National Aeronautics and Space Administration

The In-Air Coronagraph Testbed: An agile technology demonstrator of advanced techniques for exoEarth Imaging

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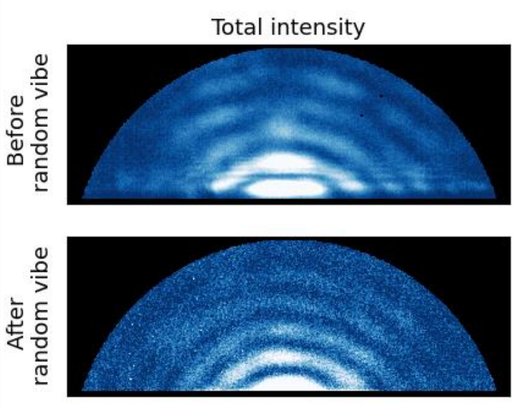
The Astro2020 decadal survey has recommended the future NASA flagship mission to be a ~6m IR/O/UV telescope equipped with a coronagraph instrument to **directly image exoEarths** in the habitable zone of their host star. To reduce costs, NASA will run the Great Observatories Mission and Technology Maturation Program that aim to study every promising path to this ambitious goal, especially regarding in-lab telescope simulations. But vacuum testing facilities are expensive and time consuming. The **In-Air Coronagraph testbed** (IACT), commissioned in 2020 fills the need for quick preliminary testing of new ideas and technologies at high-contrast levels.

Deformable mirrors



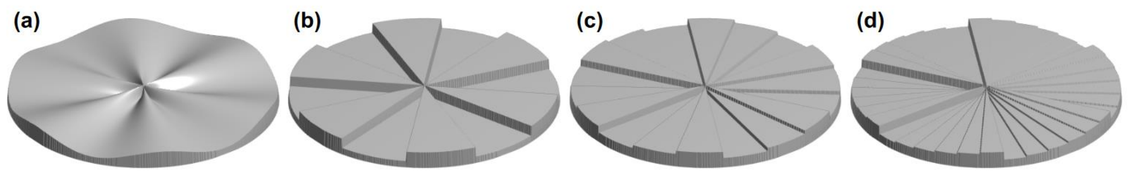
Potier et al. (Submitted) – IACT contrast levels are similar before and after the DM underwent a flight-like random vibration testing.

ExoEarth imaging is closely linked to the **control** accuracy **of high-order optical aberrations with deformable mirrors** (DMs). A few technologies have been studied for space-based telescopes. IACT confirmed the survivability of MEMS DMs that underwent launch-like vibration testing and will analyze performance of new DM electronics.

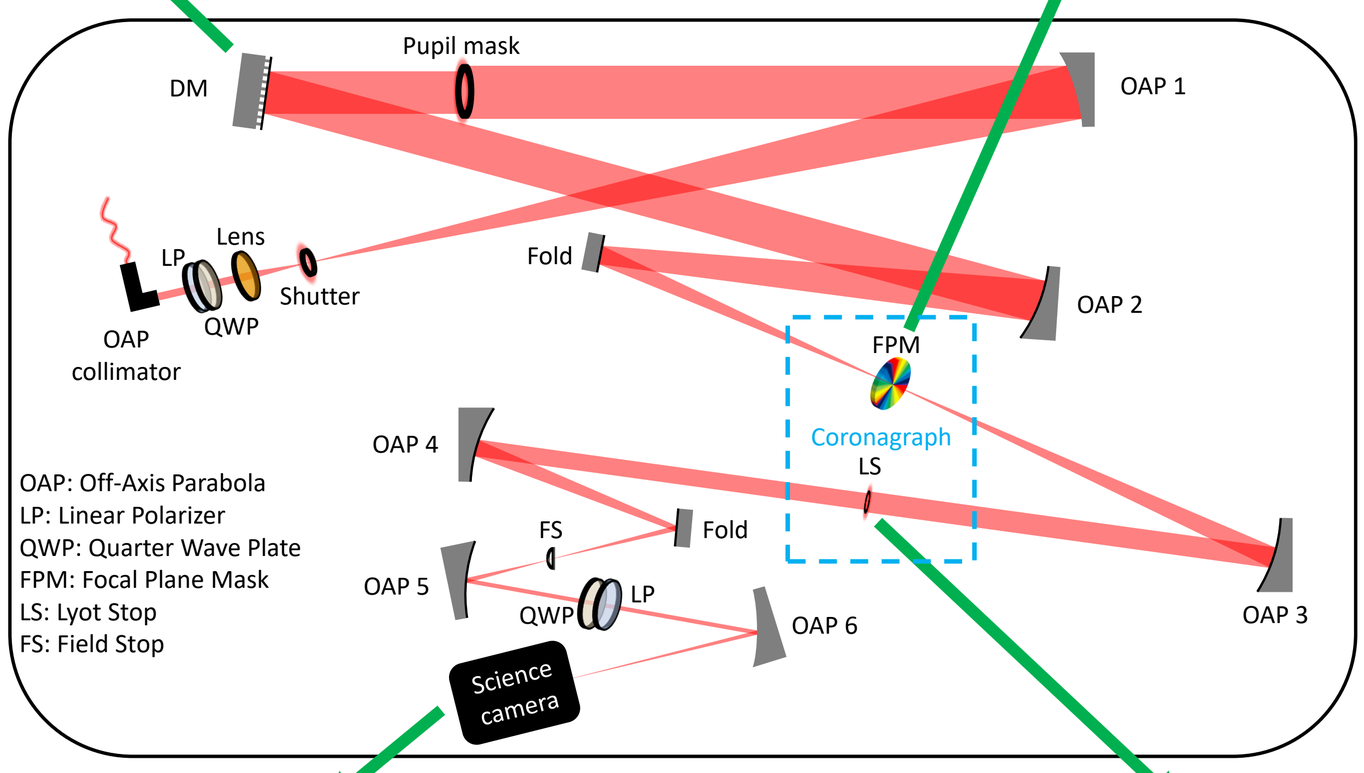
Hardware demonstration

Coronagraph designs

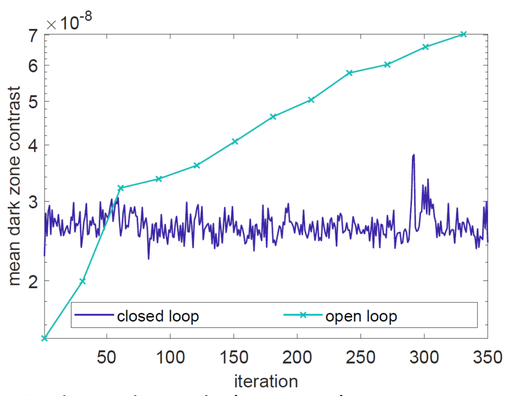
Coronagraphs attenuate the starlight to reveal closely orbiting exoplanets in images. We need 1) high extinctions of the starlight, 2) high throughputs of the exoplanet light, 3) small inner working angles to detect close-in companions and 4) broadband capabilities for atmosphere analyses through spectroscopy. IACT has already tested two new kinds of promising vortex-like coronagraph mask designs.



Ruane et al. (2019) – Charge 6 Scalar vortex mask designs.



Contrast maintenance

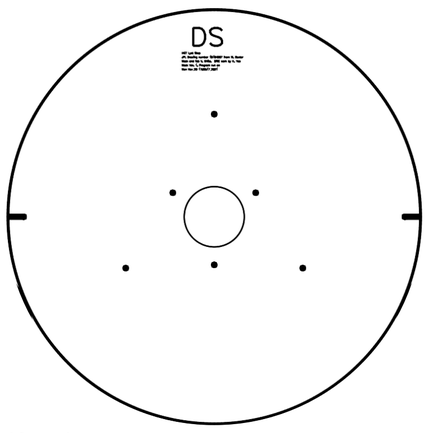


Redmond et al. (In Prep.) – Contrast stability on IACT with and without contrast maintenance algorithm.

Thermal instabilities induce sub-nanometer flexures in high-contrast imaging instruments, making the initial optical calibration obsolete. Some algorithms are being developed to **preserve contrast levels in the images**. Requiring no additional hardware, we are currently comparing two of these algorithms on IACT.

Software demonstration

Calibration of optical aberrations



Self-Coherent Camera Lyot stop design. Light going through the additional pinholes recombines with the science path, creating fringes and allowing the sensing of aberrations.

The future flagship mission will aim to find companions 10^{10} fainter than their host star. A precise calibration of the optical aberrations should be performed. Currently, such calibration is model-based and is therefore sensitive to advanced instrument architectures. We manufactured a new coronagraph design to **test alternative model-free wavefront sensing capabilities**.

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Publications:
Baxter et al. (2021) – Design and commissioning of an in-air coronagraph testbed in the HCIT facility at NASA's Jet propulsion Laboratory. Proc. Of SPIE.
Prada et al. (2021) – Environmental testing of high-actuator-count MEMS deformable mirrors for space-based applications. Proc. Of SPIE
Ruane et al. (2019) – Scalar vortex coronagraph mask design and predictive performance. Proc. Of SPIE
Baudoz et al. (2006) – The Self-Coherent Camera: a new tool for planet detection. Proc of IAU

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