A New Infra-Red Camera for COAST

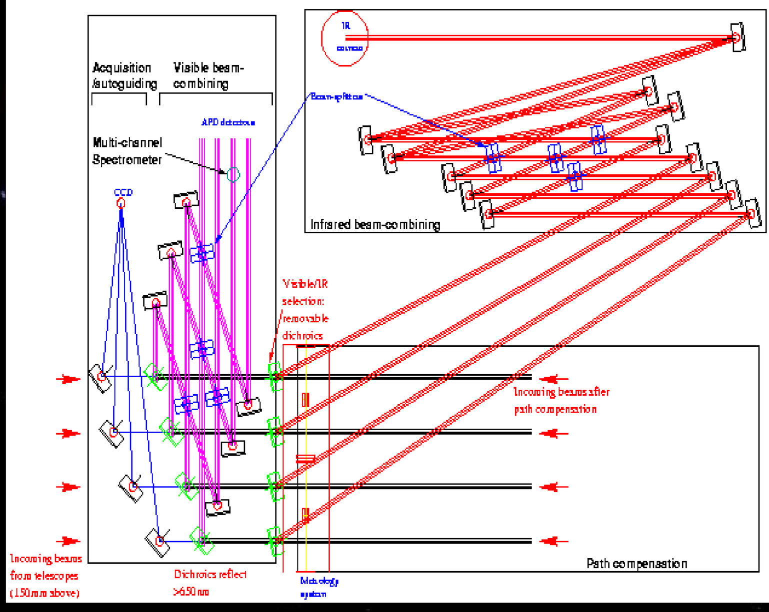
The Cambridge Optical Aperture Synthesis Telescope

COAST is a long-baseline 5-element interferometer which has the ability to measure closure phases. It can obtain images by Aperture Synthesis. The baselines may be configured to be up to 100m, providing a resolution of 1 milli arcsecond.

COAST operates in the Red and near Infra-Red between 600nm – 2.3µm. The limiting magnitude is 6.4 in the I-band. Each siderostat is a 40cm Cassegrain telescope, with a moveable flat mirror for pointing. Up to 4 of the 5 may be used simultaneously.

COAST is also used as a test-bed for MRO.

How COAST Works



Light from the siderostats enters the bunker. It is then processed as shown.

Firstly, the optical path lengths are equalised by moveable mirrors, mounted on trolleys. The trolley position is itself tracked by a laser interferometer. The 4 beams are then combined, and interfered, resulting in fringes. These fringes are then tracked.

Red light is detected by 4 Avalanche Photo Diodes: Infra-red is detected by 4 pixels of the IR camera. The outer annulus of the light is used by the auto-guider to track the star.

The trolleys sweep back and forth every 100/250ms to encode temporal fringes. The typical fringe frequencies are 250Hz (IR) and 700Hz (optical).

Magdalena Ridge Observatory

MRO is a facility class interferometer, whose design is based on our experience at COAST. It is in New Mexico, at an altitude of 3.2km above sea level, and will be completed in 2008.

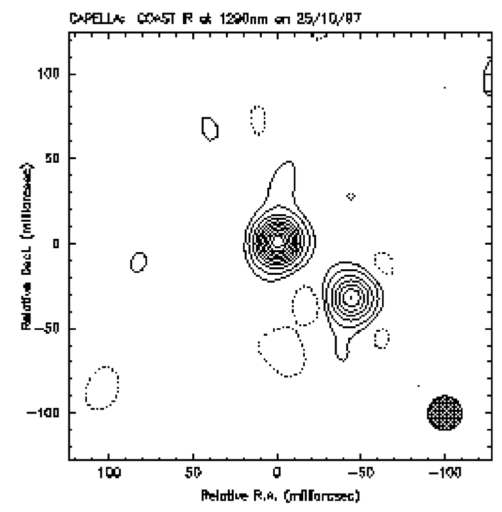
MRO will have 8-10 elements, with 1.4m diameter mirrors, on baselines up to 400m. The resulting array will have extremely high sensitivity and and an angular resolution of ¼ milli arcsecond.

MRO will be used to study the formation of planets, stellar accretion and mass loss, and active galactic nuclei.

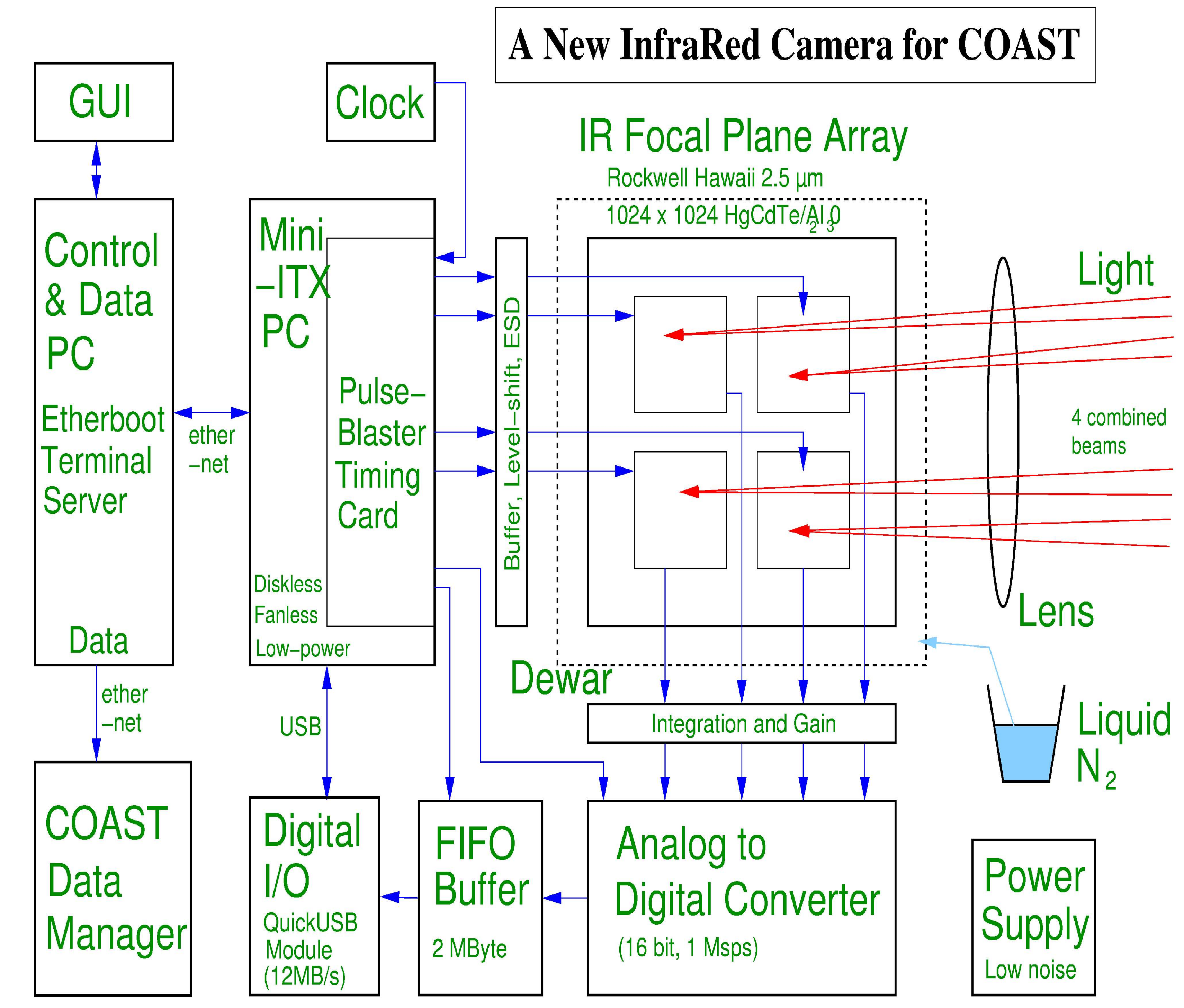
The New (Hawaii) Sensor and the Old (NICMOS) Camera compared

The existing, NICMOS/Astromed-based camera was "state of the art" 15 years ago. Using correlated double sampling (CDS), it is capable of reading 4 pixels once each at 1kHz, or 16 multiple reads of a single pixel at 1kHz. This is insufficiently fast to obtain closure phases when using all the available light (i.e. all 4 combined beams) at COAST. The read noise is 16 electrons for single reads; up to 8 multiple reads are possible on a single pixel, at a cost of reduced dynamic range. We have made observations at an H-magnitude of 2.5.

The Hawaii sensor has a read noise below 3 electrons (for multiple reads with CDS), and will be able to read out much faster. At COAST, we aim for frame rate of 10 kHz with many multiple reads; faster at MRO. Spectroscopic readouts will be possible by using multiple pixels and a diffraction grating. The 4 quadrants will be read simultaneously, with their own ADCs for greater speed. The new system will be Linux-based and will have improved software and networking.



The binary star Capella, imaged at COAST in 1997 using the NICMOS camera. This is the first infra-red image from an aperture synthesis array.



Hawaii 2.5µm IR FPA

The camera is based upon a Rockwell Hawaii 2.5µm CMOS HgCdTe Focal Plane Array. This is an array of 1024x1024 pixels, each 18.5µm across, arranged in 4 independent quadrants. It is designed to minimise glow and dark current, at a running temperature of 78K and a cutoff wavelength of 2.5µm.

Each well has a capacity of 10^5 electrons and a gain of 3-6 µV/e. 16 bits of A-D conversion covers almost the entire range without the need for adjustment of the gain. The read noise is < 3 electrons for Fowler Sampling (multiple reads).

Software Development

To generate the camera clocking signals, we are using *Spincore's PulseBlaster* digital timing card. This emits a programmable stream of pulses on 24 channels with 10*ns* resolution. An instruction parser has been written for this.

For fast Digital I/O, we use a *BitwiseSystems QuickUSB* module which implements a fast (16 Mbyte/sec continuous) parallel port via USB 2.0 (This is shown in the background)

The Mini-Itx computer is a VIA EPIA ME6000 system; it requires only 4 Watts, and is booted over the network via Etherboot. It is the host for the PulseBlaster, and serves to relay data from the ADC/FIFO over Ethernet to the Data Manager.

All the software we have written will be released under the *GNU* General Public License.

System Overview

The Hawaii FPA is cooled to 78K in a dewar using Liquid Nitrogen. Light from the beam combiner is focussed onto it: each of the 4 beams is contains the same information and ¼ of the total light, and is concentrated onto a single pixel, one beam per quadrant.

Every sweep of the trolleys (usually 250 ms) restarts the clocking sequence. The pulseblaster resets the array addresses, and then initiates a correlated double sampling scheme (Reset, Read, Wait, Read) with multiple reads. Each sample is integrated to reduce noise; it is then passed to a sample-and-hold circuit and then digitised. The clocking scheme, integration time and gain may be varied.

The FIFO buffer can store up to an entire frame of data, and this is then read into the computer via the quickusb module. The data is then sent out over the network. The mini-itx system was chosen to minimise heat emissions in the vicinity of the optics. The Pulseblaster has its own FPGA to which is programmed with the clocking schema: it is independent of its host while running. This minimises jitter, and eliminates the need for a hard-real-time OS. It also allows for quick changes to the readout mode if desired.

Further Information

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MRAO CAMBRIDGE

The Cambridge Optical Aperture Synthesis Telescope:
http://www.mrao.cam.ac.uk/telescopes/coast/index.html

The Magdalena Ridge Observatory:
http://www.mro.nmt.edu/

MRO Magdalena Ridge Observatory

MRO is a collaboration between the Cambridge Astrophysics group, teams in New Mexico and Puerto Rico, and the Naval Research Laboratory in Washington DC.

Thanks are due to the United Kingdom Infra-Red Telescope (UKIRT) for the loan of the Hawaii sensor.