MOCAM: A 4Kx4K CCD MOSAIC FOR THE CANADA-FRANCE-HAWAII TELESCOPE PRIME FOCUS

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1. ABSTRACT

MOCAM is a wide field CCD camera, currently nearing completion, which will be offered to the Canada-France-Hawaii Telescope (CFHT) user community in 1995. The project is a collaboration between the CFHT, the Dominion Astronomical Observatory (DAO, Canada), the Institut des Sciences de l'Univers (INSU, France), Laboratoire d'Astrophysique de Toulouse (LAT, France) and the University of Hawaii (UH). In the interests of producing a reliable and effective camera in the shortest time, it was decided to use existing technologies rather than innovative ones. Two-edge buttable 2048×2048 15 μm pixel CCDs were obtained from the LORAL aerospace foundry, based on a mask designed by J. Geary at Smithsonian Astrophysical Observatory (SAO). They are mounted in a dewar designed by G. Luppino (UH); the focal plane mounting keeps the mosaic flat to within 2 pixels and the CCDs are aligned to within 2 pixels width. A mechanical interface designed and fabricated by the DAO holds a 150mm shutter and a filter wheel which has a positioning repeatability better than 5 μm. The four CCDs are operated in parallel by a San Diego GenIII controller adapted by LAT. The mosaic is read out in 7 minutes and a single 33Mbytes FITS file is generated to enable convenient on-line preprocessing. The user will control the system through a single CFHT Pegasus environment session. The camera field is 14'×14' with a 0.2" pixel sampling and the readout noise is less than 7 electrons. The scientific goals of the initiators of the project are studies of distant clusters, deep galaxy counts and quasars surveys.

2. INTRODUCTION

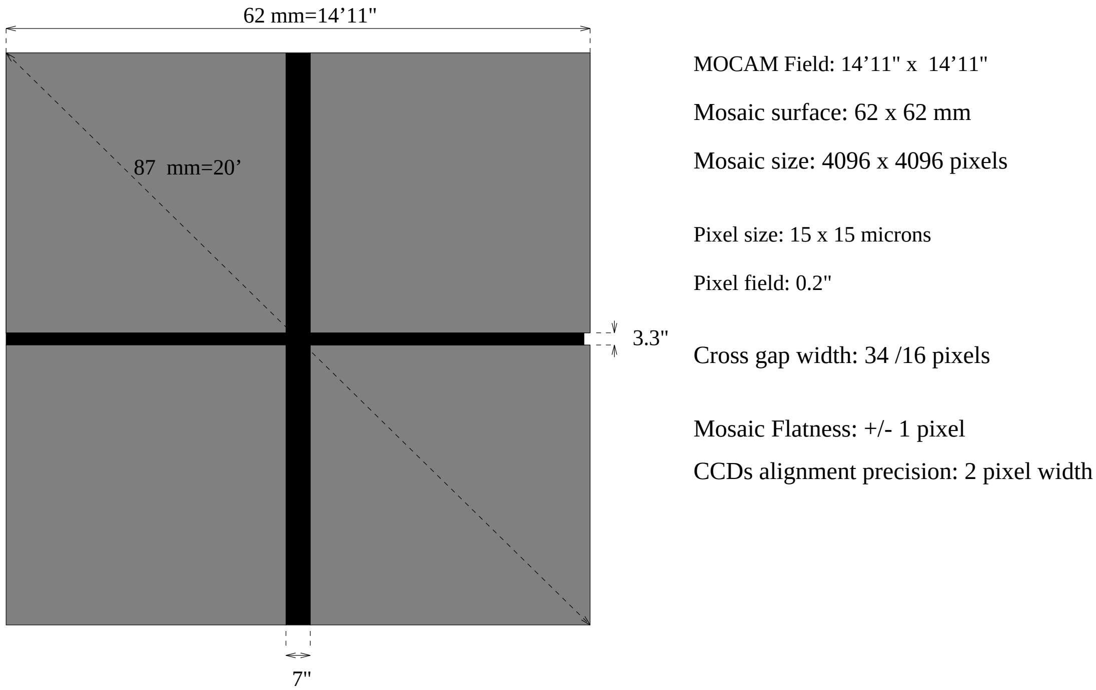

Figure 1: MOCAM field at the CFHT prime focus

After the CFHT users meeting in May 1992, the Scientific Advisory Council (SAC) of CFHT recommended building a large mosaic CCD for the prime focus of the telescope, as it had been proposed by a Canadian-French collaboration. The mosaic design consisted of a 2×2 2048×2048 array with 15 micron pixel, giving a total field of view of $14'\times14'$. It was found that the scientific impact of such a wide field CCD camera on the world's best image quality telescope would benefit a large number of scientific projects, from asteroids and comets, to quasars or faint galaxies (Crampton 1992). It was also emphasised that the Canadian-French mosaic camera (MOCAM), which covers less than 8% of the total field of view of the prime focus, could be a first step toward the development of a larger CCD camera.

The MOCAM project is now near completion and the camera is ready. MOCAM will be with the dual mosaic cameras designed by Stubbs et al. (1993), the second large CCD mosaic camera in operation on a telescope. Its first light is expected by the end of November 1994 when deep scientific observations of lensing clusters should reveal the full capability of MOCAM before the final acceptance tests and a delivery to CFHT for the users.

3. MOCAM PROJECT OVERVIEW

The objective of this project is to produce a reliable facility instrument for the whole scientific community in the shortest time. The dewar developed by G. Luppino from the University of Hawaii was chosen because its design had been fully developed and optimized (Luppino et al. 1992) as a prototype of the $8K\times8K$ mosaic that is currently near completion (Luppino et al. 1994).

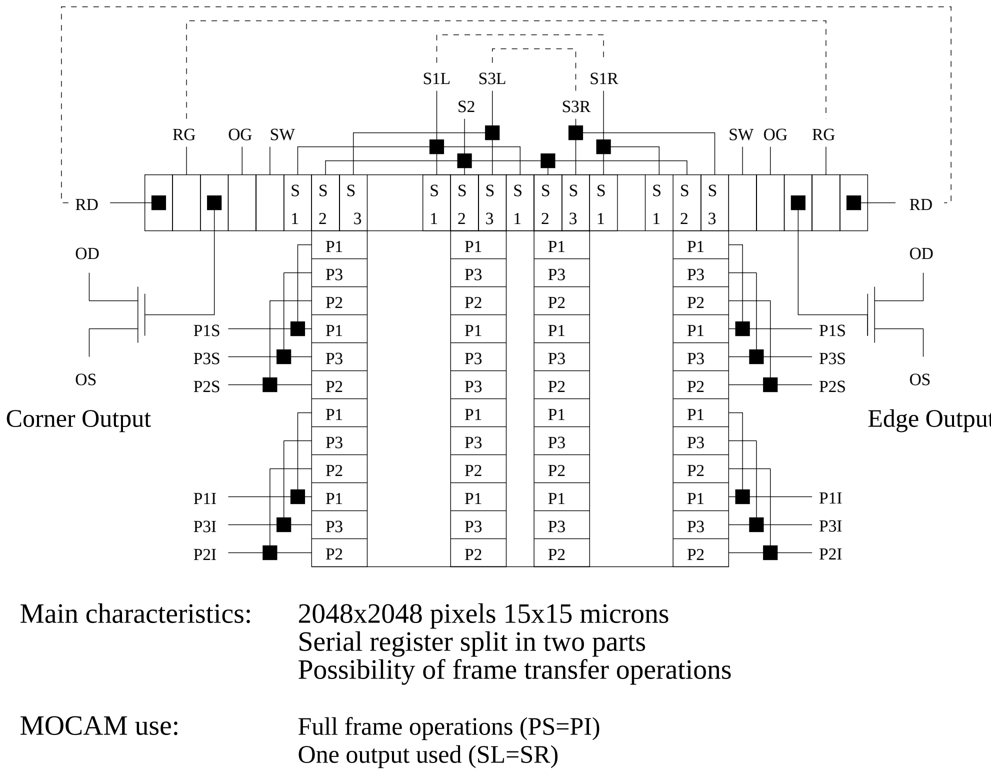

Figure 2: 2K×2K 2-Edge buttable LORAL CCD schematic diagram

The CFHT hardware and software environment were used by the LAT group to develop the parallel readout mode on the SDSU Generation III CCD controller (Leach 1988) adapted by the CFHT for its own use (Kerr et al. 1994). The software was developed under the CFHT Pegasus software environment. DAO built the filter wheel, its associated hardware and the software that control the filter wheel and the shutter. DAO was also in charge of the selection and cryogenic tests of the individuals CCDs. The whole system was integrated, tested and optimized at Toulouse. Because of staffing priorities at CFHT, their participation in MOCAM was limited in software support to LAT.

4. MOCAM DEWAR AND CCDs

The dewar has been fully described by Luppino et al. (1992). It was designed to handle a CCD mosaic of four 2K×2K two-edge buttable LORAL 15 μm pixel CCDs. The characteristics are excellent as the hold time with a 3.0 liters nitrogen fill exceeds 24 hours with a fully wired mosaic operating at -100^{o}C. A single high density connector simplifies the connection to the controller and one of the two vacuum ports enables the pressure to be monitored.

Light enters the dewar through a 5mm thick 14cm diameter quartz window. Spot diagrams analysis shows that the effect of the field curvature on the image quality is negligible, but the image quality slightly degrades when moving out to the edge of the CCD field. For an f/4 beam, homogeneous image quality can be obtained on the overall field by

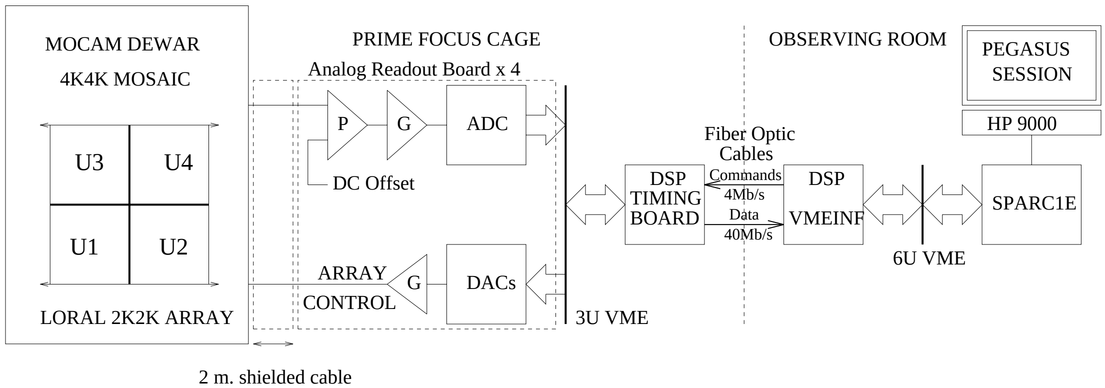

Figure 3: MOCAM GenIII controller system

focusing on stars close to the mosaic edges. Figure 1 gives the focal plane characteristics at the CFHT prime focus. The larger gap between the CCDs is $500\mu m$ and thanks to the recent development that uses new techniques to cut the packages (Luppino et al., 1992) onto which the CCDs are mounted, the alignment between the different CCDs is kept within 2 pixels and the mosaic is kept flat to about 2 pixels, introducing no defocusing effect at the the f/4 prime focus.

The 2K×2K 2 edge buttable CCDs were designed by J. Geary (SAO) and produced by LORAL (Geary et al. 1990). These CCDs have two low-noise outputs and are capable of frame storage operations. MOCAM is wired to allow full frame readout through one output per CCD (see figure 2). Switching from one CCD output to the other one is achieved simply by downloading a new DSP code to the controller and inverting the two coaxial video cables inside the controller. Frame transfer operations are possible by simply downloading a new DSP code and installing an appropriate mask over the storage regions, but MOCAM is initially planned to be used only in full frame mode with four CCDs parallel readout.

5. CCD CONTROLLER HARDWARE AND SOFTWARE

Figure 3 shows the MOCAM CFHT's Generation III controller based on the same design of the Redeye controller (Kerr et al. 1994). This multi-amplifier readout system consists of a data acquisition computer running the Pegasus Software system on a Unix platform, communicating through a client-server protocol with the CCD interface control computer that manages the data acquisition and the DSP controller based on the SDSU design.

The four CCDs are read out in parallel but the data are sent sequentially through the single fiber optic connection to the VMEINF SDSU board, which sends them onto the VME bus in DMA mode. At the end of the transfer, the data are descrambled in the CCD computer by a Unix routine. The four CCDs are read out by the four corner outputs with a fixed number of overscan pixels in each column and row. As the CCDs mirror each other about the central gaps, the overscans simulate the mosaic gap cross and then enable to keep the field astrometry in the final single FITS file.

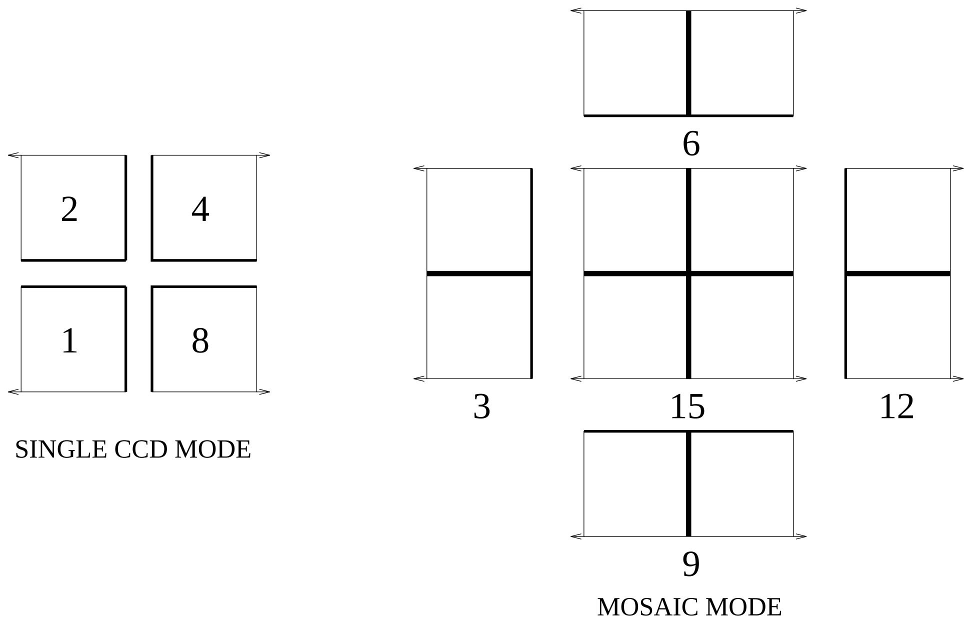

Figure 4: MOCAM virtual detectors: the topologies concept

When adapting the CFHT software at LAT, there was a big concern over keeping the existing single CCD readout mode as a possible multi-amplifier readout option. With this aim, the concept of topologies was introduced to address all the physical possibilities available with the mosaic. Each individual CCD has a unique 2^n weight with $n = 0,..,3$ (see figure 4, left) so that each mosaic configuration has a unique topology code (figure 4, right). In this software operating mode, FOCAM the actual CFHT single CCD camera, would be managed by the mosaic software as the CCD having the weight 1. This concept is used from the higher Unix layer (MOCAM Pegasus session) to the lower one in the DSP code. Because of the hardware design, the four CCDs are always clocked together even in the case of a single raster acquisition. Consequently the data transmission depends on the current topology so that the CCD computer receives only the required data to perform the descrambling process.

Unix is not suited for real time process and some unexpected lost of data happened when sending large amounts of data through the fiber optic. We solved this problem by slowing down the DSP controller so that the CCD computer became the communication master. The drawback is a higher four pixels mosaic readout time of $48\mu s$ as a delay of at least $7\mu s$ is required between each optic data. This problem should be fixed with the new CFHT software release being currently implemented. Figure 5 shows the mosaic pixel readout cycle, where the overlap of functions are used as much as possible to save time. The full 4K$\times$4K mosaic can be read out in 3 mn 30 sec and the descrambling process adds 1 mn more.

Developing MOCAM as a CFHT instrument required use of a 2 meter long cable from the CCD controller to the dewar. Because there are no electronics inside the dewar, the cable had to be very highly shielded. The four CCD harnesses are completely isolated

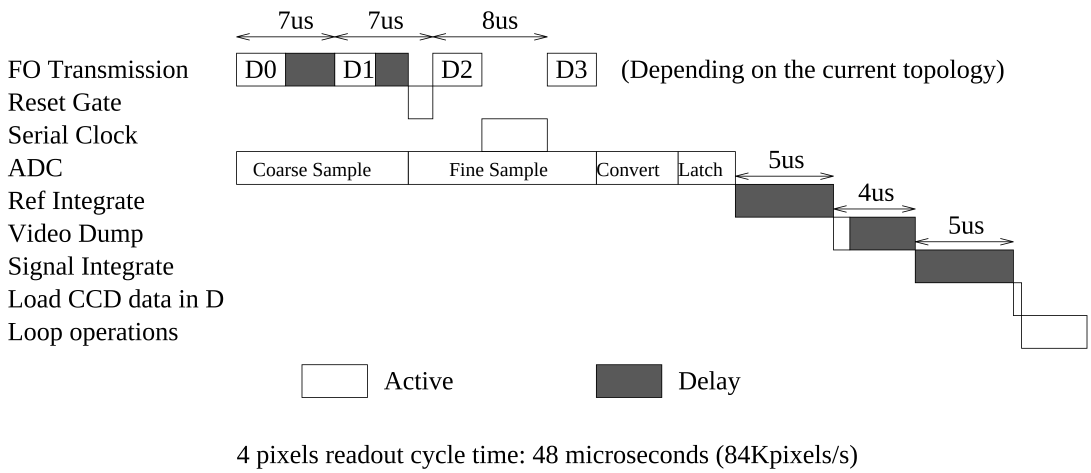

Figure 5: MOCAM pixel readout diagram

from each others to avoid interchannel crosstalking through capacitive coupling. High level crosstalking is avoided by a short delay after the video dump to take into account the limited slew rate of the CCDs outputs (figure 5). There are a lot of interconnections between the MOCAM devices (see figure 6) and in order to keep the readout noise as low as possible, the best ground configuration found was to connect the dewar body to the digital ground whereas the analog board is the ground node for each CCD harness. The readout noise is 6.7 electrons with small variations between the four CCDs.

6. FILTER WHEEL AND SHUTTER

The filter wheel which also has the function of mechanical interface with the prime focus, incorporates a 15 cm iris shutter. Its opening time of 50 ms and its closing time of 200 ms, which are long, make the standard dome flatfielding operation rather inaccurate for ultra-deep imaging. We recommend that observers use superflats as much as possible rather that twilight flats or dome flats even if some simple computational methods can be applied to correct the shutter response (Surma 1993).

The filter wheel can support five filters but MOCAM will initially use only V, R and I band photometric filters since MOCAM is equipped with 4 thick CCDs. In a second stage, we plan to mount thin CCDs in the camera head and can make use of U and B filter positions. The filter wheel position is controlled by two stepping motors giving a positioning repeatability of $5\mu m$, which is enough to get very reliable flat fields.

The filter wheel and the shutter are run by a Pro-Log Controller communicating over the serial port with a server running on the CFHT serial server host which communicates with a client which can be anywhere over the network (figure 6). The Pro-Log shutter control signal is comes from the GenIII controller, which manages all exposure tasks.

7. CONCLUSION

Less than three years after the MOCAM proposal, the camera is ready to be used and become a CFHT instrument available for the whole scientific community. Some Canadian

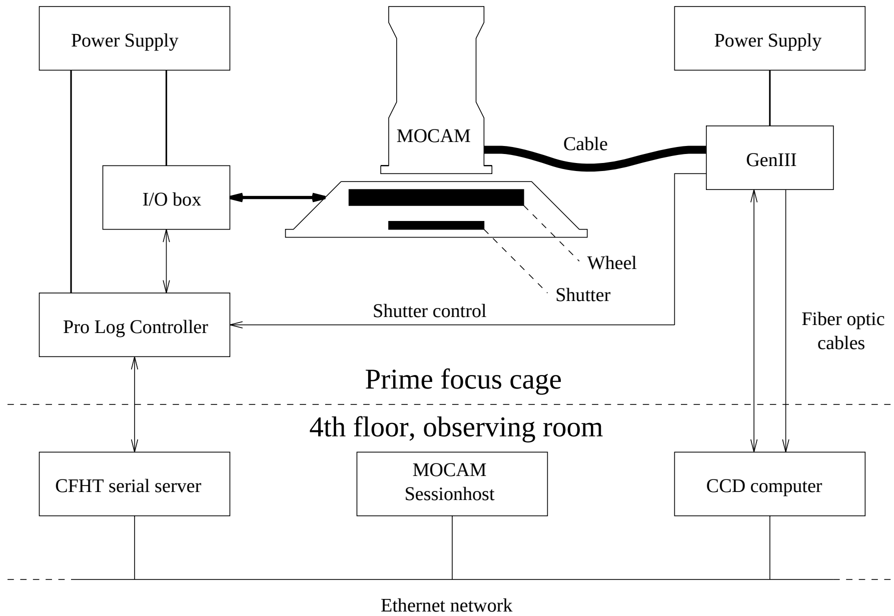

Figure 6: MOCAM hardware

and French astronomers have already applied to observe with MOCAM, but we must wait for first observations at the end of November before having a fully operational camera. We hope that in 1995 the first 14'×14' CCD imaging capability will be available at CFHT and will be a unique instrument on 4 meter class telescopes.

For the future, we are now considering a very large CCD camera with a one square degree field of view. We already have compelling evidence that a wide field CCD camera on a high image quality telescope such as CFHT can make a major breakthrough in cosmology, because it combines subarcsecond images, a large field of view and a large collecting area. It is almost certain that planetology, galactic and extragalactic astronomy need such instrument. This second generation of wide field CCD camera must be considered seriously for the future.

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