New results in light ion beam fusion promise breakthrough by 1990s

by Charles B. Stevens

Almost lost among the revelations of major breakthroughs in beam weapons, the April 17-19 University of Rochester conference on "Lasers and Particle Beams for Fusion and Strategic Defense" saw the announcement of advances in the Sandia, New Mexico light ion beam fusion program which ensure that commercial fusion energy can still be realized by the 1990s despite the general curtailment of the U.S. research effort over the past 8 years. In order to achieve high gain inertial confinement fusion needed for commercial power generation, it is necessary to deliver energy pulses containing millions of joules at power densities of several hundred trillion watts per square centimeter to a small target containing hydrogen fusion fuel. The high gain result is that hundreds of millions of joules of fusion energy are generated in the resulting microexplosion.

As detailed to the Rochester conference, recent experiments have shown that the Sandia National Laboratory PBFA II light ion beam accelerator has the potential of delivering millions of joules at power densities of ten thousand trillion watts per square centimeter, far above that required for high gain fusion! The PBFA II (Particle Beam Fusion Accelerator II) will begin operation in January 1986. Fusion target experiments are scheduled for early 1988.

Dr. J. Pace VanDevender, Sandia Pulsed Power Sciences Director, and Professor Ravindra N. Sudan, Director of the Cornell University Laboratory of Plasma Studies, detailed the experimental and theoretical advances underlying this happy prognosis. Professor Sudan showed that experiments with high current ion beam pulses over the past decade have shown that they act contrary to the simple minded pictures presented by such anti-beam weapon "experts" as MIT's Kostas Tsipis. First of all, instead of diffusing, high current ion beam pulses tend to non-linearly self-focus to higher power densities. Second, weak magnetic fields do not interact and change the trajectory of such extremely high current beam pulses.

Dr. VanDevender reviewed experiments on Proto I in which 1.5 trillion watts per square centimeter were delivered to a target in May 1984. This Spring PBFA II delivered an 8 trillion watt pulse onto a spot 4 to 4.5 millimeters in diameter. This demonstrated that the Sandia light ion beam focussing process is maintained as the current is increased. Proto I puts out a 1.4 million volt and 0.4 million amp beam, while PBFA I operates at 2 million volts and 4 million amps. PBFA II will demonstrate scaling with voltage since its lithium ion beam will have 30 million volts and 5 million amps. These recent experimental successes demonstrate that PBFA II has the potential of exceeding its original design specs by a factor of 100. This means that PBFA II will be able to go well beyond fusion breakeven for which it was originally designed.

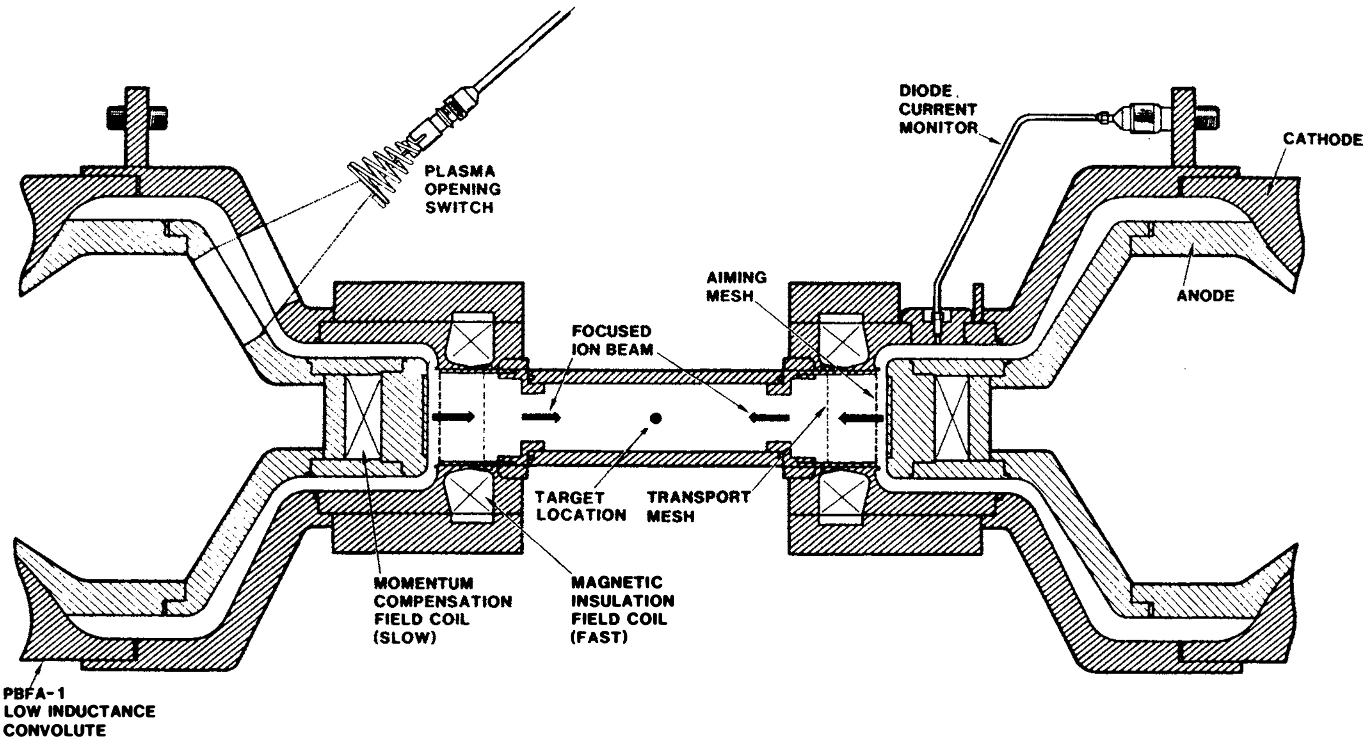
How it's done

The Sandia program is among the youngest in the fusion field. Beginning in the early 1970s and making use of electron beam accelerators, which were otherwise being utilized to produce intense bursts of x-rays in order to simulate nuclear weapon effects, the Sandia pulsed power effort has placed itself at the forefront of fusion research and on the brink of realizing commercial fusion. In little more than a decade Sandia converted the inherent high efficiencies and low costs of oil and water insulated pulsed power capacitors and Blumleins into the frontline fusion program with a minute fraction of the total program's resources.

The scientist most responsible for this is the former Sandia Pulsed Power Director, Dr. Gerald Yonas, who is currently the deputy director and chief scientist for President Reagan's beam-weapon program.

Plasma engineering

In many ways the Sandia particle accelerators are no more complicated than an ordinary spark plug and look very much the same—except on a much larger scale. You begin with a large, high voltage pulse of electrical current lasting tens of billionths of a second. This is delivered to two pieces of metal



CROSS SECTION OF DIODE

Sandia National Laboratory's Particle Beam Fusion Accelerator (PBFA) may prove capable of delivering energy pulses far denser then required for fusion breakeven. The PBFA II will begin operation in January 1986.

which are separated by a vacuum—a sort of glorified vacuum tube diode. One metal piece is called the anode because it has a positive electric charge and the second the cathode because of its negative charge.

Ordinarily, when the high voltage, high current electrical pulse arrives at the diode, electrons would be accelerated from the cathode to the anode and positive ions would be accelerated from the anode to the cathode. Because the electrons are thousands of times lighter than ions, they make it across first and thus an electron beam is generated. A thin foil properly placed at the anode will permit the e-beam to pass out of the machine.

Alternatively, if a magnetic field is placed across the cathode, as originally suggested by Dr. F. Winterberg, the lighter electrons will become trapped and prevented from proceeding to the anode. In this case the positive ions will make it across first and a high current, intense ion beam will be formed.

Besides properly arranging the geometry of the diode to permit the formation of a focused ion beam, a transparent plastic mesh is introduced between the cathode and anode. This mesh is transformed into a plasma—plasma is the ionized state of matter—when the electric pulse arrives at the diode. The plasma mesh acts as a "virtual cathode" which evens out the intense electric field within the diode and therefore results in an even acceleration of the ions. The chief moving parts of the Sandia particle beam accelerators are "plasma"!

Another plasma engineered improvement is to use intense bursts of extreme ultraviolet radiation to pre-ionize the surface of the anode. This allows the more efficient and rapid formation of the ion beam when the electrical pulse arrives.

Commercial prospects

While many technical hurdles remain for converting the scientific demonstration of light ion beam fusion into a practical, economic power plant, the pulsed power technology upon which this approach to fusion is based has made major advances over the past decade, and with the Reagan beam weapon program, this rate of progress will be greatly accelerated. Already advances in high power switching are clearing the way to rapid refiring rates needed for power plants. Pulsed power has always operated with high efficiencies—better than 30% of the input electrical power being converted into ion beam output. Continuing work in the beam weapon program is pointing to solutions to the most significant, outstanding problem—that of propagating the ion beam over a sufficient distance in order to decouple the beam generating diode from the fusion microexplosion. In any case the future for light ion beam fusion is bright. It remains to be seen what Gerry Yonas will do with the large resources of the U.S. Strategic Defense Initiative.