Agile Deflectometry

Randy C. Brost, PhD*, Braden Smith, and Felicia Brimigion

Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, USA

* Corresponding author: rcbrost@sandia.gov

1. Introduction

Concentrating solar power (CSP) mirrors must have high optical accuracy to achieve high solar concentration. This includes accurate mirror surfaces as well as accurate mirror-to-mirror alignment in multi-faceted heliostats. The primary optical parameter controlling accurate solar reflection of a single or multi-facet reflector is surface slope, or the direction of the mirror surface normal at each point on the mirror. Deflectometry is an optical measurement technique which can produce high-resolution maps of surface slope across a CSP mirror facet [1] or a multi-facet collector [2]. Deflectometry has been demonstrated *in situ* outdoors [3], and is even available as a commercial product [4].

Figure 1 shows an example measurement produced by Sandia's deflectometry system, named SOFAST. For this prototype mirror, the measured *y* slope error and curvature reveal deformations in the mirror which are due to structural components on the mirror backside that "print through" to the mirror surface, thus reducing CSP performance. This type of diagnostic information is very useful during the design/prototyping phase of CSP mirrors.

In this presentation we will describe improvements to Sandia's deflectometry system, SOFAST/AIMFAST, to make it flexible and easy to use across a wide range of applications. We have improved SOFAST's documentation, extensibility, traceability, and analysis capabilities, and decoupled data acquisition and analysis to support both prototyping and factory automation. To improve the user experience when installing SOFAST, we have implemented CAD layout tools which enable interactive layout of SOFAST components, including automatic reflection visualization. Figure 2 shows two example configurations to measure a given mirror, comparing a normal and compressed configuration requiring less space. We plan to complete companion software which will compute a configuration-specific sensitivity analysis similar to [5], but customized for each new configuration. To further ease deployment of SOFAST to new situations, we have streamlined the calibration process, including automating the projector screen calibration shown in Figure 3. We are also developing methods of checking setup accuracy using ground-truth standards.

This improved flexibility enables new deflectometry applications. Examples we are currently pursuing include combining deflectometry measurement with environmental test chambers to assess mirror shape change across a wide range of temperatures, simultaneous measurement of multi-facet slope and facet canting (see Figure 4), and outdoor measurement of full heliostats. These improvements are well suited for prototyping and developing individual CSP mirrors as well as aligning multi-faceted heliostats. We are also envisioning small-scale configurations suitable for easy-to-access student education.

The improvements enable use of SOFAST across a wider range of problems, but also provide a more capable baseline system to use for calibrating and checking future high-performance CSP metrology systems.

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References

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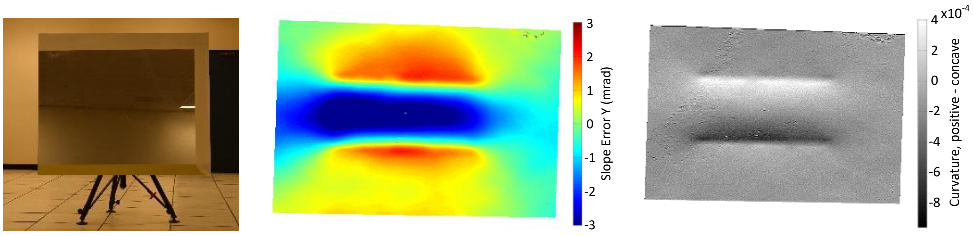


Mirror   Y Slope Error   Y Curvature

Fig. 1: Diagnosing a mirror with print-through artifacts.

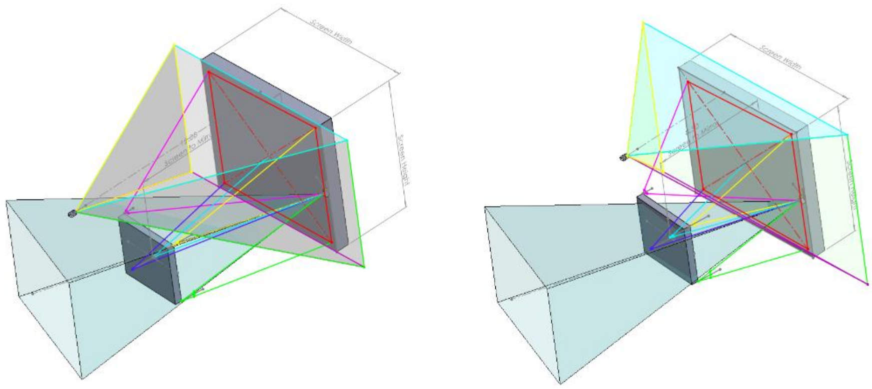


Fig. 2: Layout analysis with automated reflection calculation.

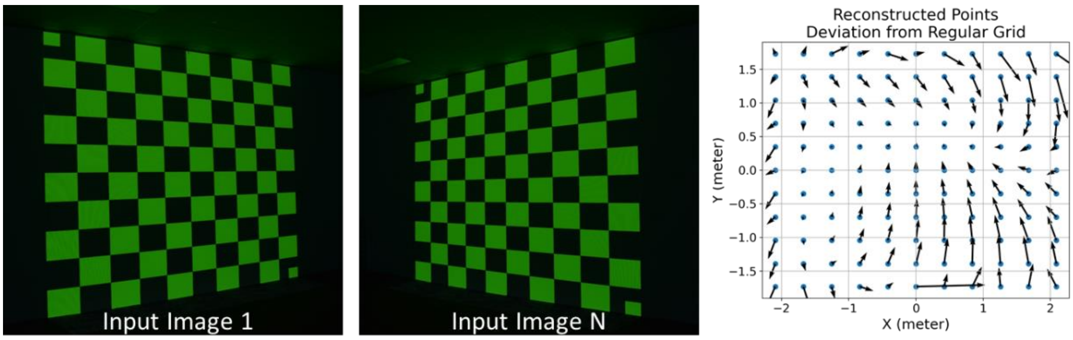
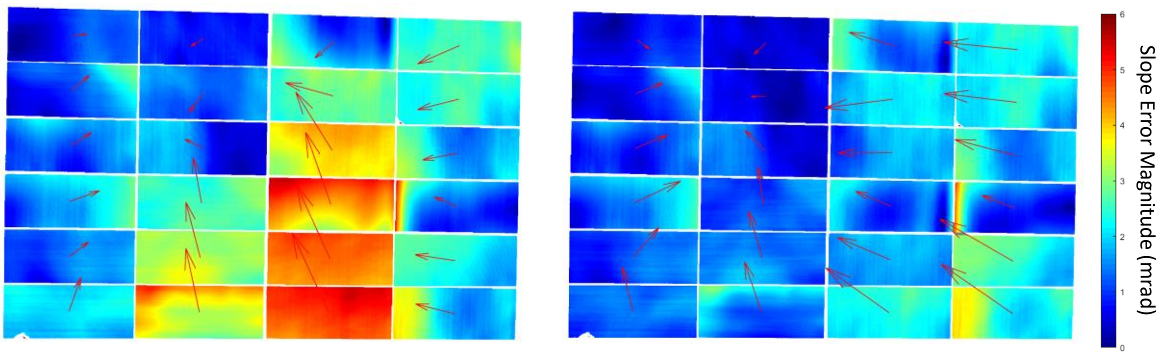


Fig. 3: Automated projector screen calibration results.



Initial   After Modifying Canting Angles

Fig. 4: Multi-facet measurement showing both surface slope and facet canting angles.