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Recent applications, designs, and sundry improvements in PDV optical probes

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Topics

- Improved performance of Argus NX3b fisheye probe
- New potentials afforded by multicore fiber (MCF)
- An inquiry into back-reflections at the lens-fiber interface in Argus probes
- A possibly ridiculous proposal for a new PDV architecture

Argus NX3b fisheye probe

- Envisioned as an improvement over NX1 (the current standard), and as a development and demonstration platform for improved methods and processes
- Improvements over NX1
  - Negligible distortion over full field of view
  - Flat collection efficiency over the field of view
  - No mirrors

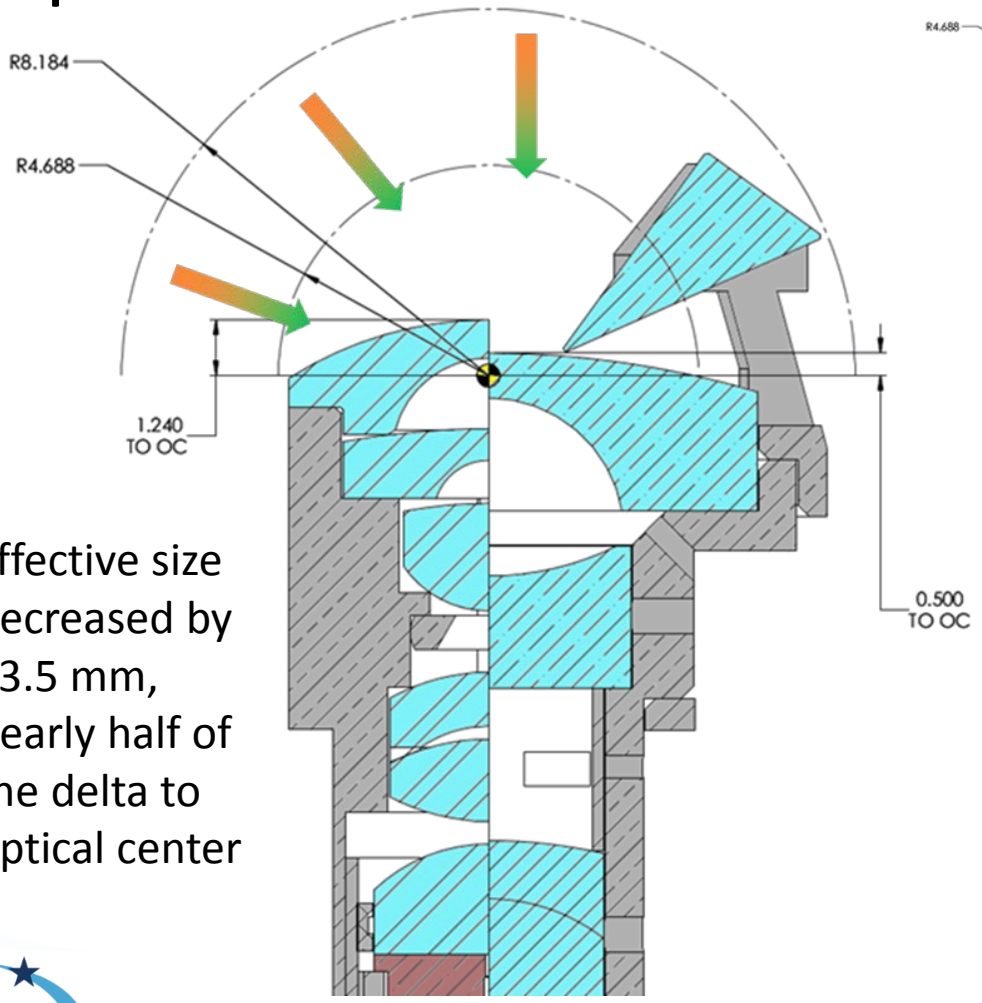
Argus NX3b fisheye probe

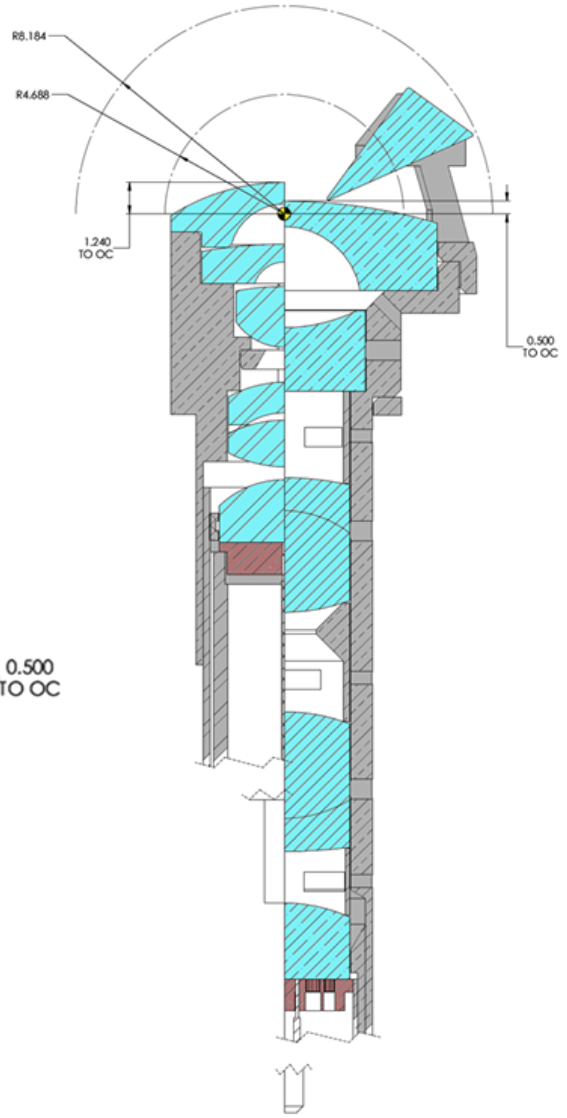
- A smaller lens = improved data collection
- Incorporation of multi-core fiber (MCF) enables better angular spacing in any geometry[1]
- Tighter, more sophisticated tolerancing
  - Working with vendors to develop an integrated design, tolerancing, assembly, and qualification process
  - Developing new processes and standards for design and qualification
- Lower back-reflections
  - *Working with Cargille to develop a better-matched coupling fluid*[1]
  - *Developing a new process for optical coupling*[1]

[1] *Currently under investigation*

Argus NX3b fisheye probe

Comparison to NX1: Size





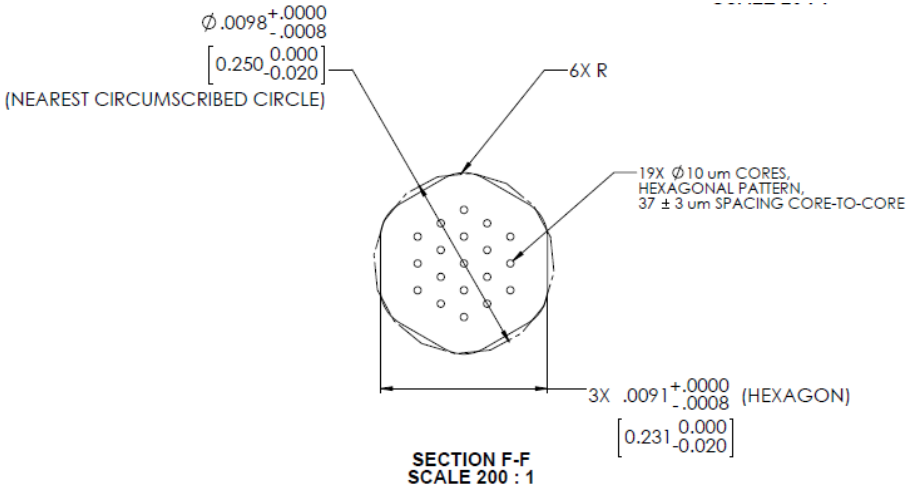
Effective size decreased by ~3.5 mm, nearly half of the delta to optical center

Incorporation of MCF

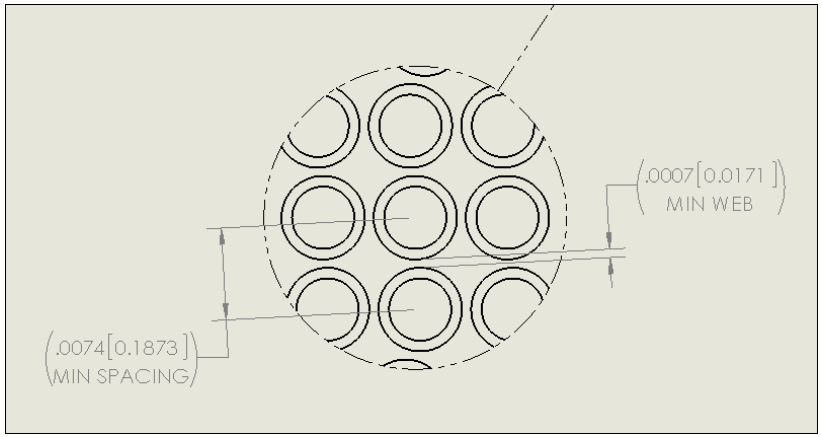
- Chiral Photonics makes customizable PROFA multi-core fiber arrays with smaller fiber-to-fiber spacing than is possible with standard fiber arrays, and greater flexibility than fiber bundles
- One end is a hexagonal array, and the other is broken out into pigtails

Incorporation of MCF

	PROFA fiber	**125-micron fiber**	**80-micron fiber**
Fiber-to-fiber spacing	37 microns	187.3 microns	80 microns (dense pack)



PROFA fiber, 37 µm spacing, 10 µm core



Minimum spacing for individual 125 µm fibers

Improving back-reflections

- Multiple back-reflections currently limit MPDV optical probe performance. Of these, we decided to look at those at the interface between the fibers in the ferrule and the first lens.
- These are governed by the difference in the two indices of refraction, the index of the material in the gap, and the thickness of the gap

$$R = \frac{(n_0^2 + n_1^2)(n_1^2 + n_2^2) - 4n_0 n_1^2 n_2 + (n_0^2 - n_1^2)(n_1^2 - n_2^2)\cos 2\delta_1}{(n_0^2 + n_1^2)(n_1^2 + n_2^2) + 4n_0 n_1^2 n_2 + (n_0^2 - n_1^2)(n_1^2 - n_2^2)\cos 2\delta_1}$$

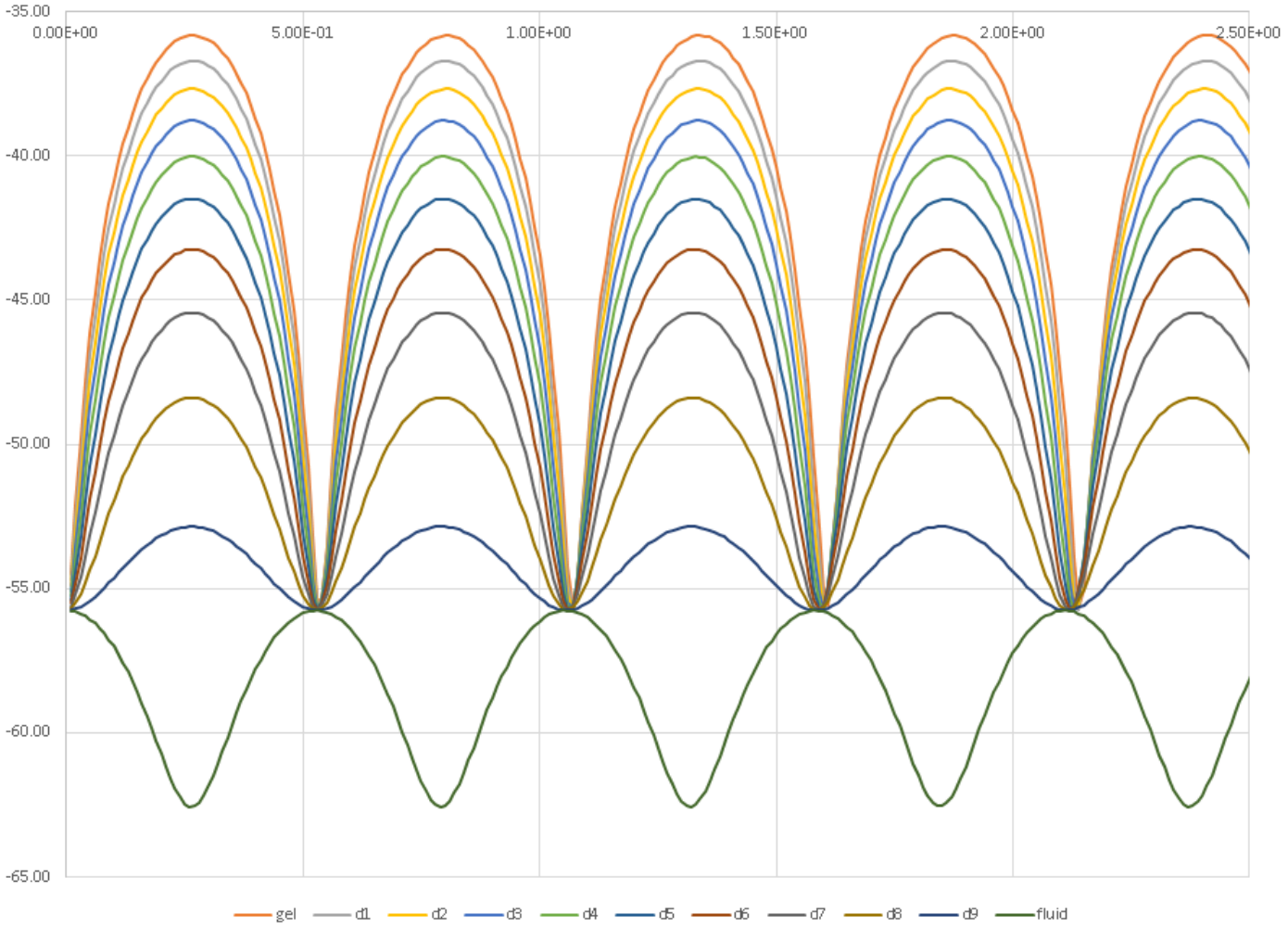
$$\delta_1 = \frac{2\pi}{\lambda} n_1 d_1 \cos \varphi_1$$

Improving back-reflections

- We know the lens index very accurately
- We know the fiber material index to first order
- We expect to know the optical couplant index to reasonable accuracy
- We don't have any idea what the thickness of the gap is.

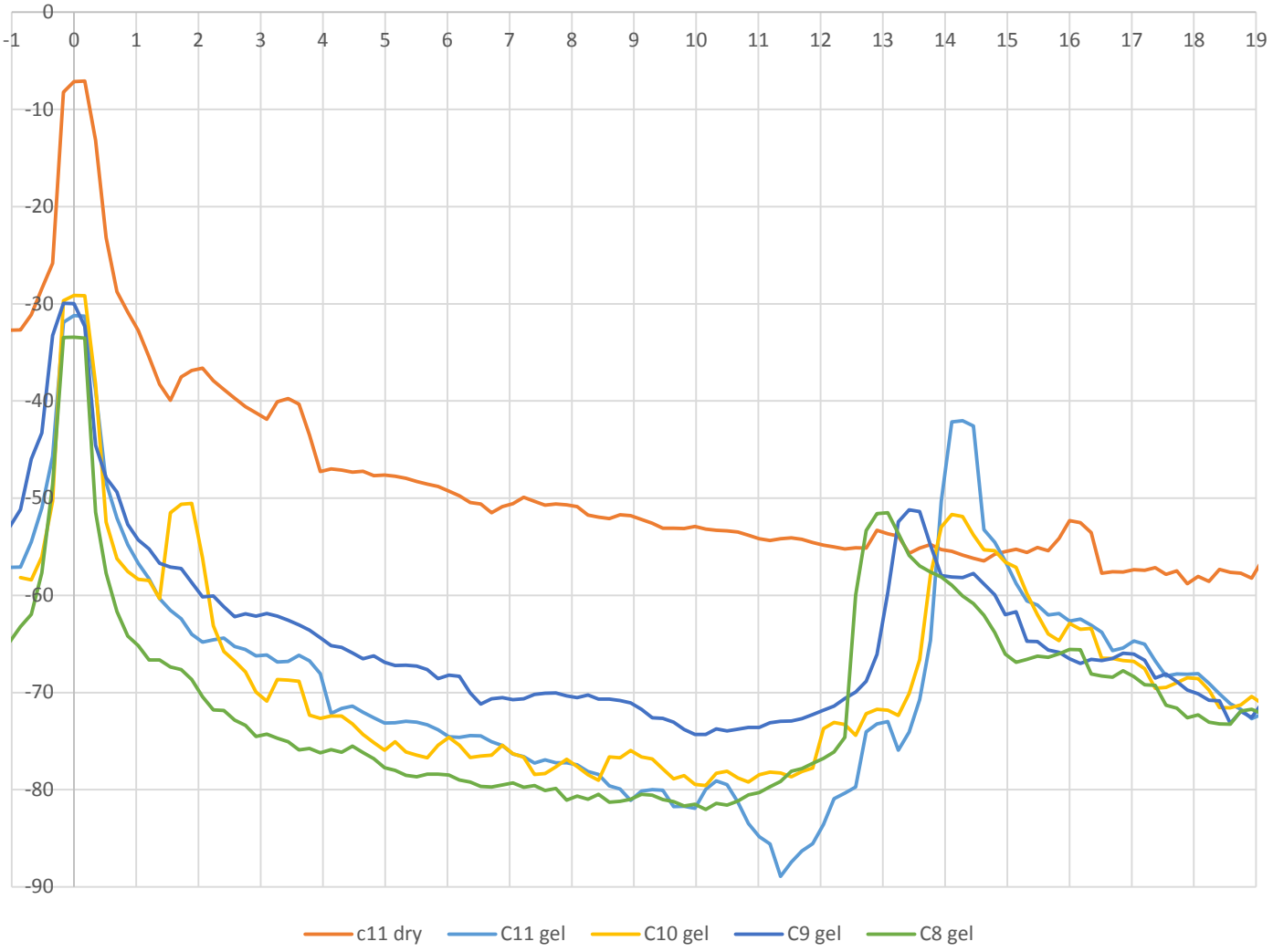
Improving back-reflections

Regardless of gap size, we expect increasing index to improve back-reflections



Improving back-reflections

Intra-lens reflections show up as second peaks



Improving back-reflections

Measurements

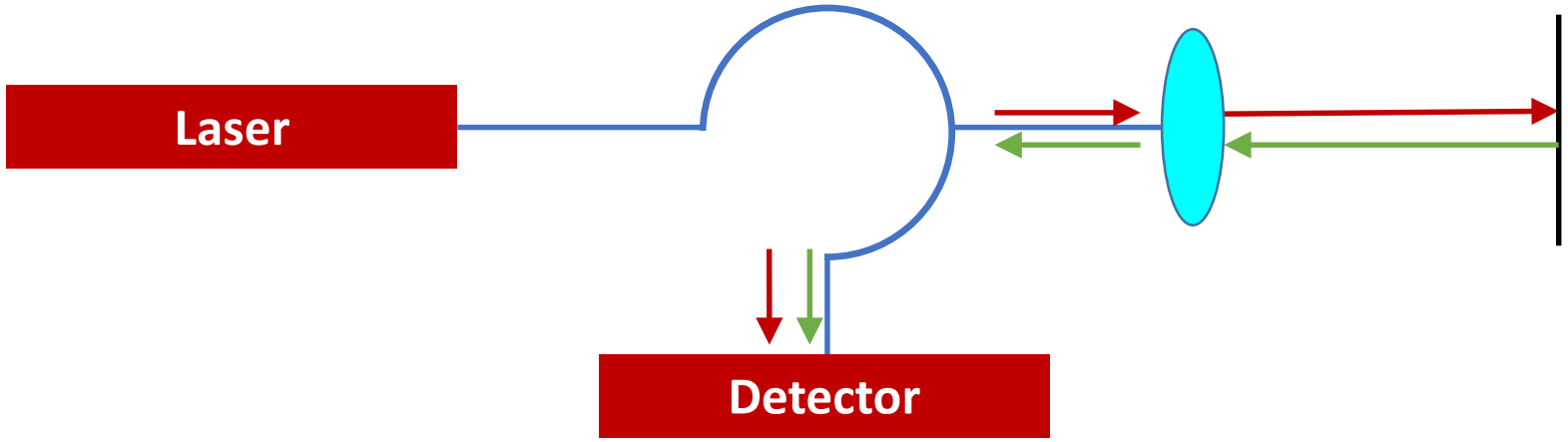
	Index	Back-reflections	
		(average)	(standard deviation)
Air gap	1	–18.276	6.294
Standard gel	1.4470	–41.829	2.366
Custom liquids	1.4690	–44.959	3.291
	1.4695	–44.211	3.152
	1.4700	–45.822	3.745
	1.4710	–46.007	4.424
	1.4720	–45.572	3.332
	1.4730	–45.308	3.497

- Air and gel measurements are consistent with a gap of ~100 nm
- Liquid indices bottom out well above their predicted values
- Intra-lens reflections eliminated via Luna measurements
- Intra-fluid bubbles? Volatility? Measurement technique?

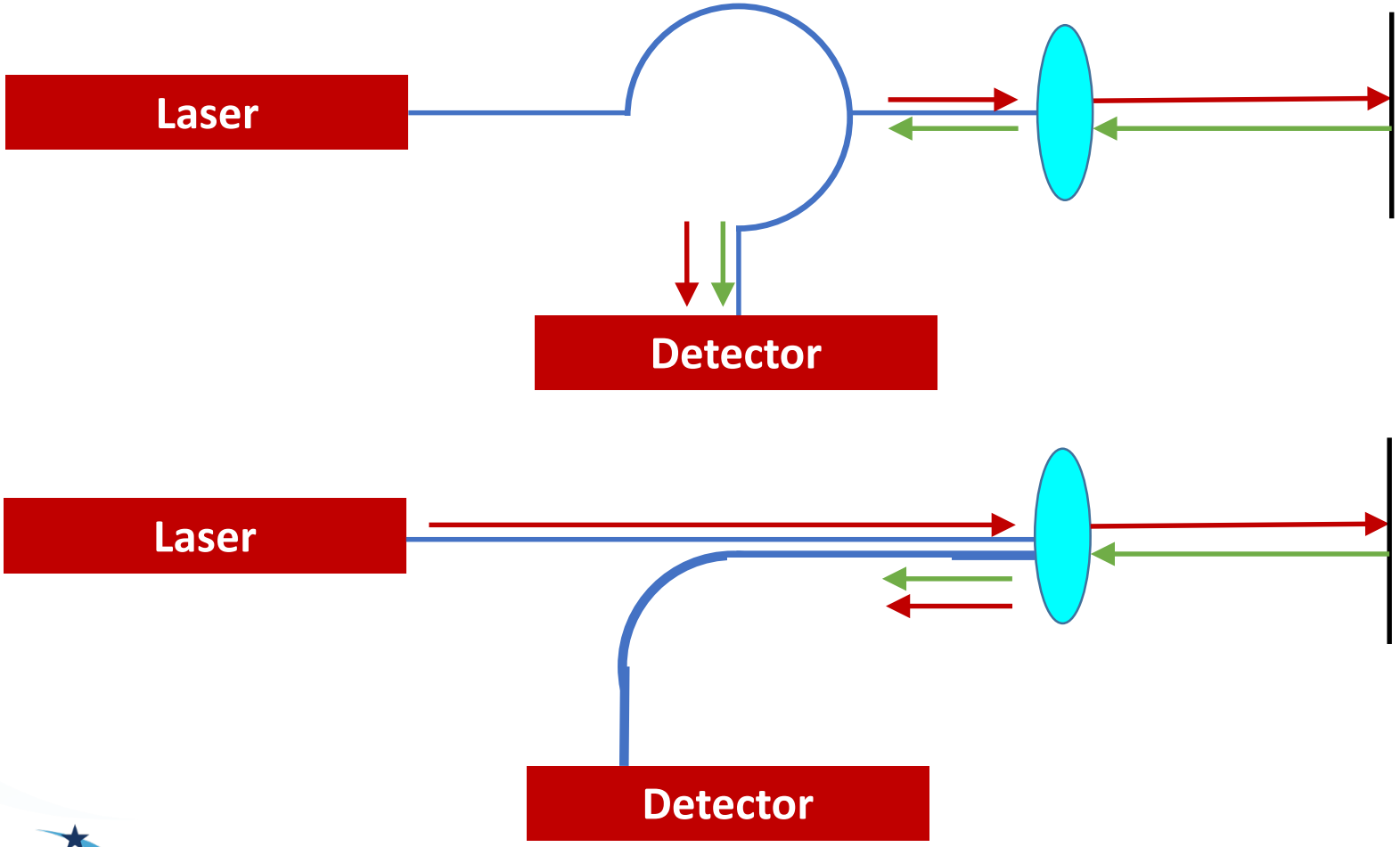
A proposal for a new architecture

- Recent experiments with separate send and receive paths have shown significant promise for reducing back-reflections
- Some applications require long stand-off distances, longer travel, or greater collection efficiency than possible with the current architecture

A proposal for a new architecture



A proposal for a new architecture



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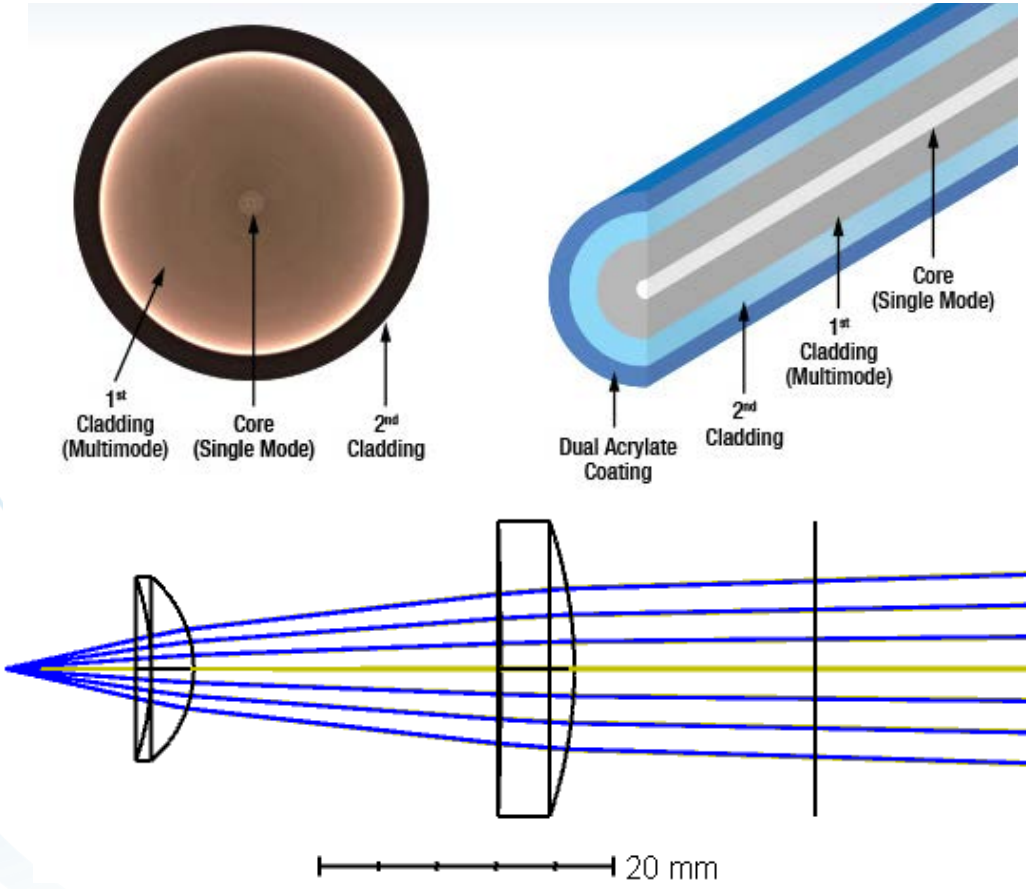

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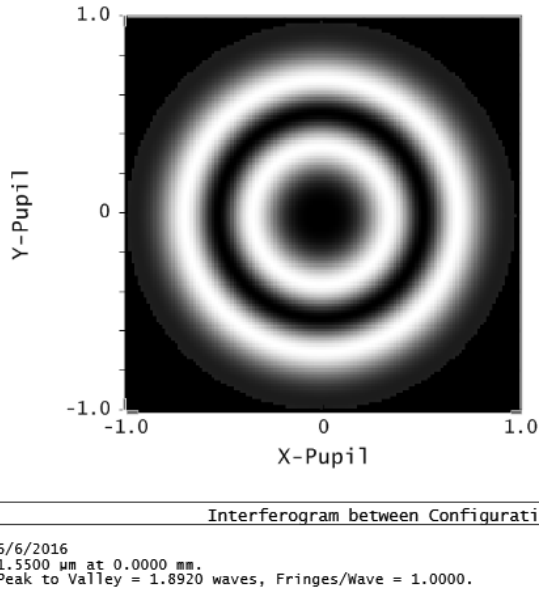

A proposal for a new architecture

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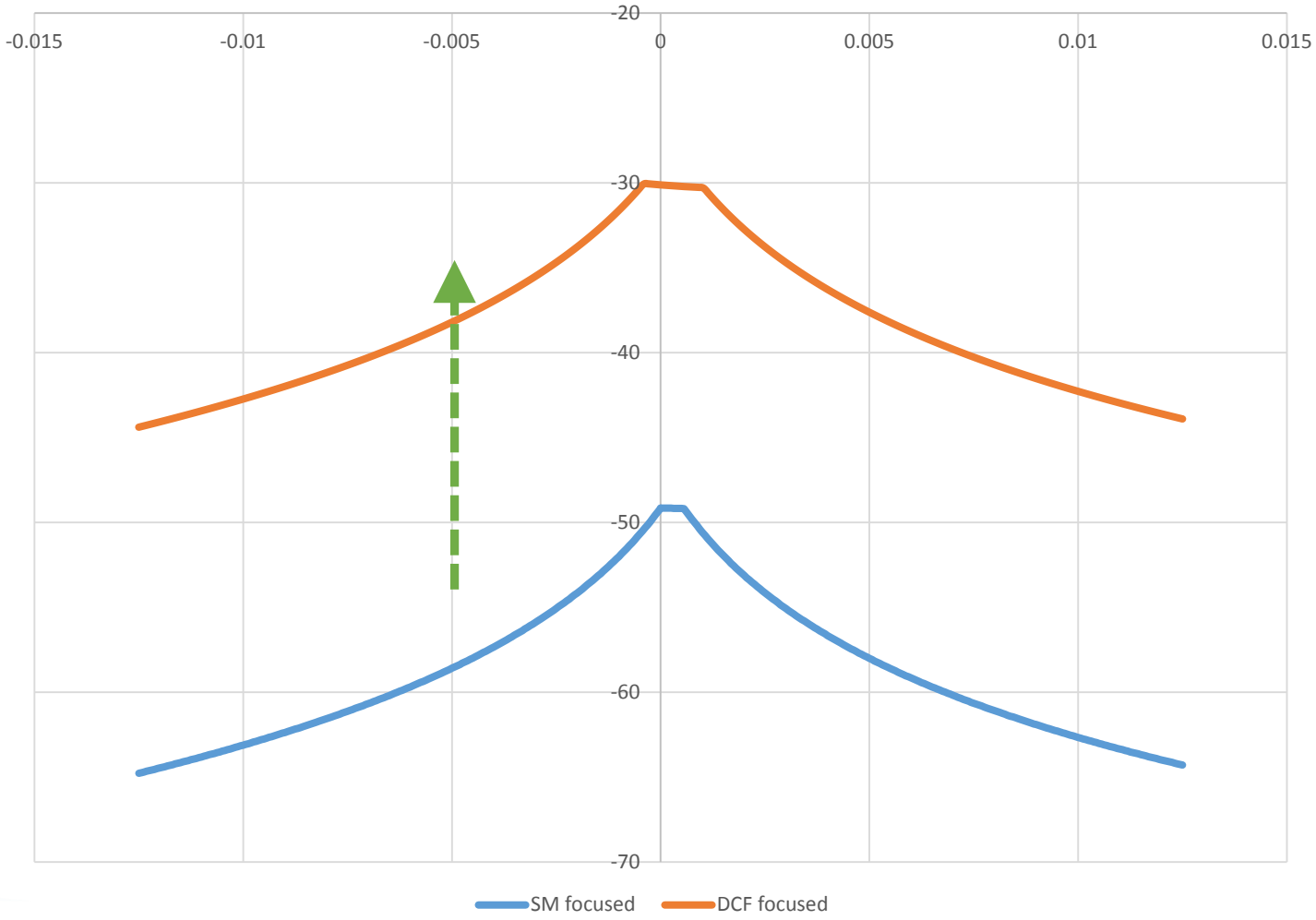
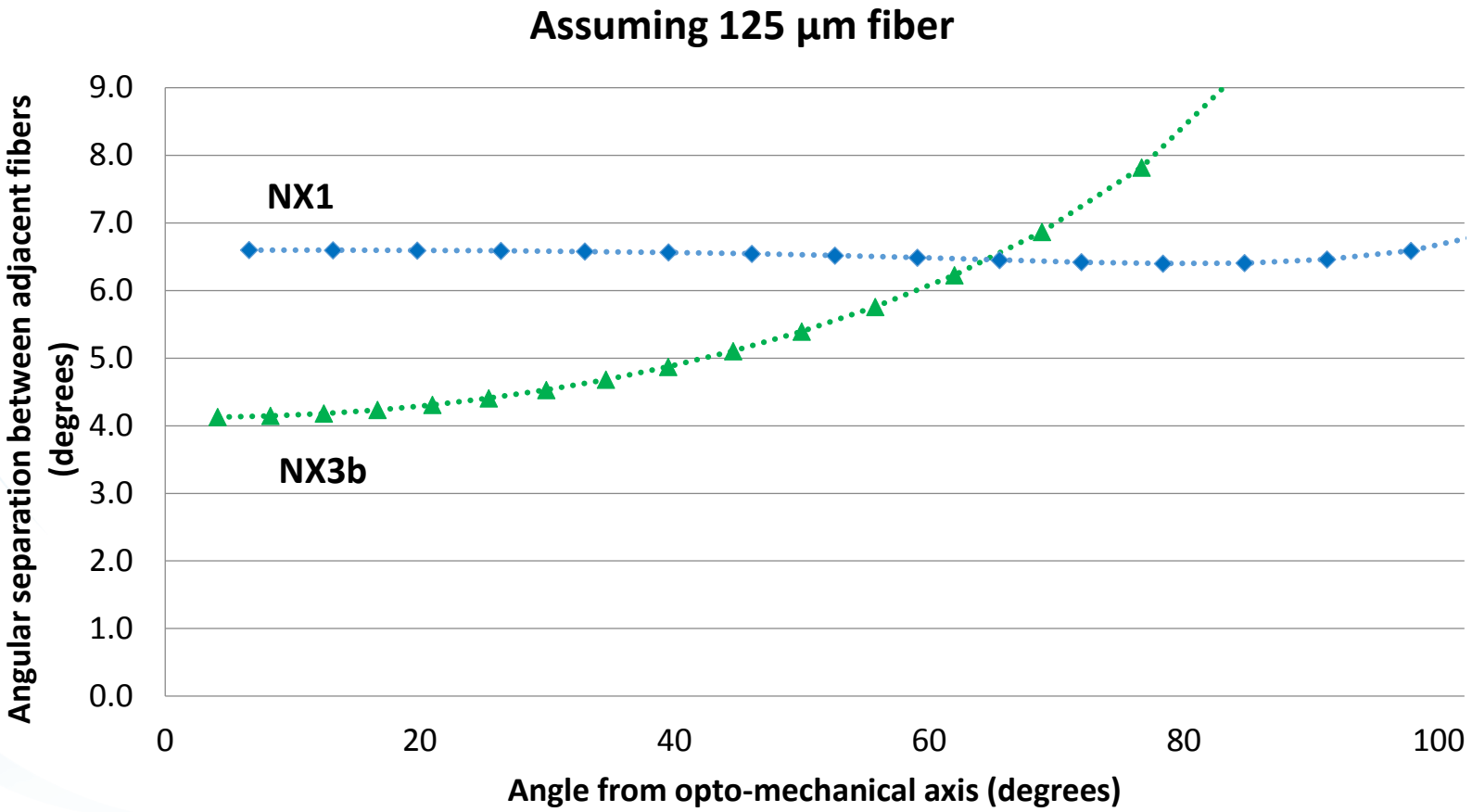


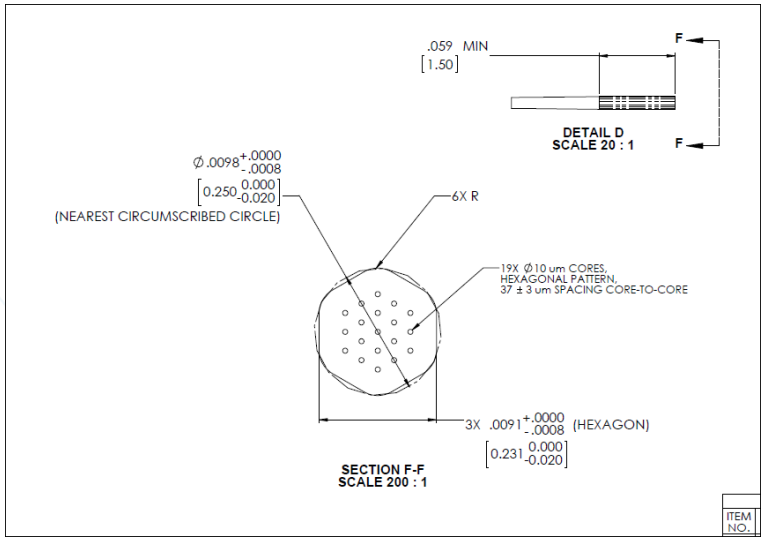
Argus NX3b fisheye probe

Comparison to NX1: distortion

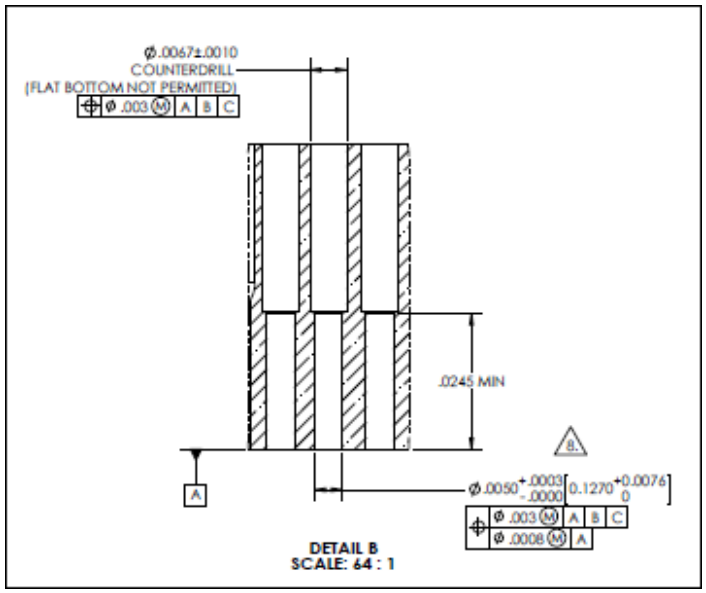


Incorporation of MCF

- The locational tolerance for individually potted fibers is good because the radial clearance between the fiber and hole will be small: 1 to 5 µm
- The radial clearance between a PROFA fiber and its hole is large: 13 to 18 µm
- End result: The location of the PROFA fibers is less determinate than that of the potted fibers



PROFA hexagon profile tolerance = +0/–20 µm
Hole tolerances for PROFA +15 µm/–0
Hole location tolerance: ±8 µm



Corning fiber cladding diameter:
125 µm ±0.3 µm
Hole dimension: 127 µm +8/–0
Location tolerance: ±6 µm