Large Synoptic Survey Telescope

www.lsst.org

The Camera for LSST and its Focal Plane Array

Andrew Rasmussen[1], K. Gilmore[1], S. M. Kahn[1], J. Geary[2], S. Marshall[1], M. Nordby[1], P. O'Connor[3], S. Olivier[4], J. Oliver[5], V. Radeka[3], T. Schalk[6], R. Schindler[1], J.A. Tyson[7], R. Van Berg[8], LSST Camera Team

[1]SLAC National Accelerator Laboratory, [2]Harvard College Observatory, [3]Brookhaven National Laboratory, [4]Lawrence Livermore National Laboratory, [5]Harvard Univ., [6]UC Santa Cruz, [7]UC Davis, [8]University of Pennsylvania

Optically fed by LSST's fast and wide-field optics, the camera has a 9.6 square degree field of view and a 3.2 Gigapixel focal plane array. The focal plane is tiled by 189 4Kx4K CCD science sensors with 10μ (0.2 arcsec) pixels and also houses four diagnostic ("corner raft") packages that provide guide and wavefront-sensors at opposing sides of the field. The modular focal plane array has a parallelized readout scheme, allowing the entire array to be read in 2 seconds. Dedicated front- and back-end electronics boards housed within the cryostat operate sensors in raft groups (3x3 sensors; 144 data channels) while mechanically identical "rafts" are precision-mounted on a rigid silicon carbide grid structure. Three large, refractive lens elements act as the optical corrector (the third, L3, provides the vacuum barrier for the cryostat), and one of six possible band-pass filters is positioned in the beam at any given time. Mechanisms within the camera include a mechanical shutter and a carousel filter changer assembly. The camera control system manages all aspects of camera operation including image capture, thermal monitoring and control, vacuum control, filter changes, and communication with the observatory control system. The data acquisition system records and pre-processes raw images, provides up to 3 days of storage capacity, and provides very high throughput data transfer to downstream data management.

The 3Gpix Camera

LSST combines a wide-field (9.6 deg^2), 8.4m class primary mirror, and a 3.2 Gpix CCD array. 15 sec exposures generate ~20 TB of science data per night. Short slew- and settling-times of the telescope, together with fast shutter-actuation, sensor read-out and filter exchange are each crucial for high efficiency observing: a high observing efficiency – étendue product.

Image quality is maintained through a combination of fine guide control and active optics (AO) compensation of the three mirror surfaces and camera mutual alignment via two hexapods. AO compensation data are acquired using wavefront curvature sensors and guide sensors located on the focal plane.

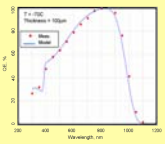
The science CCD array is highly modular: 16 channels per sensor, 9 sensors per raft, and 21 rafts mounted in the focal plane assembly (FPA) grid. Each channel represents a small fraction – 0.000330 – of the FPA and the channels (1 Mpix each) are read out synchronously in < 2 seconds.

Front- and back-end electronics are located in the raft tower assembly behind each science raft, all located inside of the cryostat vacuum. Power dissipation per channel (FEE+BEE) is ~0.6 watts during readout and half of this value (quiescent) during exposure.

Lens deformations induced by equilibrium thermal gradient and gas pressure differential create small aberrations in the compensated, "best-focus" image quality. This necessitates pre-correcting for such effects in the design. Together with a "flat" (~10μm max peak-to-valley) focal surface composed of 189 individual surfaces, this design meets the image quality requirements ***under operating conditions***. Extensive finite element analysis modeling, thorough physical characterization of parts and synthesis of inspection data – each play integral roles in this precision instrument assembly.

Sensors and filter band definitions

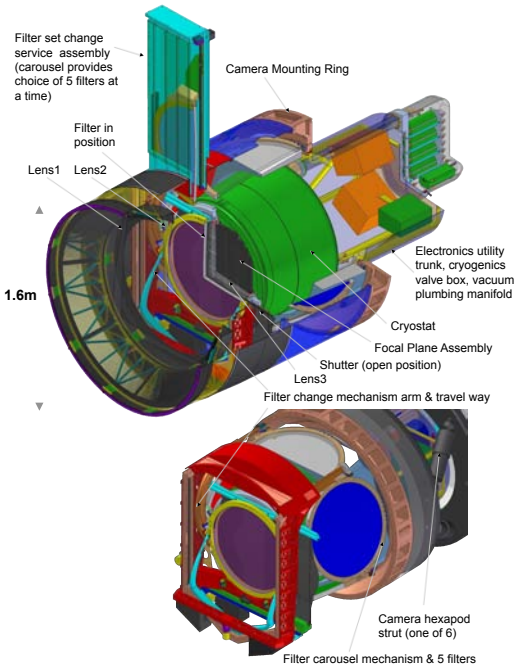
Left: sensor quantum efficiency measurements (dots), overplotted by a model efficiency (blue line). Right: filter band details for the six LSST camera filters.



	Half-Maximum Transmission Wavelength		
	Blue Side	Red Side	Comments
U	330	400	Blue side cut-off depends on AR coating
G	400	552	Balmer break at 400 nm
R	552	691	Matches SDSS
I	691	818	Red side short of sky emission at 826 nm
Z	818	922	Red side stop before H_2O bands
Y4	930	1070	Red cut-off before detector cut-off

Camera Mechanical Overview

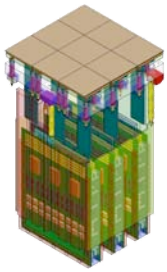
Cut-away sectional view of the camera, showing the 3 lenses, a filter in position, and shutter and the focal plane. Below is a inside view showing more detail of the filter exchange mechanism, carousel and camera hexapod.



Science raft tower detail

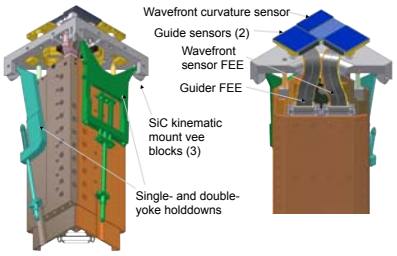
A building block of the full FPA. Flexible cables and thermal straps join the 3x3 raft of sensors (top) to the front-end electronics. The back end module is not shown.

- Thick (100um) CCD sensors
- Packaged sensors mounted onto AlN carriers & SiC mount with 3 differential screw adjusters; 9/raft
- Rigid SiC raft base with kinematic mount
- Front End Board: 6/raft
- ASPIC (Analog Signal Processing ASIC): 2/CCD; 18/raft
- SCC (Sensor Control Chip – ASIC): 3/CCD; 27/raft
- Slow controls/monitoring



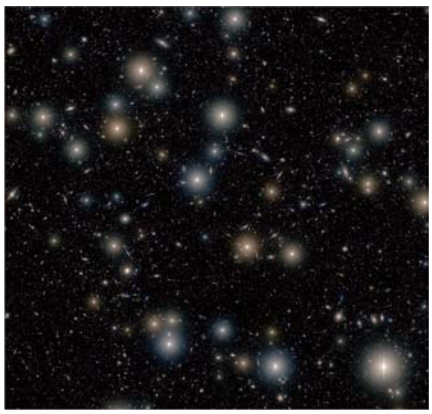
Corner raft tower detail

Mechanical hold-downs shown here are shared with the science rafts



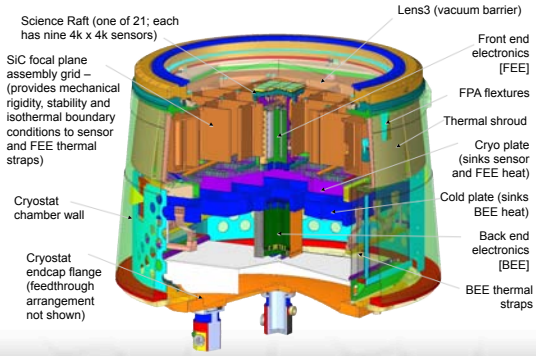
A unit of science data

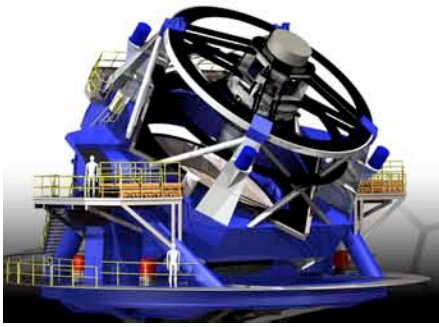
15 second exposures on one science sensor (186 square arcminutes; 1/189 of focal plane). This true color image is from three log scale *gri* 15 sec "snapshots". (Courtesy, image simulation team.)



Cryostat detail

The heart of the camera. This cut-away view shows only one raft tower installed for clarity. The cryogenic system draws heat out of the cryo- and cold-plates, which in turn cool the FPA grid & sensor rafts, FEE and BEE modules.





January 2010

LSST is a public-private partnership. Design and development activity is supported in part by the National Science Foundation. Additional funding comes from private gifts, grants to universities, and in-kind support at Department of Energy laboratories and other LSSTC Institutional Members.