NGAO NGS WFS design review

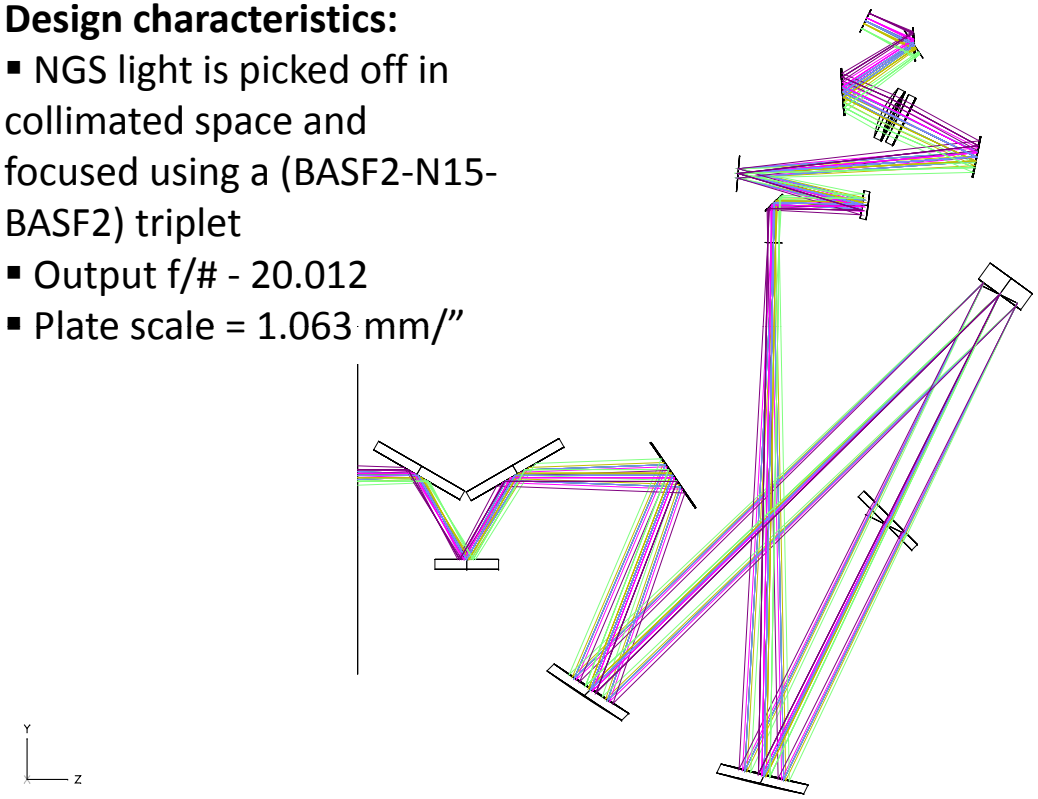
Caltech Optical Observatories

31st March 2010

Input to the NGS sensor

Design characteristics:

- NGS light is picked off in collimated space and focused using a (BASF2-N15-BASF2) triplet
- Output f/# - 20.012
- Plate scale = 1.063 mm/”



3D LAYOUT

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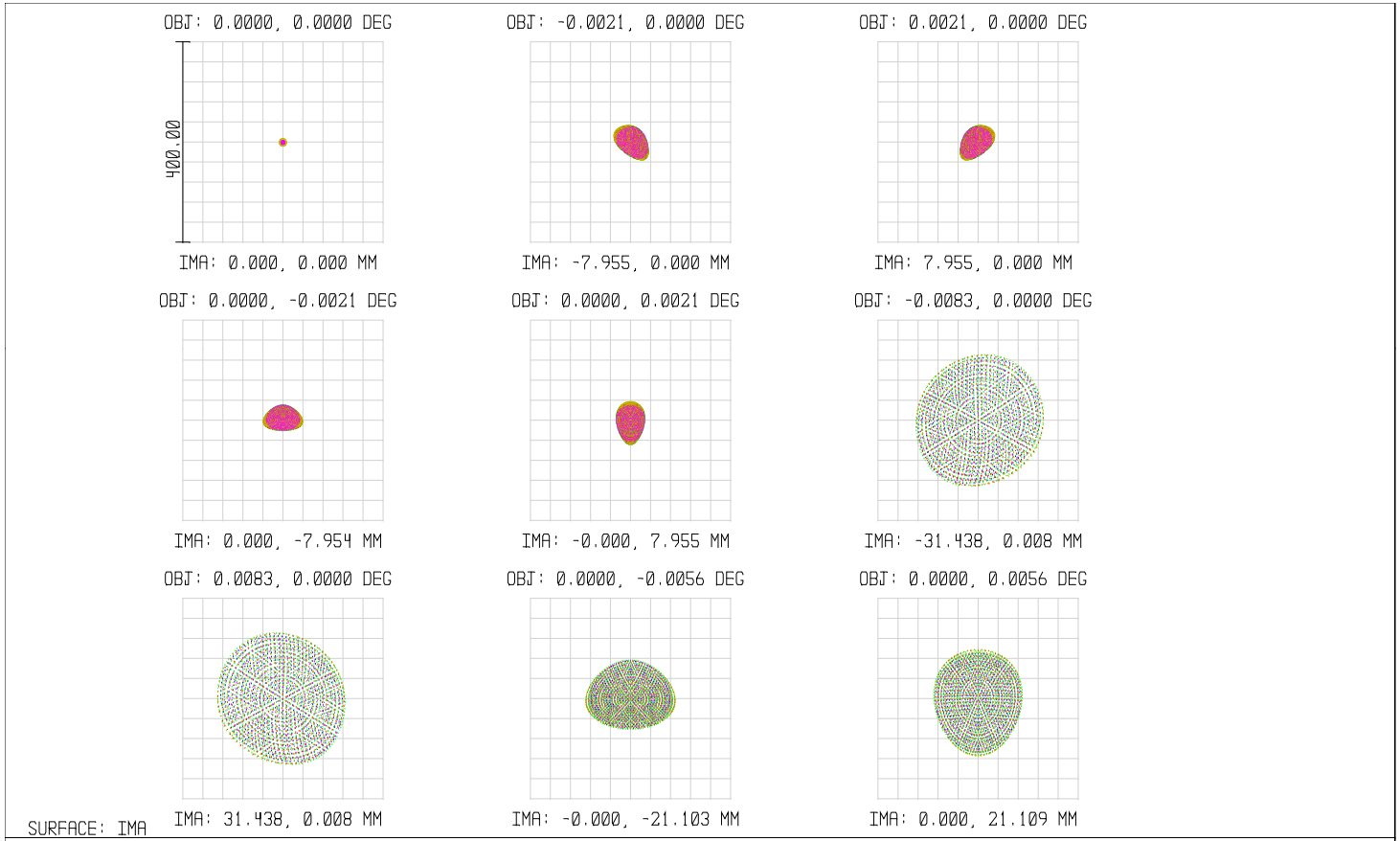
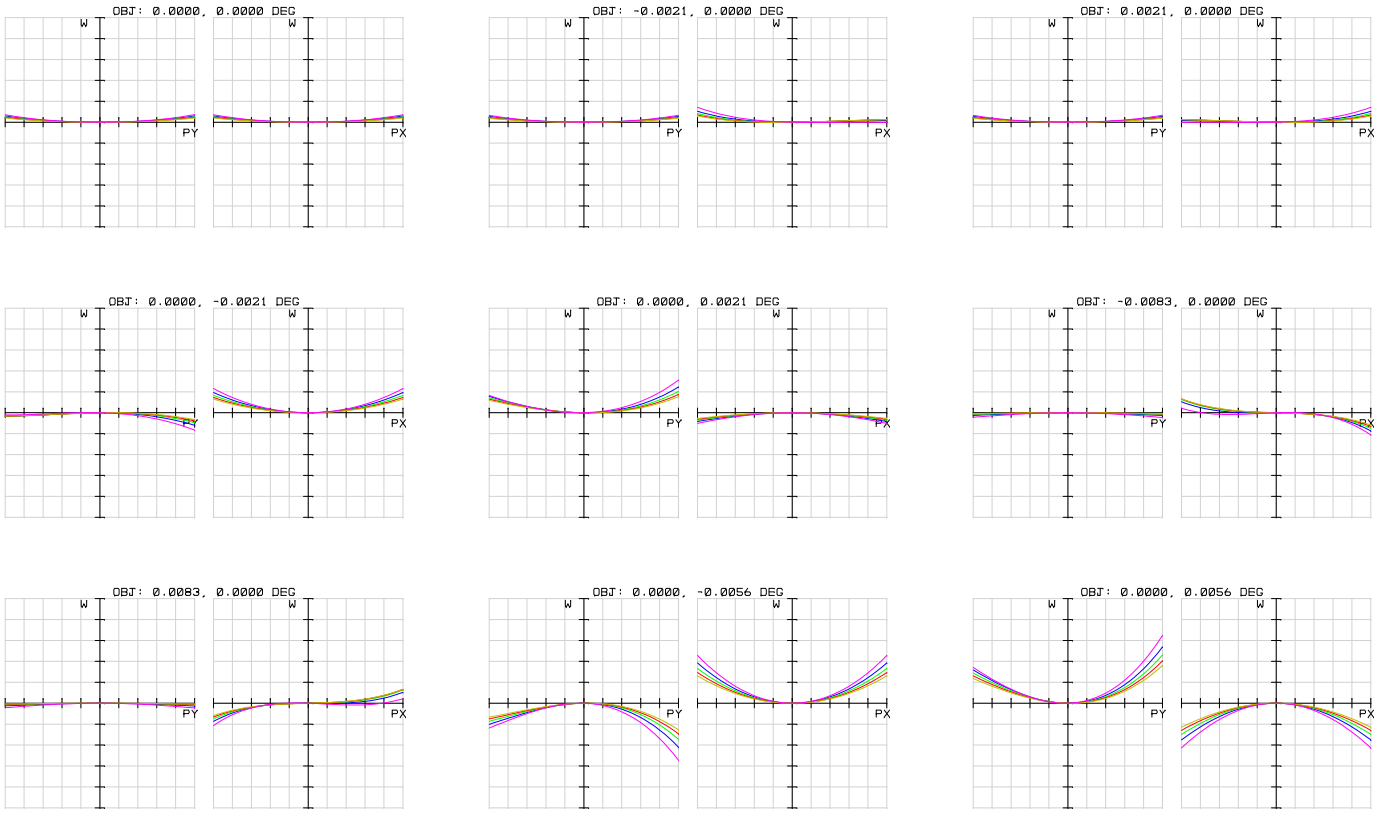
KNGAO_100MMPUPIL_120ARCSECRELAY_V9_LGSFOLDED_REV18.ZMX
CONFIGURATION: ALL 1

Input to the NGS sensor – spot diagram at the NGS sensor pick-off focal plane



Ray fans at the NGS sensor pick-off focal plane



OPTICAL PATH DIFFERENCE

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MAXIMUM SCALE: ± 5.000 WAVES.
0.600 0.700 0.800 0.900 0.500

SURFACE: IMAGE

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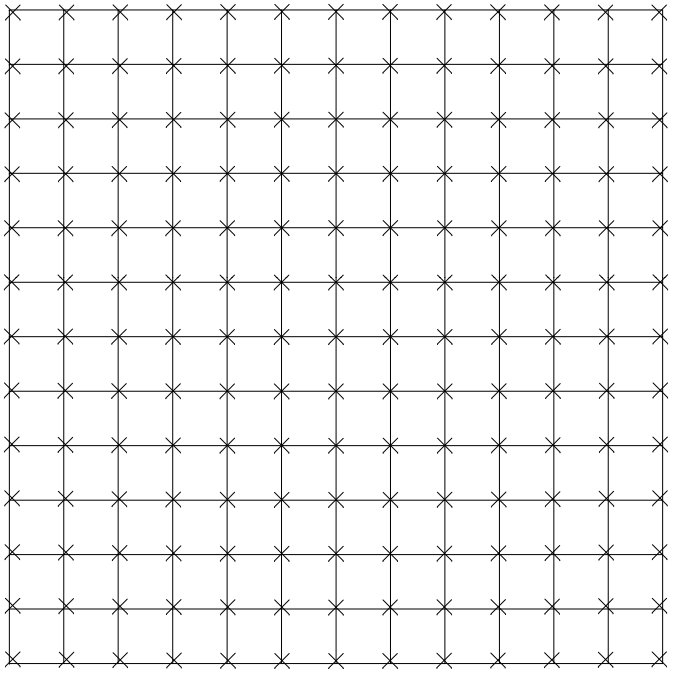
CONFIGURATION 1 OF 1

Grid distortion at the NGS WFS input



GRID DISTORTION

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FIELD: 0.0118 W 0.0118 H DEGREES
IMAGE: 45.03 W 45.03 H MILLIMETERS
MAXIMUM DISTORTION: -0.1217%
SCALE: 10.000X, WAVELENGTH: 0.6000 μm

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CONFIGURATION 1 OF 1

What's the implication on the NGS sensor?

- Wavefront error is 1.15 waves RMS (6 waves P-V) @ 600 nm at the extreme (and worst case) field points. This is mostly astigmatism.
- As per KAONs 685 we know that this corresponds to (y = ar^2 -> 0.69 *10^(-6) = 25 * a -> a = .276*10^(-7); dy/dr = 2*a*r ->) *[c.f. Figure 13 in the KAON]*
- Figures 9 and 10 along with corresponding analysis also indicate that for a large # of sub-apertures (60 in our case) the sub-ap. Spot size due to input aberration is going to be of the order of 2 um (RMS).

NGS wavefront sensor parameters

- Based on the pupil geometry, we design the sensor to have 60 sub-apertures across the a circle that inscribes the Keck primary mirror. We also support another calibration mode with 5x5 pupil samples across the Keck primary mirror.
- The detector plate scale is 4” because the sensor needs to track extended objects that are 4” in diameter. One could also work out the spot size.

Seeing			
Natural seeing FWHM at GS wavelength		0.46	arcsec
Subaperture Tip/Tilt corrected FWHM		0.36	arcsec
AO-compensated FWHM		0.06	arcsec
Contribution due to seeing		0.36	arcsec
System Aberrations			
Aberrations in AO thru to WFS		0.25	arcsec
Atmospheric Dispersion			
ADC in HOWFS?	NO		
RMS blurring due to atmospheric dispersi		0.000	arcsec
Total size of detected return beam:		0.44	arcsec
Charge Diffusion			
Charge Diffusion		0.25	pixels
Contribution due to Charge Diffusion		0.40	arcsec
Subaperture Diffraction			
Lambda/d (for sensing)		0.71	arcsec
Spot size used for centroiding		**0.93**	**arcsec**

Modes of operation

- 60x60 mode of operation - since all the visible wavefront sensing detectors are identical (for spares and cost consideration in procurement and software development) in the NGAO we use 4 physical pixels per sub-ap. Which can be binned on chip and read as 2x2 pixels/sub-aperture with almost zero read noise penalty. This gives us the flexibility of 2 modes, one with high linearity and another with lower read noise.
- 5x5 mode of operation – to simply the size of moving parts while facilitating the two pupil sampling modes, we use the same collimator for both configurations. The table in the next page summaries all the design parameters.

WFS design parameters

Parameter	60x60 mode	5x5 mode	units
f_collimator	60	60	mm
Input plate scale	1.063	1.063	mm/"
Binned pixel size (# of pixels)	1	4	pixels
Detector plate scale (mm/")	0.021	0.084	mm/"
Plate scale ratio (IPS/DPS)	50.61904762	12.6547619	
input f/#	20.012	20.012	
pupil sampling	60	5	sub-aps across pupil
d_lenslet	0.049970018	0.599640216	mm
de-magnification (m)	1.681008	0.560336	
f_lenslet	0.705127253	8.461527035	mm
f# lenslet	14.11100659	14.11100659	
wavelength (for worst case FN calc.)	0.0009	0.0009	mm
fresnel #	0.983669058	11.80402869	
radius of curvature of lenslet	0.364409764	4.372917172	mm

60x60 NGS WFS layout

- Total relay length = 285 mm
- Components from (left to right) – doublet collimator, lenslet, field lens, doublet focusing lens followed by the window and the detector.
- Wavelength of operation – 500-900 nm

3D LAYOUT

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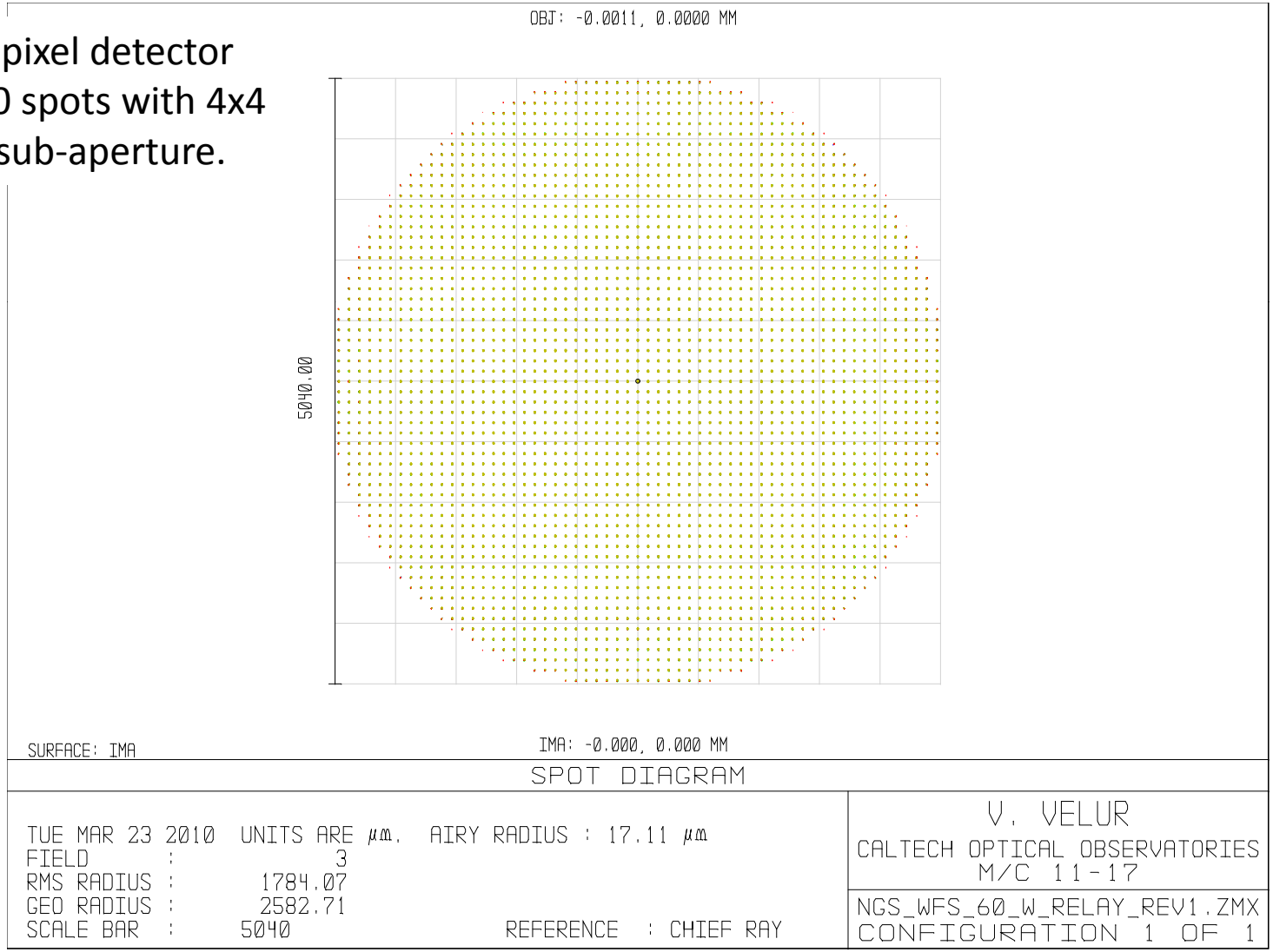
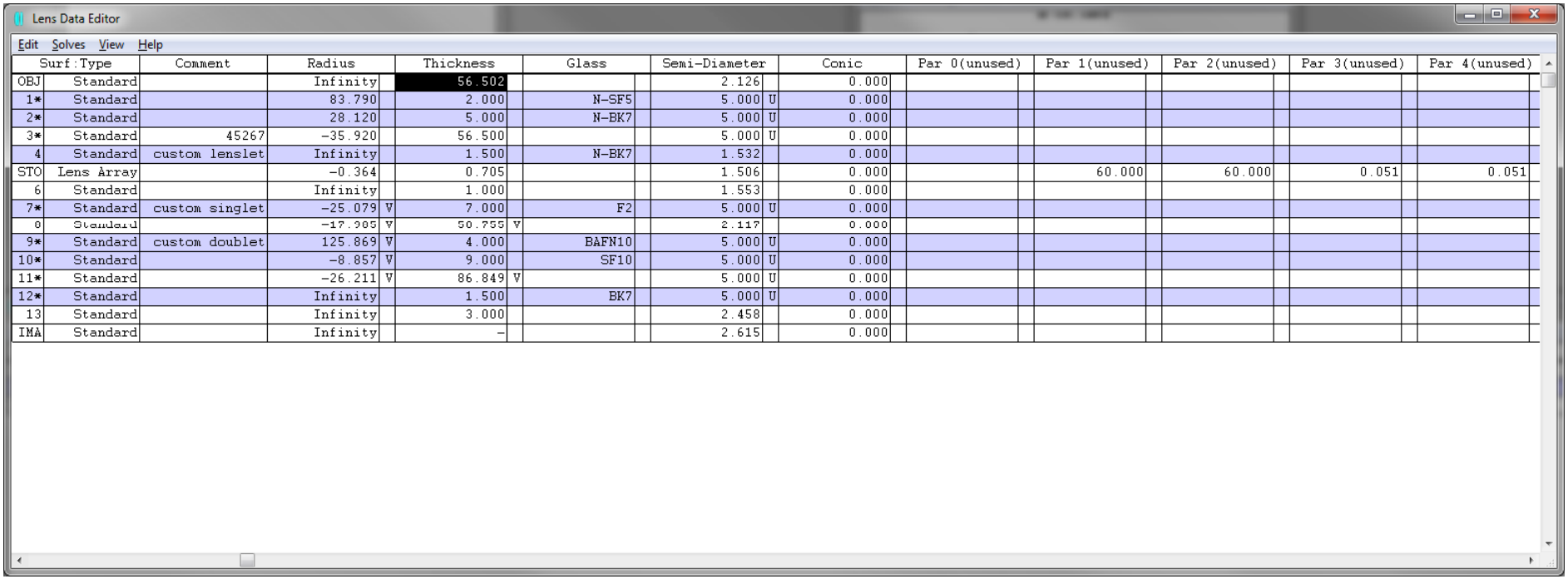
NGS_WFS_60_W_RELAY_REV1.ZMX
CONFIGURATION: ALL 1

60x60 NGS WFS layout

21 um pixel detector with 60 spots with 4x4 pixels/sub-aperture.



60x60 NGS WFS layout



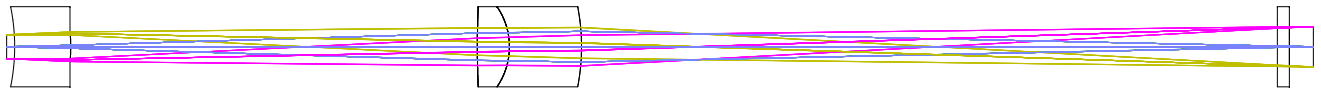
Lens Data Editor

Edit Solves View Help

Surf:Type		Comment	Radius		Thickness		Glass	Semi-Diameter		Conic	Par 0(unused)	Par 1(unused)	Par 2(unused)	Par 3(unused)	Par 4(unused)
OBJ	Standard		Infinity		56.502			2.126		0.000					
1*	Standard		83.790		2.000		N-SF5	5.000	U	0.000					
2*	Standard		28.120		5.000		N-BK7	5.000	U	0.000					
3*	Standard	45267	-35.920		56.500			5.000	U	0.000					
4	Standard	custom lenslet	Infinity		1.500		N-BK7	1.532		0.000					
STO	Lens Array		-0.364		0.705			1.506		0.000		60.000	60.000	0.051	0.051
6	Standard		Infinity		1.000			1.553		0.000					
7*	Standard	custom singlet	-25.079	V	7.000		F2	5.000	U	0.000					
8	Standard		-17.905	V	50.755	V		2.117		0.000					
9*	Standard	custom doublet	125.869	V	4.000		BAFN10	5.000	U	0.000					
10*	Standard		-8.857	V	9.000		SF10	5.000	U	0.000					
11*	Standard		-26.211	V	86.849	V		5.000	U	0.000					
12*	Standard		Infinity		1.500		BK7	5.000	U	0.000					
13	Standard		Infinity		3.000			2.458		0.000					
IMA	Standard		Infinity		-			2.615		0.000					

60x60 NGS WFS post lenslet relay

- Mag. = 1.681
- Total relay length = 164 mm



3D LAYOUT

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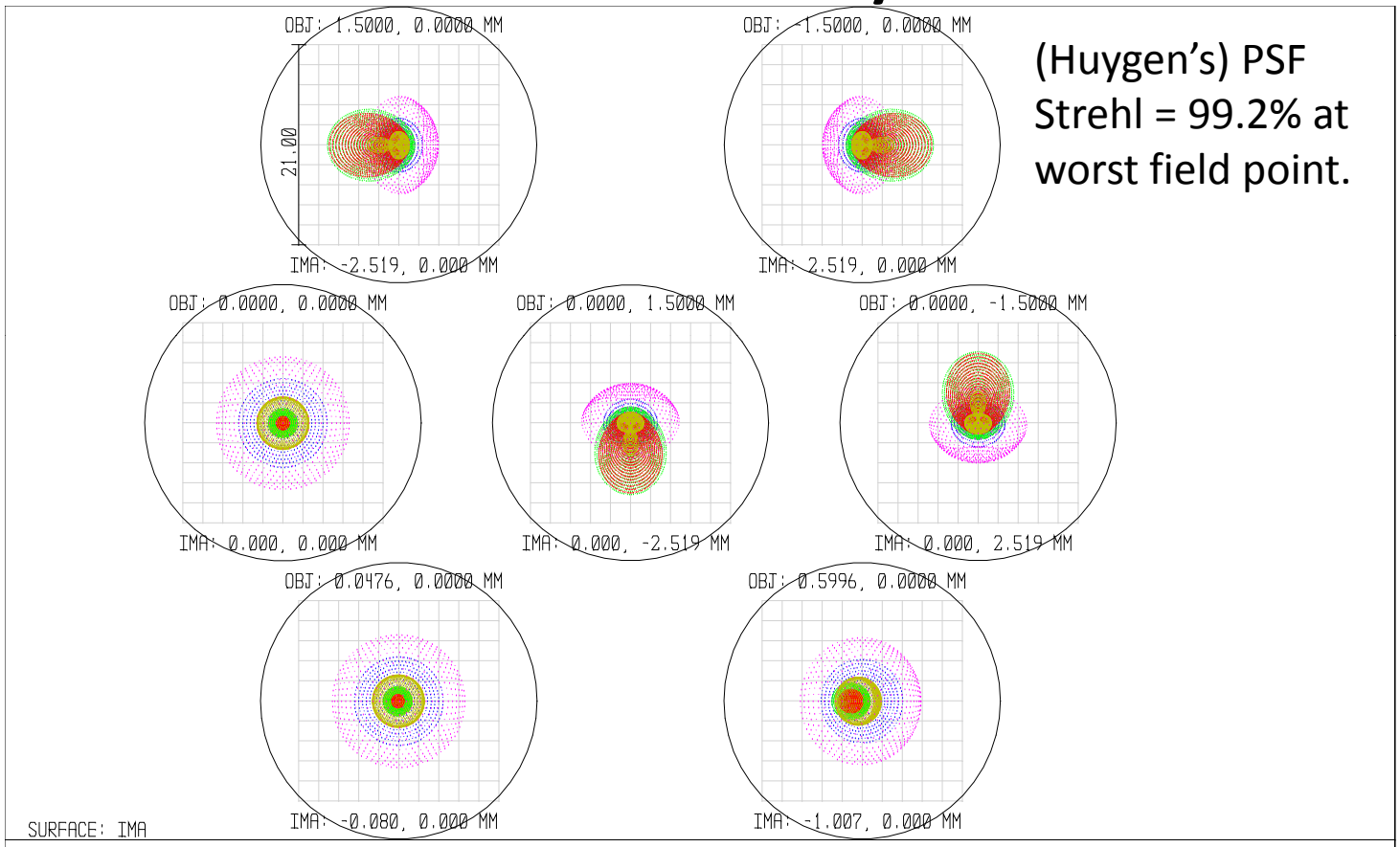
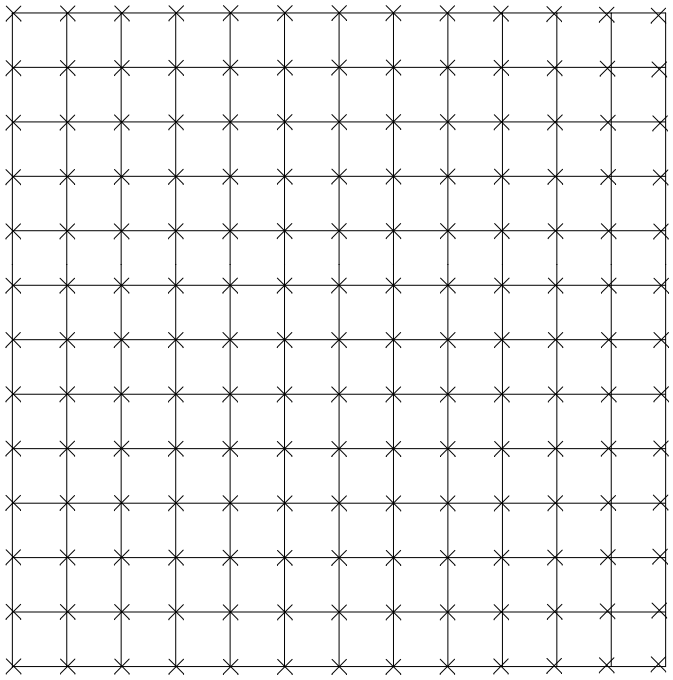
NGS_60_RELAY_REV1.ZMX
CONFIGURATION: ALL 1

Post lenslet relay – spots delivered by the relay



(Huygen's) PSF Strehl = 99.2% at worst field point.

Post lenslet relay – grid distortion



700 nm is the central wavelength, GD at 500 nm is 0.047% and GD at 900 nm is 0.013%

GRID DISTORTION

TUE MAR 23 2010
FIELD: 2.12 W 2.12 H MILLIMETERS
IMAGE: 3.56 W 3.56 H MILLIMETERS
MAXIMUM DISTORTION: -0.0167%
SCALE: 100.000X, WAVELENGTH: 0.7000 μm

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NGS_60_RELAY_REV1.ZMX
CONFIGURATION 1 OF 1

5x5 NGS (calibration) WFS layout

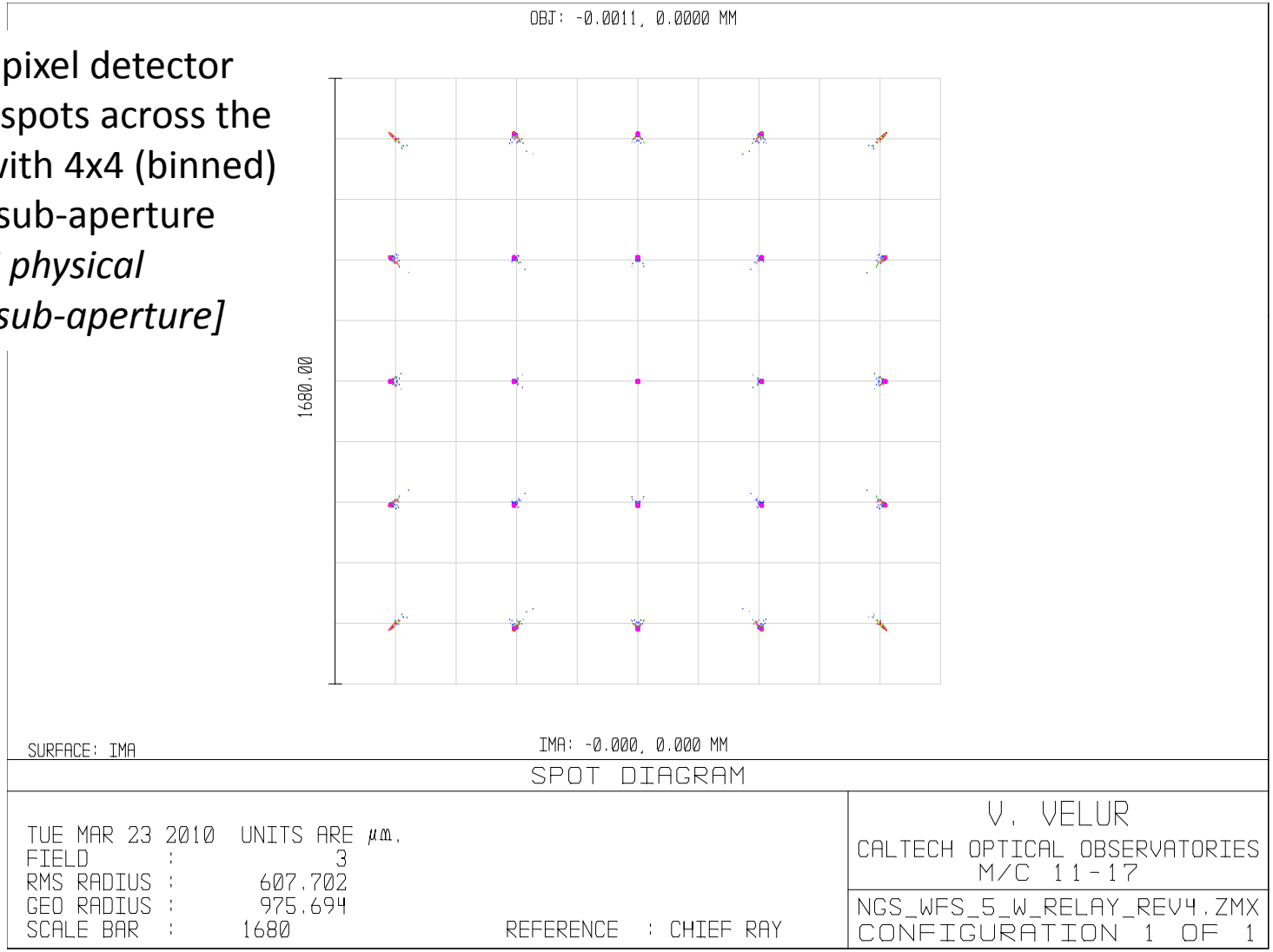
- Total relay length = 265 mm
- Components from (left to right) – doublet collimator, lenslet, field lens, doublet focusing lens followed a field flattener detector window and the focal plane array.
- Wavelength of operation – 500-900 nm

3D LAYOUT

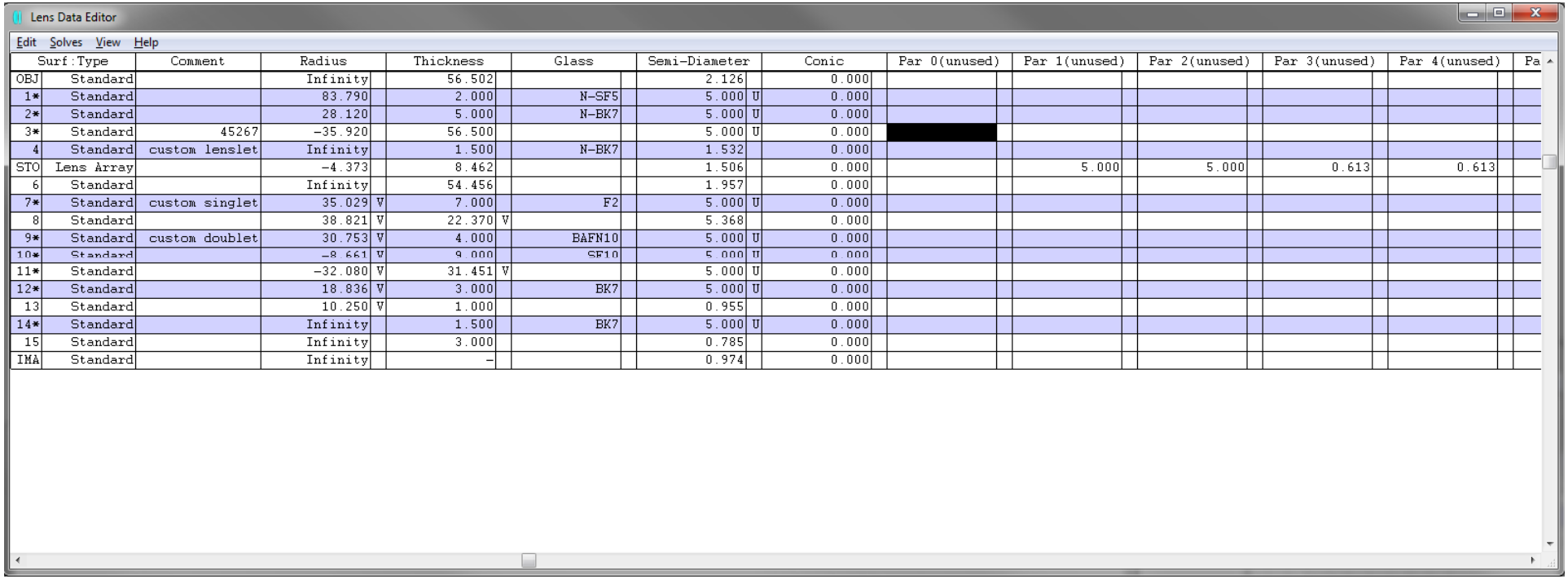
TUE MAR 23 2010	V. VELUR CALTECH OPTICAL OBSERVATORIES M/C 11-17
	NGS_WFS_5_W_RELAY_REV4.ZMX CONFIGURATION: ALL 1

5x5 NGS WFS layout

21 um pixel detector with 5 spots across the pupil with 4x4 (binned) pixels/sub-aperture *[16x16 physical pixels/sub-aperture]*



5x5 NGS WFS layout



Lens Data Editor

Edit Solves View Help

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1*	Standard		83.790		2.000		N-SF5	5.000	U	0.000						
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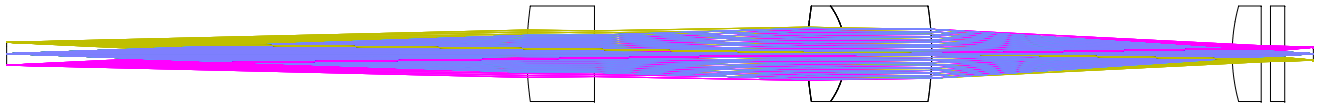
3*	Standard	45267	-35.920		56.500			5.000	U	0.000						
4	Standard	custom lenslet	Infinity		1.500		N-BK7	1.532		0.000						
STO	Lens Array		-4.373		8.462			1.506		0.000		5.000	5.000	0.613	0.613	
6	Standard		Infinity		54.456			1.957		0.000						
7*	Standard	custom singlet	35.029	V	7.000		F2	5.000	U	0.000						
8	Standard		38.821	V	22.370	V		5.368		0.000						
9*	Standard	custom doublet	30.753	V	4.000		BAFN10	5.000	U	0.000						
10*	Standard		-8.661	V	9.000		SF10	5.000	U	0.000						
11*	Standard		-32.080	V	31.451	V		5.000	U	0.000						
12*	Standard		18.836	V	3.000		BK7	5.000	U	0.000						
13	Standard		10.250	V	1.000			0.955		0.000						
14*	Standard		Infinity		1.500		BK7	5.000	U	0.000						
15	Standard		Infinity		3.000			0.785		0.000						
IMA	Standard		Infinity		-			0.974		0.000						

5x5 NGS WFS post lenslet relay

- Mag. = -0.560
- Total relay length = 137 mm



3D LAYOUT

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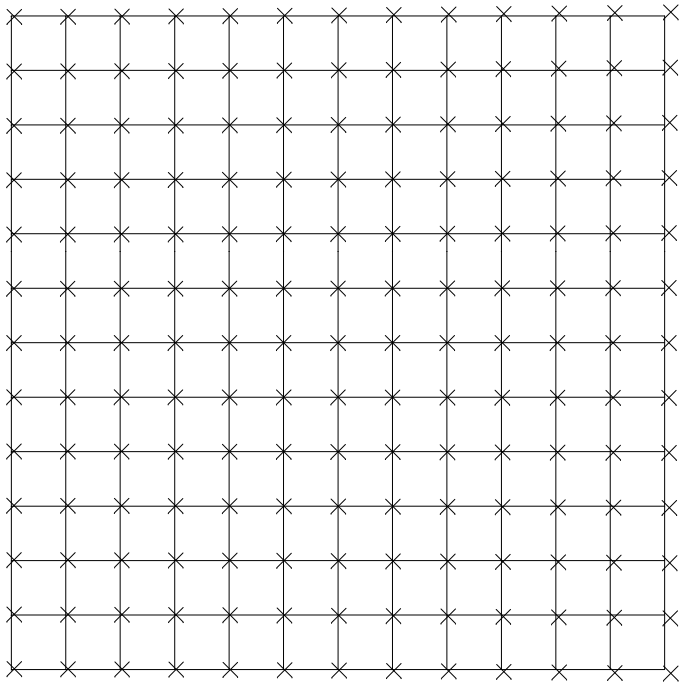
NGS_5_RELAY_REV5.ZMX
CONFIGURATION: ALL 1

Post lenslet relay – spots delivered by the relay

(Huygen's) PSF Strehl = 95% at worst field point.

Post lenslet relay – grid distortion



700 nm is the central wavelength, GD at 500 nm is 0.015% and GD at 900 nm is 0.016%

GRID DISTORTION

TUE MAR 23 2010
FIELD: 1.6971 W 1.6971 H MILLIMETERS
IMAGE: 0.9521 W 0.9520 H MILLIMETERS
MAXIMUM DISTORTION: 0.0157%
SCALE: 100.000X, WAVELENGTH: 0.7000 μm

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NGS_5_RELAY_REV5.ZMX
CONFIGURATION 1 OF 1