

SECOND GENERATION IR DETECTORS FOR THE WIDE FIELD CAMERA 3

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Abstract: High-energy particles induce a glow on the ZnCdTe substrate of the HgCdTe detectors of WFC3 that may increase the background noise and reduce the scientific performance of the instrument. To eliminate this problem, a second generation of infrared detectors with substrate removed is under construction. Early tests indicate that the glow problem is eliminated and the quantum efficiency increases dramatically at shorter wavelengths, potentially providing a substantial improvement in the limiting sensitivity of the instrument.

Key words: Hubble Space Telescope (HST); Wide Field Camera 3 (WFC3); HgCdTe detectors; ZnCdTe substrate removal.

1. INTRODUCTION

The Wide Field Camera 3 (WFC3) is the latest imager built for the Hubble Space Telescope (HST) and is planned to replace the Wide Field Planetary Camera 2 (WFPC2) in the next servicing mission to the HST. WFC3 (Fig.1) is configured as a two-channel instrument (Kimble et al. 2004). The UVIS channel provides diffraction limited imaging from the 2000 Å to ~1 μm and uses two large format E2V CCD43 4k×2k CCD devices optimized for near-UV sensitivity. The IR channel is optimized for the 0.8-1.7 μm region. It uses a HgCdTe focal plane from Rockwell Scientific Company (RSC) with long wavelength cutoff at 1.7 μm. The

detector, operating at 150 K, is hybridized on a Hawaii-1R multiplexer providing 1024×1024 pixels of 18 μ m pitch, including 5 outer rows and columns of reference pixels.

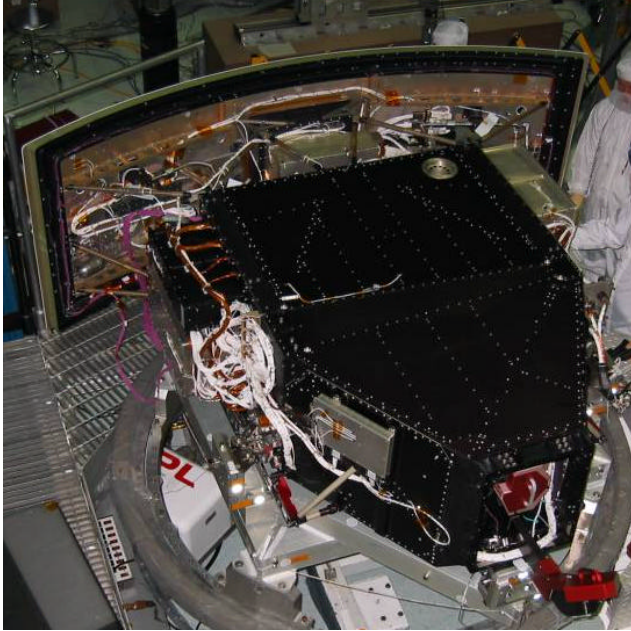


Figure 1. Fully assembled WFC3 at the Goddard Space Flight Center prior to installation of thermal blankets.

WFC3 has successfully conducted in September 2004 thermal vacuum performance characterization test at the Detector Characterization Laboratory (DCL) of the NASA Goddard Space Flight Center (GSFC). Its installation on the HST is contingent upon authorization of shuttle-based servicing of HST after successful return-to-flight.

2. CURRENT IR FLIGHT DEVICES: FPA64 AND FPA59

The production of the original flight detectors for WFC3-IR ended in Summer 2003 with the selection of two devices, FPA#64 as prime and FPA59 as backup (Robberto et al. 2004). FPA#64 has been packaged in its flight assembly (Fig.2) and underwent extensive thermal vacuum testing. In parallel with the integration and system level tests done at Ball and at the GSFC, the WFC3 team has carried out further test activities to characterize

the performance of similar devices in the space environment. In particular, the effects of cosmic ray radiation have been evaluated in two runs at UC Davis, exposing the detectors to proton beams of different energy and flux while they were operated in standard data acquisition mode. A surprising result of these tests (Hill et al. 2005) was the appearance of an extra diffuse background between the pixels directly hit by the protons. Systematic investigation of the phenomenon vs. input proton energy demonstrates that the source is the deposition of proton energy in the thick (~0.8mm) ZnCdTe substrate, while the morphological similarity of the background to the shape of short-wavelength flat fields suggests that the physical mechanism is likely luminescence near the short-wavelength cutoff of the ZnCdTe (near 800nm).

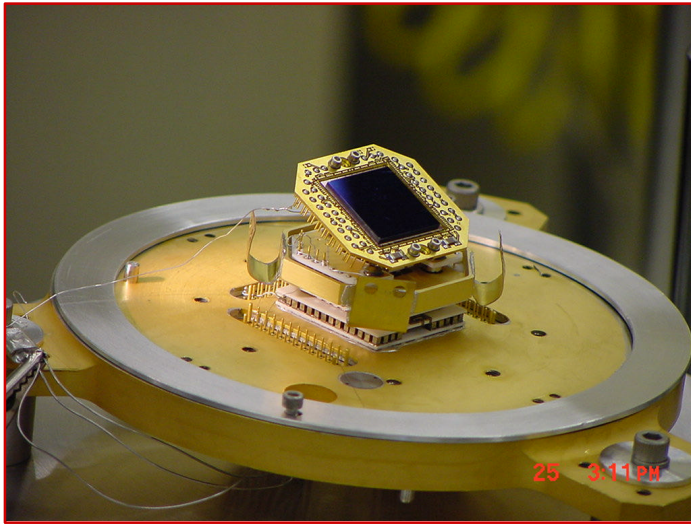


Figure 2. FPA64 packaged in its flight assembly.

Scaling of the laboratory results to the on-orbit high-energy particle fluxes suggests that this mechanism could add ~0.25 e/s/pixel to the diffuse background rate in the space environment, though in the absence of a detailed understanding of the physical mechanism this estimate is necessarily highly uncertain. This level of background could lead to a significant degradation of the sensitivity of the instrument.

RSC suggested that removing the entire ZnCdTe substrate should eliminate the anomaly. Substrate removal also offers the advantage of increasing the quantum efficiency in the J-band and pushes the blue cut-off of the detector down to 0.4 μ m.

3. SECOND GENERATION DETECTORS WITH SUBSTRATE REMOVED

The substrate removal process has been carried out by RSC on two early WFC3 detectors. Radiation tests made at U.C. Davis have demonstrated that with these devices the extra background is now undetectable, with upper

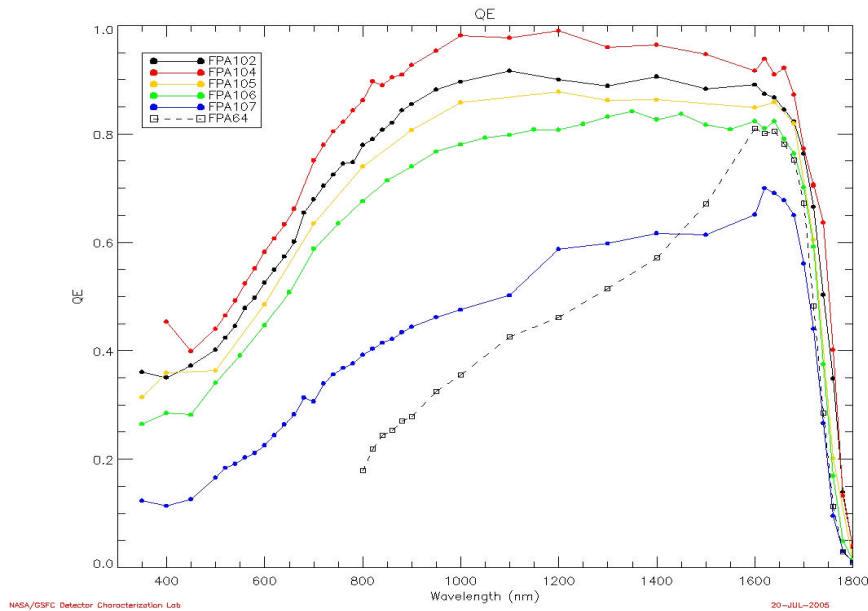


Figure 3. Comparison of the GSFC/DCL measured Quantum Efficiency of the current flight detector FPA#64 with a number of second generation, substrate removed, WFC3-IR FPAs. From top to bottom: FPA#104, FPA#102, FPA#105, FPA#106 (all substrate removed), FPA#107 (incomplete substrate removal), FPA#64. Detector gain was measured with photon transfer mode.

limits approximately three orders of magnitude lower than the previous substrate-induced background levels; scaled to the orbital environment, these limits correspond to a negligible level of background signal compared with the intrinsic dark current of the devices. Two new lots of detectors have since been produced, and recent measurements at the GSFC Detector Characterization Laboratory confirm the expected increase of QE at shorter wavelengths (Fig.3).

4. SCIENTIFIC PERFORMANCE

To illustrate the change in sensitivity, we compare in Fig.4 the performance attained by WFC3 with FPA#64 vs. the new substrate removed FPAs. We consider a few representative cases: 1) FPA#64 and WFC3 as-built; 2) FPA#64 with 1 e/s/pixel of extra glow due to cosmic rays (worst case scenario); 3) FPA#64 with 0.25 e/s/pixel extra glow (best guess scenario); 4) Second generation FPA with same RON of FPA#64 (24e/pixel DCS); 5) Second generation FPA with high RON (40 e/pixel DCS); 6) Second generation FPA with low RON (15e/pixel DCS). We consider 4 filters, F110W and F160W (approximately the standard J and H passbands); F126N (a representative narrow-band filter) and F093M, roughly corresponding to the z-band often used with CCD detectors (e.g. ACS/HST).

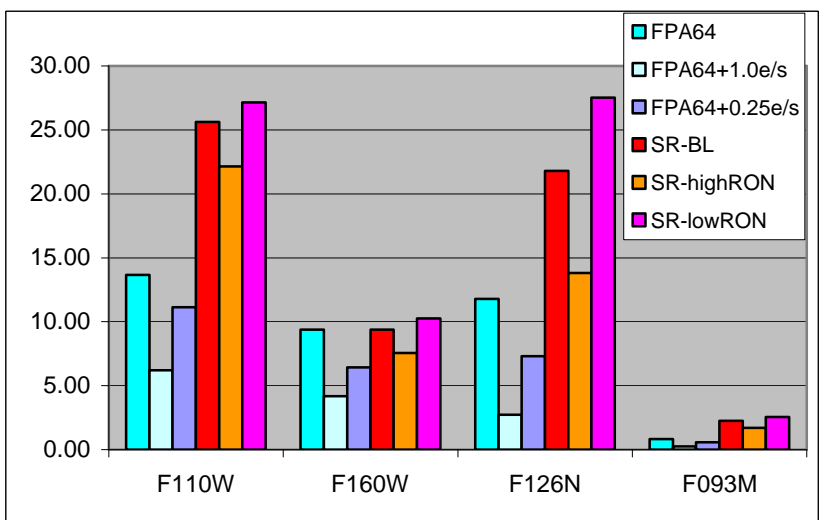


Figure 3. Discovery efficiency of WFC3 normalized to NICMOS Camera (F110W, F160W, F126N) and ACS/WFC (F093M).

Figure 3 shows the discovery efficiency (1/observing time needed to reach a given SNR on a faint point source \times the detector area in square arcmin) normalized to the current NIC3 values (to ACS for F093M). The second generation detectors could nearly double the discovery efficiency at short wavelengths and also be competitive with ACS in the F850LP (note however the different pixel scale: 013" of WFC3-IR vs. 0.05 of ACS); for broad-band surveys the gain in blue QE easily offsets a potential increase of readout noise. On the other hand, a luminescence of 1 e/s/pix would have a dramatic impact on the discovery efficiency with FPA#64.

5. CONCLUSION

ZnCdTe substrate removal on the WFC3 HgCdTe detectors eliminates proton-induced glow and significantly increases the detector QE at short wavelengths. Substrate removal therefore has two positive impacts on the limiting sensitivity of the instrument. Extensive tests are currently underway at GSFC/DCL to fully characterize the new devices. Early results are promising and suggest that WFC3 will significantly benefit from the inclusion of a substrate removed IR FPA.

REFERENCES:

Kimble, R. A., MacKenty, J.W., and O'Connell, R.W., and the WFC3 Team 2004, Proc. SPIE, 5487, 266

Robberto, M., Baggett, S. M., Hilbert, B., MacKenty, J. W., Kimble, R. A., Hill, R. J., Cottingham, D. A., Delo, G., Johnson, S. D., Landsman, W., Malumuth, E. M., Polidan, E., Russell, A.M., Waczynski, A., Wassell, E., Wen, Y., Haas, A., Montroy, J. T., Piquette, E. C., Vural, K., Cabelli, C., and Hall, D.B. 2004, Proc. SPIE 5499, 15

Hill et al. 2005, these Proceedings