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An adaptively corrected composite material telescope

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Meter class, composite astronomical telescopes are lightweight and, with adaptive optics, provide high-fidelity wave fronts and images.

Revolutions in telescope technology have consistently driven the next generation of astronomical discoveries. Over the last century the development of the 1.5 and 2.5m telescopes at Mount Wilson Observatory, the 5m at Palomar Observatory, and so on through to the 10m Keck telescopes, have led to new discoveries based on the increase in telescope aperture. The Hubble Space Telescope, while not having the largest aperture, continues to be at the forefront of discovery because of its use of space technologies. Still, these telescopes all have something in common: they are made from steel and glass. The next revolution in telescope technology is being driven by changes in the materials that make up the telescope and optics. Telescopes now being constructed for use at the Navy Optical Prototype Interferometer[1] (NPOI) are being made entirely from carbon fiber reinforced polymers (CFRP). These CFRP telescopes are remarkably rigid and have excellent optical figure. As well, adaptive optics can enhance the performance of these telescopes.[2] Composite telescopes with adaptive optic correction will play a key role in increasing the performance of the NPOI instrument and fulfilling its mission.

Traditional mirror fabrication techniques require long periods of controlled grinding and polishing, and a typical meter-class mirror can take several months to complete. A significant advantage to building telescopes and their optics from composite materials is the reduction in construction time. The composite optics are constructed using glass mandrels that, once fabricated, can be used to reproduce a large number of telescope mirrors. One major advantage is that the high-quality mandrel eliminates the need for optical polishing of the surface, so once the mirror is formed from CFRP it is ready for coating.

The optical tube assembly for the NPOI telescope is also manufactured from CFRP, providing both low weight and excellent structural rigidity. The result is a 1.4m aperture telescope that weighs a fraction of what a similar telescope of steel and glass would weigh. As a result, the telescope can be accurately moved and positioned using mounts that are also much lighter and often significantly less expensive. This increases the opportunity to use larger aperture telescopes for a given project.

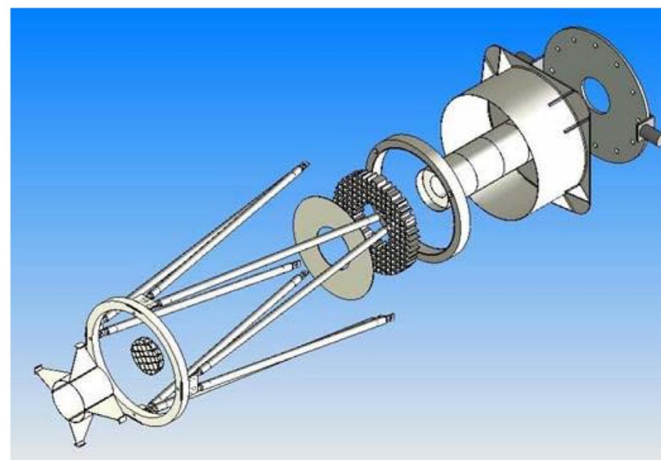

Figure 1. *This exploded view of the CFRP telescope shows the position of the composite optics.*

Figure 2. *The CFRP fabrication sequence appears from left to right: processing the glass mandrel; lay-up of CFRP over the glass mandrel; and release CFRP mirror from the mandrel, ready for coating without additional figuring or polishing.*

An exploded view of the CFRP telescope is shown in Figure 1. The NPOI telescope is a classical Cassegrain design with the primary and secondary optics and the optical tube assembly constructed from CFRP.

CFRP mirrors are fabricated, as shown in Figure 2, by optical

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Figure 3. *The 40cm, all-CFRP composite telescope weighs 10 kg complete with optics (left). The telescope installed on its mount is shown on the right.*

surface transfer using a mandrel polished to the optical prescription of the mirror, but with a negative curve. CFRP material is then laid-up over the mandrel in a quasi-isotropic orientation, yielding a mirror with uniform, in-plane mechanical properties. The mirror structure is attached to the back of the mirror face sheet, and after curing the mirror is released from the mandrel and ready for optical coating. The completed NPOI telescope is shown in Figure 3.

Active and adaptive optics are used on telescopes to remove the effects of atmospheric turbulence, or seeing, as well as tracking errors and aberrations in the optical system. Active optical systems are often integrated into the telescope itself as there are few components,[3] while adaptive optics systems are often constructed on large optical benches[4] and for most large telescopes this poses little problem. A lightweight, portable telescope, however, requires a lightweight and portable adaptive optics system. To reduce the weight of an adaptive optics system, the size and number of optics must be minimized and the optical bench must be greatly compacted.

A novel adaptive optics system has been developed for the NPOI telescopes that both mounts on a small optics table and uses a minimum number of components. The key to minimizing the number of components has been the development of the adaptive tilt mirror, which combines a lightweight Micro-Electro-Mechanical Systems (MEMS) deformable mirror on a standard tip-tilt platform and a pair of off-axis parabolas, mounted in a single fixture that is used to shorten the beam path and provide collimation.[5] As a result, many of the reimaging optics have been eliminated from the system.

A lightweight telescope system coupled with adaptive optics has many uses in astronomical systems, but is also suitable for many more diverse applications. These lightweight systems have potential for use in optical communications, remote sensing and surveillance, and mobile platform imagers for land and sea, to name a few of the possibilities.

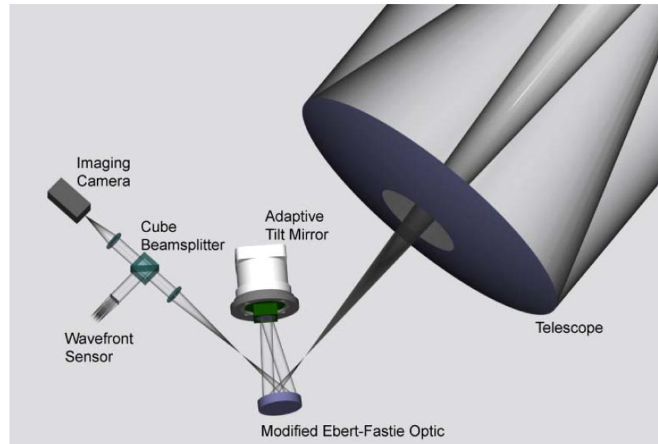

Figure 4. *The adaptive optics system shown here is used for the lightweight telescope.*

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