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SNL PROGRAM OVERVIEW*

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ABSTRACT

Advances in ion beam theory, diagnostics, and experiments in the past two years have enabled efficient generation of intense proton beams on PBFA II, and focusing of the beam power to 5.4 TW/cm^2, averaged over a 6-mm-diameter target. Target experiments have been started with proton beams, since the range of 4-5 MeV protons is equivalent to 30 MeV lithium. Range-thick conical targets have been used for development of target diagnostics and beam uniformity measurements. Seeded foams have been used to diagnose ion deposition. In order to increase the power density for target experiments, we are now concentrating on development of high voltage lithium ion beams.

PROGRAM LOGIC

The light ion program logic has two parts, as shown in Figure 1. The left branch is the PBFA II program. It includes development of beam focusing (protons first, then lithium), target interaction experiments (hohlraums), and target hydrodynamics leading to ignition scaling experiments. A cross-sectional drawing of PBFA II is shown in Figure 2. The PBFA II ion beam is not pulse-shaped, but instead, we are developing concepts for pulse shaping internal to the target. The branch on the right of Figure 1 is the LMF program. It includes development of extraction ion diodes, ion bunching for pulse compression, and module firing time variation for pulse-shaping at the target. The target for LMF does not require internal pulse shaping. The light ion LMF design, shown in Figure 3, consists of 36 pulsed power modules. Twelve of these are rated at 20 MV and have electrical characteristics very similar to the Hermes III accelerator, shown in Figure 4, but they are operated in positive polarity. The remaining 24 modules are rated at 30 MV and 1.5 MA, a factor-of-three scale-up from the 20 MV, 0.7 MA level of Hermes III.

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For PBFA II to drive implosion targets effectively, it must provide an ion beam with adequate power, adequate power density, and proper range in the target. Adequate power (50-100 TW) on PBFA II requires the plasma opening switch (POS) and full energy operation. Adequate power density (50-100 TW/cm^2) requires an ion beam with high magnetic stiffness. Proper range in the target (30-40 mg/cm^2) requires the POS and a magnetically stiff ion beam. In order to increase the power density for implosion target experiments while maintaining an adequately short ion range in the target, we are developing high voltage lithium ion beams. Our goal on PBFA II is to provide 1 MJ of energy in a 30 MeV, 15 ns, 50-100 TW/cm^2 lithium ion beam to an ICF target for studying implosion hydrodynamics and investigating ignition scaling.

Considerable progress in developing light ion beam technology for ICF has been made on PBFA II (the Particle Beam Fusion Accelerator II) within the last two years. Advances in ion beam theory, diagnostics, and experiments have enabled efficient generation of intense proton beams on PBFA II, and focusing of the beam power to 5.4 TW/cm^2 on a 6-mm-diameter target.[1] Target experiments have been started with the intense proton beams, since the range of protons at 4-5 MeV is equivalent to that of lithium at 30 MeV.

TARGET EXPERIMENTS

EXPERIMENTAL FACILITIES

The Saturn and PBFA II accelerators provide large amounts of energy for weapon physics experiments. A table of parameters for these machines at the present time is given below:

	Saturn	PBFA II - Now	PBFA II - Goal	PBFA II - Goal (with energy upgrade)
Configuration	Z-Pinch	Protons	Lithium	Lithium
Voltage	2 MeV	5-6 MeV	24 MeV	30 MeV
Current	10 MA	3 MA	4 MA	6 MA
Pulse Width	25 ns	40 ns	15 ns	15 ns
Total Energy	500 kJ x-rays	600 kJ ions	1.35 MJ ions	2.7 MJ ions
Focused Energy	N/A	180 kJ, 20-mm spot 73 kJ, 6-mm spot	0.9 MJ ions	1.8 MJ ions
Spot Size	6 mm	6 mm	6 mm	6 mm
Power Intensity	---	5.4 TW/cm^2	50 TW/cm^2	100 TW/cm^2

The first series of target experiments in the z-pinch configuration has just recently been completed on the Saturn accelerator, shown in Figure 5. The purpose of this experimental series was to evaluate the potential of z-pinch configurations for weapon physics experiments. By characterizing large volume hohlraums that persist for tens of nanoseconds, these experiments provide a benchmark for our code predictive capability and a testbed for developing diagnostic techniques in spatial and temporal regimes similar to those produced by ion beams.

Three series of target experiments have been completed on PBFA II so far. These experiments are discussed at greater length in the accompanying paper by Derzon, et al.,[2] at this conference. The first series used large (15-20 mm midplane diameter) range-thick cones for development of target diagnostics. The second series used smaller cones (7.5-10 mm midplane diameter) for measurement of azimuthal beam uniformity and correlation of diagnostic data obtained at large radius with that obtained on the diode axis. The third series began the study of intense ion beam deposition in a low-density foam seeded with chlorine for x-ray imaging.

The configuration of the target experiments is shown in Figure 6. The ion beam, created at the ion source radius of 15 cm, is accelerated through the 1-2 cm anode-cathode gap, and passes through the 2 micron mylar gas cell window and into a few-torr Ar-filled propagation region. The beam is focused in the vertical direction from its initial 5-10 cm height to its 5-6 mm height at the target by bending in the self-magnetic field, bending in the applied magnetic field, and vertical shaping of the anode profile.

In these series of experiments, we have made considerable progress on developing PBFA II as a target shooter and beginning to demonstrate the utility of light ions for targets by using the following types of targets:

- large conical targets (CF_2) to develop and characterize target diagnostics, and to benchmark a CRE code,
- planar Rutherford scattering targets and large conical K-alpha targets (Au) to cross-correlate on-axis and off-axis diagnostics,
- small conical targets (Ti) and x-ray diagnostics to diagnose the stagnation of the range-thick target material on the axis,
- large "apron" (conical) targets (Au) to directly measure the azimuthal uniformity of the ion beam passing through the foil on its way to the diode axis,
- using small conical targets (Al) to make the first-ever observation of K-alpha satellites (up to boron-like Al) in an ion beam heated target, and
- using chlorine-seeded carbon foam targets to diagnose ion beam deposition uniformity in low density foam, in preparation for integrated hohlraum experiments.

Future target experiments will concentrate upon diagnosis and improvement of ion beam deposition uniformity, measurement of the uniformity of the pressure pulse for driving implosion targets, and the hydrodynamics of target implosions. These target experiments will be more interesting if we are successful in developing intense lithium beams. Our strategy is to increase the energy we can deliver to a lithium beam by increasing the beam purity and increasing the diode voltage. We believe we can increase the ion beam focal power intensity by about a factor of 9 from the 5 TW/cm^2 level we have achieved using protons if we can go from the present 50% proton purity with hydrocarbon sources to a 90% pure lithium beam, and increase the ion energy from 6 MV to 30 MV.

SUMMARY

Advances in ion beam theory, diagnostics, and experiments in the past two years have produced a 5 TW/cm^2 proton beam. Target experiments using this beam have produced data on total proton energy, proton beam uniformity, and beam-target interaction physics. Experiments are being planned to measure ion beam deposition in heated material quantitatively. With success in lithium beam production, we will begin implosion experiments driven by intense lithium beams, and demonstrate the utility of light ion beams for ICF.

REFERENCES

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2. M. S. Derzon, J. E. Bailey, G. C. Chandler, R. J. Dukart, P. Grandon, R. Humphreys, T. Hussey, D. J. Johnson, R. J. Leeper, T. R. Lockner, J. Maenchen, M. K. Matzen, E. J. McGuire, T. A. Mehlhorn, W. E. Nelson, P. Rockett, C. L. Ruiz, W. A. Stygar, and D. K. Wiemann, "Target Experiments At PBFA-II," this conference.

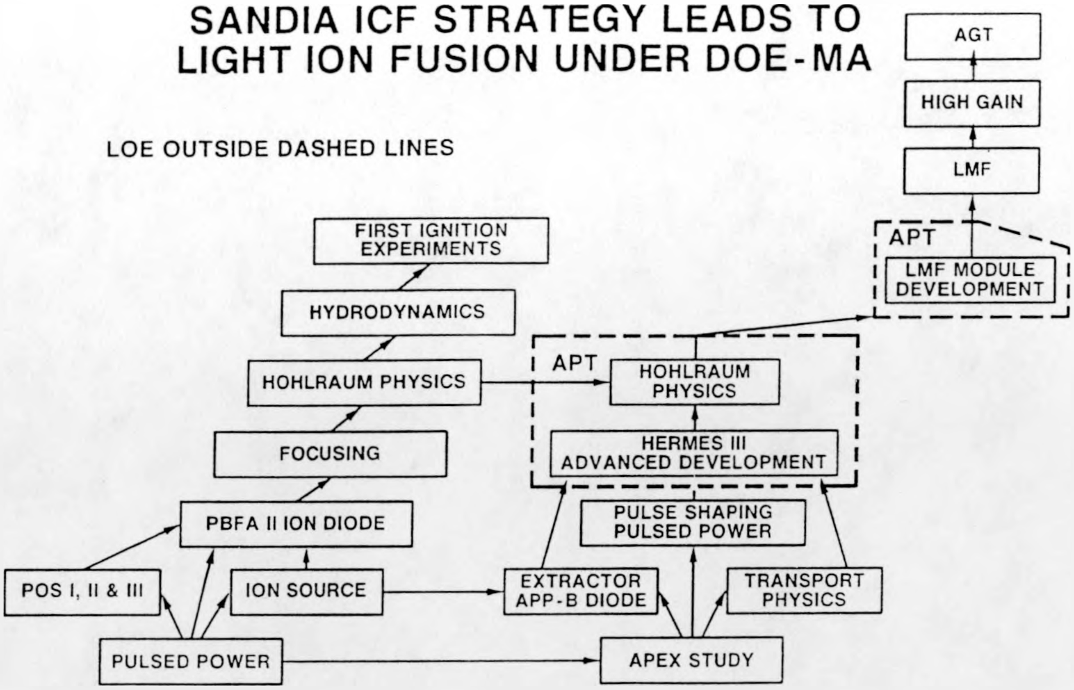

Figure 1. Sandia National Laboratories program logic

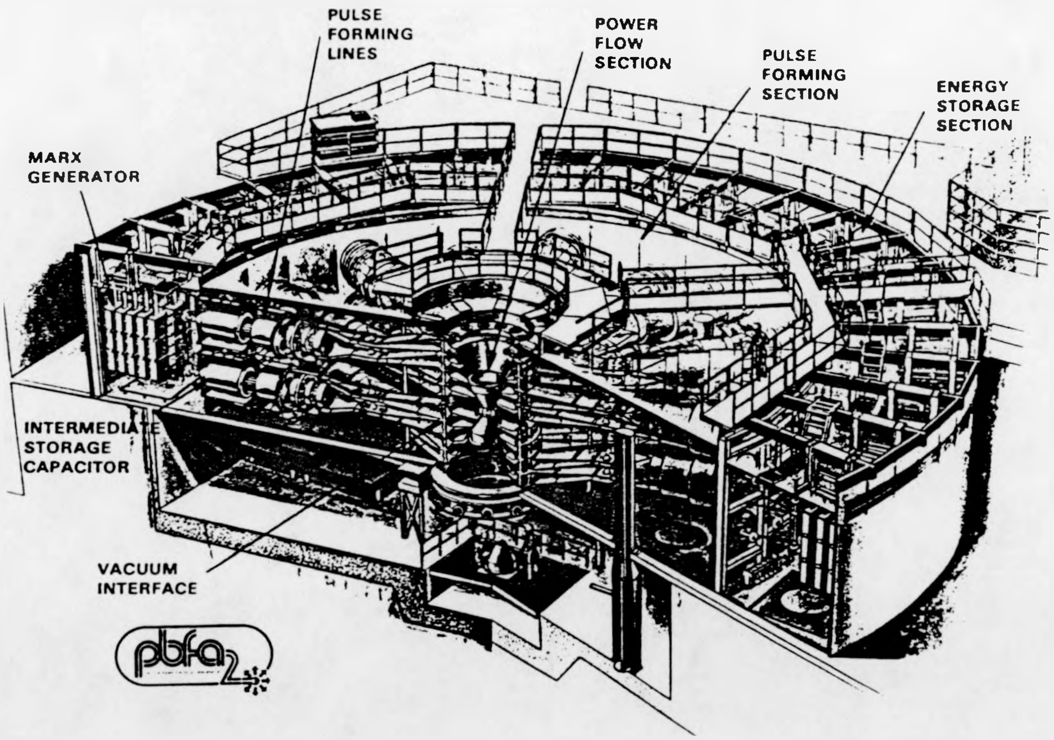

Figure 2. Cross-sectional drawing of PBFA II

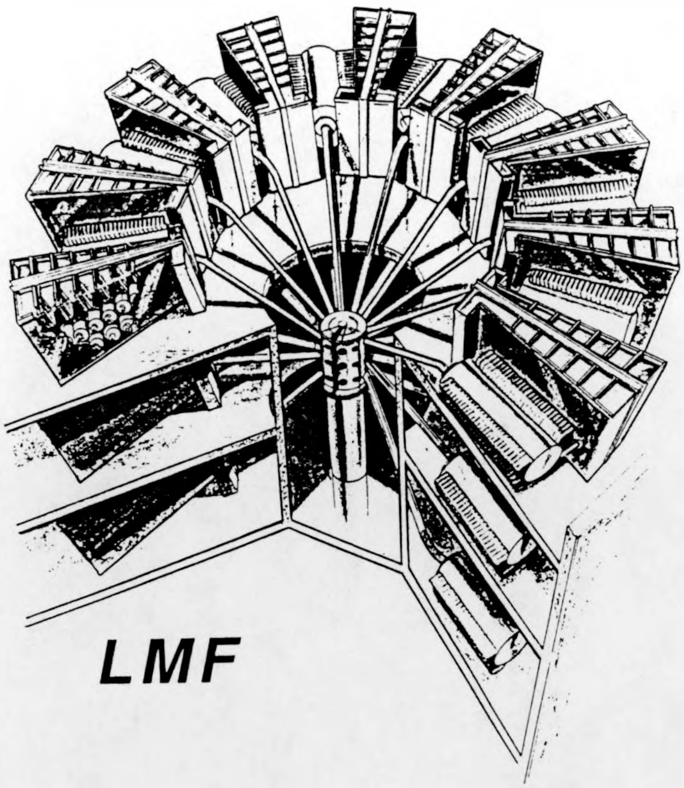

Figure 3. Artist's drawing of the light ion Laboratory Microfusion Facility

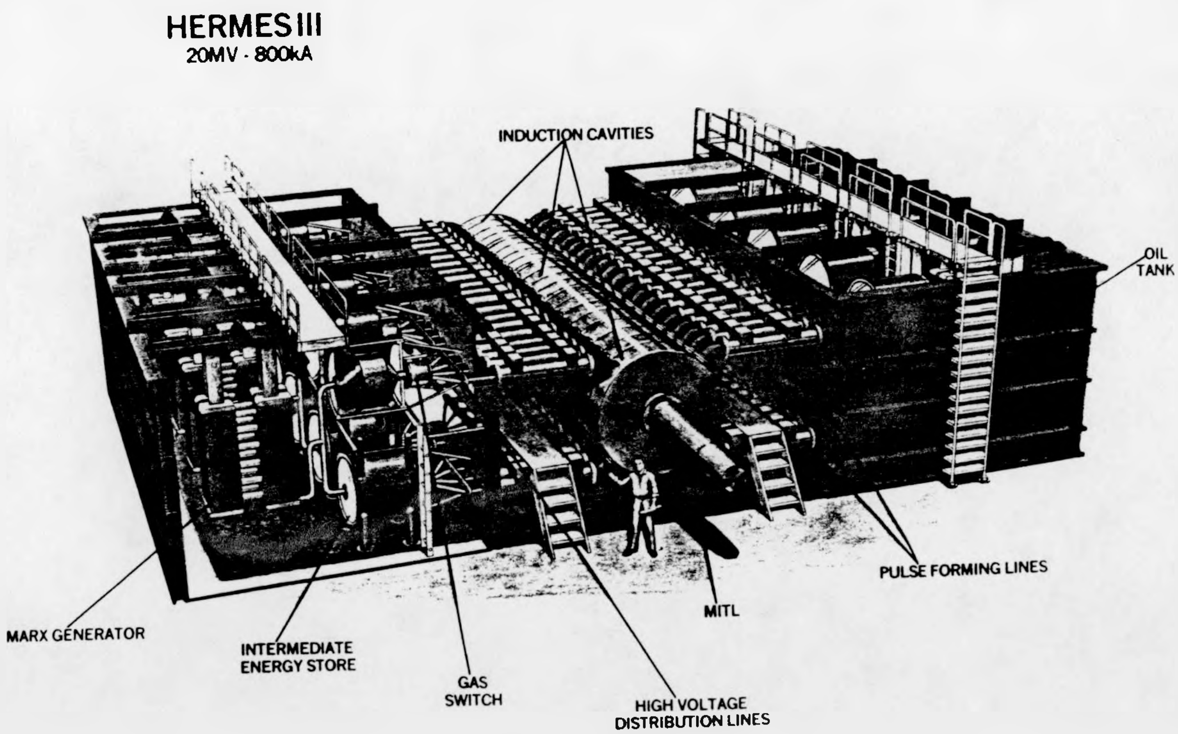

Figure 4. Artist's drawing of the Hermes III accelerator

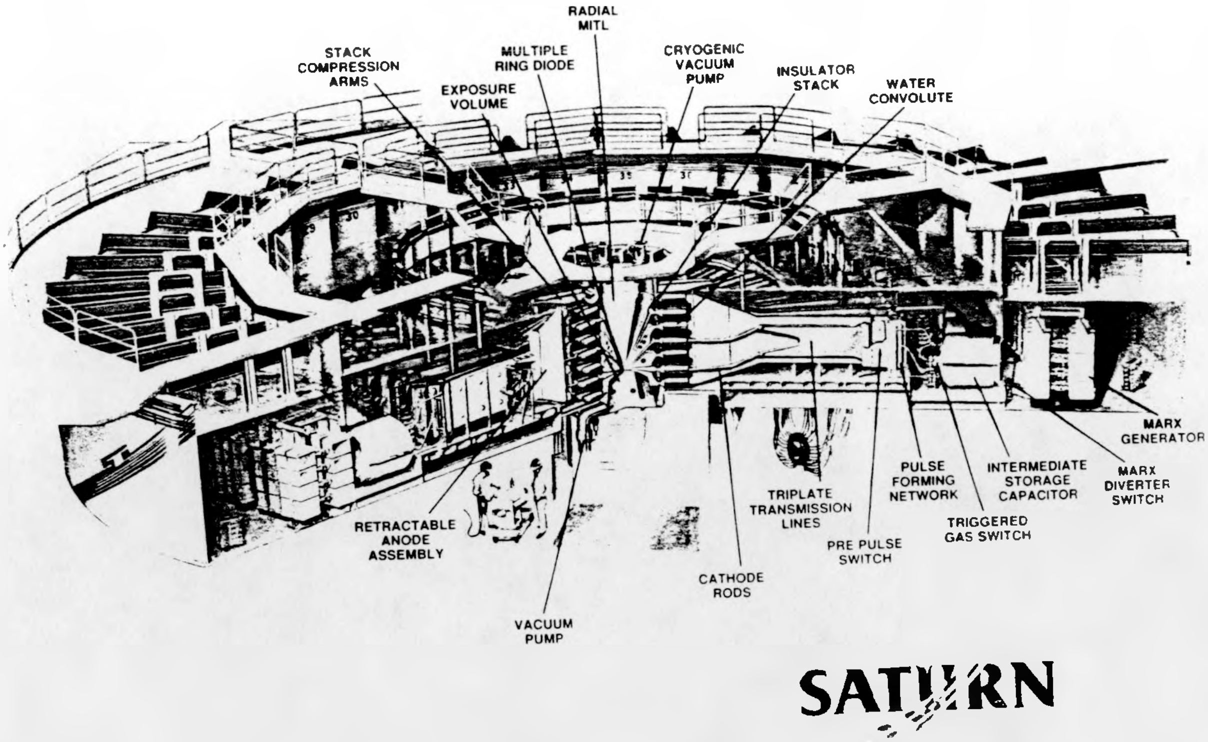

Figure 5. Cross-sectional drawing of Saturn

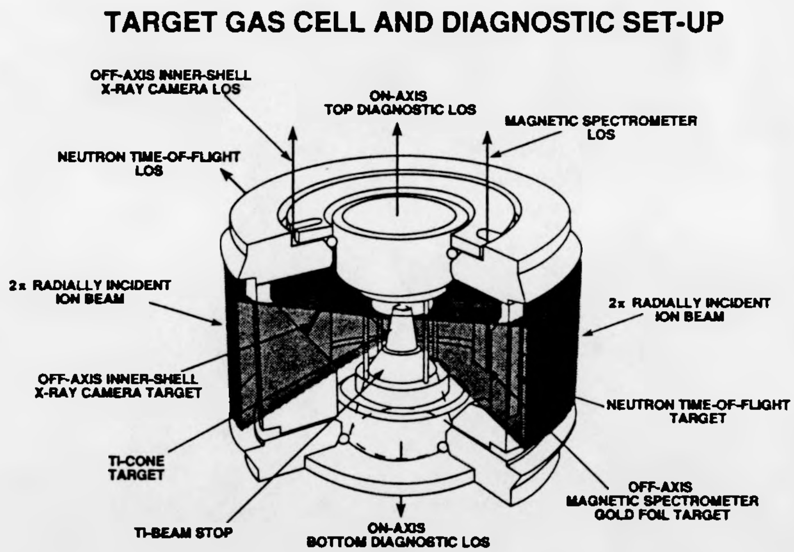

Figure 6. Configuration for target experiments on PBFA II