WFIRST Coronagraph Technology Development Testbeds: Status Update and Recent Testbed Results

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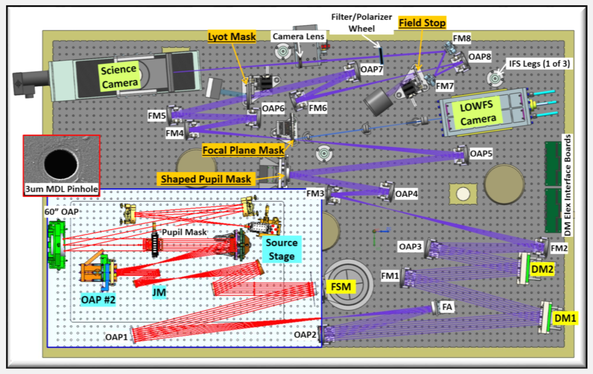
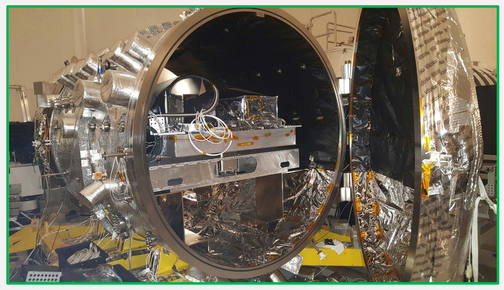
WFIRST Technology Development Testbeds

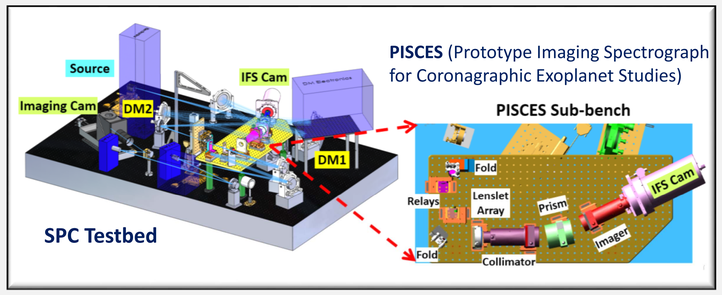
Occulting Mask Coronagraph (OMC) Dynamic Testbed



OMC Testbed

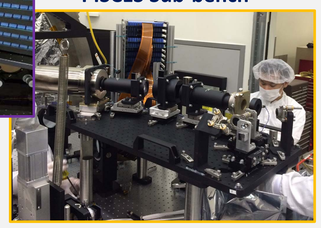


Shaped Pupil Coronagraph (SPC) & Integral Field Spectrograph (IFS) Testbed

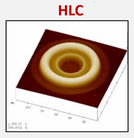


SPC Testbed

PISCES Sub-bench



HLC

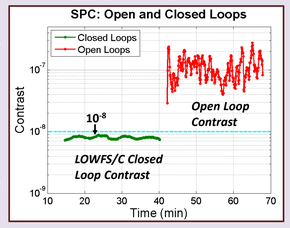


SPC Planet

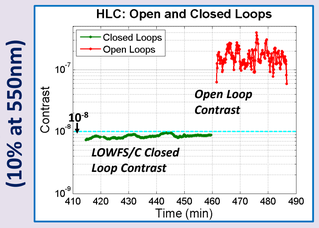
SPC Disk Science

OMC Testbed: Coronagraph & LOWFS/C Dynamic Test

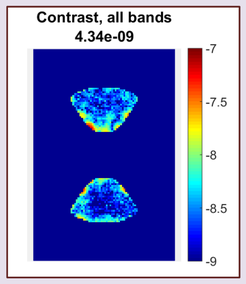
SPC Dynamic Test (10% at 550nm)



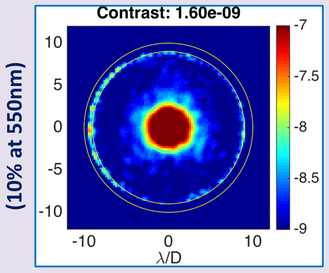
HLC Dynamic Test (10% at 550nm)



Best SPC Static Contrast (10% at 550nm)



Best HLC Static Contrast (10% at 550nm)

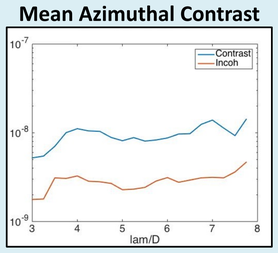


- **LOWFS/C has demonstrated to maintain coronagraph contrast stability to better than 10^{-8} in the presence of WFIRST like line-of-sight and low order wavefront disturbances for both SPC and HLC modes (Milestone 9).**
  - Three dominant WFIRST wavefront disturbance modes demonstrated (tip-tilt and focus).
  - LoS error injected: 14 mas rms LoS drift + CBE LoS jitter at 600 rpm wheel speed with 72 harmonic tones.
  - Low Order WFE Injected: ±1 nm (SPC) and ±0.5 nm (HLC) focus disturbance.

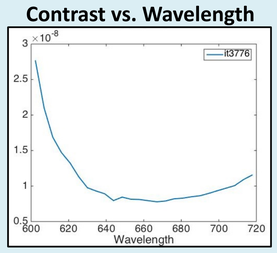
SPC/IFS Testbed: IFS Broadband Nulling

- **SPC IFS (PISCES) has reached contrast level of 1.1×10^{-8} in an 18% band using EFC control from IFS**
  - Careful IFS wavelength calibration is done using a tunable broadband source.
  - IFS data extraction creates 26 image slices and 7 slices spread across the 18% band are used to do EFC control.
  - IFS 18% EFC control is centered at λ = 660 nm.
  - IFS contrast score: two sides dark field, 26 wavelength channels centered at λ = 660 nm, between 3-8 λ/D
    - Contrast floor is mostly coherent and dominated by one bright speckle.

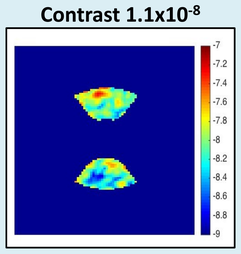
Mean Azimuthal Contrast



Contrast vs. Wavelength



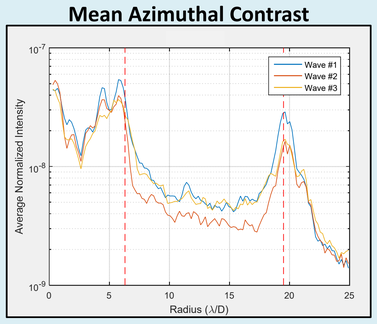
Mean Broad Band Contrast 1.1×10^{-8}



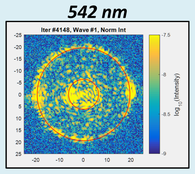
SPC/IFS Testbed: Disk Science Mask Nulling

- **Disk science mask (DSM) is one of the three coronagraph modes for WFIRST CGI.**
  - DSM's 360 degree dark hole extends up to 20 λ/D.
  - DSM provides a powerful tool to study exozodiacal dust clouds associated with stellar debris disks to gain insight of the exoplanet formation and stellar disk dynamics.
- **DSM masks were fabricated by JPL's Micro Device Lab**
  - The mask is fabricated on the 35mm x 35mm x 4mm silicon substrates with Al and black silicon binary features.
- **Current best contrast from DSM is 8×10^{-9}, 10% centered at λ = 565 nm, between 6 – 19.5 λ/D.**

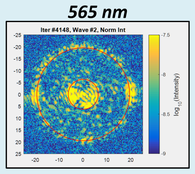
Mean Azimuthal Contrast



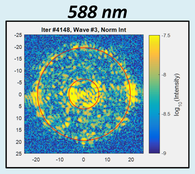
542 nm



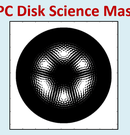
565 nm



588 nm



SPC Disk Science Mask



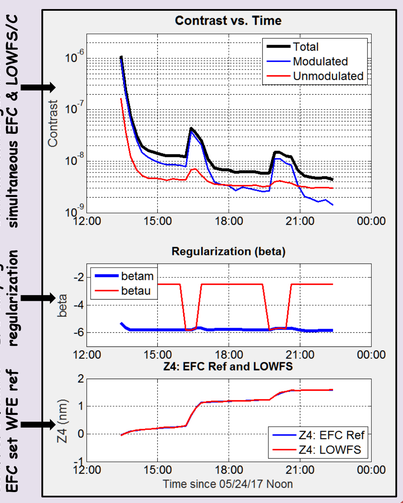
OMC Testbed: Simultaneous EFC & LOWFS/C Test

- **WFIRST like disturbances using OMC Testbed's OTA Simulator**
  - LoS drift = 8 mas; LoS jitter = 1 CBE at RWA = 600 rpm; Focus (Z4) drift = 1 nm sinusoidal with 60 minutes period
- **LOWFS/C closed loops using FSM and DM:**
  - LoS feedback loop (FSM)
  - LoS feed forward loop (FSM)
  - Low order WFE loop (DM #2): LOWFS DM loop follows WFE target set by EFC.
- **HLC EFC dark hole nulling operation:**
  - Use 3 band from filter wheel in front of Science Camera simulating flight operation.
  - Start with poor contrast to show case EFC convergence.
  - EFC control set reference for LOWFS/C (LoS and low order WFE).
  - EFC control with varying regularizations.
- **Test results have shown the successful simultaneous EFC and LOWFS/C operations:**
  - Contrast converges with simultaneous EFC & LOWFS controls.
  - LOWFS/C follows EFC set WFE target and coordinates the DM commands with EFC.
  - LOWFS/C is helping EFC by correcting/reducing the low order WFE disturbances.

Contrast converges with simultaneous EFC & LOWFS/C

EFC varying regularization

LOWFS/C follows EFC set WFE ref



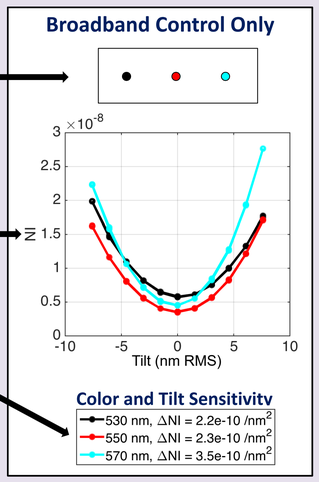
OMC Testbed: Improving HLC LoS Jitter Sensitivity with Off-axis EFC

EFC control channels: color channels + off-axis channels

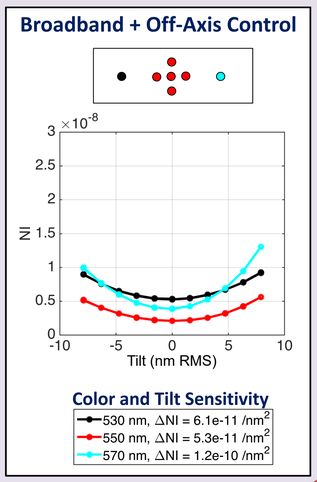
Normalized intensity vs. tilt: The flatter curves indicates NI is less sensitive to tilt

By including the off-axis EFC control channels, the coronagraph line-of-sight sensitivity is reduced by more than factor of 2.

Broadband Control Only



Broadband + Off-Axis Control



Conclusion and Future Work

- WFIRST coronagraph technology development testbeds have been successful and effective in developing and demonstrating the needed technologies for WFIRST Coronagraph Instrument.
- WFIRST technology development milestones for 2017 have all been achieved. This poster only highlights some of the testbed results in 2017.
- The WFIRST tech testbed activities continue. Major technology development testbed milestones for 2018:
  - Further improve disk science SPC mask performance including model matching.
  - Coronagraph and LOWFS/C demonstration with photon flux equivalent to target stellar magnitude: Mv = 2 for achieving starlight suppression (EFC), and Mv = 5 for maintaining starlight suppression (LOWFS/C).
  - Improve the IFS 18% raw contrast to match the requirement specified by WFIRST CGI system engineering.
  - Demonstrate line-of-sight jitter suppression with the latest observatory jitter profile which includes LoS disturbances from multiple reaction wheels.