Fusion Power in 1970's

Soviets Announce New Approach to Laser Fusion

Two leading Soviet scientists have announced a new approach to laser fusion which will explode all previous timetables for the development of controlled thermonuclear fusion, potentially making this virtually unlimited source of clean, cheap fuel a reality within this decade. In an article in the Soviet physics journal JETP Letters, published Jan. 20, 1975 but only recently made available to U.S. readers, Drs. N.G. Basov and Yu.V. Afanas'ev propose using existing laser-fusion technology with a new fusion-fuel design.

Until this article was published, official Soviet estimates and those of sane U.S. scientists were that — at best — laser fusion or the other major approach to controlled fusion, Tokamak magnetic confinement, would be demonstrated to be scientifically feasible in 1976. Then, after several new technological components had been developed over the following four years (efficient fast-pulse, high-energy lasers in the first case, superconducting magnets in the second), prototype reactors could be build by 1980, with realization of significant inputs to the world economy by the late 1980s. Of course, Rockefeller's professional fusion saboteurs, who run the U.S. fusion research program, continue to claim that controlled fusion will not be realized until the 21st century.

The new approach laid out in Basov and Afanas'ev's article, however, because it allows the use of existing laser technology, will mean that pilot power platns could be completed by 1978 and a world fusion economy realized by 1981!

The Soviet article lights a second potential political bombshell under the U.S. scientific community with its clear implication of the close links between the gigantic Soviet push for controlled fusion and the Soviet arms program. This poses an obvious challenge to the U.S. fusion effort, which is presently crippled by repressive "weapons security classification" restrictions and narrowly focused, "limited project" orientation.

The Physics of Fusion

In the laser approach to fusion, a high-energy laser beam is used to compress and heat a minute pellet of fusion fuel until thermonuclear burn is ignited in the core of the pellet. In the resulting implosion, the condition which produce thermonuclear fusion in the core of stars are duplicated. Figure 1 shows a schematic of a laser-fusion reactor design. The major scientific problems involved are: 1. how to efficiently convert the energy of the laser beam into a compression shock within the fuel pellet, preventing the reflection of the laser light (in effect, preventing the laser light from "bouncing off" its target); and 2. how to control the evolution of the compression shock as it proceeds from the surface to the core of the fuel pellet so as to maximize thermonuclear energy output relative to laser energy input, i.e., energy gain.

Over the past year scientists have experimentally demonstrated what appears to be a satisfactory solution to the first problem. In several laser-fusion laboratories throughout the world, pellets of fusion fuel have been successfully compressed by factors of at least 100, with more than 50 per cent of the laser beam energy absorbed rather than reflected.

The second problem, however, has been the subject of intense debate among scientists in the United States, while essential portions of the scientific research involved remain locked up under "Top Secret" security classifications. Basov and Afanas'ev have now proposed a dramatically simple solution, thus potentially clearing away this major barrier to the quick realization of a fusion-based world economy.

Before elaborating on the scientific questions involved in this problem and the proposed Soviet solution, it is necessary to outline a few of the basic physical parameters involved.

First, the amount of fusion eneryg produced in any form of fusion process is proportional to what is called the Lawson number, the product of the time during which the fusion fuel is confined and the density at which it is confined. In order to produce more fusion energy than is used to ignite thermonuclear burn, the Lawson number must be greater than 10 to the 14th power (seconds time nucleii) per cubic centimeter.

In the case of laser fusion, net energy release is obtained at densities of 10 to the 25th power nucleii per cubic centimeter, with confinement times of less than one billionth of a second. Under these condition the fusion fuel is compressed more than 1,000 times its normal solid density.

A second condition required for net energy production is that of true thermonuclear ignition. As the thermonuclear reaction is sparked, the fusion fuel must be of sufficient density and constitute sufficient mass such that the fusion energy released is trapped within the fuel itself and therefore sustains the thermonuclear burn. For laser fusion this means that the product of the density and the final radius of the compressed pellet must be greater than .3 grams per square centimeter.

The Exploding Pusher

As part of the effort to control the evolution of the compression shock set off by the laser-pellet interaction (problem 2. cited above), much work has been done in developing new designs for the fusion pellet, a relatively simpler task than the immensely complicated problem of tailoring the laser pulse itself.

One important design is the "exploding pusher" model. In May of 1974 researchers at KMS Fusion laboratories in Ann Arbor, Mich. achieved significant laser-driven implosion of fusion pellets with production of a small quantity of thermonuclear energy. The pellet used (see Figure 2) was a hollow glass microsphere filled with fusion fuel consisting of deuterium and tritium (D-T, the heavy isotopes of hydrogen) in gas form. The pellet, which would easily fit on the head of a pin, measures 50 millionths of a meter in diameter, and the glass shell is one millionth of a meter thick.

Sixty joules of laser energy in a simply shaped pulse was symmetically directed onto the sphere in two beams. A significant portion of the glass shell exploded outward, creating an equal inward-directed force which imploded what was left of the glass shell, in the same way that a rocket's backward thrust impels the rocket forward. The implosion of the shell pushed the D-T gas inward, resulting in the compression and heat sufficient to produce thermonuclear energy.

Isentropic Compression

Exploding pusher pellets have also been successfully imploded at the Lawrence Livermore Laboratory (LLL), one of the U.S. government's main weapons research labs. But scientists there have argued that despite the initial successes, true thermonuclear ignition cannot be achieved with this design of pellet, and have proposed an alternative isentropic compression pellet design.

This design is geared to preventing excessive preheating of the fusion fuel before the compression shock set off by the laser light reaches the pellet's core. With exploding pusher pellets, such preheating of the fusion fuel makes compression much harder to achieve by diverting energy away from the inward push into random motion (heat). In the isentropic compression model, the laser pulse is carefully controlled and shaped in the pellet to prevent preheating. Second, the exploding pusher model wastes much of the laser energy due to the significant explosive blowoff of the glass shell. These factors mean that the exploding pusher model uses laser energy less efficiently, and therefore would require much larger lasers than the isentropic pellet to achieve true ignition. Even with the largest lasers now being built in the USSR and U.S., of approximately 10,000 joules of energy, the exploding pusher would not reach the requisite density-radius product of .3 grams per square centimeter and so could not achieve true thermonuclear ignition, as the LLL scientists have argued.

In hollow pellet compression the intense energies of laser beams are used to develop gigantic pressures, roughly one trillion times normal atmospheric pressure. A hollow spherical shell, if it can be uniformly compressed, would reach greater compressions than a solid pellet, and would therefore utilize laser energy more efficiently. The reason is fairly obvious. Because the hollow shell does not meet any significant resistance as it implodes until reaching the center of the pellet, it achieves greater momentum and therefore greater compression than would a solid pellet. The larger the ratio of the overall pellet radius to the thickness of the hollow shell (called the pellet aspect ratio), the more efficient the compression.

The problem with thin-shelled pellets, i.e., pellets with large aspect ratios, is that a thin shell tends to crimp and ripple during compression. This leads to the Rayleigh-Taylor instability (among others) in its most virulent form; as final compression is reached in the core, portions of the rippled pellet splurt outward, thus preventing true compression.

Even with the more efficient isentropic compression design, the laser requirements are far greater than any existing laser system can produce. The Livermore group believes that compressions on the order of 1,000 to 10,000 would have to be reached in order to produce net energy. In other words, the final density reached by the hydrogen fuel would have to be greater than 1,000 grams per cubic centimeter, 1,000 times normal solid density. The minimum laser requirement for attaining this compression, based on the LLL isentropic pellet compression, would be a laser which puts out 100,000 to 1,000,000 joules in a pulse lasting no more than 10 billionths of a second, with a short wavelength between .3 and .6 millionths of a meter, and a peak power output between a trillion to 100 trillion watts, with the efficiency of the laser greater than 10 per cent. In almost every category, existing laser systems fail to meet these requirements by a factor of 10, and in some cases by much more.

Tampered Pellets

Another method of increasing the efficiency of compression is to use outer shells made of heavy materials, such as gold. (See Figure 3) Such a heavy shell shields the fusion fuel from preheat before full compression is reached at the pellet core. By providing better containment of the fusion fuel, the heavy shell aids in realizing true thermonuclear ignition. In addition, the shell also helps stabilize the pellet compression and makes the implosion more uniform, avoiding the "splurt" and other instabilities of the exploding pusher's thin glass shell.

The problem with the heavy shell approach is that the gold tamper, or for that matter a tamper made of any material, displaces the actual fusion fuel. Such a design would relax laser requirements and achieve high energy gains only if the pellet was increased significantly both in terms of aspect ratio and overall size, although this of course would increase the likelihood of the onset of hydrodynamic instabilities, such as the Rayleigh-Taylor instability mentioned above.

Soviet Laser Fusion Approach

Drs. Basov and Afanas'ev propose to do precisely that. The pellet design they put forward in their article is approximately 2 centimeters in diameter, 400 times larger than the KMS and LLL pellets, with a gigantic aspect ratio of 100 to 1 — a really **big** pellet. The design also differs from the LLL and KMS models in that only compressions to final fuel densities of 100 grams per cubic centimeter are needed to produce significant fusion energy. In fact, this pellet would achieve a net energy gain of 1,000, i.e., a 1,000 times more fusion energy than laser energy output. This is orders of magnitude greater than the best projections of U.S. models.

The key to this Soviet pellet design is the large density-final radius product which would be obtained. This would be ten times greater than the minimum .3 grams per square centimeter requirement — sufficient to create a thermonuclear inferno.

The laser parameters for this giant pellet design are relaxed significantly compared to those for the KMS and LLL models. First, because of the pellet's large size, the laser pulse duration would be as much as a 100 times larger than in the KMS and LLL cases. Second, the necessary peak power would be tremendously decreased due to the large aspect ration. Further, since the Soviet design uses a gold shell more as a **"barrier"** than as a pusher, the wave-length of laser light could be significantly lengthened. the total laser energies would be of the same magnitude, but the energy gain would be much greater. Most important, the projected relaxation of the necessary laser requirements means that existing laser systems, electron-beam-excited carbon dioxide and chemical lasers such as the hydrogen-flouride and iodine lasers now being successfully developed, would be more than adequate for functioning laser-fusion power plants.

The major questions with this new approach are whether efficient compression can be achieved and whether hydrodynamic stability can be assured. As to the first, Basov and Afanas'ev "emphasize that in the experiments of (KMS and LLL) the D-T gas is compressed with the aid of a heavy shell with mass much larger than the D-T gas." Tis, as they point out, leads to much lower energy gains with less efficient compression. They instead propose that the evolution of the compression shock can be tailored through utilizing alternating layers of shells of different densities. In this way the compression can be made quite efficient.

The essential question is the second, hydrodynamic stability. On this score Basov and Afanas'ev write at the end of their short article, "It should be noted in conclusion that the gas dynamic calculations of the targets are based on the experience gained by high-temperature hydrodynamics research in the USSR."

"Experience"!

We will now offer some speculation on what exactly is meant by this unprecedented bold statement by these leading Soviet scientists, since the prognosis for realization of the approach they propose hinges on this statement.

The H-Bomb Link

The Soviet Union has the largest thermonuclear weapons, hydrogen bombs which have an explosive force of 100 million tons of TNT, many times larger than U.S. bombs. It is very likely that this is what Basov and Afanas'ev mean by "experience gained by high temperature hydrodynamics research in the USSR."

H-bombs are triggered by nuclear fission bombs. To make thermonuclear weapons more efficiently, and also scale them up in size, it is necessary to increase the ratio of fusion energy versus fission energy released. There are only three ways this can be achieved. First, the thermonuclear fuel mix can be rearranged. Second, the coupling of the fission-fusion reactions can be improved, that is, thermonuclear-produced neutrons can be used to increase the rate of the fission chain reaction. Third and most important — since the first two methods are actually dependent on this parameter — the fission and fusion fuels can imploded to high densities. This compression of the fission and fusion fuels increases the rates of reaction in both cases.

Replacing the gold outer shell of the proposed laser fusion pellet with a shell of Uranium-235, as is done in actual H-bomb and as has been proposed by the Soviets as a possible laser fusion pellet design, would mean that as the pellet is compressed the uranium reaches critical mass and explodes, which then further compresses the fusion fuel to much higher densities. In H-bombs, the initial compression of the basketball size pellet would be obtained with chemical explosives, which can currently reach pressures 10 million times greater than normal atmospheric pressure. The critical phenomena involved would be the **hydrodynamic stability** of the imploding hollow sphere.

Application of implosion physics to atomic weapons was first initiated by Dr. Seth Neddermeyer in the U.S. during the Manhattan Project of World War II. The idea was that imploded spheres would achieve more efficient fission bombs with less fissionable mass. When it developed that Plutonium 239-fueled fission bombs could only be detonated by compression, the whole Los Alamos Laboratory directed its attention to this problem, and John Von Neumann developed the first comprehensive theoretical model of imploding hollow spherical shells.

But in regard to the application of these initial breakthroughs to the current pressing problem of realizing controlled fusion, the effort in the U.S. has been deliberately restricted to narrow, limited lines of approach. Significant areas of this vital work are roped off under the pretext of security, and fusion scientists are left to compete with each other in rival empires of specialized expertise.

As to the methodology implied by this outlook, with respect to the problem under consideration here, Dr. John Nuckolls of the Livermore Lab comments in the LLL 1974 annual report that the non-linear dynamics of large pellets with high aspect ratios (i.e., with shell thickness much greater than the laser wavelength) can not be studied with the linear Lagrangian computer models that are used at LLL. Furthermore, Keith Boyer of Los Alamos also notes "that these simulations ignore nonlinear effects, which might prove to be stabilizing."

As the history of Soviet fusion research shows, and as the Basov-Afanas'ev article further implies, the USSR is increasingly focusing its resources on the broadest possible research effort into the basic questions of thermonuclear and plasma physics research, drawing both weapons and controlled fusion applications out of this basic effort as spin-offs. The Soviets' growing predominance in the fusion research arena indicates the far greater effectiveness of their methodology.

The range of final densities projected in the Basov-Afanas'ev laser fusion pellet design are on the order of those which would be achieved in the hydrogen bomb design discussed above. While the actual hydrodynamic compression processes are quite different in the two cases, the "quality" of the nonlinear physics involved are essentially the same, i.e., producing symmetry from turbulence. In fact the H-Bomb model is much more difficult to realize. Therefore it is very likely that the hydrodynamics research "**experience**" (both theoretical and experimental) which Basov and Afanas'ev refer to was precisely that which had been developed to solve these problems in thermonuclear weapons design.

As reported last week in New Solidarity, Basov and company will begin to fire their giant laser early next year. In combination with the new pellet design, experiments may very well signal the death knell of Rockefeller, capitalism, and all other **fossil** fuels!