The NASA Marshall Space Flight Center (MSFC) has developed a science camera suitable for sub-orbital missions for observations in the UV, EUV and soft X-ray. Six cameras were built and tested for the Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), a joint National Astronomical Observatory of Japan (NAOJ) and MSFC sounding rocket mission. The CLASP camera design includes a frame-transfer e2v CCD57-10 512x512 detector, dual channel analog readout electronics and an internally mounted cold block. At the flight operating temperature of -20C, the CLASP cameras achieved the low-noise performance requirements (≤25 e⁻ read noise and ≤10 e⁻/sec/pix dark current), in addition to maintaining a stable gain of ≈ 2.0 e⁻/DN. The e2v CCD57-10 detectors were coated with Lumogen-E to improve quantum efficiency (QE) at the Lyman-α wavelength. A vacuum ultra-violet (VUV) monochromator and a NIST calibrated photodiode were employed to measure the QE of each camera. Four flight-like cameras were tested in a high-vacuum chamber, which was configured to operate several tests intended to verify the QE, gain, read noise, dark current and residual non-linearity of the CCD. We present and discuss the QE measurements performed on the CLASP cameras. We also discuss the high-vacuum system outfitted for testing of UV and EUV science cameras at MSFC.

**Abstract**

The purpose of CLASP is to measure the linear polarization profiles caused by scattering processes and the Hanle effect in the Ly-α line (121.6 nm).

- Highly sensitive polarization measurements impose strict performance requirements on the CLASP cameras.
- The CLASP cameras achieved stable, high speed, low-noise performance.
- Extensive testing was performed in high-vacuum (<10E-6 torr) to measure and verify performance requirements for dark current, read noise, gain, and quantum efficiency.

**Introduction**

- CLASP Instrument
- Chamber Set up
- Telescope

**Results**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Requirement</th>
<th>SN1</th>
<th>SN4</th>
<th>SN5</th>
<th>SN6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left/Right Gain [e⁻ / DN]</td>
<td>2.0 ± 0.5</td>
<td>1.97</td>
<td>2.04</td>
<td>1.92</td>
<td>2.04</td>
</tr>
<tr>
<td>Left/Right Dark Current [e⁻/sec/pix]</td>
<td>&lt; 10</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Left/Right Read Noise [e⁻]</td>
<td>≤ 25</td>
<td>5.4</td>
<td>5.6</td>
<td>5.3</td>
<td>5.6</td>
</tr>
<tr>
<td>Quantum Efficiency [%] *</td>
<td>30*</td>
<td>14.2</td>
<td>1.5</td>
<td>12.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

* Quantum efficiency requirement based on data sheet of QE of Lumogen from Princeton Instruments. This was later found to be an error in the data sheet.

**Dark Current & Read Noise**

- To determine dark current, CCD was cooled to -20 C (the expected flight temperature for CLASP).
- A set of dark images was obtained at a range of exposure times between 0.3 ms (the flight exposure time) and 10 s.
- The average dark current was calculated for each exposure time. A linear regression was then performed to determine the average dark current rate.
- The standard deviation in the signal was also calculated to determine read noise.
- Each side of the detector was treated independently.

**Camera Gain**

- To calculate camera gain, an Fe 55 source was moved in front of the detector (see Chamber set up figure).
- Data was recorded with a 0.3 s exposure time for 10 minutes.
- Fe 55 decays and releases photons of fixed, known energies. This energy can be deposited into one or more pixels. We selected pixels from the data that appeared to be “single pixel hits” meaning the pixel had a high signal and all pixels surrounding it was at the level of the noise.
- We generated histograms of the signal associated with single pixel hits and fit with a quadruple Gaussian functions. The fitting routine fixed the width of the Gaussians to be the noise and the relative amplitudes and centroids to be the known offsets from atomic data.

An example of the gain calculation for a single tap of one camera. The black line is the data, the red line is the fit.

**Conclusion**

- The camera designed by Marshall Space Flight Center meets the CLASP requirements for read noise, dark current, and gain.
- The quantum efficiency measured for the flight cameras was lower than expected based on the Princeton Instruments data sheet for Lumogen. It was determined through discussions with the vendor that the data sheet was in error.
- Cameras based on the CLASP design, but with larger detectors, will be used for the upcoming Hi-C, ESIS, and MaGIMS rocket instruments.

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