ic field at the tape's surface. Physicists turn each atom into a miniature bar magnet by exciting them with lasers, imparting the inherent magnetic properties of one of the atom's electrons to the atom as a whole. As each suitably prepared atom approaches the mirror, it is repelled by the field.

Focusing atom beams adds a whole new level of complexity, however, because the mirror must be curved very precisely in three dimensions. To make their focusing mirror, Hinds's team first used a specially designed recording head to imprint an audio sine wave onto the tape. This tape they then glued across the end of a hollow ceramic cylinder, creating a drum. They then pressed a high-quality optical lens into the tape to form a lens shape and backfilled the cylinder with epoxy resin to hold the tape in that shape when the optical lens was removed. "It's a simple technique, but it's the result of probably 4 years of farting about doing things not right," says Hinds. The resulting curved tape surface is still not perfectly smooth, but the team got around this roughness, which would blur the reflection, by ensuring that the field is strong enough to stop atoms from getting close to the surface. Far from the tape, any roughness fades away, leaving a smooth field.

Hinds and his group tested the mirror by using it as an atom trampoline. They positioned the mirror horizontally and, using a magneto-optical trap that confines atoms in space, released a millimeter-wide cloud of atoms from a height above the surface equal to a quarter of the mirror's radius of curvature. After the first bounce, the atoms formed a flat disk above the mirror, and on the second bounce they recombined back into a cloud, exactly as predicted by the rules of atom optics, which take account of the fact that atoms follow curved paths as they fall under the influence of gravity. "The ability to reconstruct the initial atom cloud quite closely after many focused reflections indicates that the quality of the reflection process is quite good," says Hannaford.

Meanwhile, other teams are devising novel ways of creating magnetic mirrors. Hannaford and Geoff Opat at the University of Melbourne and their colleagues have made a prototype mirror of a fine wire grid that will be published next month in *European Physical Journal D*. The mirror is not unlike a miniature version of a car's rear window demister, with gold wires spaced 0.1 millimeters apart. The grid produces an alternating magnetic field when a current passes through, repelling atoms by the same principle as Hinds's mirror. Two teams at Harvard, led by Mara Prentiss and Robert Westervelt, have taken a similar tack with a grid shrunk by 40%. They have now joined forces with Bill Phillips at the National Institute of Standards and Technology in Gaithersburg, Maryland, and with Aspect in Orsay and, in work yet to be published, have measured how well their mirror reflects atoms. "It really is a very good mirror," says Aspect.

With all this activity, researchers are looking forward to more adventurous atom optics. Hannaford and Opat envisage cylinders for piping atoms about and a new generation of atom microtraps. Hinds hopes to build a kind of magnetic table on which atoms can roll around. With microfabrication, "you can make something like a printed circuit for atom optics," says Hinds. Adds Wolfgang Ketterle of the Massachusetts Institute of Technology, "I think we are experiencing a golden age of atomic physics."

–ANDREW WATSON

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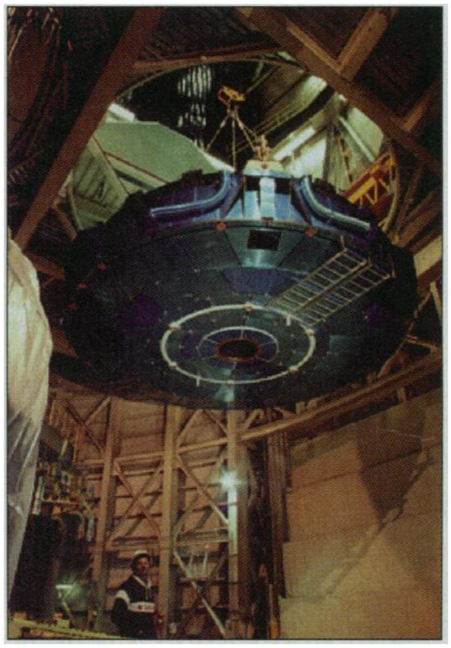
ASTRONOMY

Subaru Opens Up World for Japan

TOKYO—This week, Japanese astronomers hope to capture the first scientific images from the country's new Subaru Telescope atop Mauna Kea in Hawaii. Its 8.3-meter mirror makes it the world's largest single-mirror telescope, and one of a handful of telescopes globally in the 8- to 10-meter range. As the country's first major scientific project ever built on foreign soil, Subaru also marks Japan's entry into the top tier of scientific nations with a global scientific reach. "It's a symbol of a new stage for basic science in Japan," boasts Keiichi Kodaira, director-general of the Tokyo-based National Astronomical Observatory, which built Subaru. "We are contributing to worldwide efforts with a scientific facility that is truly up to international levels."



A new vision. Subaru's primary mirror being moved into place in preparation for "first light" this week.

CREDIT: NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN

Kodaira says Subaru will let Japanese scientists work on "an equal footing" with colleagues in the United States and Europe. The $348 million optical-infrared Subaru is expected to make vital contributions to sky surveys and the search for planets orbiting nearby stars. It will also stand out among the thicket of domes atop Mauna Kea, with an innovative cylindrical enclosure that is expected to minimize wind turbulence around the telescope.

Equally novel, but less obvious, is the use of 261 computer-controlled actuators to push and pull the mirror to counter the distortions of temperature and gravity. That's nearly 50% more than are being used for the 8-meter Gemini telescope on Mauna Kea, a multinational consortium that is also preparing to capture its first images. "The larger the number of actuators, the better the control of the surface," says Subaru's director, Norio Kaifu. They are used in combination with the telescope's adaptive optics system, which filters out the flicker that results from Earth's atmosphere.

This kind of accuracy will be critical for some of the ambitious observations astronomers hope to make with the telescope's instruments. A coronagraphic imager, for example, has a mask that blocks the light from the center of a star to allow astronomers to search for orbiting planets or protoplanetary discs. "We now have only indirect evidence of planetary systems around nearby stars," Kaifu says. "Our objective is to get direct images of those planetary systems."

Another unique instrument is the Subaru prime focus camera. It will have the widest field of view among 8-meter-class telescopes and capture images quickly, making it particularly valuable for sky surveys.

The observatory plans to offer international use of Subaru after its yearlong shakedown period. "Subaru is going to be a key component in worldwide efforts to take astronomical observations to the next level," says Matt Mountain, director of the Gemini Observatory. Access to Subaru will be particularly important to Asian colleagues, adds Tsay Wean-shun, an optical astronomer at the Institute of Astronomy at Taiwan's National Central University in Chung-Li. "It means we will be able to compete with astronomers in Europe and America," he says.

–DENNIS NORMILE