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

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PerkinElmer Lambda Interest Group meeting May 8th, 2014 Greenbelt, Maryland
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
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:

• Regularly used filters:

• UV filters:

• Other measured or soon to be measured 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).
Figure 8. Filter placed into beam path (left) with respect to the five-point scan measured (right).
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.
Figure 10. WF2 CCD UVFLAT illuminated with deuterium lamp within calibration module using F160BW 1994(left) 2008(right).
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 confirms 50% transmission loss from Gonzaga & Biretta 2009.
- Peak transmission wavelength shifted from 3432Å to ~3434Å and FWHM increased ~3Å.
Figure 15. F343 Visual Inspection
Figure 16. F170W Pre & Post Flight Optical Density vs. Wavelength. Filter remained consistent before & after orbit.
Figure 17. F122M Pre & Post Flight Optical Density vs. Wavelength. Filter remained consistent before & after Orbit.
Figure 18. F300W Pre & Post Flight Transmission vs. Wavelength. About 4% Transmission drop from Pre-flight data. Also, visual inspection of filter (right).
Figure 19. Pre & Post Flight Transmission of Filter F850LP. There is a ~5-6% transmission increase after orbit.
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.

<table>
<thead>
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<th>Passband</th>
<th>Table</th>
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<td>series</td>
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SNAP IN-BAND RESULTS (FILTER #1)

ASAHI Filter (S# 257 A019)
SNAP IN-BAND RESULTS (FILTER #7)

ASAHI Filter (S# 258 A022(1))
SNAP IN-BAND RESULTS (FILTER #7)
Cont...

BARR Filter (S# 012609)
SNAP IN-BAND RESULTS (FILTER #7)
Cont..

JDSU Filter (S# 28203_D7)
SNAP OUT-OF-BAND RESULTS (FILTER #1)

ASAHI Filter (S# 257 A019)
SNAP OUT-OF-BAND RESULTS (FILTER #7)
Cont..

ASAHI 258 A022(1) Filter

Transmittance (%) vs Wavelength (nm)
SNAP OUT-OF-BAND RESULTS (FILTER #7)

Cont..

Barr Filter S# 012609

Transmission [%]

Top Left
Top Right
Center
Bottom Left
Bottom Right

Wavelength [nm]

300 500 700 900 1100 1300 1500 1700 1900
SNAP OUT-OF-BAND RESULTS (FILTER #7)
Cont..

JDSU Filter (S# 28203-D7)
## SNAP FILTER ANALYSIS (FILTER #1)

<table>
<thead>
<tr>
<th>Filter #</th>
<th>$\lambda_0$ (nm)</th>
<th>Average $T$ (%)</th>
<th>FWHM (nm)</th>
<th>$\lambda \pm 0.50^\circ T_{ave}$ (nm)</th>
<th>$\Delta \lambda_{50%} / \lambda_{FWHM}$</th>
<th>$\Delta \lambda_{50%} / \lambda_{FWHM}$</th>
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</thead>
<tbody>
<tr>
<td>ASAHI-A019</td>
<td>488.3</td>
<td>96.35%</td>
<td>155.0</td>
<td>410.8</td>
<td>-0.00827</td>
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<td>ASAHI-A020</td>
<td>488.2</td>
<td>95.78%</td>
<td>154.9</td>
<td>410.7</td>
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<td>ASAHI-A021</td>
<td>488.4</td>
<td>96.17%</td>
<td>155.1</td>
<td>410.9</td>
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<td>0.02610</td>
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<tr>
<td>Specification</td>
<td>520.0</td>
<td>90.00%</td>
<td>150.0</td>
<td>412.0</td>
<td>&lt; 0.02</td>
<td>&lt; 0.02</td>
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# SNAP FILTER ANALYSIS (FILTER #7)

<table>
<thead>
<tr>
<th>Filter #</th>
<th>(\lambda_0) (nm)</th>
<th>Average T</th>
<th>FWHM</th>
<th>(\lambda_{Cut-on}) (nm)</th>
<th>(\lambda_{Cut-off}) (nm)</th>
<th>(\Delta\lambda_{50}% / \lambda_{FWHM})</th>
<th>(\Delta\lambda_{50}% / \lambda_{FWHM})</th>
<th>(\Delta\lambda_+)</th>
<th>(\Delta\lambda_-)</th>
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<tbody>
<tr>
<td>ASAHI-A022</td>
<td>1472.5</td>
<td>95.93%</td>
<td>489.1</td>
<td>1228.0</td>
<td>1717.1</td>
<td>-0.04200</td>
<td>0.02744</td>
<td>-20.0</td>
<td>13.1</td>
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<tr>
<td>ASAHI-A023</td>
<td>1471.3</td>
<td>95.96%</td>
<td>486.9</td>
<td>1227.8</td>
<td>1714.8</td>
<td>-0.04233</td>
<td>0.02259</td>
<td>-20.2</td>
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<tr>
<td>ASAHI-A024</td>
<td>1472.7</td>
<td>95.93%</td>
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<td>1228.0</td>
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<td>BARR-Filter #1</td>
<td>1461.8</td>
<td>91.78%</td>
<td>483.3</td>
<td>1220.2</td>
<td>1703.5</td>
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<td>JDSU-28203-D7</td>
<td>1456.0</td>
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<td>1214.5</td>
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<tr>
<td>JDSU-28203-D8</td>
<td>1455.5</td>
<td>95.17%</td>
<td>482.0</td>
<td>1214.5</td>
<td>1696.5</td>
<td>-0.01116</td>
<td>-0.00008</td>
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<tr>
<td>Specification (BARR &amp; JDSU)</td>
<td>1458.2</td>
<td>90.00%</td>
<td>476.7</td>
<td>1219.8</td>
<td>1696.5</td>
<td>&lt; 0.02</td>
<td>&lt; 0.02</td>
<td>-5.3</td>
<td>0.0</td>
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<tr>
<td>Specification (ASAHI)</td>
<td>1476.0</td>
<td>90.00%</td>
<td>456.0</td>
<td>1248.0</td>
<td>1704.0</td>
<td>&lt; 0.02</td>
<td>&lt; 0.02</td>
<td>-5.3</td>
<td>0.0</td>
</tr>
</tbody>
</table>
SNAP FILTER SLOPE ANALYSIS

\[
\text{slope} = (\lambda_{85\%} - \lambda_{15\%})/\lambda_{50\%}
\]

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Short-Side</th>
<th>Long-Side</th>
<th>Specification</th>
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<td>Barr Filter 7</td>
<td>0.04</td>
<td>-0.03</td>
<td>0.03±-0.01</td>
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<tr>
<td>ASAHI (Filter 7)</td>
<td>0.01</td>
<td>-0.02</td>
<td>0.03±-0.01</td>
</tr>
<tr>
<td>ASAHI (Filter 1)</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.03±-0.01</td>
</tr>
<tr>
<td>JDSU (Filter 7)</td>
<td>0.03</td>
<td>-0.03</td>
<td>0.03±-0.01</td>
</tr>
</tbody>
</table>
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.