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Progress Report to DOE
Inertial Confinement Fusion Program
Naval Research Laboratory
Washington, DC 20375

FY 1988

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II. FY88 ACCOMPLISHMENTS

The FY88 research closely followed the agreed-upon work statements. There were two major series of experiments in FY88; one was very successful and one was not successful.

The successful experiments studied the effect of ISI on the Raman instability using half-micron laser light, and compared these results with earlier NRL studies with one micron laser light. We showed for the first time anywhere that Raman experiments and theory are in agreement if one uses ISI optics.

The unsuccessful experiment attempted to measure the growth rate of the Rayleigh-Taylor instability using half micron laser light.

The theoretical and computational program included a detailed study of the effect of ISI upon the early-time mass perturbations of a target that demonstrated that the Japanese random phase plate will destroy an accelerated target; our computer codes were extended to include multigroup x-ray propagation and we showed that this provided additional stabilization of the Rayleigh-Taylor growth; a detailed study of the coupling between the acceleration RT and the deceleration RT showed that mix was much less dangerous than commonly assumed; a study of pellet symmetry showed that small kilojoule laser facilities will require at least 24 beams for a uniform implosion; we completed development of the first large 3D hydrodynamic code with high resolution; and we continued our effort to develop an improved analytic theory of the ablative stabilization of the RT instability.

A. Raman Instability Experiments: Although there has been a great deal of progress in previous years to understand and control the Raman instability, there has been no detailed agreement between the traditional convective theoretical model and the experimental thresholds, with the experimental thresholds much less than the theoretical prediction when one uses low-Z targets. This could have a serious impact on the success of an LMF direct-drive pellet, since the predictions of success are based upon the use of the standard convective model. This year NRL found that the experimental and theoretical predictions for convective Raman backscatter were in agreement if one uses ISI optics and modifies the theory to include the statistical fluctuations in intensity that occur with ISI. This is the first such agreement between the standard convective-amplifier model of Raman scatter and experiment in the history of the laser fusion program. We have detailed experimental data on the convective Raman backscatter with both one-half and one micron laser light, with and without ISI. The amount of backscatter is also much less with ISI than with an ordinary laser beam with hot spots. We

believe that this reduction of Raman scatter occurs because ISI controls hydrodynamic profiles, probably preventing laser light filamentation in the plasma. The basis for this view is that broadband ISI reduces the Raman while narrowband ISI does not. Since the broadband ISI still has a bandwidth that is less than the Raman growth rate, the reduction must be due to an effect on the hydrodynamics. These experiments provide support for the predictions of our theoretical study last year that ISI with a short laser wavelength is both necessary and sufficient to control the filamentation instability. We also have substantial new data on other backscatter emissions, from SBS etc., that we are still reducing.

B. Rayleigh-Taylor Instability Experiments: Approximately two months were spent trying to measure the growth rate of the Rayleigh-Taylor instability with half-micron laser light. Although we were very successful in previous experiments, these FY88 experiments failed because of a large series of technical problems with both the laser and the target diagnostics. We stopped the experiment and re-evaluated our experimental approach and project management. We believe that there is a very good chance for success in the next set of experiments planned for early in FY89.

C. Rayleigh-Taylor Computations

1. In a major computational study, we examined the influence of ISI and the random phase plate upon the growth of the Rayleigh-Taylor mode. Our concern was that during the first nanosecond of the laser pulse there is very little plasma corona to smooth out the rapid spatial and temporal fluctuations in these "smooth" laser beams, and therefore that the residual nonuniformities would imprint on the target. We found that the random phase plate causes a gross distortion of the target and drives a large amplitude RT mode that breaks the target shell. Thus the random phase plate, invented by the Japanese and used by Rochester, is therefore inappropriate for smooth hydrodynamic acceleration of targets. With ISI we found that the acceleration was much better, but not as good as desired. In FY89 we will investigate various physical phenomena that can provide additional smoothing with ISI.
2. Previously, our 2D codes did not contain detailed multigroup x-ray propagation. In FY88 we added this physics to our codes and found

- that the x-rays increased the mass ablation rate for direct drive targets. The higher ablation then led to additional stabilization of the RT growth rate. This further improves the prospects for an LMF with direct drive.
3. Previous studies by most other laboratories of Rayleigh-Taylor during deceleration -- the so-called mix problem -- have used a model in which the pellet shell has sharply defined outer and inner edges; we call this the "flying door model". In fact of course the shell is not sharply defined and has a smooth density gradient on its inner surface that gradually decreases to a low density. In FY88 we used our 2D eulerian sliding zone code to study the deceleration and mix of a shell that has realistic density gradients. We found that the density gradient buffers the outer "ablative" RT instability from the inner "mix" RT instability. The mix is therefore much less deleterious than had been previously assumed. This major result will have favorable implications for all types of driver-pellet ICF concepts.
  4. Laboratories in England and France are proposing new direct drive implosion facilities with the use of only 6 or 12 laser beam lines. As a follow-on of our earlier study of LMF-sized pellets, this year we studied the potential of kilojoule lasers to produce uniformity on a pellet. We found that 6 or 12 beams did not produce good uniformity, and that 24 beams were necessary for symmetric implosions. This work has been written up and will be distributed to the European labs soon.
  5. All computational studies of RT so far have used 2D codes. There is a real possibility that the physics is actually three-dimensional, especially during the deceleration phase. This year we successfully completed development of a large 3D code for RT physics; this code also has a large variety of graphic diagnostics to interpret the results of the calculation. The code requires a Cray 2 computer. In FY89 we will utilize this new code for studies of 3D Rayleigh-Taylor physics.
  6. Work is continuing on an improved analytic model of Rayleigh-Taylor with ablation. Although the work has not been completed in FY88, we hope to have results in FY89.

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