Optical Design & Analysis
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July 6th, 2004

Outline

- Optical Design
- Filters and Grisms
- Pupils
- Throughput Estimate
- Ghost Analysis
- Tolerance Analysis
- Critical Areas
- Task List

Requirements

- Multislit spectroscopy over a wide field low to moderate resolution
- Wide field imaging
- Slit mask exchange during daylight
- Illuminate a 2048x2048 HAWAII-2 array with adequate sampling

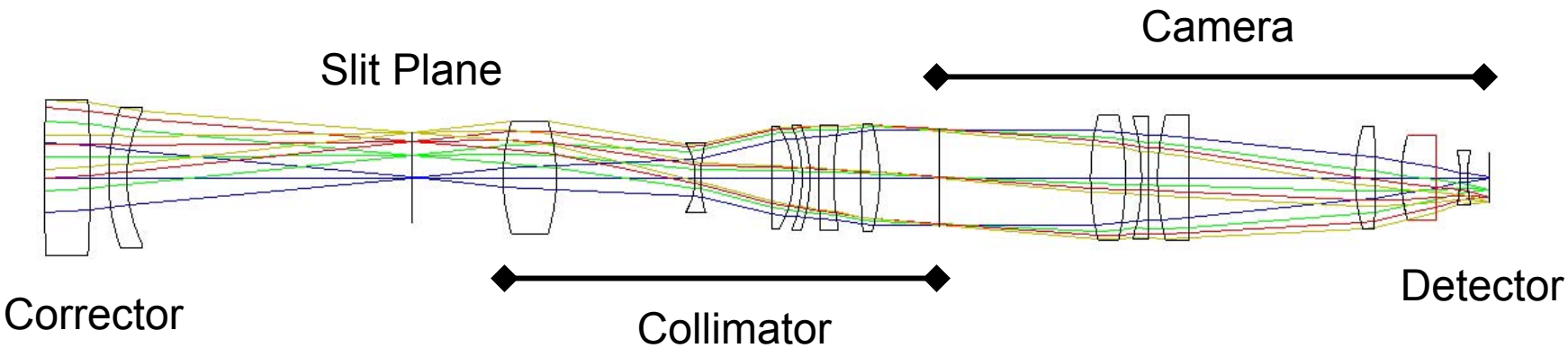
Heritage

- Two-dewar design from R. Elston
- Original MMIRS design by H. Epps
- Modifications by D. Fabricant

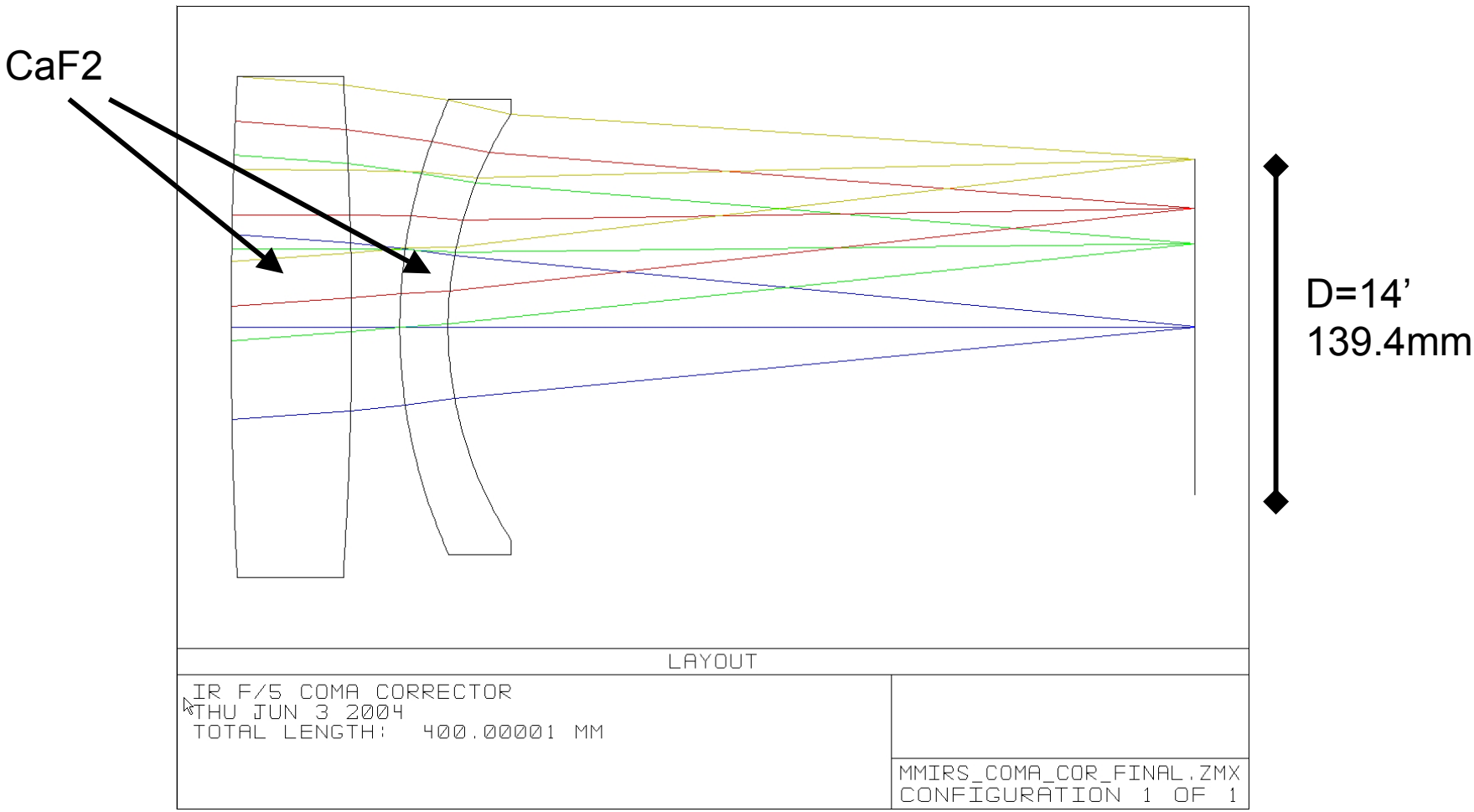
Overview

- Fully illuminated 7’x7’ field of view
- Multislit spectroscopy over 4’x7’
  - Some loss of spectral coverage outside 2’x7’
- J+H or H+K spectroscopy at R=1500
- J, H, or K spectroscopy at R=3000
- Y, J, H, K, J+H, and H+K filters

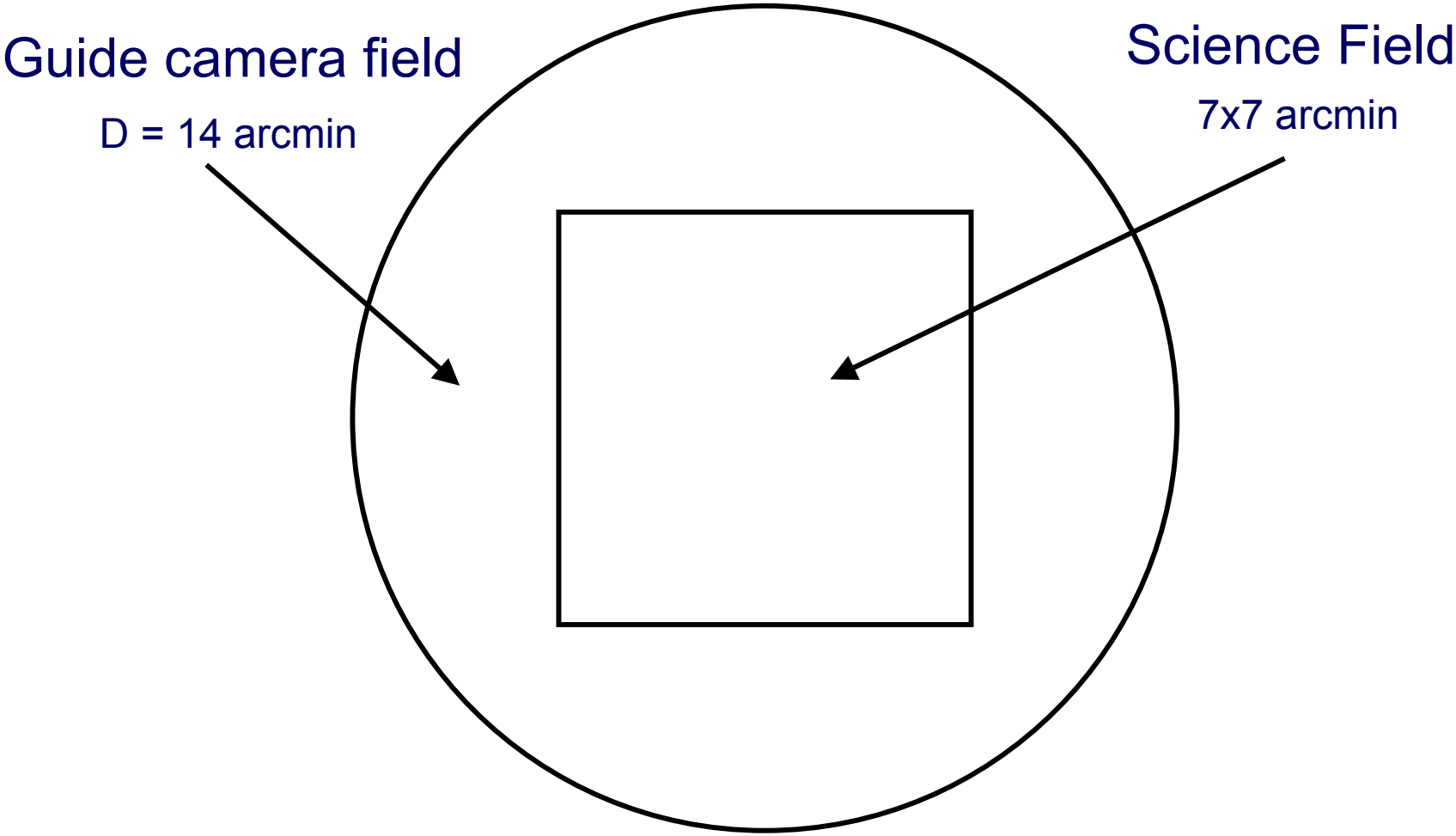
Optical Layout



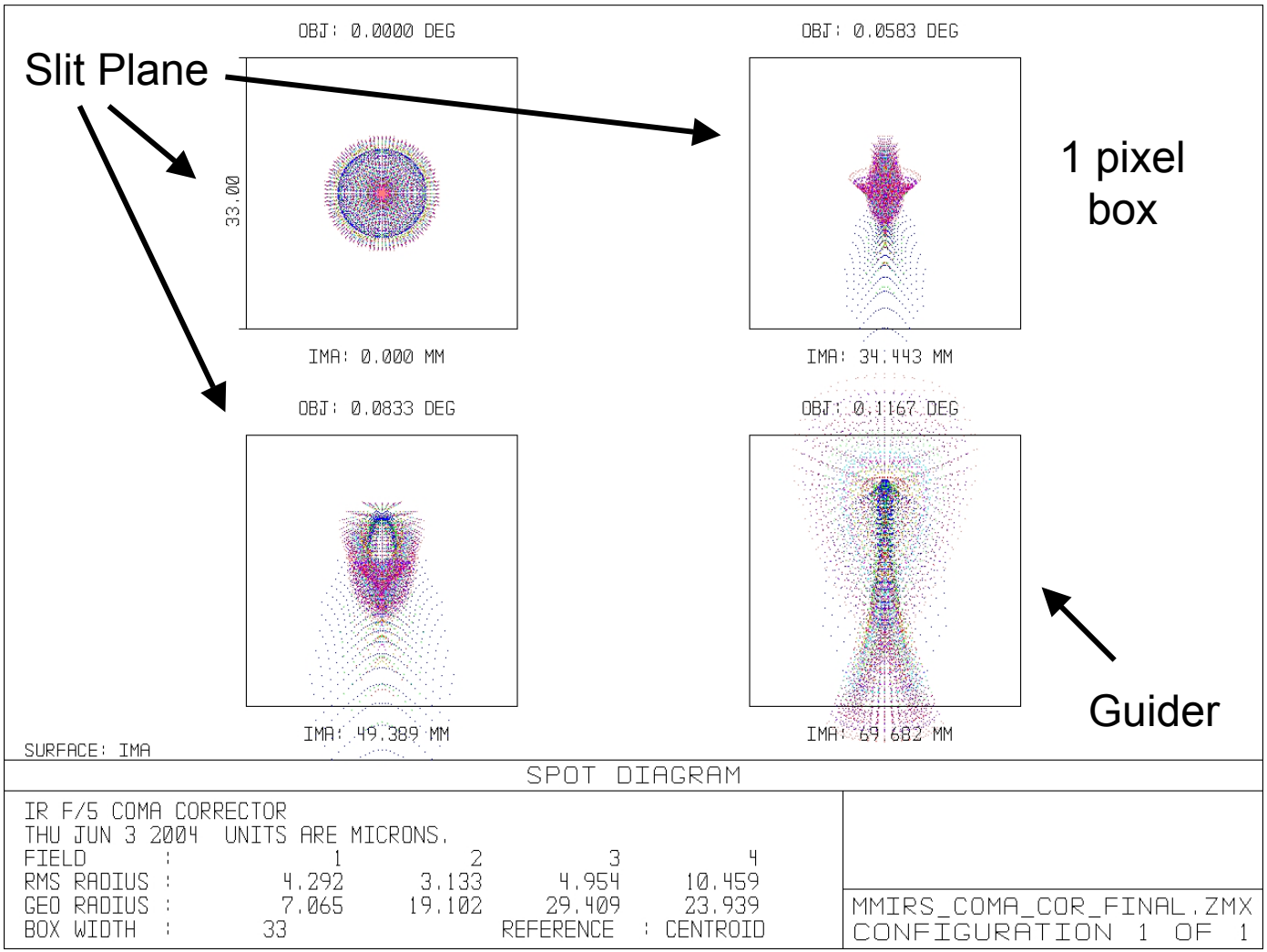
Corrector Detail



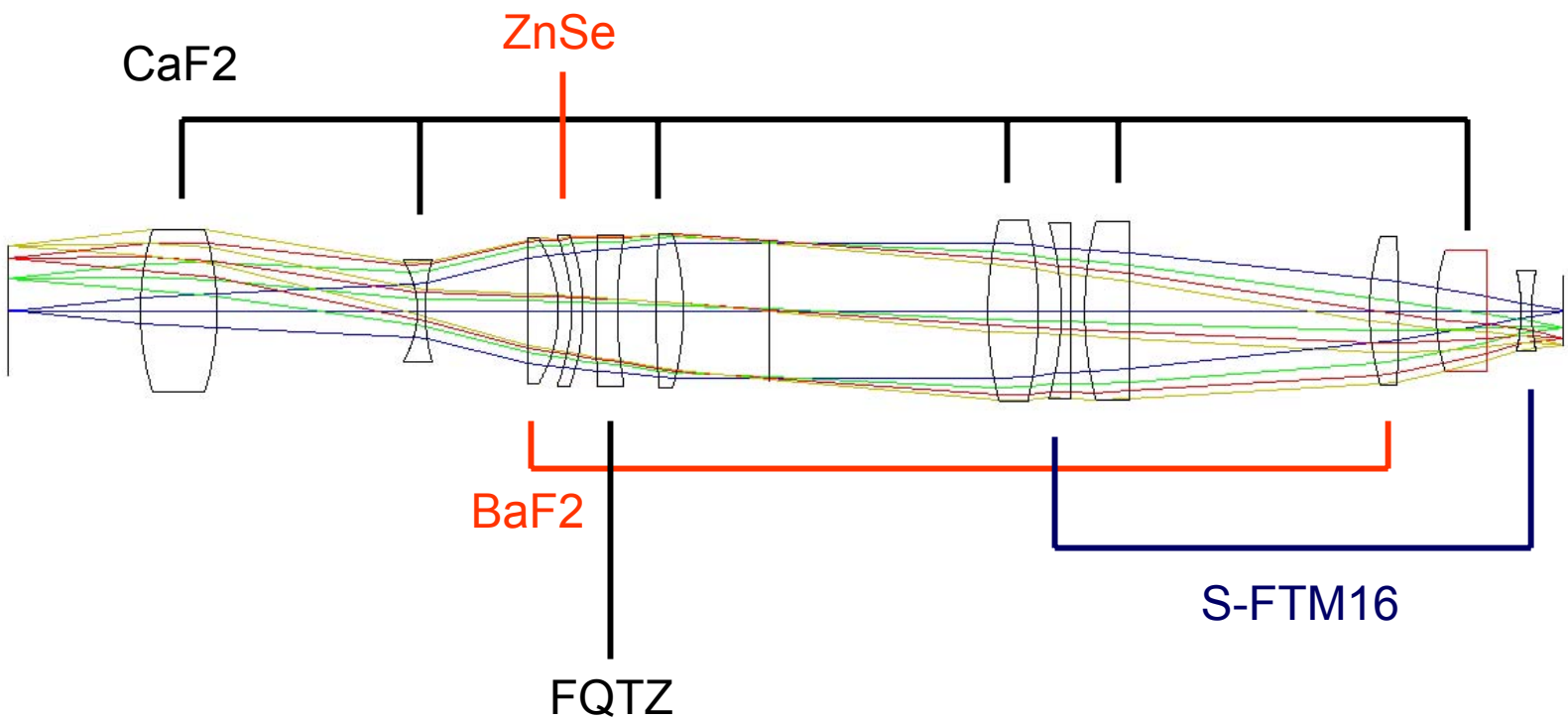
Full Corrected Field



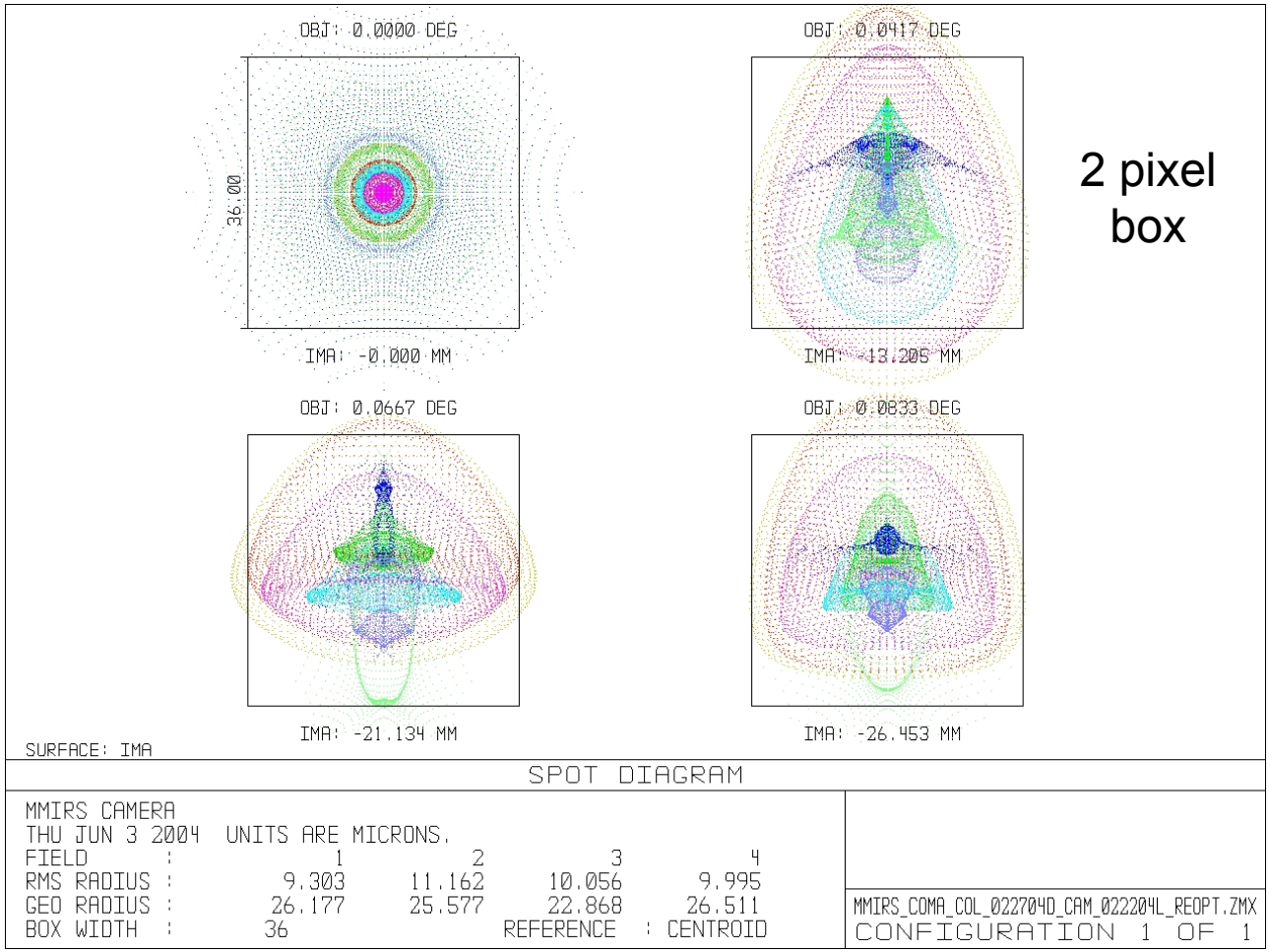
Corrector Performance



Collimator/Camera Detail



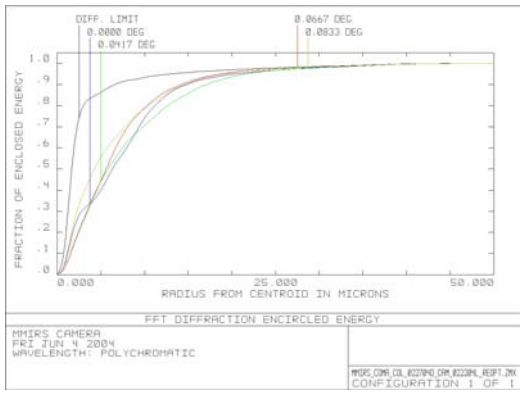
Collimator/Camera RMS Spots

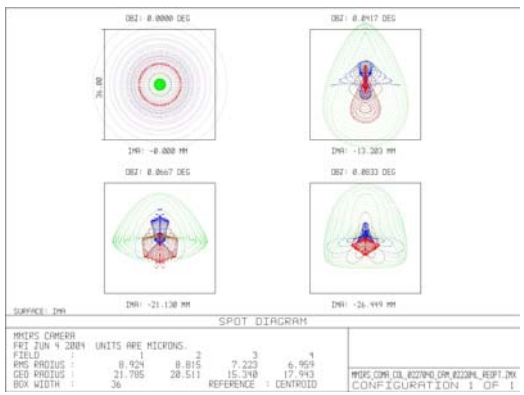


2 pixel box

Collimator/Camera Spots & EE

J





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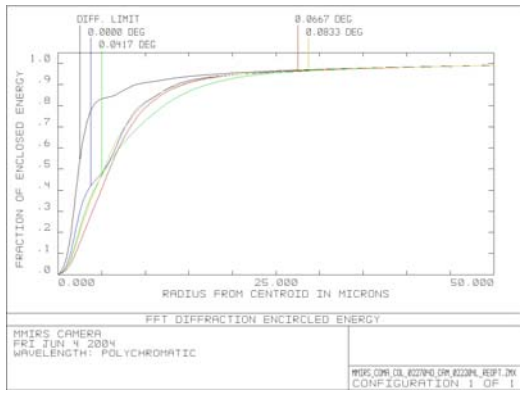
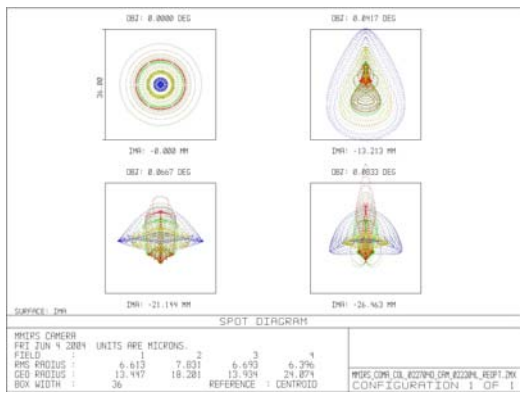
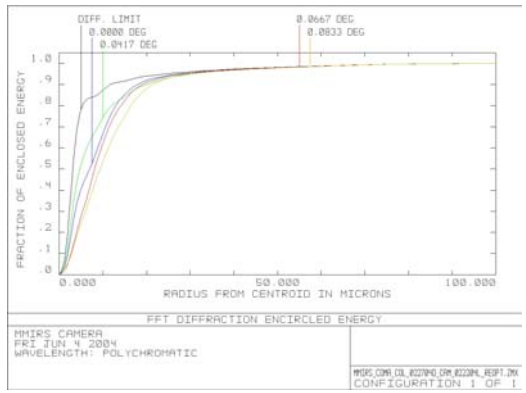
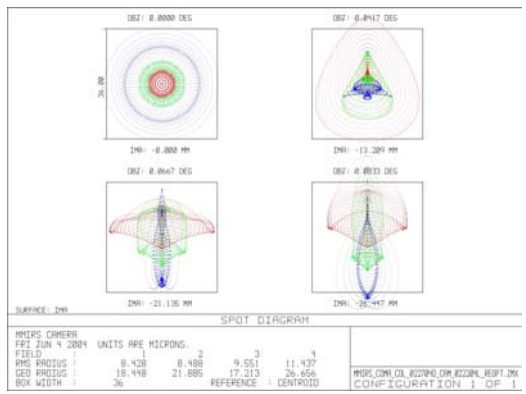




K





Filters

- 2 filter wheels with 6 positions each
- Y, J, H, K filters
- J+H and H+K filters for spectroscopy
- Large filters: 120mm diameter
- Identified a consortium to reduce cost
- Space for several future filters

Grisms

- Five Grisms on CaF2

Band	Angle	Grooves/μm	R	Flamingos-2	
J	41	0.23	3000		
H	41	0.175	3000		
K	41	0.13	3000		
J+H	18	0.094	1500	18	0.098
H+K	21	0.080	1500	21	0.082

Pupils

- Two pupils as compromise between throughput and thermal blocking
- Fixed, oversized pupil used by all observing modes
- Undersized pupils directly attached to K and H+K filters (one for each) to minimize thermal contamination

Throughput Estimate

- Imaging estimate: 40%
- Spectroscopy estimate: 30%
- Assumptions:
  - Surface losses: 2% per surface (28 surfaces in imaging mode) or 56%
  - Filter losses: 10% (2 more surfaces)
  - Pupil losses: 0-5%
  - Grism losses: 25% (3 more surfaces)
  - Detector QE 75%

Ghost Analysis

- Lenses assumed to be 1% reflective, detector 40%
- Ghosts minimized in optical design stage
- Imaging mode
  - Reflection off filters avoided by tilting filters
- Spectroscopy mode
  - Reduced transmission, although addition of surface at a conjugate point

Ghost Results

- Reflectance of (back of) slit masks should be minimized
- No ghost images identified
- Strongest ghost pupils are either very vignetted or uniformly fill the field

Tolerance

- Present design produces rms spot radius of 10 microns on the detector and 4 microns at the slit plane
- Goal: <14 micron spot radius at the detector and <10 micron spot radius at the slit plane

Error Budget

- Lens constraints:
  - surface radii and quality
  - surface decenter and tilt
  - element thickness
- Element constraints:
  - element decenter and tilt
  - spacing between elements
  - group decenter and tilt

Input Lens Constraints

- Radii: 0.1%
- Flats: 2 fringes
- Surface Irregularities: 0.5 fringes
- Thickness 0.05mm
- Surface tilt: 0.01mrad
- Surface decenter: 0.01mm

Input Element/Group Constraints

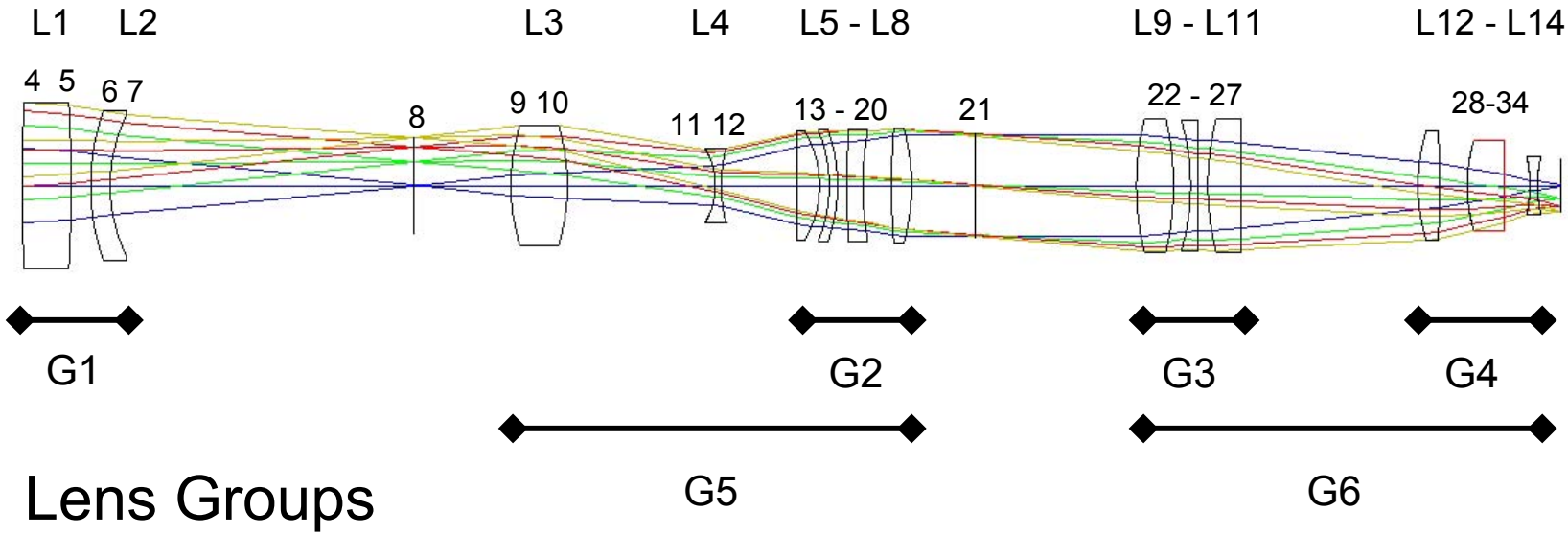
- Spacing: 0.1mm
- Element tilt: 0.1mrad
- Element decenter: 0.05mm
- Group tilt: 0.2mrad
- Group decenter: 0.1mm

Analysis Method

- Inverse Sensitivity analysis in ZEMAX to compute first pass tolerance budget
- Identify critical constraints and rebalance the tolerance budget
- Set goal of <14 micron spot radius
- Run Monte Carlo realizations
- Determine mechanical constraints that achieve goal with 90% probability

Tolerance Simulations

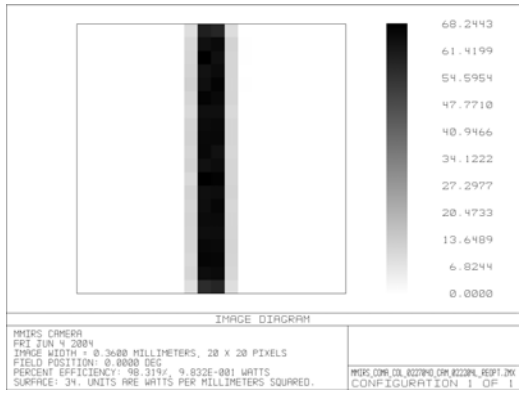
Lenses and Surfaces

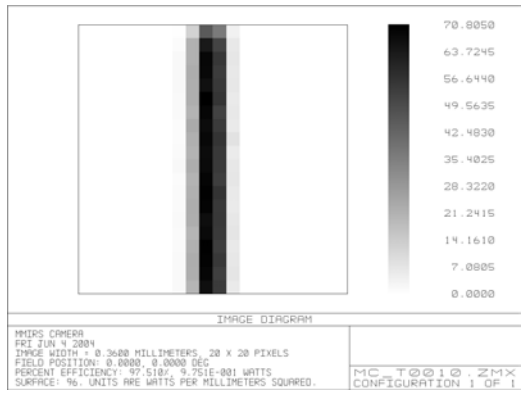


Lens Groups

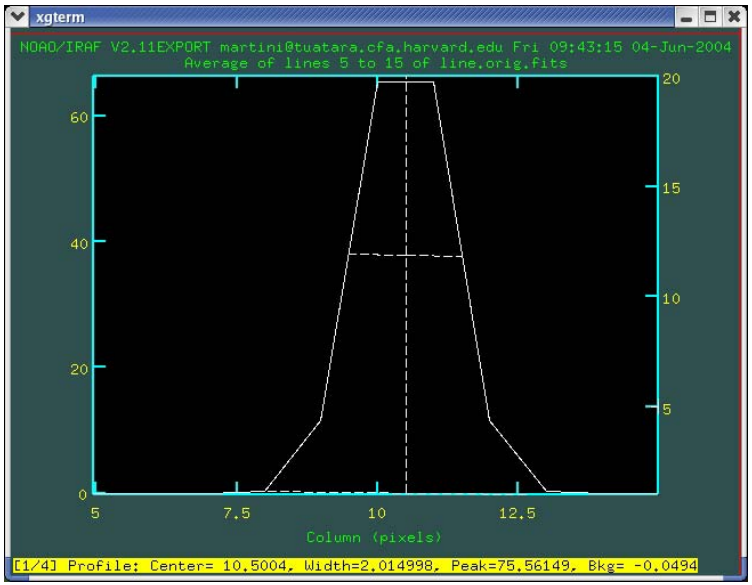
Potential degradation

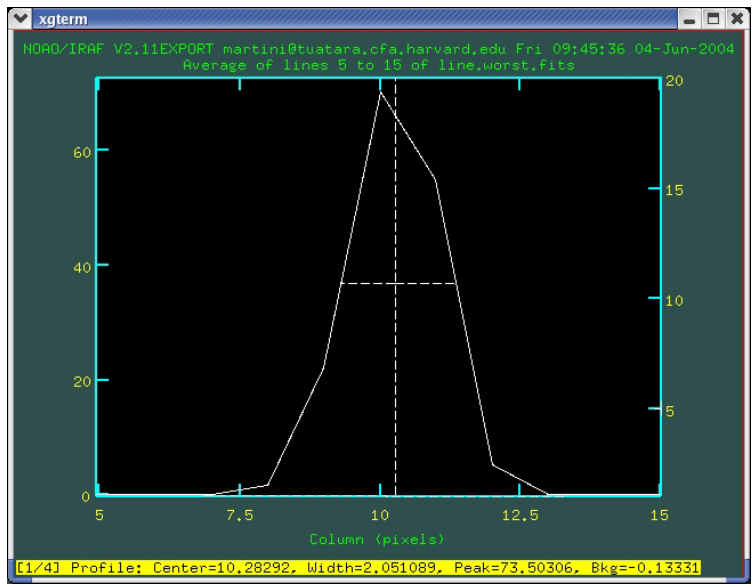
As designed





"Worst case"





Mechanical Requirements

- Lens spacings: several require 0.05mm
- Lens tilts: many require 0.1mrad; one 0.05 mrad (although most closely packed)
- Lens decenter: several require 0.025mm
- Group tilt: several require 0.1mrad
- Group decenter: several require 0.05mm; one 0.025mm

Critical Areas

- Lens spacing: L4-L5, L9-L10, L13-L14
- Lens tilt: L3, L4, L10-L13
- Lens decenter: L4, L5
- Group tilt: G2, G3, G4, G6
- Group decenter: G2

Task List

- Identify vendors for optics and coatings
- Finalize design with melt sheet data
- Test plate fitting to reduce costs
- Thermal gradient sensitivity study
- Mechanical deflection sensitivity study
- Finalize selection of Grisms
- Obtain filters
- Stray light analysis (in progress)

Summary

- “Penultimate” optical design in hand
- Lens sizes and materials are available from multiple vendors
- Filters and Grisms are attainable
- Ghost images and pupils are negligible
- Tolerance analysis has identified critical areas for consideration in mechanical design