Laser Fusion: Frequency Not So Critical

Experimenters trying to produce controlled thermonuclear fusion by imploding targets of fusible material (deuterium and tritium) by bombarding them with laser light have been saying that the best possible laser for the purpose should be one of fairly short wavelength. Something in the blue or green part of the spectrum, most say, would have the ideal qualities for most efficient coupling of energy from the light into the pellet of fuel. Such a laser should also have high power and the ability to run at a high repetition rate. In other words, it should be an easily cooled laser, probably one in which the lasing material is a gas.

Such an object does not yet exist. The highest-powered lasers are made of glass doped with neodymium, which means they need a lot of cooling time. Still, they have the power and the fairly good wavelength of 1.06 microns, so they are being used for experiments (especially at the Lawrence Livermore Laboratory). Meanwhile, work on gas lasers is coming from the opposite direction, high power and easy coolability, but a wavelength that seems far out of the range of usefulness, 10.6 microns. (Green = 0.5 microns.)

Now comes Damon V. Giovanelli of the Los Alamos Scientific Laboratory, where much of the work on carbon dioxide lasers is in progress, to say wavelength doesn't really matter all that much. Experiments show, he argues, that even the factor of 10 difference between 1.06 microns and 10.6 microns of neodymium-glass and carbon dioxide is not all that important at the high-power density levels that will be involved in real-life laser fusion. He presented his case at the annual meeting of the Plasma Physics Division of the American Physical Society last week in San Francisco.

Calculation of the expected mode of energy deposition in the target had led to the negative opinion regarding long wavelengths. It was expected that shorter wavelengths would penetrate further into the target. Long wavelengths would invest too much of their energy in making very hot electrons at the surface, which would penetrate the target and preheat it, making the ultimate compression more difficult. The shorter the wavelength, the deeper it would go, delivering more energy to produce a significant ablation of atoms from the surface of the fuel pellet. A more energetic ablation causes a stronger implosion.

However, the real world of laser fusion is an area of power flux greater than 10^{15} watts per square centimeter. Here experiment seems to show, Giovanelli says, that the energy invested in hot electrons is not so different even over the factor of 10 difference in wavelength nor is the difference in the penetration of the target so critical. In the absorption region of targets, where laser beams produce an expanding, ablating plasma to drive the implosion of the rest of the target, the expansion rates seem to be comparable for both kinds of lasers.

The neodymium-glass and carbon dioxide lasers are the only two kinds with which laser-fusion experimenters have extensive experience. The region between these wavelength extremes is largely unexplored. But the implication of what Giovanelli says is that if this comparability in performance holds across the board, future searches for the right laser may be able to pay less attention to the question of wavelength and more to such questions as power, coolability, repetition rate and economy of production. It could relieve a serious bottleneck in the progress toward the laser fusion reactor, because experts have been saying all along that the main outstanding problem was development of the proper laser. □

Princeton Large Torus: Big surprises

The Princeton Large Torus is alive and well and working happily at the Plasma Physics Laboratory associated with the university in that peaceful New Jersey town. The PLT is important because it is the largest experimental apparatus for controlled thermonuclear fusion of the type called tokamak yet built in the United States, and it was deliberately designed to push the technology of tokamaks to outer limits.

A tokamak is a toroidal or doughnut-shaped device in which the plasma of atomic nuclei and electrons that have been stripped from them is confined in the doughnut-shaped tube by magnetic fields along and around the tube. The plasma is heated by electric currents running around the circle through the center of the doughnut tube to provide the confinement and temperature necessary for fusions to happen.

An entire session of the meeting of the American Physical Society's Plasma Physics Division last week in San Francisco was devoted to the Princeton Large Torus.

The PLT, as one of the group working with it, Wolfgang Stodiek, describes it, is a doughnut almost without a hole. The hole is only 30 centimeters in radius, while the cross section of the tube is 50 centimeters in radius. This required putting a lot of the electromagnetic circuitry that would normally go outside the tube on the inside. This ultrafat doughnut shape was chosen because according to theory, improvements in temperature and confinement time, the prime parameters to be increased as the experiment moves toward a practical thermonuclear reactor, bear a direct relation to the increase in the ratio of tube size to hole size. It's a case of concentrating on the doughnut and not the hole.

The first big surprise, says Stodiek, was that the experimenters could get a plasma to form and perform in a machine of this shape and with this distribution of magnet windings and current elements.

The second big surprise, he says, is that the apparatus seems to work well without the traditional copper shield around it. Shields of electrically conducting copper have been a feature of tokamaks since their earliest design and have long been thought necessary to get the proper configuration of magnetic and electric fields to do the work of the experiment properly. Not only are the shields expensive, they are a nuisance to experimenters and a big impediment in any schemes to scale up the tokamak configuration to a true fusion reactor. In a reactor, energy would have to be gotten out by making use of energetic particles coming away from the nuclear fusions going on in the plasma, and these could hardly get through such a shield. For tokamak progress the shield had to be eliminated, which now seems possible.

The machine has been operating for about half a year but only at about half the plasma current it was designed for and with a toroidal magnetic field of 35 kilogauss instead of the designed 50 kilogauss. These magnetic fields are ultrastrong and touchy to work with. A picture of the machine shows the doughnut almost entirely obscured from view by a frame of heavy steel bars intended to counteract the twisting force of the magnetic field. The plans are to approach the highest possible field slowly and carefully.

Experiments with plasmas of helium and hydrogen show relatively good behavior with plasma densities up to 7.3 particles per cubic centimeter, ion temperatures on the order of a kilo-electrovolt and confinement times for the total plasma energy up to 53 milliseconds. All this tends to surpass smaller tokamaks and to compare favorably with the Soviet apparatus of comparable size, T-10. The figures vary according to the number of kiloamperes plasma current put through the doughnut. The full 50 kilogauss of magnetic field, 1 megapere of plasma