SCIENCE NEWS

Simulations of early experiments show laser project is on track

By Nancy Garcia
Newsline staff writer

The National Ignition Facility's Early Light campaign in 2003-2004 included four shots using four laser beams at high energy on a full-scale target for the first time. The resulting data has enabled unprecedented computer simulations, so closely matched to experimental results that the achievement has been published in the prestigious journal *Nature Physics*.

"Getting agreement on that scale is really something new," said principal investigator Siegfried Glenzer. "You have to resolve microscale phenomena over previously inaccessible space, volume and time scales."

The paper indicates that NIF's laser beams will propagate effectively in plasma-filled targets designed to produce the world's first demonstration of inertial confinement fusion.

The paper examines two sets of conditions. In one set, an unsmoothed laser beam entered the target and stalled when the hot plasma in the target rippled and clumped, causing about 30 percent of the light to backscatter and fail to reach the target center. Plasma physics theory had anticipated a lack of uniformity, or nonlinearity, as the plasma was heated, Glenzer said. The challenge was to accurately predict the amount.

"Nonlinearity was suspected, but we couldn't quantify it," he said.

Then in another experiment, using NIF's three beam-smoothing capabilities simultaneously, the laser was able to fully propagate through a seven-millimeter tube of carbon dioxide. Effective laser beam propagation through dense plasma will be required for NIF to ignite a sustained fusion reaction.

"Now we are going to close the loop and use the tools to design the next set of experiments," Glenzer said. Experiments next summer will use 96 beams focused on a gold hohlraum (the eraser-sized capsule containing the fusion target) filled with a lighter gas mixture to help select the optimum target radiation temperature for ignition experiments. The researchers hope to hold backscattering to less than 15 percent.

"We will look at symmetry and shock timing and all of the physics questions we need to answer for ignition," Glenzer said. "We hope the 2008 experiments will lead us down the path to full-scale ignition."

In ignition, plasma – a turbulent soup of ions and free electrons – is compressed and heated by the shock waves created by intense laser beams that deliver 1.8 million joules of energy in a pulse lasting about 10 nanoseconds (billionths of a second). This energy is equivalent to 1,000 times the electrical generating power of the United States in the same brief time period. The lasers will trigger a controlled laboratory fusion reaction that will yield more energy than is required to start the thermonuclear burn.

First experiments and unprecedented computer simulations show laser fusion plans are on track at the National Ignition Facility

Inertial confinement fusion experiments will create conditions similar to those inside an exploding thermonuclear weapon or in the cores of stars and giant planets. The resulting information will be used to help ensure the reliability and safety of the nation's nuclear stockpile without underground testing. The data also will reveal new details about the nature and structure of the universe.

When completed in 2009, NIF will focus 192 lasers on a millimeter-sized target filled with deuterium and tritium, two isotopes of hydrogen. Full-scale shots will produce extremely hot, dense physical regimes never before seen in a laboratory setting.

Laurent Divol oversaw the computation effort reported in the Sept. 2 online edition of *Nature Physics*. The simulation tracked 3.5 nanoseconds of beam pulse, more than 1,000 times longer than the typically short 100 picoseconds (trillionths of a second) usually modeled with the laser-plasma code pF3D. The code was originally developed in AX Division of the Defense and Nuclear Technologies Directorate.

Because the beam being modeled is cylindrical, the team took advantage of the symmetry and modeled aspects in two dimensions. The researchers simulated how the target evolves with time as well as the geometry of the beam propagation, revealing details down to the wavelength scale (a few hundred nanometers, or billionths of a meter).

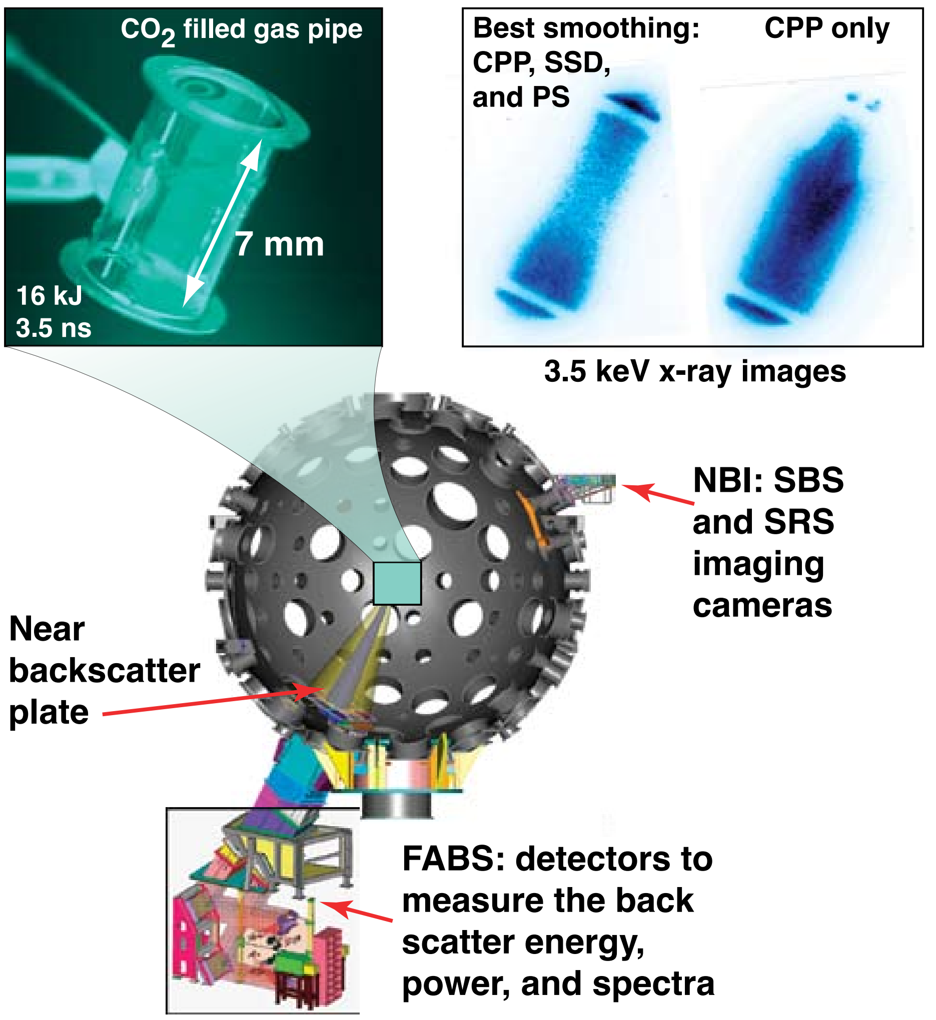
Milo Dorr of the Computation Directorate's Center for Applied Scientific Computing led the code modification effort. Dorr said even one beam is difficult to simulate at the wavelength scale because it is thousands of wavelengths wide. That fine-grain simulation was combined with a three-dimensional view of the plasma heating, modeled on a coarse grid, which is much faster to compute. Computing each aspect still took a few weeks of time on a few hundred central processing units.

Next summer's 96-beam experiments are called "Eos," for the goddess of dawn. They are meant to determine the right radiative temperature to be reached in the hohlraum for ignition. The team is doing some simulations now, examining three dimensions for 100 picoseconds. The simulations are primarily being run on about 10,000 nodes of LLNL's Atlas supercomputer.

"It's a very nice marriage between some of the best capabilities the Lab has," Glenzer said, "namely the NIF super laser and the Lab's supercomputers."

Simulations are a key research tool that bridge theory and experiment, providing a forecasting shortcut to predict what may occur and refine and optimize experimental design.

Divol summed up the hope and satisfaction such results represent, saying that after spending 15 years to develop NIF, researchers are excited to approach discovering, over the next few years, whether ignition will be achieved. "This was showing we can simulate it and it works," he said of the *Nature* paper. "It worked quite well."



This schematic diagram shows the laser beam propagation experiment. Images at the upper right show the X-ray emission of the plasma. When all three beam-smoothing methods were used, there was full propagation of the beam. When only one smoothing method was used (continuous phase plates, or CPP), the beam stalled before propagating all the way to the target.