Developments at COAST

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ABSTRACT

The Cambridge Optical Aperture Synthesis Telescope (COAST) is a four element interferometer which measures visibility amplitudes and closure-phases. It produced its first images in 1995 and is now in a complete form, very similar to the original conception. In this paper we discuss the design and current status of the interferometer.

Keywords: astronomy, interferometry, telescopes, optical, detectors, imaging, closure phase.

1. INTRODUCTION

The principle development at COAST - The Cambridge Optical Aperture Synthesis Telescope - has been the production of our first images. These images of Capella and another of Betelgeuse are described elsewhere in these proceedings,[1] so we deal here only with technical advances that made this important step possible. New detectors which extend the capability of the instrument in the visible and into the near infra-red have recently been commissioned.

2. COAST

The instrument, located at the Lord's Bridge Observatory 5 miles west of Cambridge, comprises four 40 cm fixed horizontal afocal Cassegrain telescopes, each fed by a 50 cm siderostat, sending light via alloy pipes into a temperature stabilised laboratory. Within the laboratory various sub-systems are responsible for path compensation and fast auto-guiding of the beams from each telescope, as well as beam combination so as to allow measurement of the interference fringes from all pairs of array elements simultaneously. The beam mixing is performed using four 50:50 beam-splitter plates which provide four collimated outputs, each of which contains one quarter of the light from each telescope. Interference between all pairs of telescopes is present in every output. Each is focused onto, and detected by, a separate avalanche photo-diode (APD) operating in photon-counting mode. In this arrangement, interference takes place in the pupil plane, and so the optical path in each arm of the interferometer is modulated by about 50 μm in order to scan the fringes past each photo-diode. Further details of the design and operation of COAST have been described elsewhere.[2,3]

The relationship of the optical components of COAST within the lab is illustrated in figure 1.

3. CURRENT OPERATIONAL STATUS

We now describe the current status of, and note recent changes to, the various components of the system outlined above.

Four telescopes have been built and commissioned: to date we have only used three at a time for astronomical observations. The maximum baseline is currently 9 m. The mechanical stability of the telescopes supported on Cambridge clay appears

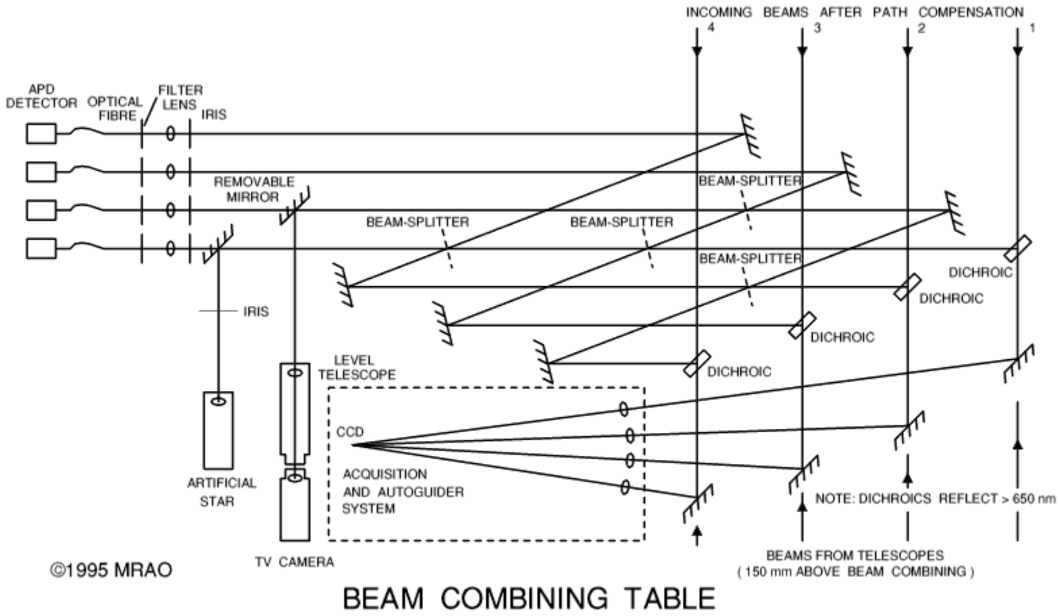

Figure 1: The layout of the optical beam combining table.

to be very good. Night to night variations are $\lesssim 50\mu$m and longer term changes perhaps 250 μm. The air filled alloy pipes we use to bring the beams back to the optics laboratory reduce the internal path variations to about 1 wavelength in 100 s.

We have built four path compensation trolleys, two of which are currently in use. The remaining track will be accurately aligned shortly and the 3rd and 4th delay lines commissioned. The system's laser metrology and servo control work exceptionally well.

Limits to the useable fractional bandwidth set by the effects of dispersion in the air delay line have been discussed by Lawson.[4] A bandwidth of 40 nm is available at a 30 metre baseline reducing to ~20 nm at 100 metres.

The path compensation trolleys are also used to modulate the phase of each telescope beam with a distinct signature so that the complex visibility of each baseline may be extracted from the measured photon counts. Saw-tooth wave-forms are used each with a different amplitude but all at the same frequency, typically 10 Hz. We have successfully tested the system at the higher speeds required for the 6 baselines obtained from 4 telescopes. The APD control electronics has been modified to allow 10 kHz sampling. The photon counts are now passed in real-time to the Norsk Data control computer.

The acquisition and fast guiding system has recently been improved by the installation of a new CCD and controller. The camera has a Peltier cooler, rather than a liquid nitrogen dewar. We hope to install a thinned CCD chip soon, which should provide a factor of 2 in sensitivity. We have been able to aquire and guide on a star of m_v=6.03, 61 Cyg (HR 8086).

Power spectra and visibilities are available within a minute of the observation being made. A comprehensive set of data analysis tools is available. A 9 GByte disc has been added to the system.

4. NEW DETECTORS

We are currently making observations with two new detectors - a near infra-red beam combining system and NICMOS camera and a visible light channeled spectrometer.

The infra-red system picks up the long wavelengths after the path compensation system and reflects them to a separate beam combining table - Figure 2. Specifically partial gold mirrors are mounted at the top right of Figure 1 to do this: some of the visible light passes through to the guider which operates as before.

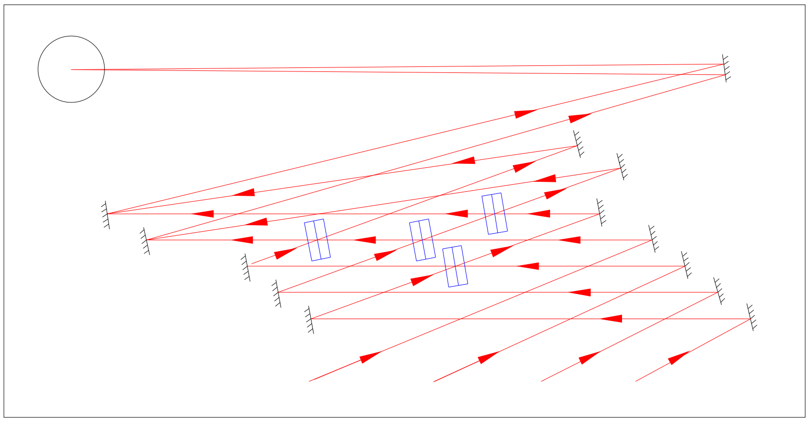

Figure 2: The layout of the infrared beam combining table. The circle in the upper left quarter of the picture represents the NICMOS III camera in its dewar. The "double blocks" in the centre of the picture are beam-splitters, and the shaded blocks represent mirrors. The paths of all four incoming beams are shown.

The beam combination scheme is essentially the same as the visible one. Four 1–2.5 μm beam-splitters are used to feed just 4 pixels of the NICMOS III camera, installed in a liquid nitrogen dewar.[5] These can be read at 1 kHz with a read noise of 20 e^- rms. The camera, which is managed by a PC + CCD controller, is currently operating at 1.3 μm. We plan observations at 1.6 μm.

Internal fringes with 85% visibility can be obtained easily (Figure 3). We also show an example of stellar fringes from α Boo (Figure 4). Closure phases of just a few degrees have been measured internally.

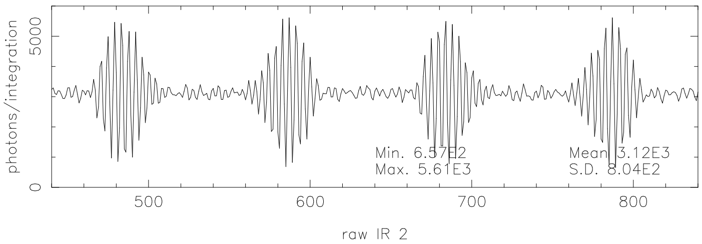

Figure 3: Internal fringes obtained using the IR system. The figure shows 0.4 seconds of data.

We have recently obtained channeled spectra on a number of stars from a visible spectrometer installed in place of one of the APDs. A 60° prism of BK7 glass and a 400 mm achromatic doublet feed a fast CCD camera. Vertical binning gives a 1-D spectrum at the readout register and hence allows a 100 pixel spectrum covering the wavelength range 650–950nm to

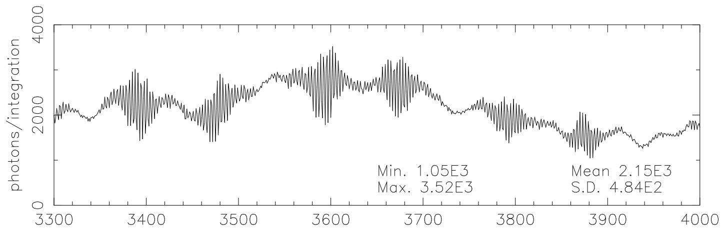

Figure 4: Stellar fringes from α Boo obtained using the IR system.

be read at 200 Hz. Fringes are obtained by offsetting the path compensation system a suitable distance which corresponds to more wavelengths in the blue than the red. Any combination of baselines can be recorded. Examples of time sequences of channel spectra from a single baseline are shown in Fig 5. These show the effects of atmospheric path variations, visibility fluctuations and scintillation. Lawson[6] also discusses the effects of dispersion in these spectra.

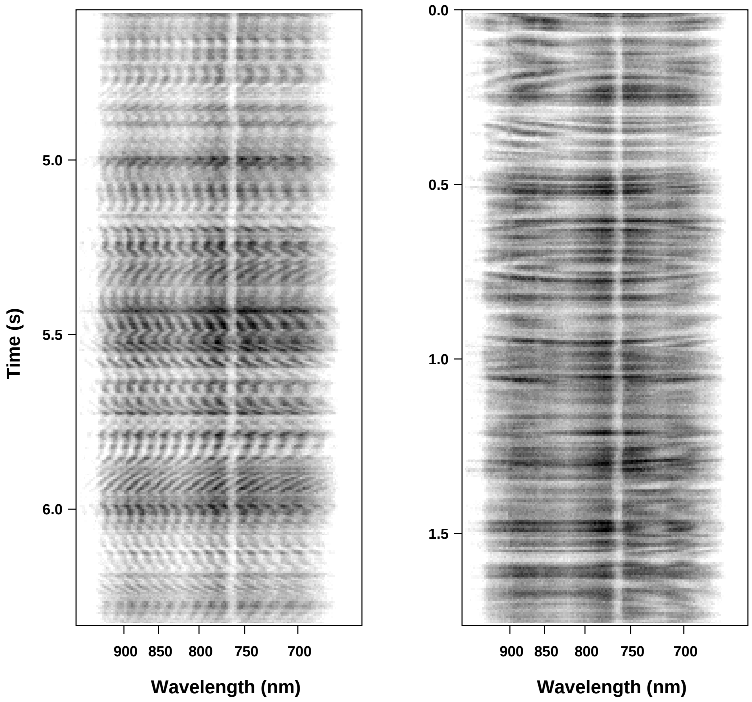

Figure 5: Time sequences of channeled spectra showing fringes from the star α Boo. In the left figure, the delay trolley is moved to display about 15 fringes across the wavelength range of 650–950 nm. On the right, the trolley is repositioned near the zero group delay and often there are less than two fringes across the band.

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