

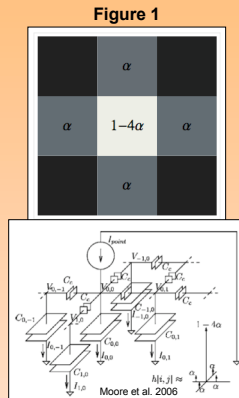
The ^{55}Fe X-ray Energy Response of HgCdTe Near-Infrared Detectors

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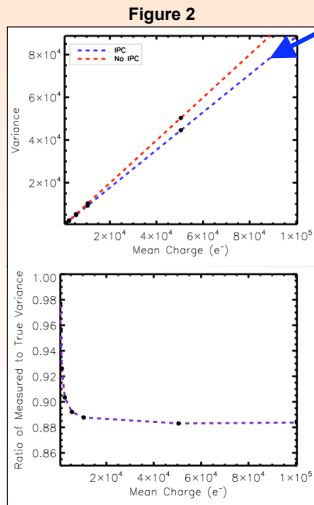
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Motivation

The accurate determination of a detector's fundamental parameters, including read noise, dark current, and QE, relies on a proper determination of a detector's conversion gain (e^-/ADU). It is becoming more important to measure these parameters to a higher precision as the demand for low-signal observations increases and the scientific requirements evolve in complexity (e.g. SNAP requires measurements to within 2% (Schubnell et al. 2006)). The traditional photon transfer technique to measure gain, however, is limited in that it does not account for charge sharing between pixels. **Figure 1** (right) illustrates interpixel capacitance, one of the more dominant charge coupling mechanisms. Moore et al. (2006) provide a full description of how small amounts of stray capacitance couple the signal from the central pixel into the neighboring pixels, where α is the coupling coefficient.



Charge coupling means less variance

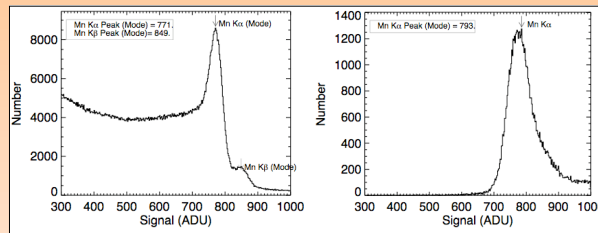


Charge coupling effects, such as interpixel capacitance, attenuate photon shot noise and result in an overestimation of conversion gain when implementing the traditional photon transfer technique. **Figure 2** (left) shows the effects of interpixel capacitance on the measured variance versus signal. For coupling of just $\alpha=1.5\%$, the variance is underestimated by $\sim 12\%$ (and hence gain is overestimated by $\sim 12\%$) at high signal levels where photon shot noise dominates.

Methods

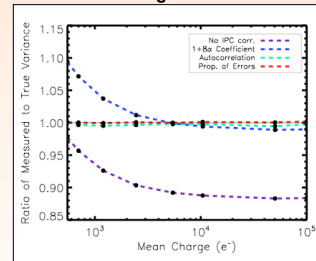
A technique involving ^{55}Fe X-rays provides a potentially straightforward measurement of conversion gain by comparing the observed instrumental counts (ADU) to the known charge (e^-) liberated by the X-ray. This technique is already preferred within the CCD community, as the pair production energy for silicon is well established. In contrast, the pair production energy is unknown for HgCdTe, a material commonly used for near-infrared detectors. **Figure 3** (below) plots histograms of the observed ^{55}Fe X-ray response of HgCdTe, in ADU, for a flight grade WFC3 1.7 μm -cutoff HgCdTe detector.

Figure 3



The histogram on the left of **Figure 3**, which includes only individual pixel intensities, ignores signal that has been lost to neighboring pixels. The histogram on the right compensates for lost charge by adding the 4 nearest neighbor intensities. While the charge is restored, the additional noise blends the 2 peaks.

Figure 4



Ultimately, the HgCdTe response is measured in electrons. Conversion from ADU to electrons requires an independent and accurate measurement of the conversion gain. **Figure 4** (left) shows a Monte Carlo simulation of several different techniques by which to restore the "true" variance from uniformly illuminated (flat-field) exposures. This plot validates a technique that utilizes the classical propagation of errors. We describe this technique in more detail in our paper.

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Preliminary Results

The measured HgCdTe response of 8 Teledyne flight grade WFC3 H1-R 1.7 μm detectors is 1849 ± 46 electrons for each ^{55}Fe X-ray. This result corresponds to a pair production energy of 3.21 ± 0.08 eV. **Figure 5** (below) plots the results along the values of several other common semiconductor materials, as well as the semi-empirical trend, given by Alig & Bloom (1975). These are only preliminary results as we have not accounted for any systematic errors, such as fitting the ^{55}Fe histogram peak, accounting for diagonal coupling, and tracking charge that may recombine before reaching the depletion region. We believe that up to $\sim 10\%$ of the charge could be lost in this manner. Nonetheless, these results now make the ^{55}Fe gain measurement technique of potential interest for near-infrared arrays, as it has been in the CCD community for many years.

1849 electrons per X-ray

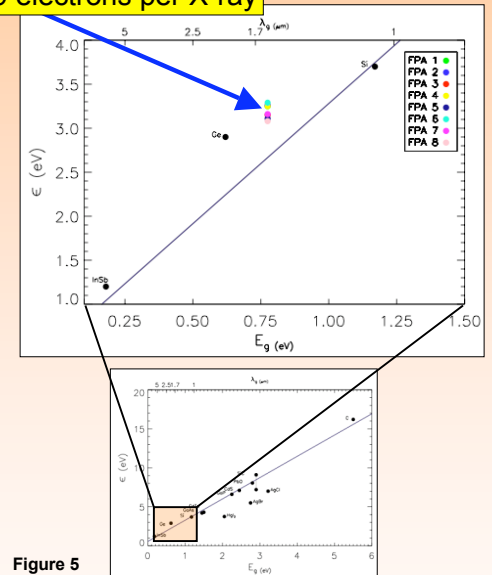


Figure 5

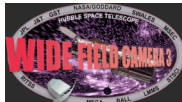
Future Work

Although these measurements were made using Teledyne HAWAII detectors, we believe that they are likely to be applicable to HgCdTe detectors from other vendors, so long as differences in cutoff wavelength are correctly accounted for. In the future, we plan to perform similar tests on HgCdTe with other cutoff wavelengths (e.g. 2.5 and 5 μm).

References

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