CHARA TECHNICAL REPORT

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Choice of Material for Small Optics

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1. INTRODUCTION AND GENERAL INFORMATION

The CHARA Array will employ five 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 follow a path to the Coudé focus of the telescope, where there will be one to three reflections required to balance the polarization and phase delay properties of the various beams. The light will be directed by subsequent flat mirrors through vacuum pipes to the central laboratory. There, additional flat mirrors will further balance the polarization and phase delay, then direct the beams in the POPs, which are optical delay segments of various length, required to equalize the optical delays. The light will then be directed through a periscope arrangement into the OPLEs, for fine adjustment of optical delay. The light will pass through beam compressors, reducing the nominal beam diameter to several centimeters. Flat mirrors will then direct the beams into the beam combination room and the various parts of the beam combination system.

This document summarizes considerations in the choice of substrate materials for these optics.

2. SUBSTRATE MATERIAL

Owing to the large number of surfaces in the CHARA optical train, mirrors must be very flat and very stable. Among the possible candidates, only ULE[2] and Zerodur[3] are reasonably well characterized in refereed technical literature.

ULE is a fused silica glass doped with 7% titanium silicate. Zerodur is described as a glass ceramic, consisting of a crystalline phase and a glassy phase. In each case the compositions are adjusted to give a low CTE.

At present, ULE (glass 7971) is in short supply due to rapid ramp-up of use in the microlithography industry. New furnaces are now being commissioned. These will use a

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[2]Corning Corporation; contact Claude Davis, 607/974-9000

[3]Schott Corporation; contact Joseph Nimmerfroh, 717/457-7485, ext 312

chlorine-free process to produce glass 7972, which will be functionally indistinguishable from 7971. It will be available in the third quarter of 1998. Corning from time to time has access to enough 7971 to fill some orders.

There have been reports in the literature of changes in the CTE characteristics of regular Zerodur (Jacobs et al., 1987), which have been traced to cooling the material through 130K at differing cooling rates. This has been associated with significant figure changes in regular Zerodur optics. An improved material, Zerodur M, has been developed which does not exhibit such CTE changes (Jacobs & Bass, 1989). This probably means that there are no related figure changes, but there is no published study to this effect.

Tests of ULE do not show a similar problem (Jacobs et al., 1987).

Astro-Sital is probably a more risky material, as the CTE is significantly higher than either ULE or Zerodur, there is little referreed technical literature, and the use in the professional astronomy community is still so small that second-order problems very likely would not have been revealed yet.

The CTE of these materials increases in the order: ULE, Zerodur (M), Astro-Sital. The CHARA specifications for surface finish, below, are 0.01 waves RMS. This is an exceptionally tight tolerance. If the CTE is not effectively zero, handling of the blank can cause temperature gradients which must be allowed to disappear before testing or polishing. This greatly increases the optical shop time and effort. For this reason, the lowest CTE is strongly preferred.

The clear preference of materials for CHARA is ULE. Zerodur M has a high probability of serving satisfactorily, but tests of figure stability have not been carried out. Backup alternatives, which could be considered for budgetary reasons, are regular Zerodur and Astro-Sital, both of which may be risky to a degree which is impossible to judge. Astro-Sital is probably the riskiest of these, as there is not a great deal of documented experience.

The substrate material can be purchased in bulk, and then sawed and polished in separate contracts. This has the advantage of moving the purchase ahead in a way that is expected to be the most economical, before detailed specifications are available for all components. It has the disadvantage that CHARA assumes some risk for shipping and perhaps other factors.

Based on preliminary contacts, it appears that Schott does not market bulk material. The bulk material may be available from a secondary source.

The total volume of the optics required is approximately 5600 cubic inches. This should be multiplied by about 1.2 to account for loss of material in cutting, so a total of 7000 cubic inches is required. The component list already includes a considerable number of spares, so there is no reason to worry about cutting the material requirement too close. For the density of ULE, the total weight of material is about 600 pounds.

3. PRICE INFORMATION

Table 1 gives the prices (all are estimates) for substrates for a list of 120 required CHARA optical elements. The estimates are for mirror blanks, cut to the specified dimensions $+0.04/-0.00$ inch and ground with #80 grit or finer. (Additional cutting for holes, etc, would be done at the optical shops.)

TABLE 1. Mirror substrate price estimates.

Source	Material	CTE	Estimate (dollars)	Availability
Schott	Zerodur	100×10^{-9}	41,000	3-4 weeks
Schott	Zerodur M	100×10^{-9}	55,000	3-4 weeks
Corning	ULE	30×10^{-9}	48,000	8-10 weeks

The material 7972 (test) corresponds to material that is currently being produced in the process of commissioning the new furnaces. It does not meet the ULE spec (higher CTE), but has lower CTE than competing materials and has good CTE constancy.

From the foregoing discussion and Table 1, it is clear that ULE offers the best combination of price and performance for the CHARA optics.

4. REFERENCES

Jacobs, S.F., & Bass, D. 1989, *ApplOpt*, **28**, 4045.

Jacobs, S.F., Johnston, S.C., Sasian, J.M., Watson, M., Targrove, J.D., & Bass, D. 1987,*ApplOpt*, **26**, 4438.