Jet Propulsion Laboratory
California Institute of Technology

WFIRST Coronagraph Technology Testbed Update

Testbed team

20 March 2018

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91109

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Outline

- **OMC testbed low flux test update**
  - The test is still on going
  - Understanding testbed photon flux
  - Low flux test assumption and success criteria
  - Low flux test recent results
- **Disk science mask test results**
- **Testbed future work**

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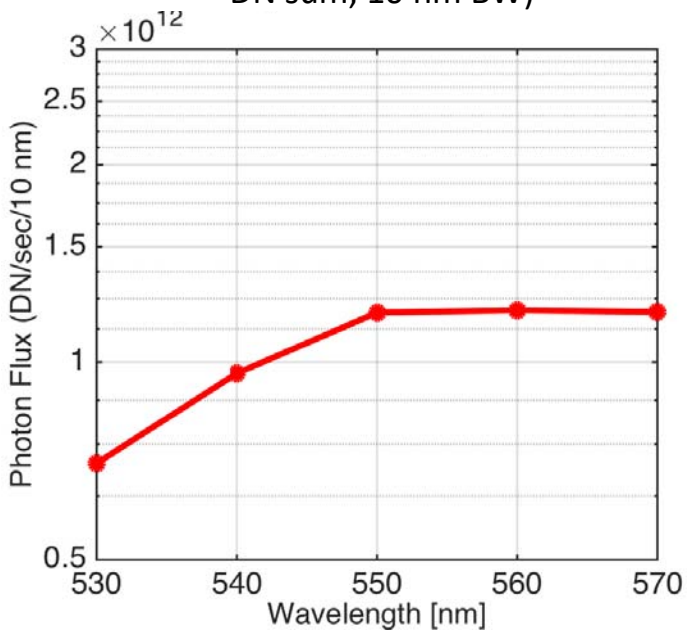
Flux Comparison : Testbed vs. Flight

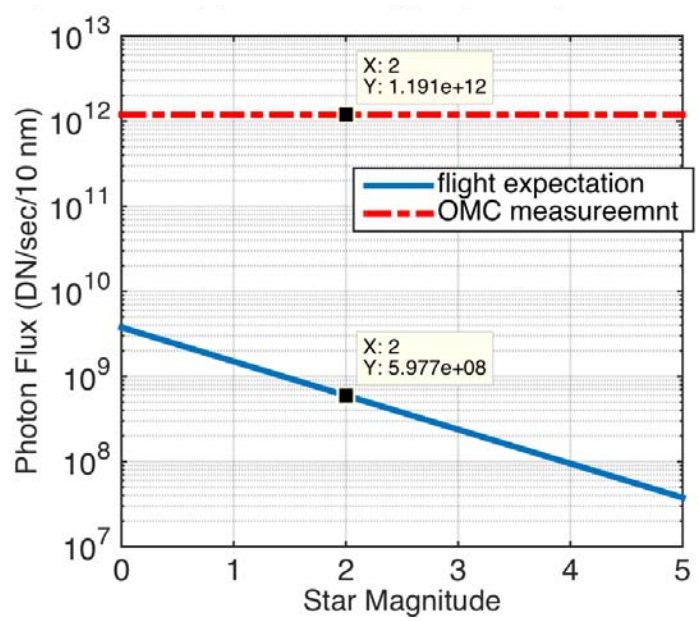
OMC Flux Measured

(Occ/Lyot/FS out pupil image total DN sum, 10 nm BW)



WFIRST Flux Needed

(G0V Type, QE, Loss, Ph to DN considered)

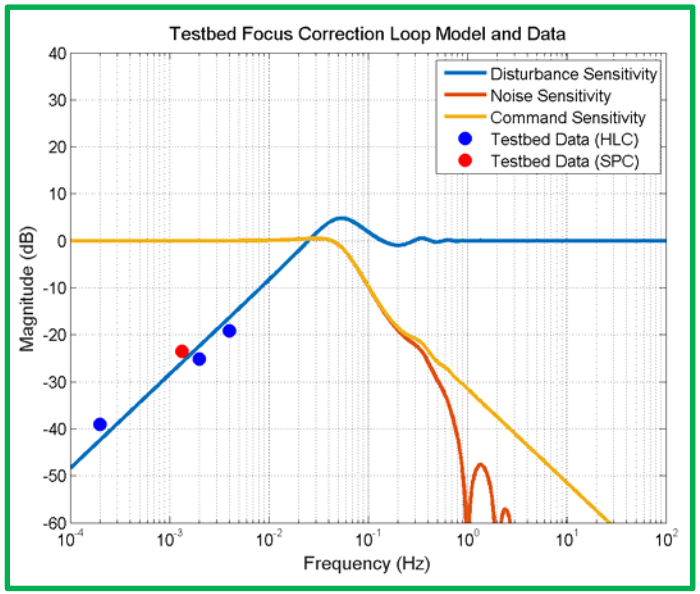


- Assumptions for WFIRST flux estimation
  - G0V type star, QE=92.9% (Flight CBE@575 nm), optical trans loss = 0.566x0.9 (flight CBE, Req=0.4 (CGI-L3-7))
- **For V=2 (G0V) star, flight photon flux is ~2000X dimmer than current OMC source level.**

Low Flux Test : Success Criteria

- ***EFC success criteria***: Demonstrate that the final contrast reaches to L3 raw contrast requirement after EFC iterations with short t_{th} (100/2000 sec, TBD) exposure time for a single image.
  - Final Contrast : L3 Raw Contrast Requirement
  - Single image exposure time : t_{th} (100/2000 sec in OMC, equivalent to 100 sec for flight)

- ***LOWFS/C success criteria:*** Test will be carried out in a shorter (compared to flight) time scale with equivalent low photon flux (V=5). Success of LOWFS/C low flux is to match testbed post correct WFE residual on the modal predicted WFE reject function curve.
  - Avoid testbed drift becoming a dominate factor



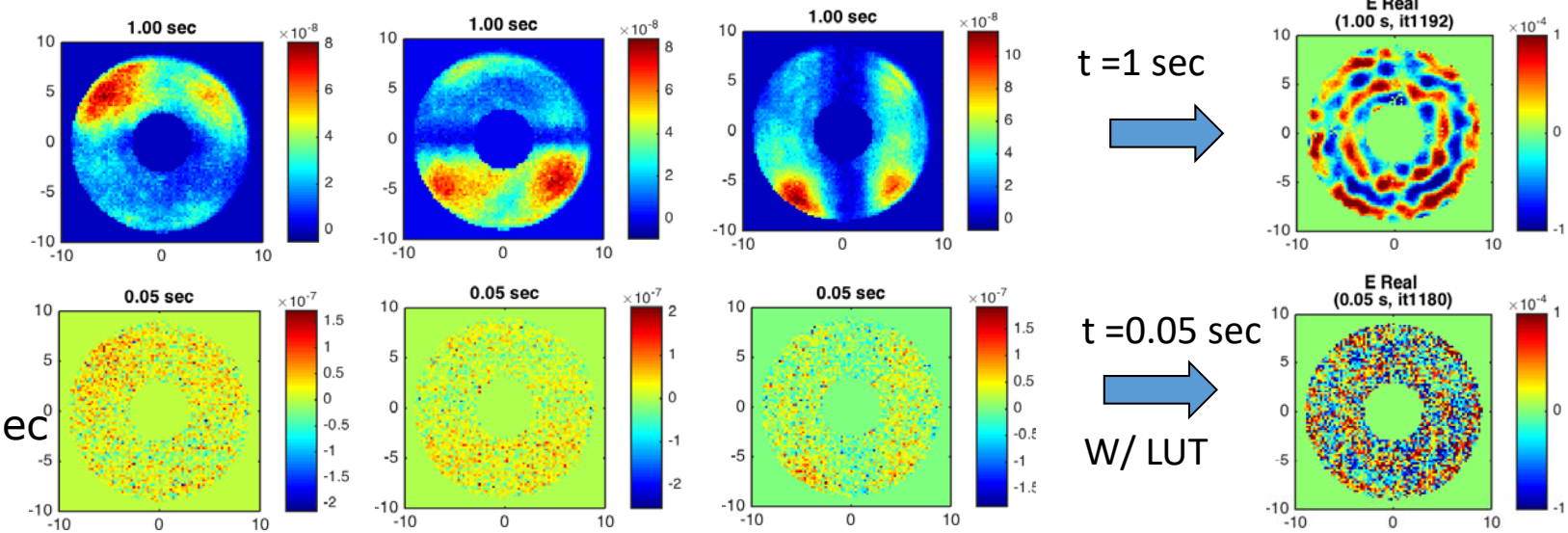
Update: Probe Amplitude LUT

$$|\Delta p_j| = \sqrt{\frac{I_j^+ + I_j^-}{2} - I_o}$$

Measured $|\Delta P_1|$ | Measured $|\Delta P_2|$ | Measured $|\Delta P_3|$ | E field Estimation

When t =1 Sec

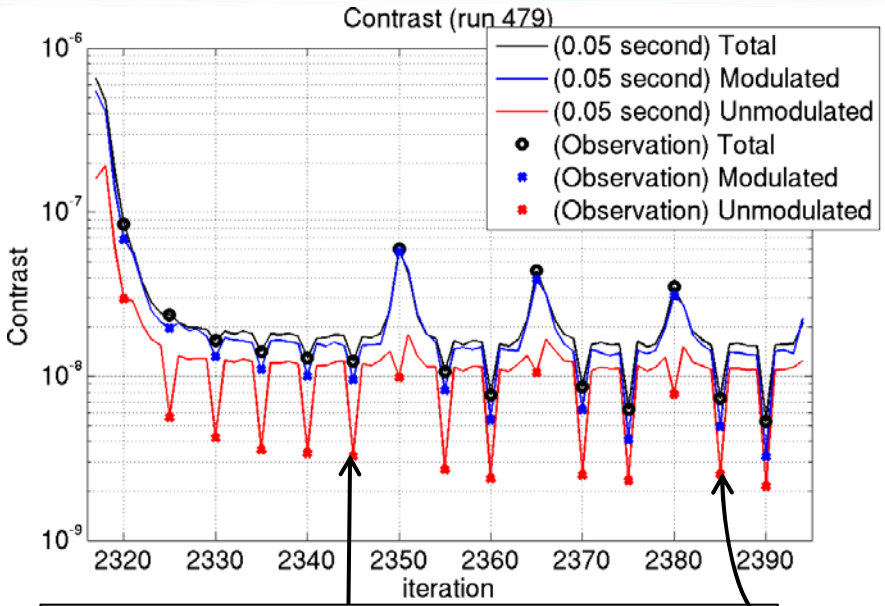
When t =0.05 Sec



Update with Probe Amplitude LUT

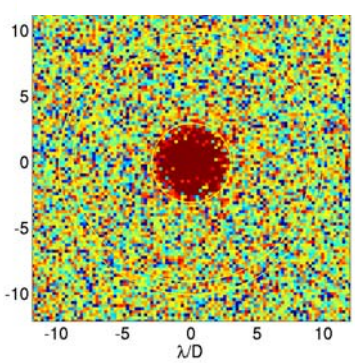
- We use a specific probe *pattern* and *strength* and save their measured amplitudes (|ΔP|) as a LUT.
- This improves measured accuracy.
- LUT shall be generated in GSE for flight.

EFC Trial with LUT

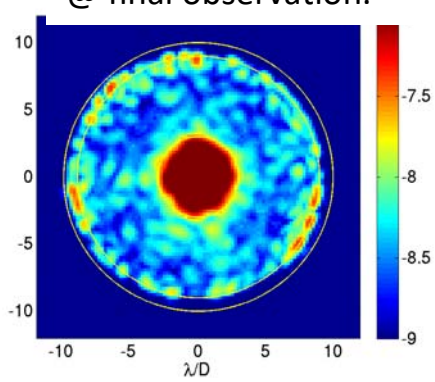


Every 5 iteration is the observation cycle (Freeze the DM, increase the exposure time for correct measurement)

Contrast not meaningful @ 0.05 sec



Contrast 5.32E-9 @ final observation.



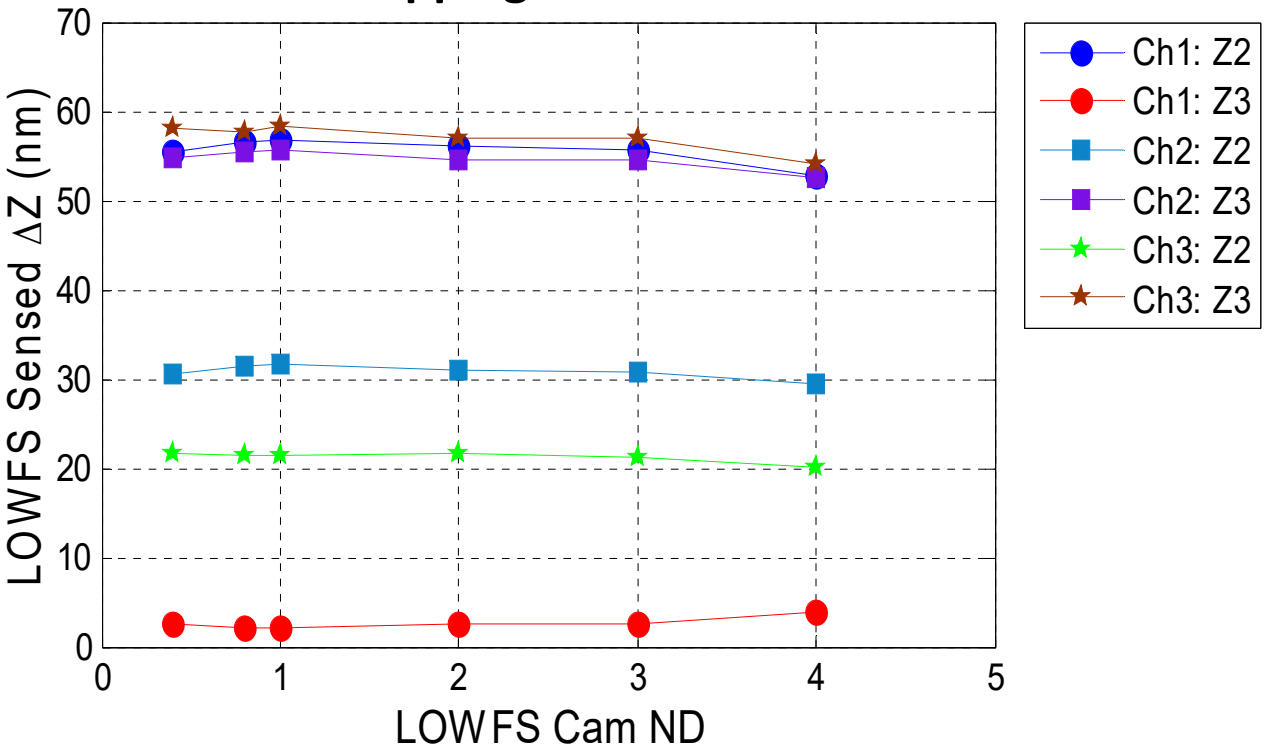
- **Testbed Test Configuration**
  - Star
    - BW 10 % @ 550 nm
  - LOWFS
    - High flux condition
    - LoS loops closed all the time to remove the lab drift. No other disturbances introduced.
  - EFC (star light suppression control)
    - Starting from an existing solution that provided contrast ~1E-6.
    - Use 0.05 sec single image exposure (Equivalent = 100 sec on V=2, G0V for flight)

- ***This initial trial shows EFC is meeting the L3 req. and algorithm is very promising.***

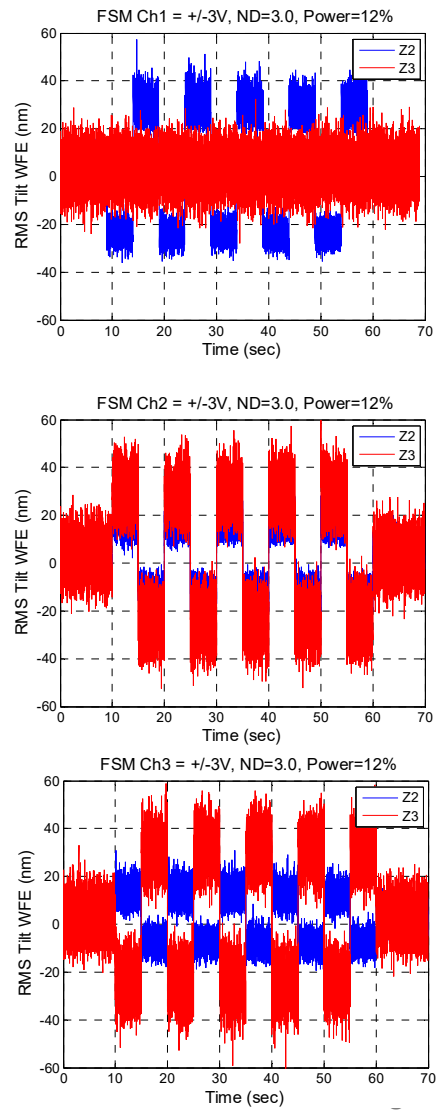
FSM Chopping Signal vs Photon Flux

- **Testbed Setup**
  - NKT source BW=100nm @ 550 nm
  - HLC: asymmetric mask
  - FSM: strain gauge on, chopping DAC signal = +/-3 V
  - Use the ND filter in front of LOWFS Cam to change the flux
    - ND=4 data is from ND=3 and NKT Power=12% (equivalent V=5.5)

FSM Chopping vs. LOWFS Cam ND



LOWFS chopping signals at low flux



FSM Loop Low Flux Test: Closed LoS Loop in Lab Environment

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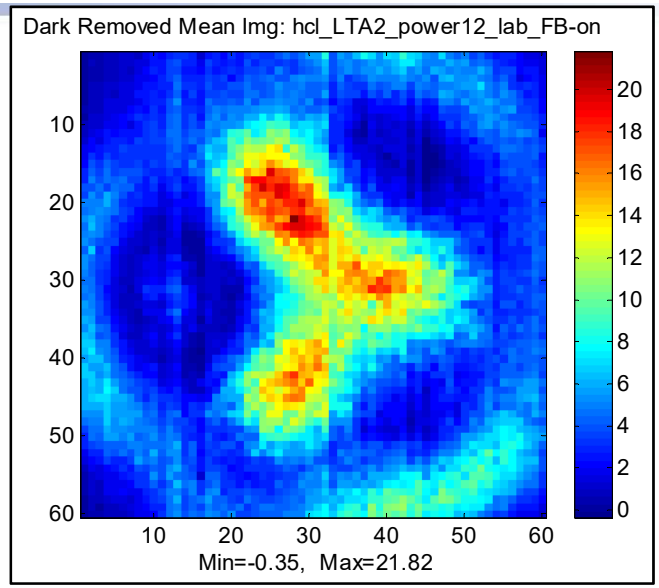
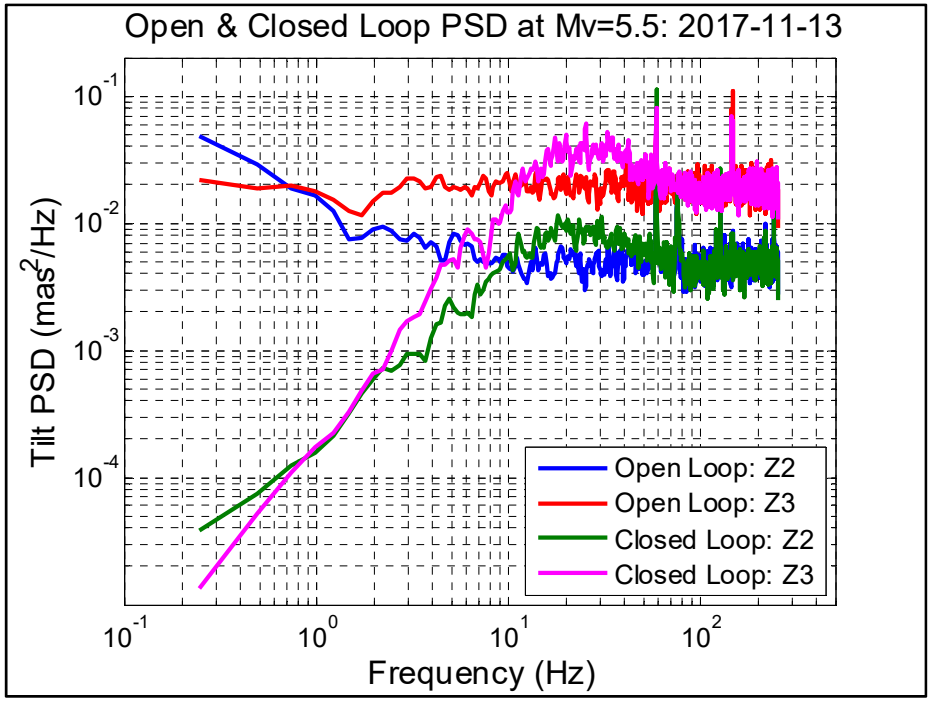
- **Testbed setup:**
  - Source bandwidth = 100 nm BW @ 550 with NKT spectrum
    - Flight: 128 nm at 550 at stellar spectrum
  - LOWFS camera flux: equivalent stellar magnitude: V = 5.5
    - ND=3 in front of LOWFS cam, NKT Power = 12%
  - Line of sight disturbances: lab drift only
- **LoS loops stable under low flux**
  - Loop gain was tuned with high flux and need to be tuned for low flux





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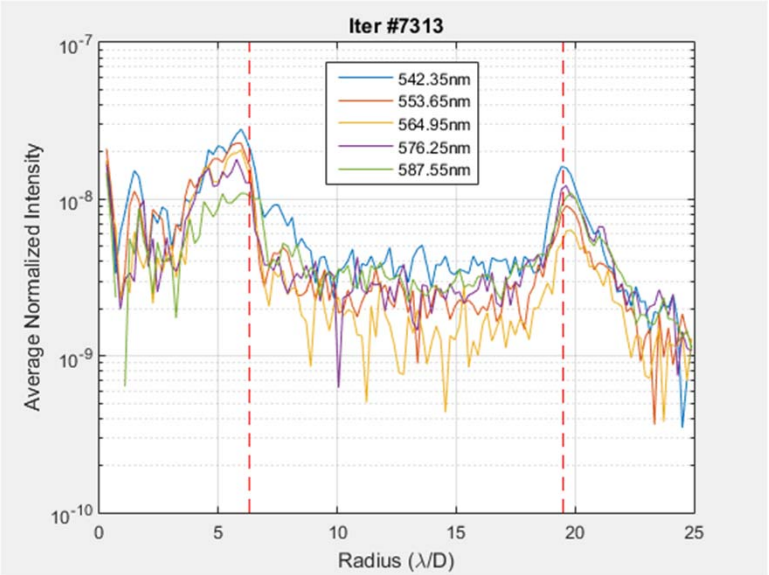
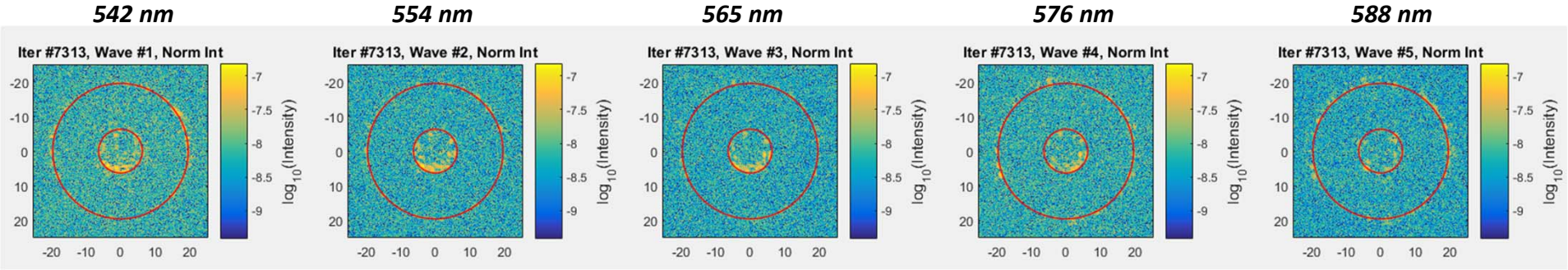
Disk Science Mask Test on SPC/IFS Testbed

- **Disk science mask (DSM) nulling has achieved the indented contrast level**
  - Current best contrast from DSM: averaged 10% contrast evaluate between 6.3 – 19.5 λ/D is ***4.3e-9***
- **Recent improvement:**
  - Improved the DM #2 actuator influence function of the control model, which greatly improve the nulling
  - Better SPC pupil mask representation in the control model to match the testbed
- **Current activity and near term plan:**
  - Wrapping up the DSM contrast to wavefront error sensitivity test
  - Plan to exit SPC/IFS chamber before 3/30/2018

Radially Averaged NI Profile

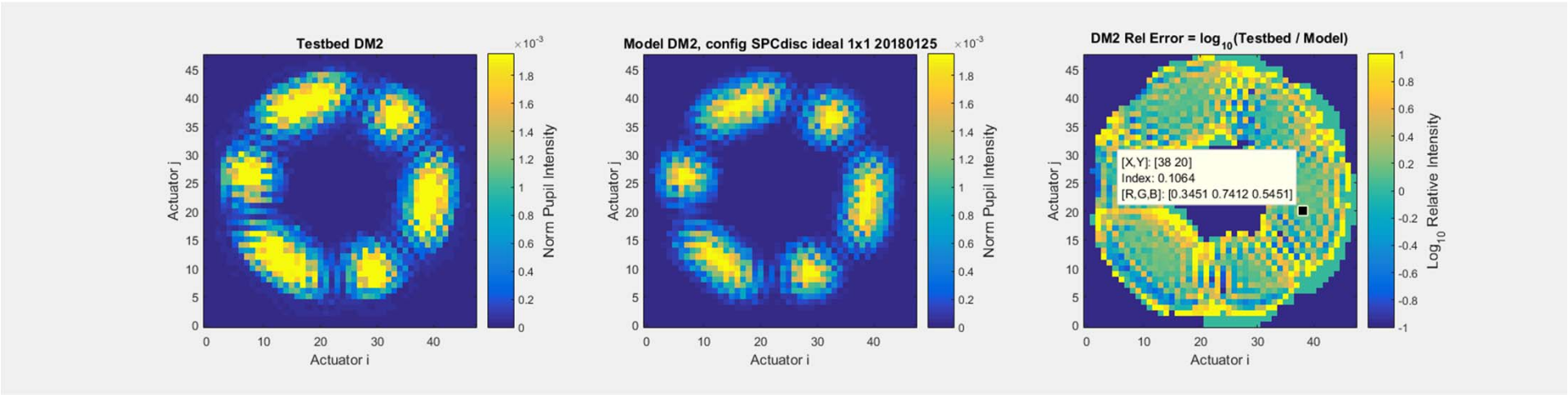


SPC imager 5 bands normalized intensity:

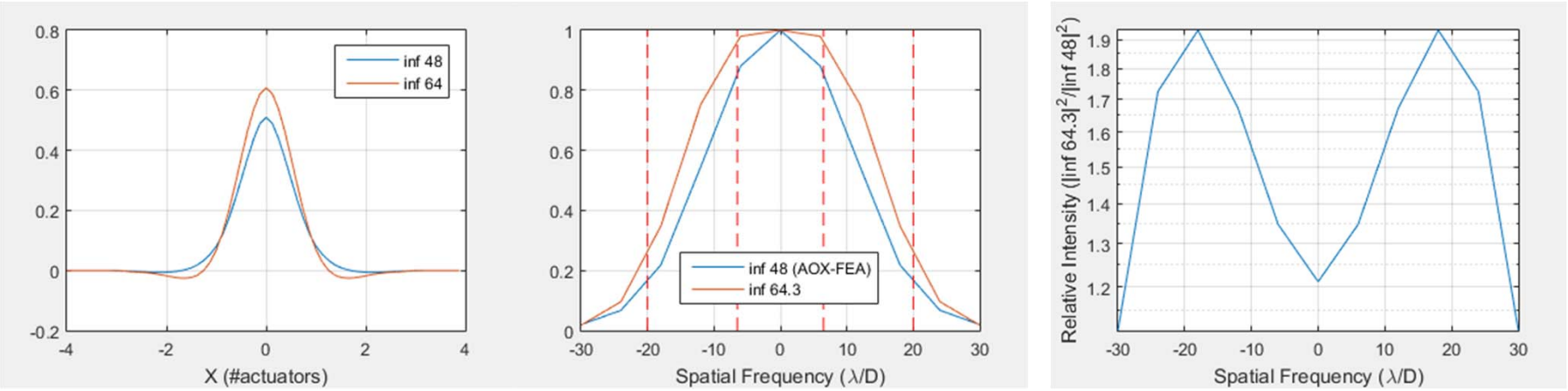


Understanding and Improvement of DM Actuator Influence Function

- **Testbed measurement: Poke Intensities in the Lyot Plane**
- **Testbed Measures <u>Stronger</u> Pokes Than Model Predicts**



- **Effect of influence function: the "shape of wing" impacts the higher spatial frequency**



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Testbed Plan

- **Key testbed milestones for 2018**
  - Finish disk science SPC mask test including model matching (tilt and WFE sensitivities).
  - Coronagraph and LOWFS/C demonstration with photon flux equivalent stellar magnitude, Mv = 2 for EFC, and Mv = 5 for LOWFS/C.
  - Improve the IFS 18% high contrast margin to the requirement specified by CGI system engineering and the model validation for the key parameter (tilt and WFE sensitivities).
  - Test LOWFS/C with WFIRST Phase A line-of-sight jitter which includes disturbances from multiple reaction wheels.

Backup

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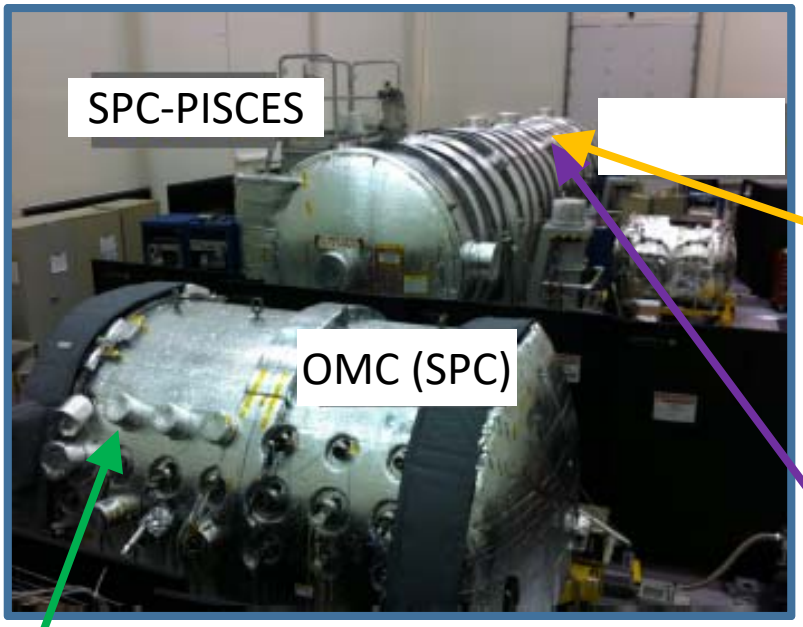
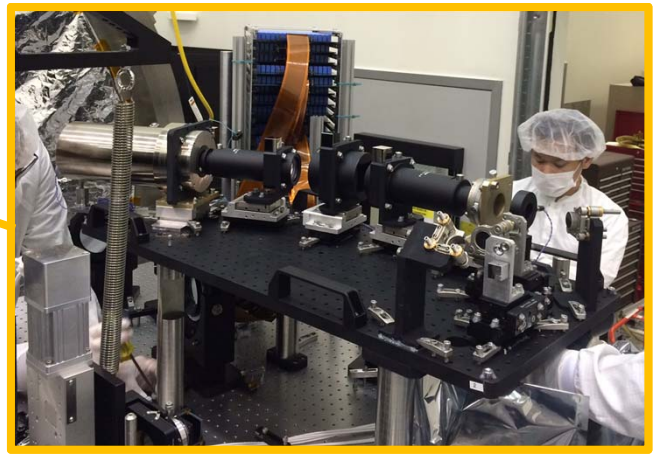
WFIRST Tech Testbeds in Pictures

HCIT Testbeds

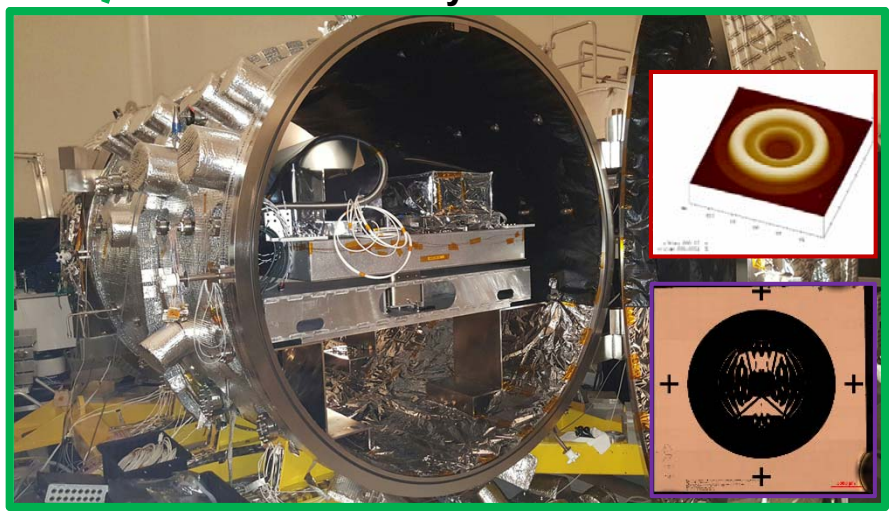


PISCES

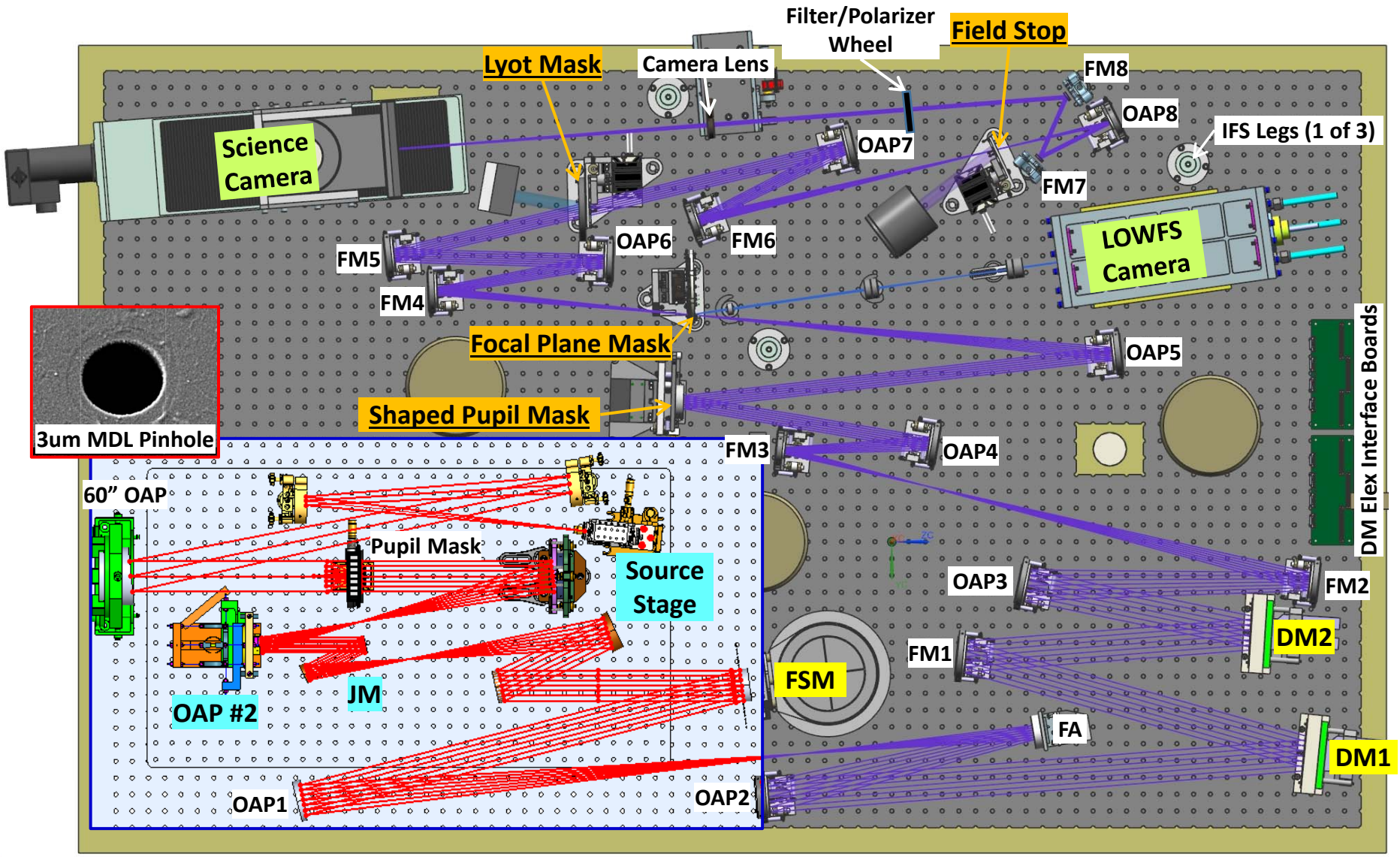


SPC Testbed

OMC Testbed for Coronagraph-LOWFS/C Dynamic Test



Occulting Mask Coronagraph (OMC) Dynamic Testbed



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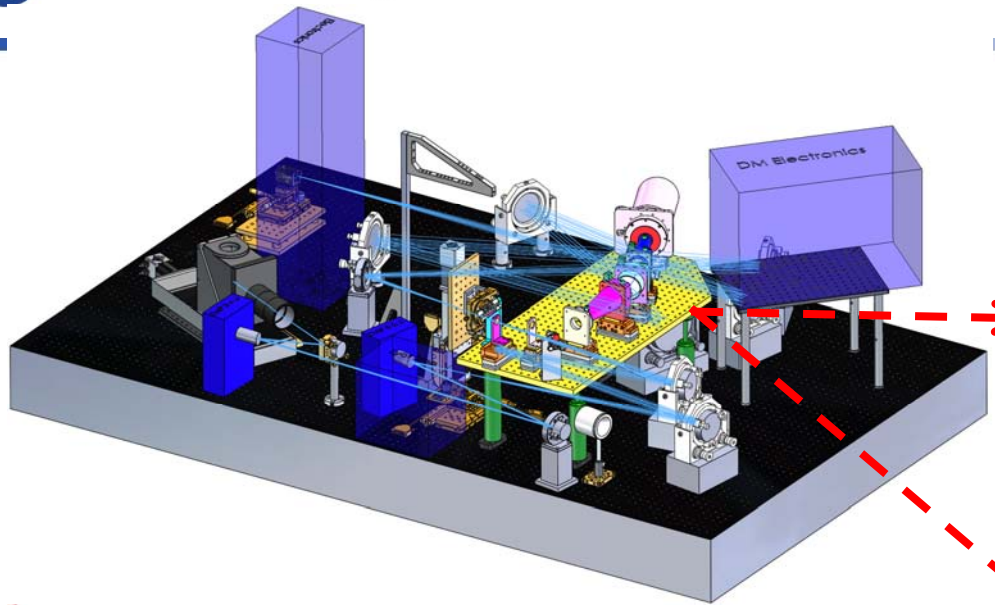
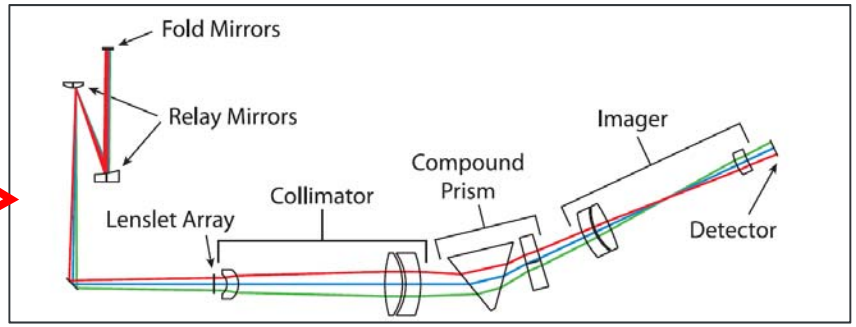
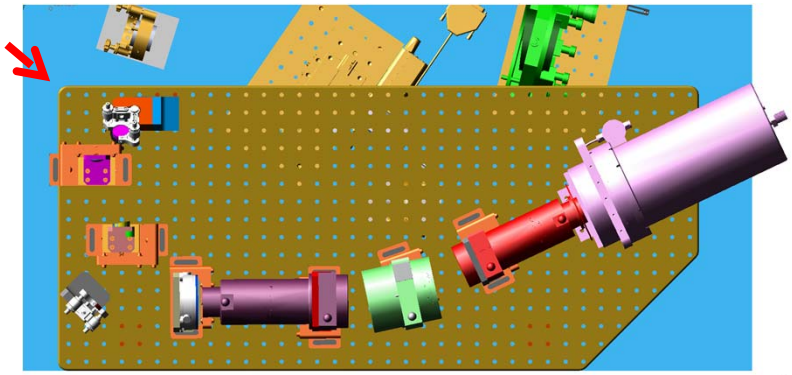
SPC / IFS (PISCES) Testbed



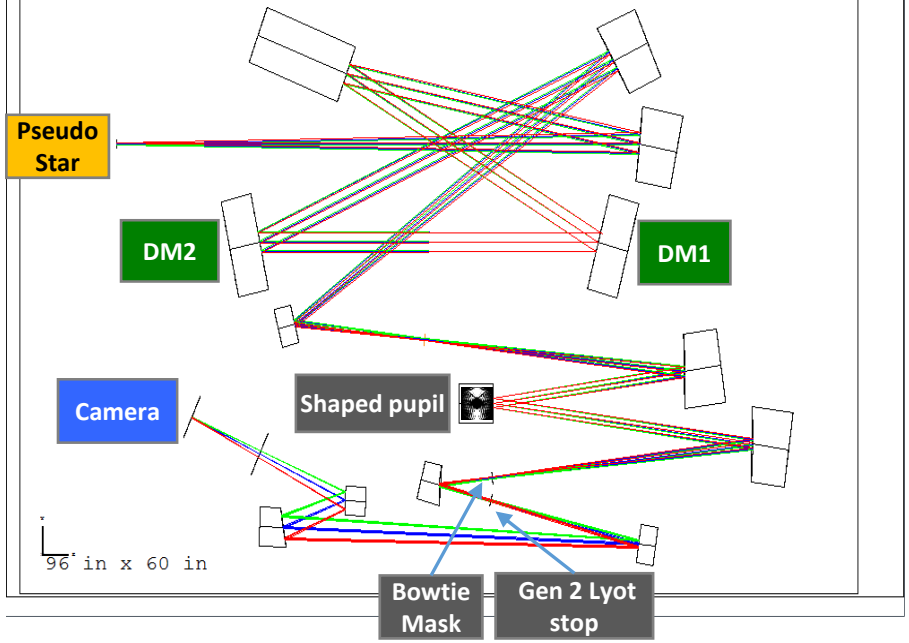
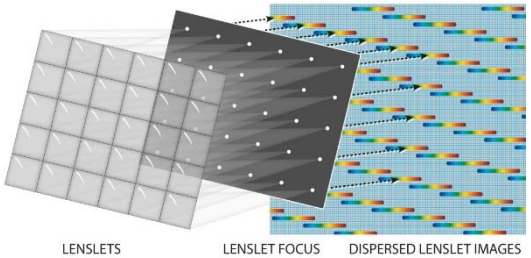
PISCES Optical Layout



PISCES Sub-bench



SPC/IFS Testbed Optical Layout



PISCES Spectral Image