CCAT

Telescope Interface

Germán Cortés-Medellín

Outline

- Introduction
- Re-Imaging Optics at the Nasmith Foci
- Re-Imaging Optics: Common Optics
- Instrument Layout
- Conclusions

CCAT Telescope Interface Instruments

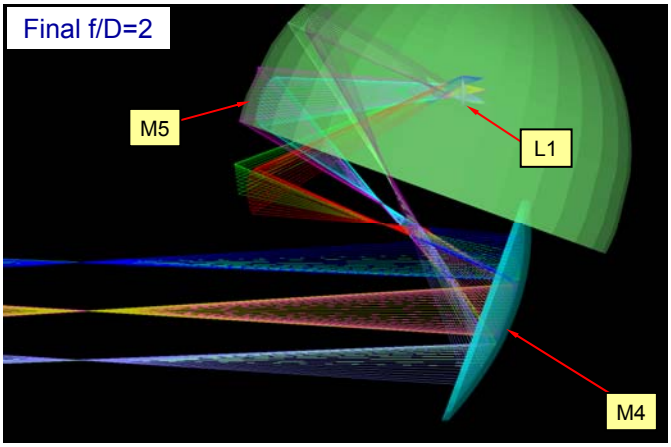
- Location
  - Nasmith Optics
    - Re-imaging Optics: Common Optics ?
  - Bent Cassegrain Optics
- Metrology Interface
- Practical Aspects
  - Power consumption, weight, volume, cryogenics, telemetry/ control
  - Telescope restrictions: max load

Re-Imaging Optics at the Nasmith Foci

LW-Cam Re-imaging Optics

LW-Cam Re-imaging Optics

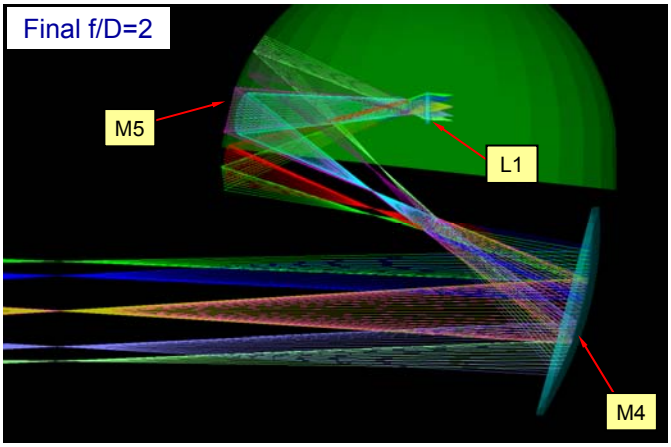
for 20' Diameter FOV, θ_{inc}=20°, f_1/0.6



LWCam f_1/0.6, θ_{inc}=20°, f/2

LW-Cam Re-imaging Optics

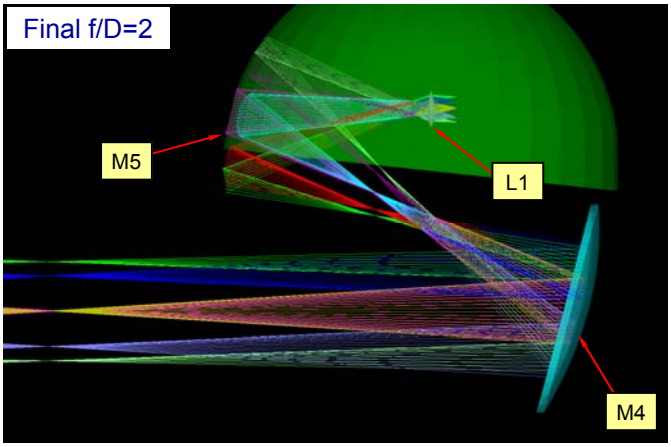
for 20' Diameter FOV, θ_{inc}=15°, f_1/0.6



LWCam f_1/0.6, θ_{inc}=15°, f/2

LW-Cam Re-imaging Optics

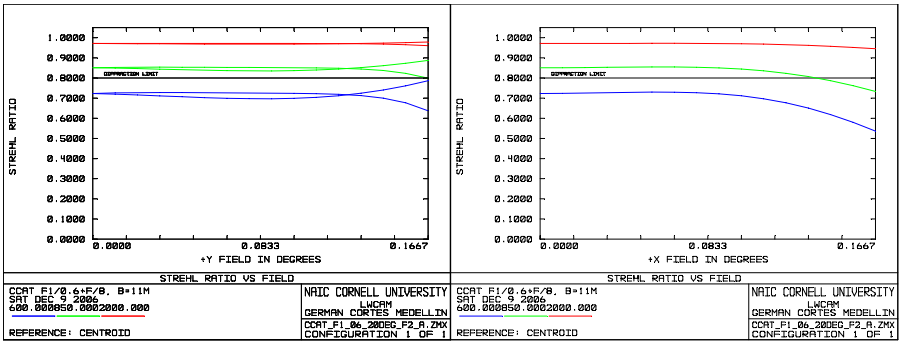
for 20' Diameter FOV , θ_{inc}=15°, f_1/0.4



LWCam f_1/0.4, θ_{inc}=15°, f/2

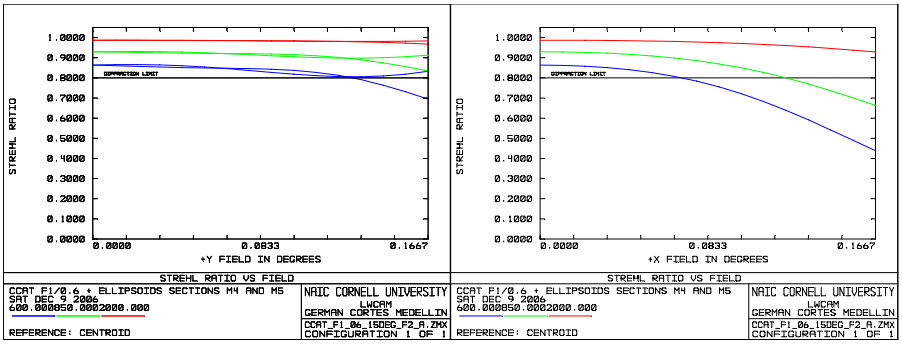
LW-Cam Strehl Ratio over FOV

θ_{inc} = 20°, f_1/0.6



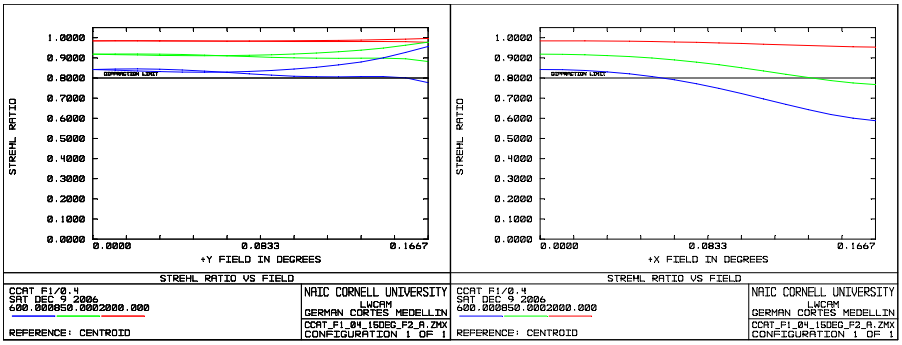
LW-Cam Strehl Ratio over FOV

θ_{inc} = 15°, f_1/0.6



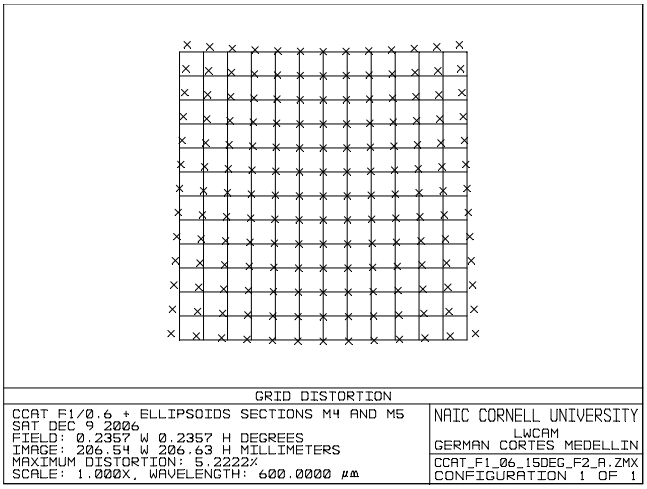
LW-Cam Strehl Ratio over FOV

θ_{inc} = 15°, f_1/0.4



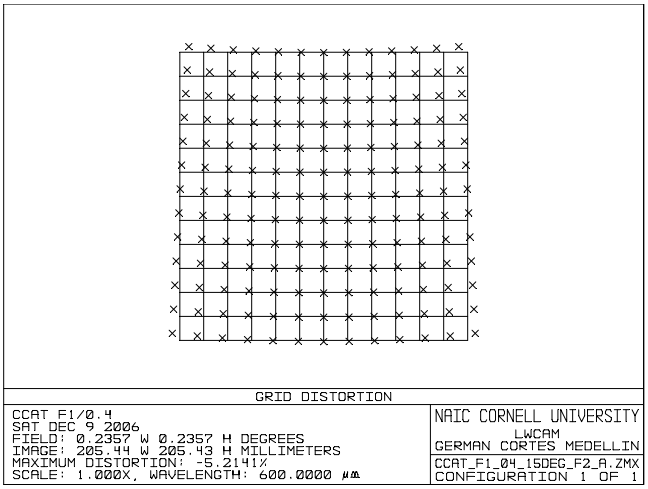
LW-Cam Distortion over FOV

θ_{inc} = 15°, $f_1/0.6$



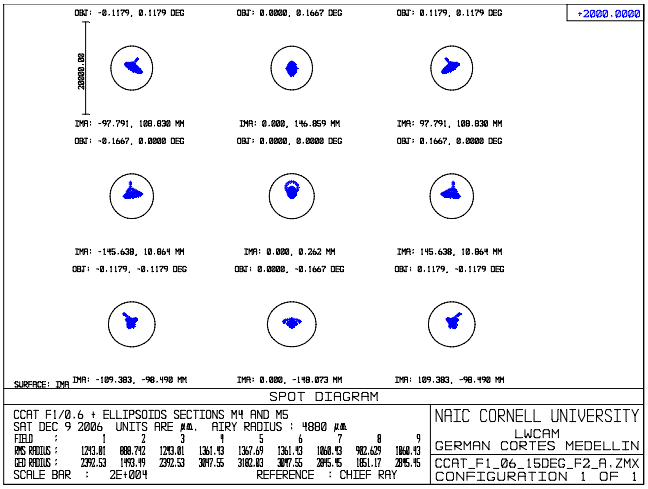
LW-Cam Distortion over FOV

θ_{inc} = 15°, $f_1/0.4$



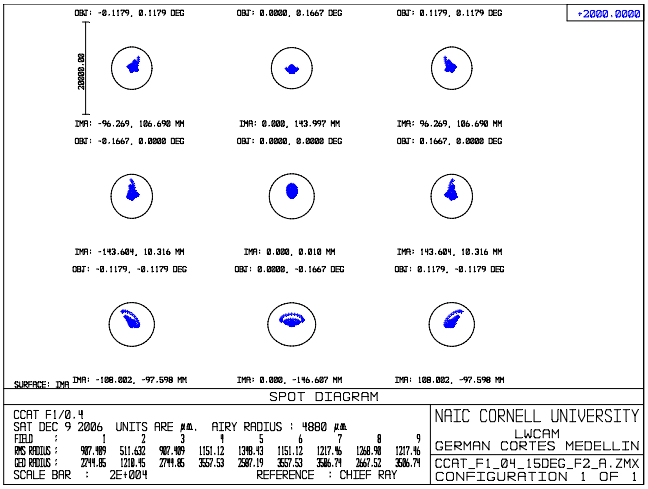
LW-Cam Spot Diagram

θ_{inc} = 15°, f_1/0.6



LW-Cam Spot Diagram

θ_{inc} = 15°, f_1/0.4



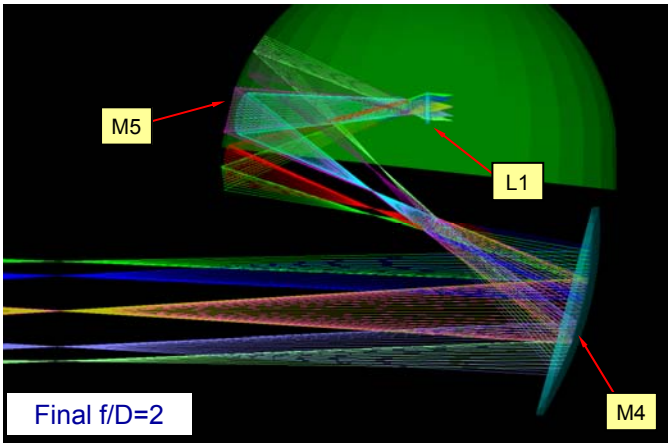
Common Optics
SW-Cam and LW-Cam

Common Optics
SW-Cam and LW-Cam

- Only LW-Cam M4 same, or
- Both LW-Cam Re-imaging M4 and M5
- +Different Lens System
- Optimized for SW-Cam f/4.8 for 20'∅ FOV

LW-Cam Optics

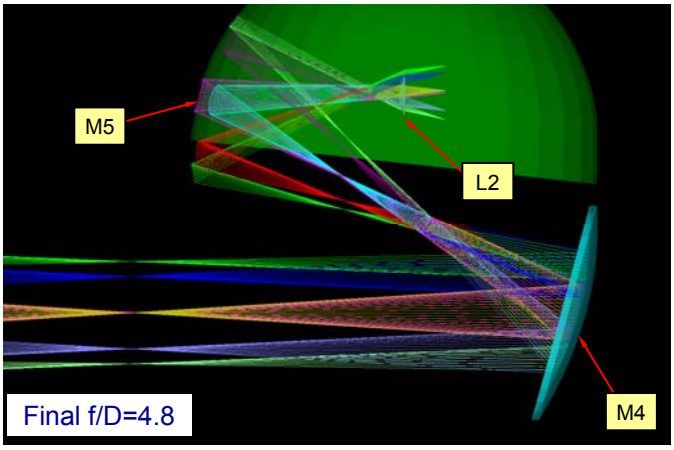
for 20' Diameter FOV, θ_{inc}=15°, f_1/0.6



LWCam f_1/0.6, θ_{inc}=15°, f/2

SW-Cam Optics

for 20' Diameter FOV, θ_{inc}=15°, f_1/0.6



LWCam f_1/0.6, θ_{inc}=15°, f/4.8

Common Optics
SW-Cam and LW-Cam

- Only LW-Cam M4 same, or
- Both LW-Cam Re-imaging M4 and M5
- +Different Lens System
- Optimized for SW-Cam f/4.8 for 20'∅ FOV
- Initial Results: Promising
- Possible improvements:
  - More degrees of freedom reflectors
  - Additional lens
  - Further reduction of θ_{inc} to 12° or 11°
  - Reduced FOV

Work in Progress…

Nasmith
Instrument Layout

(First Round)

Considerations and Limitations

- Required FOV, wavelength and f/D
- Size
- Weight
- Associated Moment of Inertia
- Power
- Cryogenics
- Accessibility
- Telemetry/Control
- Others

CCAT Instrumentation

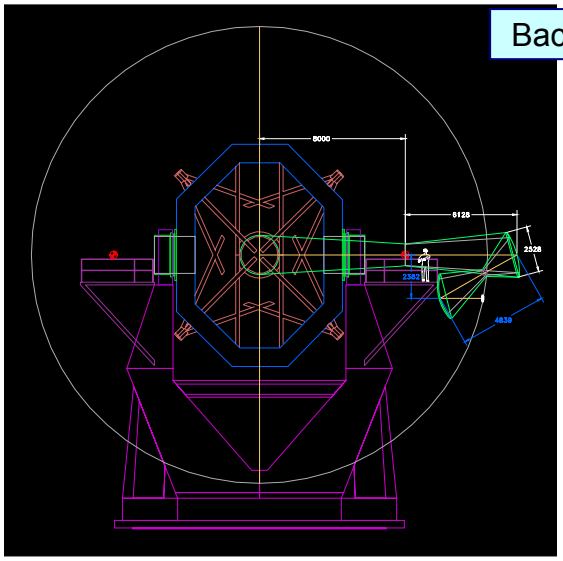
Instrument	Wavelength μm	FOV arc-min	Final f/D
SW Cam	650 – 200	5' x 5'	4.8
SCUBA-2	850 – 450	3'(5') x 3'(5')	2.4?
LW Cam	2000 – 740	20' x 20'	2
Heterodyne Camera	450 – 350	1' x 1'	8
Spectrometer(Singl/Mult-Object)	450 – 350	2' x 2'	:
ZEUS (echelle spectrometer)	450 - 200	:	2.5
Z-Spec (wguide spectrometer)	1600 - 1000	:	:
Polarimeters	1000 - 200	5' x 5'	:
ALMA Instrumentation	:	:	8

CCAT Instrumentation

Instrument	Weight Tons	Vol m^3	Pow kW	Cryogens Operation Liters/day	Cryogens Pre-cool Liters
SW Cam	:	0.5	:	:	:
SCUBA-2	3.5	5.0	45	~5	600
LW Cam	1.0	:	:	:	:
Heterodyne Camera	0.9	1	20	:	:
Spectrometer(Singl/Mult-Object)	2	4.5	5-22	:	:
ZEUS (echelle spectrometer)	:	:	:	:	:
Z-Spec (wguide spectrometer)	:	:	:	:	:
Polarimeters	:	:	:	:	:
ALMA Instrumentation	:	:	:	:	:

LW-Cam Location

LW-Cam Location I



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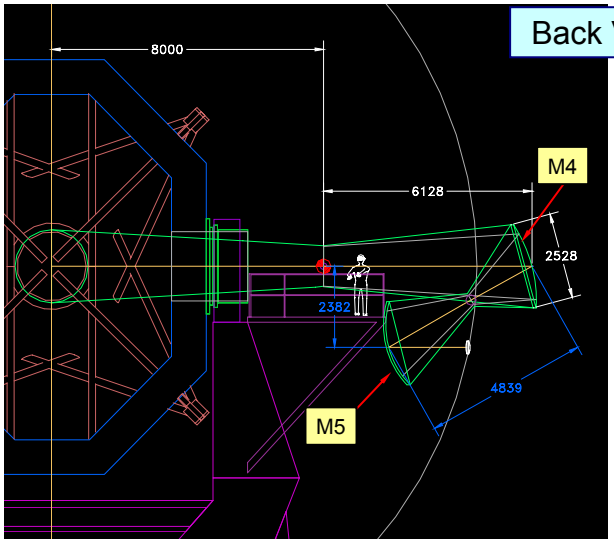
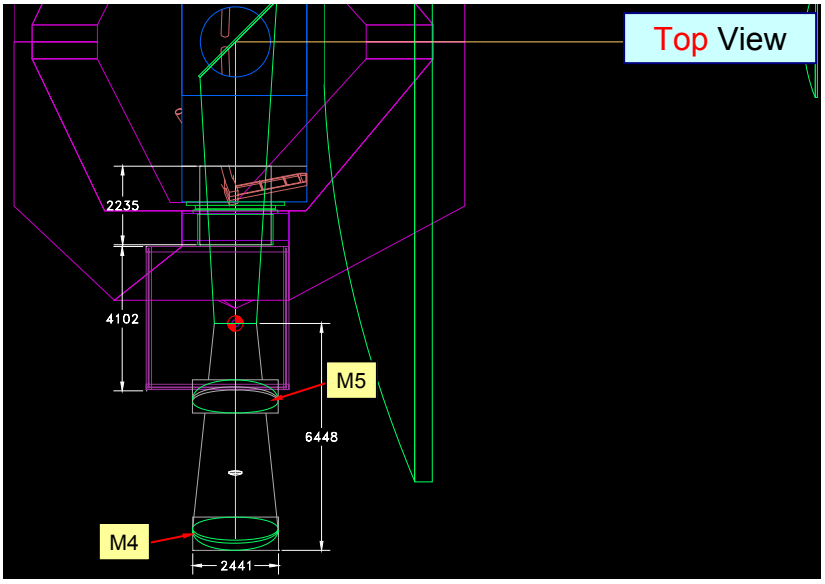
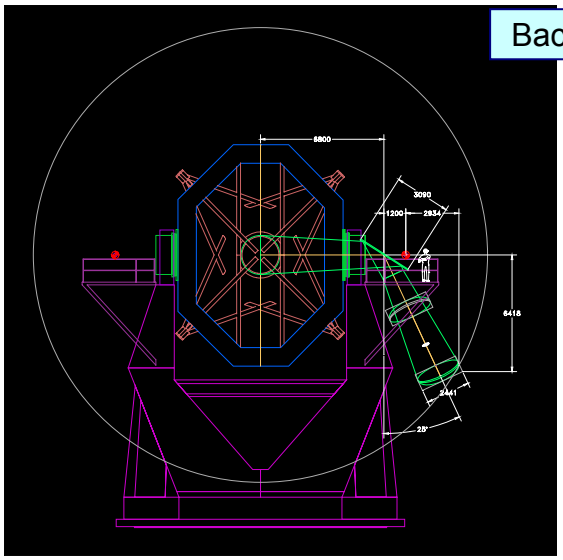
LW-Cam Location I



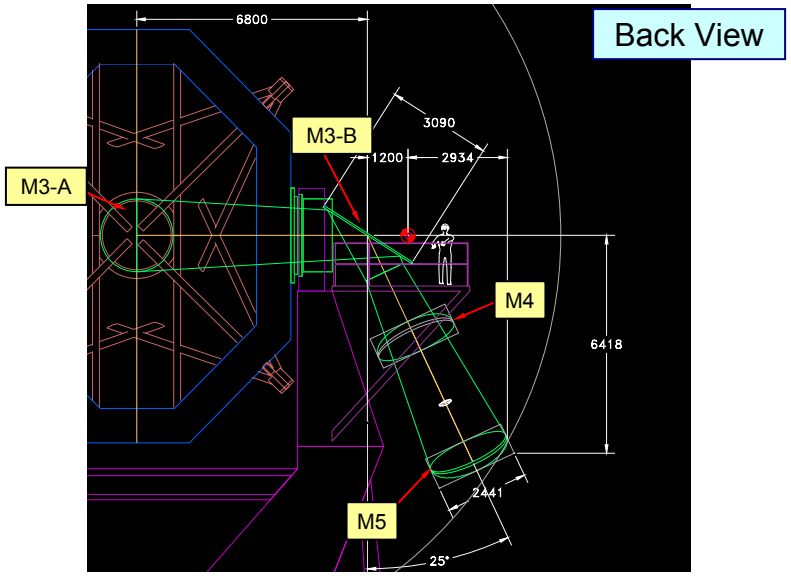
LW-Cam Location I



LW-Cam Location II



LW-Cam Location II



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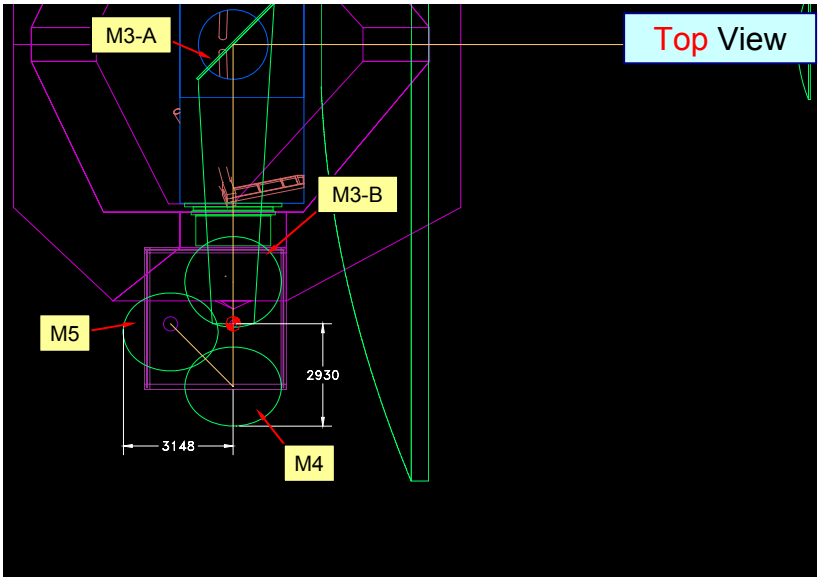

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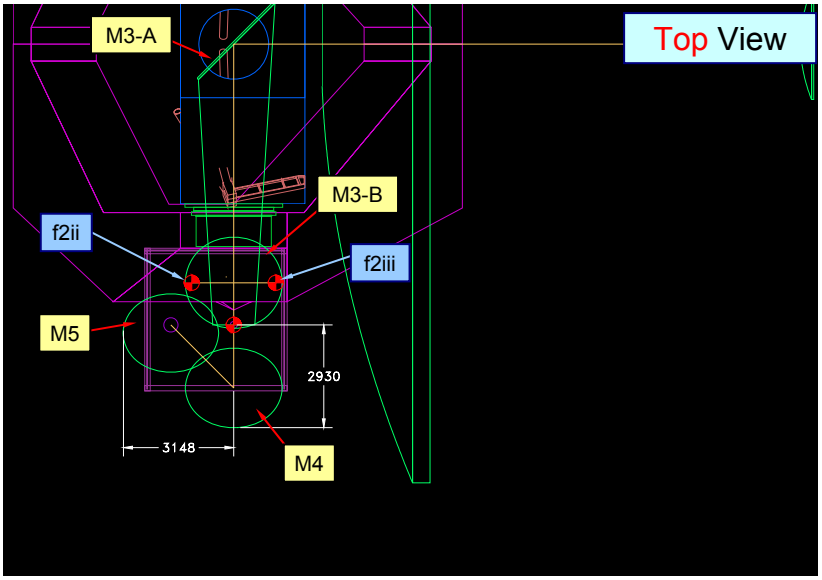
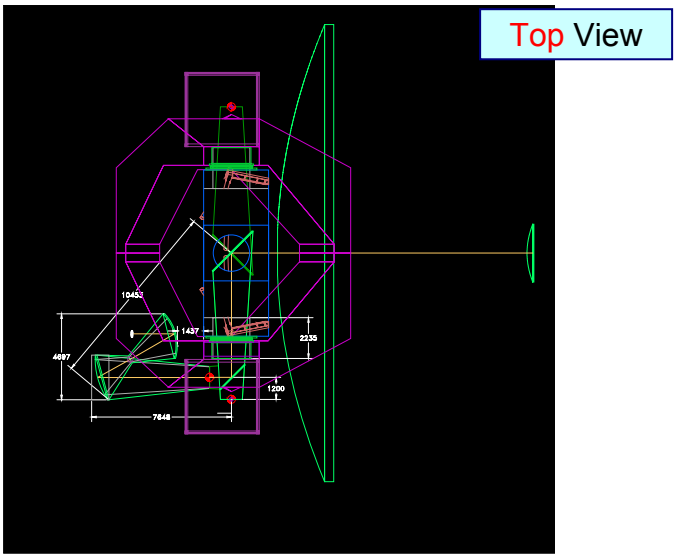


LW-Cam Location III



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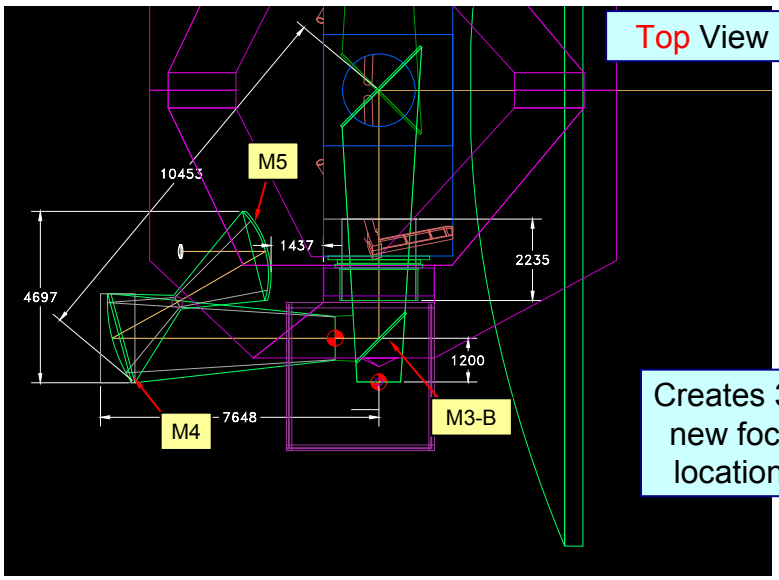

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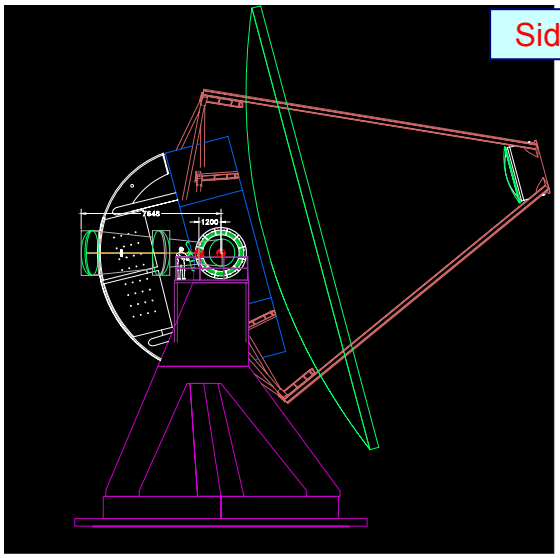
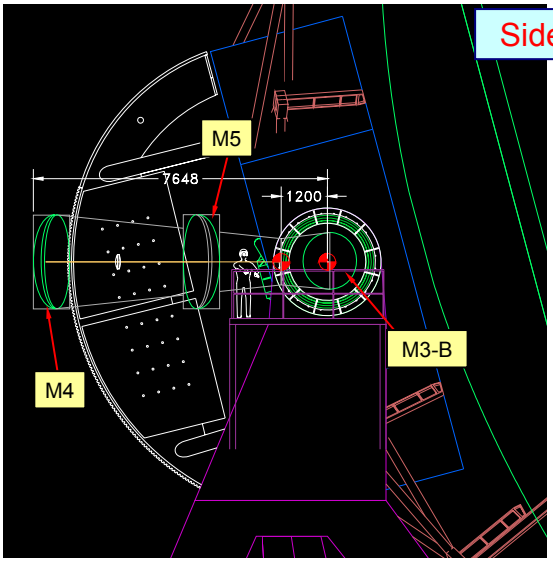
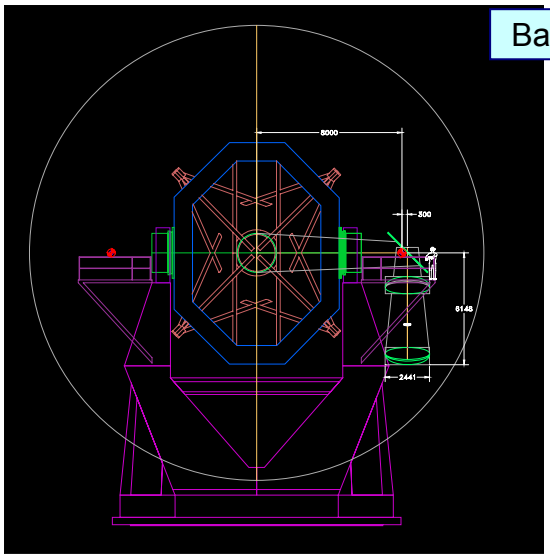
LW-Cam Location III



LW-Cam Location III



LW-Cam Location IV



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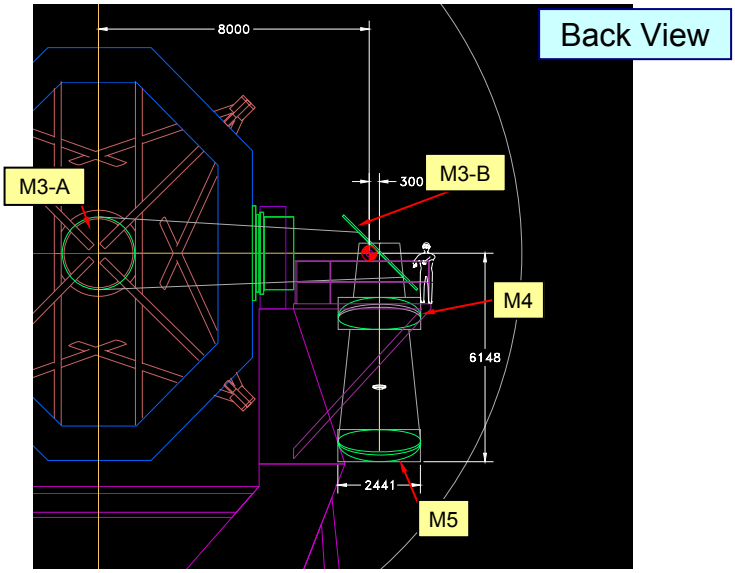
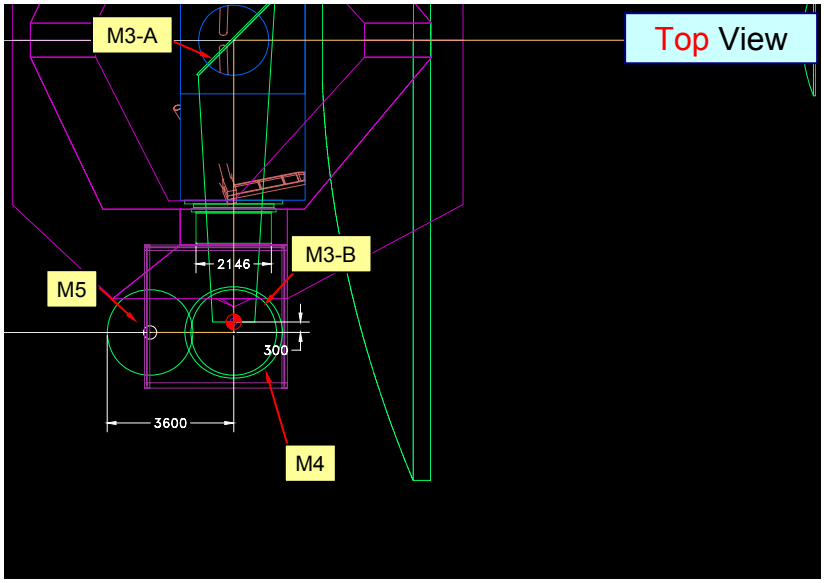
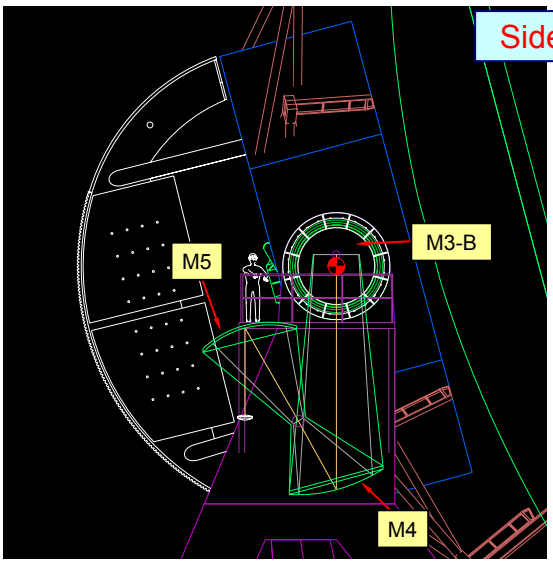


LW-Cam Location IV



LW-Cam Location IV



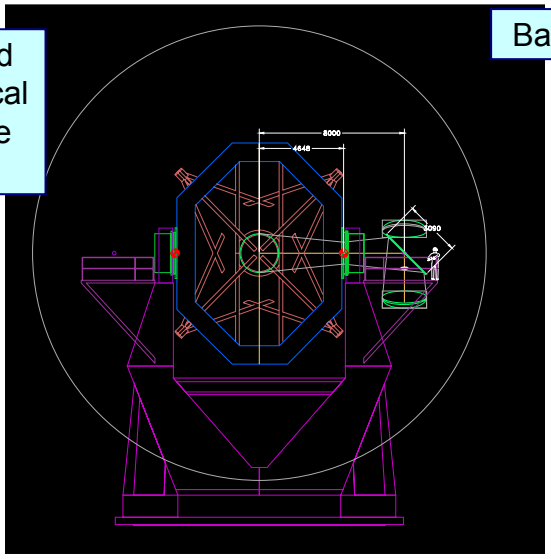
LW-Cam Other Possibility V

Reduced Back Focal Distance B 11m→8m, and f/D f/8→f/6.5

LW-Cam Other Possibility V

Reduced Back Focal Distance and f/D

Back View



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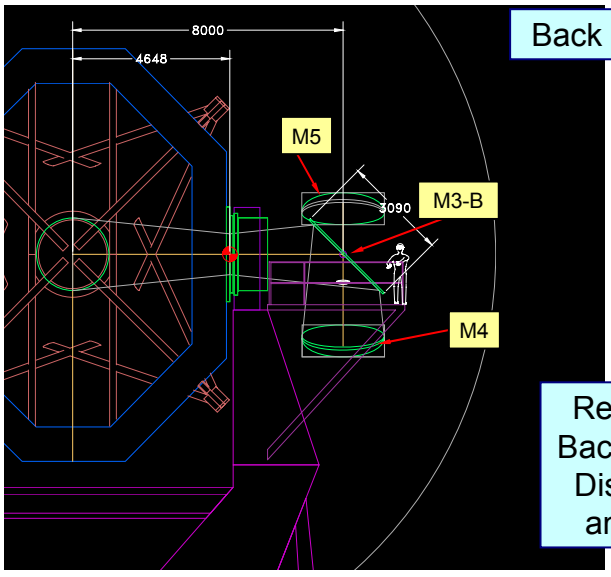
LW-Cam Other Possibility V

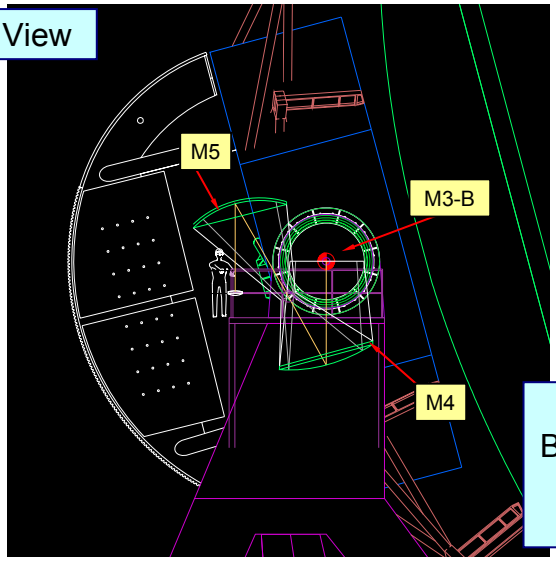
Back View



Reduced Back Focal Distance and f/D

LW-Cam Other Possibility V

Side View



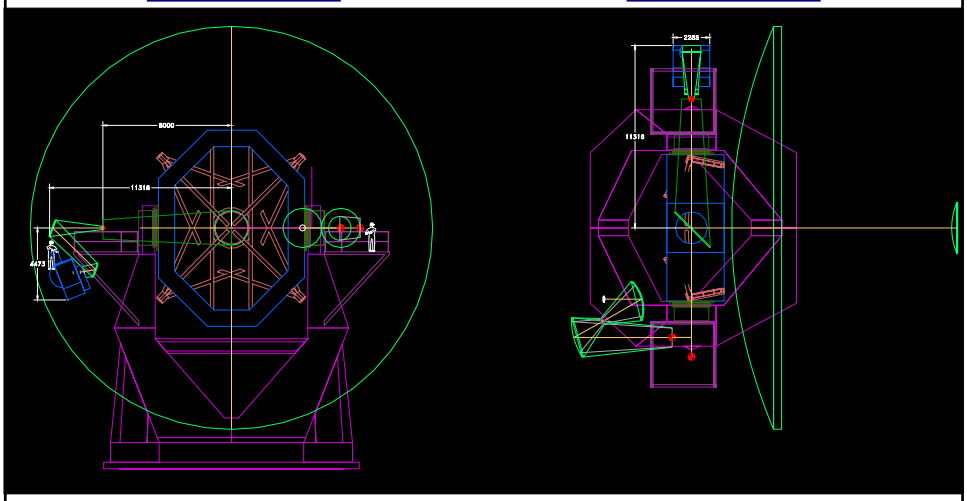
Reduced Back Focal Distance and f/D

SCUBA-2 Location

SCUBA-2 Location I

Back View

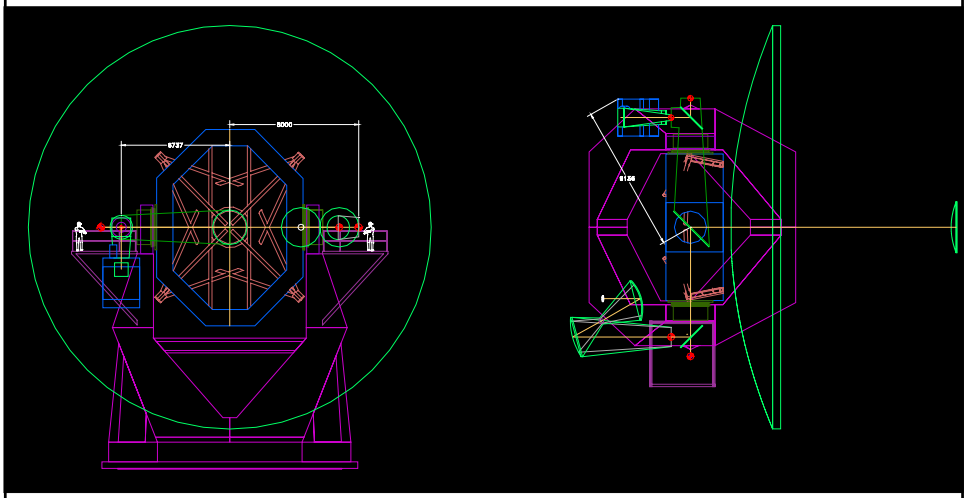
Top View



SCUBA-2 Location II

Back View

Top View



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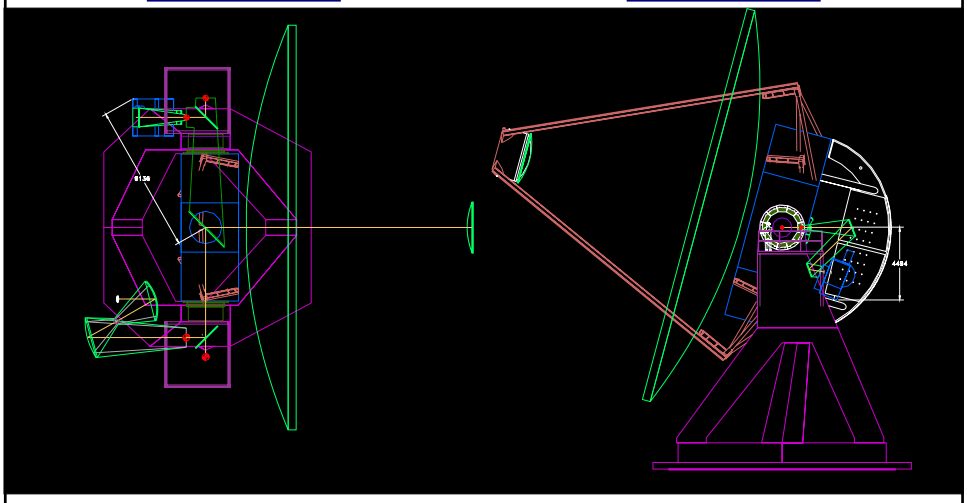
SCUBA-2 Location II

Top View | Side View



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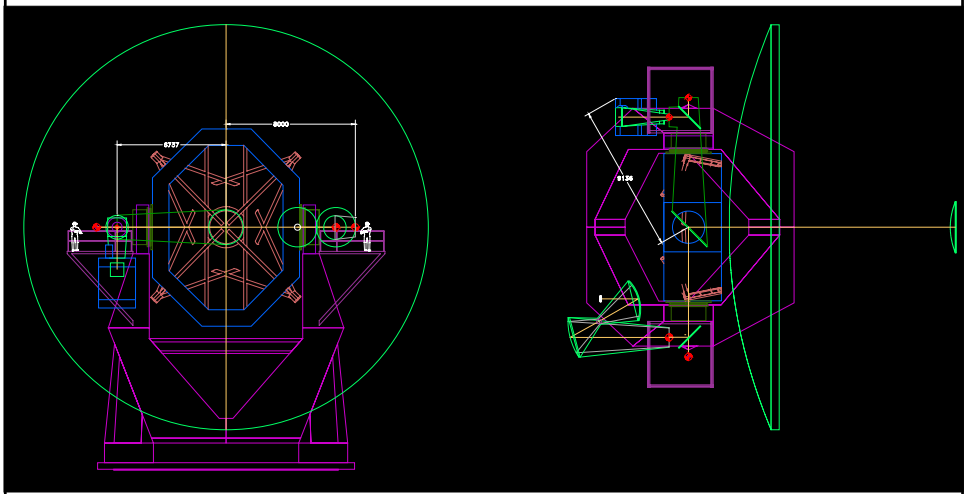
SW-Cam + SCUBA-2 Location I

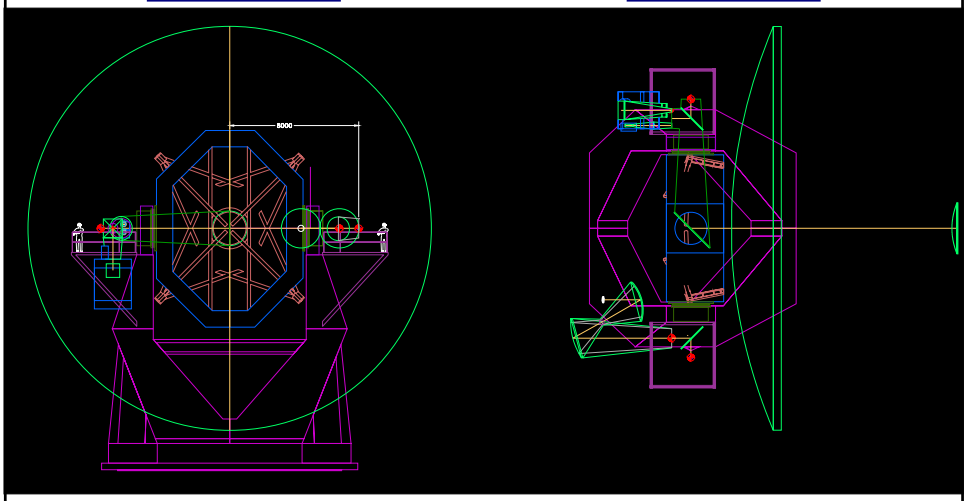
Back View | Top View



SW-Cam + SCUBA-2 Location I

Back View

Top View



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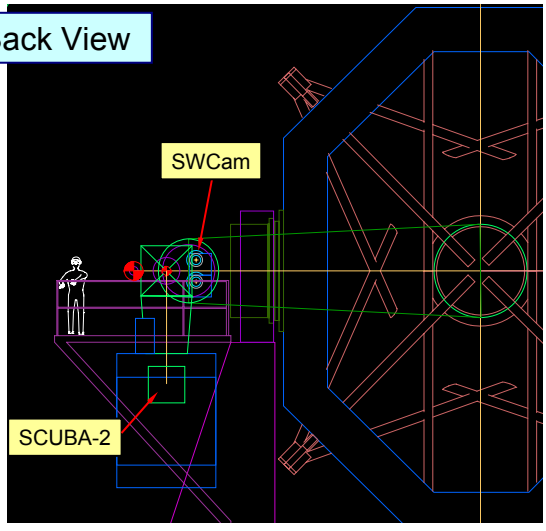
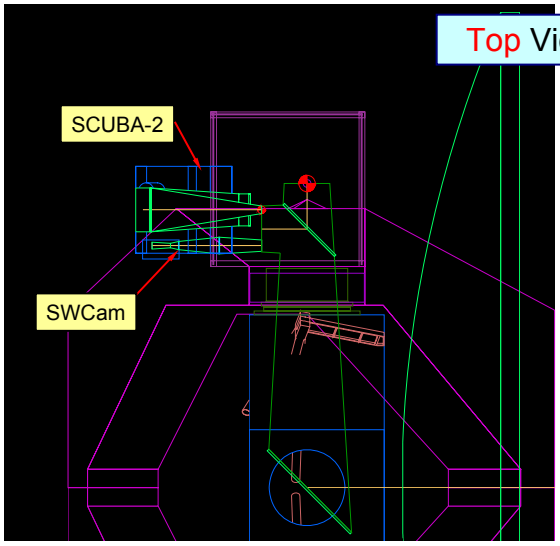
SW-Cam + SCUBA-2 Location I

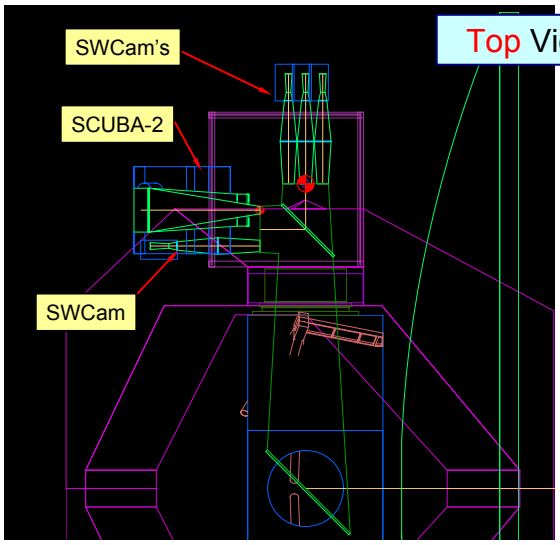
Back View



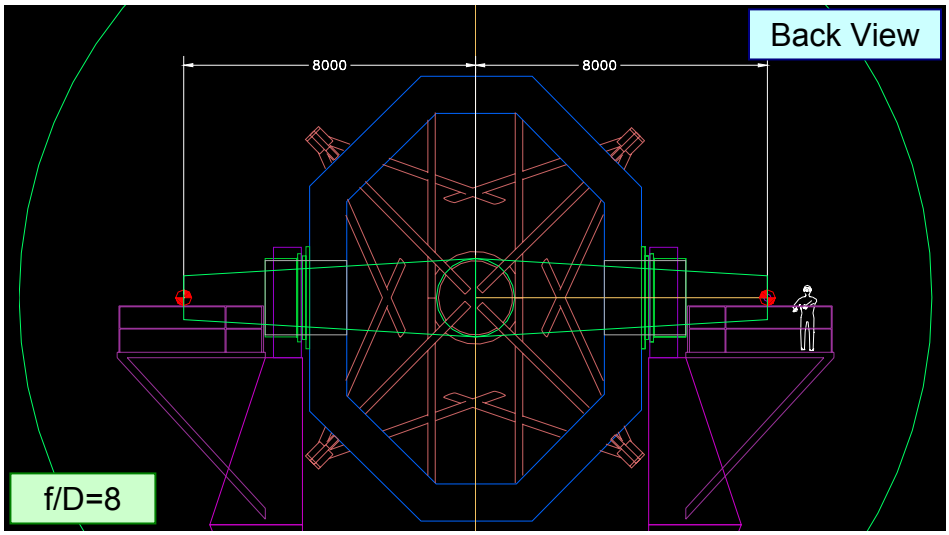
SW-Cam + SCUBA-2 Location I



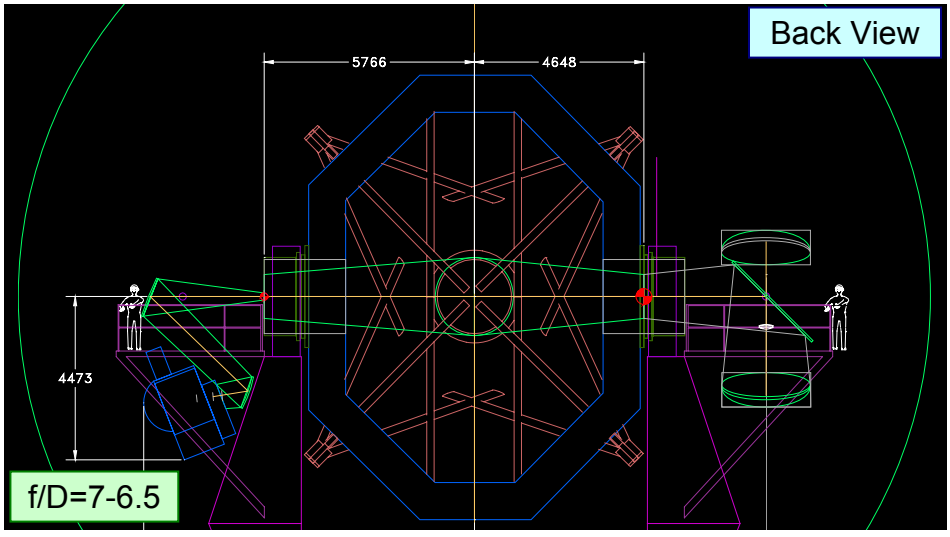
SW-Cam + SCUBA-2 Location II



LW-Cam + SCUBA-2 Location
with Reduced Back Focal Distance and f/D



LW-Cam + SCUBA-2 Location
with Reduced Back Focal Distance and f/D



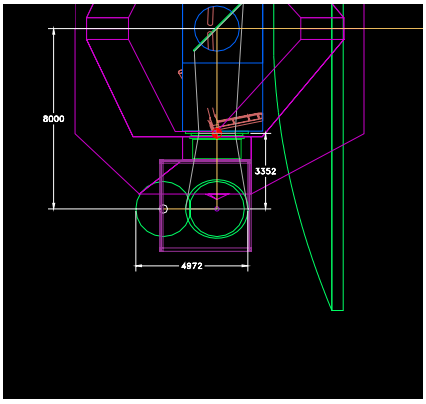
Reduced Back Focal Distance and f/D
Advantages

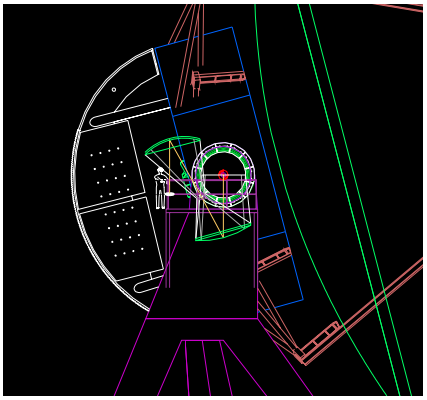
- Better optical match for low f/D instruments
- Bent-Cassegrain becomes more compact
- Reduced curvature of Re-imaging reflectors will improve image performance (Strehl ratio, distortion, etc) over a large bandwidth.
- More compact Nasmith optics: improves antenna stiffness, moment of inertia, reduces load on the azimuth drivers

Reduced Back Focal Distance and f/D
Possible Disadvantages

- May limit the number of big instruments.
- Although… Doesn't precludes to have additional secondary focal (F_{2i}) points at the Nasmith platforms as the f/8 system

Reduced Back Focal Distance and f/D
Additional focal planes





Reduced Back Focal Distance and f/D
Possible Disadvantages

- May limit the number of big instruments.
- Although, a f/8 system offers the possibility of direct access to multiple folded Nasmith focal points,
- Does not preclude the possibility of having additional indirect Nasmith focal points.
- Other possibilities include to position the instruments on a linear or circulating track to alternatively have access to the Nasmith focal region.

Conclusions

- Obtained a optical design for the re-imaging optics of the LW Cam based on off-axis ellipsoidal sections with a single lens system to provide the and f/D=2 at the image plane.
- The calculated Strehl ratio is better than 80% over a 20'∅ FOV from 850 μm to 2mm and reduced FOV performance down to 600 μm.
- The angle of incidence θinc=15°, works well at f_1/0.6 and f_1/0.4
- Fill distortion is about 5.2% for both f_1/0.6 and f_1/0.4
- The use of the same reflector system for both, LW- Cam and the SW-Cam is plausible, work is still in progress…

Conclusions Cont…

- We have an initial exploration of different possibilities of instrument locations at the Nasmith focal points based on the known dimensions of the instruments: the LW-Cam, the SW-Cam and SCUBA-2.
- A system f/8 offers the possibility of three or even four additional third focal points at each of the Nasmith platforms.
- Nevertheless, the bent Cassegrain optics for an f/8 system requires several bents to fit the optics inside of the telescope hub.
- We have also initially explored the possibility Sof a reduced f/D system between 6.5 and 7, which offers the advantage of a better optical match to the instruments, and a more compact optics.

End