Ocean Color Experiment Ver. 2 (OCE2)

~ Optics~

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Overview

- First Order Layout
- Fiber Bundle / Detector Geometry
- Fore-Optics Design Form - Modified Schmidt Telescope
- Aft-Optics Design Form -Singlet Relay
- Mass Estimate
- Concerns
- Conclusions

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First Order Layout

	Tel EAP	**180**	**mm**
	Tel fl	**520**	**mm**
	-> Tel f/#	2.89	f/#
	-> Convergance	0.17	rad
		9.92	deg
	-> Min NA:	0.172	NA
	Orbit Height	**650**	**km**
	Nader Spot	**1**	**km**
	-> FOV:	0.00154	rad
		1.53846	mrd
		0.0881	deg
		5.29	amin
	-> Image Size	0.800	mm
	Fiber Core Size	**0.8**	**mm**
	Fiber NA	**0.22**	**NA**
	-> Acceptance	12.71	deg
	Fiber spacing	0.88	mm
	FIBER OUTPUT		
	-> Output angle	0.222	rad
		12.71	deg
	Collimation fl	**42**	**mm**
	-> Lens size	19.7	mm
	-> Field spread	0.0	rad
		0.5	deg

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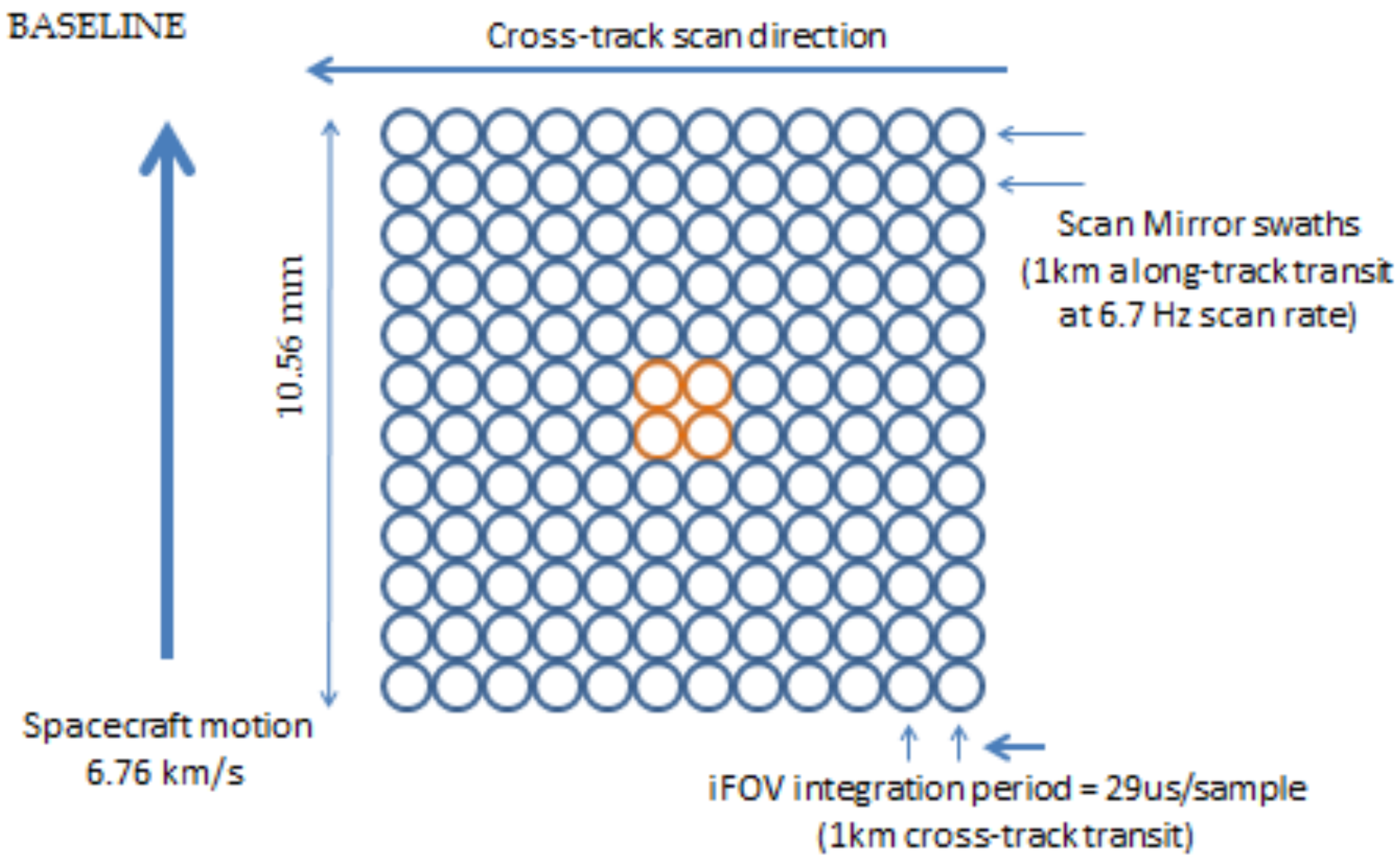
Fiber Layout Geometry

Focal plane image = 12x12 Fiber array – 800(ID)/880(OD)um ea.
Each Fiber core (800um) = 1km dia. GSD (iFOV)
=> 144 measurement channels



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Fore-Optics Design Form - Modified Schmidt Telescope

Integrated Design Capability / Instrument Design Laboratory

This modified Schmidt telescope design form was chosen based on the needs for a

- Compact design
- Modest 2-D FOV
- Minimal crosstalk
- Low polarizance

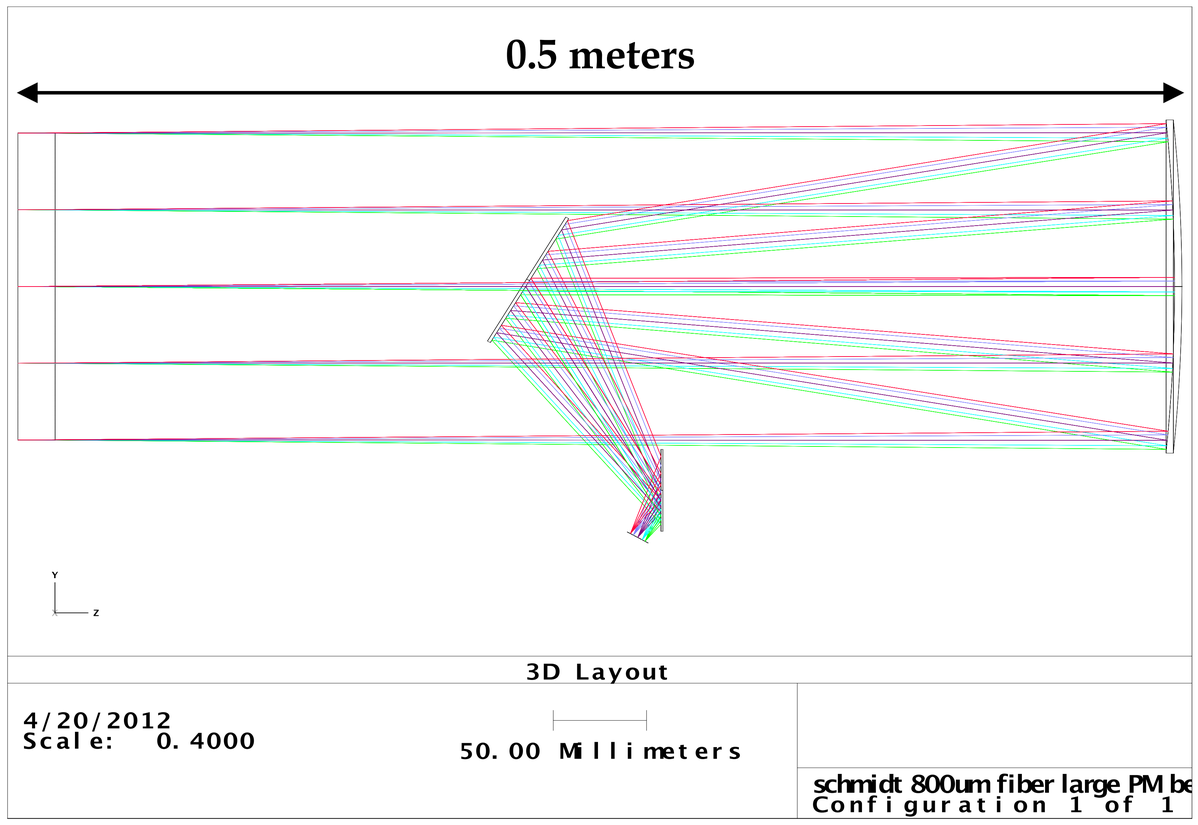
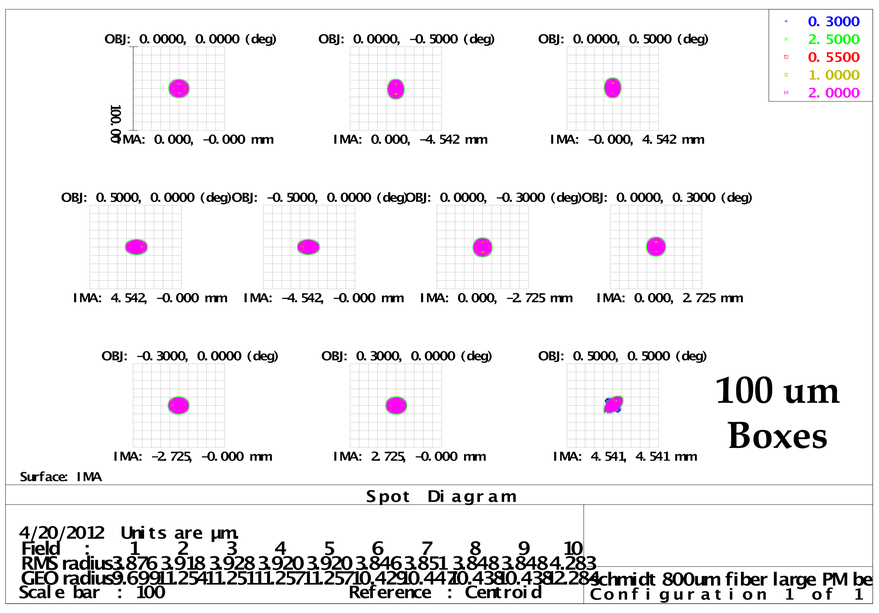


Image Quality at Fiber



Effective Focal length (mm)	520.36
F/#	2.89
Plate scale	1 km / fiber core (0.8mm)
FOV	1° × 1°
Wavelength range (nm)	350 - 2400
Pupil Diameter (mm)	180

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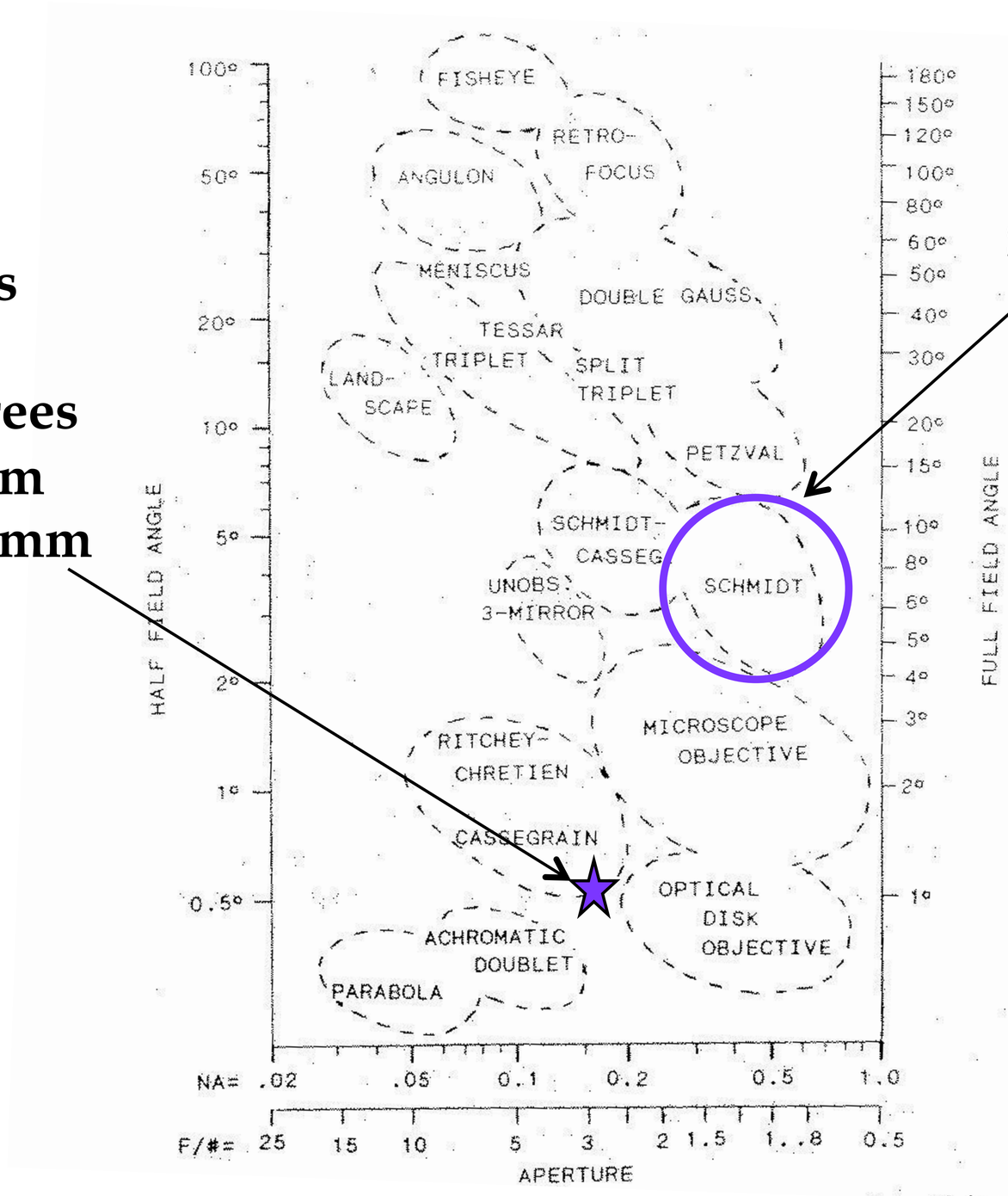
Warren Smith Optical Design Map

Integrated Design Capability / Instrument Design Laboratory

OCE2 Specs
- **f/2.9**
- **FOV 1.0 degrees**
- **EFFL 522 mm**
- **Aperture 180 mm**



Schmidt Camera Design Form

The Schmidt design is appropriate for this application

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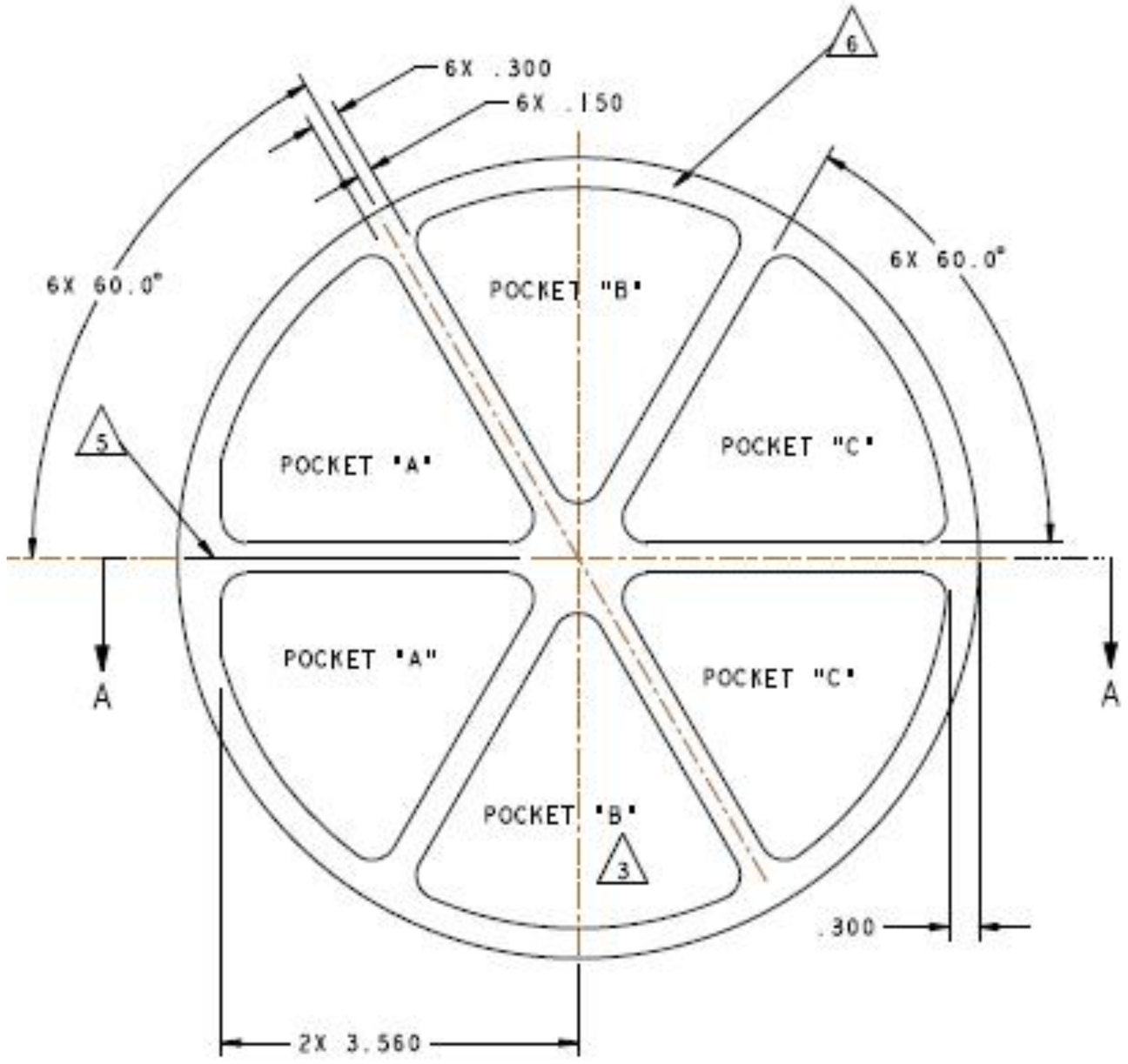
60% Lightweighting was Assumed for the Primary Mirror



Example of a 100 mm Lightweighted ULE Mirror

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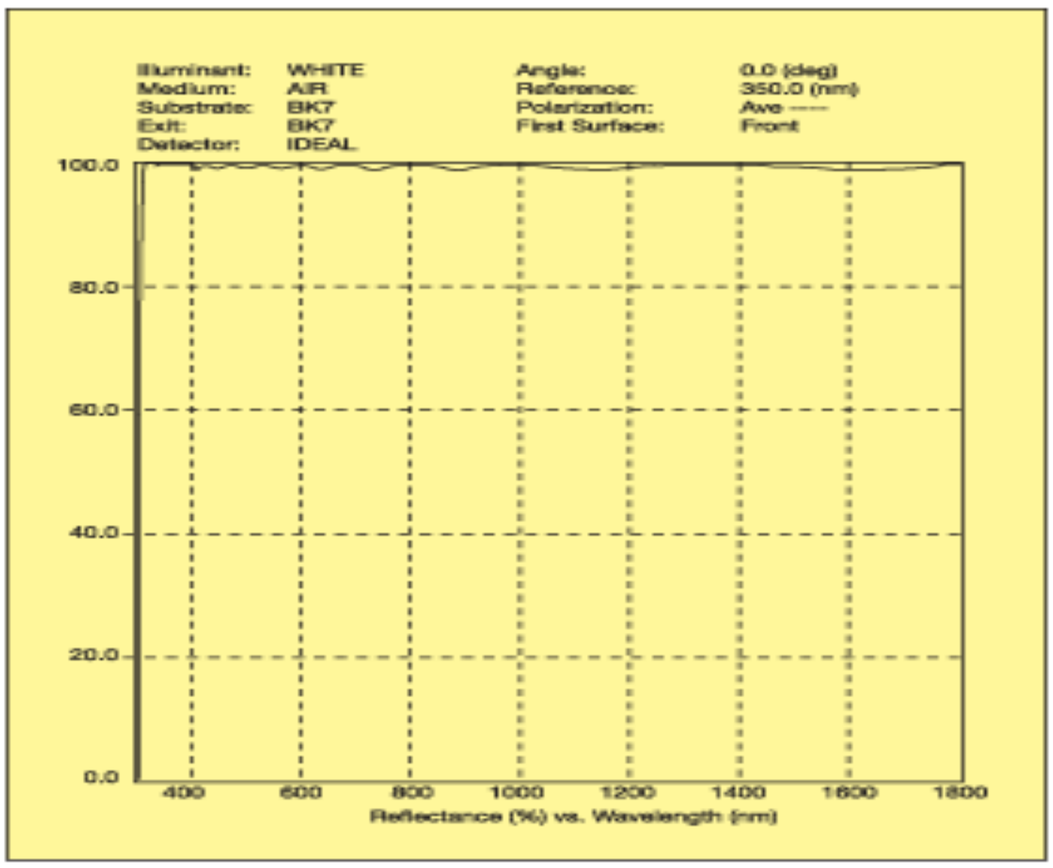
Mirror Coating – UV Enhanced Silver

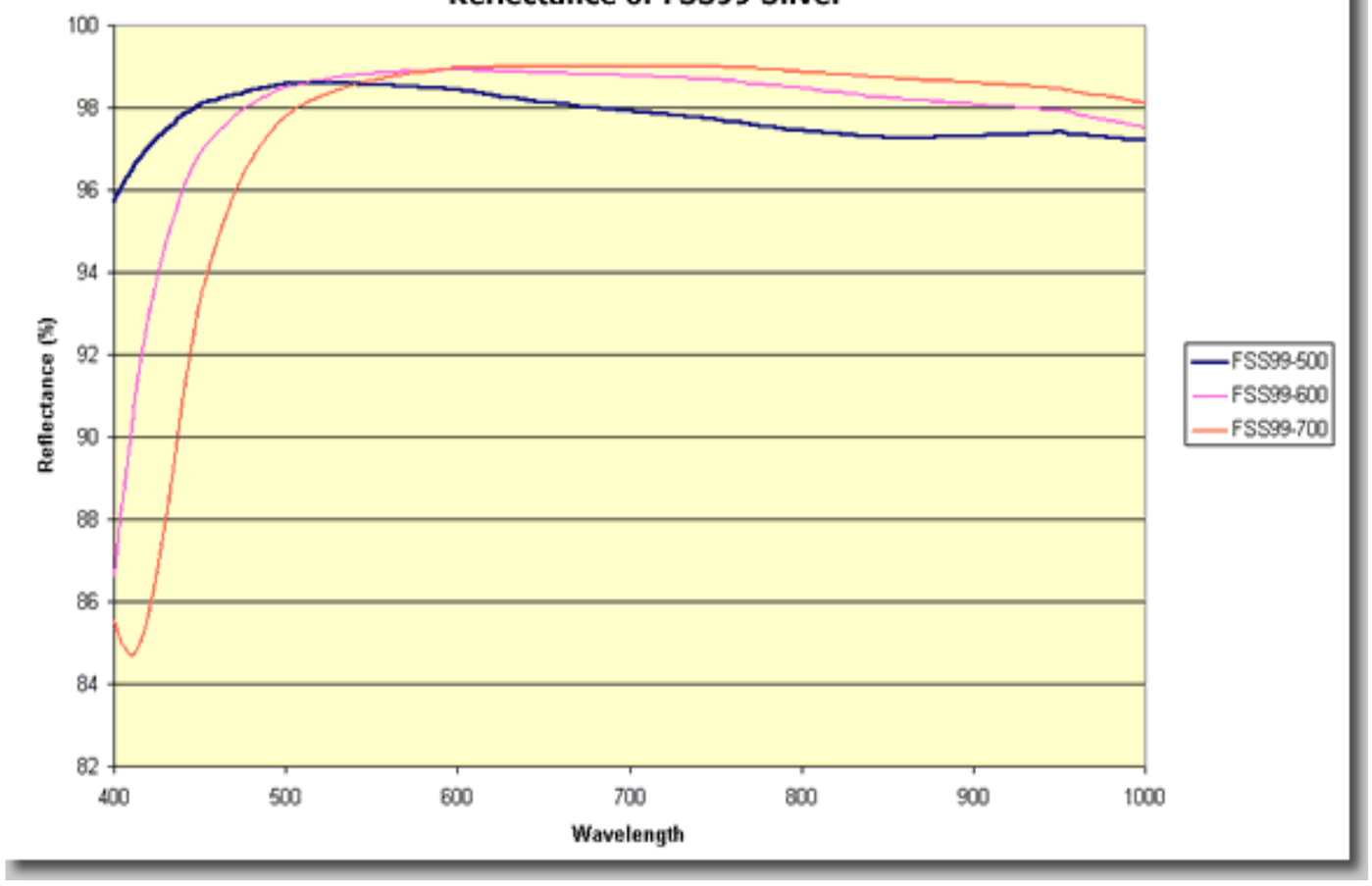
Advertised reflectance >98% from .320 to 3.000 um!

Spectrum Thin Films UV Enhanced Silver



UV SILVER UVS-100

Quantum UV Enhanced Silver



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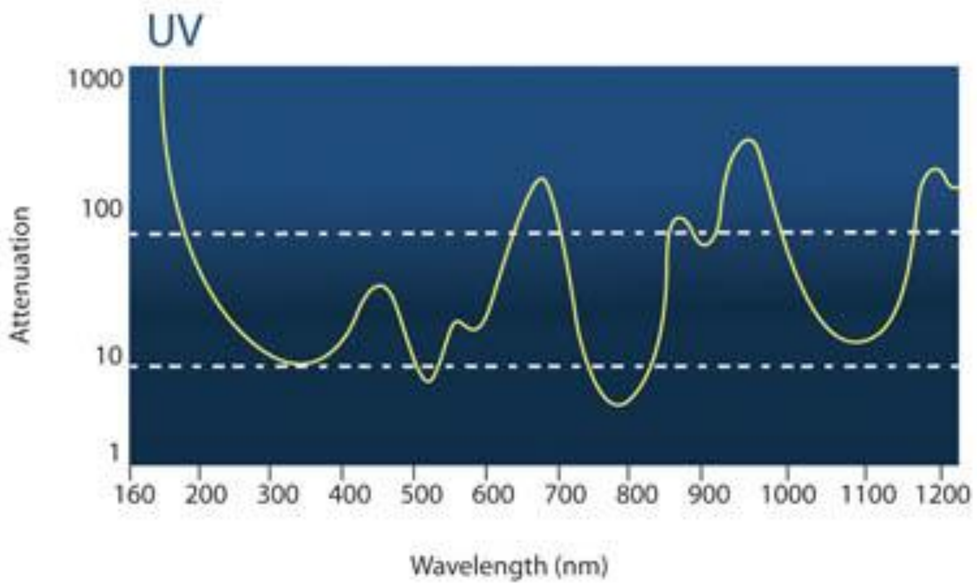
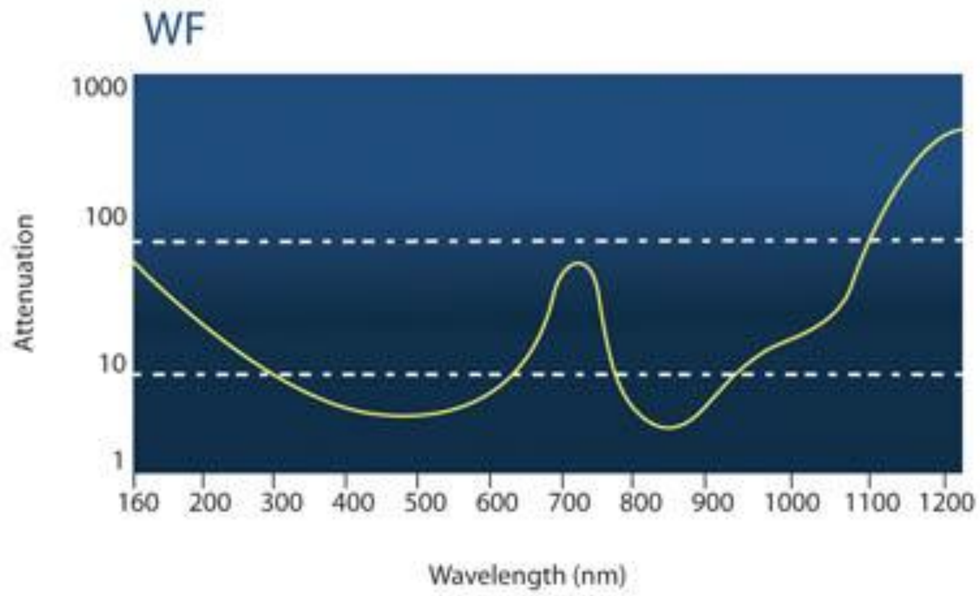
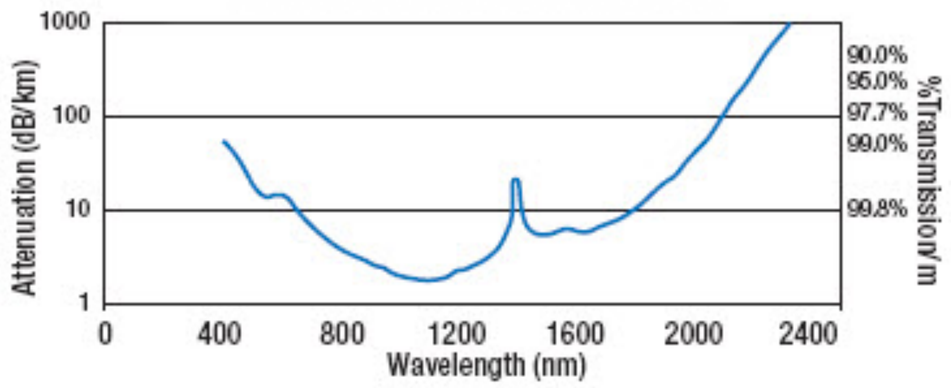
Fiber Optic Attenuation

Maximizing throughput may require using a blend of fused silica fibers (with varying OH content)





Low-OH Multimode Fiber



***Attenuation based on 1 km fiber**

http://www.afwtechnologies.com.au/mm_core_patchcord.html
http://www.thorlabs.com/NewGroupPage9.cfm?ObjectGroup_ID=360

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Singlet Relay Aft-Optics Design

Spectral Broadening Due to Bandpass Filter

PERFORMANCE:			
Wavelength	**1000**		**nm**
Bandpass	**5**		**nm**
TELESCOPE FOCAL PLANE:	**WORST**	**BEST**	
-> Shift	0.39%	0.14%	%
-> Broadening	3.9	1.4	nm
-> FWHM	8.9	6.4	nm
FIBER OUTPUT:	**WORST**	**BEST**	
-> Shift	0.55%	0.21%	%
-> Broadening	5.5	2.1	nm
-> FWHM	10.5	7.1	nm
WITH COLLIMATOR:	**WORST**	**BEST**	
-> Shift	0.02%	0.01%	%
-> Broadening	0.20	0.09	nm
-> FWHM	5.20	5.09	nm

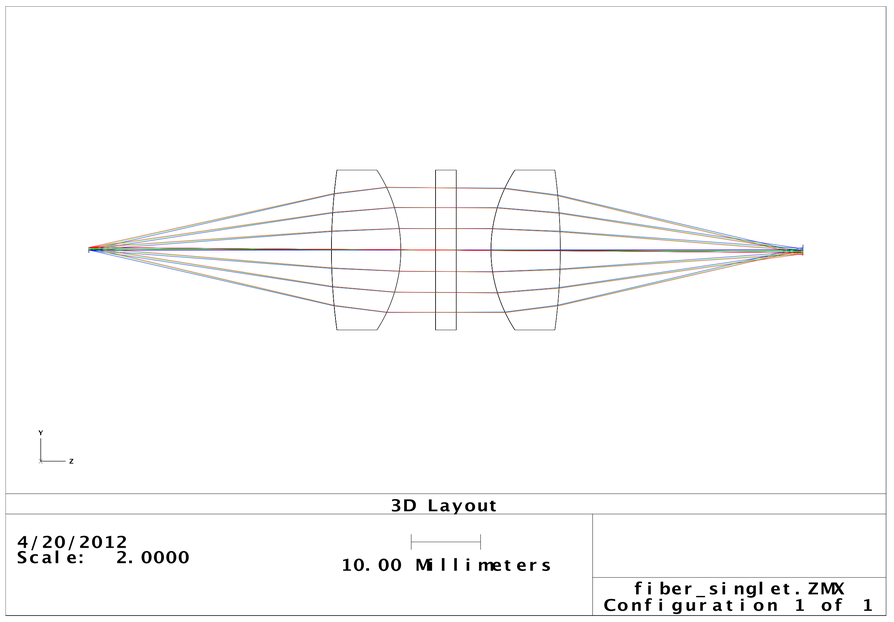
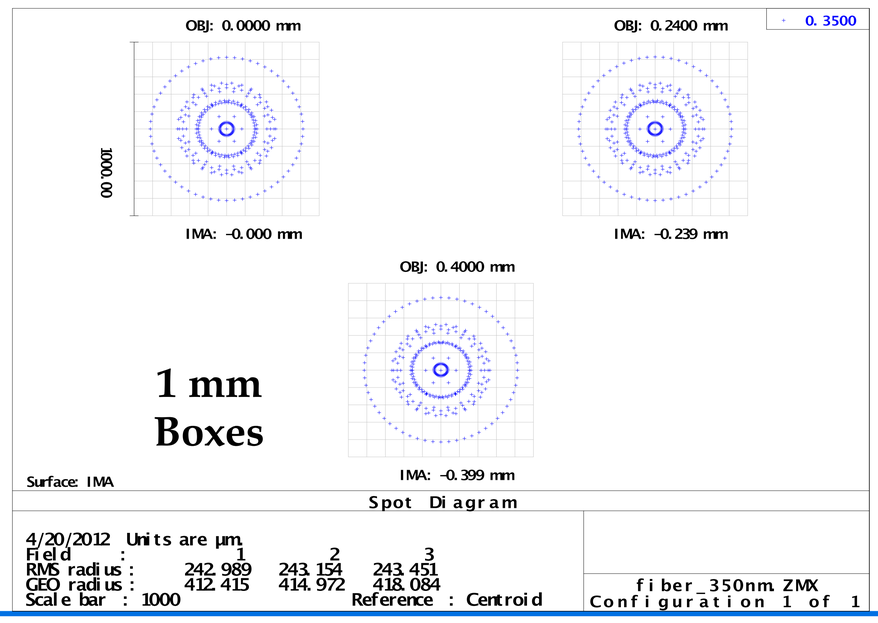


Image Quality at Detector



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Broadband AR coating (Moth-eye)

Integrated Design Capability / Instrument Design Laboratory

www.telaztec.com/

NASA SBIR/STTR Technologies
S2.04-9466 - Enhanced ORCA and CLARREO Depolarizers Using AR Microstructures

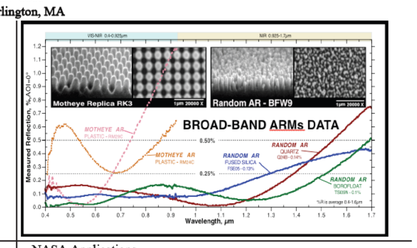
PI: Douglas Hobbs
TelAztec - Burlington, MA

Identification and Significance of Innovation

The hyper-spectral imagers ORCA and CLARREO require scene depolarizers with ultra-low levels of stray light noise over a wide optical bandwidth. Conventional internal reflection suppression technology based on thin-film material coatings cannot satisfy the 0.1% back reflection loss mission requirement.

An antireflection (AR) treatment based on surface relief micro-structures (ARMs) can meet the glare suppression specifications.

In addition to high performance AR over wide bandwidths and fields of regard, a novel alternative ARMs configuration is proposed that has the potential to produce a strong depolarizing function and can be applied to multiple optical elements within the spectrometer system.



Estimated TRL at beginning and end of contract: (Begin: 4 End: 5)

Technical Objectives and Work Plan

OBJECTIVES
Refine and Optimize the ARMs fabrication process to produce uniform, high performance, full-scale MgF2 and quartz depolarizers.
Demonstrate a mission specific ultra-low reflection loss depolarizing optic operating over the wavelength range of from 320 to 2000nm.
Demonstrate a lower bulk and weight alternative depolarizer design based on surface relief microstructures.
Establish a commercialization path for ARMs in catalog depolarizers.

WORK PLAN
Scale up fabrication of ARMs in MgF2 and quartz depolarizers.
Conduct Theoretical Modeling for microstructure depolarizers.
Measure the scattered light level produced by ARMs - NIST.
Deliver 10 full-scale ARMs treated depolarizers.
Conduct space qualification testing - radiation, temperature, vibration.

NASA Applications

ORCA - Carbon Radiometer
CLARREO – Imaging Spectrometers (IR, Hyperspectral)
LIDAR (ACE, Calipso), LADAR (HgCdTe arrays- ALHAT)
ACCLAIM (Hyper-spectral imaging), GLORY (solar irradiance measurement), GEO-CAPE (spectrometer); ASCENDS

Non-NASA Applications

Depolarizing Optics: telecom architectures, optical source polarization randomization, Raman amplifier and EDFA pump laser, fiber optic gyroscopes, satellite communications ARMs Treatment for imaging sensors, display films, optics, filters, and windows, PV energy conversion, and sold state lighting (OLED)

Firm Contacts Douglas Hobbs
TelAztec
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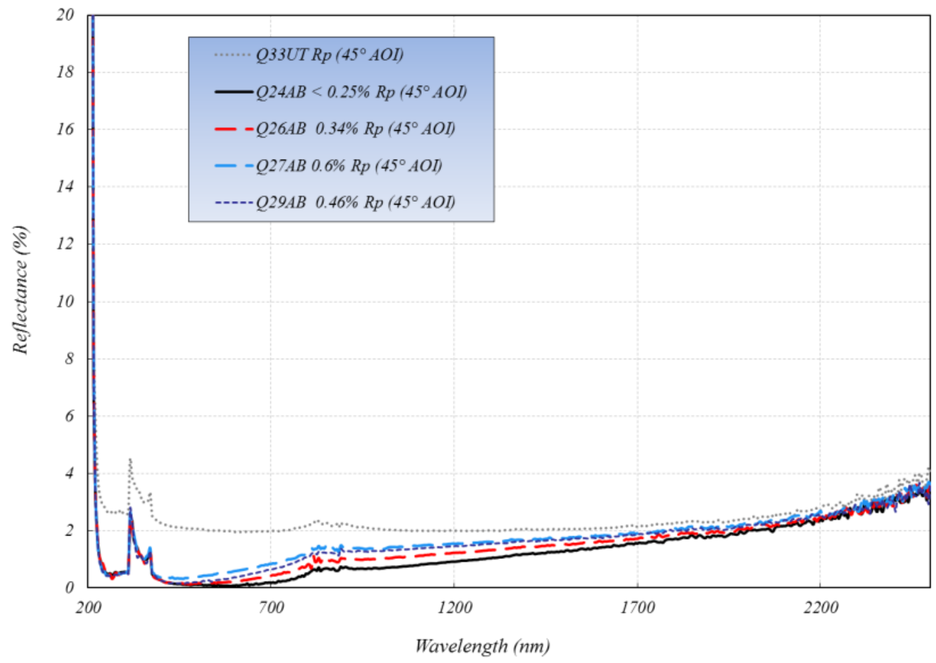
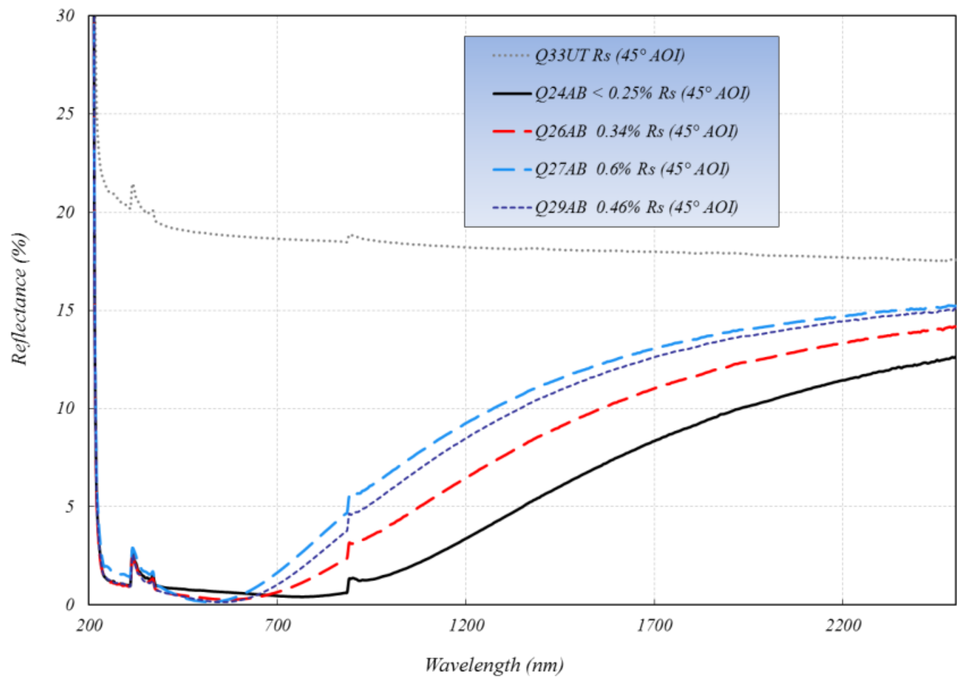
Burlington, MA, 01803-3404
PHONE: (781) 229-9905
FAX: (781) 229-2195

NON-PROPRIETARY DATA

Reflectance Data Provided by the NASA Goddard Optics Branch





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Mass Estimate

Component Name	SubSystem	Engineer	Flight Quantity	**Unit Mass CBE kg**	**Unit Assembly Mass kg**
Telescope Options					
Depolarizer		P Hill			
Wedges		P Hill	4	**0.712**	**2.846**
Schmidt Plate		P Hill	1	**1.423**	**1.423**
Primary Mirror		P Hill	1	**1.688**	**1.688**
Fold Mirror		P Hill	1	**0.290**	**0.290**
HAM Mirror		P Hill	1	**0.031**	**0.031**
Summed Mass					**6.278**
Fiber Bundle					
Fibers		P Hill	144	**0.001**	**0.145**
Summed Mass					**0.145**
Spectrometer					
L1		P Hill	144	**0.009**	**1.233**
Bandpass Filter		P Hill	144	**0.003**	**0.467**
L2		P Hill	144	**0.009**	**1.233**
Summed Mass					**2.932**

Total	**9.354**

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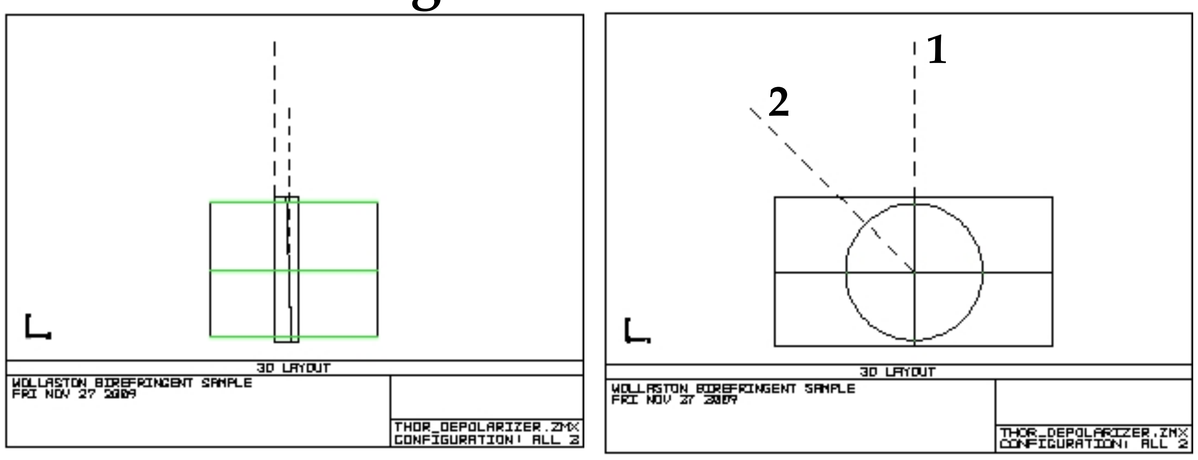
Depolarizer Trade Study

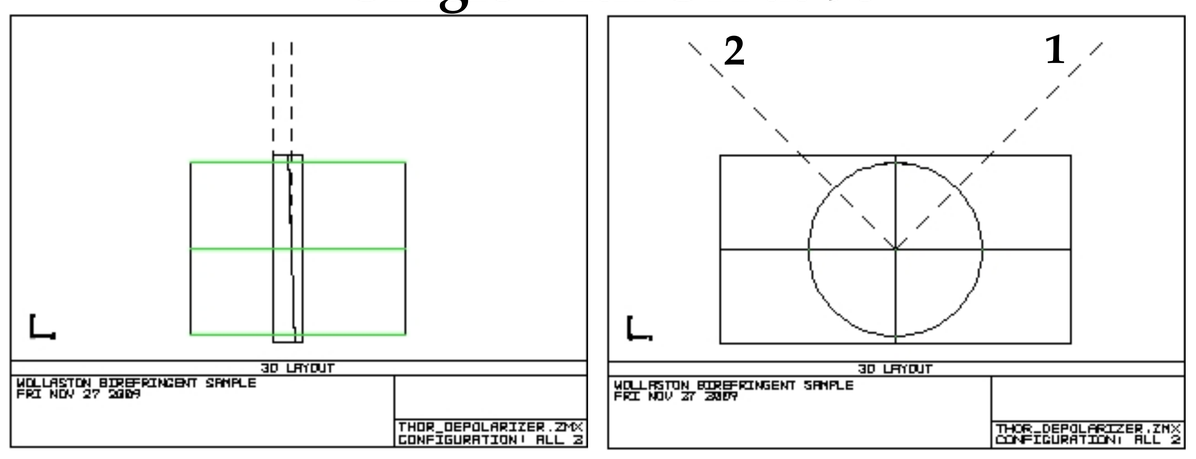
Material: Quartz-Quartz **Thickness ratio: 2:1** **Wedge Angle: 2.0⁰**

Sea-WIFS Scrambler

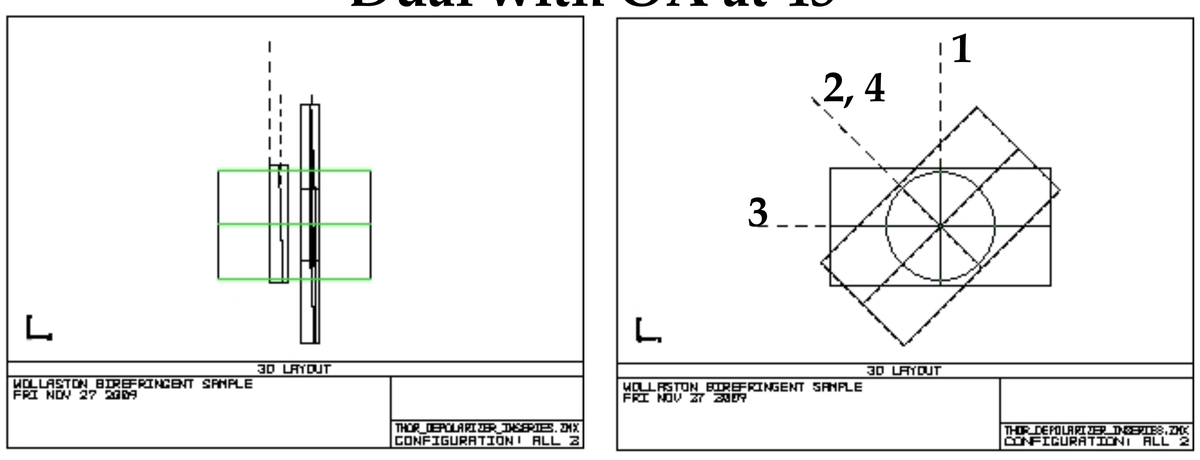
Single with OA at 45⁰



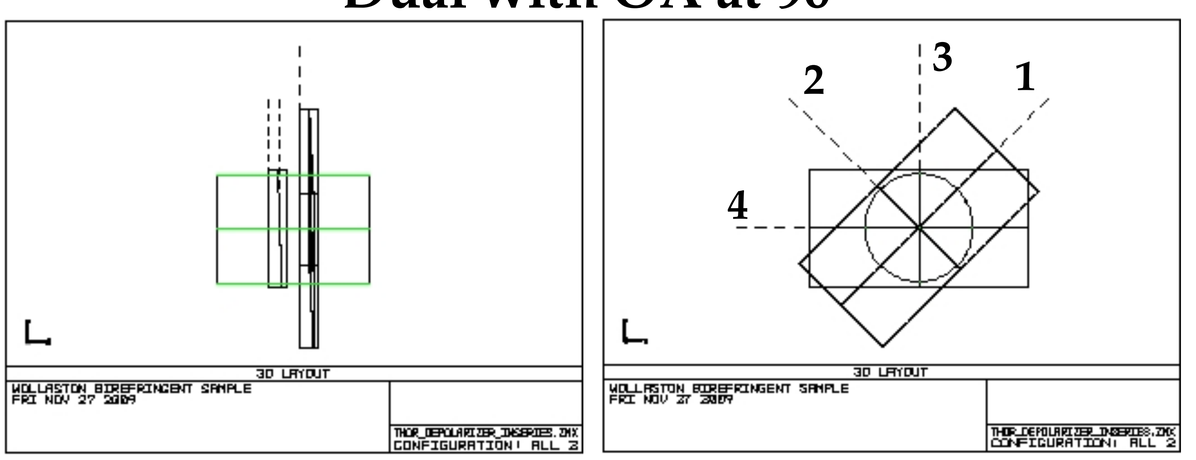
Single with OA at 90⁰



Dual with OA at 45⁰



Dual with OA at 90⁰



Wedge angles clocked at 45⁰

Wedge angles clocked at 45⁰

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Depolarizer Trade Study

Material : Quartz-Quartz
Thick. Ratio : 2:1
Wedge Ang. : 2.0°
Pupil Diam. : 42.3 mm
Pupil Samp. : 51 x 51

PSF Degree of Linear Polarization:

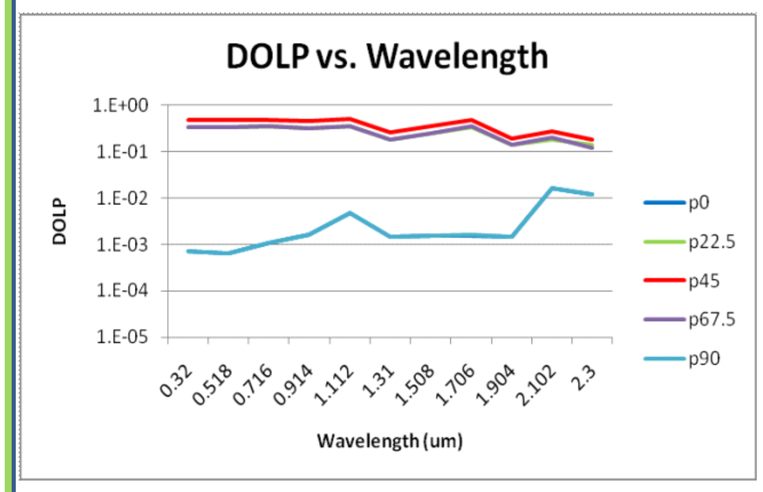
$$DOLP_{PSF} \equiv \frac{\sqrt{(\Sigma S_{1i})^2 + (\Sigma S_{2i})^2}}{\Sigma S_{0i}}$$

$$\vec{S} \equiv \begin{bmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{bmatrix} \equiv \begin{bmatrix} (P_0 + P_{90}) \\ (P_0 - P_{90}) \\ (P_{45} - P_{135}) \\ (P_R - P_L) \end{bmatrix}$$

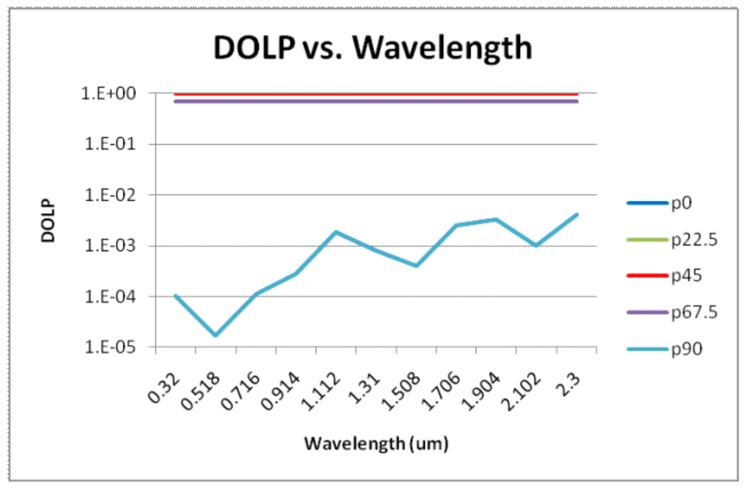
Note : Circular polarization (S3) is ignored due to the usual assumption that the scene exhibits *negligible* circular polarizance *and* the instrument induces negligible circular dichroism.

Sea-WIFS Scrambler

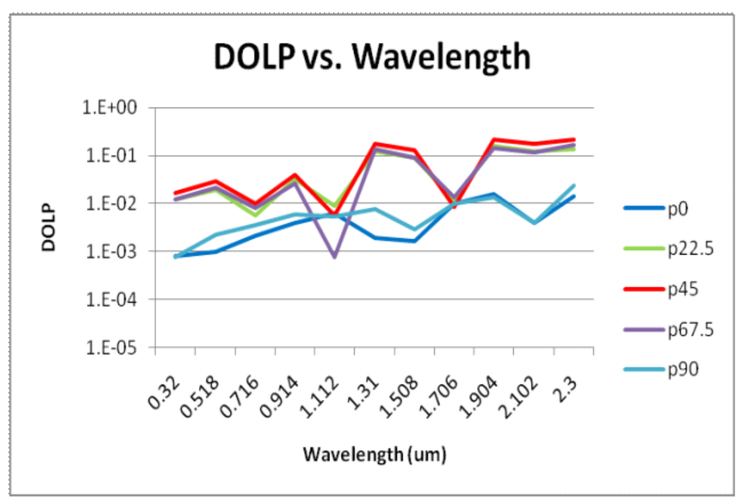
Single with OA at 45°



Single with OA at 90°

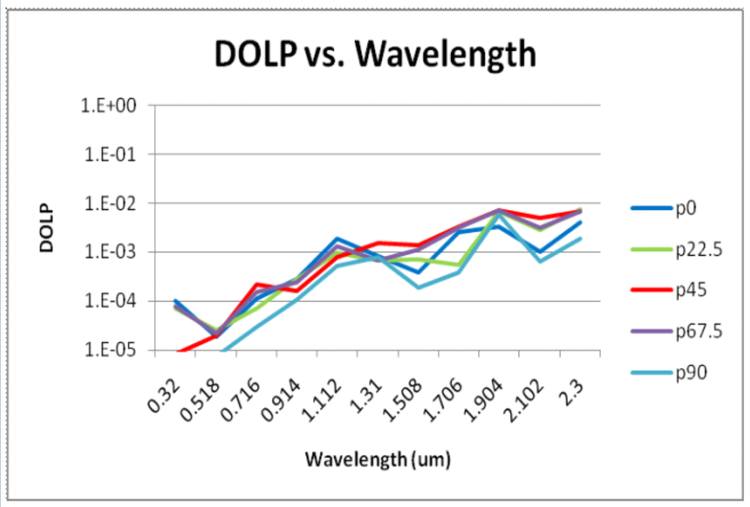


Dual with OA at 45°



Wedge angles clocked at 45°

Dual with OA at 90°



Wedge angles clocked at 45°

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Concerns

- Throughput uncertainties
  - Performance of the broadband AR coatings for the depolarizer, Schmidt Plate, and fiber optic bundle (Potential Solution -> Motheye coatings).

- Design requires unique alignment of each aft-optics subassembly to each fiber (Solution -> Doublet Design).

- Depolarizer performance may lead to either undesirable cross talk (multiple images / “blur”) or instrument polarizance (trade off).

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Next Steps

- Re-optimize fore-optics (telescope) to accommodate change in altitude (650km -> 700km).
- Evaluate attenuation of fibers for each wavelength bands.
- Evaluate cost vs. assembly trade between singlet and doublet aft-optic design.
- Optimize depolarizer geometry to minimize both cross talk and instrument polarizance.
- Evaluate the possibility of using a two mirror off-axis design + HAM (may offer packaging advantage for the HAM mechanism).

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