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Progress Report to DOE

Inertial Confinement Fusion Program
Naval Research Laboratory
Washington, DC 20375

FY 1979

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NRL LASER FUSION

PROGRESS REPORT

Aug. '78 - Feb. '79

EXPERIMENTS: By the end of October we completed the first phase of our new experimental program, designed to accelerate a planar target to implosion level velocities, and to evaluate the ablation physics, the hydrodynamic stability limit, and the associated laser-plasma coupling physics.

In this first phase of our program we studied the physics of absorption, heat conduction, fast electron spectra, ablative acceleration efficiency, ablation pressure, edge effects, and rear surface motion in 1-D and 2-D. The experiments were carried out at 10^{12} - 10^{14} watts/cm², using a 3 nsec pulse duration. The light absorption was high at the lower intensity (80-90%), and the foils were successfully accelerated to up to 10^7 cm/sec with good hydrodynamic efficiency (up to 20%). This (near-isentropic) acceleration of disc targets to implosion level velocities agreed well with a simple analytic ablation-rocket model, and also in more detail with NRL's computer calculations. The favorable physics we found, and the success of our near-isentropic acceleration, are re-enforcing our belief that the undesirable physics at high irradiance will be reduced to an acceptable level with pellet designs that are restricted to low irradiance ($\lesssim 10^{14}$ watts/cm² at one micron).

In calendar year 1978 the laser was fired 714 times on target for laser-plasma coupling experiments; several times that number of shots were used for associated set-up, testing, and alignment. (For just the September-October series of experiments, the laser was fired 293 times on target for experimental laser-plasma coupling data). A large number of experimental diagnostics were used in parallel, many for the first time. Our physics results from the thin

foil experiments were presented at the Colorado Springs At. Meeting at the end of October, and are summarized in NRL Memorandum Report 3890, which is enclosed with the Progress Report.

From November through mid-February, the laser was down for necessary maintenance, and the installation of several modifications and improvements, described below. We re-instituted experiments in mid-February and have already tested several new diagnostics, in addition to new laser-target parameter variations. These will be reported in the near future.

PHAROS II LASER: In November the modified pieces for the 67 mm amplifier were in hand, and allowed us to determine if the improved sealing would substantially eliminate the low spatial frequency disturbances on the laser beam. The experiment was totally successful and we have installed this modified amplifier in our laser chain. The improved sealing technique is also used in the 105 mm amplifier design.

The remainder of November was devoted to totally tearing down the glass laser system and the master oscillator for conversion to phosphate glass and Nd:YLF, respectively. The first Faraday rotator was replaced with a Pockels' cell. All amplifier heads were disassembled and indicated maintenance work performed. The conversion to Nd:YLF proved more difficult than expected for several reasons. The Quantel flashlamps aged prematurely and several iterations were required to obtain lamps that would trigger reliably. The oscillator lased on the 1.047 line instead of the 1.054 line; this was cured with a glan polarizer. And recently, a Corning treated tube was inserted in our final rod amplifier to allow more latitude in parasitic suppression.

Overall, the laser has been tuned up and has been operating since mid-February at an acceptable level of performance. Although individual components are not behaving yet as well as hoped for, the baseline operational level has been met.

LASER UPGRADE: The detailed design and fabrication of the laser upgrade components has been done by Commonwealth Technology, Inc. The cleaning and assembly of the 105 mm amplifier is in progress now, with the only missing component being the shaped reflector. The capacitor bank has been assembled and tested with a flashlamp to ensure that there are no electrical problems. The relay telescopes for the first beam will be delivered in mid-March, and should be operational by the end of the month.

Thus our effort is back on track after some delay caused by the delayed receipt of DOE funding. At the present time the most realistic schedule for the upgraded system appears to be for operation of the first beam at 300-500 joules in mid-April, and operation of the second beam 45-60 days later.

1730-11.925.15
24 APR 1979

Dr. Gregory Canavan
Director
Office of Inertial Fusion
U.S. Department of Energy
Washington, D.C. 20545

Dear Dr. Canavan:

Please find forwarded herewith the IRL Progress Report for March 1979 in accordance with the Interagency Agreement between IRL and DOE.

Sincerely,

Timothy P. Coffey
Superintendent
Plasma Physics Division
By direction of the Commanding Officer

Encl.

Copy to: Dr. R. Schriever
Dr. John L. Emmett
Dr. Moshe Lubin
Dr. Henry Gomberg
Mr. Rex Purcell
Dr. Roger B. Perkins
Dr. Sheldon K. Kahalas
~~Dr. Jay S. Pearlman~~
Dr. Gerold Yonas

NRL LASER FUSION

PROGRESS REPORT

MARCH 1979

INTERACTION EXPERIMENTS: We are continuing our experiments on the acceleration of disc targets. Three series of experiments were run in March. First, we time-resolved the bremsstrahlung emission from the cold back surface, to obtain a temperature measurement of the accelerated material. Excellent resolution was obtained using five spectral components, each about 4A wide, in the region from 3600 A to 6000 A. Typically, we found a temperature of 7000°K on the back surface of a 7 micron thick aluminum target irradiated at 10^{13} W/cm^2 . This data provides additional evidence for ablative acceleration, and information on the adiabat of the accelerated material.

Second, additional experiments were performed with our doppler-shift diagnostic of the rear surface, with improved spatial resolution. This data is now being reduced. Third, we have performed preliminary experiments on another Rayleigh-Taylor diagnostics using a new light-scattering technique.

THEORY: Our ray-retrace theory of stimulated scatter has now been complemented by a computer code. The code uses Maxwell's equations (in a 2-D diffusion approximation) for the pump and scattered waves, and includes effects such as density profile modification of the plasma, self-focusing, and filamentation.

We recently used this computer code to analyze the two types of stimulated scatter experiments. In the NRL experiments, the target was placed in or near the focal plane, and the backscatter showed a good ray-retrace effect. In the LLL experiment the target was placed out-of-focus, nearer to the lens, and the backscatter was over a relatively large solid angle. We

recently used our computer code to study both experimental conditions, and, as expected, we were able to fit both types of experiments. These calculations are now being written-up for publication.

LASER SYSTEMS: We have performed tests on a tube of the new Corning antireflection treated pyrex, as a means of suppressing parasitic oscillations in our rod amplifiers without the use of very corrosive liquids. The tests were successful, and will allow us to use ethylene glycol instead of the zinc chloride-samarium chloride solution.

The first 10.5 cm disc amplifier and the first two beam relays were in the final fabrication phase in March, with operation planned in April.

6730-145:SEB:ls
22 JUN 1979

Department of Energy
Office of Inertial Fusion
Dr. Gregory Canavan
Washington, D.C. 20545

Dear Dr. Canavan:

Please find forwarded herewith the NRL Progress Report for April-May 1979 in accordance with the Interagency Agreement between NRL and DOE.

Sincerely,

Timothy P. Coffey
Superintendent
Plasma Physics Division
By direction of the Commanding Officer

Enclosure

Copy to: Dr. R. Schriever
Dr. John L. Emmett
Dr. Moshe Lubin
Dr. Henry Gomberg
Mr. Rex Purcell
Dr. Roger B. Perkins
Dr. Sheldon L. Kahalas
Dr. Gerold Yonas
Mr. John Ruckolls

NRL LASER FUSION

PROGRESS REPORT

APRIL-MAY 1979

INTERACTION EXPERIMENTS: Hydrodynamic acceleration studies on disc targets, rather than spherical targets, have the advantage that one can diagnose the cold rear surface. We have successfully developed a number of diagnostics that temporally probe the rear surface spatial structure, velocity profile, and temperature. With these diagnostics, we can evaluate hydrodynamic efficiencies, symmetry and stability requirements, adiabaticity, spall, etc. However there is the corresponding disadvantage of edge effects when a disc target is used. In our experiments last fall, we observed these edge effects: lateral heat transport, and extra ablated mass. As a result, in our current April-May series of experiments, we concentrated on an investigation of these edge effects.

One way to reduce edge effects is to use a limited mass disc target, rather than accelerating a section of a wide plasma foil. We have compared wide foils with limited mass disc targets of varying diameter and material. Two types of disc mounting were tried: fine glass wires ($2-5\mu$) and thin membranes ($500\text{\AA}$). For all types of disc targets with diameter less than 600 microns, we have found, so far, an energy flow ($\sim 20\%$) around the disc to the rear side. This energy flow did not occur for targets greater than a millimeter. (Diagnostics in this series included charge collectors, mini-calorimeters, multiple-frame interferometry, and ballistic pendula.)

Edge effects are not a basic limitation on planar target experiments, but we have demonstrated their nuisance value. This summer, with our upgraded system, we will make a final decision as to which target geometry will minimize edge effects: mm-sized discs or wide foils.

We have also brought several new diagnostics on line. We can now take two separate shadowgraphy frames on a single shot, with the two frames separated by any desired time interval. On the same shot, we also obtain a high resolution shearing plate interferometry picture. This diagnostic is unique in that not only are the three pictures all taken on one laser shot, but they also go through the identical optical path. (The system utilizes a polarization-dependent beamsplitter). In addition, we are now scattering the probe beam off the rear surface for spatial perturbation measurements. And, finally, arrays of ballistic pendula are now being used for momentum distribution measurements.

LASER PHYSICS: The new 10.5 cm disc amplifier was operated in April, as planned. Two types of phosphate glasses, one disc of each, were tested at 150 kilojoules of pump energy. For EV-2, with 2% doping, we obtained an equivalent 6-disc small signal gain of 17.8. For Q-88, with 3% doping, we obtained 22.6. Both of these glasses are within our design specifications for the Pharos II upgrade. (The transverse αD values were 2.9 and 3.1, respectively). No rolloff in efficiency with pump energy was seen, consistent with earlier NRL data on the 67 mm disc amplifier; this is in contrast with the roll-off seen when pumping with cerium-doped lamps. Saturation fluxes with 3 nsec laser pulses were 2.3 and 2.8 joules/cm², respectively.

Final alignment of the upgraded system is now underway.

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C. 20375

IN REPLY REFER TO:

7 March 1979

6730-60 SB.TID

Dr. Richard L. Schriever
Acting Director
Office of Inertial Fusion
U.S. Department of Energy
Washington, D.C. 20545

Dear Dr. Schriever:

Please find forwarded herewith the NRL Progress Report for August 1978/February 1979 in accordance with the Interagency Agreement between NRL and DOE.

Sincerely,

Timothy P. Coffey
Superintendent
Plasma Physics Division
by direction of the Commanding Officer

Encl.

Copy to: Dr. Gerold Yonas
Dr. John L. Emmett
Dr. Moshe Lubin
Dr. Henry Gomberg
~~Lt. Col. E.D. Braunschweig~~
Mr. Rex Purcell
Dr. Roger B. Perkins
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Dr. Jay S. Pearlman

**DATE
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8 / 16 / 93

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