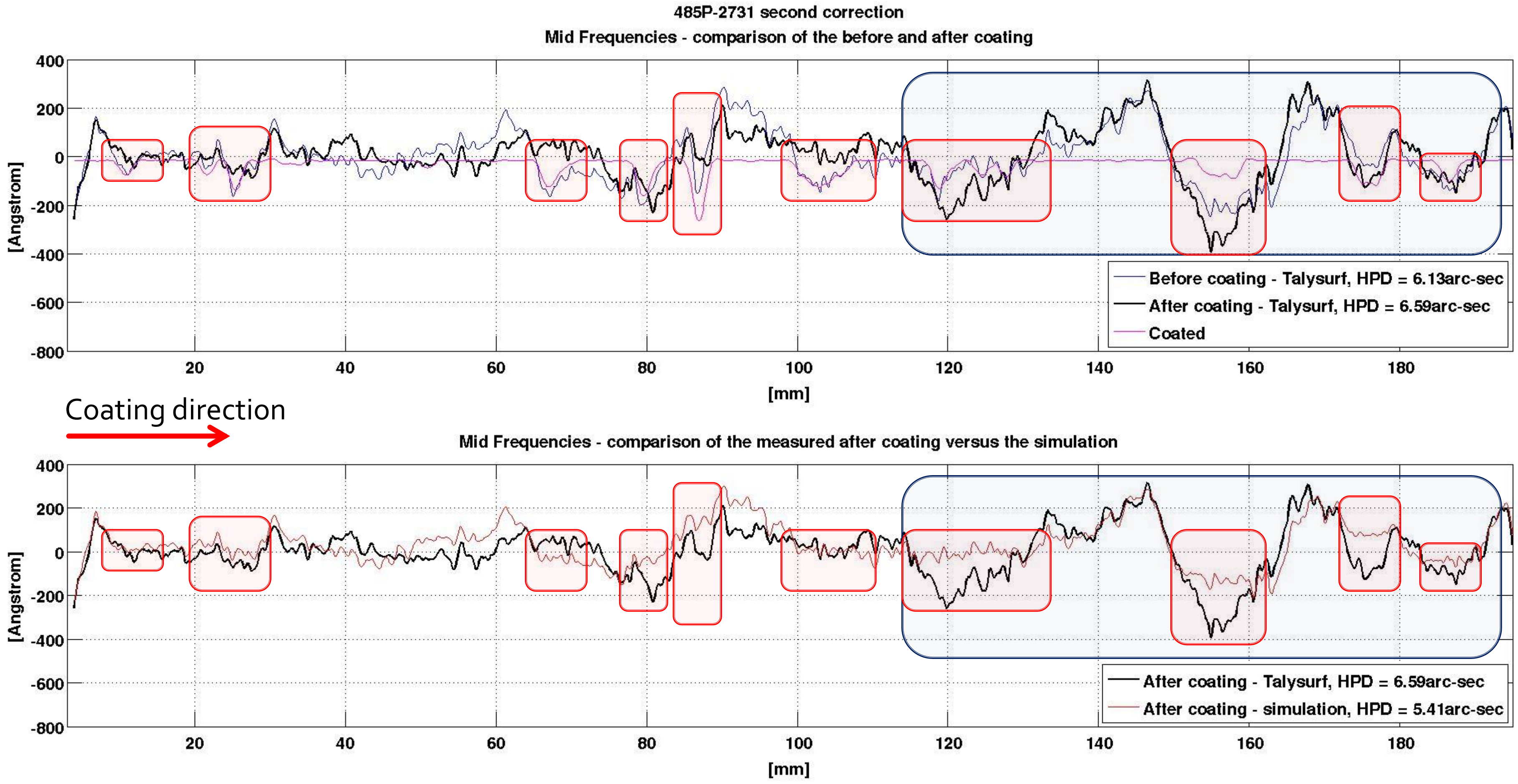
Initial Results – Optic 2, coating 2



In the second correction 3 areas were targeted in order to 'smooth out' the profile.

Although the improve is slight, the measured data compares well to the simulation. In this case the kinematic mount had not been moved from the previous measurement and therefore it provided ideal measurement conditions.

Initial Results - Optic 3, coating 2



Experimentation on Optic 3 (and Optic 4) highlighted the same problem in the second half of the profile.

Initial Results – Mounting 1

First, coating just the second half of the optic was investigated to see if a cumulative thermal-stress effect built up over time. The results indicated that this was not the case.