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LA-UR 11-06800

Lens-array PDV probe using a pyramid prism

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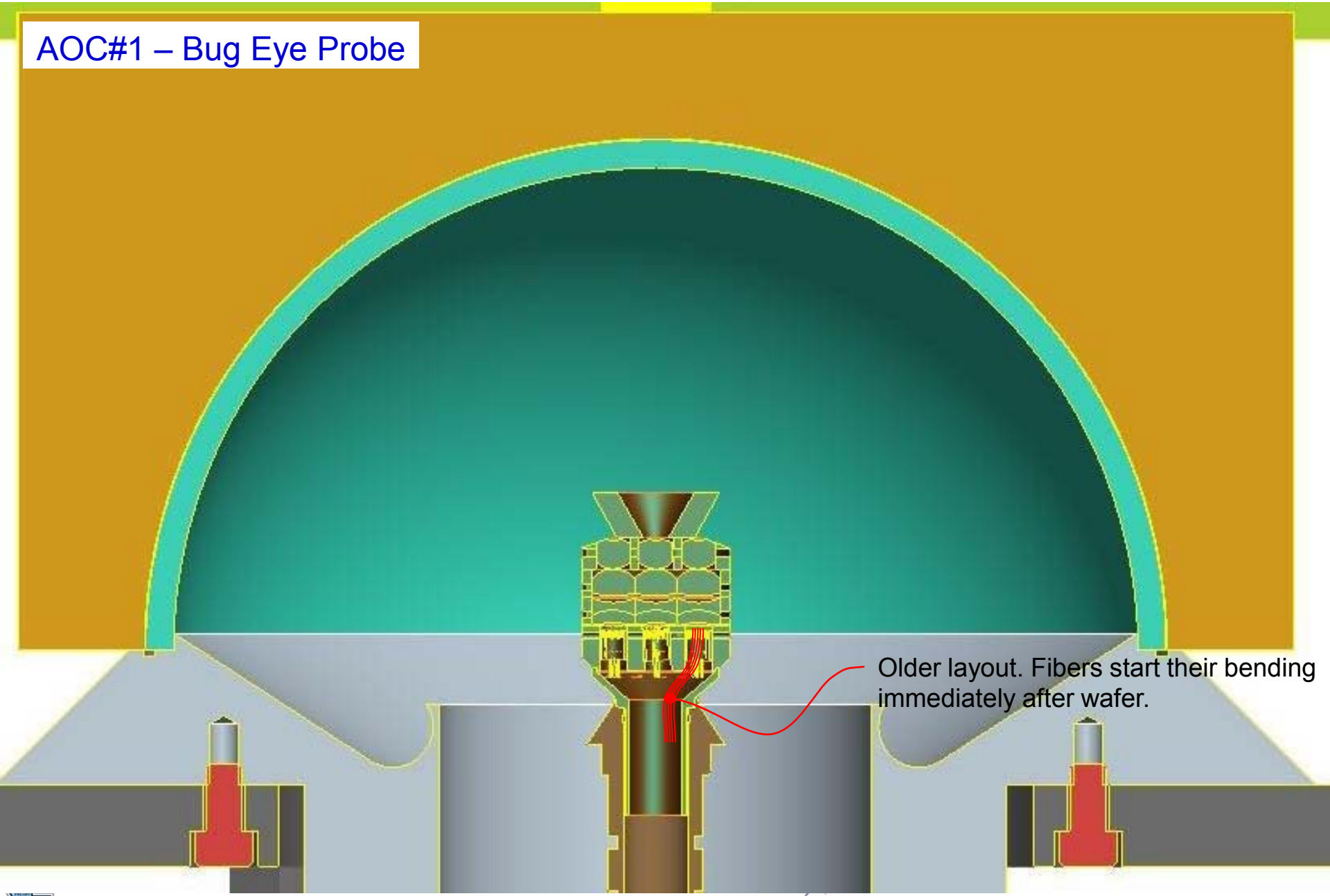
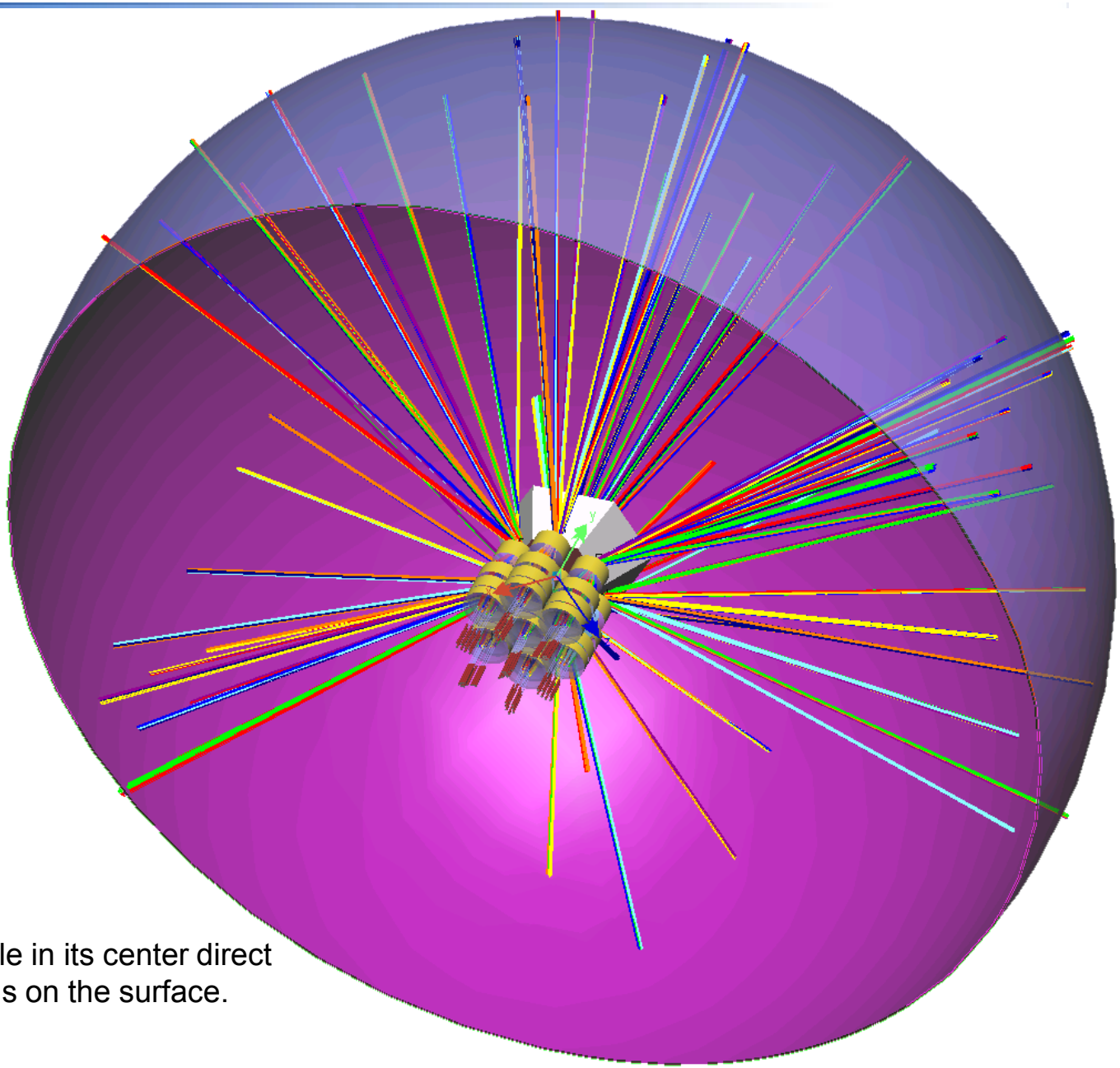
AOC#1 – Bug Eye Probe

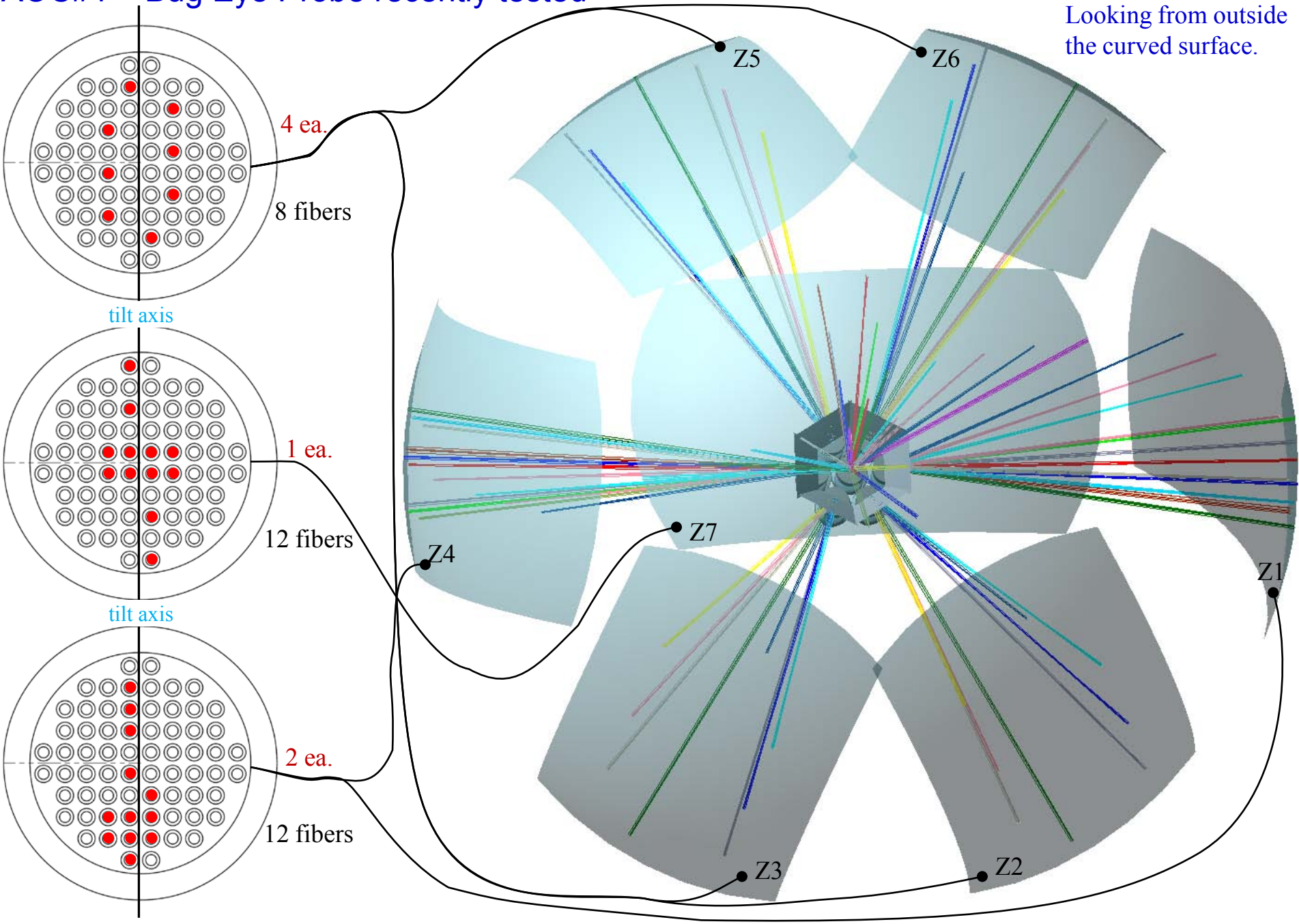


AOC#1 – Bug Eye Probe



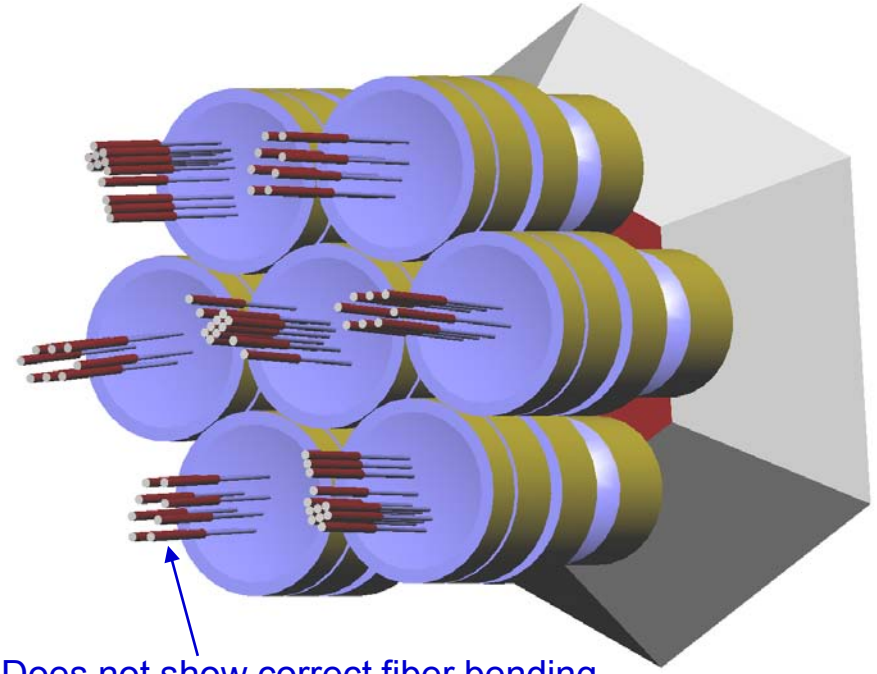
A 6-faceted prism with a cone hole in its center direct the PDV fiber's light into 7 regions on the surface.

AOC#1 – Bug Eye Probe recently tested

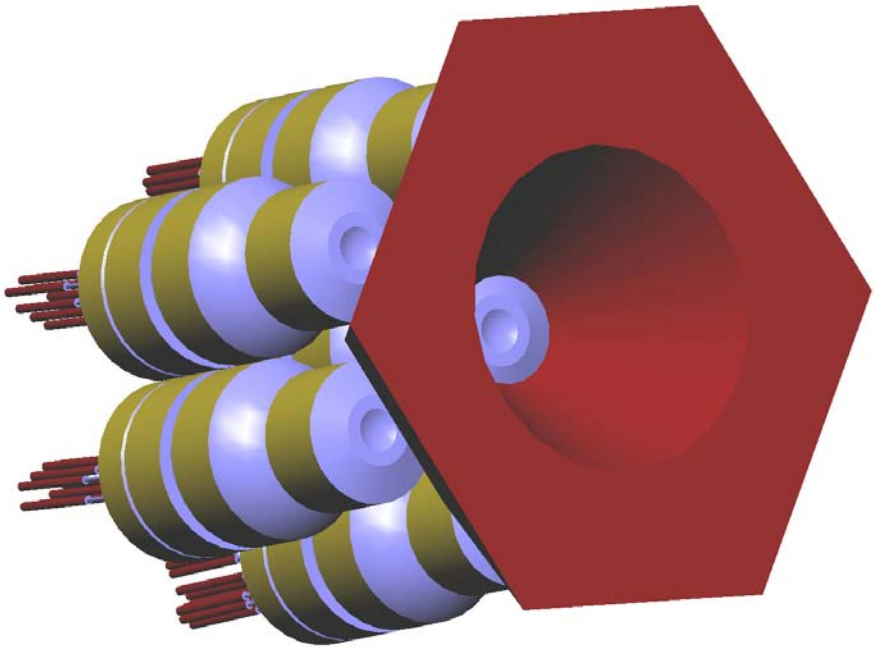


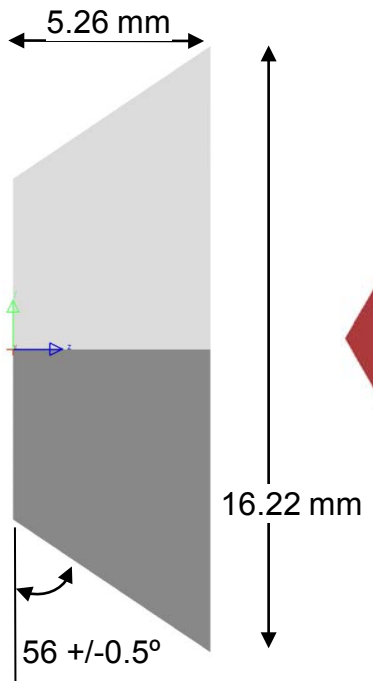
AOC#1 used for Hemi shot #3.

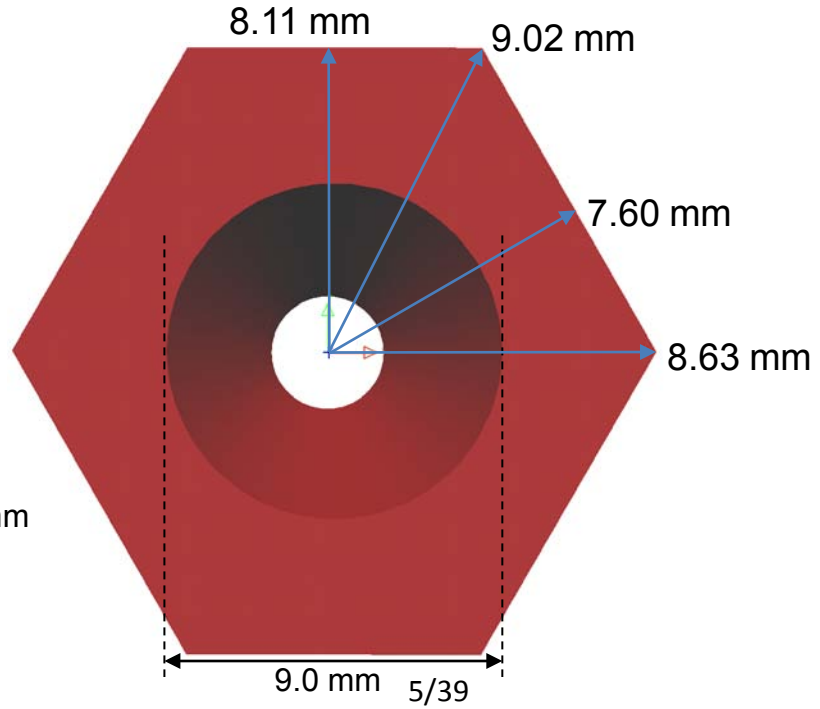
2 facets are at 56º and 4 facets are at 61º.



Does not show correct fiber bending.







AOC#1 – Bug Eye Probe

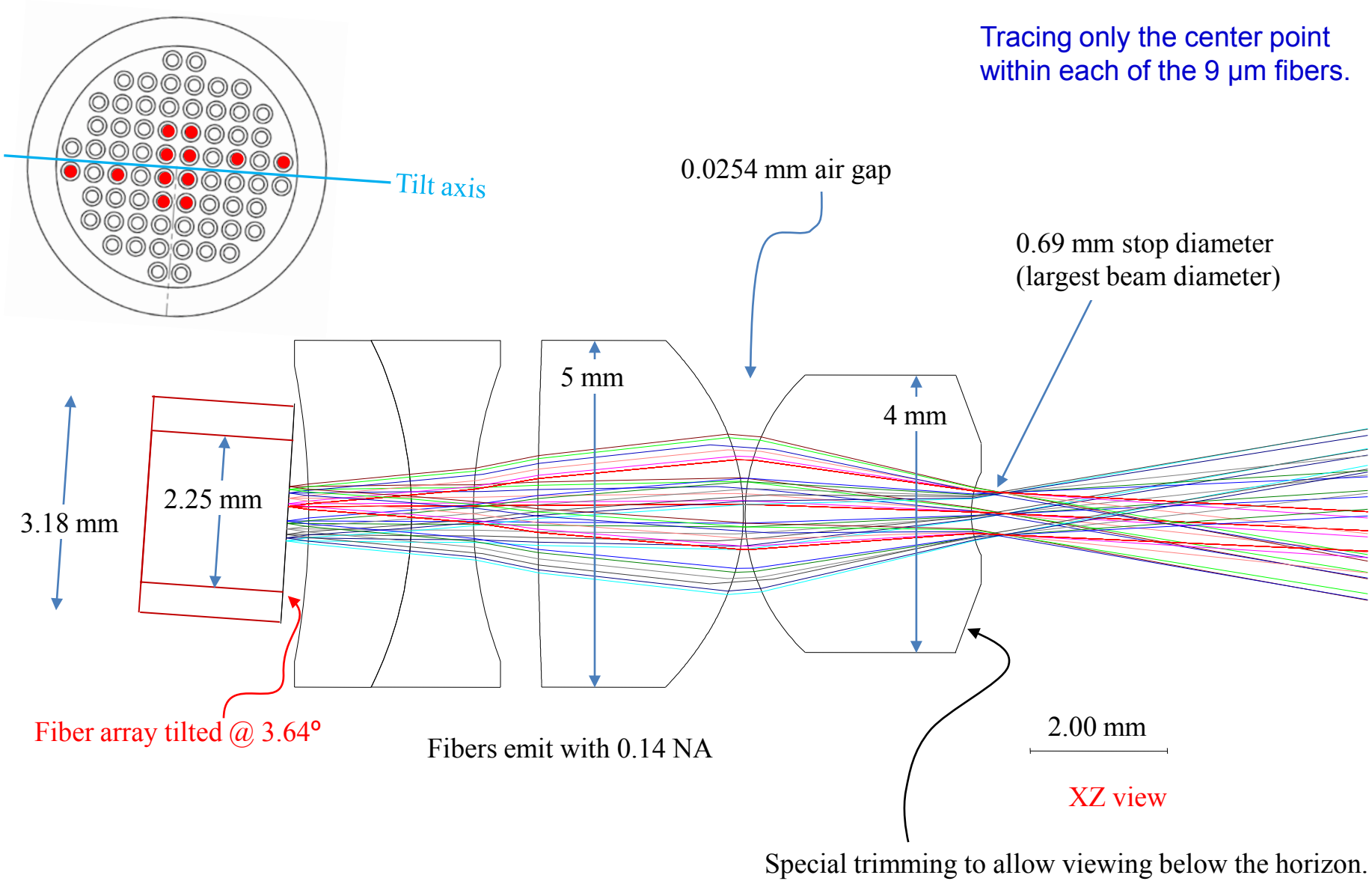
Advantages:

1. Each of the 7 fiber arrays can have different rotations to change area coverages.
2. Each mirror facet can have different tilts to change area coverages. We used 56º and 61º.
3. This probe accommodates several hundreds of fibers. We assembled the first probe with 68 fibers.
4. Accommodates imaging along with the PDV channels.
5. By trimming sharp corners of prism facets, PDV can gain 1.4 mm more data recording.

Disadvantages:

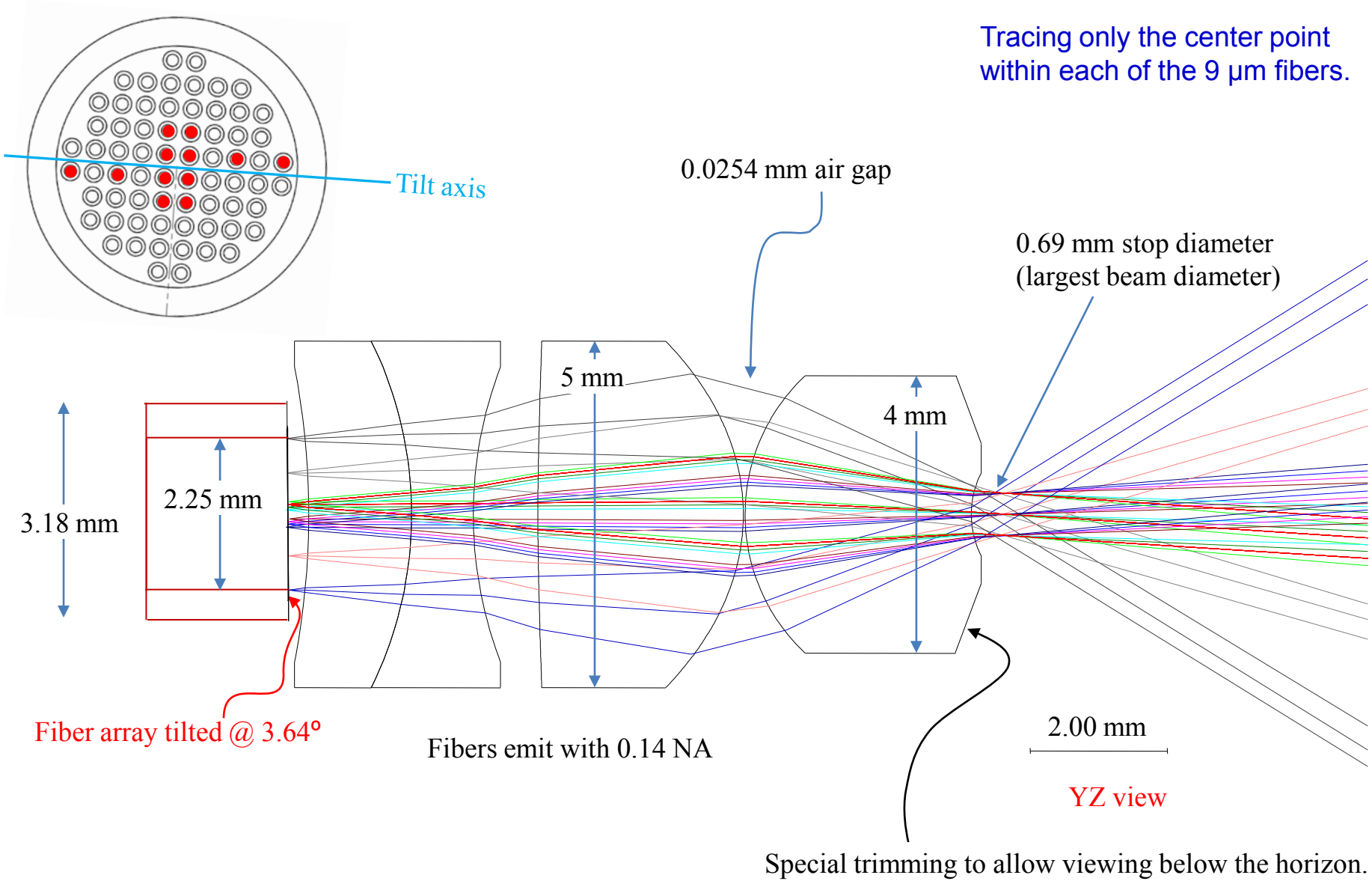
1. Because of short procurement time, one of the lenses used broadband AR coating instead of 1550 nm coating.
2. Zero crossings are shifted 5-mm for 6 of the 7 zones.
3. Extra assembly time required to angle polish each fiber (add one extra week).
4. Cleaning of the fiber arrays is very important to minimize back reflections.
5. Angle cleaving the fibers does not work as well as angle polishing.

Each fiber in the array is cleaved at 8°, so now array is only tilted 3.64°

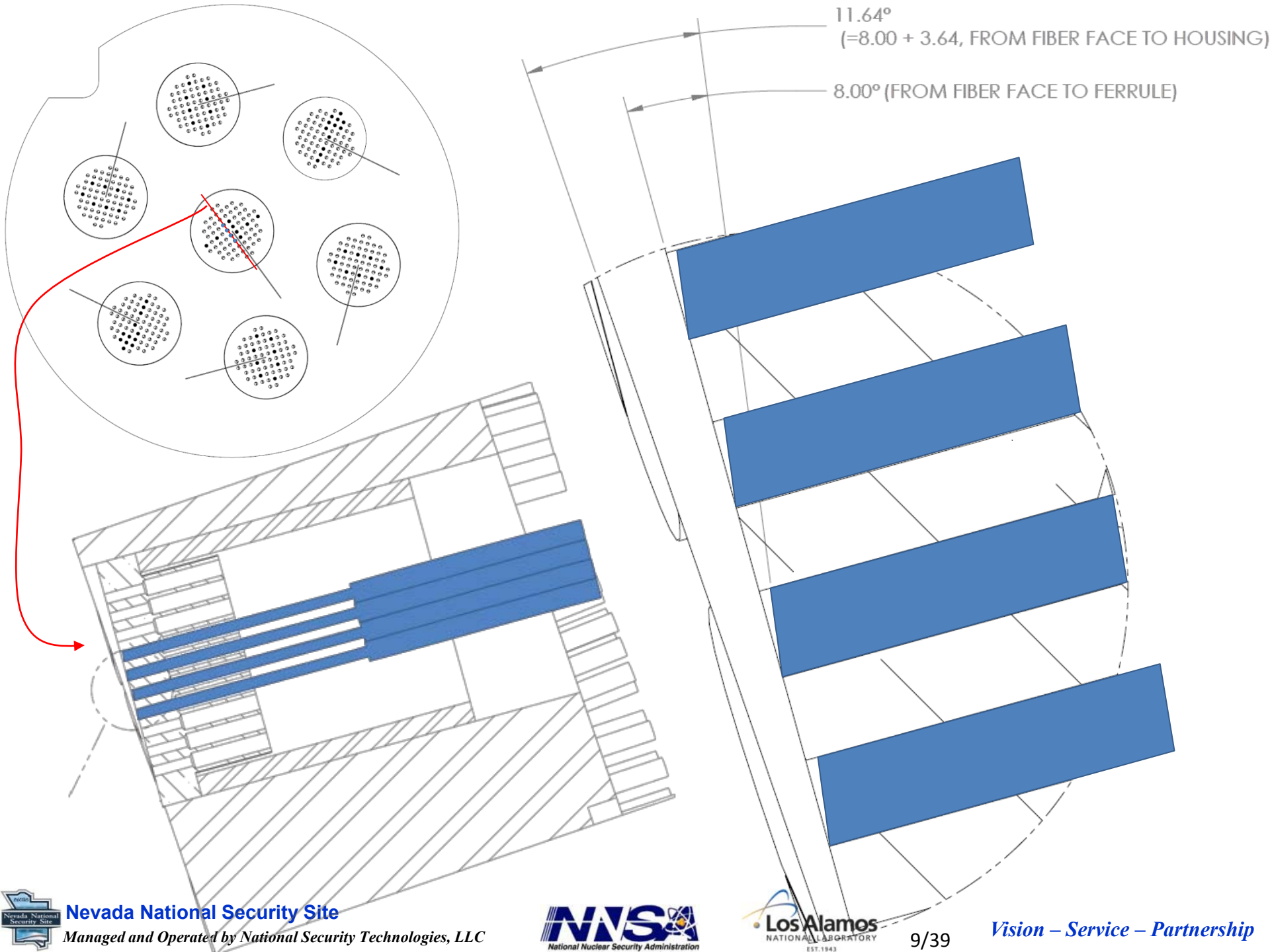


Magnification by the lens group = ~29 at a distance of 100 mm from the stop.

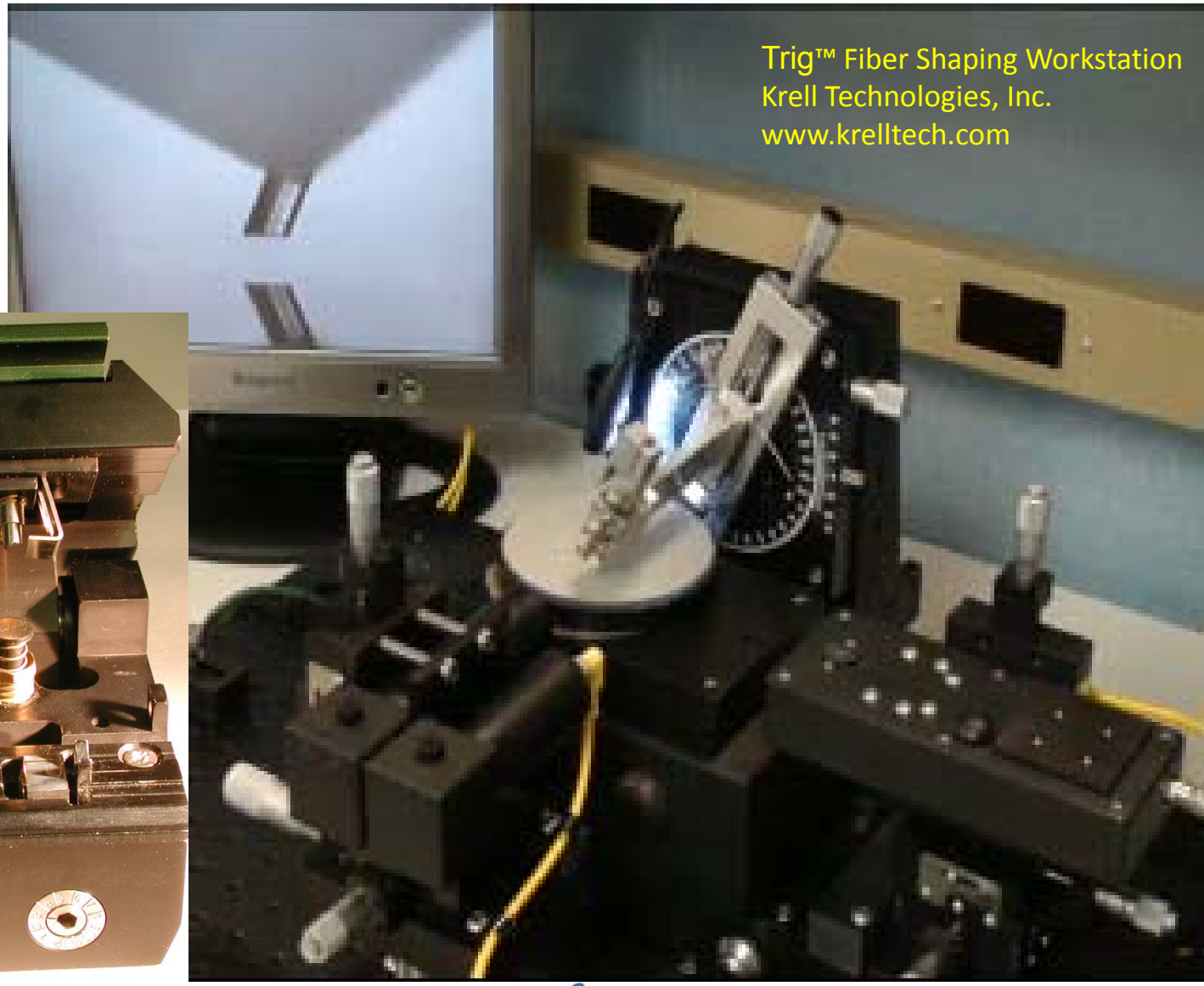
Each fiber in the array is cleaved at 8°, so now array is only tilted 3.64°

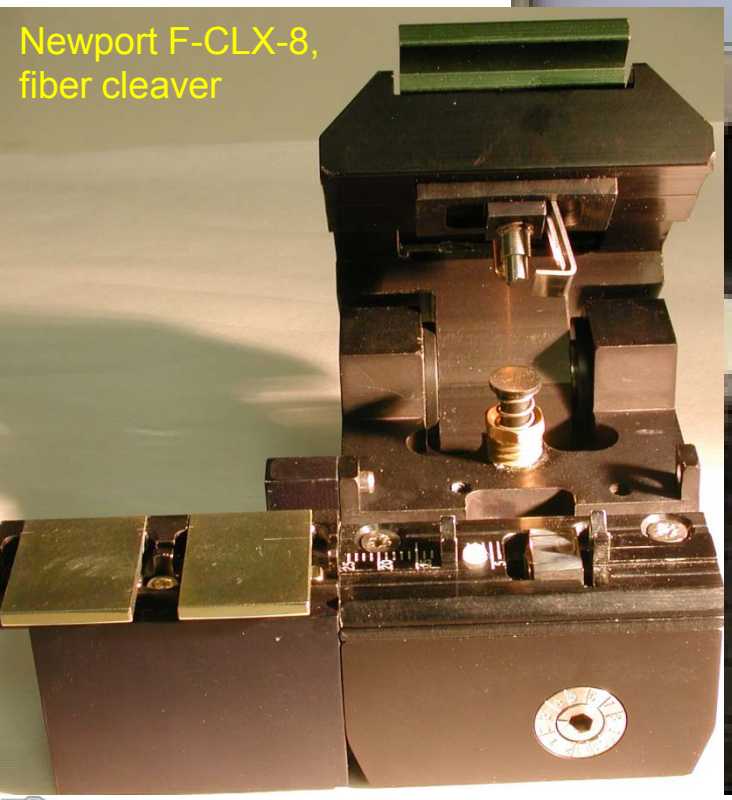


Magnification by the lens group = ~29 at a distance of 100 mm from the stop.


11.64°
(=8.00 + 3.64, FROM FIBER FACE TO HOUSING)
8.00° (FROM FIBER FACE TO FERRULE)

NSTec/LAO recently purchased a single fiber angle polisher. It will angle polish the 80 µm fibers needed for the AOC imaging option.





Second attempt with correctly orientated fiber arrays. 2 alignment marks rotated 180º.

After_correctly_rotating_fiber_arrays_DSCN0143.JPG, 9/4/2011

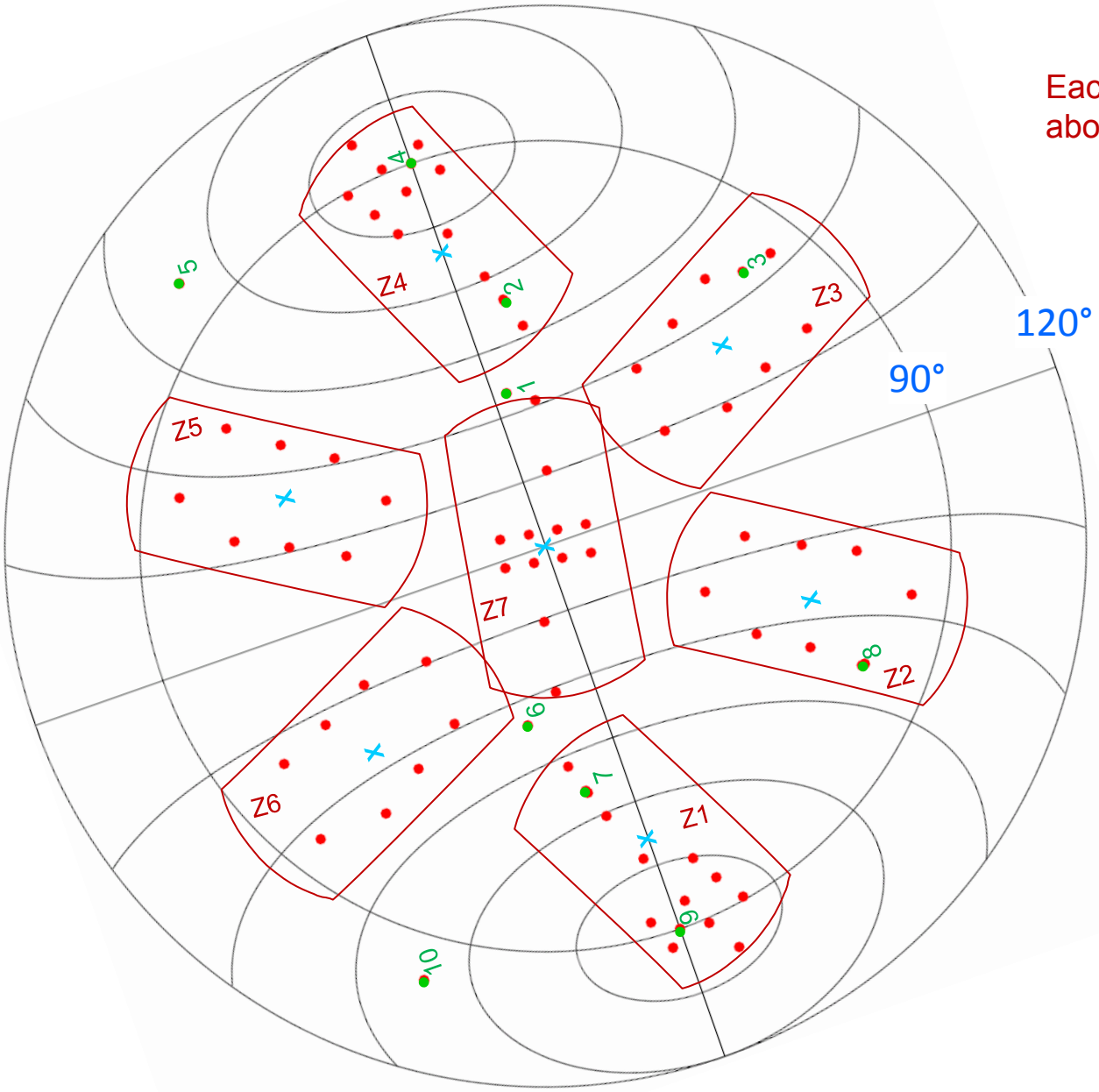
AOC#1-Malone

Green dots are required coverage.

(looking from fiber array towards the curved surface)
(light coming out of page)

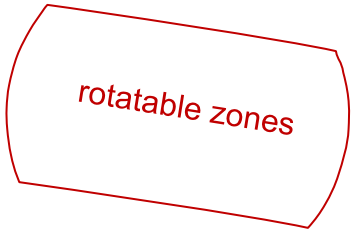
68 fiber dots are displayed.

Tilt of zones 1 & 4 were chosen to get to +/- 1.0 coverage.
Tilt of zone 7 was chosen to get to +/- 0.5 coverage.

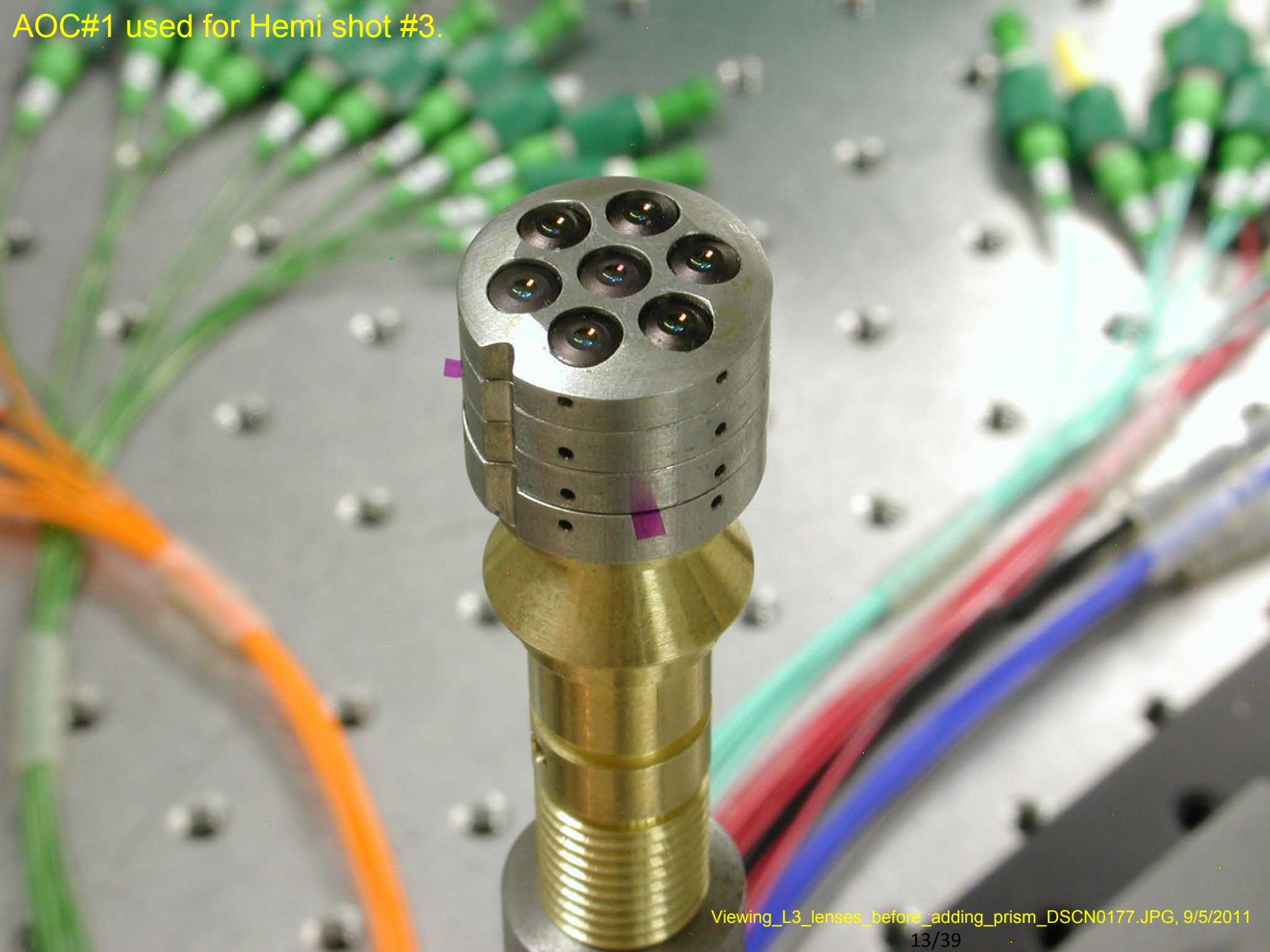


Each array zone can be rotated about its pivot.

x = zone pivot



Z1 rotated -19°
Z2 rotated 0°
Z3 rotated 0°
Z4 rotated -19°
Z5 rotated 0°
Z6 rotated 0°
Z7 rotated -9°


AOC#1 used for Hemi shot #3.
Viewing_L3_lenses_before_adding_prism_DSCN0177.JPG, 9/5/2011

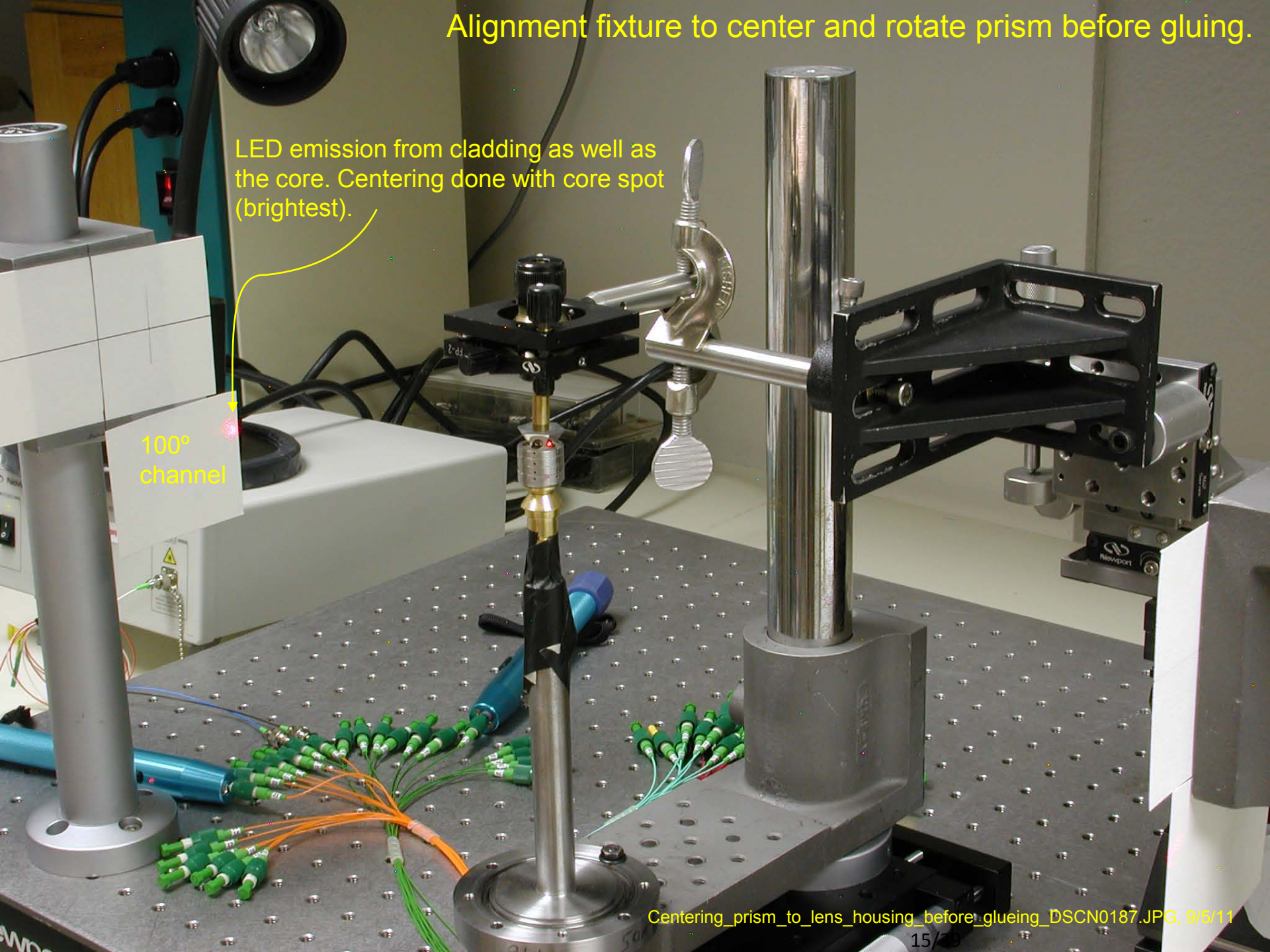
AOC#1 used for Hemi shot #3.

Enhance aluminum coating on BK7 glass prism

17.35 mm diameter metal housing

Prism_not_yet_glued_to_metal_housing_DSCN0184.JPG, 9/5/2011

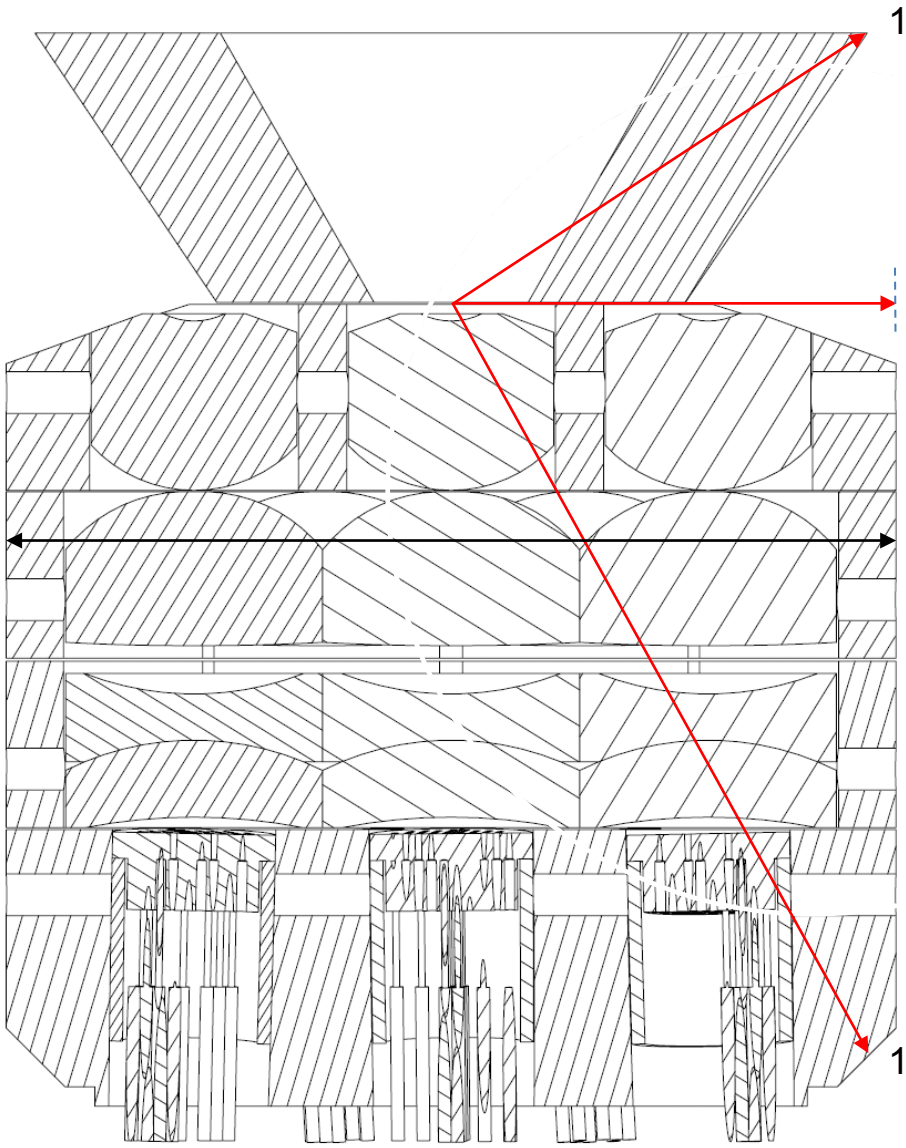
Alignment fixture to center and rotate prism before gluing.



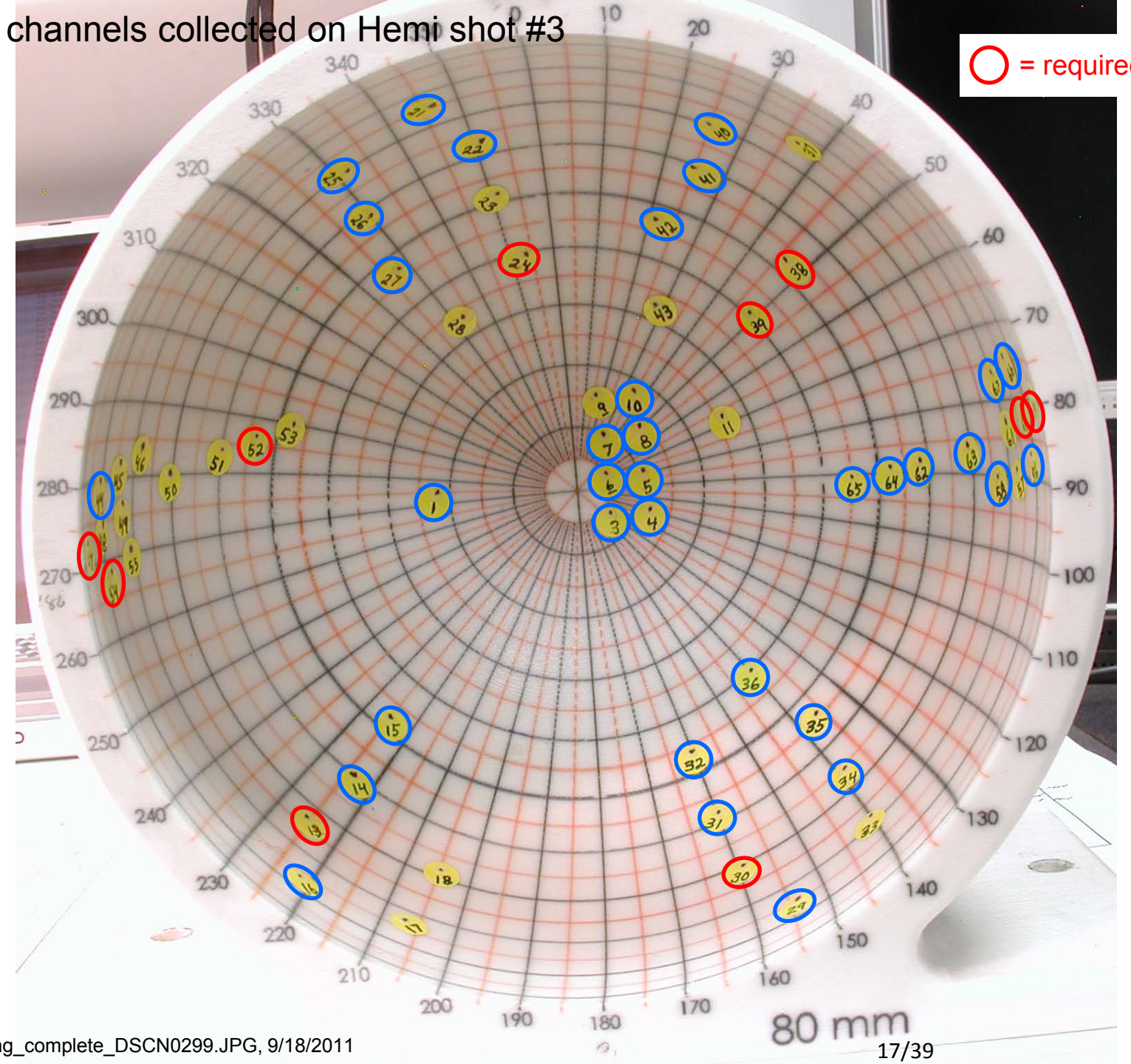
Centering_prism_to_lens_housing_before_glueing_DSCN0187.JPG, 9/5/11

AOC#1 used for Hemi shot #3.

Calculating distances from the “zero crossing.”



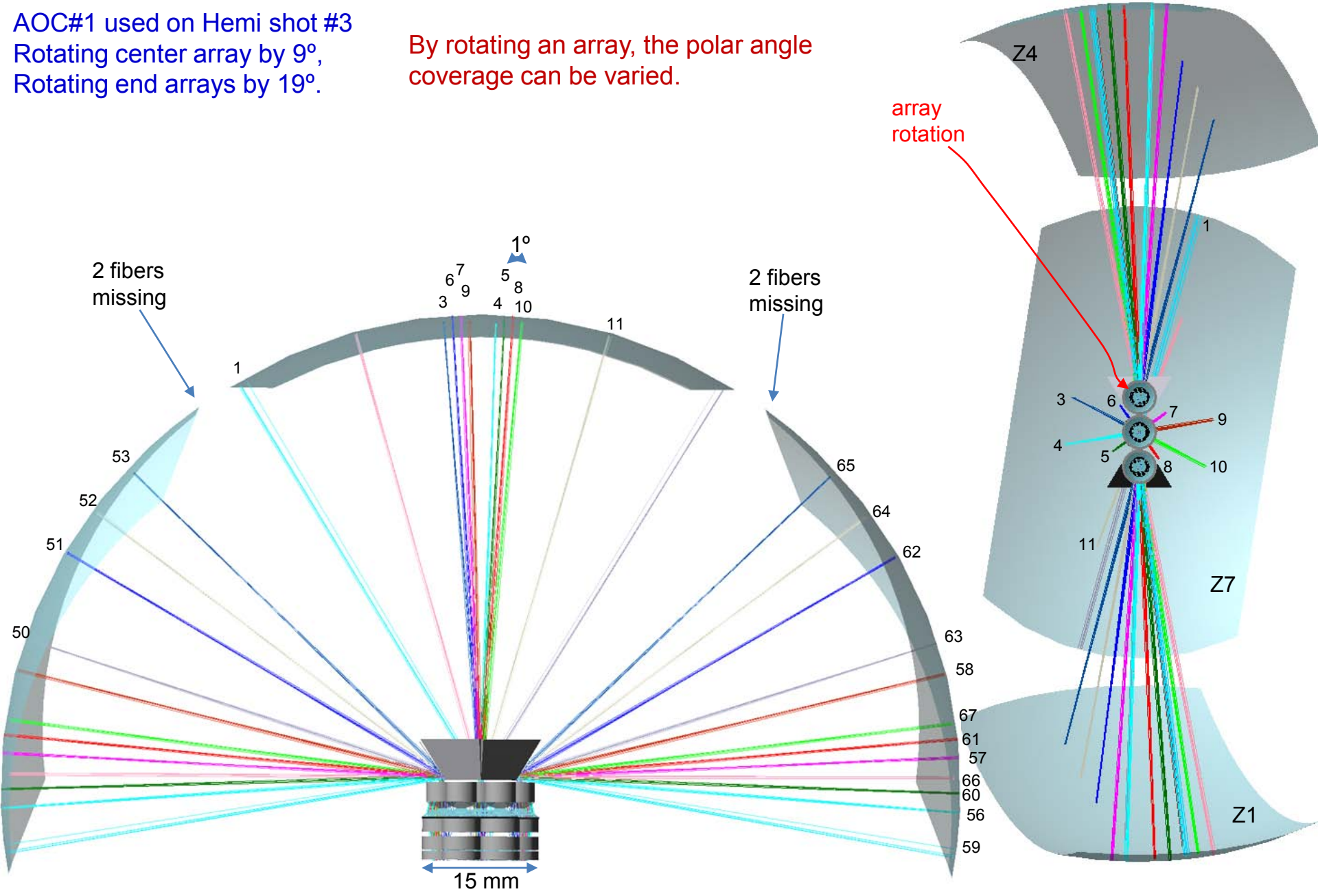
44 PDV channels collected on Hemi shot #3



Dome_mapping_complete_DSCN0299.JPG, 9/18/2011

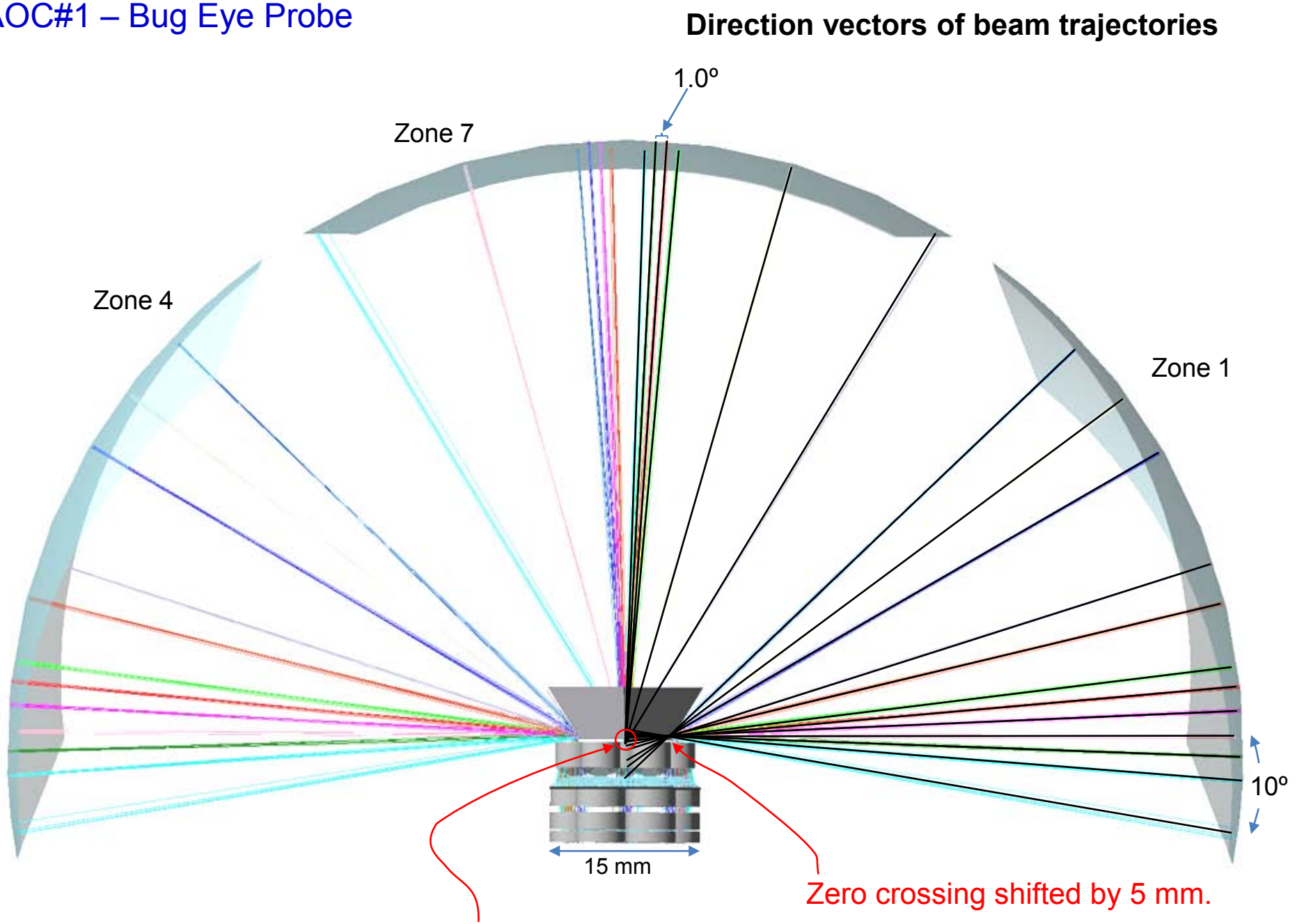
AOC#1 used on Hemi shot #3
Rotating center array by 9º,
Rotating end arrays by 19º.

By rotating an array, the polar angle coverage can be varied.



AOC#1_used_on_Hemi#3_V2.len

AOC#1 – Bug Eye Probe

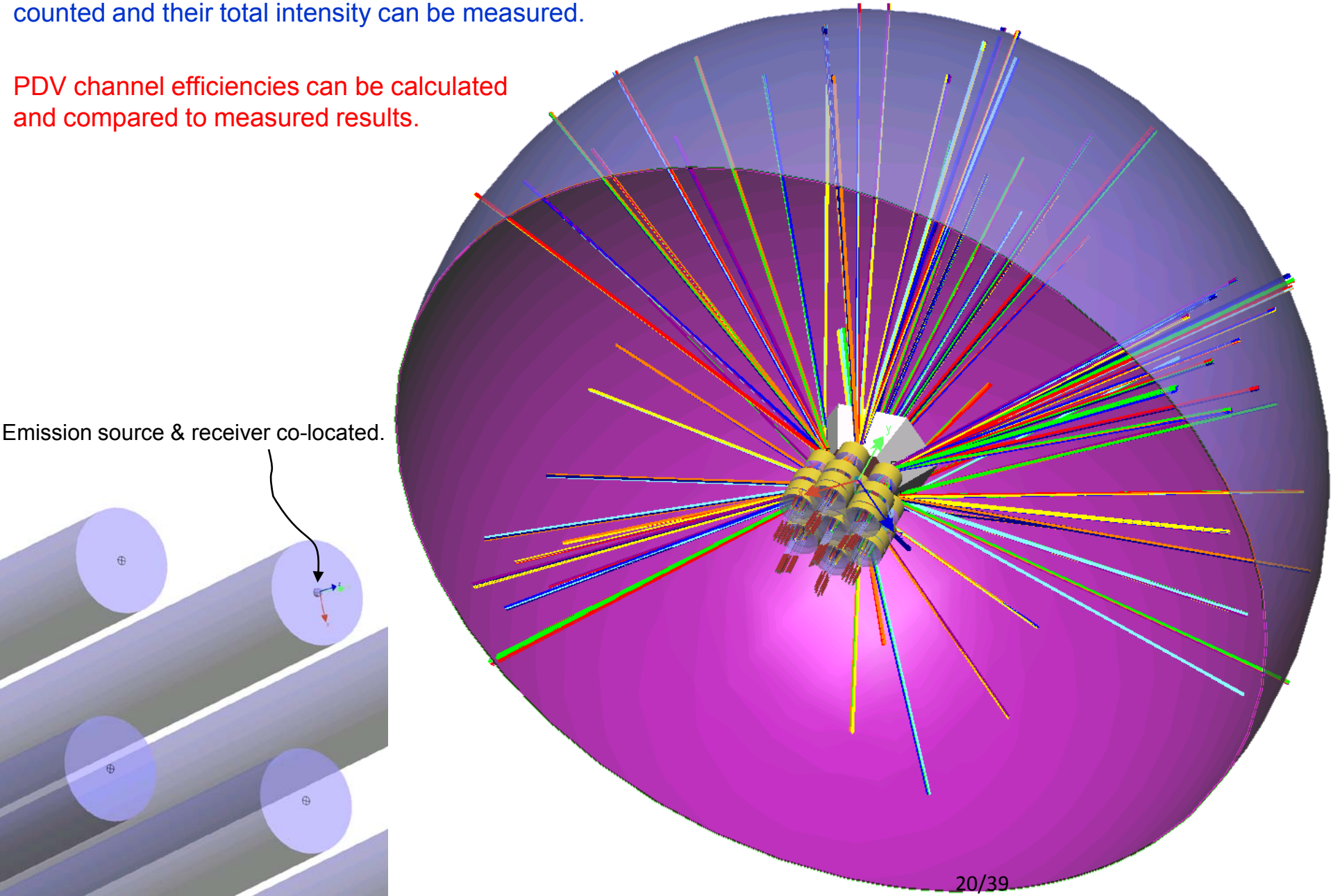


3 out of 12 fibers from Z1 fall outside 2 mm diameter zero crossing volume.

AOC#1_used_on_Hemi#3_V2.len

New optical design capability: Light is sent from 10 μm fiber, through the lenses, reflected off the dome, back through the lenses and into the same fiber. Scatter parameters of dome can be varied. Dome diameter and shape can be varied. Transmission and reflectivity of optical components can be defined. % of received rays can be counted and their total intensity can be measured.

PDV channel efficiencies can be calculated and compared to measured results.

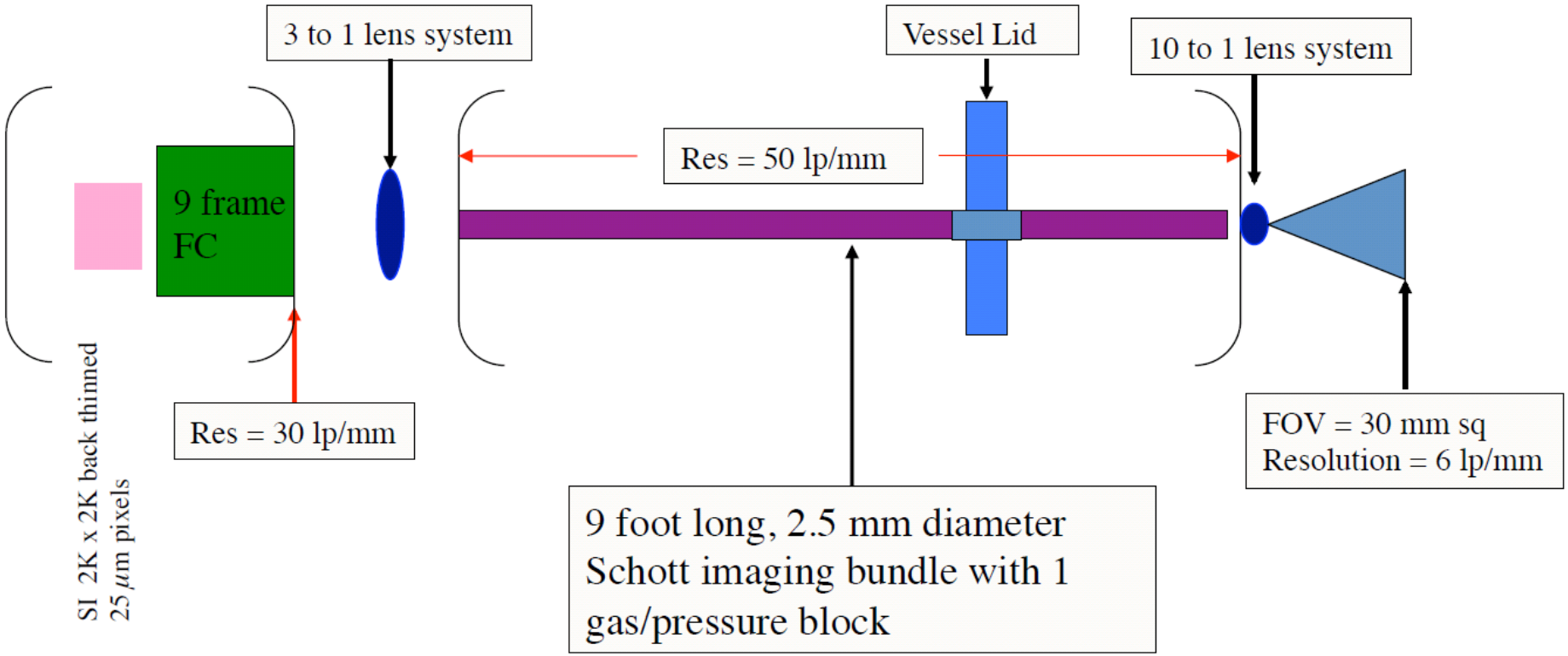


Emission source & receiver co-located.

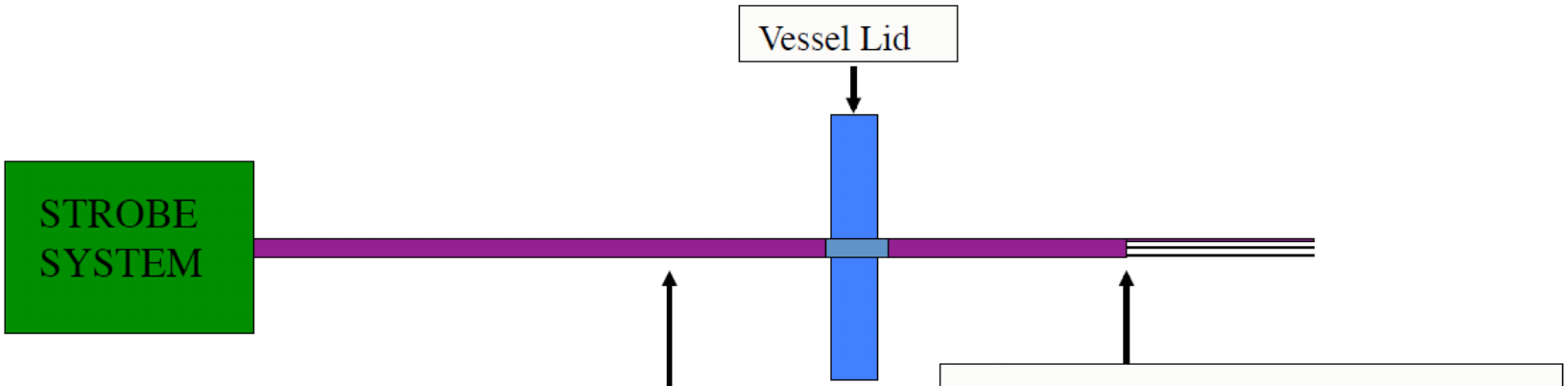
Introduction: Why Imaging

- *Static color images* over 25 mm diameter FOV, with better than 100 micron resolution
  - *characterize surface condition (e.g. oxidation) at TA-55, DAF, U1A*
  - Provide a check of the PDV laser spot locations (within the FOV of the imaging) for the fully assembled package at the U1A facility
- *Nine dynamic visible images over 25 mm FOV*
  - *Shock waves moving across the surface (measure: symmetry and timing) [Note: Barolo pRad data confirms this measurement]*
  - *Up to 10 mm of motion of two features.*

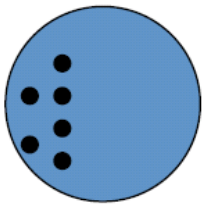
Overview: Schematic of Imaging System Components



Overview: Schematic of Illumination System components



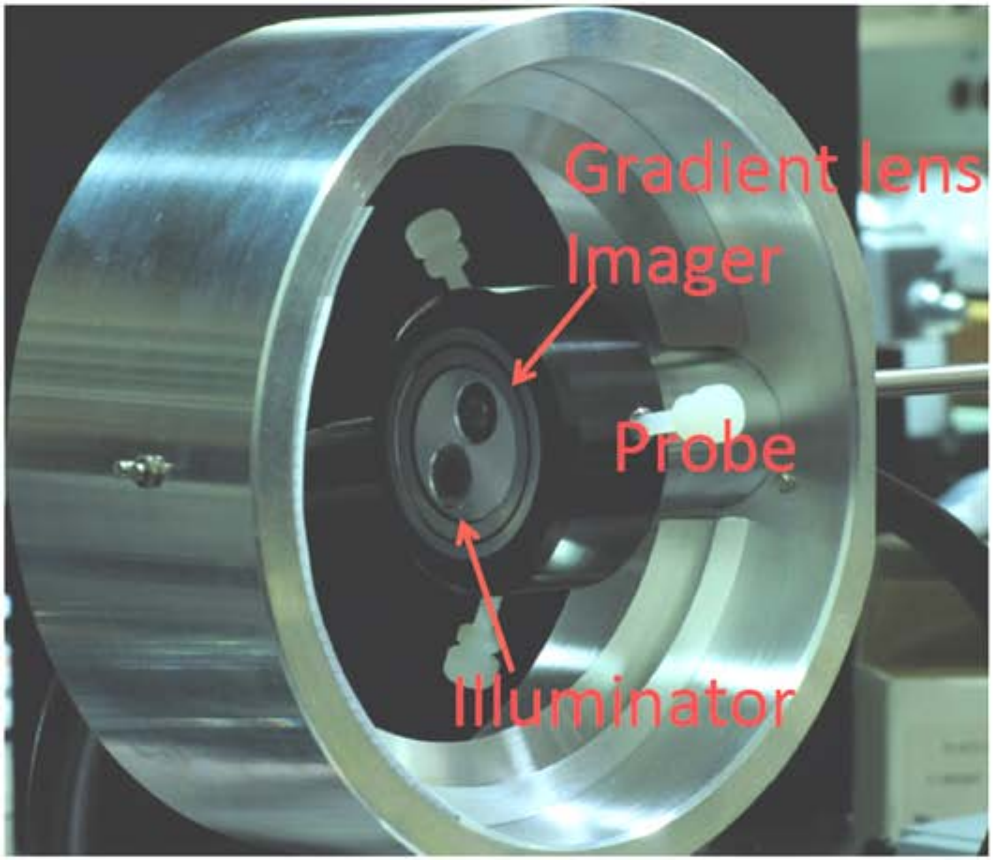
5 mm diameter fiber array implies 20 mm^2 area.

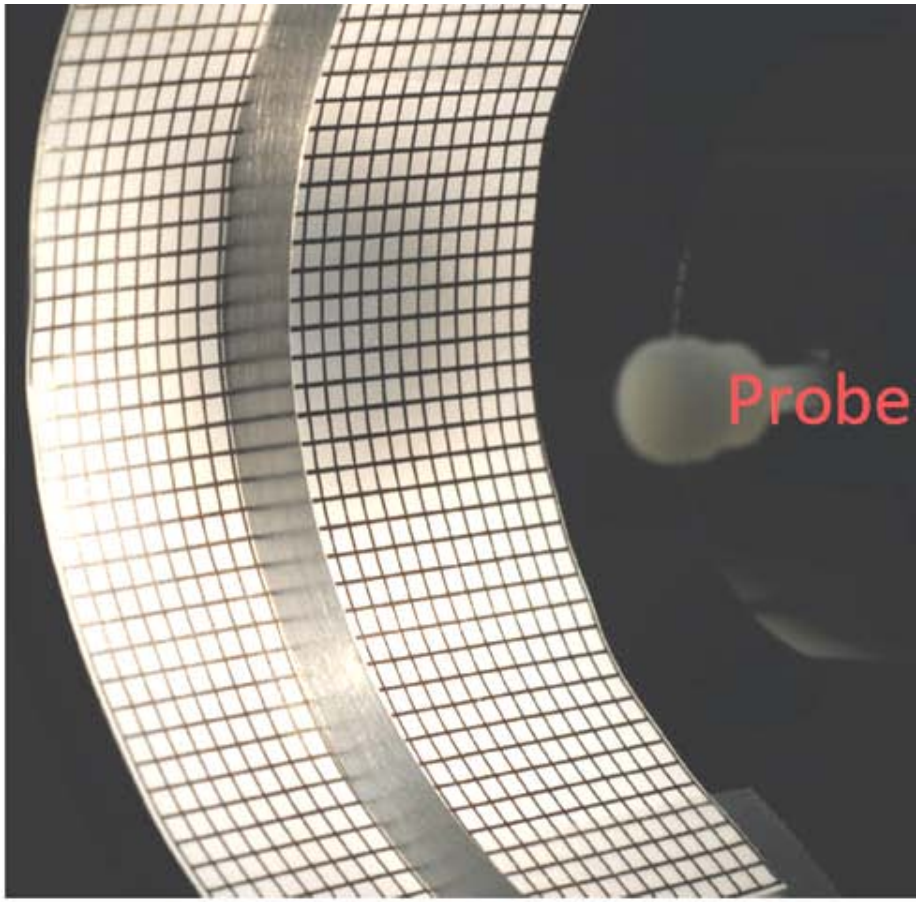


Fibers spread into 5 separate 2 mm diameter bundles to be integrated into optical dome

9 foot long, 5 mm diameter fiber optic bundle (50 micron fibers) N.A. TBD with 1 gas block

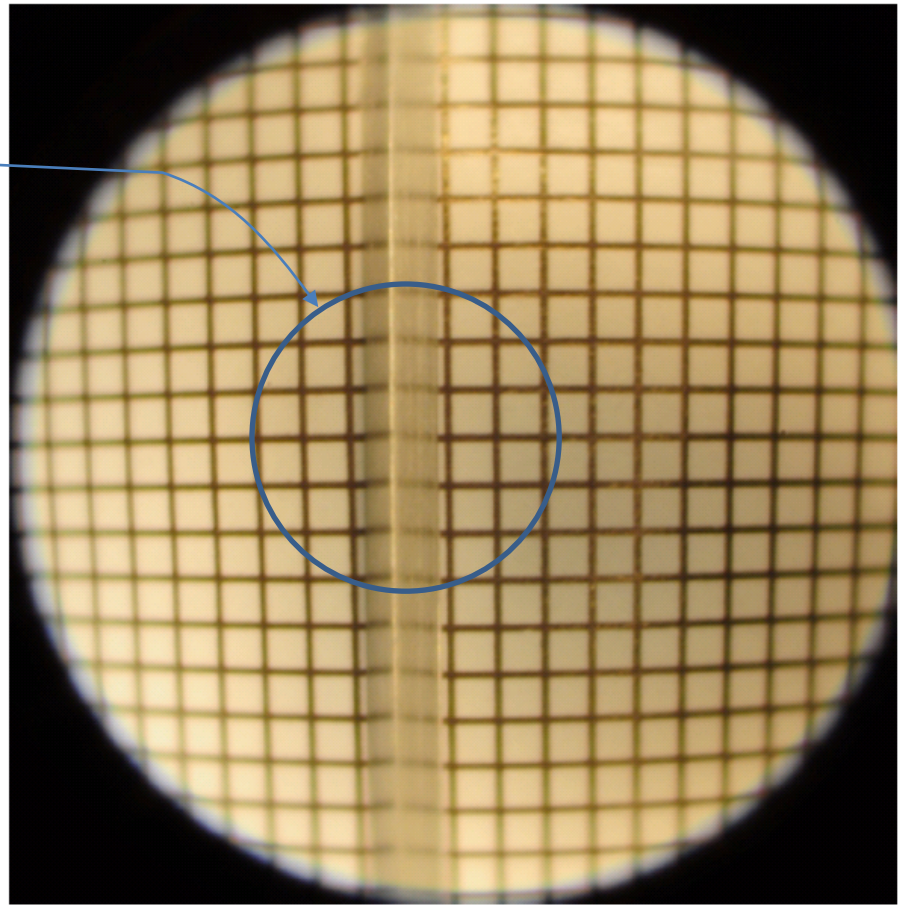
Dynamic Imaging Mock-up





Example of an image viewed directly onto a surface

- Image FOV approximately 25 mm in diameter
- Resolution better than 100 microns
- DOF allow coverage of moving surface over approximately 10 mm
- FOV encompasses two features of interest



Placing the 2.5 mm diameter bundle inside the 4.8 mm dia. zone still leaves room for 255 PDV fibers.
3 zones for illumination fibers.
AOC gamma can only image 2.4 mm diameter.
Cutoff switches line the inside of the 5.0 mm ID pipe.

FIBER PACKING PROGRAM DATA

Output Data

Packed fiber number =1092

Packing Configuration

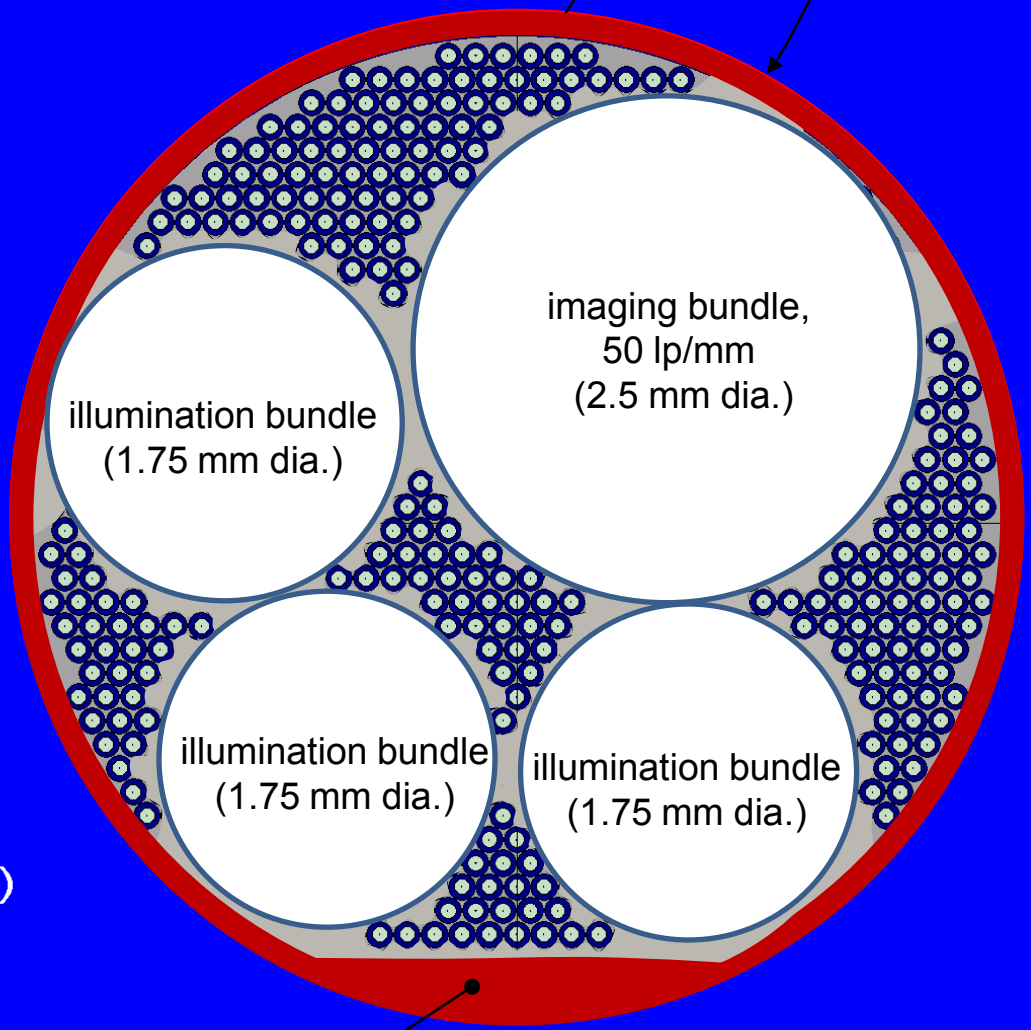
Triangular Close Pack

Input Data

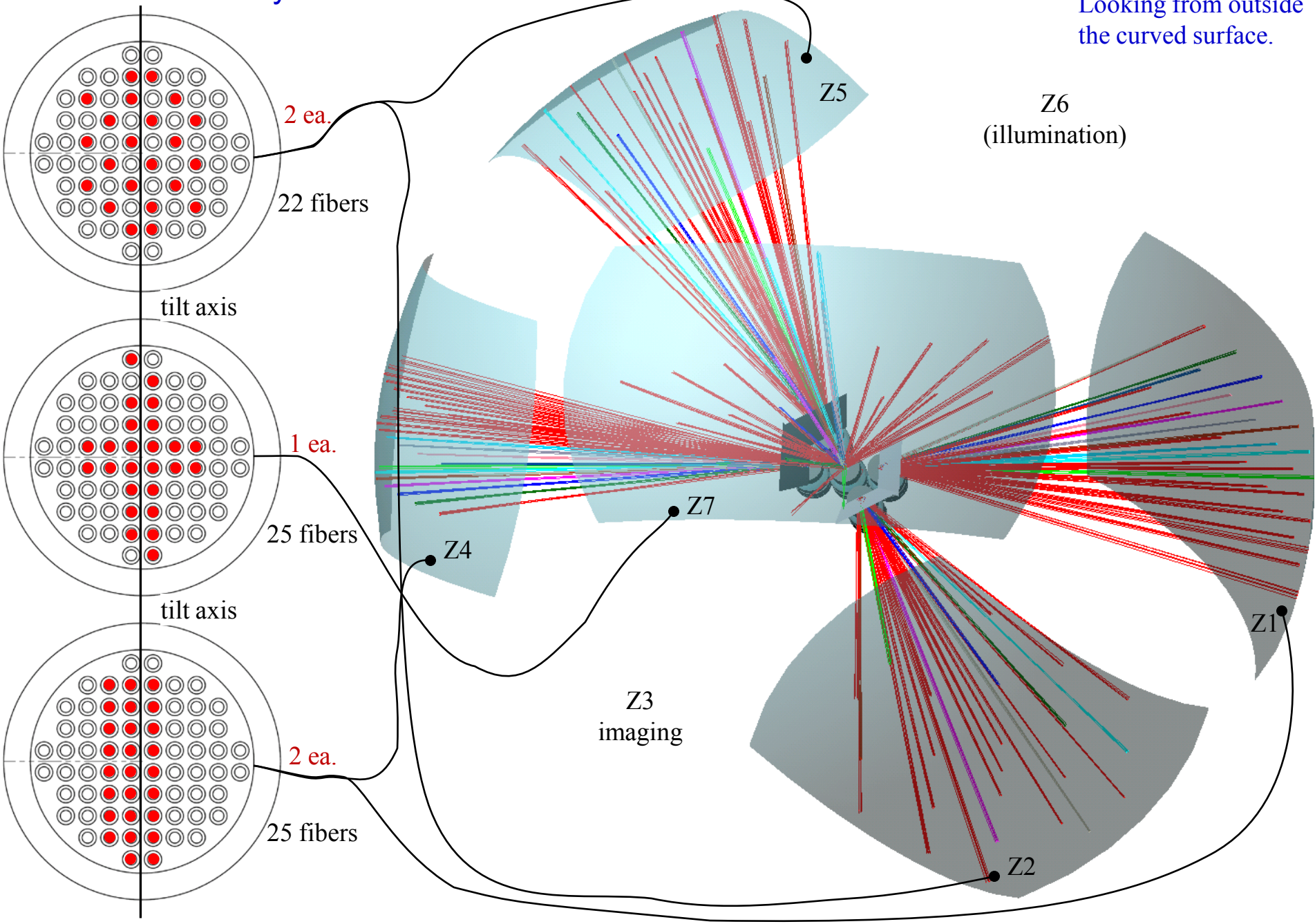
Tube Diameter (mm)	=4.797
Coating Diameter (um)	=135
Cladding Diameter (um)	=80
Core Diameter (um)	=10

Area (Square mm)

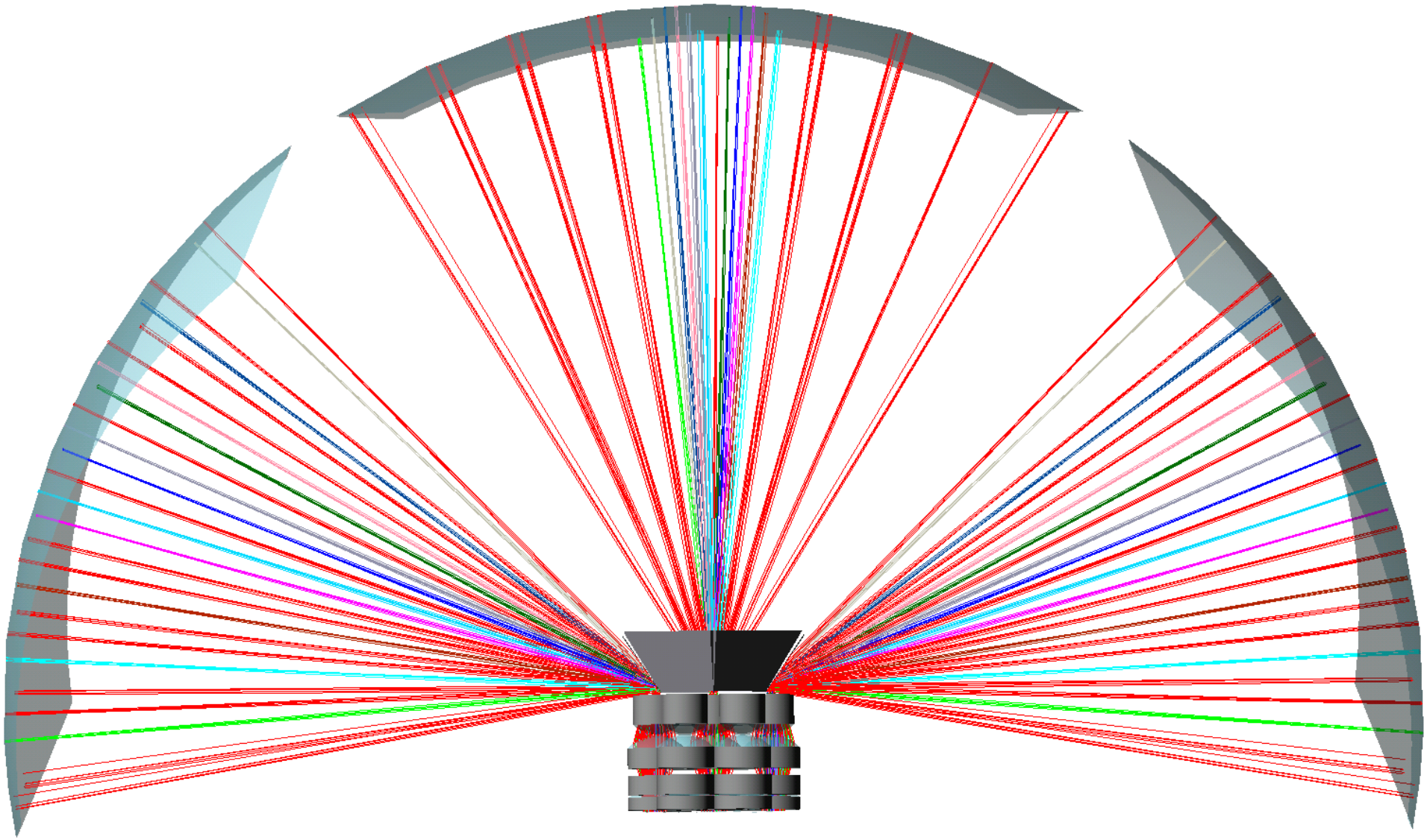
Tube	=18.07	
Coating	=10.14	(56.1%)
Cladding	=5.403	(29.9%)
Core	=0.08577	(0.475%)
Dead Area	=2.442	(13.5%)

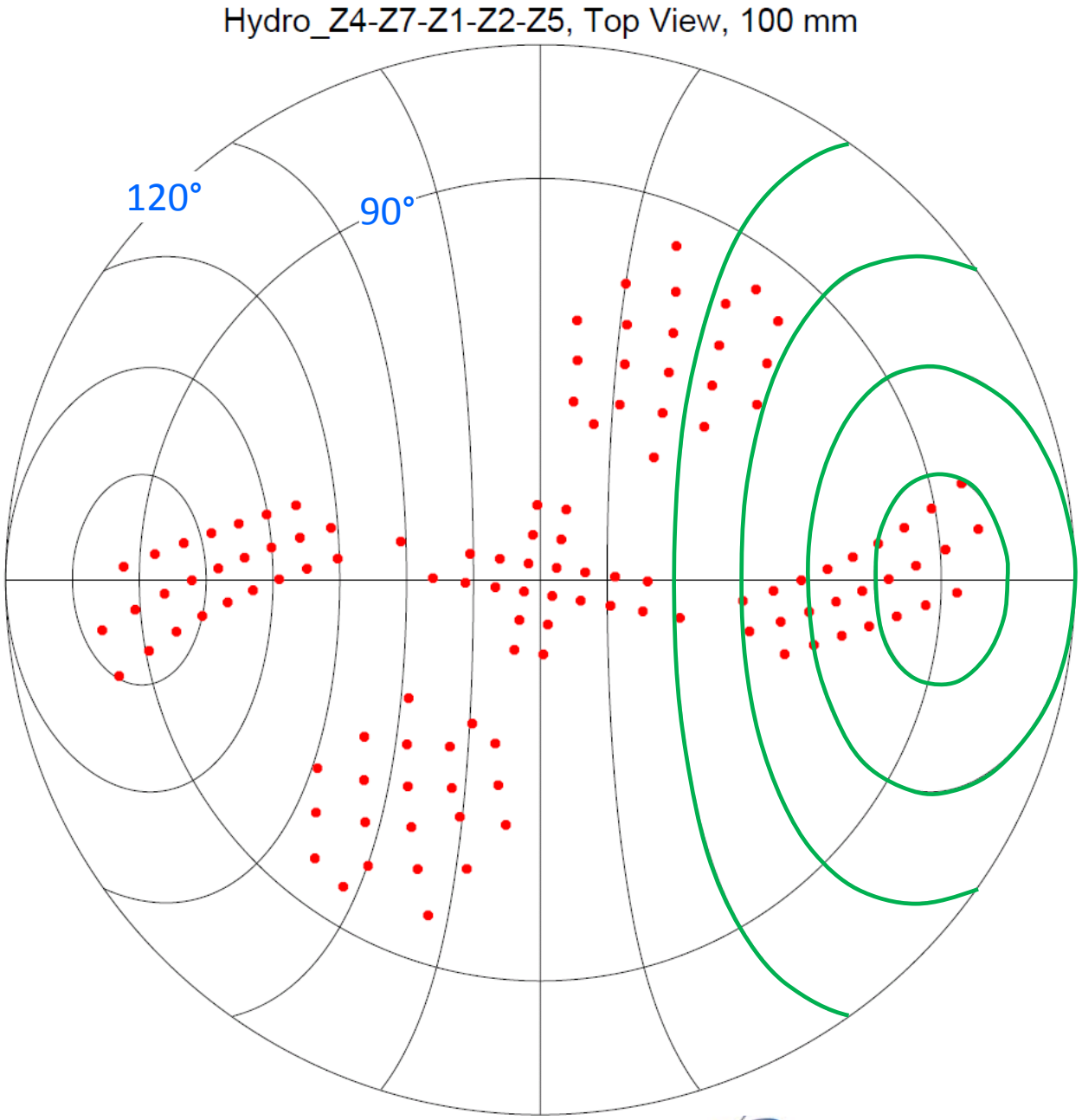


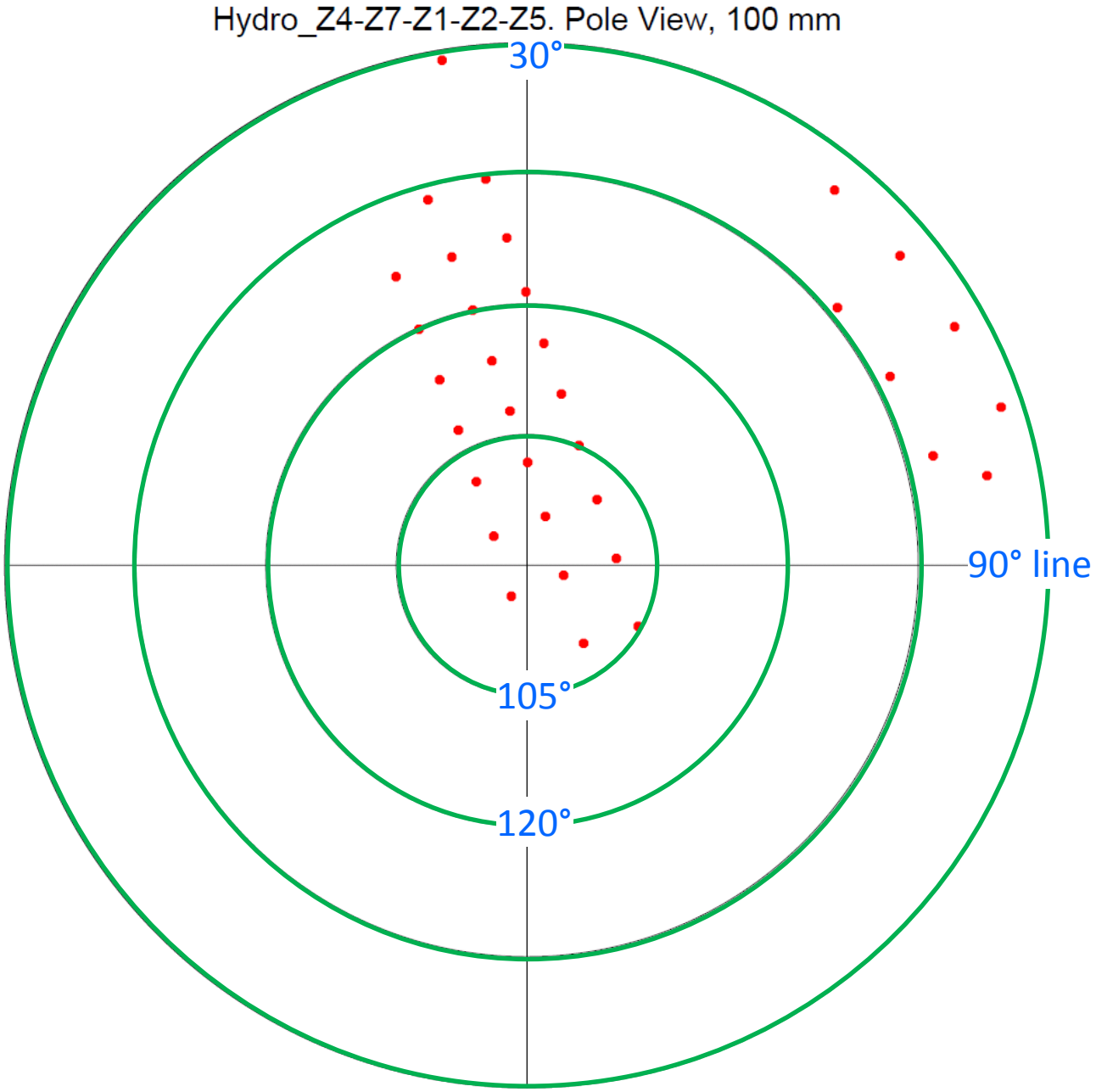
AOC#1 used for Hydro.



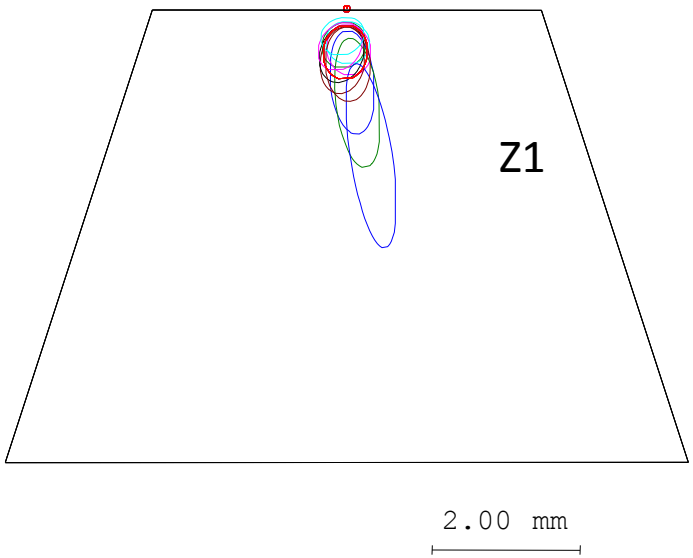
AOC#1 – Bug Eye Probe

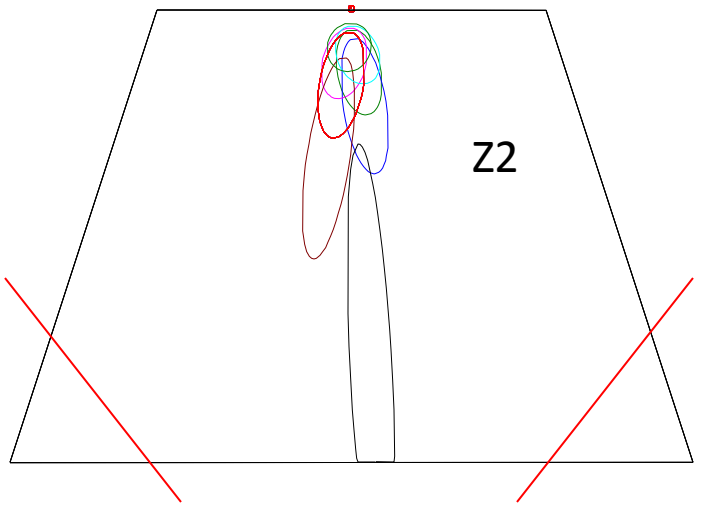



Hydro_Z4-Z7-Z1-Z2-Z5, Top View, 100 mm
120°
90°


Hydro_Z4-Z7-Z1-Z2-Z5. Pole View, 100 mm
30°
90° line
105°
120°

Analyzing used area of prism facets





SURFACE 19 : prism facet

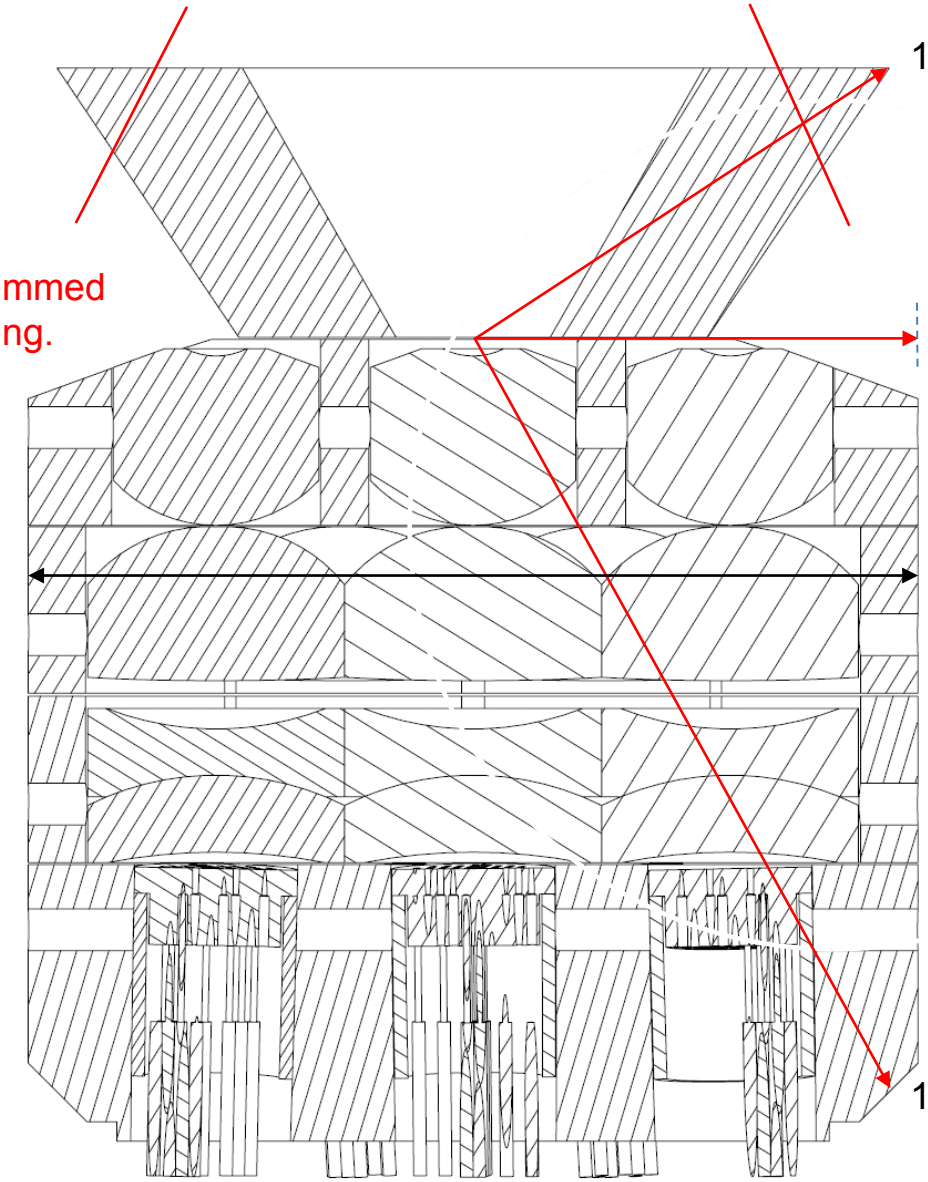
Corners of prism facets can be trimmed to gain 1.4 mm more data recording.

AOC#1_used_on_Hemi#3_V2.len

AOC#1 used for Hemi shot #3.

Calculating distances from the “zero crossing.”

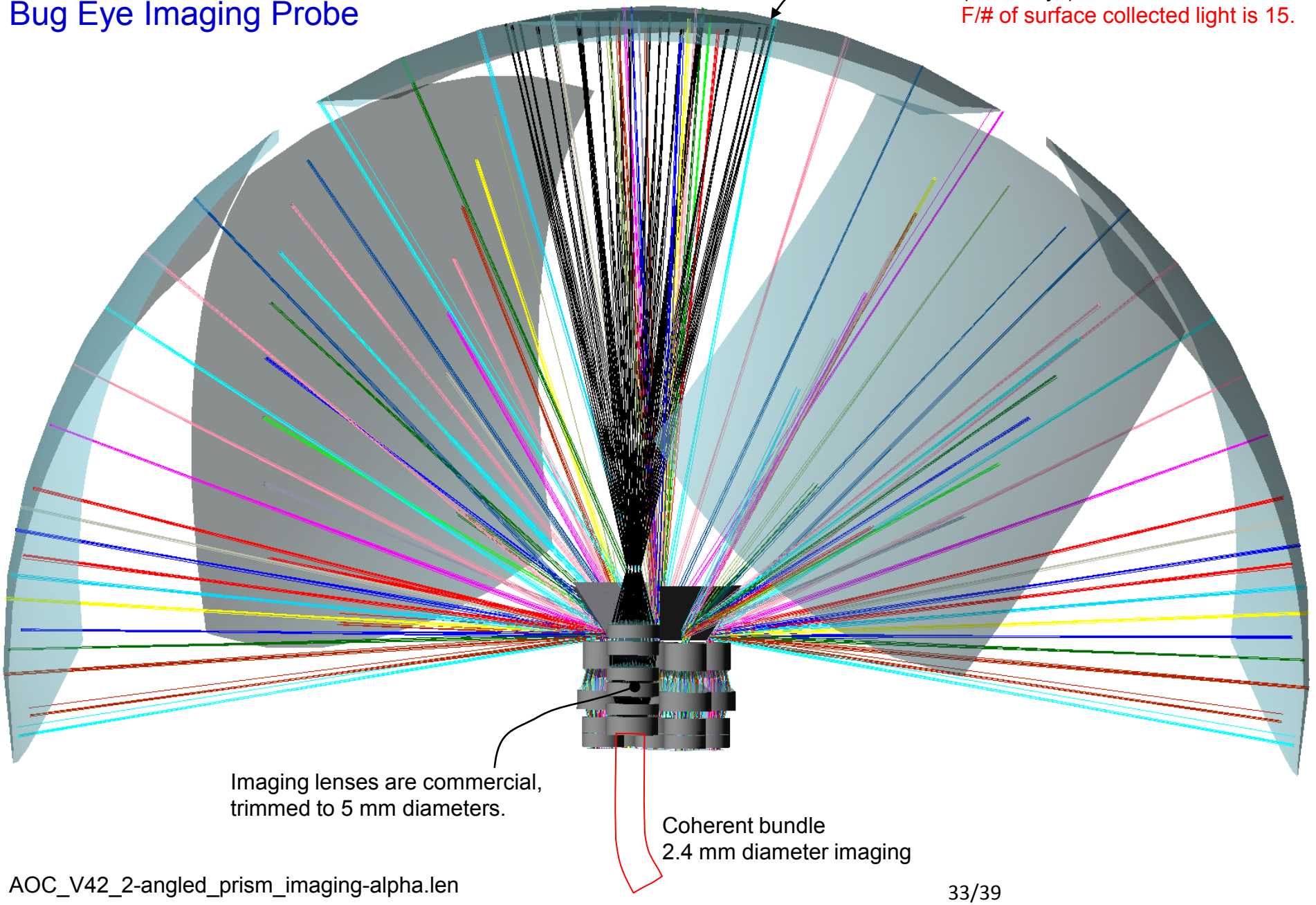
Corners of prism facets can be trimmed to gain 1.4 mm more data recording.



Advanced Optical Cavity Velocimetry

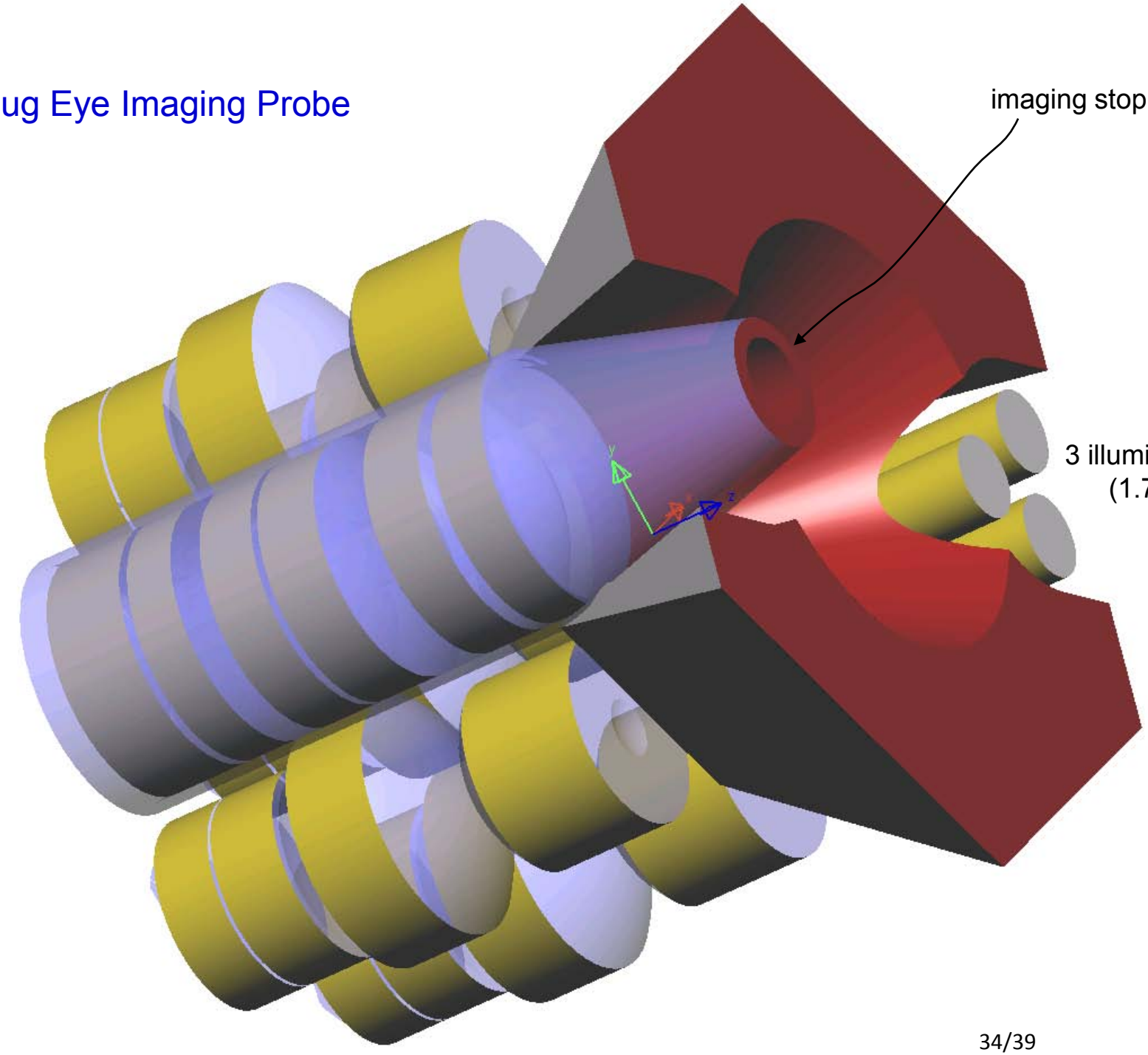
Gamma version, tilted array, showing imaging capabilities

Bug Eye Imaging Probe

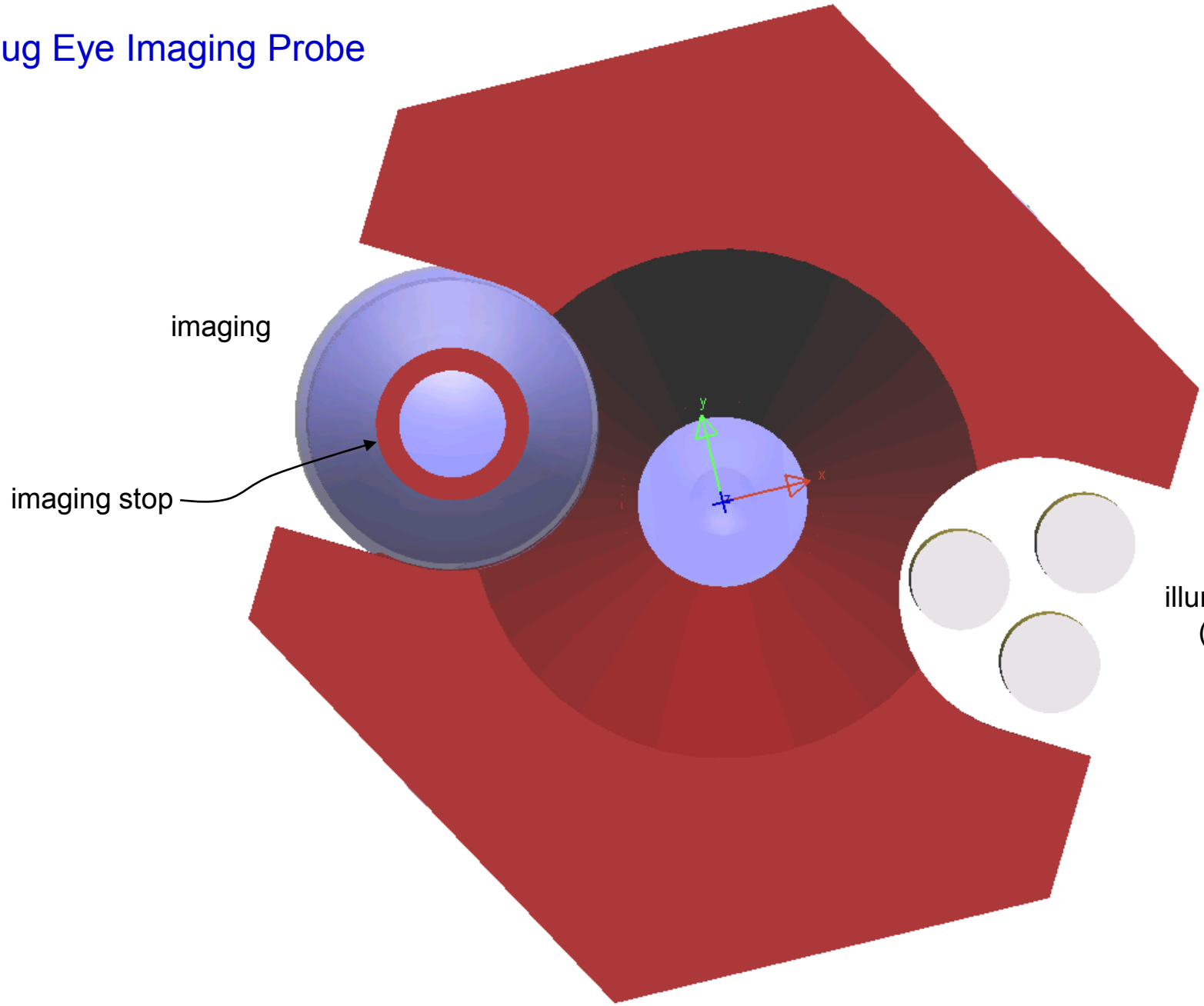


AOC_V42_2-angled_prism_imaging-alpha.len

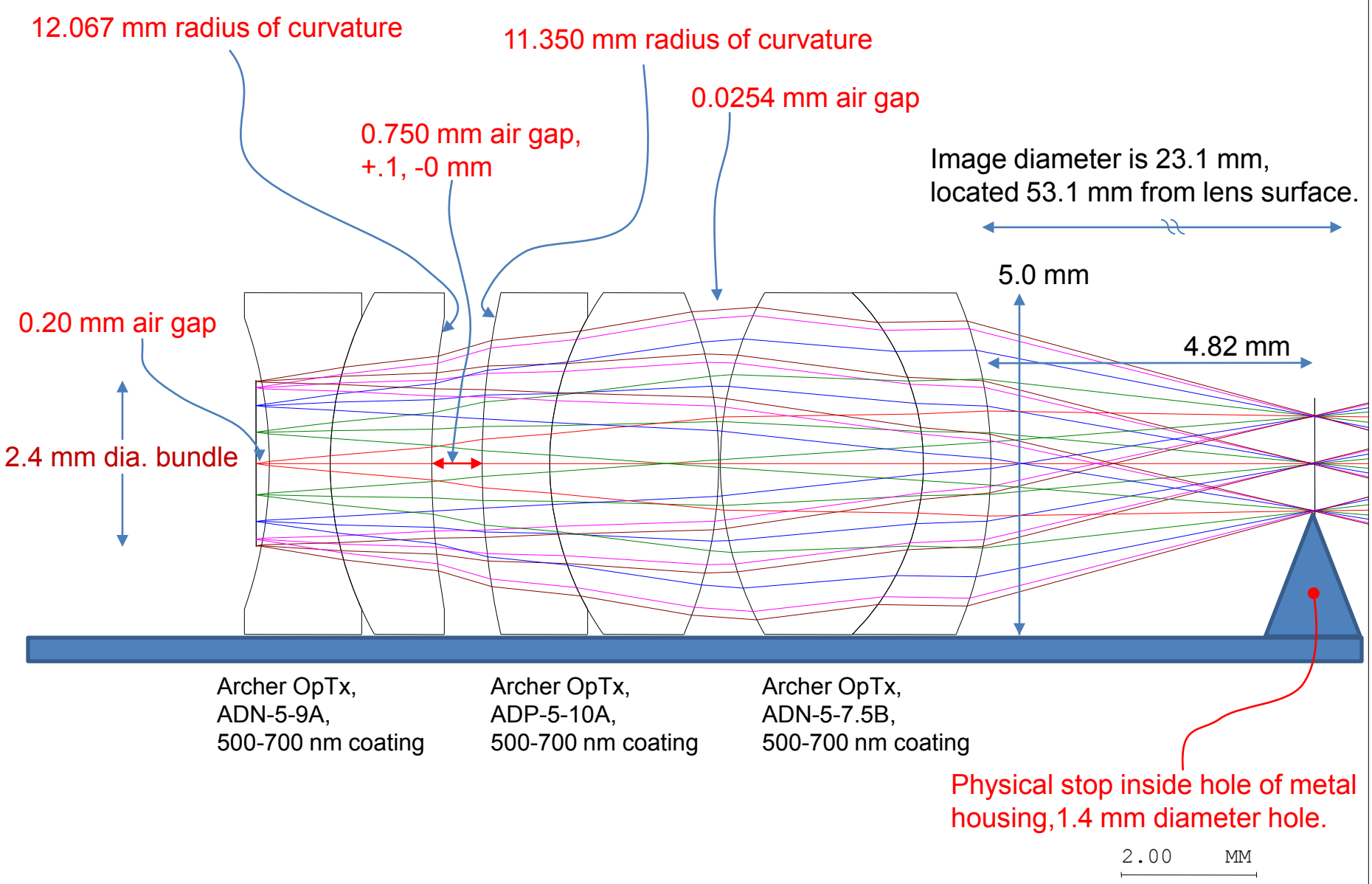
Bug Eye Imaging Probe



Bug Eye Imaging Probe

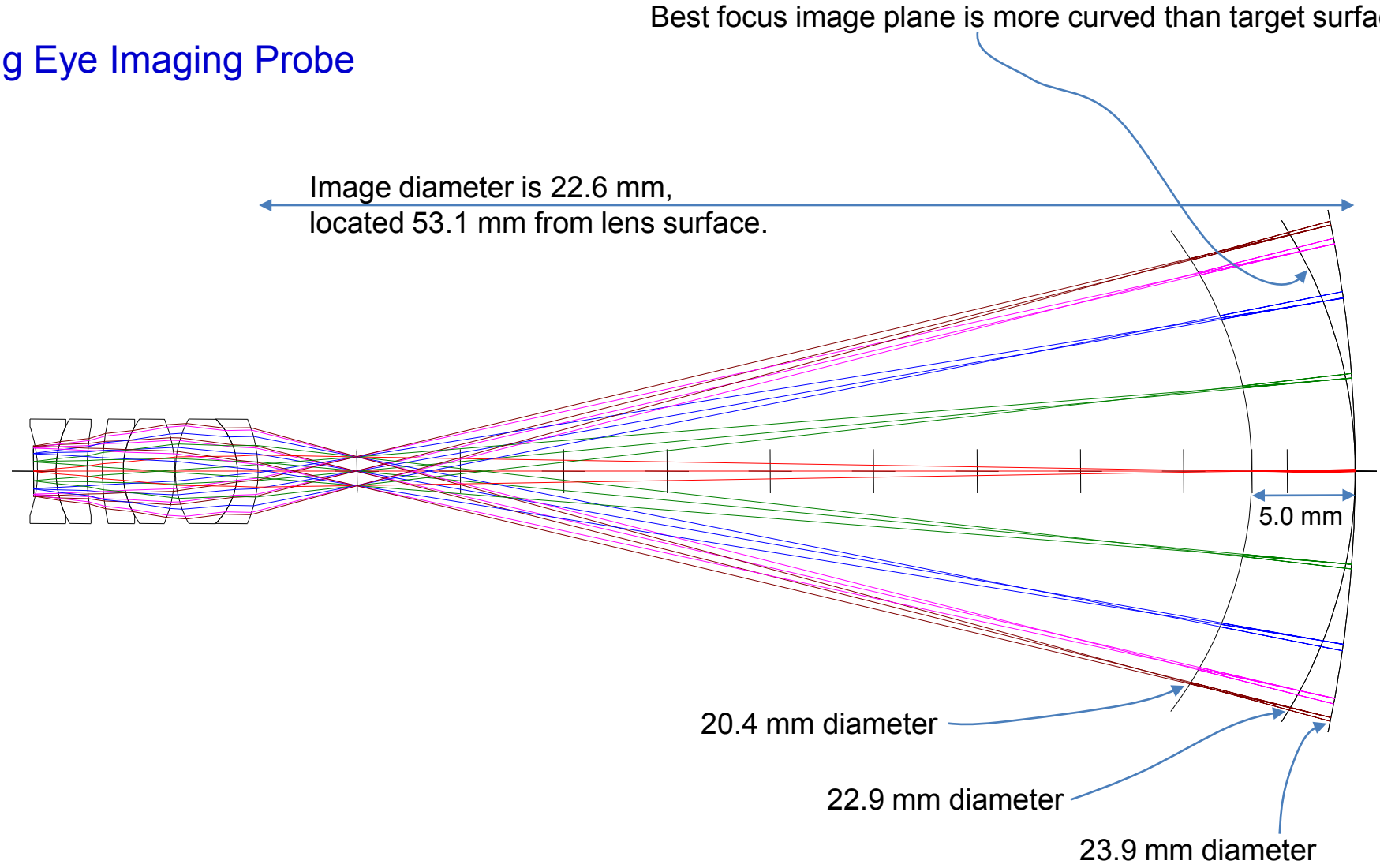


Bug Eye Imaging Probe



AOC_V41_alpha_imaging.len RMM 27-Sep-11

Bug Eye Imaging Probe



AOC_V41_alpha_imaging.len RMM 27-Sep-11

AOC_V41_alpha_imaging.len

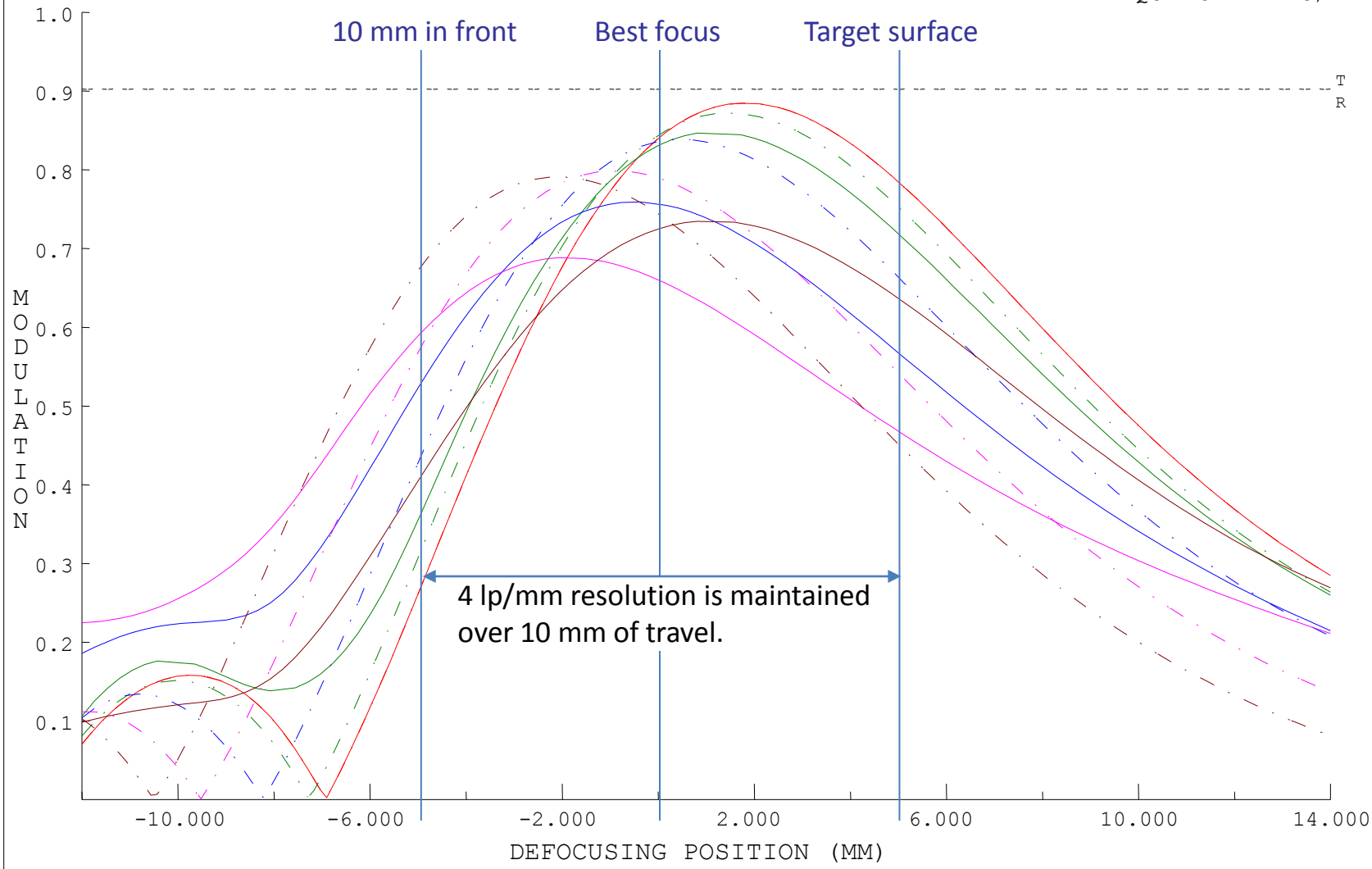
DIFFRACTION MTF

RMM 27-Sep-11

DIFFRACTION LIMIT
TR 0.00 mm @ bundle
TR 0.30 mm @ bundle
TR 0.60 mm @ bundle
TR 0.90 mm @ bundle
TR 1.20 mm @ bundle

WAVELENGTH	WEIGHT
700.0 NM	1
600.0 NM	1
500.0 NM	1

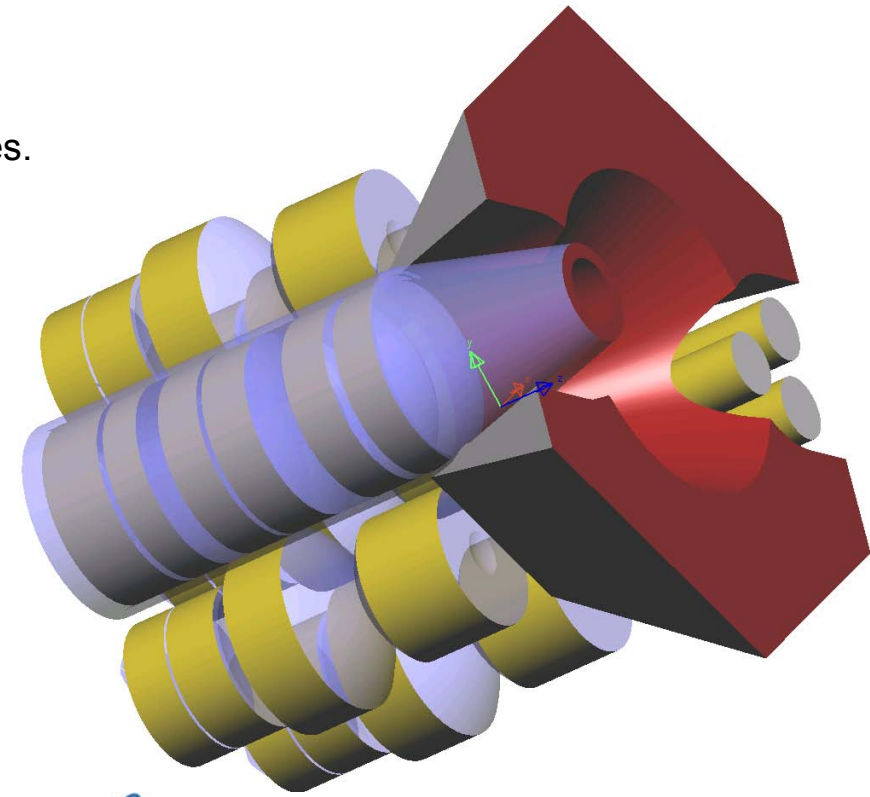
FREQUENCY 4 C/MM



Bug Eye Imaging Probe

Advantages:

1. Accommodates imaging along with the PDV channels. Imaging does not have to be used for dynamic recording, it could also serve as a surface inspection tool. We have a 1550 nm converter for visible cameras allowing images of surface features surrounding a PDV spot.
2. Each of the 5 fiber arrays can have different rotations to change area coverages.
3. Each mirror facet can have different tilts to change area coverages. We used 56º and 61º on first design.
4. Data recorded down to 9.0 mm from the zero crossing.
   (This will be further reduced using 4-mm diameter lenses.)
5. This probe accommodates several hundreds of fibers.
6. Future work may lead to the use of cell phone camera lenses.



Disadvantages:

1. Extra assembly time required to angle polish each fiber (add one extra week).
2. Zero crossings are shifted 5-mm for 4 of the 5 zones.
   (This will be further reduced using 4-mm diameter lenses.)
3. Must show that imaging is cheap and easy to perform.