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A Fisheye Lens for Many-Point PDV

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National Security Technologies, LLC

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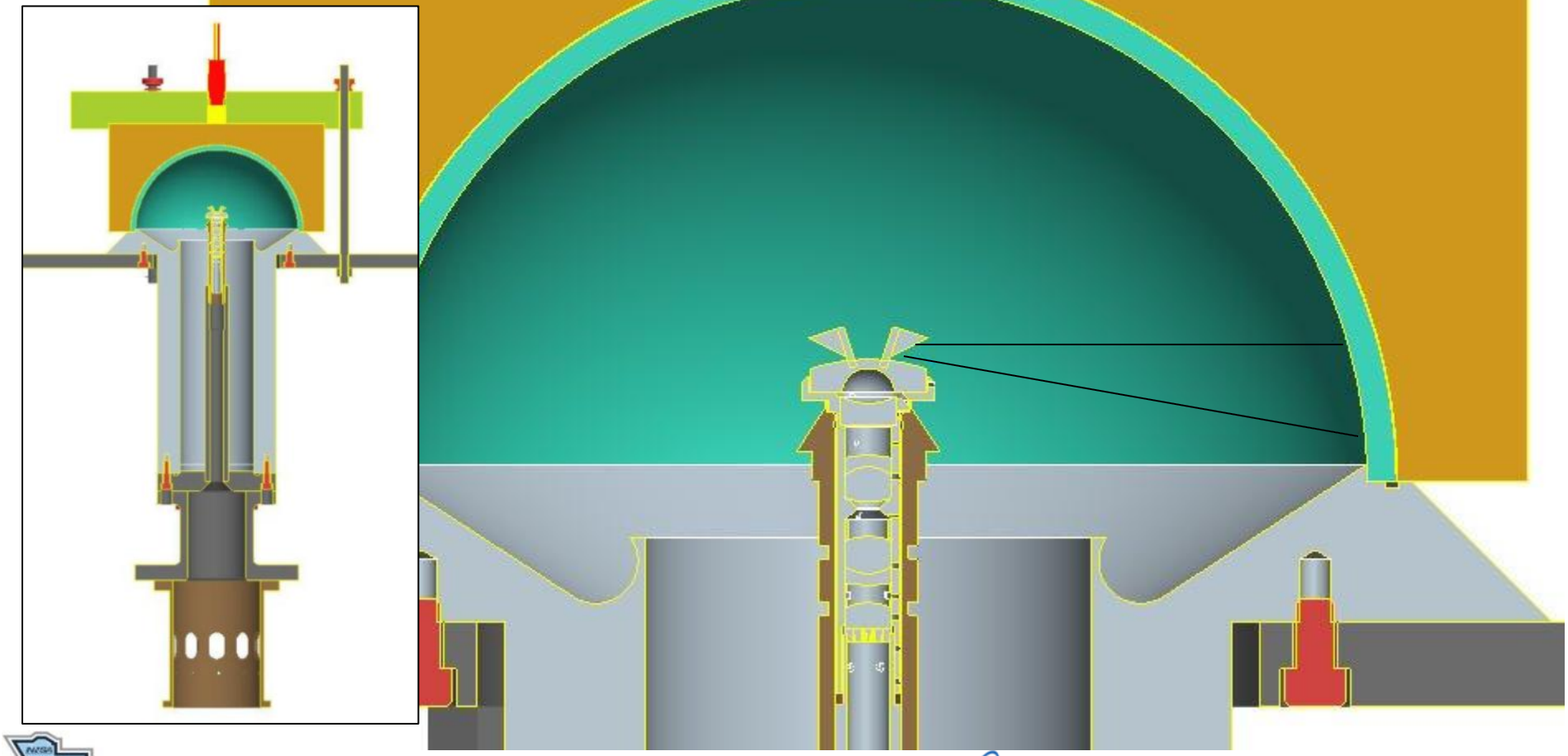
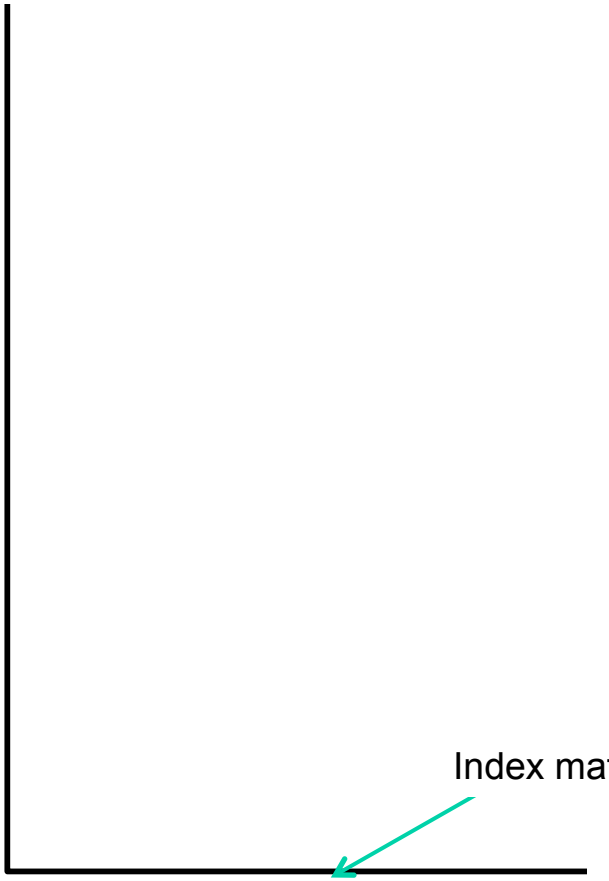
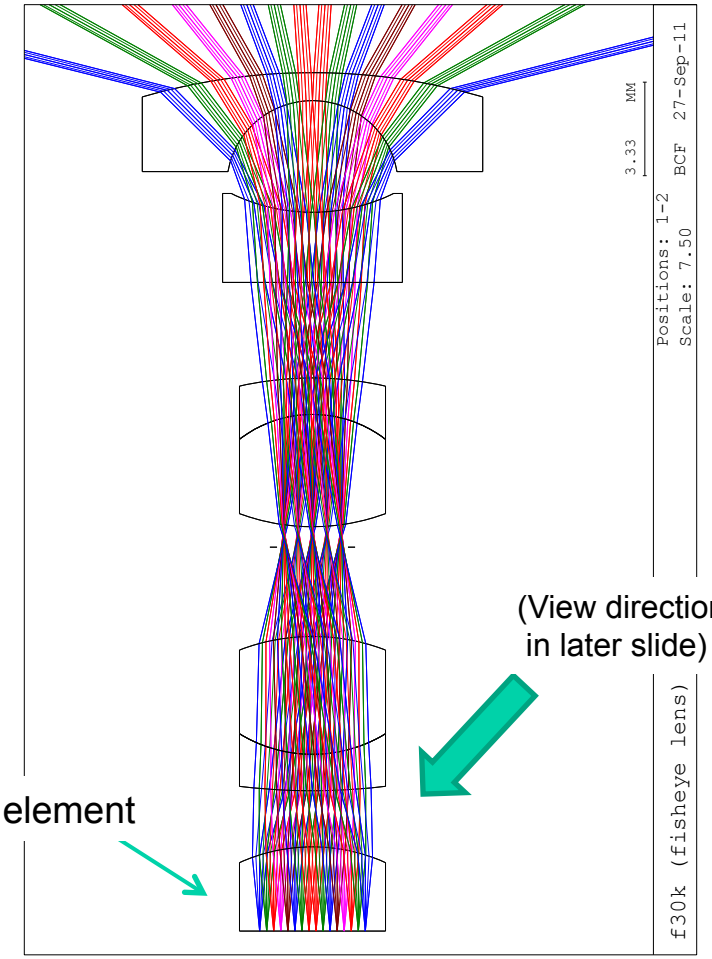
AOC 2 in Optical Dome



AOC 2: Fisheye Lens Features



Index matching lens element

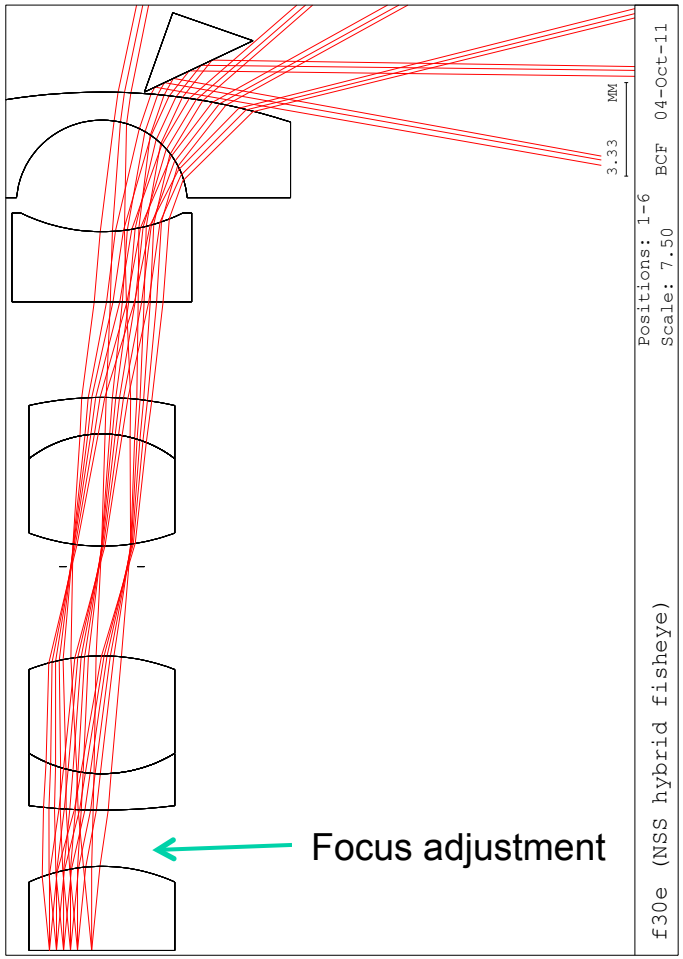


(View direction in later slide)

Prototype Build 2
High angular coverage
Index matching element to fibers

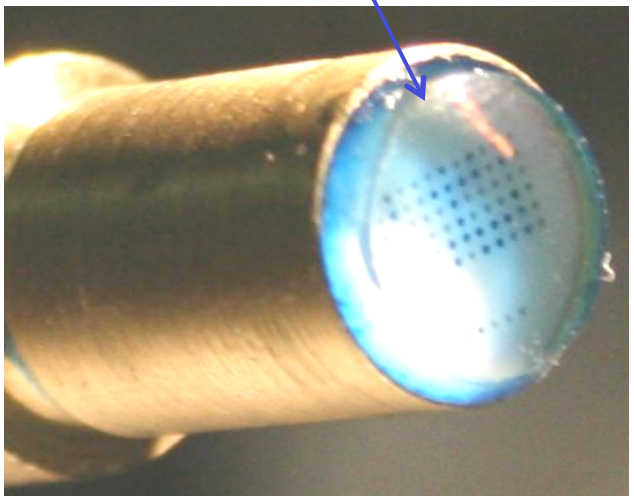
Hemi 2 lenses
Better anti-reflection coatings
Cut down lens element diameters
Not using highest angles

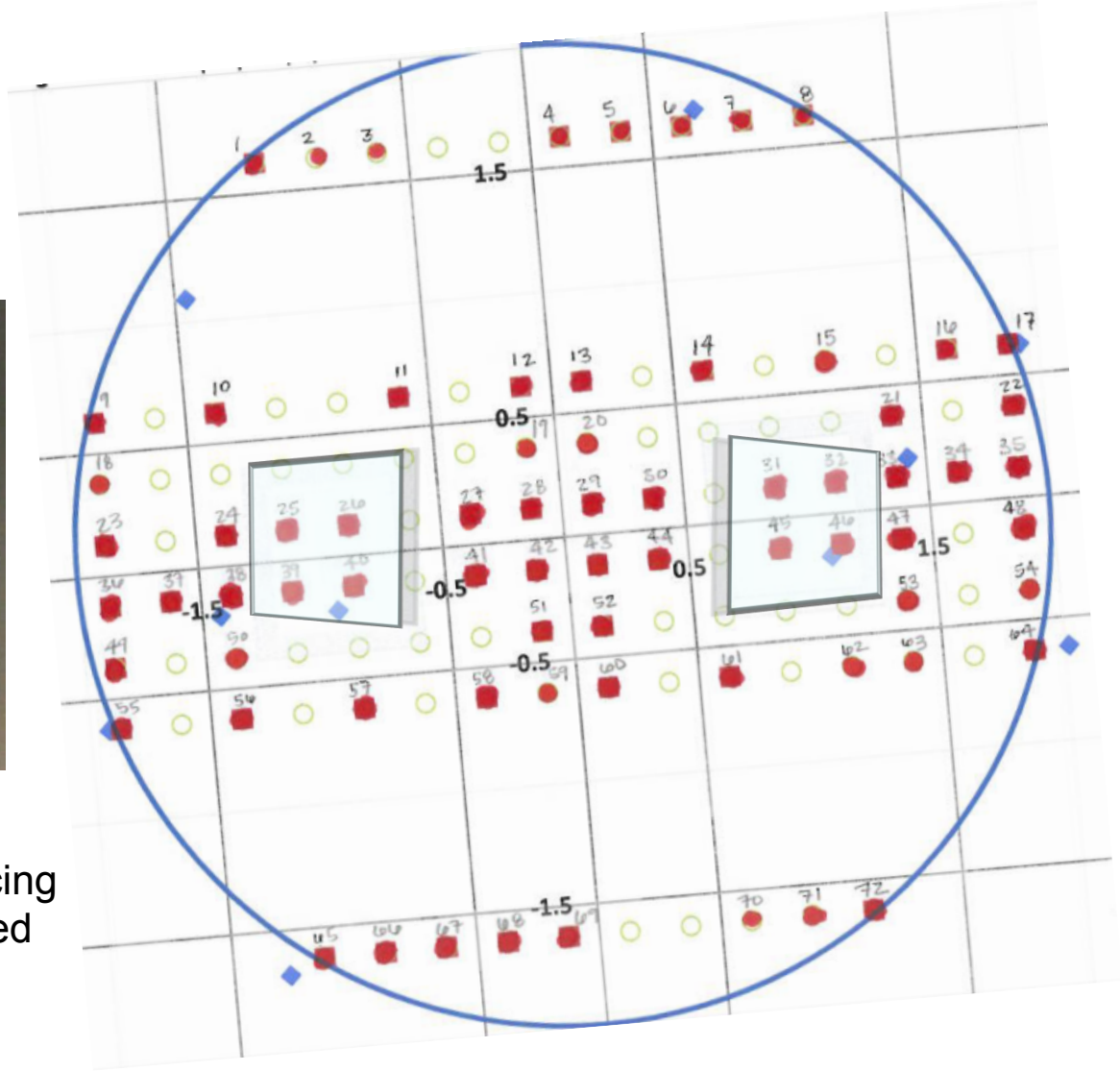
AOC 2: Fisheye with Reflector Prisms



AOC 2: Fisheye Fiber Map

Index matching lens element

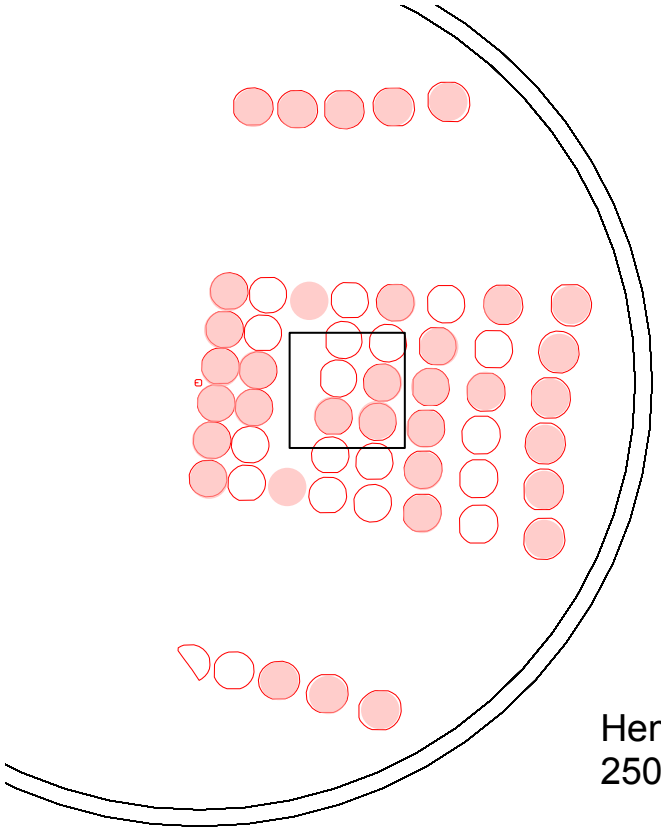




Hemi 2
250-micron spacing
not fully populated

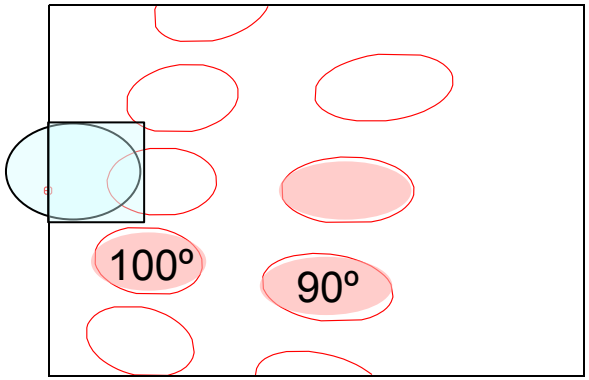
Footprints of Beams

Top of fisheye lens element
(only half of points shown)



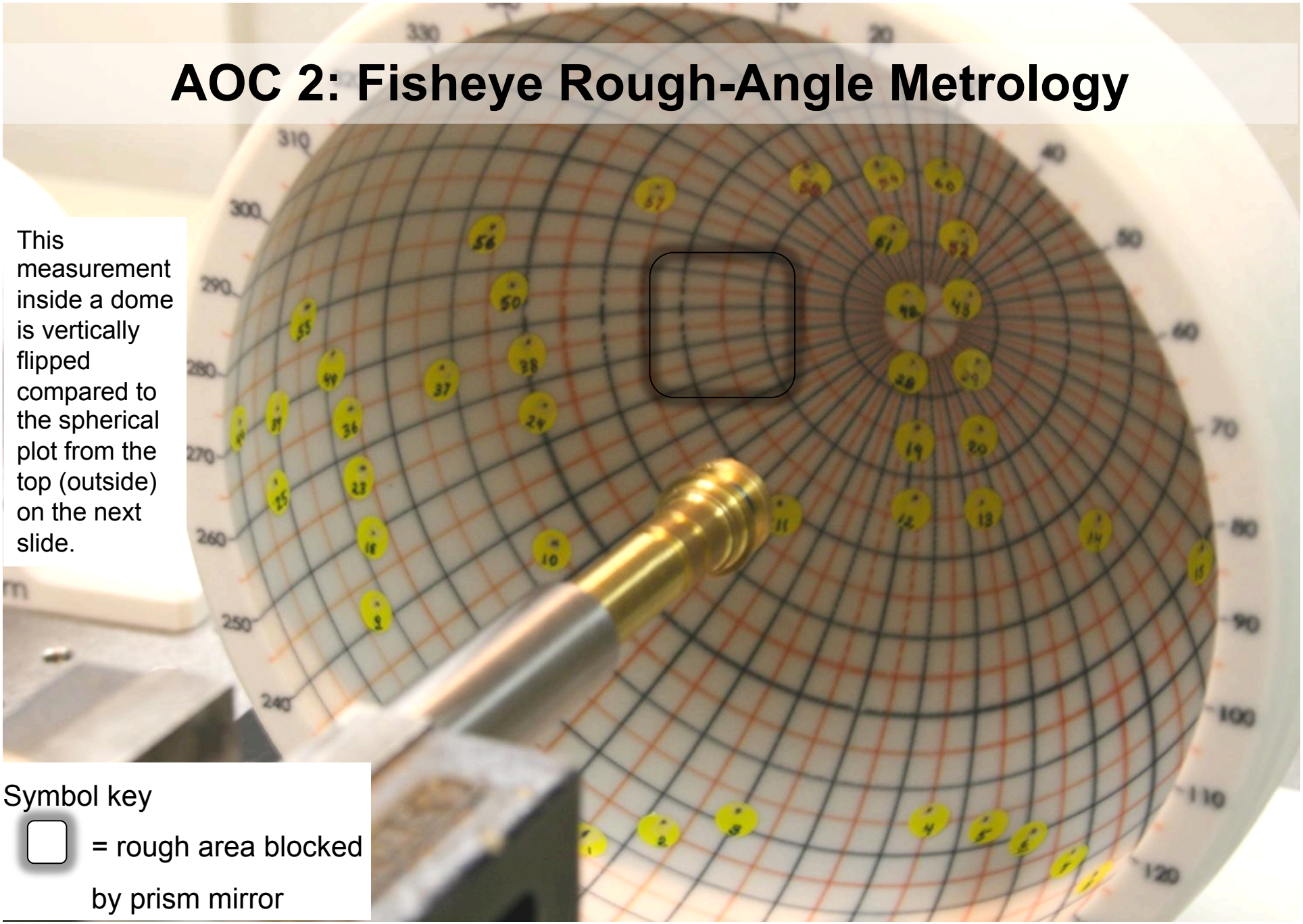
Hemi 2
250-micron spacing

Right prism mirror face



AOC 2: Fisheye Rough-Angle Metrology

This measurement inside a dome is vertically flipped compared to the spherical plot from the top (outside) on the next slide.



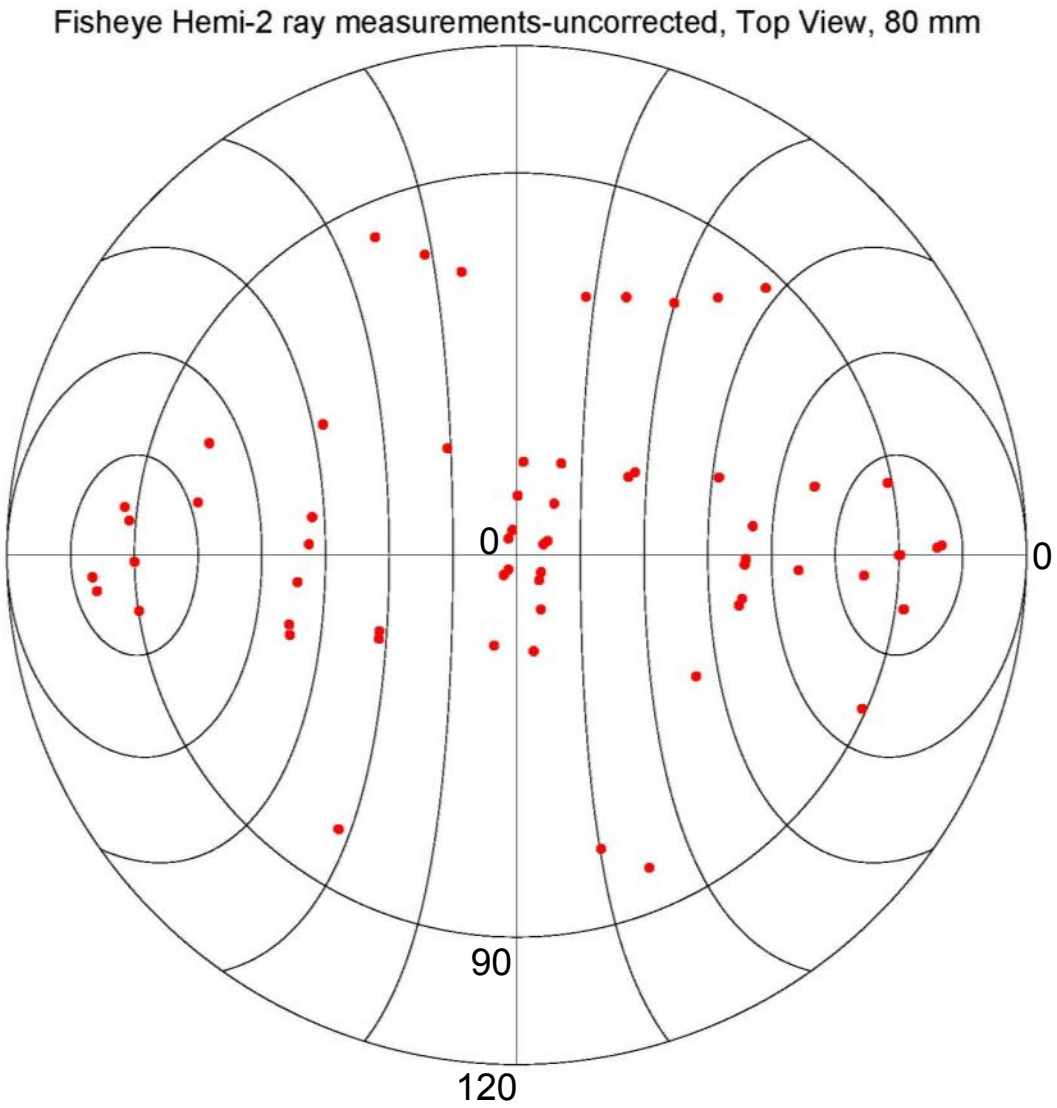
Symbol key

= rough area blocked by prism mirror

AOC 2: Used Locations in Spherical Plot

with center as 'up'

Doubled points are both pin measurement machine and rough metrology (uncorrected)



AOC 2: Fisheye Lens

- Disadvantages
  - This lens type has some distortion at the edge of the field-of-view. This causes a change in measurement point spacing with angle—high-angle spots become elliptical and less efficient. Therefore, mirrors were added for better high-angle spots causing some ‘dead’ regions.
  - The fiber plane is larger than standard array connectors and is custom made.

AOC 2: Fisheye Lens

- Advantages
  - A ‘fisheye’ lens can image measurement points over greater than a hemisphere without ‘dead’ regions.
  - The front fisheye element does not encroach much into the center of the cavity allowing for longer tracking distances.
  - This design uses an index matching element to keep all fibers at the same plane without high return loss.

Data Quality

- Static back-reflections (minimum, mean, maximum in dB):
  - <–70, –58, –46 without target (out of 44 used fibers; two at –27 not used)
  - –58, –45, –33 with target
- Burn paper spot sizes:
  - 10 mm away: ~280-micron diameter
  - 50 mm away: ~320-micron diameter
  - 90 mm away: ~400-micron diameter
- Focus adjusted for entire probe at once

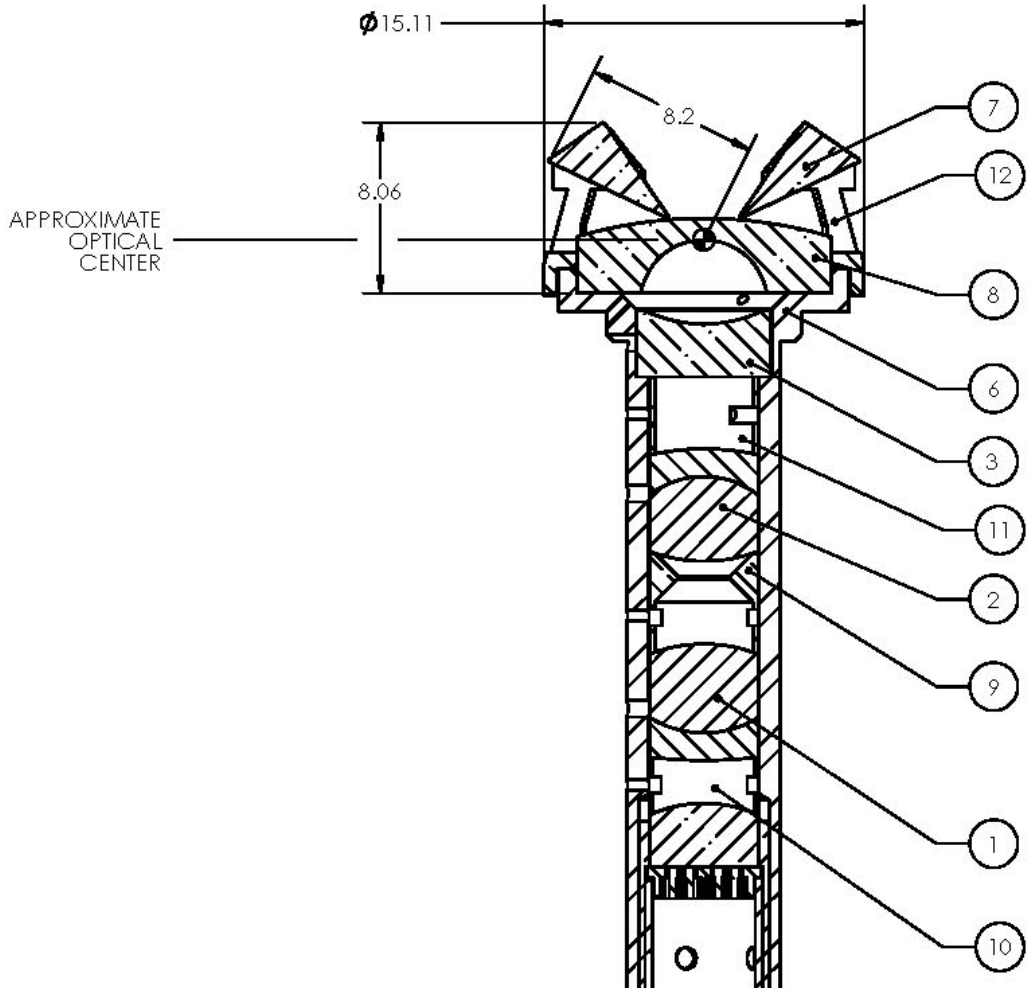
Lessons Learned

- Good 1550-nanometer anti-reflection coatings needed on lenses.
- Index matching gel works better for us than index matching epoxy.
- Fiber polishing for coupling to index matching element is sensitive.
- Focusing to best position is sensitive and best done actively using an IR camera.
- Highest angle points are less efficient unless reached using mirrors.
- Some areas require fibers closer together.
- We have cut down the lens diameters to fit the small blast tube.
- We can put the fiber bundle through the blast tube before attaching it to the lenses so fiber connectors do not need to be cut.

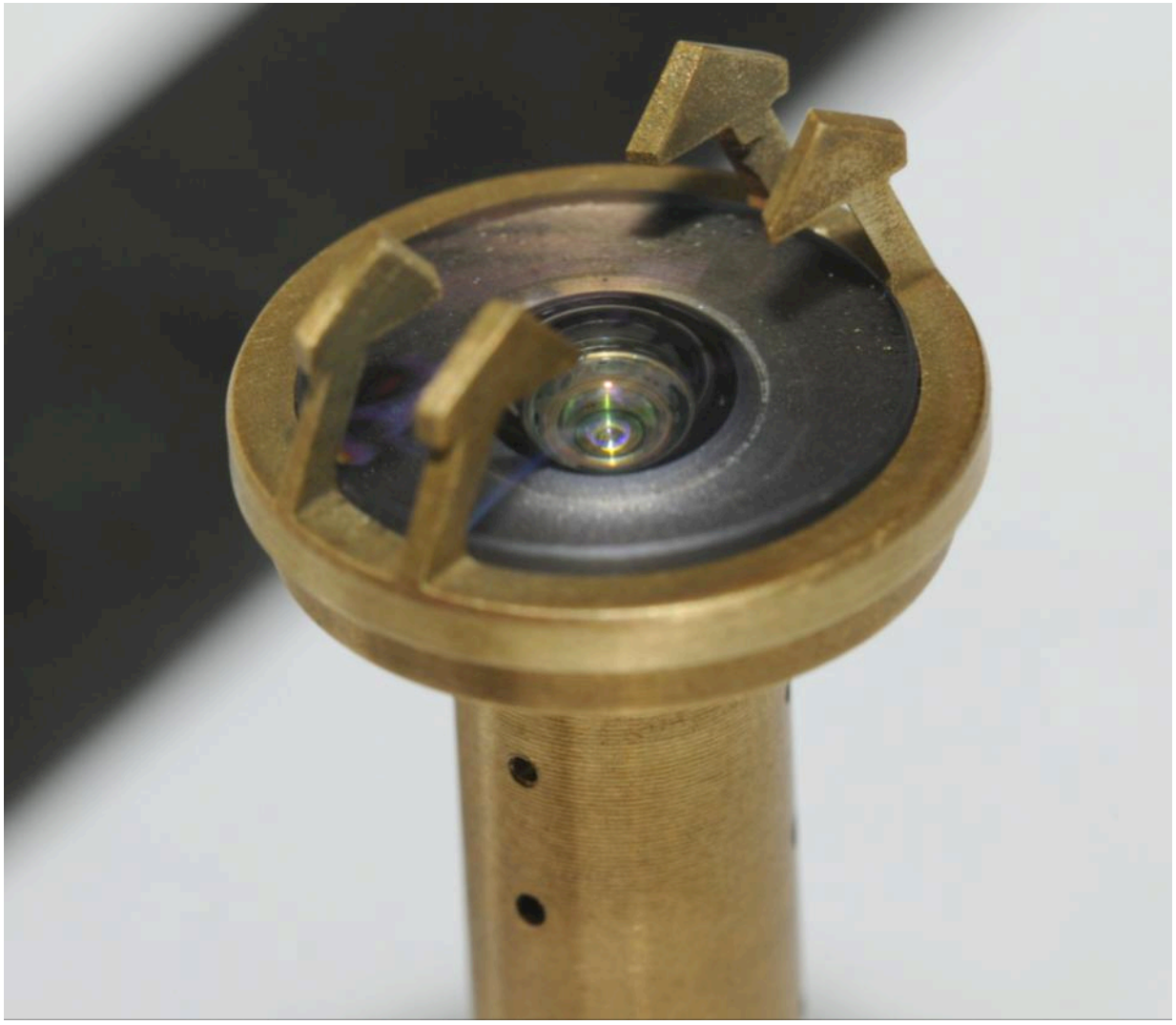
Next Iteration

- Slightly smaller top fisheye lens element
- Larger prism mirrors and better prism mounting
- Different fiber arrangements

AOC 2: Fisheye with Longer Reflector Prisms



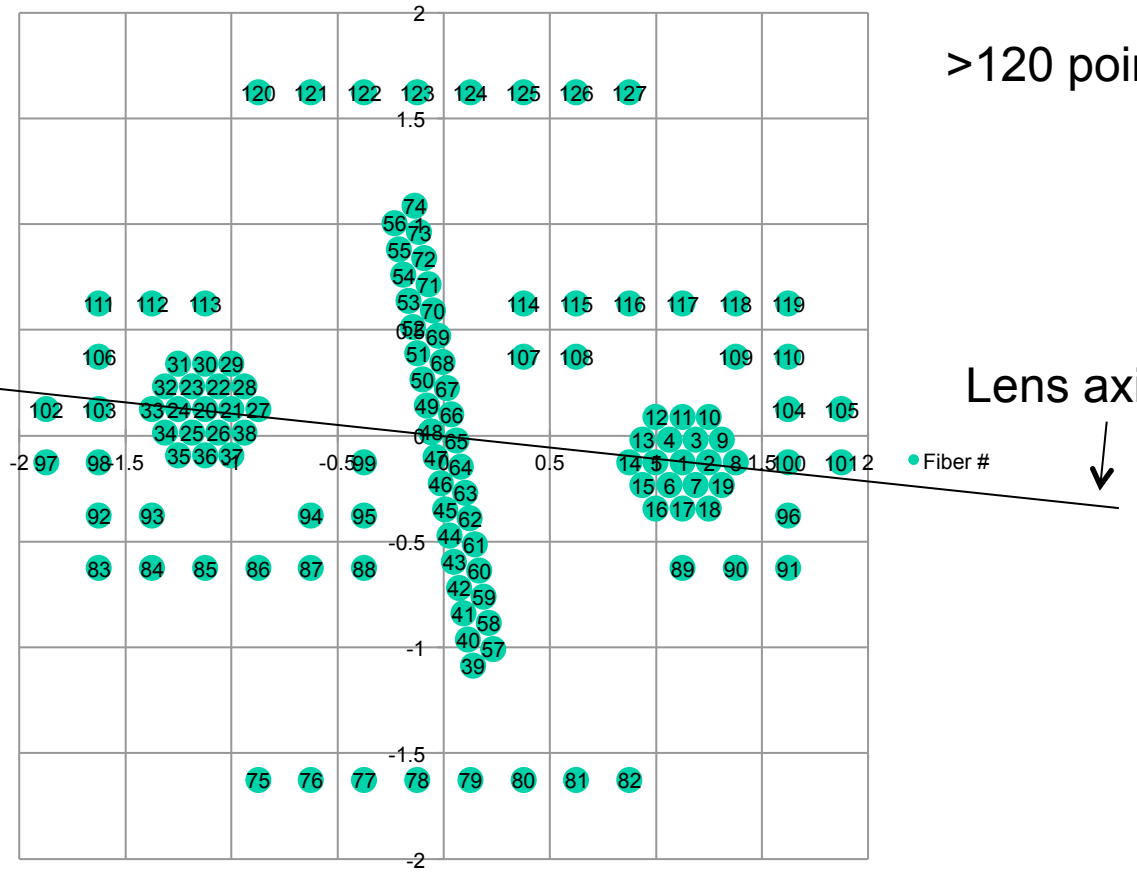
AOC 2: Fisheye with Mounting for Longer Reflector Prisms



Example Fisheye Lens Fiber Map

Points can be added and positions shifted.

Close-pack could be 64% tighter with 80-micron cladding fibers.



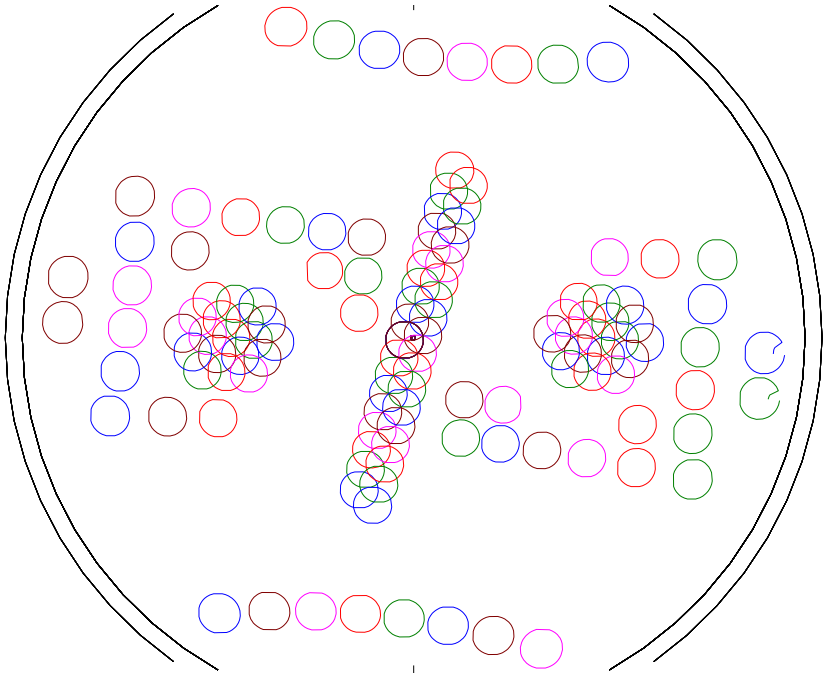
>120 points plotted

Hemi 4

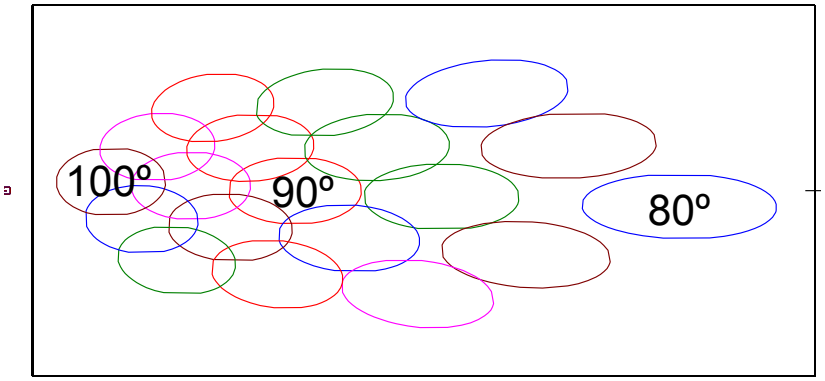
Some 125-micron cladding close-packed fibers (many other fiber patterns are possible)

Footprints of Beams

Top of fisheye lens element



Right prism mirror face



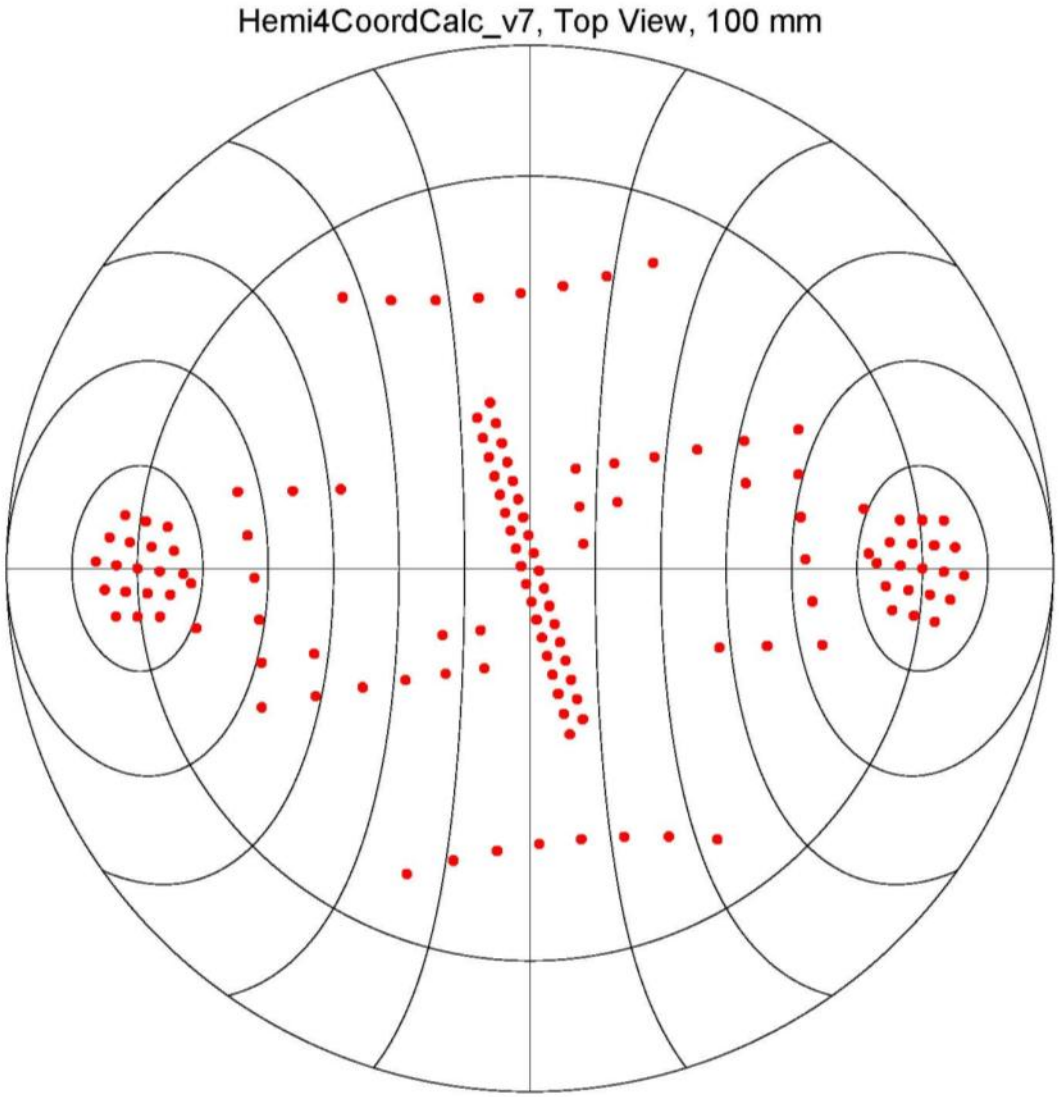
Hemi 4
Some 125-micron cladding close-pack fibers

S2 Plot

S2 axis lined up to fiber.

Points can be added and positions shifted.

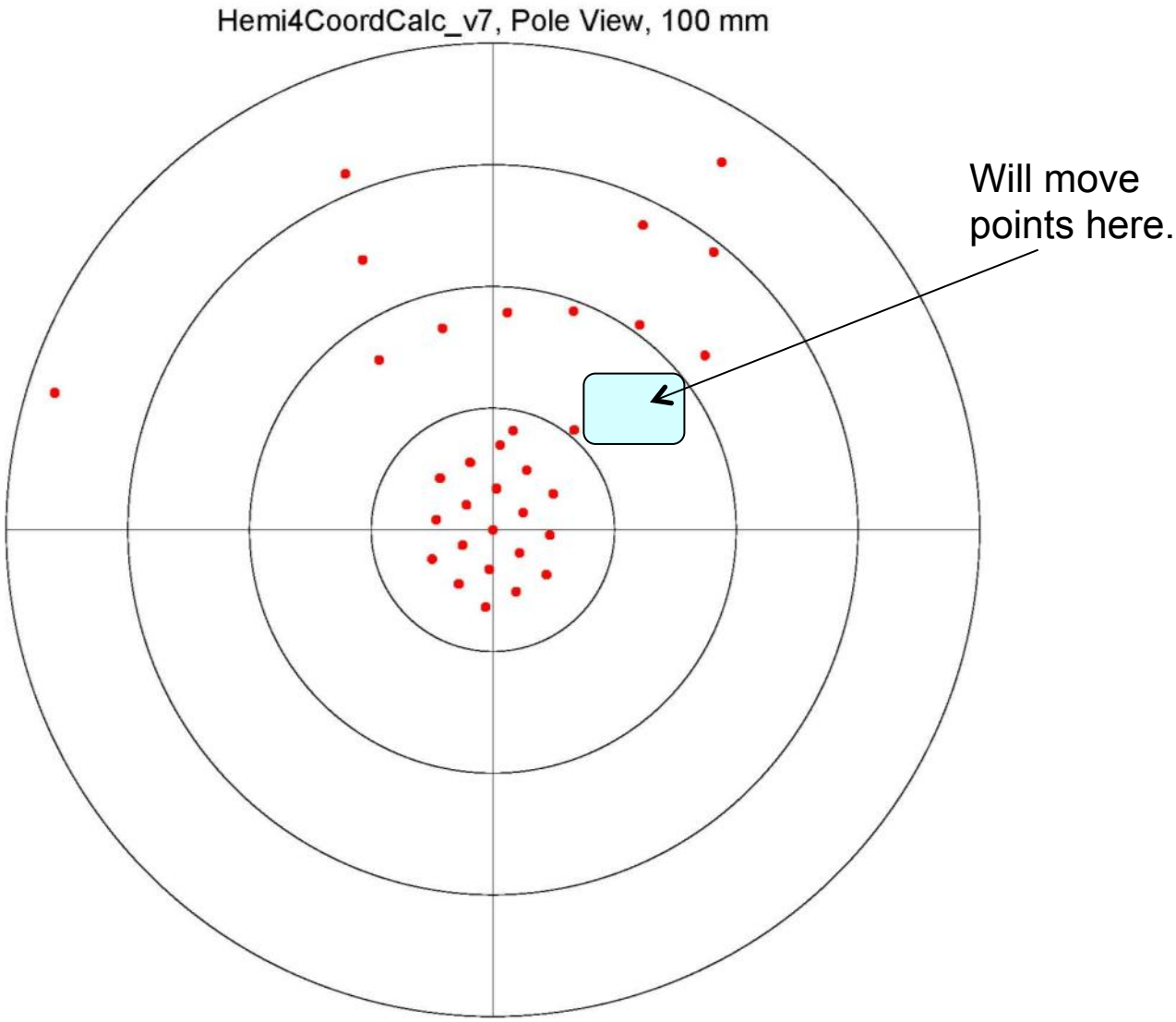
>120 points plotted.



S2 Plot

S2 axis lined up to fiber.

Points can be added and positions shifted.

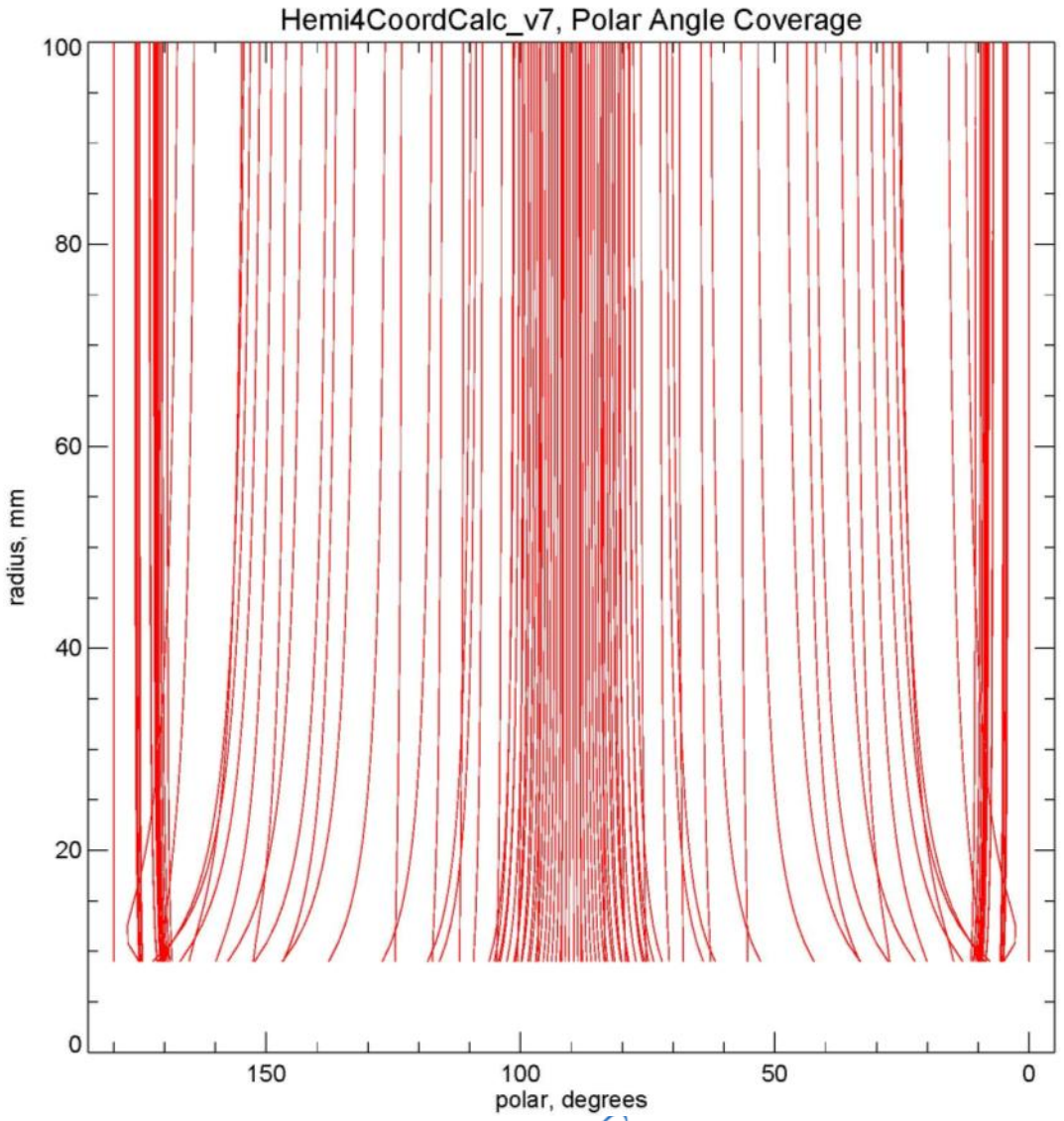


S2 Plot

S2 axis lined up to fiber.

Points can be added and positions shifted.

>120 points plotted.

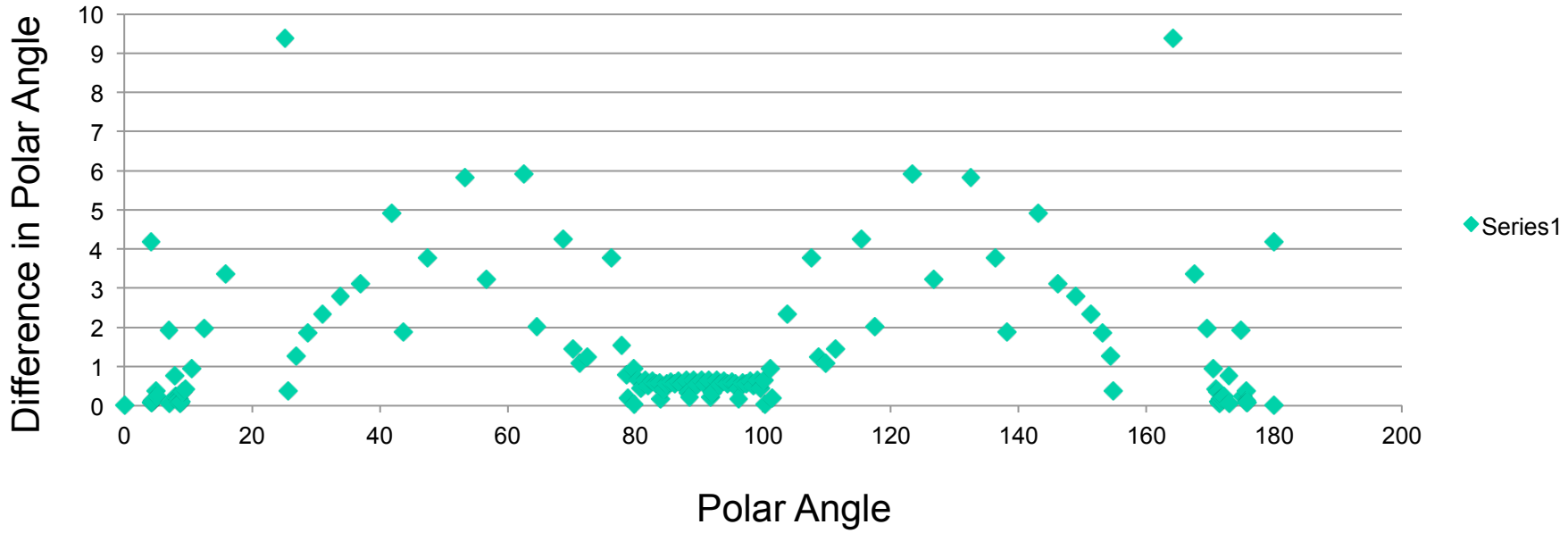


Angular Separation

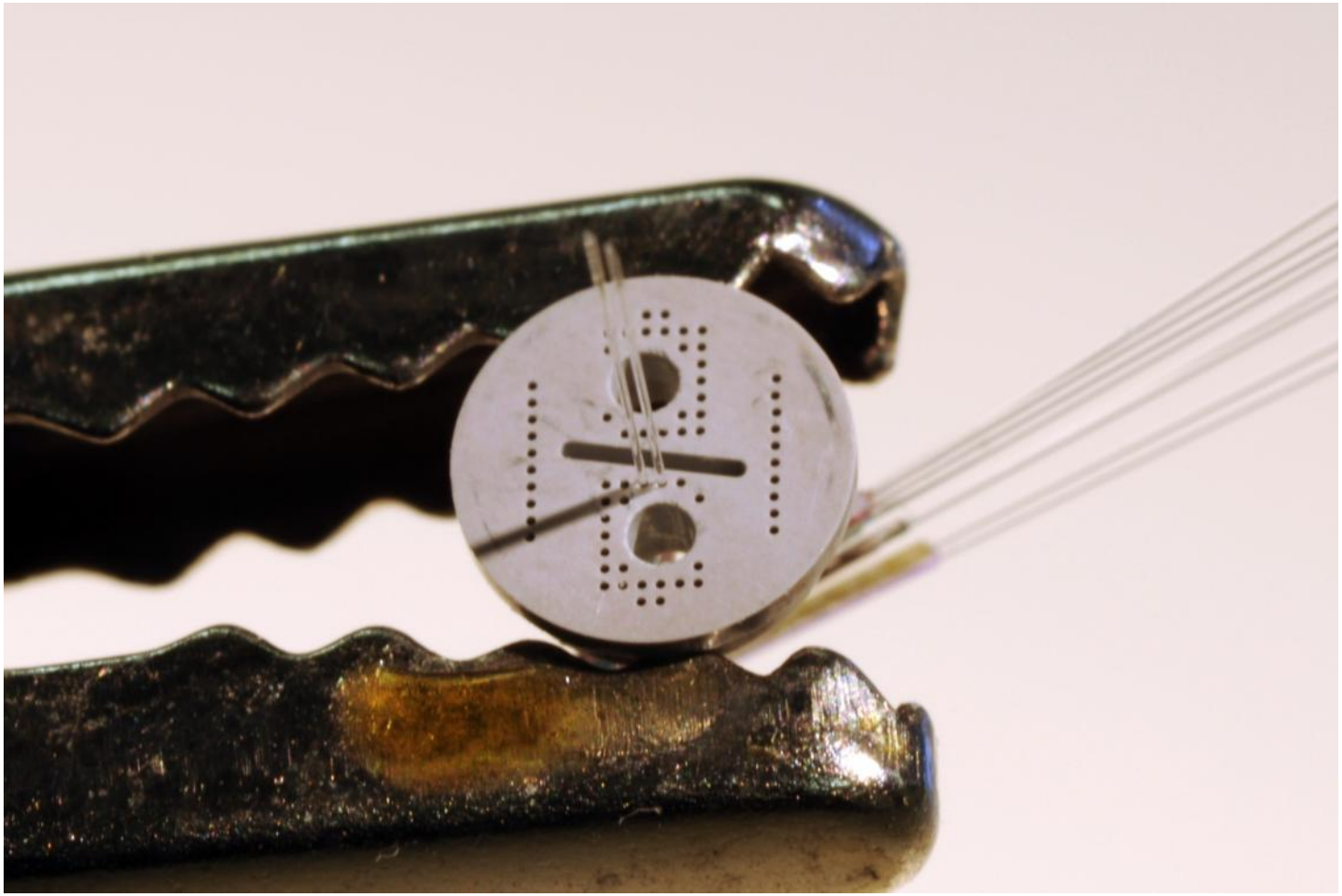
S2 axis lined up to fiber.

Points can be added and positions shifted.

>120 points plotted.

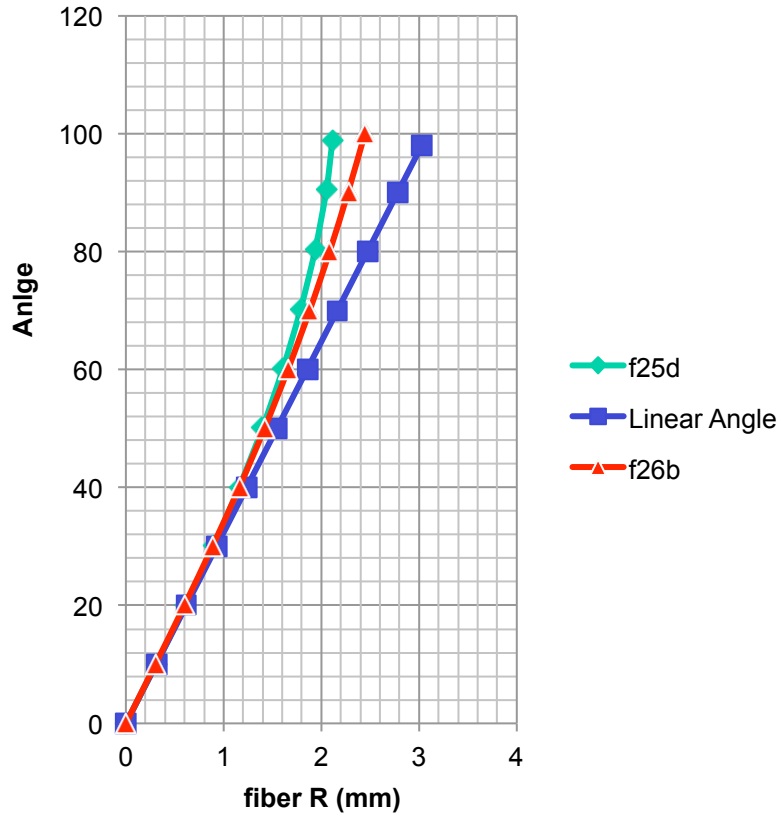


Ferrule for Fibers



Lens Design Changes

Current design



Future reduced distortion design
(still in progress)

Summary for Fisheye Lens Probe

- Long tracking distance (probe less than 9 mm radius)
- Maximum polar angle coverage: ~ ±100 degrees (dome) using mirrors
- Rays go to a <3 mm radius common center point near hydro center
- Uses glues and index matching gel (sealed inside)
- Includes many spare fibers (measurement points)
- Point accuracy using aiming can be <1 mm
- Point angular separation:
  - Up: Polar 0.5, azimuth 2.6 degrees (if using 80-micron cladding fibers)
  - Side: 1st–2nd point, polar 2.6 degrees (if using 80-micron cladding fibers)

Acknowledgments

We have an exceptional team.

Some team members are:

Brian Cata, Brian Cox, Edward Daykin, Douglas DeVore, David Esquibel, Daniel Frayer, Cenobio Gallegos, Robert Malone, Morris Kaufman, and Vince Romero (NSTec)

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Thank you to everyone who contributed – Great Job!