CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

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Project Number

S1803

Project Title

Quick Aligning Telescopes

Abstract

Objectives/Goals

The goal of my project was to develop an efficient method of aligning an optical telescope. Optical telescopes are expected to have a very small wavefront error in order to achieve high resolution. Wavefront errors in optical instruments are measured using an interferometer. The specific goal of this project was to develop a deterministic method of aligning a Keplerian telescope to a wavefront error that was limited by the wavefront error of the lenses in the telescope.

Methods/Materials

My approach to aligning the telescope was to associate certain aspects of the wavefront error with specific misalignments. I chose to characterize the aberrations as a result of specific misalignments of the telescope#s elements. Since the telescope is radially symmetric, there are only three unique degrees of freedom to misalign, one which is eliminated by changing the viewing angle. Using a computer model built in an optical design platform (Zemax OpticStudio), I predicted the aberrations as a function of misalignment and confirmed my model using an interferometer. I matched these misalignments to the coefficients of Zernike polynomials (orthogonal polynomials that can be used to describe wavefront error). Rotated misalignment resulted in a parabolic function describing a Zernike coefficient, and translated misalignment resulted in a linear function describing a different Zernike coefficient. I used linear algebra to fit three random misaligned points to a parabola, then determined the minima and aligned the telescope to that rotation. Then I took two misaligned translations, plotted them to a line, and solved for the location with minimized error.

Results

To test my method, I ran two separate tests on a telescope that was randomly misaligned to test both important degrees of freedom. Both tests succeeded in aligning the telescope better than I could by hand. Before alignment, the wavefront error of the telescope was almost six waves. After alignment, the wavefront error was only an eighth of a wave, and the only remaining aberrations were due to flaws in the lenses.

Conclusions/Discussion

The method I devised reached the accuracy goal, and was significantly more efficient than linearly adjusting the degrees of freedom in small steps. The process aligned the telescope to within the accuracy goal on the first iteration. The process is methodical enough that given future work, it could easily be automated.

Summary Statement

I devised a method to align a Keplerian telescope using measurements of the wavefront error.

Help Received

Brian Catanzaro (father) provided instruments and technical assistance in using instruments