

# 30-meter cabin refurbishment for a large Field Of View: status of on-going study

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# New Optics Specifications

1. FOV  $\geq 10^\circ$  for bolometers, FOV  $\geq 7^\circ$  for heterodynes.
2. Mirrors size  $< 1.6$  m and surface accuracy  $\leq 15 \mu\text{m}$  RMS.
3. Optical systems fit in limited room (+ hardware & operator).
4. Number of optical elements as small as possible.
5. M3 rotating system efficient and simple.
6. Bolometer size  $\approx \lambda + 5..10 \%$  & sample  $\theta_{\text{HPBW}} = 1.03 \lambda/D \rightarrow 11.4..10.8^\circ$  on 8 inches wafer ( $\Delta\text{ImageSize} \sim 5$ ).
7. Smallest cryostat window possible for bolometers ( $D < 18$  cm).
8. Minimum cost  $\rightarrow$  no new M2 and all elements in receiver cabin.

# Current optics versus proposition

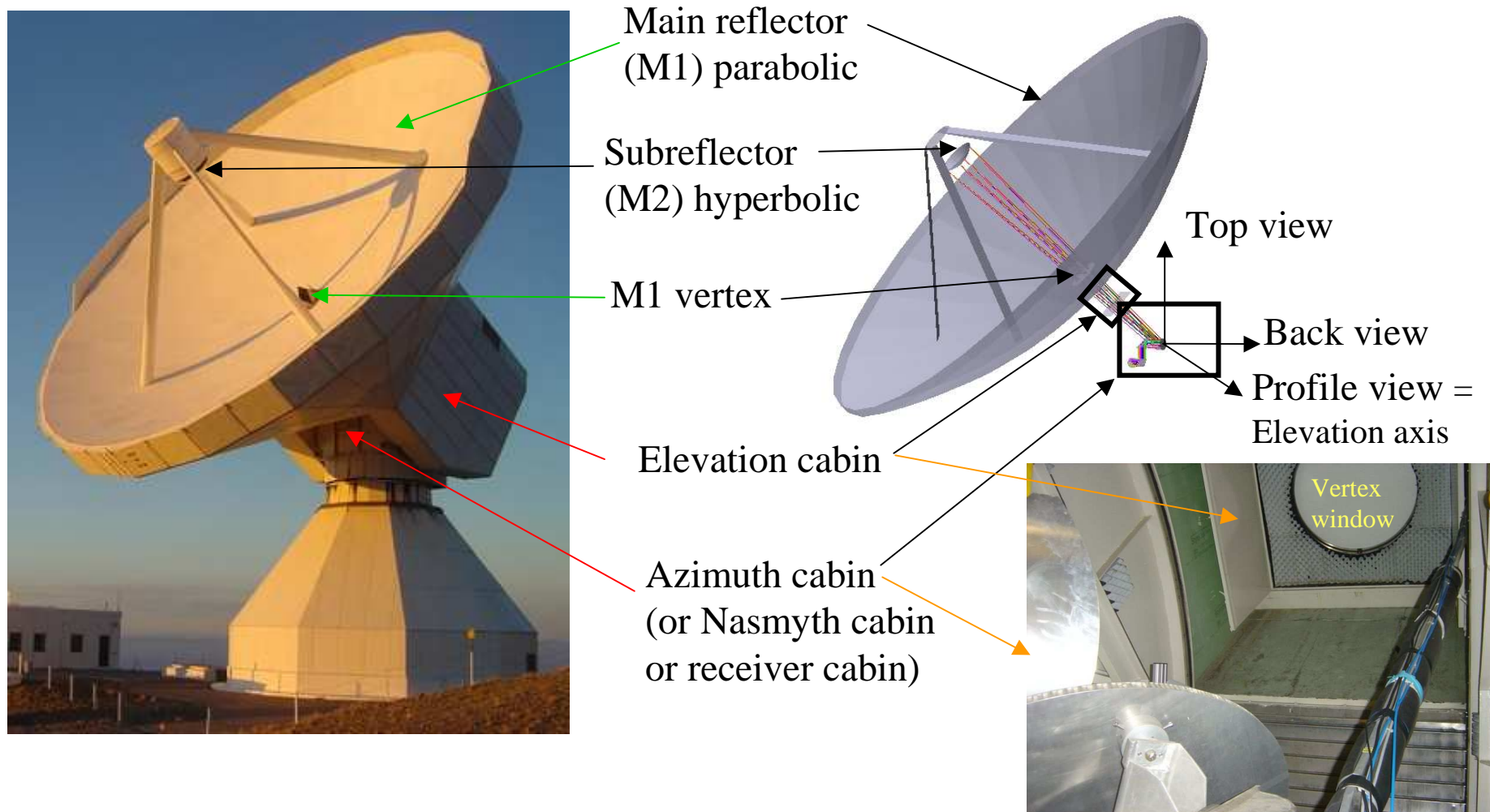
## Current

- FOV = 4.5 arcmin available for both bolometers and heterodynes.
- 7 mirrors in cabin + 1 or 2 lens(es) for bolometers
- $M \geq 3$  flat
- M3 elliptic contour =  $1040 \times 740$
- M4 elliptic contour =  $920 \times 650$
- M3 rotate on elevation axis (Nasmyth)
- M3-M4 = 700 mm

## Proposed

- FOV = 10 arcmin for bolometers, 7.4 arcmin for heterodynes.
- 2 mirrors in cabin + 2 lenses for bolometers
- $M_h \geq 3$  flat,  $M_b > 3$  curved
- M3 elliptic contour =  $1440 \times 1200$
- M4h elliptic contour =  $1170 \times 810$   
M4b elliptic contour =  $1070 \times 990$
- M5b elliptic contour =  $980 \times 930$
- M3 Nasmyth for heterodyne, 2 axes of rotation for bolometers
- M3-M4h = 860 mm  
M3-M4b = 1500 mm

# Reference frame for Zemax simulations

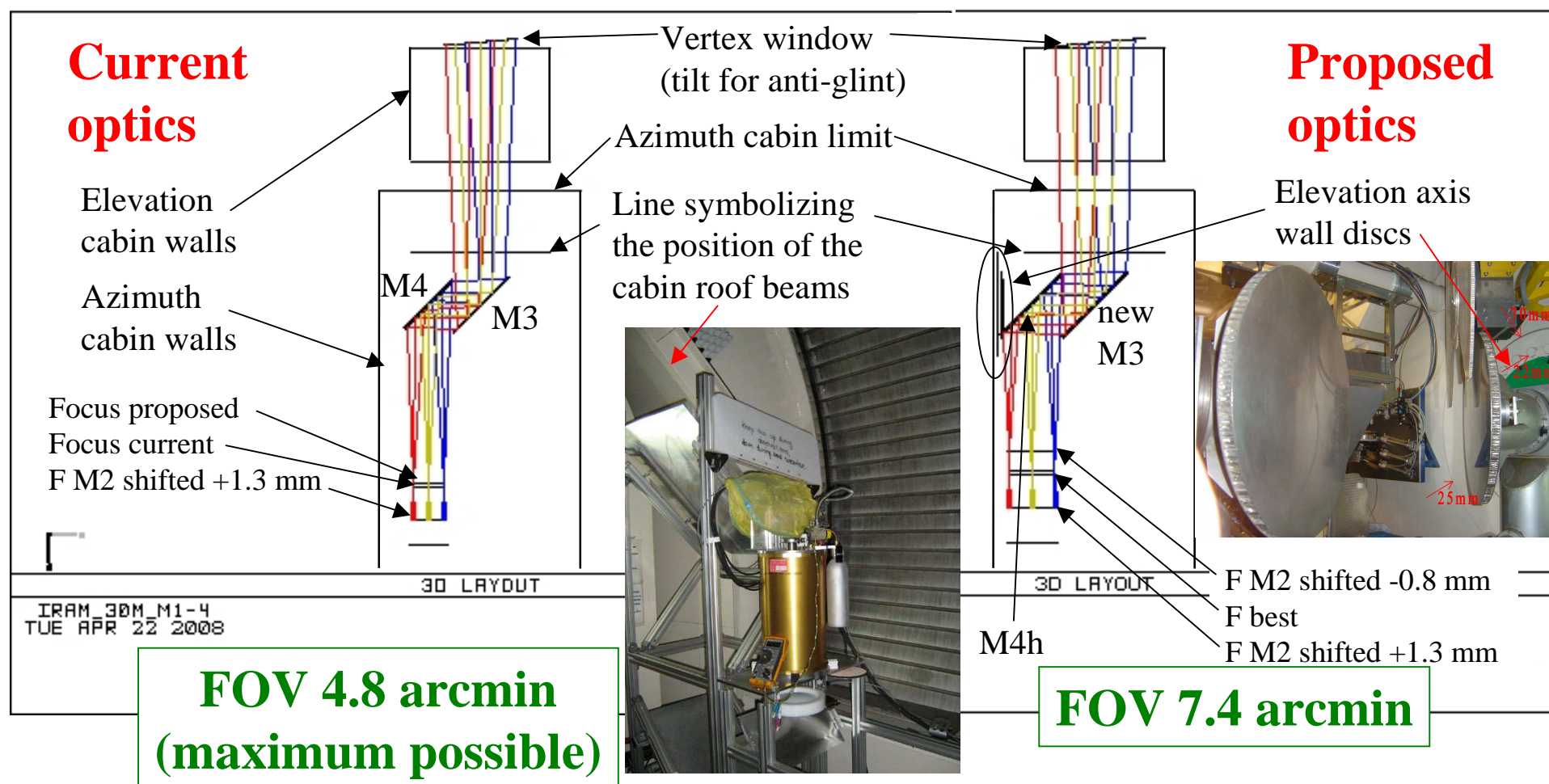


→ Simulation of the whole telescope (not equivalent lens)

# Heterodynes optics: current vs proposed

Top view at 0 degree elevation angle

Blue rays =  $(+FOV/2;0)$ , Green rays =  $(0;+FOV/2)$ , Red rays =  $(-FOV/2;0)$ , Yellow rays =  $(0;-FOV/2)$

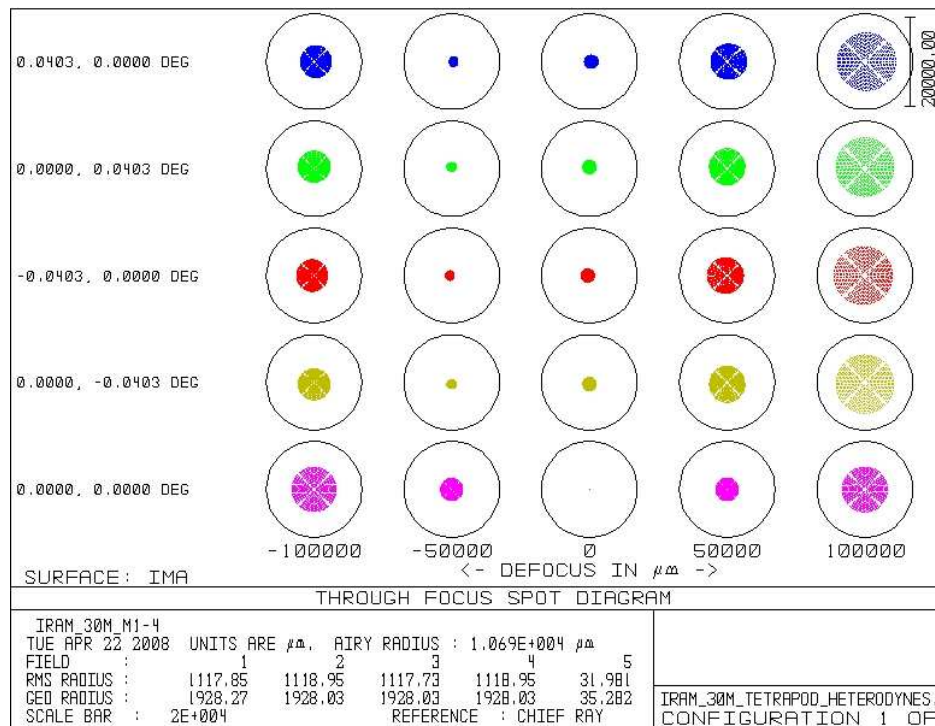


# Through focus spot diagram, heterodynes

$\lambda=0.87\text{mm}$        $\Delta\text{foc}=5\text{cm}$       circle = Airy disc

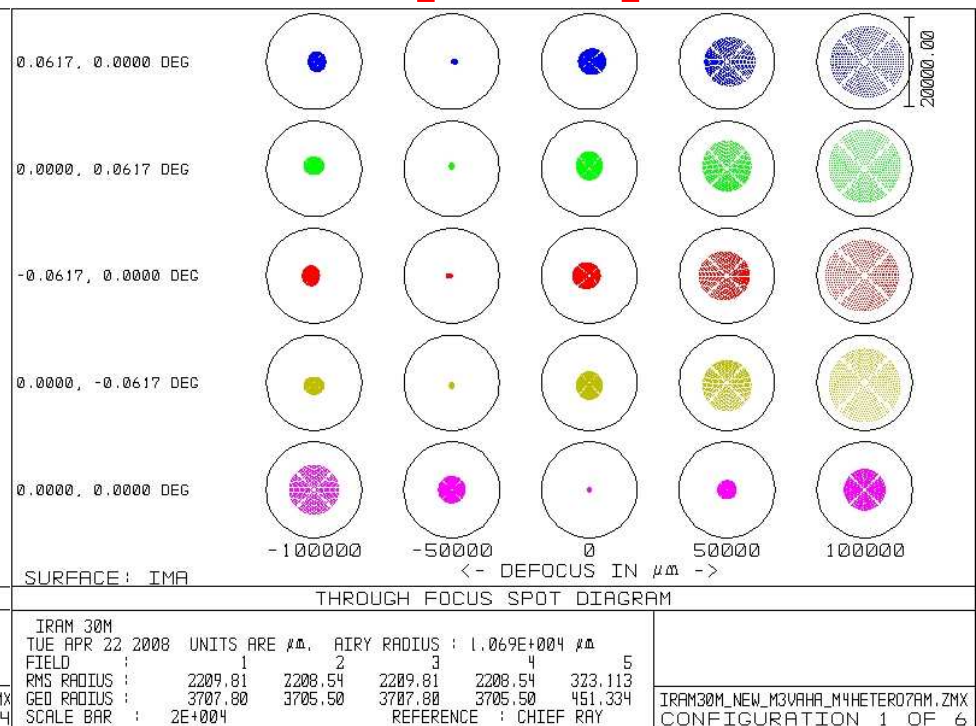
Blue =  $(+\text{FOV}/2;0)$ , Green =  $(0;+\text{FOV}/2)$ , Red =  $(-\text{FOV}/2;0)$ , Yellow =  $(0;-\text{FOV}/2)$ , Magenta =  $(0;0)$

## Current optics



**FOV 4.8 arcmin**  
(maximum possible)

## Proposed optics



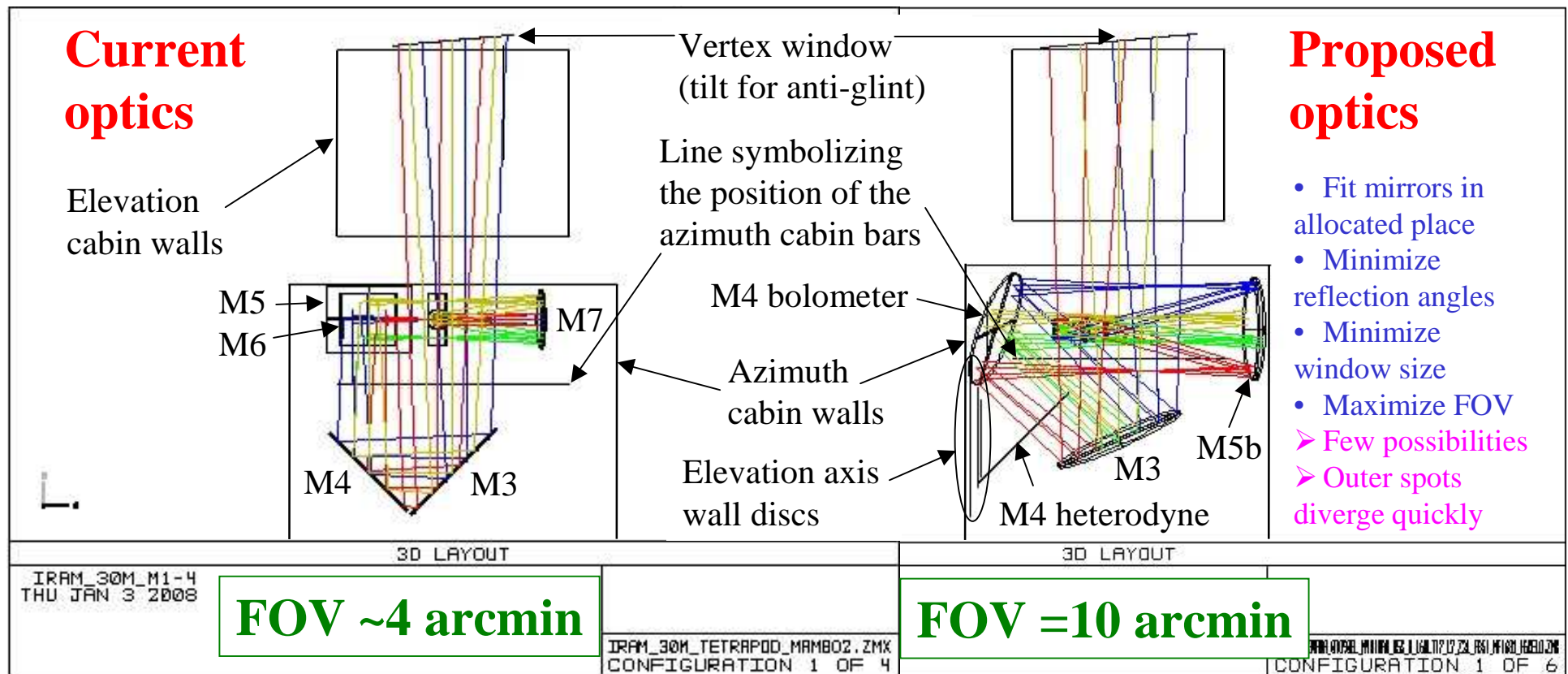
**FOV 7.4 arcmin**



# Bolometers optics: Current Vs Proposed

Top view at 0 degree elevation angle

Blue rays =  $(+FOV/2;0)$ , Green rays =  $(0;+FOV/2)$ , Red rays =  $(-FOV/2;0)$ , Yellow rays =  $(0;-FOV/2)$

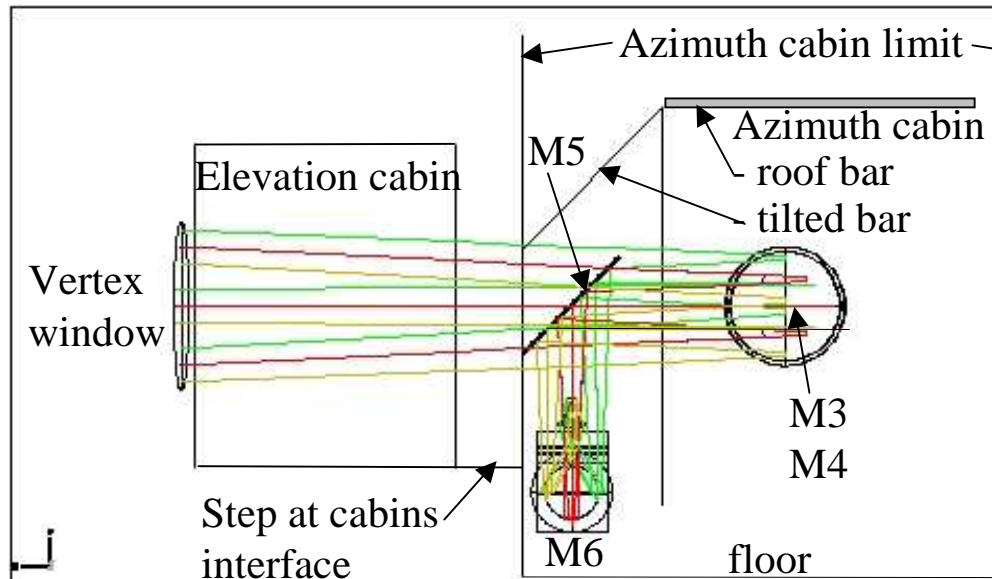


# Bolometers optics: current vs proposed

Profile view at 0 degree elevation angle

Blue rays =  $(+FOV/2; 0)$ , Green rays =  $(0; +FOV/2)$ , Red rays =  $(-FOV/2; 0)$ , Yellow rays =  $(0; -FOV/2)$

## Current optics



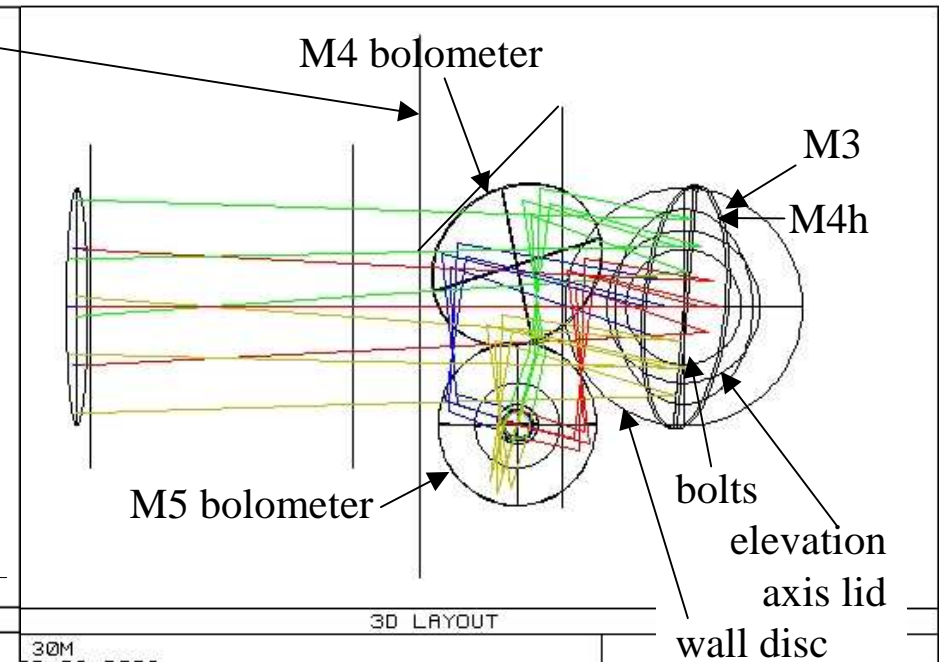
3D LAYOUT

IRAM\_30M\_M1-4  
THU JAN 3 2008

**FOV ~4 arcmin**

30M\_TETRAPOD\_MAMBO2.ZMX  
CONFIGURATION 1

## Proposed optics



3D LAYOUT

30M  
PR 22 2008

**FOV =10 arcmin**

30M\_TETRAPOD\_MAMBO2.ZMX  
CONFIGURATION 1 OF 6

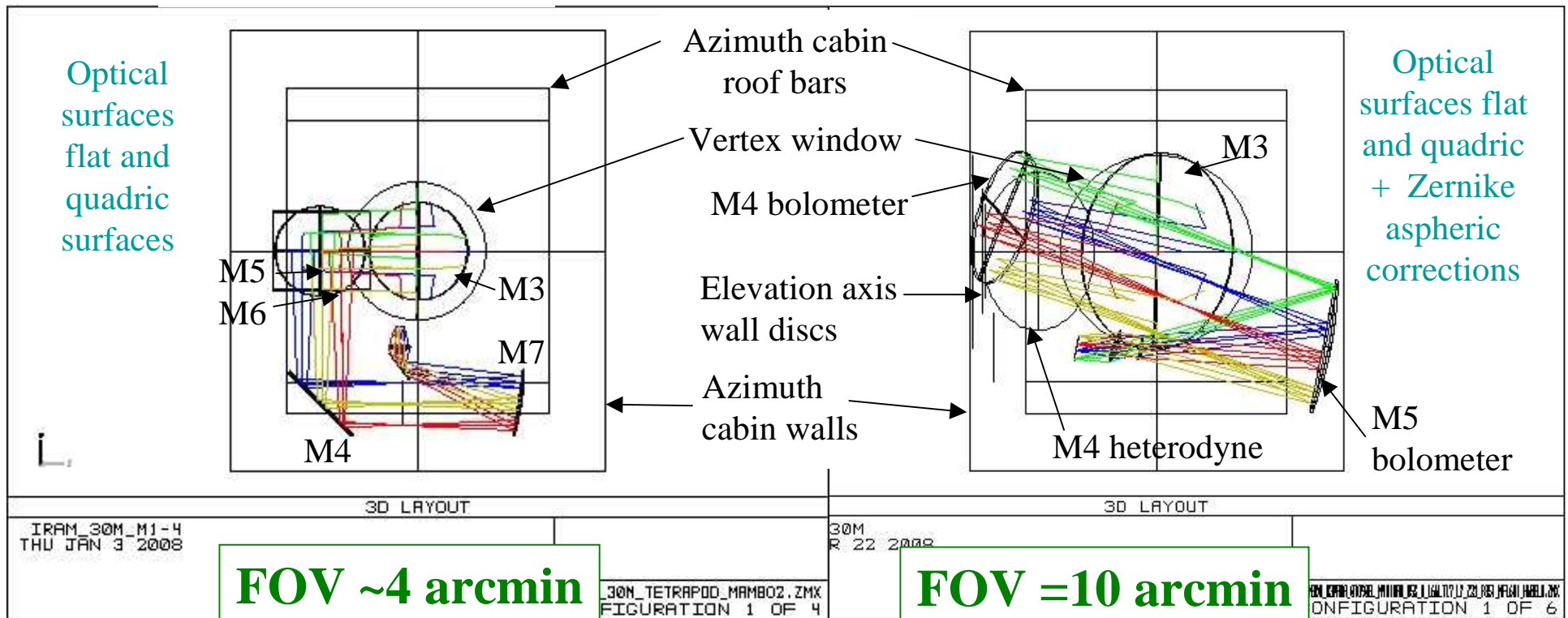


# Bolometers optics: current vs proposed

Back view at 0 degree elevation angle

Blue rays =  $(+\text{FOV}/2; 0)$ , Green rays =  $(0; +\text{FOV}/2)$ , Red rays =  $(-\text{FOV}/2; 0)$ , Yellow rays =  $(0; -\text{FOV}/2)$

## Current optics



# Through focus spot diagram, bolometers

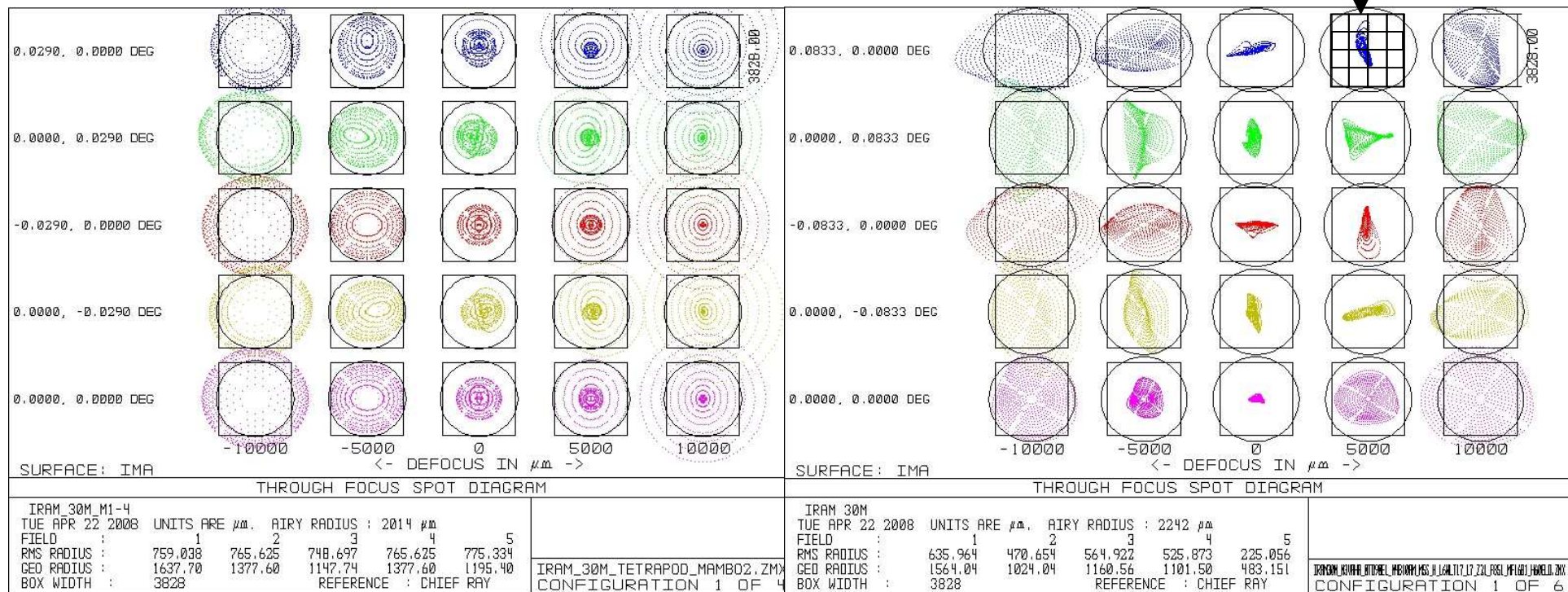
$\lambda=0.87\text{mm}$        $\Delta\text{foc}=5\text{cm}$       circle = Airy disc

Blue =  $(+\text{FOV}/2;0)$ , Green =  $(0;+\text{FOV}/2)$ , Red =  $(-\text{FOV}/2;0)$ , Yellow =  $(0;-\text{FOV}/2)$ , Magenta =  $(0;0)$

## Current optics (MAMBO 2)

## Proposed optics

4×4 pixels to sample HPBW



**FOV 3.5 arcmin**

PSF = Airy \* Aberration

**FOV 10 arcmin**

M2 shift = 0.9 mm

M2 shift = 0 mm. Acceptable M2 shift =  $\pm 0.8$  mm  $\rightarrow \Delta F \sim 15$  mm



# Through focus spot diagram, bolometers

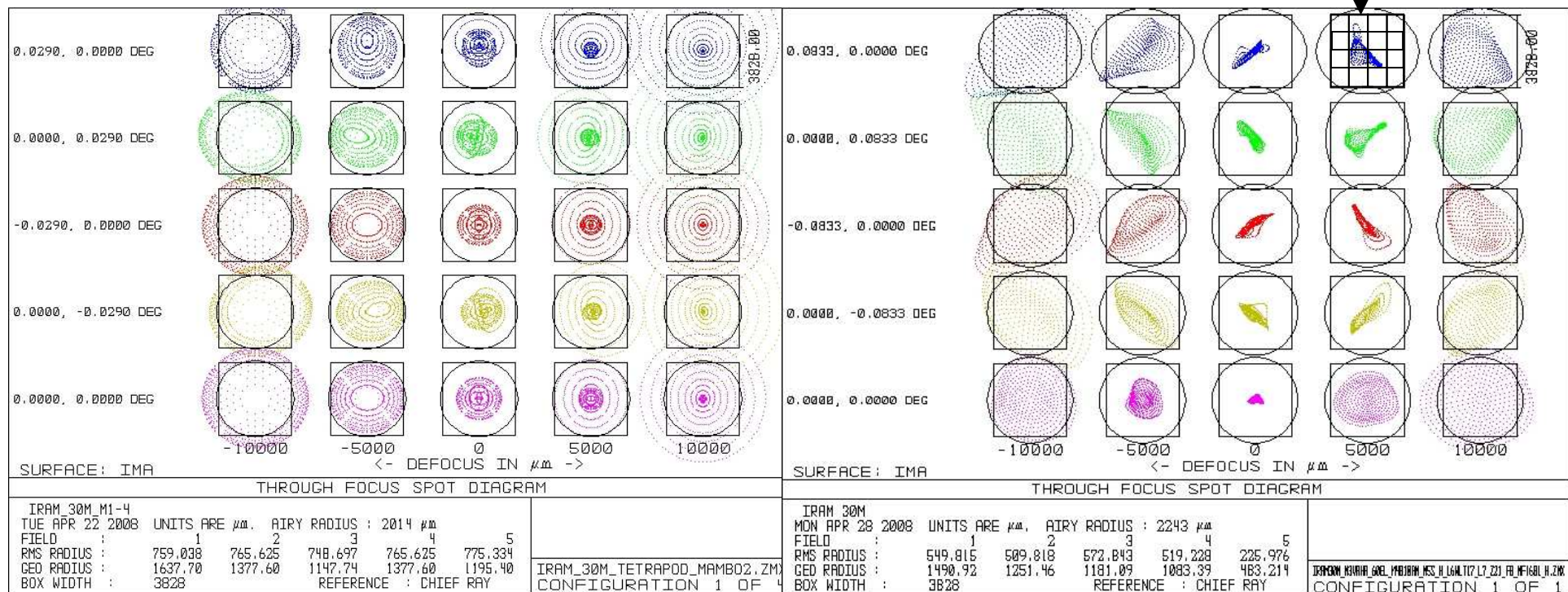
$\lambda=0.87\text{mm}$        $\Delta\text{foc}=5\text{cm}$       circle = Airy disc

Blue =  $(+\text{FOV}/2;0)$ , Green =  $(0;+\text{FOV}/2)$ , Red =  $(-\text{FOV}/2;0)$ , Yellow =  $(0;-\text{FOV}/2)$ , Magenta =  $(0;0)$

## Current optics (MAMBO 2)

## Proposed optics

4×4 pixels to sample HPBW



**FOV 3.5 arcmin**

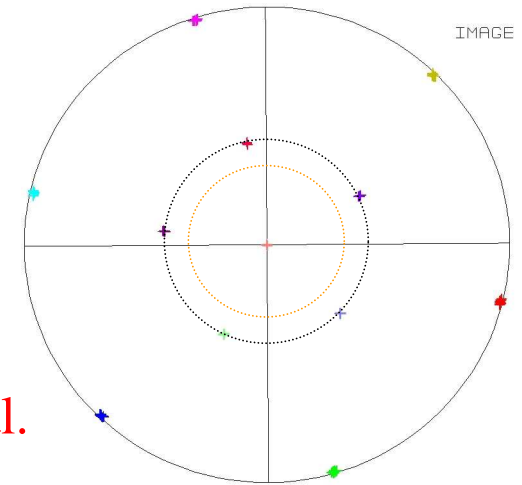
PSF = Airy \* Aberration

**FOV 10 arcmin**

M2 shift = 0.9 mm

M2 shift = 0 mm. Acceptable M2 shift =  $\pm 0.8$  mm  $\rightarrow \Delta F \sim 15$  mm

# Conclusion



- Heterodyne optics ready for realization phase.
- Bolometer optics need refinement, but is ready for approval.
- FOV significantly increased while keeping everything in the receiver cabin  
→ efficient, cheap and secured solution.
- New M3 must be mounted on 2 rotating axes (its own azimuth and elevation)  
→ electronics and software control, laser alignment.
- M4h must be mounted on translation rail.
- M4b, M5b, L6 and L7 have curved surfaces with complex aspheric corrections.
- *To do: Solid Works ; M3 and M4h motorized mounts ; mechanical structure & support ; laser system ; electronics ; control software ; buy raw material ; chopper replacement ; machining ; mounting.*
- Estimated budget ~ 150-200 keuros.
- Estimated timing ~ if design approval in may → ready for winter 2009.

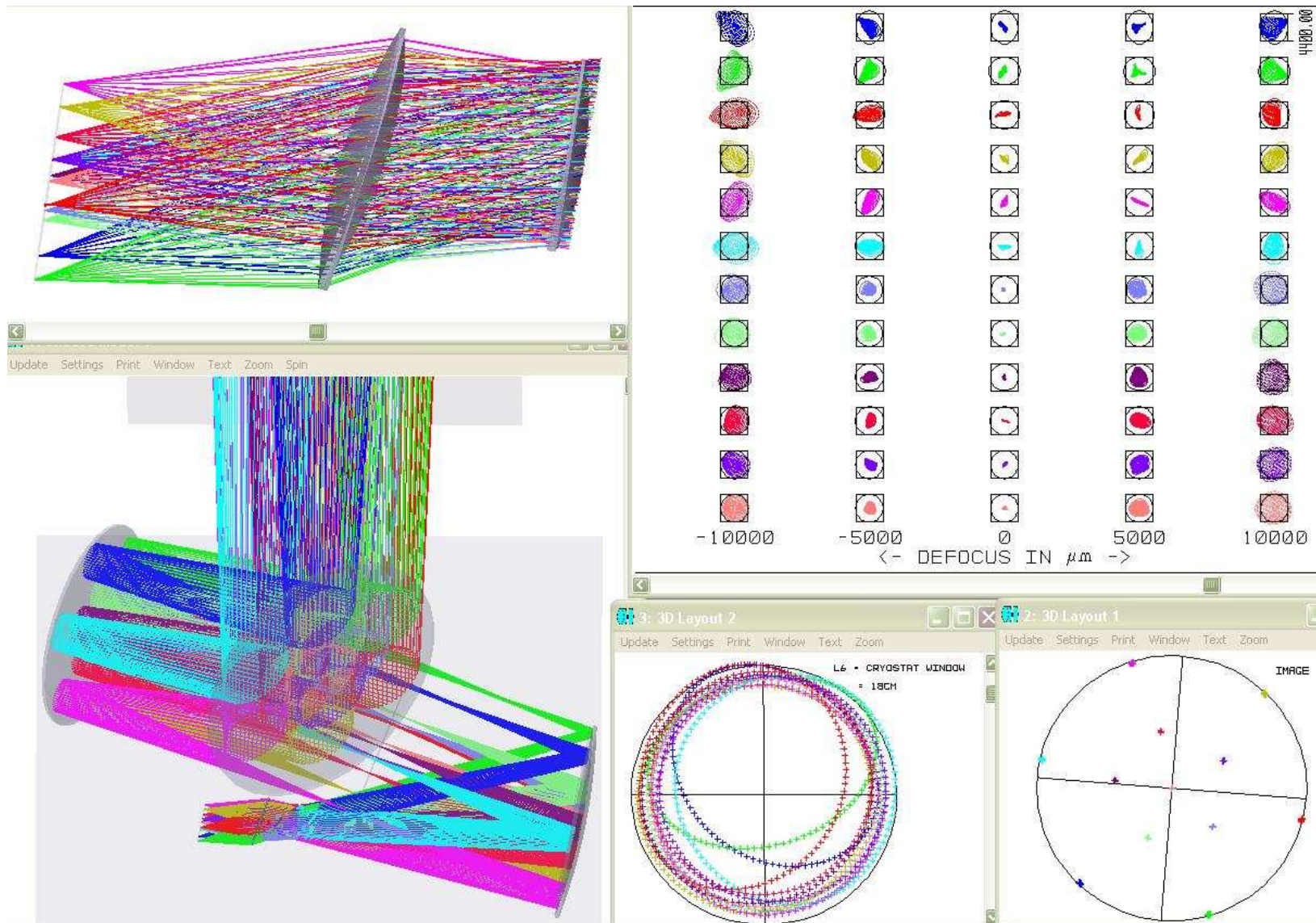
Extra slides

# Short chronology of the study

- Late 90s: Astrophysics and technology → large Fields Of View (FOV).
- 2003-2006: Early concepts to increase the 30m FOV (S.Navarro) → new optics in receiver cabin, elements in main dish (M1) structure, new subreflector (M2).
- Fall 06: Optical software, current system in Optalix and **Zemax**, FOV study.
- **May 07: 1<sup>st</sup> proposition** for a new optical design, all in “receiver cabin” with a non-Nasmyth motorized M3 → 14.5’ for bolos @ low cost.
- **Jan 08 : 3<sup>rd</sup> proposition** refining specifications → 11.4’ for bolo, 7.4’ for hetero.
- Feb 08 : start optimization of designs based on 3<sup>rd</sup> proposition.
- **Apr 08 : 1 design meets specifications → 10’ bolo, 7.4’ hetero.**
- *June 08 : start realization phase if proposed design is approved.*
- *Winter 09 : new optics in the 30m receiver cabin.*



# New bolo optics: multi fields shaded model, cryostat window, image spots, through-focus spot diagram



# New bolo optics: behaviour with elevation change

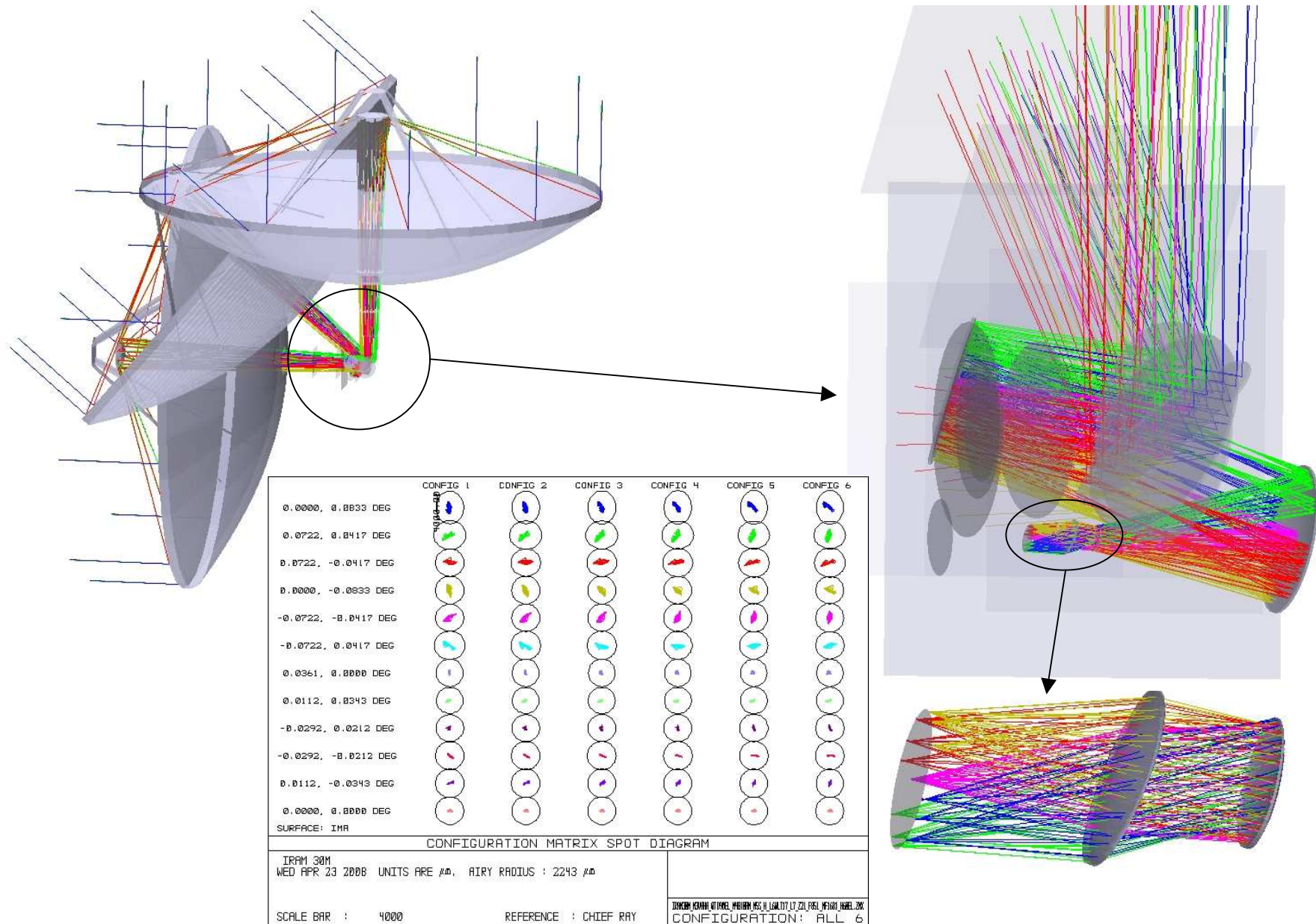


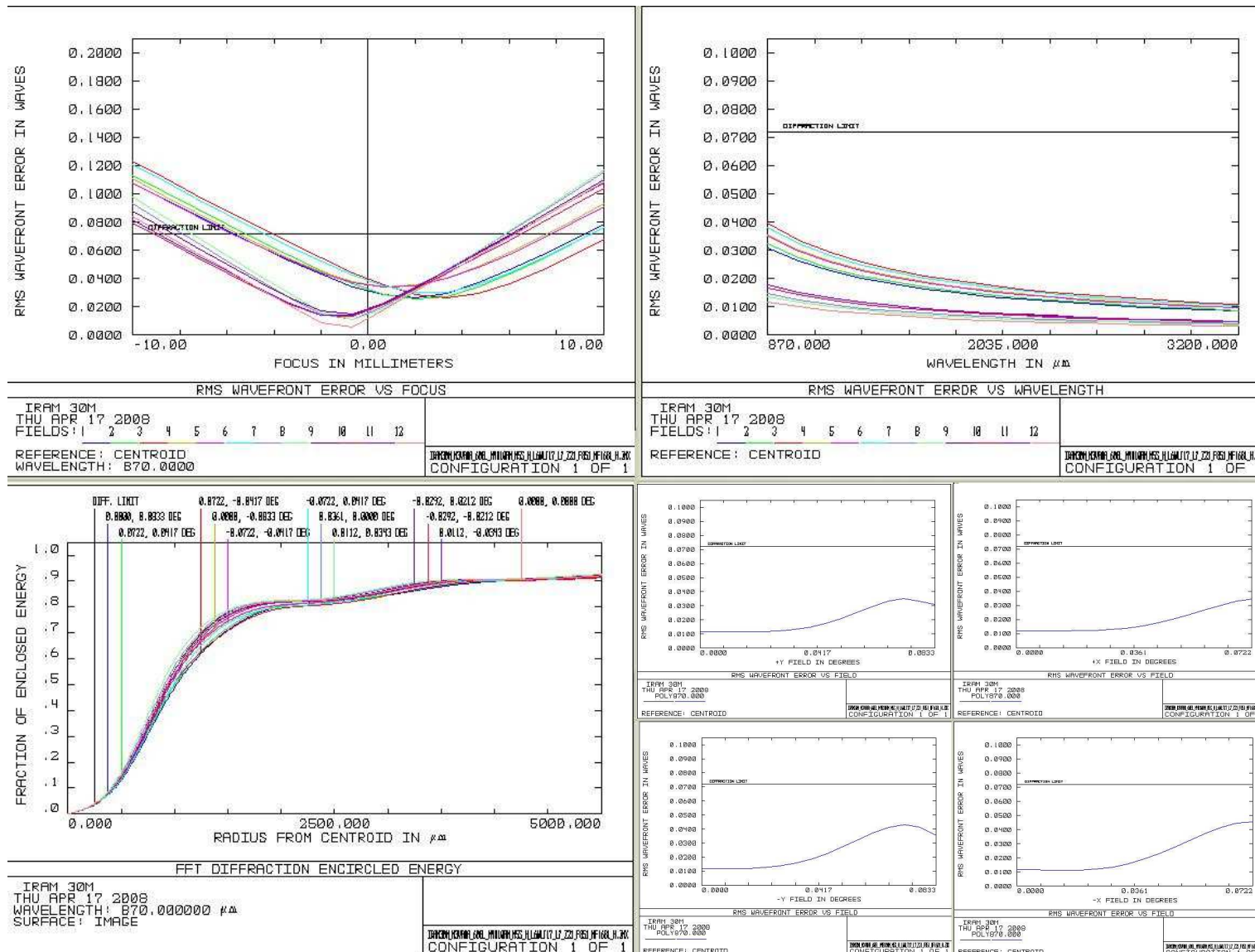


Figure 10 displays the effect of increasing the number of rays on the Point Spread Function (PSF) and Modulus of the Transfer Function (MTF) for a system with a wavelength of 0.5770  $\mu\text{m}$  and a pupil diameter of 1.2500 mm. The plots are arranged in three rows, corresponding to different ray counts: 10, 12, 14, 16, 18, and 20 rays.

The top row shows the 3D PSF plots, which are visualized as a series of concentric rings. The middle row shows the 2D PSF plots, which are visualized as a series of concentric rings. The bottom row shows the Polychromatic Diffraction MTF plots, which show the Modulus of the OTF (Optical Transfer Function) versus Spatial Frequency in cycles per mm. The MTF plots show that the contrast decreases as the spatial frequency increases, and the contrast is higher for a larger number of rays.

The plots are labeled with the number of rays and the wavelength. The 3D PSF plots are labeled "10-RTT-PSF 10", "12-RTT-PSF 12", "14-RTT-PSF 14", "16-RTT-PSF 16", "18-RTT-PSF 18", and "20-RTT-PSF 20". The 2D PSF plots are labeled "10-RTT-PSF 10", "12-RTT-PSF 12", "14-RTT-PSF 14", "16-RTT-PSF 16", "18-RTT-PSF 18", and "20-RTT-PSF 20". The MTF plots are labeled "POLYCHROMATIC DIFFRACTION MTF".

# New bolo optics: RMS vs Focus, RMS vs wavelengths, Encircled energy, RMS vs Fields



# Project planning

