Large Synoptic Survey Telescope

www.lsst.org

An Automated System to Measure the Quantum Efficiency of CCDs for Astronomy

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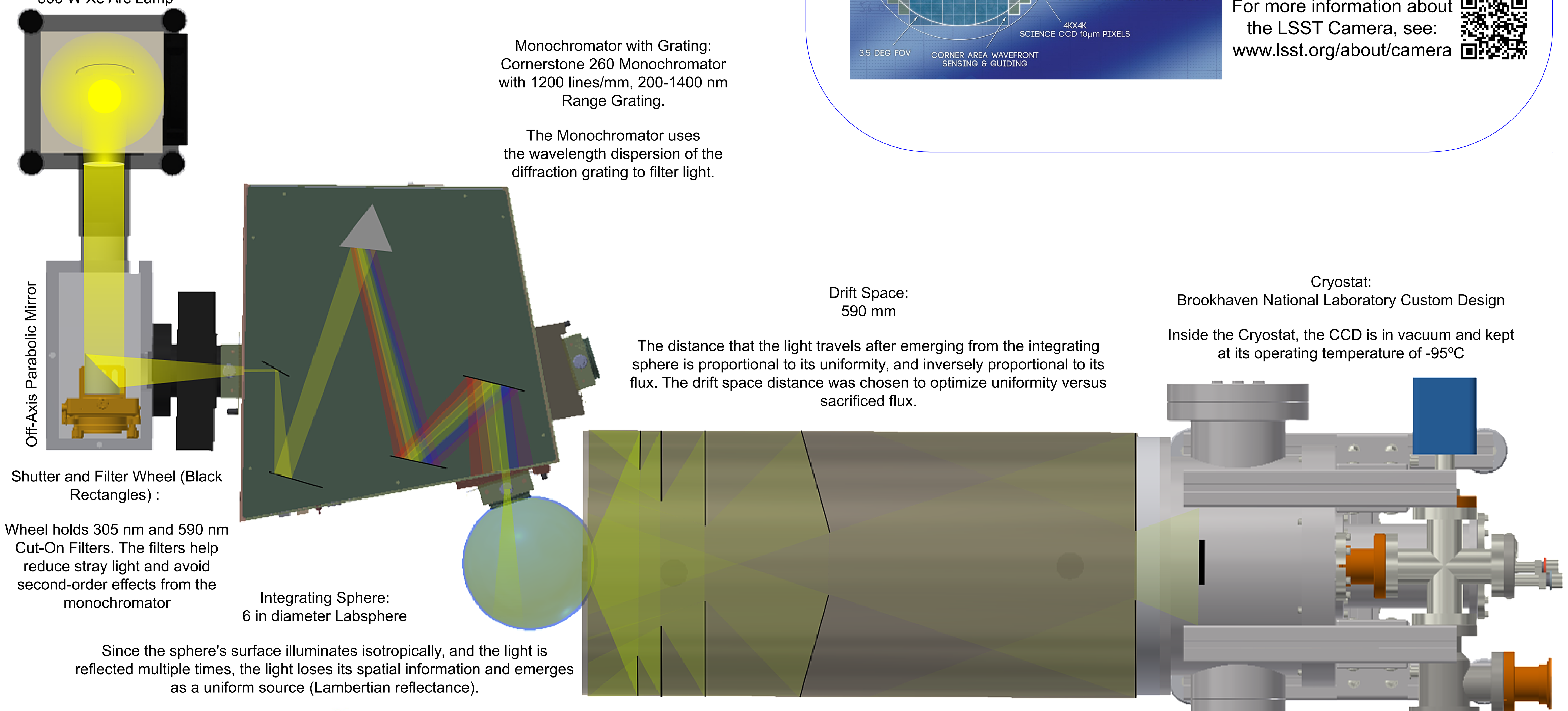
We describe a system to measure the Quantum Efficiency in the wavelength range of 300 nm to 1100 nm of 40x40 mm n-channel CCD sensors for the construction of the 3.2 gigapixel LSST focal plane. The technique uses a series of instrument to create a very uniform flux of photons of controllable intensity in the wavelength range of interest across the face the sensor. This allows the absolute Quantum Efficiency to be measured with an accuracy in the 1% range. This system will be part of a production facility at Brookhaven National Lab for the basic component of the LSST camera.

QUANTUM EFFICIENCY MEASUREMENT SYSTEM

To characterize the QE of a LSST CCD, we use a measurement station that incidents diffuse light, with a wavelength accuracy of 1 nm, on the surface of the sensor (shown below, imaging uniform light at 500nm onto the sensor in a cryostat). We then read out an image from the sensor and compare the amount of captured electrons to the photons incident on its surface.

Measurement	Component	Sensitivity Coefficient	Mean Measured Value (x)	Standard Deviation (σ_x)	Fractional Uncertainty (σ_x/x)
Reproducibility	LSST and Vendor QE Measurement Stations	√(1/3)	47.3% (at 400nm)	2.3% (maximum)	0.05
Instrument Bias	Lamp Drift	1	1.06×10^{-10}A	2.28×10^{-12}A	0.02
Instrument Bias	Glass Cryostat Window	1	3.23%	0.13%	0.04
Instrument Bias	Gain	1	4.45e/ADU	0.16e/ADU	0.04
Instrument Bias	NIST Photodiode Absolute Calibration	1	1.21A/W (at 955nm)	0.006A/W (maximum)	0.005
Total					0.067

Uncertainty Budget for LSST QE Measurement System

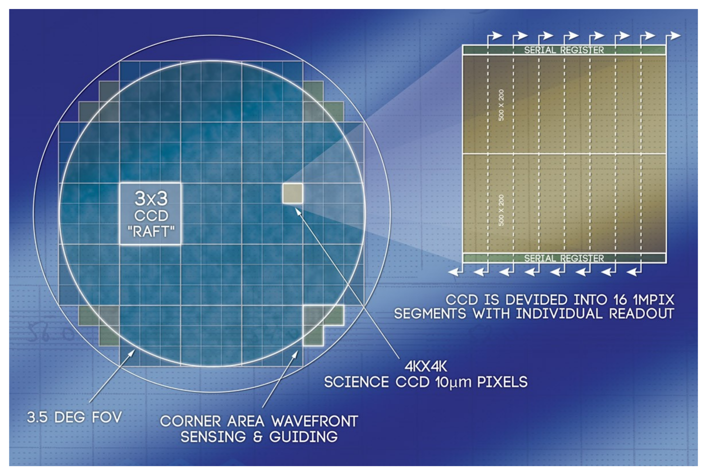


LSST: LARGE SYNOPTIC SURVEY TELESCOPE

The construction of the LSST telescope, charged with taking images to create a 3D map of the universe in startlingly high detail, has motivated the Instrumentation Division at the Brookhaven National Laboratory to create superior testing systems to verify the quality of the Charge-Coupled Devices (CCDs) in the LSST camera. Over 700 participants in the LSST Collaborations will use the images, including the notable LSST Dark Energy Science Collaboration who will use the data gathered in their ongoing effort to understand the nature of the dark energy that permeates our universe.

LSST CAMERA

The camera in the LSST is set to break the world record for the largest digital camera ever constructed. At 5.5 ft by 9,8 ft (1.65 m by 3 m) it is about the size of a small car. Its large-aperture and wide-field optical view can capture images of celestial bodies with viewable light from the near ultraviolet to near infrared (300-1000 nm) wavelengths. The 25.2 in (64 cm) diameter focal plane employs a mosaic of 189 16 megapixel CCDs arranged on 21 RAFTS to provide a total of 3.2 gigapixels.



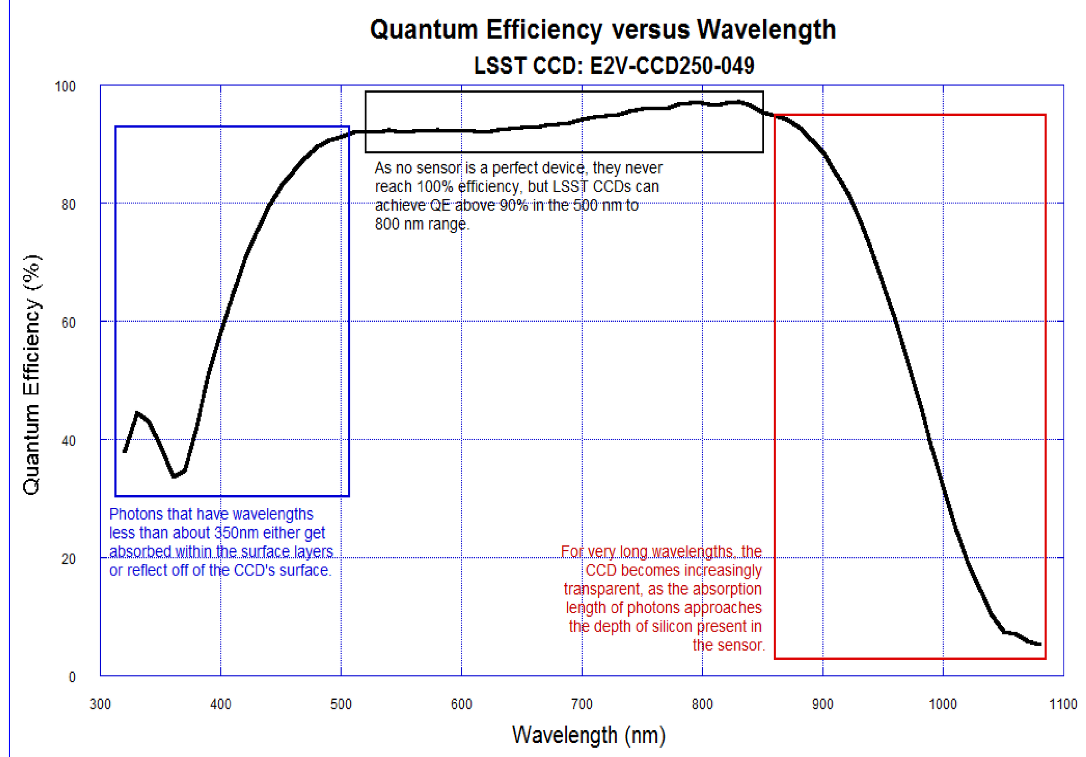
The LSST Focal Plane: the focal plane will be comprised of 21 RAFTS. A RAFT is a group of nine LSST sensors and their readout electronics, that can function as an individual camera.

For more information about the LSST Camera, see: www.lsst.org/about/camera

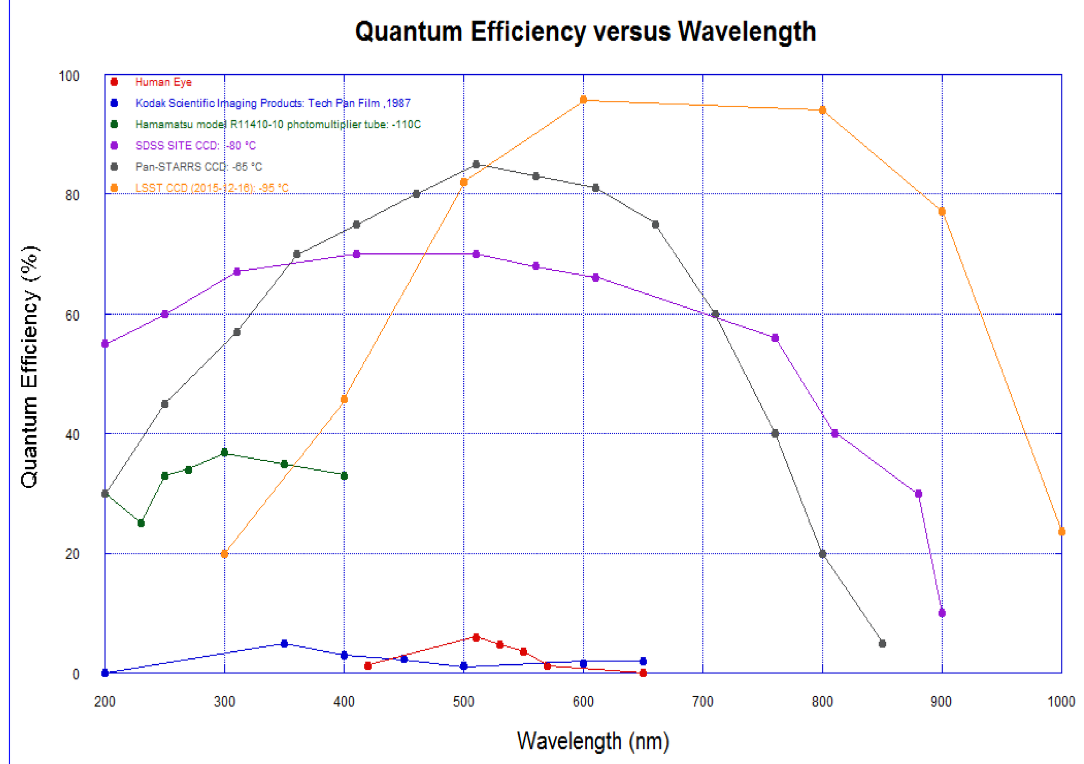
LSST SENSOR QUANTUM EFFICIENCY

Quantum efficiency is the ratio of photons incident on the CCD to electron-hole pairs successfully created in the CCD's depletion region, that are read out by the sensor's electronics. Since the energy of a photon is inversely proportional to its wavelength, we measure the QE over a range of wavelengths to characterize the sensors efficiency at different photon energies.

The larger impact of these QE measurements will be their use in camera calibration. Properly calibrating the data taken by the LSST requires detailed measurements of atmospheric transmissivity, optics, and detector efficiencies; the latter being measured by the QE test systems.



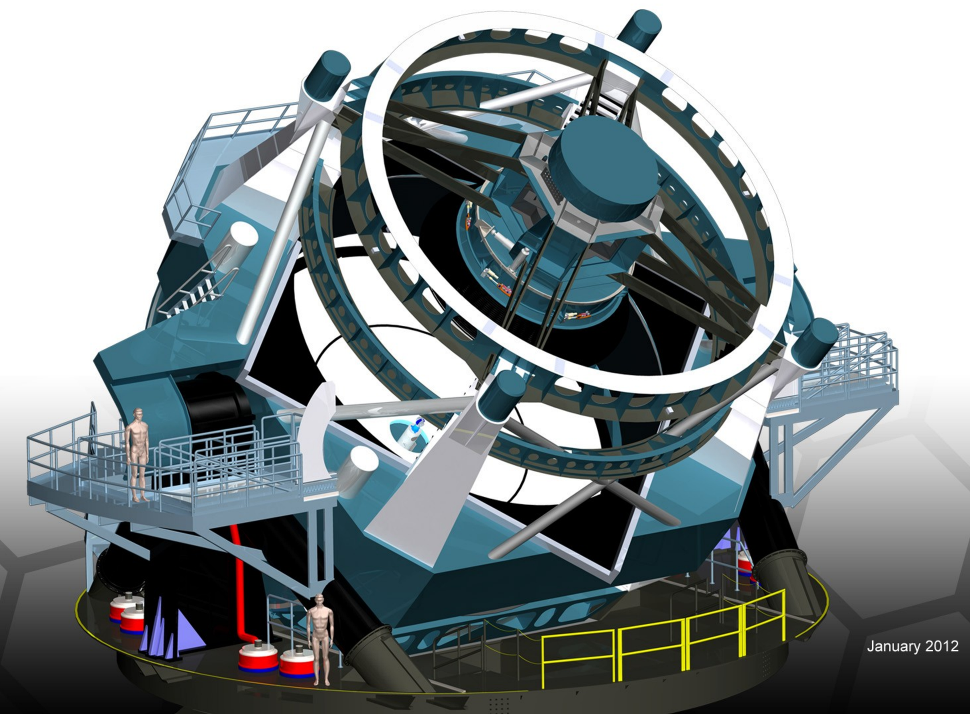
Quantum Efficiency Curve for LSST CCD: Back-side illuminated, n-channel sensor. Produced by vendor e2v.



QE of multiple devices: human eye, Kodak astronomical Tech Pan Film, Hamamatsu photomultiplier tube, Sloan Digital Sky Survey (SDSS) CCD, Pan-STARRS CCD, LSST CCD.

BETTER CALIBERATION FOR BETTER SNe Ia DATA

Knowing the efficiency of LSST sensors, in regard to the amount of incident light that they collect relative to the actual light emanating from celestial objects, is vital to achieve photometric accuracy. For objects that are used to determine measurement standards, such as type Ia supernova, a poor calibration of apparent brightness could easily lead to an inaccurate calculation of valuable information, such as redshift. Our work with the QE systems at BNL will create calibration data to reduce such uncertainties. Given the importance of SNe Ia to dark energy research, the need to obtain accurate photometric measurements is vital.



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