Open-source Data Analysis and Visualization Software Platform

Measurement of Freeform Objects with IR Deflectometery

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Motivation

What are we doing?

Testing and optimizing a long IR deflectometery system for measuring freeform objects with a rough surface.

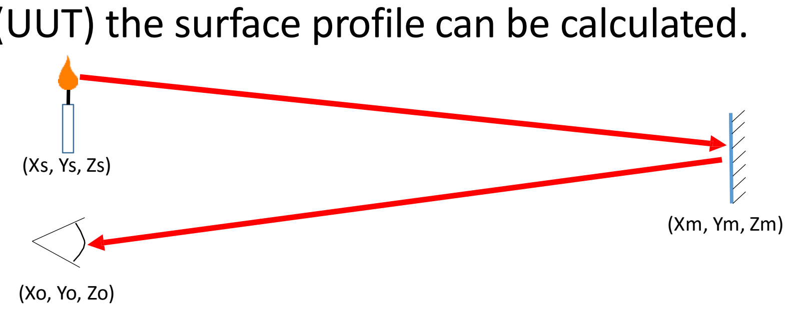
Why do it?

Current options for accurate surface metrology of non-spectrally reflective surfaces were previously extremely limited and expensive. IR deflectometery provides accurate, high dynamic range, rapid metrology method for rough surface optics, as well as a wide range of previously challenging to measure materials.

Background

Deflectometery

By taking a known source and measuring rays deflected off of a unit under test (UUT) the surface profile can be calculated.



This can be thought of as being in a room with a mirror at a known position. If you move a candle around the room, at some point the light will hit the mirror and reflect into your eyes. Knowing the positions of you, the mirror, and the candle, you can calculate the local slope of the mirror. By doing this for all points on the mirror, the surface slope map can be calculated.

Software Package

The IR deflectometery software package runs on the SAGUARO platform. Benefits include

- Modular design
- Standardized formats
- Cross platform support

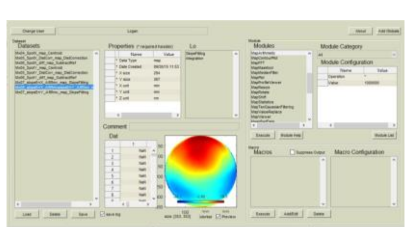


Figure 1, SAGUARO platform processing SLOTS data.

A raytrace is performed to calculate the surface slope. This is done by communicating with a raytrace program. An idealized system is made and the spot diagram of Real vs. Ideal is compared to find slope map differences.

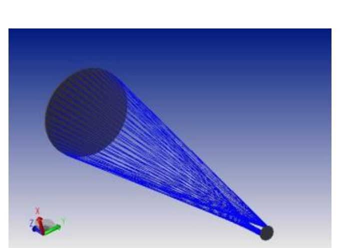


Figure 2, Zemax system layout of DKIST Primary using SLOTS setup.

Design

IR Source

The IR deflectometer utilizes a scanning IR source, which emits from roughly 7-14 microns. In the visible region there are a multitude of options for displays. This is not the case for IR. To create an ideal source, we used a heated tungsten ribbon, which approximates a rectangular IR source.

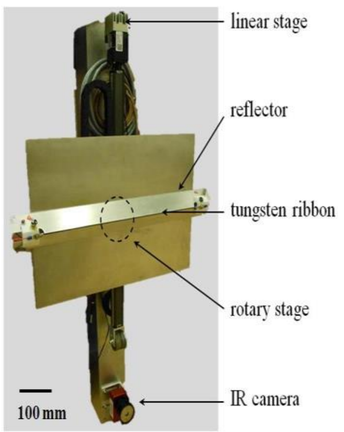


Figure 3, SLOTS system layout. [1]

Grinding Phase vs. Polishing

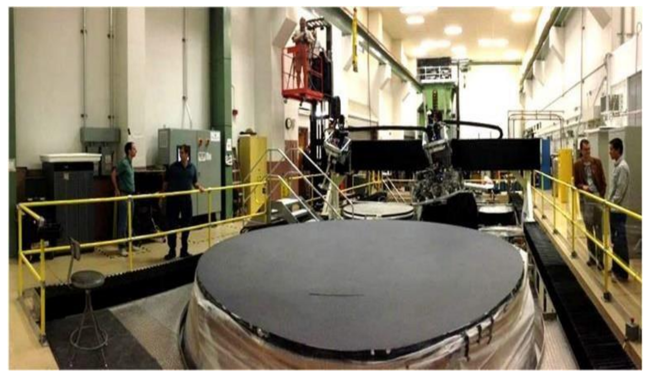


Figure 4, DKIST Primary during rough grinding phase [2]

Main methods to measure rough surface optics were **IR inteferometery** , which requires expensive null optics, or **Laser tracker** measurements, which have low sampling rates and is tedious.

Alternatively, the surface can be polished, measured, and figured in the polishing phase, allowing for the use of traditional metrology methods.

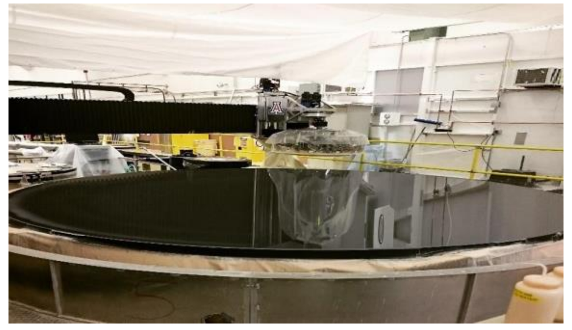


Figure 5, DKIST Primary during fine grinding phase. Surface is spectrally reflective.

It is **1000x faster** to remove surface errors in the grinding phase than by polishing. It would take **2 years** to polish out an error that only takes **1 week** of grinding. IR Deflectometery allows us to obtain rapid, high accuracy, high dynamic range surface maps at low cost, letting us make huge strides in the surface profile of an optic during the grinding phase.

References

[1] Su, T. (2014). *Asphercial metrology for non-specular surfaces with the scanning long-wave optical test system*. Tucson, Arizona: University of Arizona.

[2] D. Kim, T. Su, P. Su, C. Oh, L. Graves, J. Burge (2015) Accurate and rapid IR metrology for the manufacture of freeform optics. *SPIE Newsroom*. DOI: 10.1117/2.1201506.006015

[3] Su, T., Wang, S., Parks, R. E., Su, P., & Burge, J. H. (2013). Measuring rough optical surfaces using scanning long-wave optical test system. 1. principle and implementation. *Applied Optics, 52*(29), 7117.

Acknowledgments

This material is partly based on work performed for DKIST. DKIST is managed by the National Solar Observatory, which is operated by the Association of Universities for Research in Astronomy Inc. under a cooperative agreement with the National Science Foundation.

Also, this material is based in part upon work performed for the Post-processing of Freeform Optics project supported by the Korea Basic Science Institute.

SAGUARO based SCOTS and IR SCOTS research is funded by the II-VI Foundation Block grant.

Results

DKIST Primary

SLOTS, an in house IR deflectometery system built by Dr. Tianquan Su, successfully provided accurate surface maps of the DKIST primary mirror. This is a 4.2 m off axis parabola. As the wire scanned the reflected shape could be observes, as shown to the right.

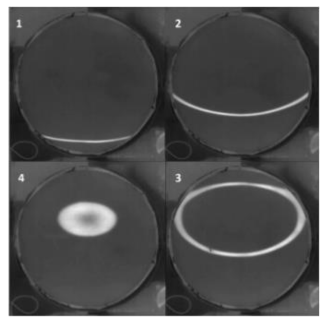


Figure 6, DKIST Primary during SLOTS measurement [2]

Convergence Rate

The DKIST surface error was able to converge from **110 µm PV error to 37 µm in 97 hours**.

Total runtime required was 97 hours. Compare this to the required polishing time for the same convergence, 9700 hours.

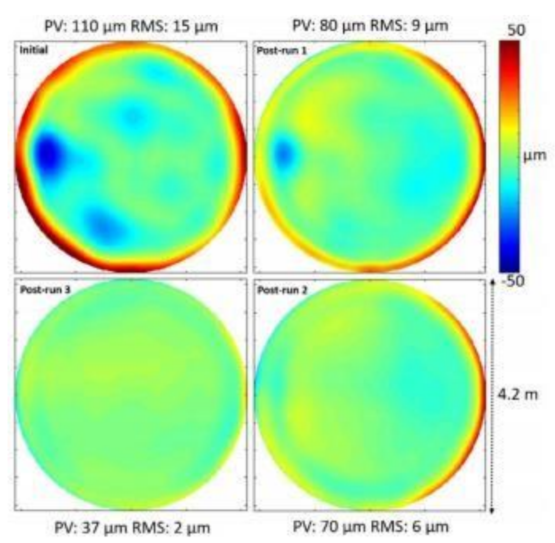


Figure 7, DKIST surface maps obtained by SLOTS during consecutive grindings [2]

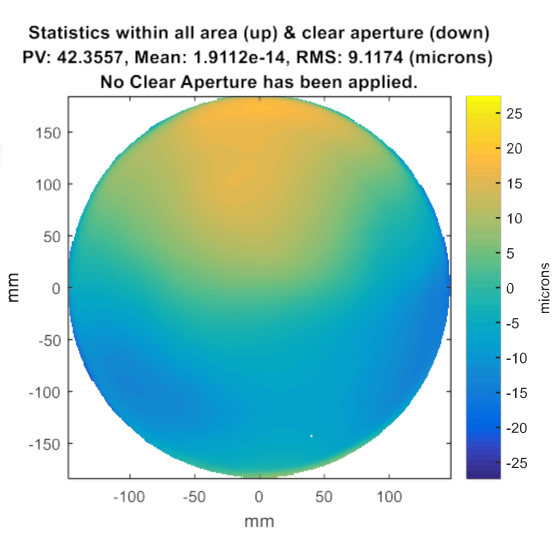


Figure 8, Surface map obtained by SLOTS. Output from the SAGUARO processing platform.

Next Steps

New materials and surfaces are being investigated for SLOTS ability to provide accurate surface measurements. These include:

- Dynamic Measurements of Deforming Object
- Machined Parts
- IR Materials
- 3D Printed Parts

A machined surface comparator was recently successfully measured using SLOTS, as seen to the right. This opens up the scope of applications.

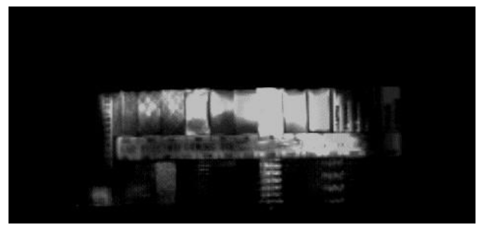


Figure 9, Image of surface finish comparator illuminated by IR deflectometery system