SPIE's Astronomical Telescopes and Instrumentation 27-31 March 2000, Munich

CFHTIR: 1k x 1k NIR Spectro-Imaging Camera for the CFHT

Barry Starr[a], Rene Doyon[b], Jean-Luc Beuzit[a], Phillippe Vallee[b], Robert Calder[a], Jamey Eriksen[a], Jean-Charles Cuillandre[a], Bernt Grundseth[a], Greg Barrick[a], Jeff Ward[a], Wiley Knight[a], Daniel Nadeau[b],

[a] Canada-France-Hawaii Telescope (CFHT) Corporation, PO Box 1597, Kamuela, HI 96743

[b] Département de Physique, Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, H3C 3J7, Canada

ABSTRACT

The CFHTIR is a large format (1kx1k) near infrared (1-2.4um) camera based on the Rockwell HAWAII Array. CFHTIR is designed for both direct imaging at the f/8 Cassegrain focus, as well as spectroscopy on the OSIS multiobject spectrograph. The camera provides 0.21"/pixel sampling in both applications with a single set cold transfer optics and pupil mask. The camera includes two eight-position filterwheels driven by cryogenic stepper motors with position control using a novel Hall effect sensor technique. CFHTIR also uses a novel dewar wiring technique employing flexible circuit vacuum feedthrus. CFHTIR is the second large format infrared camera based on the Hawaii array constructed at CFHT, the first being the KIR camera for the CFHT Adaptive Optics Bonnette which was commissioned in 1997. This paper describes the system architecture of the CFHTIR highlighting key design concepts and detailing the physical elements.

Key words: Infrared cameras, infrared instrumentation, wide-field imaging, SWIR, near-infrared, cryogenic flex circuits.

1. INTRODUCTION

The Canada France Hawaii Telescope (CFHT) is a 3.6m telescope located on the summit of Mauna Kea, Hawaii. The CFHT provides excellent image quality in both the visible and near infrared regions. To exploit this capability CFHT has been actively developing a number of large format imaging systems (other papers published in this proceedings detail work on visible wide-field imaging , CFH12K [1,2] and MEGACAM[3]), the CFHTIR represents the latest development effort in the infrared.

The CFHTIR is designed as a dual use instrument providing both direct imaging capability at the CFHT f/8 Cassegrain focus and multiobject spectroscopy when combined with the Optionally Stabilized Imager and Spectrometer (OSIS [4]).The CFHTIR camera will replace an existing NICMOS3 camera (Redeye[5]) which has been in use at CFHT for a number of years in both of these configurations, providing increased performance, larger field, and improved image sampling. The spectral range for direct imaging at Cassegrain focus will be 0.75 to 2.5 um with a total unvignetted field of 3.6 x 3.6 arcminutes. When used with OSIS the spectral range will be reduced to 1.8 um due to background limitations of the "uncooled" refractive optics within the OSIS instrument. The OSIS-IR configuration will provide a choice of multiple operational modes across the same 3.6 x 3.6 arcminute field: direct imaging, long slit spectroscopy, and multiobject spectroscopy, with or without the use of image tip tilt correction.

The CFHTIR project is a collaborative effort between the CFHT corporation and the University of Montreal (UdM). Broadly speaking, the UdM is providing the optical and opto-mechanical design and fabrication of the system (along with filterwheel cryomechanism) while the CFHT provides the electronics, software, external packaging, system test, final integration and characterization. The CFHTIR camera is the second near infrared camera based on the Rockwell 1k x 1k HgCdTe (HAWAII) Focal Plane Array (FPA) [6] to be developed by the CFHT/ UdM team. The first system constructed being the KIR[7] camera for the CFHT Adaptive Optics Bonnette[8]. This fact is mentioned since the CFHTIR project has benefited greatly from this previous work on KIR, while CFHTIR will also provide an upgrade path for KIR in a number of important technological areas. Essentially from the FPA through electronics to software the two systems will be identical, the real differences are present in the optics and cryomechanisms. The CFHTIR is currently under development at both the CFHT facility and at Montreal. First light is scheduled for summer 2000.

Send Correspondence to Barry Starr: starr@cfht.hawaii.edu

2. SYSTEM ARCHITECTURE

The relatively short (compared to visible imaging) integration times used in infrared broad-band imaging and the large data sets generated through the use of multiple exposures and multiple-sample readout modes require attention to a large number of system design issues from readout electronics to telescope control interface. Numerous design choices were made to improve system performance and maximize open-shutter "on-sky" integration time. These efforts included optical throughput and image quality of the camera, low-noise acquisition systems, and reduced system overhead times from detector readout to image display and archiving. Other efforts extended work to the development of numerous software tools to prepare observations, automate calibration frames, interface to telescope and instrument control functions, and reduce image data.

Based on previous experience with the KIR camera, several issues relating to ease of operation and system reliability have also been addressed. The CFHT is a highly configurable telescope supporting multiple foci, instruments, and camera systems. Camera systems must be robust, reliable and easy to install and remove from their respective locations. To support this the CFHTIR camera is a highly- integrated physical unit with the required control and acquisition electronics mounted directly to the dewar body. Setup simply requires bolting the camera to the appropriate instrument spacer, then connecting DC power and a fiberoptic link. The need for system reliability is further emphasized due to the remote physical location of the summit of Mauna Kea (almost 14,000 feet in elevation), and CFHT's desire to support remote observing in the future. So in addition to efforts in the areas of design and quality construction to improve system reliability, extensive work was done to provide remote reset and diagnostic features. The CFHT observatory is a hostile environment in terms of electromagnetic interference, a number of imaging system have failed to reproduce noise figures from the lab while on the telescope. Careful attention to system grounding and power distribution is needed to maximize system noise performance. Galvanic isolation is provided between the FPA acquisition electronics and all other electrical elements in the system and the observatory. The dewar body, which is maintained at the Detector Controller system ground, is isolated from the camera mount by the use of a delrin spacer. The use of this spacer has been instrumental in reducing system noise to detector limited levels[1]. Optical isolation from auxiliary electronic functions allows FPA readout to be immune to interference from the shutter and filterwheel operation.

The CFHTIR design contains the following functional components: (1) Cryostat Assembly - containing FPA, optics and filterwheels; (2) IR Preamplifier; (3) IR Auxiliary Control Electronics; (4) IR Detector (FPA) Controller ;(5) IR Shutter Assembly(6) Detector Host Computer; (7) System Remote Reset and Diagnostics.

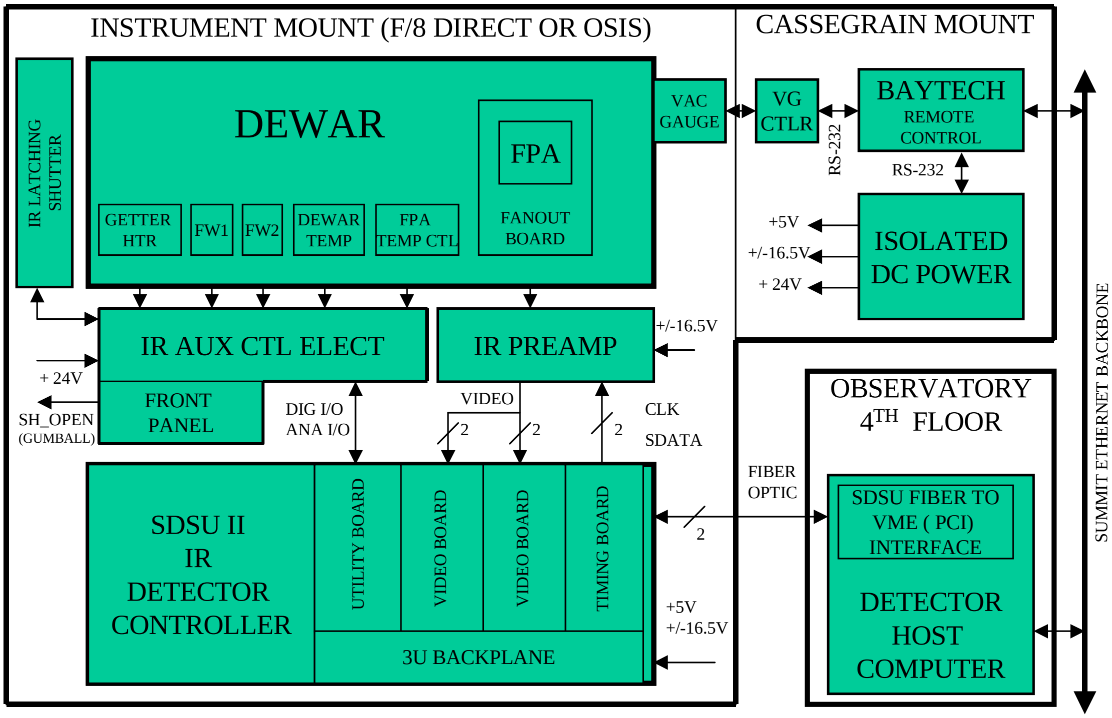

Figure 1. System Block Diagram. *Shows the location of the major functional components of the system.*

2.1 Cryostat Assembly

The cryostat contains the single fixed reimaging optics, two 8-position filterwheels, corresponding drive motors and position encoders, the FPA, temperature sensors, and electrical connections. These elements will be detailed further in the following subsections. The cryostat itself is a custom design from Infrared Laboratories. It is a modified ND series liquid nitrogen (LN2) cooled aluminium dewar with a single 8.5 liter cold tank and a surrounding radiation shield. Measured hold times have exceeded 48 hours in a side-looking configuration. Operating temperature is 77 to 80K. The cryostat is internally gold plated to reduce surface emissivity and increase vacuum integrity. All internal surfaces providing optical baffling are painted using 3M Black Velvet vacuum-qualified paint. The cryostat contains a carbon getter with it's own thermal circuit-breaker protected getter heating element and temperature sensing elements. The focal plane mount is on a similar yet completely independent thermal stage. Strict attention was paid to dewar materials and construction to maintain low outgassing and high vacuum. As previously mentioned extra attention was also paid to optical considerations in order to maintain low emissivity and minimize stray light sources. Included with the cryostat is a "Full-Range" Pfieffer vacuum gauge, providing "real-time" monitoring from atmospheric to operational ($<10^{-7}$ Torr) pressures. Measured vacuums of 10^{-5} Torr warm (on pump) and 10^{-7} Torr (cold, getter installed) have been recorded. Residual gas analysis has shown the warm vacuum to be dominated by water vapor. Temperature sensors are installed at the FPA cold surface, the dewar cold work surface, the getter assembly, the filterwheel assembly, radiation shield, and on the optical bench near the entrance lens, to provide detailed thermal profiling of the system.

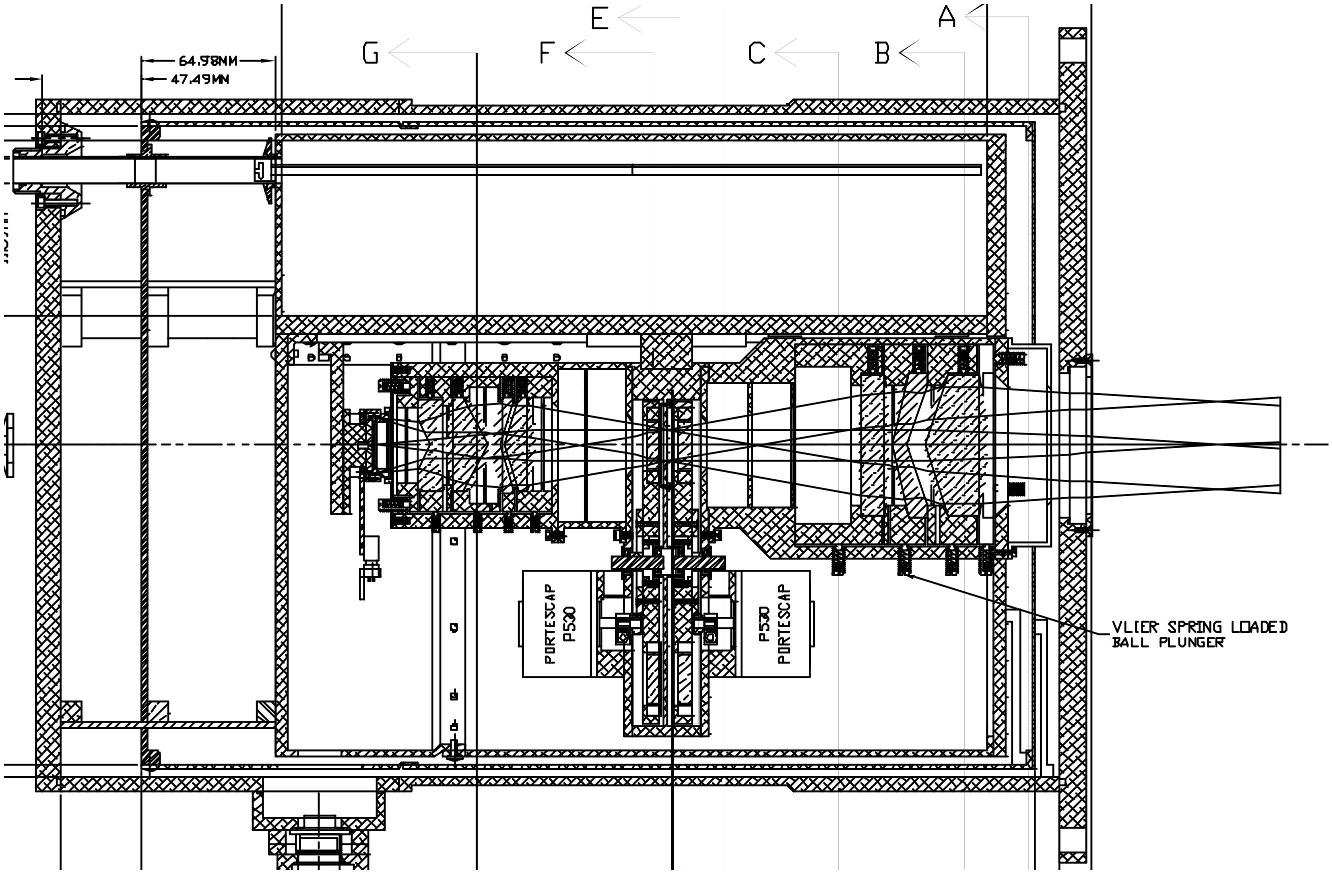

Figure 2. CFHTIR Cryostat. *Mechanical drawings of the cryostat showing cold tank, cold work surface, optical bench, filterwheel assembly and focal plane assembly.*

2.1.1 Optics

The optics accept a f/8 beam over an unvignetted field of 3.6 x 3.6 arcminutes for direct imaging at Cassegrain focus and when positioned on OSIS. The fixed seven-element optical design reimages the input beam at f/5.03 on the FPA, providing a magnification ratio of 1.523:1.0. This yields a 0.211arcsec/pixel resolution in both applications. The optical layout is shown below in Figure 3. All optical surfaces are anti-reflection coated. The opto-mechanics are designed to be mechanically stable at the camera's operating temperature and at orientations ranging from +/- 180 degree. A cold stop is placed at the image of the OSIS spectrometer exit pupil, which is also identical with the location of the telescope exit pupil image. The optical transmission of the CFHT-IR camera optical system (without filters) is designed to be greater than 85% for all wavelengths in the 0.75 µm to 2.5 µm spectral range. The optical transmission of the new OSIS spectrometer camera elements is designed to be greater than 95% between 1.1 µm and 1.8 µm. To support camera operation on OSIS for both visible (with CCD) and IR modes, the OSIS final lens set was designed to be removable. The IR mode lens set was redesigned to provide the desired telecentric f/8 exit beam.

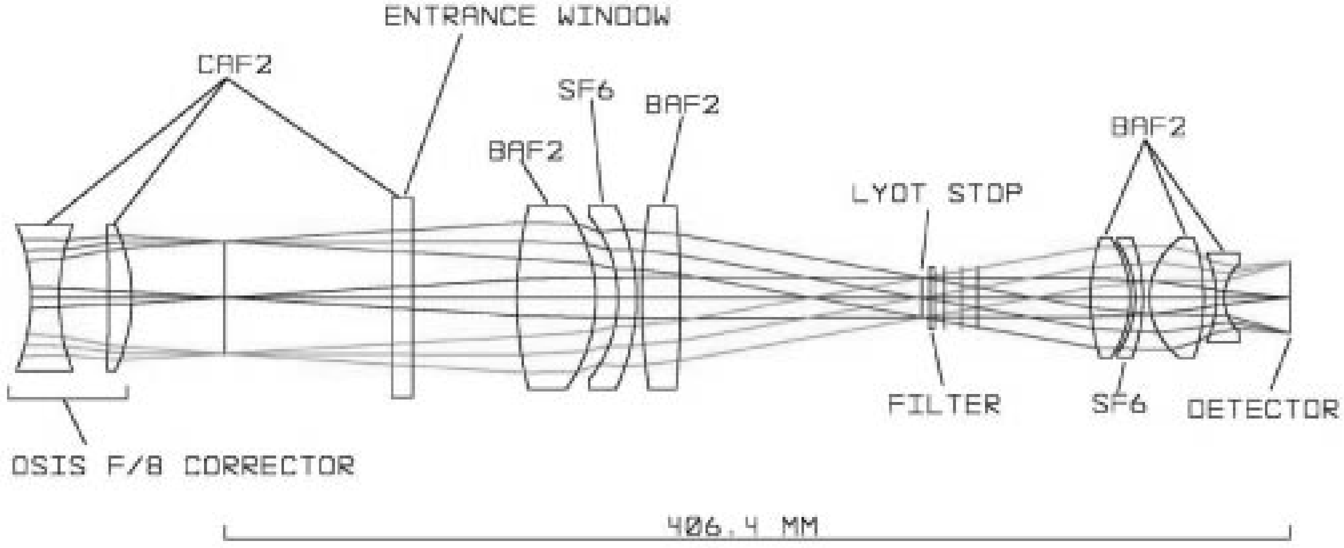

Figure 3. Optical Layout. Drawing illustrates the optical layout of the system, with the respective materials of the lenses. The f/8 corrector (warm) is not part of CFHTIR but rather part of the OSIS spectrograph.

2.1.2 Flexible Circuit Vacuum Feedthrus

A key feature of the dewar is the use of flexible circuits with hermetic vacuum feedthrus for all electrical connections internal to the dewar. In other applications we have used internal flexcircuits[1], mated to hermetic circular connectors. This has proven very successful for CFHT and other instrument builders, and a major improvement to discrete dewar wiring using standard thermal wiring techniques of constantan, manganin or stainless steel coax. For those of us who have had the "pleasure" of working with these materials, it is a welcome relief to have a prefabricated wiring assembly ready to install in the dewar. A number of people have previously experimented with this approach to varying success, but the experience at CFHT has been extremely positive. The circuits we employ are simple single layer copper enclosed in Kapton, with polyamide stiffeners located at the connectorized ends. No acrylic adhesives or sophisticated multiplayer techniques are used. Performance to LN2 temperatures and 10^{-7} vacuum ranges have been excellent with no known failures to date. If you consider the ratio of electrical conductivity to thermal conductivity to be a figure of merit for dewar wiring, one in which larger is better, copper is superior to those other material previously listed. The issue has been the difficulty of handling a copper wire of sufficiently small size to provide the requisite thermal standoff. Current printed circuit board fabrication technology has solved this problem. Copper flexible circuits can easily be fabricated using 5mil traces in ½ ounce copper. This geometry provides excellent thermal standoff along with the significantly higher electrical conductivity of copper. In addition, the ability to design minimum electrical path length circuits, with no intermediate connections or discontinuities, fixed trace geometries, spacing, and orientations for critical signals is extremely valuable. Furthermore the trace widths are easily variable along the circuit path using standard printed circuit layout software (ORCAD), so for signals where voltage drop across the wire is a concern, after the trace has passed the thermal standoff region it can be increased in size for better overall conductance and lower I* R losses. Variable trace width also allows appropriate sizing of the trace pads for high reliability contacts to the mating connectors. In our design a number of circuit traces have been "broken" midway (in the thermal standoff region, see Figure 4) with two appropriate surface mount exposed pads. This allows the selective use of additional circuits for a "standard" vacuum subassembly. In our case the two flexible circuit assemblies designed for CFHTIR will also be used in an upcoming upgrade to KIR. The idea behind this is if the trace is not needed to support a circuit it is left unconnected and then presents no undesired thermal load.

So while our experience with flexible circuits to hermetic circular connectors has been successful there was still room for improvement. The connection to the circular connectors can be problematic, especially in high-density circulars, and the need for additional external wiring to interface to the detector interface electronics still existed. We decided to take it a step further and bypass the hermetic connector by passing the flex directly through the aluminium vacuum flange with the desired final electrical connectors on each end. This design removes the need for constantan or manganin wiring internal to the dewar, the use of hermetic circular connectors at vacuum feedthrus, and external wiring to interface electronics. The flex is passed through an aluminium flange then potted into place using a proprietary epoxy process by PAVE Technology [9]. The region of flex passing through the flange has a section of the top-layer of Kapton removed to assist in the vacuum seal formation. The aluminium flange is designed with the appropriate O-ring seal to form a vacuum-tight connection to the dewar wall.

There are two flexible circuit designs, one for the focal plane fanout board (FPA) interface, and one for the utility connections (filterwheel and temperature control circuits). The fanout board flex circuit provides a direct connection from the IRLabs IRLF25A fanout board to the CFHT IR preamp. The preamp is mounted directly to the side of the dewar with the design providing the most direct and efficient interface for the most critical of system signal interconnects (video outputs, biases, and clocks). Figure 4 below illustrates the preamp to fanout board flex circuit assembly. The Utility flex circuit connects the IR Auxiliary Control Electronics to a small interconnect board thermally mounted to the dewar work surface. All motors, heaters, temperature sensors, and Hall effect sensors connect to this interconnect board using Teflon coated copper wire.

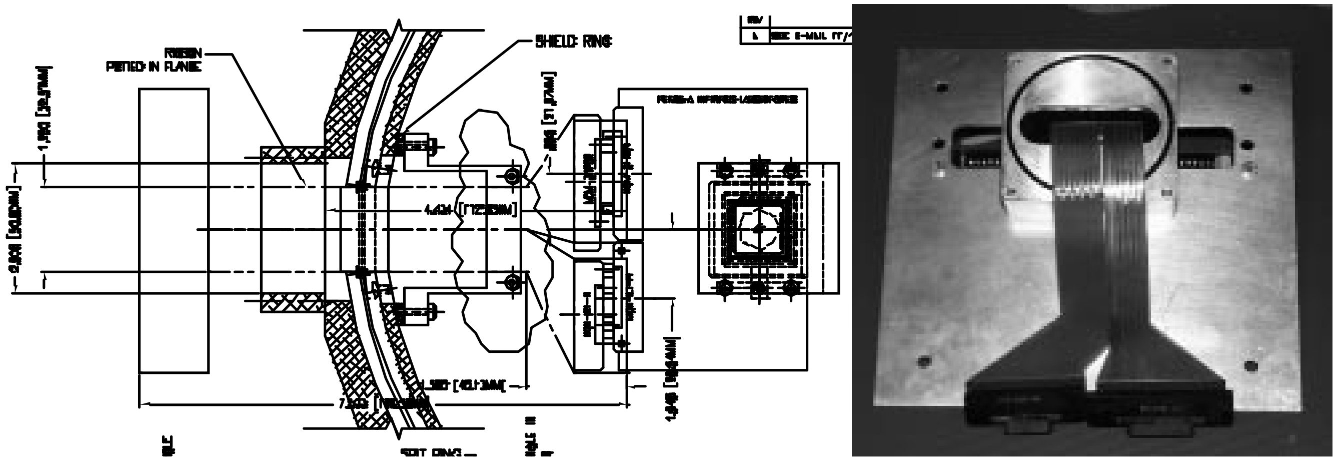

Figure 4. CFHTIR Fanout Board to Preamp Flex Circuit. *Illustrates the thermal tiedown mechanism, vacuum seal, and mechanical connection of the preamp to fanout board flex circuit.*

An added feature of the design is that the entire wiring assembly can be easily removed from the dewar for electrical test, rework, or for initial development work. Figure 6 below in the IR Preamplifier section of the paper shows the actual system detector fanout board, flexible circuit and preamp all connected and working on the test bench independent of the dewar.

2.1.3 Focal Plane Assembly

The FPA will be a Rockwell 1k x 1k HAWAII HgCdTe array[6], featuring 18.5 μm pixels and 4 output readout. The HAWAII FPA is mounted in an IRLabs IRLF25A Fanout Board and positioned on a thermally controlled stage at the camera focal plane. The focal plane assembly provides the requisite thermal and electrical connection to the FPA. The IRL25A is configured for differential video output for noise rejection issues. The IRLF25A uses a pair of discrete JFETs configured as source followers for each video output. One JFET buffers the BUS output of the FPA (bypassing the on chip source follower), while the second JFET buffers the BIASGATE signal. All electrical connection to the fanout board is through the fanout flex circuit assembly detailed above. The fanout board and internal dewar wiring are designed for FPA-limited performance during 4-quadrant simultaneous readout. The FPA will be temperature controlled through the use of an internal 35 Ohm, 5W heating element. FPA temperature will be monitored using both an RTD and a temperature-sensing diode.

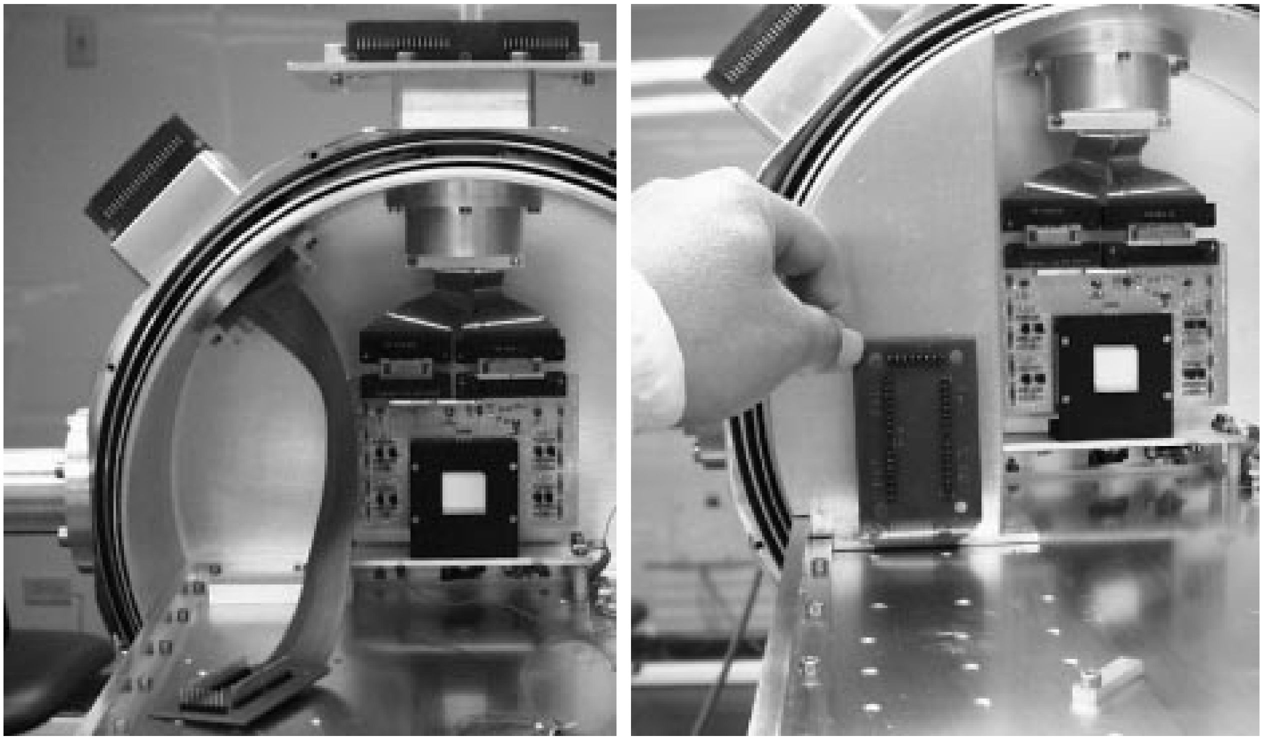

Figure 5. Focal Plane Assembly. *Picture on left shows the FPA Fanout Board and thermal mount, along with the two flexprint circuits to outside mating connectors. The picture on right shows the final mounting location of the internal Utility fanout board.*

2.1.4 Filterwheel Assembly

The system provides two eight-position filterwheels. Each wheel accepts eight 25.4mm (1”) by 6mm thick filters. The wheels are “in series” with each other along the optical axis (shown in Figure 2 above). One of the positions of the front wheel will be left open so as to provide an unaltered spectrum to the second wheel if desired. One of the positions of the second wheel will be occupied with a blank to provide “cold” dark images. The filters are maintained at a working temperature such that their thermal emission is less than the specified dark current as seen by the FPA. The filterwheel assembly is designed to be removable from the dewar as a single assembly. It is also designed for ease of filter removal and replacement. The filterwheels will maintain position without applied power.

Each filterwheel is driven by an off-axis stepper motor, and utilizes a novel single Hall effect position sensor. A discrete F.W. Bell Hall effect sensor element is positioned at the end of a small barrel assembly, inside this assembly is a spring-loaded plunger which rides along the edge of the filterwheel. The filterwheel has identical depth notches located on the wheel edge at seven of the eight filter positions with a deeper notch at the eighth or home position. Since the signal output from the Hall sensor is a function of the plunger’s distance from the sensor this design describes three defined positions: home, on a filter other than home, and not on a filter. Details on the required interface electronics are described in the IR Auxiliary Control Electronics section later in this paper. A working prototype of this system is currently under test, where issues such as the temperature dependence, repeatability, long term drift and interface requirements are being explored. A key parameter in this application is filter position repeatability since this allows proper flat fielding of science data with a single set of calibration frames. The CFHTIR filterwheels achieve filter repositioning to the pixel level by the forced wheel alignment caused by the "plunger" force in the wheel notch. The filterwheel drive mechanism is easily accessible through a removable cover, and the entire drive unit can be quickly replaced if necessary. The standard broad-band and narrow-band filters will be offered for astronomical use.

2.2 IR Preamplifier

The preamplifier provides complete analog electronic interface to the HAWAII array: gain and offset correction of the four video output signals, biases and clocks for the FPA inputs. It is a highly configurable, high performance, low-power circuit in a very small form factor. The same preamp is used at CFHT for all infrared cameras using Rockwell detectors (Hawaii and NICMOS in KIR and Redeye respectively). The preamplifier is mechanically mounted on the external side of the dewar in the closest possible proximity to the internal fanout board connections. Interconnection to the fanout board is provided by the dewar flexible circuit described previously.

The preamplifier provides four-channel DC-coupled gain (x5 currently) and offset correction of the FPA outputs in a simple single stage. The preamplifier is designed to support full FPA-limited noise (10 e-) performance during 4-quadrant simultaneous readout at 1M pixel/second/quadrant rate. Preamp and acquisition system combined noise with a 500 Ohm load simulating the FPA output impedance has been measured at 5e-. The preamp video input network has jumper selectable programmable current sources or 10K pull-up resistor to provide bias to FPA output FET if desired.

The preamplifier also provides all FPA clocks and biases. The biases are low-noise, low output impedance circuits. The preamp can be configured such that BIASGATE, and VRST can be programmed from external analog input signals such as that available from the SDSU IR Video Board. Or as done with CFHTIR, the biases can be generated on-board by a fixed low-noise network.

In addition to providing clock driver and wave-shaping capability, the preamp also supplies all clocking patterns to the HAWAII array. Clock pattern generation is provided through the use of a small yet powerful on-board field programmable gate array (FPGA). Pixel clocking pattern and pixel rate can be altered in a number of ways. For the CFHTIR project, the SDSU Timing Board provides two control lines to the preamp, a 50MHz system clock and a serial data line. The pixel rate and clocking mode (Reset Frame, or Read Frame) are selected by a simple 4- bit pattern sent over the serial data line. This protocol is an extension of the SDSU II multiple controller synchronization method[10] used when synchronizing more than one SDSU controller. The SDSU II system was designed to support this function by passing the common 50MHz clock between two controllers, then providing a "SYNC" pulse to initiate readout. We were familiar with this from our efforts on the CFH12K project, so we decided to extend this concept to support a serial data stream which would then allow not only synchronization of readout but also selection of readout parameters. It worked quite well, simplifying system wiring, lowering system power consumption and saving cost by removing the need to purchase a separate multifunction clock driver board from SDSU.

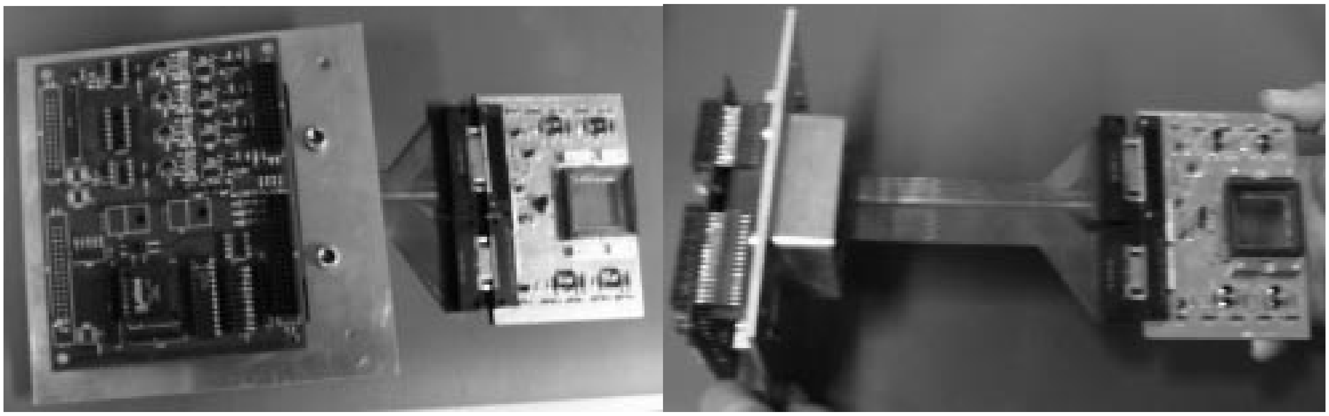

Figure 6. Preamp. *Pictures show the preamp board on the left connected via flex circuit to the FPA fanout board, illustrating the short electrical path length. The entire physical interface from the FPA to the preamp can be removed from the dewar for test and development. The 4-channel preamp circuit occupies the top half of the PCB, while the clock pattern generator FPGA and driver IC with series wave-shaping resistor occupies the lower half of the PCB.*

2.3 IR Detector Controller

The SDSU II Controller configured for infrared use is used for the detector controller in the system. The controller chassis is directly mounted to the side of the dewar. Synchronization of the SDSU controller and the preamp clock circuitry is accomplished by passing two signals (a 50MHz clock and a Serial Data signal) from the "master" Timing Board to the "slave" Preamp FPGA Clock Generator. Total array read-time is expected to be detector "noise"- limited at 200-300k pixels/sec/output or 1.3 - 0.87 sec per 1kx1k frame. Standard correlated double sampling implies a minimum of two frames per image so a total read-time of 1.8 to 2.6 sec per image is anticipated. A number of readout modes such as subrastering, single quadrant readout, multiple sample readout, Fowler Multisampling, etc will be supported. Following 16-bit digitization in the IR Video Board, digital data is passed via fiberoptic cables from the Cassegrain focus environment to the Detector Host Computer located on the 4th floor of the observatory (refer to Figure 1 above).

The SDSU Controller contains: one Timing Board, one Utility Board, and two 2-channel IR Video Boards. The SDSU system is based on Motorola 56000 series DSPs. DSP code is generated which provides all necessary low-level interface to the preamp as well as interface to the Auxiliary Control Electronics. All real-time executable functions such as readout patterns or exposure timing reside in the controller/preamp FPGA, thereby removing any real-time requirements from the UNIX-based Detector Host Computer.

2.4 IR Latching "No Quiescent Power" Shutter

The shutter is a modified Prontor mechanism. Two latching solenoids have replaced the Prontor solenoid and spring mechanism. Hall effect position sensors are employed to sense blade open and closed positions and provide shutter timing and diagnostic information. Shutter blade timings have been measured on the order of 60ms (open and close times). Actual timing is measured at 1ms intervals by the SDSU Utility Board and recorded in image FITS headers for each exposure. A key feature of this shutter is it's bistable latching mechanism which dissipates no power in either open or closed positions, only during transition. Therefore it's thermal signature will not present a background thermal emission issue for the system.

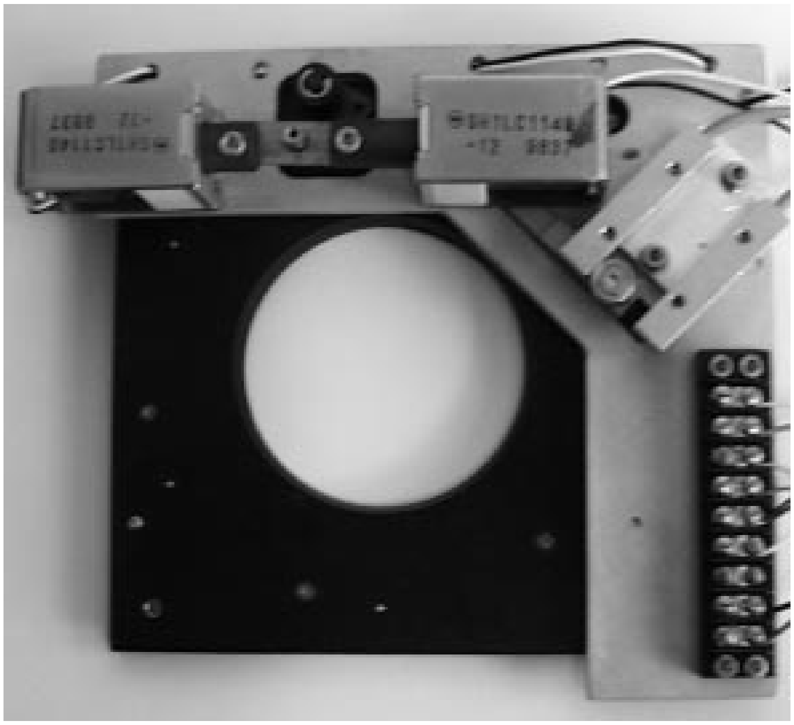

Figure 7. Shutter. *Shows dual latch mechanism located at the top of the shutter, Hall effect position sensors at upper right corner.*

2.5 IR Auxiliary Control Electronics

The InfraRed Auxiliary Control Electronics (IRACE) handles all system functions other than FPA readout and exposure timing, which are handled by the SDSU Controller / Preamp combination directly. These functions include: shutter, filterwheel, focal-plane temperature control, and system temperature measurement. Based on a single FPGA and six identical H-bridge pulsewidth modulated power integrated circuits (ICs), the IRACE provides a compact, low-power, opto-isolated, intelligent, configurable control-block for those functions not efficiently supported by the SDSU Utility Board. The IRACE provides a close-coupled interface to the SDSU Utility Board digital IO port to provide expanded system capability within the SDSU control paradigm. It also provides a convenient method to couple front panel control and feedback of the auxiliary functions to the SDSU system. The IRACE acts as an extension to the SDSU Utility Board concept, providing increased intelligence along with isolated motor and solenoid drive capability to the SDSU IR Controller. The front panel connection is very “low-tech”, but it is highly effective for system set-up and troubleshooting. All internal dewar functions can be operated and tested without operation of the SDSU Controller, fiberoptic link, or the Detector Host Computer . The only requirement is DC power to the IRACE for filterwheel, temperature, shutter functions, and DC power to the preamp for FPA clocking and video output verification.

The two primary functions of the IRACE are operation of the shutter and filterwheel. The physical drive block for both of these operations is identical, only the Hall sensor interface is different due to the novel filterwheel Hall position sensor (see filterwheel section above). Functionally the design is an opto-isolated FPGA with pulse-width modulated motor /solenoid driver ICs. This functional block receives input control lines from the SDSU Utility Board digital output port (or IRACE front panel), then provides step and direction pulses for stepper motors (or drive level and direction for DC motors) to the PWM motor drivers until the Hall effect sensors indicate the proper physical position is reached. Operational feedback is provided both to the front panel LEDs and the SDSU Utility Board digital input port. If there is a failure, the system is providing detailed information on the nature of that failure.

The filterwheel control is as follows. The Hall effect position sensor is biased by a constant current source, it produces a voltage output signal in the mV range. This output signal is connected to a instrumentation amplifier (IA) for amplification of the signal and common-mode rejection of unwanted pickup. The IA output is then fed to a dual-comparator network , which has temperature compensated reference circuit linked to temperature sensors within the cryostat. The reference circuit defines two thresholds for the comparators and thereby three ranges: home, filter other than home, no filter. Since the Hall effect output signal is affected by temperature, compensation circuitry provides for use of the filterwheel from room temperature down to 80K continuously.

An interesting feature of the design is that the FPGAs used are “in-circuit reprogrammable” either by down-load from an external PC, or by down-load through the SDSU fiberoptic link via the Utility Board. This feature would allow adjusting the function of the IRACE dynamically if desired, or perhaps more likely using the same circuit board design in multiple applications.

All electrical connections to the IRACE are opto-isolated from the SDSU Controller so as not to interfere with the noise performance of the system. The shutter, filterwheel, and temperature sensors should all be able to be operated without affecting FPA readout. This noise immunity is significant in maintaining a low noise system performance along with reduced overhead times.

2.6 Detector Host Computer

The Detector Host Computer provides the primary data acquisition and control link necessary to communicate with the CFHTIR hardware. For the initial development of CFHTIR we are using the existing KIR Detector Host system. Physically it is a VME SPARC running UNIX, configured with a 32MByte Chrislin VME Memory Board with on-board ALU for image arithmetic (MSR, Coadd, etc.). The SDSU VME Interface Board provides the fiberoptic interface to the Detector Controller. The ethernet link provides communication to the Baytech MDAC Unit (described later) as well as to the Session Computer. Software control is provided through “DetI” [11] the data acquisition software developed for KIR at CFHT.

In CFHT parlance, the Session Computer provides the user interface, image display, and interface to telescope or instrument functions required to unite the observatory to the astronomer. The Session Host is an UltraSPARC II running under Solaris, configured with dual 200Mhz CPUs, 512Mbytes of memory, 100Gbyte hard disk, and 100Mb/s ethernet link. Exposure sequencing, telescope control interface, data storage for the nights observing, as well as interface to the CFHT archiving system are all handled at the Session Computer. Exposure sequencing, including telescope control, relies heavily on UNIX shell scripting techniques, while data storage and archiving is largely transparent using NFS mounted system disks for image storage. Available scripting methods are extremely flexible and easy to implement. The user interface front-end known as "Director" [12], a command-line interpreter, allows the user to choose between a graphical user interface (GUI) or a simple command line. The GUI is founded on a custom XML-based webserver, while the command line provides easy scripting for sequence definition and control as well as a "no frills" front end for power users. The future upgrade of the Detector Host to a fiberoptic to PCI bus interface installed on a high performance PC running LINUX is currently in the planning stages.

During a typical exposure sequence, exposure parameters are received from the Session Computer, recorded in the local memory of the Detector Host for post exposure FITS packaging and downloaded to the SDSU Controller. The desired set of pre-exposure parameters include integration time, exposure type, raster, etc. The Detector Host Computer will then request an exposure. This causes the FPA to be reset, and the first image to be directly deposited from the SDSU Controller over the fiberoptic link into VME memory using DMA controlled by the SDSU VME Interface card. This resulting image is descrambled by the SDSU VME Interface Board as pixels arrive over the fiber. Following the specified integration time, the second image data is handled identically but now image arithmetic functions can be handled in real-time as pixels arrive by utilizing the SDSU VME Interface Board and on board ALU of the Chrislin VME Memory Board. The resulting image is then combined with relevant system and observatory operating parameters and packaged in a FITS formatted image file. The relevant system and operating parameters include actual measured open shutter exposure time, telescope position, observatory conditions, etc. This image file is stored over the ethernet to an NFS mounted disk on the Session Computer. Multiple image formats are supported, the standard frame based correlated double sampling (CDS), or each individual image stored in a 1k x 2k format first image on top of the second (diagnostic imaging) or individual images and CDS on the bottom in a 1k x 3k format (composite imaging). These modes are typically not utilized for science exposures, but are extremely valuable for diagnostic and setup functions.

In the event of an error condition, software will query the system to acquire detailed diagnostic information, log this information and attempt to save all potentially viable image data, as well as take appropriate corrective action. In all cases, the user is alerted of activity via the Session Host and an appropriate course of action recommended if necessary.

2.7 System Remote Reset and Diagnostics

A fundamental system design concept that was first employed at CFHT on the CFH12K was that of "camera systems as remote image servers": a reliable standalone system yielding high quality astronomical images from a remote physical location. Employing this concept the CFHTIR was designed to provide high reliability, high efficiency operation for extended operational periods. To facilitate this the system was configured to provide extensive on-line diagnostics on all primary system parameters: power supply voltages and currents, vacuum, temperature, system failure modes, data logging, etc. The system will automatically detect, log, notify the users, then attempt to correct all known or identified potential system failure modes.

One of the key elements of this system is the control of DC power and Detector Controller reset from a separate connection other than the standard SDSU fiberoptic link connection. In the event of a system crash, a technique was needed that would not require an individual to visit the Cassegrain environment in order to reset the system. To provide remote DC power control and Detector Controller reset for the CFHTIR we employed an ethernet port connection to the Baytech MDAC Control Unit, along with programmable DC Supplies. The Baytech unit provides a flexible interface hub from the ethernet backbone to: multiple RS-232 ports, AC power control, and general purpose analog and digital I/O. The RS-232 ports allow the system to interface to intelligent DC power supplies for the camera electronics (these supplies provide output control along with voltage and current readback capability), and interface to the Pfiefer Vacuum Gauge Controller. AC power control, using an add-on Remote Power Control (RPC) module, allows the system to control DC supplies and other elements in the system such as cooling fans, lights, etc. The digital and analog I/O is used for SDSU Controller reset and future connection to other Cassegrain environmental sensor and control functions. The communication protocol to the Baytech is based on telnet and provides a simple link to the Detector Host Computer over the existing CFHT ethernet backbone.

3. CONCLUSION

The CFHTIR represents another important contribution to the CFHT wide-field imaging program. Providing a significant improvement over the NICMOS infrared camera previously in use. Every attempt was made to consider the CFHTIR in the larger context of the total CFHT observing environment so as to provide the most efficient and powerful system possible. Novel techniques for cryomechanism control and dewar wiring show improvements over previous approaches. System level engineering efforts for reliability, diagnostics and performance have been applied throughout the design. Operational support issues have been addressed as well, providing a system that will be easy to set-up and move to the different instruments and physical locations where the camera will be operated. Efforts for the CFHTIR project will also be leveraged for upgrade to the existing KIR 1k x 1k camera used on the CFHT Adaptive Optics Bonnette, thereby improving value across the observatory and to other programs not directly serviced by the CFHTIR camera.

REFERENCES

1. B.Starr, G.Luppino, J. Cuillandre, S.Isani, “Design of the CFH12K: 12k x 8k CCD mosaic camera for the CFHT Prime Focus”, same SPIE proceeding, Optical and IR Telescope Instrumenation and Detectors, Munich 27-31 2000.
2. J. Cuillandre, G.Luppino, B.Starr, S.Isani, “Performance of the CFHT 12k x 8k CCD mosaic camera”, same SPIE proceeding, Optical and IR Telescope Instrumenation and Detectors, Munich 27-31 2000.
3. O. Boulade et al. “Development of MegaCam: the next generation of wide-field imaging camera for the 3.6 m CFHT telescope”, same SPIE proceeding, Optical and IR Telescope Instrumenation and Detectors, Munich 27-31 2000.
4. Le Fevre O., Crampton D., Felenbok P., Monnet G., 1994, CFHT MOS/SIS spectrograph performance, A&A, 282, 325-340
5. Simons D.A., Clark C.C., Kerr J.M., Massey S., Smith S.S., Toomey D. W., 1993, Canada-France-Hawaii telescope near-infrared camera project, SPIE Proceedings 1946, 502-512
6. Hodapp K.-W. et al., 1996, The HAWAII Infrared Detector Arrays: testing and astronomical characterization of prototype and science-grade devices, New Astronomy, 1, 177-196
7. R.Doyon, D.Nadeu, P.Valee, B.Starr, J.Cuillandre, J Beuzit, et al “KIR: the high-spatial resolution 1024 x 1024 near-infrared camera of the Canada-France-Hawaii Telescope”, SPIE 3354, pp 760-768, 1998
8. Rigaut F., Salmon D., Arsenault R., Thomas J., Lai O., Rouan D., Veran J.-P., Gigan P., Crampton D., Fletcher J.M., Stilburn J.,Boyer C., Jagourel P., 1998, Performance of the Canada-France-Hawaii Telescope Adaptive Optics Bonnette, PASP, 110, 152
9. http://www.pavetechnologyco.com
10. R. Leach, F. Beale, J. Eriksen, “New-generation CCD controller requirements and an example: the San Diego State University generation II contoller”, SPIE 3325-31, pp. 512-519, 1998.
11. http://www.cfht.Hawaii.edu/Instruments/Detectors/DetI/
12. http://rpm.cfht.hawaii.edu/director/