1-1-2017

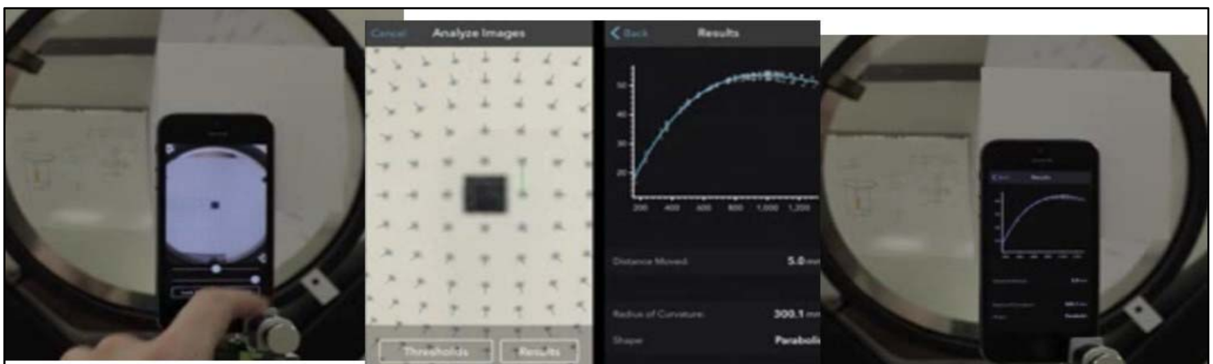
Advanced Optical Metrology with a Smart Device Camera

Patrick J. Reardon
University of Alabama in Huntsville

RCEU Proposal: Advanced Optical Metrology with a Smart Device Camera

Faculty Mentor: Patrick J. Reardon, ECE
Asst. Prof., ECE Dept., & Assoc. Director, CAO
Office: OPB400, Phone: X2530
patrick.reardon@uah.edu

<u>Project Summary</u>: Metrology of optical systems requires different optical methods depending on the type of optic being measured and the fidelity necessary to ensure sufficient results. For x-ray telescopes, the surfaces must be measured to confirm their shape to within nanometers, but for reflectors for solar energy systems, errors on the order of 0.1mm could be acceptable. Given the large difference between these two requirements, an instrument with the necessary dynamic range and resolution capable of measuring both elements may not exist. The PI guided a Senior Design team from the OPE program in the development of a new, relatively low-fidelity optical test that can determine the basic shape parameters of a concave optical mirror. The system operates by taking two images with a smart phone of a specifically designed target in reflection from the mirror, running image processing software on the two images, and computing two fundamental parameters that define the surface: the radius of curvature and the conic constant. Although successful as a Senior Design Project, the method was not fully analytically



Images from smartphone measuring a mirror surface. (a) Acquiring images, (b) processed images, (c) smartphone with results displayed.

understood. For example, the alignment (or misalignment) of the smart phone to the mirror resulted in distinct structures in the processed data that appeared to be dependent on whether the error between the two images was a result of angular or lateral misalignment. If these "features" in the data can be assigned to specific misalignments, then it is possible that numerical methods can be developed to computationally remove them. Computational realignment is the approach followed by the most stringent optical test methods, such as the cryogenic interferometric testing the PI performed when measuring the massive mirrors for NASA's James Webb Space Telescope.

Unfortunately, the limited time available for Senior Design Projects meant that, although the method and phone App were able to measure the two fundamental mirror properties to within less than 1% error, the misalignment effects could not be addressed in sufficient detail. This

RCEU project will integrate the student with new research being performed by a PhD student which is directed towards using this kind of test to achieve measurements with the fidelity of instruments costing $100k's. This RCEU will immerse the student in a program to develop a deeper understanding of the test method, both experimentally and with computational optical models of the system, to determine the misalignment parameters which affect the measured data.

Student Duties: The student will perform a series of tests of a known optical mirror and assist in the analysis of that data. Specifically, the student will be responsible for the following:

1. *Assembly and Documentation of Experimental Setup*: The tests require laterally and angularly misaligning the setup, but by known amounts. The student will, with guidance from the PI and the PhD student, assemble the translation and rotation stages for the misalignment system. The student will then use optical techniques to verify the performance of the misalignment system and will document its accuracy and precision.
2. *Data acquisition*: The student will acquire and record a number of measurements using the smart phone process, looking at a well-characterized conic optical mirror, given specific misalignments. The proposed test matrix will include a set of independent lateral misalignments of 0.5mm increments in both transverse directions, a set of independent angular misalignments of 0.5 arcminutes about the transverse axes of the system, and various mixed transverse and angular misalignment states.
3. *Comparison between Numerical Model and Measured Data*: The student will operate a state-of-the-art optical design program, CodeV, to fit the measured data to a theoretical model of the system. This will require the student to appropriately define the model to match the different misalignments used in the test matrix.
4. *Final report*: The student will write a final report describing the research and the results.

The student will learn, by instruction and independent experimentation, various forms of optical element testing available to an optical engineer or scientist. The student will also be introduced to CodeV, the industry standard for optical design and analysis. Finally, the work performed by the student will form the experimental results of a journal article that will be submitted about the optical test method, for which the student will be co-author.

Student Prerequisites: The student must have a science and/or engineering background. Experience in using computers is a necessity, and programming, such as MatLab, is desired. Courses in geometrical optics and/or physical optics would be preferred.

Mentor Supervision and Interaction: The PI will provide primary training for all optical tests and analysis being performed. Informal meetings will nominally occur daily, with a scheduled weekly meeting. The student will also work with the PhD student, CAO staff and other students who can provide additional assistance with locating necessary optical components and operating the equipment.