Packaging and Operation of Philips 7kx9k CCDs

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Introduction

The development of 150 mm full wafer silicon detectors requires that new packaging techniques be employed to allow for flat imaging surfaces, low temperature operation, and convenient mounting and handling. In a collaboration with American Digital Imaging, Inc., we have developed packaging techniques for the very large area Philips 7kx9k 12 μm pixel CCDs. We describe our packaging materials, the camera systems used to characterize these detectors, and present preliminary characterization results.

The physical specifications of the Philips 7kx9k CCD are summarized in Table I. The devices are produced using Philips' mKxnK modular CCD process which places 1kx1k blocks of pixels together during manufacture to create larger format arrays (1,2). Each CCD has four amplifiers (one in each corner), although we have read only one amplifier at a time during these preliminary tests.

Data regarding the testing of the 7kx9k devices at both the Steward Observatory CCD Laboratory and at DLR (3) are presented here as a summary of the first results with these detectors.

Table 1.
Philips 7kx9k CCD Physical Characteristics

Architecture	Front-Illuminated, Full Frame CCD
Number of Pixels 7k x 9k	7168 x 9216
Pixel Size	12 μm
Size of Photosensitive Area	86.0 x 110.6 mm

Packaging

A major packaging goal at Steward Observatory has been to maintain a flat and stable imaging surface over the entire device from room temperature to approximately -130 C. Because the CCD is cooled in a liquid nitrogen dewar, we have not attempted to minimize the mass of the package. We have developed an Invar-36 carrier for the basic CCD package. We chose Invar-36 because of its machinablity, stiffness, and adequate thermal expansion and conduction properties. We attach to the carrier two identical FR-4 printed circuit boards with gold plated copper traces for wire bonding and fanout. Each board is located at the shorter (serial register) end of the device and contains one 37-pin Nanonics cryogenic connector for external I/O connection. The two connectors per CCD have identical pinouts.

The Invar-36 carrier is machined and polished flat to a specification of 2.5 μm peak-to-valley. The thickness is 7.62 mm to maintain flatness during thermal cycling. We have measured all final Invar packages to have less than 1 μm peak-valley flatness deviation. The packages and attachments have been successfully rapidly thermally cycled between liquid nitrogen (77 K) and room temperature. We have imaged devices as cold as -165 C. The entire CCD and package weighs approximately 1000 grams. The CCD is attached to the Invar-36 carrier with a electrically conductive thermoplastic.

In order to substantially reduce the mass of the Invar carrier, the DLR group will replace the Invar with a modern ceramic matrix composite C/C-SiC provided by the DLR Institute of Structures and Design (Stuttgart). A prototype of the C/C-SiC base-plate has already been manufactured. The main advantage of the ceramic composite is its lower density compared Invar. All other material parameters of C/C-SiC (modulus of elasticity, CTE, thermal and electrical conductivity, specific heat, corrosion resistance) are similar or more appropriate than Invar.

Camera System

Controller

Characterization of the devices at the Steward Observatory CCD Laboratory utilized our standard San Diego State University camera controller (4). We have slightly modified our standard system to allow for a 3.3 kΩ output load resistor and to bias the NSUB and PSUB CCD connections, which other CCDs we have tested do not use. The NSUB voltage is connected to the backside of the device, and therefore connects directly to the package. Biasing this (to +24 V) means that the package itself is must be electrically isolated from internal dewar ground connections.

At the tested pixel rate of 33 kHz pixel rate, the device would take over 30 minutes to read through one amplifier. We therefore read the device in various binning modes, from 2x2 to 10x10 binning factors.

The DLR camera system is designed for high speed, room temperature or Peltier cooled operation. The camera is a 12-bit system capable of 4 MHz per channel readout, with current tests limited to about 2.5 MHz readout rate.

Dewar

The cryogenic system at Steward Observatory utilizes a Kadel Engineering 3 liter LN_2 dewar to cool the CCD during testing. The Invar-36 package is bolted to a copper base-plate with an attached heater and temperature sensor for thermal control. Two wire harnesses lead directly from the CCD connectors to the dewar-wall hermetic connectors. The controller electronics box is mounted directly on the outside of the dewar.

The dewar window is 6" diameter fused silica, 0.5" thick. A 6" diameter shutter with a 100 msec open/close time is mounted on the front end of the dewar. The dewar and shutter are then placed on an optical bench in the Lab or directly on a filter holder at our telescope.

Preliminary Device Performance

Device Parameters

We list in Table 2 the operating voltages used for a 7kx9k CCD which was imaged both at Steward Observatory and DLR. Note that at Steward Observatory the CCD was imaged cryogenically at 33 kHz while at DLR the same CCD was operated at room temperature with a 2.5 MHz read rate.

Table 2.
Operating voltages (V) of the Philips 7k x 9k LA (W16)

Voltage	Prelim. Data Sheet	Steward (slow)	DLR NE-PE (fast)
SFD	16...20...24	23.5	20
SFS	0...0...4	0	0
VPS	1...5...7	6	3
VNS	18...22...27	24	24
RD	13...15...18	16	15
OG	1...4...6	3	6
VCS	1...2...7	0	0
vertical	0...10	0...10	0...10
horizontal	3...8	0...10	2.4...8.1
SG	3...8	0...10	2.4...8.1
RG	0...10	0...10	2.4...9.9

Noise

Read noise as low as 10 electrons rms was measured at Steward Observatory at the slow readout rate (using a dual-slope correlated double sample with 4 microseconds integration time each on noise and signal). The DLR total system noise was measured to be about 80 electrons at 2.5 MHz and 25 C.

Full Well

Full well capacity of at least 100,000 electrons has been measured. The serial register is 3-phase while the parallel image section is 4-phase.

Dark Current

Dark current was not measurable in preliminary tests when operated cold. The room temperature dark current was measured to be under 200 electrons/pixel/second at 25 C.

Telescope Results

We have taken one device to the University of Arizona/Steward Observatory 2.3 meter telescope on Kitt Peak for a one night engineering checkout of the CCD and camera. We were very successful and easily acquired several gigabytes of image data, binned 5x5 to provide 0.6 arcsec/pixel resolution. We found the device robust and very similar in operating characteristics to other CCDs we have tested. We used a dry air purge over the large dewar window to avoid frosting due to ambient humidity, but otherwise operated the same as in our Laboratory. Characterization results of this telescope data will be presented in a future paper.

Modular Structure

Very slight QE variations are seen at the interface of the 1kx1k modular building blocks used to manufacture the large format CCD. For this structure to be noticed, the device must be imaged with an extremely uniform illumination source. As expected, these variations are most visible in the blue where reflection and absorption in the frontside structures are most pronounced. We did not see these features in any of the Laboratory or sky images, but only during flat field calibration exposures at the telescope. The QE variations are approximately 0.5% using a 1000 A bandpass filter centered near 4500 A.

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