TECHNOLOGY DEVELOPMENT FOR EXOPLANET MISSIONS

Final Technology Milestone Report
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INTEGRATED CORONAGRAPH DESIGN AND WAVEFRONT AMPLITUDE CONTROL USING TWO DEFORMABLE MIRRORS

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1. Executive Summary

In this final report, we document the results of our ROSES Technology Development for Exoplanet Missions (TDEM) two-year research program to advance the technology associated with using two deformable mirrors to perform amplitude and phase control in a coronagraph. We described the the goals of the program in our Technology Milestone Whitepaper, JPL Document D-81164 dated October, 2013. We will refer to that often in this report.

While we did not meet our milestone, largely due to a reprioritization of facilities at JPL after the start of the WFIRST/AFTA coronagraph development, we did verify the effectiveness of using two deformable mirrors to create dark holes on both sides of the image. We achieved a monochromatic contrast of 3.6×10^{-9} in the High Contrast Imaging Testbed (HCIT) using one 32×32 DM (with 23×23 actuators illuminated) and one 64×64 DM (with 48×48 actuators illuminated) and a shaped pupil coronagraph, just shy of our primary millstone requirement of 1×10^{-9}.

As a reference, our milestones from the whitepaper were:

TDEM Primary Milestone:

- Demonstrate with 90% confidence that the system can achieve symmetric dark holes in the image plane in monochromatic light with an expected average contrast plus 3-sigma $\leq 1 \times 10^{-9}$ from 5-9 λ/D using two deformable mirrors in series.

TDEM Secondary Milestone:

- Demonstrate with 90% confidence that the system can achieve symmetric dark holes in the image plane in a 10% band about the central wavelength with an expected average contrast plus 3-sigma $\leq 5 \times 10^{-9}$ from 5-9 λ/D using two deformable mirrors in series.

In the remainder of this report we describe the design of the shaped pupil coronagraph, the algorithm development, and the experiments we performed.

2. Certification

In this section, we reference the list of items for the certification data package from Section 6 of the milestone whitepaper and identify where they can be found in this report. The certification item description from the whitepaper is given in italics followed by the reference information in roman type.

(1) *A narrative report, including a discussion of how each element of the milestone was met, and a narrative summary of the overall milestone achievement.*
This narrative report responds to item (1) of the certification data package.

(2) *A complete description of the HCIT layout and optical system used with the significant characteristics.*
See Section 5.

(3) *The sets of images used for calibration of the reference star.*
Calibration was performed using the standard HCIT procedure by the HCIT personnel. The procedure they follow is to: 1) calibrate the contrast of the quilting order to the main PSF, 2) put the focal plane mask in place, and 3) use the quilting order peak brightness from then on to calibrate the contrast in the dark hole (without ever moving the mask again). We unfortunately don't have the images used for this process.

(4) *Microscope images of the shaped pupil and focal plane masks with simulated PSFs.*
See Section 4.