

Strap Effects in the TESS CCDs

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Abstract

TESS is a photometric mission to discover exoplanets¹. TESS CCDs² are deep-depletion BI devices fabricated with metal straps running beneath the depleted regions to allow fast frame store transfers. At long wavelengths, light can penetrate to these depths, get reflected back into the depletion region, and be absorbed. In addition to these straps, other metal lines run beneath the depletion regions. Aluminum-Copper straps are used to act as temperature sensing devices, and lines to drive the charge injection serial register complete the strap complement. Spot sources simulating stars were scanned across these straps to determine photometric effects. Strap reflectivity increases consistently with the measured QE³, and rises to 14% in the red most region of the TESS passband.

Strap Effects on the TESS mission

- Straps can affect the shape and brightness of stars falling on or at the edge of stars
- Incident light from f/1.4 lens penetrates the silicon at different angles and creates a PSF; reflections off the straps can create additional blur to the PSF
- Cooler red stars (such as the M dwarfs TESS targets) are more affected than the hotter blue stars, with overall fractional contributions from 1-2%⁴

Flat Illumination of the CCD at Different Wavelengths

- Tree rings readily visible at shorter wavelengths (used for flat field calibration)
- Metal straps, visible for $\lambda > 900$ nm
- Diffraction patterns, visible between $900 \text{ nm} < \lambda < 1000$ nm
- Brick wall pattern exists due to dark current, and can be present in dark, warm frames

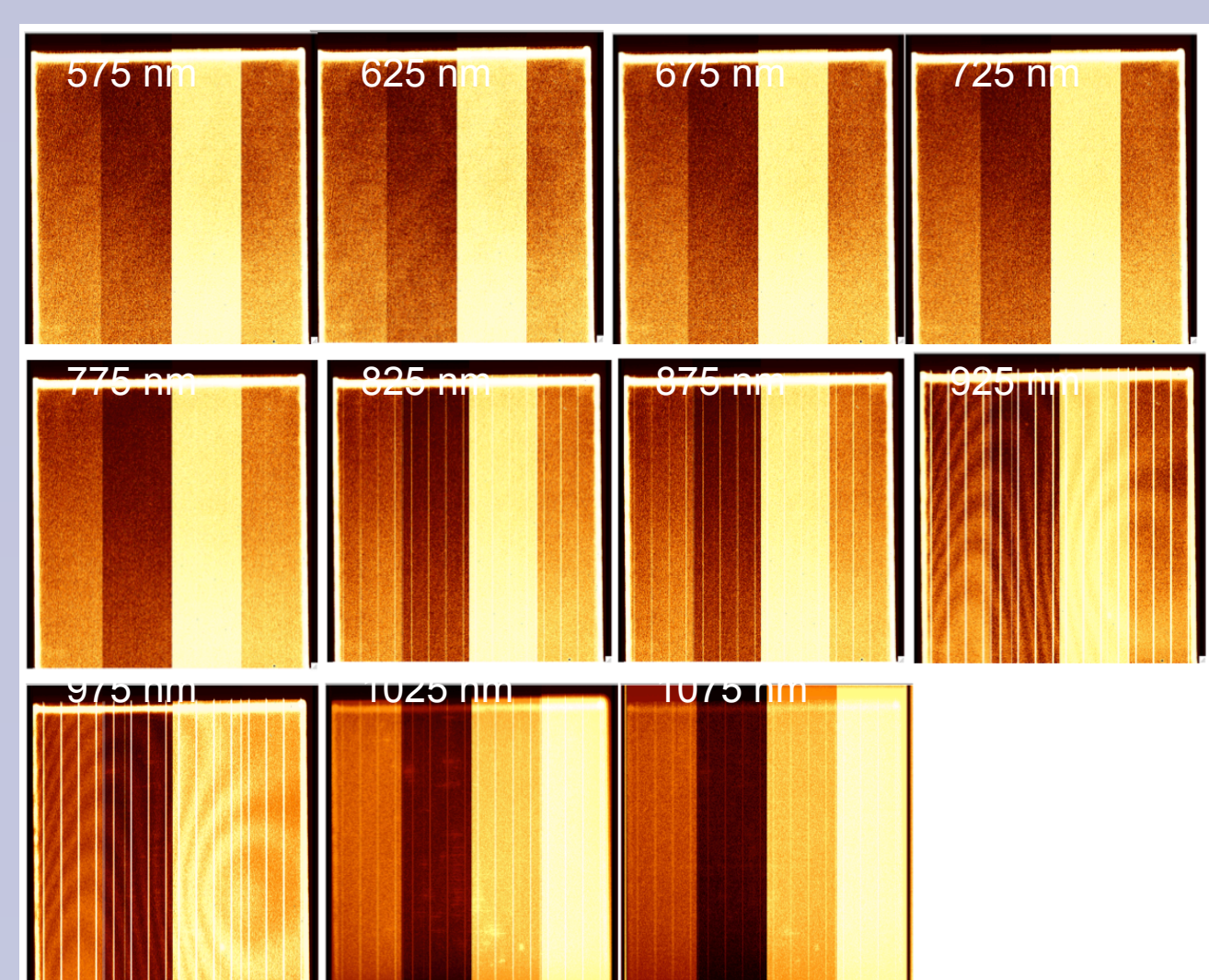


Fig. 1 A wavelength scan reveals features according to the penetration depth. Each box represents a CCD with its 4 nodes, each having a slight bias offset. These images were taken at colder temperatures $< -30\text{C}$.

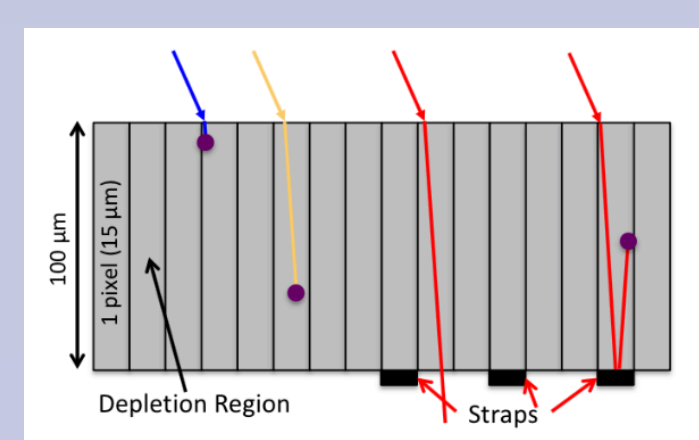


Fig. 3 CCD cross section showing the penetration of various wavelengths

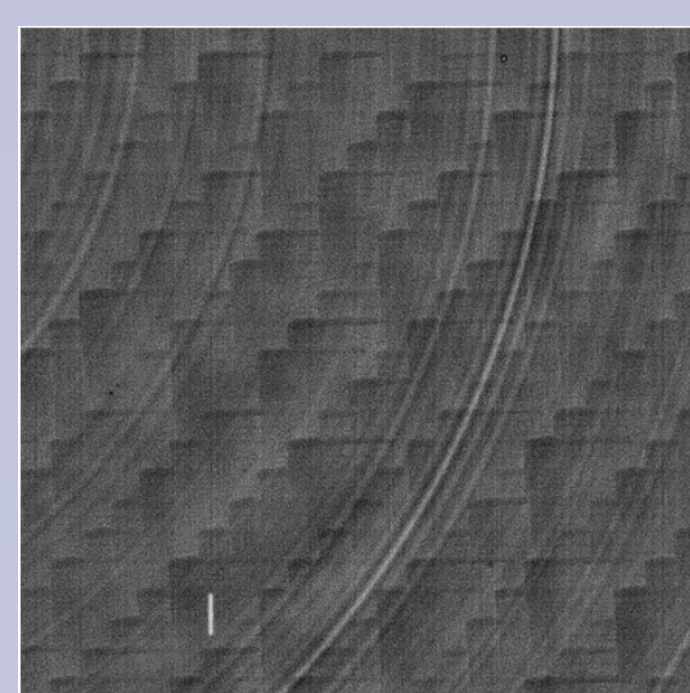


Fig. 2 Brick wall pattern is most readily seen at room/warm temperatures, and fades as the device is cooled. This pattern is the result of a stepped laser annealing to passivate the back side

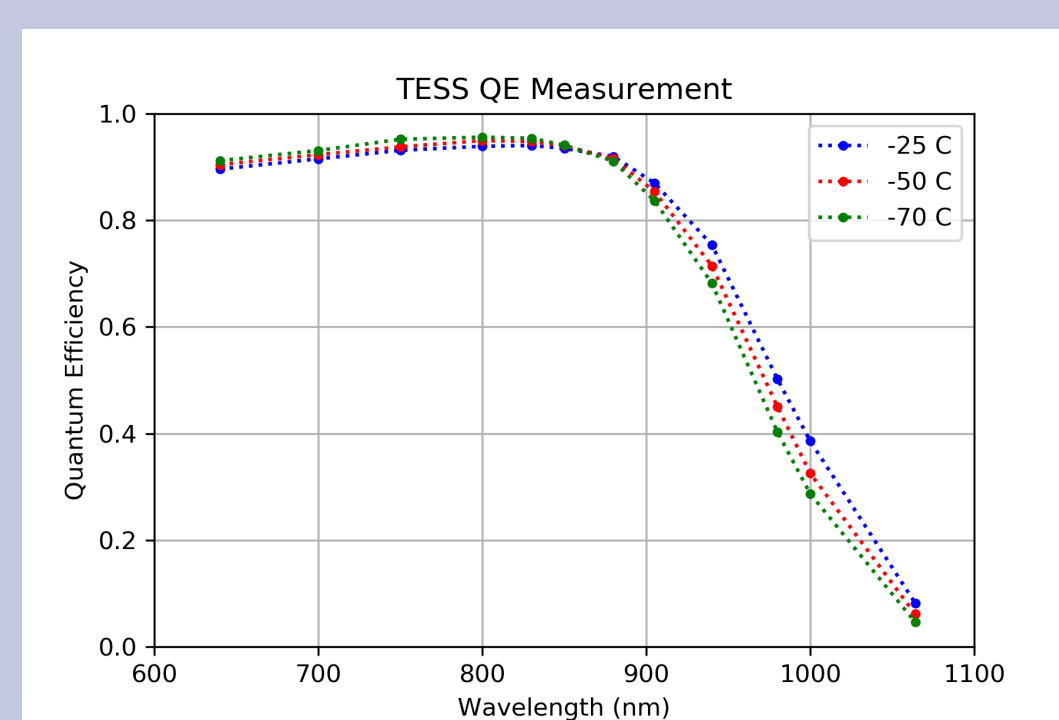


Fig. 4 Measured QE of the CCID-80. The silicon is more transparent at red wavelengths

Strap Types

- IAC Image Array Clocks
- USRC Upper Serial Register Clocks
- RTD (Aluminum Copper)

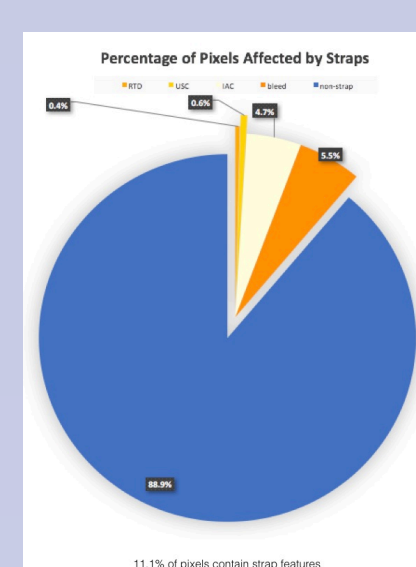


Fig. 5 Percentage of CCD affected by straps

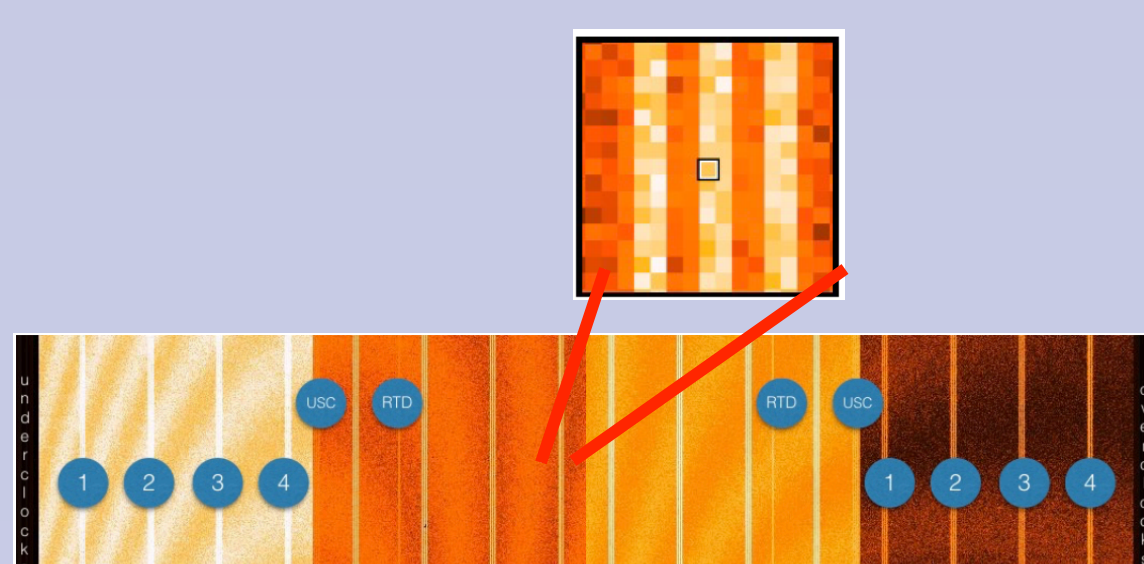


Fig. 6 Blow up of the image to the right, showing that each of the IAC straps is composed of 3 lines, each approximately 2 pixels (30 microns) wide. The separation between straps is also 30 microns.

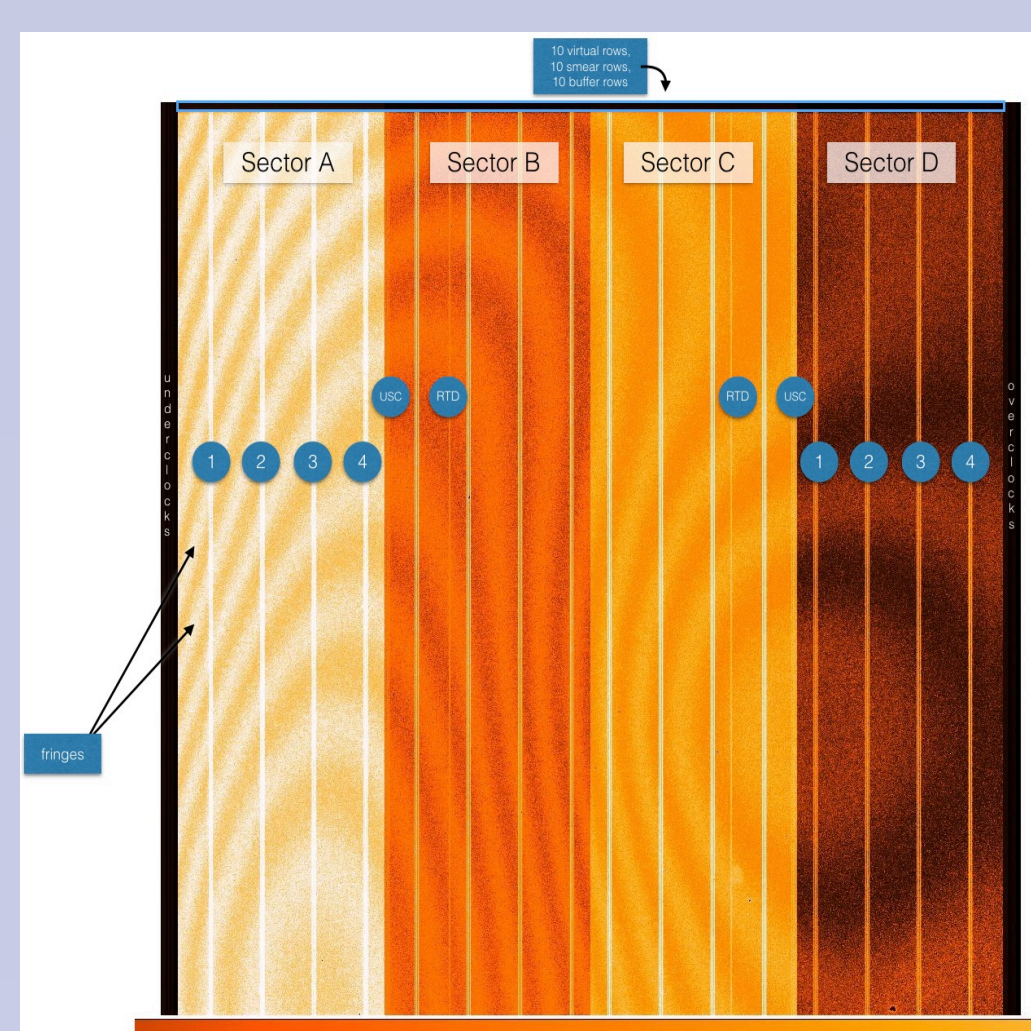


Fig. 7 The different types of straps spread across the CCD

Experimental Setup

- Use an engineering TESS focal plane array, mounted inside a thermal vacuum chamber
- Focused light source spot radius ~ 1 pixel radius (focused with Z-stage piezo)
- Spot moved along a row using a piezo X-Y stage; angle of incidence $\sim 0^\circ$
- Illumination intensity kept well below full well capacity
- Scan across the lines at different wavelengths
- Simple box photometry (10x10 pixels) to determine spot intensity

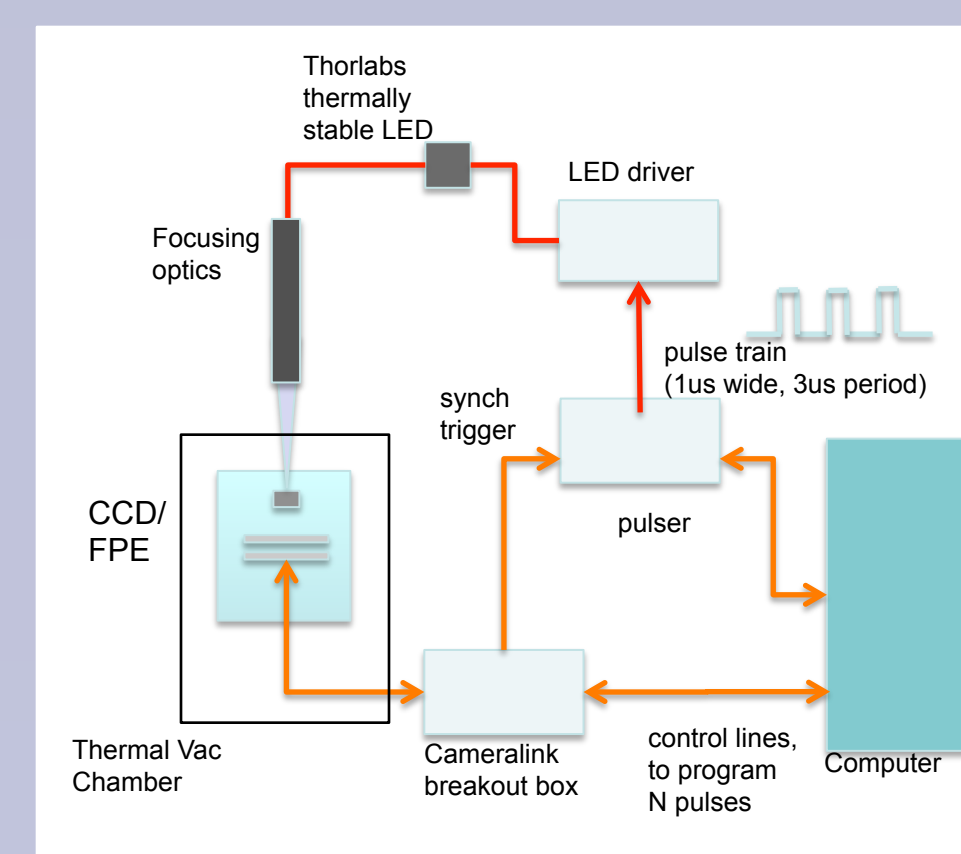


Fig. 8 Experimental Schematic

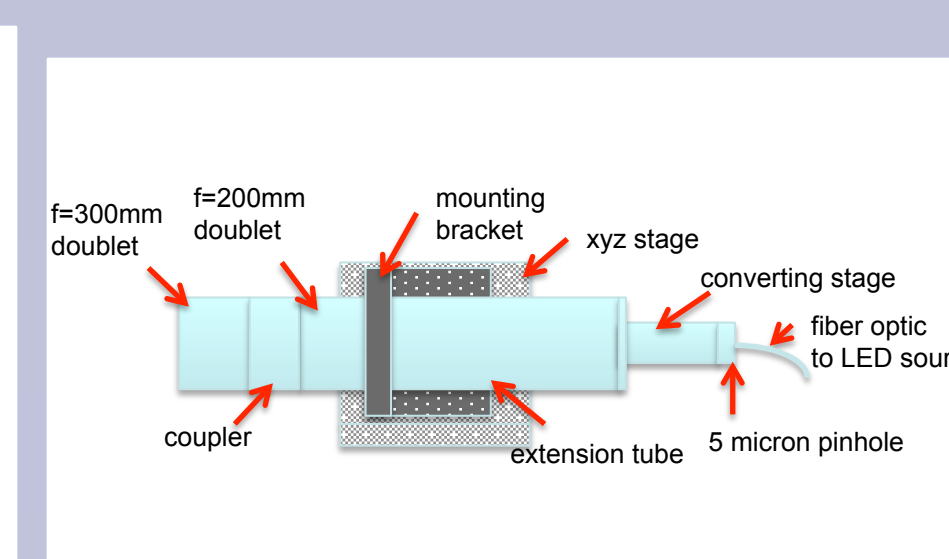


Fig. 9 Detail of the light source used, consisting of a pin hole and doublets mounted on an XYZ stage

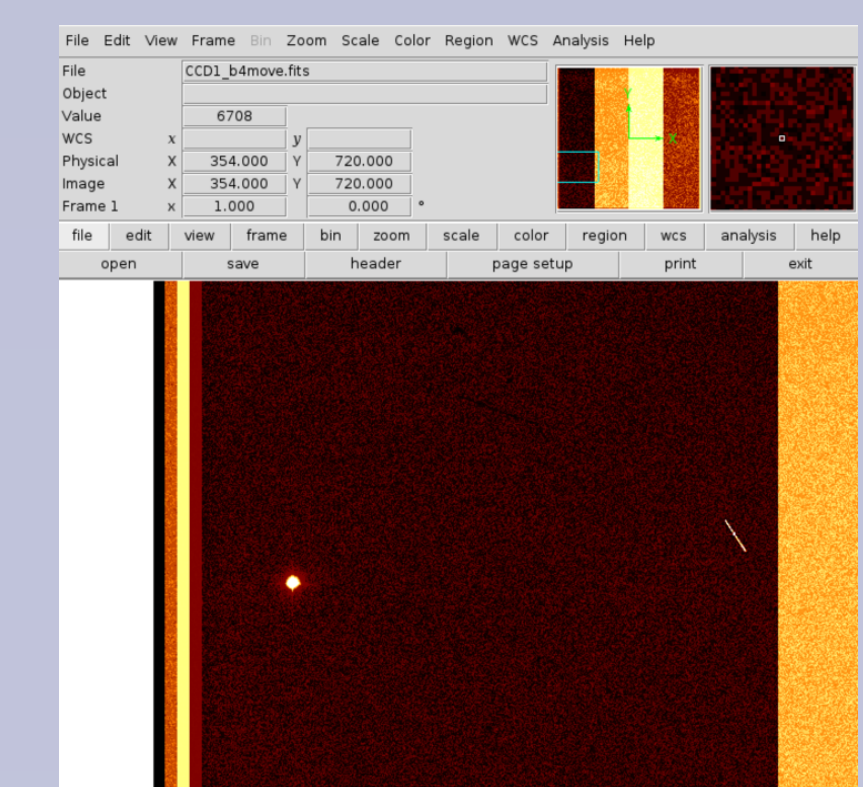


Fig. 10 image of the spot illuminating a portion of the CCD. The straps are not illuminated until the light spot traverses them

Results

- Scans across columns show varying reflectivity at different wavelengths
- Scans also carried out at different substrate voltages, no variation
- Scans along columns do not show discernible variation

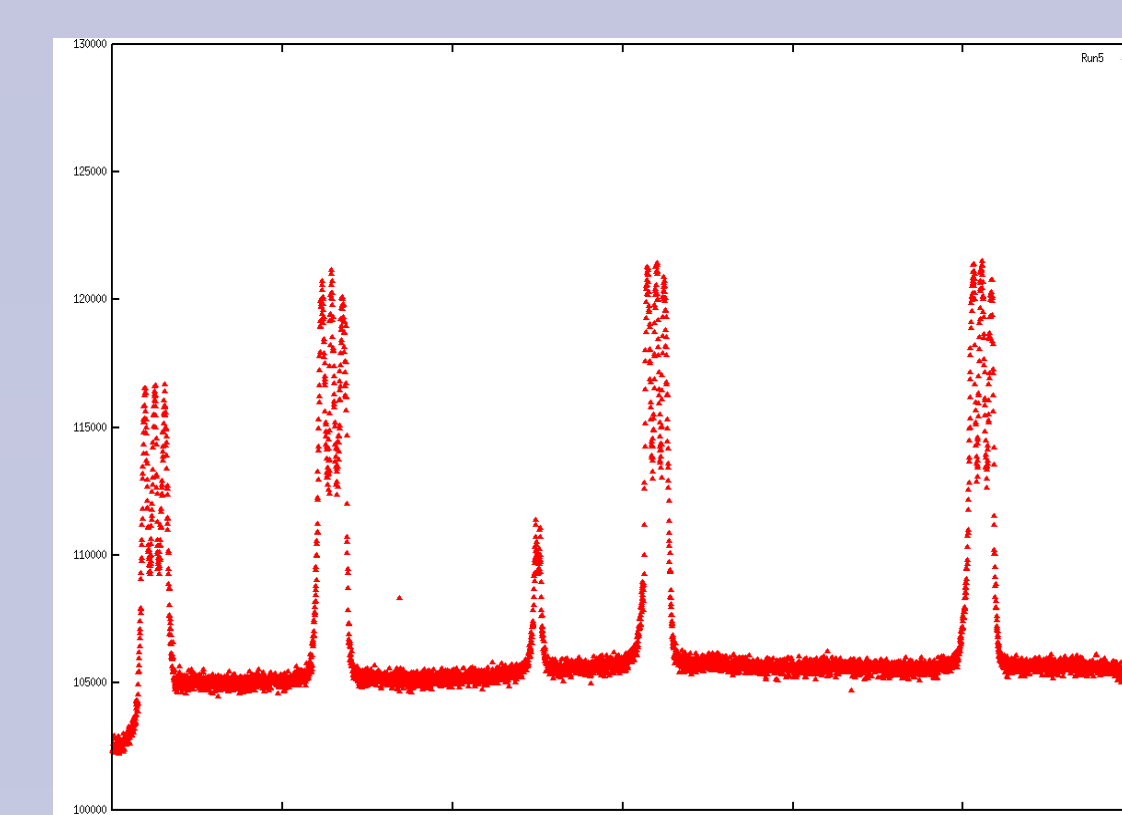


Fig. 11 Integrated counts swept across the CCD showing the reflection differences (data taken at 1050nm). A USRC strap is followed by an IAC strap and a RTD strap. Two more IAC straps follow.

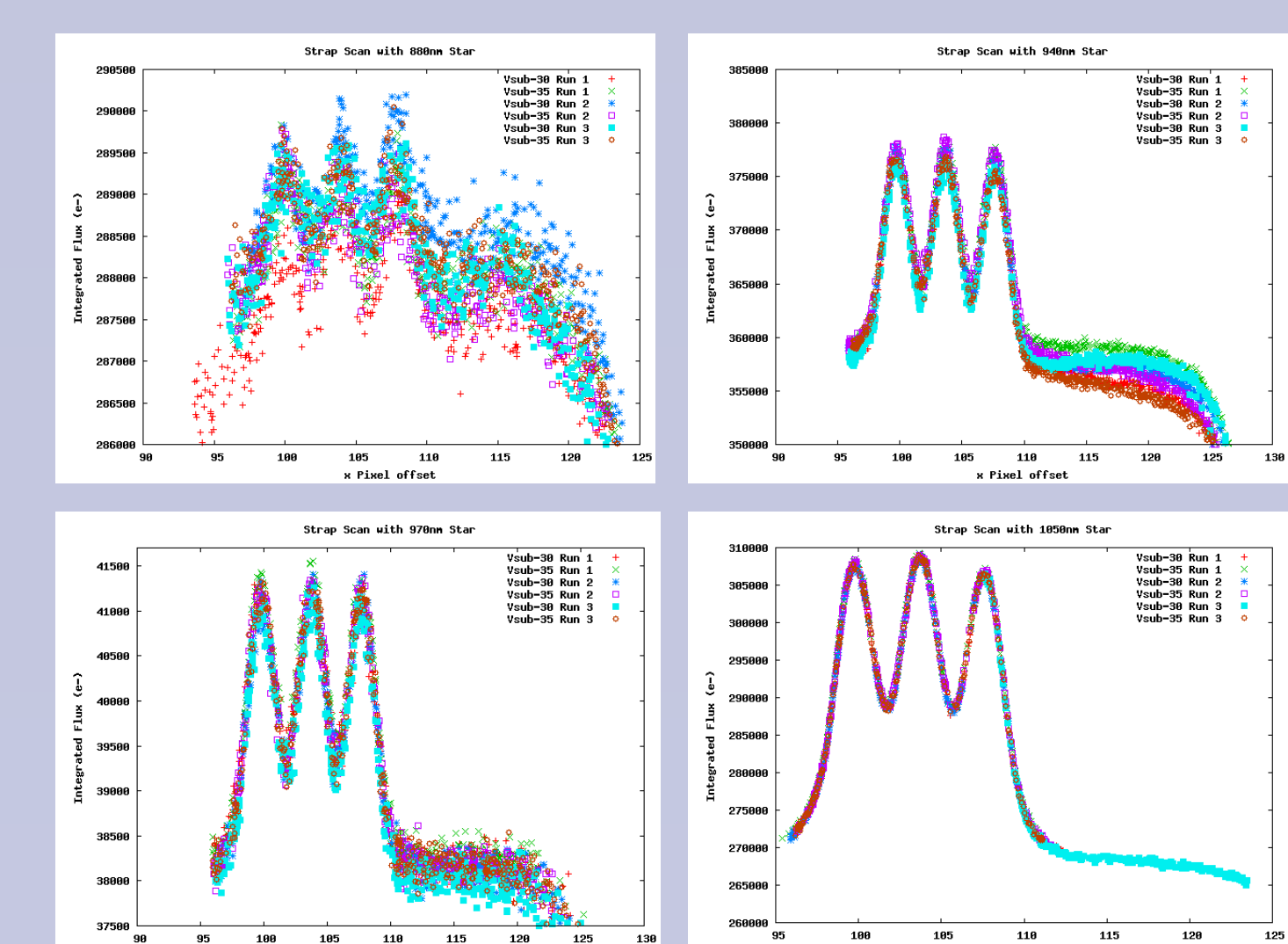


Fig. 13 Scans conducted across the same set of IAC straps at different wavelengths. The dip at the end is an effect of the integration box extending past a CCD sector (uncorrected gain)

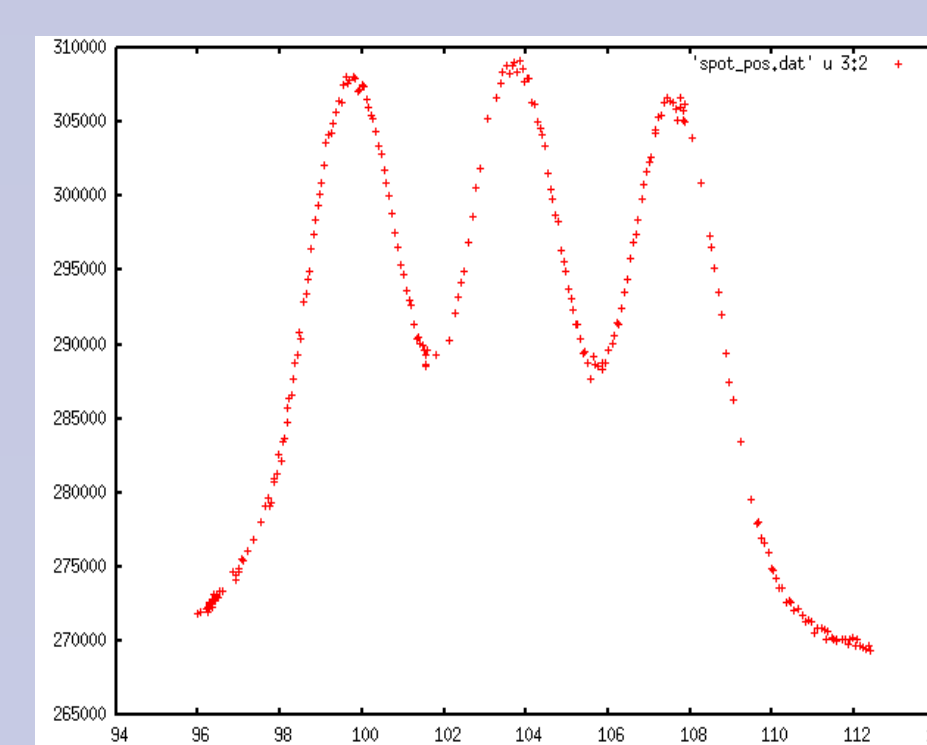


Fig. 12 Close up of the strap scan. The depth of total intensity trough decreases with longer wavelength, indicating greater reflectance from adjacent straps

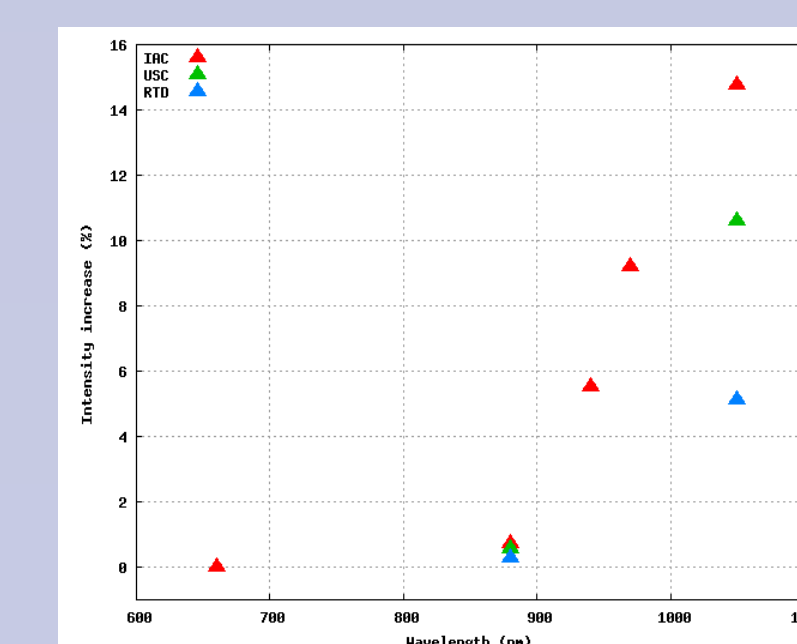


Fig. 14 Strap reflectance as a function of wavelength. The break at 890nm is consistent with the QE dropping precipitously at that wavelength.

References

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2. Suntharalingam, V., Prigozhin, I., Young, D. et al, "Deep depletion CCD detectors for the Transiting Exoplanet Survey Satellite," Proc SPIE 9915, 9915-28 (2016)
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