AFTA-WFIRST Project technical update

Outline

- Wide field instrument update
  - Overall approach, Cycle3 liens, and changes
  - Cycle4 grism {preliminary}
  - Cycle4 IFU (more compact, same performance)
  - Cycle4 filter set & temperature trade
- Instrument carrier redesign
- Observatory STOP analysis status & plan
  - STOP == structural/thermal/optical performance

Wide field instrument update

Overall approach, Cycle3 liens, and changes

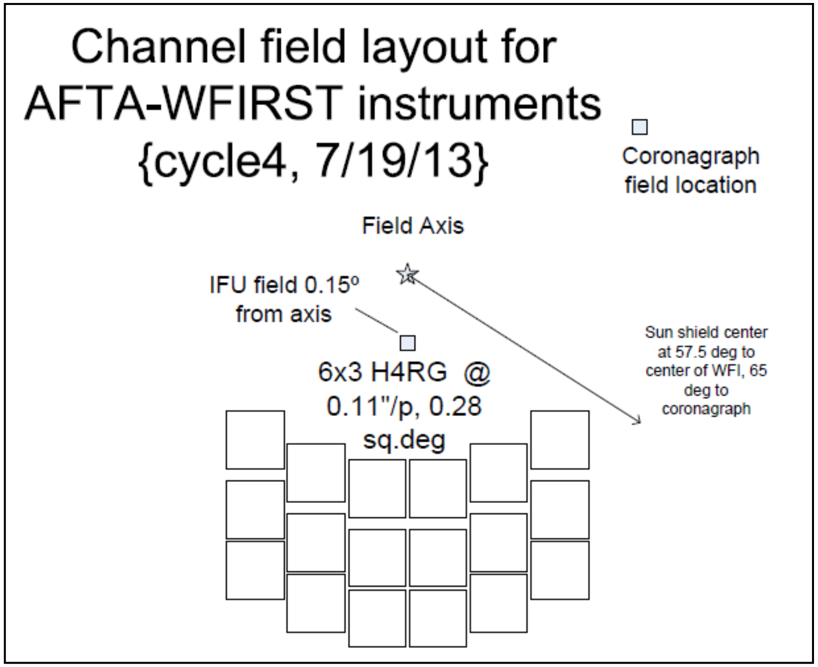
- Approach: look for simpler telescope and wide field optical elements and system; separate coronagraph and wide field better to create viable thermal and mechanical interfaces
- Liens from cycle3:
  - Latch locations {both instruments}
  - Instrument carrier thermal interface
  - Complex forms, symmetry lost for T1, T2, M3, filter
  - Electrical interface between the main instrument volume and the instrument electronics volume was not optimized.
  - Red wavelength limit & temperature implications for WF

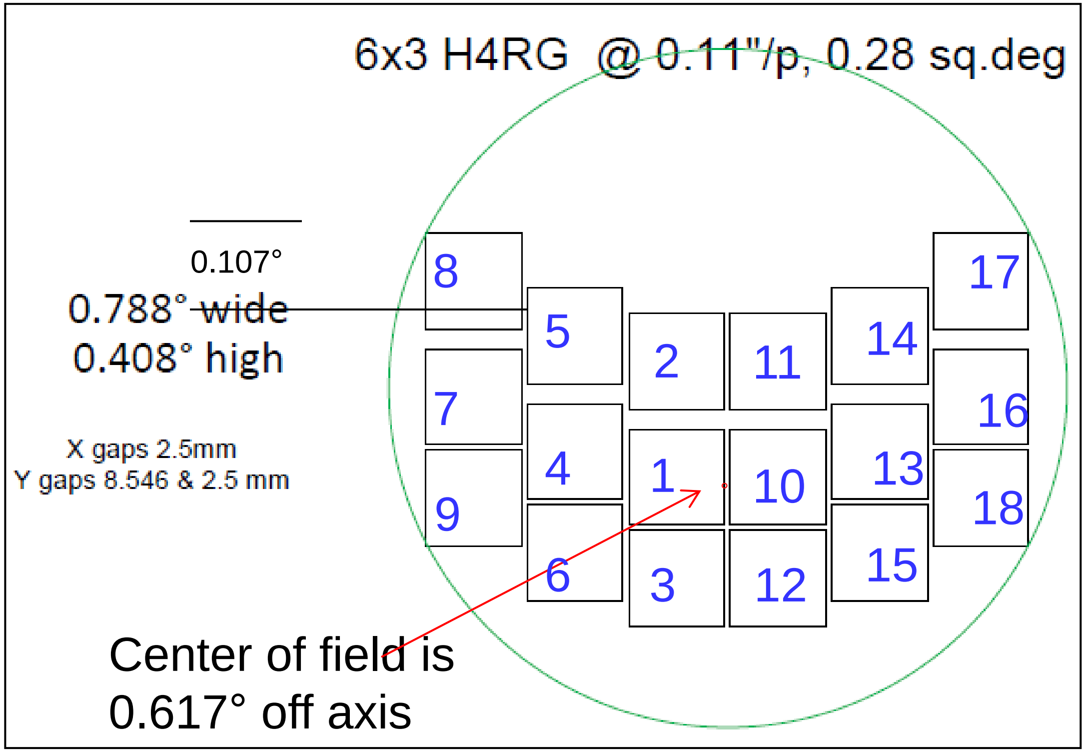
AFTA-WFIRST cycle 4 payload optical redesign

- Following the completion of the Report, we have taken the next step towards an overall optimization of the payload
  - Addressing liens on the initial design, E.g. coronagraph/WFI thermal and mechanical interface issues
  - Fairly high complexity of some of the optics, e.g. WFI M3, filters
  - Desire to keep T2 closer (w/in mechanical range) of the axis
  - Long optical path for WFI IFU
  - High complexity on Coronagraph tertiary
- We present here the global solution, as a progress report, with much work still in progress or to come
- Elevator version of result:
  - Telescope is again coaxial
  - Powered mirrors (T1, T2, M3) all on-axis conics; filters spherical
  - Wide field of view is arced 6x3 instead of rectangular
  - Science performance unchanged to first order
  - Coronagraph field is moved from on axis to off axis with better mechanical and thermal interfaces; possibly improved optical I/F
  - Because of Δconic, T1 radius of curvature changes very slightly to minimize required Δsag {6um}

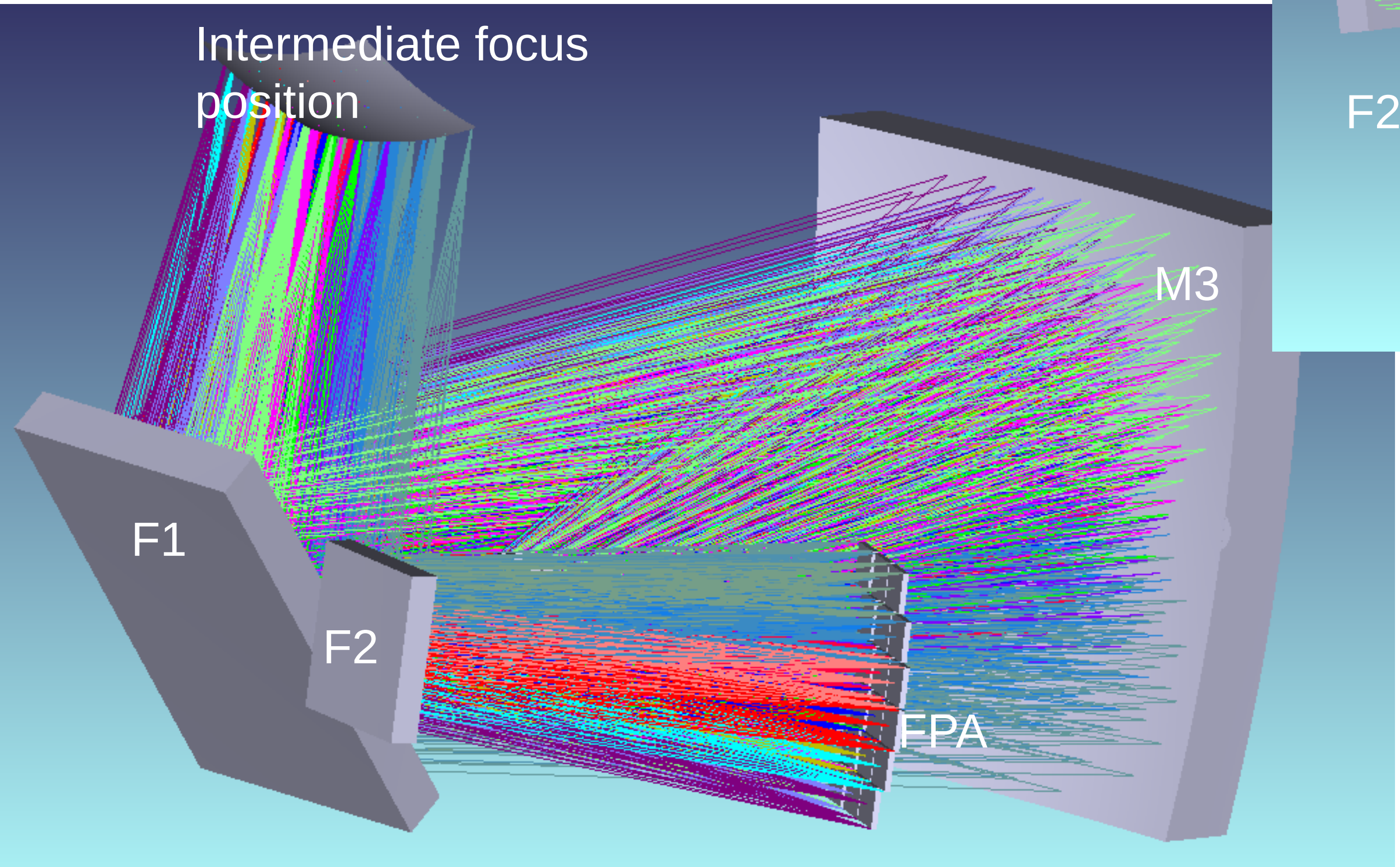
FOV diagram

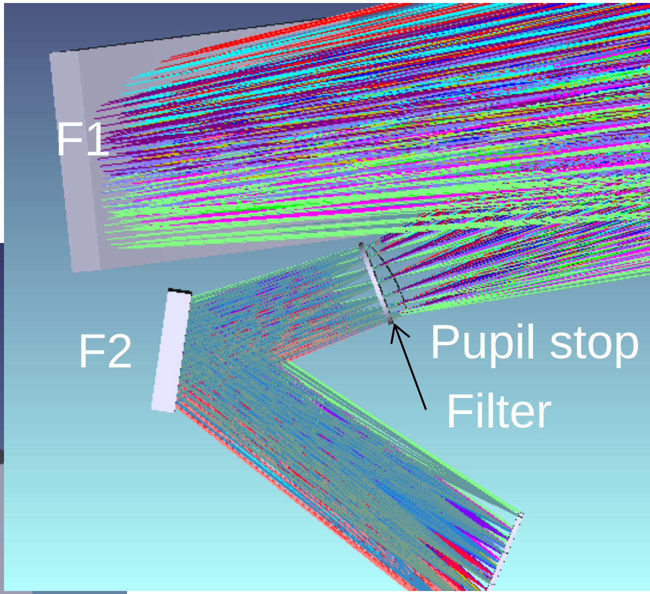
- ‘smile’ shape to overall FOV
  - "smile" shape rotates with S/C roll (so smile in Spring is frown in Fall); may have slight impact on efficiency for repeat visits to a field, such as SNIa discovery, μlensing
- Relative Location of coronagraph is shown {IFU not finalized yet}





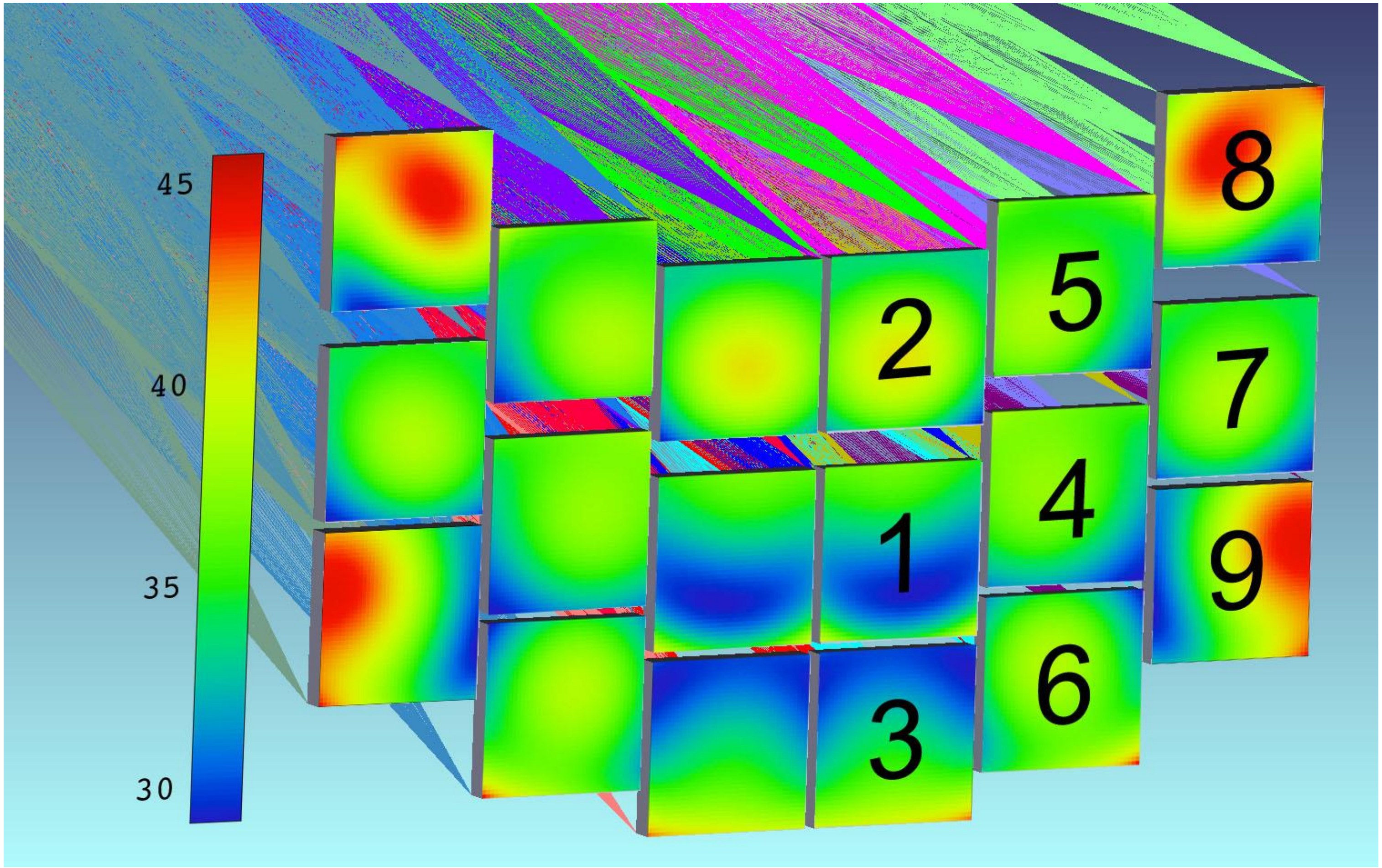
Instrument ray trace views





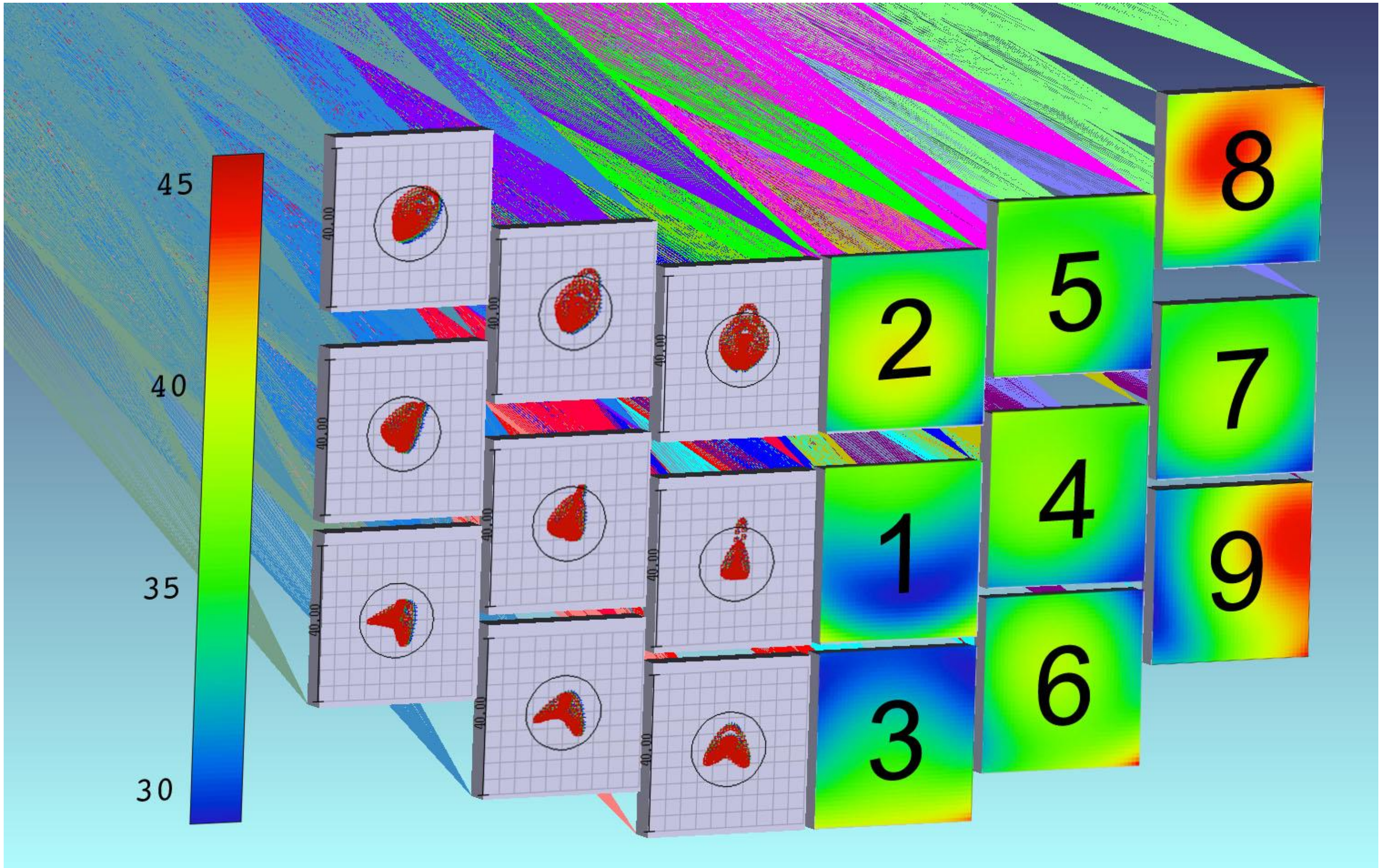
Imager performance

- Actual WFE RMS on Individual Sensors

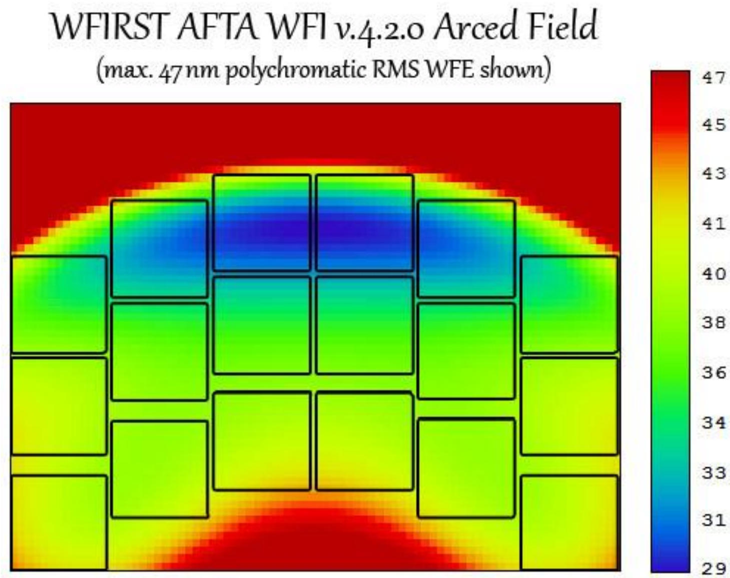


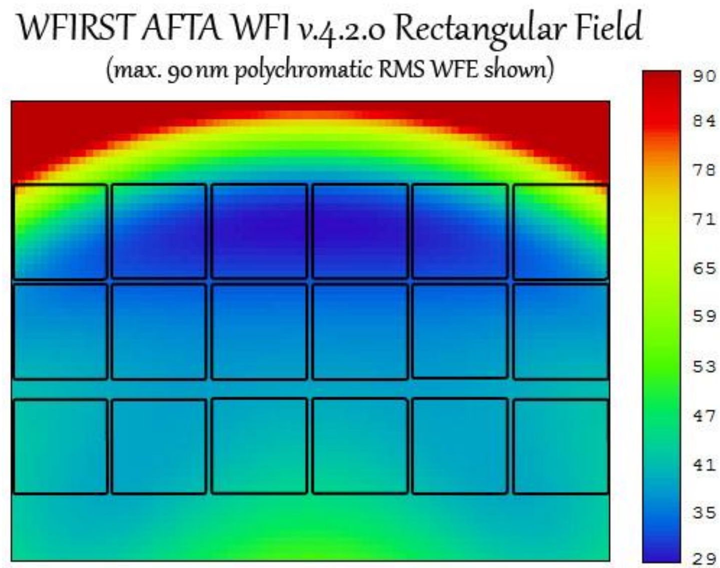
Imager Performance

- Comparative Polychromatic Spot Sizes



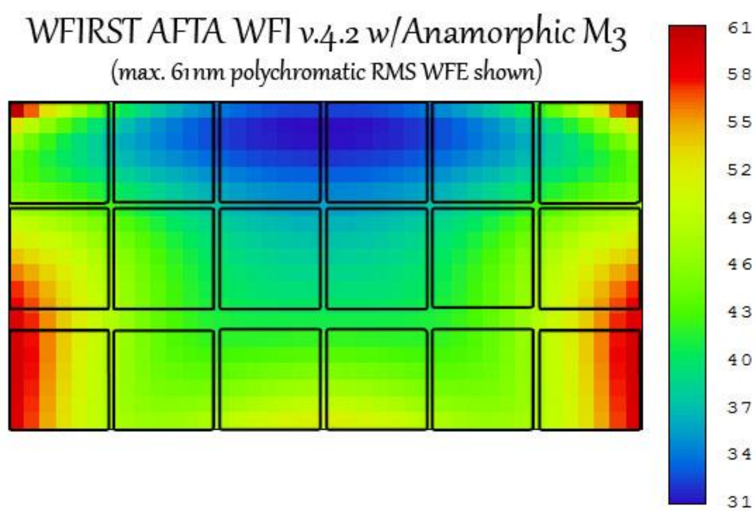
Performance cost of rectangularizing field layout





Conic M3 costs 2x in WFE

Baseline cycle4



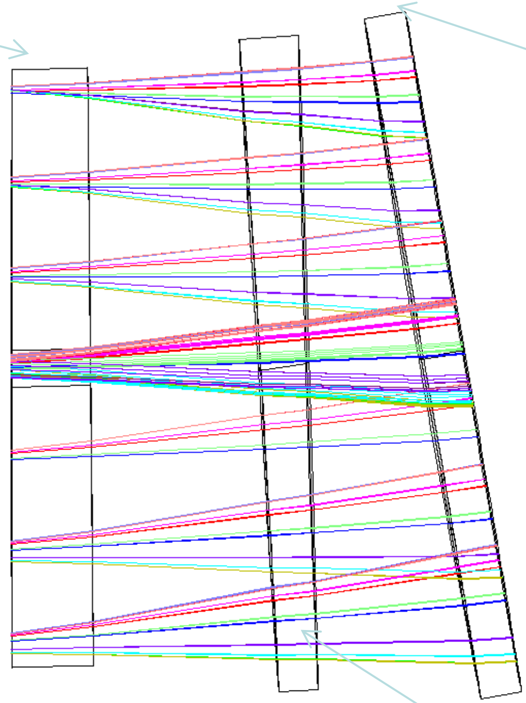
More complex M3 still costs 50% in WFE, out of spec

Simpler, 3 element grism design w/ improved performance

Element1 – corrector prism 1
Material: Fused silica
1st surface is a sphere
2nd surface is a binary lens on flat surface

Element 3 – transmission grating
Material: Fused silica
1st surface is a sphere
2nd surface is flat & contains a variable line space grating

Incident light

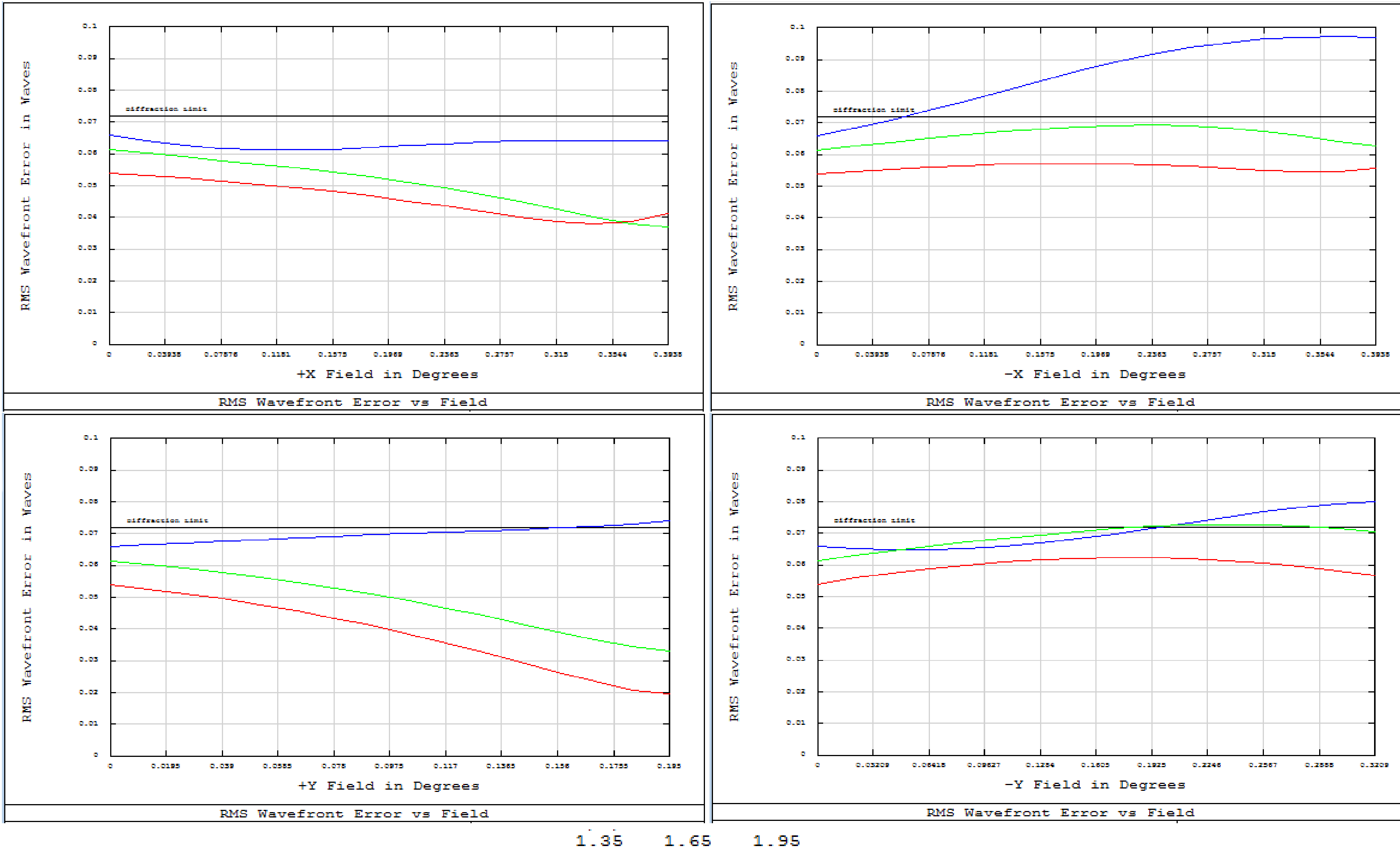


Element2 – corrector prism 2
Material: Caf2
Both surfaces are spheres

Y Z

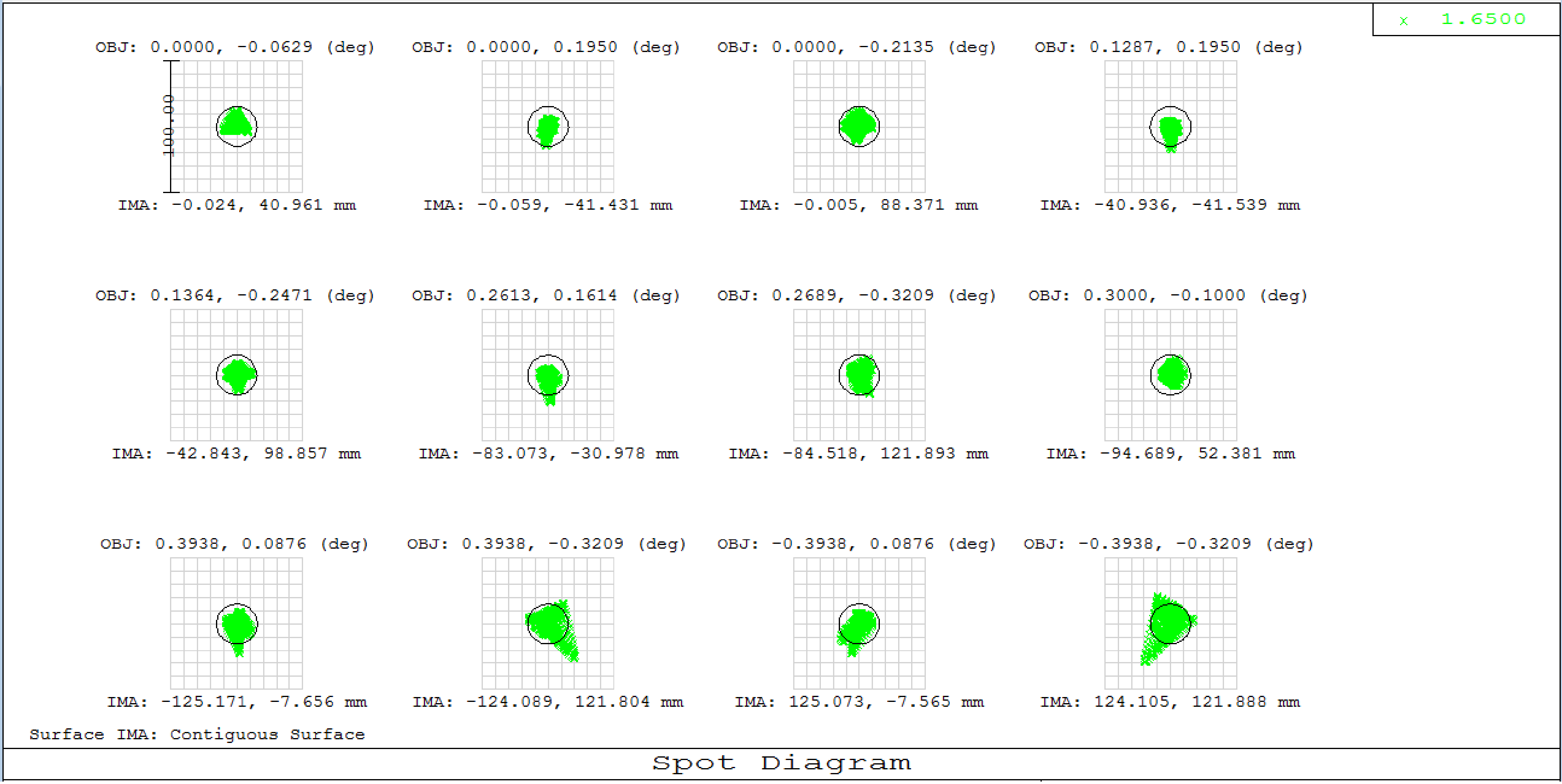
3D Layout

Wavefront is improved; close to diffraction limited



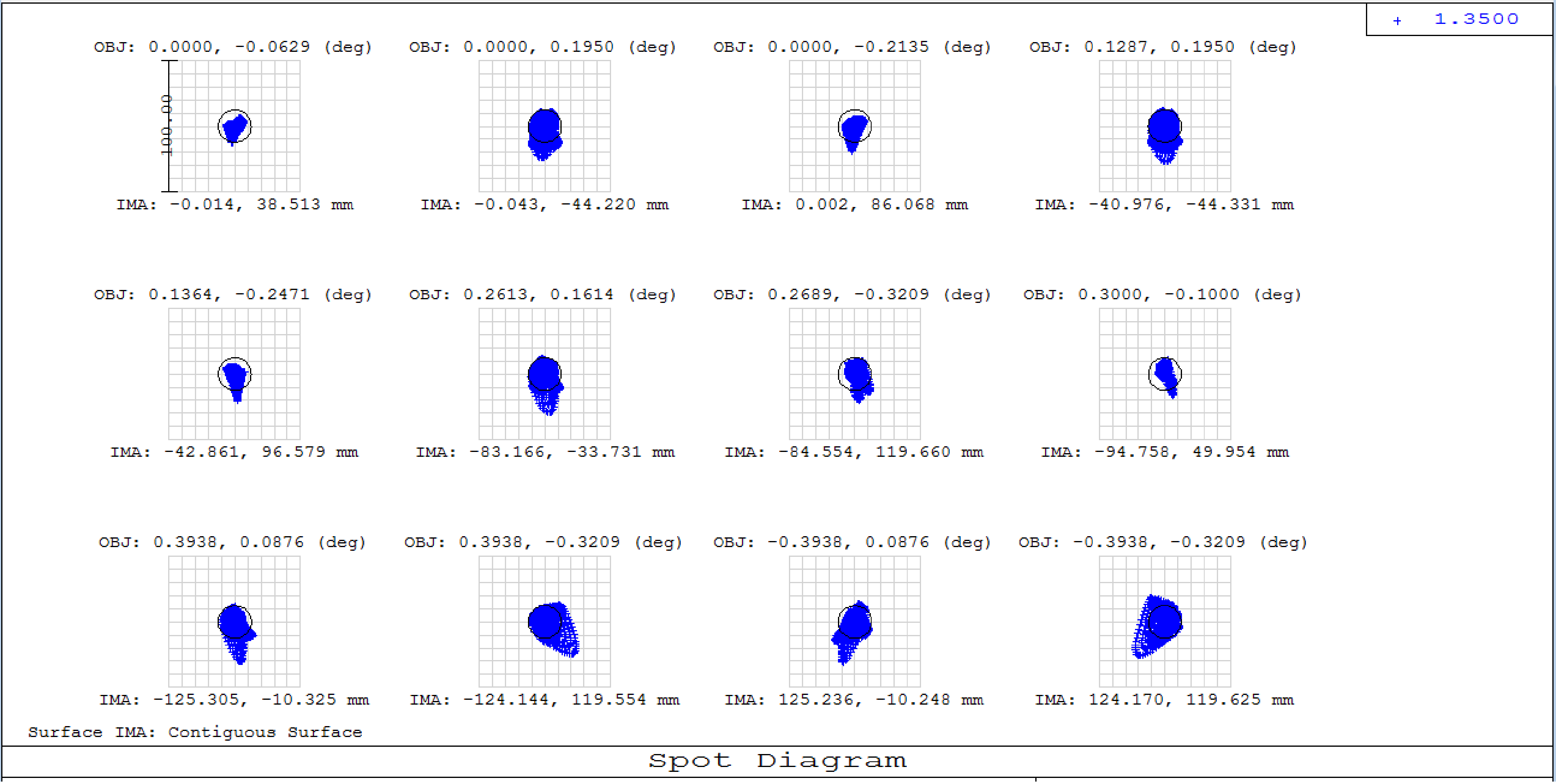
Worst field Cycle3 performance was ~0.16 λ at 1.35um, 0.11 λ at 1.95um [off scale here]

Grism Spot diagram at central wavelength



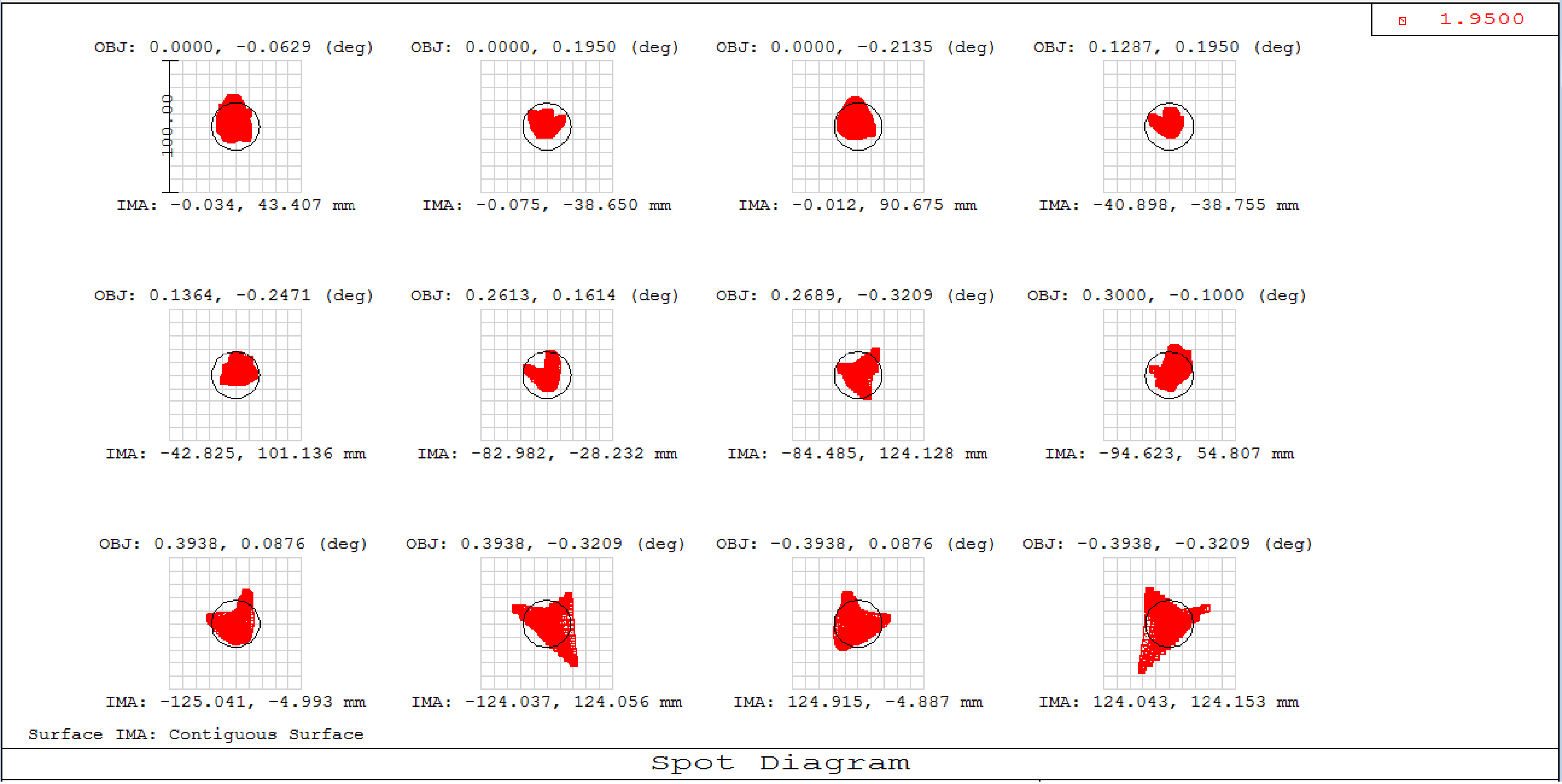
Significant improvement in performance could lead to margin on redshift accuracy

Grism Spot diagram at shortest wavelength



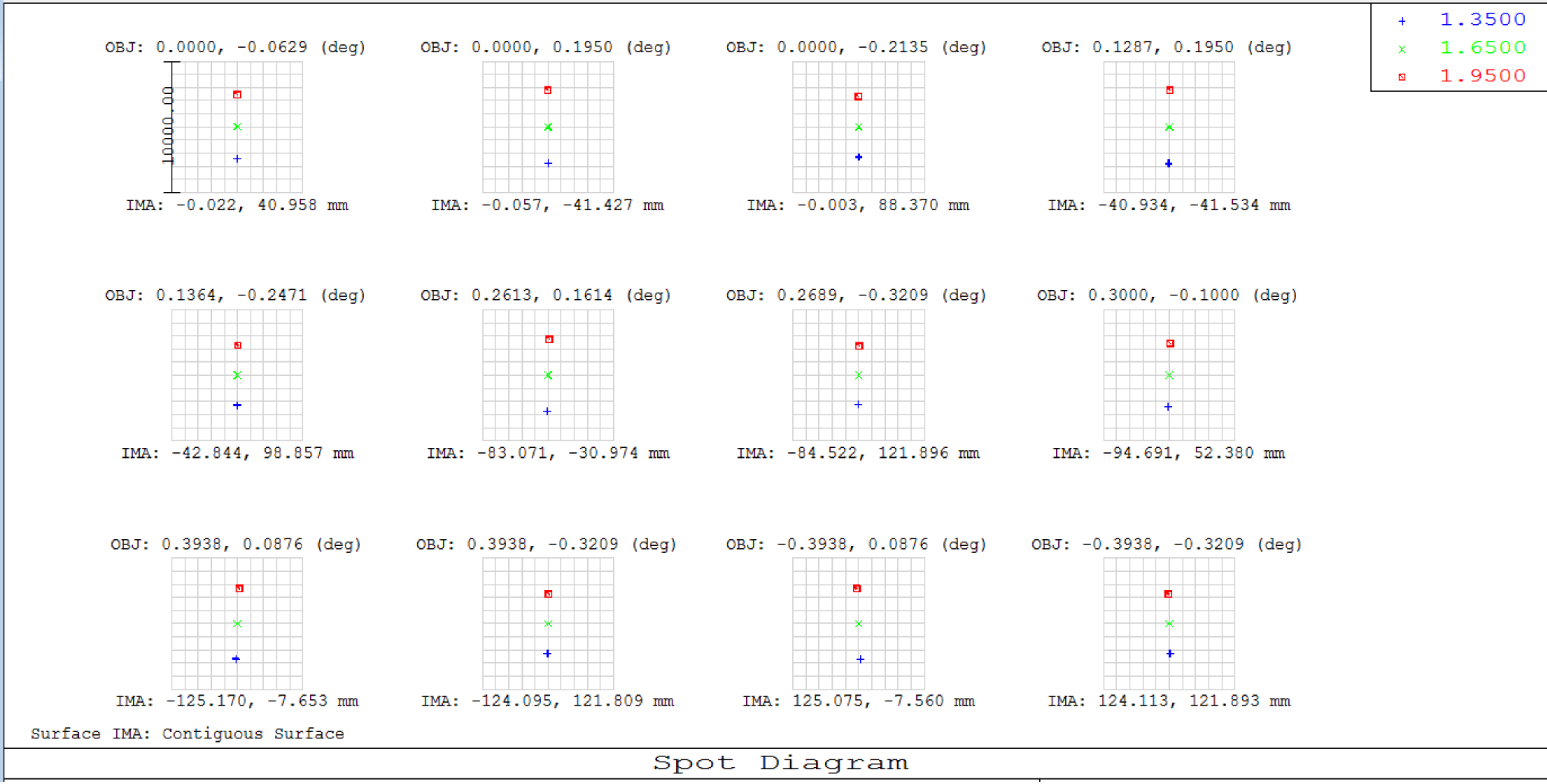
Significant improvement in performance could lead to margin on redshift accuracy

Grism Spot diagram at longest wavelength



Significant improvement in performance could lead to margin on redshift accuracy

Spectral dispersion



Grism Summary and path forward

- The three element design uses binary surface to compensate the portion of the aberration created by the grating for which the amount of aberration is linear to wavelength. This aberration is very difficult to compensate using non-diffractive optics.
- The performance is very close to diffraction limited except a few fields at shortest wavelength. Fine tuning may be able to make everything diffraction limited.
- All elements are buildable.
- Next step is fine tuning the design. It may be possible to simplify to only 2 elements.
- Search for potential vendor to make samples for non-spherical surfaces.
- Study the test methods; plan fabrication, alignment, and test of a prototype

Filter set and temperature trades

WFI red edge:

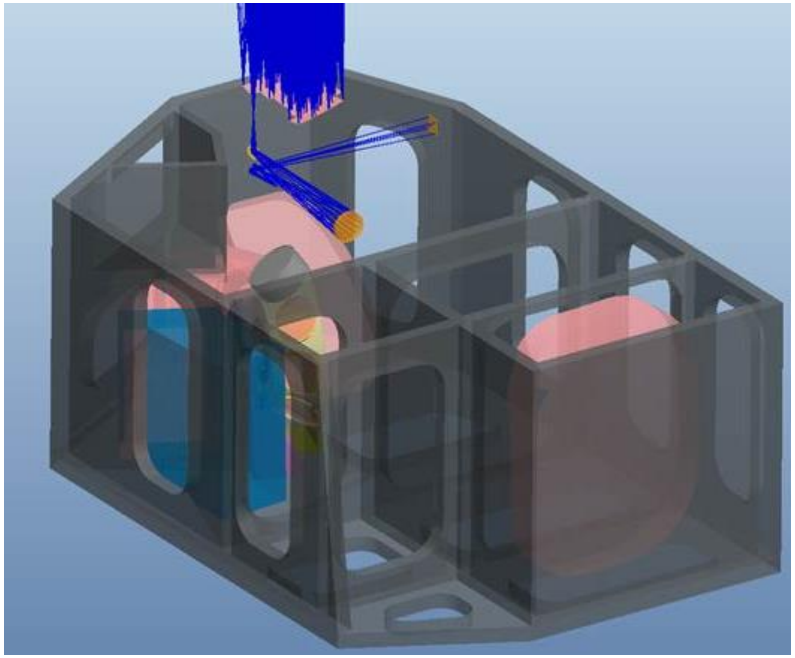
- Notional filter set if we extend red science cutoff to 2.4um [2.4um filter, 2.5um red edge of nominal detector response]
- It has been pointed out that the reddest R~4 and the μlensing wide filters would have high in-band internal emissions from a 270 K telescope
- For cycle4, we are leaving the IFU and Grism bandpasses as for cycle3, and leaving the filter set TBD – the # of filters is the same and there is no coupling of the filter bandpass to other elements of the engineering

#	min	max	center	width	R	Overlap
Z088	0.760	0.997	0.878	0.237	3.71	0.05
Y109	0.947	1.242	1.094	0.295	3.71	0.062
J136	1.179	1.547	1.363	0.367	3.71	0.078
H170	1.469	1.927	1.698	0.458	3.71	0.097
K212	1.830	2.400	2.115	0.570	3.71	0.120
W167	0.947	2.400	1.673	1.030	1.44	0.062
GRS	1.350	1.950	1.650	0.600	75.00	

Potential filter set for 250K telescope temperature, 2.5μm detector cutoff

Cycle4 IFU

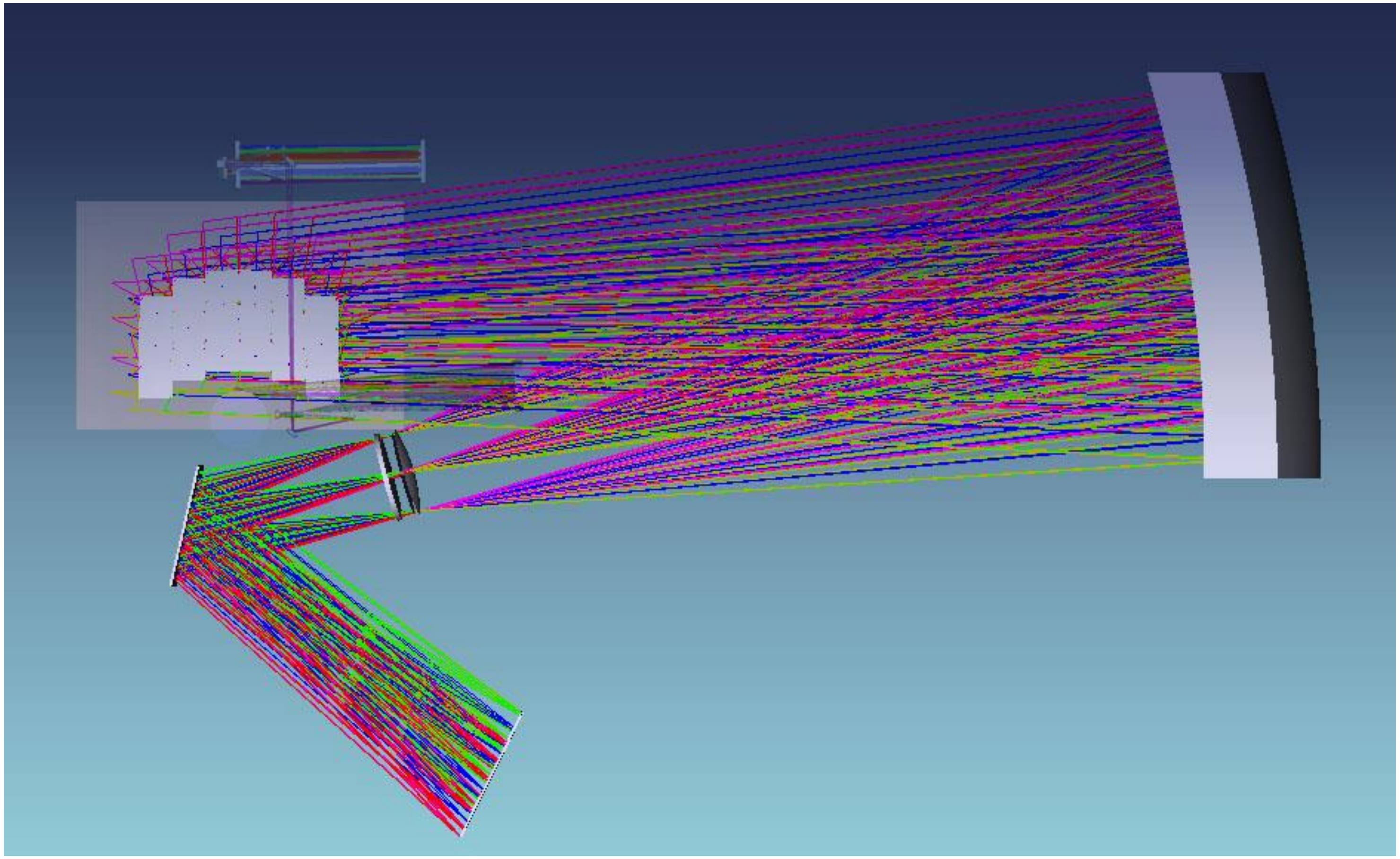
- No change in requirements from April report
  - E.g. not pushing for redder cutoff than 2.0μm
- Desire for more compact overall form – optical path length from intermediate telescope focus to slicer was ~3m
- Result is good optical performance, shorter path
- Relay field is larger (~4x in area), enabling future trade study on IFU form:
  - Slicer based (most mature, TRL~6)
  - {rad hard} Fiber based [lots of ground heritage]
  - Micro-optic [mirrorlet or lenslet] based
  - Goal would be even more compact but potentially larger field



Shorter IFU relay [slicer & spectrograph similar to Cycle3]

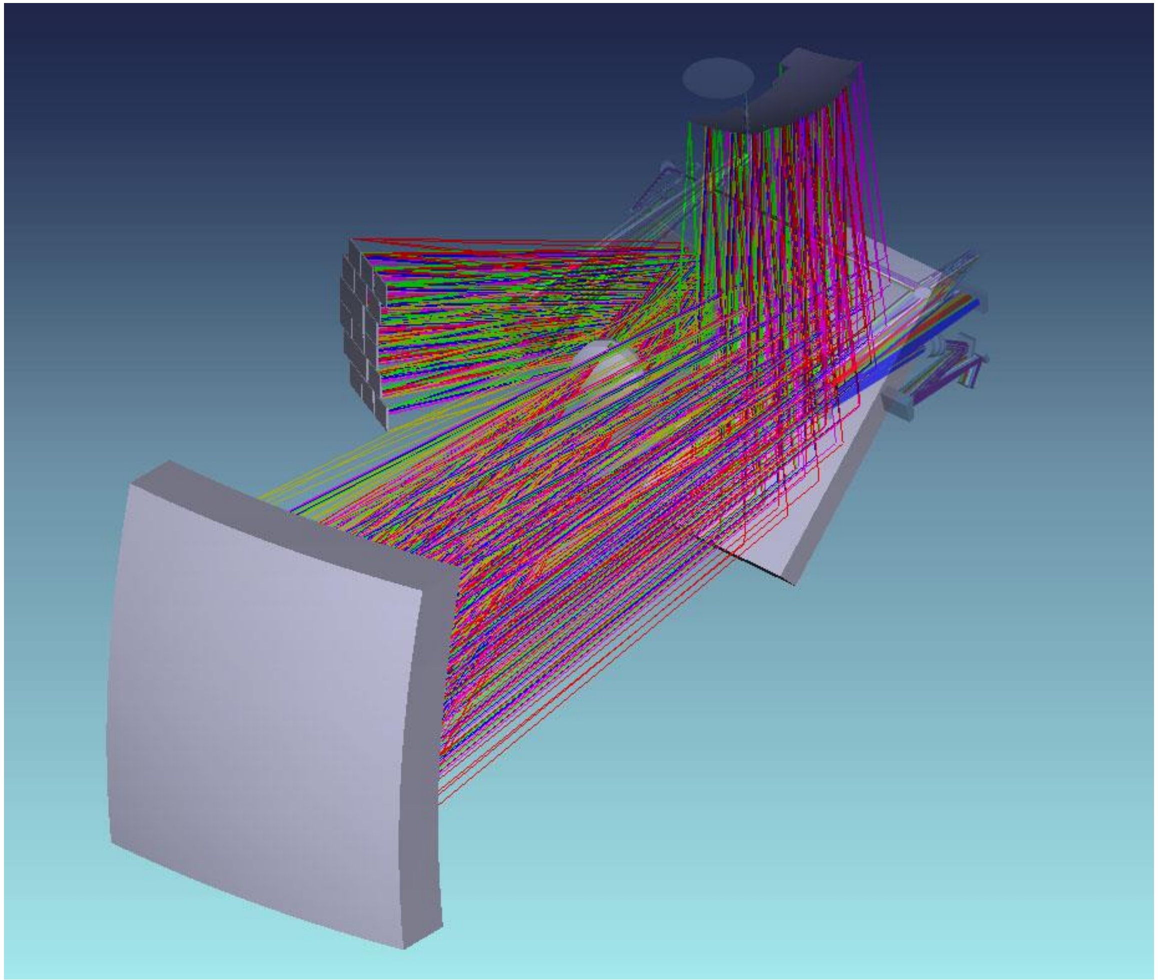
IFU Layout

- Top View



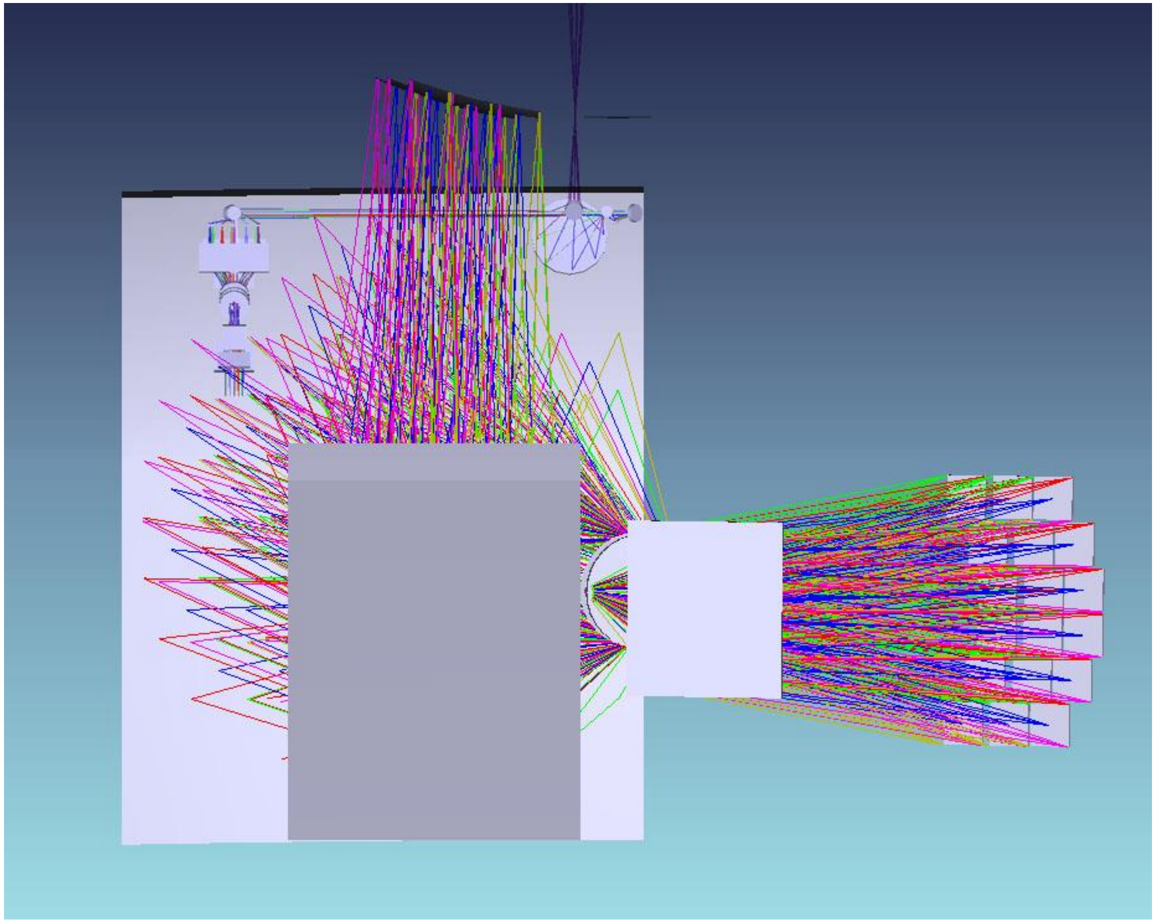
IFU Layout

- Perspective View



IFU Layout

- End View



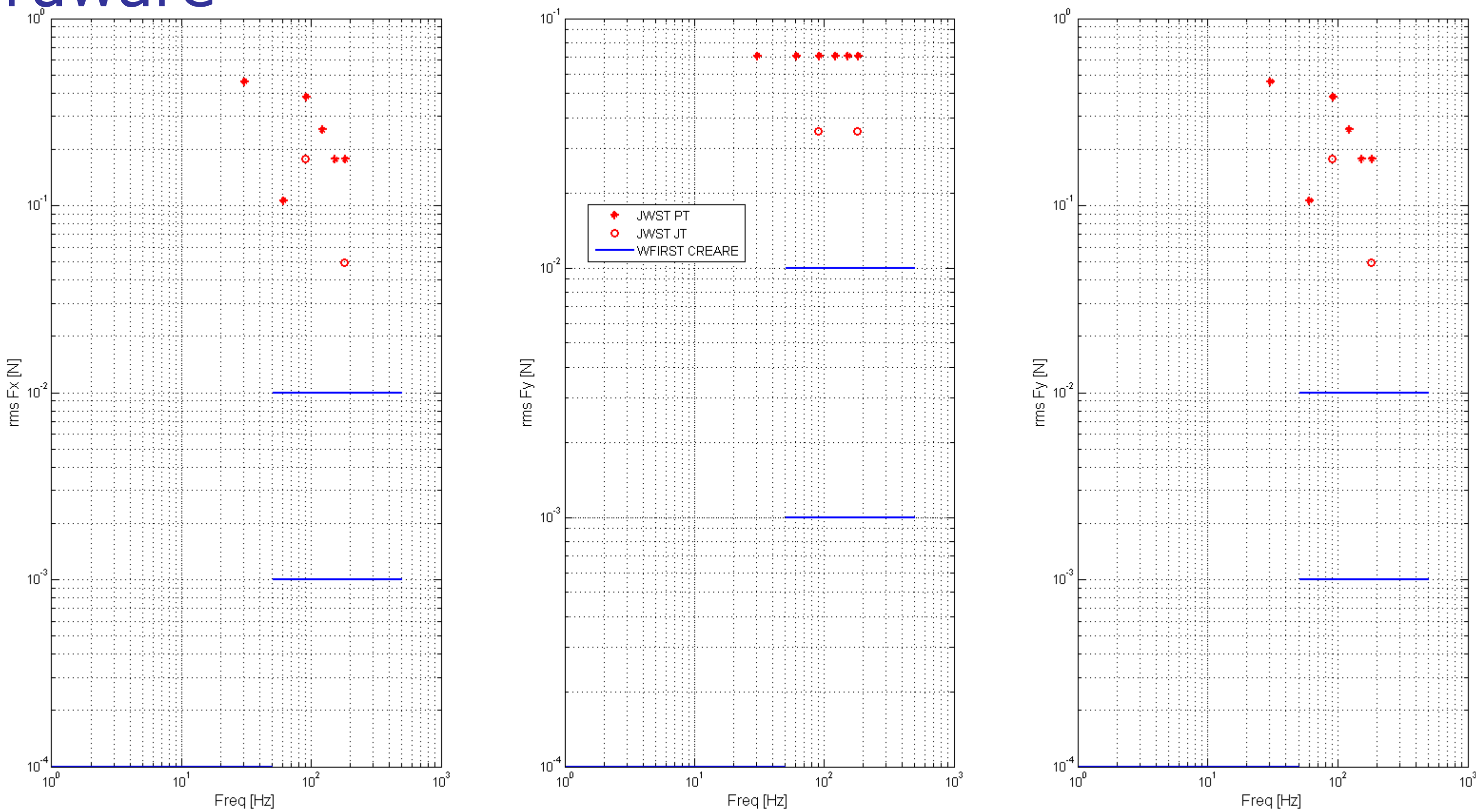
Thermal design for cutoff >2.0um [study per SDT/project charter]

Temperature of FPA and FPA temperature stability:

- 2.4um needs colder FPA to limit dark current
  - Intermediate cutoffs would need T_{FPA} in range 90-120K
- Cycle3 WFI FPA stability requirement was 0.3K over >300sec, 10mK up to 300sec.
- We have started gathering data on the telescope hardware to ascertain its ability to operate below 270 deg. Work in progress.
- To get colder FPA, we introduced for Cycle4 a low vibration cryocooler
  - Evolved version of the Turbo Brayton cooler used on HST/NICMOS
    - Very low [not measurable] incremental jitter on HST
    - Consistent with serviceability [no cooling h/w across interface]
    - Sufficient power, with margin, to hold 90K FPA to ~mK stability

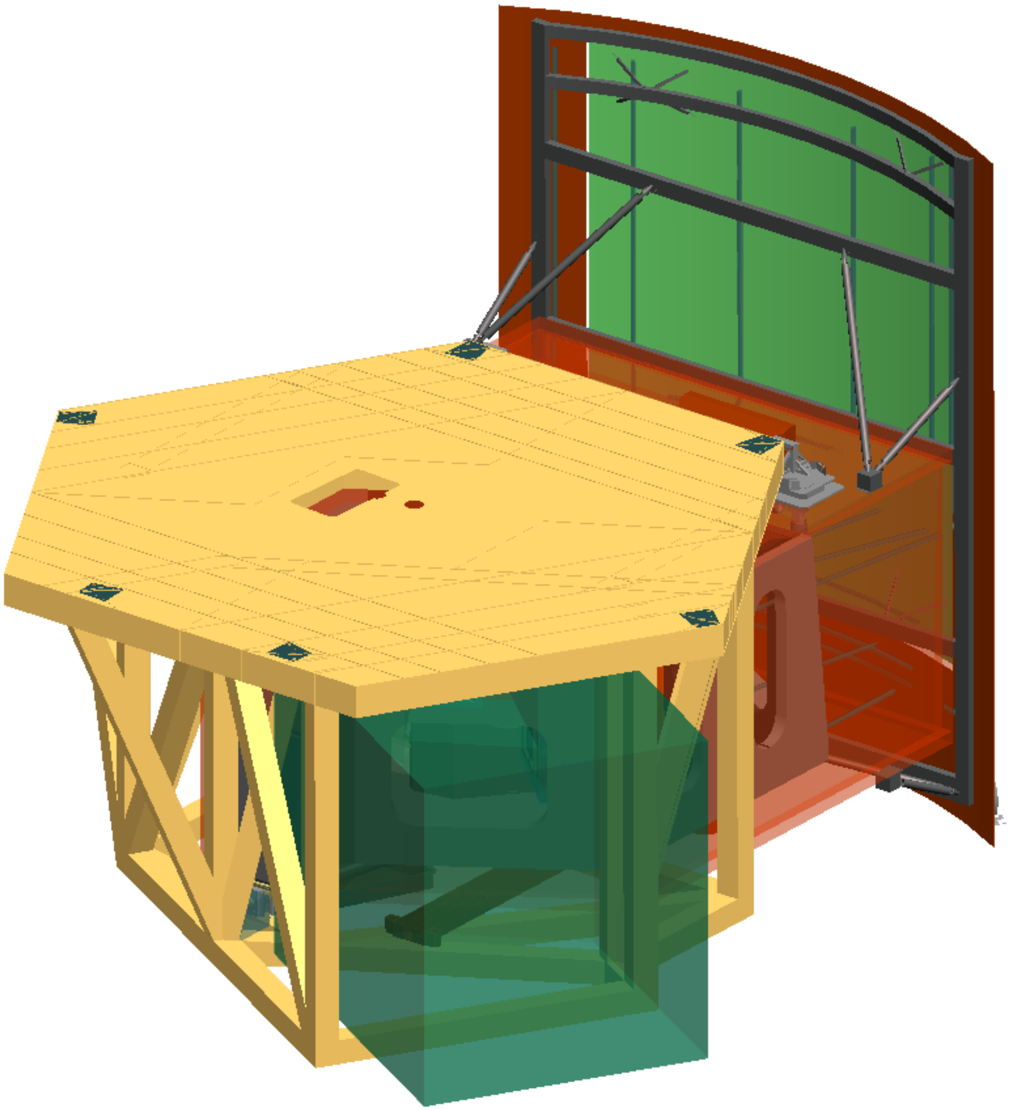
Cooler not expected to add jitter

- This cooler has no harmonics in 1-1000 Hz; disturbance model simply two flat sections; 1 and 10 mN levels shown are << levels from JWST cooler hardware



Instrument carrier redesign

- Redesign to improve structural performance and allow more stable metering of instruments to telescope



STOP Analysis: Status & Plan

- Preliminary Structural/Thermal/Optical Performance [STOP] on-orbit stability results for the Telescope, Carrier, WF Channel, and Coronagraph Interface are targeted to be available for presentation at ACWG#2.
- Tracking of WF Channel delta WFE/LOS/PSF_ellipticity on 1-hr intervals over a 24-hour period will provide a quick look assessment
  - to be followed with in-depth examination of the more sensitive periods after the initial results have been studied and validated.
- In addition to the WFI Linear Optical Model-based assessments noted above, the following raw data will be made available at hourly intervals for specialized post-processing:
  - 6-dof ideal optical element rigid body motions and low order shape distortions;
  - Motions of the coronagraph optical bench kinematic mounting latch points on the Carrier relative to the initial cooled position.
- No one orbit/attitude can fully assess Payload thermal absolute shifts and stabilities.
  - The orbit chosen is a B=11° hot case with no eclipses, with a fixed attitude chosen to place the Telescope LOS as close to the orbit plane as allowed by stray light requirements (38.9°) while locating the WF channel radiator normals ~as close to the orbit plane as required by uL ops concept (33.92° vs Hirata uL rqt of ≤28°; for HLS ≤47.5° is OK).
  - The Solar Array is normal to the Sun for this case, with pitch/roll effects to be studied in the near future.

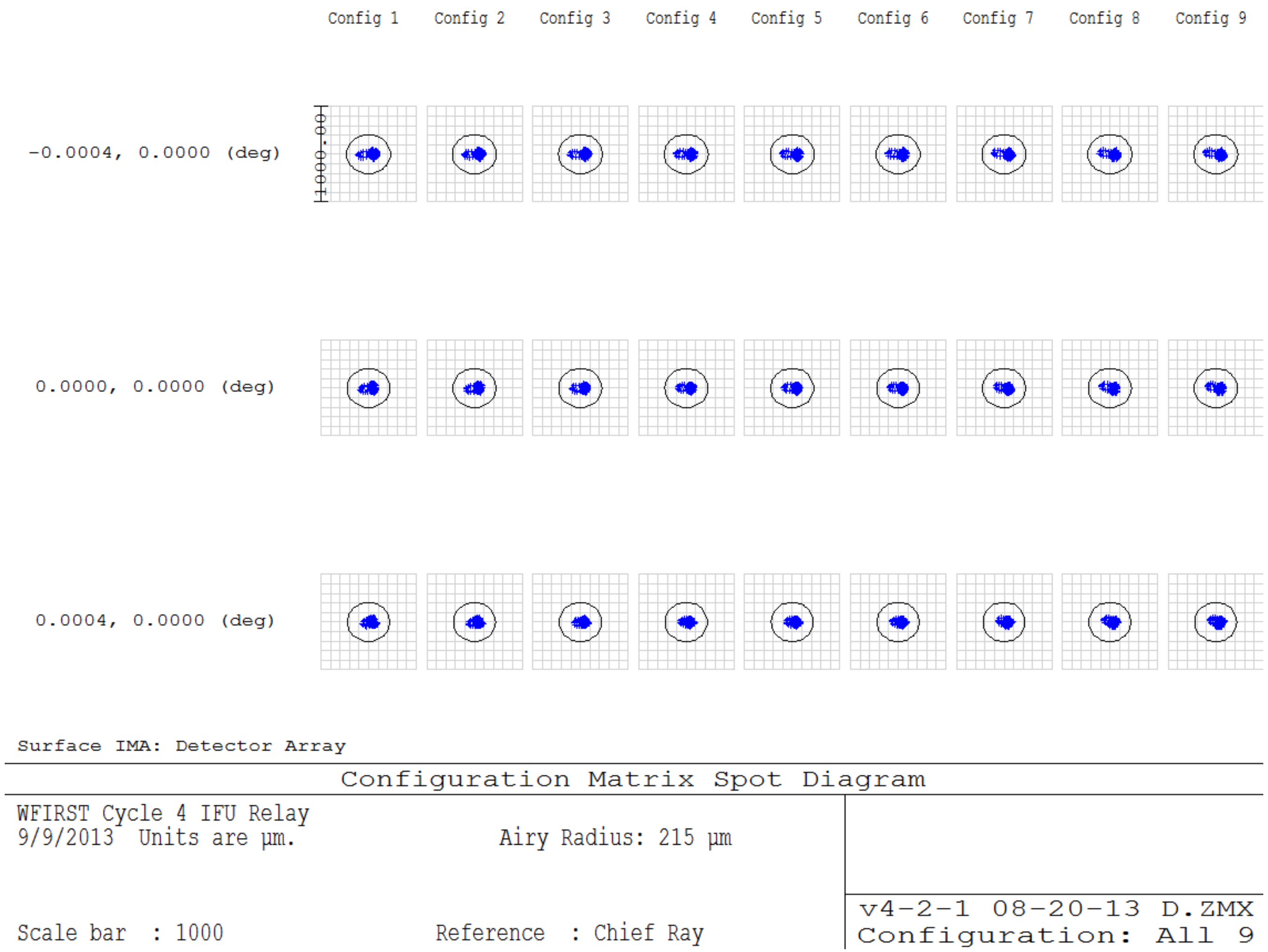
backup

Configuration optics comparison

parameter	cycle3/4-13 report	current / cycle4
SCA layout	6x3	6x3
coronagraph field location	on axis	off axis
Field of view shape	rectangular	arced
T1, T2 optical prescription	12th order	conic
T2 position	decentered & tilted	coaxial with T1
M3 optical prescription	anamorphic asphere	conic
M3 position	decentered	coaxial with T1 & T2
Filter optical prescription	Zernike sphere	sphere

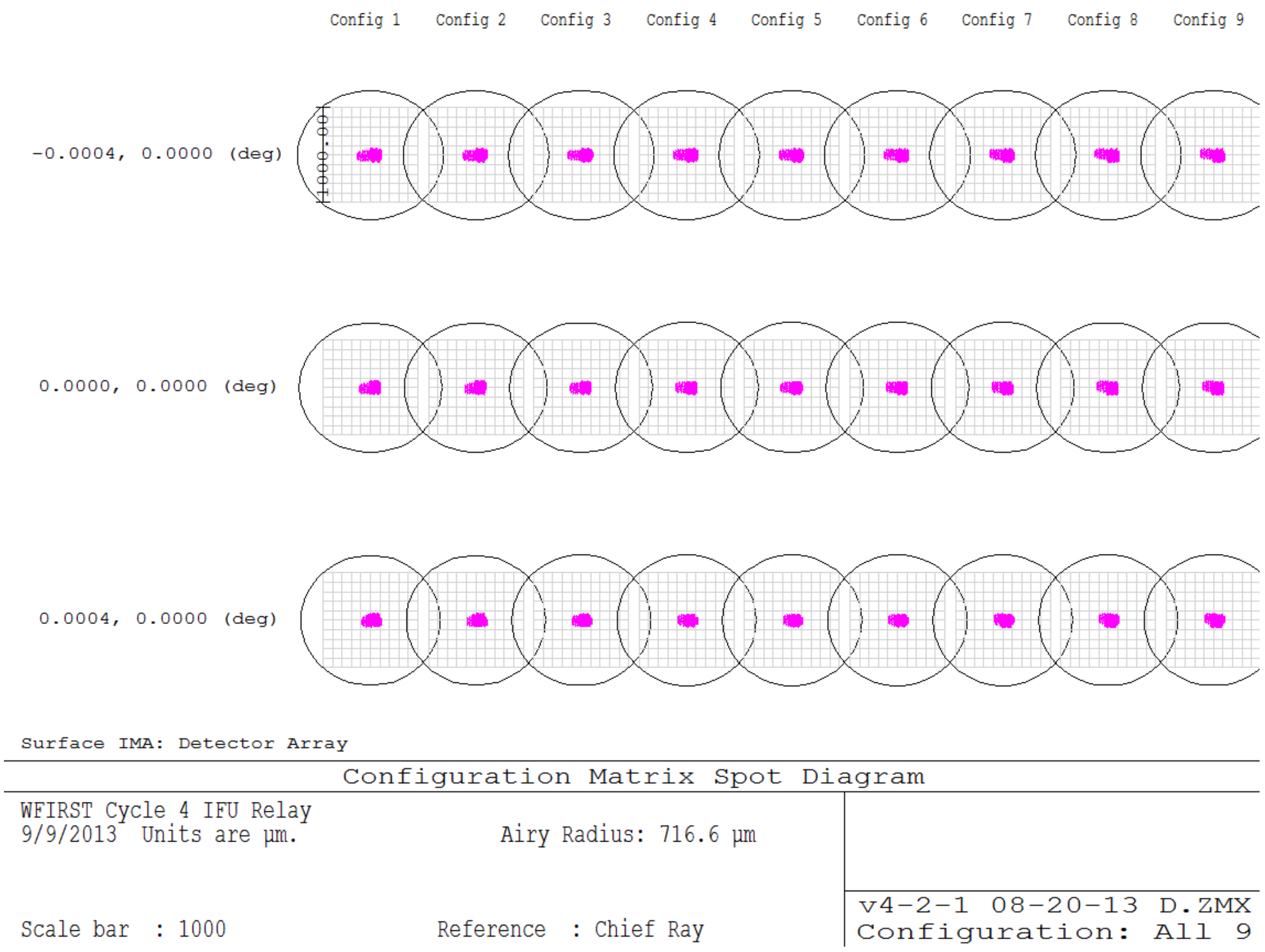
IFU Performance

- Shortest Wavelength (0.6μm)



IFU Performance

- Longest Wavelength (2µm)



Cycle4 filter set

- This really can't be settled until we have a better handle on potential reduction [from 270K] in telescope temperature
- If telescope temperature stays at 270K, the filter set from cycle3 would probably remain the same
- Below is a notional filter set for a 250K telescope temperature, should we decide the risk is acceptable
- Substantial planning ongoing by the telescope team to gather data on going colder

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Potential filter set for 250K telescope temperature, 2.5µm detector cutoff

Plan for maturing [qualifying] Turbo-Brayton cooler

- 1. A turbo-Brayton cooler using the same technology was successfully flown on HST and worked for 6+ years.
  - It was turned off because it was deemed to be no longer useful by STScI.
- 2. The basic design of the AFTA-WFIRST cooler will be very similar to the HST design because the performance required (heat lift and ultimate temperature) are similar.
- 3. The exact implementation will use current machining/ manufacturing techniques and EEE parts.
- 4. AFTA-WFIRST will allow for a completely sealed system, which improves reliability.
  - HST by necessity had a final cooling loop that was not sealed until the unit was on-orbit, leading to some concerns about contamination in the plumbing.
- 5. The exact thermal, mechanical, and electrical characteristics will be optimized for the AFTA-WFIRST configuration.
- 6. A engineering test unit will be built to ensure proper qualification of the AFTA-WFIRST configuration. Life testing can be included if we start early enough.