

# Parabolic Trough Optical Characterization at the National Renewable Energy Laboratory

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# Parabolic Trough Optical Characterization at the National Renewable Energy Laboratory

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## ABSTRACT

Solar parabolic trough power plant projects are soon to be implemented in the United States and internationally. In addition to these new projects, parabolic trough power plants totaling approximately 350 MW already exist within the United States and have operated for close to 20 years. As such, the status of the technology exists within several different phases. These phases include R&D, manufacturing and installation, and operations and maintenance. One aspect of successful deployment of this technology is achieving and maintaining optical performance. Different optical tools are needed to assist in improving initial designs, provide quality control during manufacture and assembly, and help maintain performance during operation. This paper discusses several such tools developed at SunLab (a joint project of the National Renewable Laboratory and Sandia National Laboratories) for these purposes. Preliminary testing results are presented. Finally, plans for further tool development are discussed.

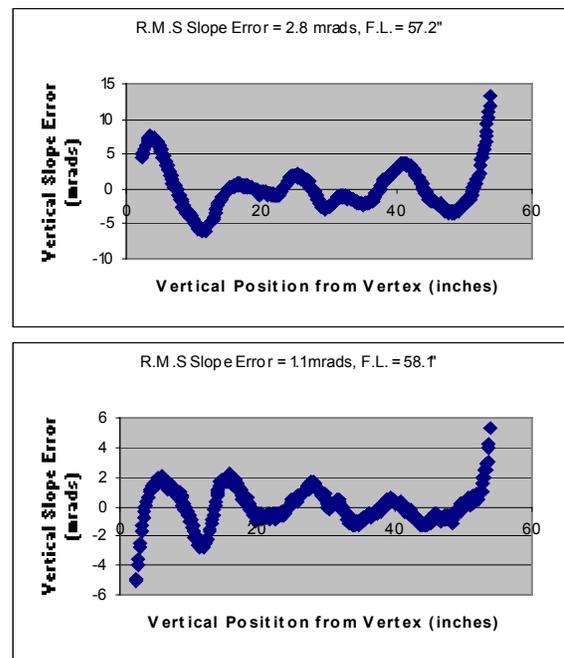
## 1. Objectives

The objective of this work is to develop and use optical testing tools to assist the trough industry in three different phases of technology deployment: concentrator development, installation, and maintenance. Each phase possesses unique data collection requirements. Detailed and thorough optical testing is needed to meet the R&D goal of minimizing the cost/performance ratio of the technology. During manufacture and installation, quality control of mirror panels, and support structure and receiver assembly require less-detailed and speedy optical quality testing. Finally, when trough systems are deployed, tools are needed to periodically monitor and help maintain ongoing optical performance. SunLab has developed two such optical tools, which can provide capabilities within these three areas. These tools are currently being used to assist industry but are also being modified and improved to provide the best capability possible.

## 2. Technical Approach

One tool developed by SunLab is the Video Scanning Hartmann Optical Test or VSHOT [1]. Although originally designed to test point-focus optics, it has recently been modified to more easily test line-focus optical concentrators (i.e. troughs). The system uses a laser to scan the concentrator. A video camera captures the laser reflections, which are imaged on a target. The position of these return images is a function of the optical contour of the

concentrator. Many thousands of data points are collected as the laser scans the trough parabolic contour, and these data are used to generate a mathematical fit to the contour. Statistical variations from the fit are also reported. Vector plots can be generated that illustrate the direction and magnitude of the slope errors relative to the desired surface fit. As a technology development tool, the slope error that the VSHOT measures as a function of vertical position on the trough contour quickly illustrates where the actual contour deviates from the desired one. Figure 1 shows an example for a first-generation developmental mirror module and an improved version [2].

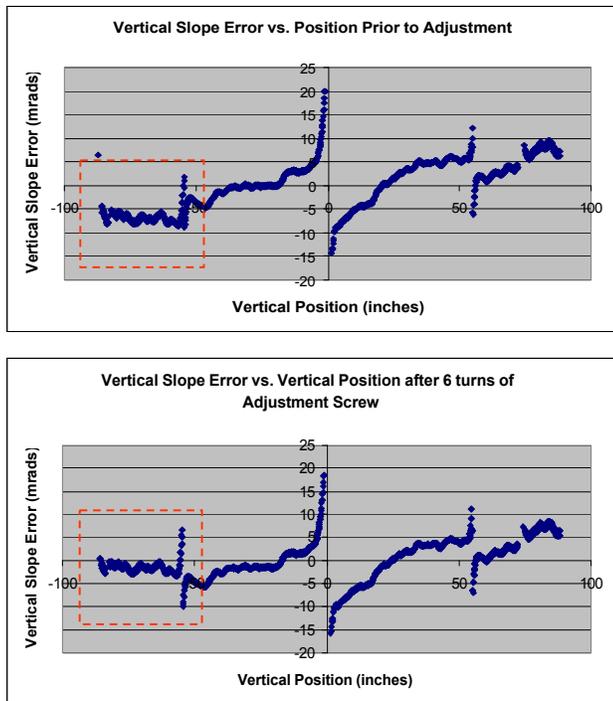


**Figure 1.** Slope error plots for a first-generation mirror module and an improved second-generation module.

Recently the VSHOT was used to assist in measuring the orientation accuracy of mirrors installed on a new trough module designed by Solargenix, Inc. It thus proved its usefulness as a quality-control tool in the manufacturing and assembly process.

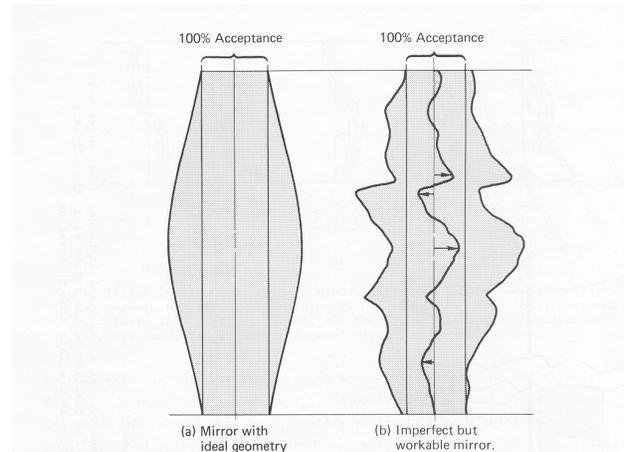
Figure 2 shows two slope-error plots of data taken by the VSHOT on a fully assembled Solargenix trough module. One full contour spans four mirror panels: two outer panels and two inner panels. Each panel can be delineated in the plots because each panel is tilted slightly differently, which

accounts for the discontinuities in the data sets. The objective of the experiment was to see if the tilt could be observed and measured, and then used to make tilt adjustments. Note in the first plot that the lower panel (as seen in the red box) has a relatively flat, but nonzero ( $\sim 5$  mrad) slope error curve. This implies a slope offset (or tilt) that deviates from the desired surface. After adjustments were made, the tilt error was brought close to zero as observed in the second plot. The objective of the tilt experiment was successful, but, as the plots indicate, the other mirrors have additional optical problems, which will be addressed in future testing sessions.



**Figure 2.** Slope error plots of a complete four-mirror module before and after lower-mirror tilt adjustment.

The other trough optical testing tool developed by SunLab is the Line Focus Optical Characterization System or LFOCS. This tool was designed to provide in-the-field characterization of concentrator-optical performance, including the affects of receiver position. As such, it is considered a maintenance tool. The hardware used in this test is considerably less complicated than that used in the VSHOT. A video camera takes snapshots of the virtual image of a receiver as seen from a distance as a function of changing view angle. The images are assembled to generate an acceptance-angle envelope. An ideal acceptance-angle envelope would be a symmetric shape such as that shown in the first plot of Figure 3a. Distortions from the ideal shape result from receiver-positioning errors, and mirror-tilt and mirror-contour errors as illustrated in Figure 3b. Although less quantitative than the VSHOT, these effects can be separated out to provide a rapid and useful characterization of optical performance.



**Figure 3.** Acceptance-angle envelopes for an ideal trough cross-section and one with various optical errors.

### 3. Results and Accomplishments

In fiscal year 2004 (FY04), the VSHOT was modified and used to successfully characterize trough mirror modules during mirror-panel development, manufacture, and assembly. Industry is pleased with what has been learned to date using this instrument and with what will be learned in fiscal year 2005 (FY05) after several new trough plants come on line.

The LFOCS was initially developed almost a decade ago. In FY04, work was done to scope out the necessary hardware and software components to update it and improve its usability. This will be the focus of FY05 work.

### 4. Conclusions

Two optical tools, the VSHOT and the LFOCS, have been developed and successfully used by SunLab to characterize trough optical performance during various stages of deployment. In FY05, both the VSHOT and LFOCS will be updated with state-of-the-art hardware and software to improve their usability in the field. Optical-testing support will be provided to the trough industry using both these instruments, which will assist them in bringing two new trough plants on line with optimum optical performance.

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