LA-UR-98-4600

Title: THE APPLICATION OF 2-D SIMULATIONS TO Z-PINCH EXPERIMENT DESIGN AND ANALYSIS

Author(s): D. L. Peterson, R. L. Bowers, W. Matuska,
G. A. Chandler, C. Deeney, M. S. Derzon, M. K. Matzen,
R. C. Mock, T. J. Nash, T. W. L. Sanford
R. B. Spielman, and K. W. Struve

Submitted to: Megagauss VIII Conference, Tallahassee, FL
October 1998

Los Alamos
NATIONAL LABORATORY

DISCLAIMER

The Application Of 2-D Simulations To Z-Pinch Experiment Design And Analysis*

D. L. Peterson, R. L. Bowers and W. Matuska
Los Alamos National Laboratory

G. A. Chandler, C. Deeney, M. S. Derzon, M. K. Matzen,
R. C. Mock, T. J. Nash, T. W. L. Sanford,
R. B. Spielman and K. W. Struve
Sandia National Laboratories, Albuquerque

Abstract

The successful 2-D simulations of z-pinch experiments (reproducing such features as the measured experimental current drive, radiation pulse shape, peak power and total radiated energy) can lead to a better understanding of the underlying physics in z-pinch implosions and to the opportunity to use such simulations in the analysis of experimental data and in the design of new experiments. Such use has been made with LANL simulations of experiments on the Sandia Saturn and Z accelerators. Applications have included "vacuum" and "dynamic" hohlraum experiments; variations in mass, radius and length; and "nested" array configurations. Notable examples include the explanation of the power/length results in reduced length pinches and the prediction of the current best power and pulsewidth nested array experiment. Examples of circumstances where the simulation results do not match the experiments will be given along with a discussion of opportunities for improved simulation results.

Introduction

Two-dimensional simulations of hollow z-pinches have been successful in reproducing important experimental results on a variety of machines, loads, currents and timescales.[1] As an illustration of the utility of such simulations in experiment design, analysis and interpretation, we consider here experiments in a series leading to dynamic hohlraum (DH) designs (where a tungsten plasma shell strikes an on-axis target cylinder of foam which may have a gold coating).[2]

Experiments Without a Central Target

Two-dimensional simulations of experiments for pinches 2-cm and 1-cm long provided an explanation for the result that the energies radiated in both cases were nearly the same, and that the 1-cm pinches had higher-than-expected powers.[3] In addition, simulations by Douglas, et al, have indicated, and experiments subsequently confirmed that reduced pulsewidths could be obtained by the use of nested arrays.[4] Two 1-cm long experiments, Z-104 with a single

---

* Work supported by US Department of Energy.

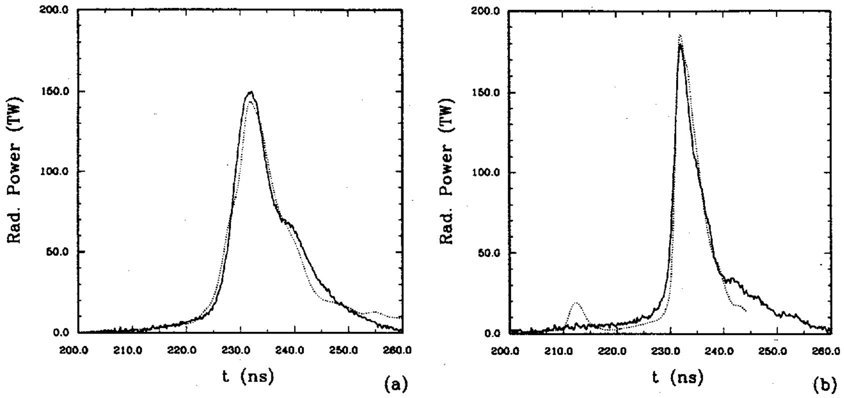

Figure 1. Measured side-on radiation power (solid) and 2-D simulation (dotted) for: (a) Z-104 (single array) and (b) Z-215 (nested arrays).

array, and Z-215 with nested arrays, were conducted and employed as the baseline loads for later DH experiments. The side-on (radial) radiation powers along with the results from 2-D simulations are shown in Fig. 1. An example of a difference between simulation and experiment can be seen in Fig. 1b, which shows a radiation pulse associated with the collision of the nested arrays while the measured result does not. Nonetheless, these simulations gave good overall agreement with measured currents, timings, peak powers, pulsewidths and shapes as well as total radiated energy.

DH Experiments

The DH experiment Z-112 gave promising if somewhat puzzling results. Using the Z-104 simulation as a starting point, the 2-D simulation of Z-104 indicated that the large on-axis electrode aperture could be expected to allow the tungsten plasma to blow past the end of the CH obscuring the end-on view of the foam as illustrated in Fig. 2a. This conclusion was consistent with end-on images of the foam which showed an early-time bright spot on-axis. Subsequently, the simulations were employed to redesign the electrode, including a 3° inward slope and smaller aperture size as shown in Fig. 2b. Experiment Z-216, employing these changes, showed improved performance without any indication of tungsten obscuration of the view of the foam.

As can be seen by comparing Figs. 1a and 1b, we should be able to expect improved performance for DH targets driven by plasmas from nested arrays as the rise time is shorter and the peak power is higher for these loads. The simulations indicated that instability growth at the time of impact on the DH target in the nested array load would be considerably less than that for the single array and this would create a more uniform hohlraum with higher radiation temperatures. Two DH experiments, Z-258 (6 mg/cc CH coated with 0.6 μm of

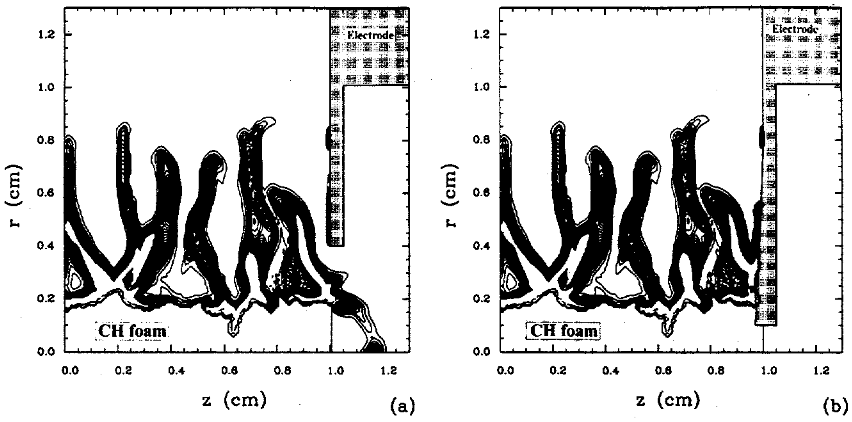

Figure 2. 2-D simulation tungsten density contours impacting the CH foam target: (a) Z-112 with a large aperture and (b) Z-216 with the re-designed aperture and electrode.

Au), and Z-255 (uncoated 6 mg/cc CH) are compared here to the predictions created by including these DH targets into the simulation used to match Z-215.

The on-axis power during the DH time period (after the plasma has struck the DH target but before the combined tungsten and target final pinch on-axis: about t=225 to 237 ns in Fig. 3) is shown for Z-258 and the 2-D simulation in Fig. 3a. Uncertainties exist in both the simulation and experimental powers at the final pinch time (after t=240 ns in Fig. 3) due to material jetting through the on-axis aperture. The side-on radiation pulse shape and timing is compared with that of the simulation in Fig. 3b. No reliable determination has been made for the absolute scale of this power, so the results have been normalized to show a

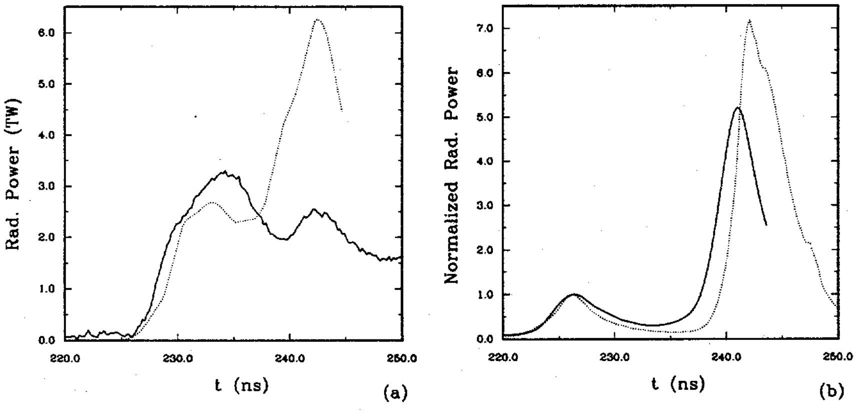

Figure 3. Radiation powers, measured (solid) and 2-D simulation (dotted) for Z-258 (Au coated CH): (a) absolute end-on and (b) normalized side-on.

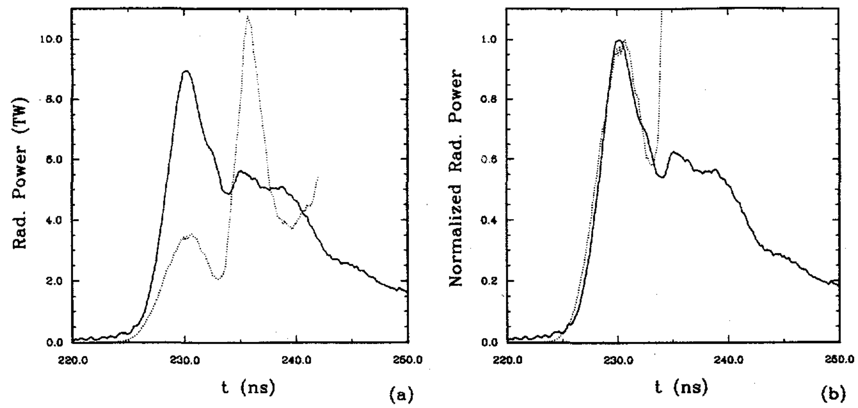

Figure 4. End-on radiation power for Z-258 (uncoated CH), experimental (solid) and 2-D simulation (dotted): (a) absolute scale and (b) normalized.

value of 1.0 for the first peak of the plasma strike on the foam, as the dynamic hohlraum is created. Reasonable agreement in pulsewidth, shape and timing can be seen. There is also a reasonable agreement in pulsewidth and shape in the final peak, though the timing is off by about 1 ns and the relative of size of the first and second peaks are different for the experiment and simulation.

Side-on data was saturated for Z-255, but a comparison of end-on data is shown in Fig. 4. As can be seen in Fig. 4a, the simulation does indicate a small increase in end-on power for the uncoated foam target but the experimental value increased by much more. In Fig. 4b, the normalized first peaks of the end-on power are seen to be similar in shape and duration.

Conclusions

The examples shown here indicate the usefulness of 2-D simulations in interpreting and understanding experimental data, and enhancing results by using the 2-D code as a design tool. Such codes allow some predictive capability (as seen in the improvement of nested vs single wire arrays) though in other cases, the codes may only indicate trends (as seen in the comparison of end-on powers for coated vs uncoated foam DH experiments). Though much room for improvement remains, the combination of experiments and simulations has been fruitful in improving results and in understanding the underlying z-pinch physics.

References

1. Peterson, et al, *Phys. Plasmas* **3**, 368 (1996); Matuska, et al, *Phys. Plasmas* **3**, 1415 (1996); Peterson, et al, *Phys. Plasmas* **5**, 3302 (1998).
2. Brownell, et al, *Phys. Plasmas* **5**, 2071 (1998).
3. Deeney, et al, *Phys. Plasmas* **5**, 2605 (1998).
4. Deeney, et al, "The enhancement of x-ray powers from a z-pinch using nested wire arrays," accepted for publication in *Phys. Rev. Lett.*