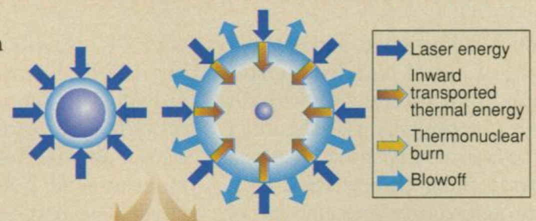
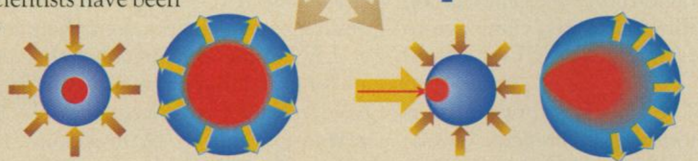
Laser Fusion With a Fast Twist

TOKYO—Researchers hoping to ignite a fusion reaction by blasting a pellet of deuterium and tritium with lasers face two big problems: power and consistency. The lasers have to be scaled up to unprecedented power levels, and they must generate extremely uniform pressures in the pellet. For the past 5 years, scientists have been quietly working on a way to ameliorate both problems by delivering very fast laser pulses to an already compressed fuel pellet to spark a burn. This year, the technique, known as fast ignitor, will be put to the test at new facilities in Japan and the United States. If it succeeds, the results could be applicable to the planned National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL) (see main text).





Burning issue. Both conventional and fast-ignitor inertial-confinement fusion (ICF) rely on lasers or particle beams to heat the target and form a plasma. But conventional ICF, lower left, relies on a steady pressure to ignite the core and trigger a burn, while fast-ignitor ICF, right, sends two laser pulses to the core, causing the burn to spread from the point of ignition.

SOURCE: UNIVERSITY OF CALIFORNIA/LLNL

The fast-ignitor approach starts out much the same as conventional laser fusion, using a barrage of lasers to compress a fuel pellet. Then, two additional intense, short laser pulses are directed at the core. The first, lasting about 100 picoseconds (trillionths of a second), blasts a path through the plasma surrounding the pellet. Then, a second pulse, even shorter and more intense, follows that path to the edge of the compressed-fuel core. That pulse generates hot electrons, which ignite the fuel. The burn then spreads through the fuel, releasing the fusion energy. "It's similar to a gasoline engine, where the fuel is compressed and then the combustion reaction starts from the heating of the spark plug," says Yoshiaki Kato, a physicist at Osaka University's Institute of Laser Engineering.

In theory, the fast-ignitor method would require far less energy than is needed for conventional inertial-confinement fusion because it triggers a burn at lower compression. And because uniform compression of the fuel would not be as critical, the confinement laser system could be made simpler. But the physics involved is not well understood. "Fast ignitor, although extremely promising, is based on a lot of untested physics," says Livermore physicist Michael Perry.

Perry and his team are now putting the finishing touches on an ultrashort-pulse Petawatt laser system that should provide a critical test of the physics. In experiments planned to begin in April, nine of the 10 beams of Livermore's Nova laser, which deliver relatively long pulses, will compress the fuel, while the Petawatt—which set a peak power-output record in a test firing last May—provides the ultrashort ignitor pulses.

At about the same time, scientists at Osaka's laser institute expect to start experiments with a new 100-terawatt ultrashort-pulse laser in conjunction with the institute's GEKKO XII 12-beam laser system. While Livermore's Petawatt has the edge on peak power, the GEKKO XII system holds the record for recorded fuel densities, at 600 grams per cubic centimeter. Neither group will actually achieve ignition. But they do expect to replicate the conditions necessary to explore whether the fast-ignitor approach warrants further work.

If the results are promising, a fast-ignitor capability might be added to NIF. But scientists are cautious about claiming too much too soon. "We're just at the starting point for this concept," Kato says. "It's probably too early to say [whether] fast ignitor can replace the standard approach."

–Dennis Normile

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organized a NIF user council, similar to ones used by civilian DOE labs, to ensure that a broad range of disciplines has a say in the facility's operation. "We've got to learn how to engage civilian researchers," Campbell says. Cooper adds that his stewardship computer effort, which will be fully operating by the end of 1998, will allot at least 20% of its capacity for unclassified research.

But being unclassified isn't enough. Some of the work will relate to specific experiments and, therefore, be of little interest to civilian researchers. And while Campbell says he hopes NIF will at least match the 10% share that Nova now devotes to outside scientists, he and other managers say that national security will remain NIF's number-one priority. "I don't want anyone to get illusions that this is a science sandbox we're trying to sell through defense programs," Campbell cautions.

Another potential sticking point is access by foreign-born scientists. While common on U.S. campuses, graduate students from countries with active nuclear weapons programs, including China, India, and Pakistan, are not now welcome at NIF. "What if [a faculty member] wants one of his Chinese students to have access on a Sunday morning?" asks one lab scientist. "It's a big problem."

The hippopotamus effect

In spite of such concerns, even skeptics of the stewardship program say Tartar has begun to change the lab's cloistered image. Increasing numbers of graduate students from Europe and Canada are working at the lab, and some areas no longer require visitors to carry a badge. But the presence of NIF has led some Livermore researchers to worry that other efforts will be pushed to the sidelines. "NIF has the potential to be a hippopotamus in the bathtub," complains one official. He notes that NIF will offer few opportunities for those engaged in biomedical, environmental, and chemical-engineering work at the lab. And Cochran's organization and a local citizens group remain opposed to NIF, seeing it as unnecessary or unsafe.

Even some who would benefit directly from the facility fear its costs may eat up money better spent on science (*Science*, 24 May 1996, p. 1092). So far, the money for NIF—its construction budget will peak at $229 million in 1998—has been added to the lab's overall budget. But it's too soon to tell whether the lab will have to curtail other programs to pay for operations.

Critics like Cochran say Livermore managers should be worrying about the long-term effects on the lab if NIF is not a useful tool to study nuclear explosions. "Then, you are not going to attract a lot of top scientists," he says. "And it would be very damaging to the inertial-confinement fusion community." But top lab officials are confident of NIF's success, and they see few other ways to draw new talent like Cooper. Attracting outsiders is essential for survival in this new era, they say, and new facilities, they add, are a key ingredient. Says Tartar: "We don't have to live behind a fence anymore."

–Andrew Lawler