

Lightweight optical telescope structures built from plastic composites

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Two new astronomical instruments feature carbon fiber-reinforced plastic materials in both the optical tube assemblies and the optics.

Lightweight optical technologies are compelling for several telescope applications. Field-deployable systems, airborne observers, and rapid-tracking telescopes are examples where low system mass would improve operational performance. Composite Mirror Applications (CMA) of Tucson, AZ, has invested considerable effort in developing lightweight optics. The CMA process involves unidirectional carbon fiber-reinforced plastic (CFRP) prepreg (preimpregnated material) layered over a mandrel (form) that has the complementary shape of the desired mirror. After the lay-up structure is cured and removed from the mandrel, the mirror surface is aluminized in the same manner as conventional glass mirrors. The mandrel can be reused to generate multiple copies of the same mirror shape.

The development of this technique has been very positive. The quality of the optical surface now produced at CMA is limited by the quality of the mandrel.¹ The CFRP optics are an order of magnitude lighter than similar mirrors made in traditional glass. To take full advantage of the CFRP optics, CMA has undertaken the design and fabrication of optical tube assemblies (OTAs) and steering mounts using CFRP.

This material has a number of advantageous material properties. For example, the stiffness-to-weight ratio of CFRP is about five times greater than that of steel, the Young's modulus similar, and the density much lower. Thus, stiff, lightweight structures are possible. In addition, the coefficient of thermal expansion for CFRP is very low at 1–2ppm, roughly 20 times lower than for aluminum. For this reason, CFRP structures do not deform with temperature changes. Also, the thermal conductivity of CFRP is similar to that of steel. This property, coupled with the lower mass of a CFRP structure, means that telescope components rapidly come to the same temperature as their surroundings,



Figure 1. The 1m Ultra Lightweight Telescope for Research in Astronomy (ULTRA) on Mount Laguna after installation in June 2007.

which reduces image distortion. Furthermore, because CFRP structural elements are fabricated as a lay-up of unidirectional prepreg fiber, the structural elements can take advantage of the

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Figure 2. The OTA for the Naval Research Laboratory 1.4m telescope under construction in the shop at CMA.

CFRP nonisotropic properties or can be tailored to yield quasi-isotropic behavior.

The OTAs designed at CMA have incorporated several key fabrication techniques that exploit these mechanical features of CFRP. For example, if tubes are loaded only in an axial direction, the tubing can be optimized for stiffness by running most of the prepreg fiber layers in the axial direction. Sandwich panels of CFRP facesheets and aluminum honeycomb core are used extensively in the structural design. The in-plane thermal and mechanical properties are dominated by the CFRP material properties, and the panel stiffness is a strong function of the thickness. Appropriate orientation of the panels in the overall design makes the most of the CFRP characteristics. In some circumstances, CFRP is difficult to use for structural elements. For example, metals are used for fasteners and other small hardware.

The meter-class telescope systems being developed at CMA are the first all-CFRP telescopes.² The 1m Ultra Lightweight Telescope for Research in Astronomy (ULTRA) has both the optics and the OTA fabricated from CFRP.^{3,4} This telescope was recently installed at the San Diego State University Mount Laguna

Observatory near San Diego (see Figure 1). A 1.4m telescope for the Naval Research Laboratory is currently under construction at CMA (see Figure 2). The optics, OTA, and mount are all made with CFRP composites. A unique feature of both of these telescopes is the very lightweight secondary mirror, top end, and head ring, which are connected to the lower OTA structure via a hexapod assembly (six strut tubes). This allows for complete adjustment of focus and optical alignment through small motors on the lower part of the legs. This elegant arrangement is possible because of the light, stiff, and stable design enabled by CFRP.

The ULTRA OTA was tested at CMA for mechanical resonance and stiffness. The first resonances of the OTA structure are above 50Hz. Movement of the optical alignment (between the two mirrors) was negligible. Field testing of the ULTRA is planned for 2008.

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