DESIGN AND CONSTRUCTION OF A BEAM COMBINER AND RELATED HARDWARE.

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ABSTRACT. The beam combiner for the Big Optical Array[1] will eventually combine 6 beams. Initially it will use the 3 way beam combiner shown in Figure 1. This combiner is assembled on a 4'x7' super-invar breadboard. Simultaneous white light fringes have been detected on all three baselines in the laboratory. This paper describes this beam combiner and the design decisions upon which it is based.

1. Overview

If light from all baselines of a multi-way beam combiner is combined on a single detector, the fringe signal-to-noise will be higher then if separate detectors are used for each baseline. Each baseline is modulated at a unique frequency. The signals from different baselines can be separated after detection. Unfortunately, shifts in modulation frequency due to atmospheric fringe motion result in crosstalk between baselines. Because calibration problems resulting from this crosstalk may be severe, we decided to use pairwise combination. This decision results in a 30% sensitivity loss.

The centroid of the star position from each siderostat can be determined from the centroid of each pair of star images. Since this is possible in a pairwise beam combiner, the same optical elements can be used for both fringe and angle sensing. This should result in a more stable instrument.

A pairwise combiner can be built with a symmetric side: the light from each telescope has the same number of reflections and transmissions from each type of surface. On the symmetric side, the system visibility is not reduced by polarization dependent delays introduced by beam splitter coatings. This should increase the system visibility.

A disadvantage of pairwise combination is the need for a closure phase metrology system. Also, for more than three baselines, a pairwise design can be very large.

2. The Beam Combiner

The beam combiner design is shown in figure 1, along with all the support hardware. The beam combiner proper consists of only two beam splitters (optics 20 and 23) and three mirrors (optics 21, 22, and 24). Alignment mirrors 83, 84, and 85 are removed during operation allowing starlight to enter the beam combiner.

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[1]The Big Optical Array is the imaging portion of the Navy Prototype Optical Interferometer at Lowell Observatory.

J.G. Robertson and W.J. Tango (eds.), Very High Angular Resolution Imaging, 177–180.

Mirror 22 can be pistoned without tilt and will be controlled with a servo during observations to maintain zero closure phase. The servo error signal is provided by the closure phase metrology system.

The combined beams on the symmetric side are sent to spectrographs for fringe detection. The combined beams on the asymmetric side are routed to the angle sensors.

The angle sensor consists of off-axis parabolic mirrors (59, 60, 61) and achromats (53, 54, 55) to increase the effective focal length. The position of each combined image is sensed with four avalanche photodiodes (APD) each fed by optical fibers. The fibers are bonded together forming a square, 2x2 array. A lenslet array is bonded to the input of the fibers.

This quad cell can have very good performance. The lenslets are squares on 400 μm centers with 2 μm dead space between lenslets. Each corner is rounded with a radius of 30 μm. These radii produce a dead zone at the center of the quad which improves the quad cell performance. The best signal to noise occurs (6% improvement in sensitivity) when the central obscuration blocks about 40% of the starlight. When 70% of the light is blocked, the signal to noise is the same as with no blockage. This suggests the use of a 5-cell, where light from a central aperture is used for fringe detection and the outer four quads are used for angle sensing. However, wavefront distortions either from bad optics or from seeing may limit this technique.

3. Closure Phase Metrology

A metrology system is required for measuring the system closure phase. We use a hetrodyne metrology system. The light from an infrared laser is divided into three beams. The frequency of each beam is shifted with an AOM. Spatial filters (11, 12, 13) beam expanders (14, 15, 16) and mirrors (17, 18, and 19) are used to match the metrology beam to the starlight beam at beam splitter 20. Dichroics 25, 26, and 27 deflect the metrology light into detectors 89, 90, 91. Mirror 22 can be pistoned to maintain constant system closure phase. As long as the closure phase error is small, the IR laser need not be frequency stabilized. This metrology scheme is not affected by self-interference which limits the accuracy of normal hetrodyne metrology. The accuracy will probably be set either by misalignment of the metrology beam relative to the stellar beam, or by stray reflections off the back side of the beam combiner coupled with their thermal expansion. These errors should be of order 1 nm.

4. Alignment

The rest of the optics is for alignment. Mirrors 40 and 45 can be removed to inject a narrow laser beam. This beam is bright and is convenient for rough beam combiner alignment and alignment of the beam combiner with the rest of the

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system. The laser can be spatially filtered at 44 and expanded into a 35 mm diameter beam at 42. This is used for accurate beam combiner alignment and to measure the system visibility. Mirror 43 can be removed allowing the white light source 49 to be used as an artificial star for measurement of internal delay constants. All of the beams can be viewed with a video rate CCD camera at 39.

5. Status

All of the optics have been assembled. A double pass fringe visibility amplitude of 0.9 has been measured using the 35 mm diameter laser beam retro-reflecting off mirrors 83, 84, and 85. These mirrors have been adjusted, along with mirror 22 until white light fringes were observed on all three baselines simultaneously. The system is stable: white light fringes remained observable for several days with no adjustments.

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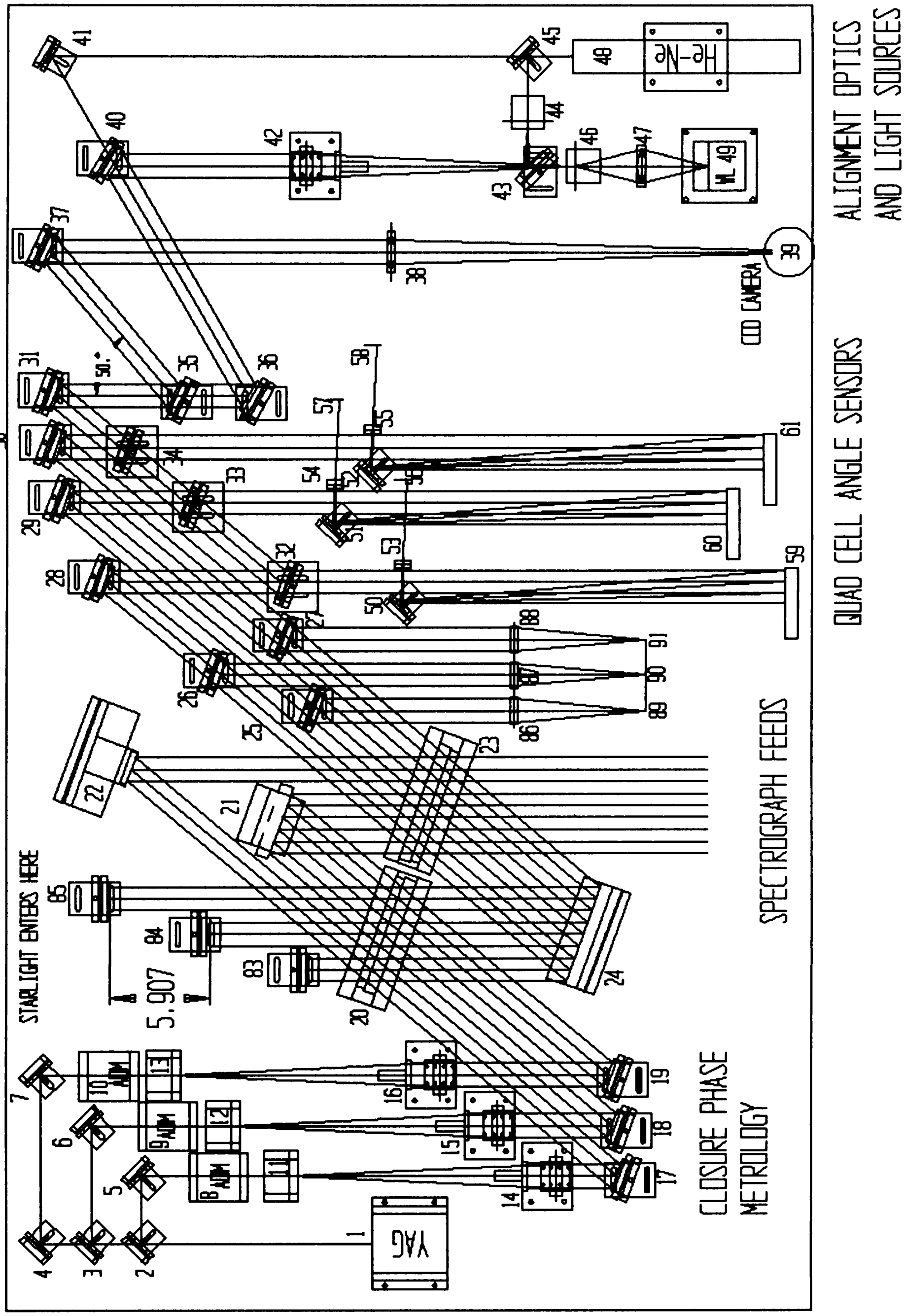

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