THE MMT MEGACAM
Focal Plane Design and Performance

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Abstract: The MMT Megacam is a mosaic camera with 36 2048x4608 pixel CCDs, covering a 25'x25' field of view and mounted at the f/5 Cassegrain focus of the 6.5m MMT. Megacam was commissioned in November 2003 and has been conducting scientific observations since then. In this paper we describe some of the design and performance characteristics of the Megacam focal plane.

Key words: MMT Megacam, mosaic cameras

1. INTRODUCTION

The MMT Megacam is a mosaic camera that resides at the f/5 Cassegrain focus of the converted MMT telescope on Mt. Hopkins, Arizona, USA. The science focal plane is comprised of 36 2048x4608 pixel CCDs, model CCD42-90, manufactured by E2V Technologies. An additional two CCDs of the same type are used for guiding and focus corrections. A three-element refractive corrector plus a field-flattener that serves as the entrance to the Megacam dewar provide a flat focal plane which is 35 arcmin in diameter. The Megacam science field of view is 25'x25' square. Megacam was commissioned in November 2003, and has been scientifically productive since then (see e.g. Hartman et al., 2005). In this paper we describe some of the features relating to the focal plane and CCD operation. Further description of the shutter, filter assemblies, and electronics can be found in McLeod et al (1999), and Geary & Amato (1998). An up-to-date comprehensive description of the instrument is in preparation.

2. CCD MOUNTING

One of the challenges in building a large CCD mosaic is getting all the detectors in-focus simultaneously when they are cold. The CCD42-90 package is ideally suited for this purpose. The CCD is epoxied to an Invar block. To the bottom of this block are attached 3 precision shims, lapped by the manufacturer so that they define a plane 14 mm from the CCD surface. We then were left with the task of providing a flat surface to bolt them to. We chose to mount them to a 6 mm thick Invar plate, suspended around the edge by six Titanium flexures from a warm support ring (see Figure 1). These flexures provide the necessary thermal isolation. The tilt and axial position of the cold plate was set by adjusting the location of the warm ring with a set of spring loaded screws. Once the location was set, precision spacers were machined and bolted into place. The mounted plate was measured to be flat to ~10µm P-V before any CCDs were installed. (We note that our original design used a Molybdenum plate, which provides a factor of several better thermal conductivity. However, this plate arrived from the vendor broken in two pieces, so we chose to replace it with the less brittle material.)

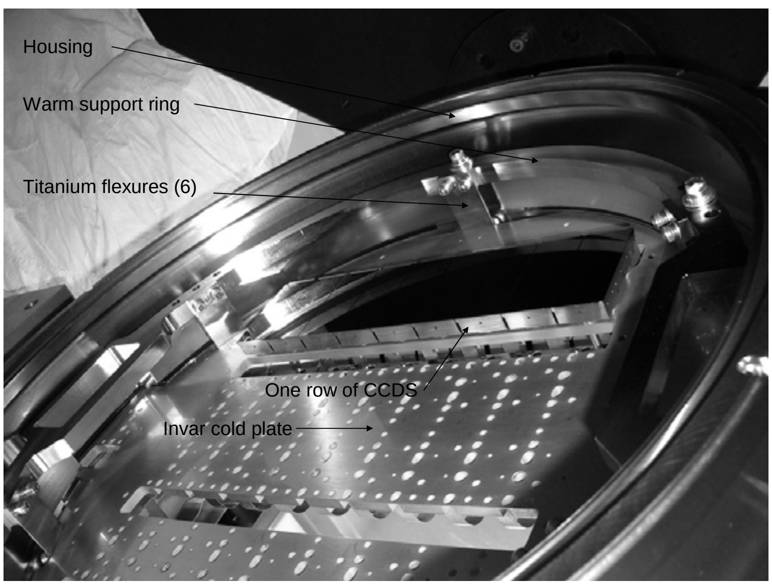

Figure 1. The Megacam cryostat.

To verify the focal plane flatness we relied on focus measurements on the sky. Our current measurements indicate that that there is roughly 100µm P-V of deviation from the best focus across the plate. This is larger than expected, but has a completely negligible effect on the image quality. An image taken in 0.4 arcsec seeing shows essentially no variation in FWHM across the entire Megacam field. There are no discontinuities from one CCD to the next, showing that the CCD packages were manufactured well.

3. THERMAL DESIGN

The thermal layout is shown in Figure 2. The cooling path from the CCDs goes through the CCD42-90 package's precision shims to the Invar mounting plate. Copper straps connect the Invar plate to a set of four cold copper bars. These copper bars are connected to two IRLabs ND-14 dewars mounted on opposite sides of the central dewar. The copper straps were trimmed once after the initial cool down and the CCDs vary in temperature from -130C to -115C across the focal plane. A more uniform distribution could have been obtained with further iterations of trimming. The temperature of the CCDs can be stabilized using a set of heater resistors mounted on the back side of the Invar plate. The heaters are all wired in a single zone.

The total LN2 consumption of the Megacam is 40 W or 20 liter/day. The ND-14 dewars are filled from the bottom and thus contain a tube that extends up inside the tank to prevent the liquid from running back out. We have chosen to make this tube extend 60% the height of the tank. This means we can fill the tank only 60% full, but don't have to worry about dumping out large quantities of LN2 when the telescope tips over. The hold time in this configuration is roughly 36 hours. The thermal load is dominated by radiation coupling from the dewar window to the CCDs. Several features minimize other sources of thermal loading. We have gold-plated the Invar plate and copper straps and bars. The flex circuits connecting to the CCDs have two ground layers to provide electrical isolation between the AC and DC signals. Instead of a solid plane, these layers are laid out in a serpentine path to minimize the thermal conductivity. Titanium was chosen for the flexures because of its high stiffness and low thermal conductivity. The flexures contribute only 5W of the 40W load. Finally, we put radiation shields between the flex circuits and the Invar cold plate.

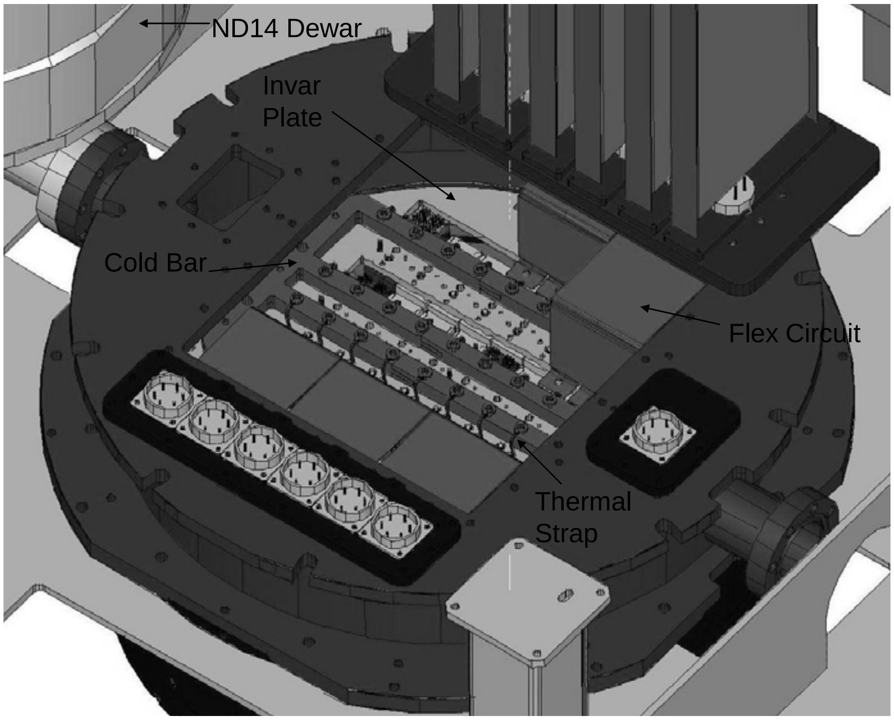

Figure 2. Megacam thermal connections. Note that thermal straps are actually 0.005" thick copper sheet rather than the wires shown. Radiation shields (not shown) are located under the horizontal part of the flex circuit.

4. ELECTRONICS

4.1 Electronics Design

Here we describe the CCD electronics, working our way towards the CCDs. The data acquisition computer is currently a Sun Workstation running Solaris, but soon to be replaced with a rack mounted Linux server. The computer contains an EDT PCI-FOI interface card, which is connected to the CCD electronics via optical fiber. There are two electronics racks, dubbed master and slave, each of which drives one half of the focal plane. Each rack contains its own power supplies. The CCD electronics, which are 6U format, have the following cards: 1) one I/O card in the master rack which contains the EDT fiber interface, 2) one timing generator in the master rack, 3) 9 A/D cards in each rack, 4) 6 driver cards in each rack, and 5) one driver/receiver card in each rack which drives command and data signals between the two racks. These boards are connected together via a VME-style backplane. From the driver and A/D cards, connections to the CCDs pass via connectors on the backplane to preamplifier cards which are then connected to hermetic connectors via discrete wiring (see Figure 3). These connections are the only discrete wiring in the system.

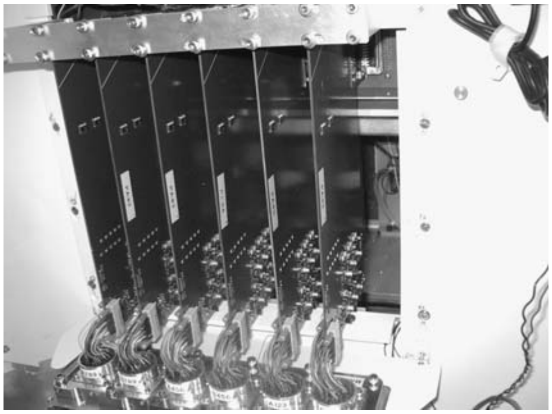

Figure 3. Preamp cards. The upper end of each card connects to the electronics rack backplane. The bottom end connects to the hermetic connectors. Each preamp card serves 3 CCDs.

Figure 4. Flex circuits inside the cryostat. In this photo, one of the outer rows of CCDs is already installed and connected. Zener diodes are soldered onto the flex circuit to provide ESD protection.

Inside the cryostat, the signals travel on custom flex circuits, 3 CCDs per flex (see Figure 4). Each CCD electronics driver board drives three CCDs. To reduce the number of wires going into the cryostat, we generate the following signals in common for the three CCDs and split them on the flex circuit in the cryostat: S1L, S1R, S2L, S2R, S3, SW, DG, and OG1. The following are generated per CCD: P1, P2, P3, and RD. The following are generated per amplifier: OD, OG2, RG, and, obviously, OS. A thermistor on one of every three CCDs is wired out. The connection from the flex circuit to the CCDs is made by a ZIF connector (Tactic Electronics, model 40-H). Initially we had some continuity problems between the ZIF and the CCD because we did not solder the flex circuit to the ZIF with the two parts flush against each other. This allowed the pins inside the ZIF to move and not lock properly. This problem was completely resolved by resoldering all the ZIFs with the flex circuits flush against the connector body and each pin pulled fully out from the connector as it was soldered.

4.2 Electronics Testing

Before we installed all the CCDs we verified every signal at the ZIF connector. To do this, we manufactured a set of dummy CCD packages which we installed in the focal plane. Instead of a CCD on the top, they had a circuit board which contained capacitors to mimic the CCD capacitance, and a D-connector. These D-connectors were mated in turn to a test box (Figure 5) which allowed us to dial up each of a CCD's signals onto an oscilloscope in quick succession. The test box also contained a video generator circuit that fed the dummy CCD with an artificial signal which then made its way up the signal chain. This testing system proved itself very valuable and efficient in tracking down problems before any CCDs were installed.

4.3 Electronics Performance

We experimented with operating the output amplifier of the CCD42-90 in a state which lowers the gain by a factor of 5 and increases the full-well capacity by a similar factor. This is accomplished by raising OG2 to roughly 12V above the substrate voltage (see the manufacturer's data sheet). Unfortunately, limitations in our electronics only permitted us to reach 10V above substrate. With this value of OG2 we realized a factor of 3 reduction in gain, but also observed a noticeable amount of non-linearity. We are not currently supporting this mode for observers.

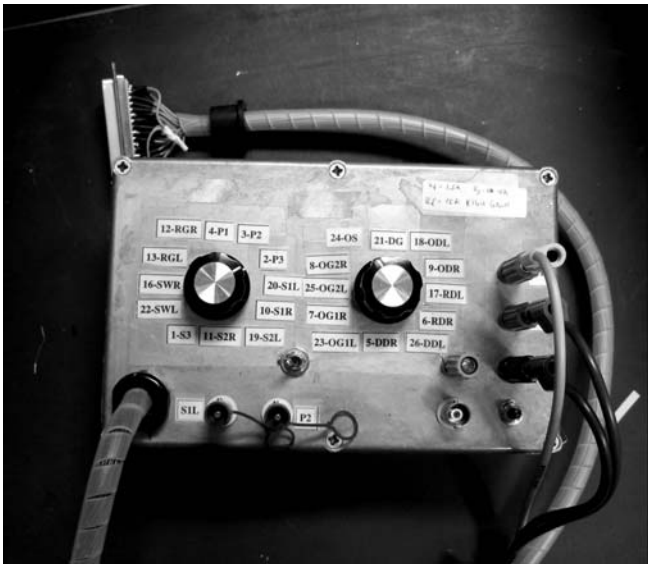

Figure 5. CCD Test Box

In normal operation we use a gain of 3.5 e-/ADU, and a 200kHz pixel clock. In this mode, we measure a read noise of 4-5e-. The output amplifier of the CCD saturates around 60,000 ADU, giving us nearly optimal dynamic range. We have measured no channel-to-channel crosstalk down to the 10^{-5} level.

References

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