1.13 ACIS CCD Sensitivity Ionizing and Non-Ionizing Radiation

Preliminary radiation damage tests of ACIS front illuminated ccds have been performed with two types of ionizing radiation sources. The Fe-55 x-ray source is expected to produce damage in the oxide layer and bulk oxide interface causing increased surface dark current and flat band voltage shifts. Because of the anticipated exceptional focusing of the HRMA this type of test is pertinent to the issue of overexposure and "burn-in" caused by bright x-ray sources. The high energy proton beam at the Harvard Cyclotron represents a class of radiation that primarily cause damage through collisions with silicon atoms. This displacement damage can result in trapping centers resulting in increased CTI and bulk dark current.

1.13.1 Ionizing Dose Effects

The x-ray ionizing dose test was made by placing an Fe-55 source in proximity to an engineering front illuminated ccid-17 with a geometrical baffle that limited exposure to a small section of the image array. No part of the frame store or serial register output node was exposed. The exposed region experienced a flux of 7 counts per pixel per second for 10 hours for a total equivalent dose of 900 rads. This exposure was made while the ccd was at room temperature in vacuum. The standard calibration timed exposure readout method was employed for all testing.

The most noticeable result of this test was the production of an area of enhanced dark current directly coincident with the exposed region (see figure 1.120). The dark current was uniform on small distance scales and no exceptionally hot pixels were seen. The enhanced dark current could only be measured for operating temperatures above -80 c. At the standard -120 c operating temperature no enhanced dark current could be measured even for exceptionally long integration times. Furthermore no increase in CTI was seen at any temperature. Long periods of high temperature bakeout (20 hours at +80 C) had no affect upon the damaged region, which appears to be a permanent feature. Experience with overexposure to x-rays at BESSY-PTB, XRCF-2CACIS and SES confirms the enduring nature of this type of radiation damage.

A similar x-ray ionizing dose experiment was made with a back illuminated ccd which yielded qualitatively similar results. A special overexposure of focussed bare carbon anode radiation on the backside w134c4 S3 was made as part of the XRCF testing. At -40 c an apparent spot of increased dark current can be seen but at lower temperatures this feature is not evident.

1.13.2 Effects of Energetic Protons

High-energy proton dose tests were made at the Harvard Cyclotron Laboratory where an engineering front illuminated ccid-17 was exposed to a well-characterized proton beam with 40 MeV peak energy. Exposures were made at room temperature in ambient air with a lead aperture that allowed irradiation of a controlled section of the image array. Irradiation occurred in incremental steps to a final total of 400 Rads. A minimum 48 hour period at ambient condition elapsed between exposure and all subsequent characterization. While there is evidence to suggest changes in post radiation behavior immediately following exposure with time scales of hours no changes were seen following the 2 day period - all damage features appear permanent and unaffected by subsequent temperature cycles.

As with the x-ray test the most noticeable result of proton beam exposure was the production of an area of enhanced dark current coincident with the exposed region. This dark current could not be measured for temperatures below -90 c. No flickering or hot pixels were detected at any temperature.

Proton damage is expected to produce traps whose presence can be seen by an increase in CTI, and indeed a gradual increase in CTI at a rate of 2 x 10-5 per kRad was seen when tested with a spatially uniform 25 count/sec/output Fe-55 source. A clocking method was used to create an adjustable line of charge in the image array. At -120 c this sacrificial charge technique only influenced pixels in the next few rows suggesting a detrapping time of order 100 microseconds. At -90 c the CTI is four times greater and the utility of the charge injection method more pronounced although improvements of any performance measure such as CTI or resolution could never be increased beyond levels achieved by normal operation at -120 c. Additional proton irradiation of just the frame store area had no affect upon the measured CTI but did continue to degrade the gain and resolution of the device. This is a consequence of the way in which CTI is measured.

Figure 1.121 shows the observed variation of CTI with proton dose.

1.13.3 Search for Effects of Short Exposure to Low-Earth Orbit on ACIS CCD Peformance

Two calibrated ACIS ccid17 units were flown aboard Space Shuttle Discovery for a 12 day mission in August 1997. (STS 85, OV-103) The devices, w157c1 and w147c3 (back illuminated) were in the normal input-shorted storage configuration in the standard shipping container which was stowed in the pressurized crew compartment.

Testing immediately before and after flight showed no change in performance for either device. Neither an increase in the number of hot or flickering pixels nor any CTI increase due to radiation exposure was seen.

Pre- and post-flight mean dark current maps for the two test devices are compared in figures reffig:w157dc and reffig:w147dc. These images are averages of at least ten individual exposures, each of 18 seconds. All except the pre-flight image of w157c1 (the front-illuminated device) were obtained with the detector temperature at -120C; the pre-flight image of w157c1 was obtained at -60C. The front illuminated device w157c1, which had a small edge glow and a bright defect prior to flight, showed no evidence of either feature during any post-flight testing. This change may have been a consequence of handling and may have nothing to do with the shuttle orbital environment. We conclude that low earth orbit shuttle cabin environment has no impact upon ccd performance for 1 week exposures.

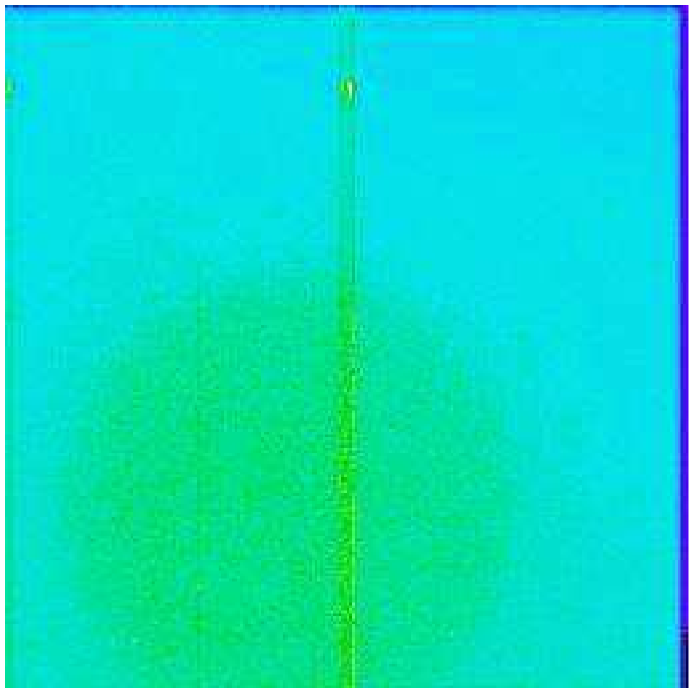


Figure 1.120: Dark current map showing circular area of exposure to 5.9 keV photons. Total dose was 900 rads (Si); this map was obtained with the device at -60C. At nominal operating temperature (-120C) no increase in dark current is measurable. Device quadrants 0-3 are from left to right; the serial register is toward the top of the picture.

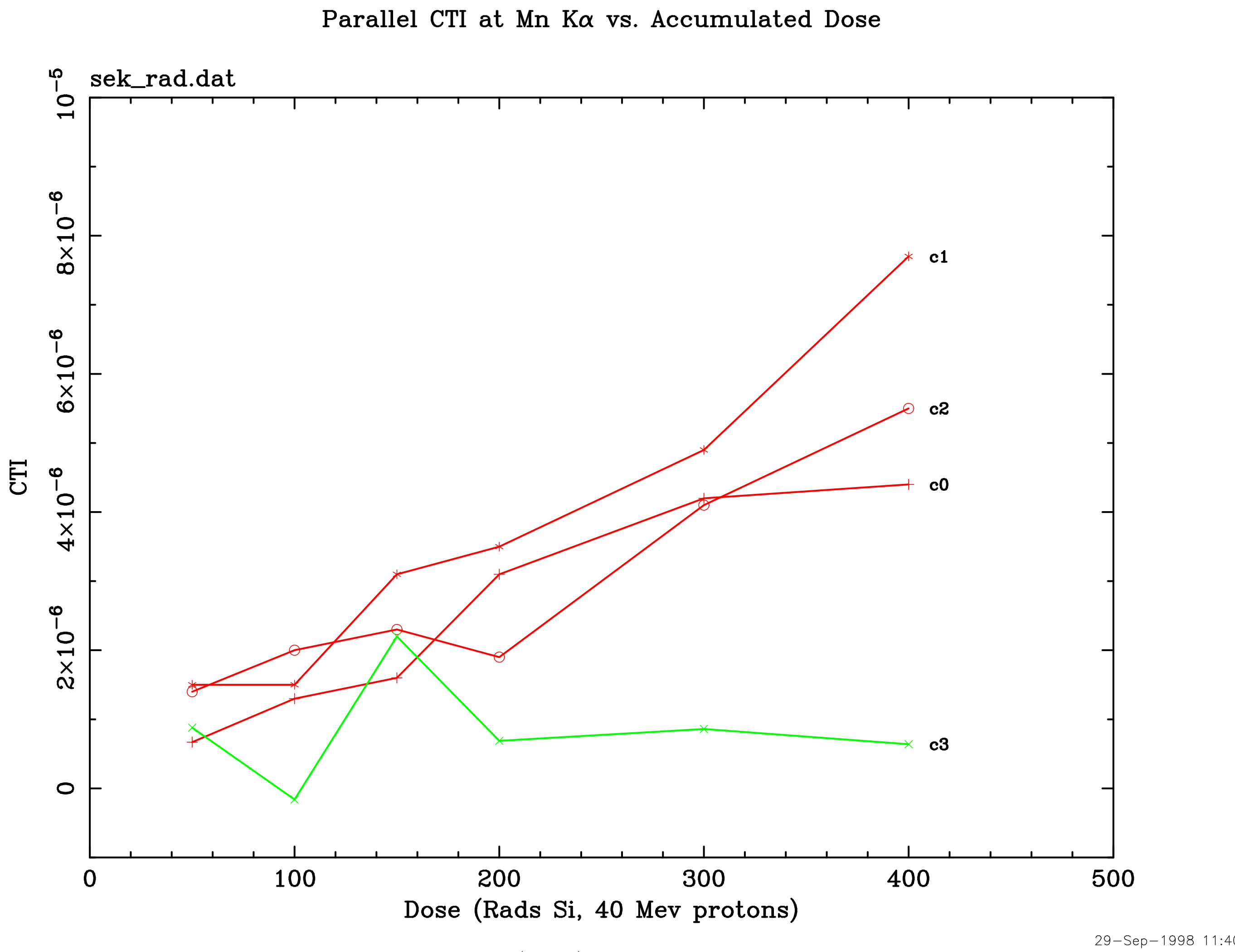
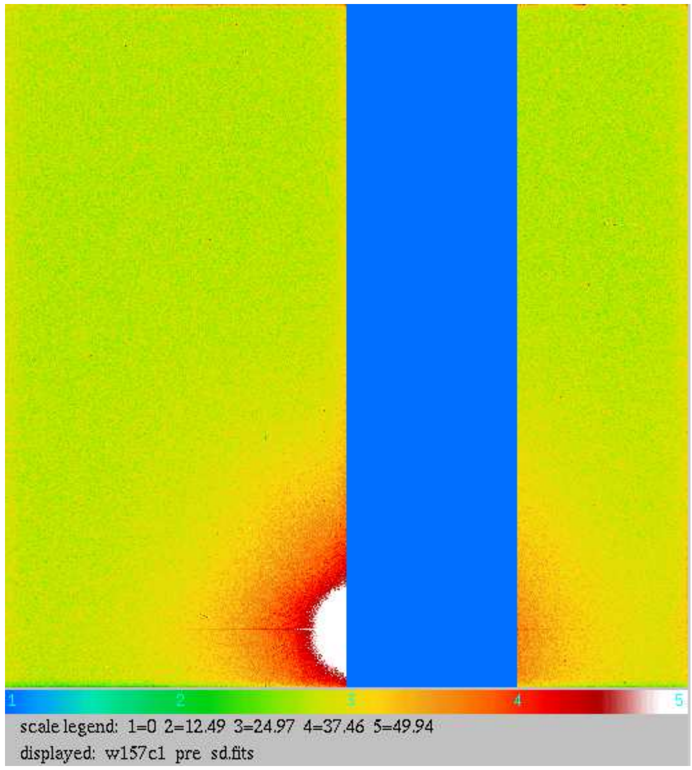


Figure 1.121: Charge transfer inefficiency (CTI) vs. accumulated ionizing dose of 40 MeV protons for a front-illuminated ACIS CCD. The curves labelled c0,c1, and c2 pertain to exposed areas of the device. The curve labelled c3 pertains to an area well-shielded from proton radiation.



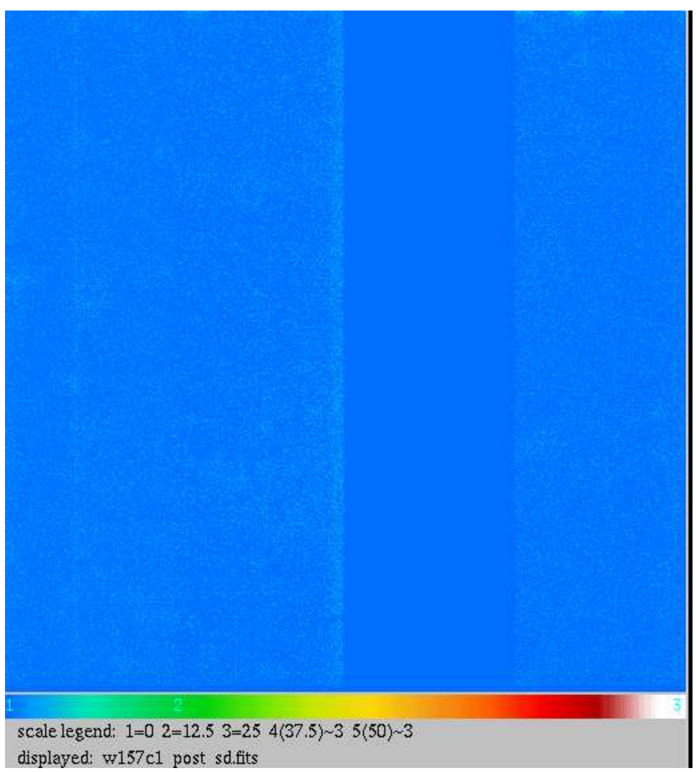
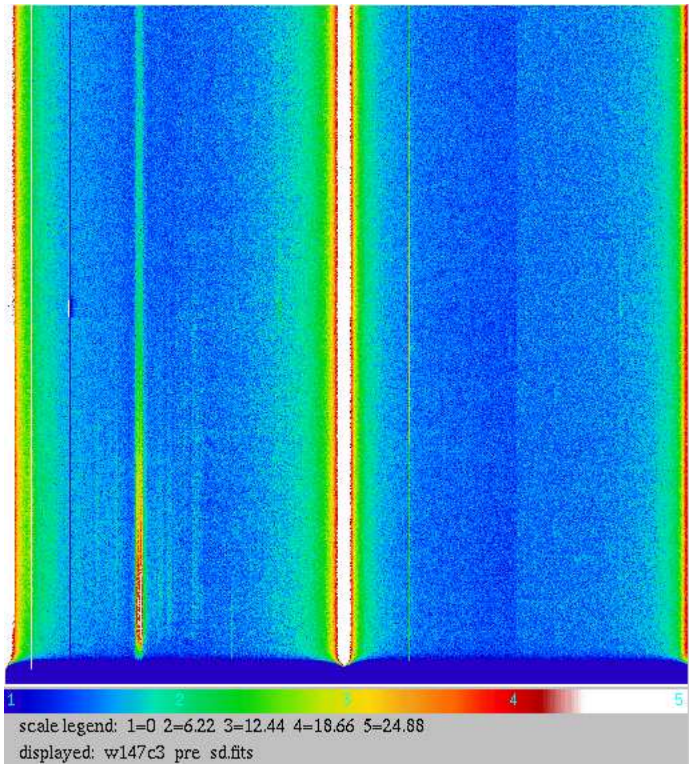


Figure 1.122: Dark current for the front-illuminated device w157c1 before (top) and after (bottom) its flight on STS-85. The preflight image was obtained at -60C and the postflight image at -120C. The bright defect was invisible at any temperature after the shuttle flight. The images are shown with identical colors scales; the signal level, in electrons per pixel per 18 s, is shown. Quadrant C was defective before and after the flight.



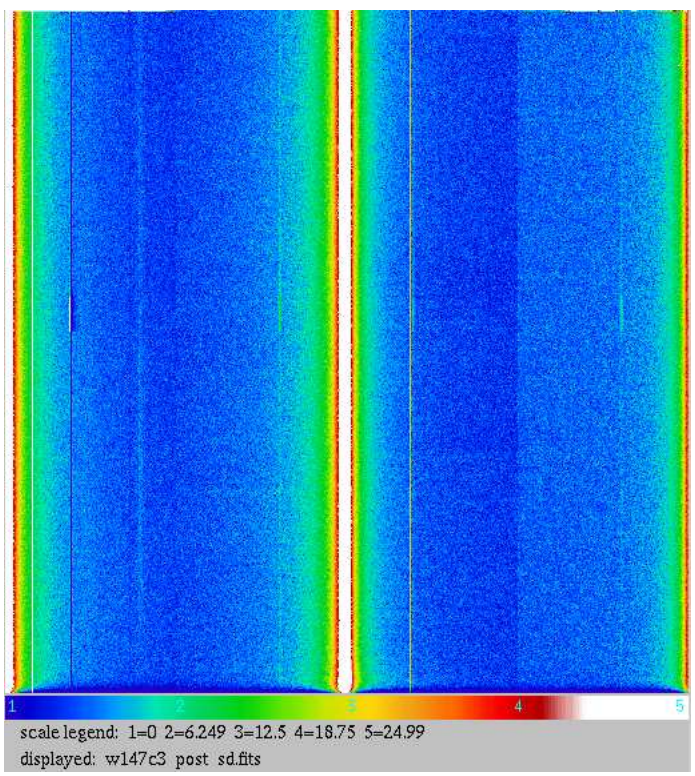


Figure 1.123: Dark current for the back-illuminated device w147c3 before (top) and after (bottom) its flight on STS-85. There is no apparent increase in the dark current. Both images were obtained at -120C. The same color scale is used for the two images; the signal level, in electrons per pixel per 18 s, is shown on the color bar.