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# PDV Probe Design with Stereo Imaging

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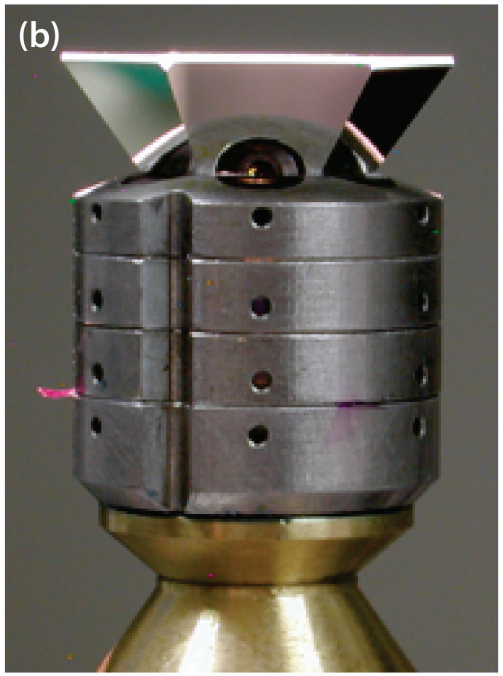
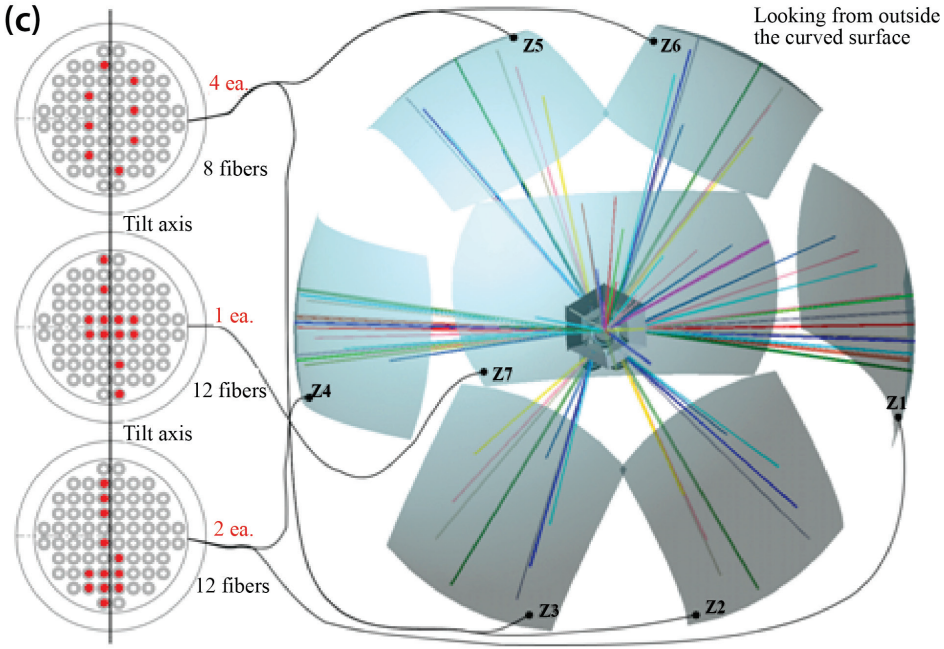
# Multiple lens array probe for hemisphere experiments

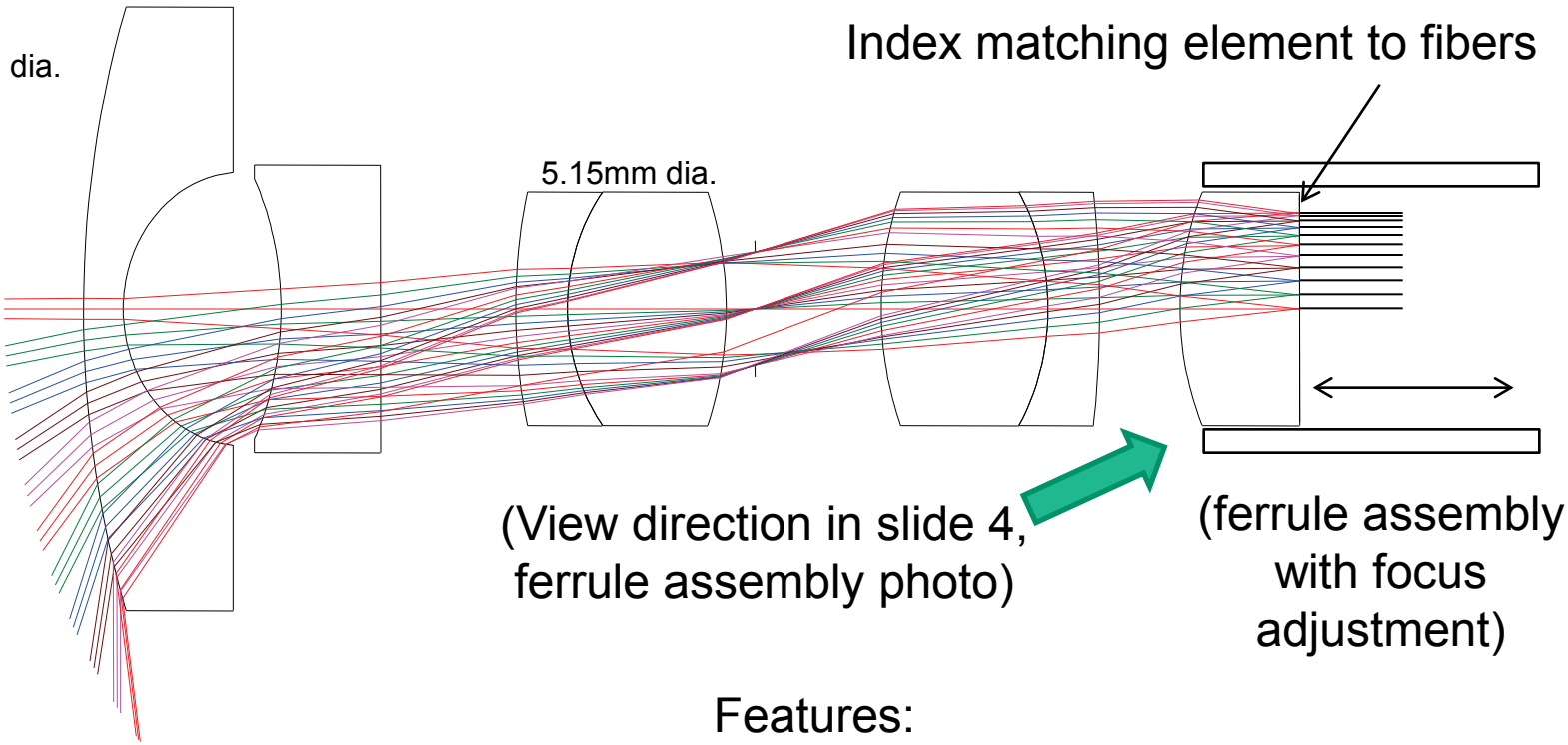




(a) Without multi-faceted prism

(b) With prism

(c) Fiber points in zone coverage (zone positions can be changed if prism face angles are changed or zones rotated)

# PDV fisheye lens ray trace - features

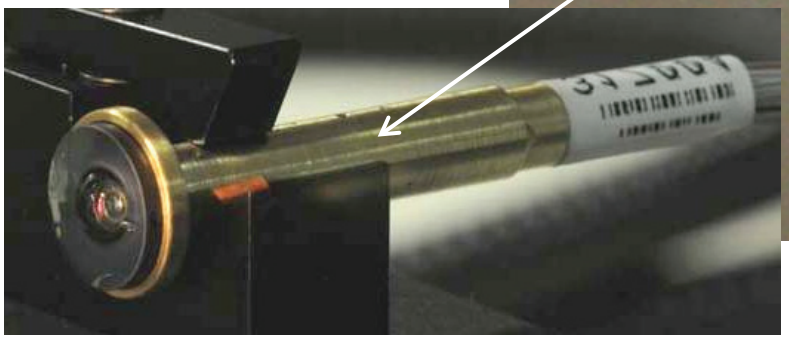


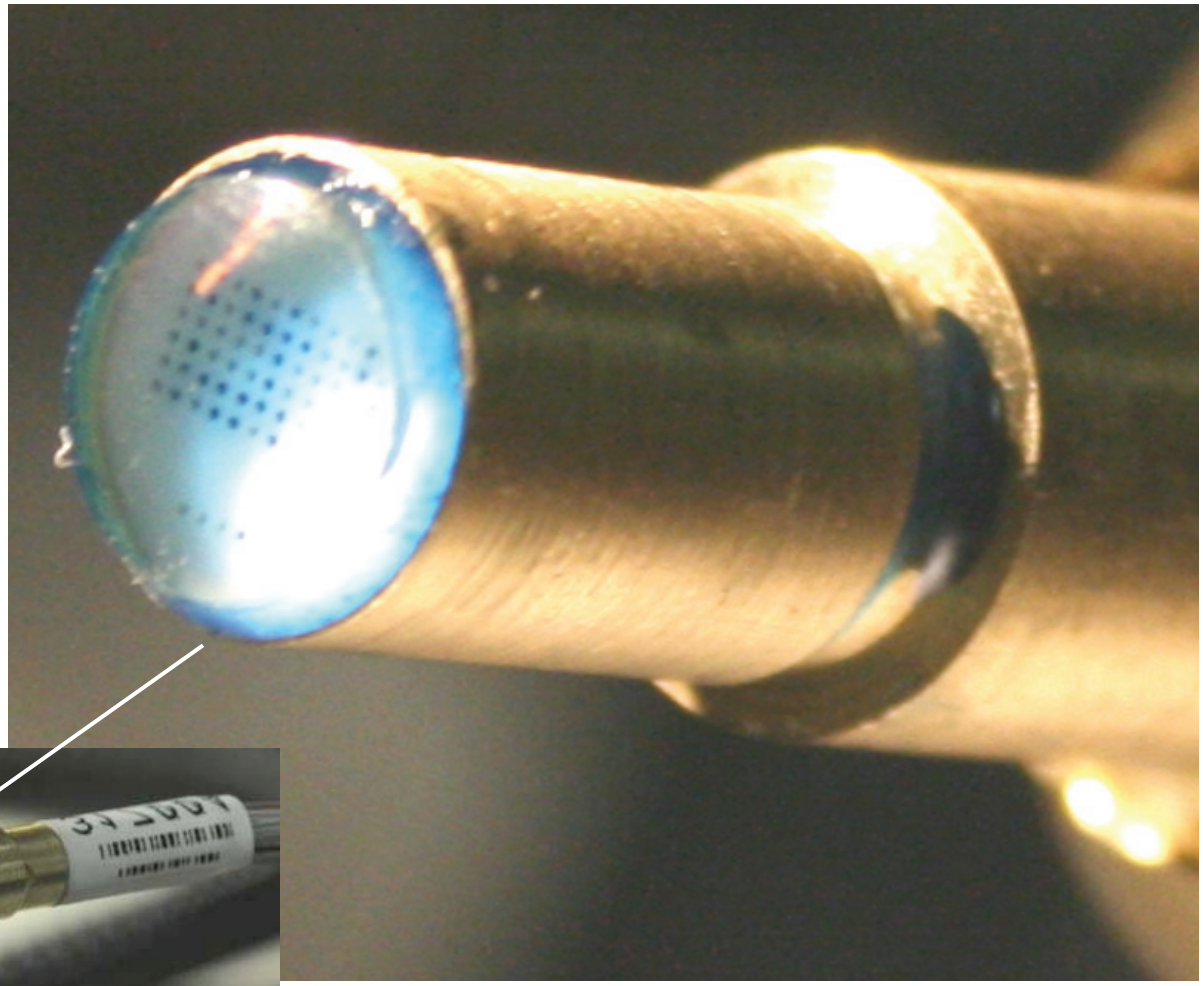

Features:

- Light incident normal to optical fibers
- Index match to optical fibers to reduce back reflections
- Distance from index-matched element and fibers can be adjusted for fine focusing
- Needs good anti-reflection lens element coatings and limited number of elements

# Fisheye probe ferrule and lens assembly

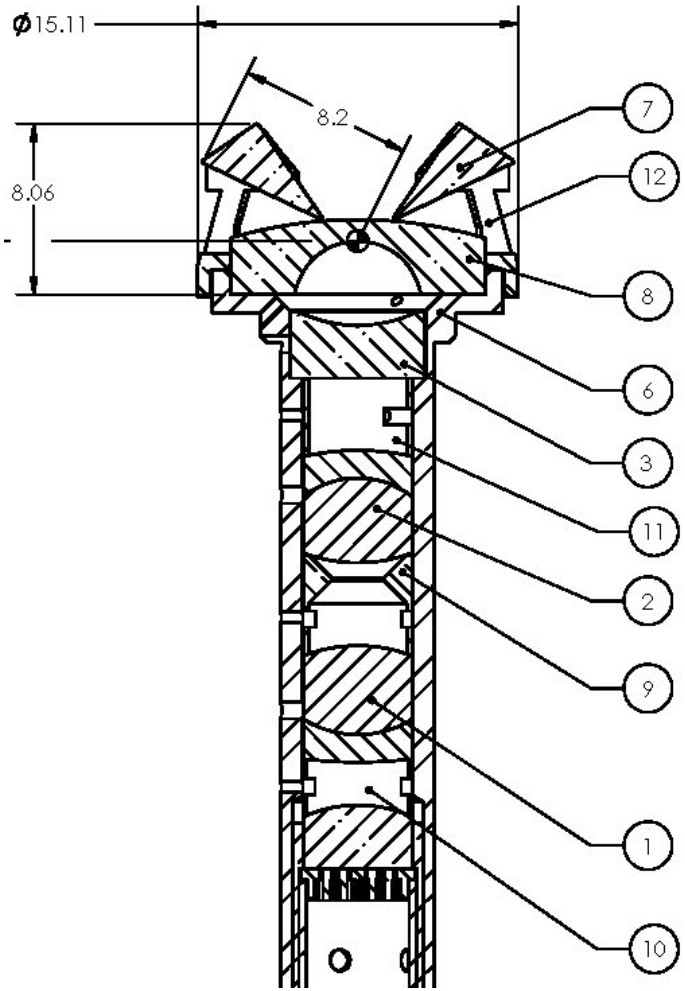
(View direction in slide 3)

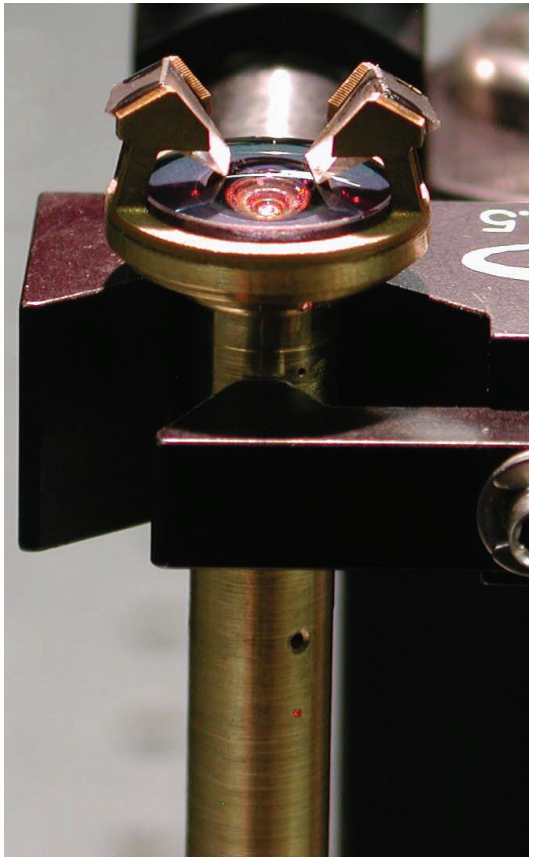




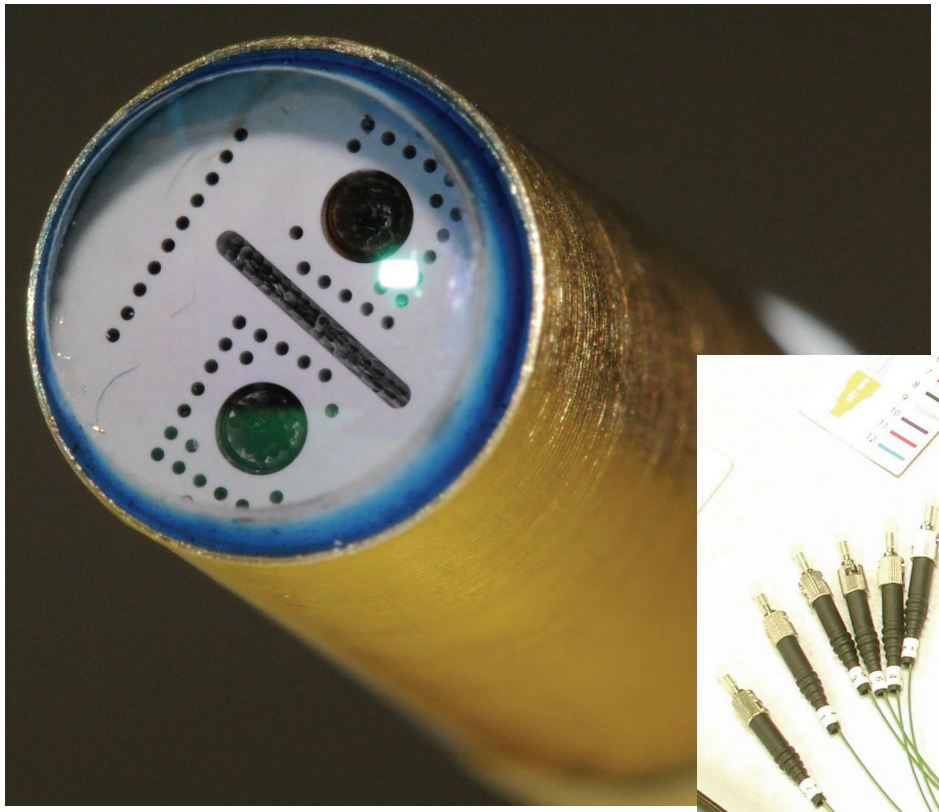
Tip shown is about halfway down tube at left; the inner tube slides in or out to adjust.

# AOC 2: Fisheye with mounting for longer reflector prisms

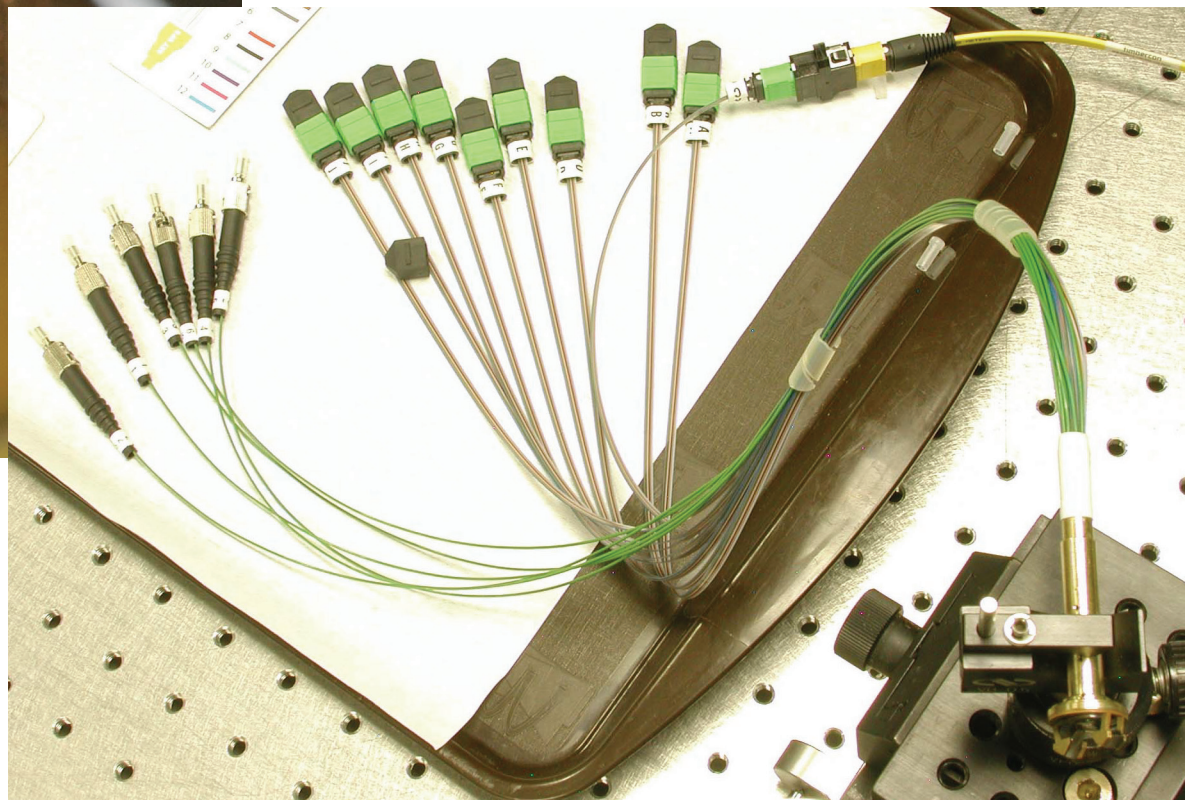


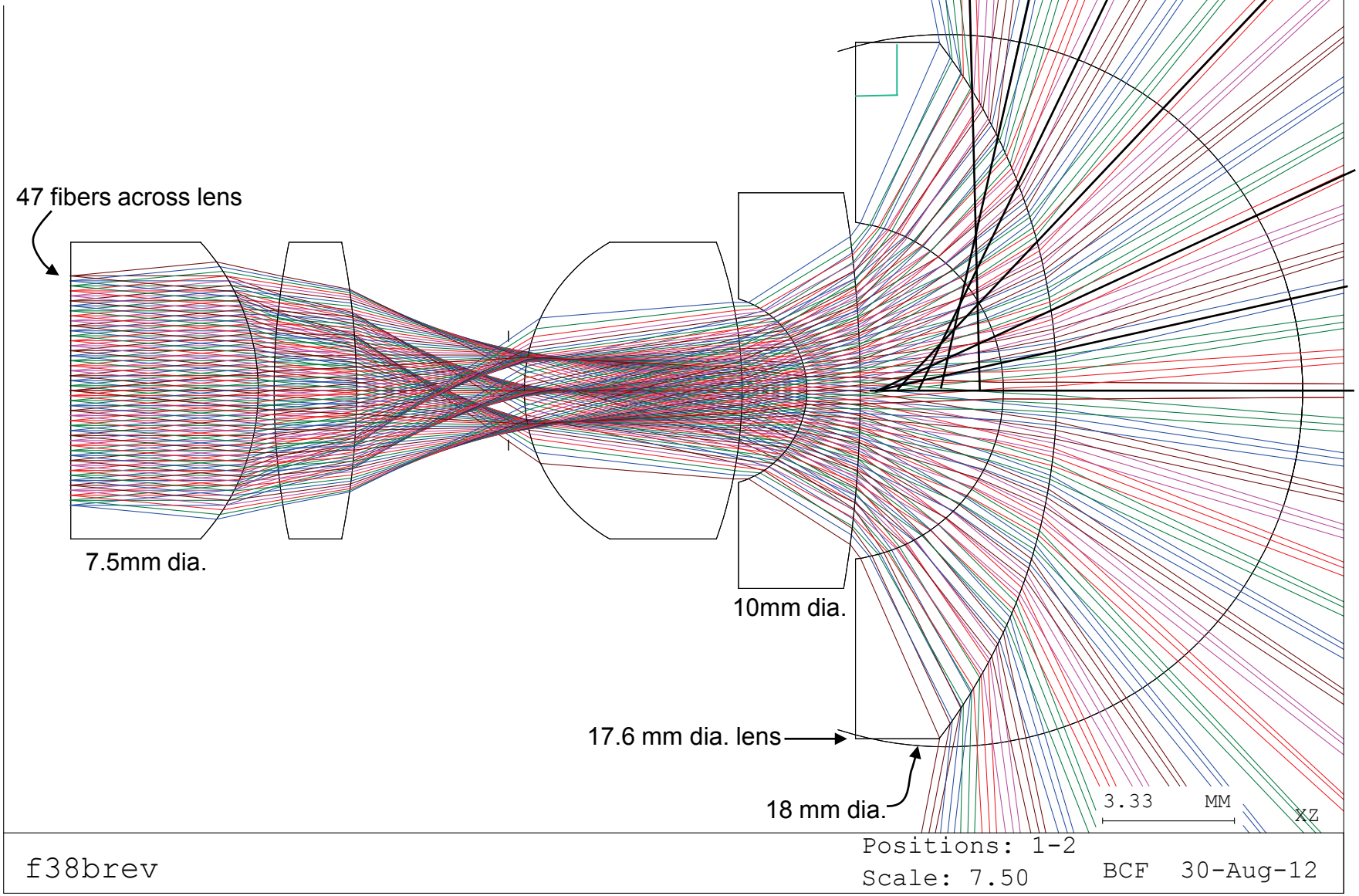
# Ferrule for fibers and completed assembly



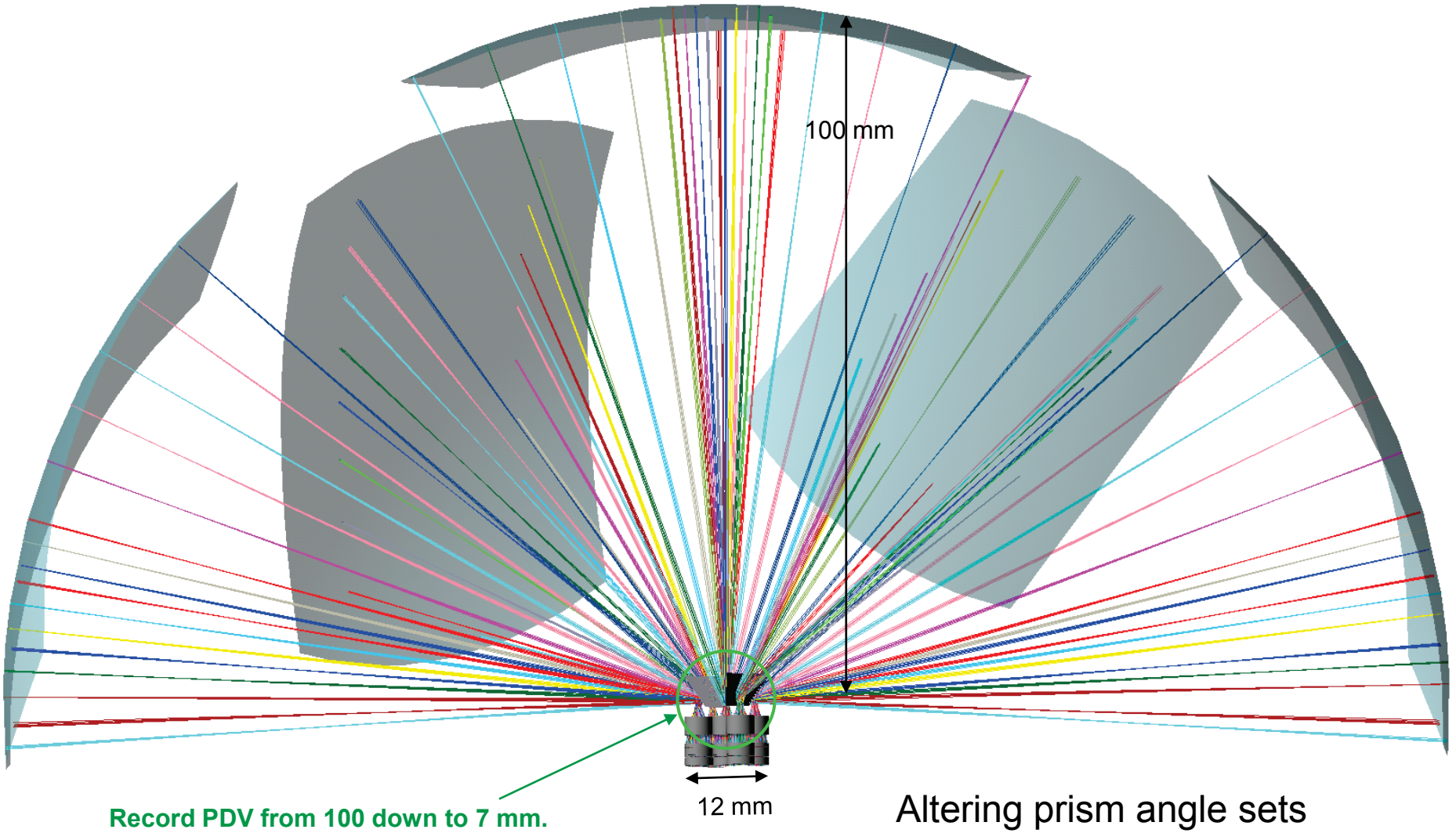
Ten 12-fiber ribbons
plus six multimode fibers



# Fisheye probe with a line of 126-micron spaced fibers



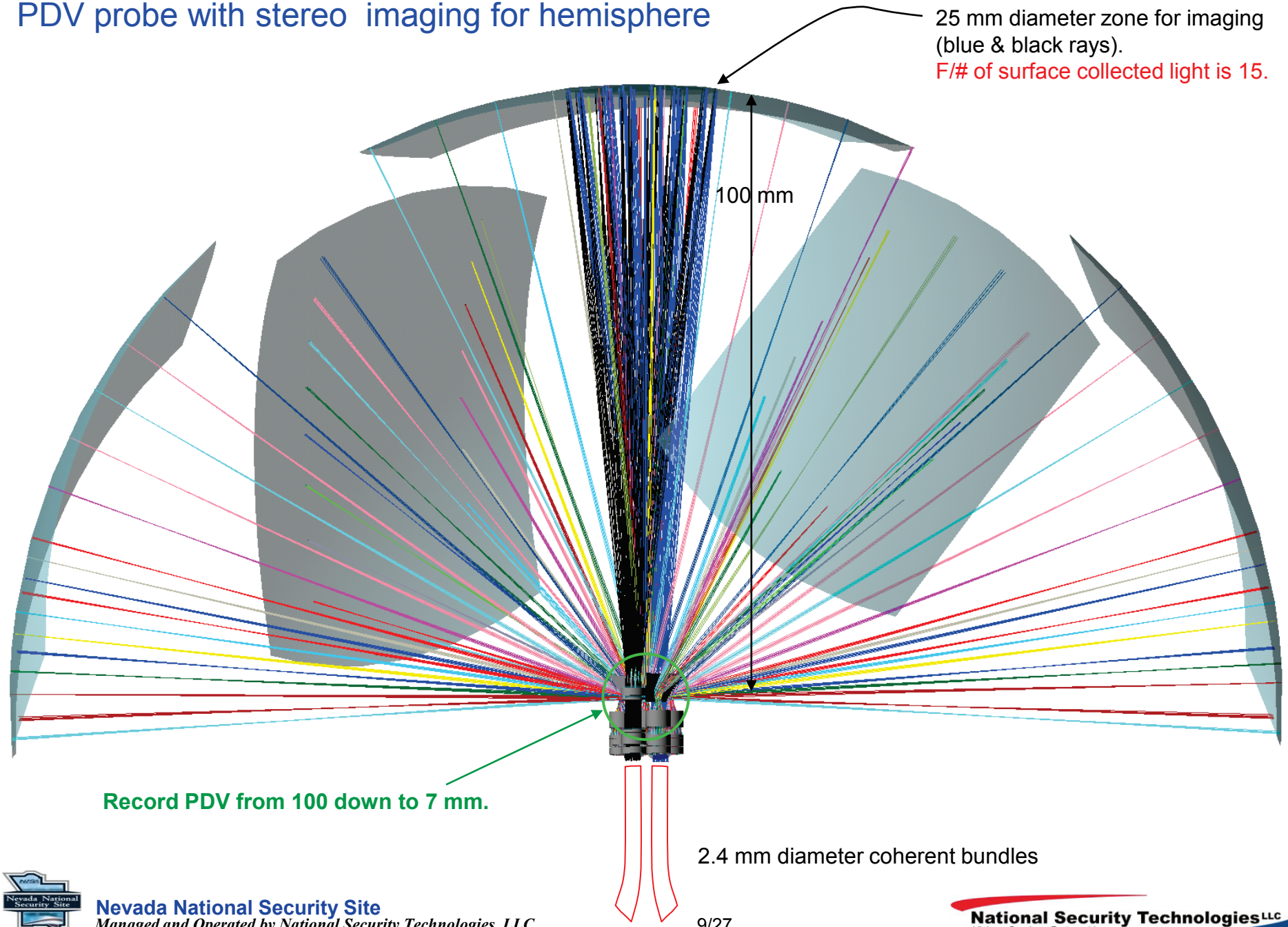
# PDV probe with stereo imaging for hemisphere




Record PDV from 100 down to 7 mm.

Altering prism angle sets viewing below the horizon.

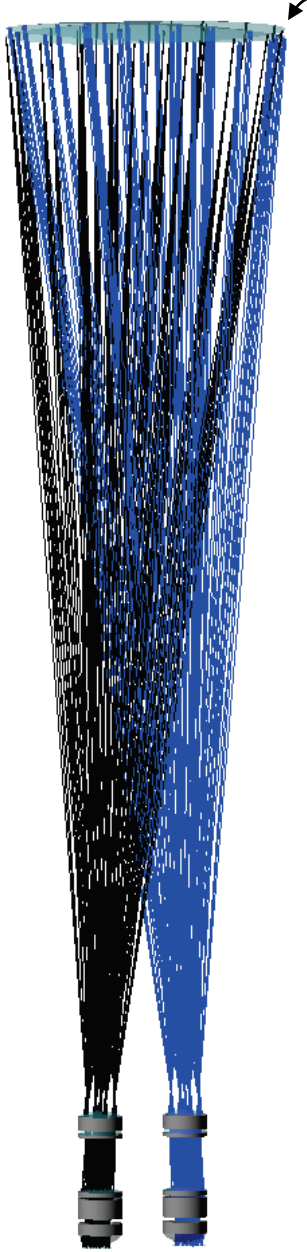
# PDV probe with stereo imaging for hemisphere

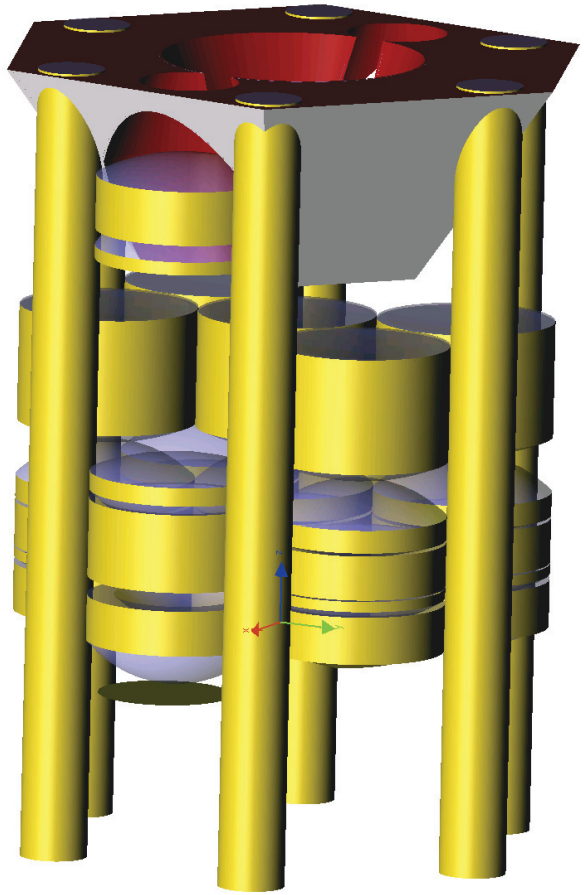


25 mm diameter zone for imaging (blue & black rays).
F/# of surface collected light is 15.

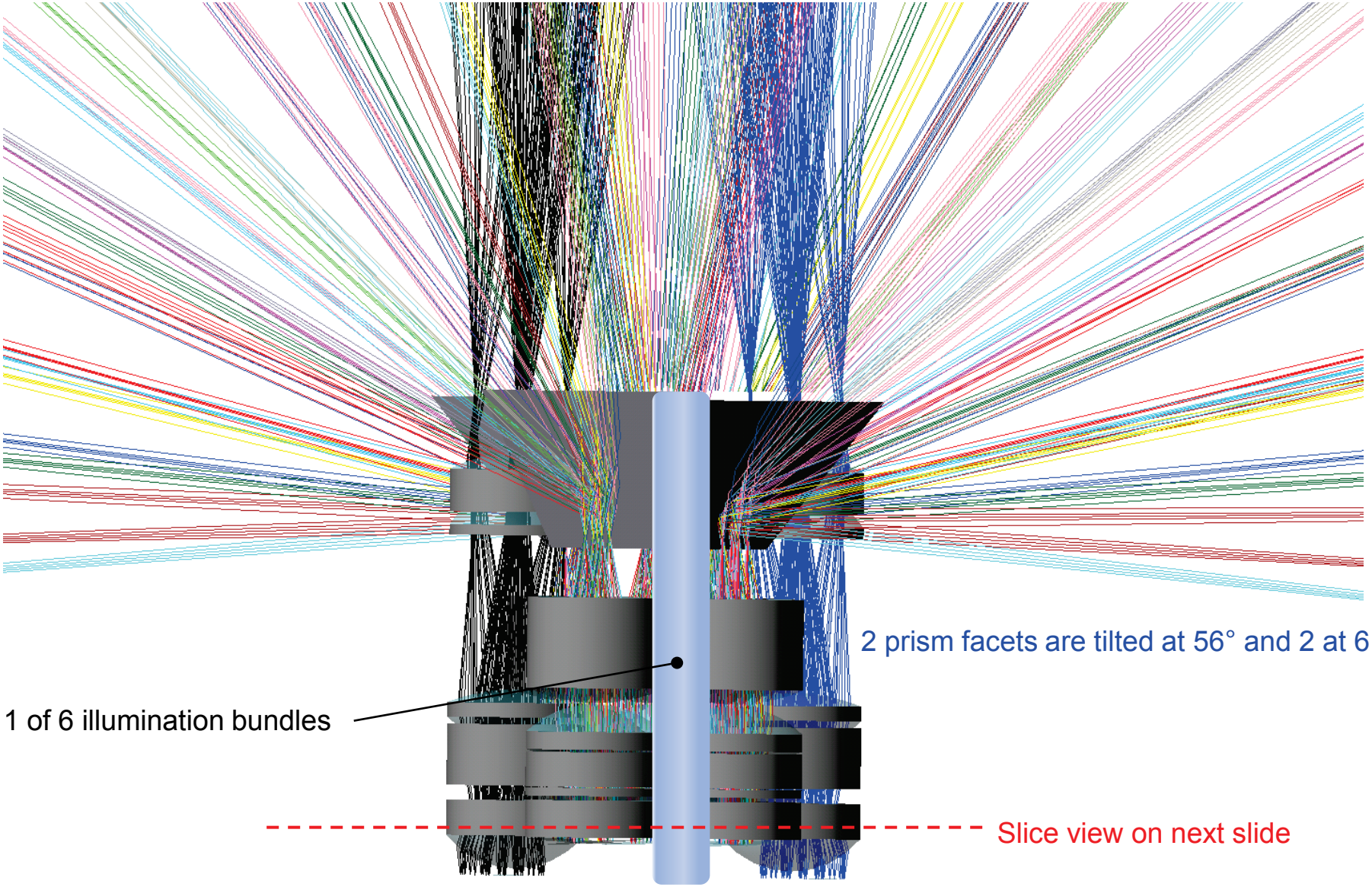
Zone 3 & 6 are used for stereo imaging

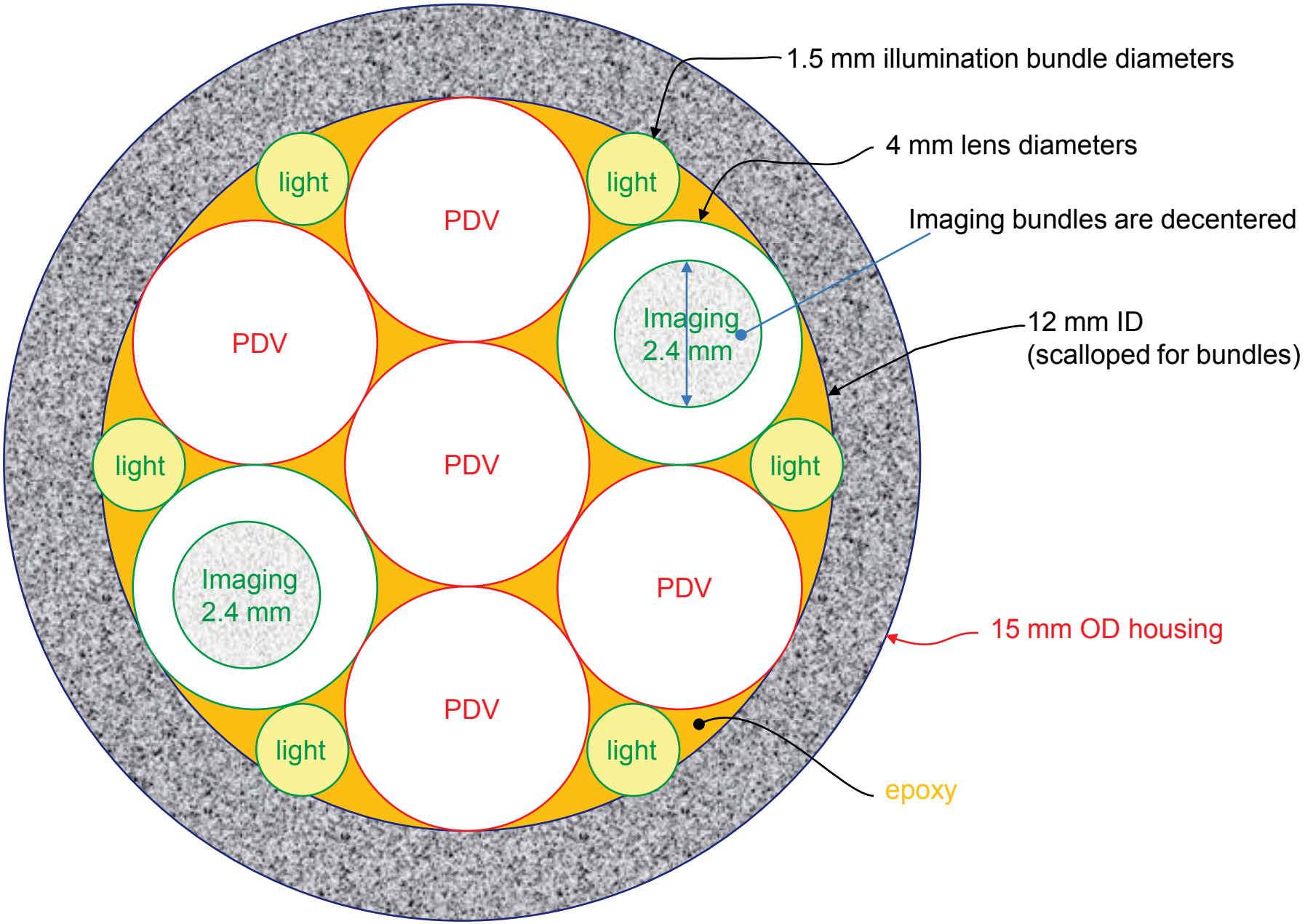
Assuming 24 mm diameter FOV at surface and 2.4 mm diameter bundle, @ 50 lp/mm. Resolve 200 µm at surface (5 lp/mm).





Fiber arrays are translated 0.36 mm, so that the image areas overlap.


2 prism facets are tilted at 56° and 2 at 61°
1 of 6 illumination bundles
Slice view on next slide
Coherent bundles offset to allow overlap imaging


1.5 mm illumination bundle diameters
4 mm lens diameters
Imaging bundles are decentered
12 mm ID
(scalloped for bundles)
15 mm OD housing
epoxy
light
light
light
light
light
light
PDV
PDV
PDV
PDV
PDV
Imaging
2.4 mm
Imaging
2.4 mm

Placing 2 of the 2.5 mm diameter bundles plus 6 of the 1.5 mm illumination bundles leaves room for **> 346 PDV fibers** (ignoring fibers that touch anything).
AOC probe can only image 2.4 mm diameter.
Cutoff switches line the inside of the 6.5 mm ID pipe.

## FIBER PACKING PROGRAM DATA

### Output Data

Packed fiber number =2017

### Packing Configuration

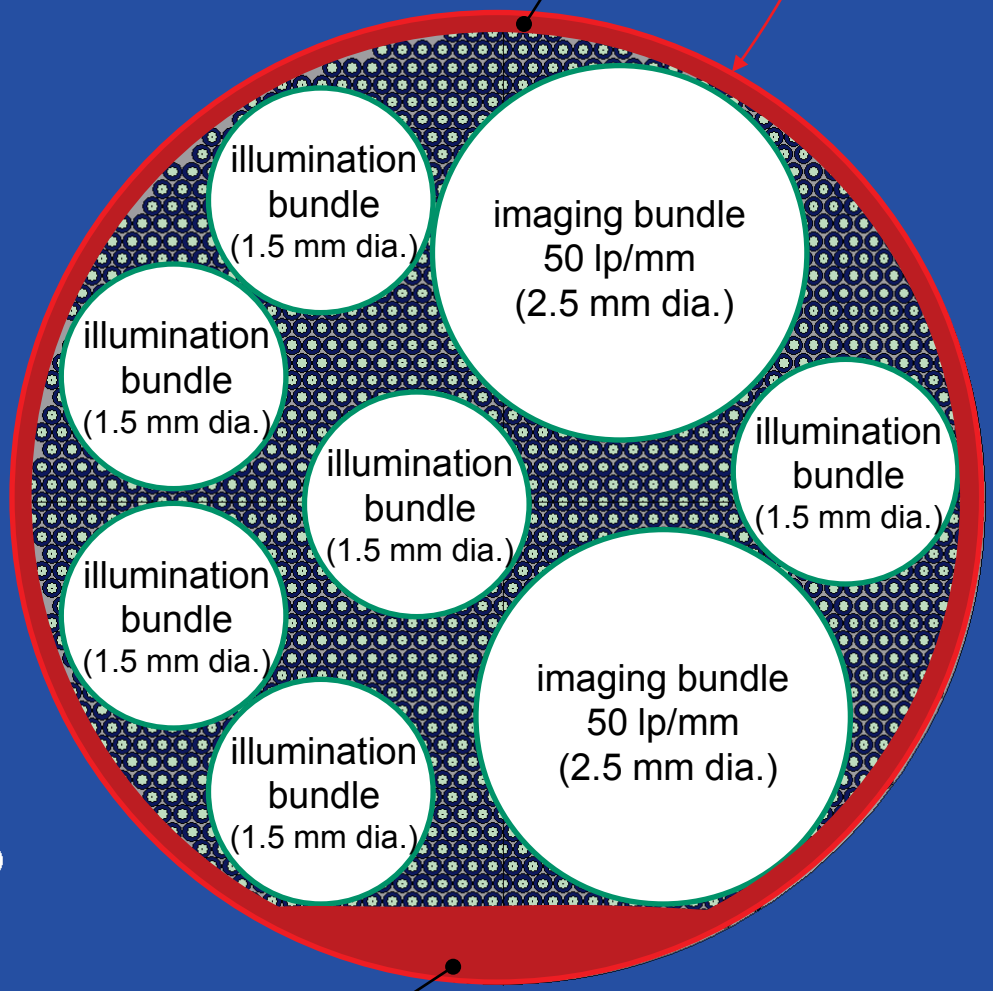
Hexagonal Close Pack

### Input Data

| | |
|---|---|
| Tube Diameter (mm) | =6.5 |
| Coating Diameter (um) | =135 |
| Cladding Diameter (um) | =80 |
| Core Diameter (um) | =10 |

### Area (Square mm)

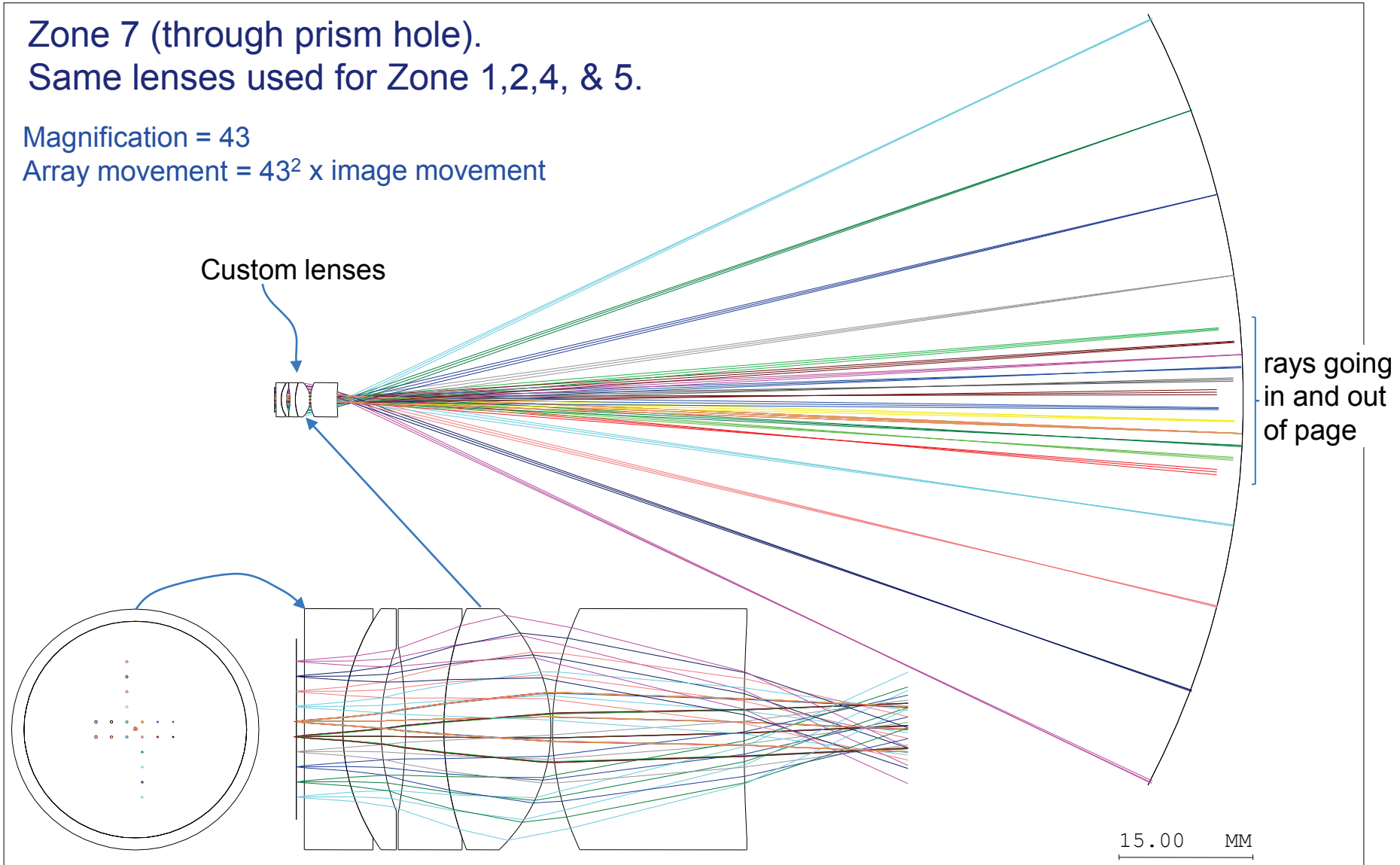
| | | |
|---|---|---|
| Tube | =33.18 | |
| Coating | =18.73 | (56.5%) |
| Cladding | =9.98 | (30.1%) |
| Core | =0.1584 | (0.477%) |
| Dead Area | =4.312 | (13%) |

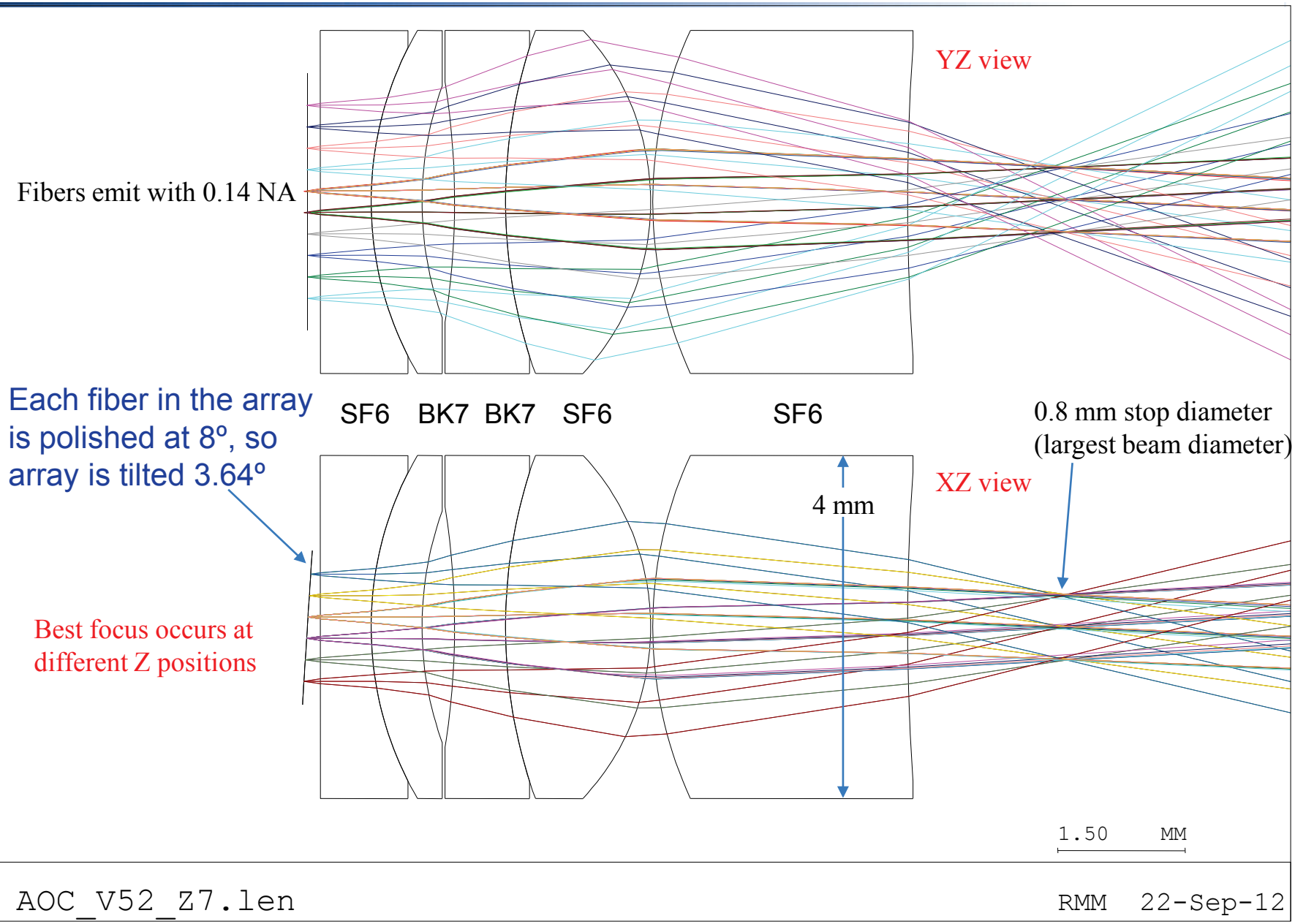


# Zone 7 (through prism hole).
# Same lenses used for Zone 1,2,4, & 5.

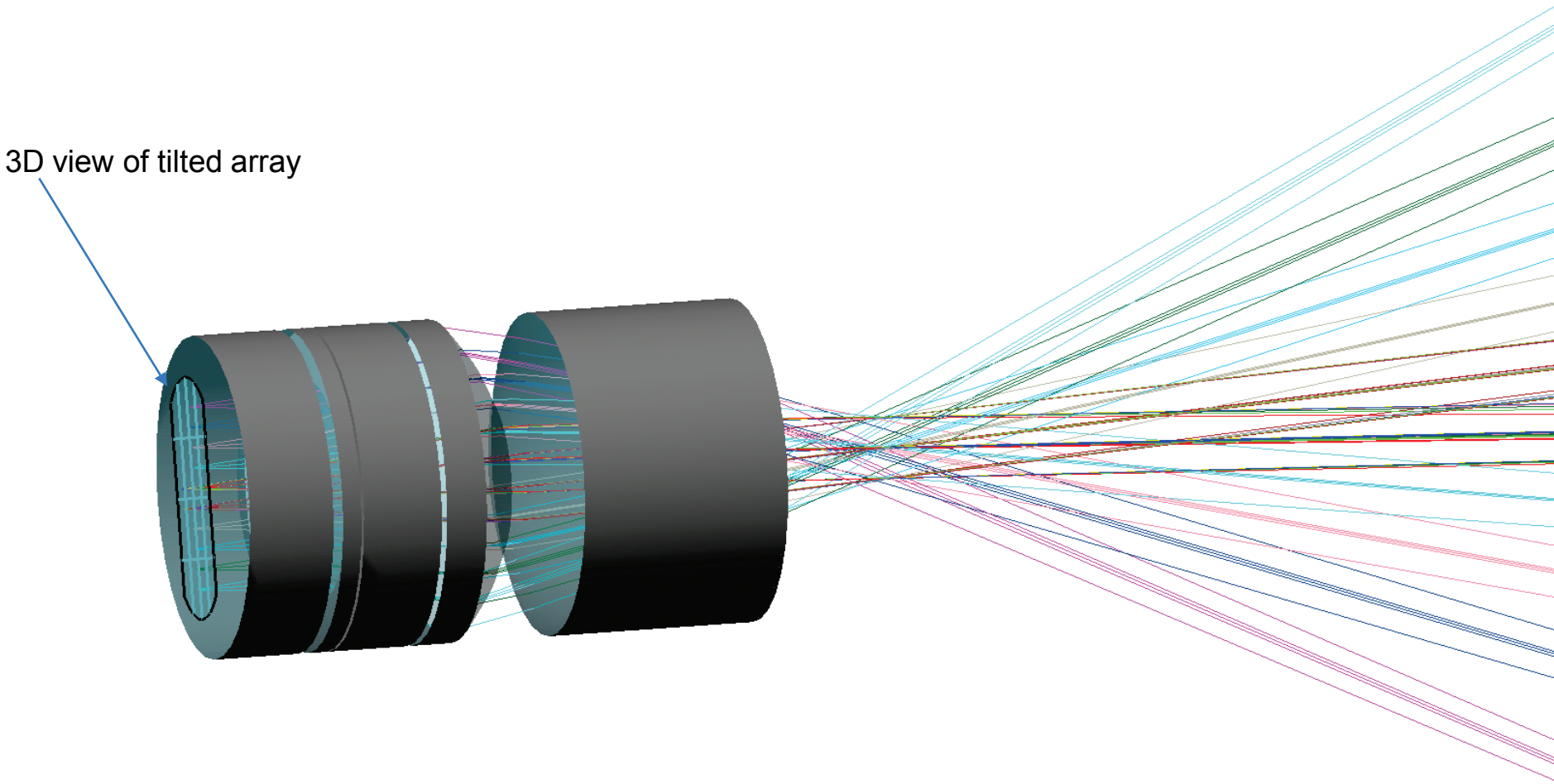
Magnification = 43

Array movement = $43^2$ x image movement

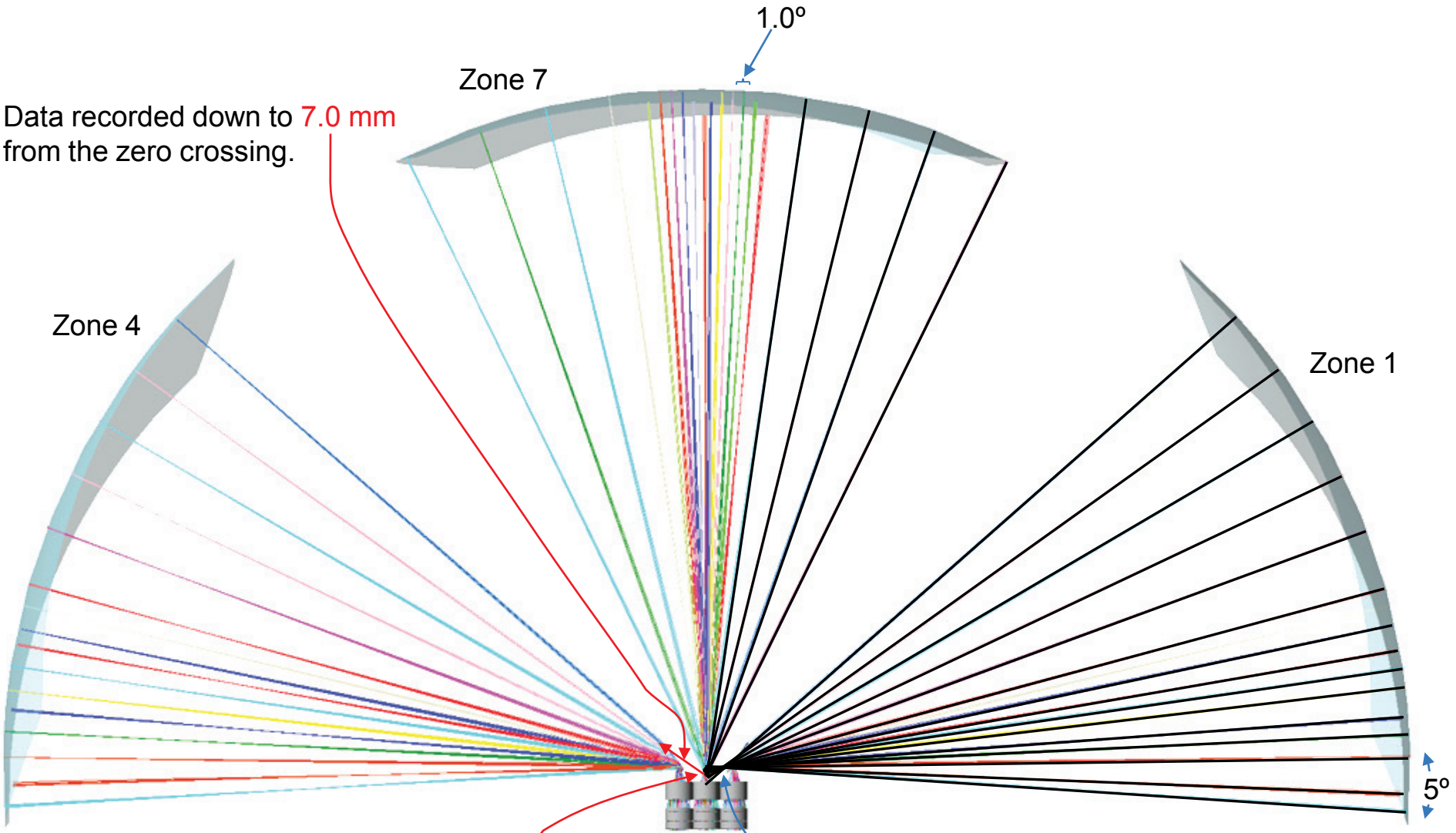



YZ view
Fibers emit with 0.14 NA
Each fiber in the array is polished at 8°, so array is tilted 3.64°
SF6 BK7 BK7 SF6 SF6
0.8 mm stop diameter (largest beam diameter)
XZ view
4 mm
Best focus occurs at different Z positions
1.50 MM
AOC_V52_Z7.len
RMM 22-Sep-12

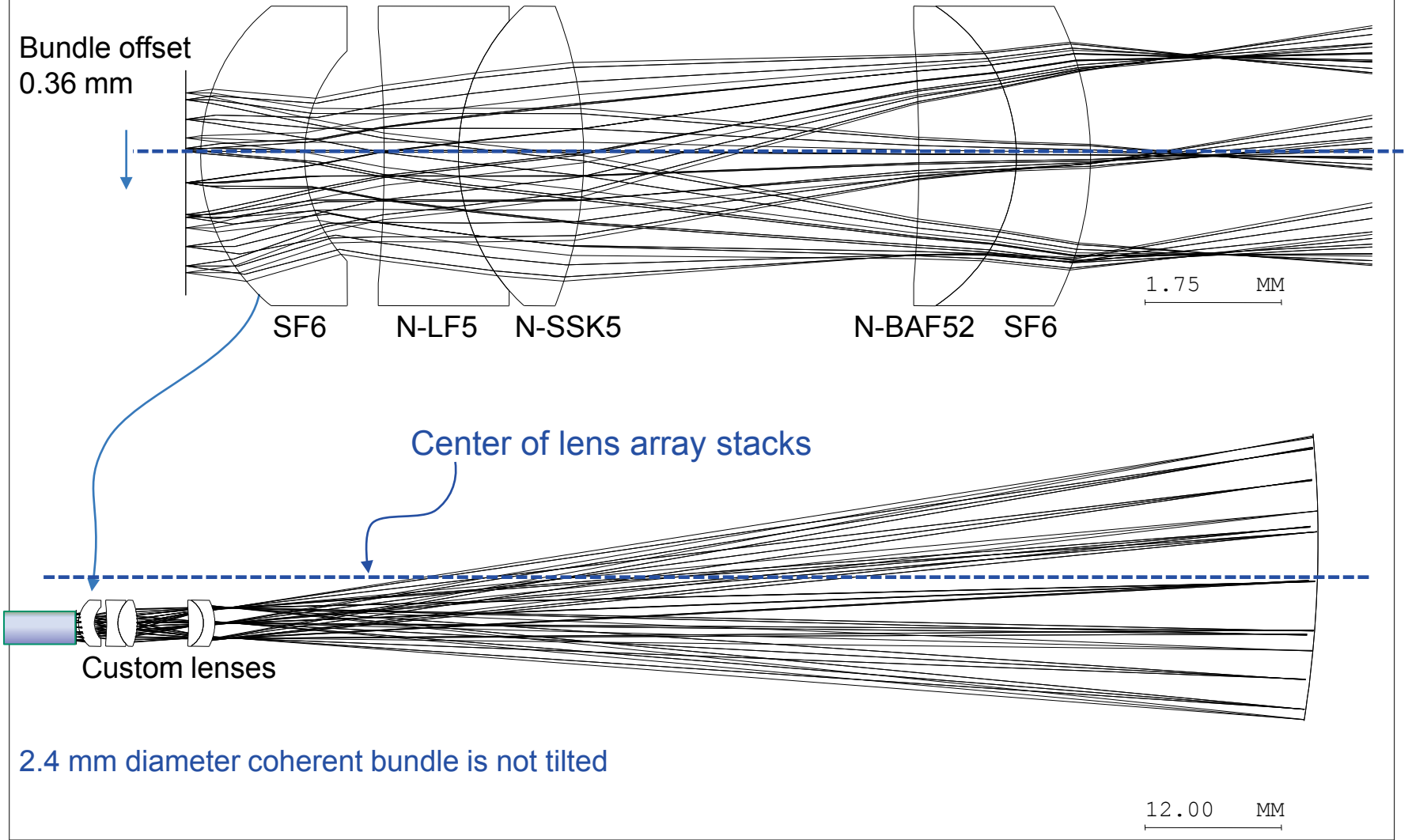
# These rays go through the hole in the pyramid prism (not shown)



# Direction vectors of beam trajectories

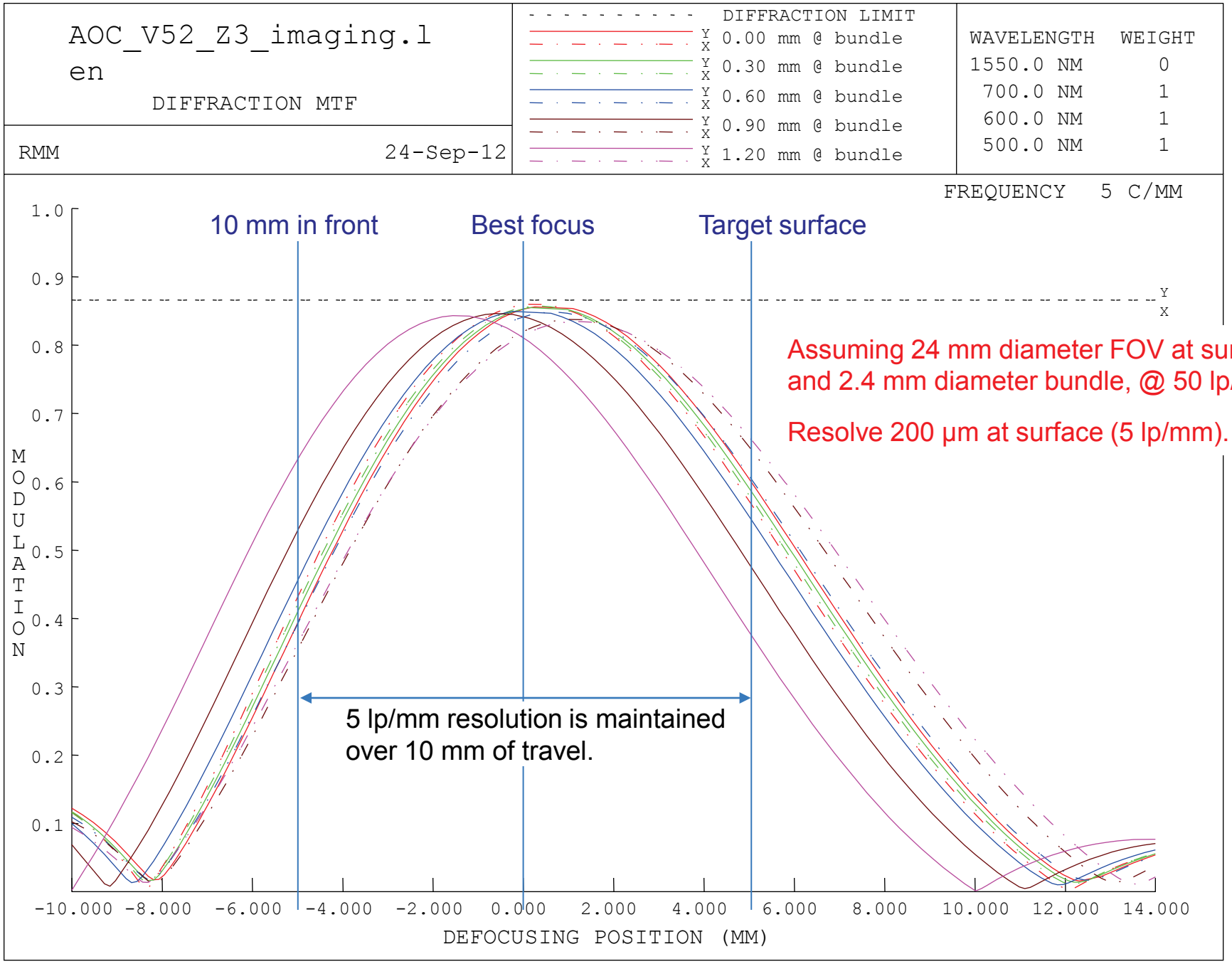


# Zone 3 & 6 are used for stereo imaging (500-700 nm)




2.4 mm diameter coherent bundle is not tilted

AOC_V52_Z3_imaging.len RMM 23-Sep-12

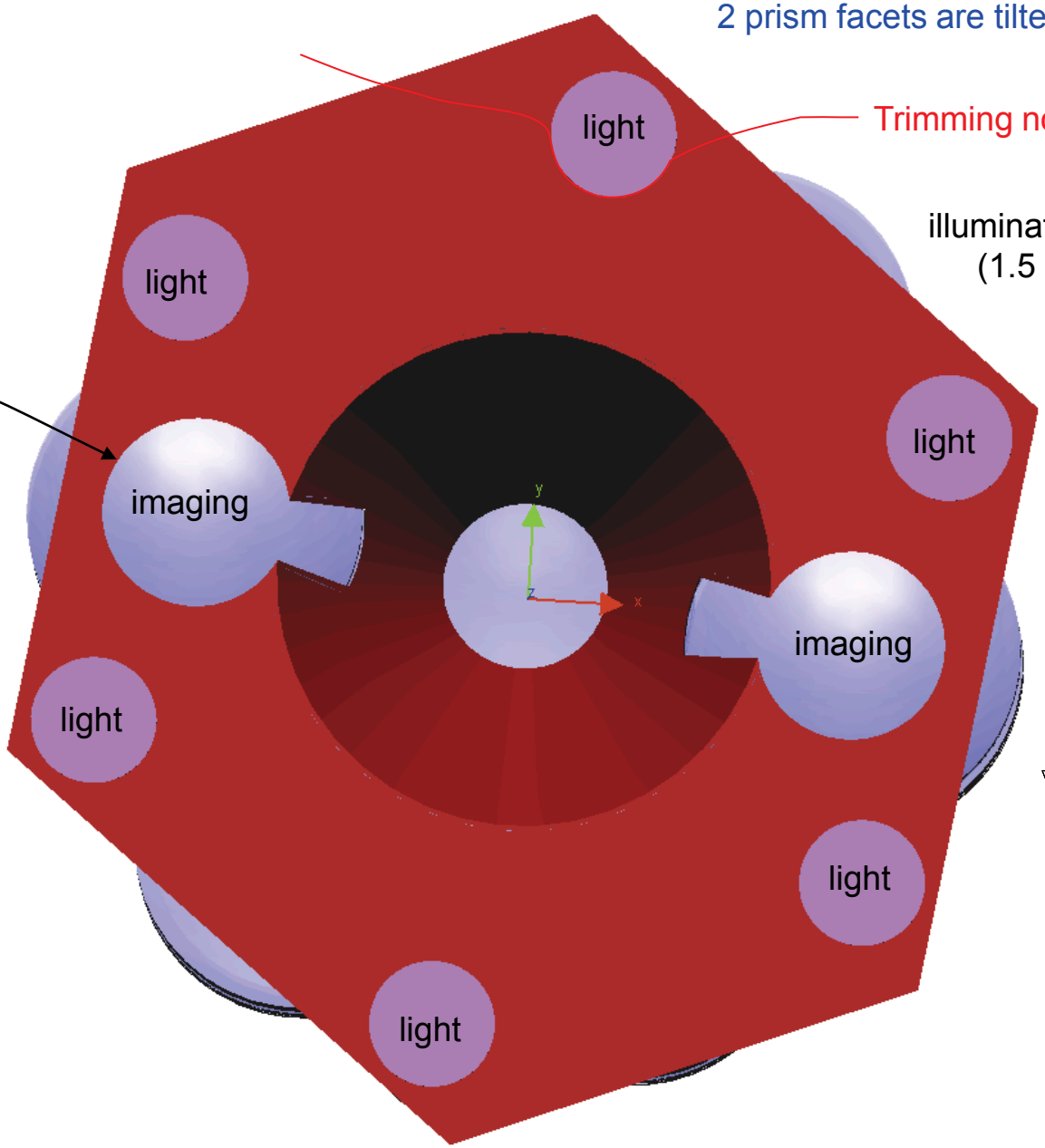

AOC_V52_Z3_imaging.len
DIFFRACTION MTF
RMM
24-Sep-12
DIFFRACTION LIMIT
0.00 mm @ bundle
0.30 mm @ bundle
0.60 mm @ bundle
0.90 mm @ bundle
1.20 mm @ bundle
WAVELENGTH WEIGHT
1550.0 NM 0
700.0 NM 1
600.0 NM 1
500.0 NM 1
FREQUENCY 5 C/MM
10 mm in front
Best focus
Target surface
Assuming 24 mm diameter FOV at surface and 2.4 mm diameter bundle, @ 50 lp/mm.
Resolve 200 µm at surface (5 lp/mm).
5 lp/mm resolution is maintained over 10 mm of travel.
MODULATION
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-10.000 -8.000 -6.000 -4.000 -2.000 0.000 2.000 4.000 6.000 8.000 10.000 12.000 14.000
DEFOCUSING POSITION (MM)

2 prism facets are tilted at 56° and 4 at 61°

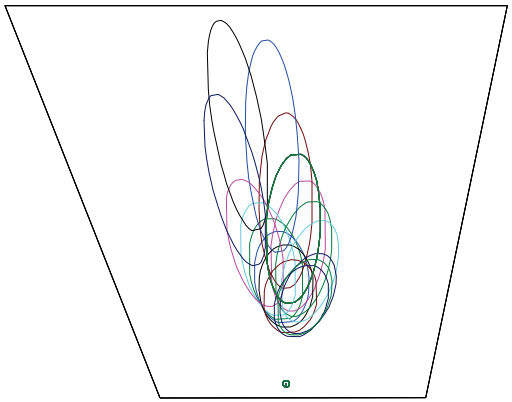
Trimming not finished

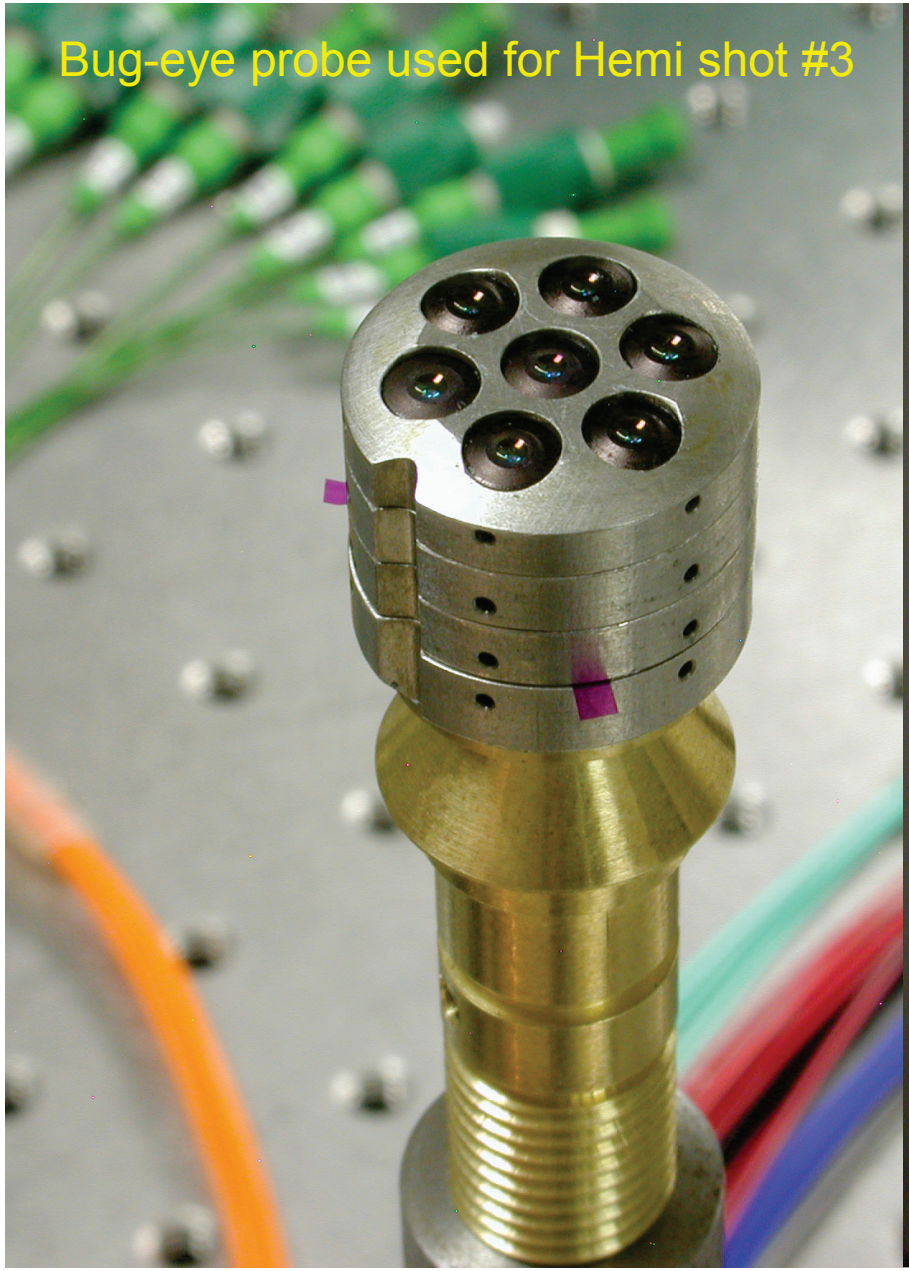
illumination bundles
(1.5 mm dia.)

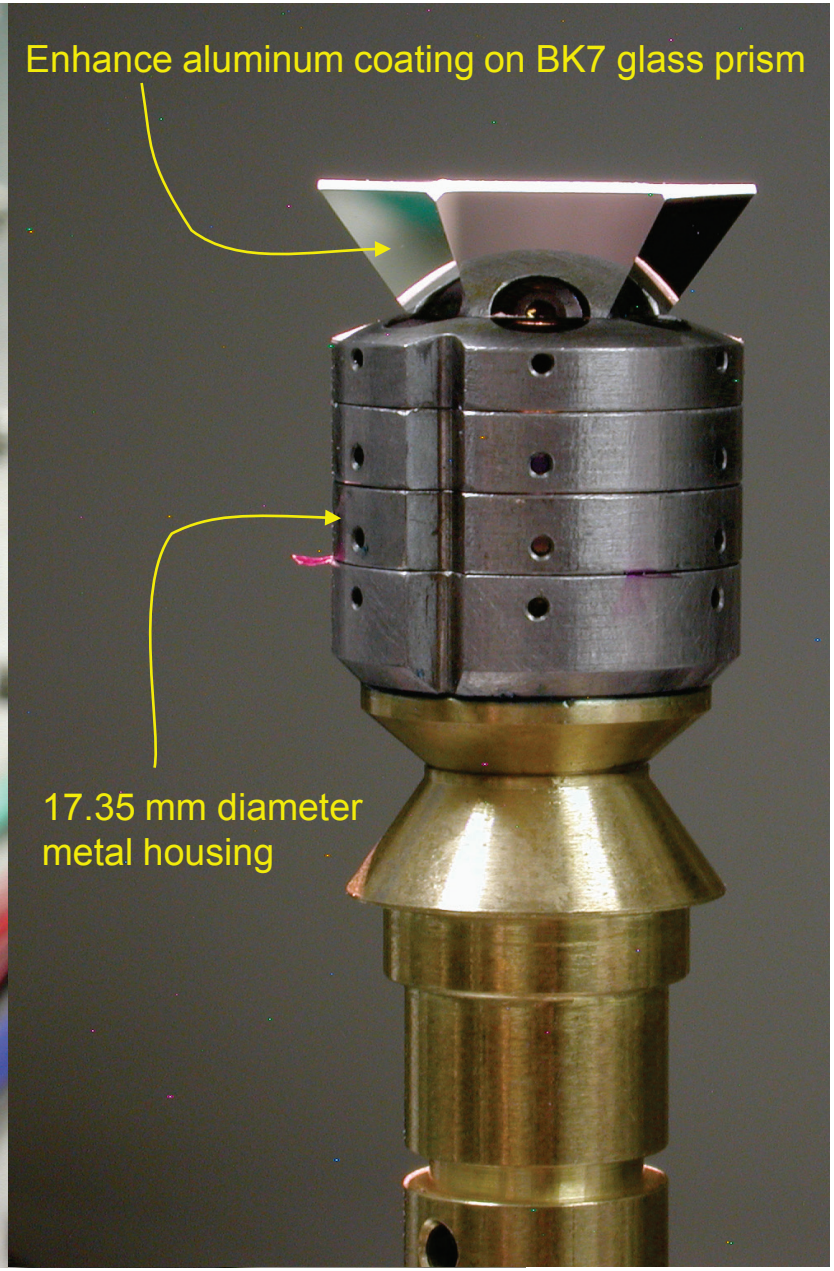
imaging stop



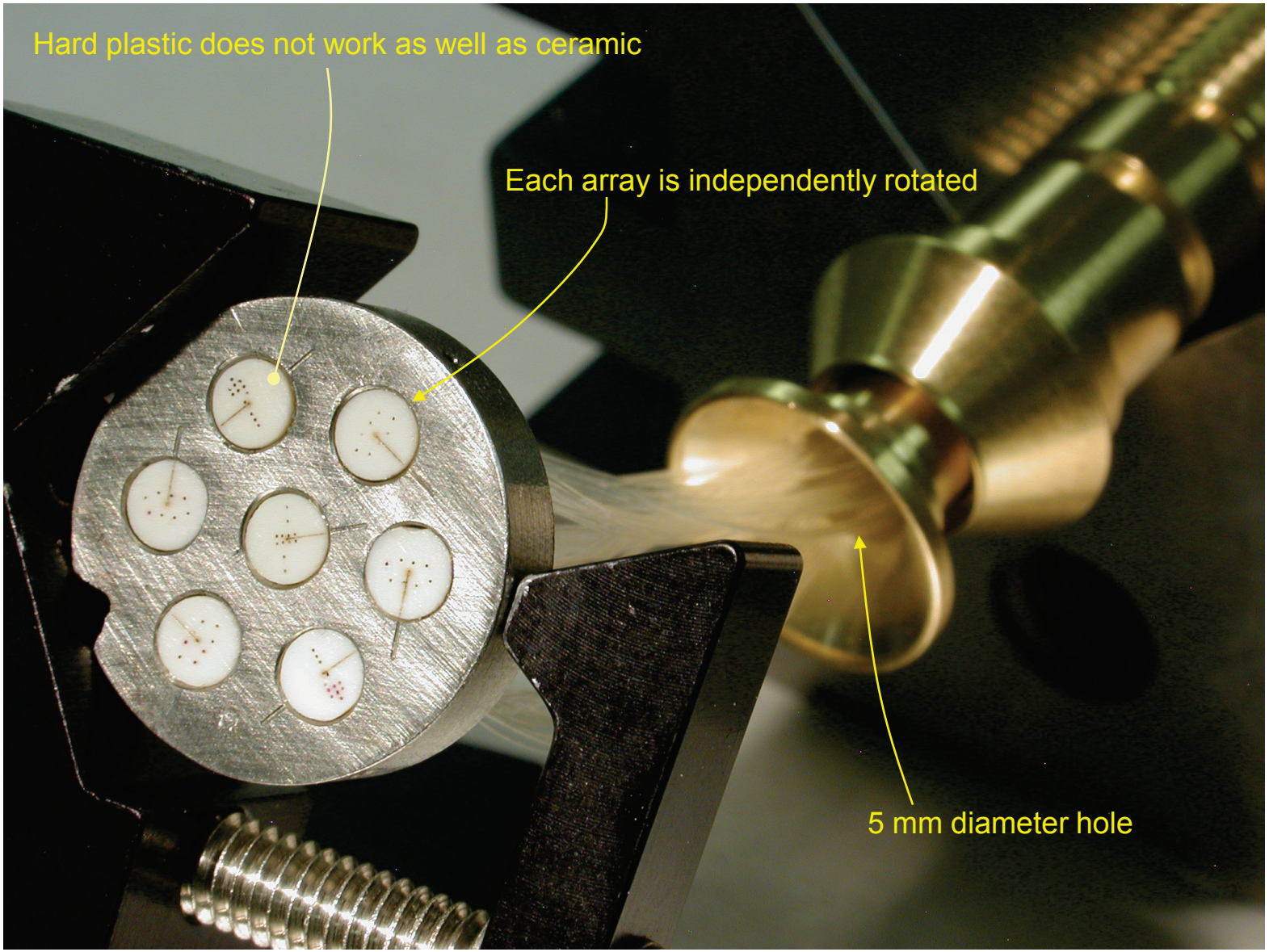

Footprint plots show only
center of facets are used.



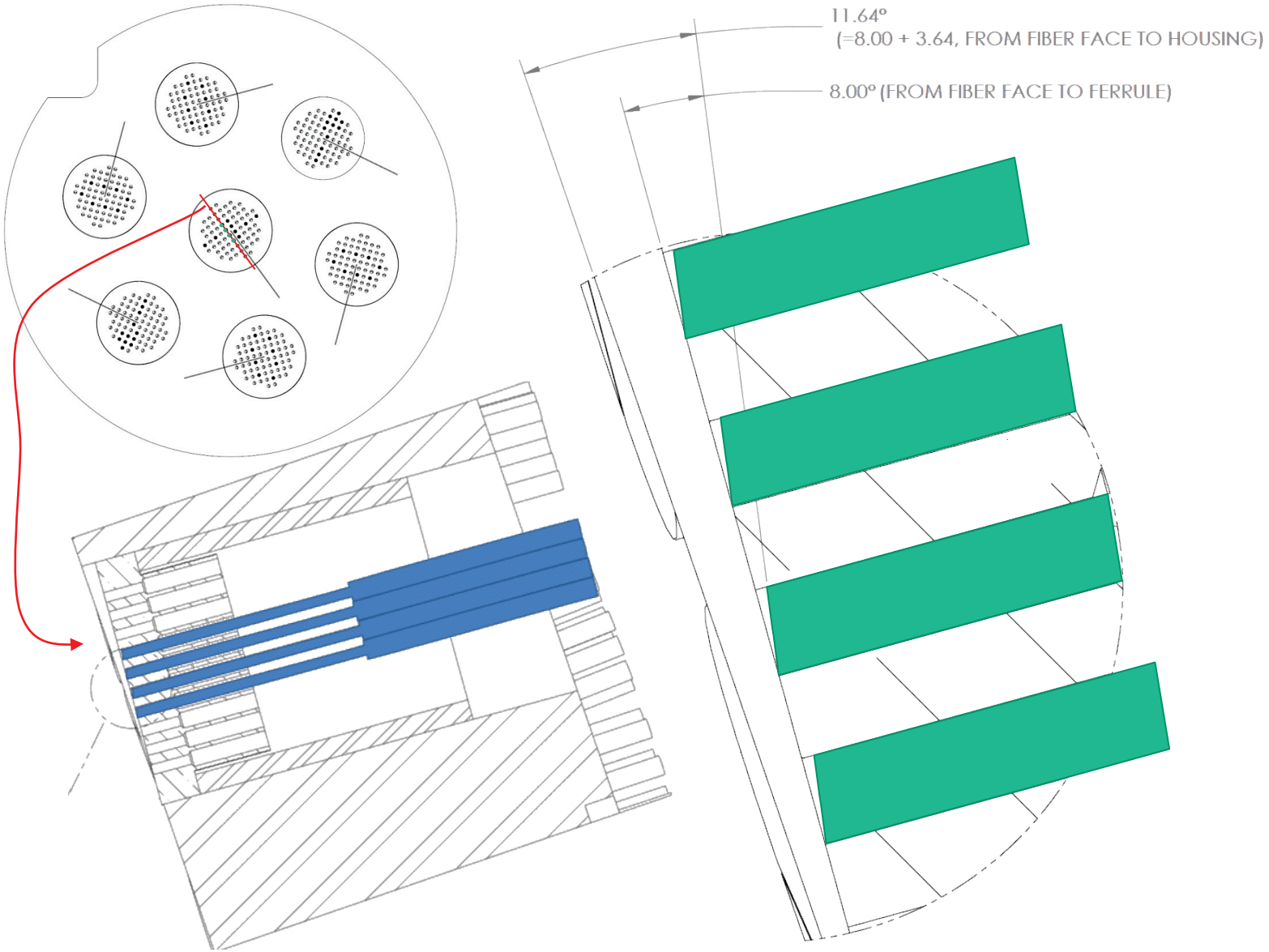

Bug-eye probe used for Hemi shot #3

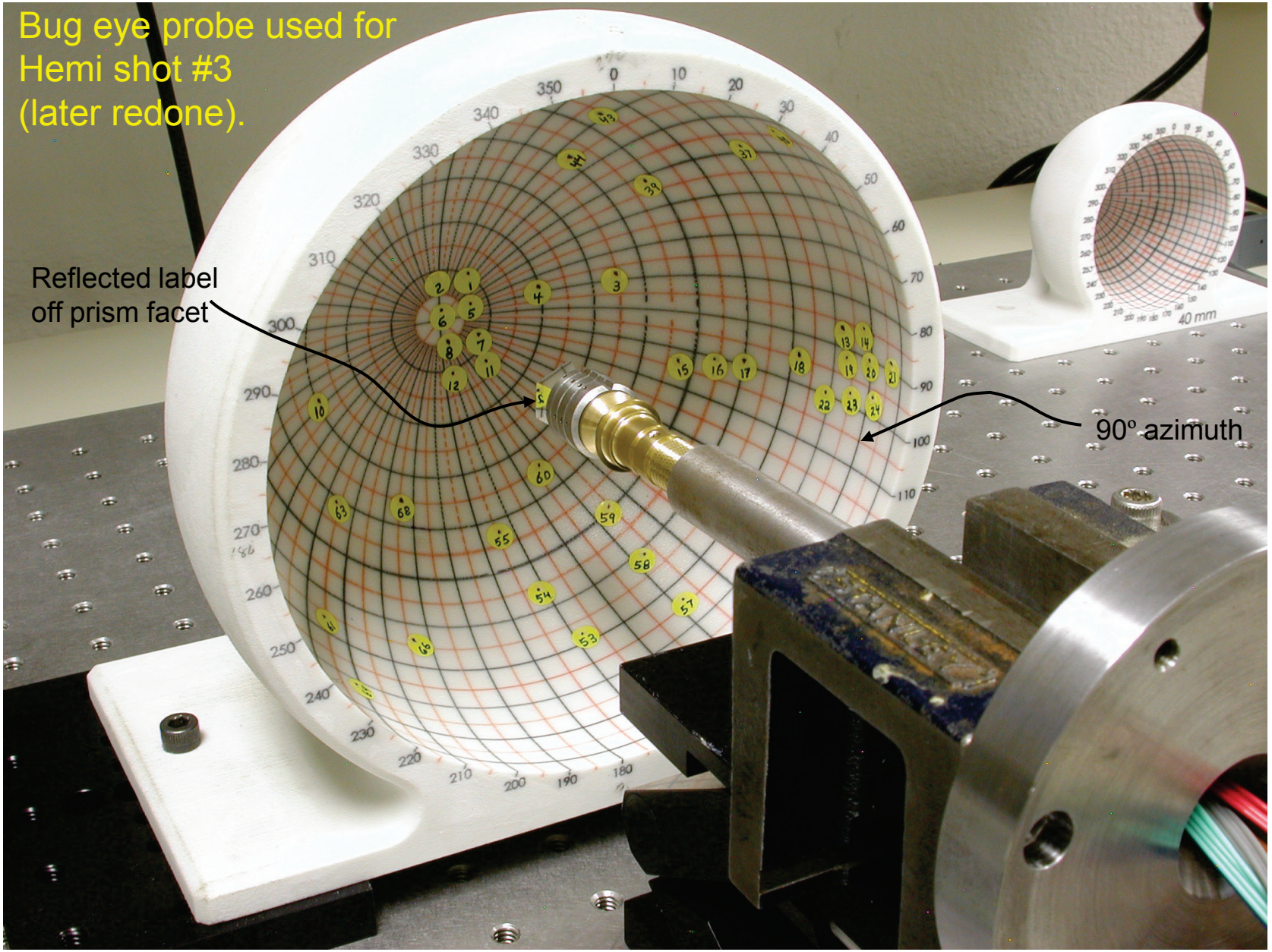

Enhance aluminum coating on BK7 glass prism
17.35 mm diameter
metal housing

# Second attempt with correctly oriented fiber arrays. Two alignment marks rotated 180º.

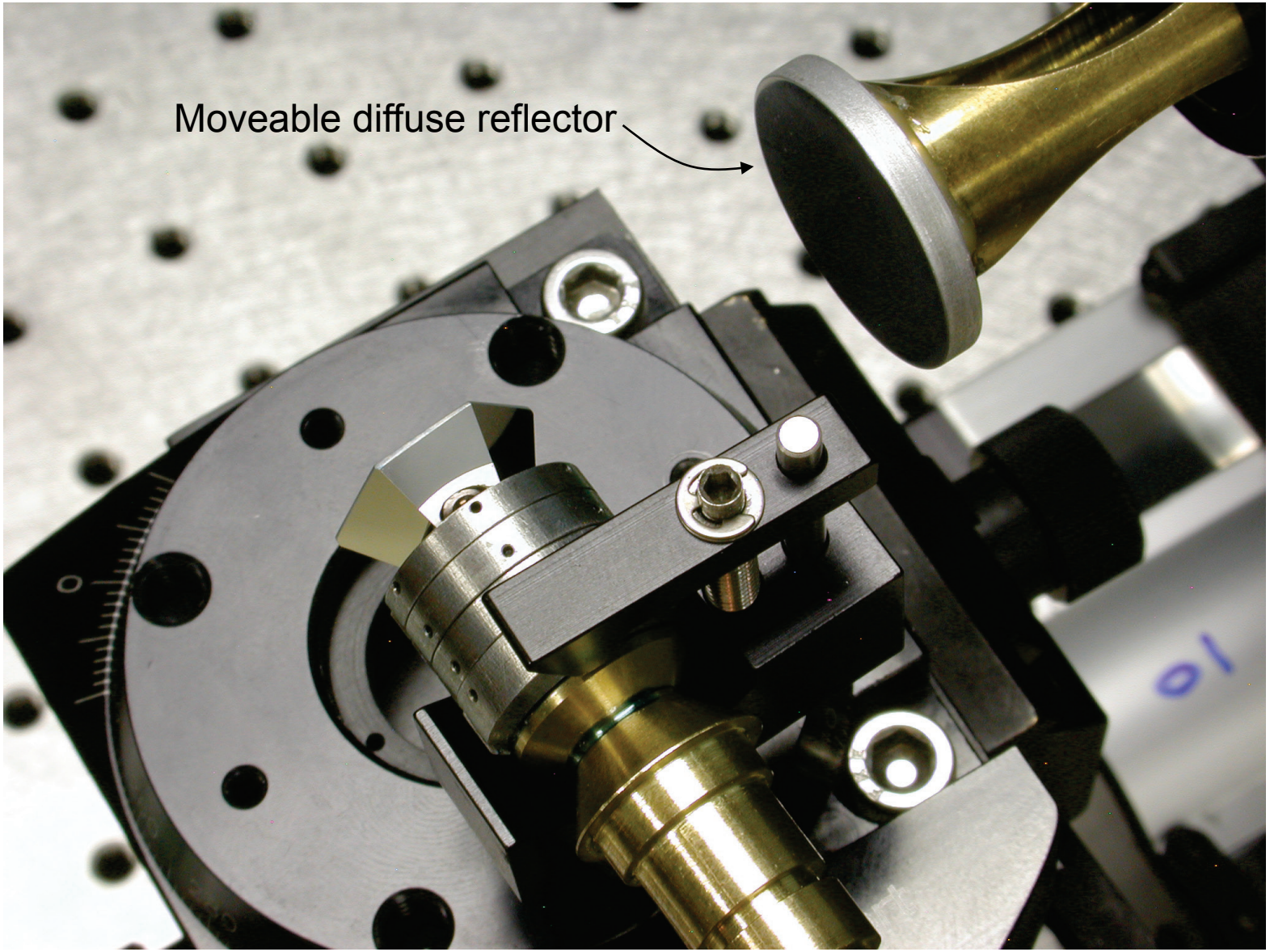


# Fiber rotation and cleaning are issues.

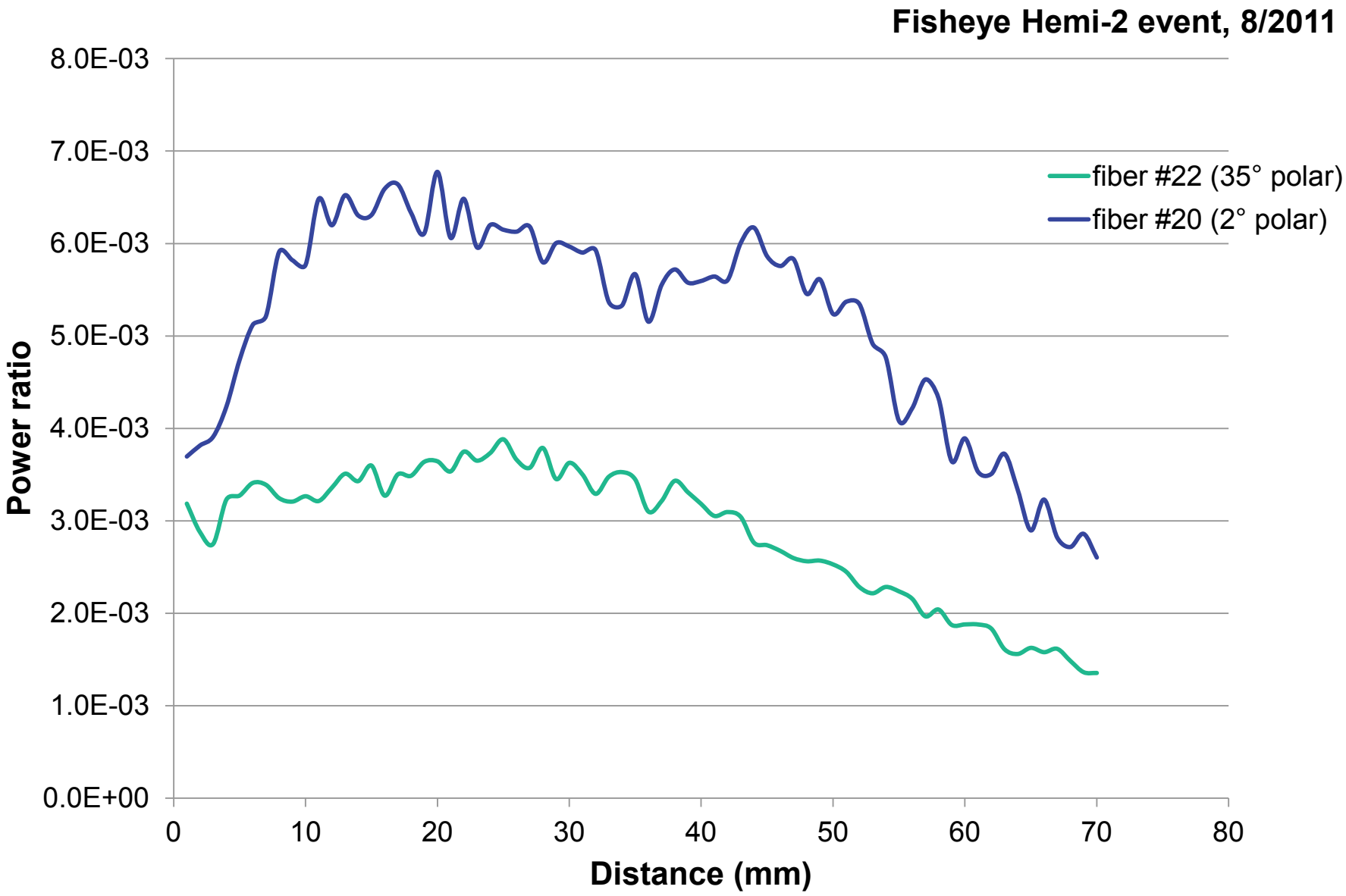



Bug eye probe used for
Hemi shot #3
(later redone).
Reflected label
off prism facet
90° azimuth
40 mm

Efficiency measurement of each fiber channel can be measured versus their tracking distance. The diffuse reflector is on a computer-controlled motorized mount. Probe is in rotatable mount.

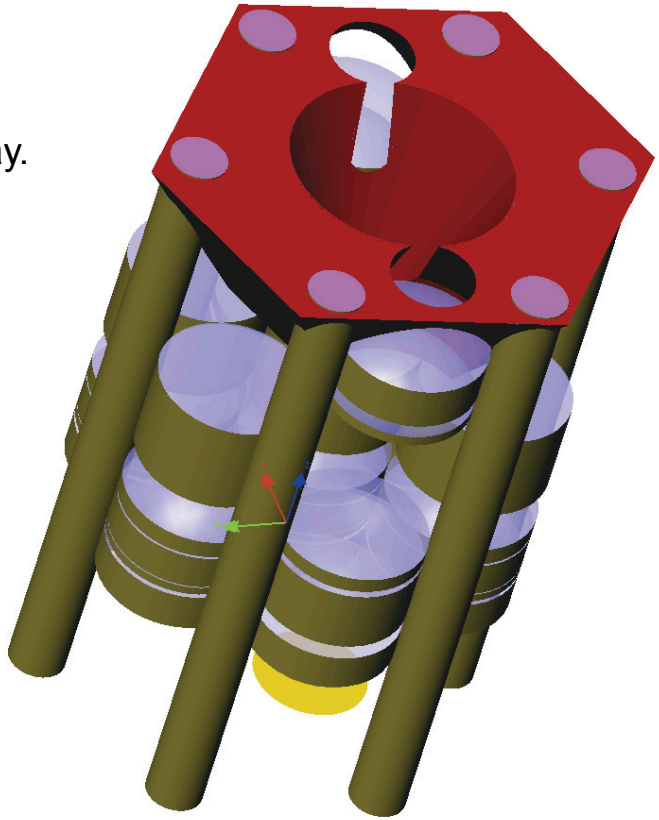


# The efficiencies of each fiber can vary in shape and magnitude.



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 7.0 mm from the zero crossing.
5. This probe accommodates several hundreds of fibers.
6. Each lens stack can have different focal lengths. (modular design)
7. Future probe design will use Fused Silica lens and flat coupled fiber array.



Disadvantages:

1. Extra assembly time required to angle polish each fiber (add one extra week).
2. Zero crossings are shifted ~2.5-mm for 4 of the 5 zones.
3. Must show that imaging is cheap and easy to perform.