

## 4.1.2 OPTICS THROUGHPUT

**Reference 4.1.2-1 - "Cassini Flight Narrow Angle Camera Optical Throughput Calibration - Final Report", Brad D. Wallis, Ken S. Manatt, November 15, 1997**

**Reference 4.1.2-2 - "Cassini Flight Wide Angle Camera Optical Throughput Calibration Final Report", Brad D. Wallis, Ken S. Manatt, Revised November 14, 1997**

The optical throughput of the NAC and WAC flight optics was measured in the UV Calibration Lab and was reported in Reference 4.1.2-1 and Reference 4.1.2-2. Throughput calibration was performed on the portion of the optical path (reference Figure 4.1.1-1 from the previous section) containing the flight optics subassembly, 2 quartz spacers (representing the clear/clear (CL1/CL2) filter combination), and a quartz plug (representing the sensor head assembly field flatteners). As noted in Reference 4.1.2-1 and Reference 4.1.2-2, the data reduction of the optical throughput calibration test data backed-out the transmission of the quartz spacers (CL1/CL2 filter combination), providing the optical throughput due to the optics subassembly and the sensor head field flatteners. Note : System optical throughput, as a whole, would require consideration of these additional elements : filter transmission data for the specified filter combination (reference Section 4.2), and CCD/window QE (reference Section 4.4.2).

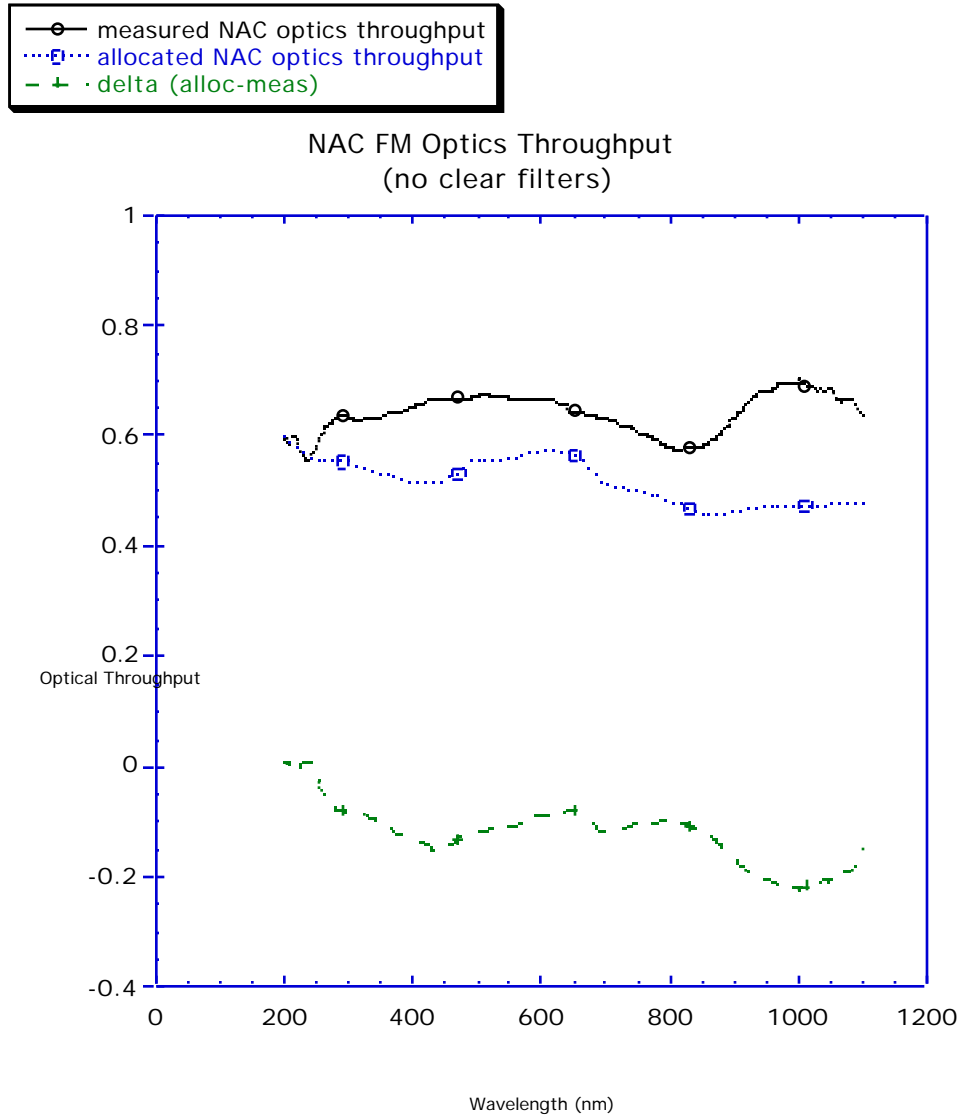
Other data reduction notes from the referenced reports include the following : 1) a correction factor for scattered light was applied to the data, 2) only the leading dark current measurements were used (a trailing data set is also available), 3) a more detailed fitting of the raw data from 900 nm and above still needs to be performed due to the noise in the data sets produced by a dying QE response of the silicon detector used to collect this data, and 4) a thorough error analysis still needs to be performed.

The NAC and WAC optics throughput allocations can be seen in Table 4.1.2-1, where the following information is shown : 1) the optics throughput allocations as originally documented (allowing for the CL1/CL2 filter combination), 2) the measured transmission of the CL1/CL2 flight filter combinations, and 3) the optics throughput allocations factoring out the transmission factors associated with the CL1/CL2 filter combination (for comparison to reduced data reported in Reference 4.1.2-1 and Reference 4.1.2-2).

| Wavelength<br>(nm) | Optics Throughput<br>Allocations<br>(including CL1/CL2<br>filters) |          | CL1*CL2<br>Filter Transmissions<br>(from flight filter test<br>data) |         | Optics Throughput<br>Allocations<br>(excluding CL1/CL2<br>filters) |          |
|--------------------|--|----------|--|---------|--|----------|
|                    | NAC  | WAC      | NAC  | WAC     | NAC  | WAC      |
| 200.00             | 0.46000  |          | 0.76856  |         | 0.59852  |          |
| 250.00             | 0.48000  |          | 0.86545  |         | 0.55462  |          |
| 300.00             | 0.50000  |          | 0.90743  |         | 0.55101  |          |
| 350.00             | 0.49000  |          | 0.92491  |         | 0.52978  |          |
| 400.00             | 0.48000  | 0.30000  | 0.92743  | 0.89646 | 0.51756  | 0.33465  |
| 450.00             | 0.48000  | 0.60000  | 0.92413  | 0.96525 | 0.51941  | 0.62160  |
| 500.00             | 0.51000  | 0.70000  | 0.91919  | 0.96942 | 0.55484  | 0.72208  |
| 550.00             | 0.51000  | 0.73000  | 0.91404  | 0.94256 | 0.55796  | 0.77449  |
| 600.00             | 0.52000  | 0.73000  | 0.90957  | 0.94742 | 0.57170  | 0.77051  |
| 650.00             | 0.51000  | 0.73000  | 0.90462  | 0.96540 | 0.56377  | 0.75616  |
| 700.00             | 0.46000  | 0.60000  | 0.90155  | 0.95489 | 0.51023  | 0.62835  |
| 750.00             | 0.45000  | 0.50000  | 0.89828  | 0.92720 | 0.50096  | 0.53926  |
| 800.00             | 0.43000  | 0.35000  | 0.89556  | 0.90796 | 0.48015  | 0.38548  |
| 850.00             | 0.41000  | 0.25000  | 0.89364  | 0.90692 | 0.45880  | 0.27566  |
| 900.00             | 0.41000  | 0.15000  | 0.89104  | 0.91773 | 0.46014  | 0.16345  |
| 950.00             | 0.42000  | 0.12000  | 0.88831  | 0.93510 | 0.47281  | 0.12833  |
| 1000.0             | 0.42000  | 0.10000  | 0.88853  | 0.95126 | 0.47269  | 0.10512  |
| 1050.0             | 0.42000  | 0.090000 | 0.88662  | 0.95254 | 0.47371  | 0.094485 |
| 1100.0             | 0.42000  | 0.080000 | 0.88539  | 0.94000 | 0.47437  | 0.085107 |

Table 4.1.2-1- Optics Throughput Allocations

NAC FM Optics - Figure 4.1.2-1 shows the measured versus allocated throughput for the NAC FM optics (CL1/CL2 filters omitted from the data). As can be seen from the plot, the measured optics throughput *surpasses* the allocated throughput, except for the region between 200 and 240 nm, where the measured optics falls as much as 1.64 % below the allocated throughput. See Table 4.1.2-3 for the statistics on the delta between the allocated versus measured optics throughput, and Table 4.1.2-4 for the Measured NAC FM Optics Data (no clear filters).



**Figure 4.1.2-1 - NAC FM Optics Throughput (optics w/ field flattener; no filters)**

| NAC FM Optics Throughput Allocation vs. Measured Delta Statistics |          |                        |
|---|----------|------------------------|
| Min of Delta  | -0.22882 | falls above allocation |
| Max of Delta  | 0.009489 | falls below allocation |
| Mean of Delta   | -0.12373 | falls above allocation |
| Std Dev of Delta  | 0.053225 |                        |

**Table 4.1.2-2 - NAC Optics Throughput Allocation vs. Measured Delta Statistics**

WAC FM Optics - Figure 4.1.2-2 shows the measured versus allocated throughput for the WAC FM optics (CL1/CL2 filters omitted from the data). As can be seen from the plot, the measured optics throughput *falls below* the allocated throughput, except for the region between 442.5 and 490 nm. It must be noted, however, that the policy regarding the inherited Voyager optics is “use-as-is”. See Table 4.1.2-3 for the statistics on the delta between the allocated versus measured optics throughput, and Table 4.1.2-5 for the Measured WAC FM Optics Data (no clear filters).

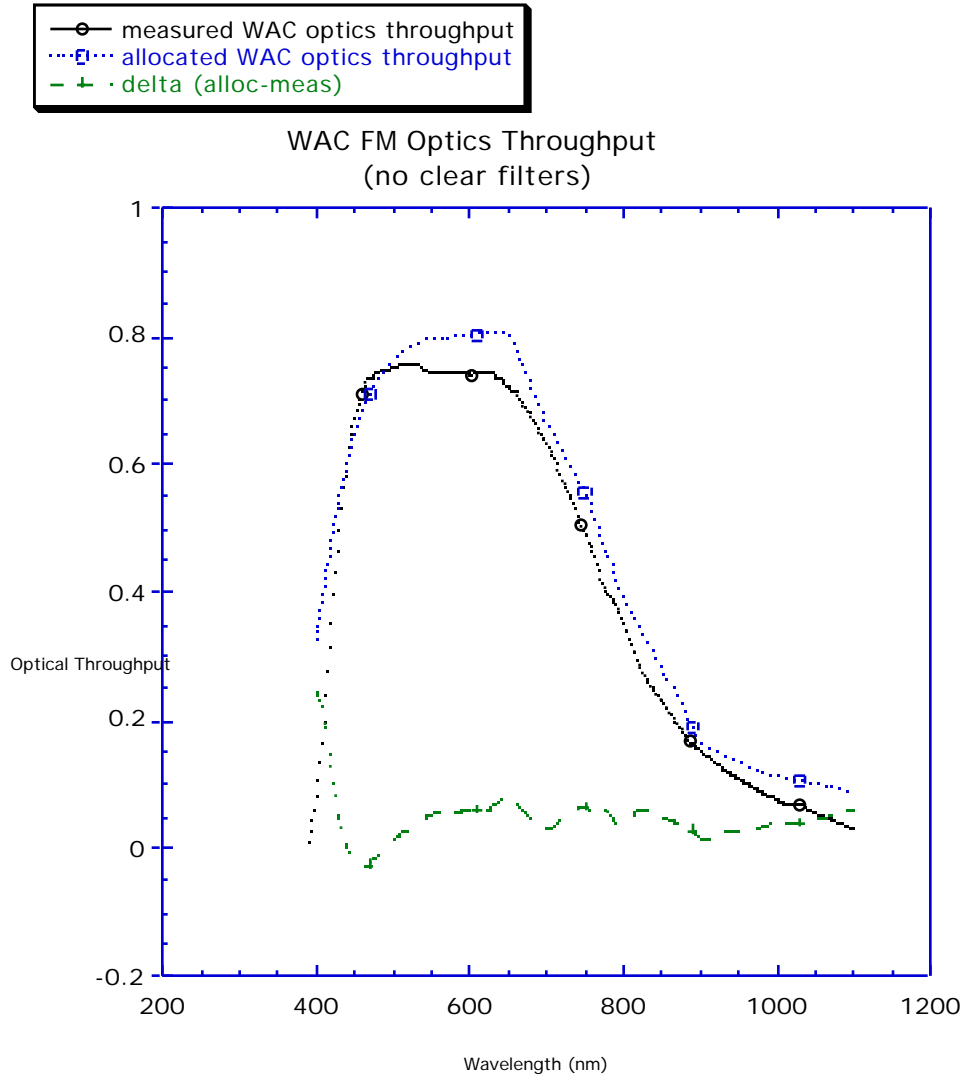


Figure 4.1.2-2 - WAC FM Optics Throughput (optics w/ field flatteners ; no filters)

| WAC FM Optics Throughput Allocation vs. Measured Delta Statistics |           |                        |
|---|-----------|------------------------|
| Min of Delta  | -0.028535 | falls above allocation |
| Max of Delta  | 0.24373   | falls below allocation |
| Mean of Delta   | 0.045439  | falls below allocation |
| Std Dev of Delta  | 0.036809  |                        |

Table 4.1.2-3 - WAC Optics Throughput Allocation vs. Measured Delta Statistics

**Table 4.1.2-4 - Measured NAC FM Optics Throughput Data (no clear filters)**

| Wavelength (nm) | NAC FM Measured Optics Throughput (no clear filters) | Estimated Error | Wavelength (nm) | NAC FM Measured Optics Throughput (no clear filters) | Estimated Error |
|-----------------|--|-----------------|-----------------|--|-----------------|
| 200.0           | 0.589031   | +/- 0.04-0.05   | 347.5           | 0.633707   | +/- 0.02        |
| 202.5           | 0.597175   | +/- 0.04-0.05   | 350.0           | 0.633566   | +/- 0.01        |
| 205.0           | 0.585817   | +/- 0.04-0.05   | 352.5           | 0.634435   | +/- 0.01        |
| 207.5           | 0.584288   | +/- 0.04-0.05   | 355.0           | 0.635183   | +/- 0.01        |
| 210.0           | 0.585239   | +/- 0.04-0.05   | 357.5           | 0.63723  | +/- 0.01        |
| 212.5           | 0.593266   | +/- 0.04-0.05   | 360.0           | 0.637738   | +/- 0.01        |
| 215.0           | 0.596172   | +/- 0.04-0.05   | 362.5           | 0.639317   | +/- 0.01        |
| 217.5           | 0.593503   | +/- 0.04-0.05   | 365.0           | 0.639267   | +/- 0.01        |
| 220.0           | 0.587889   | +/- 0.04-0.05   | 367.5           | 0.641219   | +/- 0.01        |
| 222.5           | 0.580501   | +/- 0.04-0.05   | 370.0           | 0.642625   | +/- 0.01        |
| 225.0           | 0.572899   | +/- 0.04-0.05   | 372.5           | 0.643695   | +/- 0.01        |
| 227.5           | 0.56648  | +/- 0.04-0.05   | 375.0           | 0.644404   | +/- 0.01        |
| 230.0           | 0.561569   | +/- 0.04-0.05   | 377.5           | 0.644259   | +/- 0.01        |
| 232.5           | 0.557681   | +/- 0.04-0.05   | 380.0           | 0.643256   | +/- 0.01        |
| 235.0           | 0.554367   | +/- 0.04-0.05   | 382.5           | 0.64358  | +/- 0.01        |
| 237.5           | 0.553247   | +/- 0.04-0.05   | 385.0           | 0.64406  | +/- 0.01        |
| 240.0           | 0.554881   | +/- 0.04-0.05   | 387.5           | 0.645039   | +/- 0.01        |
| 242.5           | 0.559089   | +/- 0.04-0.05   | 390.0           | 0.646739   | +/- 0.01        |
| 245.0           | 0.564825   | +/- 0.04-0.05   | 392.5           | 0.648442   | +/- 0.01        |
| 247.5           | 0.570852   | +/- 0.04-0.05   | 395.0           | 0.649528   | +/- 0.01        |
| 250.0           | 0.576946   | +/- 0.04-0.05   | 397.5           | 0.650809   | +/- 0.01        |
| 252.5           | 0.583431   | +/- 0.04-0.05   | 400.0           | 0.651158   | +/- 0.01        |
| 255.0           | 0.590012   | +/- 0.04-0.05   | 402.5           | 0.651723   | +/- 0.01        |
| 257.5           | 0.596666   | +/- 0.04-0.05   | 405.0           | 0.652062   | +/- 0.01        |
| 260.0           | 0.602743   | +/- 0.04-0.05   | 407.5           | 0.652862   | +/- 0.01        |
| 262.5           | 0.608429   | +/- 0.04-0.05   | 410.0           | 0.652899   | +/- 0.01        |
| 265.0           | 0.613326   | +/- 0.04-0.05   | 412.5           | 0.652689   | +/- 0.01        |
| 267.5           | 0.617884   | +/- 0.04-0.05   | 415.0           | 0.652943   | +/- 0.01        |
| 270.0           | 0.620065   | +/- 0.04-0.05   | 417.5           | 0.65279  | +/- 0.01        |
| 272.5           | 0.622165   | +/- 0.04-0.05   | 420.0           | 0.656337   | +/- 0.01        |
| 275.0           | 0.623173   | +/- 0.04-0.05   | 422.5           | 0.659738   | +/- 0.01        |
| 277.5           | 0.626585   | +/- 0.04-0.05   | 425.0           | 0.663728   | +/- 0.01        |
| 280.0           | 0.630234   | +/- 0.04-0.05   | 427.5           | 0.665748   | +/- 0.01        |
| 282.5           | 0.632752   | +/- 0.04-0.05   | 430.0           | 0.666875   | +/- 0.01        |
| 285.0           | 0.634101   | +/- 0.04-0.05   | 432.5           | 0.668244   | +/- 0.01        |
| 287.5           | 0.635113   | +/- 0.04-0.05   | 435.0           | 0.668554   | +/- 0.01        |
| 290.0           | 0.635395   | +/- 0.04-0.05   | 437.5           | 0.668367   | +/- 0.01        |
| 292.5           | 0.636165   | +/- 0.04-0.05   | 440.0           | 0.668466   | +/- 0.01        |
| 295.0           | 0.635706   | +/- 0.04-0.05   | 442.5           | 0.668063   | +/- 0.01        |
| 297.5           | 0.634881   | +/- 0.04-0.05   | 445.0           | 0.667573   | +/- 0.01        |
| 300.0           | 0.631277   | +/- 0.02        | 447.5           | 0.666798   | +/- 0.01        |
| 302.5           | 0.63019  | +/- 0.02        | 450.0           | 0.666817   | +/- 0.01        |
| 305.0           | 0.630856   | +/- 0.02        | 452.5           | 0.666366   | +/- 0.01        |
| 307.5           | 0.629363   | +/- 0.02        | 455.0           | 0.666199   | +/- 0.01        |
| 310.0           | 0.627325   | +/- 0.02        | 457.5           | 0.666183   | +/- 0.01        |
| 312.5           | 0.625605   | +/- 0.02        | 460.0           | 0.667087   | +/- 0.01        |
| 315.0           | 0.624962   | +/- 0.02        | 462.5           | 0.668027   | +/- 0.01        |
| 317.5           | 0.625785   | +/- 0.02        | 465.0           | 0.668662   | +/- 0.01        |
| 320.0           | 0.625758   | +/- 0.02        | 467.5           | 0.668329   | +/- 0.01        |
| 322.5           | 0.625456   | +/- 0.02        | 470.0           | 0.668047   | +/- 0.01        |
| 325.0           | 0.626572   | +/- 0.02        | 472.5           | 0.666076   | +/- 0.01        |
| 327.5           | 0.629312   | +/- 0.02        | 475.0           | 0.665496   | +/- 0.01        |
| 330.0           | 0.63068  | +/- 0.02        | 477.5           | 0.664577   | +/- 0.01        |
| 332.5           | 0.630731   | +/- 0.02        | 480.0           | 0.665561   | +/- 0.01        |
| 335.0           | 0.629929   | +/- 0.02        | 482.5           | 0.667594   | +/- 0.01        |
| 337.5           | 0.630848   | +/- 0.02        | 485.0           | 0.668752   | +/- 0.01        |
| 340.0           | 0.631303   | +/- 0.02        | 487.5           | 0.668606   | +/- 0.01        |
| 342.5           | 0.632572   | +/- 0.02        | 490.0           | 0.668147   | +/- 0.01        |
| 345.0           | 0.633266   | +/- 0.02        | 492.5           | 0.668602   | +/- 0.01        |

| Wavelength (nm) | NAC FM Measured Optics Throughput (no clear filters) | Estimated Error |
|-----------------|--|-----------------|
| 495.0           | 0.669638   | +/- 0.01        |
| 497.5           | 0.670062   | +/- 0.01        |
| 500.0           | 0.670548   | +/- 0.01        |
| 502.5           | 0.671708   | +/- 0.01        |
| 505.0           | 0.672625   | +/- 0.01        |
| 507.5           | 0.673578   | +/- 0.01        |
| 510.0           | 0.673917   | +/- 0.01        |
| 512.5           | 0.674123   | +/- 0.01        |
| 515.0           | 0.673452   | +/- 0.01        |
| 517.5           | 0.67338  | +/- 0.01        |
| 520.0           | 0.671314   | +/- 0.01        |
| 522.5           | 0.670797   | +/- 0.01        |
| 525.0           | 0.670091   | +/- 0.01        |
| 527.5           | 0.670392   | +/- 0.01        |
| 530.0           | 0.671451   | +/- 0.01        |
| 532.5           | 0.671616   | +/- 0.01        |
| 535.0           | 0.671435   | +/- 0.01        |
| 537.5           | 0.671627   | +/- 0.01        |
| 540.0           | 0.671164   | +/- 0.01        |
| 542.5           | 0.671148   | +/- 0.01        |
| 545.0           | 0.671327   | +/- 0.01        |
| 547.5           | 0.670519   | +/- 0.01        |
| 550.0           | 0.669375   | +/- 0.01        |
| 552.5           | 0.668974   | +/- 0.01        |
| 555.0           | 0.668881   | +/- 0.01        |
| 557.5           | 0.669254   | +/- 0.01        |
| 560.0           | 0.668671   | +/- 0.01        |
| 562.5           | 0.669061   | +/- 0.01        |
| 565.0           | 0.668534   | +/- 0.01        |
| 567.5           | 0.667733   | +/- 0.01        |
| 570.0           | 0.667152   | +/- 0.01        |
| 572.5           | 0.667204   | +/- 0.01        |
| 575.0           | 0.667949   | +/- 0.01        |
| 577.5           | 0.667753   | +/- 0.01        |
| 580.0           | 0.666908   | +/- 0.01        |
| 582.5           | 0.666097   | +/- 0.01        |
| 585.0           | 0.664659   | +/- 0.01        |
| 587.5           | 0.66396  | +/- 0.01        |
| 590.0           | 0.662753   | +/- 0.01        |
| 592.5           | 0.662675   | +/- 0.01        |
| 595.0           | 0.662507   | +/- 0.01        |
| 597.5           | 0.663469   | +/- 0.01        |
| 600.0           | 0.664129   | +/- 0.01        |
| 602.5           | 0.664042   | +/- 0.01        |
| 605.0           | 0.66376  | +/- 0.01        |
| 607.5           | 0.663778   | +/- 0.01        |
| 610.0           | 0.663635   | +/- 0.01        |
| 612.5           | 0.663637   | +/- 0.01        |
| 615.0           | 0.662912   | +/- 0.01        |
| 617.5           | 0.663006   | +/- 0.01        |
| 620.0           | 0.662339   | +/- 0.01        |
| 622.5           | 0.661489   | +/- 0.01        |
| 625.0           | 0.660065   | +/- 0.01        |
| 627.5           | 0.659024   | +/- 0.01        |
| 630.0           | 0.657631   | +/- 0.01        |
| 632.5           | 0.657599   | +/- 0.01        |
| 635.0           | 0.657498   | +/- 0.01        |
| 637.5           | 0.653601   | +/- 0.01        |
| 640.0           | 0.649315   | +/- 0.01        |
| 642.5           | 0.644923   | +/- 0.01        |
| 645.0           | 0.644064   | +/- 0.01        |

| Wavelength (nm) | NAC FM Measured Optics Throughput (no clear filters) | Estimated Error |
|-----------------|--|-----------------|
| 647.5           | 0.643669   | +/- 0.01        |
| 650.0           | 0.644335   | +/- 0.01        |
| 652.5           | 0.643527   | +/- 0.01        |
| 655.0           | 0.642743   | +/- 0.01        |
| 657.5           | 0.642254   | +/- 0.01        |
| 660.0           | 0.641587   | +/- 0.01        |
| 662.5           | 0.639994   | +/- 0.01        |
| 665.0           | 0.638629   | +/- 0.01        |
| 667.5           | 0.637025   | +/- 0.01        |
| 670.0           | 0.635983   | +/- 0.01        |
| 672.5           | 0.636007   | +/- 0.01        |
| 675.0           | 0.636261   | +/- 0.01        |
| 677.5           | 0.635612   | +/- 0.01        |
| 680.0           | 0.635564   | +/- 0.01        |
| 682.5           | 0.635504   | +/- 0.01        |
| 685.0           | 0.635017   | +/- 0.01        |
| 687.5           | 0.63435  | +/- 0.01        |
| 690.0           | 0.633541   | +/- 0.01        |
| 692.5           | 0.632936   | +/- 0.01        |
| 695.0           | 0.630425   | +/- 0.01        |
| 697.5           | 0.629806   | +/- 0.01        |
| 700.0           | 0.628731   | +/- 0.01        |
| 702.5           | 0.628302   | +/- 0.01        |
| 705.0           | 0.626611   | +/- 0.01        |
| 707.5           | 0.627082   | +/- 0.01        |
| 710.0           | 0.624947   | +/- 0.01        |
| 712.5           | 0.625082   | +/- 0.01        |
| 715.0           | 0.624936   | +/- 0.01        |
| 717.5           | 0.624035   | +/- 0.01        |
| 720.0           | 0.621472   | +/- 0.01        |
| 722.5           | 0.620207   | +/- 0.01        |
| 725.0           | 0.618304   | +/- 0.01        |
| 727.5           | 0.616695   | +/- 0.01        |
| 730.0           | 0.616825   | +/- 0.01        |
| 732.5           | 0.616371   | +/- 0.01        |
| 735.0           | 0.615353   | +/- 0.01        |
| 737.5           | 0.614178   | +/- 0.01        |
| 740.0           | 0.611598   | +/- 0.01        |
| 742.5           | 0.611182   | +/- 0.01        |
| 745.0           | 0.610909   | +/- 0.01        |
| 747.5           | 0.608123   | +/- 0.01        |
| 750.0           | 0.605979   | +/- 0.01        |
| 752.5           | 0.604623   | +/- 0.01        |
| 755.0           | 0.604318   | +/- 0.01        |
| 757.5           | 0.603355   | +/- 0.01        |
| 760.0           | 0.601727   | +/- 0.01        |
| 762.5           | 0.600476   | +/- 0.01        |
| 765.0           | 0.598939   | +/- 0.01        |
| 767.5           | 0.598923   | +/- 0.01        |
| 770.0           | 0.598605   | +/- 0.01        |
| 772.5           | 0.596773   | +/- 0.01        |
| 775.0           | 0.594412   | +/- 0.01        |
| 777.5           | 0.592905   | +/- 0.01        |
| 780.0           | 0.591403   | +/- 0.01        |
| 782.5           | 0.588115   | +/- 0.01        |
| 785.0           | 0.585117   | +/- 0.01        |
| 787.5           | 0.584136   | +/- 0.01        |
| 790.0           | 0.584238   | +/- 0.01        |
| 792.5           | 0.582535   | +/- 0.01        |
| 795.0           | 0.580873   | +/- 0.01        |
| 797.5           | 0.5801   | +/- 0.01        |

| Wavelength (nm) | NAC FM Measured Optics Throughput (no clear filters) | Estimated Error |
|-----------------|--|-----------------|
| 800.0           | 0.578774   | +/- 0.01        |
| 802.5           | 0.577075   | +/- 0.01        |
| 805.0           | 0.575282   | +/- 0.01        |
| 807.5           | 0.574157   | +/- 0.01        |
| 810.0           | 0.573614   | +/- 0.01        |
| 812.5           | 0.573236   | +/- 0.01        |
| 815.0           | 0.573173   | +/- 0.01        |
| 817.5           | 0.573157   | +/- 0.01        |
| 820.0           | 0.57307  | +/- 0.01        |
| 822.5           | 0.574713   | +/- 0.01        |
| 825.0           | 0.576281   | +/- 0.01        |
| 827.5           | 0.576664   | +/- 0.01        |
| 830.0           | 0.576196   | +/- 0.01        |
| 832.5           | 0.577758   | +/- 0.01        |
| 835.0           | 0.578361   | +/- 0.01        |
| 837.5           | 0.578099   | +/- 0.01        |
| 840.0           | 0.576351   | +/- 0.01        |
| 842.5           | 0.57632  | +/- 0.01        |
| 845.0           | 0.577151   | +/- 0.01        |
| 847.5           | 0.57867  | +/- 0.01        |
| 850.0           | 0.580879   | +/- 0.01        |
| 852.5           | 0.581494   | +/- 0.01        |
| 855.0           | 0.582271   | +/- 0.01        |
| 857.5           | 0.582925   | +/- 0.01        |
| 860.0           | 0.584689   | +/- 0.01        |
| 862.5           | 0.586611   | +/- 0.01        |
| 865.0           | 0.588252   | +/- 0.01        |
| 867.5           | 0.589991   | +/- 0.01        |
| 870.0           | 0.591469   | +/- 0.01        |
| 872.5           | 0.594908   | +/- 0.01        |
| 875.0           | 0.59805  | +/- 0.01        |
| 877.5           | 0.601201   | +/- 0.01        |
| 880.0           | 0.603899   | +/- 0.01        |
| 882.5           | 0.607519   | +/- 0.01        |
| 885.0           | 0.609732   | +/- 0.01        |
| 887.5           | 0.611277   | +/- 0.01        |
| 890.0           | 0.613863   | +/- 0.01        |
| 892.5           | 0.616843   | +/- 0.01        |
| 895.0           | 0.622217   | +/- 0.01        |
| 897.5           | 0.626466   | +/- 0.01        |
| 900.0           | 0.63095  | +/- 0.02        |
| 902.5           | 0.63352  | +/- 0.02        |
| 905.0           | 0.636876   | +/- 0.02        |
| 907.5           | 0.639815   | +/- 0.02        |
| 910.0           | 0.642015   | +/- 0.02        |
| 912.5           | 0.64261  | +/- 0.02        |
| 915.0           | 0.646038   | +/- 0.02        |
| 917.5           | 0.650647   | +/- 0.02        |
| 920.0           | 0.656701   | +/- 0.02        |
| 922.5           | 0.659416   | +/- 0.02        |
| 925.0           | 0.660911   | +/- 0.02        |
| 927.5           | 0.663652   | +/- 0.02        |
| 930.0           | 0.666736   | +/- 0.02        |
| 932.5           | 0.669741   | +/- 0.02        |
| 935.0           | 0.672266   | +/- 0.02        |
| 937.5           | 0.674605   | +/- 0.02        |
| 940.0           | 0.676498   | +/- 0.02        |
| 942.5           | 0.677369   | +/- 0.02        |
| 945.0           | 0.677264   | +/- 0.02        |
| 947.5           | 0.677466   | +/- 0.02        |
| 950.0           | 0.679569   | +/- 0.02        |

| Wavelength (nm) | NAC FM Measured Optics Throughput (no clear filters) | Estimated Error |
|-----------------|--|-----------------|
| 952.5           | 0.678921   | +/- 0.02        |
| 955.0           | 0.680369   | +/- 0.02        |
| 957.5           | 0.682679   | +/- 0.02        |
| 960.0           | 0.683384   | +/- 0.02        |
| 962.5           | 0.684725   | +/- 0.02        |
| 965.0           | 0.686171   | +/- 0.02        |
| 967.5           | 0.688421   | +/- 0.02        |
| 970.0           | 0.690047   | +/- 0.02        |
| 972.5           | 0.691165   | +/- 0.02        |
| 975.0           | 0.691539   | +/- 0.02        |
| 977.5           | 0.691074   | +/- 0.02        |
| 980.0           | 0.69096  | +/- 0.02        |
| 982.5           | 0.694667   | +/- 0.02        |
| 985.0           | 0.69521  | +/- 0.02        |
| 987.5           | 0.691227   | +/- 0.02        |
| 990.0           | 0.693135   | +/- 0.02        |
| 992.5           | 0.694604   | +/- 0.02        |
| 995.0           | 0.694992   | +/- 0.02        |
| 997.5           | 0.695803   | +/- 0.02        |
| 1000.0          | 0.701511   | +/- 0.04        |
| 1002.5          | 0.693289   | +/- 0.04        |
| 1005.0          | 0.693104   | +/- 0.04        |
| 1007.5          | 0.691664   | +/- 0.04        |
| 1010.0          | 0.690212   | +/- 0.04        |
| 1012.5          | 0.688364   | +/- 0.04        |
| 1015.0          | 0.687829   | +/- 0.04        |
| 1017.5          | 0.688942   | +/- 0.04        |
| 1020.0          | 0.688617   | +/- 0.04        |
| 1022.5          | 0.687154   | +/- 0.04        |
| 1025.0          | 0.685143   | +/- 0.04        |
| 1027.5          | 0.682697   | +/- 0.04        |
| 1030.0          | 0.682897   | +/- 0.04        |
| 1032.5          | 0.683094   | +/- 0.04        |
| 1035.0          | 0.684078   | +/- 0.04        |
| 1037.5          | 0.682947   | +/- 0.04        |
| 1040.0          | 0.681447   | +/- 0.04        |
| 1042.5          | 0.681196   | +/- 0.04        |
| 1045.0          | 0.683318   | +/- 0.04        |
| 1047.5          | 0.685014   | +/- 0.04        |
| 1050.0          | 0.684852   | +/- 0.05        |
| 1052.5          | 0.682304   | +/- 0.05        |
| 1055.0          | 0.677682   | +/- 0.05        |
| 1057.5          | 0.670812   | +/- 0.05        |
| 1060.0          | 0.665709   | +/- 0.05        |
| 1062.5          | 0.66278  | +/- 0.05        |
| 1065.0          | 0.661294   | +/- 0.05        |
| 1067.5          | 0.661532   | +/- 0.05        |
| 1070.0          | 0.663326   | +/- 0.05        |
| 1072.5          | 0.666248   | +/- 0.05        |
| 1075.0          | 0.664435   | +/- 0.05        |
| 1077.5          | 0.667395   | +/- 0.05        |
| 1080.0          | 0.669051   | +/- 0.05        |
| 1082.5          | 0.667316   | +/- 0.05        |
| 1085.0          | 0.658981   | +/- 0.05        |
| 1087.5          | 0.656788   | +/- 0.05        |
| 1090.0          | 0.654305   | +/- 0.05        |
| 1092.5          | 0.651402   | +/- 0.05        |
| 1095.0          | 0.644742   | +/- 0.05        |
| 1097.5          | 0.635154   | +/- 0.05        |
| 1100.0          | 0.620875   | +/- 0.05        |

**Table 4.1.2-5 - Measured WAC FM Optics Data (no clear filters)**

| Wavelength (nm) | WAC FM Measured Optics Throughput (no clear filters) |
|-----------------|--|
| 390.000         | 0.00712497   |
| 392.500         | 0.0227316  |
| 395.000         | 0.0399354  |
| 397.500         | 0.0587102  |
| 400.000         | 0.0797417  |
| 402.500         | 0.103947   |
| 405.000         | 0.131734   |
| 407.500         | 0.162938   |
| 410.000         | 0.197132   |
| 412.500         | 0.23494  |
| 415.000         | 0.275205   |
| 417.500         | 0.311944   |
| 420.000         | 0.349586   |
| 422.500         | 0.393934   |
| 425.000         | 0.427976   |
| 427.500         | 0.463117   |
| 430.000         | 0.495747   |
| 432.500         | 0.525481   |
| 435.000         | 0.562746   |
| 437.500         | 0.577603   |
| 440.000         | 0.598033   |
| 442.500         | 0.622478   |
| 445.000         | 0.642025   |
| 447.500         | 0.656104   |
| 450.000         | 0.668836   |
| 452.500         | 0.681026   |
| 455.000         | 0.692338   |
| 457.500         | 0.700499   |
| 460.000         | 0.709394   |
| 462.500         | 0.718559   |
| 465.000         | 0.725693   |
| 467.500         | 0.730294   |
| 470.000         | 0.733255   |
| 472.500         | 0.734235   |
| 475.000         | 0.736712   |
| 477.500         | 0.739171   |
| 480.000         | 0.741533   |
| 482.500         | 0.744193   |
| 485.000         | 0.745977   |
| 487.500         | 0.747869   |
| 490.000         | 0.748602   |
| 492.500         | 0.748416   |
| 495.000         | 0.749029   |
| 497.500         | 0.749302   |
| 500.000         | 0.750086   |
| 502.500         | 0.750767   |
| 505.000         | 0.751649   |
| 507.500         | 0.752433   |
| 510.000         | 0.75305  |
| 512.500         | 0.753308   |
| 515.000         | 0.753704   |
| 517.500         | 0.755539   |

| Wavelength (nm) | WAC FM Measured Optics Throughput (no clear filters) |
|-----------------|--|
| 520.000         | 0.755608   |
| 522.500         | 0.756382   |
| 525.000         | 0.755976   |
| 527.500         | 0.754947   |
| 530.000         | 0.754492   |
| 532.500         | 0.753012   |
| 535.000         | 0.751759   |
| 537.500         | 0.750851   |
| 540.000         | 0.749334   |
| 542.500         | 0.747904   |
| 545.000         | 0.747416   |
| 547.500         | 0.74657  |
| 550.000         | 0.746004   |
| 552.500         | 0.74539  |
| 555.000         | 0.745099   |
| 557.500         | 0.744729   |
| 560.000         | 0.743781   |
| 562.500         | 0.744058   |
| 565.000         | 0.743895   |
| 567.500         | 0.743333   |
| 570.000         | 0.742693   |
| 572.500         | 0.741945   |
| 575.000         | 0.742037   |
| 577.500         | 0.74239  |
| 580.000         | 0.743133   |
| 582.500         | 0.744592   |
| 585.000         | 0.745351   |
| 587.500         | 0.745897   |
| 590.000         | 0.745149   |
| 592.500         | 0.744225   |
| 595.000         | 0.742661   |
| 597.500         | 0.741468   |
| 600.000         | 0.740442   |
| 602.500         | 0.740064   |
| 605.000         | 0.740444   |
| 607.500         | 0.74125  |
| 610.000         | 0.741576   |
| 612.500         | 0.741865   |
| 615.000         | 0.741709   |
| 617.500         | 0.742867   |
| 620.000         | 0.74362  |
| 622.500         | 0.743879   |
| 625.000         | 0.743525   |
| 627.500         | 0.742669   |
| 630.000         | 0.741005   |
| 632.500         | 0.738993   |
| 635.000         | 0.737015   |
| 637.500         | 0.734357   |
| 640.000         | 0.732288   |
| 642.500         | 0.729985   |
| 645.000         | 0.727255   |
| 647.500         | 0.72424  |



| Wavelength (nm) | WAC FM Measured Optics Throughput (no clear filters) |
|-----------------|--|
| 650.000         | 0.721265   |
| 652.500         | 0.718074   |
| 655.000         | 0.7164   |
| 657.500         | 0.715486   |
| 660.000         | 0.713094   |
| 662.500         | 0.707873   |
| 665.000         | 0.702052   |
| 667.500         | 0.697514   |
| 670.000         | 0.693512   |
| 672.500         | 0.689583   |
| 675.000         | 0.685293   |
| 677.500         | 0.680113   |
| 680.000         | 0.674987   |
| 682.500         | 0.669288   |
| 685.000         | 0.662933   |
| 687.500         | 0.656672   |
| 690.000         | 0.651281   |
| 692.500         | 0.646348   |
| 695.000         | 0.64189  |
| 697.500         | 0.638134   |
| 700.000         | 0.634222   |
| 702.500         | 0.629523   |
| 705.000         | 0.62368  |
| 707.500         | 0.617528   |
| 710.000         | 0.610454   |
| 712.500         | 0.601536   |
| 715.000         | 0.593337   |
| 717.500         | 0.585409   |
| 720.000         | 0.578379   |
| 722.500         | 0.571856   |
| 725.000         | 0.565401   |
| 727.500         | 0.559096   |
| 730.000         | 0.552861   |
| 732.500         | 0.546008   |
| 735.000         | 0.538516   |
| 737.500         | 0.530038   |
| 740.000         | 0.520918   |
| 742.500         | 0.511913   |
| 745.000         | 0.504012   |
| 747.500         | 0.498225   |
| 750.000         | 0.492536   |
| 752.500         | 0.486219   |
| 755.000         | 0.479375   |
| 757.500         | 0.472479   |
| 760.000         | 0.464118   |
| 762.500         | 0.454553   |
| 765.000         | 0.443188   |
| 767.500         | 0.432247   |
| 770.000         | 0.422417   |
| 772.500         | 0.414454   |
| 775.000         | 0.407985   |
| 777.500         | 0.402079   |
| 780.000         | 0.397545   |
| 782.500         | 0.393959   |
| 785.000         | 0.390366   |
| 787.500         | 0.385768   |
| 790.000         | 0.381067   |
| 792.500         | 0.375299   |
| 795.000         | 0.368807   |
| 797.500         | 0.361089   |
| 800.000         | 0.352683   |

| Wavelength (nm) | WAC FM Measured Optics Throughput (no clear filters) |
|-----------------|--|
| 802.500         | 0.344553   |
| 805.000         | 0.336478   |
| 807.500         | 0.328055   |
| 810.000         | 0.319875   |
| 812.500         | 0.311787   |
| 815.000         | 0.304202   |
| 817.500         | 0.296556   |
| 820.000         | 0.289043   |
| 822.500         | 0.282377   |
| 825.000         | 0.2761   |
| 827.500         | 0.27048  |
| 830.000         | 0.265169   |
| 832.500         | 0.259885   |
| 835.000         | 0.255035   |
| 837.500         | 0.250913   |
| 840.000         | 0.247224   |
| 842.500         | 0.243221   |
| 845.000         | 0.238979   |
| 847.500         | 0.234505   |
| 850.000         | 0.230216   |
| 852.500         | 0.226249   |
| 855.000         | 0.222377   |
| 857.500         | 0.217885   |
| 860.000         | 0.213225   |
| 862.500         | 0.208692   |
| 865.000         | 0.20423  |
| 867.500         | 0.199886   |
| 870.000         | 0.19551  |
| 872.500         | 0.191411   |
| 875.000         | 0.187067   |
| 877.500         | 0.1826   |
| 880.000         | 0.178145   |
| 882.500         | 0.173895   |
| 885.000         | 0.169856   |
| 887.500         | 0.166068   |
| 890.000         | 0.162756   |
| 892.500         | 0.159861   |
| 895.000         | 0.157103   |
| 897.500         | 0.154792   |
| 900.000         | 0.152505   |
| 902.500         | 0.150339   |
| 905.000         | 0.148244   |
| 907.500         | 0.146102   |
| 910.000         | 0.143897   |
| 912.500         | 0.141603   |
| 915.000         | 0.139176   |
| 917.500         | 0.136589   |
| 920.000         | 0.134034   |
| 922.500         | 0.13146  |
| 925.000         | 0.128902   |
| 927.500         | 0.12639  |
| 930.000         | 0.123945   |
| 932.500         | 0.121678   |
| 935.000         | 0.119615   |
| 937.500         | 0.117648   |
| 940.000         | 0.115814   |
| 942.500         | 0.114088   |
| 945.000         | 0.112348   |
| 947.500         | 0.110662   |
| 950.000         | 0.108885   |
| 952.500         | 0.107143   |

| Wavelength (nm) | WAC FM Measured Optics Throughput (no clear filters) |
|-----------------|--|
| 955.000         | 0.105364   |
| 957.500         | 0.103644   |
| 960.000         | 0.101817   |
| 962.500         | 0.100048   |
| 965.000         | 0.0982311  |
| 967.500         | 0.0964145  |
| 970.000         | 0.094628   |
| 972.500         | 0.0928785  |
| 975.000         | 0.0910693  |
| 977.500         | 0.0893278  |
| 980.000         | 0.0875891  |
| 982.500         | 0.0858167  |
| 985.000         | 0.0841241  |
| 987.500         | 0.0824661  |
| 990.000         | 0.0808593  |
| 992.500         | 0.0793609  |
| 995.000         | 0.0779913  |
| 997.500         | 0.0766841  |
| 1000.000        | 0.0755153  |
| 1002.500        | 0.0744007  |
| 1005.000        | 0.0733873  |
| 1007.500        | 0.0724537  |
| 1010.000        | 0.0716057  |
| 1012.500        | 0.0708158  |
| 1015.000        | 0.0700876  |
| 1017.500        | 0.0694216  |
| 1020.000        | 0.0687859  |
| 1022.500        | 0.0682748  |
| 1025.000        | 0.0678464  |
| 1027.500        | 0.0674233  |

| Wavelength (nm) | WAC FM Measured Optics Throughput (no clear filters) |
|-----------------|--|
| 1030.000        | 0.0668451  |
| 1032.500        | 0.0659356  |
| 1035.000        | 0.0646805  |
| 1037.500        | 0.0631702  |
| 1040.000        | 0.0615266  |
| 1042.500        | 0.0597644  |
| 1045.000        | 0.0580548  |
| 1047.500        | 0.0564068  |
| 1050.000        | 0.0549316  |
| 1052.500        | 0.0537024  |
| 1055.000        | 0.0526993  |
| 1057.500        | 0.0517382  |
| 1060.000        | 0.050836   |
| 1062.500        | 0.0498167  |
| 1065.000        | 0.0486292  |
| 1067.500        | 0.047191   |
| 1070.000        | 0.0455628  |
| 1072.500        | 0.0438525  |
| 1075.000        | 0.042118   |
| 1077.500        | 0.0404205  |
| 1080.000        | 0.0388304  |
| 1082.500        | 0.0374445  |
| 1085.000        | 0.0362172  |
| 1087.500        | 0.035167   |
| 1090.000        | 0.0342332  |
| 1092.500        | 0.033415   |
| 1095.000        | 0.0326772  |
| 1097.500        | 0.0320382  |
| 1100.000        | 0.0314832  |

Note : The electronic data from the referenced reports has be archived (see Appendix E). The data tables which show and compare the Allocated vs. Measured Optics Throughput can be found in Appendix F.