Conf-9409226--3

TITLE: Effects of Plasma Physics on Capsule Implosions in Gas-Filled Hohlraums

AUTHOR(S): Erick L. Lindman, Norman D. Delamater, Glenn R. Magelssen, Allan Hauer

SUBMITTED TO: Proceedings of the 23rd European Conference on Laser Interaction with Matter
Oxford, U.K.
12-23 September 1994

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

MASTER

Effects of plasma physics on capsule implosions in gas-filled hohlraums

E L Lindman, N Delamater, G Magelssen, A Hauer

Los Alamos National Laboratory, Los Alamos, NM 87545 USA

Abstract. Initial experiments on capsule implosions in gas-filled hohlraums have been carried out on the NOVA Laser at Lawrence Livermore National Laboratory. Observed capsule shapes from preliminary experiments are more oblate than predicted. Improvements in modeling required to calculate these experiments and additional experiments are being pursued.

1. Introduction

Capsule-implosion symmetry experiments in gas-filled hohlraums at NOVA are needed to support proposed ignition targets for the National Ignition Facility which are gas-filled to suppress spot motion and help control symmetry. In unlined gold hohlraums the region of the wall heated by the laser (laser hot spot) moves substantially. When this motion is excessive, it interferes with the achievement of the required capsule-irradiation symmetry. This motion can be controlled by placing a thin plastic liner on the inner surface of the hohlraum or by filling it with gas. The plastic liner reduces the wall motion but generates a pressure spike on the axis which destroys the symmetry of the capsule implosion through hydro coupling.

Gas-filled hohlraums are currently preferred because gas fill reduces the wall motion and avoids the hydro-coupling asymmetries. Design calculations suggest that the desired results can be achieved with 1 mg/cm^3 of helium or an equivalent equimolar mixture of helium and hydrogen. When fully ionized this initial gas fill has an electron density of $n_e = 0.033n_{crit}$. Subsequent motion of the walls and capsule ablater raise the electron density in some regions to values approaching quarter critical.

2. NOVA Experiments

The capsule-implosion-symmetry experiments were carried out in scale-1 hohlraums with standard capsules. A scale-1 hohlraum has a diameter of 1650 μm and lengths between 2100 and 2800 μm. The laser entrance holes (LEH) at the ends of the cylindrical hohlraum have diameters of 75% of the hohlraum diameter. The hohlraums were unlined and filled with 1 atm of either neopentane, propane or methane held in by a 0.6 μm thick Mylar window. Hohlraums with lengths between 2300 and 2700 μm were used with laser pointing from 1125 to 1325 μm such that the laser beams entered at the center of the LEH's.

A "standard" capsule has an inner radius of 220μm and a total wall thickness of 55 μm made up of an inner layer of polystyrene of thickness 3.5 μm, an intermediate layer of PVA of thickness 2.5 μm and an outer layer of CH of thickness 49 μm. 28.5 kJ was delivered to the target using "pulse shape 22" which consist of 1.5 ns foot followed by 1 ns main pulse with a contrast ratio between two and three.

The targets that have been shot are shown in Table 1. The 20 μm thick "symcap" included in Table 1 was a thinner-walled capsule designed to implode faster and thus sample the earlier part of the pulse. It performed as expected.

Table 1: Capsule-shell thicknesses in a gas-fill-vs-pointing array for shots that have been completed.

Gas at 1 atm.	n_e/n_c	ρ [mg/cc]	N-pentane pr. (atm) at same ρ	Capsule at 1125 μm pointing	Capsule at 1225 μm pointing	Capsule at 1325 μm pointing
N-pentane C_5H_{12}	0.126	3.2	1.0	55 μm	55 μm 55 μm	55 μm
Propane C_3H_8	0.077	2.0	0.62	55 μm	20 μm	
Methane CH_4	0.030	0.72	0.22	55 μm		

3. Data and analysis

A typical sequence of images seen by the gated-X-ray-imaging camera is shown in Fig. 1. Time goes from right to left, and the images are separated by about 65 ps. An expanded view of the brightest image at peak compression is shown, and the half-intensity contour used to calculate its eccentricity is drawn in. The cylindrical axis is horizontal and the eccentricity is defined as the length of the vertical semi-major axis divided by that of the horizontal semi-major axis. Using this definition, oblate spheroids ("pancakes") have an eccentricity greater than 1, and prolate spheroids ("sausages") have an eccentricity less than 1. This image has a calculated eccentricity of 1.52.

Experimental and calculated eccentricities are compared in Table 2. The calculations are 2-D cylindrical and include self-consistently the laser deposition, the dynamics of the window that holds the gas in the hohlraum, the gas itself and the wall of the hohlraum as well as the capsule implosion. The energy was deposited using only inverse bremstrahlung for absorption, and no scattering mechanisms were included. The lack of a consistent trend in the experimental data with either pointing or gas density sug-

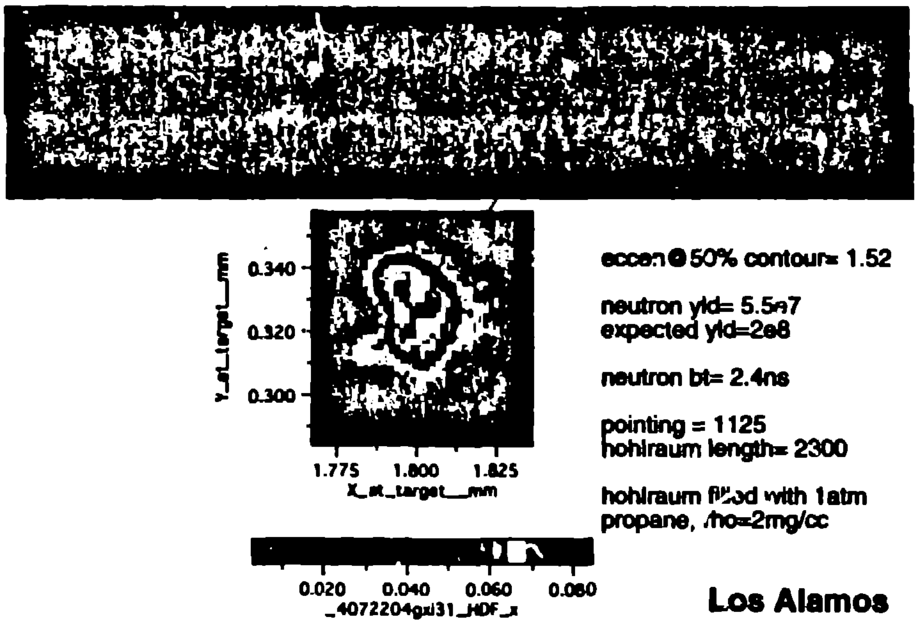

Figure 1: Gated x-ray images of a capsule imploded in propane.

gests that additional experiments with improved procedures and/or diagnostics should be pursued.

The disagreement of the calculated eccentricities with the experimental values is, however, persistent and large enough to suggest that a discrepancy exists between modeling and experiment. A value of $f_e = 0.05$ was used for the electron thermal-flux limiter in these calculations. This choice has been used successfully in the modeling of implosion symmetry in evacuated hohlraums [1]. Since the value of the electron thermal-flux limiter has been chosen in the past to obtain better agreement between theory and experiment, its change is a reasonable thing to try to improve the agreement here.

Table 2: Comparison of observed eccentricities with those calculated with an electron flux limiter of $f_e = 0.05$ and with enhanced electron thermal conductivity in parenthesis.

Gas at 1 atm.	Eccentricities at 1125 μm pointing		Eccentricities at 1225 μm pointing		Eccentricities at 1325 μm pointing	
	Exp.	Theor.	Exp.	Theor.	Exp.	Theor.
N-pentane C_5H_{12}	2.2	0.75 (1.20)	2.2	1.6 (1.8)		2.9 (2.4)
Propane C_3H_8	1.5	0.72 (0.93)				
Methane CH_4	2.1	0.61 (0.92)				
Vacuum No window	0.59	0.67				

Consequently, a series of calculations of the propane experiment was carried out in which the flux limiter was varied between 0.005 and 1.0. A consistent trend was obtained in which the eccentricity rose in value as the flux limiter approached 1. Unfortunately the largest value approached but did not agree with experiment. Since the trend was in the right direction, an additional increase in thermal conduction was included by increasing the diffusion coefficient by a factor of three. Again the calculation moved closer to the experimental values but agreement was not obtained.

The computed eccentricities obtained with a flux limiter of 1.0 and a factor of three enhancement of the diffusion coefficient are given in parenthesis in Table 2. A decrease in the discrepancy is obtained for the other cases as well, but the agreement is still not good.

4. Conclusions

With data from only seven shots, it may be premature to attempt to draw any conclusions. Additional experimental data is required and is currently being pursued. If the discrepancy between theory and experiment, seen in the data shown here, is supported by additional experiments, some changes in the modeling may be required. The inclusion of non-local thermal conduction models [2] may help. But other mechanisms, which redistribute the energy in the hohlraum, should be considered as well. Anomalous absorption which deposits the energy near the LEH is an example. Since only 100 J out of 28 kJ are seen experimentally in hot electrons, however, such mechanisms may be unimportant.

Stimulated Brillouin scatter over a range of angles is another possibility. Energy scattered into a backward cone would remain near the LEH and subsequent transport by thermal conduction or x-rays would make the imploded capsule more "pancake." Approximately 4% of the incident energy is scattered back into the laser optics for each beam in these experiments. The solid angle of one of the f4 beams is approximately .05 steradians. The additional solid angle in which the energy could scatter (4π steradians) is thus 260 times the backscatter solid angle Scattering into 4π at an average intensity of 1/10th the backscatter intensity would remove a significant fraction of the beam.

Acknowledgements

The authors would like to thank R. Berger, L. Powers, L. Suter, B. Wilde, J. Fernandez and W. Hsing for helpful discussions. The targets used in the experiments were fabricated by J. Moore, K. Gifford and M. Salazar. We would like to thank S. Evans, G. Peterson and J. Jimmerson for their help with the diagnostics as well and the NOVA operations staff for their help in carrying out the experiments.

References

[1] Hauer A, Delamater N, Hsing W, Ress D, Suter L, Powers L, Harris D, Landen O, Thiessen R, Phillion D, Amendt P, Magelssen G, Watt R and Hammel B 1993 *Bull. Am. Phys. Soc.* **38** 1884

[2] Luciani J F, Mora P and Virmont J 1983 *Phys. Rev. Lett.* **51** 1664