Fiber Optics Link Big Telescopes in Hawaii

Astronomers have long exploited the properties of interferometry to collect radio-frequency images with astoundingly high resolution. An international team is devising a scheme to link seven optical telescopes with fiber optics to bring ultrahigh resolution into the near infrared.

The mountain of Mauna Kea in Hawaii is already home to the world’s largest collection of optical telescopes. Linking them together for interferometry would create a near-infrared light collector with a virtual aperture of up to 800 m—far bigger than any of the current proposals for 30- to 50-m telescopes. The project is called the Optical Hawaiian Array for Nanoradian Astronomy, or ‘OHANA, which in the Hawaiian language means “extended family” (the apostrophe is part of the name).

The collaboration among French, British, Japanese and U.S. astronomers produced the first connection when they linked the two 10-m William M. Keck Observatory telescopes with single-mode fibers last June (Science 311, 194).

According to Keck scientist Julien Woillez, scientists have been kicking around the idea of fiber-optic interferometry for a quarter century. However, it wasn’t until the early 1990s that astronomers from the Observatory of Paris in France solved the dispersion-matching problems that had stood in the way of successful implementation. They first measured the optical fiber’s dispersion with a lab interferometer and adjusted one of the fiber lengths accordingly.

The twin Keck telescopes already had an optical interferometry link that used a system of flat mirrors that transmitted light to an underground combining room. The new design replaces the classical system with two 300-m single-mode fiber cables made of fluoride glass. At the near-infrared (roughly 2 μm) wavelengths of the ‘OHANA test, fluoride fibers transmit more light than silicate ones.

The single-mode fibers preserve the phase of the incoming light from the telescopes, Woillez said. The team’s main concern is insulating the system from vibrations.

The team reported that the fiber coupling transmitted at least as much light as the classical interferometry setup—1 percent of the light gathered by each telescope—but still below their predicted 4 percent transmission. Eventually the researchers want to improve the setup’s transmission to 10 percent with optimized optics and shorter fibers. The optics of telescopes place unavoidable limits on the interferometer’s collection efficiency.

Even though the twin Keck baseline is only 85 m, the team chose to test the 300-m fibers on the Keck pair for eventual use with the more widely separated telescopes on the mountain. The next two instruments to be linked with fiber—the Canada-France-Hawaii and Gemini North telescopes—will require 300-m fibers. The ‘OHANA team is building an underground conduit for those fibers.

The most widely spaced instruments on Mauna Kea, the Subaru and Gemini North telescopes are 800 m apart. Woillez cautioned that those two telescopes still couldn’t collect as many photons as an 800-m telescope—an instrument too massive to be built in the foreseeable future.

A goal of ‘OHANA is to produce images with a resolution approaching 0.001 arcsecond at near-infrared wavelengths. Even with its newest adaptive-optics system (OPN, March 2006, p. 10), a single Keck telescope can resolve objects a few tenths of an arcsecond apart.

— Patricia Daukantas

Did You Know?

Veterinarians have learned how to use a fiber-coupled holmium-YAG laser to blast away canine bladder stones. The researchers designed the apparatus to pass the 2,100-nm pulses from the 20-W laser down a standard cystoscope (an eyepiece-equipped tube) that is inserted into a dog’s urethra while the animal is under general anesthesia. In a presentation to Photonics West’s BiOS session, Larry Adams of Purdue University reported that the female dogs responded successfully to an average of 30 minutes of treatment, but the male dogs needed more than twice as much laser therapy.
The Robust Optical Design of the Human Eye

The separate optical components of the human eye—corneas, lenses and axial lengths—exhibit a wide variety of individual aberrations. Yet, in many cases, the errors roughly cancel each other out and the eye can still see reasonably well. A team of Spanish physicists is studying the ways in which the eye’s robustness develops (J. Vision 6, 1).

Advances in both sensor technology and ray-tracing software have given researchers the ability to study the optical properties of the eye’s constituent parts. The physicists measured the vision of young adults with varying amounts of myopia (nearsightedness) and hyperopia (farsightedness)—refractive errors that result from variations in the axial length of the eyeball.

In each case, the team used a Hartmann-Shack wavefront sensor to measure the optics of the entire eye and a corneal topographer to measure the shape of the cornea. The aberration of each eye’s intraocular lens came from subtracting the corneal errors from the eye’s total errors. The range of corneal and lens aberrations turned out to be wider for hyperopic eyes than for the myopic ones.

The group also studied so-called higher-order aberrations such as coma and spherical aberration, which conventional eyeglasses cannot correct but are generally too small to affect human vision. Most eyes, regardless of their overall refractive errors, had optical components that compensated for each other’s higher-order irregularities.

Even though the eye has a lot more aberrations than a professional optical system—in which researchers strive for the most error-free components possible—it actually has a well-balanced, robust design, said Pablo Artal, professor of optics at the University of Murcia in Spain.

“If you have an excellent optical system, it’s not very tolerant,” Artal said. “But the eye is more tolerant. The lens and cornea can have aberrations, and the eye is still of reasonably good optical quality.”

Artal said he believes that eyes are not actively compensating for the aberrations of their components. Rather, the robust design of the eye has evolved passively so that the acuity of the whole visual system is generally greater than that of its individual parts.

This type of research into the basic behavior of the eye could lead to the development of better artificial intraocular lenses for cataract patients, Artal said.