PerkinElmer Lambda 950 measurements in support of NASA's Hubble Space Telescope

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Outline

- Details of PerkinElmer Lambda 950 at NASA-GSFC
  (Layout, sources, detectors, accessories, capabilities)
- Hubble Space Telescope's Wide Field Planetary Camera 2
- JDEM Prototype Filters Report

SPECTRAL MEASUREMENTS AT GSFC

Spectrophotometer: A Perkin-Elmer Lambda 950 double-beam, ratio recording.

a) Spectral range and resolution: 200-2000 nm (1nm band-pass)
b) Photometric accuracy: 7 Absorbance units
c) Sample beam size: Sample sits at a focused (f/# ~ 7.8) beam with rectangular shape (1mmx7mm)
d) Transmittance is done on five locations: four corners and center of sample.
e) Sample temperature and relative humidity during testing: 25 °C and 50% respectively.

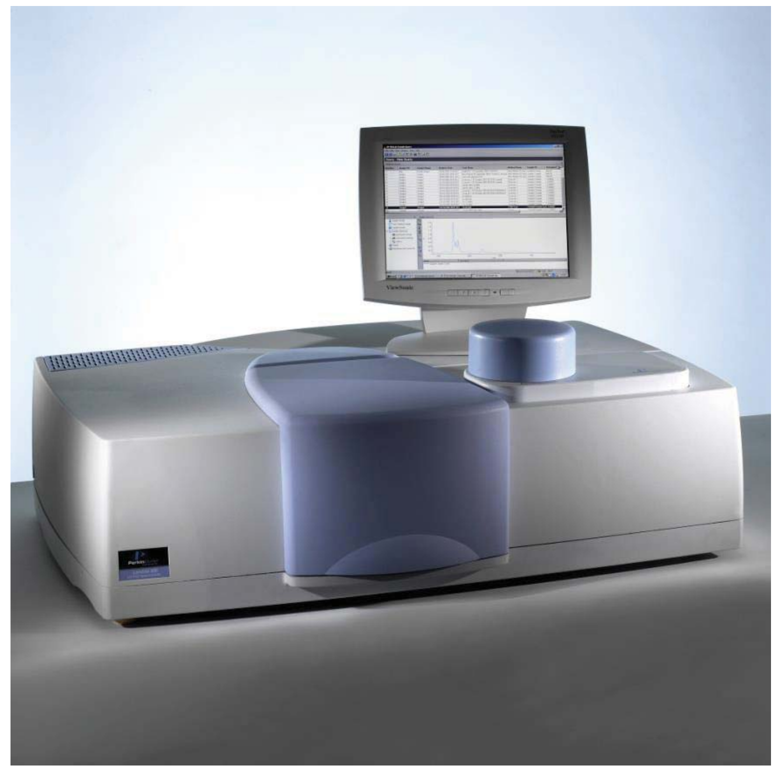


Figure 4. Astronauts removing WFPC2

WFPC2 History

- Built at JPL as backup of WF/PC-1
- Replaced WF/PC-1 during HST first servicing mission December 1993
- Contains 4 cameras for imaging: WF2, WF3, WF4, PC
- Recorded 186,481 images
- In orbit through May 2009
- Greatly Reliable despite higher than expected amount of scattered light around bright objects & lower than expected UV efficiency

WFPC2 Imaging Parameters

- Wavelength Range: 115-1100 nm
- Silicon CCD detector
- Image format: 4x800x800 pixels
- Spatial Field of View: 150”x150” for 3 CCDs @ .1”/pix (“L” shaped FOV) and one 34”x34” @ .046”/pix

WFPC2 Optical Configuration

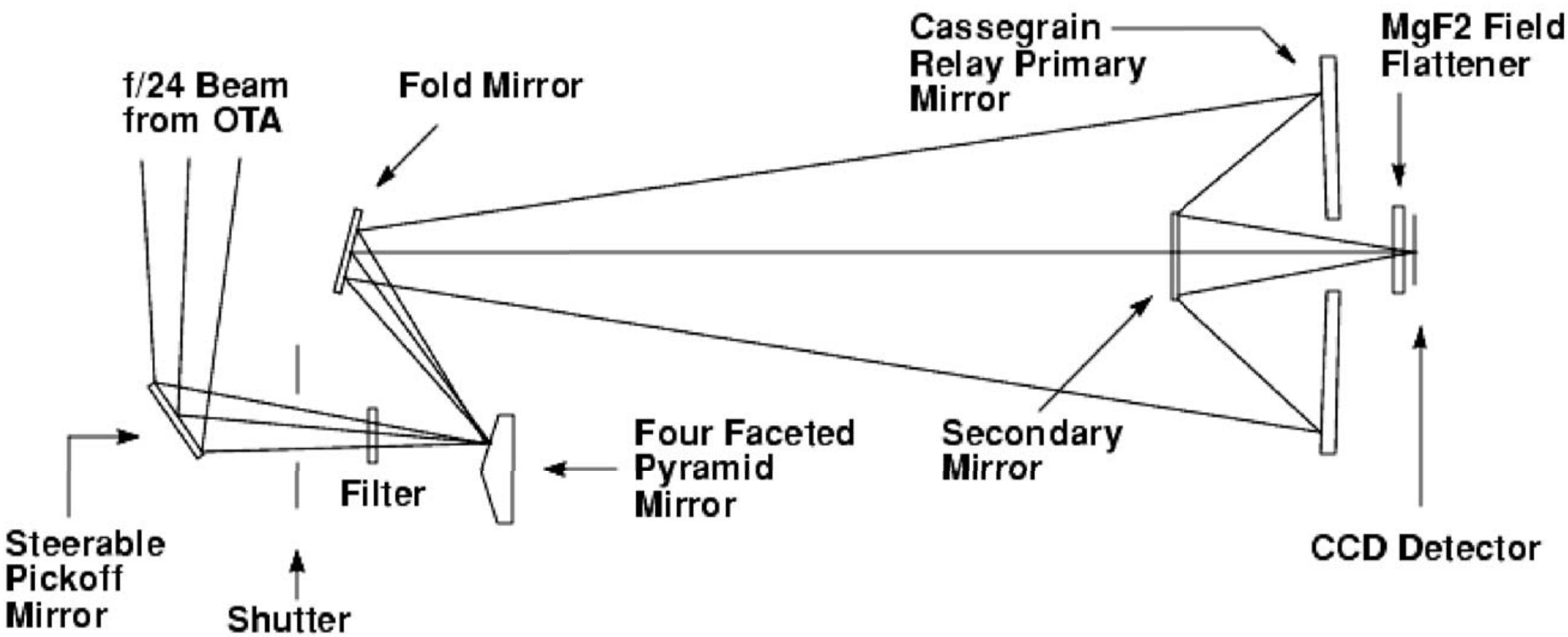


Figure 5. Optical Configuration of WFPC2

SOFA

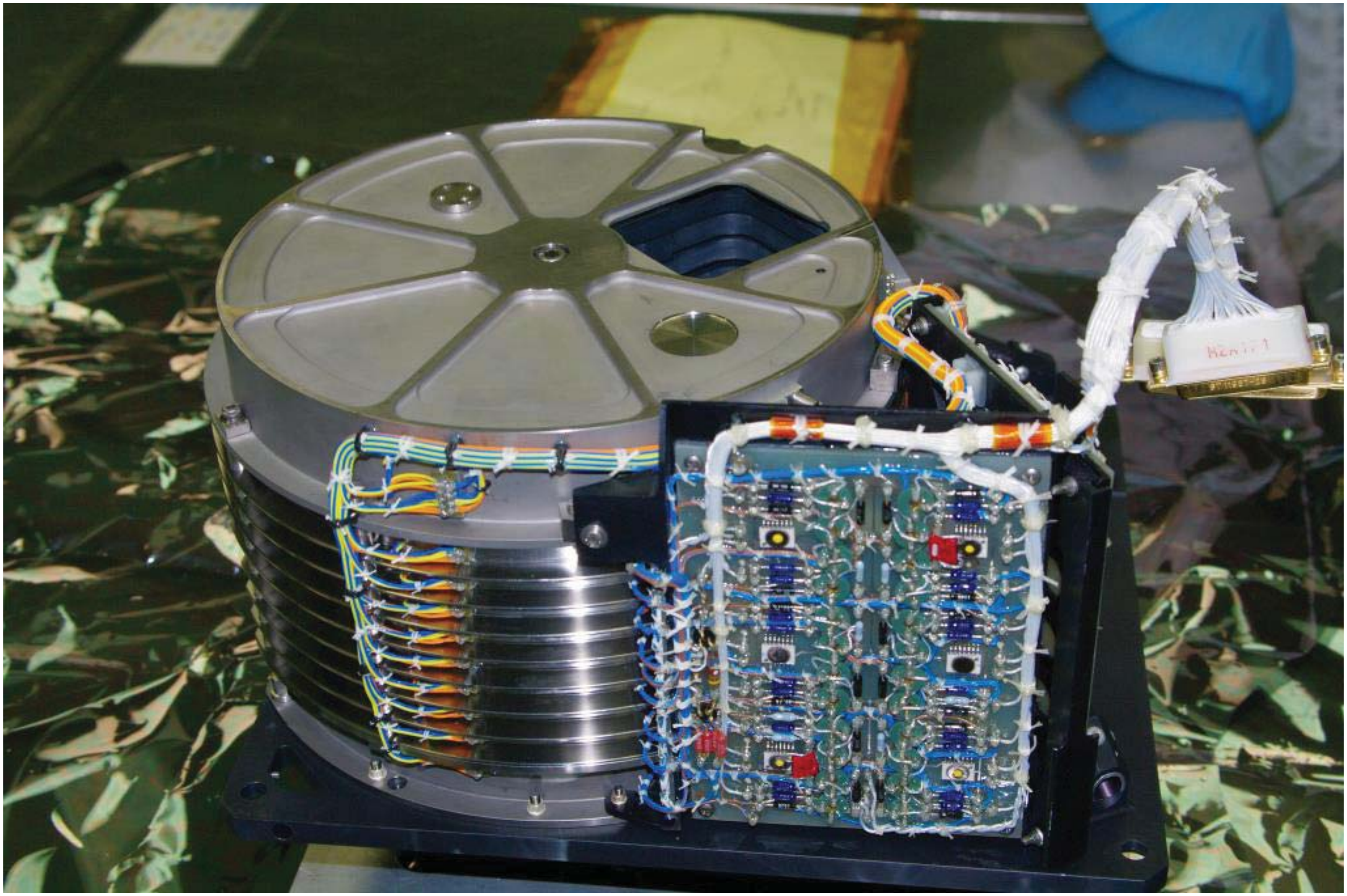


Figure 6. Selectable Optical Filter Assembly from WFPC2

Motivation

- Improve calibration of data from WFPC2
- Generate the data into a uniform quality (same parameters from early to late years)
- Examine the stability of the filters through time in orbit

Measured Filters

- Known change on orbit filters:
  - F122M, F160BW, F343N
- Highly used filters:
  - F300W, F450W, F555W, F606W, F675W, F702W, F814W, F850LP
- Regularly used filters:
  - F255W, F336W, F439W, F502N, F656N, F658N, F673N
- UV filters:
  - F160AW, F160BW, F170W, F185W, F218W
- Other measured or soon to be measured filters
  - F130LP, F165LP, F375N, F380W, F390N, F437N, F467M, F469N, F487N, F1042M, ramp filters

Methods

- Cosmetic inspections to determine which additional filters to measure (look for pinhole growth, contaminants, haze, etc)
- Measure filter transmission with spectrophotometer
  - Wavelength range: 190-2000nm, $\Delta\lambda$=1-5 nm
- Compare Pre-flight, In-Flight, & Post Flight data

Filter Wheel Provided

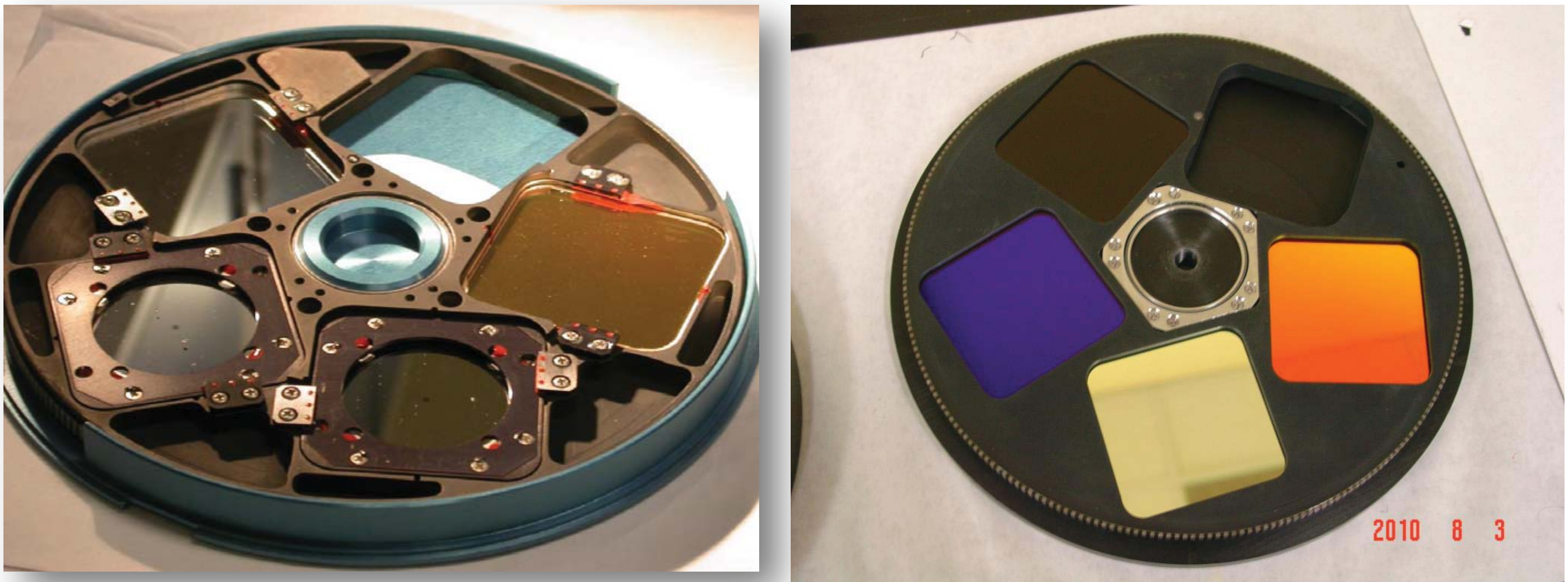
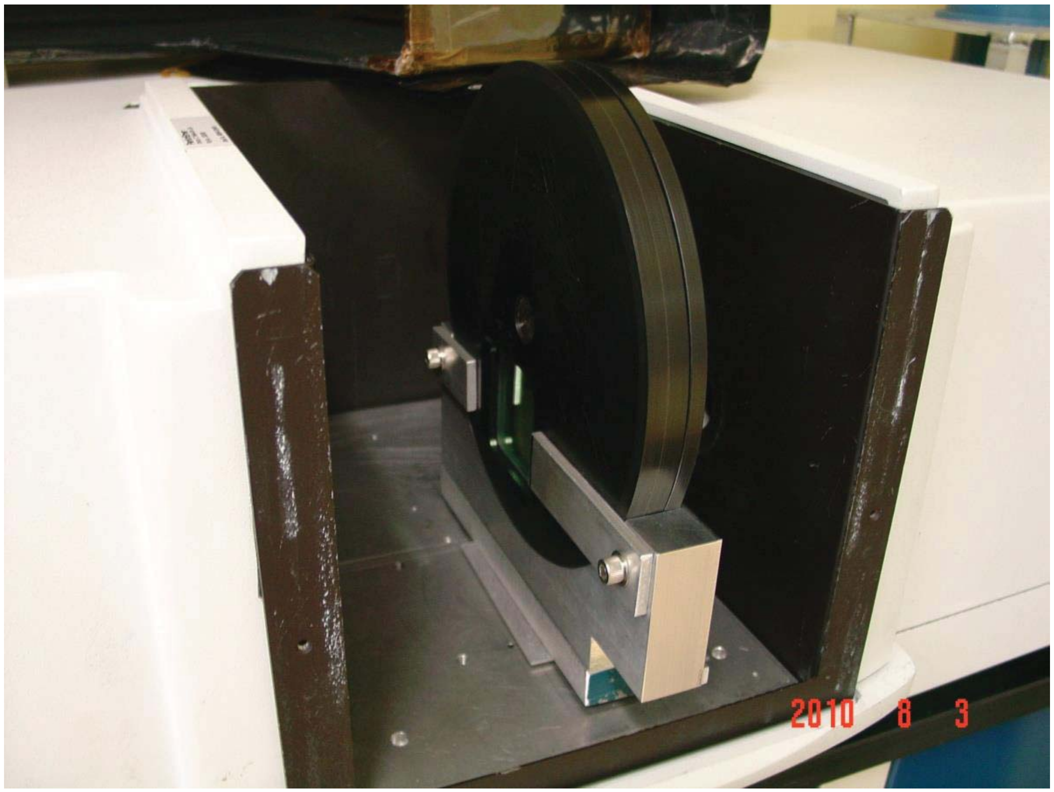


Figure 7. Filter wheel in provided housing (left) & filter wheel in housing with placer to prevent rotation when measuring(right).

Filter Wheel positioned into PE950



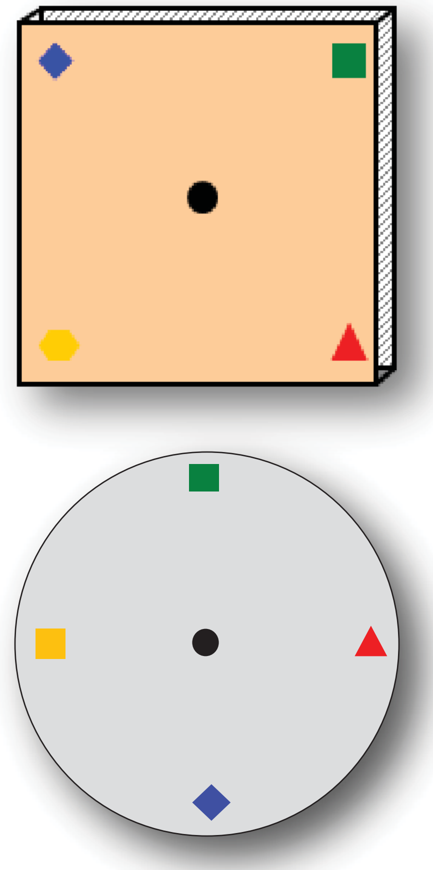


Figure 8. Filter placed into beam path (left) with respect to the five-point scan measured (right).

PE950 Setup

Figure 9. Black Cover used for more accurate calibration of instrument and to set baselines (normal cover would not allow all 5 point measurements to be covered)

Changes Previously Measured

- F122M
  * Up to 20-25% throughput drop (Biretta 2008)
- F160BW
  * Growth of pinhole (WFPC2 ISR 2009-01)
- F343N
  *50% throughput drop (WFPC2 ISR 2009-02)
- However, most filter changes are expected to vary by only a small percentage

Red-Leaks for UV Filters

- UV filters transmit red light due to insufficient blocking or pinhole change
- Red-leak was measured on orbit by crossing UV and red filters on standard stars
- F160BW known to have rapidly growing pinhole (WFPC2 ISR 2009-01)
- Proven using PE950 spectrometer in W090 lab

F160BW

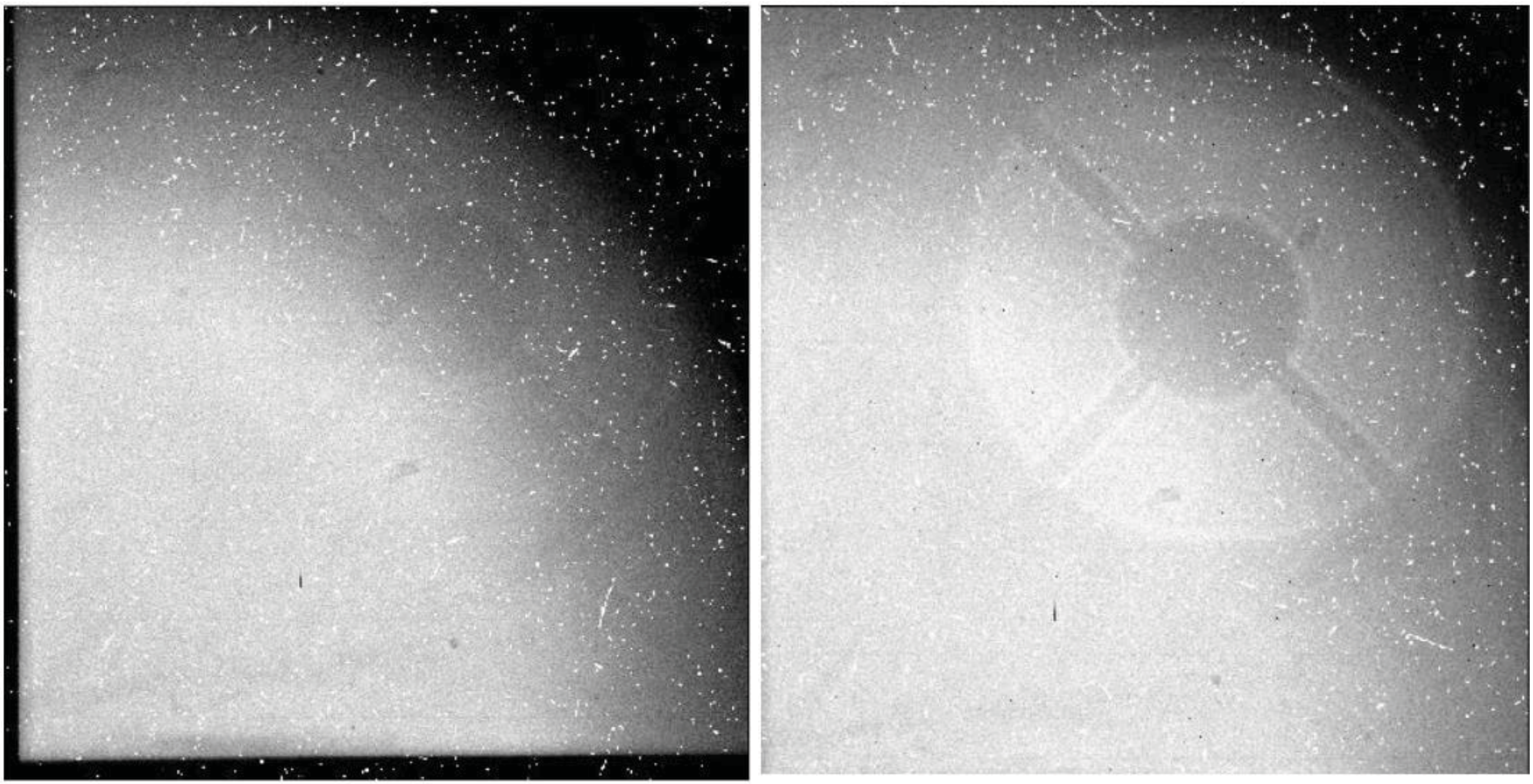
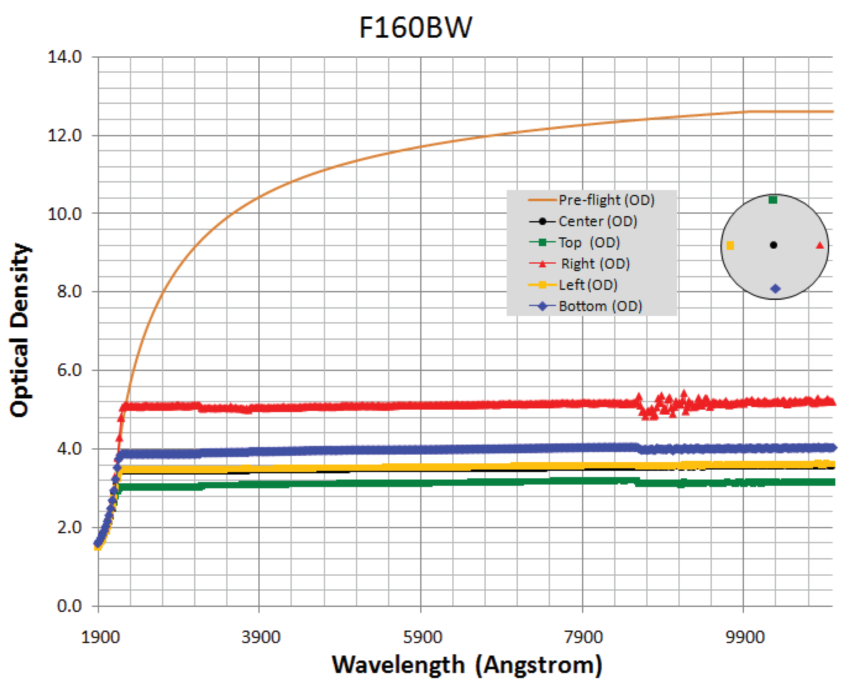


Figure 10. WF2 CCD UVFLAT illuminated with deuterium lamp within calibration module using F160BW 1994(left) 2008(right).

F160BW



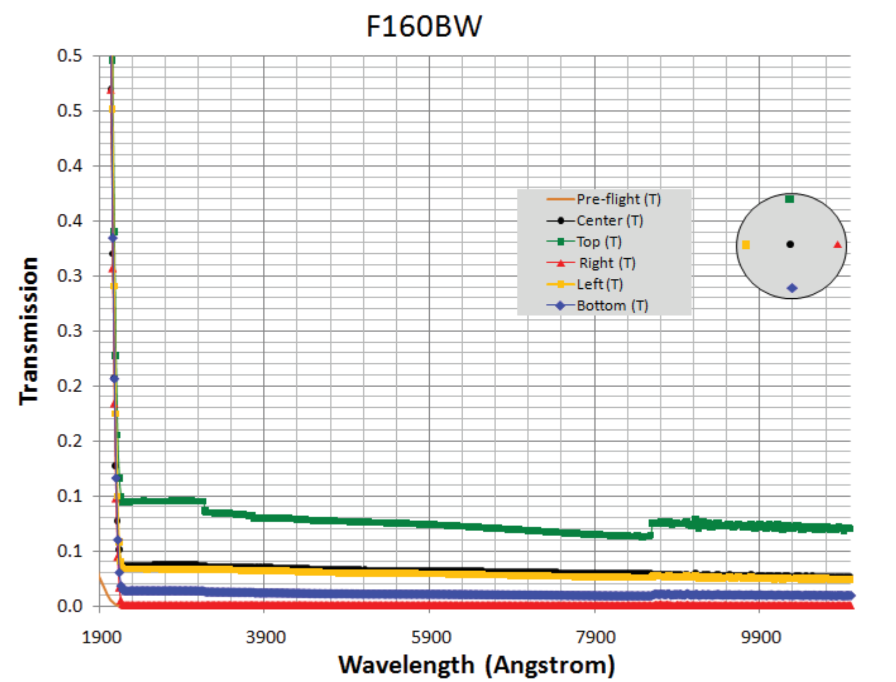
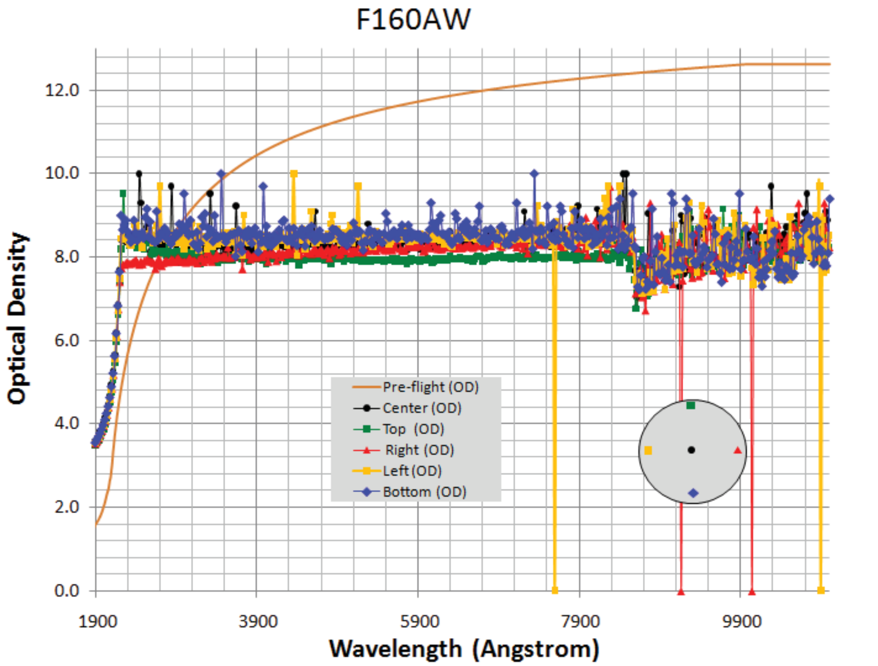


Figure 11. Optical Density and Transmission vs. Wavelength for F160 BW filter

F160AW vs. 160BW



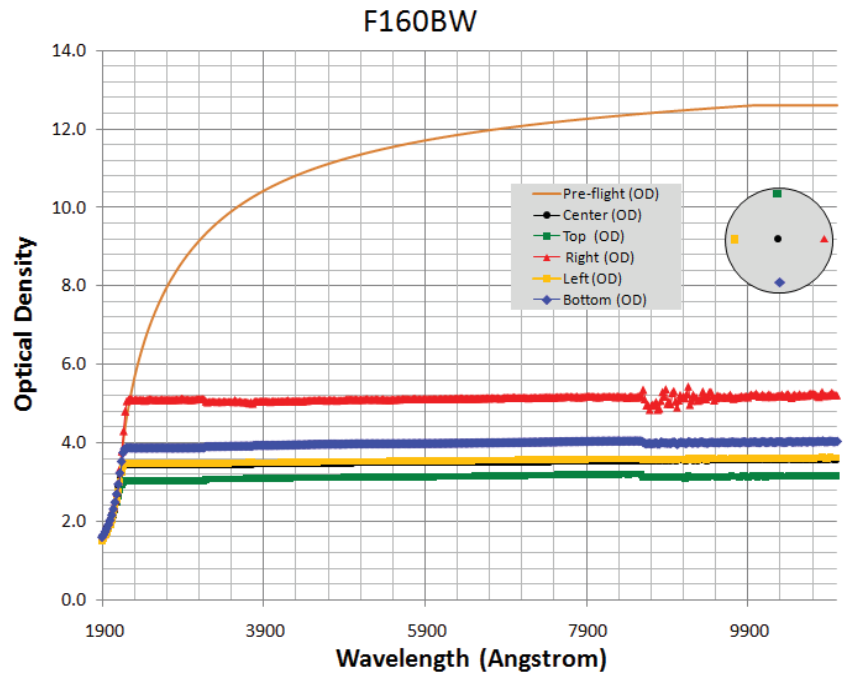
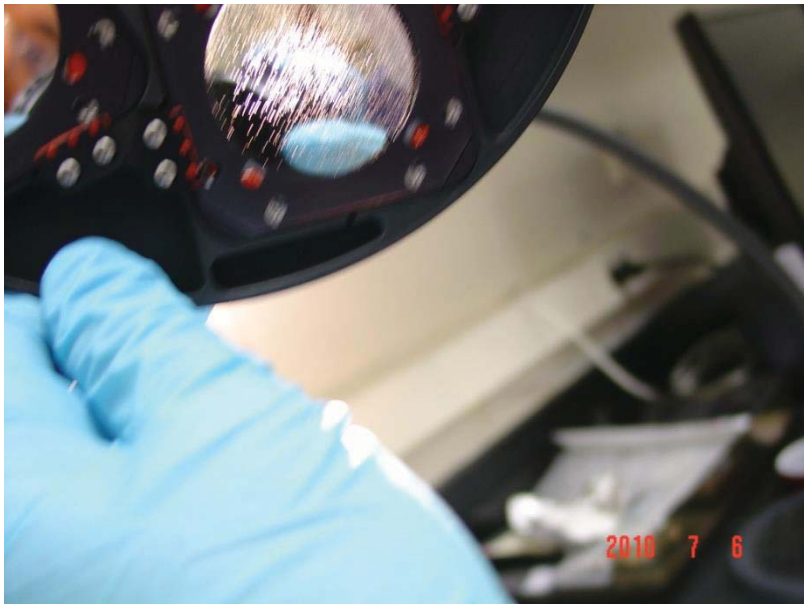


Figure 12. F160BW and F160 AW filters.

F160BW

- F160 AW was not used in flight due to pinholes
- F160BW now worse than F160AW
- No detectable red leaks of F160BW as of May 2009 (on-orbit)
- F160BW may have worsened during re-entry
- Pin-hole effects may be different in lab than In-flight (lab from pinholes more spread than F/24 OTA and be poorly imaged on CCD (not sharply imaged)

Figure 13. F160BW filter. The pinholes are clearly visible.



F343N

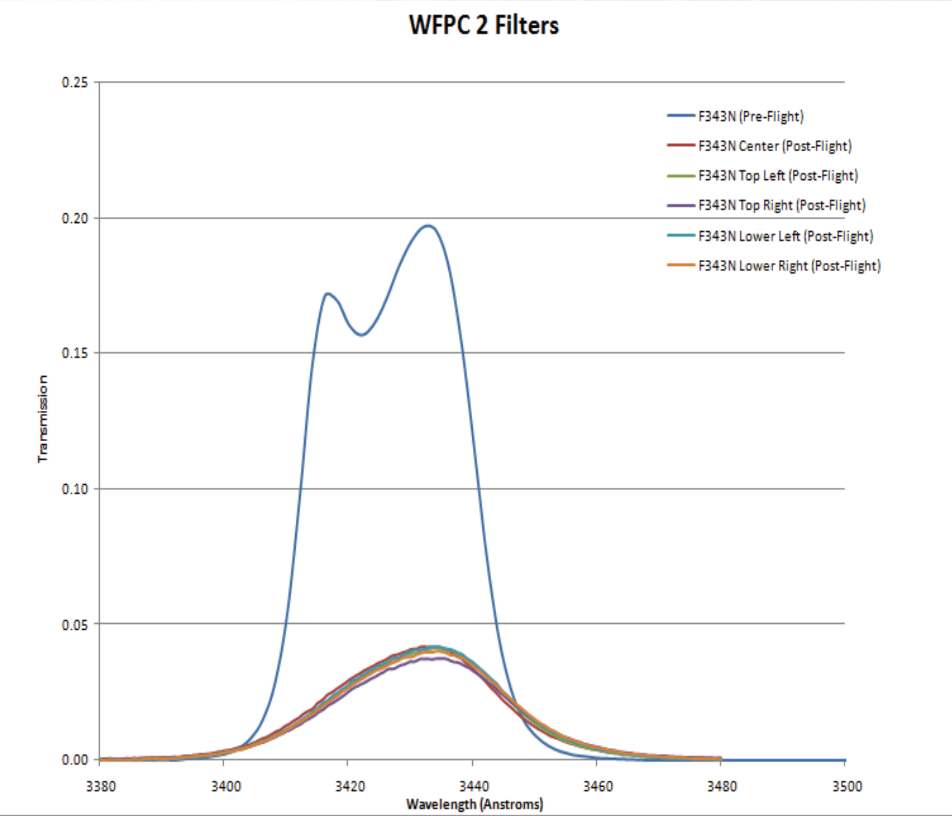
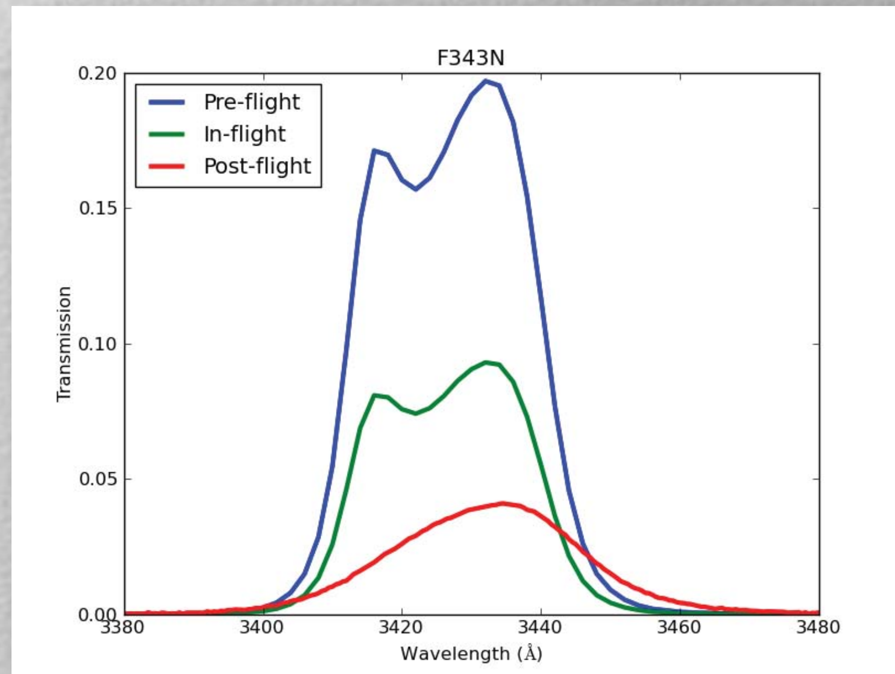


Figure 14. Transmission Curves for F343N pre & post flight.



- This confirm 50% transmission loss from Gonzaga & Biretta 2009
- Peak transmission wavelength shifted from 3432Å to ~3434Å and FWHM increased ~3Å

F343N

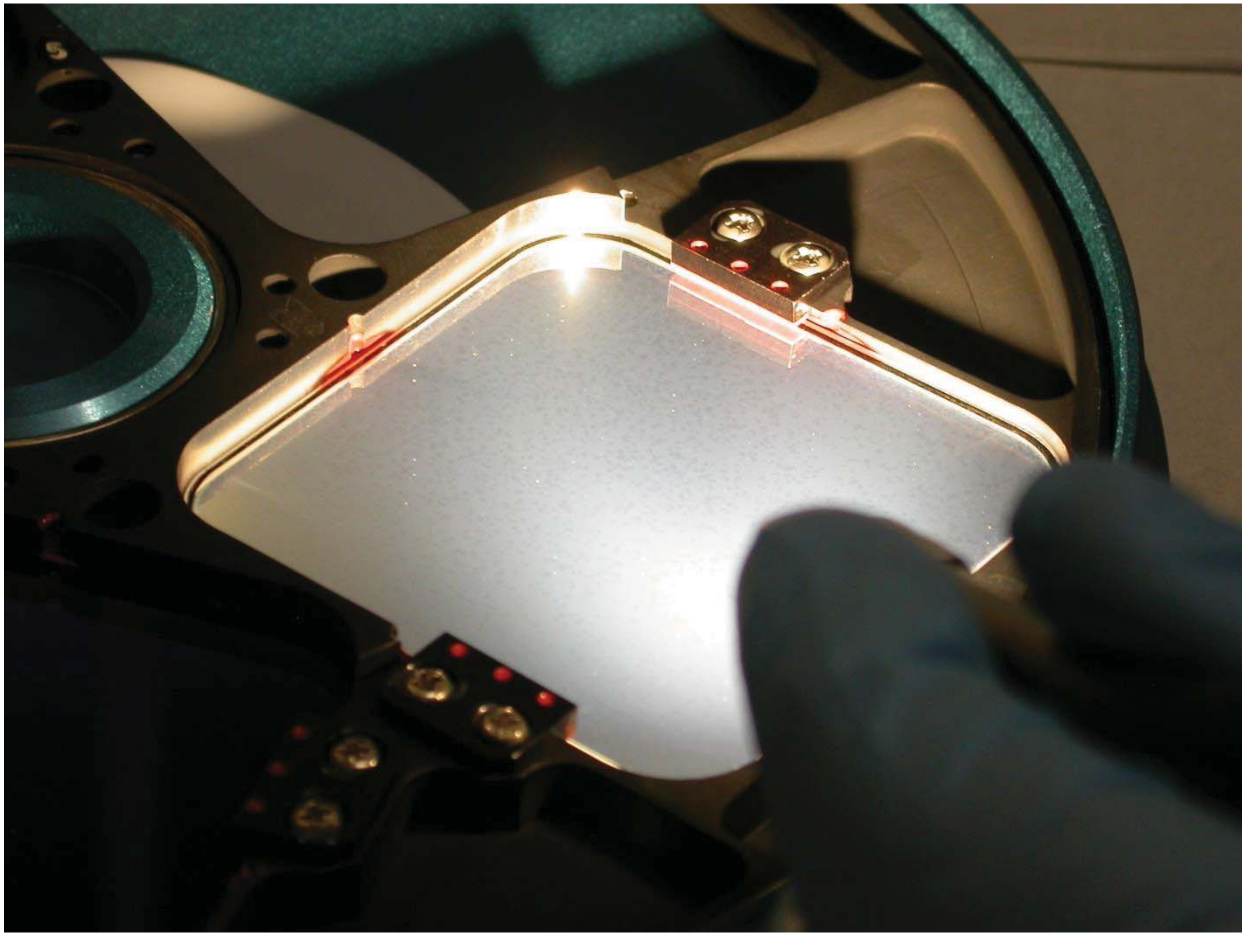


Figure 15. F343 Visual Inspection

F170W (UV)

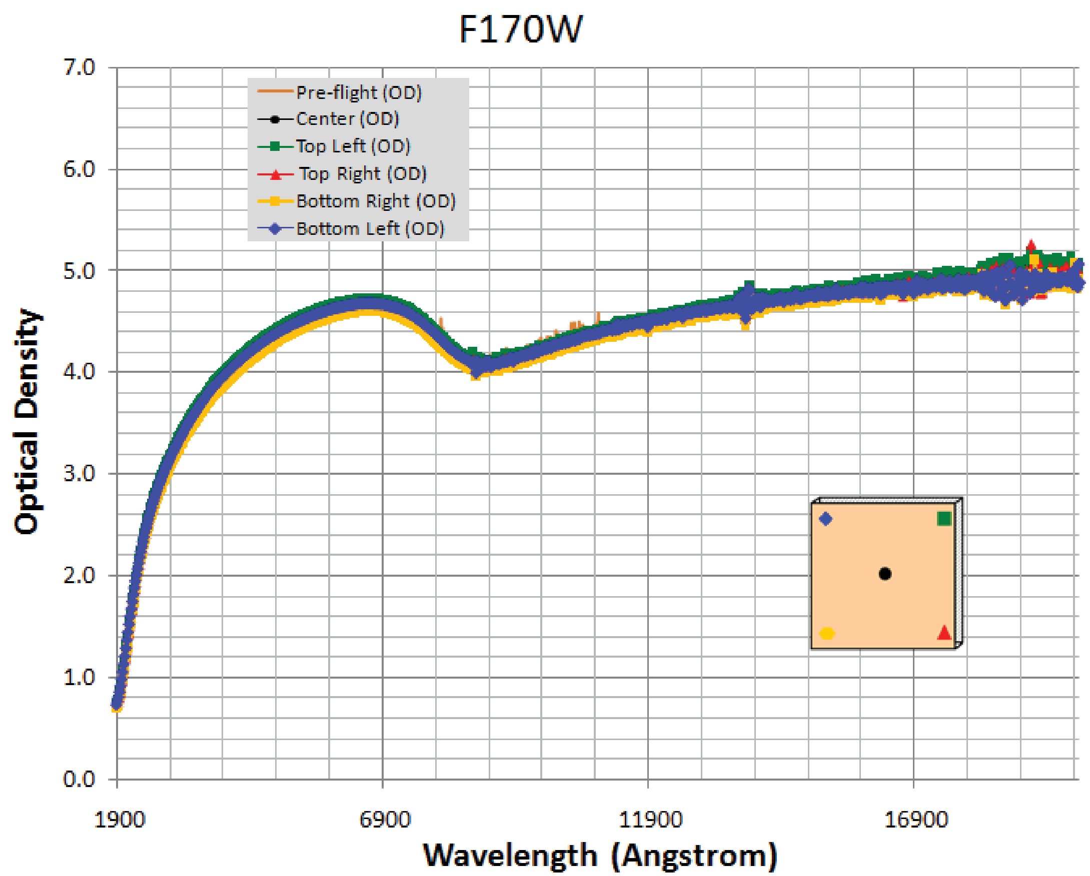


Figure 16. F170W Pre & Post Flight Optical Density vs. Wavelength. Filter remained consistent before & after orbit.

F122M

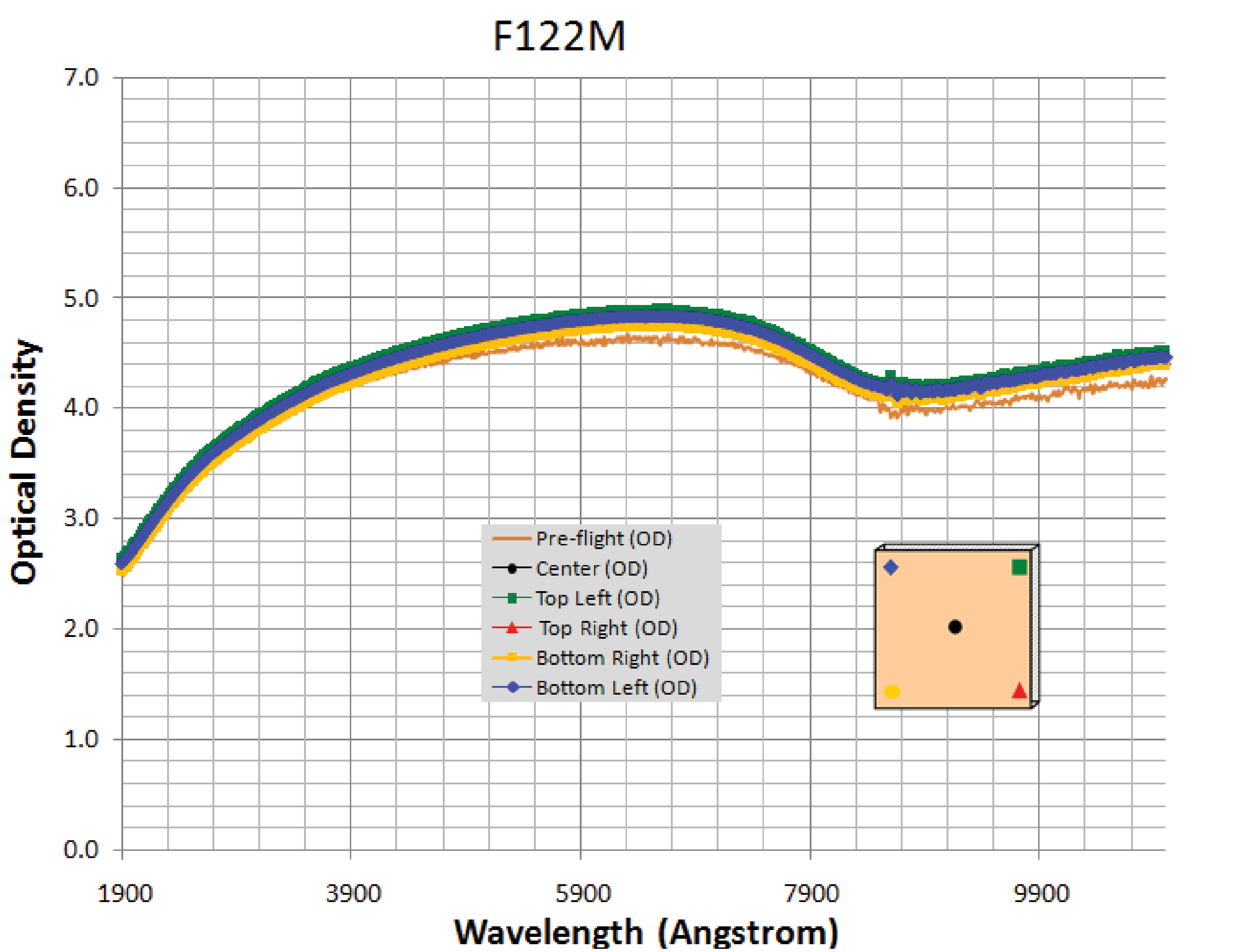
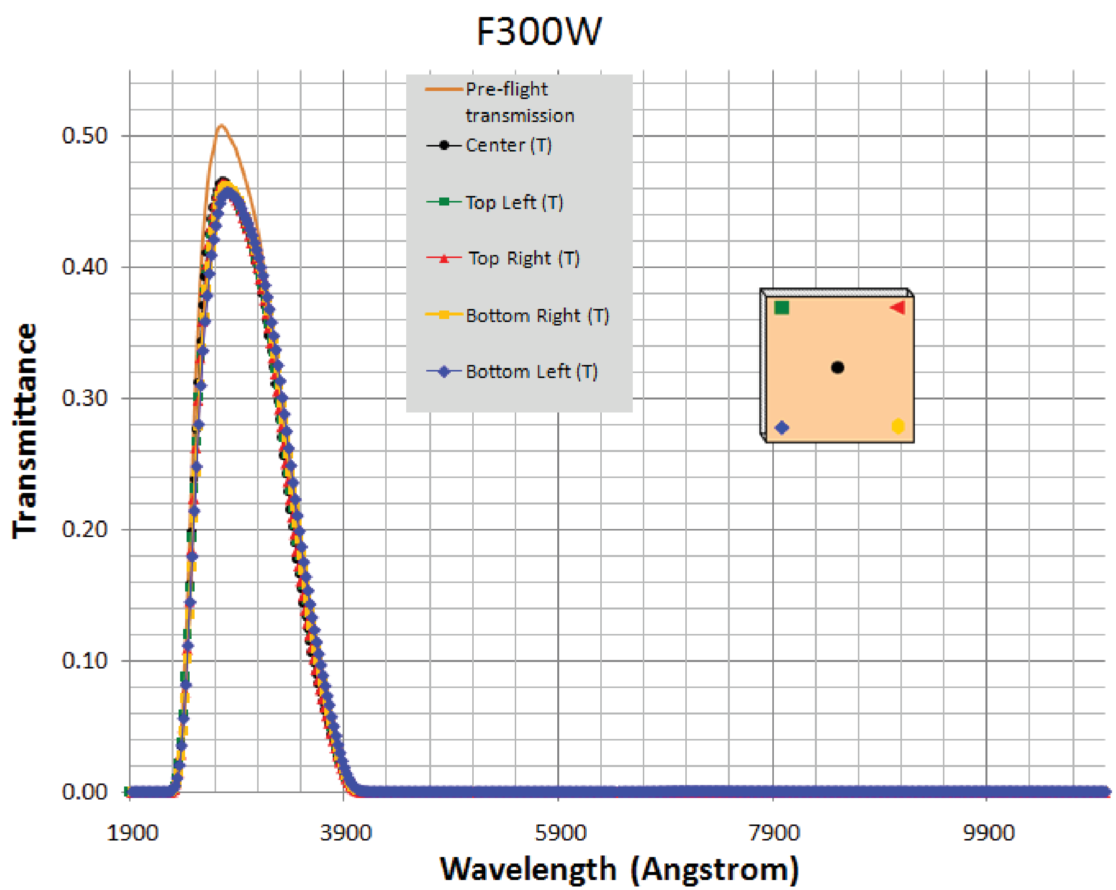


Figure 17. F122M Pre & Post Flight Optical Density vs. Wavelength. Filter remained consistent before & after Orbit.

F300W



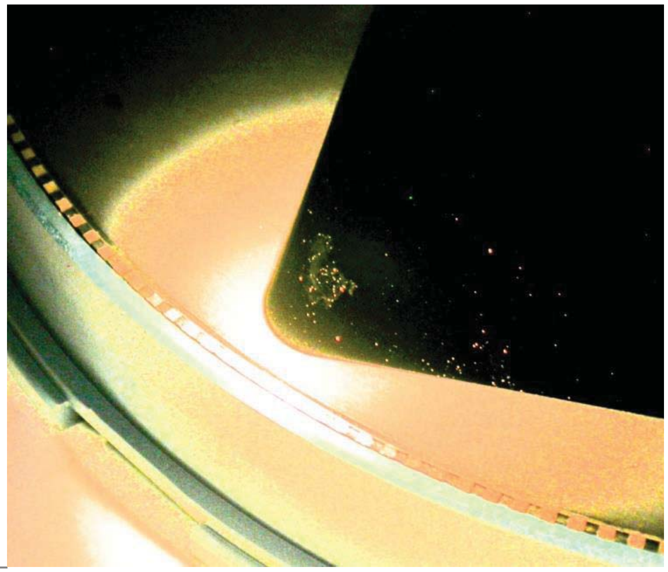


Figure 18. F300W Pre & Post Flight Transmission vs. Wavelength. About 4% Transmission drop from Pre-flight data. Also, visual inspection of filter (right).

F850LP

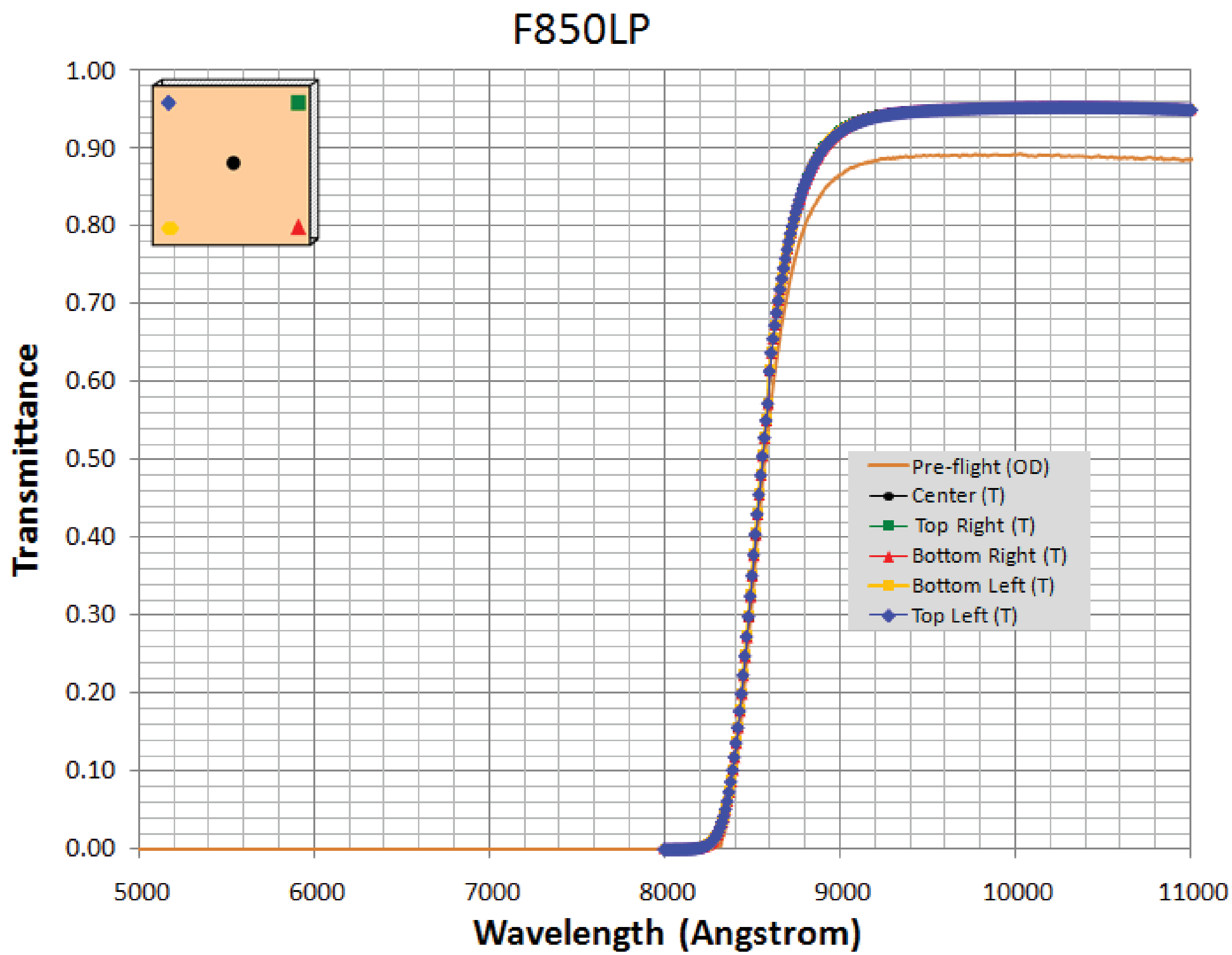
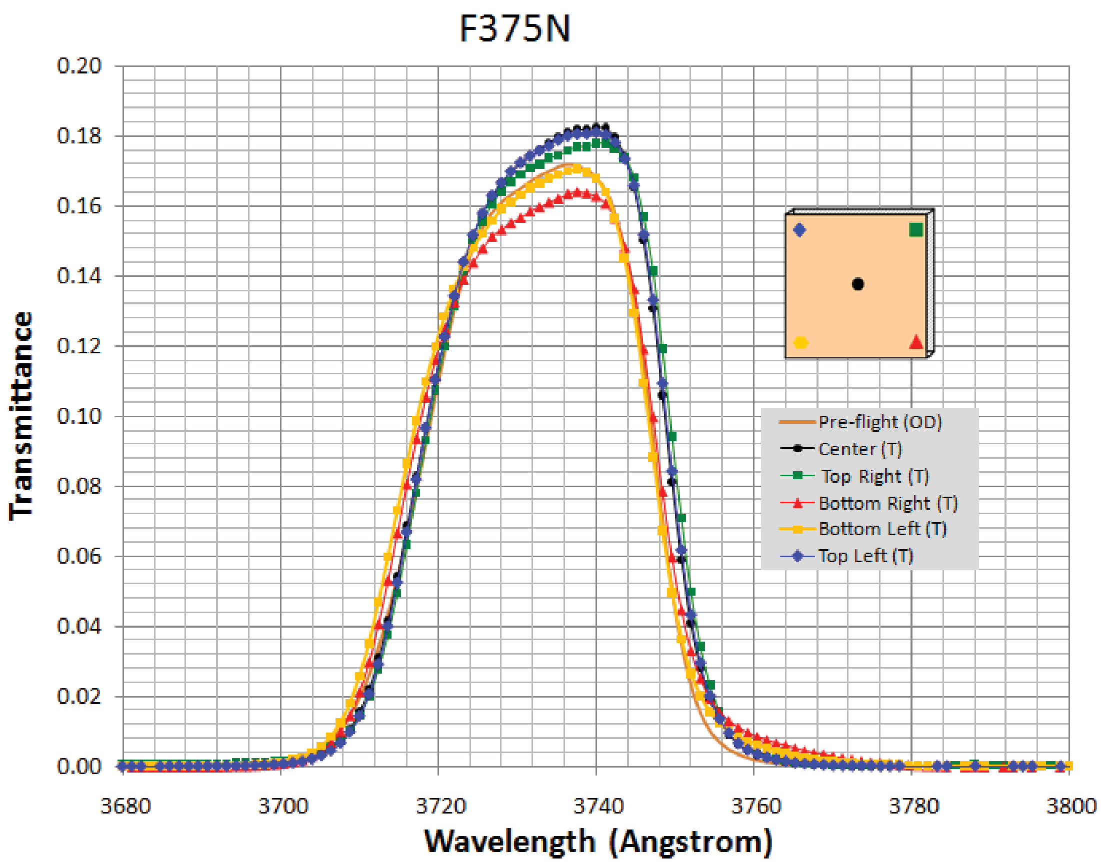


Figure 19. Pre & Post Flight Transmission of Filter F850LP. There is a ~5-6% transmission increase after orbit.

F375N



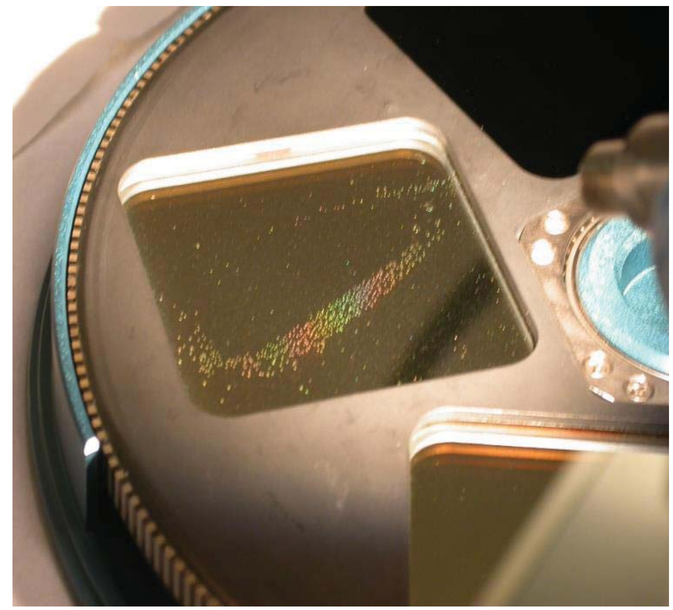
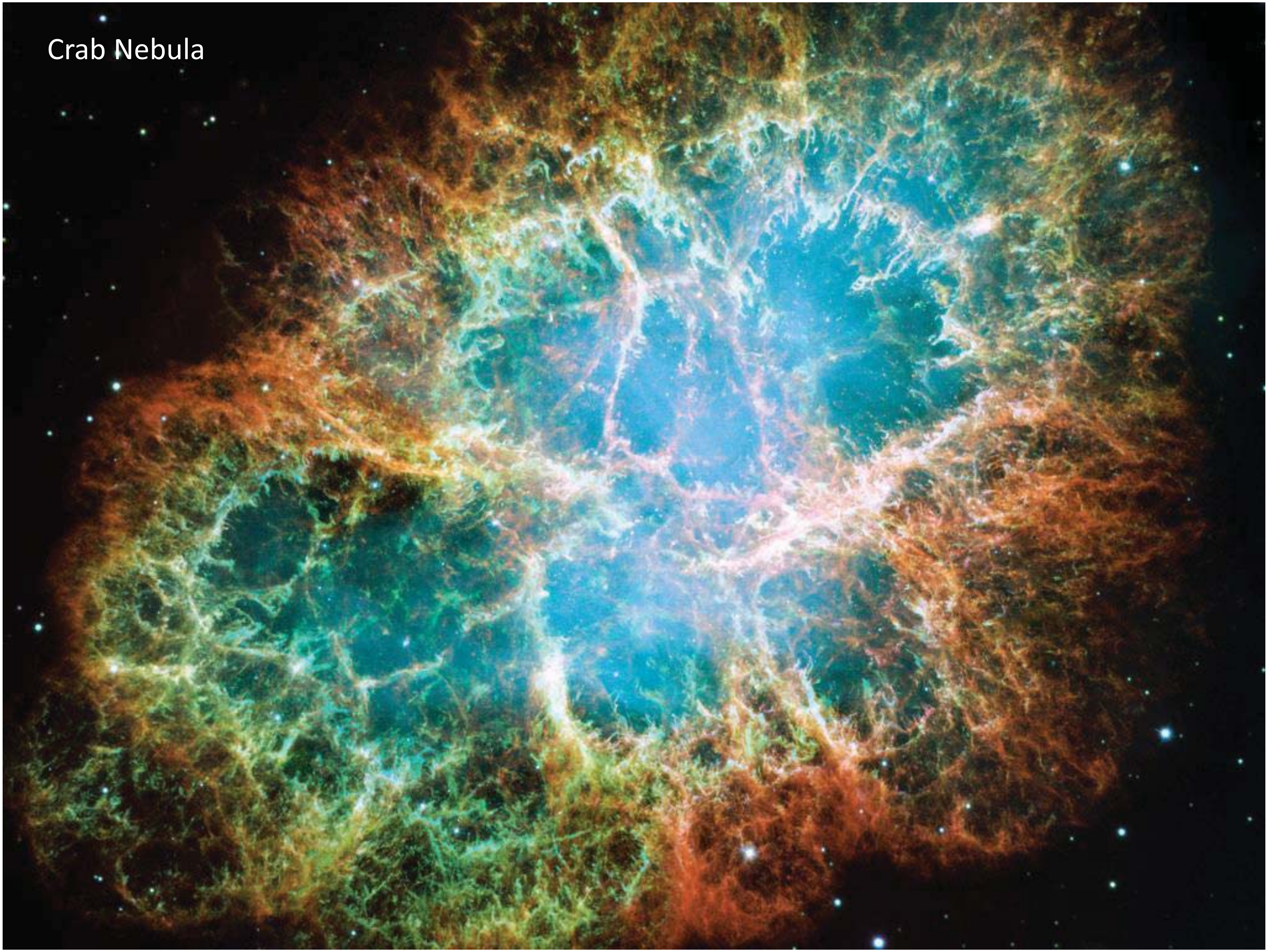


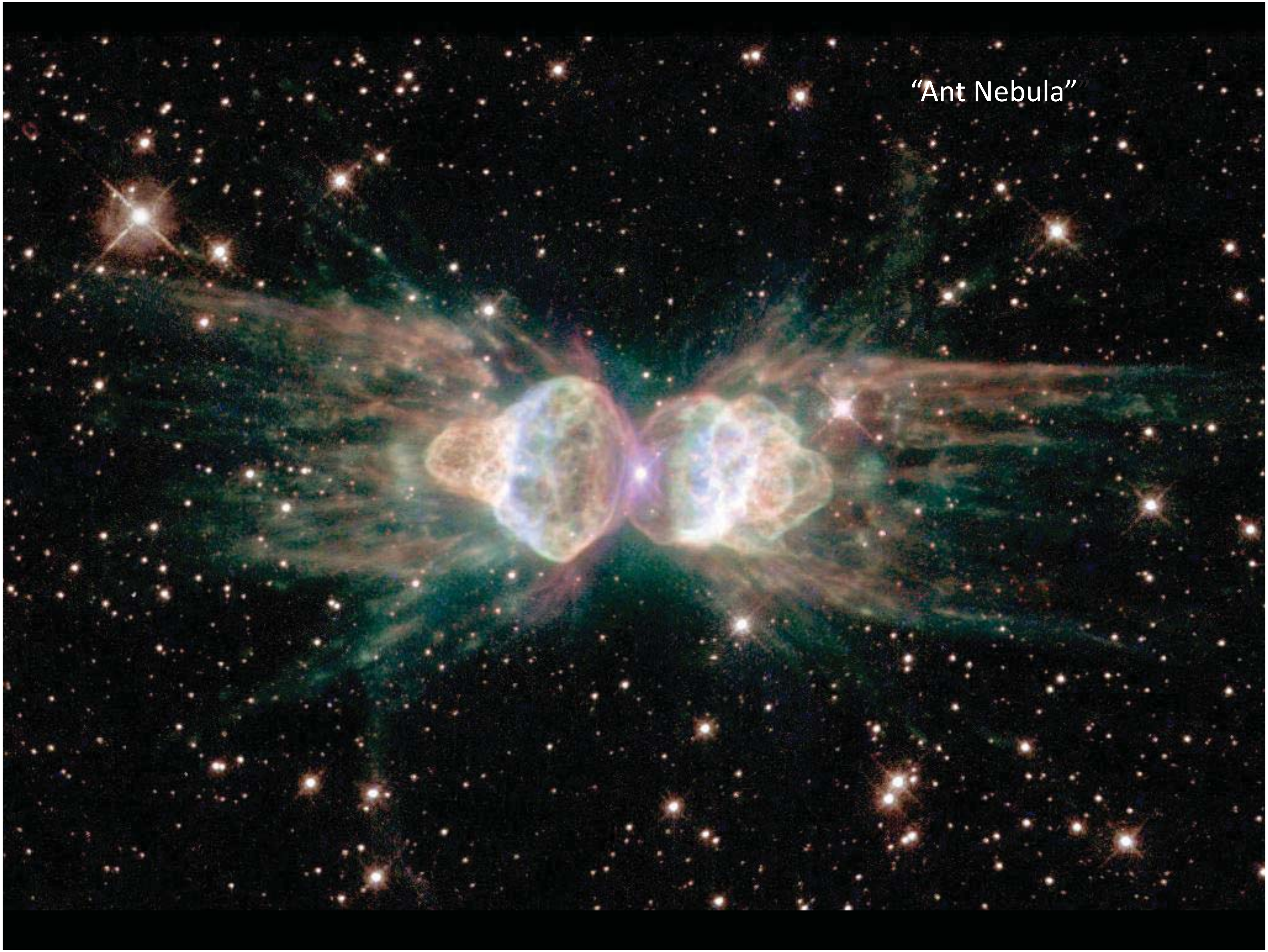
Figure 20. F375N Filter Pre & Post Flight Transmission vs. Wavelength. The filter slightly lacked homogeneity as there was ~1.8% difference between the bottom right & center of the filter. There is also a slight shift to the red side of the spectrum for some areas in the filter. Also visual Inspection of filter(right).

WFPC2 Summary Points

- Work is to Improve Calibrations and examine the long term effects of the filters in orbit
- Inspection & Transmission scans are on-going but are nearly finished
- Results of most dramatic changes & recent measurements were presented
- Work is in progress and the results will be published on Oct 2010 by the STScI
- Most memorable WFPC2 pictures taken with various filter combinations will conclude presentation from the nasa.gov website


Eagle Nebula


Crab Nebula


“Ant Nebula”


Whirlpool Galaxy

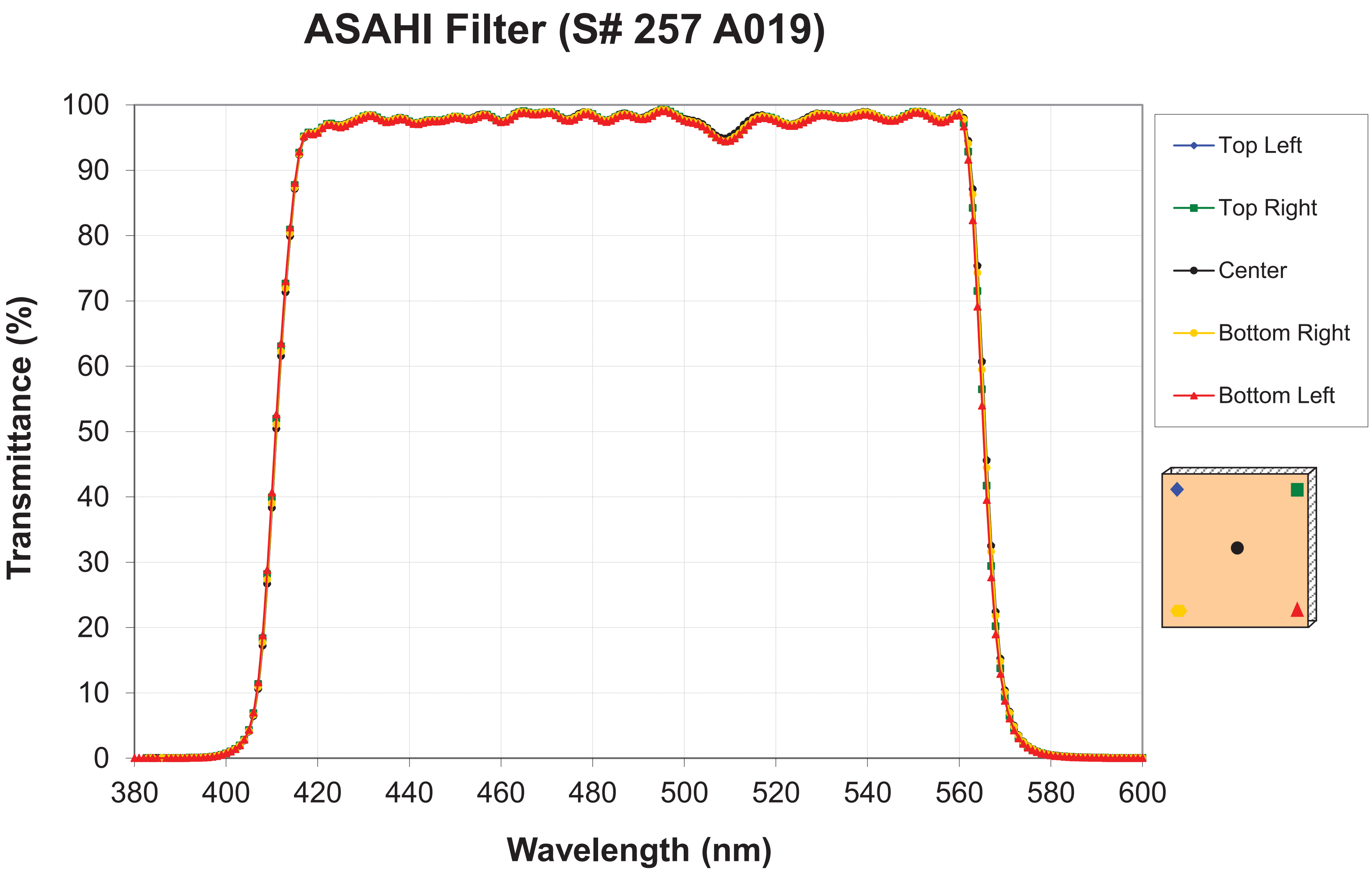
JDEM Prototype Filters

We compare the requested and measured transmittance performance of prototype SNAP filters for Band 1 and Band 7 from three different vendors. These are ASAHI, BARR and JDSU.

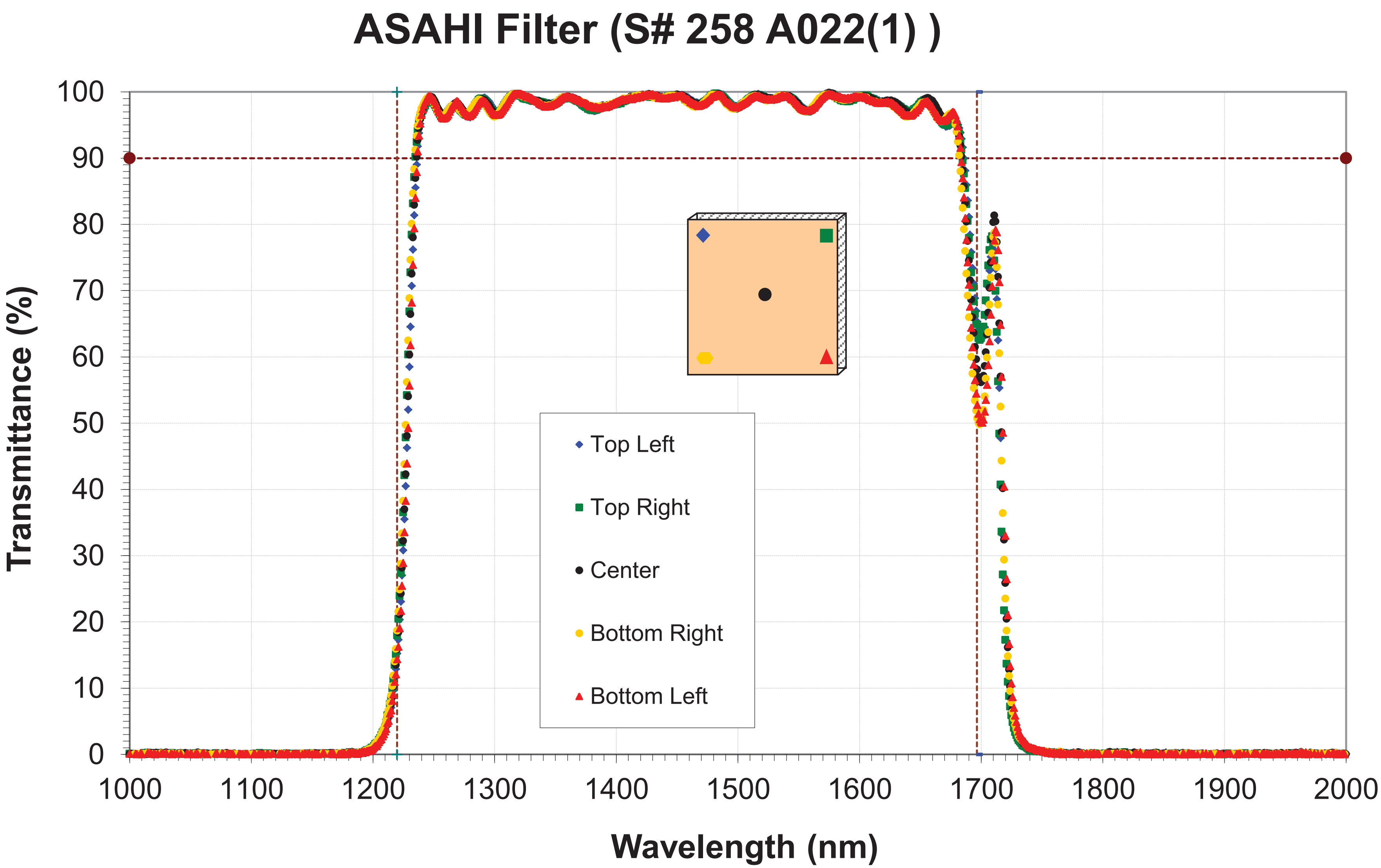
The Passband Table below gives the edge locations and the Out of Band Rejection criteria for the prototype SNAP bandpass filters.

	Passband	Table	
series name	filter name	edge loc. 50% Tmax (nm)	edge loc. 50% Tmax (nm)
8b	0	325.9	451.5
8b	1	435.0	605.0
8b	2	516.6	718.4
8b	3	613.4	853.1
8b	4	728.4	1013.1
8b	5	865.0	1203.1
8b	6	1027.2	1428.6
8b	7	1219.8	1696.5

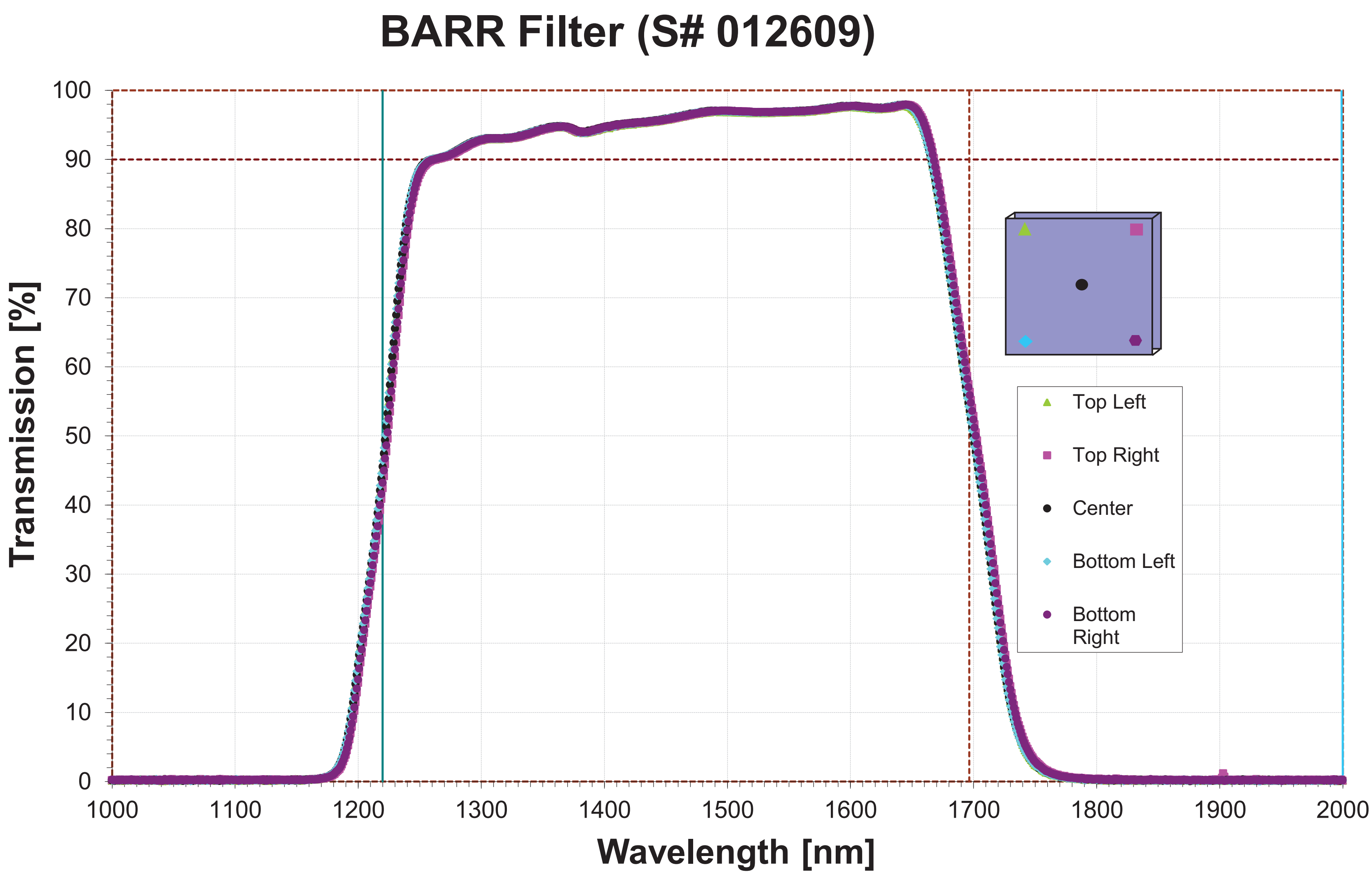
SNAP IN-BAND RESULTS (FILTER #1)



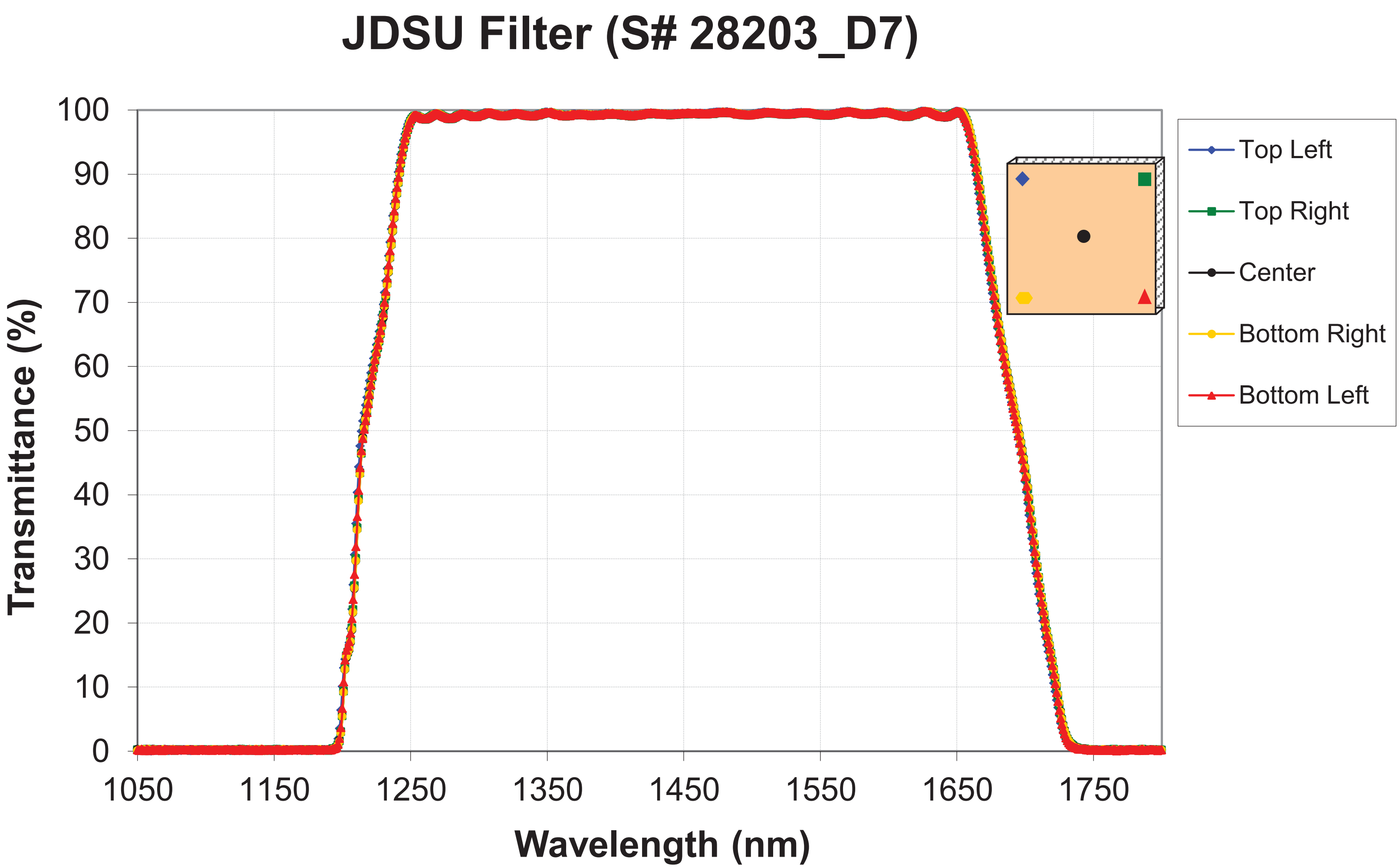
SNAP IN-BAND RESULTS (FILTER #7)



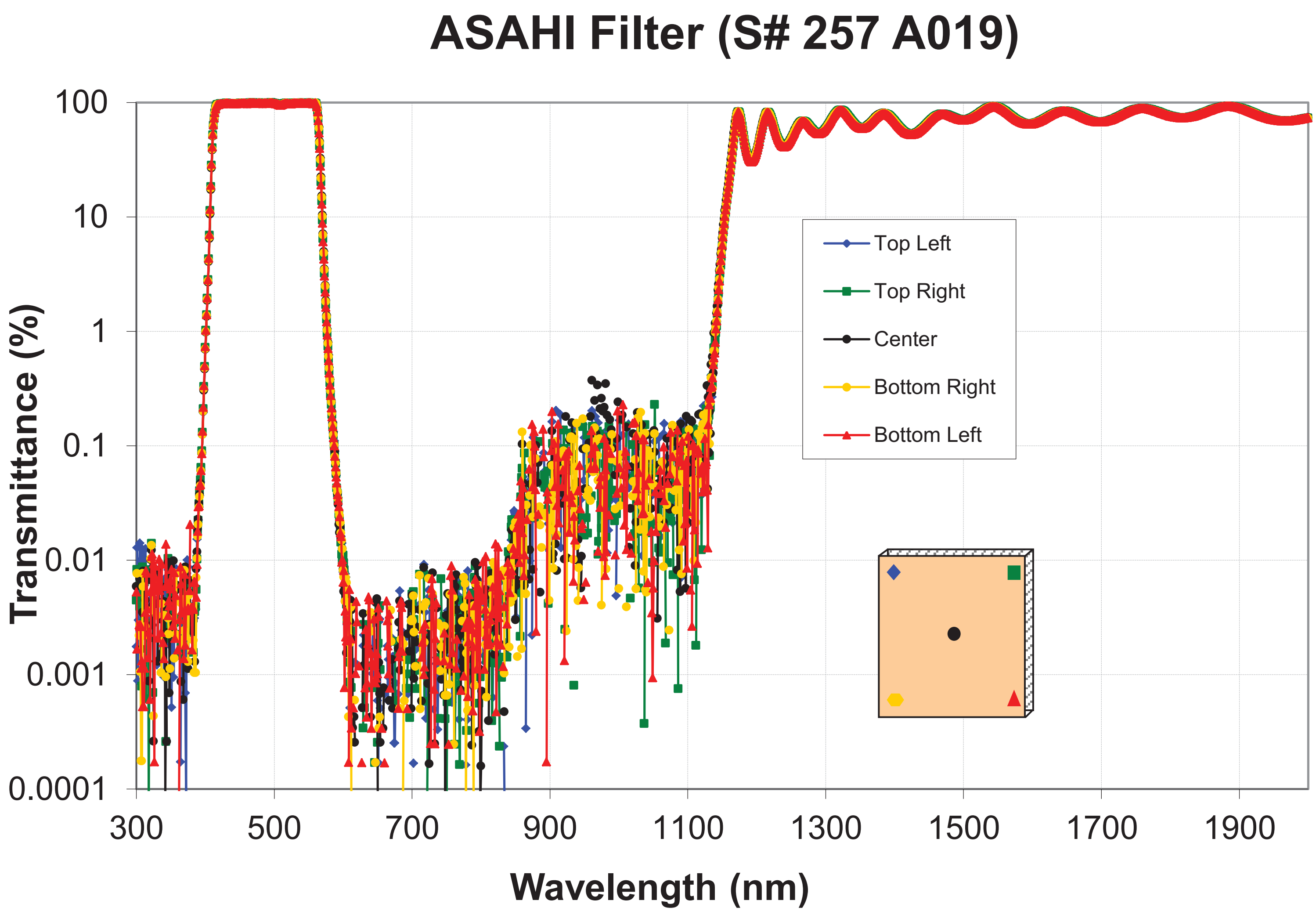
SNAP IN-BAND RESULTS (FILTER #7)
Cont…



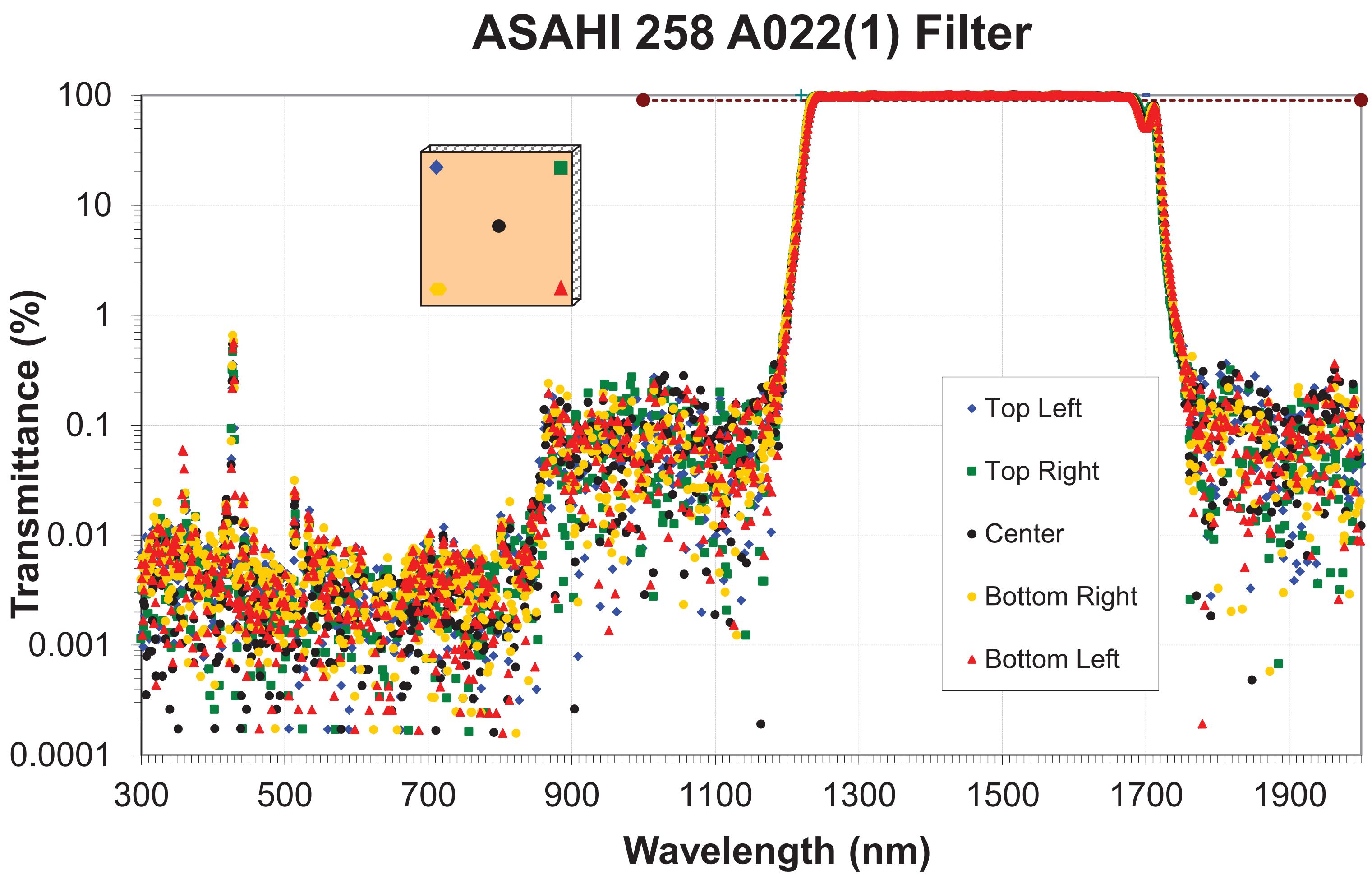
SNAP IN-BAND RESULTS (FILTER #7)
Cont..



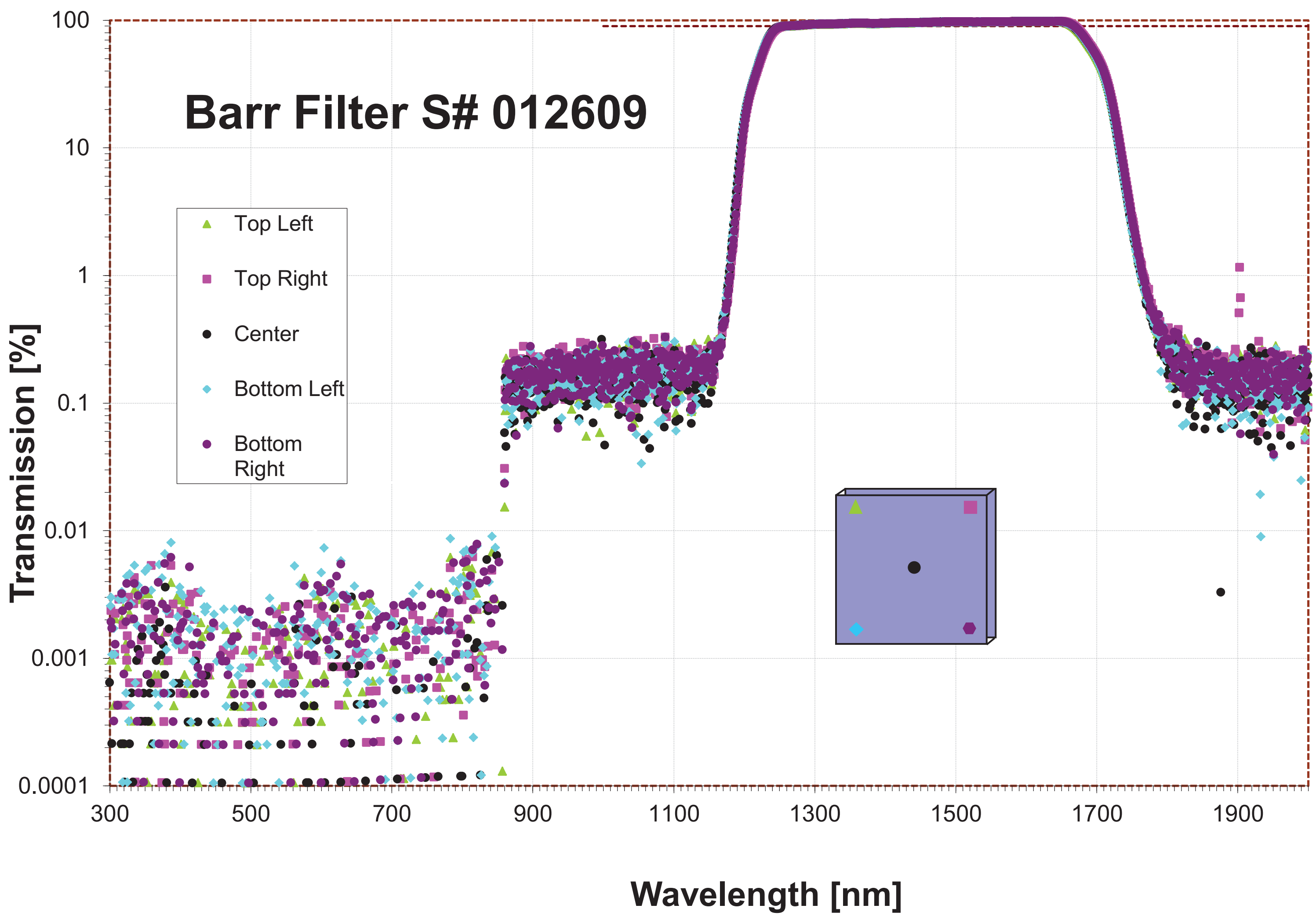
SNAP OUT-OF-BAND RESULTS (FILTER #1)



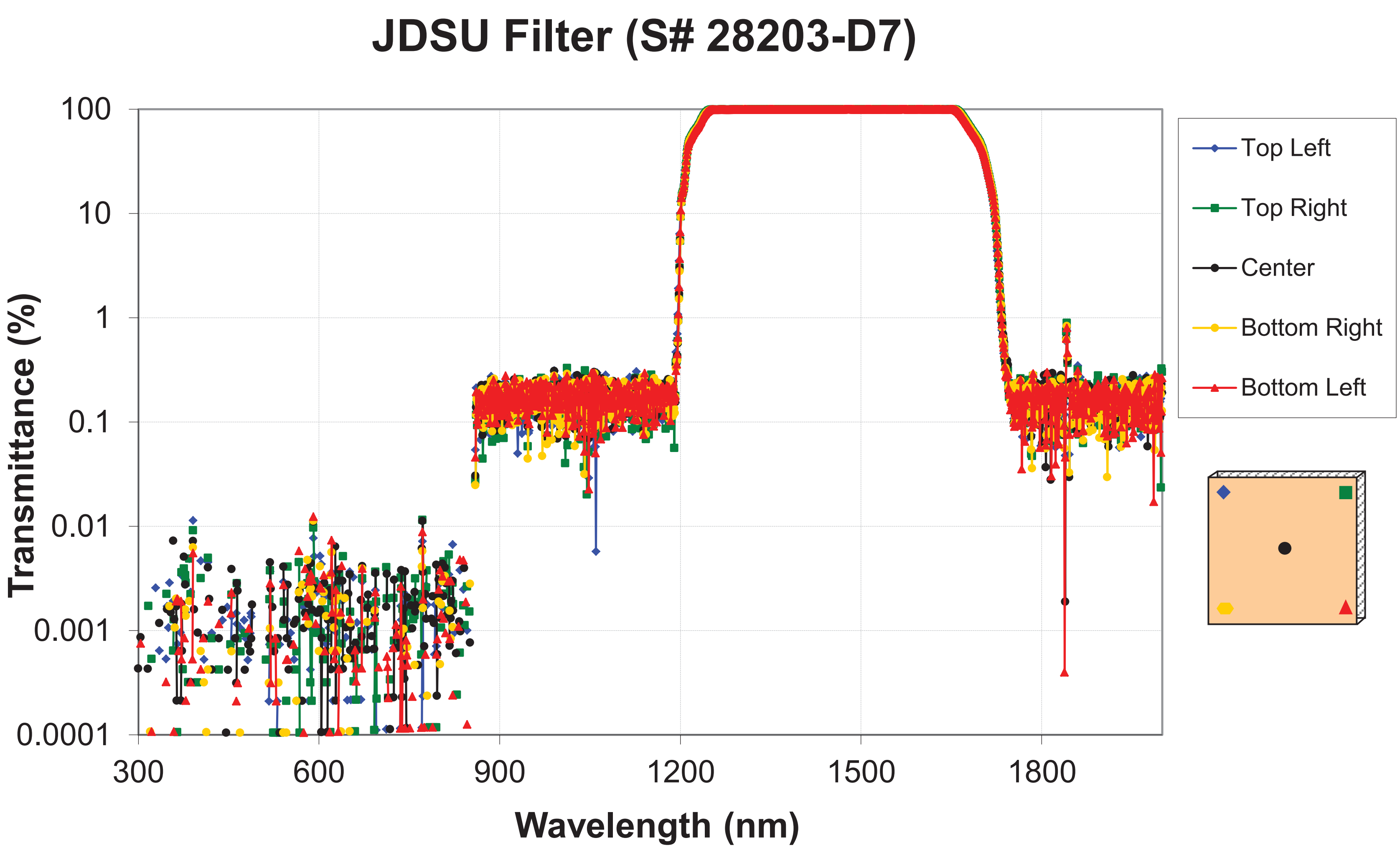
SNAP OUT-OF-BAND RESULTS (FILTER #7)
Cont..



SNAP OUT-OF-BAND RESULTS (FILTER #7)
Cont..



SNAP OUT-OF-BAND RESULTS (FILTER #7)
Cont..



SNAP FILTER ANALYSIS (FILTER #1)

Filter #	λ_0	*Average T*	FWHM	λ@±0.50*Tave (nm)				Δλ+	Δλ-
	(nm)	in λ±0.50*Tave	(nm)	λ_{cut-on}	$\lambda_{cut-off}$	$\Delta\lambda_{50\%}/\lambda_{FWHM}$	$\Delta\lambda_{50\%}/\lambda_{FWHM}$		
ASAHI-A019	488.3	96.35%	155.0	410.8	565.8	-0.00827	0.02501	-1.2	3.8
ASAHI-A020	488.2	95.78%	154.9	410.7	565.6	-0.00846	0.02426	-1.3	3.6
ASAHI-A021	488.4	96.17%	155.1	410.9	565.9	-0.00765	0.02610	-1.1	3.9
Specification	520.0	90.00%	150.0	412.0	562.0	< 0.02	< 0.02		

SNAP FILTER ANALYSIS (FILTER #7)

Filter #	λ_0	*Average T*	FWHM	λ@±0.50*Tave (nm)				Δλ+	Δλ-
	(nm)	in λ±0.50*Tave	(nm)	λ_{cut-on}	$\lambda_{cut-off}$	$\Delta\lambda_{50\%} / \lambda_{FWHM}$	$\Delta\lambda_{50\%} / \lambda_{FWHM}$		
ASAHI-A022	1472.5	95.93%	489.1	1228.0	1717.1	-0.04200	0.02744	-20.0	13.1
ASAHI-A023	1471.3	95.96%	486.9	1227.8	1714.8	-0.04233	0.02259	-20.2	10.8
ASAHI-A024	1472.7	95.93%	489.3	1228.0	1717.4	-0.04187	0.02807	-20.0	13.4
BARR-Filter #1	1461.8	91.78%	483.3	1220.2	1703.5	0.00080	0.01468	0.4	7.0
JDSU-28203-D7	1456.0	95.22%	483.0	1214.5	1697.5	-0.01112	0.00199	-5.3	1.0
JDSU-28203-D8	1455.5	95.17%	482.0	1214.5	1696.5	-0.01116	-0.00008	-5.3	0.0
Specification (BARR & JDSU)	1458.2	90.00%	476.7	1219.8	1696.5	< 0.02	< 0.02		
Specification (ASAHI)	1476.0	90.00%	456.0	1248.0	1704.0	< 0.02	< 0.02		

SNAP FILTER SLOPE ANALYSIS

slope = $(\lambda_{85\%} - \lambda_{15\%})/\lambda_{50\%}$

Manufacturer	Short-Side	Long-Side	**Specification**
Barr Filter 7	0.04	-0.03	0.03±-0.01
ASAHI (Filter 7)	0.01	-0.02	0.03±-0.01
ASAHI (Filter 1)	0.02	-0.01	0.03±-0.01
JDSU (Filter 7)	0.03	-0.03	0.03±-0.01

JDEM Filters Summary Points

1. ASAHI met the specifications for their version of the SNAP prototype filter #1 in terms of band-pass, slope, and uniformity.

2. The prototype version for filter #7 proved to be problematic for both the ASAHI and BARR manufacturers.

3. The version for filter #7 from JDSU met the band-pass and slope specifications (unlike the other two vendors).

4. Uniformity was excellent for the JDSU filter as well.