

# Large Metal Mirrors for Atmospheric Telescopes

Guoyu Yu<sup>1</sup>, David Walker<sup>1,2,3</sup>, Hongyu Li<sup>1</sup>, Abdullah Shahjalal<sup>1</sup> and Trevor Walker<sup>4</sup>

<sup>1</sup>SciTech Daresbury National Science & Innovation Campus, U-of-Huddersfield Laboratory for Ultra Precision Surfaces, G6, TechSpace One, Keckwick Lane, Daresbury, WA4 4AB, UK

<sup>2</sup>Zeeko Ltd, Coalville, Leicestershire, LE67 3FW, UK

<sup>3</sup>University College London, Dpt Physics and Astronomy, Gower St, London, WC1E 6BT, UK

<sup>4</sup>Thin Metal Films Ltd, Basingstoke, Hants, RG24 8UG, UK

**Abstract.** We are developing technologies in processing and metrology to fabricate a 1.4-meter aperture, aspherical surface Aluminium prototype mirror for Cherenkov Telescope Array. The aim is to fast process these large aperture mirrors at low cost. The technical development will ensure the high specifications on the surface quality. Different metrology methods including Swinging Arm Profilometry (SAP) and phase measuring deflectometry (PMD) are being developed. Recent results have shown very promising progress on these developments. We have excellent record in transferring our research results into industry. These cutting-edge technologies will be transferred to our industry partner to explore further developments.

## 1 Background

The Cherenkov Telescope Array (CTA) is proposed to be the next generation ground-based observatory for gamma-ray detection at very high energies [1]. The CTA will be the world's largest and most sensitive gamma-ray telescopes. The CTA consists of around 100 telescopes of 4m to 23m primary mirror with segment mirrors.

At the Laboratory for Ultra-Precision Surface, University of Huddersfield, we have long established record in large optical mirror processing. The research and development of European Extremely Large Telescope (E-ELT) [2] that has been successfully delivered is a very challenging project and has similar objective as that of CTA. The R&D on metrology and processing is reported.

## 2 Research and Development

The first challenge addressed was the metrology of large aperture aspherical surfaces. To facilitate the processing development, a swing arm profilometer (SAP) was developed to enable accurate profile measuring and removal rate calibration. Deflectometry is also under development to enable 3D surface metrology. A further funding is secured to procure a MicroFinish Topographer for surface texture measurement.

### 2.1 Profilometer

SAP have been developed for different projects [3] having the advantage that the base radius can be cancelled out by setting an appropriate tilting angle of the arm. We have adopted an inverse design in that the component will be

tilted instead of the arm. This design suits our development by avoiding the adjustment of delicate probe and arm. Assuming that  $R$  is the workpiece's radius of curvature and  $l$  the effective arm length, shown in Fig. 1., the tilt angle can be calculated using the equation:

$$\theta = \sin^{-1} \left( \frac{l}{R} \right) \quad (1)$$

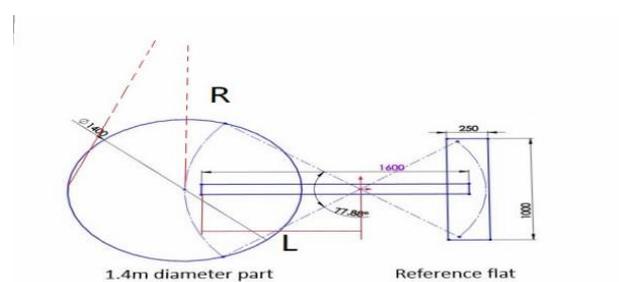


Fig. 1. Design of SAP for segment mirror development.

When implementing this design, (Fig. 2) a tilt stage is employed to provide necessary tilting of the workpiece.



Fig. 2. SAP measuring a full-size mirror.

\* Corresponding author: [g.yu@hud.ac.uk](mailto:g.yu@hud.ac.uk)

## 2.2 Deflectometry

Deflectometry have been reported to measure large aperture optics [4]. It has the advantage of large dynamic range, flexibility and high accuracy and is especially suitable for the floor level surface metrology. With this technology, a CGH can be avoided for measuring aspherical surfaces so that it is very cost effective. The calibration process is the key step to ensure the accuracy and stereo calibration have been adopted.

## 2.3 Processing

From previous development work in E-ELT project, we have gained valuable knowledge in process development for such large projects. It is not only to meet the high specifications, but also be able to process the mirrors fast and cost-effectively. Different pads and abrasive grades, shown in Fig. 3., can be used at different process stages to achieve varied removal rates and surface texture. Optimisation is performed to ensure the smooth transition of the process stages and to achieve final specifications.

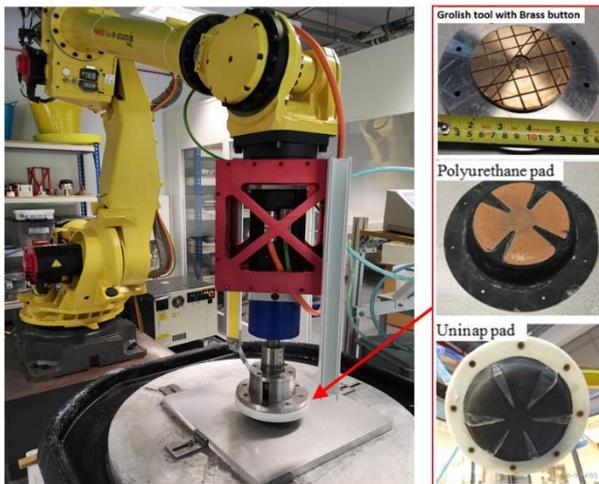


Fig. 3. Process development and optimisation.

The process development is on a smaller 400mm square sample with the same material. A narrow engraving on the surface is used to calibrate the removal rate of each step with the SAP (Fig. 4 and Fig. 5). Different combination of process steps can be optimised and the total worktime is calculated for the full-size mirror. The surface texture is measured with a MicroFinish Topographer.

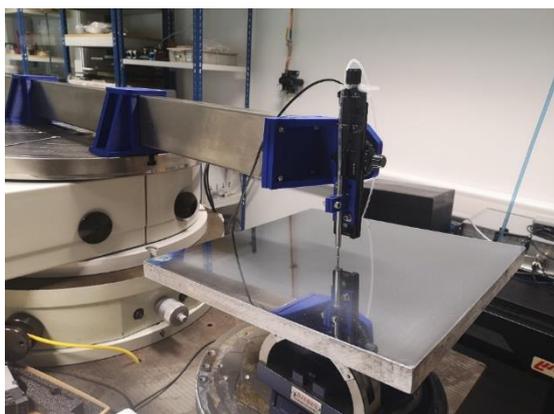


Fig. 4. Metrology during process development.

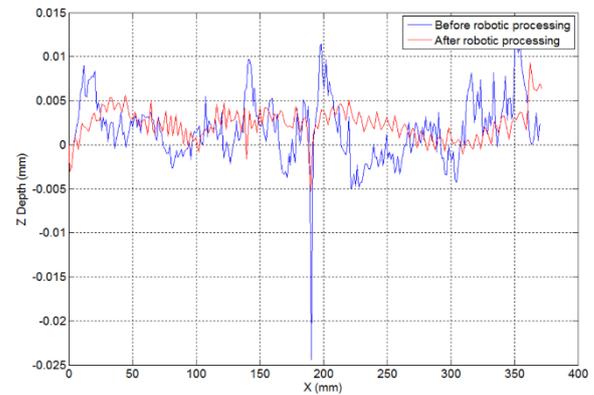


Fig. 5. Calibration of material removal.

## 3 Results and Discussion

During the process development, Kemet International Ltd, has collaborated on the polishing slurry development. The newly developed slurries have been adopted to compare and superior results on surface texture have been achieved of Sa 4.98nm, as shown in Fig. 6.



Fig. 6. Processing results with different slurry.

The research and development have been progressed and achieved the defined specification for the full-size mirror processing. The total processing time calculated for this mirror is 220 hours to achieve the final specification.

## References

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