CHARA TECHNICAL REPORT

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Optical Performance of the First Primary Mirror

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1. INTRODUCTION

The purpose of a trip completed 20 August was to inspect the first one-meter mirror for the CHARA Array telescopes and to generally look at the LOMO (Leningrad Optical and Mechanical Works) facilities in St. Petersburg (Leningrad), Russia.

CHARA has contracted with Telescope Engineering Company, Inc. of Lakewood, Colorado to import five one-meter parabolic f/2.5 primary mirrors (with an option for two more). These mirrors are being made by LOMO according to CHARA specifications. The mirrors are made out of Sitall low-expansion glass and are lightweighted to a weight of 136 kg by having a number of plugs bored out of the glass. The mirror is designed to be supported by an 18 point whiffle-tree support designed by Larry Barr. (This was actually used during final testing.) Optically, the most critical specifications were the radius of curvature (5000 $\pm$25 mm), the RMS surface over full aperture (0.030 wave, and 0.020 over 20-cm subapertures), and the peak-to-peak deviation from the parabolic surface over the mirror (0.150 wave).

Analysis of the data provided by LOMO confirms that the mirror meets the specifications.

2. THE TRIP

On August 15, 1996, I went to the LOMO office downtown and to the factory some three miles away. The downtown office had about 20 people, mainly management. The LOMO factory was a large complex about three blocks long by one block wide that produced a large fraction of the optics of the former Soviet Union. I was given a standard briefing about the company by several management people. The firm is a large vertically integrated company that literally starts with sand and ends up with finished optical assemblies. They had an interesting museum of the company's products.

The section devoted to large optics covered several large buildings. In them I saw about 12 mirrors of about 0.5-m to 2.2-m aperture in various stages of completion. There were grinding, polishing, and figuring areas. The testing and figuring areas had several vacuum chambers capable of testing mirrors up to 6-m diameter. I saw one master flat of about 2-m diameter. They tend to do figuring with fairly large laps with individual pieces of

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pitch stuck on. This should produce a smoother surface than excessive reliance on small subdiameter tools.

I next saw the setup for testing the first CHARA 1-m mirror, which was with a null-corrector. I was able to move the knife edge myself to several positions in and out of focus. My impression (based on looking at a number of mirrors up to 0.75-m size) was that the surface was quite smooth, i.e. free of the high spatial-frequency "lemon peel" surface that could scatter light out of the beam. The shadings at average focus were subtle and the "terminators" out of focus were close to straight. I was looking for such high frequency defects because they would not show up in the interferograms, sampled at about 4.5-cm spacing. The edges looked satisfactory too, without being noticeably turned. I examined the mirror surface and noticed no large pits or bubbles. The glass was transparent with no large striations, such as is common in Pyrex. This suggests good annealing which could be verified by a polarized light test.

In answer to several questions I raised I found out that they tried hard to get the exact radius of curvature (only 2 mm off) and also Larry Barr's mirror dimensions. My general impression of the two opticians I talked to was that these were people who had a sense of pride in their work.

3. RESULTS

LOMO's test report indicated that the mirror met some of our specifications. The Russian version of the report also included a contour plot (10-level digitization) over a 62×36 grid. I entered the 597 points provided (in x,y,z) into an IDL program to recreate the measured mirror surface. Both a linear triangular interpolation and a quintic interpolation were tried. The former is somewhat better because it doesn't create some small artifacts noted in the latter, although both gave similar values for RMS, etc. Figure 1 shows a plot of the mirror surface. From this plot, it was found that the RMS deviation over the surface was 0.0234 waves, better than the 0.03 specification. (Their report stated 0.027.) The maximum peak-to-peak distance was 0.17 wave. For the mirror excluding the outer 1-in zone, the RMS improves to 0.0213 waves, and the p-p value to 0.128 waves. The latter meets the stated specification of 0.15 waves. I also considered 20- and 30-cm subaperture regions similar to those to be used in the Array. I took 30 possible regions at 12-degree intervals centered at the 50% zone of the mirror. Table 1 shows these results. The worst 20-cm region had an RMS deviations of 0.0132, considerably less than the 0.02 specification. Finally, as mentioned above, I could not detect any noticeable high spatial frequency components in the mirror surface. In summary, I am confident that this is an excellent diffraction-limited mirror.

TABLE 1. Mirror Surface RMS

Aperture (cm)	Mean RMS	Worst RMS	Worst P-P
100.00	0.0234	0.0234	0.168
94.92	0.0213	0.0213	0.128
40.00	0.0143	0.0210	0.0783
30.00	0.0110	0.0169	0.0637
20.00	0.0071	0.0132	0.0498

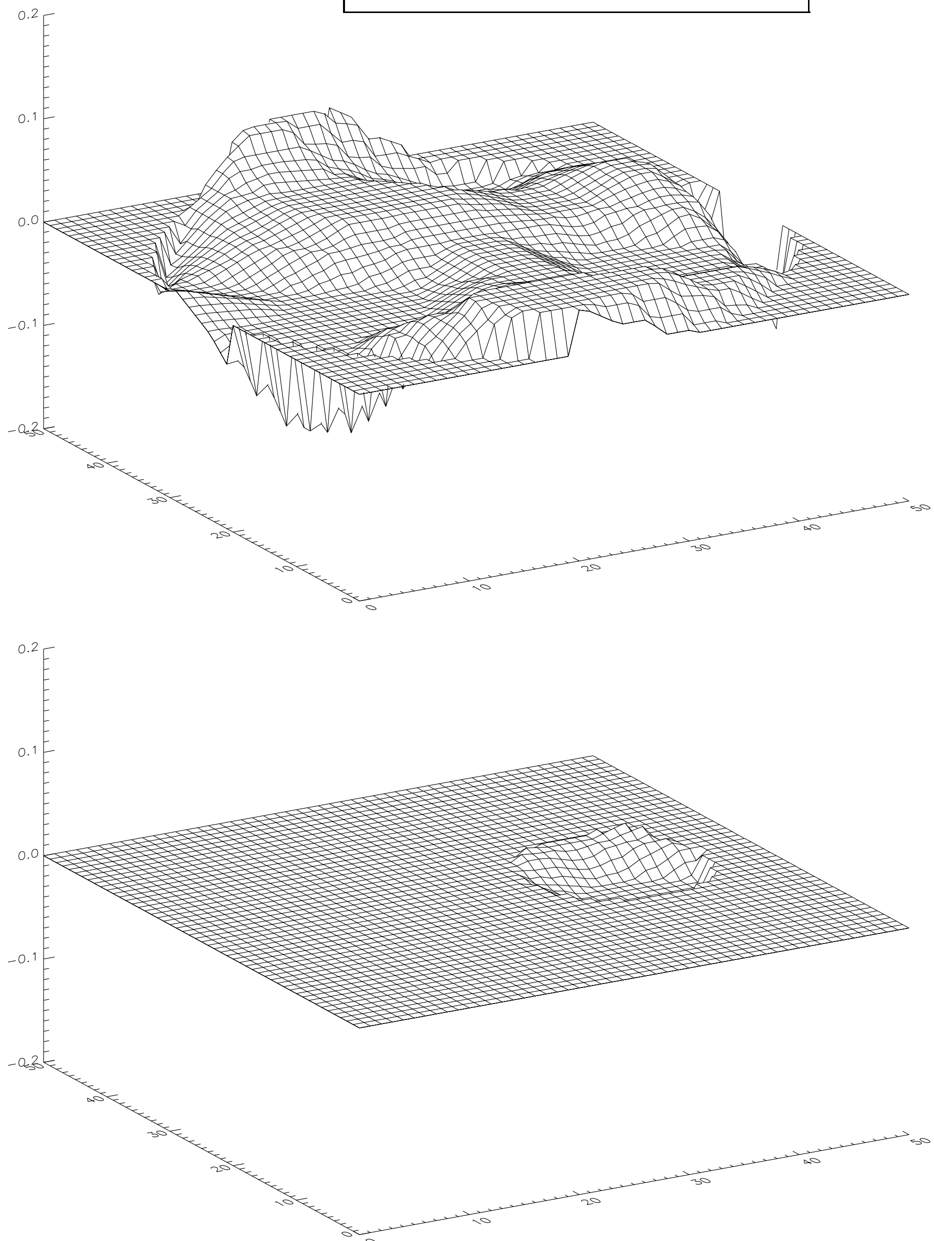

FIGURE 1. Top: Mirror surface. Bottom: A 30-cm section of the surface.