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

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New Optics Specifications

1. FOV ≥ 10’ for bolometers, FOV ≥ 7’ for heterodynes.
2. Mirrors size < 1.6 m and surface accuracy ≤ 15 μm RMS.
3. Optical systems fit in limited room (+ hardware & operator).
4. Number of optical elements as small as possible.
5. M3 rotating system efficient an simple.
6. Bolometer size ≈ λ + 5..10 % & sample $\theta_{HPBW} = 1.03\ \lambda/D$ → 11.4..10.8’ on 8 inches wafer (ΔImageSize ~ 5).
7. Smallest cryostat window possible for bolometers (D < 18 cm).
8. Minimum cost → no new M2 and all elements in receiver cabin.

Current optics versus proposition

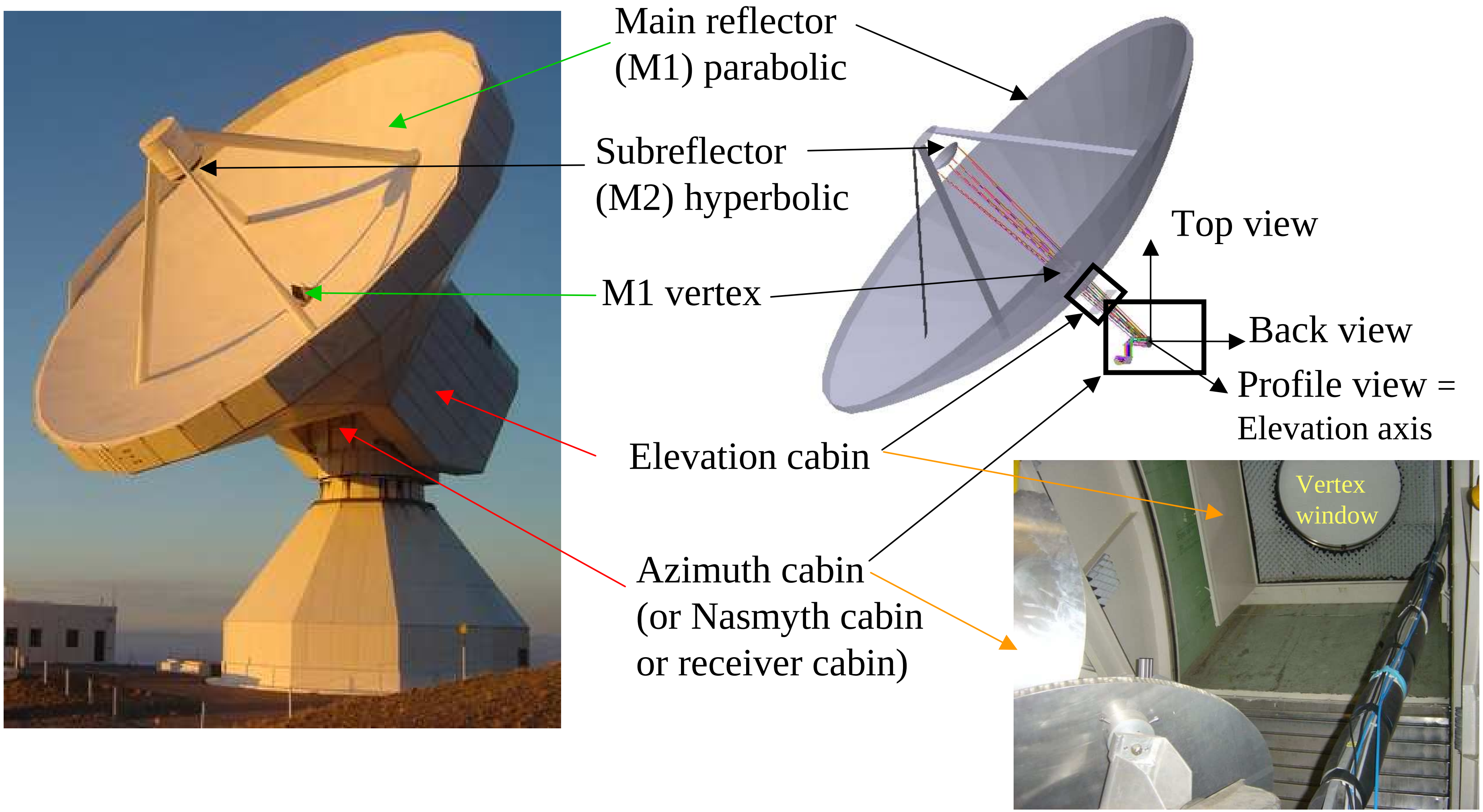
Current

- FOV = 4.5 arcmin available for both bolometers and heterodynes.
- 7 mirrors in cabin + 1 or 2 lens(es) for bolometers
- M≥3 flat
- M3 elliptic contour = 1040×740
- M4 elliptic contour = 920×650
- 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
- Mh≥3 flat, Mb>3 curved
- M3 elliptic contour = 1440×1200
- M4h elliptic contour = 1170×810
  M4b elliptic contour = 1070×990
- M5b elliptic contour = 980×930
- M3 Nasmyth for heterodyne, 2 axes of rotation for bolometers
- M3-M4h = 860 mm
  M3-M4b = 1500 mm

Reference frame for Zemax simulations

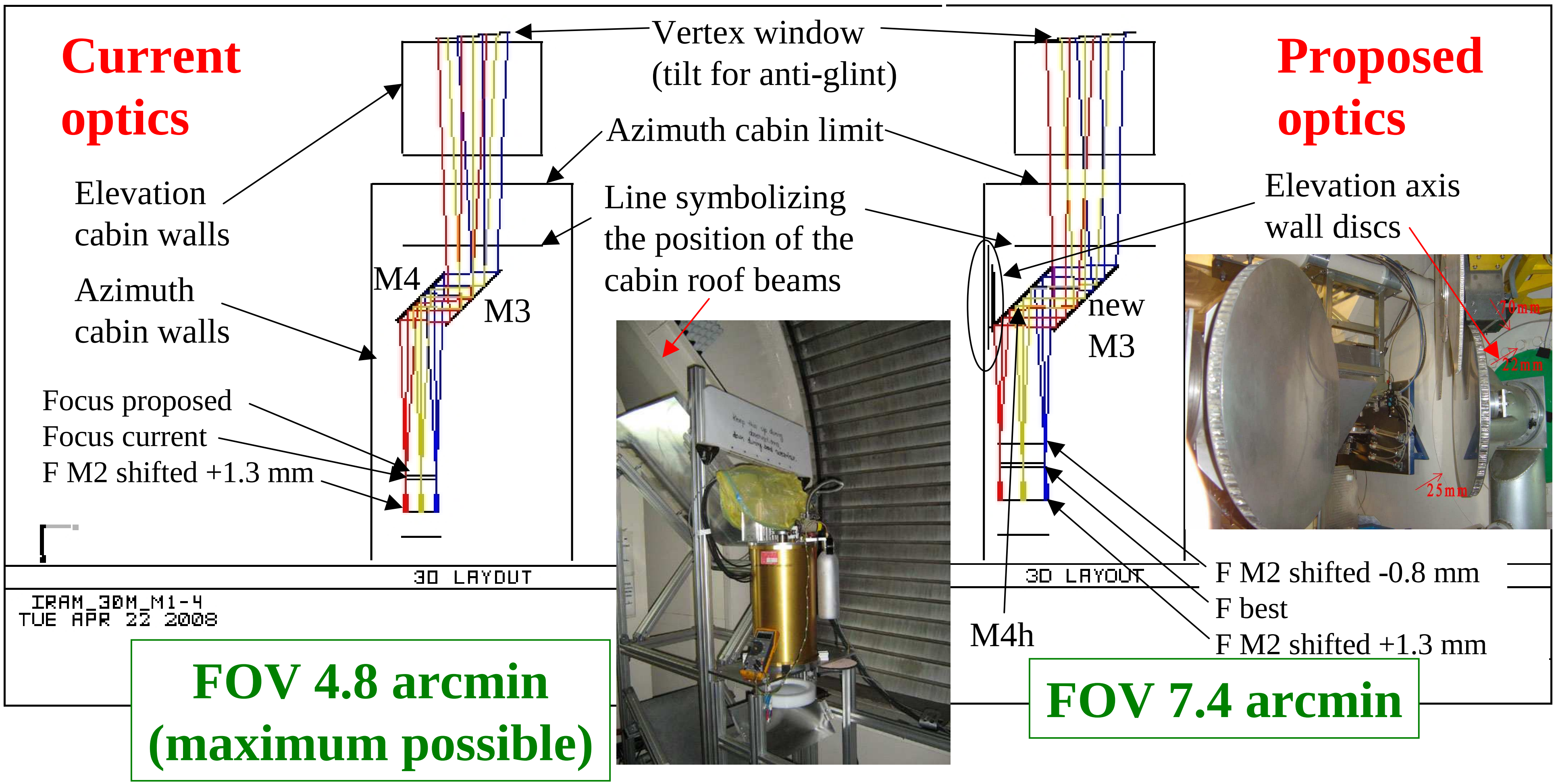


→ Simulation of the whole telescope (not equivalent lens)

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)

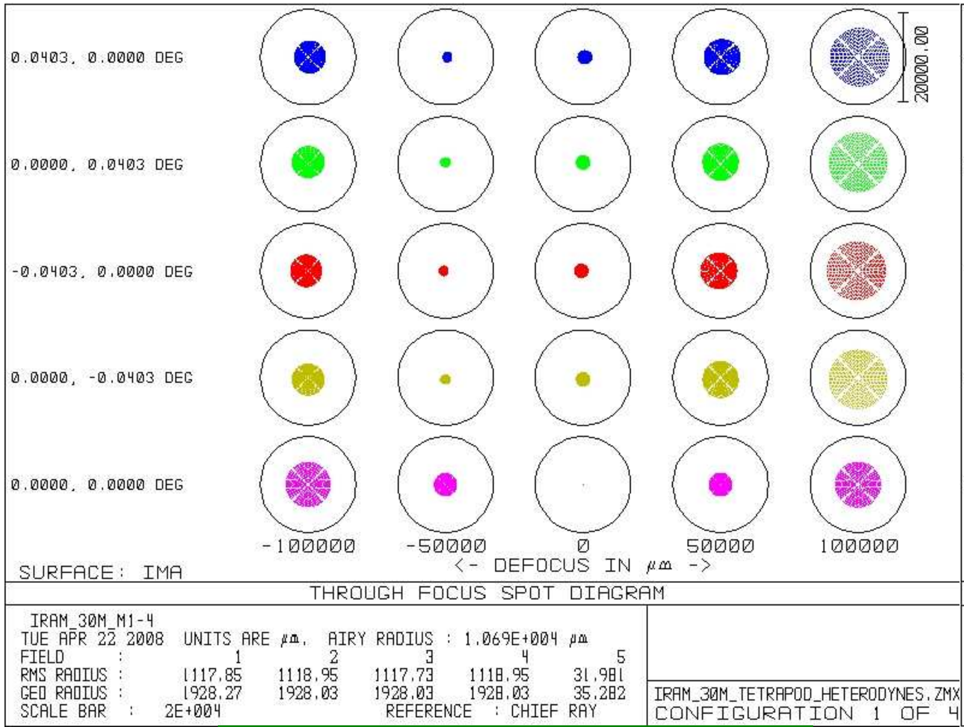


Through focus spot diagram, heterodynes

λ=0.87mm   Δfoc=5cm   circle = Airy disc

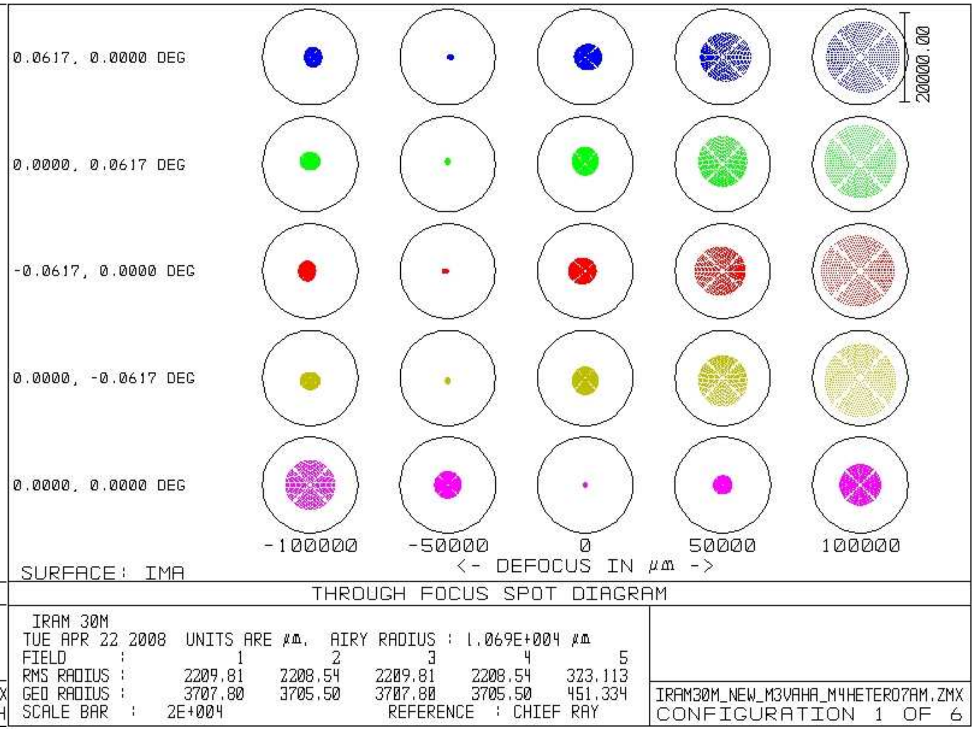
Blue = (+FOV/2;0), Green = (0;+FOV/2), Red = (–FOV/2;0), Yellow = (0;–FOV/2), Magenta = (0;0)

Current optics



FOV 4.8 arcmin (maximum possible)

Proposed optics

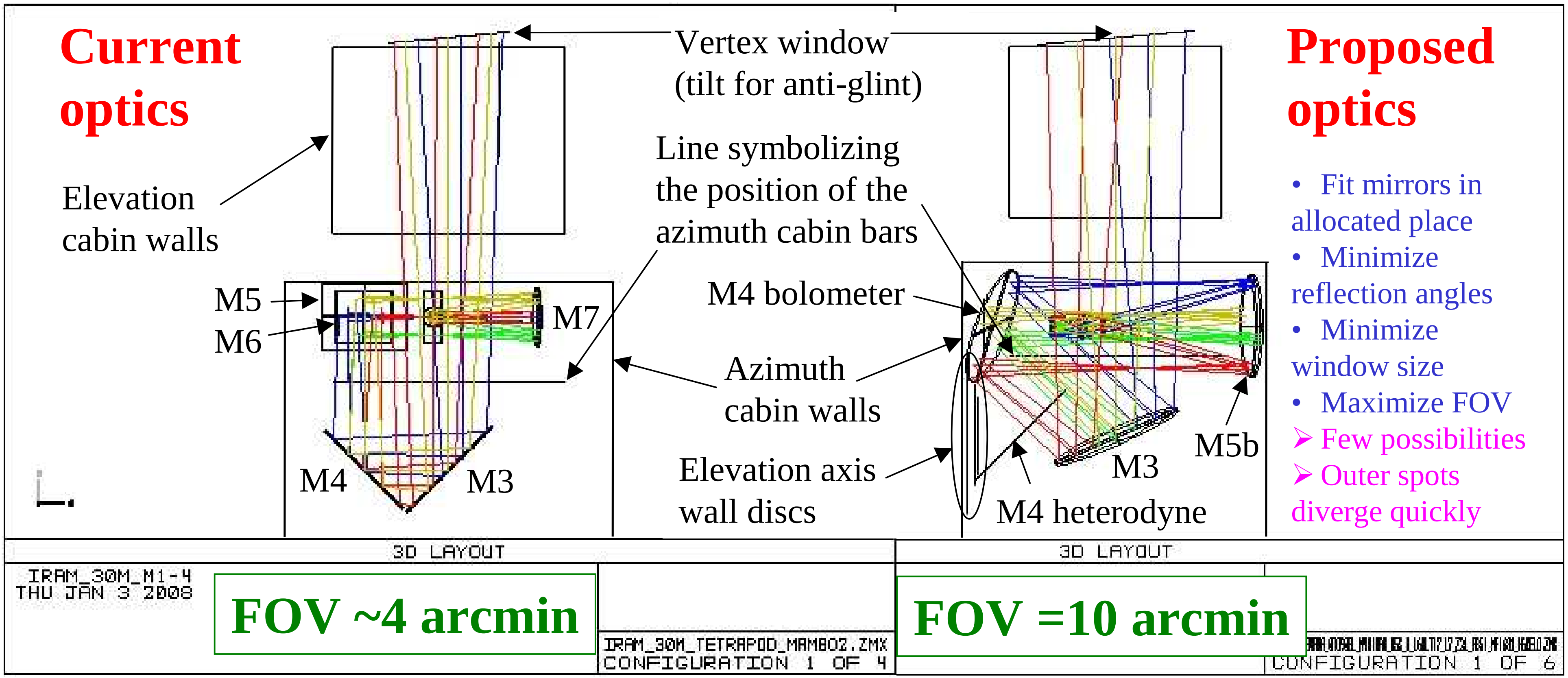


FOV 7.4 arcmin

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)

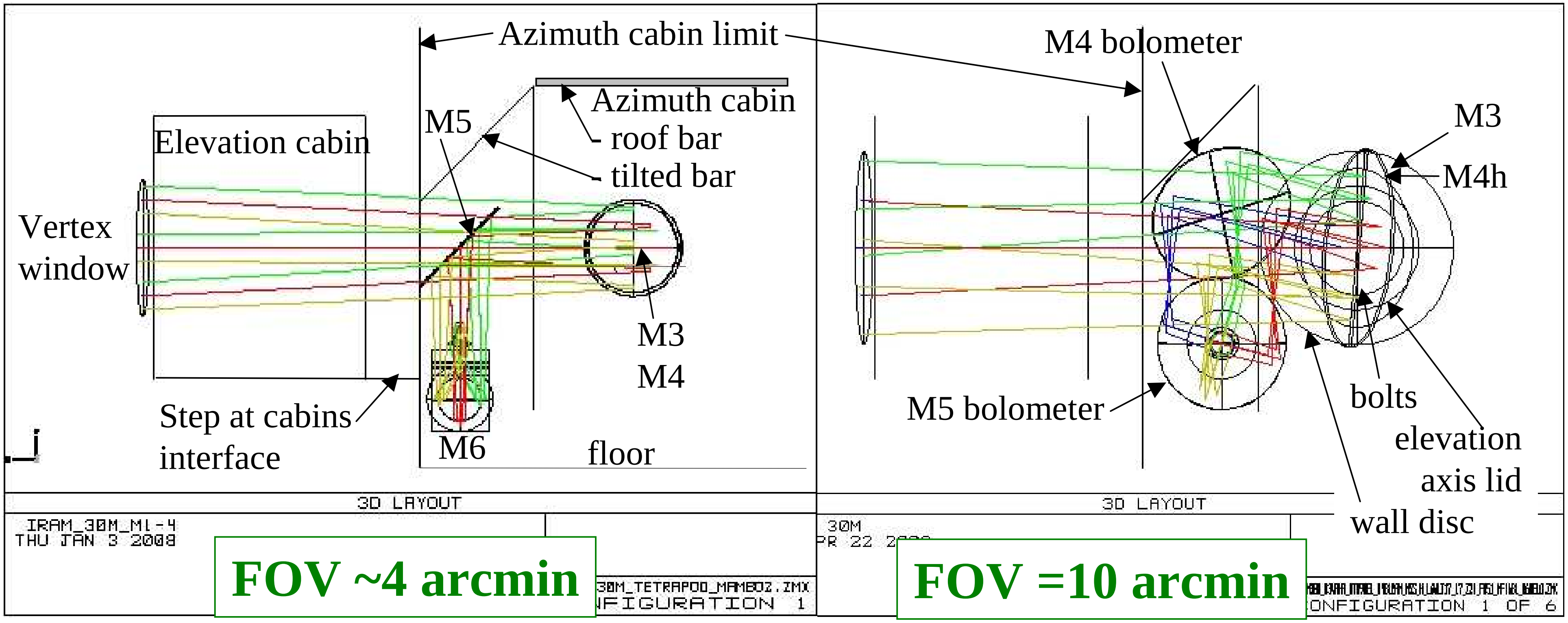


Bolometers optics: current vs proposed

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 **Proposed optics**



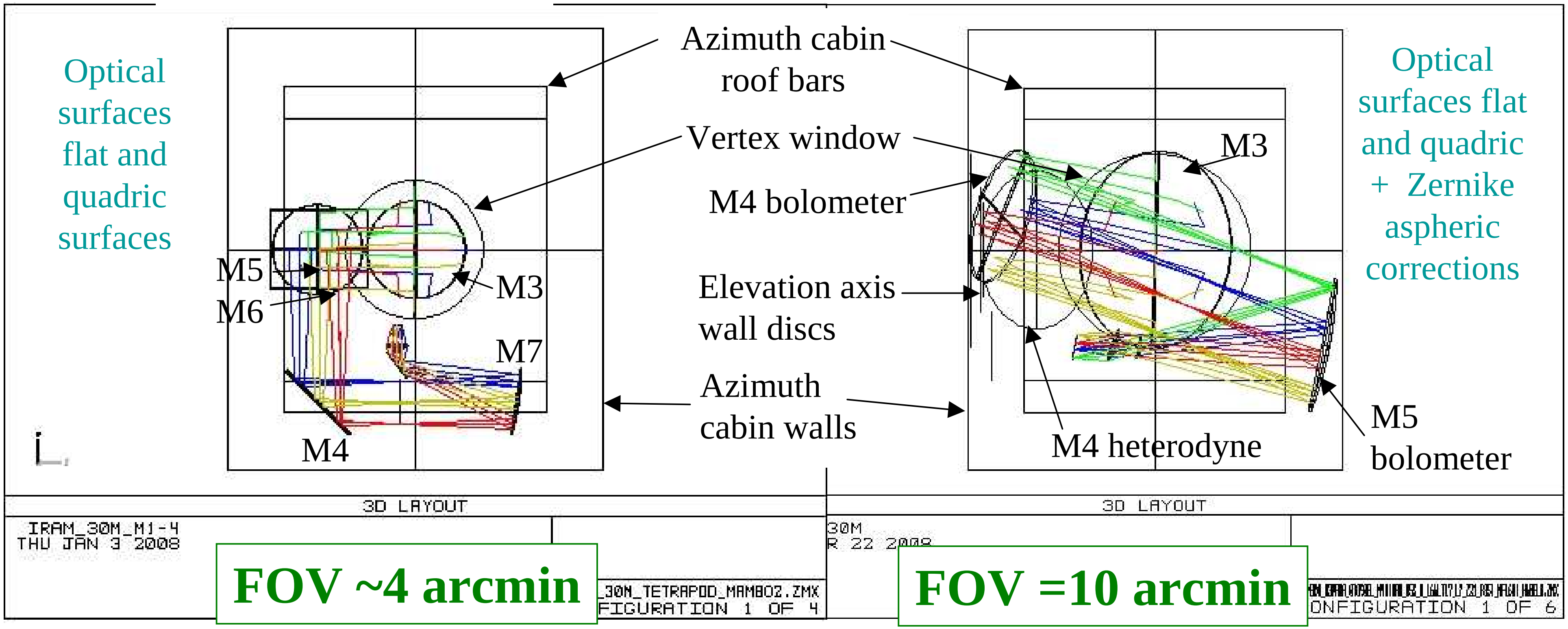
FOV ~4 arcmin **FOV =10 arcmin**

Bolometers optics: current vs proposed

Back 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 **Proposed optics**



Through focus spot diagram, bolometers

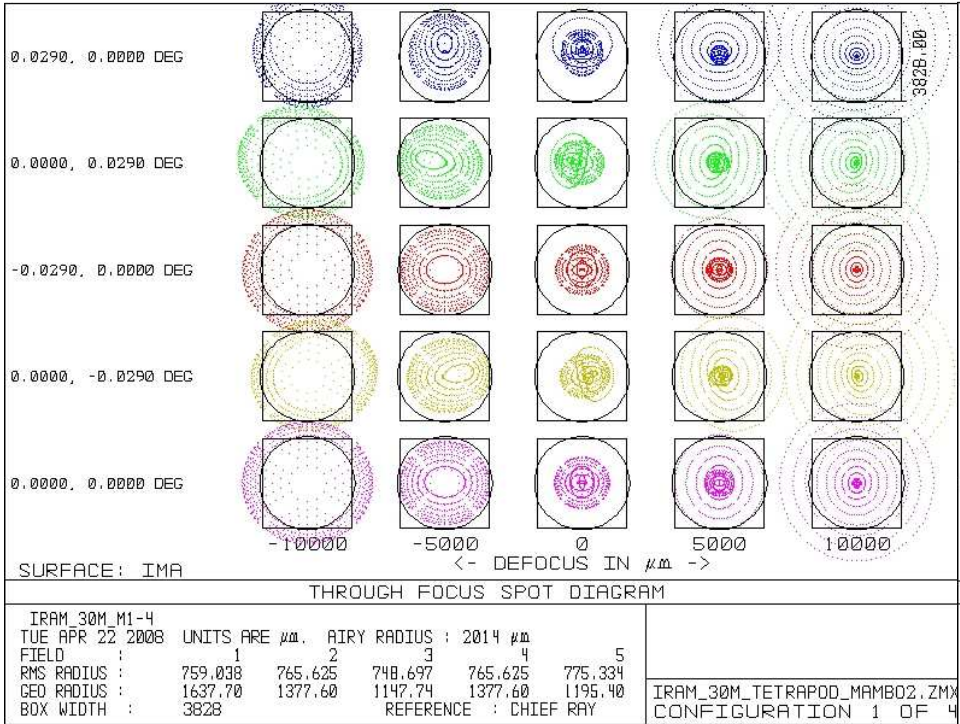
λ=0.87mm   Δfoc=5cm   circle = Airy disc

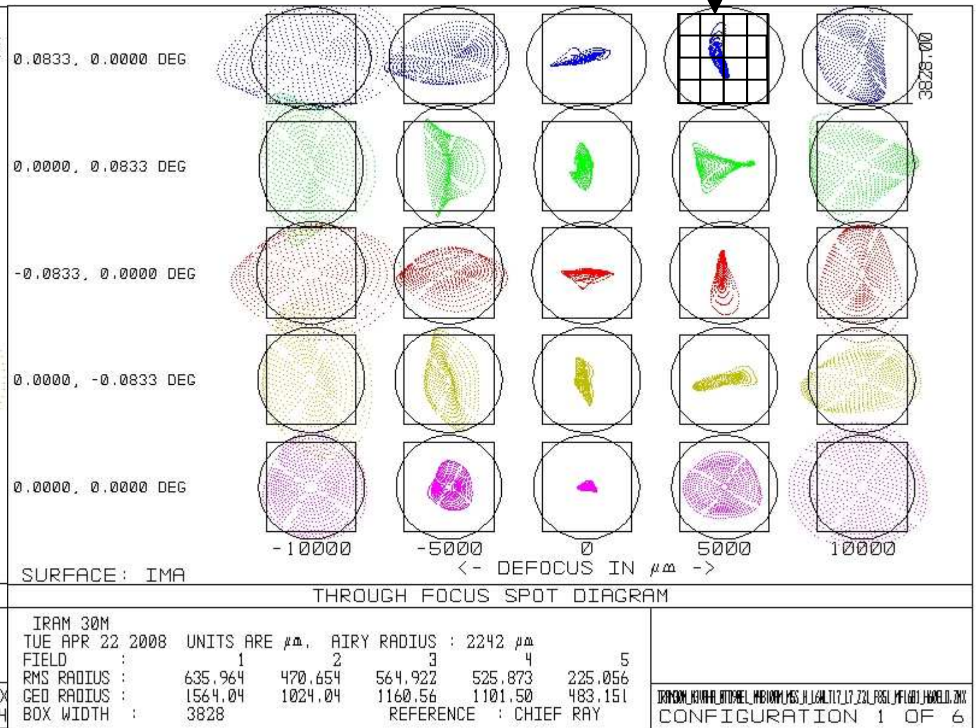
Blue = (+FOV/2;0), Green = (0;+FOV/2), Red = (–FOV/2;0), Yellow = (0;–FOV/2), Magenta = (0;0)

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

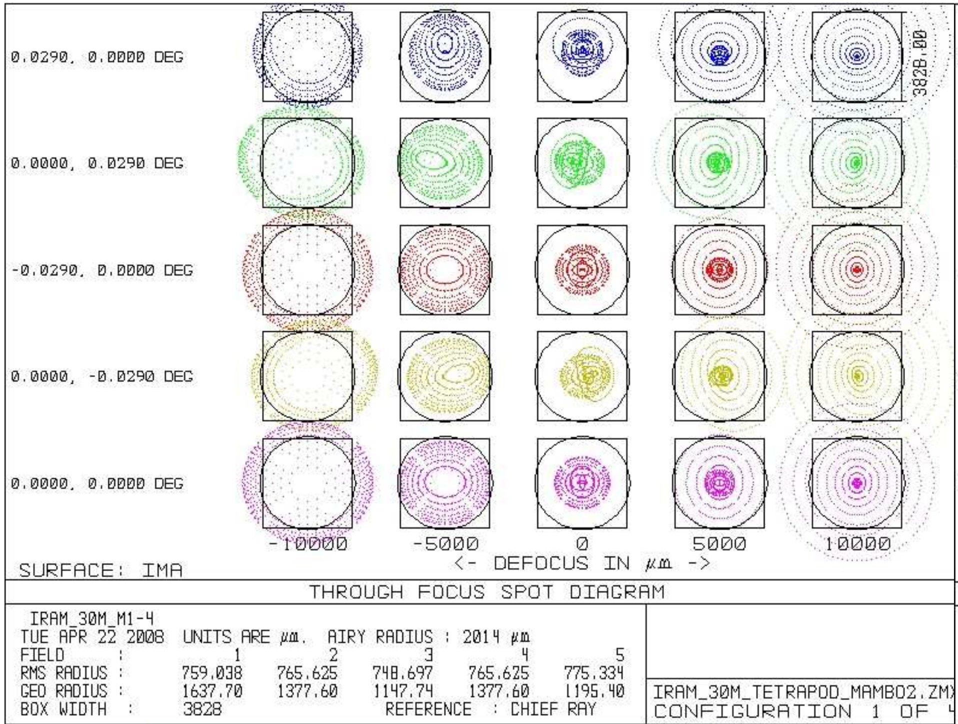
M2 shift = 0 mm. Acceptable M2 shift = ±0.8 mm → ΔF ~ 15 mm

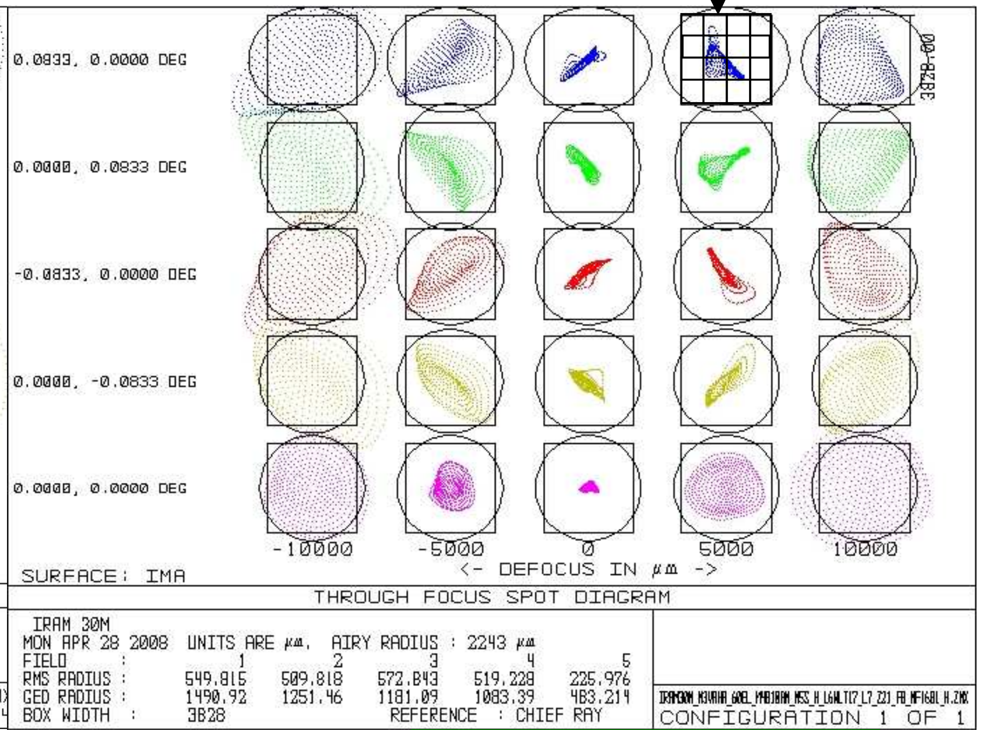
Through focus spot diagram, bolometers

λ=0.87mm   Δfoc=5cm   circle = Airy disc

Blue = (+FOV/2;0), Green = (0;+FOV/2), Red = (–FOV/2;0), Yellow = (0;–FOV/2), Magenta = (0;0)

Current optics (MAMBO 2)   **Proposed optics**   4×4 pixels to sample HPBW



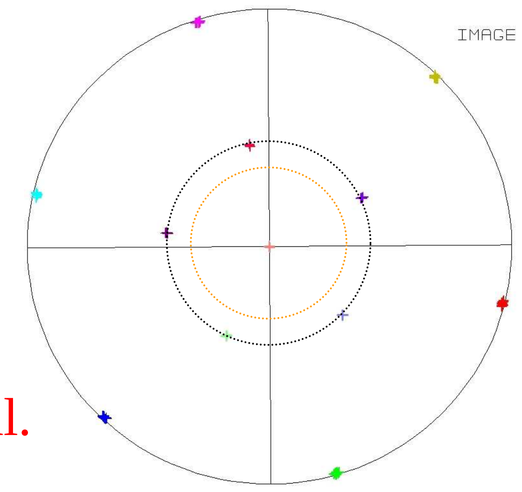


FOV 3.5 arcmin   **PSF = Airy * Aberration**   **FOV 10 arcmin**

M2 shift = 0.9 mm

M2 shift = 0 mm. Acceptable M2 shift = ±0.8 mm → ΔF ~ 15 mm

Conclusion



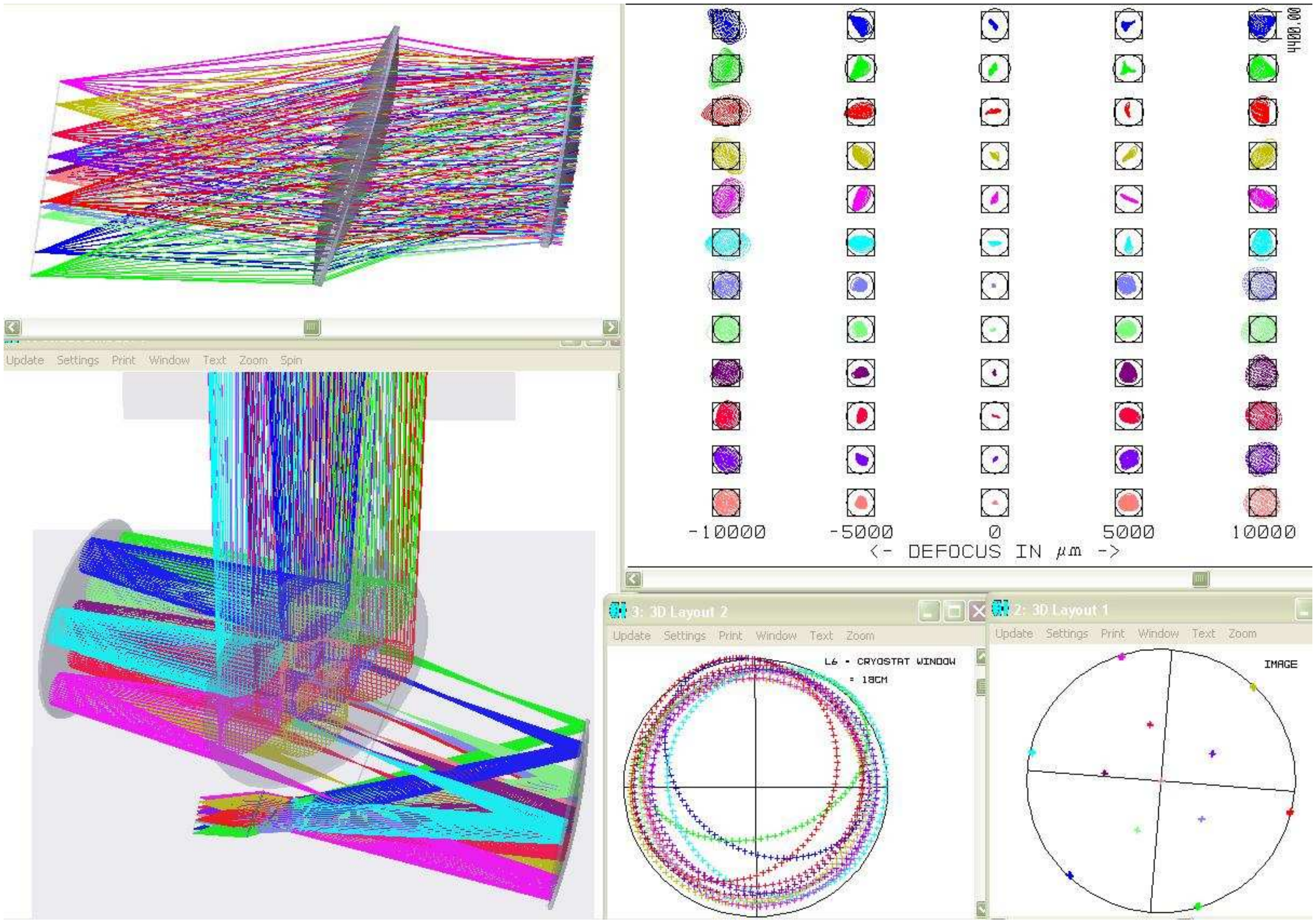
- Heterodyne optics ready for realization phase.
- Bolometer optics need refinement, but is ready for approval.
- FOV significantly increased while keeping everything in the receiver cabin → efficient, cheap and secured solution.
- New M3 must be mounted on 2 rotating axes (its own azimuth and elevation) → 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

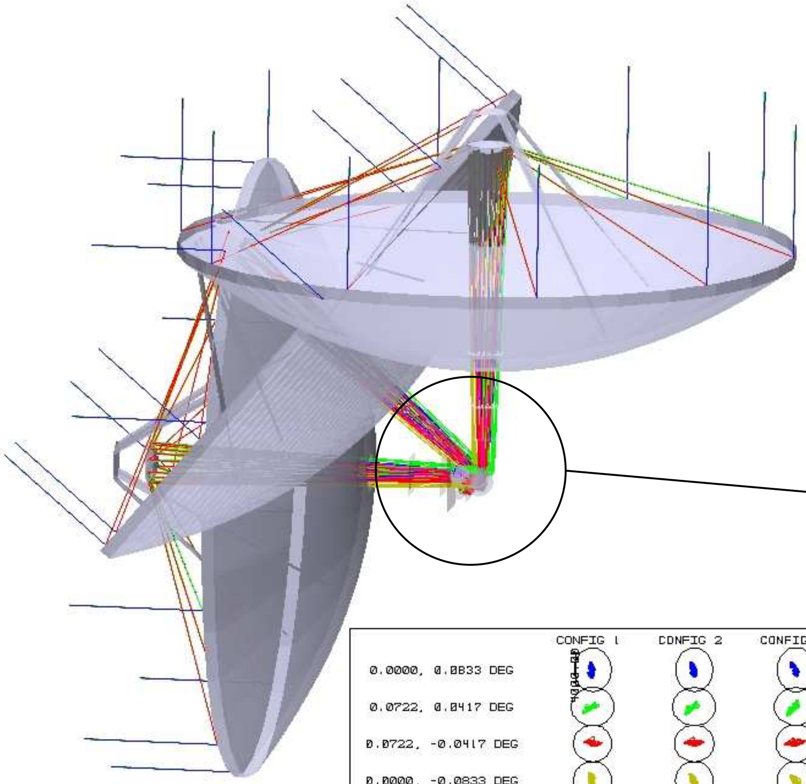
Short chronology of the study

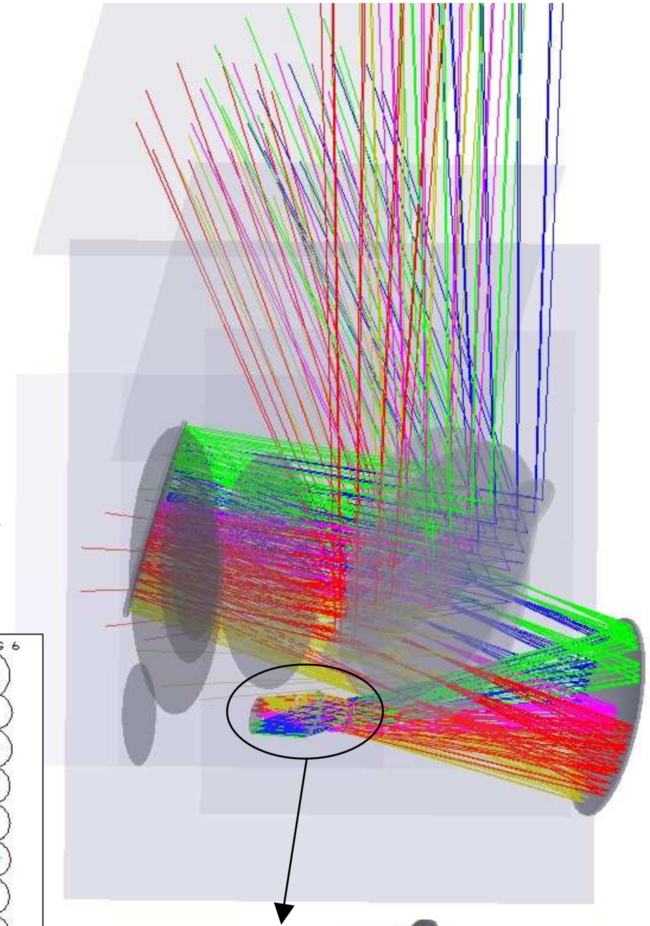
- Late 90s: Astrophysics and technology → large Fields Of View (FOV).
- 2003-2006: Early concepts to increase the 30m FOV (S.Navarro) → new optics in receiver cabin, elements in main dish (M1) structure, new subreflector (M2).
- Fall 06: Optical software, current system in Optalix and **Zemax**, FOV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

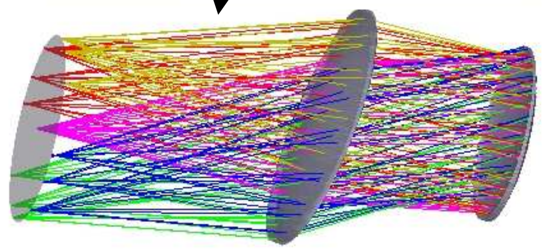
New bolo optics: multi fields shaded model, cryostat window, image spots,through-focus spot diagram

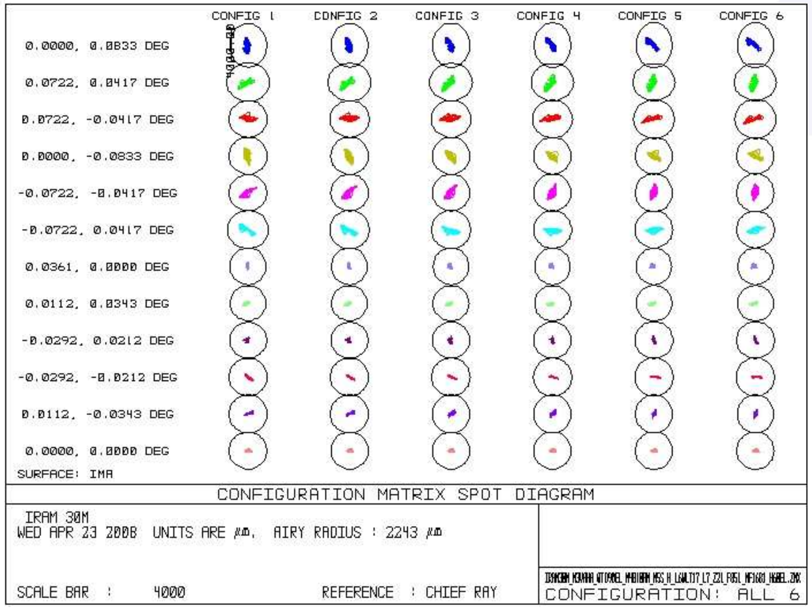


New bolo optics: behaviour with elevation change

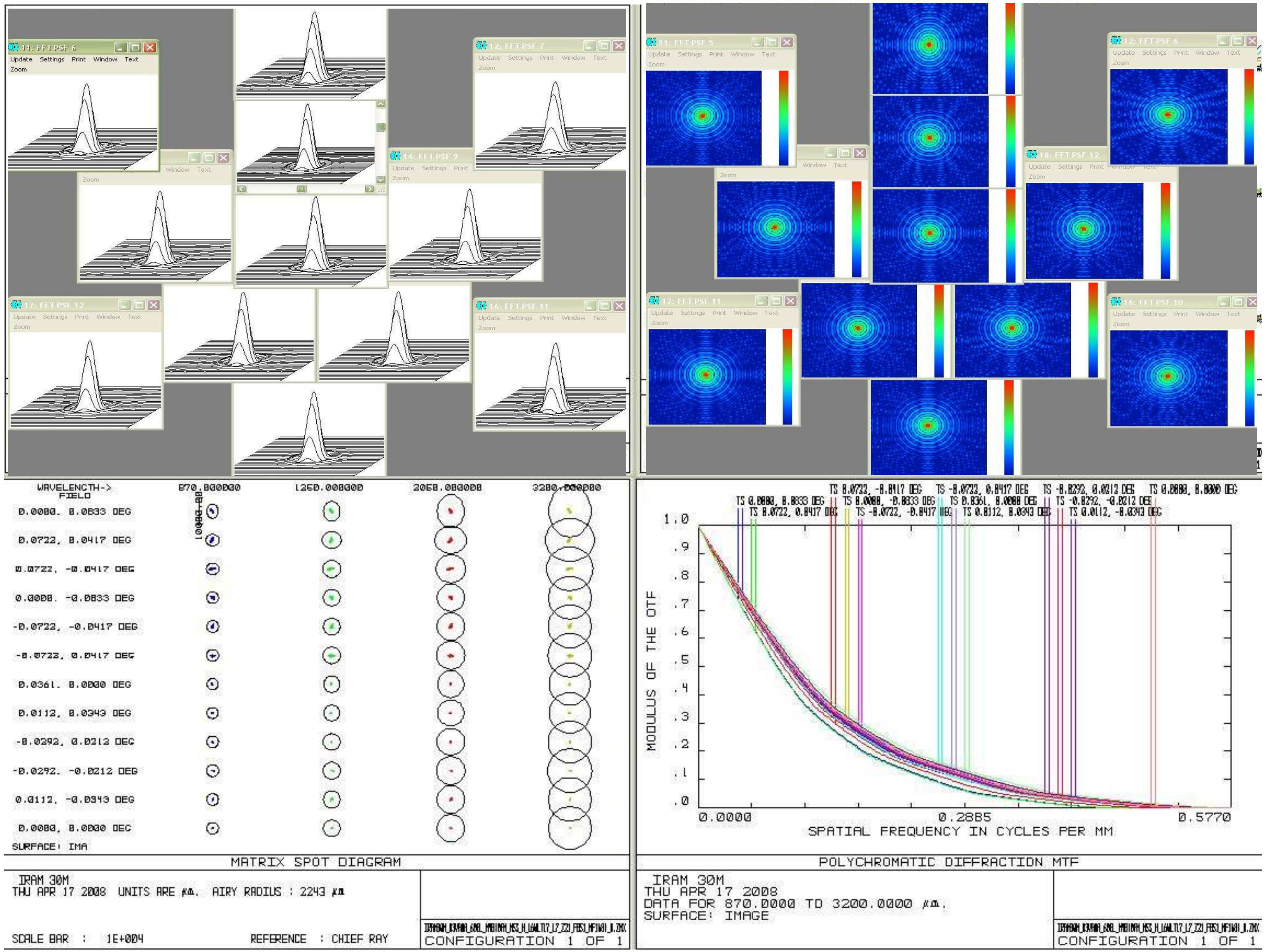




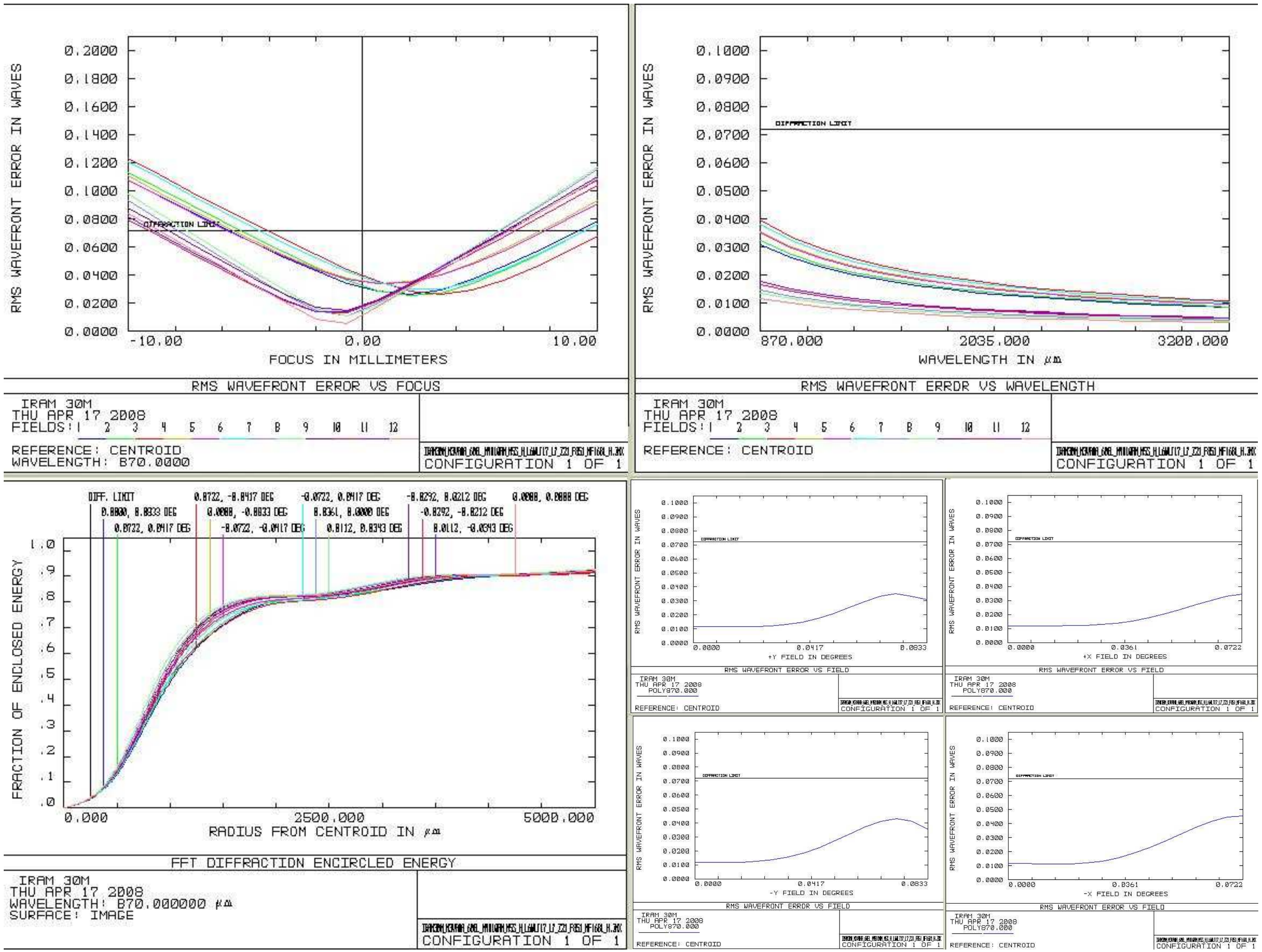




New bolo optics: FFT PSF (linear and log), Wavelengths spots diagrams, FFT MTF



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



Project planning