new design, which would have a radius of 6 to 6.5 meters instead of the original 8 meters and a price tag of about $3 billion.

The reduction in size and cost was achieved largely by compromising on the machine's main scientific objective, ignition in a burning plasma. Fusion reactors such as ITER use magnetic fields to confine a deuterium or deuterium-tritium plasma within a toroidal vessel called a tokamak. When the plasma is heated to temperatures of about 100 million degrees Celsius, nuclei fuse and give off neutrons (whose energy is harvested) and alpha particles, which reheat the plasma. Ignition occurs when alpha particle heating is sufficient to sustain the fusion reaction indefinitely without further input of energy.

Rather than achieving ignition, the new design will aim for a burning plasma, in which alpha particles provide at least 50% of the plasma heating. The new design will produce at least 10 times as much energy as it consumes, generating 400 megawatts of power in bursts of 400 seconds rather than the originally specified 1.5 gigawatts in 1000-second bursts. In a burning plasma, "alpha particles become the dominant source of plasma heating and the determinant of plasma behavior," says Aymar. "These conditions cannot be reached by present machines or by upgrades, nor satisfactorily simulated."

Now that the design is in place, the ITER team must work quickly to convince the politicians. European funding comes from the European Union's Framework research program, a 5-year cycle that begins a sixth term in 2003. "The first strategy paper on the contents of the sixth Framework program will be issued in about June 2000," Klaus Pinkau, co-chair of the special working group, told the Munich meeting. Hiroshi Kishimoto, executive director of the Japan Atomic Energy Research Institute (JAERI), says the agency has a similar timeframe to secure funding but details of the financial package must be resolved before any final agreement.

The other big decision concerns choosing a site for the reactor. "JAERI has a strong interest in [bringing] ITER to Japan," says Kishimoto, adding that Japan might be willing to pay "more than 50%" of the total project costs. While such an arrangement would ease the financial burden on Europe, several European officials suggested that they are more likely to back a bid by Canada, an associate ITER member. One big reason is that a North American site would appeal to the United States, should it wish to rejoin the project. Nuclear engineer Charles Baker of the University of California, San Diego, who led a U.S. ITER planning team, doesn't see that happening "anytime in the near term." But he says that a formal decision by Japan or Europe to build the device "might create an opportunity for the U.S. to play a limited and modest role."

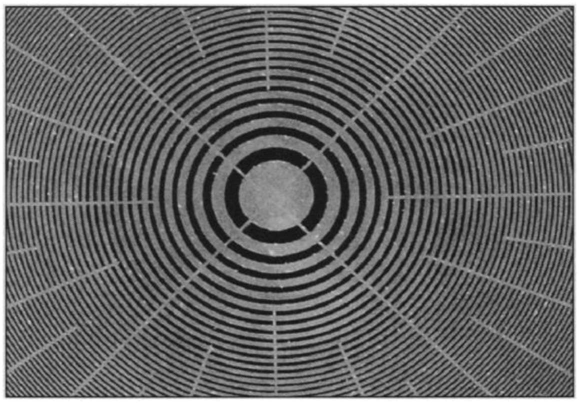
Taking an optimistic view, Aymar hopes that a site will be chosen in 2001 and a construction agreement signed in 2002. Adding in 2 years to prepare the site and sign licensing agreements, ITER could come on line around 2013. **–JUDY REDFEARN**

Judy Redfearn writes from Bristol, U.K. With reporting by Dennis Normile and David Malakoff.

MICROSCOPY

## Helium Beam Shows the Gentle, Sensitive Touch

A microscope with unprecedented sensitivity, based on a beam of atoms rather than light or electrons, is a step closer to reality thanks to a German collaboration that has coaxed helium atoms into an intense, needle-fine beam. Atoms can play the role of light in a microscope because according to quantum mechanics, they too exist as waves, albeit thousands of times shorter than light waves. Because the crispness of a microscope image is governed by wavelength, matter, or de Broglie, waves could offer a very high resolution. And in contrast to energetic probes such as x-rays or electrons, helium atoms bounce lightly off the target surface without damaging it, explains Peter Toennies of the Max Planck Institute for Fluid Dynamics in Göttingen, Germany. "With helium atoms you see the flesh, whereas with all other probe particles you see the bones," he says.



**Atom lens.** This Fresnel zone plate can focus a helium beam to a 2-micrometer spot.

CREDIT: R. B. DOAK *ET AL*, *PHYS. REV. LETT.*, 22 NOVEMBER 1999

An atom-beam microscope would be a unique instrument for examining surface structures nonintrusively, such as watching the buzzing vibrations on the surface of the minute crystals in metals, says Toennies. "Neutral atoms interact with matter in fundamentally different ways from other microscopic agents," says Jabez McClelland of the National Institute of Standards and Technology in Gaithersburg, Maryland. The Göttingen work "is really significant" as a demonstration of how to manipulate these truly inert atoms, says Jürgen Mlynek of the University of Konstanz in Germany, who led an earlier atom-focusing effort.

The starting point in the Göttingen experiment is a jet of helium atoms, spurting out of a fine nozzle. To trim down the spread of this jet to a fine pencil beam, the researchers pass the helium atoms through a "skimmer," a drawn-out glass micropipette with a tip just 1 micrometer across. "Think of it as a funnel, and we shoot the beam in through the narrow end," says Toennies. Atoms too far off the beam axis are guided away by the curving outer wall of the funnel.

A meter farther on, a type of lens called a Fresnel zone plate focuses the beam. Whereas conventional lenses bend light to a focus using refraction (the deflection that occurs on entering or leaving a denser material), zone plates rely on diffraction (the spreading of waves emerging from tiny apertures). Beams pass through a set of concentric opaque and clear rings, sized so that light diffracting from neighboring clear rings combines. Wave-peak adds to wave-peak to reinforce the light along the beam axis, focusing the beam, while peaks and troughs meet to cancel out the light just off-axis.

For the ultrashort wavelength of helium atoms, Günter Schmahl of Göttingen University's Institute of X-ray Physics, who co-leads the collaboration with Toennies, used electron beam lithography to create a zone plate in which the finest rings are just 50 nanometers wide and the entire zone plate is just a half a millimeter across. Without a zone plate, the atoms would illuminate an area 400 micrometers across. Using a zone plate, the researchers managed to create a spot just 2 micrometers wide (*Physical Review Letters*, 22 November, p. 4229)—10 times smaller and 100 million times brighter than in earlier atom-focusing efforts, says Toennies. What's more, unlike earlier efforts, the Göttingen group's atoms are in their lowest energy state, which is crucial for an atom microscope because they scatter from the surface more predictably. "What's new here is the use of ground-state helium atoms, which really have a pure 'billiard-ball' interaction with the surface," says McClelland.

Now the Göttingen group is trying to turn its beam into a full-fledged microscope. "The next step now is to detect the particles which have struck the surface within this narrow spot and then been deflected from the surface," says Toennies. "And that is what we are tooling up to do." **–ANDREW WATSON**

Andrew Watson writes from Norwich, U.K.