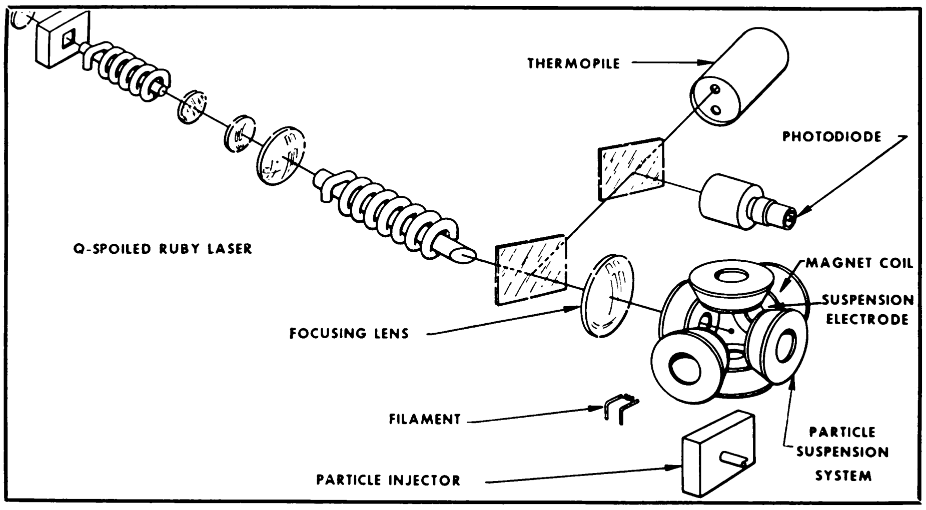
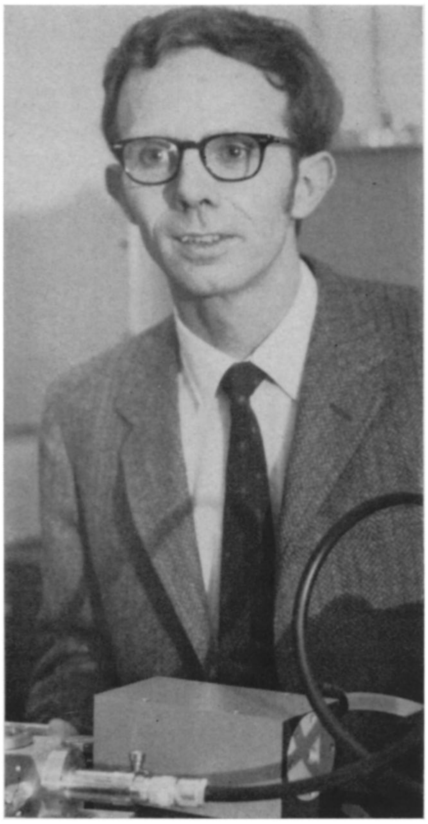




Laser-made plasmas

Feared by some as possible bomb triggers, their best future seems to be in controlled fusion

by Dietrick E. Thomsen

A concentrated burst of laser light will not only vaporize small amounts of solid matter, it will ionize them. Such ionization can produce plasmas of the sort that may be useful in research on thermonuclear fusion. The concept is promising, but to describe the laser as the answer to either controlled fusion or cheap thermonuclear weapons appears to be at least premature.

Mention of thermonuclear temperatures and reactions involving hydrogen and deuterium raises the specter of using laser systems as triggers for hydrogen bombs. Under present technology a hydrogen bomb must contain a fission bomb within it. Detonation of the fission bomb turns the hydrogen into a hot enough and dense enough plasma for explosive fusion to occur.

Speculation that lasers might be able to produce the necessary conditions by acting directly on the hydrogen was heightened last year when the Atomic Energy Commission announced its intention to classify research on laser systems that could produce a one percent increase in absolute temperatures of deuterium, tritium or mixtures of both. A laser trigger would make fusion-bomb technology both easier and cheaper and put it within the means of a dangerous number of countries.

But the Atomic Energy Commission says officially that the prospect of laser bomb triggers is remote; the power level of present laser systems is a hundred to a thousand times too low for bomb triggers.

Work on laser-produced plasmas started by focusing such beams into samples of gases to produce plasmas in small gas volumes. It turns out, however, that in gases, as the power goes up, volumes of gas behind the light cone will also be ionized. This results in heating of large volumes of material and therefore the average energy per particle remains low.

Researchers then turned to irradiation of solid surfaces to produce plasmas. Here, however, the heat from the laser beam penetrates some distance into the material. At levels where it will no longer ionize, it will still vaporize, and large quantities of neutral particles are thus released to interfere with the charged plasma. Average energy per particle is still low.

Now, however, the promise centers around experiments in which small pellets of solid material are used. Here the whole sample is ionized and there is no additional material cluttering up the proceedings. This method gives high average energies.

But there are other drawbacks. The solid-pellet plasma expands very rapidly, lowering its density and diluting the concentration of energy. Quick heating and successful confinement are both necessary for putting it to any use.

"The heating pulse must be very fast," says Dr. Alan Haught of United Aircraft. "The limitation is the shortness of the laser pulses currently available."

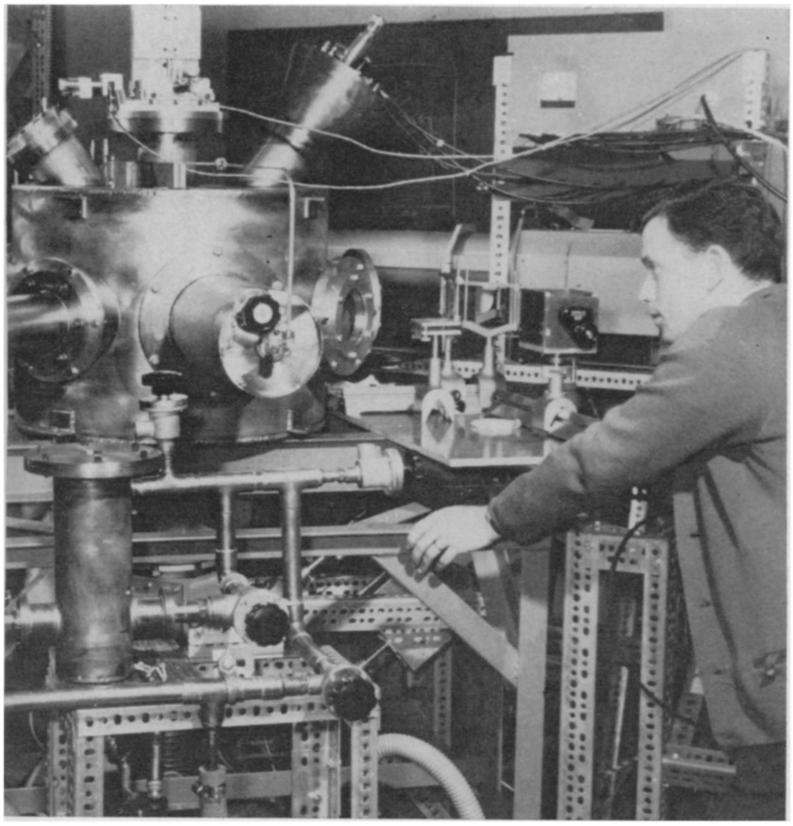
With what he has, Dr. Haught has produced plasmas with average energies per particle in the hundreds of electron volts. Dr. Moshe Lubin of the University of Rochester has gotten one thousand electron volts per particle by shining a laser that produces 1.5 billion watts in bursts about 4 nanoseconds (billionths of a second) long on a sample of lithium hydride.

A billion-watt laser with bursts a few nanoseconds long is also being used at Princeton University, where investigators are studying containment in magnetic fields of plasma produced by blowing the ends off beryllium wire. But, Dr. Dirck Dimock says, "We are not trying to achieve thermonuclear temperatures."

To get such temperatures, which mean average particle energies in the tens of thousands of electron volts, requires superquick lasers. Both Drs. Haught and Lubin would like to get there, and are developing new ultra-short-pulse lasers. They agree that a laser with a pulse duration of 0.1 nanosecond would be the optimum, and that is what they are trying to achieve.

Dr. Haught speaks of getting average energies of 5,000 to 10,000 electron volts. Dr. Lubin is developing a laser of 1.06 micron (millionth of a meter) wavelength. This will concentrate 100 billion watts in a pulse 0.1 nanosecond long, and with it he hopes to get average particle energies greater than 15,000 electron volts, using deuterium and solid hydrogen pellets.

In Albuquerque, N.M., the Sandia



Photos (L to R): United Aircraft, Princeton University, Rochester University

Dr. Alan Haught's laser apparatus for producing plasma (far left) is similar to that of Dr. Dirck Dimock of Princeton (center) and that of Dr. Moshe Lubin of Rochester.

Laboratories, a major AEC contractor, has announced that Dr. Garth Gobeli has developed a laser with a peak output of five trillion watts in bursts of 0.01 nanosecond. This, they say, can heat materials to about 11 million degrees K. This is about equivalent to the 1,000-electron-volt average energy of the most energetic plasmas now generated by lasers. Sandia physicists are not using the new laser for plasma studies now. They want to do so in the future, but so far they have no definite plans they are willing to discuss except among themselves.

Physicists at the Australian National University under the direction of Dr. E. K. Inall are studying the feasibility of a laser 100 times as powerful as any that now exists. They have a power source, a so-called homopolar generator that will give them the power; the problem is designing a laser system that will stand up to the heat and mechanical forces that would be generated by such high power. The laser is not being built for a specific use, says Dr. Inall, but thermonuclear fusion studies are a possibility.

Without this kind of fast, intense laser there appear to be insurmountable problems, for weapons, if not for research.

Within a laser-generated plasma, rapid expansion makes the plasma quickly stop absorbing energy. The yield from the fusion reaction, were one achieved, would be a small fraction of the energy invested. "You can't get enough back for it to be a baby bomb," Dr. Haught says.

But this kind of plasma can be used to fill a magnetic field. The time scale for controlled fusion is slower than that for bombs, and if the plasma can be held at high energy for long enough, it may be promising for controlled fusion.

"The outlook is interesting," says Dr. Amasa S. Bishop, assistant director for controlled thermonuclear research programs for the U.S. Atomic Energy Commission. "We will be using lasers more and more in the program."

A plasma produced by laser irradiation has a number of advantages for controlled fusion work. The plasma can be produced inside a magnetic field, without physical connections to the world outside.

If one makes a plasma outside the field, one has to make a hole in the field to put the plasma inside; charged particles will not move easily across a magnetic field. One then hopes to close the hole, not always an easy thing to do.

Alternately one can have a neutral gas inside the field, and ionize it by shooting a spark through the chamber.

But laser light will cross a magnetic field without needing a hole. It makes a plasma that needs no contact with injecting guns, or disturbing sparks.

There is no background gas left in the chamber, as there is with spark-ionized plasmas, and thus no loss of plasma energy by collisions with the background gas. Ionization is complete, and there are no neutral particles around to foul up the electrodynamics of the plasma.

Therefore there are now experiments going on all over the world designed to study how laser-produced plasmas behave in magnetic fields of various configurations. Drs. Haught and Lubin have both achieved heartening results in this department. Magnetic fields will stop the expansion of the plasma, they find, and the energy that has been used for expansion is then reconverted to kinetic temperature. In geometries called minimum B configurations they have both seen classical plasma lifetimes. That is, the plasma remains in the field for a time that depends only on Coulomb collisions, the bouncing and scattering caused by electric repulsive forces between the positively charged ions. "You couldn't expect a plasma to behave any better," says Dr. Haught.

The next step is to see whether this excellent behavior continues at higher energies.

The deuterium and hydrogen that Dr. Lubin is working with are the substances of choice for many of those who talk of actual fusion reactors. At 15,000 volts average particle energy, he figures, significant numbers of free neutrons will be produced by the reactions taking place. They can be used to study what is going on inside the plasma.

These neutrons are quite energetic, in the million-electron-volt range, and one way to get some of the reaction energy out is simply to absorb them in a tank of water and let them heat it.

A more sophisticated use for the neutrons which might be employed someday in an actual fusion reactor, would be to absorb them in a lithium blanket surrounding the plasma chamber. Their reaction with the lithium would produce tritium, and the tritium, coming back into the plasma, could help to keep a self-sustaining fusion reaction going.

Having some thermonuclear reactions taking place does not mean one has thermonuclear power. Drs. Bishop, Dimock, Haught and Lubin all stress that a fusion reactor is still a long way off. "We are not on the verge of thermonuclear power," says Dr. Lubin. "If we achieve 15,000 electron volts, we are a factor of four too low in energy. Furthermore we must have a large enough volume to get more energy out than we have to put in."

The volumes he is working with now are about 50 ten-thousandths of a centimeter across. Self-sustaining generators, he figures, would need volumes several centimeters across. As of now, the work is still only a study in achieving high temperatures and confinement. ◇