Alignment and Testing for a Freeform Telescope

Andrew Howe[1], Clark Hovis[2], Manal Khreishi[3,4], Raymond Ohl[4]

[1] Norfolk State University, [2] UNC Charlotte, [3]University of Arizona

[4]NASA Goddard Space Flight Center, Instrument System and Technology Division, Optics Branch (GSFC 551)

Abstract

There is a strong desire to make Earth science and other missions less expensive. Freeform optics make these missions less expensive because they allow an optical designer to use fewer mirrors to create roughly the same optical performance. The main issue with using freeform surfaces is how closely the substrate can be polished to its prescription. Over this summer, our team looked at two freeform mirrors made by Corning Inc. using a unique process to determine how close these optics are to their set prescriptions and how well NASA could align them.

Introduction and Goals

The Penta telescope is a proof of concept telescope design that will be used to prove that freeform mirrors are effective in Earth science missions with no significant change in measurement quality. A freeform prescription has no axes of symmetry. This makes them extremely hard to align and test. Because of this, each mirror had to be characterized using a wide variety of metrology techniques. After all the mirrors were characterized a model had to be build up and aligned to do the full system and wavefront testing. Finally, a CCD camera was put at the focus of the telescope to determine the quality of the final image.

Instrumentation

Fig. 1: M1 Aspheric Polynomial Freeform

Fig 2: M2 Aspheric Polynomial Freeform

Fig 3:Laser Radar

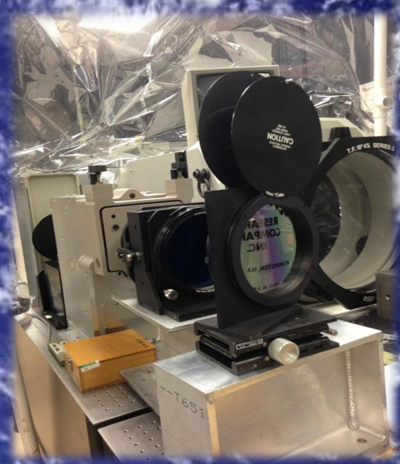


Fig 4: Zygo Interferomete

Fig 5: Theodolite

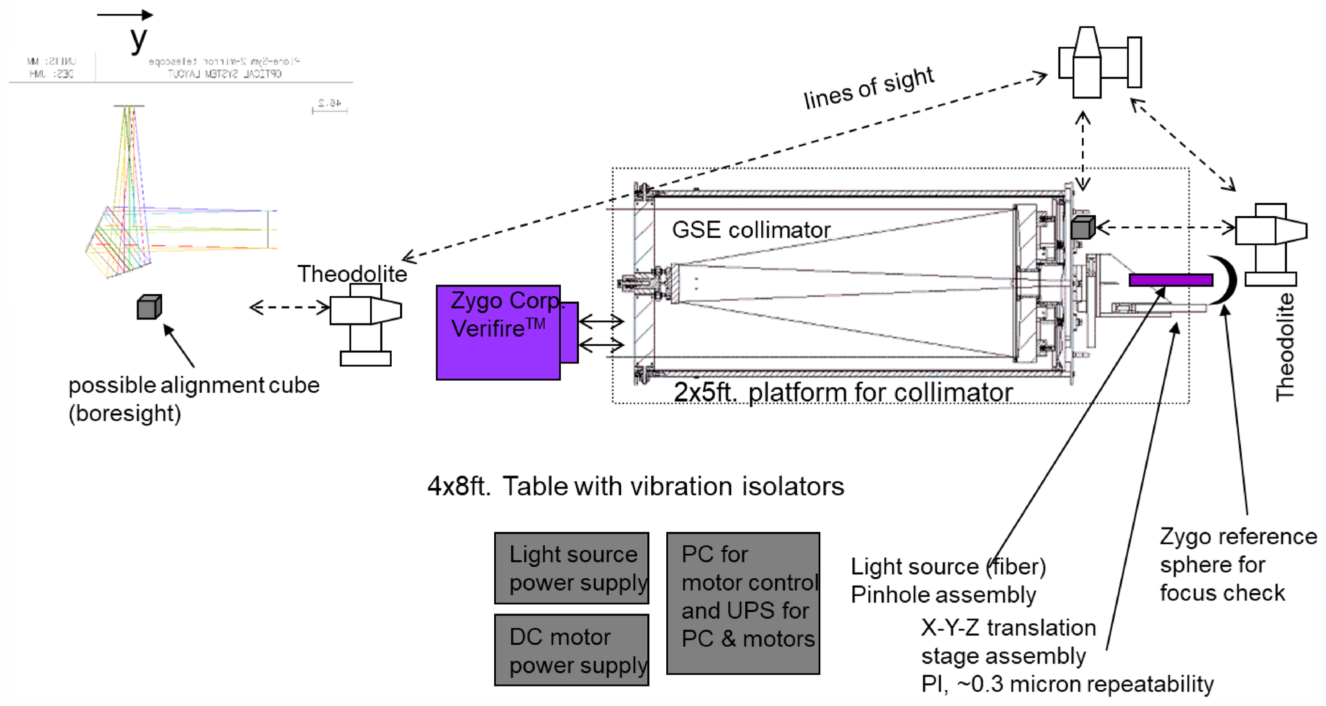
The two mirrors in this design were freeform prescriptions made by Corning Inc. using a unique process, therefore, they had to be well characterized before they could be aligned.

Fig 6: FUSE Collimator

Design

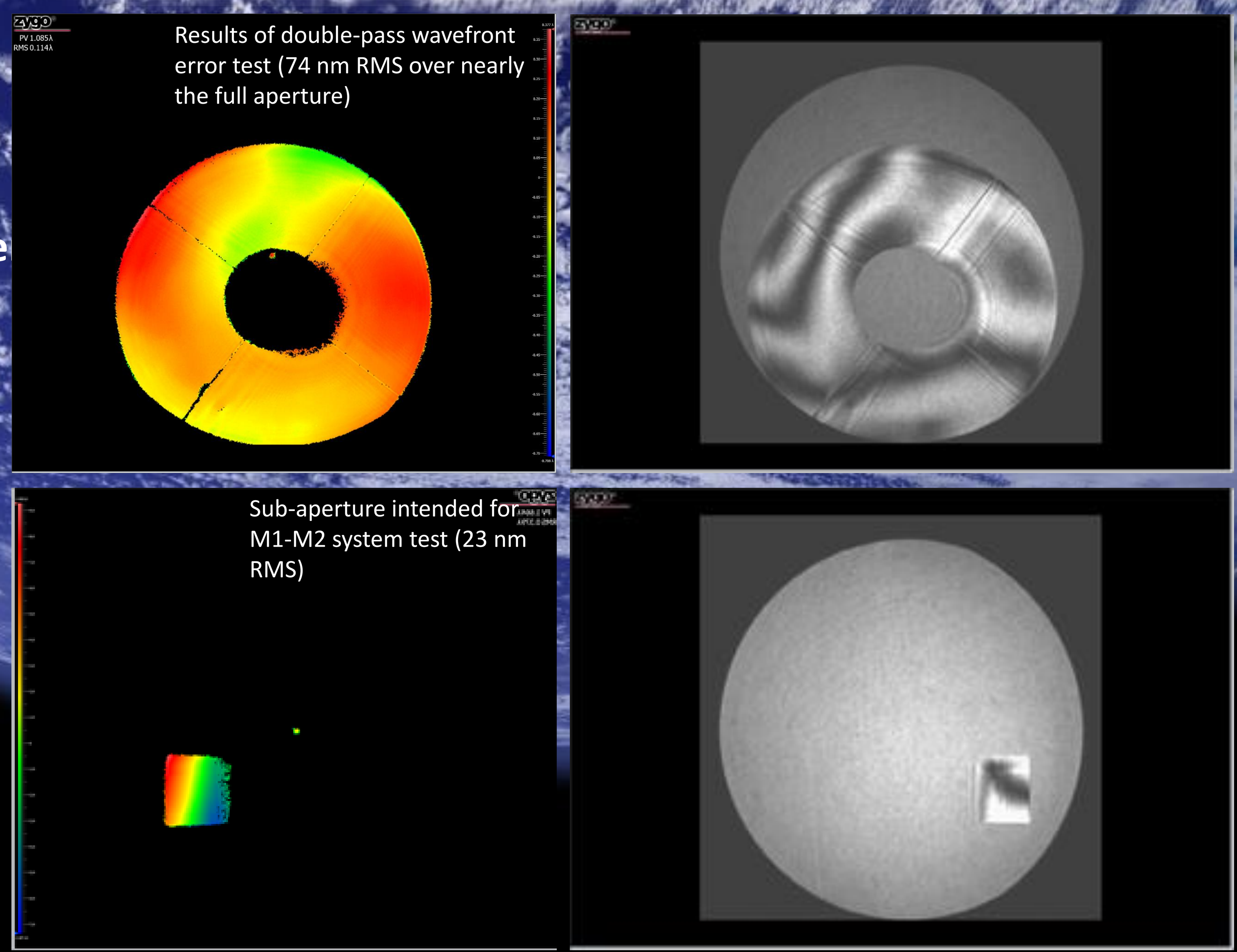
- Composed of two freeform mirrors
- The mirrors are made to polynomial aspheres
- Made for small aperture CubeSat
- The goal is to create a test setup with a simulated star to determine how well the freeform telescope will image a point source compared to expectations from an optical model

Penta Optical Set-up

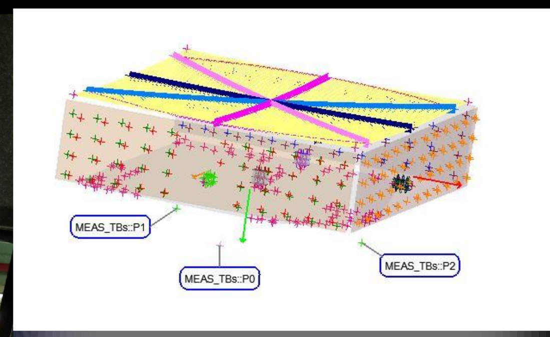


Metrology of the test device

A point source at an "infinite" distance creates essentially collimated rays. A collimator can be used to simulate these rays in a lab space. This particular collimator had not been used by Goddard in many years. It had been shipped out to an external party for use in their optics lab. Consequently, the whole system had to be recertified using interferometry. After it was recertified over the full aperture, we then masked it down to just the sub-aperture that we will test over. This minimized the surface errors on the test device.



Alignment Plan



The Coordinate Measuring Machine was used to create models of the optics which were then compared to the CAD prescriptions

- Use the CMM to measure the optical surface and fiducials
- Align the M1 and M2 mirrors to each other based on fiducial calibrations
- Align the interferometer or collimator to the M1-M2 telescope based on metrology
- Obtain interferometric and image data as a function of field angle
- Compare wavefront and image results to modeled performance using ray tracing

Conclusions

•Getting solid metrology data proved to be extremely hard in the case of the mirrors and the collimator.
•Future work is to build the test setup using a pinhole and the collimator to create collimated light to test the telescope when it is assembled
•This starts with building up our full system on a breadboard once M1 and M2 are well characterized and have good fiducials attached to them.
•The M1-M2 telescope is placed in front of the collimator with the CCD camera at the focus of the telescope to find out how well the system images from end to end.
•Comparison with model expectations is the primary metric used to determine how well freeform surfaces can be aligned

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