Implementation of Linear Dark Field Control at the UA Wavefront Control Lab

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Outline

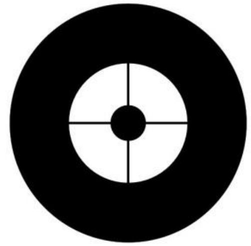
- Intro to LDFC
- EFC & LDFC Simulation Parameters
- Determining Linear Response
- Current Results
- Ongoing & Future Work

Intro to LDFC

- Purpose: To maintain ‘dark hole’ created by electric field conjugation without the need to continually re-implement EFC
- Procedure: Utilize the linear response of ‘bright’ pixels outside of the dark hole to changes induced in the pupil plane by the DM
- Goal of current work: Identify characteristics of bright pixels that can be used to close a linear control loop on the EFC dark hole
    - Linear range of pixel intensity response to DM actuation
    - Location of linear-response pixels with respect to dark hole
    - Null space of LDFC

EFC & LDFC Simulation Parameters

- Simulation of UA WFC testbed
  - λ = 550nm
  - Centrally-obscured pupil
  - f/39 system
  - Lyot coronagraph
  - 1024 actuator BMC Kilo DM (current)
  - 37 segment PTT111-L Iris AO (near-future)



- Dark hole specs:
  - Contrast ~ 10^{-8} - 10^{-9}
  - 4 x 5 λ/D square region of interest
  - Located at 5 - 9 λ/D from PSF core

UA Wavefront Control Lab

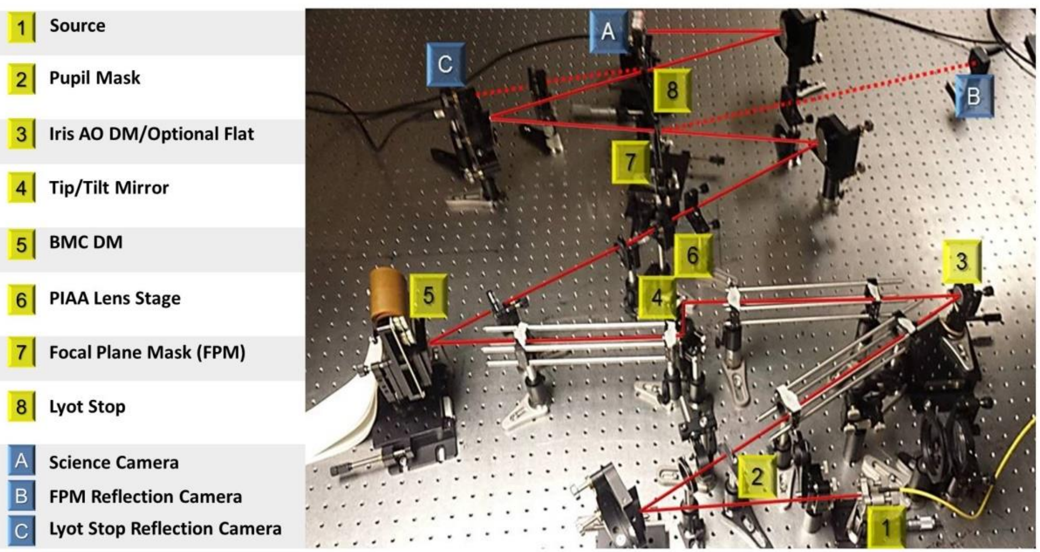


Fig. 1

Dark Hole 10^{-8} – 10^{-9} Contrast (Simulation Log Scale)

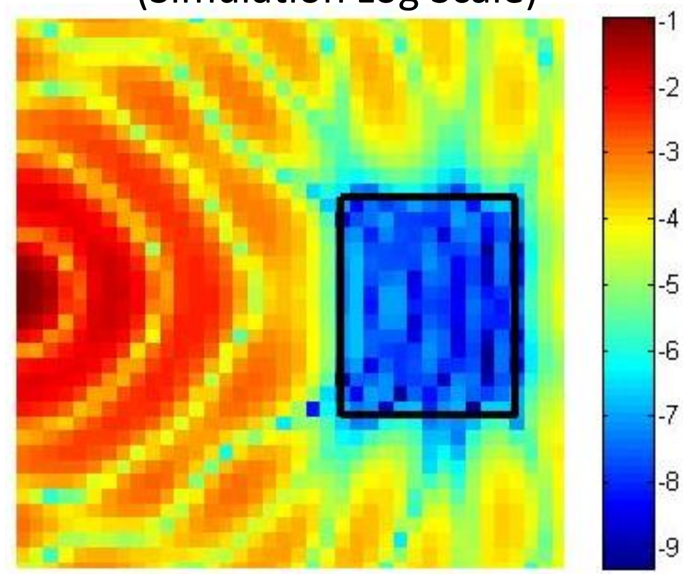
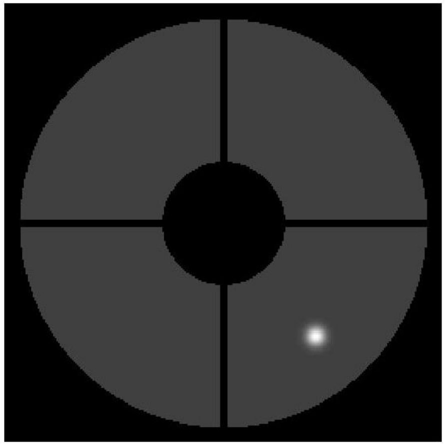


Fig. 2

Determining Linear Response

- Create 'dark hole' using DM
- Modulate single DM actuator over linear range of amplitudes: [-A, +A]
- Calculate intensity change $\Delta I = PSF_{poked} - PSF_{ideal}$ over the range of amplitude actuations on DM for all pixels in image
- ΔI over 156nm DM stroke range shown below for 5 dark hole pixels (plotted in Fig 4) and 5 bright pixels (plotted in Fig 6)



Pupil with poked DM actuator

Fig. 3

Dark Hole Pixel Response

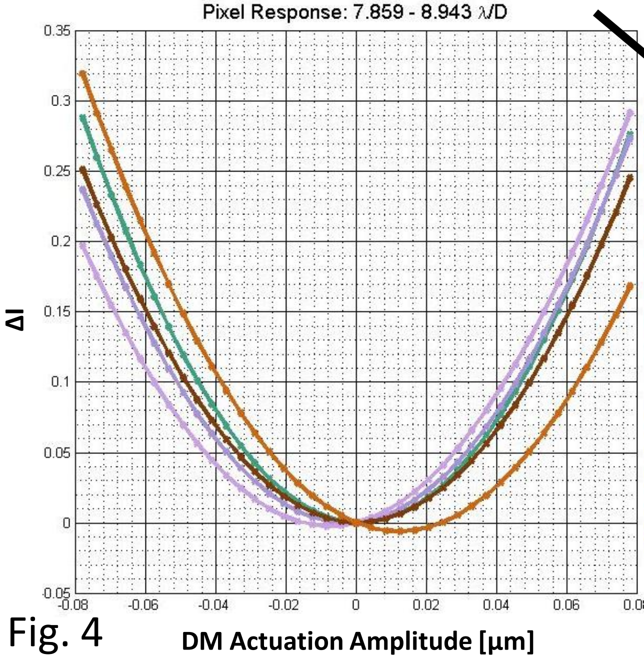


Fig. 4

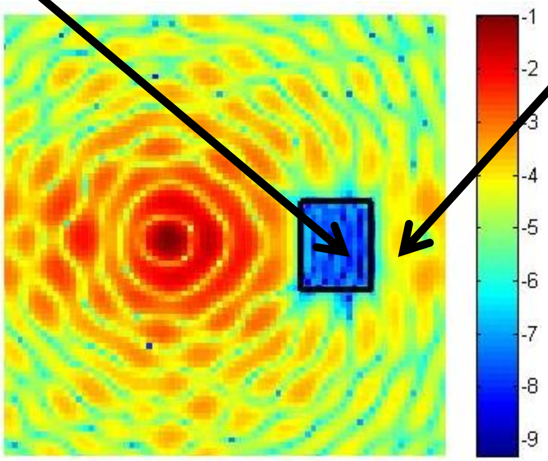


Fig. 5 (Log Scale)

Bright Pixel Response

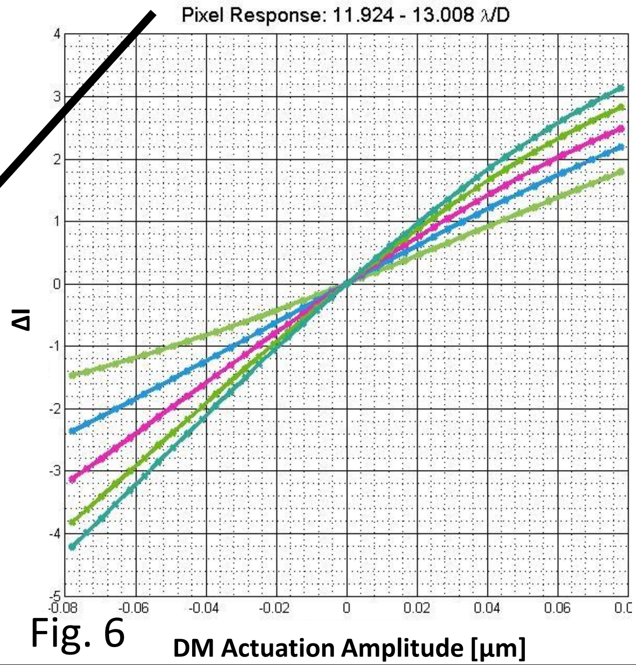


Fig. 6

Determining Linear Response

$\Delta I = PSF_{poked} - PSF_{ideal}$ and selected cross section of pixels

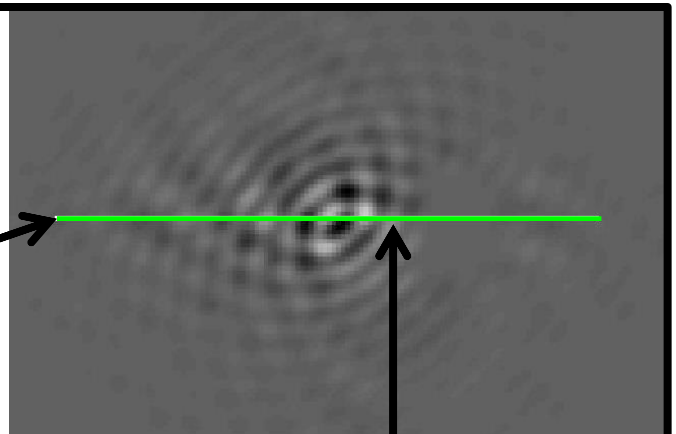


Fig. 7

- For each pixel in a selected cross section, a linear least-squares fit to the ΔI response to the DM actuation is calculated.

$$\beta = (\Delta I^T \Delta I)^{-1} \Delta I^T y$$

$$\Delta I = pixel\ response$$

$$y = \Delta I\big(DM\ poke_{Amp\ 1}\big) : \Delta I\big(DM\ poke_{Amp\ N}\big)$$

- Linear fit metric: 0.97<β<1.03

- Bright pixel response to linearly increasing DM stroke over 312nm range with amplitudes: [-156nm, +156nm]
- Shows linear bright pixel response over 156 nm DM stroke range with β = 0.998

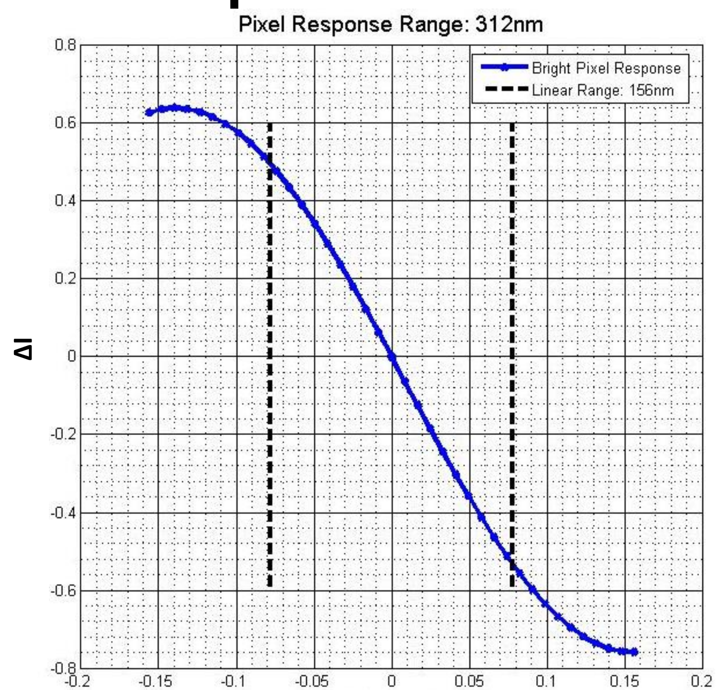


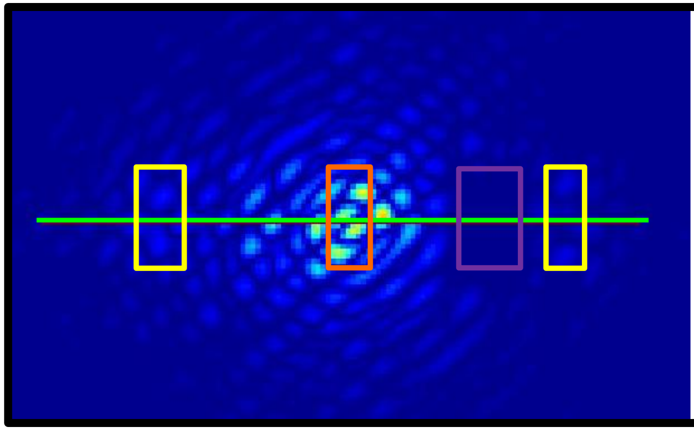
Fig. 8

DM Actuation Linear Range: 156nm

Bright Pixel ΔI Response to DM Actuation

Current Results

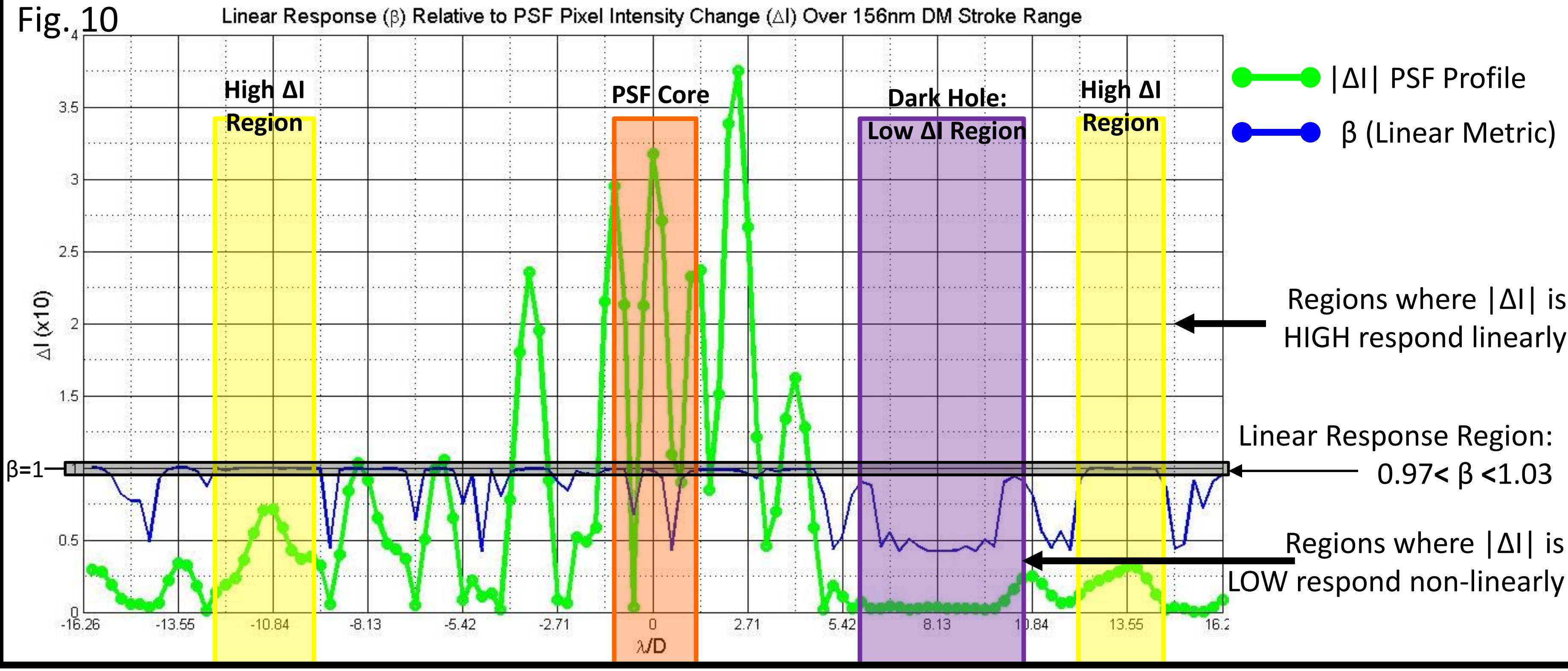
- Pixels with greatest absolute magnitude change in intensity |ΔI| show highly linear response.
- Results showing |ΔI| vs β shown below.



Profile of pixels selected for analysis across $|\Delta I| = |PSF_{poked} - PSF_{ideal}|$

Fig. 9

Fig. 10



Ongoing & Future Work

- Determine dependence of linearly-responding pixels on:
  - Location in the PSF wrt the ‘dark hole’
  - Absolute change in intensity
- Map the null space of LDFC
- Build a control loop around linearly-responding pixels
- Apply to segmented Iris AO DM
- Implement on UA Wavefront Control Testbed