Laser advance amid pros and con(fusion)s of DOE fusion path

Fusion is the process that powers the sun and stars, and it is fusion that is responsible for the fury of hydrogen bombs. For decades, scientists have hoped that with a little taming, fusion energy might also provide an essentially unlimited and relatively safe source of electricity. And so, the Department of Energy (DOE) has been sponsoring several approaches to controlling the production of fusion energy.

Last week, researchers at the University of Rochester (N.Y.) who are involved in one approach — called direct-drive inertial confinement fusion (ICF) — announced that they had passed an important milestone on the road to harnessing fusion power. Using a 2,000-joule laser, they uniformly compressed deuterium-tritium fuel capsules to more than 100 times the fuel's liquid density, which is 10 times better than their previous direct-drive laser fusion work.

The ability to uniformly compress such capsules is an essential ingredient in triggering fusion. While actually igniting the fuel will require another 10-fold increase in compression, the Rochester work shows that researchers have overcome some crucial technical problems that had threatened to stymie their efforts. According to a committee of 10 scientists who scrutinized the data earlier this month, "the results represent a significant advance in direct-drive ICF."

However, the Rochester announcement was publicly overshadowed last week by a New York Times article quoting sources who claimed that, behind a cloak of classification, a controversy is brewing over what size laser would be needed to achieve fusion. SCIENCE NEWS has confirmed that at least one scientist believes that the useful production of fusion energy will eventually require lasers with much higher energies than what is presently planned. This theorist argues that the approaches being taken by Rochester and other laser-based programs will reach a dead end because they will be too expensive. But according to other scientists, this view is an isolated one and most of the fusion community is solidly convinced that laser and other fusion programs are indeed on track.

In fusion, two atomically light nuclei — such as the hydrogen isotopes deuterium and tritium — merge into a heavier, more energetically stable nucleus. In order for this to happen, the light nuclei must be pushed very close together. This requires high temperatures, which also turn the fusion fuel into a plasma. And to ensure that many reactions occur, scientists must also compress the plasma to very high densities.

With the ICF approach, researchers heat and compress the fuel by illuminating it with radiation or ion beams. The Rochester group uses ultraviolet light from the 24-beam OMEGA laser to directly strike spherical fuel pellets from all sides. In contrast, scientists working on indirect-drive systems first convert laser light into X-rays, which then compress the fuel capsule quite uniformly.

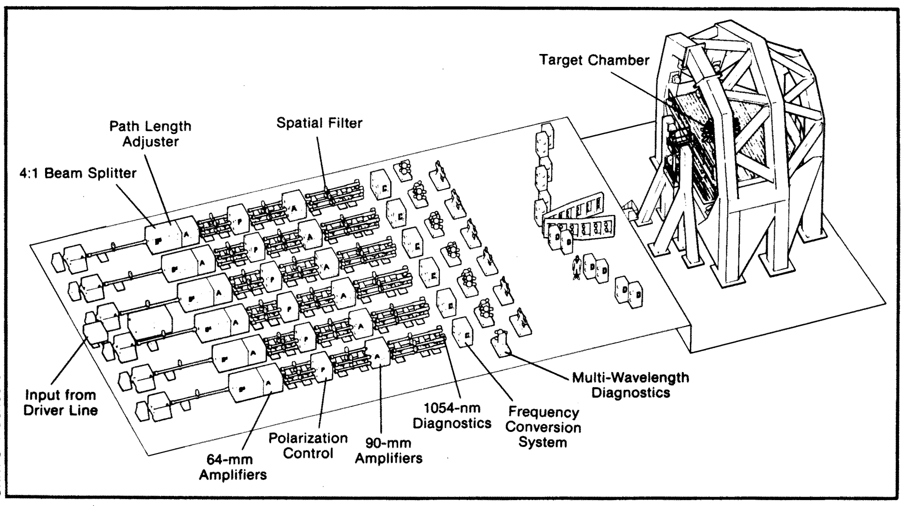
The advantage of the direct-drive approach is that it is potentially more efficient. But the U.S. ICF program has emphasized indirect drive because scientists have doubted whether direct-drive systems could compress the fusion target with sufficient uniformity. (If the compression is not uniform, some regions will "balloon out," preventing researchers from obtaining the highest possible densities). Many scientists have expected that indirect drive will be the technology chosen by the DOE when, in the 1990s, it builds its full-scale Laboratory Microfusion Facility to demonstrate high-gain fusion, in which more energy comes out than is put in.

In a March 1986 review of ICF programs, however, a National Academy of Sciences committee concluded that if the Rochester group could demonstrate high uniformity by compressing a target 100 to 200 times its liquid density, "it would be necessary to take the potential of direct drive very seriously."

Using special lenses called "phase plates" to smooth out the intensity profiles of the OMEGA beams, the Rochester researchers reached this goal and reported a density of two to four times that of lead — the highest fusion fuel density ever measured directly. Scientists working on indirect-drive ICF with 20,000 joules of laser energy at Lawrence Livermore National Laboratory in Livermore, Calif., have achieved comparable densities, although these were inferred from other kinds of measurements.

Rochester's results show that the direct-drive approach is very much in the running, says Robert L. McCrory, director of the university's Laboratory for Laser Energetics. "Although we receive far less funding, the results we're achieving are comparable to much larger and better funded programs," he says.

McCrory says the OMEGA system's yield — or the percentage of theoretically possible nuclear reactions that actually occur in the fuel — is still not as high as it could be, but he expects this will improve. And while the densities and temperatures obtained fall short of those needed to ignite the fuel in a self-sustaining burn, the researchers do plan to upgrade their system to 30,000 joules, which McCrory says should be enough to demonstrate ignition. Congress appropriated $2 million in fiscal year 1988 to complete half of the design and engineering studies for the $39 million upgrade. After that, an estimated 1 million joules (MJ) will be needed to produce a gain of 100.



Univ. of Rochester

The 24-beam OMEGA laser system sits in a room the size of a football field.

Most scientists predict that with the indirect approach, comparable gains will be possible with about 10 MJ of energy. However, P. Leonardo Mascheroni, a physicist recently laid off the from Los Alamos (N.M.) National Laboratory due to what he says was managerial politics, contends that much bigger lasers, capable of delivering 100 MJ, will be required instead.

The disagreement stems from the analysis and interpretation of data from a classified program called Centurion-Halite, in which scientists reportedly triggered fusion reactions with radiation, primarily X-rays, released by a near-by underground explosion of a nuclear bomb. The purpose of the experiments has been to learn about the behavior of fusion targets and to glean other physical data that might then be extrapolated to the lower energy conditions of the laboratory fusion programs.

Government scientists apparently arrived at the 10 MJ figure by considering the use of an ICF capsule that has not yet been made or tested. While not specifically citing the Centurion-Halite program, Mascheroni says his 100 MJ estimate is based on existing ICF capsule technology. If he is correct, all agree, the ICF program is in trouble because the cost of developing a 100-MJ laser with the technologies now planned in the ICF effort would be astronomical.

Instead, Mascheroni says he and a colleague believe that the most suitable laser for ICF is a hydrogen-fluoride (H-F) laser, which he thinks would cost much less than the other kinds of lasers being considered. Despite a cautiously favorable review of H-F laser potential by a Los Alamos National Laboratory panel in Feb. 1987, federal support for H-F laser development has pretty much dried up.

Other scientists, however, say they have great confidence in the 10-MJ estimate, and while they believe the H-F laser has merit, they argue that it also has shortcomings and that the nation simply cannot afford to investigate all fusion avenues at once. Meanwhile, Mascheroni is arguing his case with members of Congress, in the hope that they will ask the National Academy of Sciences to reassess DOE's overall laser fusion strategy.

– S. Weisburd

Following pi down the decimal trail

Japanese computer scientist Yasumasa Kanada of the University of Tokyo has set himself a task that literally can never end. Step by step, he is extending the computation of pi (π) – the ratio of a circle's circumference to its diameter – to a larger and larger number of decimal places. Earlier this year, Kanada calculated π to 201,326,000 decimal places, shattering his own 1987 record of 134 million digits (SN: 2/21/87, p.118). The digits of π now known would fill every page of every issue of SCIENCE NEWS for roughly the next 28 years.

Kanada's most recent computation required 6 hours on a new supercomputer manufactured by Hitachi. He verified the result by using a slightly different computational method. Last year's effort to reach 134 million digits took nearly 36 hours on an NEC SX-2 supercomputer. The shorter time for the new calculation reflects the use of a more advanced, faster computer and the effects of tinkering with the computer program to speed it up. The basic method, or algorithm, for computing π was not changed.

Knowing the digits of π to millions of decimal places has little practical value. In most scientific applications, 10 decimal places are sufficient. However, for Kanada and other computer experts, computing π is one way to test the speed and accuracy of new computers and to compare different computers. An error in even one of the millions of digits of π would signal a problem in the computer or in the computer program.

Kanada's motivation for pursuing π goes well beyond practical value. "It's like [Mt.] Everest," he told SCIENCE NEWS. "I do it because it's there." His present goal is to reach 400 million digits by next year. To achieve that level, he says, he needs a computer with a greatly expanded main memory for storing the results of intermediate steps in the computation and a faster means of sending data to and from the computer.

Because π is known to be an infinite decimal, there is no reason why Kanada cannot continue his quest indefinitely – subject to the limits imposed by available computer technology. "I would like to go on and on," he says. *– I. Peterson*

Skeletal aging of New World settlers

About two dozen human bones recently found on gravelly bars of the Kansas River may be the oldest human skeletal remains yet found in the Americas, according to scientists at the annual meeting of the American Association of Physical Anthropologists, held in Kansas City last week.

"Although we don't have a firm, undeniable date, all the analytic tests conducted so far on the chemistry of the bones suggest that one bone fragment is older than any other previously found in the New World," says geologist Wakefield Dort of the University of Kansas in Lawrence, who directed the project with University of Kansas anthropologist Lawrence D. Martin. A preliminary estimate, based on a technique called electron spin resonance (ESR), is that the piece of skull is 15,400 years old.

Archaeologists generally believe that humans entered the New World about 12,000 years ago, although some controversial sites have led scientists to extend that estimate as far back as 100,000 years ago (SN: 10/31/87, p.284). Most of these sites do not contain human bones. Investigators usually uncover tools, such as sharpened stone flakes and spear points, that in some cases lie among the bones of extinct animals, or mounds of debris left by early settlers (SN: 3/12/88, p.164).

Erosion along the Kansas River is uncovering bones of a wide range of extinct animals, including mastodon, mammoth, musk ox and giant beaver, mixed with those of humans, says Martin. The human remains – found near Bonner Springs, about 15 miles west of Kansas City, Kan. – consist of leg and arm bones, several skull fragments and most of the top half of one skull. No teeth or jaws have been found.

The bones are not embedded in soil, indicating that they have been moved some distance by the river, says Dort. But evidence of minimal abrasion from sand in the river and the near-perfect preservation of delicate bone features suggest the fossils traveled no more than a few hundred yards. Radiocarbon dating of sediment layers lining the river is proving to be a complex task, notes Dort, but the fossils are believed to have come from soil lower than a layer dated at 10,430 years old.

There appear to be two populations of different size represented by the bones, says Martin. The bones of smaller individuals are darker, more mineralized and denser. Cut marks on some bones may have resulted from burial practices, he says.

The shape of the human skull fragments and limb bones is similar to that of the oldest known Central Plains settlers, who lived up to 7,000 years ago, but Martin says radiocarbon dating of the Bonner Springs fossils ran into problems. A human bone burned for radiocarbon dating was found to contain no material suitable for the technique.

The investigators then turned to ESR dating, which has been used with several archaeological samples over the last decade. The technique depends on measuring the density of trapped electrons that accumulate in bone and other organic material as a result of environmental radiation after the material is buried. The natural radioactivity of the material is determined, as well as the sources of the radioactivity, such as uranium and thorium. The remains are then exposed to standardized doses of high-energy radiation. The intensity of natural and laboratory ESR signals are compared and, using an estimate of the annual radiation dose for a specimen, researchers calculate its age.

Initial ESR dating was performed by Don Robins of the University of London, England, a pioneer in its use with archaeological remains. According to Dort, this work established that the human skull fragment was older than an associated mammoth bone, giving the human specimen a minimum age of 12,000 years. The age of 15,400 years is the result of further ESR study by physicists at the University of Kansas.

The antiquity of the Bonner Springs site needs to be further explored, says Dort, by digging deeper into the river banks and, possibly, blocking off a portion of the river to expose lower layers of soil. "Then," he says, "we can see if human bones and those of extinct animals occur together." *– B. Bower*

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