

Characterization Tests of WFC3 Filters

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Abstract.

The WFC3 instrument to be installed on HST during the next servicing mission consists of a UVIS and an IR channel. Each channel is allocated its own complement of filters: 48 elements for the UVIS (42 filters, 5 quads, and 1 UV grism) and 17 slots for the IR (15 filters and 2 grisms). While a majority of the UVIS filters exhibit excellent performance consistent with or exceeding expectations, a subset show significant filter ghosts. Procurement of improved replacement filters is in progress and a summary of the characterization tests being performed on the new filters is presented. In the IR channel, while no filter ghosting was detected in any of the filters during thermal vacuum testing, the grisms were found to be installed incorrectly; they have been removed and will be reinstalled. In addition, due to the significantly improved response blueward of 800nm expected in the new substrate-removed IR detector (see Invited talk by R.A.Kimble, this volume), two IR filters originally constructed on a fused silica substrate are being remade using an IR transmitting color glass to block any visible light transmission. Tests of the new IR filters and preparations for the grism reinstallation are summarized.

1. Introduction

The replacement filters being manufactured for WFC3 are subjected to a rigorous set of characterization tests. The test suite is designed to verify conformance of the new filters to the filter requirements. Testing begins at the manufacturer, where numerous checks are performed before shipment of the filters to GSFC. Upon receipt at GSFC, the filters undergo further extensive testing, including a detailed visual inspection, imaging tests (point source and flat field), spectral scans, and environmental checks. Results are analyzed and discussed within the WFC3 team; recommendations for potential replacement filters are presented to the WFC3 Science Oversight Committee for their evaluation and approval. The WFC3 replacement filter characterization process is summarized in Figure 1; the individual steps are described in more detail in the sections that follow.

2. Characterization Tests

Vendor Tests Comprehensive checks are performed by the manufacturer prior to shipment of the filter to the customer. These tests verify the filters' compliance with the specifications and the robustness of the filter coating. Key items measured on the candidate flight pieces

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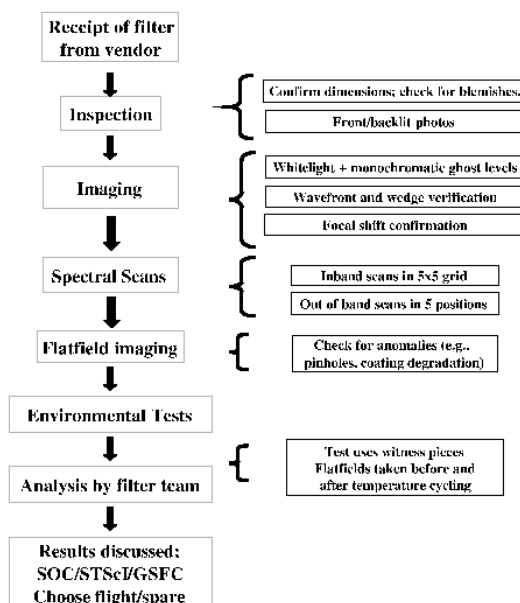


Figure 1: The characterization test process.

include the spectral throughput (primary bandpass as well as out of band blocking), transmissive wavefront (on uncoated substrate as well as the coated filter), and quality control (check of length, width, thickness, inspection for scratches and cosmetic defects, painting of any pinholes, and cleaning). Characteristics such as the coating integrity (adhesion quality, resistance to abrasions, temperature and humidity cycling) and radiation hardness are performed on witness or flight-like pieces.

Inspection Upon receipt of the filter from the vendor, a detailed inspection is performed. The dimensions of the filter are confirmed and the item is inspected for any blemishes or coating defects. Photographs, both front and backlit, are taken to document the condition of the filter and map any pinholes which may be present (see Figure 2a).

Imaging Extensive point source imaging is done with each filter; tests are performed using white (either xenon or deuterium lamp) as well as monochromatic (200-1000nm) light. These data allow for measurement of filter ghosts (strength, appearance, and behavior), as well as wavefront, wedge, and focus shift. Figure 2b shows a whitelight image of a candidate F689M filter. The image was taken at a relatively high filter tilt angle; this moves the ghost away from the PSF and facilitates measurement of the ghost level. The setup ghost is an artifact of the lab setup and appears even without a filter in the beam. Images are taken at a variety of tilt angles and translation positions as well as in configurations simulating seventeen points distributed across the WFC3 field of view. Figure 3a presents a monochromatic scan of the ghosts measured in a candidate filter. The monochromatic results are used to constrain the model, which in turn is used to predict ghost behavior as a function of target spectral type. Figure 3b shows a small subset of images from a phase retrieval dataset. Focus sweeps are obtained through a 9x9 array of 10mm apertures covering the filter, separated by steps of 5mm. Wavefront data taken without a filter are subtracted, including focus and tilt, yielding wavefront error, focus shift, and wedge.

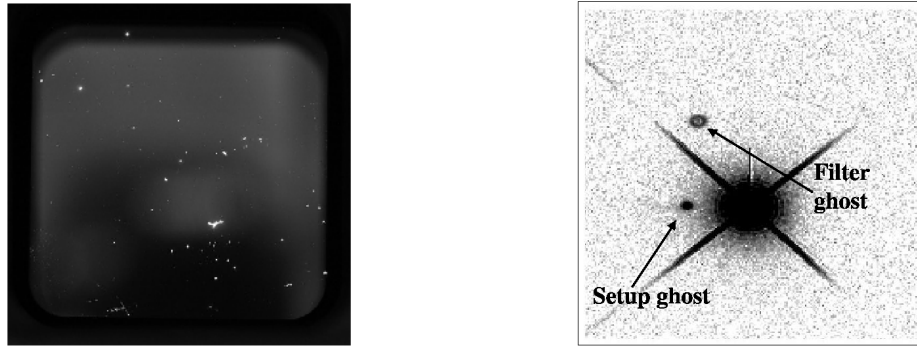


Figure 2: (a) At left is a pinhole image of F280N. (b) At right is an image of the ghost in F689M; filter ghost is at upper left; the feature to the left of the PSF is due to the lab setup.)

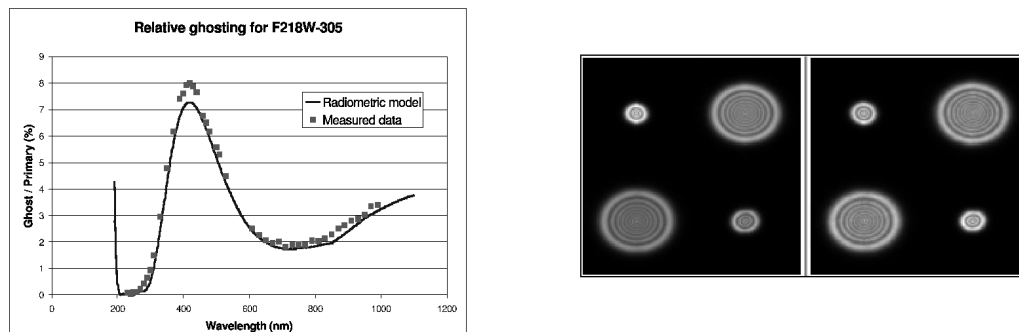


Figure 3: (a) The plot at left shows the excellent agreement between the monochromatic data and model for an F218W filter. Note: the fairly high ghost intensities shown occur out of band, where the filter blocking is significant; integrated over a continuum source, the relative ghost strengths are much lower. (b) The image at right shows a mosaic of a small subset of PSFs taken during a typical phase retrieval test.

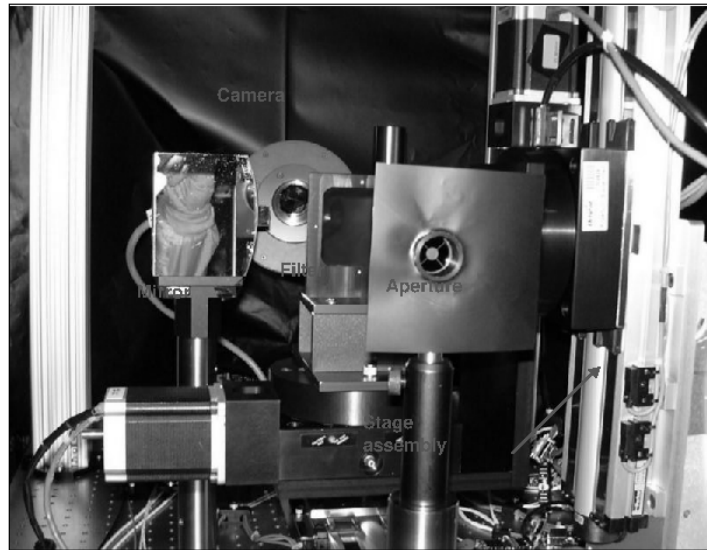


Figure 4: The FilterGEISt lab setup is used for obtaining imaging data of candidate filters.

Imaging tests are performed using FilterGEISt (filter ghost evaluation imaging station, see photo in Figure 4), a dedicated lab setup which reproduces the WFC3 UVIS + HST optical parameters. A 4-axis stage assembly provides repeatable translation/rotation motions as well as simulations of sources within the WFC3 FOV.

Spectral Scans The spectral throughput of the filter is measured both in and out of band using a PerkinElmer 950. Scans are taken at multiple points to allow an assessment of uniformity. In-band UVIS scans are performed in a 5x5 grid across the filter while out of band UVIS scans are executed in the center of the filter and at the four corners. Figures 5a and 5b illustrate typical in and out of band scans which are evaluated in light of the input specifications.

Flat field images The fine scale transmission properties of the filter are verified via flat fielding. The imaging setup is designed to simulate that of the WFC3 internal calibration system (divergent beam). The entire filter is covered, to check for blemishes, coating degradation, or any other anomalies that may be present.

Environmental Tests Filter witnesses and non-flight pieces are subjected to temperature cycling under thermal vacuum (TV) conditions in order to verify the robustness of the coatings. Baseline inspections, spectral scans, and flat fields are taken prior to the test. The cycles are designed to mimic the TV conditions the filters are expected to experience during ground testing and on-orbit. After the cycles, another round of inspections, spectral scans, and flatfields are taken to check for any evidence of coating degradation.

Filter Selection The final choice of which, if any, replacement filters to fly resides with the WFC3 Science Oversight Committee, with analysis inputs from the STScI and GSFC WFC3 teams. The decision is based upon a careful balance of the characterization test results for

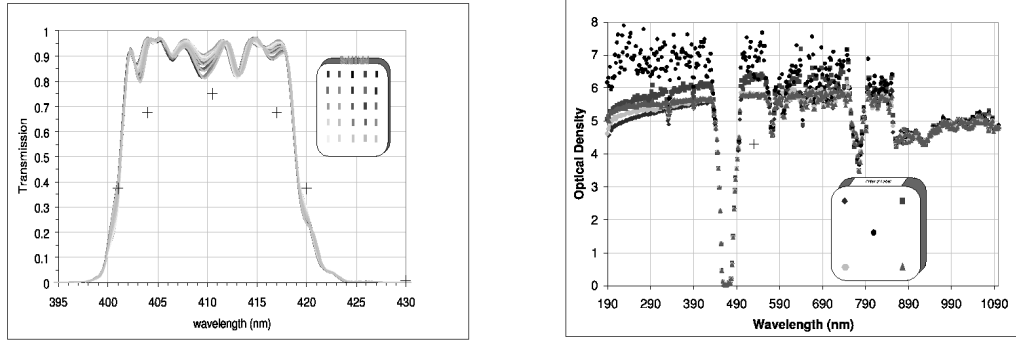


Figure 5: (a) The plot at left presents a representative inband transmission scan, in this case, for an F410M candidate. (b) The image at right shows the blocking scan for an F467M candidate.

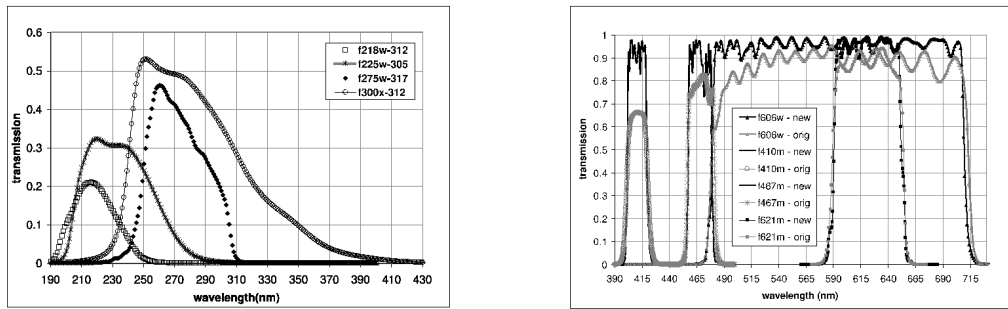


Figure 6: (a) The plot at left summarizes the new UV replacement filter bandpasses. (b) At right are spectral scans for the old and new visible filters.

the new filters versus the characteristics of the current flight filters as determined from previous filter tests as well as instrument-level ambient and thermal vacuum tests.

3. Replacement Filters

The UV is a critical part of the WFC3 bandpass coverage; Figure 6a summarizes the new UV replacement filter bandpasses. In most cases, the filter development technology now available has provided increased throughput in addition to reducing the ghost levels. For example, in F225W (which showed the most improvement) the ghost levels are reduced from about 15 percent to less than 0.3 percent and the new filter grasp (integral of the filter and WFC3 transmission over wavelength in the primary bandpass) is about 30 percent more than the original flight filter. Ghost levels in the visible filters have been reduced as well (some even eliminated) and again, in most cases the grasp of the new filter is higher than in the old filter. Figure 6b provides a comparison of the bandpasses of the original and new visible filters.

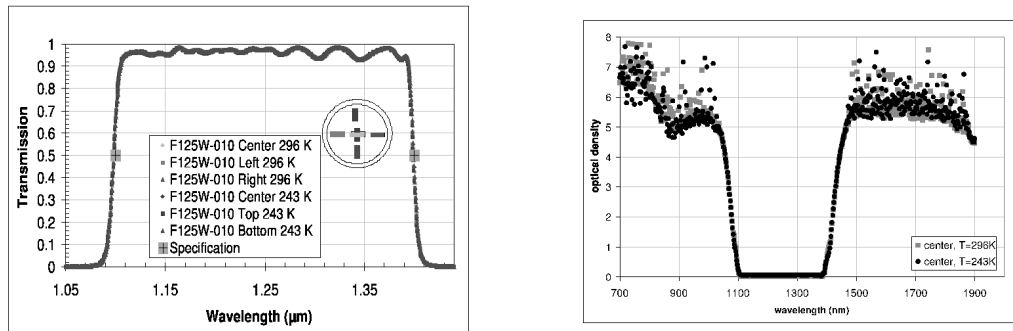


Figure 7: Plots showing typical inband (a) and out of band (b) transmission curves for a candidate F125W filter.

4. IR filter testing

No filter ghosts were found in the IR filters during instrument-level testing but two filters originally constructed on fused silica (because the QE of the original IR detector was low in the blue) must be remade on an IR-transmitting color glass (IR80). The change is driven by the new IR detectors under development, which are being thinned to reduce particle-induced luminescence in the CdZnTe substrate; the new detectors will have significant QE well blueward of 800nm. As with the UVIS filters, the IR replacement filters undergo a full set of characterization tests, including spectral scans at a variety of locations on the filter as well as at two temperatures (room temperature and nominal operating temperature of -30C). Given the relatively small filter size (25.4mm in diameter for IR, 53.2mm square for UVIS), the in-band IR scans are performed at 5 points and the out of band scans at filter center, as illustrated in Figure 7a and 7b. An IR InGaAS IR array camera will be incorporated into the FilterGEISt lab setup, in order to measure wavefront, wedge, and perform a ghost check. Finally, the two IR grisms which were installed incorrectly have been removed and will be reinstalled in the upcoming year. One of the grisms is being remade with an improved red edge in order to reduce the transmission of thermal background radiation, which led to an undesirably high background on the detector in thermal vacuum testing.

5. For more information about WFC3

<http://www.stsci.edu/hst/wfc3/> and <http://wfc3.gsfc.nasa.gov>