Recent ACIS CCD Irradiation Experiments

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We report results of recent ACIS CCD irradiation experiments aimed at understanding the effect of a possible future ACIS bakeout on detector performance. Six front-illuminated detectors were irradiated cold, and then subjected to simulated bakeouts. The CCDs were irradiated with protons ranging in energy from 100 keV to 400 keV and "baked out" at temperatures ranging from +0 C to +30C. After each irradiation and thermal cycle the CCDs were characterized at 5.9keV. We conclude that a future ACIS bakeout would probably cause only a modest degradation in ACIS detector performance.

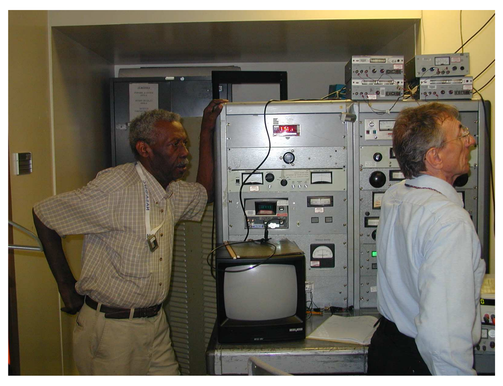
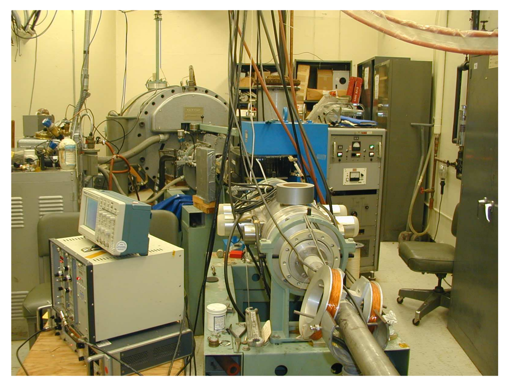
Setup

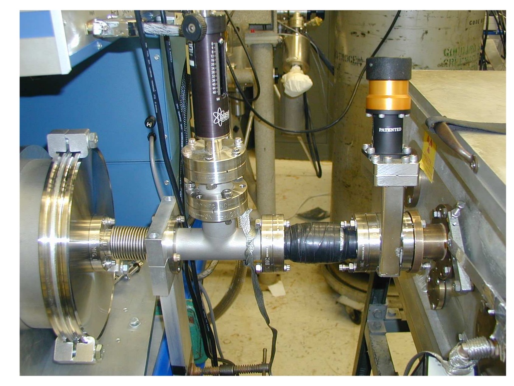
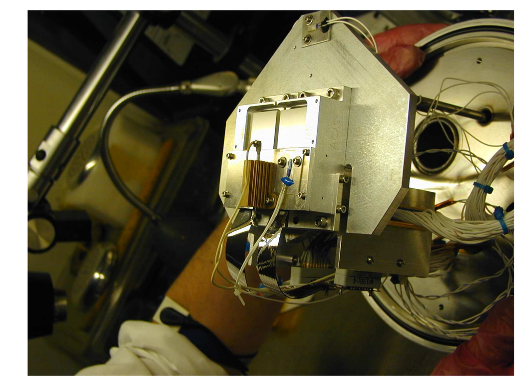
The protons at energies from 100keV to 400keV were provided by Steve and Claude using a 2 MeV van de Graff at the GSFC radiation lab.

Critical to our ability to target smaller damage regions was the flexible bellows used to attach our chamber to their beam along with a movable table (the "wobble table"). By slightly moving our vacuum chamber, then taking a quick snapshot of the beam (at a much reduced flux rate) we were able to accurately place each damage region on a single output node. The beam snapshots are below the timeline on this poster.

The beam entered our vacuum chamber through a slit that was designed to allow us to damage only a portion of each quadrants. This made it possible for us to do multiple tests with each CCD.

We used the (modified) ACIS 2-C focal plane to mount two CCDs at a time throughout the testing.

CTI Relaxation

Several damaged quadrants were characterized multiple times prior to their first thermal cycle. It was noticed that the CTI measured immediately after irradiation was always the highest value until after a bakeout.

For all of the quadrants where multiple "irradiated but not annealed" sets were available, the fraction of the original CTI is plotted below as a function of time since the irradiation. The points plotted as thick stars the average for all sets in bins of less than one hour, between one and two hours, between two and three hours, and more than three hours since irradiation.

All CTI values for data sets immediately following an irradiation were adjusted down by 11% to account for this effect.

Variations with Temperature

CTI depends on the CCD temperature. Unfortunately, it appears that the temperature was not constant throughout all of the CTI measurements. However, we do believe that once a damaged region has been annealed, it's CTI at a given temperature does not change. Whenever possible, the CTI of unannealed quadrants have been corrected using the data collected on annealed quadrants at the same time.

Using the CTI of previously annealed quadrants as a temperature monitor, it is also possible to look for changes in the fractional increase in CTI due to annealing, R, as a function of the temperature at which the CTI is measured.

While we had not planned to take a data set like this, we were lucky enough to run out of liquid nitrogen during a pre-anneal CTI set, cti25, and clever enough to leave the data capture running as the temperature warmed past -90C and then as it cooled back to -100C.

After the system was returned to MIT, CTI as a function of temperature was measured for all of the CCDs.

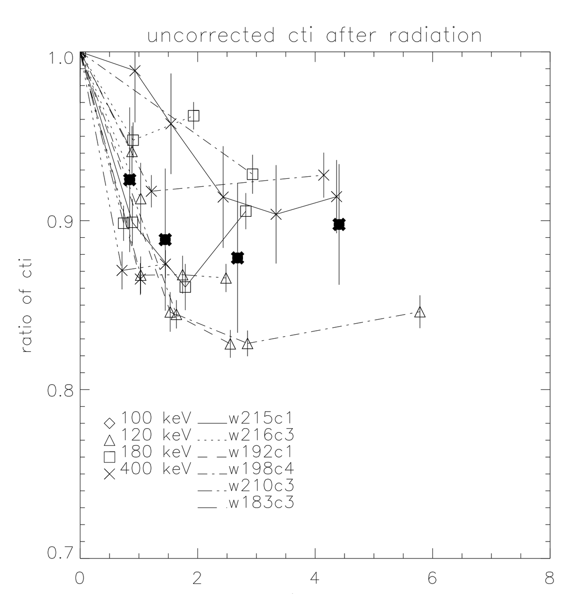
A comparison of the pre-anneal charge loss as a function of temperature and the post-anneal values suggest that the fractional increase in CTI does depend on the temperature at which it is measured. However, the effect is not large enough to account for the difference between the 2005 and 2002 experiments.

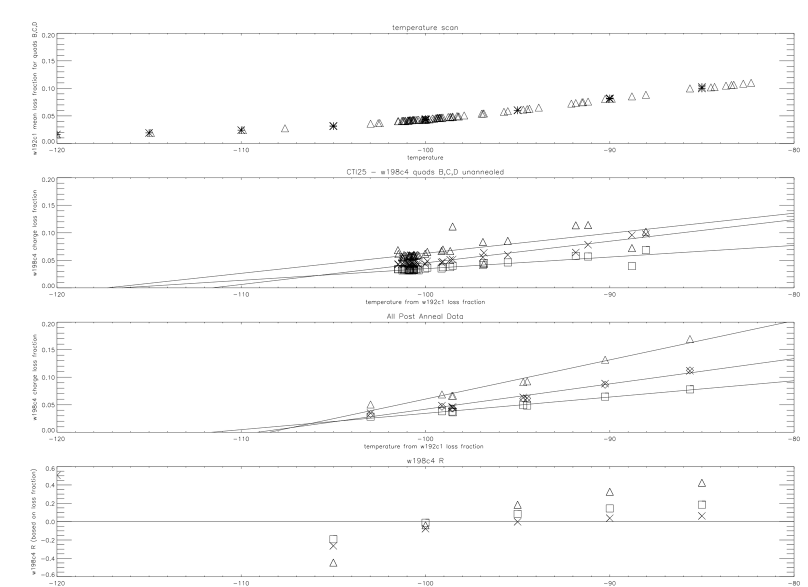
Length of Bakeout

Another variable that effects the fractional increase in CTI due to annealing is the amount of time spent at the warmer temperature.

Four of the damaged regions (on two different CCDs, with each of the four proton energies represented) were cycled to +30C twice for an hour, then for six hours, then for over 100 hours (while we all enjoyed the weekend at home).

The majority of the CTI increase occurred in the first eight hours, suggesting that 1999 on-orbit bakeout did anneal most of the original radiation damage to the flight devices.





Isochronal Annealing

During the second week of testing, an isochronal annealing data set was taken. Four different CCD quadrants were irradiated, each at a different energy, then warmed to +0C, +10C, +20C, and +30C. After each one hour dwell, the CCDs were cooled back to -100C and recharacterized.

The goal of this test was to determine the sensitivity of the annealing rate to bakeout temperature.

Analysis of the isochronal annealing sets are complicated by both the temperature uncertainty and the "CTI relaxation" noticed after irradiations.

Further work is necessary.