New 'snapshots' aid quest for fusion energy

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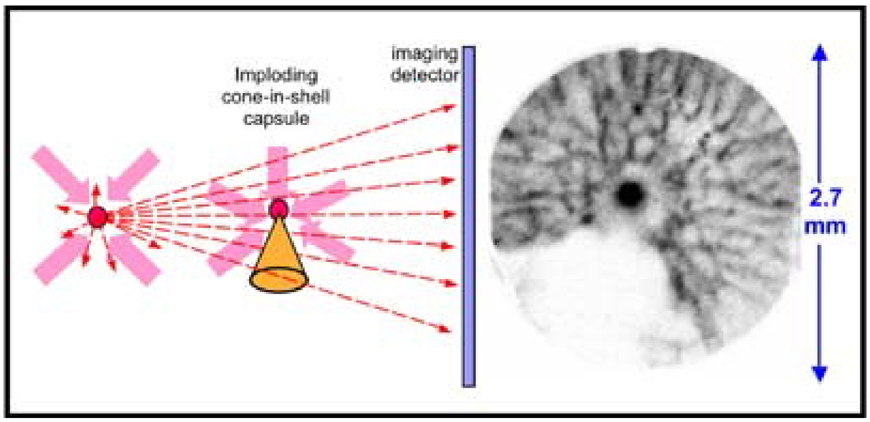

This schematic drawing shows the system MIT physicists are using to study tiny implosions of hydrogen fuel. On the left, protons streaming away from the far-left implosion travel through magnetic and electric fields generated by the other implosion. On the right is the resulting image of the fields, with the compressed hydrogen pellet in the center. Image courtesy / Richard Petrasso

Physicists at MIT and the University of Rochester have devised a new way to take "snapshots" of the high-energy, high-temperature reactions seen as key to achieving the long-held dream of controlled nuclear fusion.

The work, which is reported in the Feb. 28 issue of *Science*, could one day help scientists harness nuclear fusion as an energy source. It could also shed light on basic questions about the physics of stars.

Nuclear fusion-the process by which atomic particles clump together to form a heavier nucleus-releases an enormous amount of energy (roughly one million times of that of a chemical reaction). When nuclear fusion occurs in an uncontrolled chain reaction, it can result in a thermonuclear blast-such as the one generated by hydrogen bombs.

Achieving controlled nuclear fusion, which could be a safe and reliable source of nearly limitless energy, is one of the "holy grails" of high-energy-density physics, according to Richard Petrasso, senior research scientist at MIT's Plasma Science and Fusion Center and an author of the Science paper.

For decades, scientists at MIT and elsewhere have been working toward that goal by setting off miniature implosions that recreate the high temperatures and densities found in stars.

One way physicists create the implosions is by bombarding tiny pellets of hydrogen fuel with lasers. Inside the pellet, the compressed gas reaches about 100 million degrees, or about seven times hotter than the center of the sun. Under certain conditions, the gas's density can reach 1,000 grams per cubic centimeter (50 times the density of gold).

"It really creates conditions you can only find in the interior of stars," Petrasso said.

Until now, physicists have largely been able to study the implosions only by measuring the particles released by the imploding gas, such as protons, X-rays, neutrons and photons. Alternatively, they have also studied implosions with X-rays, creating images of the compressed pellets.

The new detection method allows scientists, for the first time, to take a snapshot of the electric and magnetic fields generated by the implosion.

The process requires two implosions: one to be studied, and a second that serves to illuminate the first implosion. The first implosion lasts about three nanoseconds (billionths of a second) and the second one can be timed to go off anytime within those three nanoseconds.

The second implosion generates a stream of protons that all have the same energy level, 15 million electron volts. Because protons are charged, their paths are influenced by the fields surrounding the first implosion. These protons can be recorded, just like photons, to create an image of the fields' effects. Photons, however, are unaffected by such fields and thus cannot detect their presence.

"It's a way of capturing images with protons instead of photons," Petrasso said.

Such images can help scientists figure out whether the implosions are close to symmetrical.

To achieve nuclear fusion, the implosion must occur with near-perfect symmetry. Such an event, also known as ignition, has never been demonstrated experimentally.

If ignition occurs, between 10 and 150 million joules of fusion energy would be released. (150 million joules is about the amount of energy in a gallon of gasoline, released from something the size of a small pin head.)

Most of this work was conducted using a laser system at the Lab for Laser Electronics at the University of Rochester. The laser system, called Omega, is about the size of a football field.

The National Ignition Facility, where scientists hope to achieve ignition for the first time, is scheduled to open at the Lawrence Livermore National Laboratory in California in 2010. Assuming ignition is achieved in the 2010-2012 time scale, scientists will begin directly addressing how one might utilize this prodigious energy for electricity generation.

Lead author of the *Science* paper is Ryan Rygg, formerly a Physics Department graduate student and a recent PhD recipient at MIT's Plasma Science and Fusion Center (PSFC) now at Lawrence Livermore. Other MIT authors are Frederick Seåguin and Johan Frenje, research scientists at the PSFC; Chikang Li, principal research scientist at the PSFC; and Mario Manuel, graduate student in aeronautics and astronautics.

Source: MIT, by Anne Trafton

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