AO Science Camera Calibration (and Maintainance)

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Agenda

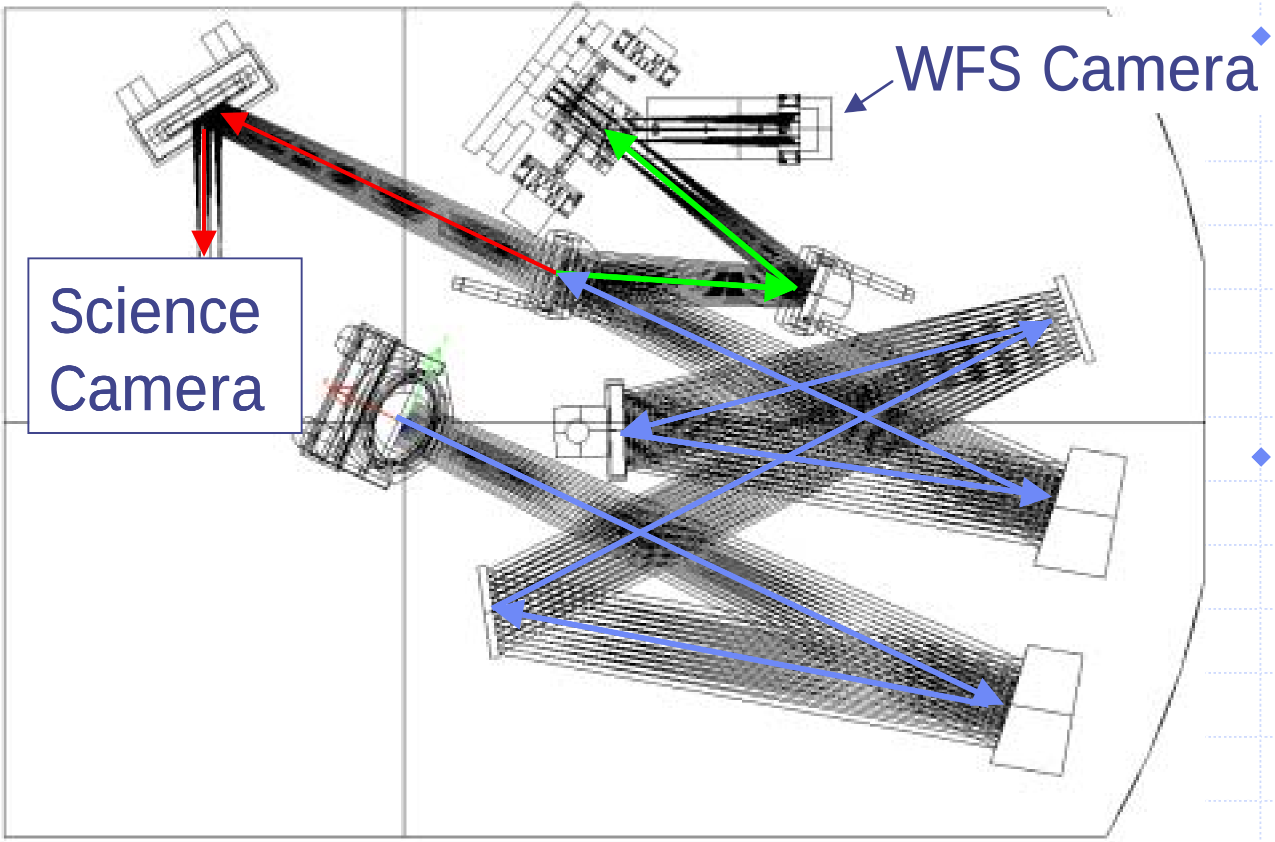
- Overview of Science Camera Calibration
- Current Practice/Capabilities
- Requirements for calibration on XAOPI
- Approaches to Calibration
- Summarize
- Next steps

Overview of Calibration

- Detailed knowledge of the image quality at the science observation plane is required...but is impossible.
- The next best thing is to measure wave front errors as common to the science camera as possible:

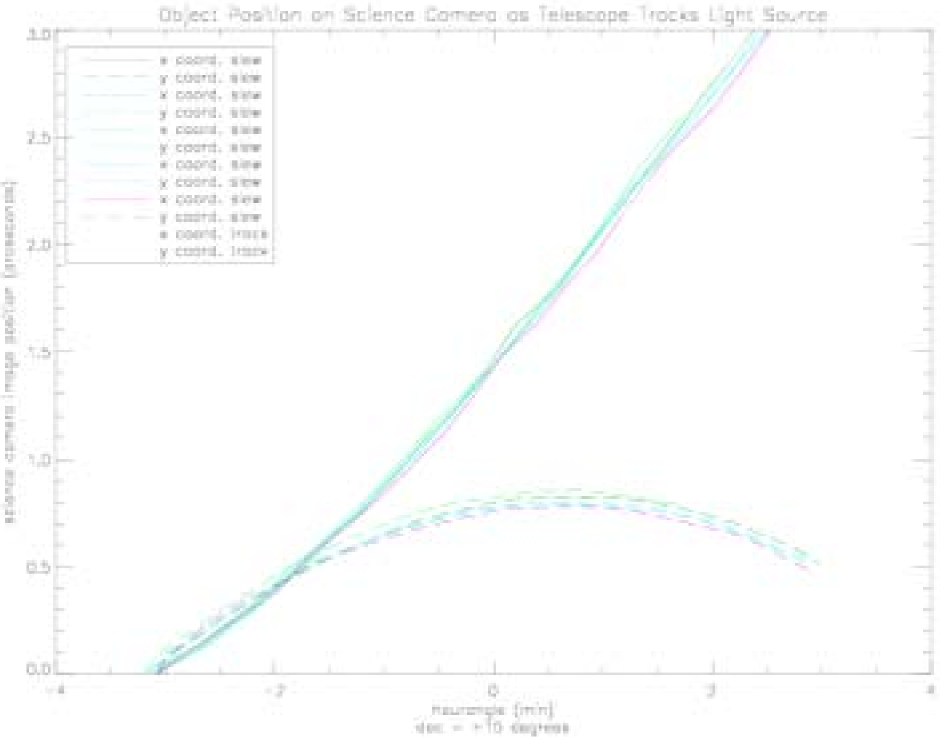
  -spectrally, spatially, temporally
- All AO systems suffer from non-commonality errors between the WFS and the science camera
- These errors are not sensed, and therefore, uncorrected

Non-commonality errors



- Instrment flexure as direction of gravity vector changes (for telescope-mounted systems)
- Vibration environment for all systems

Example: NCP Flexure on PalAO



Current Standard Practice

- Science camera calibration is considered part of the optical alignment
- Not an integral part of routine science observation
    - Manual image sharpening during the day or automated phase retrieval
- Our knowledge of science camera wave front quality is measured in Strehl and in time scales of hours (versus nm and minutes)
- Characterization of current post-ao correction on _any_ temporal and spatial scale would be enlightening.

Static Wavefront Calibration: Phase Contrast

Pupil Plane Phase

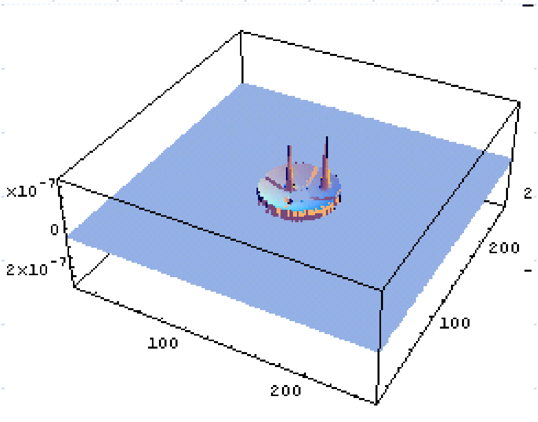
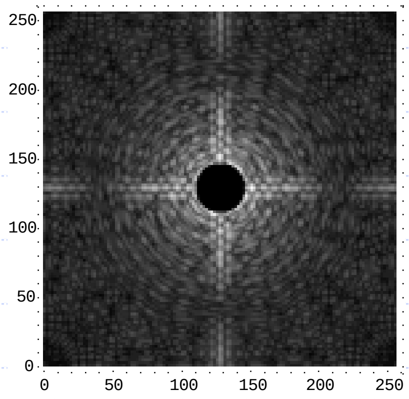
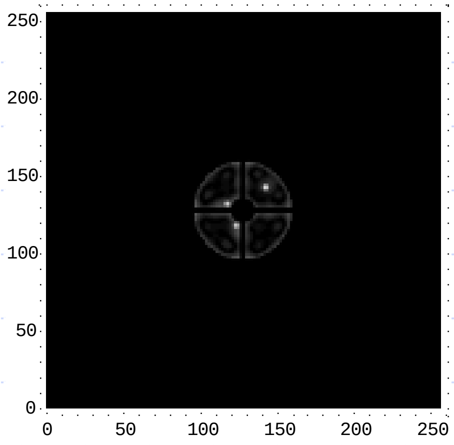


Image Plane Mask



Re-imaged pupil plane intensity



Phase contrast progress

- Palomar AO system
  - Preliminary test on single actuator
- Eclipse testbed
  - Space-born cornograph experiment
  - Technique used to calibrate system with ~1000 DM elements
- Issues remain:
  - Cross-talk between adjacent actuators

Requirements for XAOPI

- Spatial and Temporal requirements
  - For extrasolar planet searches, not all spatial frequencies need control
    - Those spatial frequencies that are controlled require unprecedented knowledge
  - However, it must be maintained over very long (~ hour) observation periods.

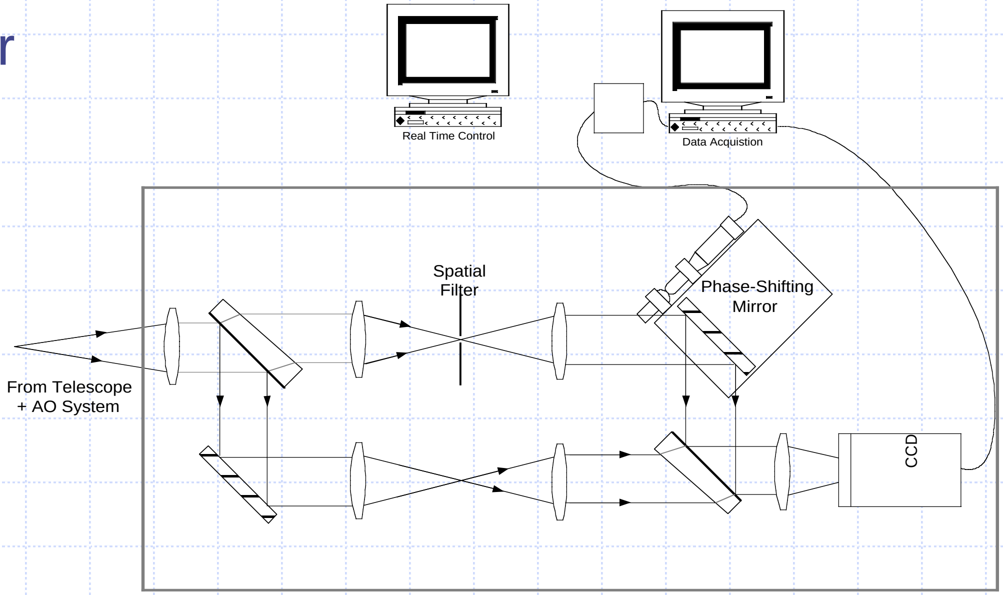
XAOPI

Error Source	0-32 cycles/pupil (nm rms)	32+ cycles/pupil (nm rms)
Fitting	0	44
Aliasing	1.5	0
WF Measurement	30-70	0
Temporal BW	32	
Telescope	3	60+
Calibration/NCP	3	0
DM	3	30

λ/50 p-v
@ 633nm

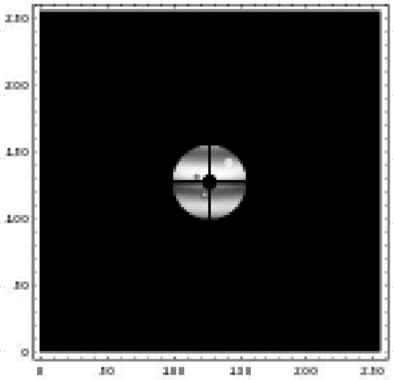
Pupil Plane Sensing

- Example: Mach-Zehnder PDI
- Computationally easy
- Good match of actuator to error signal
  - Reconstruction is well developed
  - Measure phase (and visibility) directly

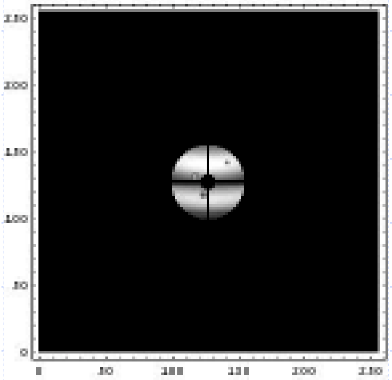


Phase-Shifting Mach-Zehnder Point-Diffraction Interferometer

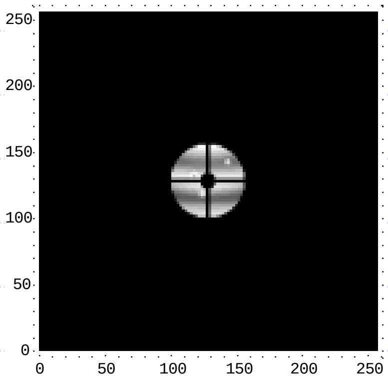
MZ PDI WFS: Four Bin Acquistion



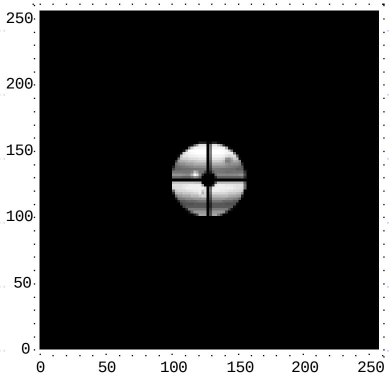
I1(x,y)



I2(x,y)



I3(x,y)



I4(x,y)

$$\phi = \tan^{-1}(I3-I1)/(I4-I2)$$

Image Plane Sensing

- Benefits:
  - For coronography, it’s ultimately where one requires knowledge of the wavefront!
- Concerns:
  - Need to measure phase and amplitude of speckle
    - Angel has proposed a novel method for doing so
  - Reconstruction: You’re only one Fourier Transform away from the DM positions

Summary

- Science calibration requirements for XAOPI require a new perspective
  - Integral part of observing scenario
  - Measured at spatial and temporal scales much different and more challenging than existing systems.
- Pupil plane and image plane sensing offer compelling advantages that require further study.

Next Steps

- We plan to investigate wave front sensing approaches in support of science camera calibration for XAOPI
    - Consider different wave-front sensing techniques
    - Perform analysis to investigate trade-offs
    - Suggest the best WFS approach, and an architecture