# Automated Optical System Alignment and Low Order Wavefront Sensing 

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## BACKGROUND

An automated alignment optical system will greatly simplify alignment tasks, increase the flexibility and utility of reconfigurable optical systems, and allow for the quick and efficient set up distributed optical systems. We demonstrate automated alignment of a tilted and decentered focal lens using only focal plane imaging by exploiting the aberration effects caused by the misalignment.


A Gaussian beam passes through the moving lens and is focused on a CCD detector. The goal is to calibrate the 4 degrees of freedoms of the moving lens: translation in x and y and tip and tilt.


The final image is sent to the measurement system and the system feeds back the measurement error to calibrate states $S_{x}, S_{y}, T_{x}, T_{y}$.

Image Detection Simulation

(a) Simulated image

(b) Gaussian fitting

(c) Aspect ratio
(a) Image detection using Center of mass (COM), principal component analysis (PCA), and (b) Gaussian fitting. (c) Aspect ratio obtained in the fitting is axis-symmetric and has a global minimum.


Experiment setup for examining the single lens mode. Focal length of the moving lens: 200 mm . Pixel size of the CCD camera: $4.54 \mu \mathrm{~m}$.

## References

[1] Savransky, D., Thomas, S. J., Poyneer, L. A., and Macintosh, B. A., Computer vision applications for coronagraphic optical alignment
and image processing, Applied Optics $52(14), 3394-3403$ (2013). and image processing, Applied Optics 52(14), 3394-3403 (2013)
[2] Macintosh, B. et al., First light of the Gemini Planet Imager, PNAS 111(35), 12661-12666 (2014).
3] Savransky, D. et al., Focal plane wavefront sensing and control for ground-based imaging, [Proc. SPIE], 8447 (2012).

## Control Procedure



Decision chart of the control algorithm. $P_{s}$ and $P_{t}$ represent the shift alignment and the tip-tilt alignment subloops.

## Results

Experimental Data


Raw


Binary


Gaussian

Precision Test


Convergence Test


The center position converges below 1 micron, and the aspect ratio converges to approximately 1.001 in 6 global steps.

## Future Work

1. Build a better observer and estimation model to minimize the state prediction error.
2. Extend the measurement and control methods to a reconfigurable system with multiple moving lenses and other optical components.
