Development of an automated system to test and select CCDs for the Dark Energy Survey Camera (DECam)

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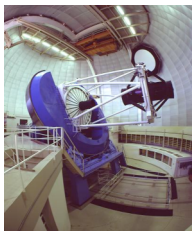
DARK ENERGY SURVEY

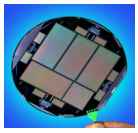
Abstract

The Dark Energy Survey Camera (DECam) will have a mosaic of 74 charge-coupled devices (CCDs). DECam is the instrument currently being built for the Blanco 4m telescope at Cerro Tololo Inter-American Observatory in Chile. It will be used for the Dark Energy Survey (DES) and will be available as a facility instrument. The goal of the DES is to measure the dark energy equation of state parameter, ω, to a statistical precision of 5% with four complementary methods. This goal sets stringent technical requirements for the CCDs. Testing a large number of CCDs to determine which best meet the DES requirements would be a very time-consuming manual task. We have developed a system to automatically collect and analyze CCD test data. The test results are entered into an online SQL database which facilitates selection of those CCDs that best meet the technical specifications for charge transfer efficiency, linearity, full well capacity, quantum efficiency, noise, dark current, cross talk, diffusion, and cosmetics.

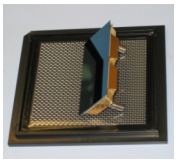


Blanco 4m telescope

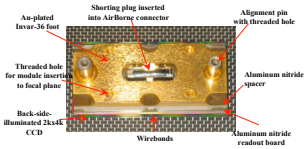
The CCDs



DES wafer with four 2k x 4k, one 2k x 2k, and eight 1k x 0.5k CCDs

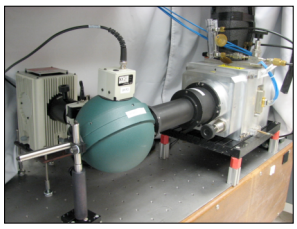


Packaged 2048 x 4096 CCD

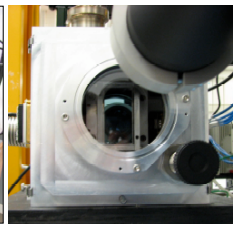


The DECam CCDs are 2k x 4k, 15 micron format devices designed by Lawrence Berkeley National Laboratory (LBNL), fabricated at DALSA Semiconductor and LBNL, and cold-probed by LBNL, then provided in die form to Fermilab for packaging and final characterization. It is a back illuminated, p-channel CCD thinned to 250 microns and biased to be fully depleted. An antireflective layer is applied to the back of the detector to optimize its performance in a wide range of wavelengths. A substrate voltage of 40 V is applied to the back surface to control diffusion and obtain acceptable image quality in 250-micron detectors.

Automated Testing

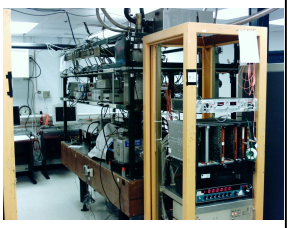


Optical test equipment
One of 3 complete test setups.
3 CCDs can be tested in parallel.



View of CCD through the dewar window

The CCDs are tested at the Silicon Detector Facility at Fermilab in a clean, ESD-controlled environment. The CCDs are housed in a vacuum dewar equipped with a fused silica window to permit illumination of the CCD. The CCDs are LN2-cooled to 173 K, with temperature fluctuations < 0.1 K achieved with PID-control loop. TCL-based software provides automated sequencing of test procedures. The exposure time and bandwidth are varied as required to measure charge transfer efficiency, linearity, full well, quantum efficiency, noise, dark current, crosstalk, diffusion, and cosmetics. The CCD is read out by the NOAO Monsoon image acquisition system with low noise (typically 7-8 e- rms) @ 250 kpix/sec, generating ~900 35-MB FITS images for each CCD. The Monsoon system will also be used to read out the survey instrument.

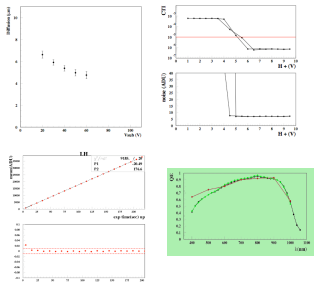


CCD test facility:
electronics and optical test bench

Automated Analysis

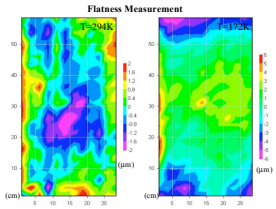
A script runs an automated analysis of the test data

- Executes the analysis programs.
- Writes the resultant plots and tables to a report.
- Links the following to an online SQL database:
  - The report
  - An image of the CCD
  - Two downloadable FITs images
  - The measured parameters corresponding to the technical requirements



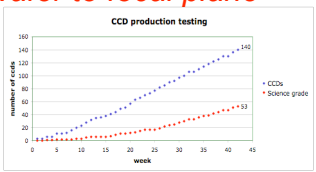
Pixel array	2048 · 4096 pixels
Pixel size	15 µm x 15 µm
# Outputs	2
QE(g,r,i,z)	60%, 75%, 60%, 65%
QE instability	<0.3% in 12-18 hrs
QE Uniformity in focal plane	<5% in 12-18 hrs
Full well capacity	>130,000 e⁻
Dark current	<~25 e⁻/hr/pixel (at 173 K)
Persistence	Erase mechanism
Read noise	< 15 e⁻ @ 250kpix/s
Charge Transfer Inefficiency	<10^{-5}
Charge diffusion	1D σ < 7.5 µm
Cosmetic Requirements	<# Bad pixels> <0.5% None worse than 2.5%
Linearity	1%
Package Flatness	10 microns.

DECam CCD technical requirements

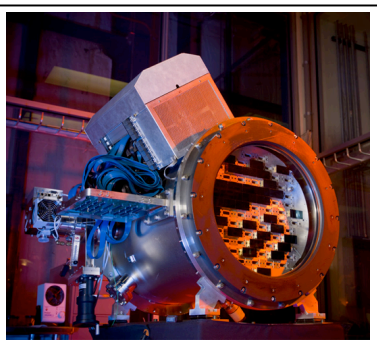


Flatness Specifications (at T=173K):
- Height difference between adjacent 1 cm² subsurfaces < 10 um (overall shape)
- Within a 1 cm² subsurface there are no deviations > 3 um (small bumps).
- This is the result (topographical map) from a typical device.

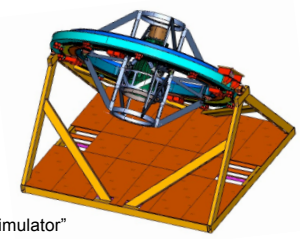
From wafer to focal plane



140 CCDs have been tested to date (~4 CCDs/week), yielding 53 science grade devices. A subset of the characterized CCDs have been installed on the focal plane in the MultiCCD Test Vessel (MCCDTV) for integration with the final electronics and data acquisition system.



DECam CCDs installed in the MCCDTV



"Telescope Simulator"

DECam systems will be commissioned at Fermilab prior to shipping the camera to the telescope. The telescope simulator will allow all systems to be tested in any physical orientation.