

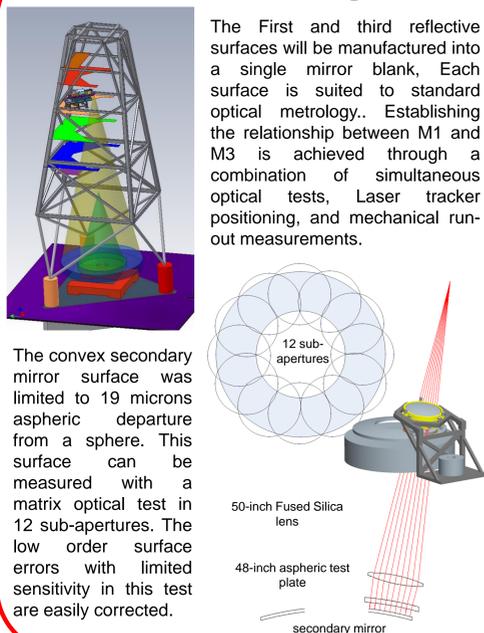
LSST Large Synoptic Survey Telescope

Performance and Analysis of the LSST Optical System

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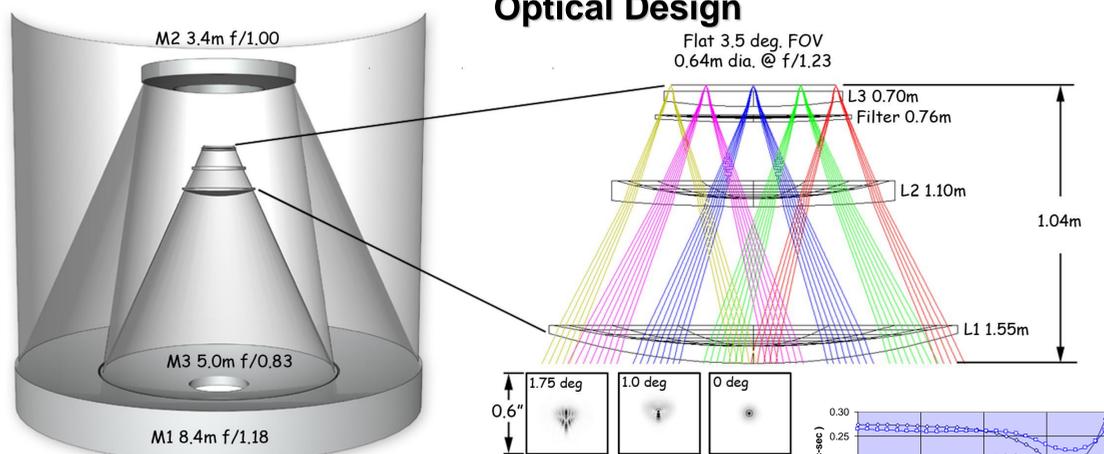
The LSST uses a modified Paul-Baker 3-mirror optical design with 8.4-m primary, 3.4-m secondary and 5-m tertiary mirrors. The system prescription has evolved to enable its deep, wide, fast mission. The proximity of the primary and tertiary surfaces enables fabrication of both mirrors from a single substrate. This unique design, referred to as the M1M3 monolith, offers significant advantages in the reduction of degrees of freedom during operational alignment and improved structural stiffness for the otherwise annular primary surface. The 3-mirror telescope feeds a 3 element refractive corrector to produce a 3.5-degree diameter field of view over a 64-cm flat focal surface in 6 spectral bands with excellent image quality. The most recent design optimization included null tests for each of the three camera lenses and resulted in significantly simpler test configurations and reduced asphericity on the secondary mirror. Detailed analysis of the optical effects of lens displacements, gravity distortions, glass quality, and fabrication errors have been carried out and show this system to be well within industry fabrications capabilities. Stray and scattered light analysis shows the LSST will achieve its signal to noise requirements. Further progress has been made on the development of mirror, anti-reflection, and filter coatings showing that the system throughput meets the depth requirements of the survey and the out of band filter rejection requirements.

Mirror Testing



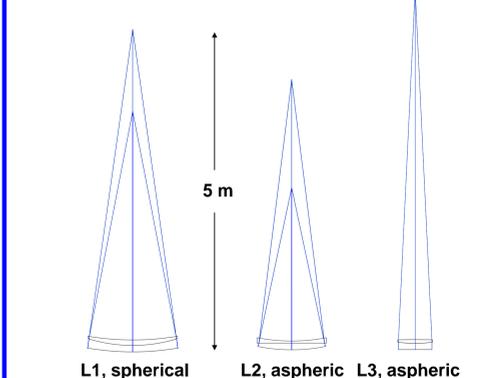
The First and third reflective surfaces will be manufactured into a single mirror blank. Each surface is suited to standard optical metrology. Establishing the relationship between M1 and M3 is achieved through a combination of simultaneous optical tests, Laser tracker positioning, and mechanical run-out measurements.

Optical Design



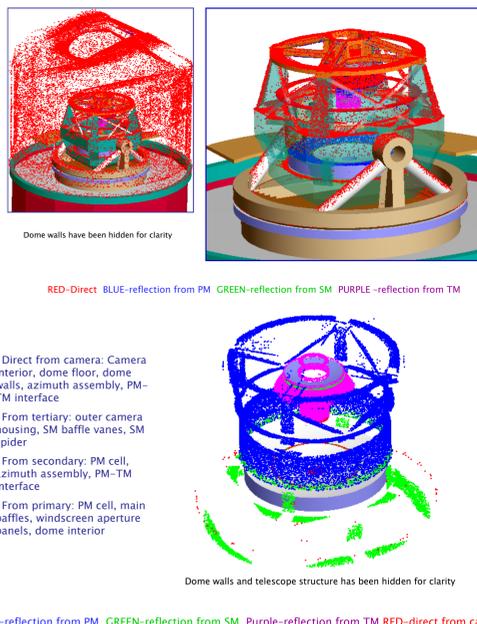
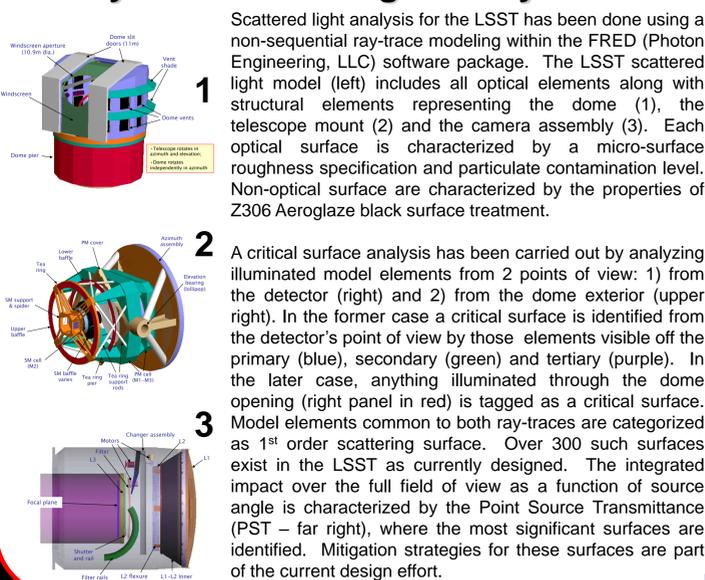
At the heart of the LSST optical design is a three mirror system that derives its origins from the Mersenne-Schmidt family of optical systems, that produce excellent image quality over very wide fields of view. The LSST system adds a 3-element refractive camera to further improve image performance, compensate for chromatic aberrations from the filters and dewar window, and flatten the focal plane. The meniscus filter substrates keep the beam telecentric across the full field of view, thus eliminating any wavelength shift in the filter response. The thickness of L3 is determined by the required stress safety margin needed to serve as the dewar window and vacuum barrier. The resulting image quality (right) is $<0.2''$ at 50% (lower curves) and $<0.3''$ at 80% encircled energy (upper curves) across the full visible spectrum (330 – 1080 Å).

Lens Null Tests

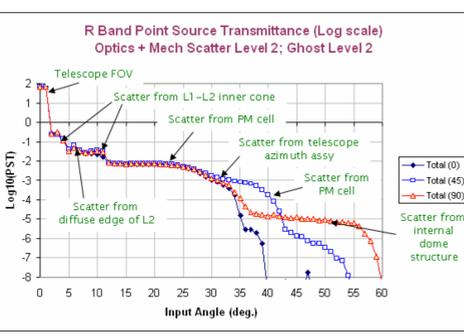


Individual null tests for each of the three refractive elements were included as part of the final design optimization. This resulted in the balancing of the aspheric terms throughout the optical system to simplify manufacturability. In the end L1 remained a fully spherical optic, a small amount of asphericity on L2 resulted in a simple null test and a reduction of asphericity on M2, similarly added asphericity on L3 greatly simplified its null test. Each null test is conducted in the orientation with gravity in the downward direction. By testing the lenses in their preferred operational orientation compensates to first order any optical error caused by gravitation distortion.

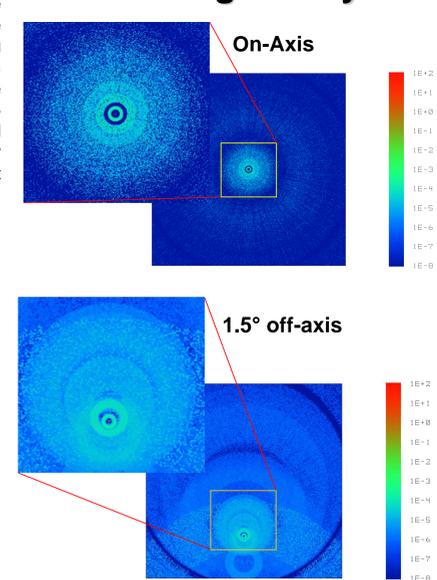
Stray & Scattered Light Analysis



With refractive elements secondary reflections will cause unwanted ghost images. All combinations of two-surface ghost in the LSST optical system have been analyzed. The fast f/1.23 LSST beam combined with anti-reflection coating on each lens surface results in very low surface brightness in the ghost images. The worst case ghost generated by the filter substrate (insets left, inner most circle) is 10^8 times (22.5 magnitudes) fainter than its source. The ghost generated from reflections off the sensor and L2 surface 2 is nearly stationary with field angle. Removal of this "pupil" will be part of the routine instrumental calibration image processing.

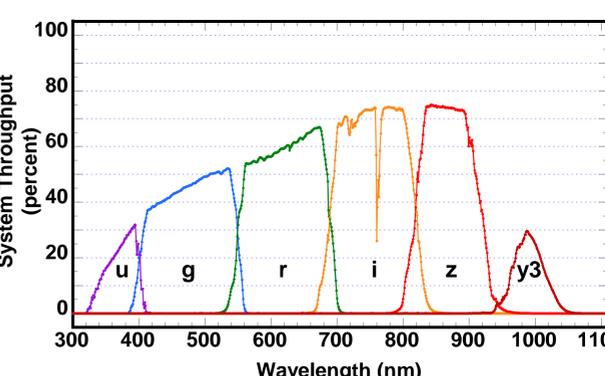
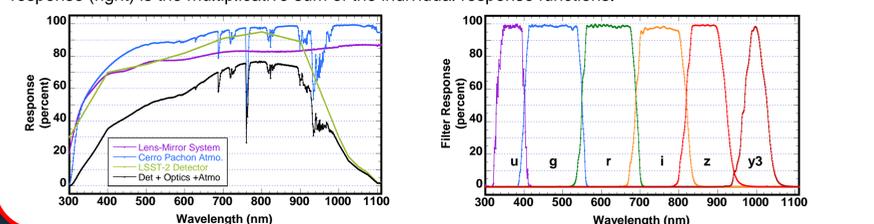


Ghost Image Analysis



System Throughput

The six-band system throughput for the LSST is determined from the product of 5 system element response functions. The full system response (lower left – black) combines the functions for the atmosphere, the optics, and sensor QE. The atmospheric transmission (lower left – blue) over Cerro Pachon has been calculated using MODTRAN under average temperature, humidity and pressure conditions at the site elevation of 2700m. The lens-mirror response function (lower left – purple) combines three mirror surfaces and six lens surfaces with broadband anti-reflection coatings. The mirror reflectivities are based on a hybrid Al-AG coating under development in collaboration with the Gemini Observatory. The ideal filter response functions (lower right) are computed with multi-layer thin-film models using TCALC. The final six-band system response (right) is the multiplicative sum of the individual response functions.



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