Physics conference throws light on the U.S.-Soviet laser fusion debate

by Vin Berg

This past November, more than 2,000 fusion scientists and engineers attended the world's largest nuclear fusion-related meeting, the annual conference of the American Physical Society's Division of Plasma Physics in San Diego, California. The physics of plasma, hot ionized gas that directly exhibits self-ordering behavior, is the branch of physics associated with fusion energy development; the international conference itself was noteworthy not only for the hundreds of progress reports presented, but for additional information concerning one branch of fusion research, inertial confinement, that allows one to piece together the history of this closely guarded field.

Since Oct. 7, 1980, when the Magnetic Fusion Energy Engineering Act was signed into law, the United States has been formally committed to achieving fusion power by the year 2000. Fusion is the power process of the sun, whose enormous gravitational force compresses atoms of hydrogen to the very high temperatures and densities at which, respectively, their electrons are stripped away (ionization), and their nuclei fuse, producing new atoms and releasing enormous amounts of energy in the form of heat and light. Lacking the sun's gravitational force to drive the fusion process, scientists are devising methods that can generate plasma fusion reactions employing inertial techniques—high-energy laser, ion or electron beams—or magnetic fields to contain and compress plasmas to the condition required.

Presentations on *inertial* fusion, in particular methods using high-power laser drivers, produced some of the greatest interest at the conference.

The history of inertial confinement fusion research has never really been told. The field has been generally security classified due to its bearing on advanced-weapons-systems research. However, recently declassified information, some it presented at the conference, begins to clarify the nature of the field's development, and illustrates the extent to which excessive "top-secret" treatment of results, by inhibiting information exchange, has actually aggravated the ability to find solutions to certain theoretical problems.

Inertial confinement history

To a large extent, research and development in inertial confinement, often called "laser fusion," has revolved around laser/plasma interactions that produce both instabilities in fuel compression and preheating of fuel by "hot," or highly energized, electrons generated by high energy, high-power dense laser beams. The beams are focused on a target "pellet" containing fusion fuel—the heavy isotopes of hydrogen called deuterium and tritium—vaporizing the pellet surface which, as it flies off, effects ablative compression—*implosion* of the pellet. A leading problem has been that the more powerful lasers favored by American scientists also produce high thermal electrons, and these "hot" electrons heat up the fuel prior to its full thermonuclear fusion burn. Since heating tends to expand the target fuel, it reduces the efficiency with which the laser beam compresses the target fuel.

Four years ago, Soviet scientist Leonid I. Rudakov proposed that laser light could be converted into soft X rays, both eliminating hot electron generation, and maximizing compressive force. A debate was provoked.

U.S. scientists in the mid-1950s had found that the X ray output from a fission chain reaction could be passed through a series of filtering materials into a "black body cavity"—"black" because it absorbs and propagates all frequencies of light—producing soft X rays that could efficiently implode hollow spherical targets with low beam power-inputs. However, the U.S. experts believed that to be economically competitive, inertial fusion would have to employ very simple, thick-shelled targets, requiring more powerful laser beams. U.S. research therefore concentrated on developing very powerful lasers.

A Soviet disagreement

Soviet scientists, however, argued that high power fluxes would generate beam/plasma instabilities; they argued that efficient compression of the plasma fuel, avoiding instabilities and other undesirable effects produced by the interaction of the plasma with the laser beam itself, required that laser beams be limited below certain definite power fluxes. Soviet research therefore concentrated on designing thin-shell hollow targets requiring less laser power input for implosion. U.S. scientists persisted in high-power beam development, arguing that thin-shell targets would themselves produce hydrodynamic instabilities.

Behind this disagreement is a fundamental theoretical question: What is primary in inertial fusion? The implicit assumption of the American view was that input energy is primary. The fusion process is implicitly assumed to be entropic, and what is therefore deemed crucial is a maximum of energy input to drive the plasma to fusion conditions before countervailing instability and energy dissipation can take over.

Implicit in the Soviet approach, however, was the opposite view (long explicitly held by America's Fusion Energy Foundation and others), that the fusion process is negentropic. Energy input does not drive the plasma to fusion. The plasma drives itself to fusion. Energy input merely establishes the initial configuration that triggers such self-ordering plasma behavior. The problem is not energy input, but how to design the target geometry and the deposition of energy input so as to best use the thermonuclear burn process the plasma itself develops. Energy input, as "trigger" for the plasma's evolution, must not interfere with it. During the 1970s, the leading features of the Soviet view were proven correct, as instabilities, decreased laser-light absorption, and pre-heating by hot electrons, reduced implosive efficiency. Each of these obstacles was an unwanted result of the plasma's interaction with a too-powerful laser beam.

Recent experiments at Lawrence Livermore Laboratory in California now confirm that when laser-beam power fluxes are kept below the limits specified by the Soviet specialists, a maximum percentage of laser light is converted to soft X rays, without generating the "hot electrons" responsible for the pre-heating problem.

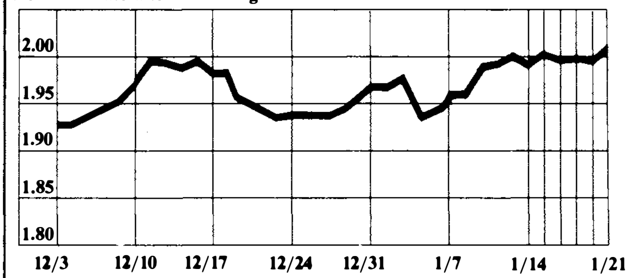
Moreover, the instabilities U.S. scientists had imputed to thin-shell targets—they now agree—are not important when soft X rays are employed.

It is now believed that the Soviet program always presumed the conversion of laser light to soft X rays, and that Soviet thin-shell target designs were therefore based on this presumption. What still remains in dispute is exactly how ignition and "burn" of fusion fuel (through thermonuclear-burn shock waves) actually proceeds. There are indications that the Soviets have made a breakthrough in this area, and may have refined their target designs on the basis of such a new appreciation of the negentropic fusion-fuel "burn" process.

Currency Rates

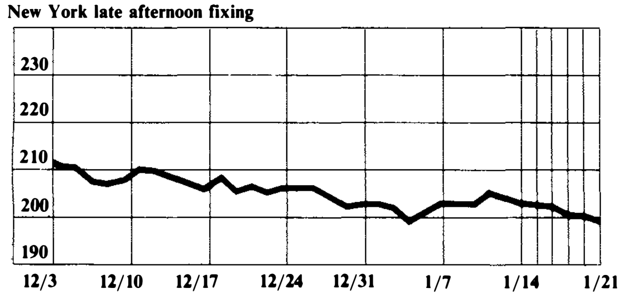
The dollar in deutschemarks

New York late afternoon fixing



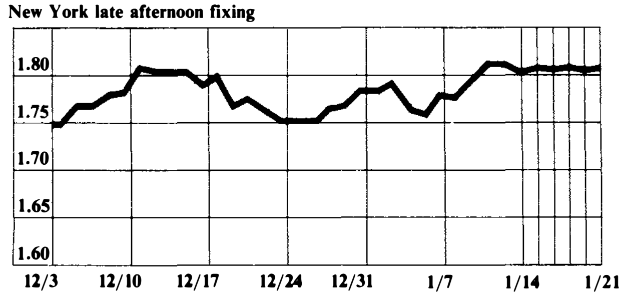
The dollar in yen

New York late afternoon fixing



The dollar in Swiss francs

New York late afternoon fixing



The British pound in dollars

New York late afternoon fixing