ARCTIC
Post-PDR Optical Design Study

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JHU/IDG

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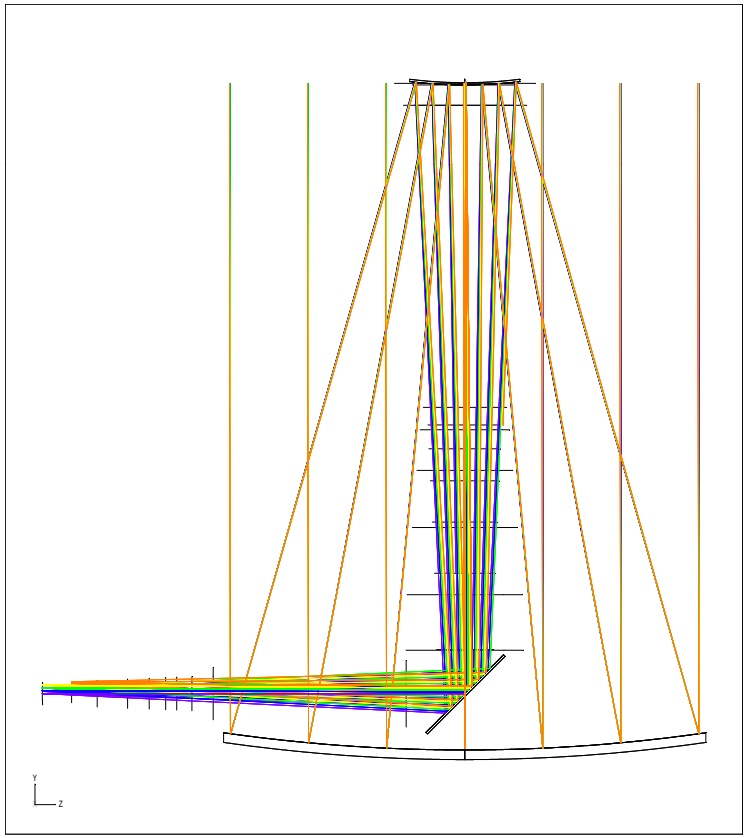
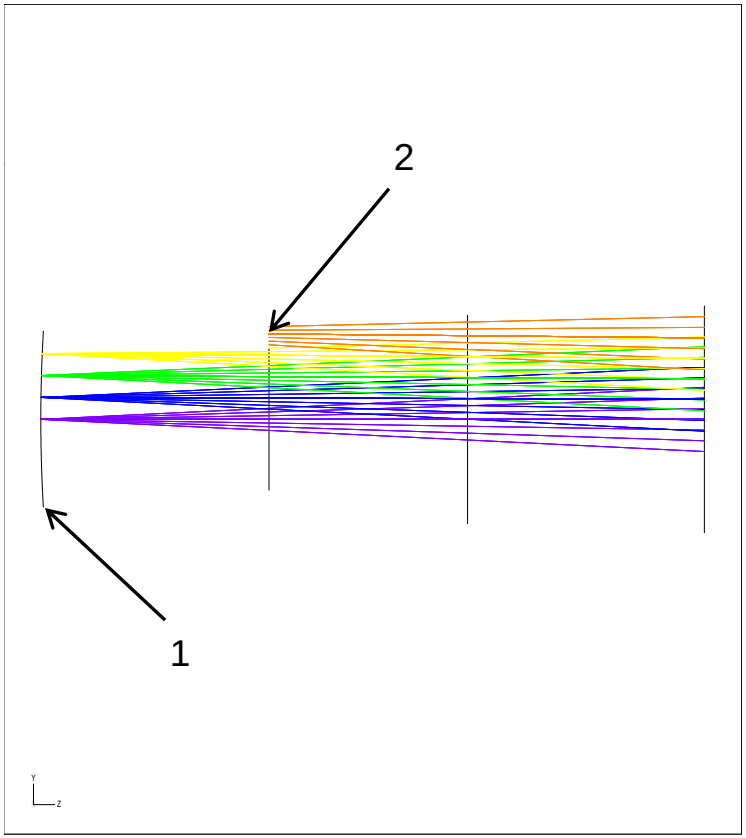
APO 3.5 m Telescope Model

From Joe H. as part of f8v240 imager model.



Note (1) curved focal surface and (2) limiting aperture (labeled “instr mount” in Zemax model).



APO 3.5 m Telescope Model

- The “instr mount” aperture in the Zemax model limits the unvignetted field of view (FOV) to 12 arcminutes in diameter.
- For the purposes of this study, this aperture will be removed from the model in order to demonstrate the full FOV that could be put onto the detector at the given f/#.

Spot Diagrams – General Comments

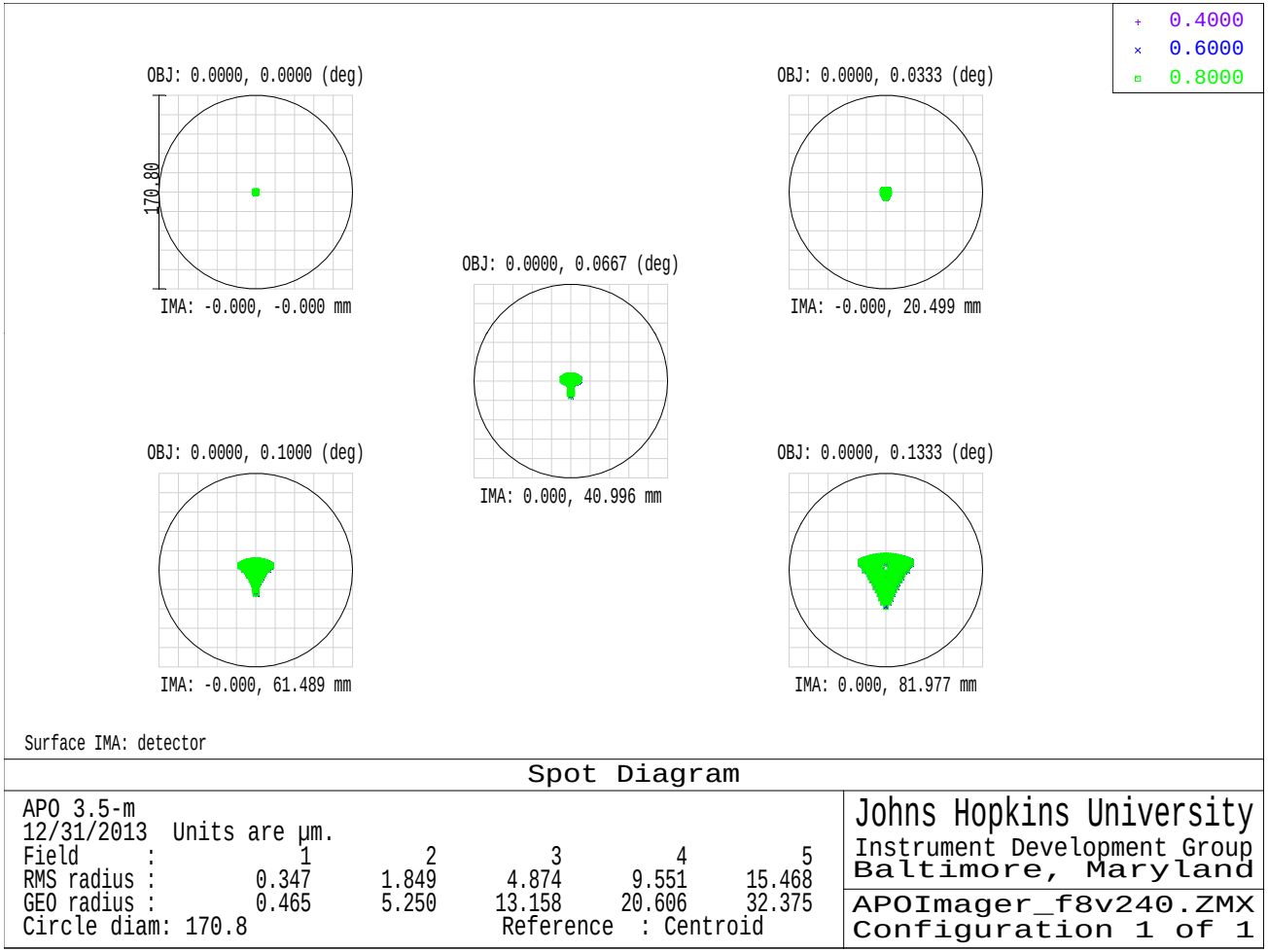
- Spot diagrams in general will cover the full FOV of the detector in a 3 x 3 grid. Due to axial symmetry most of the spots are redundant but it helps to visualize the image quality as a function of location in the focal plane.
- The exception to the above are spot diagrams for the telescope alone; for these the spots cover field angles of 0', 2', 4', 6', and 8'.
- The size of the bounding circle will be 1" for all spot diagrams shown, to maintain a consistent angular scale for comparison.

APO 3.5 m Spot Sizes – Curved Focal Surface

Spot sizes for the 3.5 m alone, assuming a best-fit spherical focal surface. This is the optical design residual only; no fabrication or collimation errors are included.

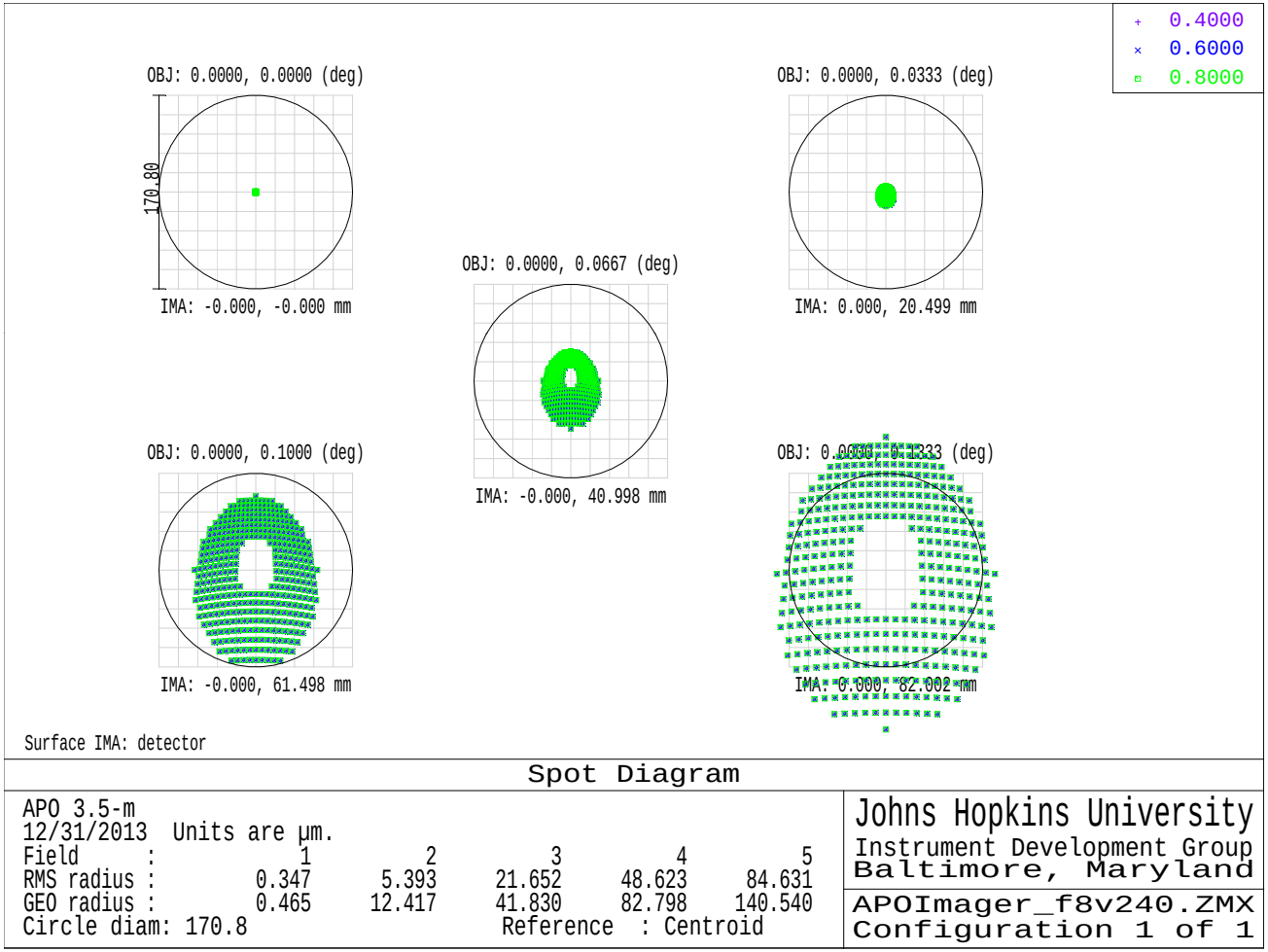
Field angles shown are for 0’, 2’, 4’, 6’, and 8’.

With a curved focal surface, the telescope design delivers excellent image quality well beyond the 16’ diameter FOV represented here.



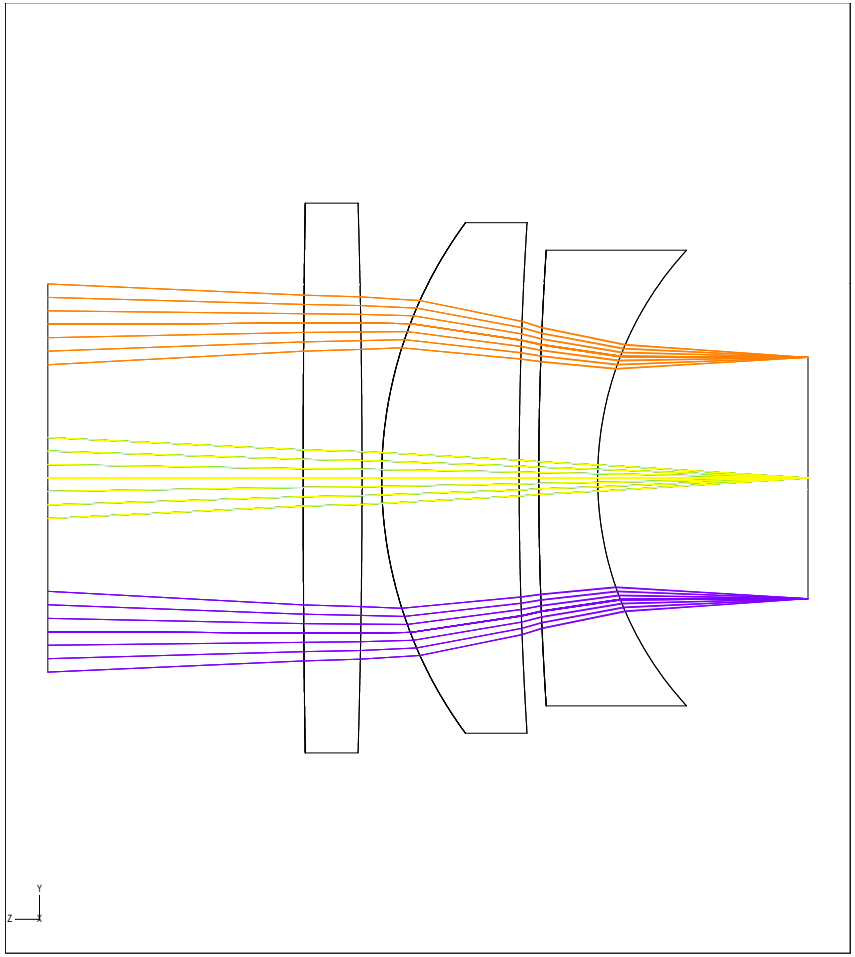
APO 3.5 m Spot Sizes – Flat Focal Surface

With a flat focal surface, the FOV is reduced over which the image quality is excellent. Here the telescope is focused for the on-axis image; a compromise focus could be used to obtain a somewhat larger usable FOV.



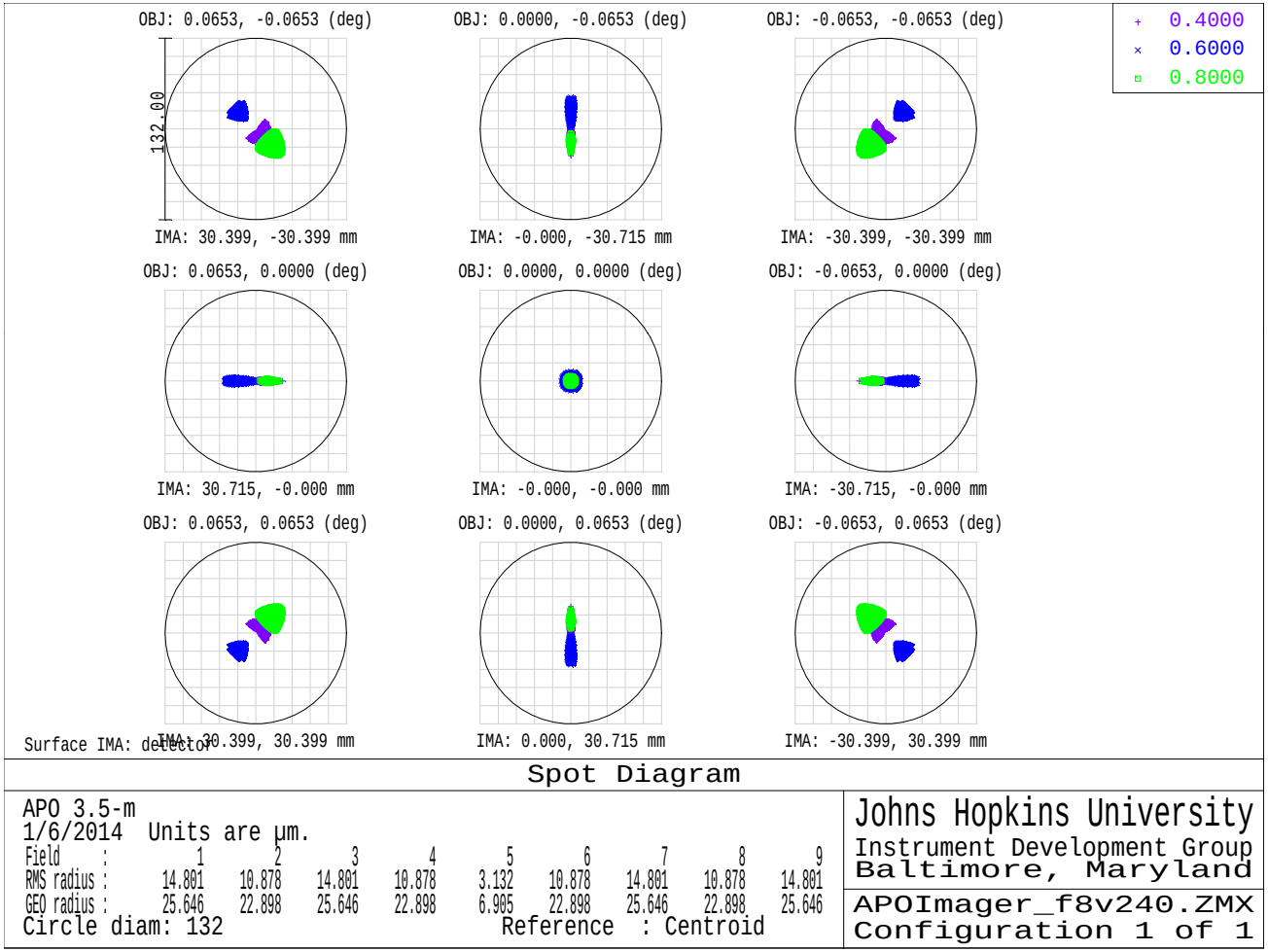
PDR Optical Design (f8v240)

- 3-element, f/8 direct focal reducer
- Provides a 7.8’ x 7.8’ FOV.
- All elements are spherical, materials are Schott standard glasses. Chosen based on cost and good UV transmission:
  - N-SK16 (95.4% at 370 nm, 10 mm thk)
  - N-SK14 (97.1% at 370 nm, 10 mm thk)
  - F2 (97.5% at 370 nm, 10 mm thk)
- Form factor and generous tolerances lead to a straightforward cell design.
- But…this design suffers from a large amount of lateral color. Issue for astrometric accuracy…?



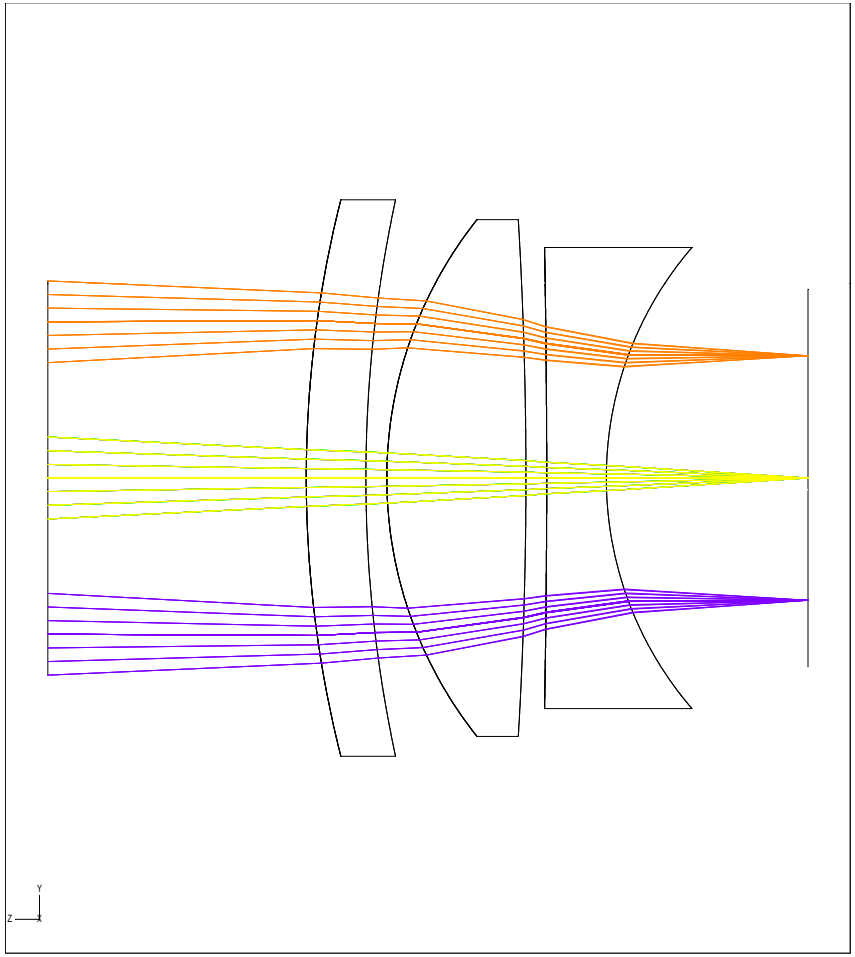
PDR Optical Design (f8v240)

The design provides images well below 1” in RMS diameter but there is significant lateral color.



3-Element, F/8 Variant #1

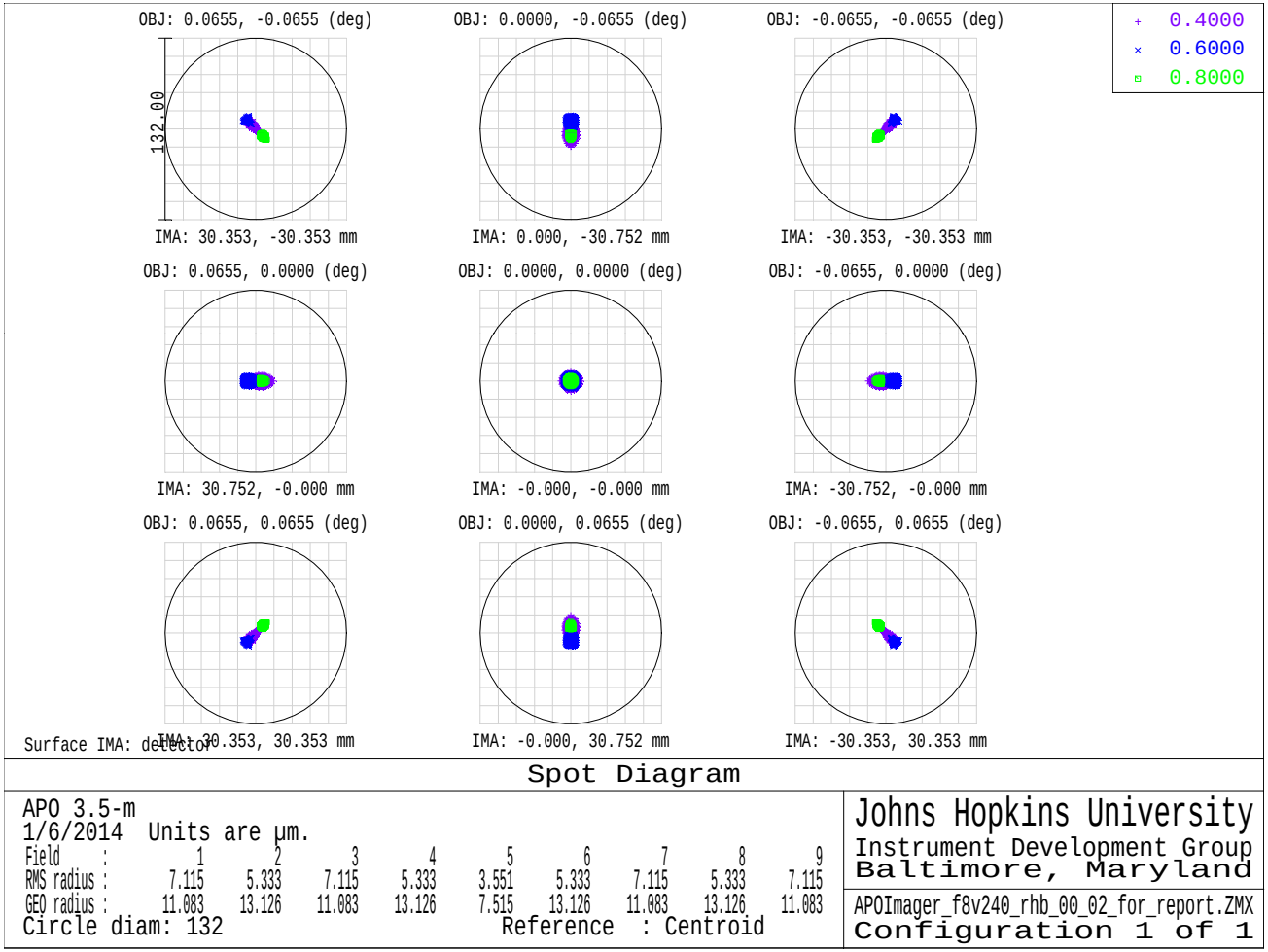
- This variant on the original PDR design uses a very similar form factor but with different glasses.
- Provides the same 7.8’ x 7.8’ FOV but with better images.
- All elements are spherical, materials are three Ohara i-Line glasses, which have enhanced UV transmission:
  - PBM2Y (99.1% at 370 nm, 10 mm thk)
  - S-FPL51Y (99.8% at 370 nm, 10 mm thk)
  - PBL26Y (99.7% at 370 nm, 10 mm thk)
- Optimized using the identical field angles and merit function as the original design.



3-Element, F/8 Variant #1

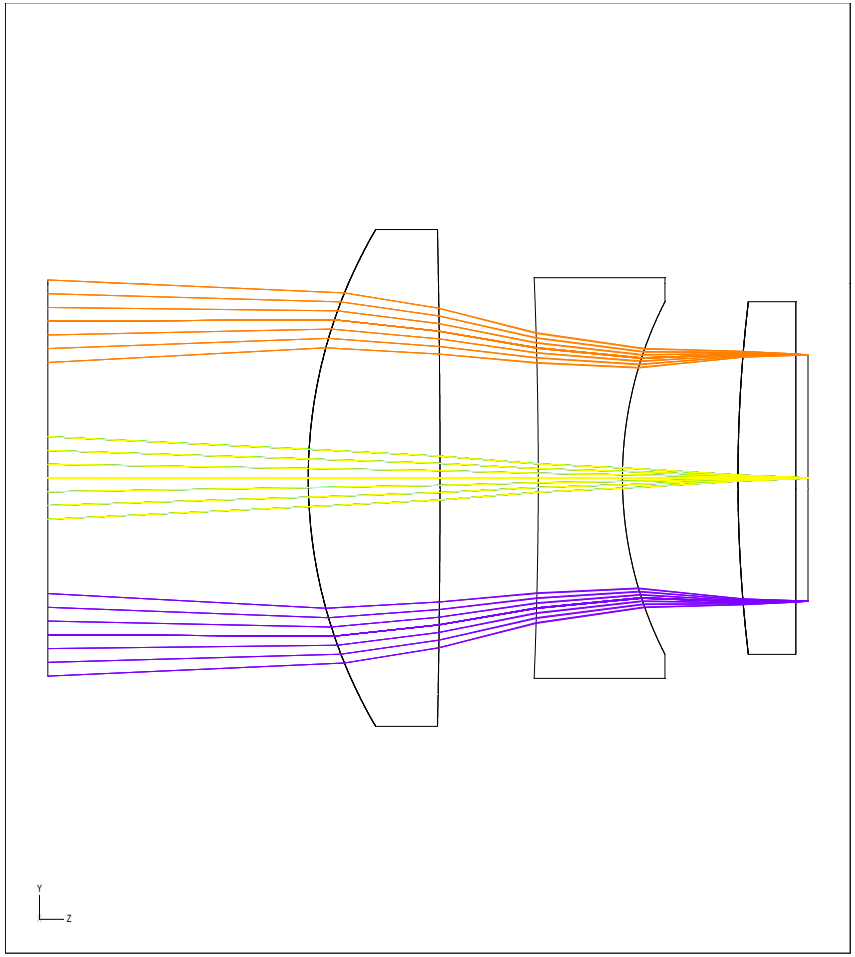
This design provides significantly better images than the original design.

The Ohara i-Line glasses are expensive but are high quality and have very good UV transmission. The increased material cost would still be quite low as a fraction of the overall cost of the optics.



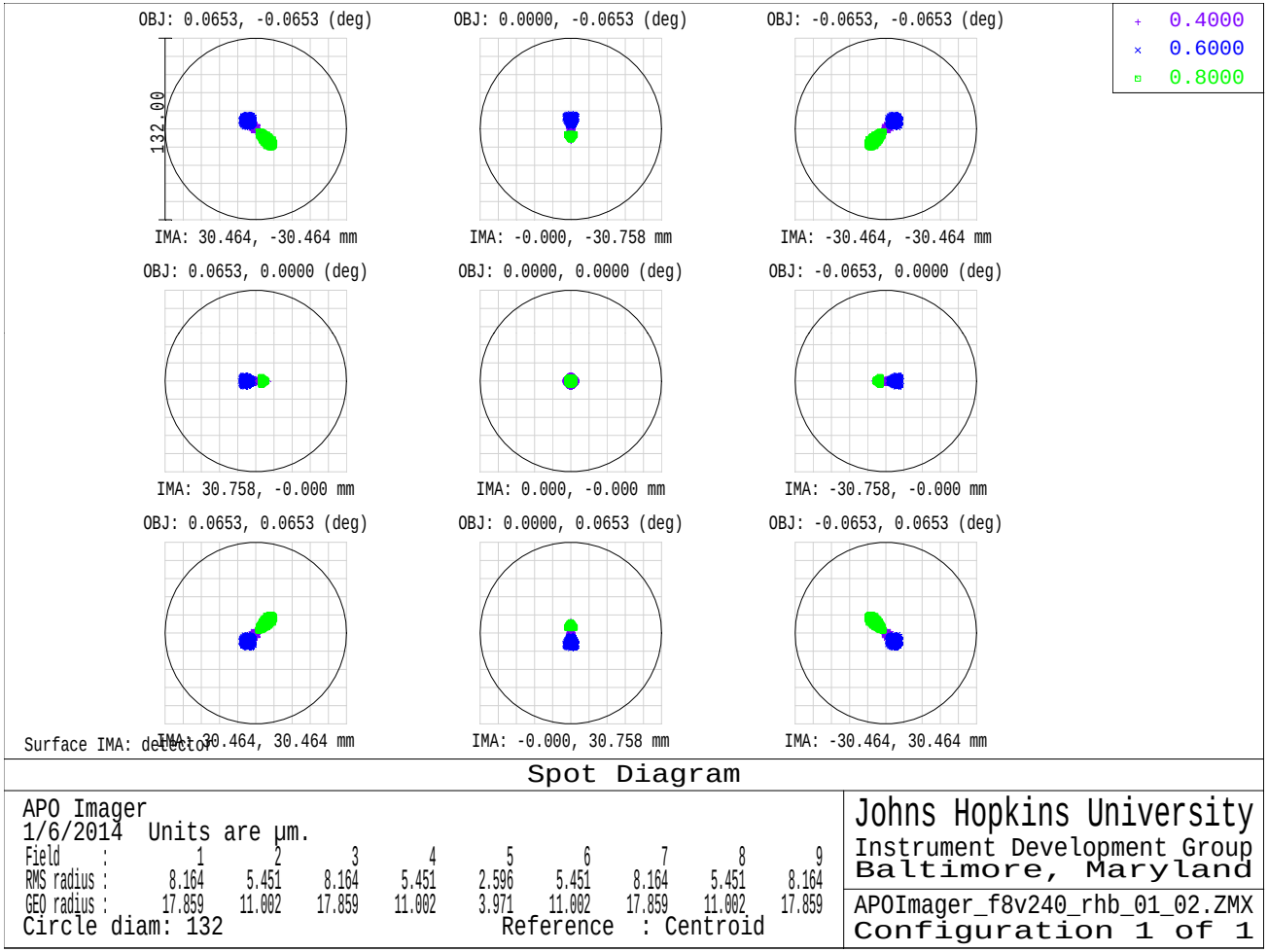
3-Element, F/8 Variant #2

- This variant on the original PDR design uses a field flattener lens with a plano surface very close to the CCD (3 mm). This is a common configuration (including the size of the gap) seen in many CCD cameras.
- Provides the same 7.8’ x 7.8’ FOV but with better images.
- All elements are spherical, materials are two Ohara i-Line glasses (high UV transmission). L2 and L3 use the same glass:
  - S-FPL51Y (99.8% at 370 nm, 10 mm thk)
  - PBL25Y (99.6% at 370 nm, 10 mm thk)



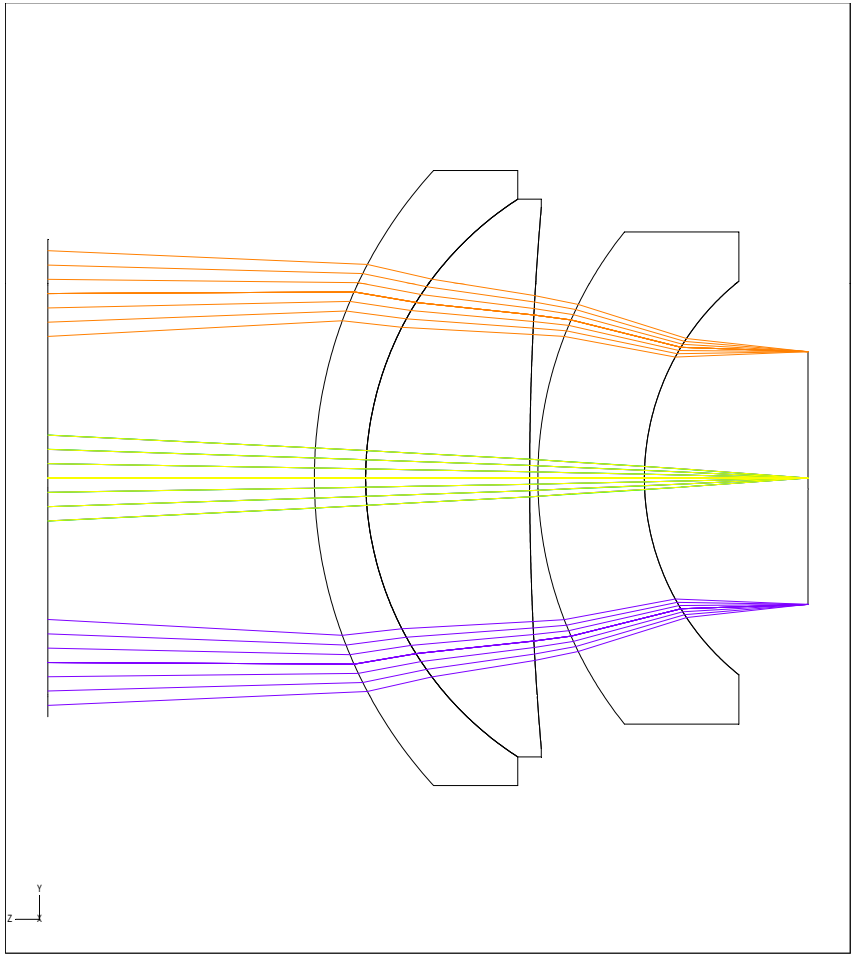
3-Element, F/8 Variant #2

This design also provides significantly better images than the original design. There is a bit more lateral color off axis.



3-Element, F/7 Design

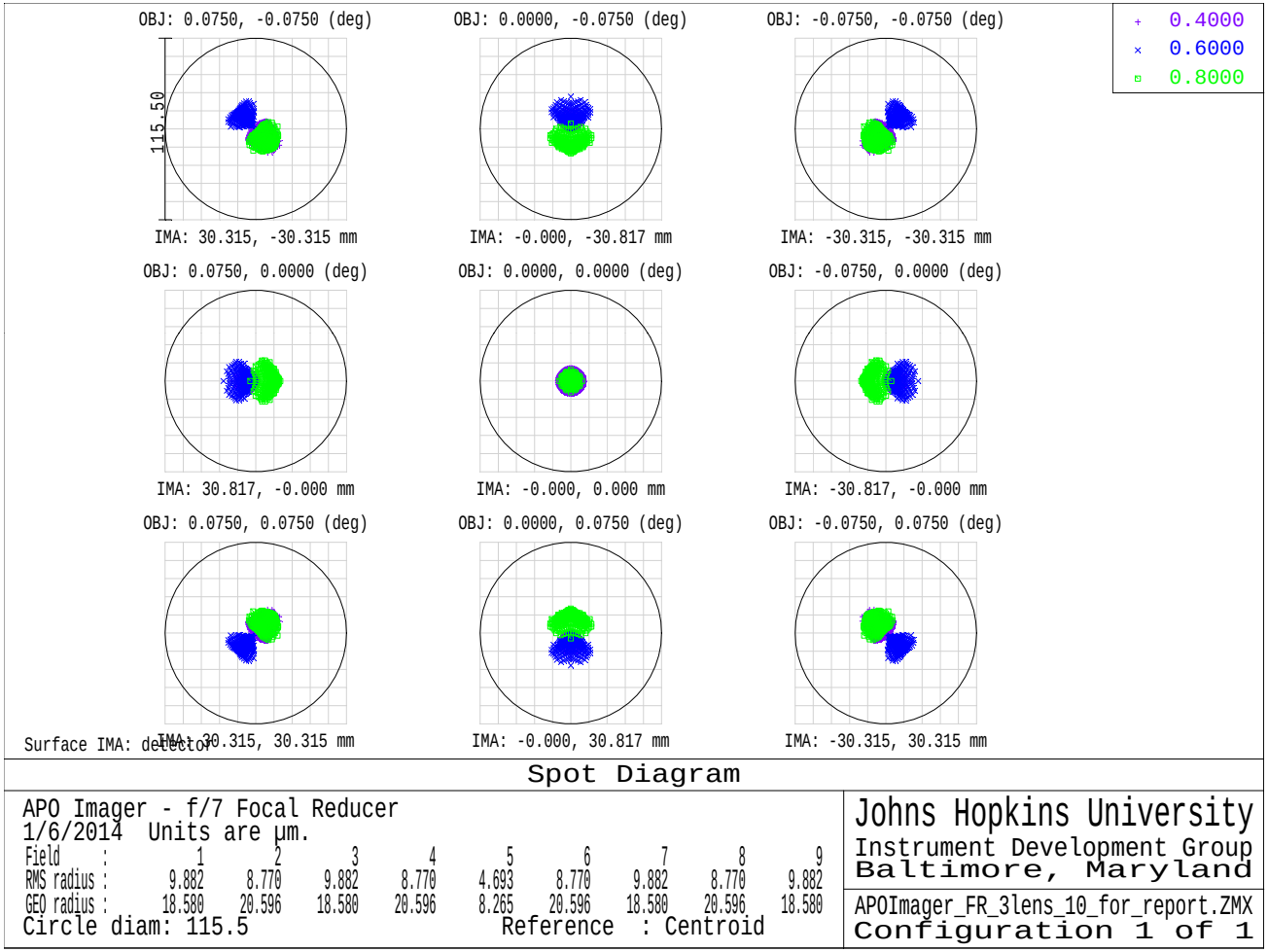
- This design uses a CaF_2 doublet along with a singlet to produce good images at f/7, providing a somewhat larger 8.9’ x 8.9’ FOV.
- This doublet probably requires a fluid-coupled cell (more involved optomechanical design) but does eliminate two air-glass interfaces:
  - Fewer potential ghost reflections
  - Better overall throughput
- All elements are spherical, materials are CaF_2 (L2) and Ohara PBM2Y (L1, L3). CaF_2 has outstanding UV transmission and PBM2Y is 99.1% at 370 nm (10 mm thk).



3-Element, F/7 Design

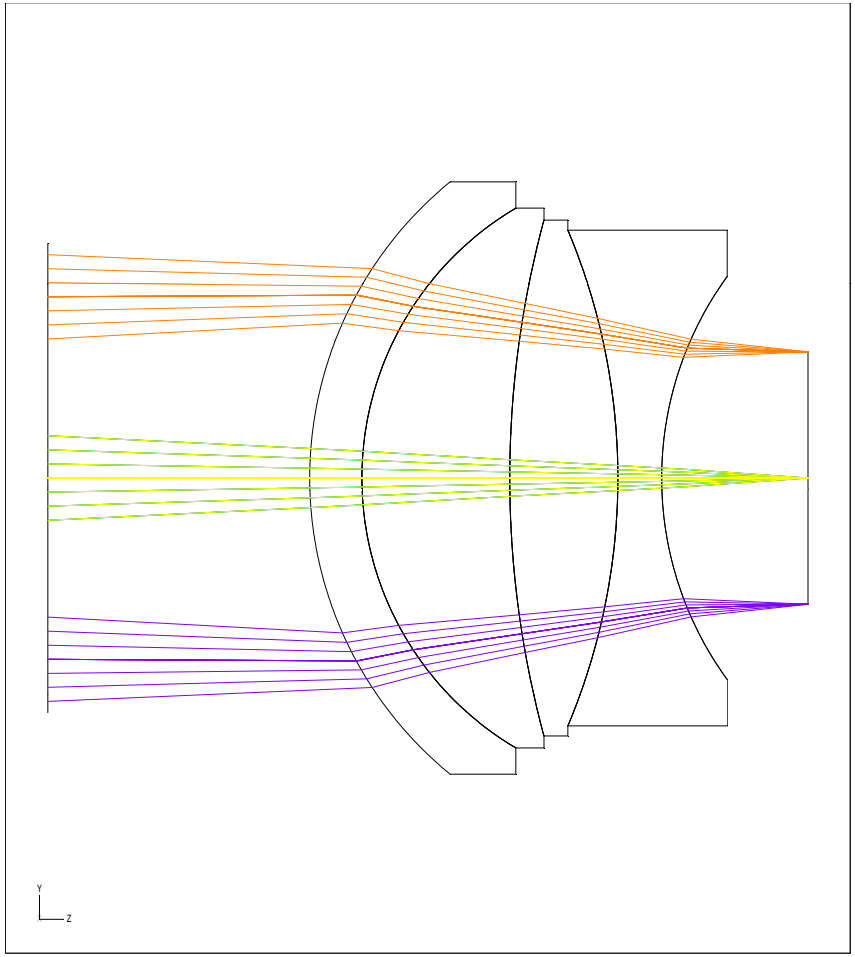
This design provides good images with a faster f/7 focal ratio (larger FOV on detector). Note here that the diameter of the 1” bounding circle is reduced to 115.5 µm.

It is likely that the previous f/8 designs could be pushed to f/7 as well, with somewhat degraded image quality.



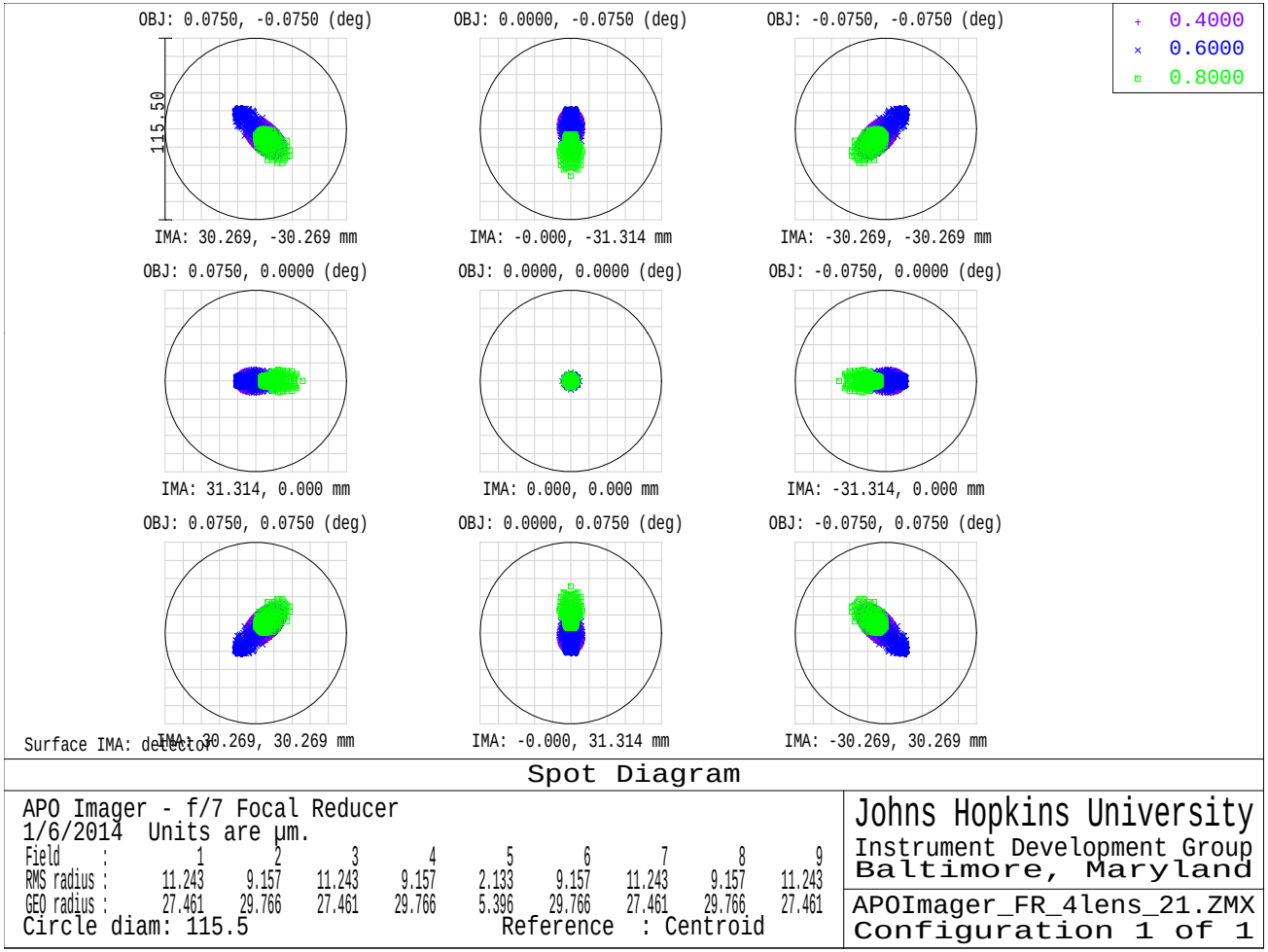
4-Element, F/7 Design

- This design uses 4 elements in a single group to provide good images over the same FOV as the previous f/7 design which used 3 elements in 2 groups.
- This quadruplet probably requires a fluid-coupled cell for the L1/L2 joint, but the others are not so steep. Only two air-glass interfaces.
- All elements are spherical, materials are:
  - PBL25Y (99.6% at 370 nm, 10 mm thk)
  - CaF2
  - BAL35Y (99.6% at 370 nm, 10 mm thk)
  - PBL6Y (99.8% at 370 nm, 10 mm thk)

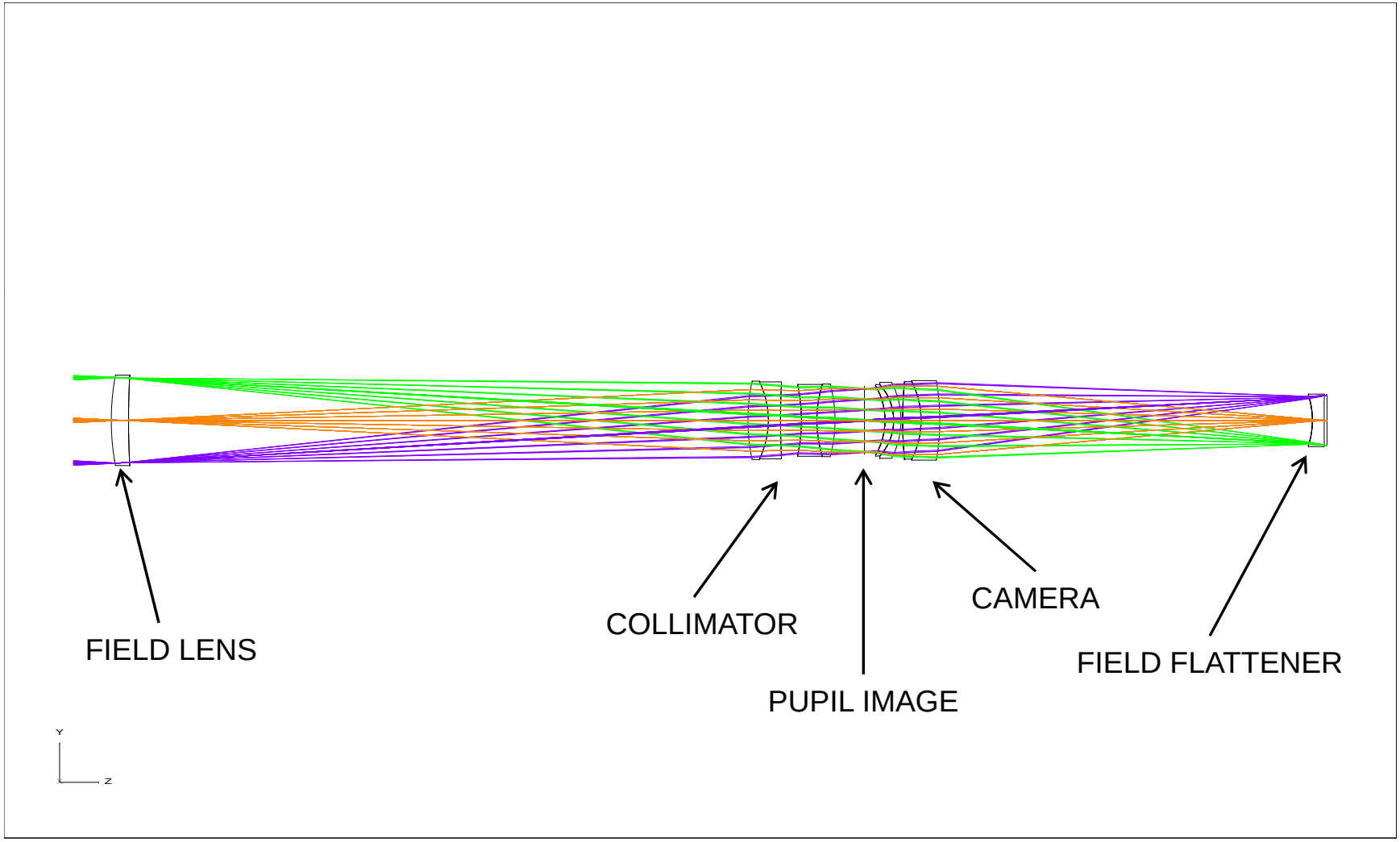


4-Element, F/7 Design

This design provides similar image sizes over the same FOV as the 3-element, 2 group design.

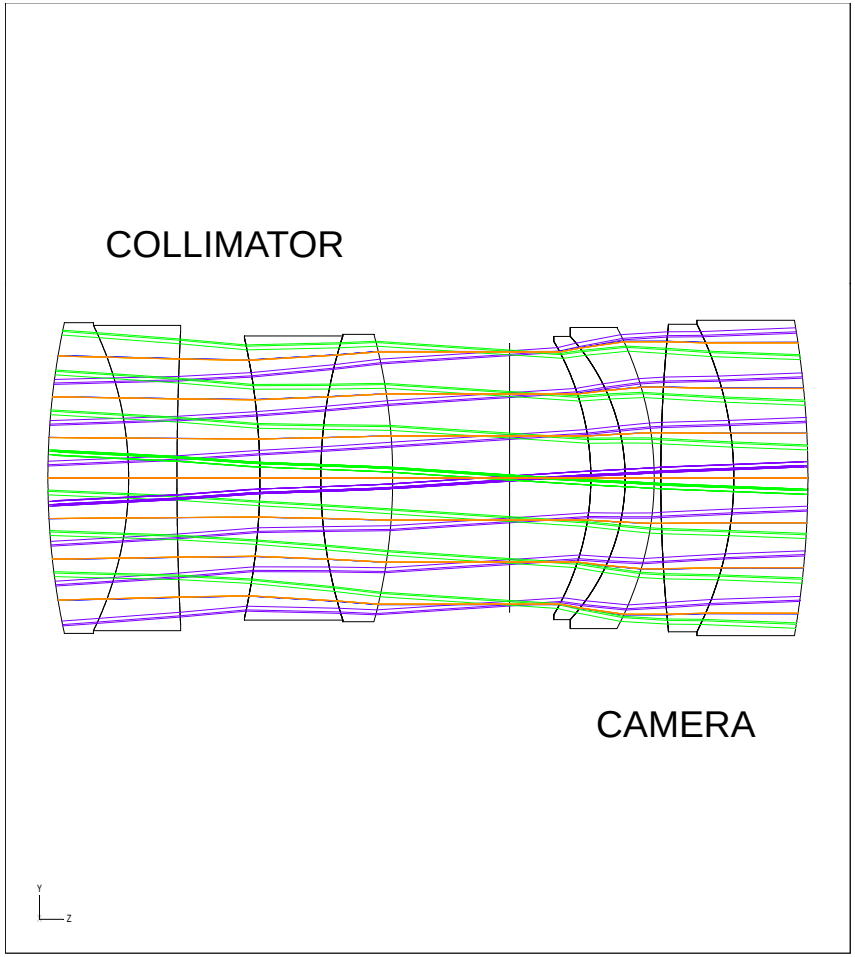


F/6 Collimator/Camera Design



F/6 Collimator/Camera Design

- This design uses two doublet lenses for both the collimator and camera. This configuration was chosen as a plausible starting point.
- The field lens is used to create a pupil in the collimated beam.
- All elements are spherical, materials are Ohara i-Line glasses and fused silica.
- F/6 design provides a 10’ x 10’ FOV.
- Image quality is approaching good enough, but not quite there.
- This design represents a significant increase in size, cost and complexity for a modest gain in FOV.



F/6 Collimator/Camera Design

Image size is less than 1/3” over the 10’ x 10’ FOV. Not terrible, but quite a bit worse than the direct focal reducer designs considered.

These results represents a decent amount of effort, it should be a fair representation of the performance available with this configuration.