Telescope design

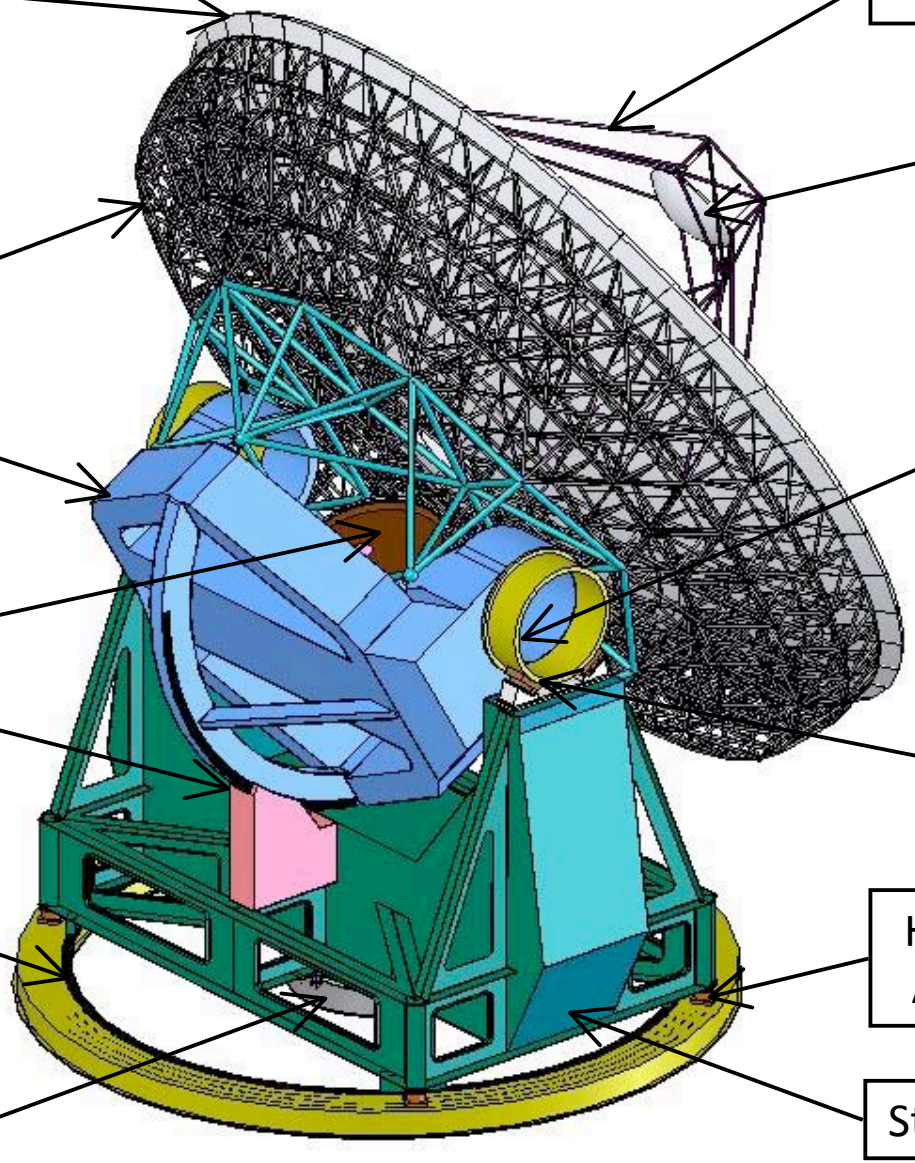
Steve Padin

The Submillimeter Universe: The CCAT View

12 November 2010

Telescope concept

HWFE<10µm rms, PE<0.35” rms



Active surface with 0.5m Al tiles on 2m CFRP subframes

CFRP tripod

Segmented secondary

CFRP truss

3m diameter Nasmyth tube holds 1° FoV instruments

Steel EL structure

Tertiary

Direct EL drive

Hydrostatic EL bearing

Direct AZ drive

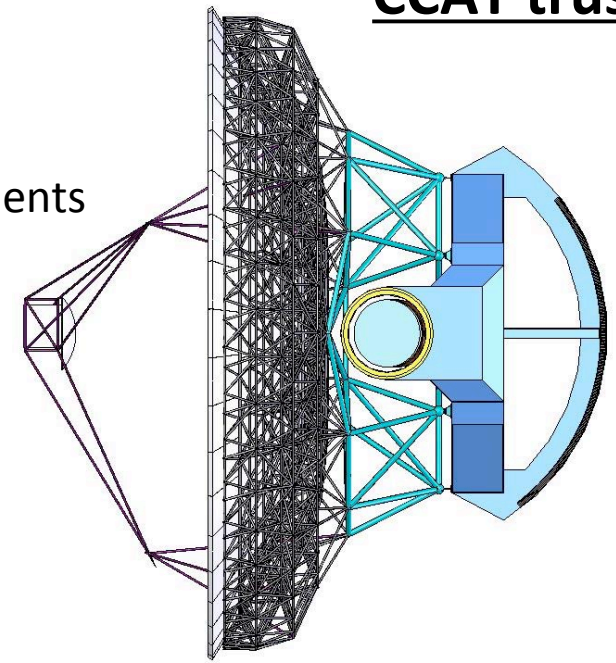
Hydrostatic AZ bearing

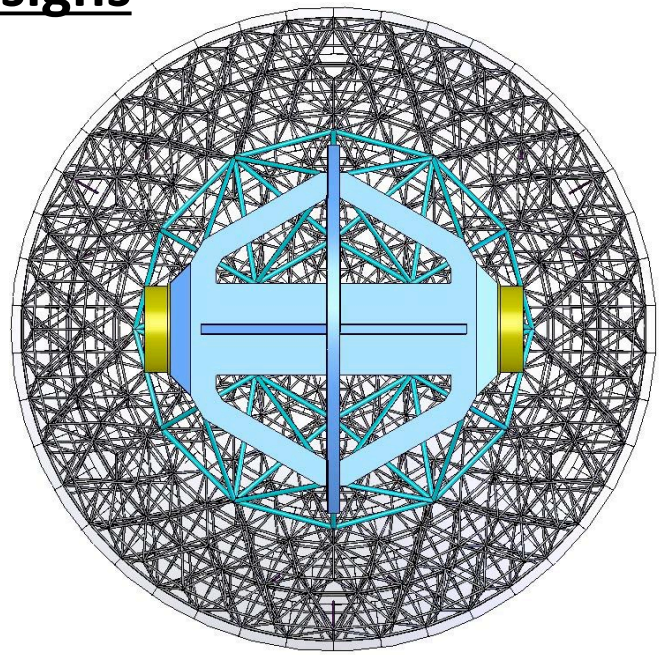
Pintle bearing

Steel alidade

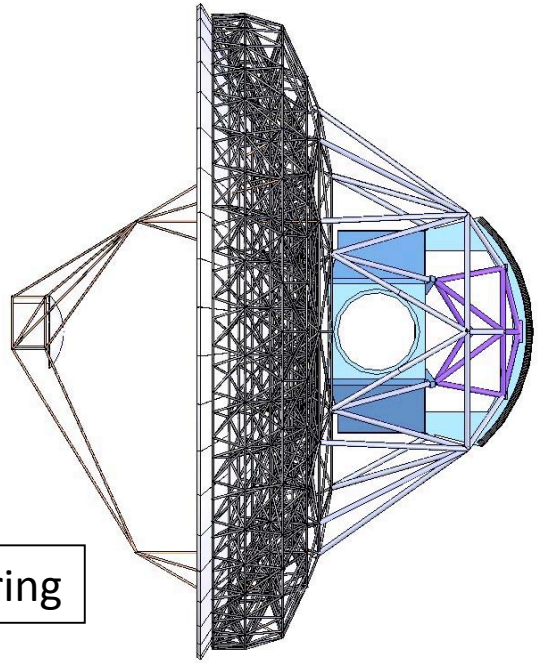
CCAT truss designs

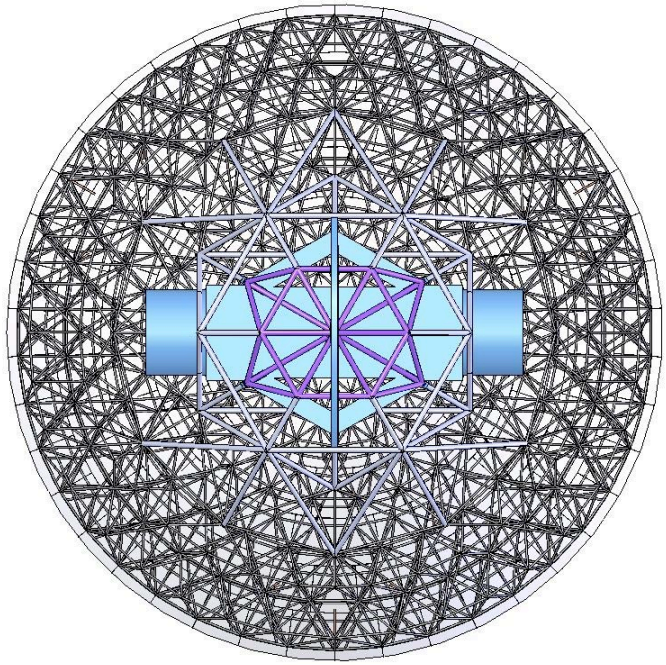
Ring & pillar
30,000 kg truss
12,000 kg segments
(25 kg m^{-2})
7-8 Hz





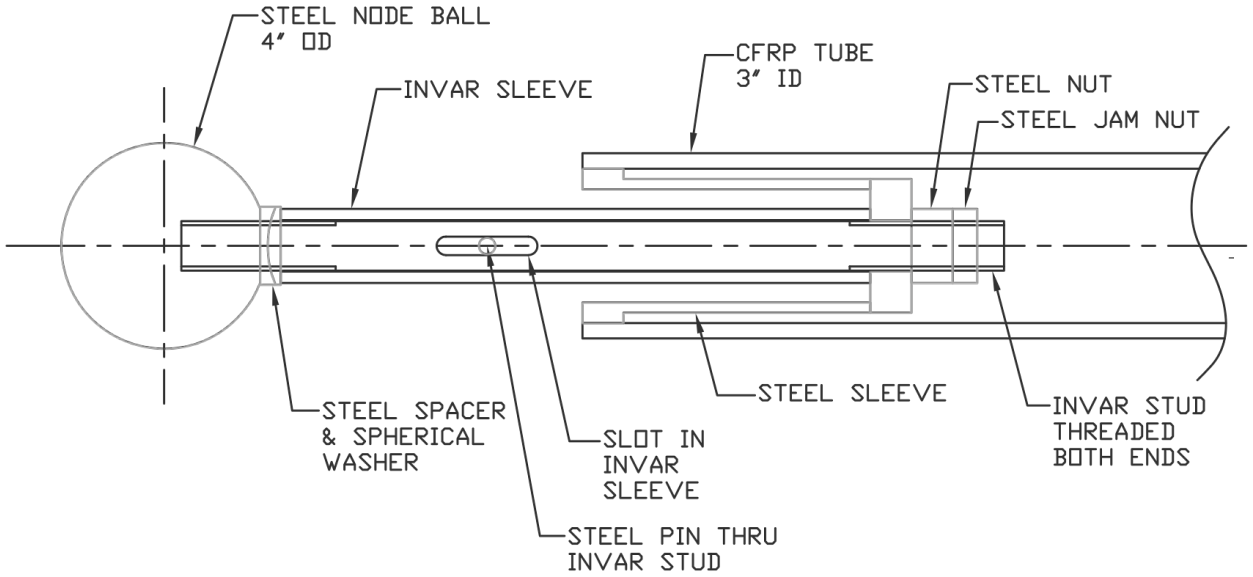
3d

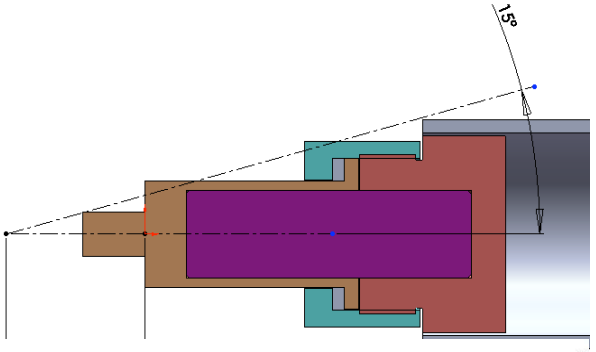




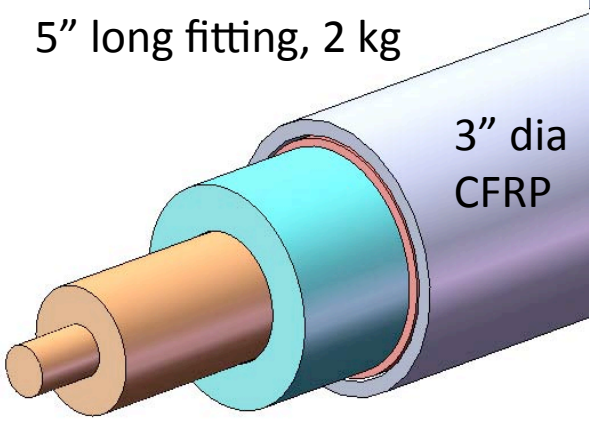
Stutzki Engineering

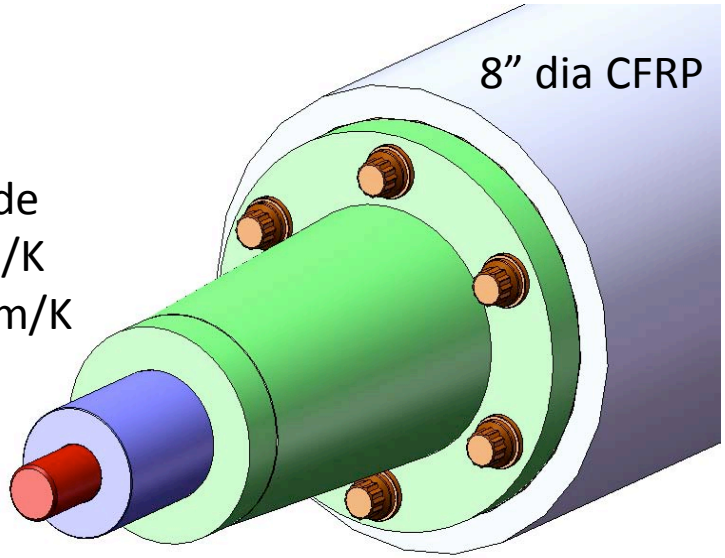
Truss rods



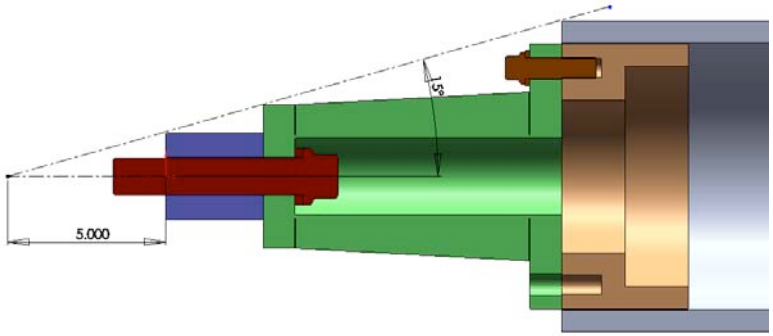


5” long fitting, 2 kg





For a rod & node
<CTE> 0.2 ppm/K
ΔCTE ±0.03 ppm/K



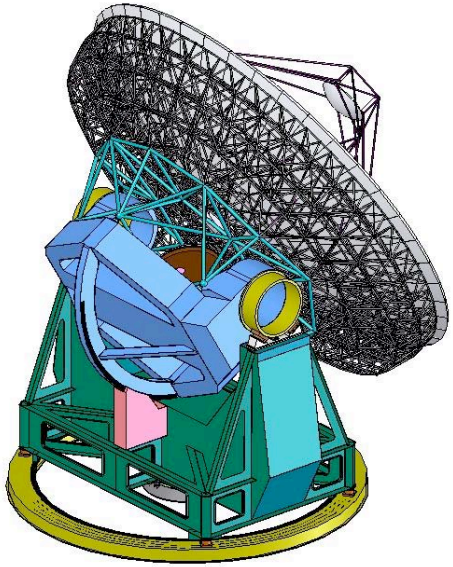
12.5” long fitting, 36 kg

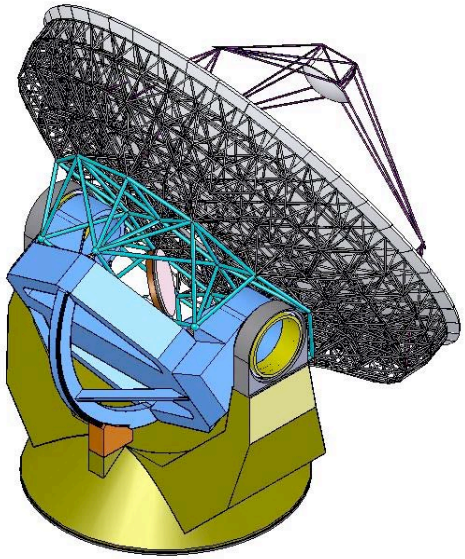
ATK (COI)

CCAT bearing & truss options

General Dynamics

Ring & pillar





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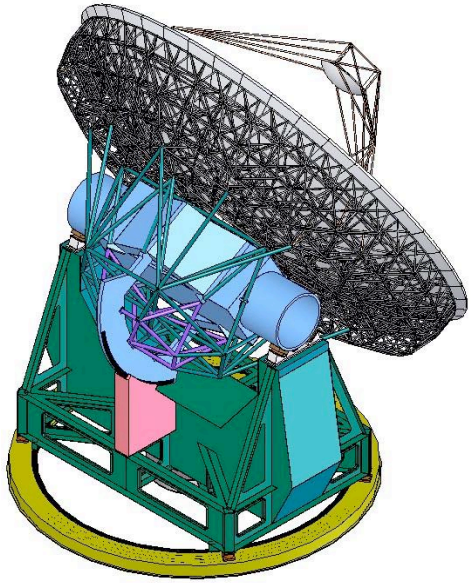
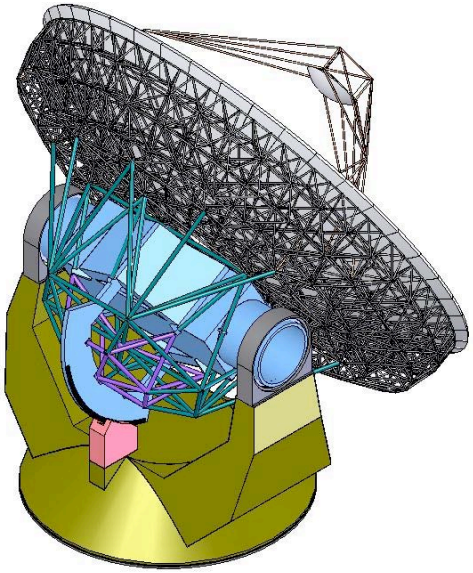
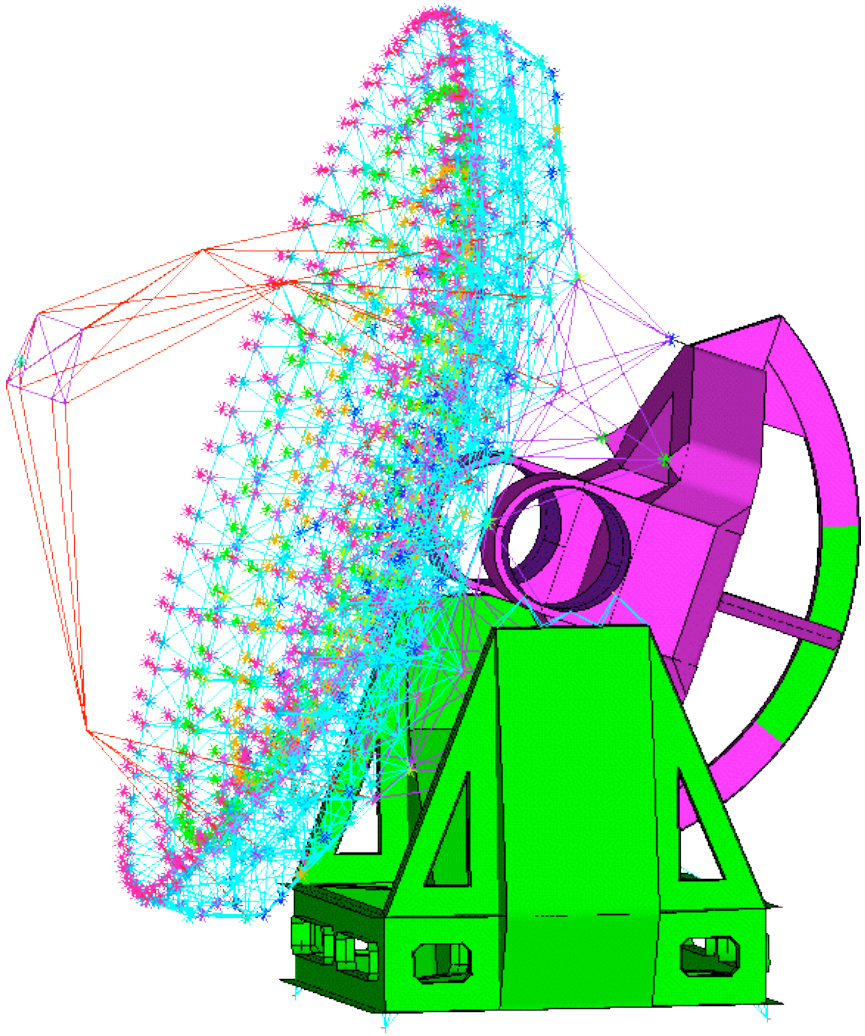




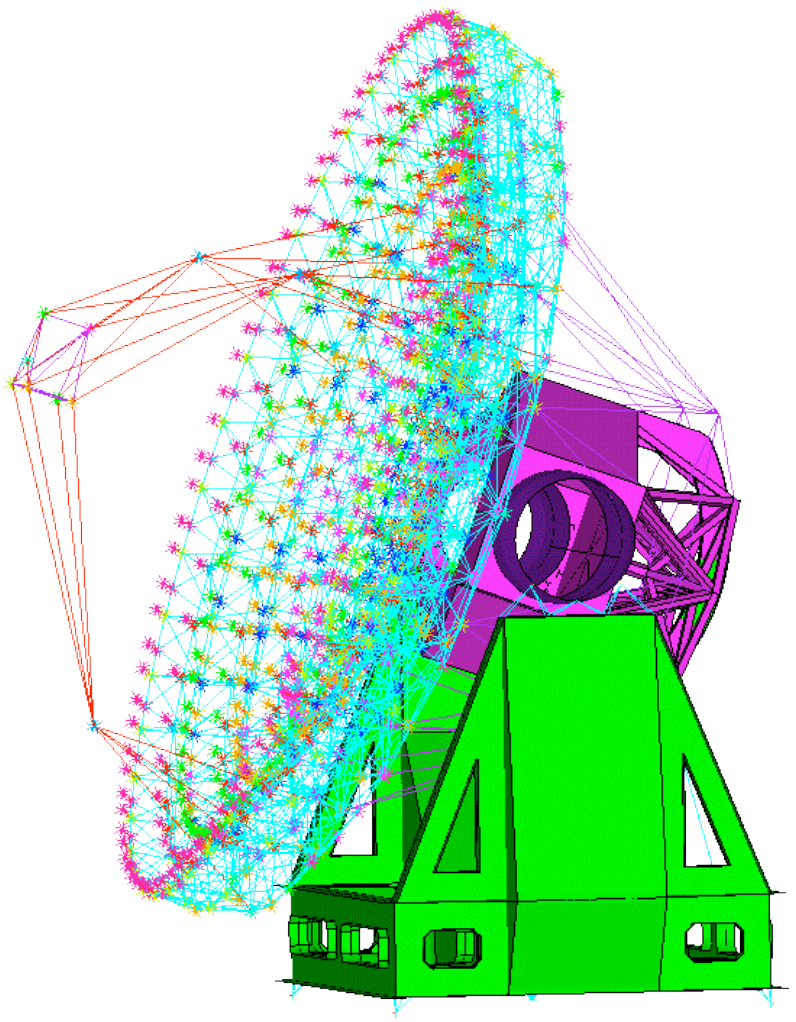
Hydrostatic bearings

Rolling element bearings

Finite element models

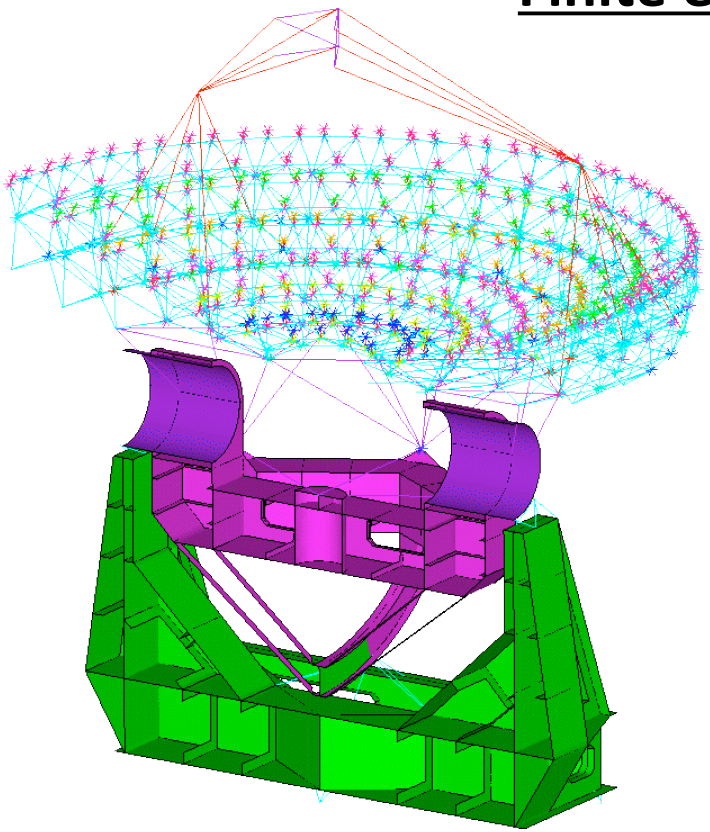


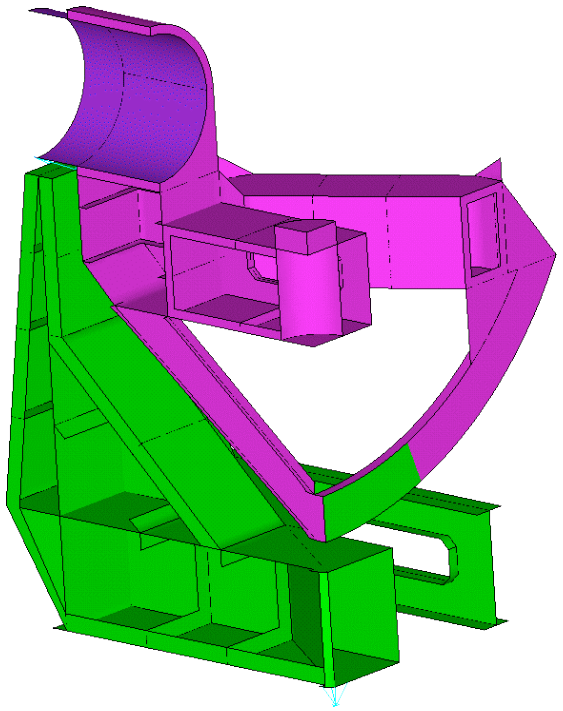
Ring & pillar

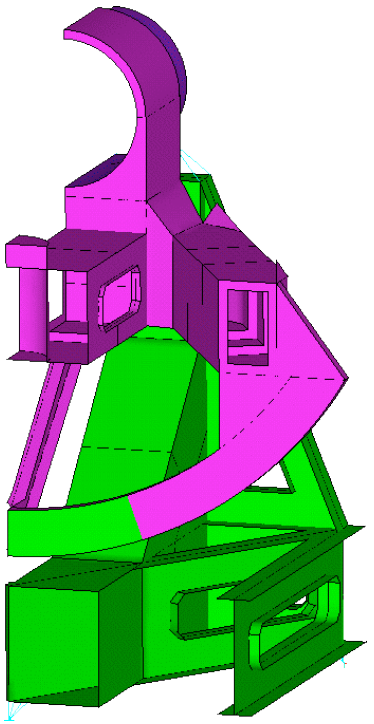


3d

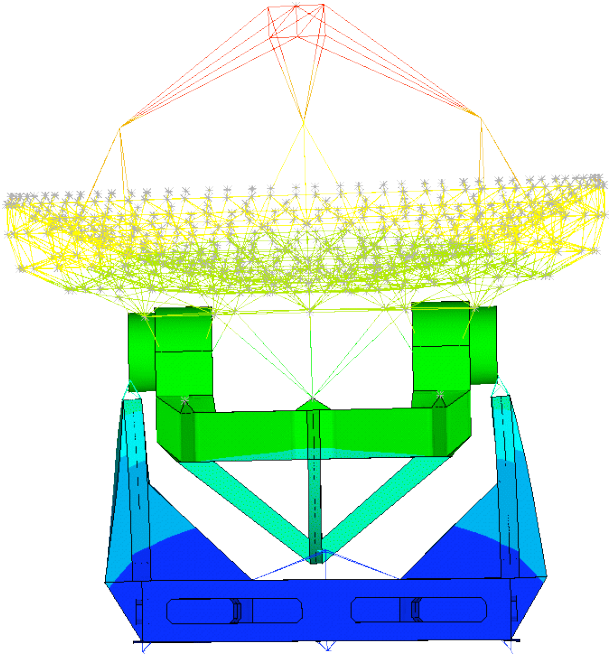
Finite element model details



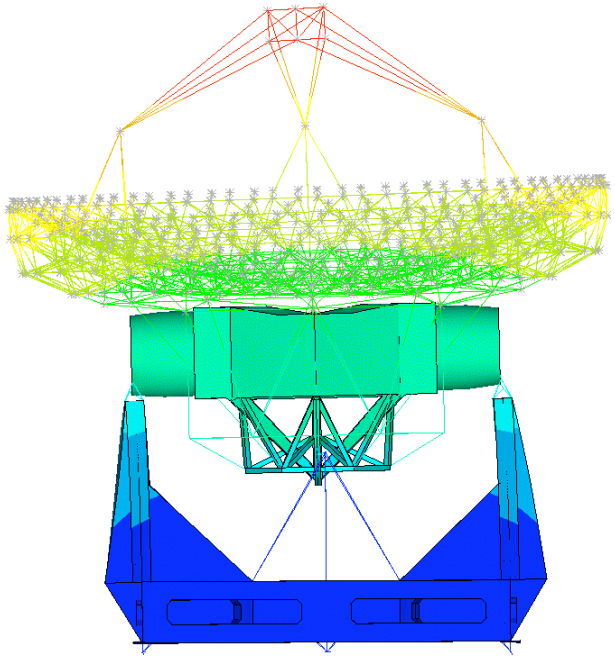




FEA results



Ring & pillar 3.5 Hz

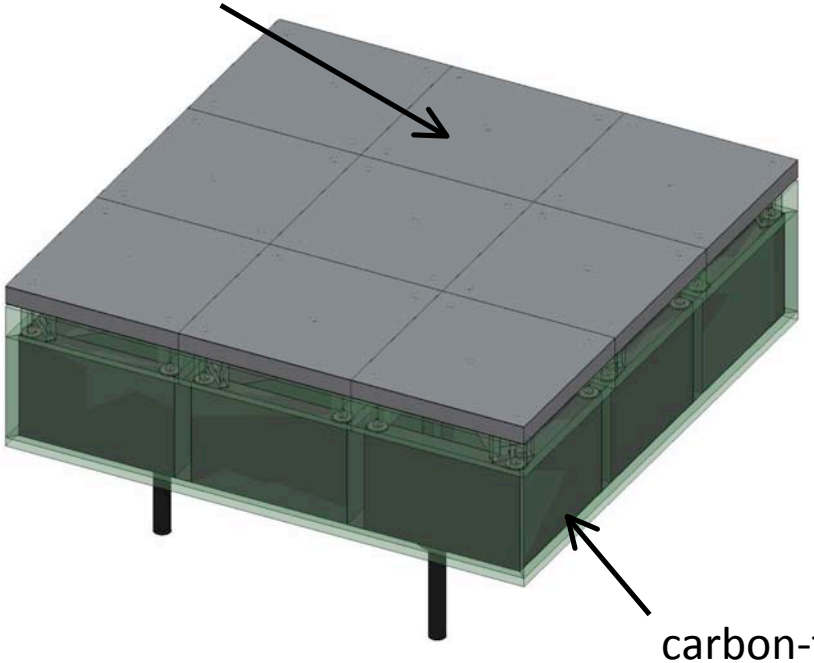


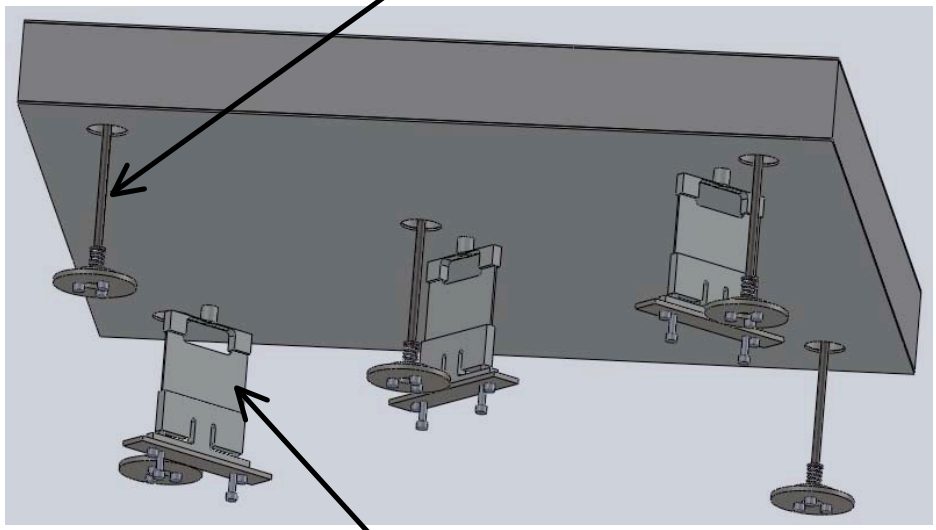
3d 3.3 Hz

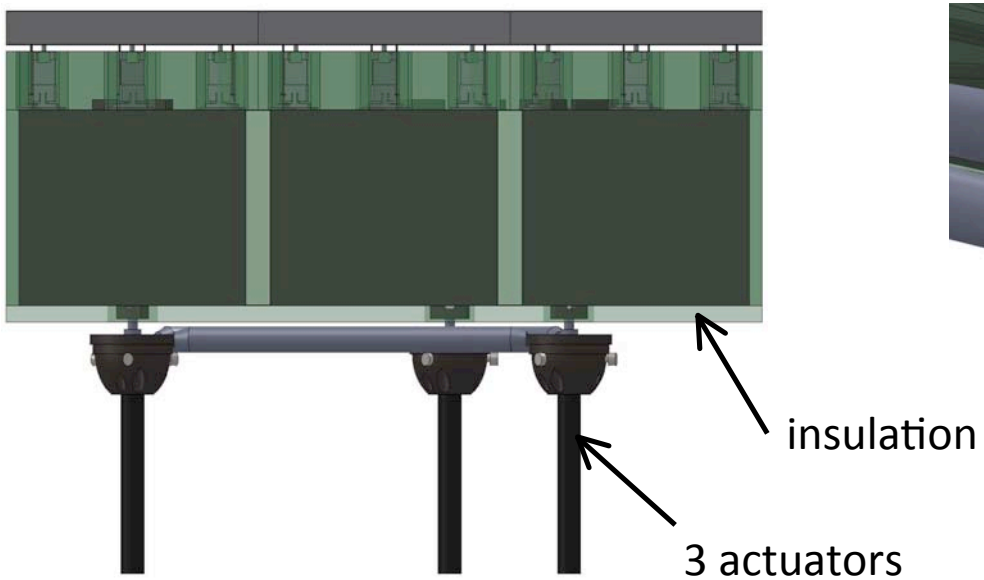
Load case	zenith	EL=20°	Analytical model µm rms
	µm rms	µm rms	
Gravity	287	276	
0.4°s^{-2} acceleration	1.7	1.3	0.7
20K soak	3.8	5.0	3.1
1K vertical	0.2	0.7	
1K horizonal	0.9	0.9	3.3

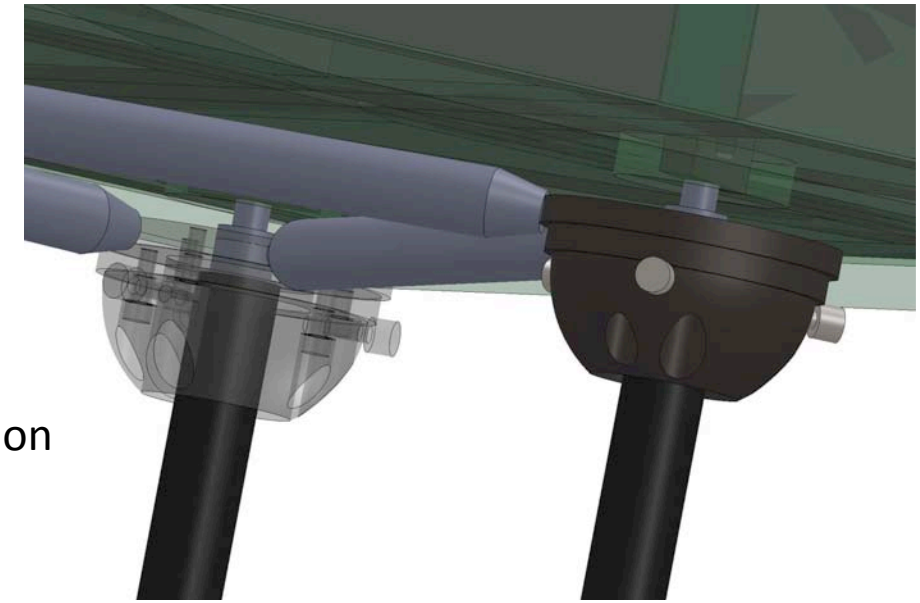
Load case	zenith	EL=20°
	µm rms	µm rms
gravity	360	187
0.4°s^{-2} acceleration	2.3	1.5
20K soak	69.2(!)	69.2
1K vertical	0.7	1.7
1K horizonal	1.8	1.8

CCAT segment concept



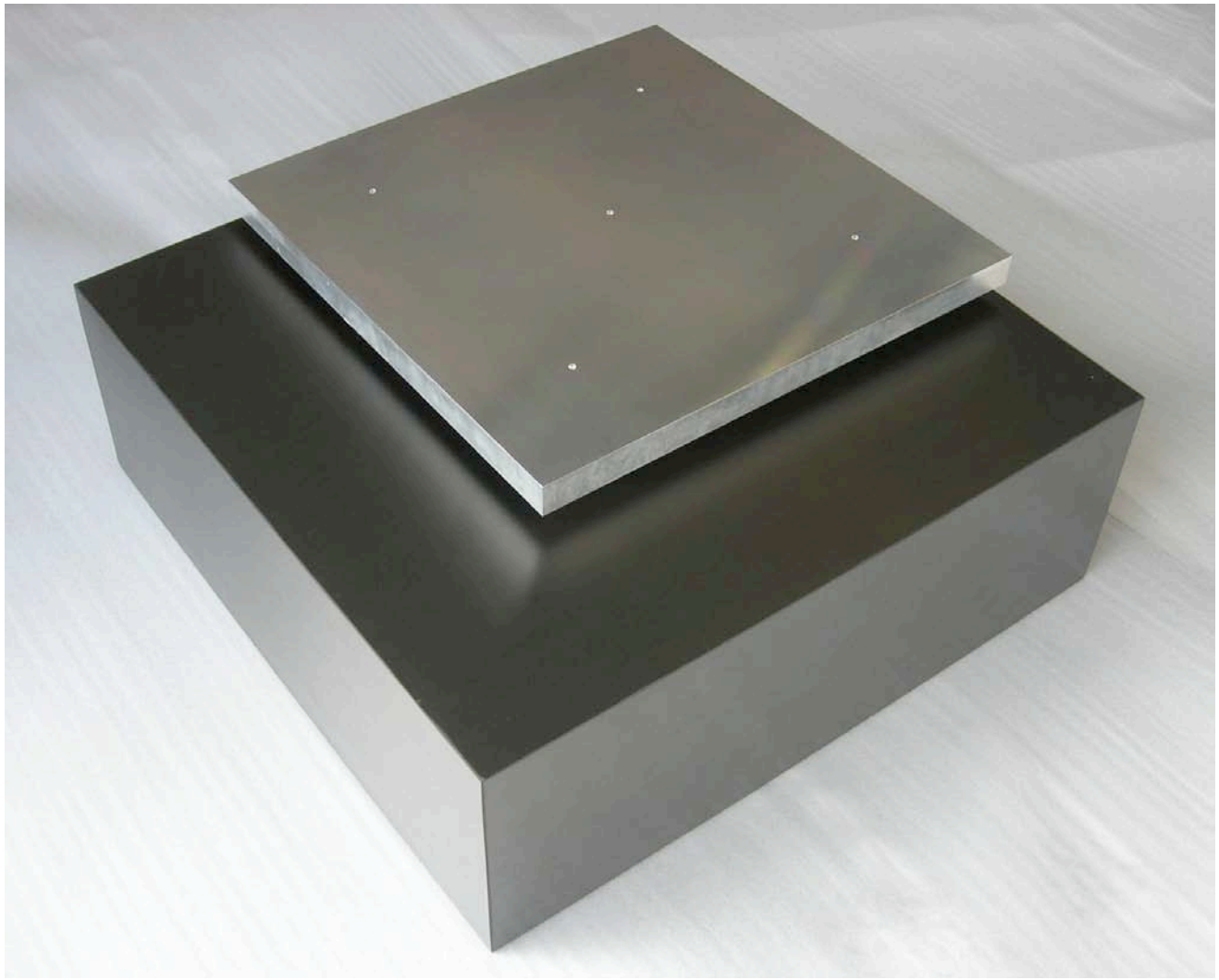






Prototype tile & subframe

Vertex Antennentechnik

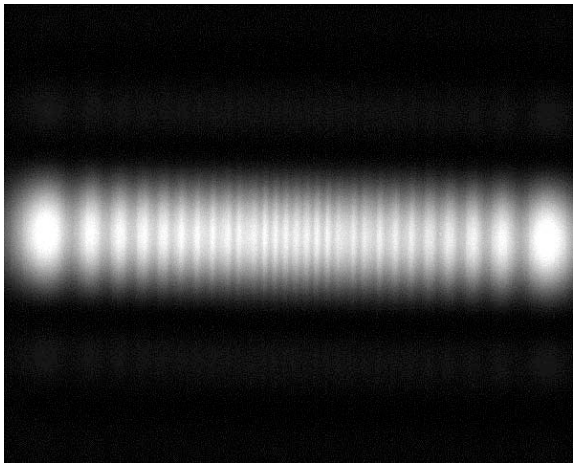


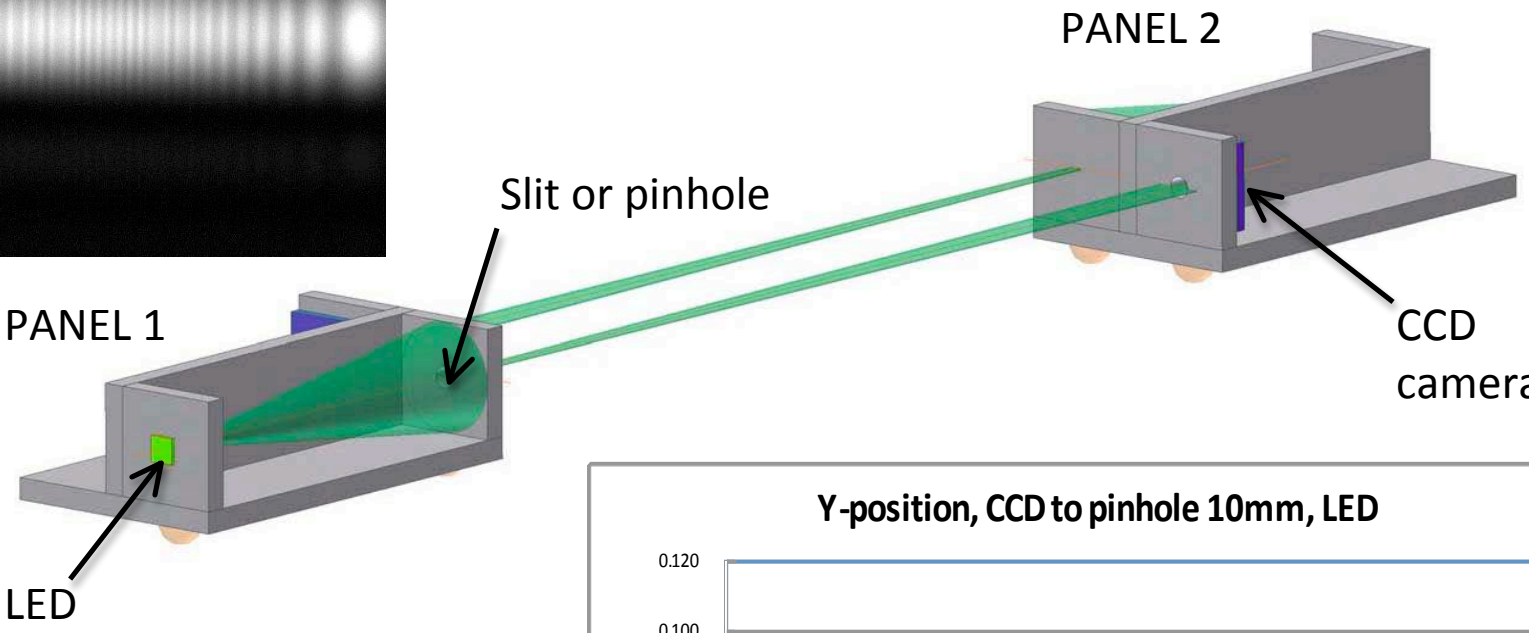
Tile surface error 2.5 µm rms

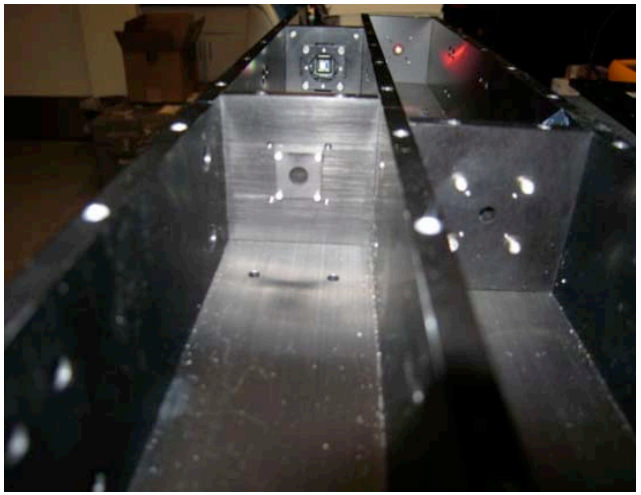
Tile + subframe areal density 19 kg m^{-2}

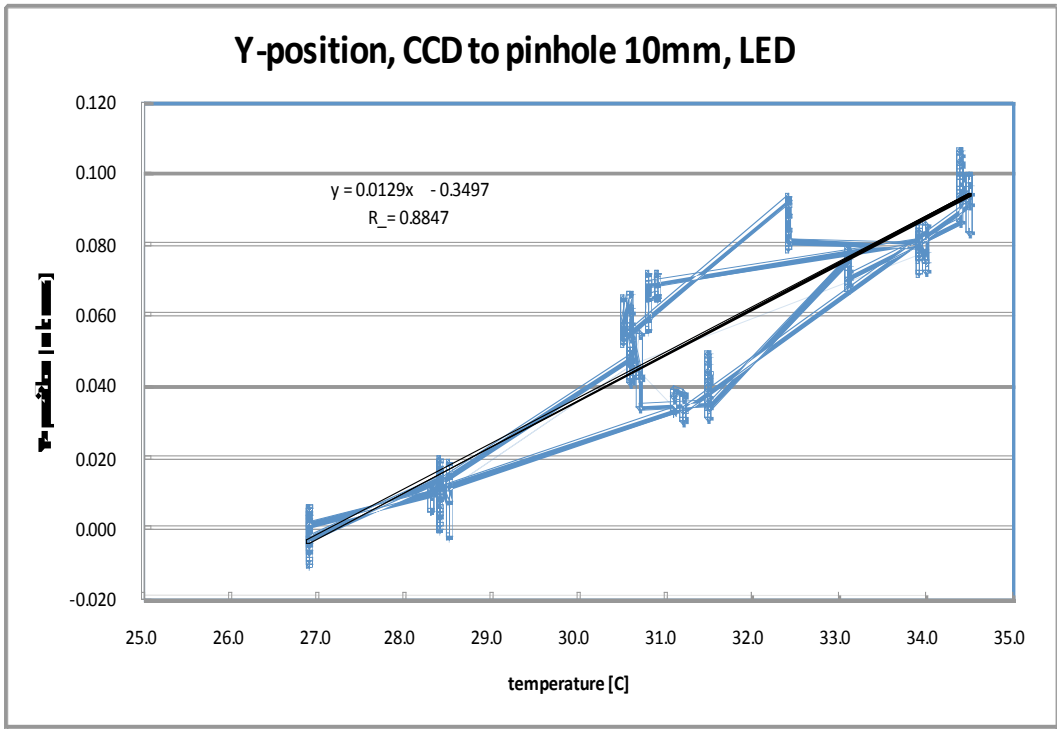
Optical edge sensor

D. Woody, Caltech

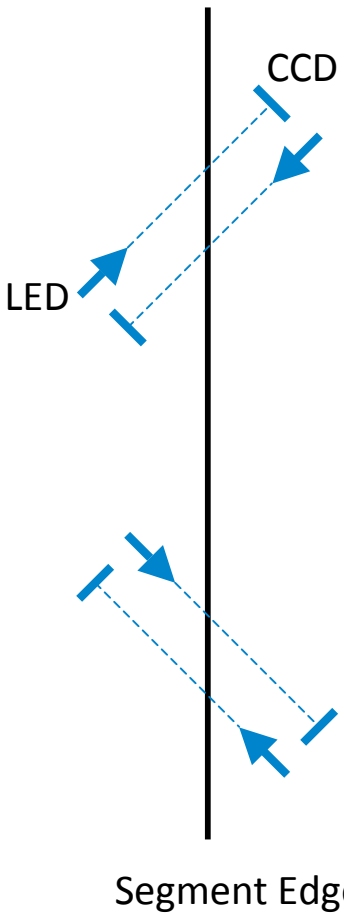


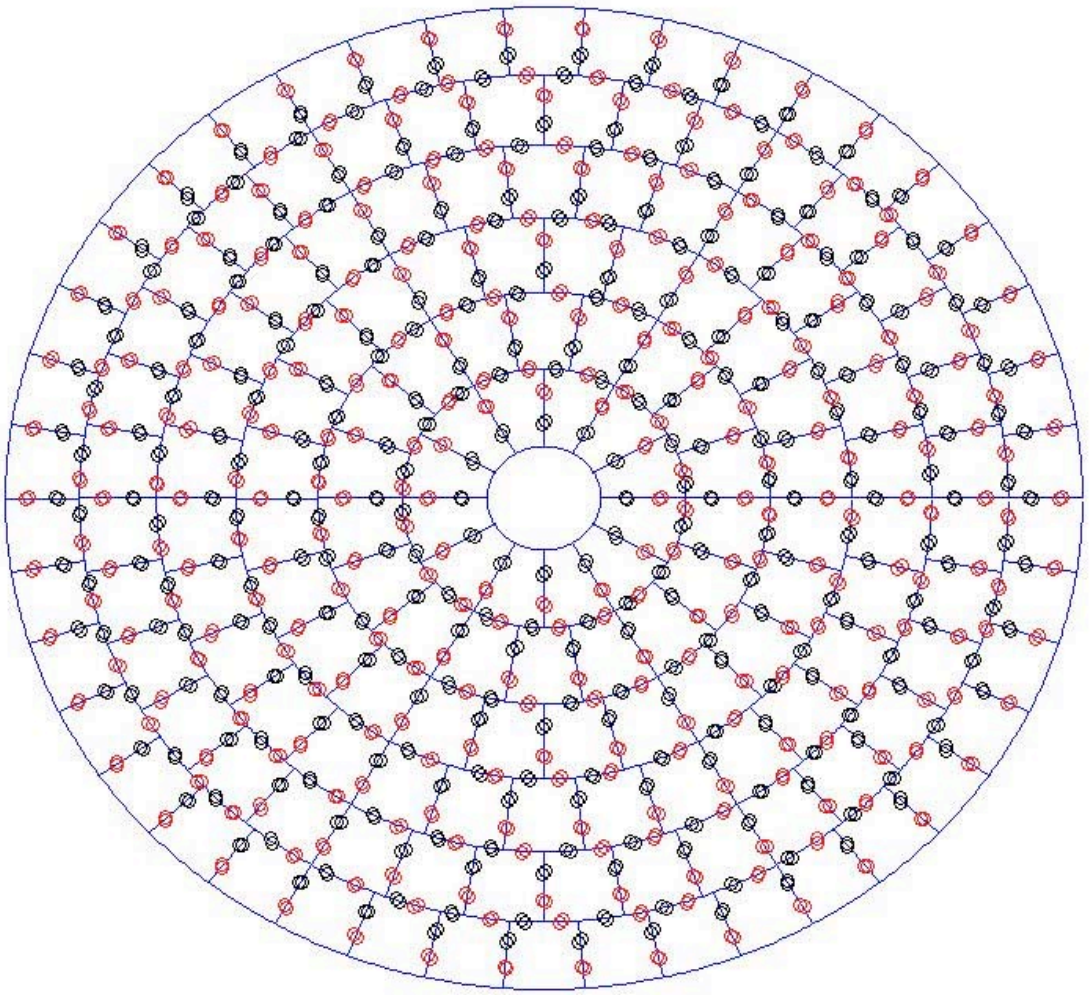






Edge sensor placement

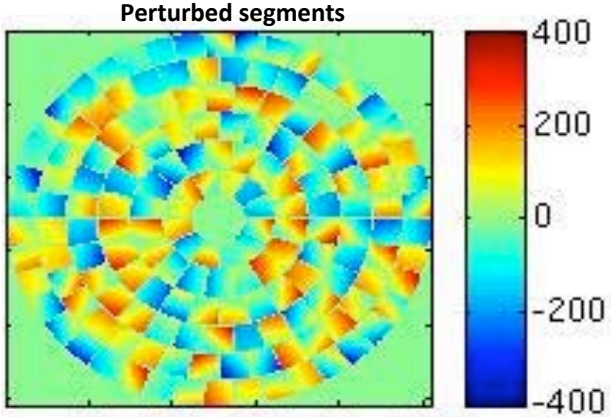




Primary surface control

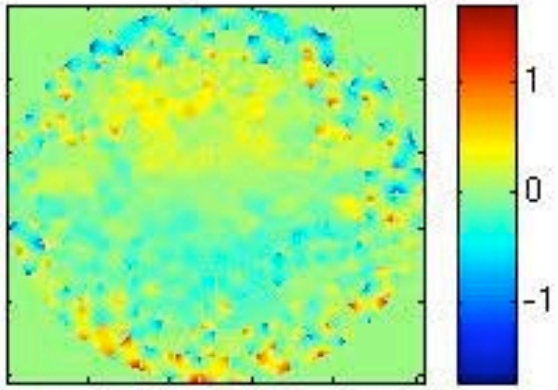
J. Lou, JPL

CCAT WF Error with randomly Perturbed segments



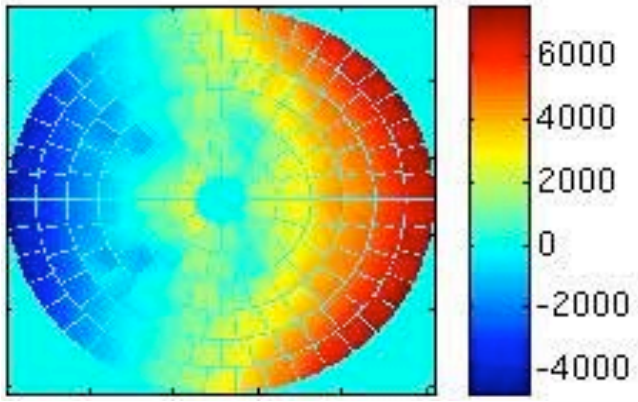
RMS WFE = 143.5 um

CCAT Controlled WF Error with Global Modes Removed



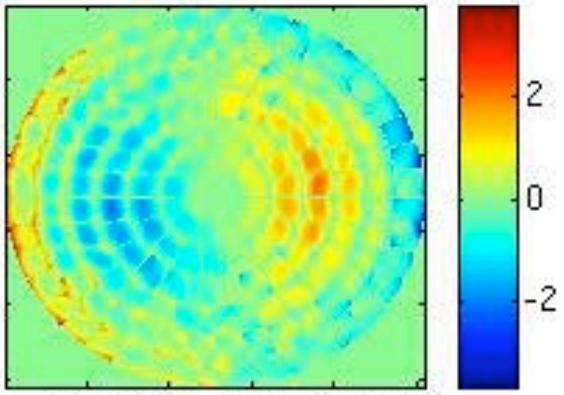
RMS WFE = 0.28 um

CCAT WF Error with *1g* load



RMS WFE = 2904 um

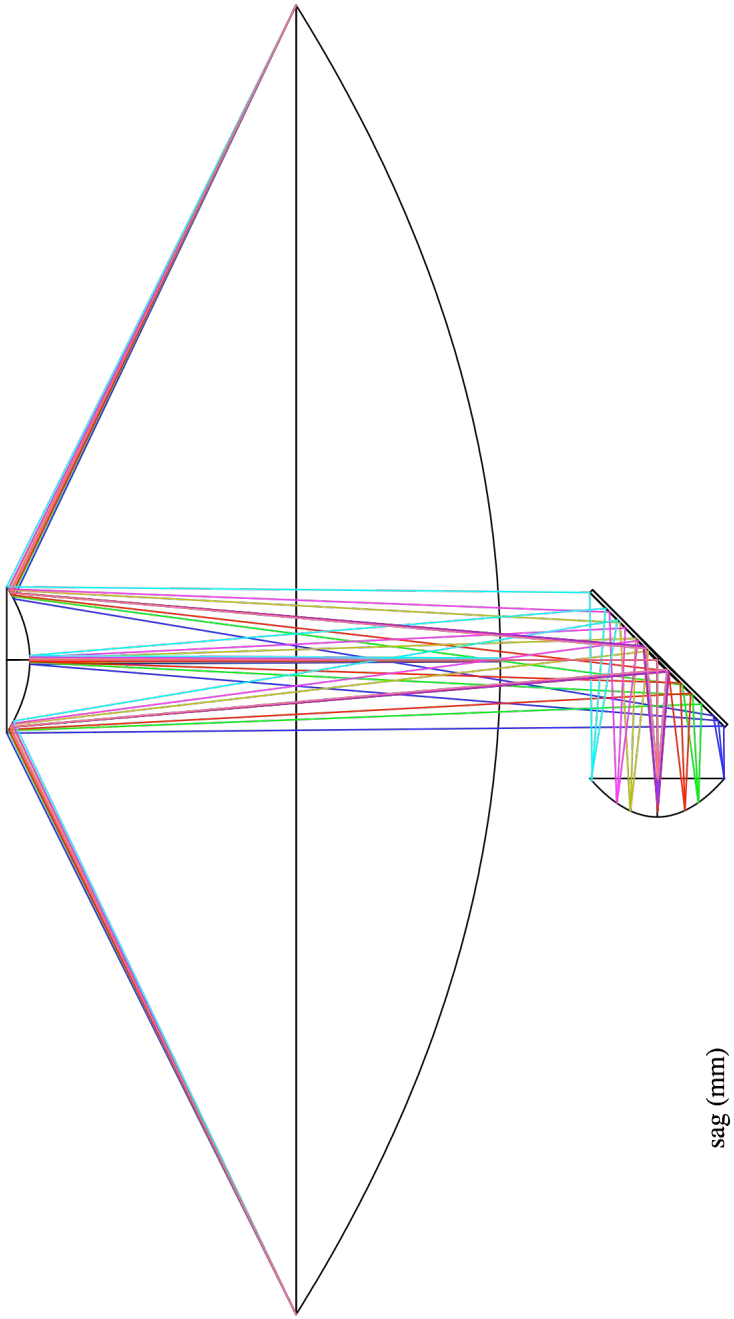
CCAT Controlled WF Error with Global Modes Removed



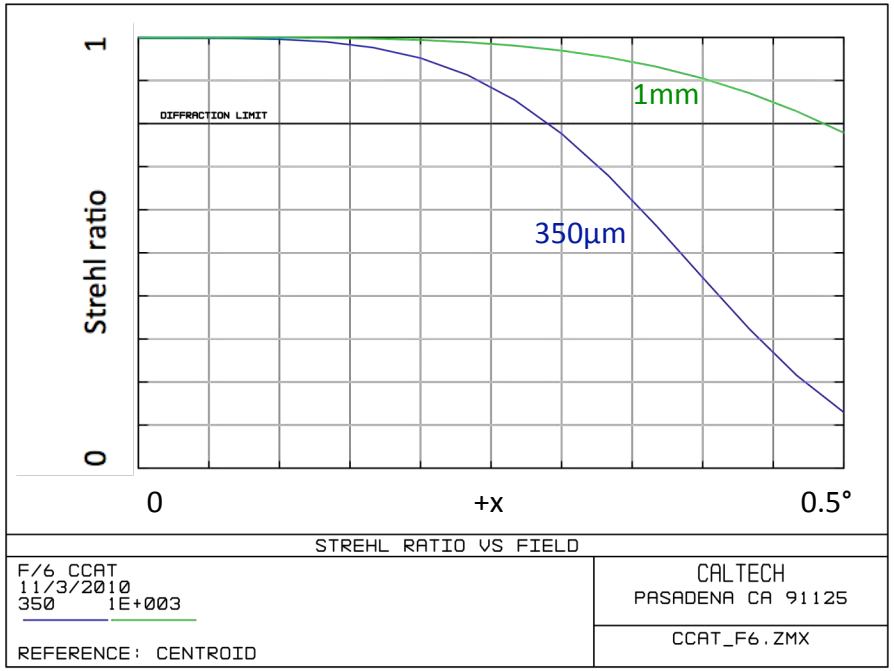
RMS WFE = 0.77 um

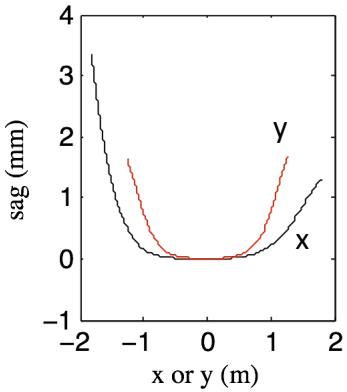
no sensor noise

CCAT optics



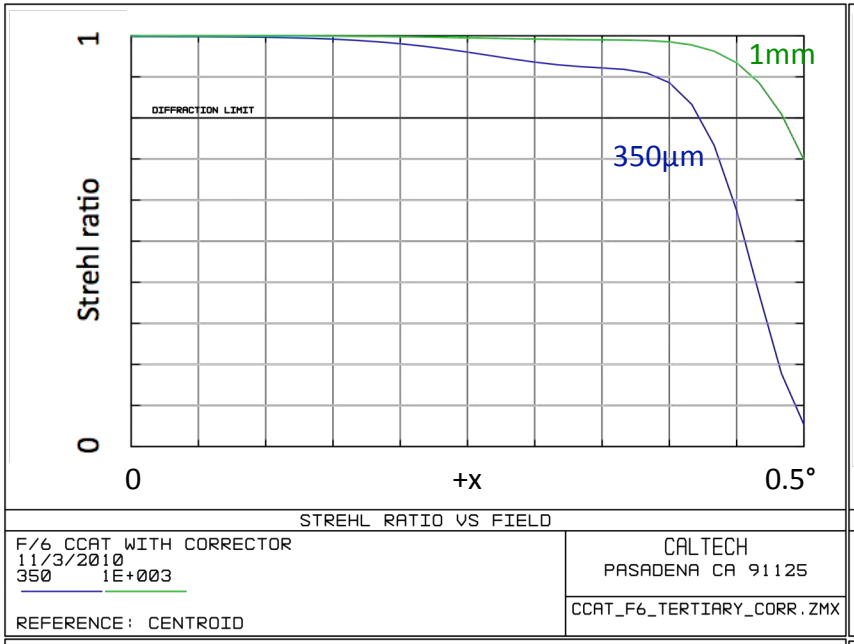
Strehl ratio vs. field angle for basic RC telescope

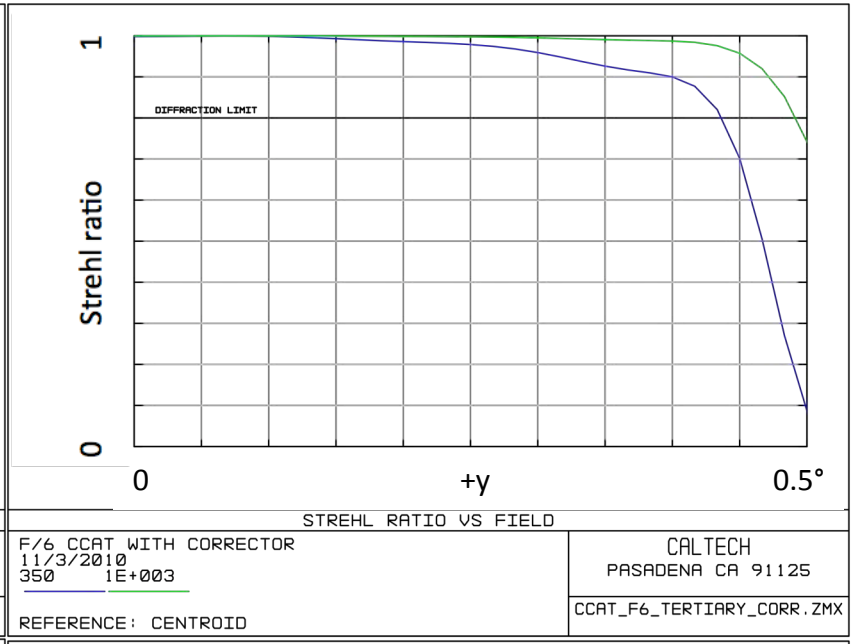


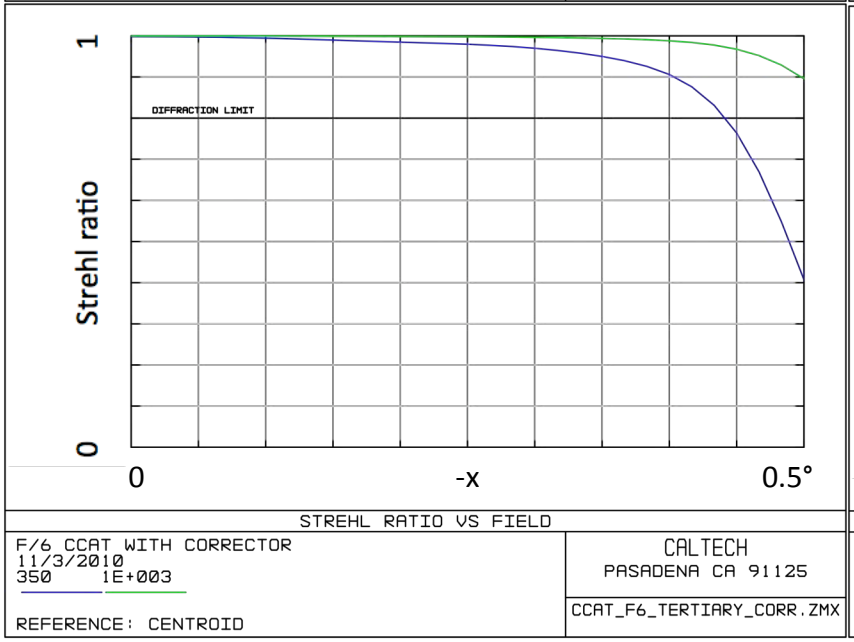


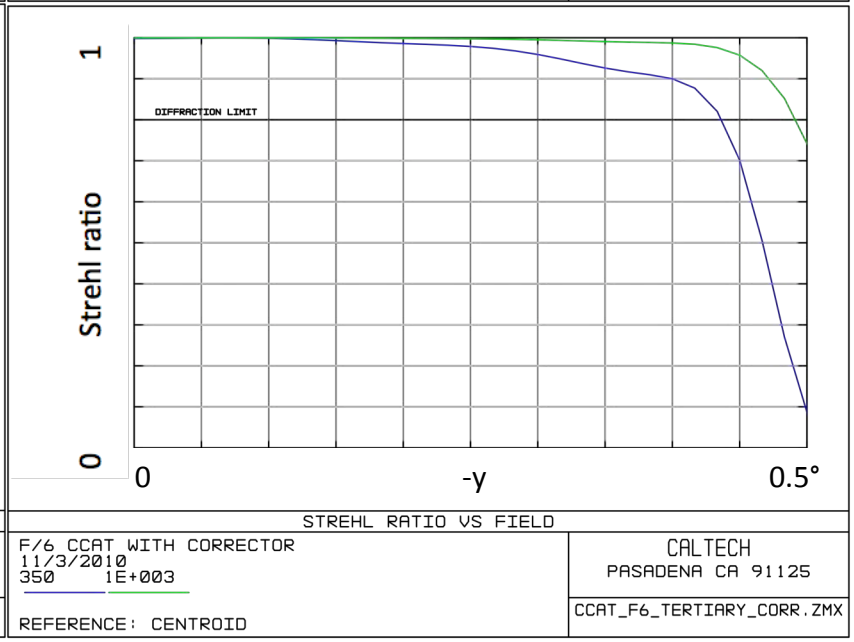
Tertiary profile
to maximize FoV

Strehl ratio vs. field angle with tertiary corrector

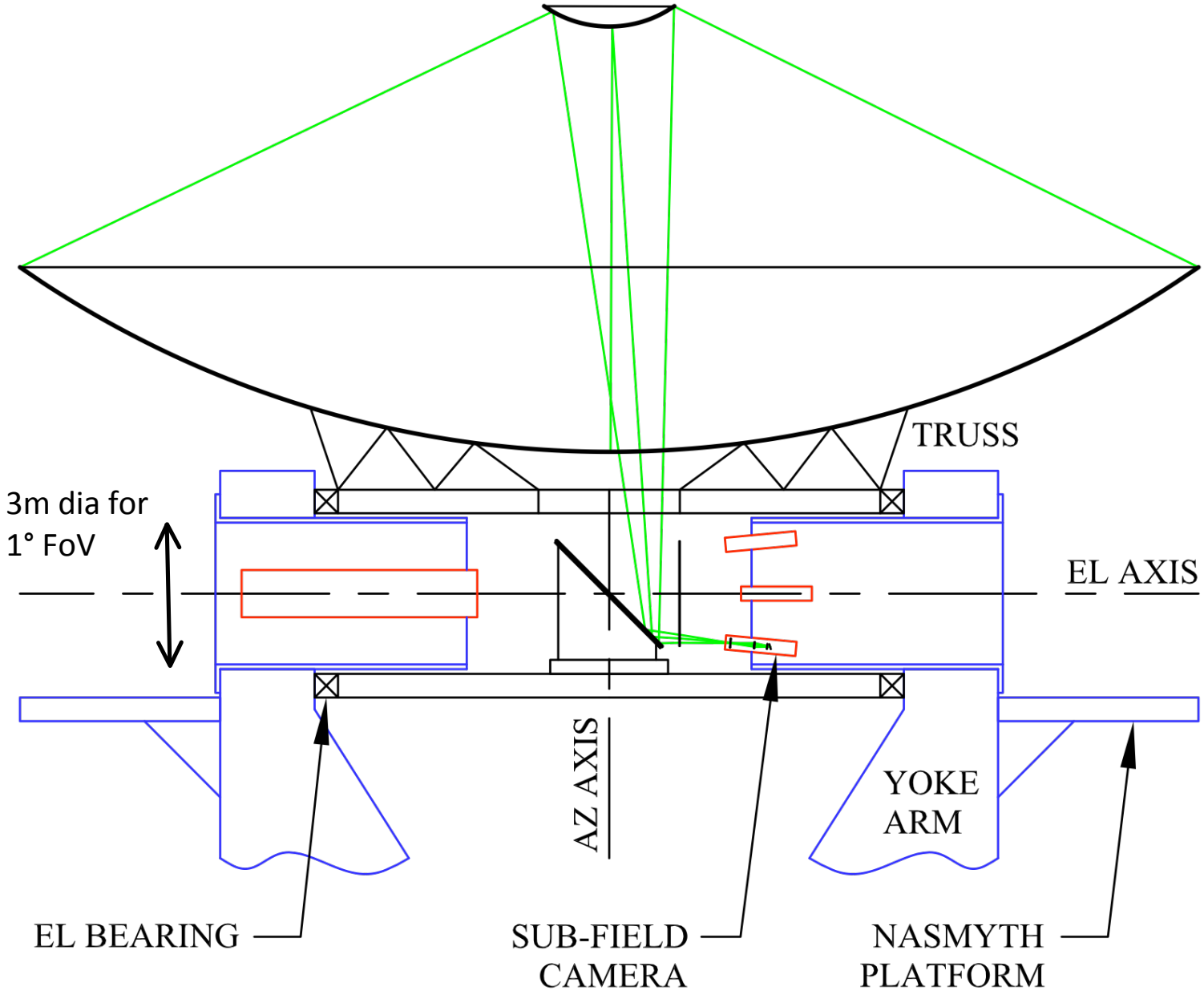




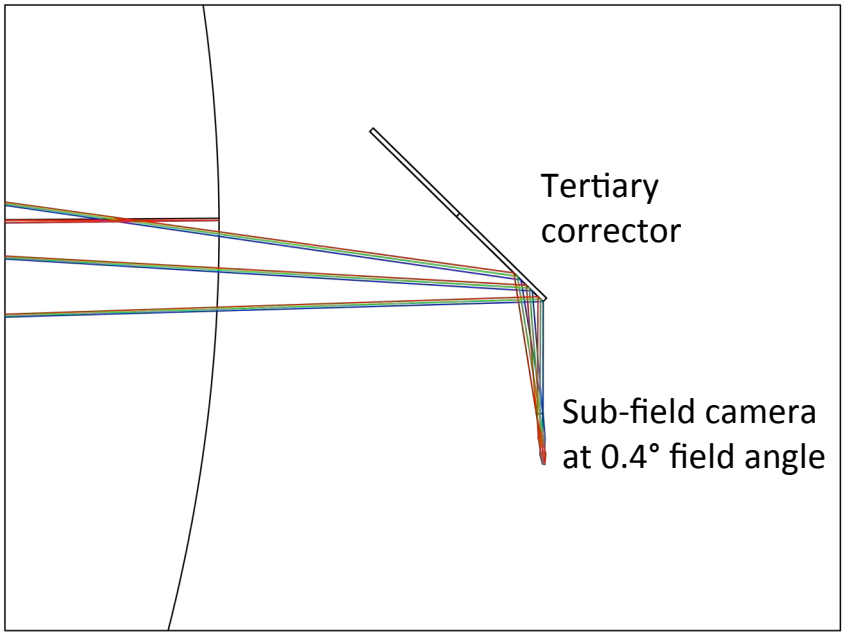


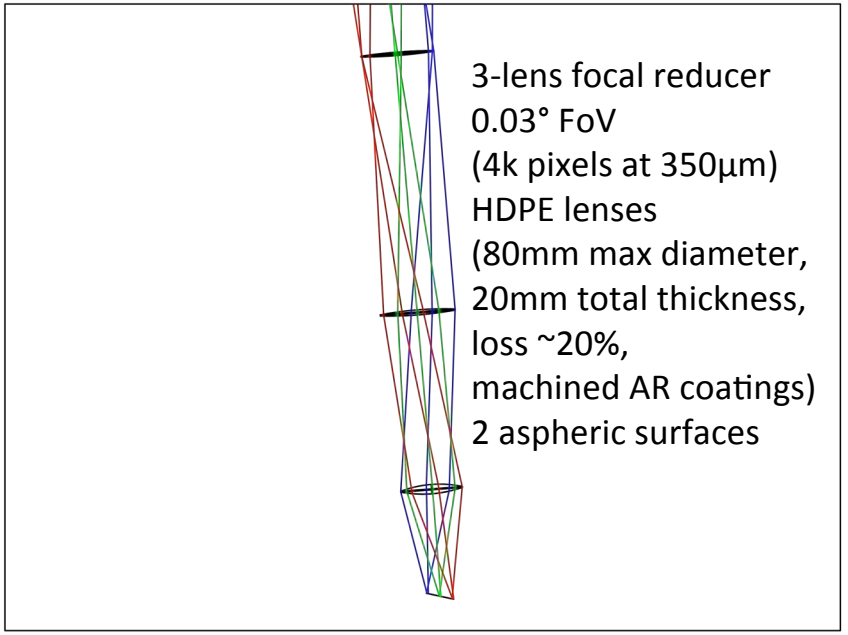


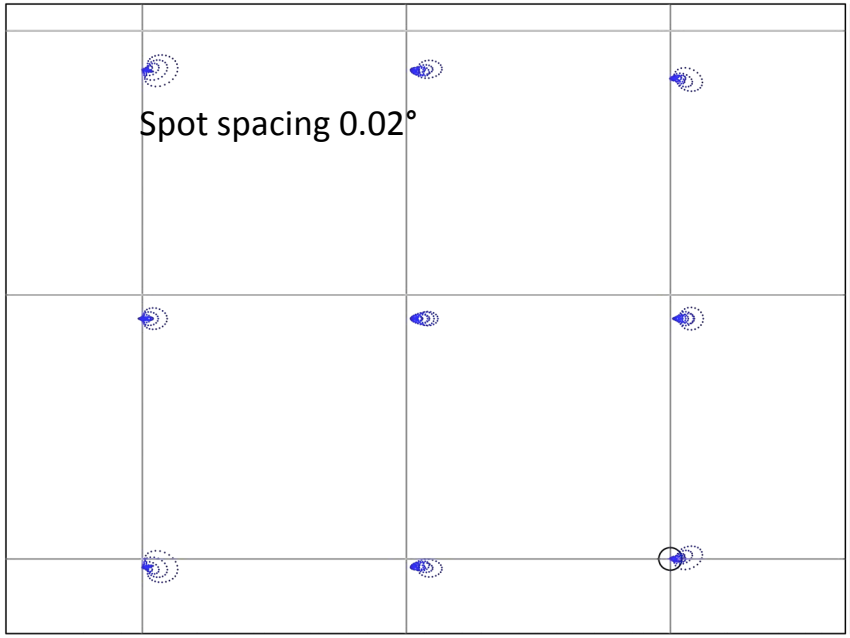
Instrument interface

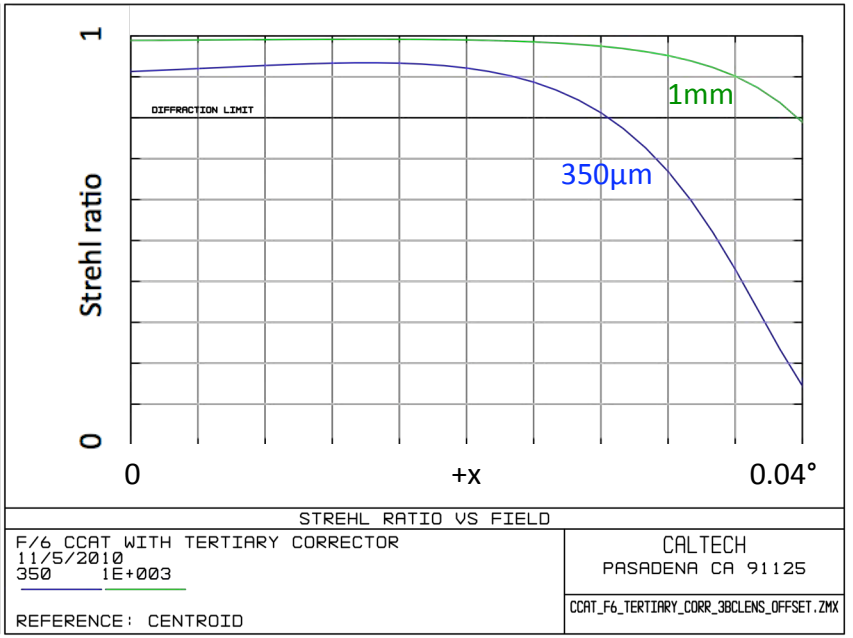


Camera relay with small HDPE lenses





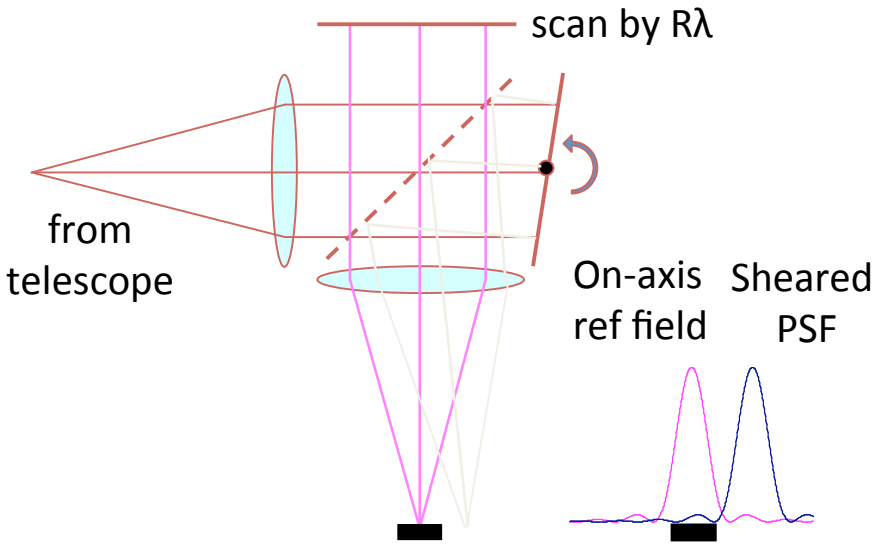




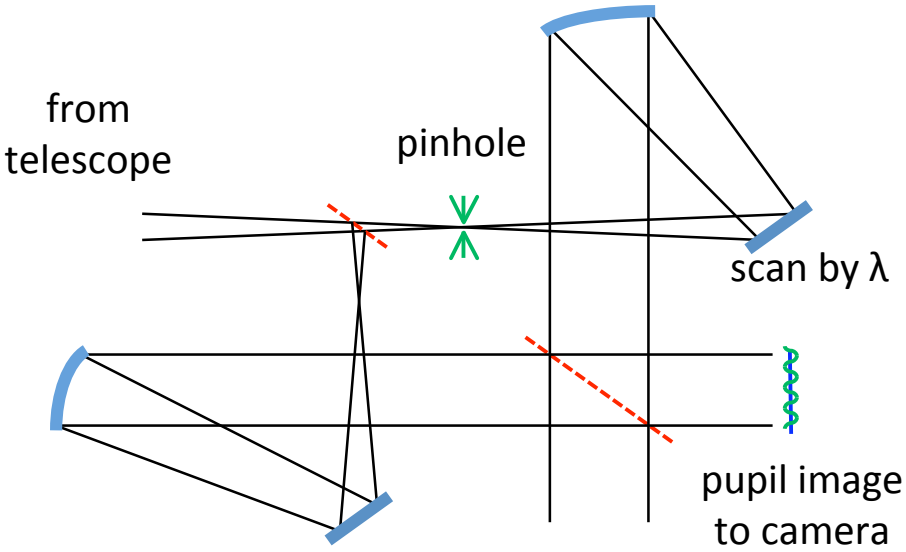
Alignment WFS

G. Serabyn, JPL

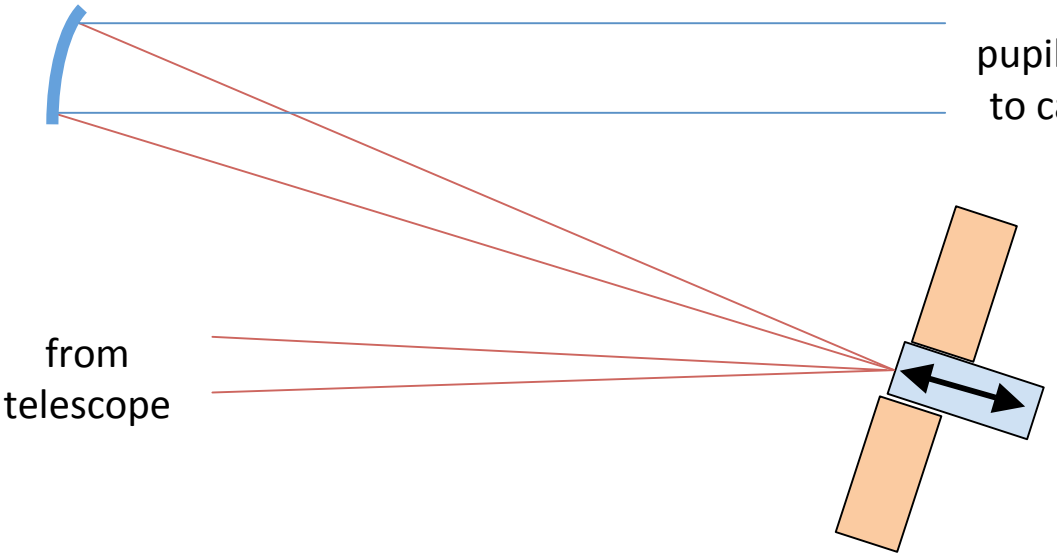
CSO shearing interferometer



Point diffraction interferometer



Phase contrast interferometer



- Small scanning mirror in the center of a large mirror
- Diameter matches PSF core
- Scan by ~ λ
- Common path for ref & signal gives good stability

CCAT performance

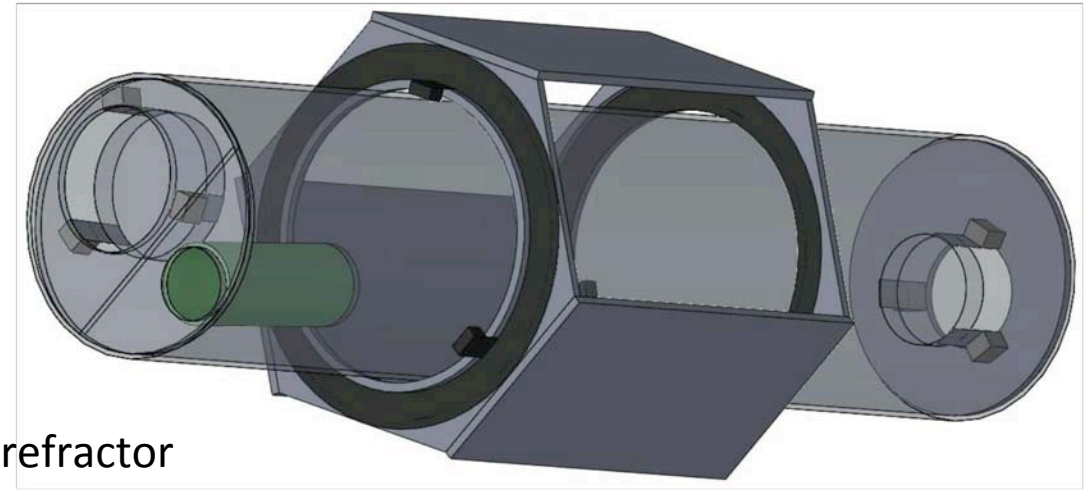
Contribution	HWFE (μm rms)	PE (arcsec rms)	Notes
Aberrations	3.65	0.00	Ritchey-Chretien design
Primary open-loop	7.21	0.03	CFRP truss
Primary closed-loop	7.48	0.52	Steel truss
Secondary	6.28	0.20	
Tertiary	4.45	0.10	
Instrument	0.05	0.04	
Mount	0.00	0.09	No HWFE from mount
Alignment	2.19	0.10	Regular pointing with science camera, occasional wavefront measurements with WFS
Telescope RSS open loop	11.37	0.26	
Telescope RSS closed-loop	11.55	0.58	
Telescope requirement	10.00	0.35	<50% increase in integration time, PE<1/10th beam, from CCAT-TM-48
Atmosphere	5.74	0.23	1st quartile

Observatory parameters

Parameter	Value	Units	Notes
Wavelength	350	μm	
Mean outside wind speed	6	m/s	3rd quartile
Wind speed for pressure	8.484	m/s	$2^{1/2}v_{outside}$, see CCAT-TM-56
Density of air	0.7	kg m^{-3}	At 5600 m altitude
Scan acceleration	0.4	deg s^{-2}	0.4 deg s^{-2} if λ<620μm, else 2 deg s^{-2}, from CCAT-TM-48
rms temp gradient in dome	1	K	From TMT CFD
Soak temp change	20	K	Diurnal & longer
Flux density of pointing source	0.1	Jy	For >1 source/deg^2, S<0.3Jy at λ=350μm and S<40mJy at λ=850μm, see Fig. 4.9 in feasibility study
Pointing integration time	120	s	< a few min for reasonable observing efficiency
Field angle	0.08	deg	

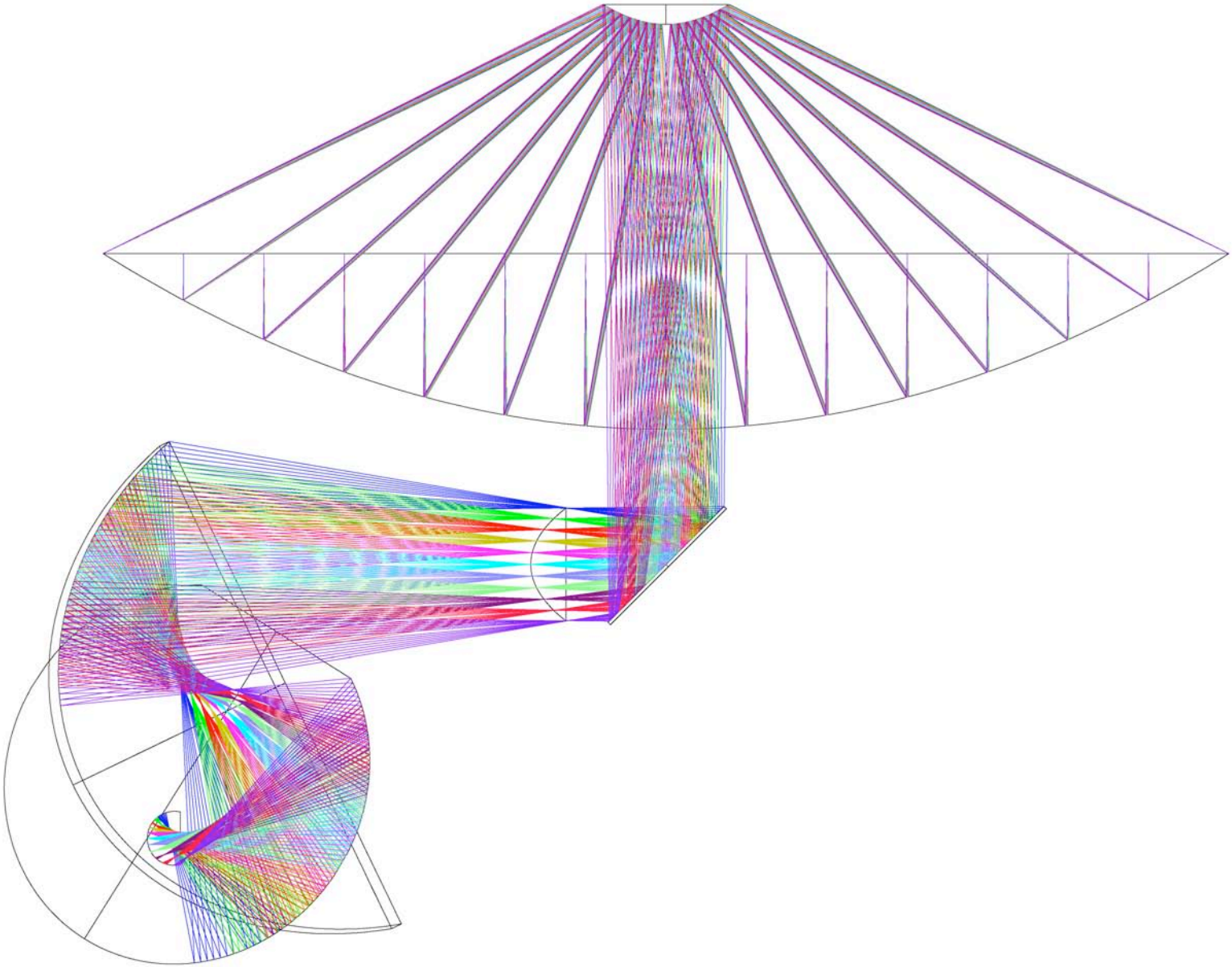
Pointing telescope concepts

100mm f/15 refractor
CFRP tube

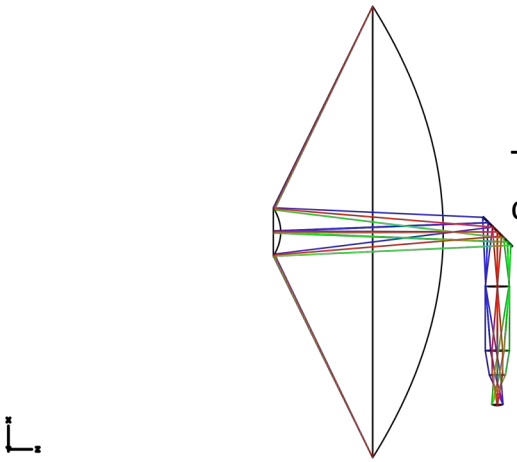


Folded refractor

Reflective relay for 1° FoV



0.5° FoV camera optics



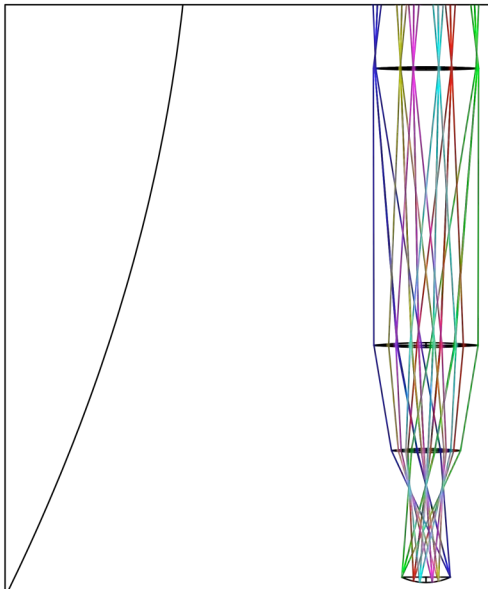
Tertiary corrector

3D LAYOUT

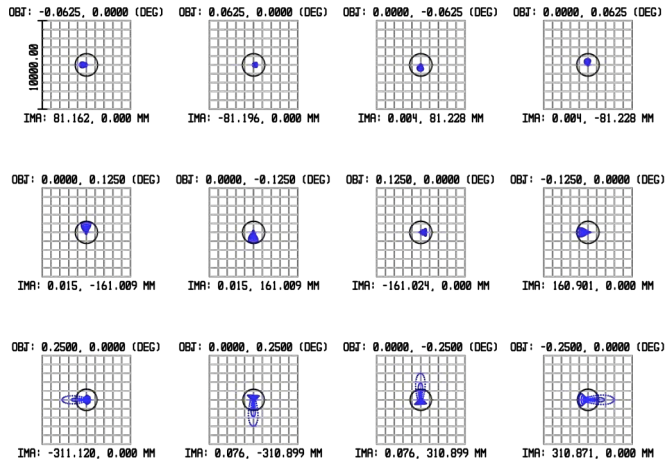
F/6 CCAT WITH TERTIARY CORRECTOR
11/3/2010

CALTECH
PASADENA CA 91125

CCAT_F6_TERTIARY_CORR_3BCLENS3.ZMX



3-lens focal reducer
Quartz lenses ~1m dia
2 aspheric surfaces



SPOT DIAGRAM

F/6 CCAT WITH CORRECTOR
11/3/2010 UNITS ARE μm. AIRY RADIUS: 1272 μm

FIELD :	1	2	3	4	5	6	7	8	9	10	11	12
RMS RADIUS :	276.679	217.922	265.392	265.392	415.535	415.535	383.388	438.988	599.318	662.818	662.818	691.139
GEO RADIUS :	792.828	438.571	691.988	691.988	1176.71	1176.71	691.799	1297.77	2768.69	2995.38	2995.38	2988.75

SCALE BAR : 1E+004 REFERENCE : CHIEF RAY

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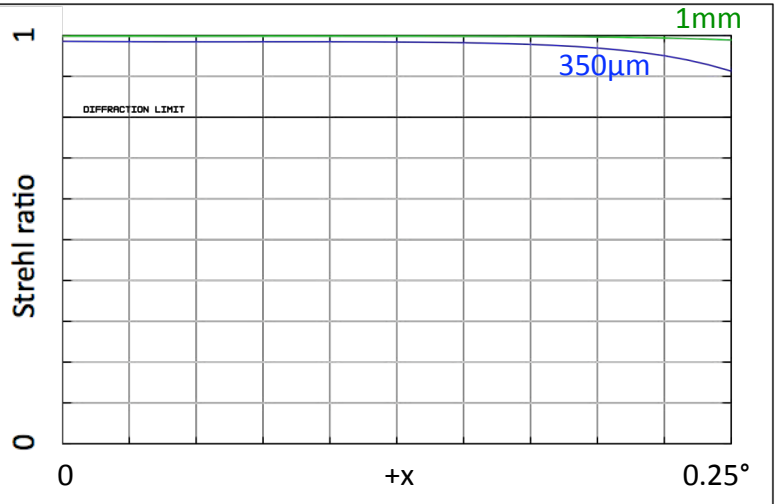

STREHL RATIO VS FIELD

F/6 CCAT WITH TERTIARY CORRECTOR
11/3/2010
350 1E+003

REFERENCE: CENTROID

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