Near Infrared Camera and Fabry-Perot Spectrometer (NIC-FPS) Optical Design Summary

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Near Infrared Camera and Fabry-Perot Spectrometer (NIC-FPS) Optical Design Considerations

- The NIC-FPS will provide near IR imaging over a wavelength range of 0.85 to 2.5 microns and medium resolution F-P spectroscopy in the 1.4 to 2.3 micron range.
  - The instrument will be used on the f/10 Nasmyth port of the Astrophysical Research Consortium (ARC) 3.5-meter telescope.
- Pixel Scale and FOV
  - 0.28 ± 0.02 arcsec/pixel for 1024 x 1024 HgCdTe detector (18.5 µm pixel pitch)
  - FOV of 4.8’ x 4.8’ (0.08° x 0.08°)
- The QE plots of the Hawaii-1 device indicate short wavelength cutoff at wavelength of 0.85µm.
- Driving Optical Design Considerations
  - Minimized and well characterized image distortion.
  - High throughput (> 60% at 2 microns)
  - F-P etalon of 50mm clear aperture
    - Desire to fill etalon nominally to a maximum diameter of 45 mm.
  - Long distance pupil relief in collimated space to accommodate F-P etalon, filter wheels, and desired “U” fold mirror configuration.

First Order Optical Design Parameters

ARC Telescope Parameters

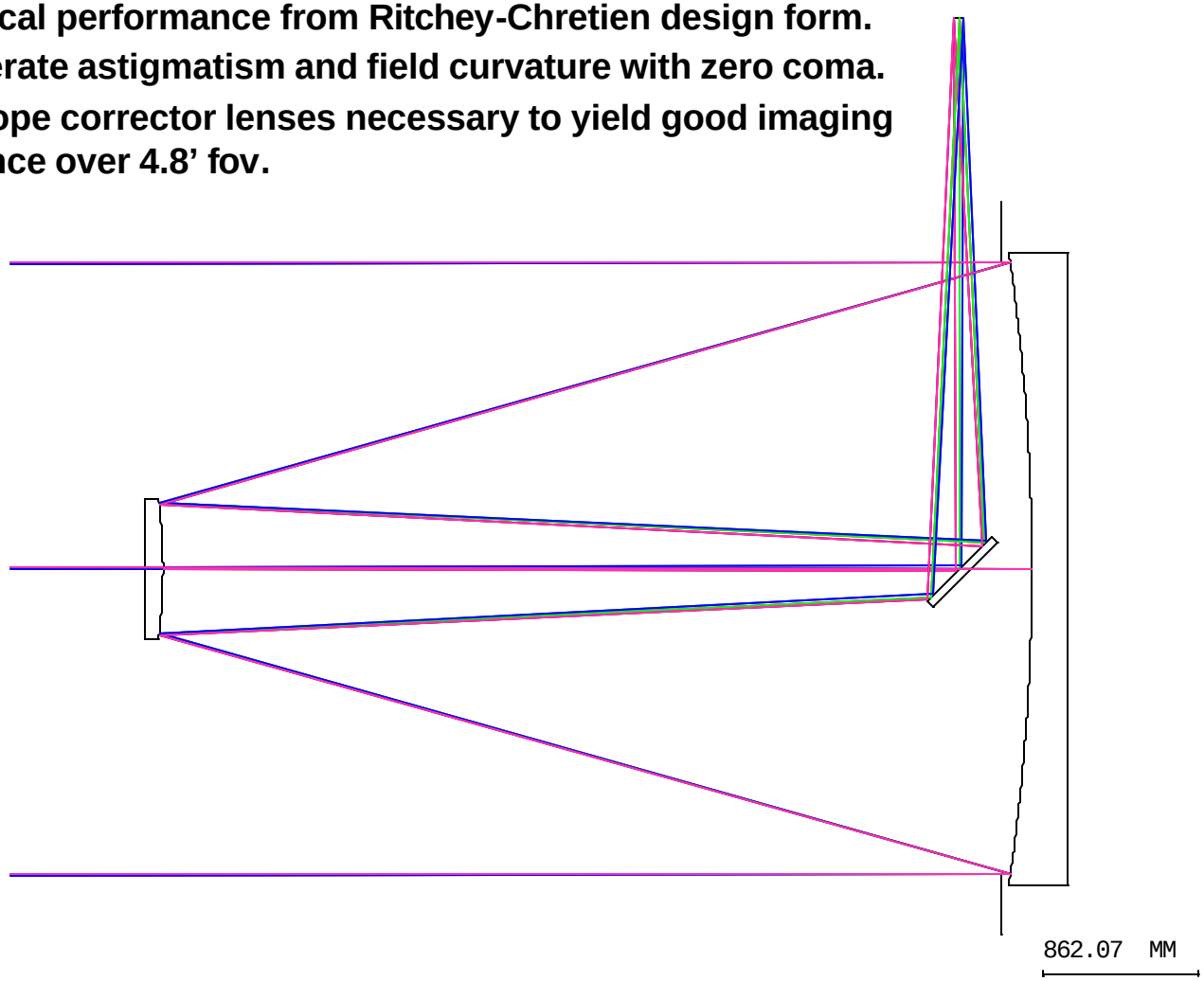
Entrance Aperture Diameter	3404.6 mm
Entrance Stop Placement	Primary Mirror
Central Obscuration	780.0 mm diameter
F/#	F/10.35

NIC-FPS Parameters

Optical Design Parameter	Design Value
Wavelength Range	0.85 – 2.5 µm
Pixel Scale	0.28 ± 0.02 arcsec/pixel (1024 x 1024 HgCdTe)
Pixel Pitch	18.5 µm
System Effective Focal Length	13567.6 mm
System F/#	3.985
System Field-of-View	± 2.4’ (± 0.04°) ± 3.4’ (± 0.0566°) at corners
NIC-FPS Internal Pupil Diameter	Driven by Etalon (40 mm)
Collimator Magnification Factor	85.115X
Pupil Relief Distance to Camera Lens 1	330 mm
Wavefront Performance	Diffraction Limited @ 1.7 µm (out to detector edge)

ARC 3.5 meter Telescope Layout

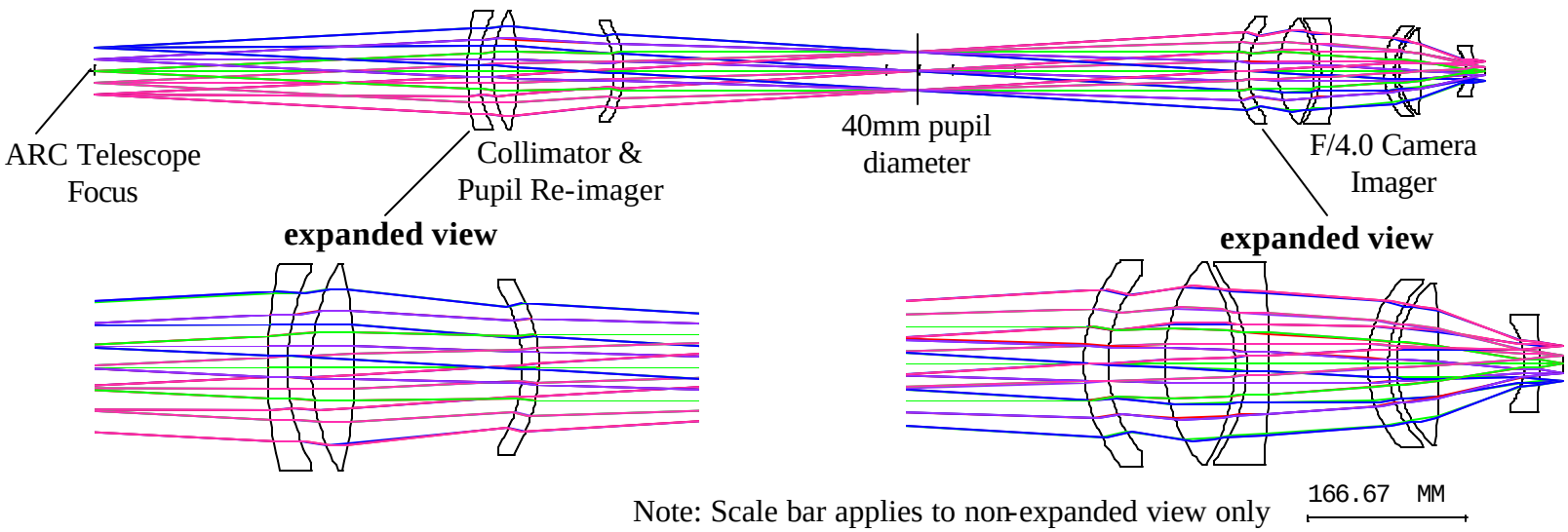
- **Good optical performance from Ritchey-Chretien design form.**
  - **Moderate astigmatism and field curvature with zero coma.**
- **No telescope corrector lenses necessary to yield good imaging performance over 4.8' fov.**



3.5m ARC Telescope Scale: 0.03 2

Current Design Layout (Unfolded)

9 refractive optical elements. (all spherical)
Materials used : Fused Silica, CaF2, ZnSe
Overall length = 1451 mm (57.13 inches)
Camera length = 260 mm (10.24 inches)
T_{avg} 0.85-2.5µm = 80% based on preliminary Janos data of BBAR coating performance
96% average for ZnSe (1.5% avg reflection per surface)
98% average for CaF2 & Fused Silica (1.0% avg reflection per surface)
Design is flexible to folding for packaging considerations.



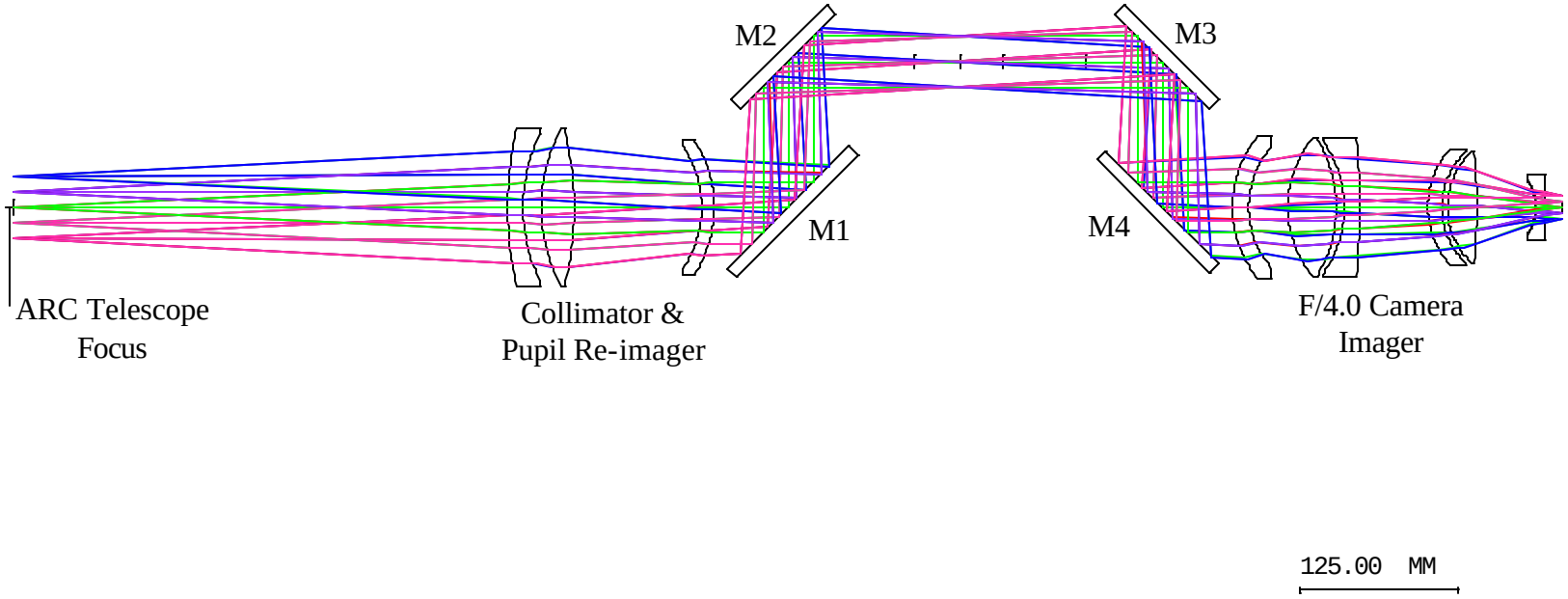
Note: Scale bar applies to non-expanded view only

NIC-FPS Refractive Option (Unfolded) Scale: 0.15 2

Current Design Layout (Folded "U" Configuration)

Folded configuration with separate camera and etalon channels (not shown) allows etalon to remain fixed while system is folded about M1 and M4.
Layout assumes 115 mm path length between Mirror 1 and Mirror 2 (and Mirror 3 and Mirror 4) to accommodate 10 element filter wheel.
Overall length = 1221 mm (48.07 inches)
T_{avg} 0.85-2.5µm = 73.8% based on preliminary Janos data of BBAR coating performance & protected gold coating on mirrors.

96% average for ZnSe (1.5% avg reflection per surface)
98% average for CaF2 & Fused Silica (1.0% avg reflection per surface)
98% average per mirror (protected gold coating)



NIC-FPS Refractive Option (Folded) Scale: 0.20 2

Nominal Optical Design Performance Values

Encircled Energy Requirements (for OTA+instrument) maintain good image quality in the best seeing conditions at APO.

Encircled Energy Requirement and Performance values are reported over a 6.3 arcmin diameter field. (6.3 arcmin diameter fov is 75% of the way from 4.8 arcmin diameter circle to the FPA corner at 6.8 arcmin.) (This includes 95% of the FPA area.)

0.85 microns, Seeing Limited

Encircled Energy Diameter	Requirement	Performance	Margin
0.56 arcsec	80%	95%	15%
0.80 arcsec	85%	96%	11%
1.00 arcsec	90%	98%	8%

1.00 microns

Encircled Energy Diameter	Requirement	Performance	Margin
0.56 arcsec	80%	92%	12%
0.80 arcsec	85%	95%	10%
1.00 arcsec	90%	96%	6%

1.50 microns

Encircled Energy Diameter	Requirement	Performance	Margin
0.56 arcsec	80%	87%	7%
0.80 arcsec	85%	93%	8%
1.00 arcsec	90%	95%	5%

Nominal Optical Design Performance Values (continued)

2.00 microns, Diffraction Limited

Encircled Energy Diameter	Requirement	Performance	Margin
0.56 arcsec	70%	82%	12%
0.80 arcsec	80%	90%	10%
1.00 arcsec	90%	94%	4%

2.50 microns, Diffraction Limited

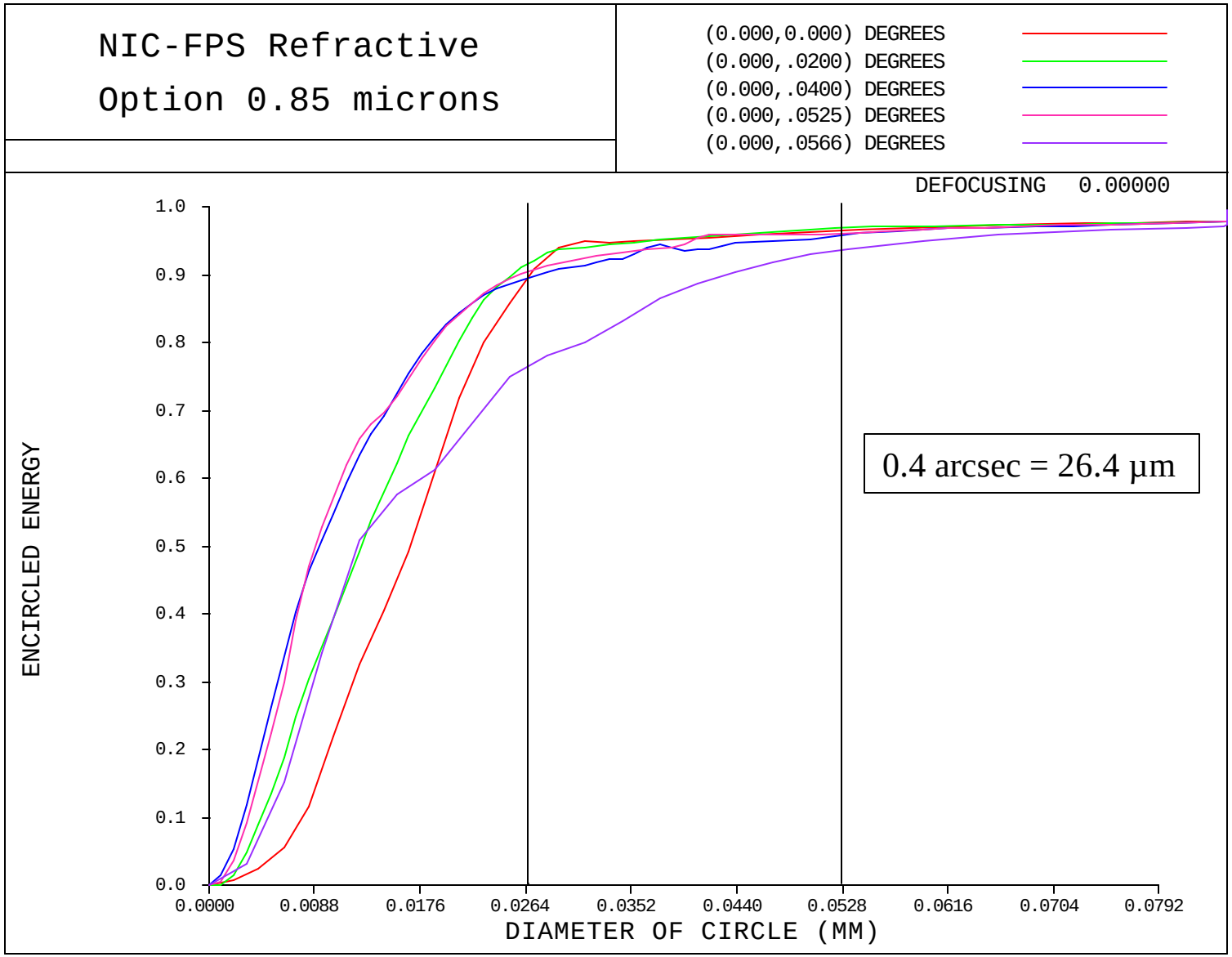
Encircled Energy Diameter	Requirement	Performance	Margin
0.56 arcsec	60%	73%	13%
0.80 arcsec	75%	86%	11%
1.00 arcsec	85%	93%	8%

Transmission:	Requirement	Performance	Margin
	> 60% at 2 microns	80% Unfolded Nominal	20%
		73.8% Folded Including Mirrors	13.8%

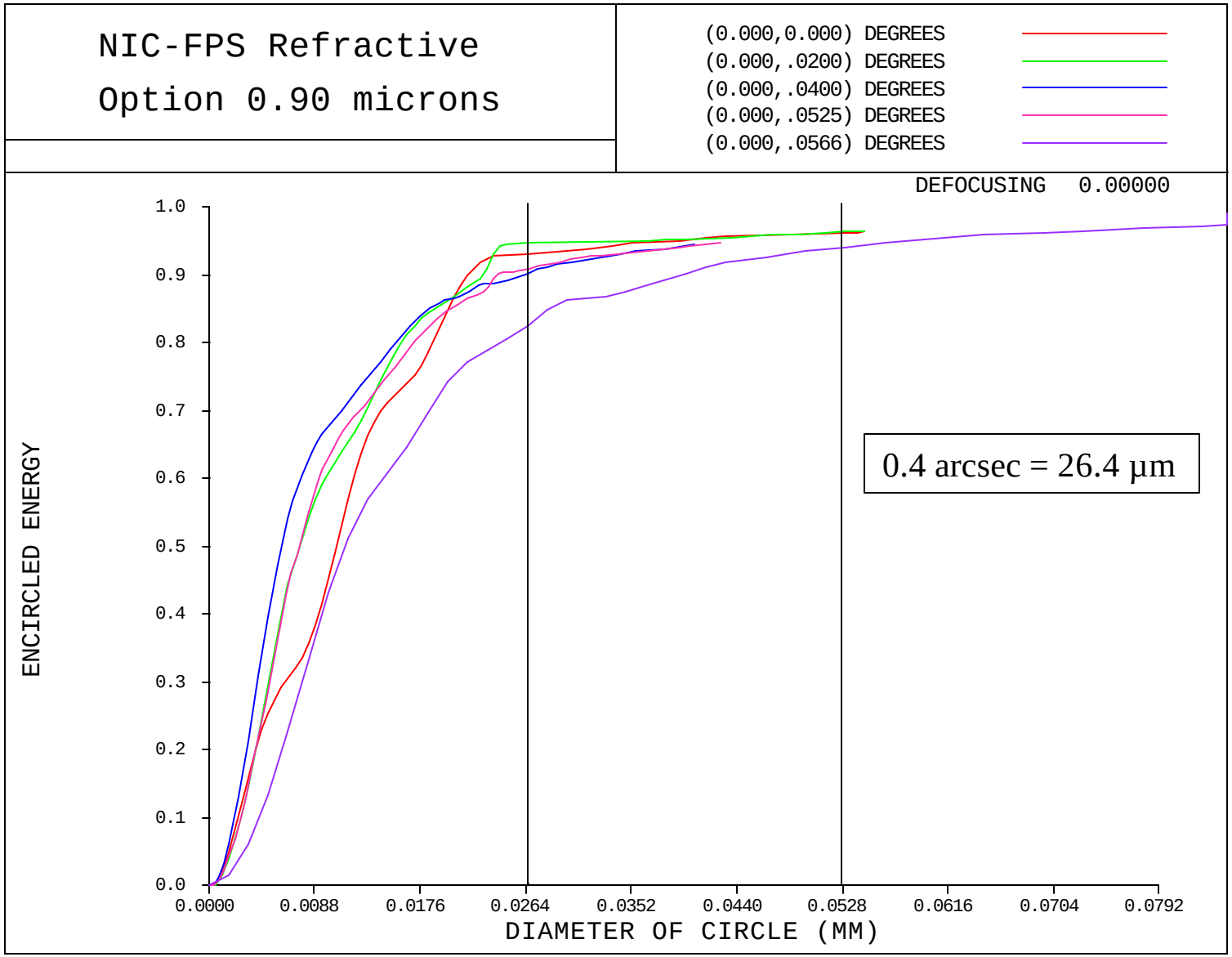
Vignetting:	Requirement	Performance	Margin
	< 3% center-to-corner	None in nominal design	3%

Geometric Distortion:	Requirement	Performance	Margin
	< 3% center-to-corner	< 1.2% center-to-corner	1.8%

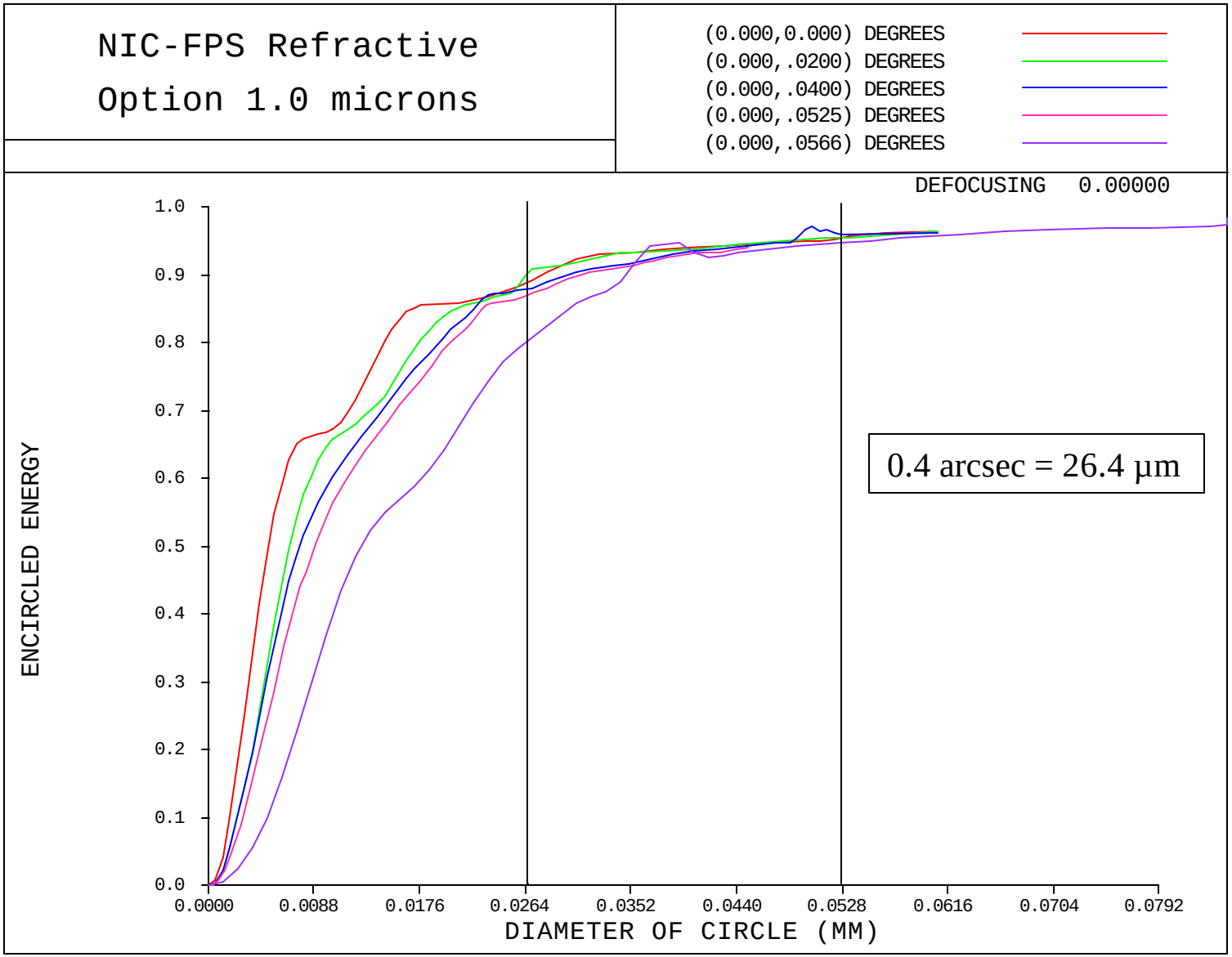
Encircled Energy Plots (Geometric + Diffraction)
0.85 µm



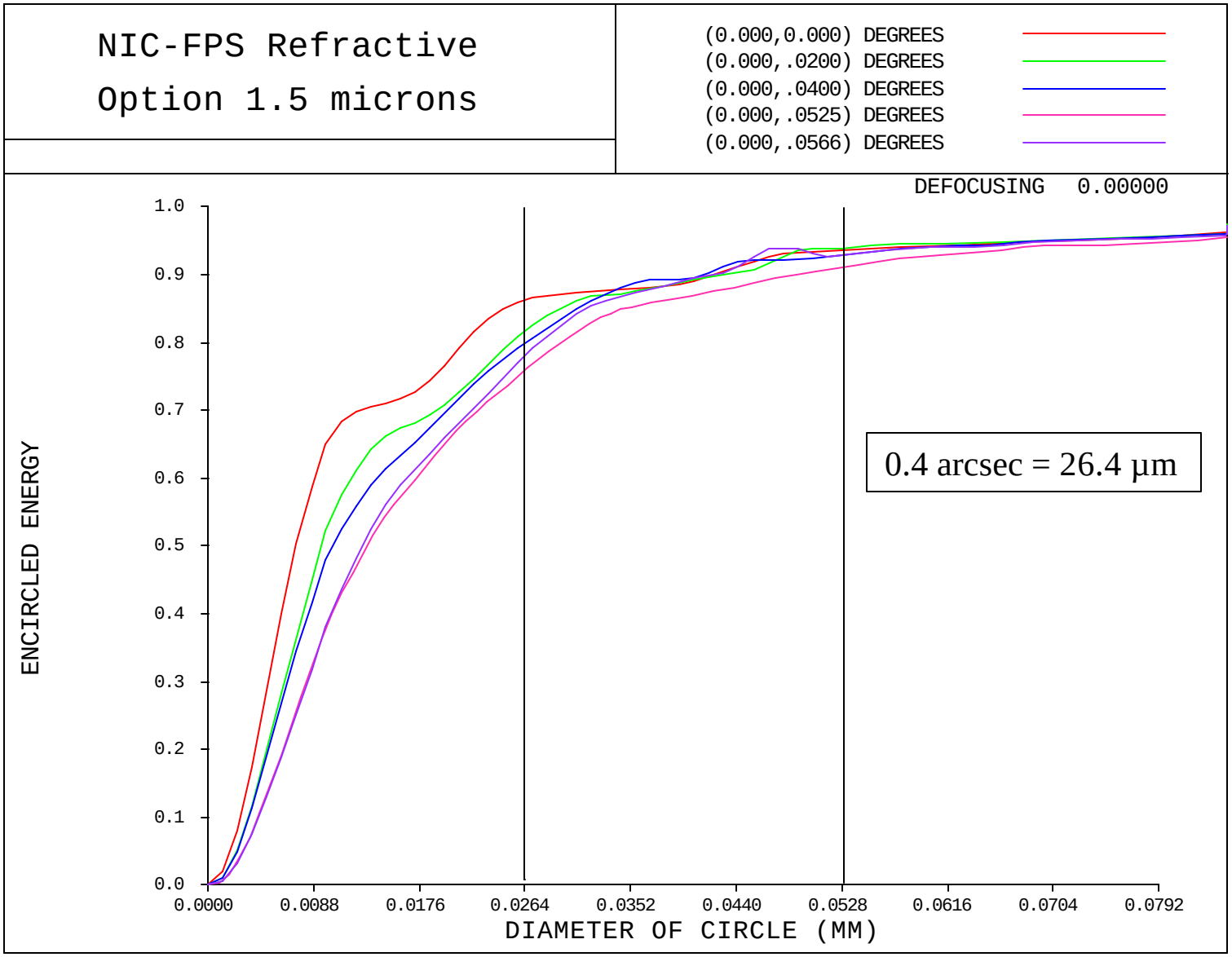
Encircled Energy Plots (Geometric + Diffraction)
0.90 µm



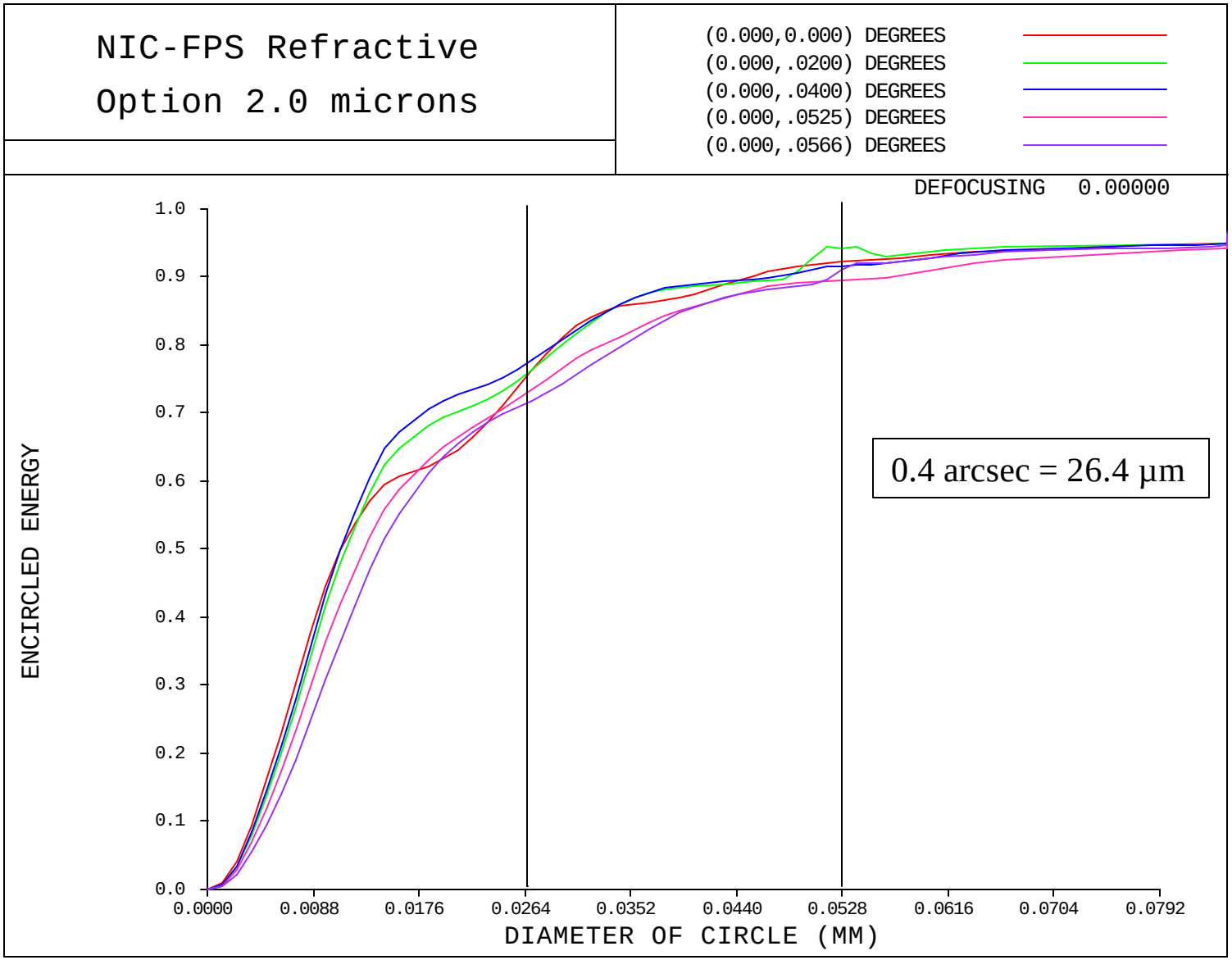
Encircled Energy Plots (Geometric + Diffraction)
1.0 µm



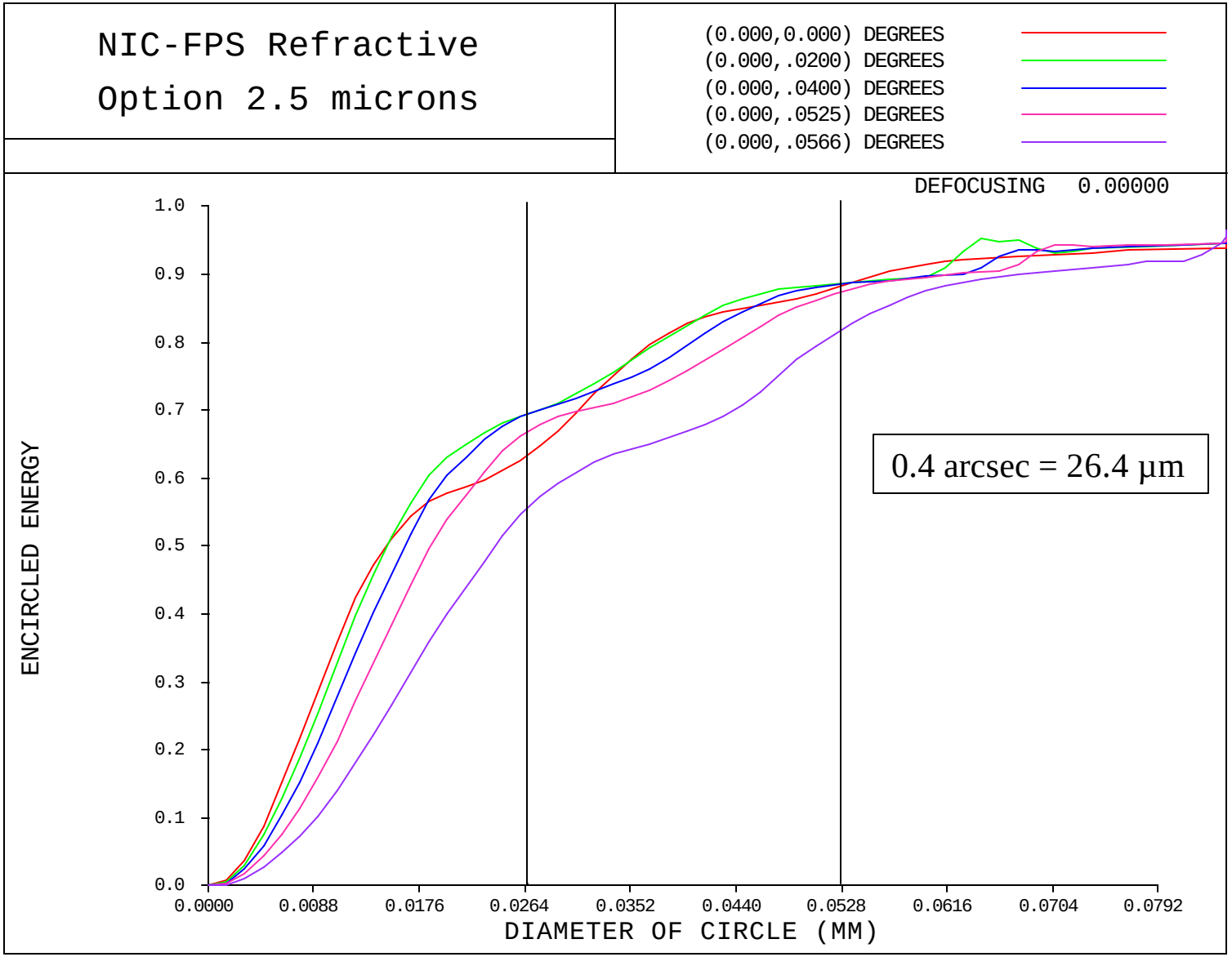
Encircled Energy Plots (Geometric + Diffraction)
1.5 µm



Encircled Energy Plots (Geometric + Diffraction)
2.0 µm

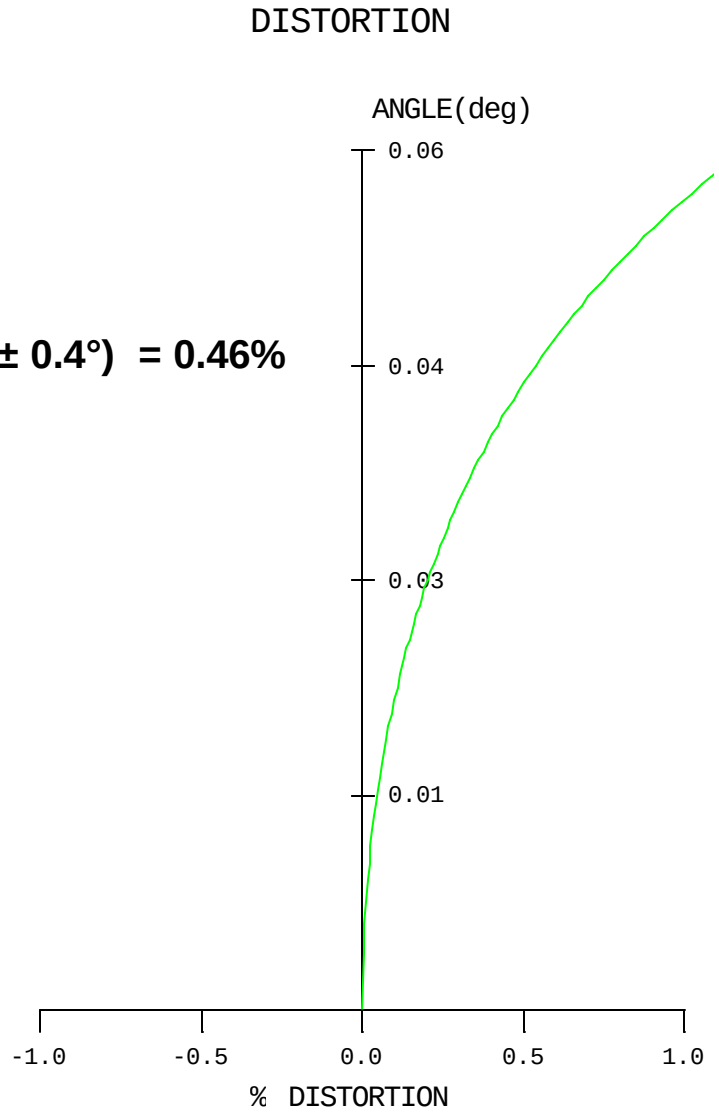


Encircled Energy Plots (Geometric + Diffraction)
2.5 µm



Distortion < 1.2% over FOV

- **Distortion at nominal (edges) ± 2.4 arcmin (± 0.4°) = 0.46%**
- **Distortion at corners = 1.2%**



Conclusions and Future Work

- **Conclusions**
  - **Current design meets desired performance criteria, and contains margin to be applied to fabrication and alignment tolerances.**
  - **Design contains only spherical surface figures (ie. no conic or aspheric surfaces) to reduce cost & improve schedule.**
  - **Current design configuration is flexible to desired mechanical packaging and folding schemes.**
- **All design performance data summarized herein assumes no telescope refocus between spectral bands, and does not include fabrication and alignment tolerances.**

- **Future Work**
  - **Design is ready for optical tolerance analysis to flow down fabrication and alignment tolerances based on performance margin.**