CHARA TECHNICAL REPORT

No. 82 19 DECEMBER 1998

The CHARA First Light Beam Combiner

S.T. RIDGWAY (NOAO/KPNO & CHARA)

1. INTRODUCTION

For purposes of first light and first fringe commissioning, CHARA will implement a very simple, classical Michelson beam combiner. Beams from any two Array telescopes will be combined on a partially reflective surface.

Most of the components are from NOAO, and were previously used in IRMA, FLUOR and IOTA beam combiners. In recognition of this heritage, the detection system will be designated the NOAO MkIV Beam Combiner.

2. OPTICAL LAYOUT

The afocal beams entering the beam combination laboratory have been compressed by a factor of 40, from 1 meter to 2.5 cm. Including beam spread due to image size, the actual beam diameter will be 1.29 inch. At a 45^o angle of incidence, the footprint will extend 1.82 inch along the major axis.

The beam combination system will be installed on an 8×5 foot optical table. The conceptual layout, not to exact scale, is shown in Figure 1. At the input, dichroic beam splitters (D1) will reflect the infrared light to the beam combiner, and pass the visible light to the tilt detection system (the configuration can be revised if the infrared is transmitted and the visible reflected). The beam switch yard will allow selection of any two of the six CHARA telescopes.

The infrared light will be combined on a partial reflecting beam combiner (BC). The two combined beams will be treated similarly and symmetrically. Each will reflect from a spherical camera mirror, which will converge the beam with a focal ratio of 60. This value is selected to match the readily available detector systems, described below. Each combined beam is then split at an infrared dichroic which reflects the H band light and transmits the K band light. The four resulting, converging beams form images of the source on the entrance apertures of four detector systems.

The list of required optics and mounts, and their availability, is shown in Table 1.

---

[1]Center for High Angular Resolution Astronomy, Georgia State University, Atlanta GA 30303-3083
TEL: (404) 651-2932, FAX: (404) 651-1389, FTP: ftp.chara.gsu.edu, WWW: http://www.chara.gsu.edu.
Funding for the CHARA Array is provided by the National Science Foundation, the W. M. Keck Foundation, the David and Lucile Packard Foundation and by Georgia State University.

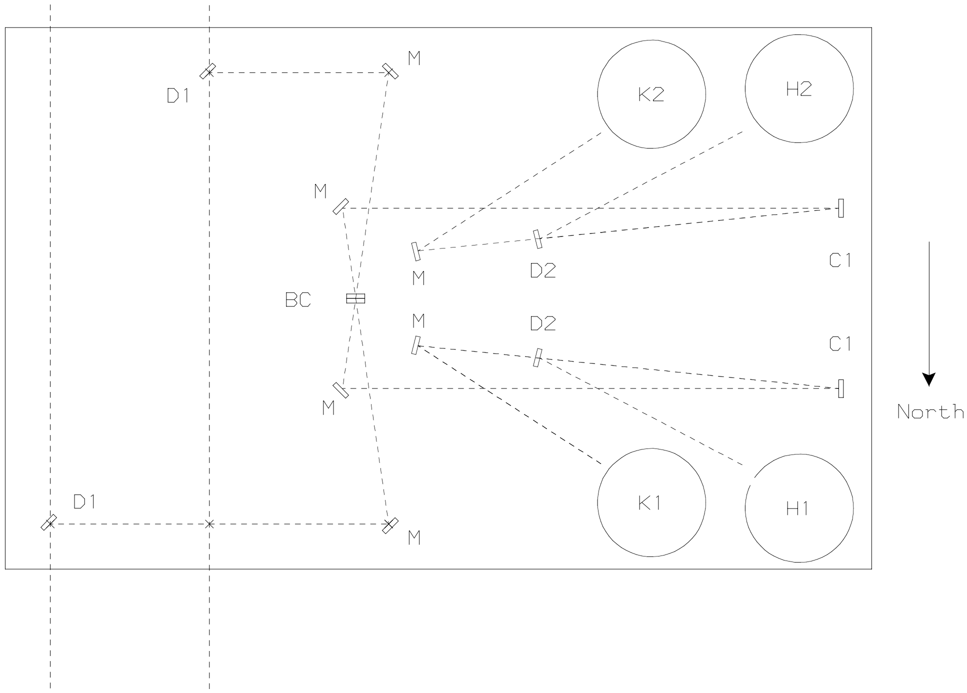

FIGURE 1. CHARA-NOAO Beam Combiner version 1, conceptual layout.

TABLE 1. Optics and optical mounts

Optic	Description	Diameter	No. Needed	Source	Mount
D1	IR/Vis dichroic	2.0”	2	Must buy	NOAO
BC	IR beam combiner	2.0	1	May have	NOAO
M	Flat mirror	2.0	6	NOAO	NOAO
C1	Sphere, 60” F.L.	2.0	2	NOAO	NOAO
D2	H/K dichroic	2.0	2	NOAO	NOAO

3. DETECTORS

The detectors planned for initial implementation are single element InSb detectors from the decommissioned KPNO FTS. These are the detector system pairs A-B and E-F. A-B are designed to operate with LN2. E-F have selectable feedback resistors, and one option works (not optimally) with LN2 cryogen.

These detectors are implemented in analog detection circuits. The strong low-pass roll-off characteristic of these detectors, due to the high RC value of the detector plus feedback resistor, is compensated with high frequency boost circuits, which are then capped with an added roll-off at 1000 Hz. Due to noise amplification, the detector related signal-to-noise is best at lower frequencies.

The optimum noise equivalent power (NEP) at low frequencies is about $1 \times 10^{-14}\ W/\sqrt{Hz}$.

Operated at f/60 in the CHARA system, the effective aperture of the detectors will be approximately 1 arcsec. In order to function efficiently, the tilt correction system will be required. In the event the tilt correction is not functioning, the camera mirrors can be replaced with faster optics (*eg* f/20-30). This will give a larger field of view, and allow detection of interference without rapid tilt correction, but at significantly reduced efficiency due to vignetting within the detector optics.

Detector mounts, with micrometer adjustments for azimuth and elevation, are available. A rack mount power supply for the detector preamplifiers is available.

An additional matched pair of detectors, in compatible mount fixtures, are available for possible future use. These are more modern single element InSb detectors, with integrated preamps. The detector size is 80 microns, resulting in a better, but unmeasured, NEP. In order to image the star onto a detector this size, it will be necessary to provide a high quality f/15 camera.

4. ELECTRONICS

A number of general purpose and custom electronics boxes are available. An Ithaco double bank tunable analog filter is available, which can be adjusted to give high or low pass filtering on two channels, or band pass filtering on one channel.

A custom analog unit is available which accepts two analog inputs, provides selectable amplification and DC offset for each, and combines the signals to form the sum and difference signals. The sum, which corresponds to the total intensity of the signal, is low-pass filtered. The difference, which corresponds to the interferometric signal, is bandpass filtered. In each case, the filter bands may be accepted from a small range of options. Additional, similar electronics units may be available.

An additional unit offers variable amplification and DC offset, and fixed-frequency cutoff (250 Hz) low pass filtering.

5. OBSERVING SCHEME

The CHARA-NOAO version 1 will be used in scanned fringe packet mode. In other words, the optical path difference (OPD) will be varied in triangle or saw-tooth fashion around the nominal zero path difference (ZPD) position. In principle, this scan motion can be provided by the optical pathlength equalizer (OPLE) system. In case this system is not fully functional, an independent scanner can be provided (available from NOAO). It can be installed to drive one of the mirrors in the optical layout over an OPD variation of a few hundred microns. As a final backup, if the OPLE system is completely non-functional, the OPLE catseye retroreflectors can be manually positioned ahead of the ZPD position and the interferometric signal can be monitored as the earth rotation varies the OPD through the ZPD position.

6. ACCESSORIES

The use of the InSb detectors will require LN2 and related equipment. There will be a need for a bulk LN2 supply, either from the observatory facilities or by means of a 100 liter (typical) storage dewar. For daily use, a smaller transfer dewar will be needed, with a capacity of 10-20 liters. A dry N2 supply will be needed for pressurized LN2 transfers. An assortment of hoses, adapters and funnels will be needed.

A vacuum pump will be required, offering a clean vacuum capability, preferably based on turbopump technology.

In order to obtain the best performance from the detectors, an industrial grade vacuum pump will be required to lower the pressure on the LN2 reservoirs, reducing the LN2 temperature to the freezing point, which is optimum for the InSb devices. Plumbing will be required to connect the pump (which should be installed outside the laboratory) to the various dewars. A pumping manifold with capacity of four dewars is available

It may be necessary to provide some of these accessories in Tucson for equipment checkout, as vacuum accessory equipment has been unavailable to the project there.

7. DATA ACQUISITION HARDWARE AND SOFTWARE

Acquiring the interferometric signal will require a minimum of 4 channels of A-D conversion. A minimum of 16 bits is recommended, in order to have both a satisfactory least significant bit magnitude and a convenient dynamic range, The conversion bursts must be synchronized with the OPD scans. Typical data frequencies will be in the range of hundreds to 1000 Hz, so required sample frequencies are up to about 2500 Hz per channel, or 10,000 Hz data acquisition rate. A lower rate will require scanning the OPD at lower speeds, which may result in atmospheric fluctuations and defeat the attempt to scan fast enough to freeze the atmosphere.

7.1. Search Mode

Until the telescope and delay line metrology are well determined, a search mode will be required to find the OPD position. Since the search for OPD can be tedious the first time, or after any optics are moved, it is important for the search mode to be as efficient and automated as possible.

A scheme which worked well with the FLUOR system was simply to monitor the difference signal (which was bandpass filtered in analog mode) and seek in each scan for peak values which exceed some multiple of the RMS noise.

For most effective operation, the search mode should scan a section of OPD, search for a peak, stop if found, and if not found, continue to scan the next section of OPD. A manual interrupt function is also required. With a bright star, even at modest visibility, the technique is fairly deterministic and it is not necessary to scan the same section repeatedly.

7.2. Data Acquisition Mode

Data acquisition consists of repeated OPD scans, with synchronized signal digitization during each scan, and storage of data for subsequent analysis. A data subset will consist of the four signals recorded during a single scan of the OPD. A data set will include multiple subsets, acquired during an interval of a few minutes. Supporting measurements will be required for sky, which must be measured frequently due to detector drift. An efficient, automated way to handle sky measurement is at regular intervals to use the tilt control to move the star off the detectors during a full OPD scan.

The ZPD position will ideally be tracked approximately by the OPLE. However, until the metrology is adequate, the ZPD will drift during observations. It is very desirable to have a means for real time correction of the ZPD position. This can be facilitated with manual intervention. An observer can note the position of the fringes on an oscilloscope, or on a near-real time display of the digitized data, and can enter an OPD correction, if the software provides the interface for this. Alternatively, the peak detection scheme used in acquisition mode can be used to identify the ZPD position, and to adjust the OPD tracking accordingly. An automated update should be provided with adequate filtering to avoid using low significance ZPD information.

8. SCIENCE OPPORTUNITIES

The NOAO MkIV is a simple combiner, and will not offer the best absolute visibility calibration. However, the availability at the CHARA Array of parallel channels at two wavelengths will offer several interesting capabilities which are at the state-of-the-art.

Both channels can be operated broadband. In that case, combined with the CHARA 1 meter apertures, the system will have the capability to reach faint sources. The array can be used to measure diameters of YSO disks in the Taurus and Orion clouds.

Alternatively, the parallelism of data acquisition can be utilized to obtain accurate relative visibilities between the two wavelengths. This can be used to determine differential apparent angular diameters at H and K bands for stars of various spectral types. Deviations from classical model predictions will be found at some luminosity level, indicating the onset of unpredicted atmospheric extension, possibly guiding understanding of the nature of the underlying physics.

An important capability will be added by operating one of the channels broadband and the other with a narrow band filter. It will be possible to guide ZPD acquisition and tracking on the wide band channel while integrating successive scans on the narrow band channel. (The broadband fringes can be used to remove the atmosphere induced OPD fluctuations, and effectively co-phase the scans.) This will allow measurement within hydrogen emission lines, for example in Be stars and some YSO's, or within molecular bands in cool stars.

All of the foregoing observations can be started with the shortest CHARA baseline. Moving to one of the largest baselines, angular resolution in the H band will be 1 millarcsec. This is a very high resolution, and when combined with the sensitivity gained with the 1 meter telescope apertures, will enable a wide range of measurements. As an example, the first systematic angular diameter study of M dwarfs should be possible.

9. FUTURE DEVELOPMENTS

While much more elaborate beam combiners will eventually be implemented for CHARA, there are still substantial possibilities for expanding the NOAO MKIV. The major limitations of the MkIV will be in sensitivity and calibration. Both can be addressed by implementing a modern infrared array detector, as planned in M. Shure's IR camera project. With the large amount of low noise detector real estate available, a reconfiguration and expansion of the MkIV can add one or more additional channels, and add calibration channels as well. The IR detector is by far the most expensive component of this expanded system, and once it is available the rest can be expected to follow. This system will then approach the ultimate Array limit for direct IR detection.

10. RECOMMENDED EQUIPMENT LOANS FROM NOAO

In the Table 2, items identified as located in the Interferometry Lab or at IOTA are already in use for optical interferometry. Those at the NOAO FTS are currently not in use, owing to the retirement of the FTS. All of these items are proposed for an 18 month loan to CHARA, for use at Mt. Wilson.

TABLE 2. NOAO equipment list.

Item	Description	Current Whereabouts
Variable filter	Ithaco	Interferometry lab
Analog Electronics	Rack mounted	NOAO FTS
Assorted optics	small mirrors	Interferometry lab
Assorted mounts	mirrors, beam splitters	Interferometry lab
IR beam splitter	with compensator	IOTA
Short delay line	slide and electronics	Interferometry lab
LN2 pump manifold		IOTA
Dichroic	H/K band	NOAO FTS
A,B	IR detectors	NOAO FTS
E,F	IR detectors	Interferometry lab
Mounts	for InSb dewars	NOAO FTS