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# Sensors and Front-end Electronics for the Large Synoptic Survey Camera

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The Large Synoptic Survey Telescope (LSST) is the flagship US ground-based optical astronomy facility for the next decade. At the heart of its 3Gpixel camera are the 21 focal plane modules, each of which is a fully autonomous and serviceable unit comprised of 9 CCDs and 144 channels of low-noise processing electronics. To minimize noise, power, and beam obscuration the electronics is ASIC-based and operates in shared vacuum space in close proximity to the CCDs. Successful demonstration of an end-to-end prototype meeting its noise, power, speed, and compactness goals is presented in this talk.

## Summary

The Large Synoptic Survey Telescope, whose construction started this year, will be an all-sky survey in the optical and near infrared using 8m-class collecting optics, an agile alt-azimuth mount, and wide-field 3.2 Gpixel camera. The key science missions of the LSST include investigating the nature of dark energy and dark matter using weak gravitational lensing, baryon acoustic oscillations, supernovae, and galaxy cluster counts. In addition, the fields of intra-galactic and solar system astornomy will reap enormous benefits from the full LSST dataset. A unique feature of the telescope is its rapid patrol cadence, enabled by advanced mount mechanics and a highly-parallelized readout system, which allow the entire visible sky to be observed every three nights, thus opening a new time domain window beyond static sky mapping of previous surveys.

To simultaneously achieve wide wavelength coverage, low noise, and rapid readout, the camera incorporates new-generation fully-depleted CCD sensors and ASIC electronics. The sensors are back-illuminated, 4K x4K format, four-side buttable CCDs on 100um-thick silicon with 16 independent video outputs. Their demanding electro-optic and physical requirements have been met by two manufacturers through a seven-year development program. Both company's devices have compatible mounting and pinout making them interchangable. Two CMOS ASICs were developed to handle clock and bias generation and video processing. By operating the CCDs and electronics at 550kpix/s, we achieve 9 electrons rms noise and 18-bit dynamic range at a total power dissipation of 350mW/channel, allowing the full camera to read out a 13GByte image in 2 seconds with SNR dominated by shot noise from the night sky background and resolution dominated by atmospheric turbulence. 3024 channels of electronics are housed in 21 small crates which share the cryostat vacuum with the CCD focal plane; only power and high speed serial I/O penetrate the vacuum vessel. CCD and electronics temperatures are separately regulated. Thanks to the use of ASIC technology the circuit board area per channel (including CCD control and signal processing, digitization, image data transmission, slow control, and special diagnostic functions) is less than 7.5cmˆ2.

We refer to the assembly of 9 CCDs and 144 electronics channels as a raft tower module (RTM). Thermal and mechanical design of the RTM is severely constrained by the need for accurate co-planarity of imaging surfaces of the 9 CCDs in the RTM sub-mosaic. This is due to the wide-field optics of LSST, which result in a shallow depth of focus (20 micron peak-to-valley). We have developed precision metrology to monitor both the flatness of the individual sensor surfaces and the planarity of the assembled mosaic, both at room temperature and at the operating temperature of -100C.

The first prototype of the complete RTM has been constructed and measurements demonstrating its electro-optic, mechanical, and thermal performance will be presented.

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