CHARA Technical Report

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Telescope Primary Mirror Specifications

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1. INTRODUCTION AND GENERAL INFORMATION

The CHARA Array will employ five or seven 40 in (1 m) size, alt-azimuth style telescopes at a site on Mount Wilson in southern California. The telescopes will be housed separately and operated remotely from a central laboratory. Light from each telescope will be directed by subsequent flat mirrors through vacuum pipes to additional optics and instrumentation at the central laboratory.

This document is an Invitation to Bid (ITB) to manufacture the primary mirrors for the telescopes of the CHARA Array. The information and specifications provided herein are intended to enable prospective suppliers (hereafter called vendors) of polished mirrors to respond to this ITB; however, it is expected that these specifications will become part of any contract for mirror blank purchase that may result from this ITB.

2. THE INVITATION TO BID

Vendors are requested to bid on providing finished mirrors to meet the requirements given in Sections 3 and 4 in the following quantities listed below. Vendors offering more than one design or solution must submit each in a separate ITB complete with all documentation and original signatures.

1. One (1) mirror to demonstrate that specifications can be met.
2. Four (4) additional mirrors to be produced pending the acceptance of the first mirror by CHARA.
3. Two (2) additional mirrors to be included as a purchase option with the four described above and meeting the same requirements [total of six (6) additional mirrors]. This option will expire one year after award of contract.

Vendors are expected to procure mirror blanks that meet the requirements of Section 3 and are therefore required to include information with this quotation concerning the mirror blanks the vendor intends to provide. At a minimum, information about the blanks should include:

[1]Center for High Angular Resolution Astronomy, Georgia State University, Atlanta GA 30303-3083
Tel: (404) 651-2932, FAX: (404) 651-1389, Anonymous ftp: chara.gsu.edu, WWW: http://chara.gsu.edu

1. A drawing with complete dimensional data
2. A listing of material properties including:
   (a) density,
   (b) coefficient of thermal expansion (CTE) in the range 0 – 80°F (-18 – 27°C),
   (c) thermal conductivity,
   (d) Poisson's Ratio,
   (e) modulus of elasticity (Young's Modulus), and
   (f) the material source.

If the material is a commercially available product, the manufacturer's product specifications for these items will be sufficient for this quotation.

Following selection of the successful bidder, within 60 days of the contract award, CHARA will provide to the vendor a specification of the mirror support locations to be used in the telescope as described in Section 3. The vendor shall decide how to support the mirrors during fabrication stages; however, CHARA will provide a finished primary mirror support cell (to be used for final acceptance testing of the mirror) within 8 months of the contract initiation date. The vendor is expected to install the mirror in the support cell and conduct the acceptance tests with the mirror resting on its axial support. In the event of delay in delivery of the mirror support cell, no penalty shall accrue to either the vendor or to CHARA.

The acceptance testing of the first mirror must be completed prior to 30 September 1996. The last of the four (4) mirrors must be delivered no later than 30 June 1998.

Acceptance testing means demonstration at the vendor's facility by the vendor to authorized CHARA representatives that the mirror meets all of the requirements of Sections 3 and 4. This acceptance testing procedure will apply to each of the additional mirrors to be purchased pending the acceptance of the first mirror.

Quoted prices to be f.o.b. delivery point including shipment costs to the CHARA Array site in California, and the mirrors must be packed in containers suitable for protecting them from damage during shipment. Vendors are required to provide a firm completion date for the first mirror, assuming that an award will be made within 30 calendar days from the bid opening date. Vendors will also be required to provide a delivery schedule for the remaining mirrors, assuming CHARA acceptance of the first mirror, within 45 calendar days of the first mirror completion.

All quotations and alternative bids shall be received within forty-five (45) calendar days of the issuance of this ITB.

3. MIRROR BLANK MECHANICAL CHARACTERISTICS AND MATERIAL PROPERTIES

General specifications are given here for mirror blanks considered suitable for the CHARA telescopes. Specifications are given in English units and, sometimes, in metric units. In case a specification is given in both units, the English units shall govern. Manufacturer testing data of material actually used in the CHARA blanks (eg cores or witness samples

from the same batch of material) will be acceptable to CHARA; however, the vendor shall be responsible for ensuring that the tests are performed and for supplying the test results to CHARA.

The mirror blank chosen by the vendor shall be compatible with the mirror support described below, which shall be used for acceptance testing of the polished mirror. Compatibility means:

1. Surfaces shall be provided on the rear side of the mirror blank for 18 required connections between the mirror and its support.
2. Stresses in the blank due to the support shall not exceed 200 lb/in^2 when the mirror is resting normally on the support in a zenith-pointing position.

3.1. Mirror Support

CHARA plans to support the primary mirror in the telescope by means of a "central post" style lateral support and an 18-point mechanical "whiffletree" axial system. For optical testing purposes, the lateral support will not be required and will not be described.

The primary mirror axial support will consist of three mechanical "whiffletrees" each comprising:

1. A cross-bar, pivoted and connected to the mirror support cell at its center.
2. A tripod connected to each end of the cross-bar through a pivot.
3. Rods, approximately 0.062 in (1.6 mm) in diameter, connected to each leg of each tripod and attached to the mirror by means of detachable metal pads. An invar pad, approximately 1.0 in (25 mm) in diameter, will be epoxy-bonded to the mirror at each rod connection point [6 total/whiffletree] with threaded holes for connection screws to the detachable metal pads.

The exact locations of the 18 attachment locations on the mirror depend upon distribution of weight in the mirror blank and its stiffness properties and cannot be specified until the vendor provides the requested information about the blank. However, it is planned to position the 18 points in two rings, one with 12 equally spaced points, the second (inner) ring with 6 equally spaced points.

3.2. Thermal Expansion Properties

Low expansion glass materials are required for the CHARA telescope mirrors. The mirror blank material shall have a coefficient of thermal expansion (CTE) no greater than $3.4\times10^{-6}/^{\circ}$F. For mirror blanks with CTE greater than $1.0\times10^{-6}/^{\circ}$F, the maximum cross-sectional thickness allowed in the blank shall be 0.75 in (19 mm).

3.3. Stress Conditions

Stress birefringence in the mirror blank shall be less than 15 nm/cm of thickness measured perpendicular to the front/rear faces.

3.4. Inclusions and Surface Defects

The "critical region" of the mirror blank is defined to be the uppermost 0.200 in (5 mm) of the surface to be polished. An inclusion is any bubble, "seed", or foreign object different from the base material of the parent blank. Within the critical region:

1. The mean diameter of any inclusion shall not exceed 0.08 in (2 mm), and no more than two (2) of these shall be present in the upper 0.04 in (1 mm) of the critical region.

2. The maximum number of inclusions per any cubic inch shall be 6. The average number of inclusions per cubic inch shall be 0.6. Inclusions smaller than 0.005 in (0.1 mm) will not be considered.

3. Fusion seams shall not exist.

4. No visible cracks shall be permitted.

In the remainder of the mirror blank (the "non-critical region"), the maximum mean diameter of an inclusion shall be less than 0.25 in (6 mm) with a maximum of one (1) inclusion greater than 0.20 in in any cubic inch. The number of inclusions with span greater than 0.1 in (2.5 mm) shall not exceed ten (10). Surface cracks/fusion joints shall be less than 0.03 in (0.075 mm) deep or else machined out to a width equal to the depth and etched to eliminate any residual high stress region at the tip of the crack. No surface irregularity shall exceed a depth of 0.25 in (6 mm).

3.5. Mirror Blank Dimensional and Weight Specifications

The finished mirror shall have a concave optical surface meeting the specifications in Section 4 after polishing. The mirror blanks, ready for polishing and as delivered to CHARA, shall conform to the dimensions given below:

Outer diameter:	40.0 in (1016 mm)
Cylindrical inner hole diameter: (or hole diameter through faceplates)	4.8 in (122 mm)
Radius of curvature of front surface:	Vendor Selection
Thickness at outer rim:	Vendor Selection
Thickness at inner rim:	Vendor Selection
Lightweighting provisions:	Vendor Selection
Rear surface contour:	Vendor Selection, but suitable for interface with the mirror support described in Section 4
Maximum weight of finished mirror:	310 lb (141 kg)
Location of mirror center of gravity:	On the central (optical) axis of the polished mirror and more than 0.8 in (20 mm) behind the vertex of the finished mirror

3.6. Notes Related to Blank Dimensions

1. Bevels (chamfers), at approximately 45° to the front/rear surface, shall be provided at corners of inner and outer rims. Bevels shall be 0.1±0.04in (2.5±1mm) in width, measured along the front/rear surface.

2. Tolerances on blank dimensions: ±0.04in (±1mm), except the inner hole diameter and its concentricity which shall be ±0.02in (±0.5 mm).

3. All unpolished exterior surfaces of the blank shall be ground with #80 grit or finer except outer rim surfaces not previously machined which are in a smooth, crack-free condition as a result of fusion at high temperature.

4. Inner hole and outer diameter shall be concentric ±0.02in (±0.5 mm).

4. OPTICAL SURFACE SPECIFICATIONS AND TESTING REQUIREMENTS

The polished mirror surface shall be a paraboloidal surface of revolution, conforming to the following requirements:

1. Polished clear aperture outer diameter: 39.4in (1000 mm) or larger

2. Polished clear aperture inner diameter: 5.5in (140 mm) or less

3. Primary (vertex) radius of curvature: 197±1in (5000±25 mm)
   [and maximum difference between any two mirrors: 0.6in (15 mm)]

Surface deviation from a perfect parabola (at 632 nm) shall not exceed:

1. 0.03 waves RMS over the full aperture;

2. 0.15 waves peak to valley over the full mirror surface excluding 1 inch (2.54 cm) wide annuli at the inner and outer edges;

3. 0.02 waves RMS over any 30 cm subaperture.

For final acceptance purposes, the mirror shall be tested on an axial support, as described in Section 3, to be provided by CHARA, or its equivalent supplied by the vendor and approved by CHARA. The axial support will essentially "float" the mirror against gravity acting in a direction parallel to the primary mirror optical axis. The primary mirror shall, therefore, be tested in a horizontal position with its optical axis vertical and no forces other than the axial support acting on the mirror.

Optical surface testing for acceptance purposes shall be done with interferometric testing equipment, or equipment with similar performance approved by CHARA, capable of resolving errors at least 50% smaller than the surface deviation specification given above.

5. EVALUATION OF QUOTATIONS

The following factors, listed in order of importance, will be used to evaluate quotations received under this ITB.

1. Total cost of the finished mirrors, delivered to the CHARA Array site, and meeting the requirements of this ITB.
2. Vendor must demonstrate satisfactory experience by having previously completed a mirror of not less than 30 in diameter installed in a functioning astronomical telescope and must have fabricated optics of at least 30 in diameter to optical tolerances similar to those in this ITB.

CHARA reserves the right, with no penalty accruing, to reject all quotations.