ExoPlanet Exploration Program

Technology Development for Exoplanet Missions

TDEM-09 Status Report

Peter Lawson, ExEP Program Technologist

Marie Levine, Technology Manager

Jet Propulsion Laboratory

California Institute of Technology

ExoPAG Meeting, Austin, TX

Saturday, 7 January 2012, 12:00 pm

Programmatic Updates

ExoPlanet Exploration Program

Updated Technology Plan: Fall 2011

Now revised for the 2011 ROSES Strategic Astrophysics Technology Solicitation

Pre-Proposal Briefing Scheduled:

Tuesday, 24 Jan 2012, 1:00 pm Eastern

Technology Milestone Whitepapers available at

http://exep.jpl.nasa.gov/technology/

STRATEGIC ASTROPHYSICS TECHNOLOGY SOLICITATION

NASA Research Announcement
ROSES 2011: Strategic Astrophysics Technology
Solicitation Summary | Pre-proposal Briefing

TECHNOLOGY PLAN

Technology Plan Appendix: Fall 2011

TECHNOLOGY ASSESSMENT COMMITTEE

Vernon Weyers, Chair
Alan Boss, Carnegie Institution for Science
Richard Capps, JPL/Caltech
Richard Harms, Consultant
David Mozurkewich, Seabrook Engineering
Joe Pitman, Exploration Sciences
Lisa Poyneer, Lawrence Livermore National Laboratory
Anand Sivaramakrishnan, Space Telescope Science Institute

STRATEGIC ASTROPHYSICS TECHNOLOGY AWARDS

Exoplanet Technology Research funded through the Technology Development for Exoplanet Missions component of NASA's solicitation on Strategic Astrophysics Technology. Awards for calls from 2009 and 2010 are listed. Links are provided to the abstracts of the original proposals and to the milestone whitepapers, where available.

Year	PI	Institution	Proposal Title
CORONAGRAPH STARLIGHT SUPPRESSION TECHNOLOGY			
2009	Olivier Guyon	Univ. of Arizona	Phase-Induced Amplitude Apodization Coronagraphy Development and Laboratory Validation Abstract | Whitepaper #1 | Whitepaper #2
2009	Martin Noecker	Ball Aerospace	Advanced Speckle Sensing for Internal Coronagraphs and Methods of Isolating Exoplanets from Speckles Abstract | Whitepaper

Coronagraph Contrast Performance Achieved to Date

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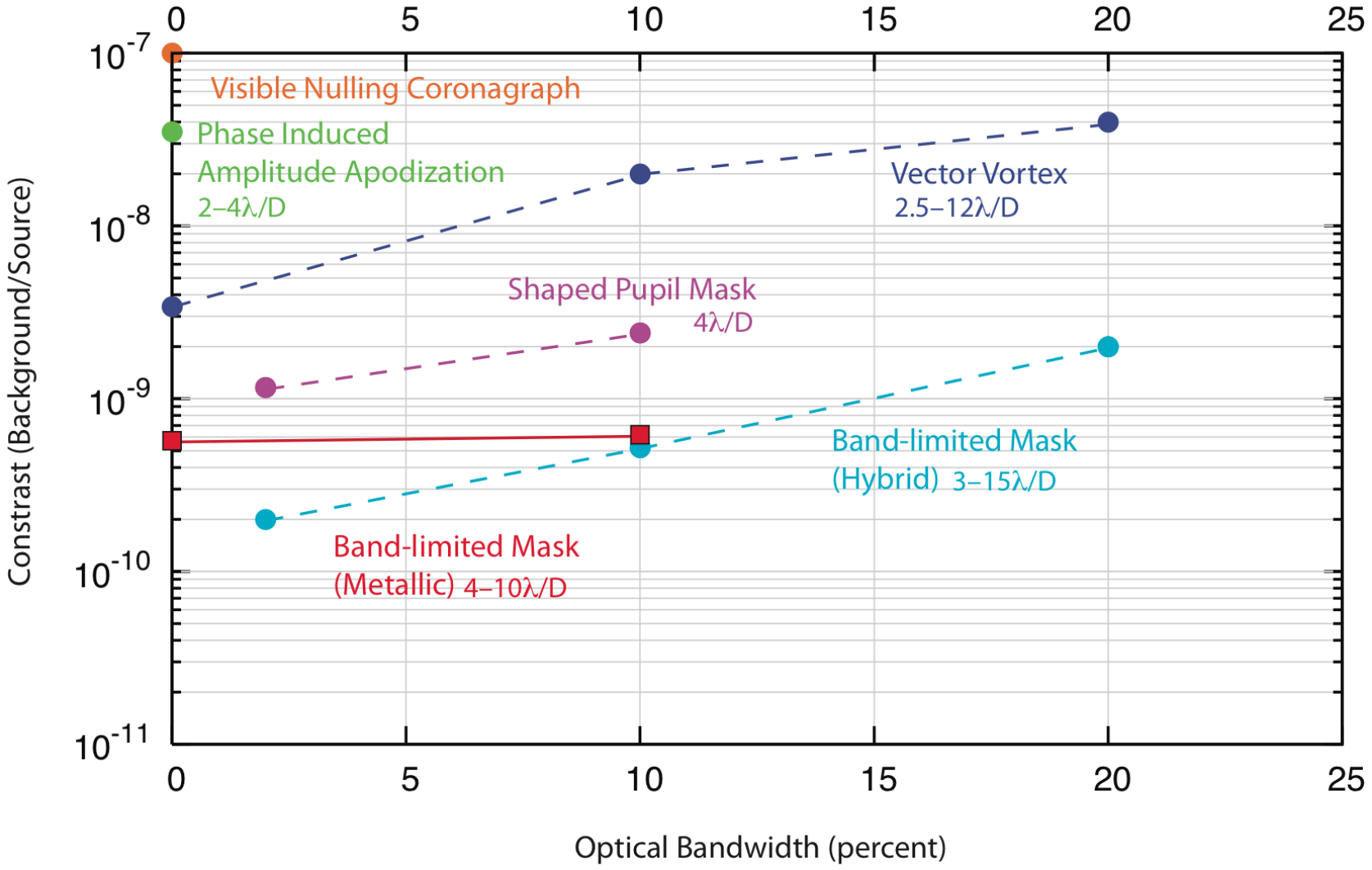

Infrastructure Upgrades in FY'11

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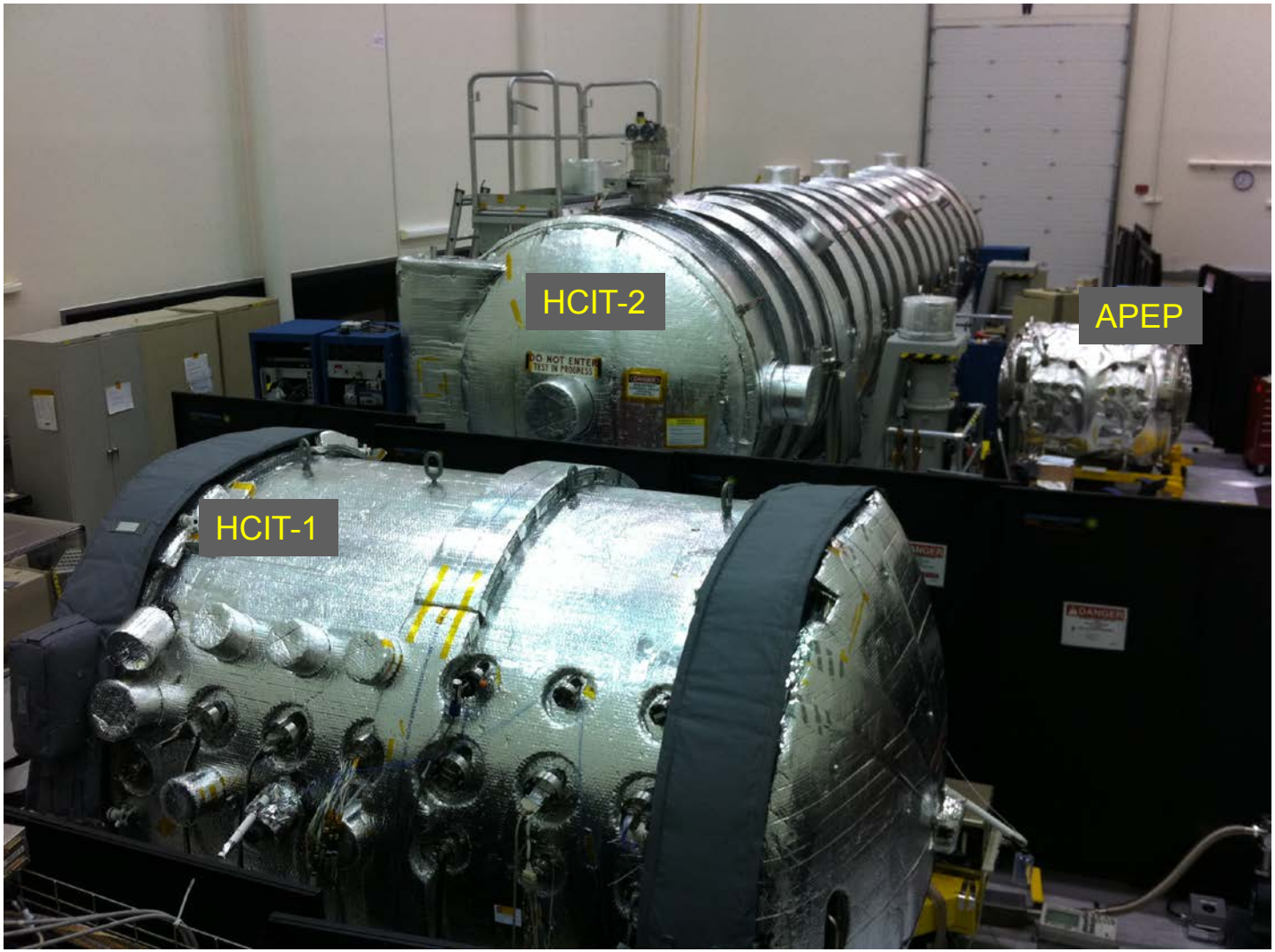


SIM chamber retrofit (HCIT-2) and new visible nuller chamber (APEP) provide augmented test capacity for starlight suppression demonstrations in Building 318 high bay.

John Trauger (JPL/Caltech)
Hybrid Lyot Masks

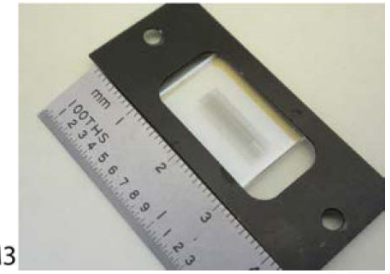
Coronagraph Technology Milestone:
Demonstration of ≤ 10^{-9} contrast w/ hybrid-Lyot Masks @ 3λ/D & 20% BWD

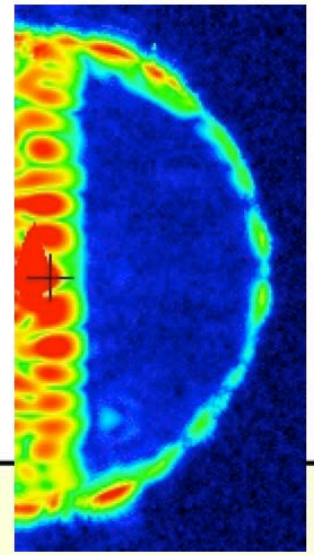
Facility: High Contrast Imaging Testbed 1, JPL

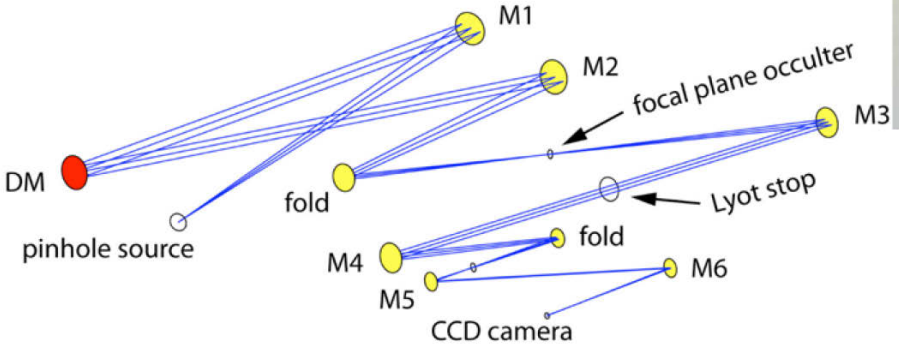
Current Status: 3×10^{-9} contrast @ 3-4 λ/D and 20%, new tests in 2012

Challenges: Controlled deposition of the dielectric layer during the mask manufacturing.

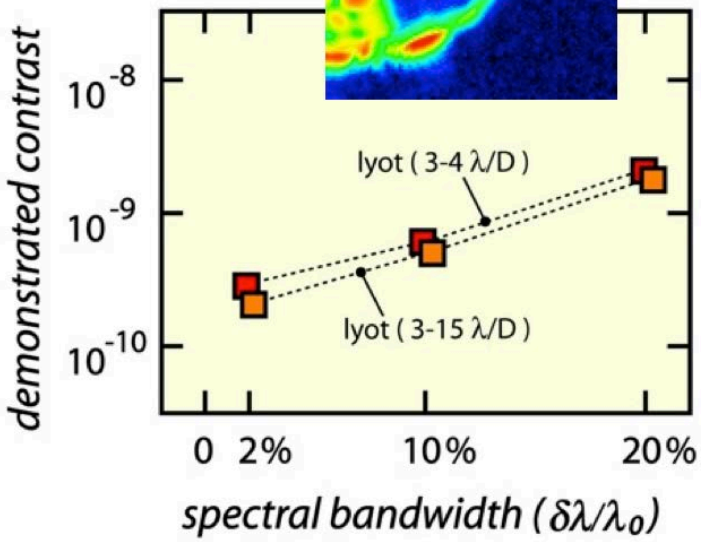
Future Work: Not funded under 2010 TDEM







Hybrid Lyot Contrast Achieved to Date (Trauger TDEM)			
Inner Working Angle	Bandwidth		
	2%	10%	20%
3-4 λ/D	$4\ 10^{-10}$	$6\ 10^{-10}$	$3\ 10^{-9}$
3-15 λ/D	$2\ 10^{-10}$	$5\ 10^{-10}$	$1.5\ 10^{-9}$



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Trauger | Guyon | Krist | Kendrick | Clampin | Kasdin | Figer

Olivier Guyon (Univ of Arizona)
Phase Induced Amplitude Apodization & Low Order Wavefront Sensing Pointing Stability

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Coronagraph Technology Milestone #1:

Demonstration of ≤ 10^{-9} contrast with PIAA coronagraph at 2λ/D in laser light

Current Status: 3×10^{-8} contrast @ 2-3 λ/D

Challenges: Image motion in air

Coronagraph Technology Milestone #2:

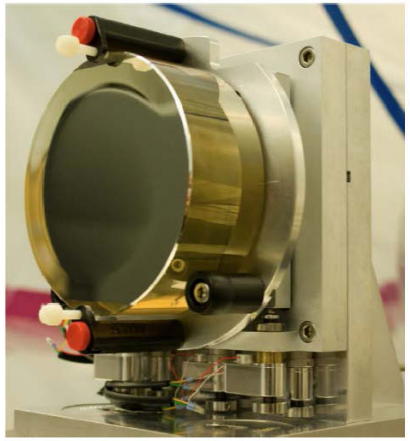
Demonstration of ≤ 0.01 λ/D pointing stability w/ Low Order Wavefront Sensor

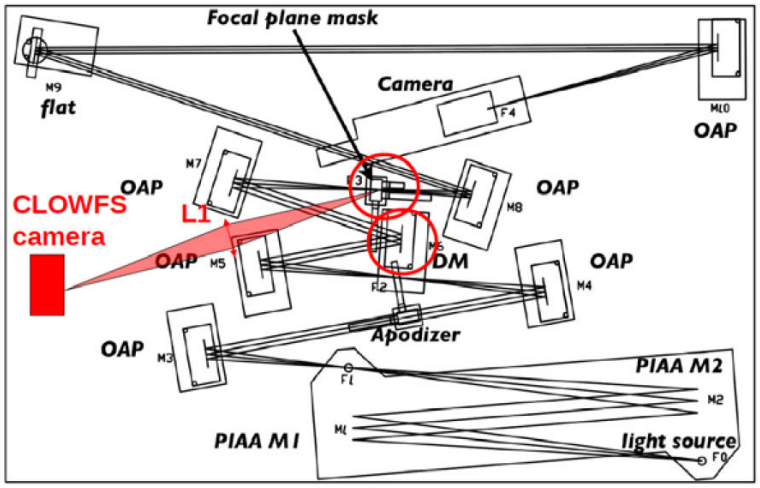
Current Status: Open-loop xxxx – Closed-loop xxxx

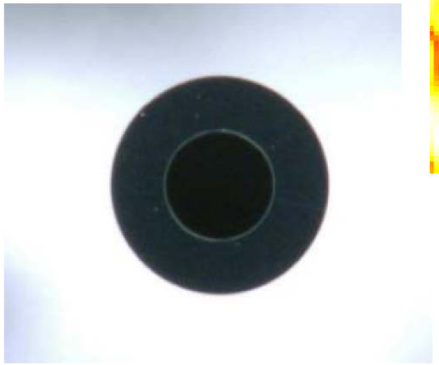
Challenges: Closed-loop control attenuation

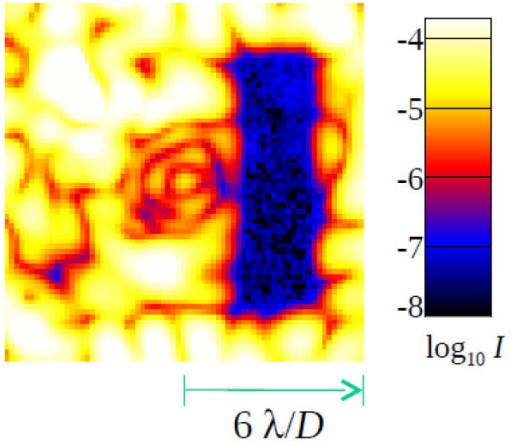
Facility: High Contrast Imaging Testbed -2 , JPL

Future Work: Milestone #2 runs in 1/2012. Milestone #1 runs afterwards then proceed with TDEM10 for 10^{-9} contrast at 2λ/D in 10% BWD









LOWFS uses light blocked by the focal plane mask to measure low order aberrations with high sensitivity

Trauger | Guyon | Krist | Kendrick | Clampin | Kasdin | Figer

John Krist (JPL/Caltech)
End-to-End Coronagraph Modeling

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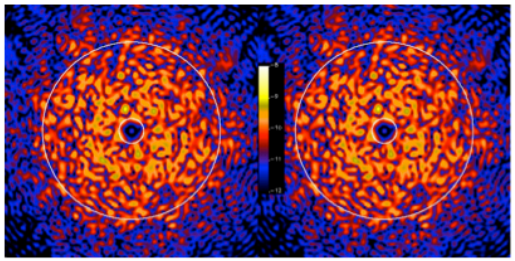
Coronagraph Technology Milestone #1:
Demonstration of fast & accurate propagator for Hybrid Lyot, PIAA, and Vector Vortex coronagraphs with ≤ 1% errors when compared to more rigorous reference algorithms, ≤ 48 hours on a modern workstation.

Coronagraph Technology Milestone #2:
Using propagators from Milestone #1, determine parameters for each coronagraph to achieve ≤ 10^{-10} mean contrast over λ = 500–600 nm in a realistically aberrated system with wavefront control.

Challenges: Modeling of Hybrid Lyot Masks has taken longer than anticipated.

Current Status:
1st Milestone: PIAA and Vector Vortex completed. Hybrid Lyot still in work
2nd Milestone: PIAA completed, Vector Vortex in progress.

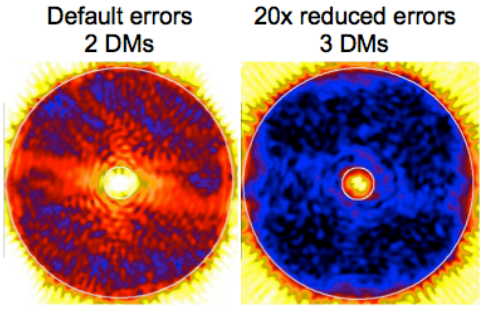
Image Plane Fields



Derived a suitable binary post-apodizer and a means to represent it with limited wavefront sampling.

Developed and optimized propagation codes for both accuracy and speed.

Verified results against reference methods.



Used propagators and wavefront control methods (EFC) to create dark holes around sources.

Determined current PIAA optics need to be 20x better to reach 10^{-10} broadband contrast.

Identified need for 3rd DM after PIAA optics to control optical errors between PIAA and occulter.

Trauger | Guyon | **Krist** | Kendrick | Clampin | Kasdin | Figer

Stephen Kendrick (Ball Aerospace)
Advanced Speckle Sensing

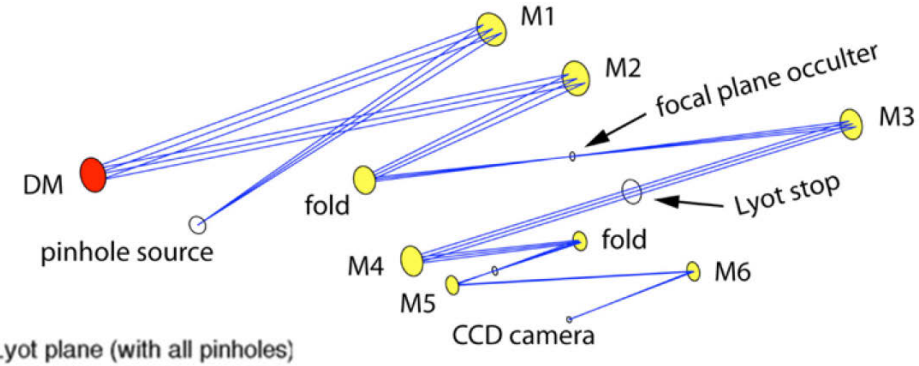
Coronagraph Technology Milestone:
Demonstration of ≤ 20% rms difference between contrast maps obtained using pinhole vs standard DM phase diversity approach, with ≤10^{-8} contrast using Lyot Masks @ 10% BWD

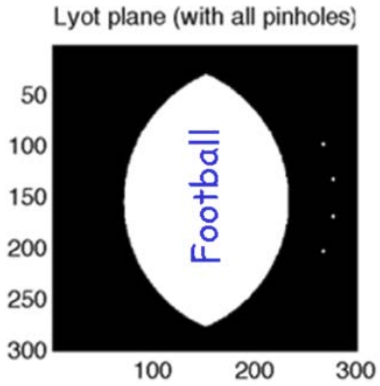
Facility: High Contrast Imaging Testbed 1, JPL

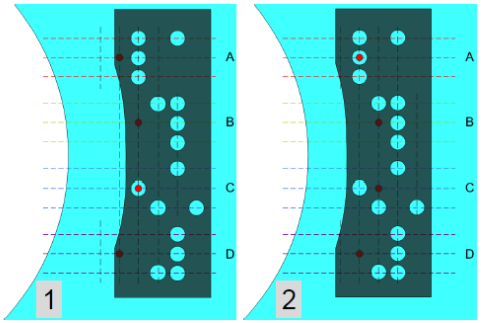
Current Status: ≤10^{-9} contrast, 18 % rms difference at 10% BWD

Challenges: Bandwidth sensitivity.

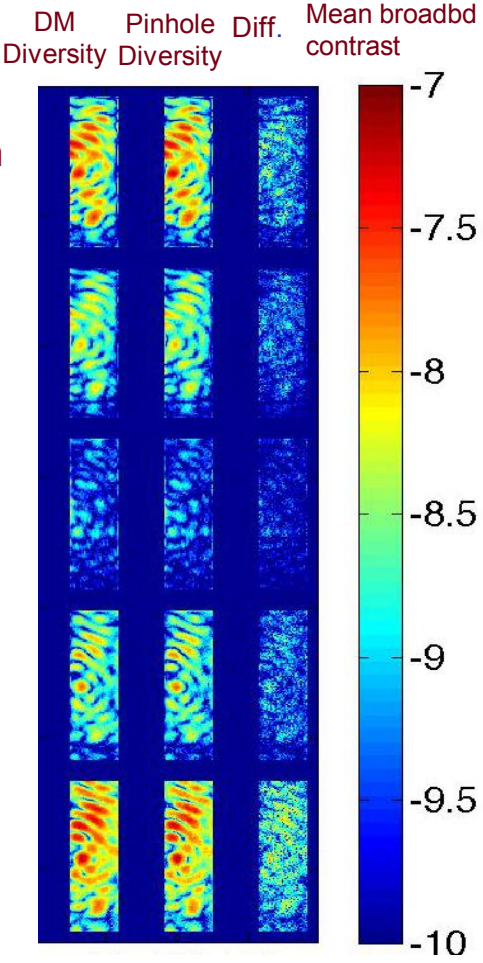
Future Work: Add incoherent background. Milestone runs in 1/2012







Sliding binary mask



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Mark Clampin (NASA GSFC)
Visible Nulling Coronagraph

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Coronagraph Technology Milestone:
Demonstration of ≤ 10^{-8} monochromatic contrast through visible nulling

Facility: Visible Nulling Coronagraph Testbed, NASA GSFC

Current Status: 1.5 x 10^{-6} @ 2λ/D contrast monochromatic. New DM installed in Dec. 2011.

Challenges: State of the art in segmented DMs.

Future Work: Complete milestone in 2012, follow-on with R. Lyon TDEM

Focal Plane Image thru Spatial Filter Arra

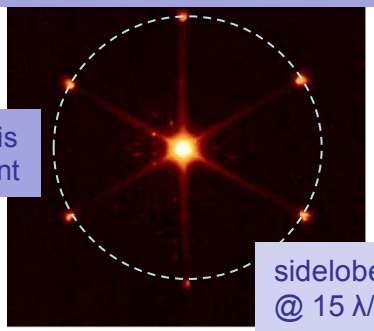
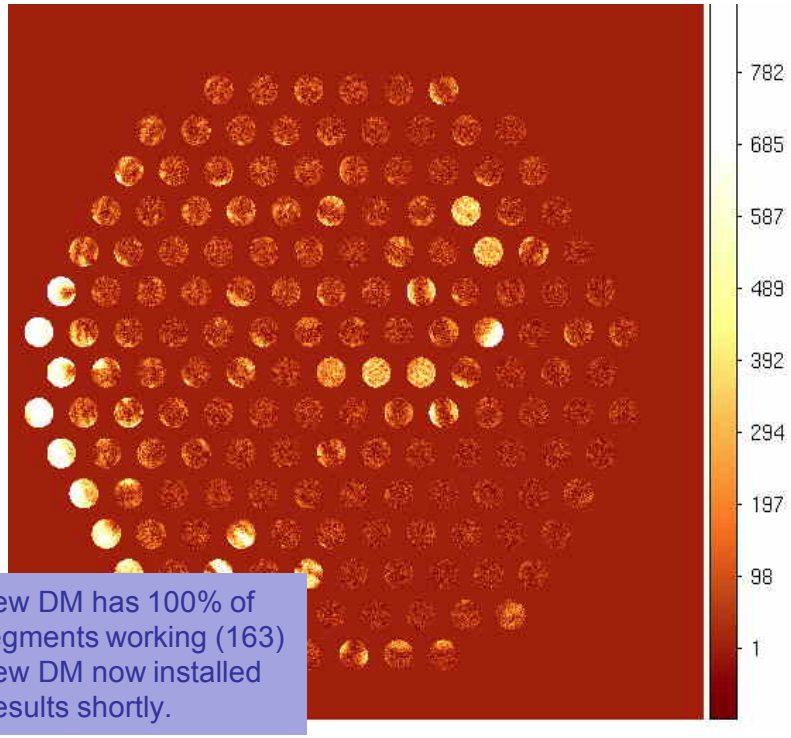
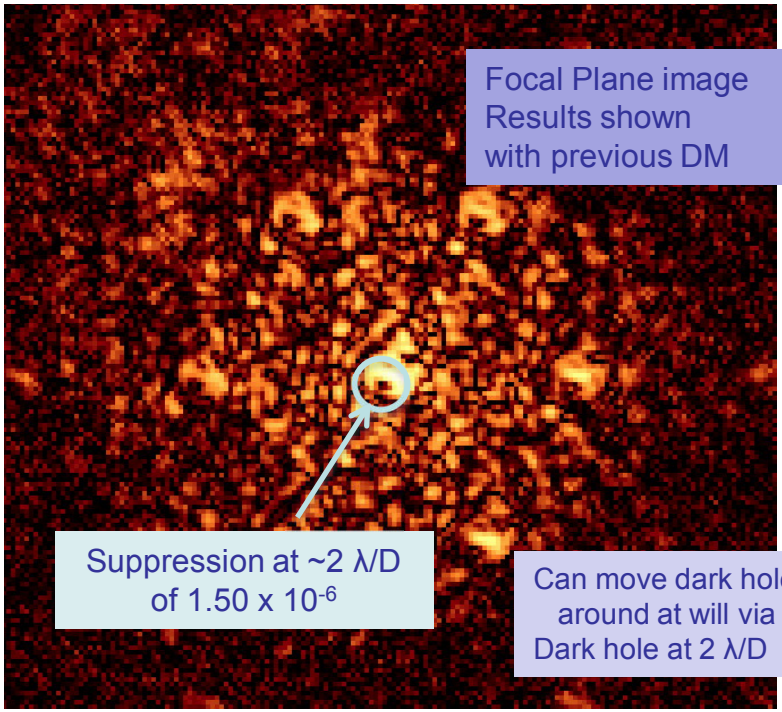


Image is coherent

sidelobes @ 15 λ/D



New DM has 100% of segments working (163)
New DM now installed
Results shortly.



Focal Plane image
Results shown
with previous DM

Suppression at ~2 λ/D
of 1.50 x 10^{-6}

Can move dark hole around at will via DM
Dark hole at 2 λ/D

Trauger | Guyon | Krist | Kendrick | Clampin | Kasdin | Figer

N. Jeremy Kasdin (Princeton Univ.)
Advanced Starshade Technology

Starshade Technology Milestone:
Demonstrate through mechanical measurements on a single petal made of flight-like materials using optical simulations based on those measurements that contrasts of $\leq 3 \times 10^{-10}$ at the inner working angle can be achieved.

Facility: Assembly Handling Facility (Bldg 299), JPL

Current Status: Mechanical structure complete, and optical edges have been fabricated & installed. The first round of measurements have been completed.

Challenges: Mechanical measurements over a large structure.

Future Work: Milestone measurements to be completed in 1/2012

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Donald Figer (Rochester Inst. Technology)
A Photon Counting Detector for Exoplanet Missions

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Detector Technology Milestone:
Demonstrate the performance of a 256 x 256 zero-read noise (Geiger mode) avalanche photodiode after radiation testing. The device must demonstrate a baseline photon detection sensitivity of at least 35% at 350 nm, 50% at 650 nm, and 15% at 1000 nm.

Facility: MIT Lincoln Laboratory and Rochester Institute of Technology

Current Status: A silicon 256x256 diode array has been bonded to a Read Out Integrated Circuit; the array has been hybridized and tested; a first light image has been obtained with good response in the 300–1000 nm range.

Challenges: Scaling to larger number of pixels (1024x1024)

Future Work: Radiation testing in 2012

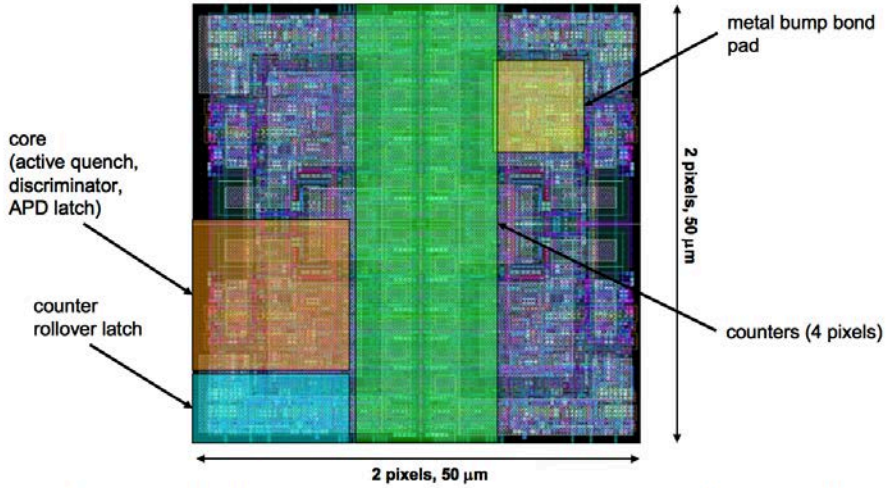

Figure 4. Close-up of the 256×256 ROIC layout, covering a 2×2 pixel area. The counter blocks for all four pixels form a contiguous region. Each pixel has its own isolated core, counter, and bump bond pads, although only one of each is highlighted in this representation.

Trauger | Guyon | Krist | Kendrick | Clampin | Kasdin | Figer

TDEM09 – Reporting of Final Results

- At the end of the TDEM09 demonstrations, Principal Investigators will deliver:
  - Milestone Report reviewed by ExEP Technology Assessment Committee (TAC)

  or
  - Final report describing accomplishments

- All reports will be posted on ExEP website
  - http://exep.jpl.nasa.gov/technology/

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TDEM10 – Award Summary

ExoPlanet Exploration Program

Principal Investigator	Title	Lead Institution	ExEP Facility
Serabyn	Demonstrations of Deep Starlight Rejection with a Vortex Coronagraph	JPL	HCIT- 1
Shaklan	Coronagraph Starlight Suppression Model Validation: Coronagraph Milestone #3A	JPL	HCIT -1
Kasdin	Integrated Coronagraph Design and Wavefront Control using 2 Deformable Mirrors	Princeton	HCIT-1
Guyon	Advances in Pupil Remapping (PIAA) Coronagraphy: Improving Bandwidth, Throughput and Inner Working Angle (B. Kern)	U of A	HCIT -2
Sandhu	Visible Nulling Coronagraph (VNC) Technology Demonstration Program	JPL	APEP
Kasdin	Verifying Deployment Tolerances of an External Occulter for Starlight Suppression (S. Shaklan)	Princeton	x
Lyon	Compact Achromatic Visible Nulling Coronagraph Technology Maturation	GSFC	x
Bierden	MEMS Deformable Mirror Technology Development for Space-Based Exoplanet Detection	Boston Micromachines	x
Helmbrecht	Environmental Testing of MEMS Deformable Mirrors for Exoplanet Detection	IRIS-AO	x

Acknowledgements

Part of this work was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration

Government sponsorship acknowledged

ExoPlanet Exploration Program