Q&A

The Future of Fusion

Will nuclear fusion help power the nation's energy supply? The director of the University's Laboratory for Laser Energetics says Rochester has set the course for finding out.

Interview by Larry Arbeiter

LASER VISION: Successful tests of the National Ignition Facility draw on decades of research and development at Rochester, says Robert McCrory, director of the Laboratory for Laser Energetics since 1983. He is also a professor of physics and of mechanical engineering.

IN DISCUSSIONS OF THE NATION'S NEED TO develop safe, clean, renewable power, nuclear fusion has long been acknowledged as the technology with perhaps the greatest potential payoff. But that recognition comes with the caveat that the necessary breakthroughs may never be achieved.

With the recent commissioning of the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory in California, the U.S. government is making a $3.5 billion bet that fusion eventually will be part of the nation's energy mix.

The Omega and Omega EP laser facilities at the University's Laboratory for Laser Energetics reigned as the world's most powerful lasers for fusion and high energy density physics research until they were surpassed this year by NIF.

The LLE remains the largest user facility for research in this field, with scientists from around the world performing experiments at the South Campus site. Founded in 1970 and supported by approximately $70 million annually, mostly from the federal government, the lab and the scores of scientists who conduct research there have laid the foundation in laser inertial confinement fusion research on which the NIF is built (see sidebar).

As director of the LLE since 1983, Robert McCrory has had a leading role in developing the nation's strategy for achieving nuclear fusion as a form of energy production. For his own research on laser-driven plasmas and their applications to controlled thermonuclear fusion, McCrory was elected a fellow of the American Physical Society and a fellow of the American Association for the Advancement of Science, and he won the international Edward Teller Medal. In 2002, the Hajim School selected McCrory for its Lifetime Achievement Award.

How has the work at the LLE made the NIF possible?

LLE was a significant partner in NIF's design and construction, including coating about half of the large optics. In addition, research carried out on the Omega Laser Facility has led to improved understanding of inertial confinement fusion and the results have been incorporated into the design of ignition targets for the NIF. This includes new technologies developed at LLE, such as high efficiency frequency tripling and smoothing by spectral dispersion, which are essential to NIF meeting its performance goals.

What do you say to the critics who argue the NIF is perhaps too large and complex to reliably meet its design goals of achieving nuclear ignition?

The NIF is about 50 times larger than the

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Omega laser facility but was built upon the experience gained from Omega, and from the Nova laser at Lawrence Livermore before that. The innovations in the laser architecture incorporated in the NIF make it possible for it to meet its design goals. It's worth noting that the new Omega EP laser was built using these same innovations and, while much smaller (4 beams compared to 192 on NIF), is operating reliably. The initial performance of the NIF is very encouraging. The Lawrence Livermore team, with its national partners, did a masterful job of completing the project. In fact, the Project Management Institute named the NIF as its Project of the Year in October, selecting NIF from three finalists drawn from worldwide nominees. The other finalists were the monumental Cowboys Stadium, the NFL's superstructure in Dallas, and the Norton Brownsboro Hospital, a facility featuring the latest in health care technology, in Louisville, Ky.

Why should we spend so much money and energy to try to achieve fusion when we already have nuclear power in the form of fission-based reactors?

It is true that nuclear fission is in widespread use in the U.S. and worldwide. There is sufficient fuel so that nuclear fission could play a significant role in meeting the nation's carbon-free energy needs over the next century. However, no new nuclear fission plants have been built in the U.S. in the past decades. This is, in large part, due to the public's fears about nuclear fission, the possibility that there could be a meltdown and concerns about how to store the spent radioactive fuel, and difficult regulatory and licensing requirements. The U.S. was planning for long-term storage at Yucca Mountain and spent over $8 billion on it, but that has been abandoned. By contrast, nuclear fusion offers the advantages of an essentially unlimited supply of fuel—contained in water—no risk of meltdown, and very little radioactive waste. Fusion also avoids many of the nuclear proliferation dangers and concerns associated with fission reactors.

With all of the advantages of fusion, why are there hundreds of nuclear fission power plants but not a single one powered by fusion?

Achieving fusion ignition in the laboratory is much more difficult than making a nuclear fission plant work. One of the reasons that nuclear fission power plants were successfully developed was the research carried out by the Navy to develop nuclear-powered vessels under Admiral [Hyman] Rickover. This was the precursor to the nuclear power industry. We are at a similar stage now with inertial confinement fusion, which is in the development stage. After a successful demonstration of ignition on the NIF, a significant inertial fusion energy program will likely begin with the goal of demonstrating a nuclear fusion power plant by the middle of this century. A National Academy of Sciences and National Academy of Engineering study will begin late in 2010 to assess the potential of inertial fusion energy.

Some financial and environmental activists are complaining that the NIF may not reach all of its deadlines on time, and should therefore be penalized or reconsidered. How do you respond to them?

Achieving nuclear fusion ignition in the laboratory is difficult, and there is a significant national research program to demonstrate ignition. But this is a research program, not an engineering project, and we cannot provide a definitive date by which ignition will be achieved. The deadlines are goals that we hope to reach, but in a research program, new discoveries can influence how the goals are met. This can make things take more, or sometimes less, time than originally anticipated. While the date that ignition will be demonstrated cannot be guaranteed, I am confident that ignition can be achieved in the next few years.

If ignition is soon achieved, and assuming we and other nations continue to pursue the long-term challenge, how far off is the payoff likely to be?

After the demonstration of ignition, an inertial fusion energy program could begin with the goal of demonstrating a nuclear fusion power plant by the middle of the century. If that is successful, nuclear fusion could meet a significant fraction of the nation's electricity needs by the end of the century. This will require the continued support of the federal government over the next few decades. It is unlikely that private industry will become a significant player until after a prototype power plant has been demonstrated. ®

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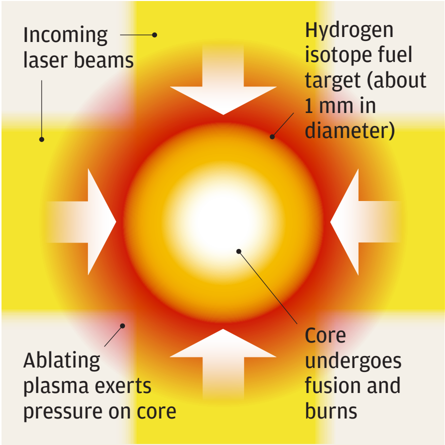

IGNITION: Heated by the 192 laser beams at NIF, the surface of the target fuel ablates, squeezing the remaining fuel into a dense core—which undergoes nuclear fusion.

Laboratory Stars

Nuclear fusion, the release of energy that occurs when the nuclei of hydrogen atoms are fused together, is something of the holy grail of energy production. Potentially providing manyfold as much energy as nuclear fission, which releases energy by splitting apart the nuclei of heavy atoms like uranium or plutonium, nuclear fusion not only would produce enormous amounts of energy efficiently, but it also would create a thousandth of the radioactive waste created by fission. While one of the isotopes needed to power the reaction must be manufactured in a reactor, the other can be found in water.

So far the only power plants using fusion as a routine source of energy are stars, which have the advantage of enormous mass to create the millions of degrees and hundreds of billions of atmospheres of pressure needed to overcome the powerful electric repulsion that exists between the positively charged hydrogen nuclei.

So how do you recreate in a lab a process that happens naturally only in stars? That's the goal of the National Ignition Facility—to compress and heat pellets of hydrogen fuel sufficiently to induce a fusion reaction that generates more energy than was required to begin it. Scientists refer to that as thermonuclear "ignition."

While achieving ignition doesn't guarantee the feasibility of limitless, clean fusion power, it's perhaps the largest single step on a path to a new role for nuclear power.

—Scott Hauser