An RC Design for the Atacama 25m Sub-Millimeter Telescope

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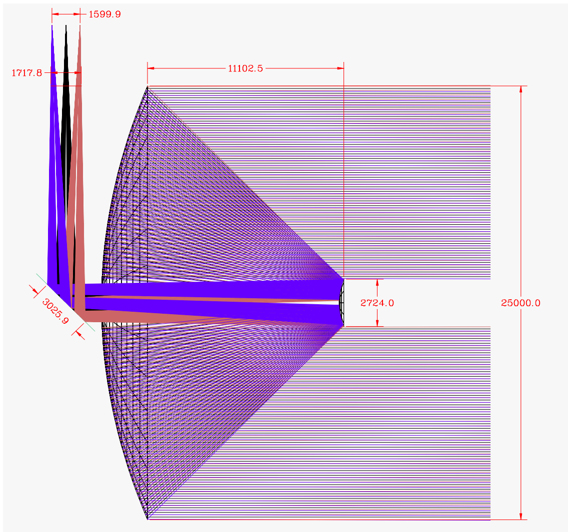
Atacama 25m Symmetric Design Parameters

Design		Ritchey-Chrétien / Nasmyth Focus
Primary Diameter		25.0 m
Primary f/#		0.6
Primary Focal Length		15.0 m
Back Focal Distance		18.0 m
Secondary Diameter		2.642 m
Secondary Diameter for a 18 ' FOV		2.725 m
Sec-Primary Distance		13.429 m
System Magnification		20.00
Total f/#		12.0
Plate Scale		0.688 "/mm
Size of 18 arcmin FOV	18 '	157.1 cm
Diffraction Limit	@ 200 um	1.980 arcsec
Diffraction Spot Size	@ 200 um	2880.0 um

Atacama 25m Symmetric Design Geometry



On Axis Performance

	Uniform Illumination	Edge Taper -11 dB	
Wavelength:	**200.0**	**200.0**	**[µm]**
Frequency:	**1499**	**1499**	**[GHz]**
HPFW Beam Width:	**1.841**	**2.122**	[arcsec]
Aperture Strehl:	100.00	100.00	[%]
Polarization Efficiency:	100.00	100.00	[%]
Beam Efficiency:	79.18	88.74	[%]
Aperture Plane Efficiency:	99.70	76.99	[%]
Side Lobe Level (SLL):	-16.92	-26.24	[dB]
Cross-Pol Level:	-325.86	-327.31	[dB]
Antenna Gain:	-------	110.43	[dB]
Overall Antenna Efficiency:	-------	**71.55**	[%]

Edge of 18” FOV

	Uniform Illumination	Edge Taper -11 dB	
Wavelength:	**200.0**	**200.0**	**[µm]**
Frequency:	**1499**	**1499**	**[GHz]**
HPFW Beam Width:	**1.841**	**2.139**	[arcsec]
Aperture Strehl:	98.72	98.42	[%]
Polarization Efficiency:	99.99	99.99	[%]
Beam Efficiency:	76.06	88.20	[%]
Aperture Plane Efficiency:	98.29	75.30	[%]
Side Lobe Level (SLL):	-16.26	-24.78	[dB]
Cross-Pol Level:	-49.68	-52.55	[dB]
Antenna Gain:	-------	110.36	[dB]
Overall Antenna Efficiency:	-------	**70.39**	[%]

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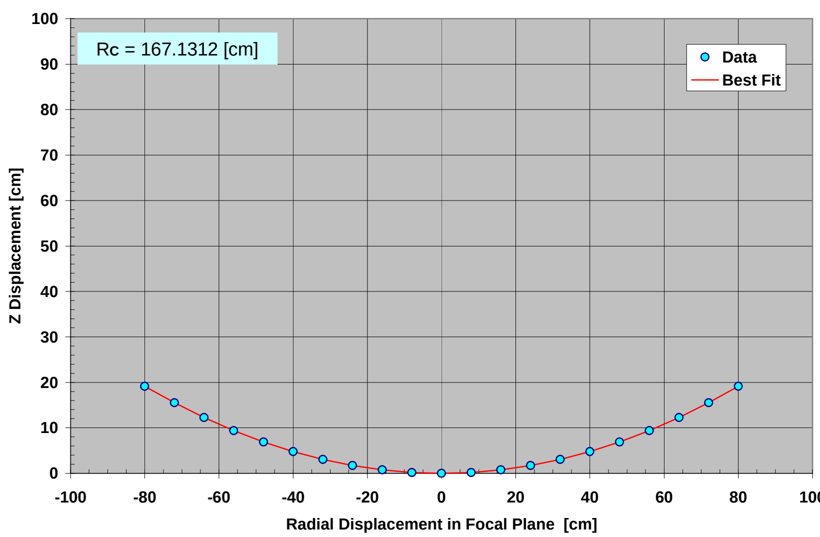
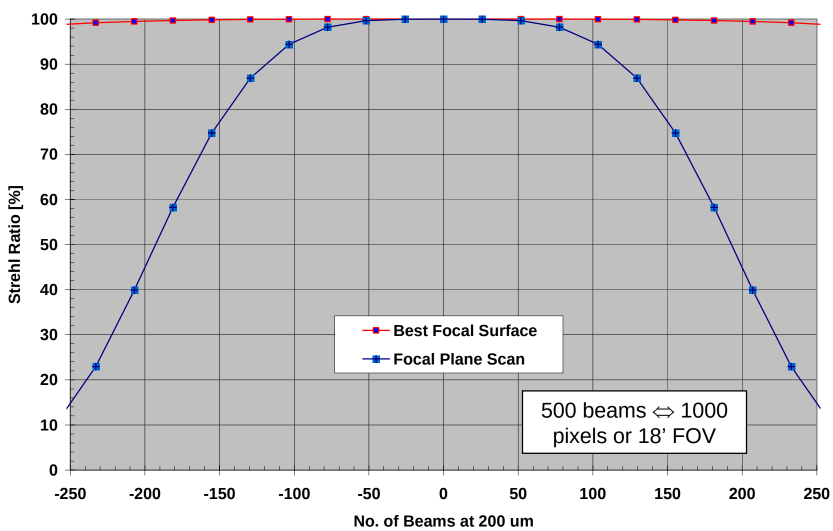
Best Focal Surface Geometry (200 µm)



Strehl Ratio Variations in FOV

Strehl Ratio vs. No of Beams at 200 μm

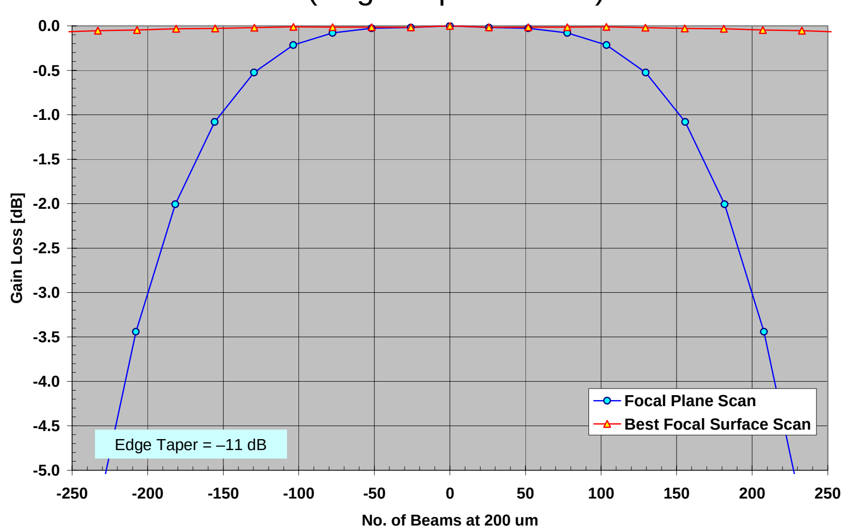


Overall Antenna Efficiency Variations in FOV

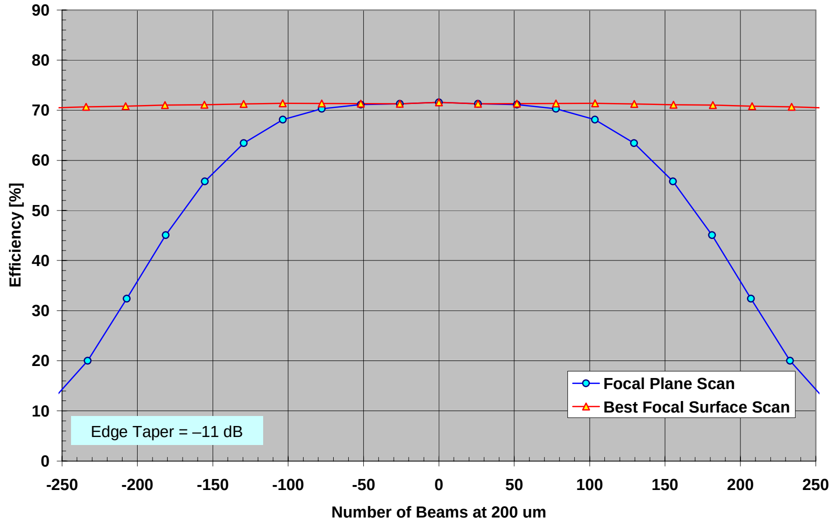
with –11 dB Edge Taper Illumination

Gain Loss vs. No. of Beams at 200 μm

(Edge Taper –11 dB)



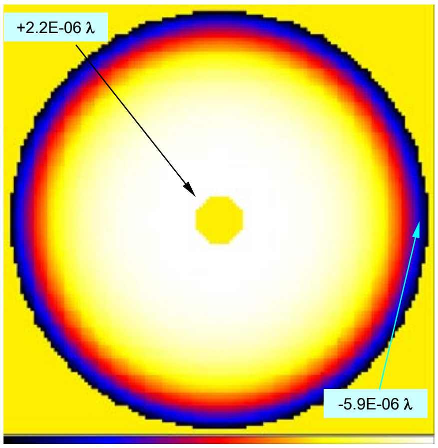
Overall Antenna Efficiency vs. No. of Beams at 200 µm (Edge Taper –11 dB)



Aperture Phase Distribution and Far Field Beam Patterns

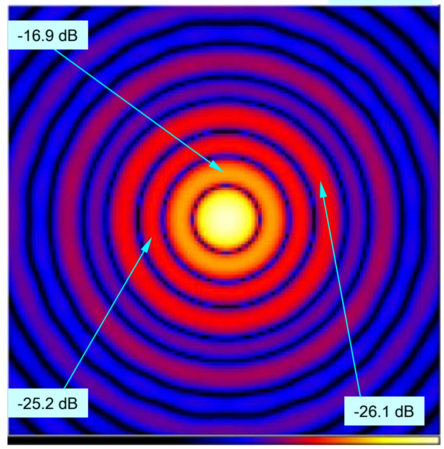
with Uniform Illumination

Aperture Phase Distribution and Co-Polar Beam Pattern at Center of FOV (at 200 μm, Uniform Illumination)



Phase Distribution at Aperture [λ]

Beam=1.84” 51”x51”



Far Field Radiation Pattern [dB]

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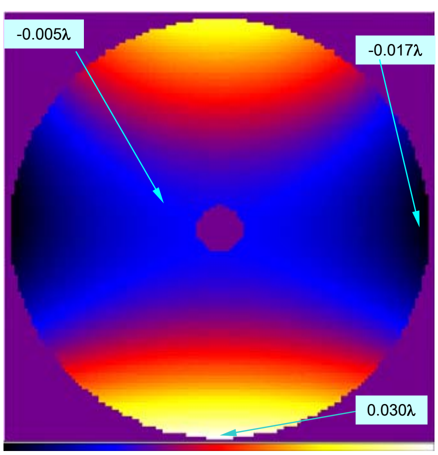
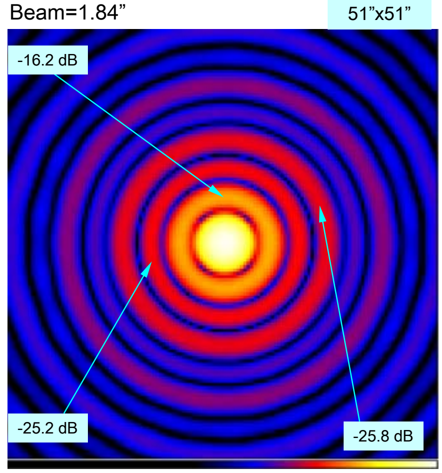
Aperture Phase Distribution and Co-Polar Beam Pattern at Edge of FOV (9’ radius at 200 μm, Uniform Illum.)



Phase Distribution at Aperture [λ]

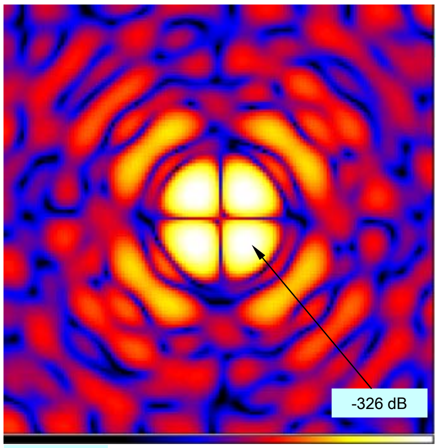
Beam=1.84” 51”x51”



Far Field Radiation Pattern [dB]

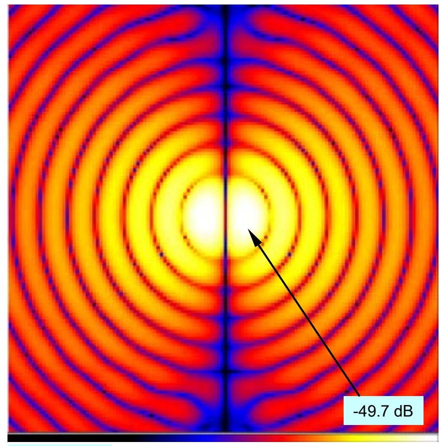
Cross-Polar Beam Patterns (at 200 μm, Uniform Illumination)

Center of FOV



51"x51"

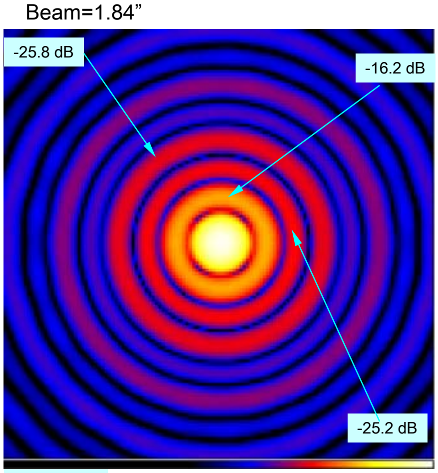
Edge of FOV



51"x51"

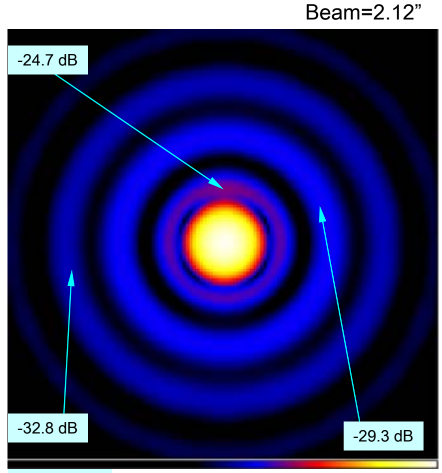
Comparison of Uniform vs. –11 dB Taper Illumination Co-Polar Beam Patterns (at 200 μm)

Beam=1.84"



51"x51" Uniform Illumination

Beam=2.12"



51"x51" Edge Taper –11.0 dB

Sub-Reflector Piston, Tip/Tilt and De-centering Sensitivities

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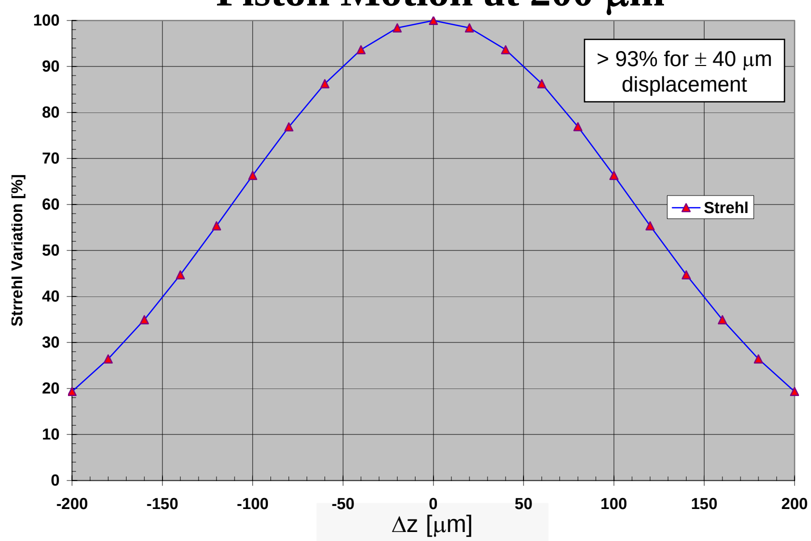
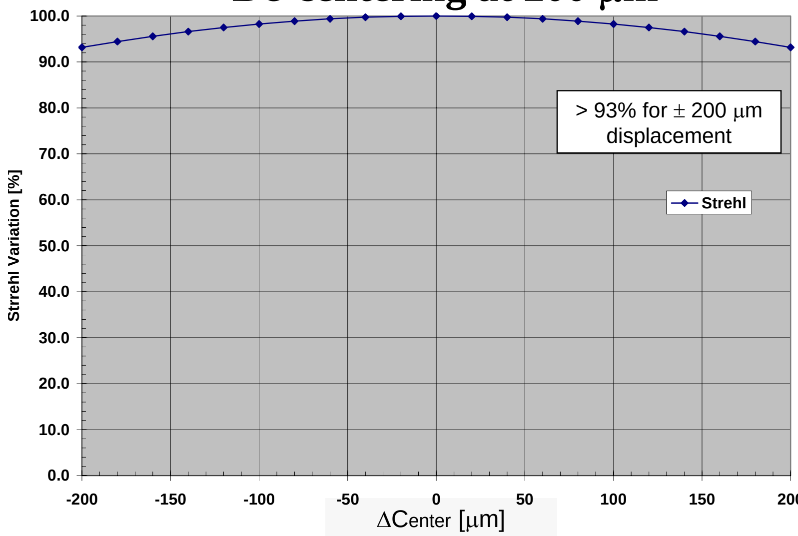
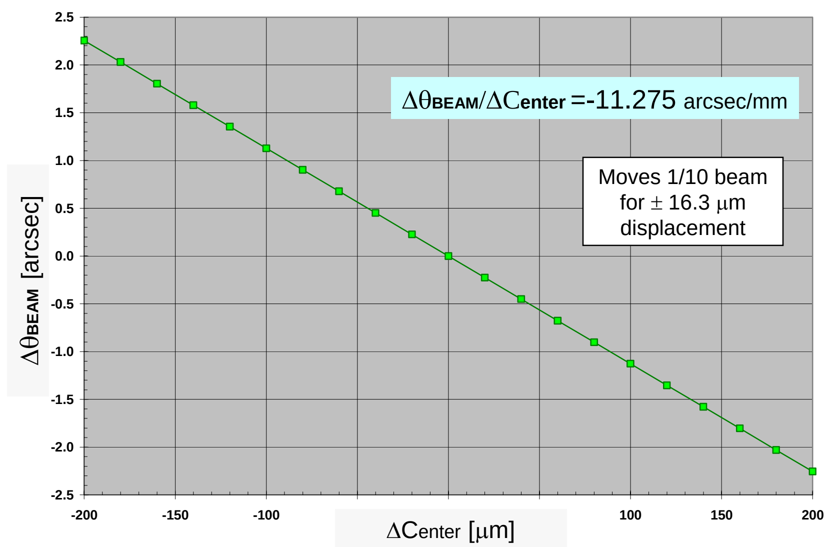
Strehl Ratio vs. Sub-Reflector Piston Motion at 200 μm



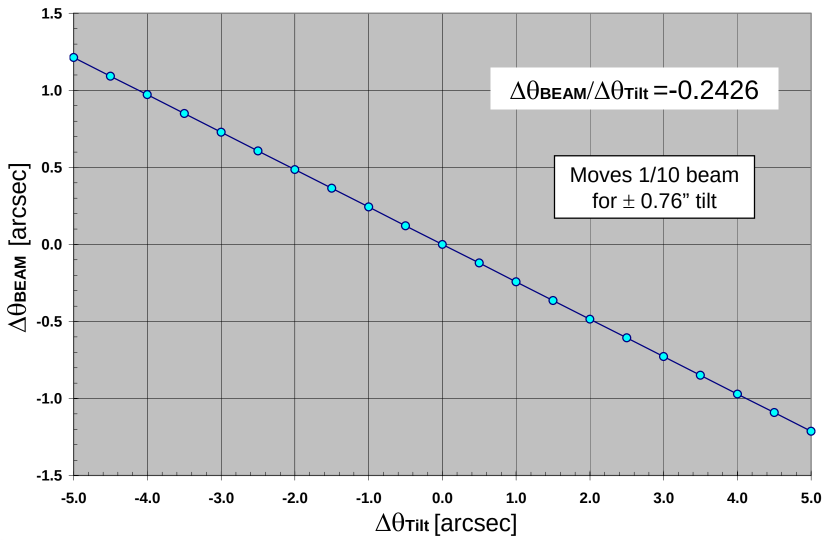
Strehl Ratio vs. Sub-Reflector De-centering at 200 μm



Beam Deviation vs. Sub-Reflector De-Centering



Beam Deviation vs. Sub-Reflector Tilt/Tip



Constraints on Sub-Reflector Motion

Sub-Reflector Motion

Max De-Focusing	**±40.0 μm**	For Strehl < 93%
Max De-Centering	**±16.3 μm**	$\Delta\theta_{BEAM\ MOTION}$ < HPBW /10
Max Tip/Tilt	**± 0.76 arcsec**	$\Delta\theta_{BEAM\ MOTION}$ < HPBW /10

This translates to ±10 μm

For a ∅2.7m Sub-Reflector

Future Work

- Surface roughness – baseline is 12 μm rms
  - Similar to goal of ALMA, achieved with SMA, CSO, nearly so with APEX
  - Ruze factor ~ 57% at 200 μm, and >83% at $\lambda > 350$ μm
- Effects of secondary and spider obstructions
- Effects of segmentation gaps
  - Point spread function
  - noise
- Off-axis designs…

Conclusions

Strawman design is a 25m Symmetric Reflector Sub-Millimeter telescope in a Nasmyth Ritchey-Chrétien configuration

- The Best Focal Surface is 1.6 m in diameter for a FOV of 18 arcmin and has a Radius of Curvature of 167 cm ⇔ 20 cm curvature at edge of field.
- We looked at a FOV of 18’ to accommodate a 1000 × 1000 (Nyquist Sampled) pixel array at 200 μm.
- The Strehl ratio is better than 98% over this FOV on the best focal surface, with uniform illumination of the aperture.
- An issue is detector size: 0.5 mm pixels ⇒ ***0.5 meter (square) array!*** (would be f/5 at 200 μm for Nyquist sampling)

Conclusions Cont…

- The Maximum Cross-polar level at the edge of FOV are –49 dB and –52 dB for uniform and Gaussian illumination, respectively.
- The Far Field Side-Lobe Level (SSL) over the FOV is < –16 dB with an uniform Illumination, and better than –24 dB with a –11 dB Gaussian illumination taper.
- We calculated the sub-reflector sensitivities of the present design for focusing of piston motion, de-centering and tilt/tip.
  - Deviations in focusing of the sub-reflector **ΔZ_{sub} < 40 μm** are required in order to maintain a Strehl ratio better than 95% at 200 μm.
  - For a beam deviation of $\Delta\theta_{BEAM} \sim \theta_{HPFW}/10$ at 200 μm:
    - the maximum dynamic de-centering of the sub-reflector should be less than **17μm**
    - edge-to-edge displacements of the sub-reflector resulting from tilt/tip

End