Low Temperature Optical Testing of CFRP Telescope Panels

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Since 1984 we have been engaged in low temperature optical testing of very lightweight mirror panels for possible use in balloon and space infrared and submillimeter telescopes. In order to accomplish this testing, we have created an ambient pressure 0.5 meter test chamber operating from 20°C to -80°C, developed techniques for measuring non-optical quality mirrors with phase modulated 10.6 μm interferometry, and created the interferogram reduction program. During the course of the program, we have tested nineteen mirrors from four manufacturers: Carbon Fiber Reinforced Plastic (CFRP) aluminum honeycomb sandwich panel mirrors from Dornier System and from a Hexcel/JPL collaboration, a CFRP sandwich panel with an added glass face-sheet from Mitsubishi Electric Corporation, and carbon fiber reinforced glass panels from United Technology Research Center. In this report we summarize the results of our panel development and test program with Dornier System which was begun in 1984 and is now complete with the fabrication and testing of five 0.5 meter panels procured directly from Dornier and an additional four panels from JPL.

Our proposed Three-Meter Balloon-Borne Telescope places several requirements on the mirror which are very similar to those of LDR. It must: (1) be very lightweight (<10 kg/m^2), (2) have 30 μm diffraction-limited figure quality and provide visible light imaging for alignment and guiding, (3) maintain its figure at room temperature for testing and at an operating temperature of -50°C, (4) come to rapid thermal equilibrium, and (5) survive high gravity loading. CFRP sandwich panels appear to be very promising candidate mirrors if they can meet the figure accuracy and temperature stability requirements.

At the time this work was started, Dornier panels achieved 350 μm diffraction-limited figure accuracy in two meter panels for ground-based submillimeter astronomy. During the development program, the 0.5 meter octagonal Dornier mirrors have shown spectacular improvement: the surface replication accuracy has improved by a factor of two, and the thermal stability, by a factor of twenty-five. In general, the largest replication errors and temperature-induced changes have been large-scale effects; primarily focus and astigmatism changes.

FIGURE 1 shows the change with temperature of the focus, XY astigmatism (the dominant astigmatism term), spherical aberration, and residual RMS (after removal of the first eight Zernike polynomial terms) for QUAD 25, the last of the Dornier panels tested. All measurements except the residual are peak-to-valley distortion over the mirror. The total change including all effects over the 80 C temperature range is 1 μm RMS. These measurements show no hysteresis above the measurement scatter. The achieved performance is summarized below:

Replication Accuracy (including the mold)	2.5 μm RMS
Residual Error (with astigmatism removed)	0.8 μm RMS
Figure change from 20 C to -60 C	
Focus (peak-to-valley)	2.5 μm
Astigmatism (peak-to-valley)	1.5 μm
Total Change	1.0 μm RMS
Change without focus and astigmatism	0.7 μm RMS

The Dornier panel, Quad 25, meets the 30 μm diffraction-limited requirements for replication accuracy and thermal stability for the balloon telescope at the 0.5 meter size. Similar performance remains to be demonstrated: (1) with the JPL Hexcel program, (2) with 1 and 2 meter panels, and (3) at the LDR operating temperature (-100 C). In addition, the surface quality must be improved to achieve optical imaging.

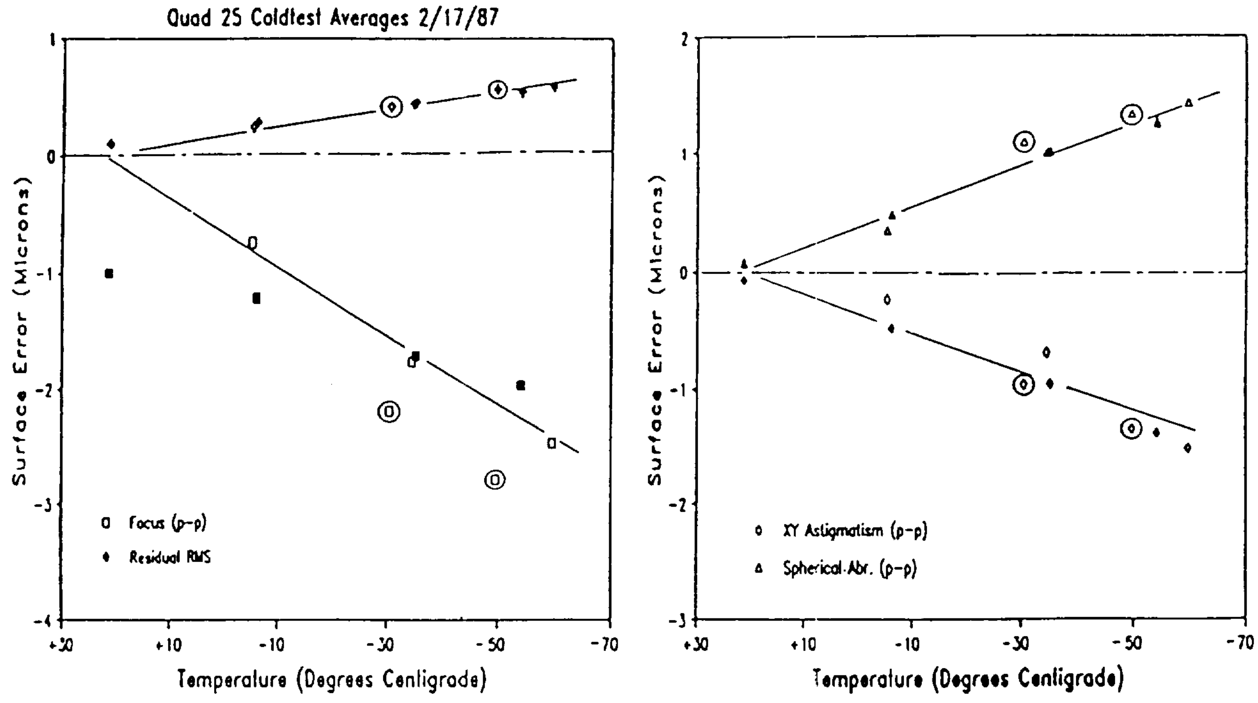

FIGURE 1. QUAD 25 Test Results showing focus, XY astigmatism, spherical aberration and residual RMS. The open, filled, and encircled symbols represent measurements made during the cool down, the warm up to room temperature, and a second cool down, respectively.

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