SPECIAL focus

BINOCULAR VISION

The Large Binocular Telescope project uses dual primaries to perform phased-array imaging.

BY JOHN HILL, UNIVERSITY OF ARIZONA, AND PIERO SALINARI, OSSERVATORIO ASTROFISICO DI ARCETRI

ILLUSTRATION BY NEAL ASPINALL

When it comes to astronomy, resolution and light-collecting power are key. Generally, we achieve higher resolution by building telescopes with larger mirrors. In the case of ground-based telescopes, the definition of "large" has grown, fueled by technology like adaptive optics, segmented mirrors, and lightweighting. Now, the Large Binocular Telescope (LBT), located at Mount Graham International Observatory in the Pinaleno Mountains of southeastern Arizona, is demonstrating a new twist—a telescope that is both bigger and better.

A collaboration between institutions in Germany, Italy, and the United States, the telescope uses two 8.4-m diameter primary mirrors mounted side by side to produce a collecting area equivalent to an 11.8-m circular aperture at a fraction of the cost. In this sense, it will be the world's largest optical/IR telescope on a single mount. Of course, several other observatories have more total collecting area in arrays of individual telescopes. The unique feature of LBT is that the light from the two primary mirrors can be combined to produce phased-array imaging of an extended field. This coherent imaging gives the telescope the diffraction-limited resolution of a 22.8-m telescope. When the telescope is commissioned, we should be able to produce images with a resolution of 0.005 arcsec in visible light and 0.020 arcsec in the near-IR spectral region.

Building the Perfect Beast

The telescope design consists of a pair of paraboloidal primaries, each with an *f*/15 adaptive IR secondary of a Gregorian design (concave mirrors rather than the more common convex Cassegrain mirrors).[1] Light passes through the optical path of the two primaries and secondaries (see figure 1). The interferometric focus combining the light from the two 8.4-m primaries will reimage the two folded Gregorian focal planes to three central locations for phased-array imaging.

The Steward Observatory Mirror Lab of the University of Arizona (Tucson, AZ) polished the first of the two 8.4-m borosilicate honeycomb primary mirrors for the LBT in 2002. During 2003, the mirror was tested in its final support cell and then transported to the mountain. These primary mirrors have a focal ratio of *f*/1.14 to allow a very compact and stiff mechanical assembly to be used for the steel optical support structure. A special computer-controlled, stressed lap was used to polish this steeply aspheric optical surface.

The fabrication team measured the optical surface using phase-shifting interferometry and a refractive null corrector near the center of curvature. The figure of the first primary mirror was measured to deviate from the ideal paraboloid by less than 27 nm rms. The second of the two primaries is being polished at the Steward Observatory Mirror Lab and will be installed in the telescope in the fall of 2005.

The adaptive secondaries are undersized to provide a low-thermal-background focal plane that is unvignetted over a 4-arcmin-diameter field of view. Each secondary will feature 672 voice-coil actuators, now in the final stages of fabrication in Italy. The electromechanics of the adaptive secondary mirrors are being designed and fabricated by ADS International (Lecco, Italy) and Microgate (Bolzano, Italy). The adaptive optics system for the telescope is a cooperative effort between these companies and the adaptive optics groups at Osservatorio Astrofisico di Arcetri (Florence, Italy) and the Steward Observatory, which is polishing the 1.6-mm-thick, 911-mm-diameter shells for the secondaries. These adaptive secondaries will update their shape at kilohertz rates to correct the wavefront distortions caused by atmospheric turbulence.

The first of two 8.4-m borosilicate honeycomb primary mirrors has been installed in the telescope on Mt. Graham in southeastern Arizona. The first primary mirror was mounted on the telescope in its support cell during March 2004. The mirror cell contains 160 pneumatic actuators that float the mirror against the force of gravity in order to preserve and adjust its accurate shape.

Telescopes in Action

The telescope is mounted on an altitude-over-azimuth mount inside a co-rotating enclosure. The rotating mass of the enclosure is 1600 tons. The rotating structure is a cubical shape with dimensions of 25 m × 28 m × 29 m. The roofline of the building is 53 m above the ground level. Hydrostatic bearings provide smooth motion with very low friction. The azimuth and elevation drives each have four brushed DC servomotors to provide smooth tracking of the telescope across the sky. The telescope elevation structure accommodates swing-arm spiders that allow rapid interchange of the various secondary and tertiary mirrors as well as prime-focus cameras.

The telescope structure accommodates installation of a 9-m vacuum bell jar for aluminizing the primary mirrors in situ on the telescope. That unit is now undergoing final tests in Columbus, OH. The detailed design of the telescope structure was done by European Industrial Engineering (Mestre, Italy) and ADS International. The telescope structure was fabricated and pre-assembled in Italy (Ansaldo-Camozzi; Milan, Italy) and shipped to Arizona in compact sections weighing up to 60 tons.

The elevation of the observatory is 3192 m. The transportation of the 8.4-m mirror to the observatory was a cooperative effort. The mirror was transported in a specially designed box that provides multiple layers of spring isolation. The mirror box was transported horizontally down Interstate Highway 10 between Tucson and Safford. Then the box was tilted by 60° at the observatory base camp and mounted on a Goldhofer trailer for the transport up the 43 km of winding mountain road.

The telescope is now completely reassembled in the completed and operational enclosure on Mt. Graham. The moving mass of the telescope structure is around 650 tons. First light with the left primary mirror and the blue channel of the Large Binocular Camera, built by a consortium of Italian groups, is expected later this year.

The international partners in the Large Binocular Telescope Corp. include Arizona (25%), Germany (25%), Italy (25%), Ohio State (12.5%), and Research Corp. (Tucson, AZ; 12.5%). The Arizona portion of the project includes astronomers from the University of Arizona, Arizona State University (Tempe, AZ), and Northern Arizona University (Flagstaff, AZ). The German portion is represented by the LBT Beteiligungsgesellschaft, which is composed of Max-Planck-Institut für Astronomie (Heidelberg, Germany), Max-Planck-Institut für Radioastronomie (Bonn, Germany), Max-Planck-Institut für Extraterrestrische Physik (Munich, Germany), and Astrophysikalisches Institut (Potsdam, Germany).

National participation in Italy is organized by the Istituto Nazionale di Astrofisica. Partners at individual institutions include the Ohio State University (Columbus, OH), Research Corp., the University of Notre Dame (Notre Dame, IN), the University of Minnesota (Minneapolis, MN), and the University of Virginia (Charlottesville, VA). Astronomers and engineers at all of these institutions are involved in building instruments for the telescope. **oe**

John Hill is director of the Large Binocular Telescope Project, University of Arizona, Tucson, AZ. Piero Salinari is deputy director, Osservatorio Astrofisico di Arcetri, Florence, Italy. For questions, contact Hill at 520-621-3940, 520-626-9333 (fax), or jhill@as.arizona.edu.

SPIE Member

References

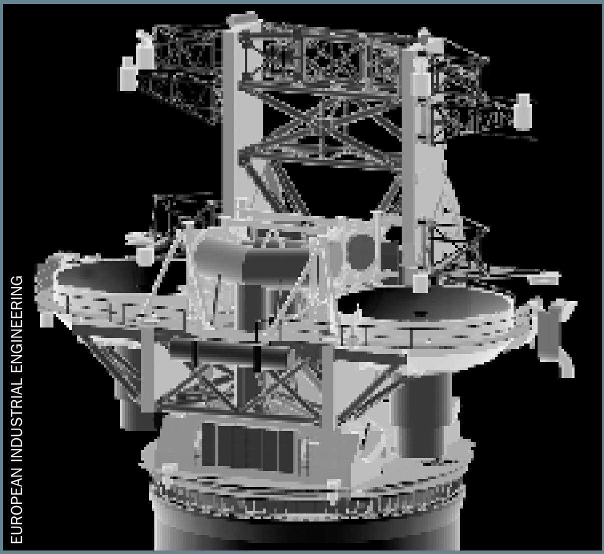

Figure 1 In the LBT, the primaries are placed side by side. A 3-D engineering diagram shows swing arms for the primary mirror covers, for the tertiary mirrors, for the prime-focus cameras, and for the adaptive secondary mirrors.