Miracle light: Can lasers solve the energy crisis?

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Next year will mark the 50th birthday of the laser, one of the most productive and widely used mega-inventions of the last century. Scientists hope that 2010 also will see the launch of laser technology's greatest challenge: creating an inexhaustible supply of clean, carbon-free energy.

In the five decades since lasers were developed, they've found a host of applications -- from the everyday to the exotic -- in industry, science, medicine, entertainment and national security.

Lasers read bar codes at checkout counters, write and read DVDs, operate laser printers, perform surgery, diagnose and treat cancers, spot military targets and measure the distance to the moon. They even remove unwanted body hair.

Next year, scientists will take lasers to a new level, trying to produce energy by imitating the way the sun creates the light and heat that support life on Earth.

"Creating star power in the laboratory," is how Edward Moses, the director of the Department of Energy's National Ignition Facility in Livermore, Calif., describes the system.

As the facility's name suggests, the project's scientists are attempting to marry lasers to nuclear fusion, the process that fuels the sun, stars and hydrogen bombs.

They hope to use a combination of 192 powerful lasers to generate the extreme heat and pressure that are needed to force hydrogen atoms to fuse, or combine. The combination loses a tiny bit of mass, which turns into a huge quantity of energy. It's Einstein's formula in action.

In contrast, nuclear power plants today work by fission, splitting apart heavy atoms such as uranium and plutonium to generate energy.

If it works, fusion eventually could power a new class of atomic energy plants. The trick is to build a system that produces more energy than it consumes, a goal that researchers admit is still many years away.

A rival fusion system, using powerful magnets instead of lasers, is being developed, but it hasn't yet proved to be successful. France also has a large laser-fusion research program.

According to the National Ignition Facility, a laser-fusion energy plant would emit no greenhouse gases, would produce few radioactive byproducts and would present no danger of a meltdown. Unlike wind or solar power, it would operate continuously to meet demand. Unlike oil, gas or uranium, its fuel source, mainly hydrogen, is virtually limitless.

To achieve nuclear fusion, the facility's operators hope to focus an array of intense laser beams on a pea-sized pellet of deuterium and tritium -- heavy forms of hydrogen -- in their $3.5 billion plant at Lawrence Livermore National Laboratory near San Francisco.

The beams, which would be transformed into powerful X-rays, would heat and compress the target so that, researchers hope, the fuel would ignite. Ignition would take place in 2 billionths of a second at temperatures of 100 million degrees Celsius and pressures 100 billion times greater than the Earth's atmosphere.

If successful, it would be "analogous to achievement of the first spark ever in an internal combustion engine," Edmund Synakowski, an Energy Department fusion expert, told a congressional panel on Oct. 29. "The pursuit is one of the most challenging programs of scientific research and development that has ever been undertaken."

Moses said the National Ignition Facility hoped to achieve ignition next year, but outside experts think it will take another two or three years to reach that goal, if ever. Many technical problems remain, such as simultaneously and precisely focusing all 192 laser beams on a miniature target without wrecking the whole machine.

"The laser has to go miraculously well" for ignition to occur, said David Hammer, a nuclear engineer at Cornell University in Ithaca, N.Y.

Stephen Bodner, a former director of laser fusion at the Naval Research Laboratory in Washington, accused National Ignition Facility managers in an e-mail of being "unscientifically optimistic. ...There is no way to use the NIF for ignition attempts."

Even the facility's managers say laser fusion won't begin providing electricity to consumers for another 20 years.

"Major technological and engineering challenges will still remain even after the demonstration of ignition," said Riccardo Betti, a physicist at the University of Rochester.

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The story of the laser is a remarkable tale of scientific and technological ingenuity, marred by the usual quarrels and patent fights.

Although the laser concept had been worked out in theory for a century, the first working device was demonstrated on May 16, 1960, by Theodore Maiman, a graduate student at Hughes Research Laboratory in Malibu, Calif.

"The laser era burst open," Anthony Siegman, a retired physics professor at Stanford University in Stanford, Calif., wrote in a book-length history of the invention.

The breakthrough was reproduced immediately by numerous laboratories, and practical applications blossomed.

The first medical use was laser surgery to destroy a retinal tumor at Columbia-Presbyterian Hospital in New York in December 1961. Nowadays lasik surgery -- changing the shape of the cornea to improve eyesight -- is a common procedure. Laser tools remove skin blemishes and tattoos. Dentists drill teeth with them. Factories use them to cut steel or glass. College professors use laser pointers to illustrate their lectures

The first laser was ruby-red, but they now come in multiple colors and strengths. Prices range from a few dollars to millions. A laser can be as small as a microscopic computer chip or as big as the National Ignition Facility, three football fields long.

Scientists use lasers to manipulate electrons, photons and other atomic particles in order to understand fundamental physics.

Just last month, NASA researchers reported using lasers to make extremely tough yarn that could be used for body armor or to shield space ships from radiation.

HOW LASERS WORK

A laser is a device that creates an intense beam of light and focuses it tightly in one direction. The difference between regular light and laser light is like the difference between a water sprinkler and a fire hose.

The name stands for "light amplification by stimulated emission of radiation."

Laser light differs from ordinary light because its photons -- tiny packets of light energy -- are all of the same wavelength and color, and they march in lockstep in the same direction. In contrast, photons in ordinary light scatter every which way.

Laser light is created by a bright flash of ordinary light aimed at a tube of special glass, crystal or gas. The flash pumps extra energy into the tube. That energy "excites" the electrons that are orbiting the nuclei of the atoms in the tube. An excited electron moves up to a higher orbit, then relaxes and drops back to a lower, less energetic orbit. In the process, it emits a photon.

A system of mirrors rapidly bounces the photons back and forth in the laser tube. Photons from one atom stimulate photons from other atoms, amplifying the intensity of the light. The result is a straight, bright beam of laser light.

Lasers can be "tuned" to produce beams of different colors and intensities. Early lasers produced about 10,000 watts. The lasers at the Department of Energy's National Ignition Facility generate trillions of watts.

ON THE WEB

National Ignition Facility: lasers.llnl.gov/
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