Proof-of-Principle Hohlraum Experiments

During a two-week period in June 1996 researchers from LANL, LLNL, and LLE performed experiments to demonstrate the utility of OMEGA for indirect drive. The main objectives of these experiments, which were all accomplished, were to verify the ability of the OMEGA system to perform hohlraum experiments, to reproduce results obtained with the Nova laser, and to demonstrate new capabilities not available on other lasers.

A total of 42 shots were taken, and the target performance was diagnosed using six x-ray pinhole cameras, two x-ray microscopes, three x-ray framing cameras, DANTE (time-resolved, absolutely calibrated soft x-ray emission), neutron yield and neutron time-of-flight detectors, a single-hit neutron detector array, and a number of other laser and plasma diagnostics. This represents one of the largest arrays of diagnostics ever fielded on a hohlraum target campaign to date.

These experiments took advantage of a number of capabilities recently added to OMEGA including pulse shaping and a new 10-in. manipulator (TIM 4). The experiments were also the first on OMEGA to simultaneously use three framing cameras. Most of these experiments were carried out using 1-ns square pulses, with 500 J per beam delivered to the target. A small number of shots were taken for pointing tests using 160-ps Gaussian pulses, with a peak power of ~0.5 TW per beam.

The targets consisted of thin-wall Nova "scale-one" hohlraums[1] mounted at an angle to the stalk of 63.4° (as opposed to 90° on Nova). The hohlraums were of 2100- to 2800-μm inside length and 1600-μm inside diameter. The walls were made of 100 μm of epoxy with a gold lining. The gold thickness was 1 μm for the pointing shots on the first shot day, but 2 μm for the rest of the shots. The laser entrance holes (LEH's) were 1200 μm in diameter except for two shots that had 900-μm-diam LEH's.

The beams were arranged in three beam cones on each side of the hohlraum, consisting of five, five, and ten beams, respectively, centered on a pentagonal diagnostic port. The half-angles of the beam cones were 21.42°, 42.02°, and 58.85° (see Fig. 68.1). (A fourth beam cone of half-angle 81.25° was not useful for these experiments since these beams cannot make it

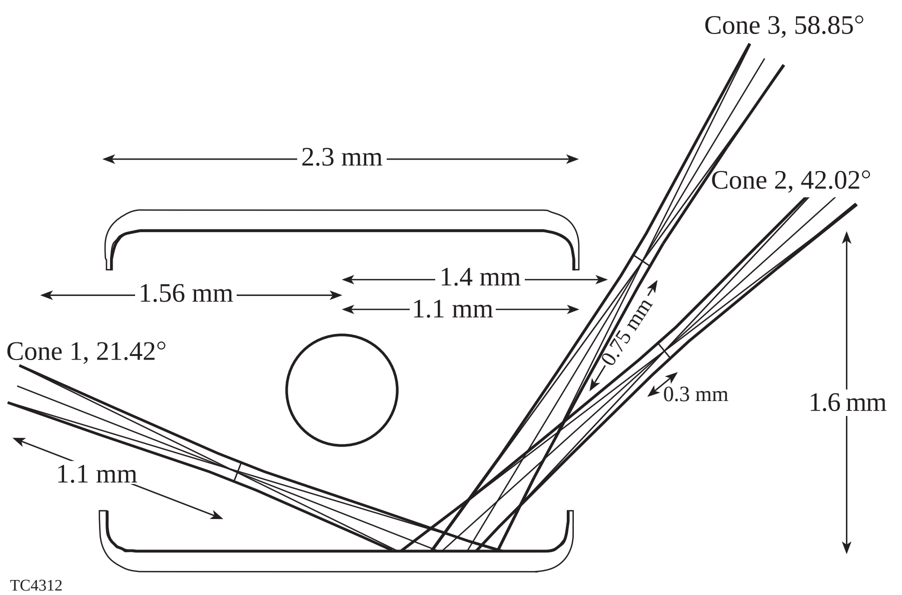

Figure 68.1
Target design and typical beam pointing for the first set of indirect-drive experiments on OMEGA.

through the LEH for cylindrical hohlraums.) Experiments were performed with some or all of the beam cones. Cones 2 and 3 were used for most experiments, with cone 1 used for a few as well. For diagnostic reasons, the hohlraums were aligned along two different axes (each passing through the centers of a ring of five beams) during the experiments.

The positions of the beams were specified by the distance from the center of the hohlraum to the point where the beams cross the axis of the hohlraum. This is referred to as the beam pointing. The focusing of the beams is referenced to that crossing point. If the best focus position is moved back toward the lens, then the defocusing is negative; if it is moved away from the lens, the defocusing is positive. The defocusing distances for these shots were set so that a beam containing 650 J would give about 10^{15} W/cm^2 on the wall of the hohlraum (Table 68.I), i.e., comparable intensities to those on Nova. The pointing was initially verified with two-sphere pointing targets consisting of two 1588-μm-diam plastic spheres coated with about 1 μm of gold (Fig. 68.2). For most of these shots, the spacing between the centers of the spheres was 2200 μm. The centers of the spheres corresponded to the pointing of cone 3 for the majority of the experiments. As a test of "dead reckoning" pointing, one two-sphere target with 2800-μm spacing was also shot after moving the beam pointing 300 μm for each beam cone.

The main purpose of the first series of experiments was to verify the ability of the system to point the beams. A short

Table 68.I Beam cone angles and defocusing distances.

	Cone Angle	Defocus
Cone 1	21.42°	+1100 μm
Cone 2	42.02°	–300 μm
Cone 3	58.85°	–750 μm

(160-ps FWHM) Gaussian laser pulse was used to illuminate a 2300-μm-long hohlraum. The targets were imaged with pinhole cameras from six locations allowing the beam positions to be verified. The results (see Fig. 68.3) indicated that the beams were pointed to their desired locations in the hohlraum to an accuracy of 30 μm.

The next series of experiments was a set of symmetry scans[2] to verify the same dependence of hohlraum symmetry on beam pointing as was obtained with previous experiments on Nova. Hohlraums with lengths varying from 2100 μm to 2500 μm were used with standard plastic symmetry capsules (440-μm inside diameter, 55-μm wall thickness, 50-atm D_2 fill, 0.1-atm Ar). Time-integrated hohlraum symmetry was determined from the distortion of the imploded core as measured by gated x-ray images.

In the first experiment, two of the beam cones were pointed in such a way that they formed a single ring of beam spots on the interior wall of the hohlraum. The results from OMEGA were consistent with results of similar Nova experiments.

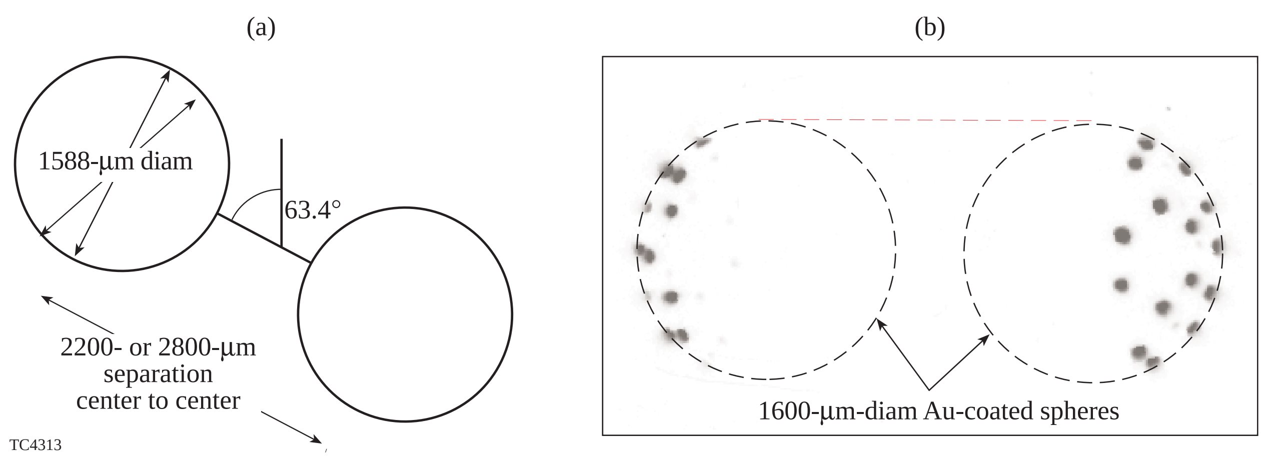

Figure 68.2
(a) Double-sphere pointing target used to verify beam pointing for indirect-drive experiments; (b) x-ray pinhole camera image from one such target.

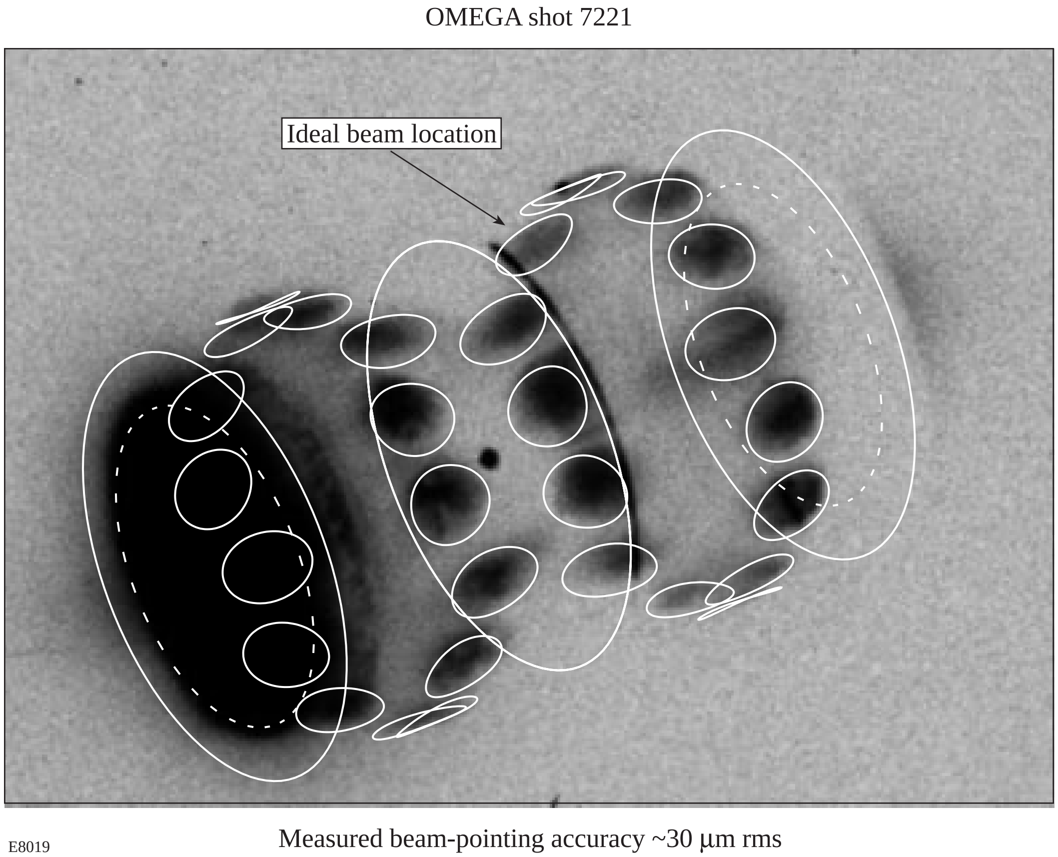

Figure 68.3
X-ray pinhole camera image of a thin-wall-hohlraum implosion target. The implosion core at the center of the hohlraum is clearly seen, as are the cut in the hohlraum midplane made when mounting the capsule, the beam spots, and the LEH on the left. The solid lines indicate the calculated locations of the laser spots, the LEH's, and the hohlraum midplane.

A different pointing scan was performed in which the pointing of beam cone 3 was held constant, while that of cone 2 was moved. A weighted spot position was then calculated, with the weight given by the number of beams in each ring and an inverse-square dependence on the distance to the center of the capsule. For one set of experiments, cone 1 was also added. The results (Fig. 68.4) indicate that, except for one experiment that utilized all three beam cones, the symmetry of the capsule is consistent with Nova results when the weighted spot position is used in place of the single-ring spot position from Nova experiments. Comparisons were also made when a simple model of spot motion[3] was included. Here, the wall was assumed to move inward by 150 μm, leading to motion of the spots toward the LEH for Nova and OMEGA cones 2 and 3, and toward the midplane of the hohlraum for OMEGA cone 1 [Fig. 68.4(b)].

Neutron yields were measured on all of the implosion experiments (Fig. 68.5) and found to be in agreement with yields from similar Nova experiments. Further, the dependence of yield on implosion symmetry was found to be similar for 15-kJ shots (a full scan was not carried out at 20 kJ). The highest yields were obtained for round (symmetric) implosions. When the drive was higher on the equator and a prolate implosion resulted, the yield dropped somewhat. A larger drop in the yield was seen in experiments with a pole-high drive resulting in an oblate implosion, consistent with Nova experiments.

A set of experiments were performed to measure the radiation drive produced in the hohlraum. For this purpose, a multichannel soft-x-ray spectrometer (DANTE) was moved from Nova to OMEGA. This spectrometer measured the flux exiting a diagnostic hole on the wall of the hohlraum and viewed an unilluminated portion of the interior wall of the hohlraum.

Several steps are necessary to reduce these data beyond those that are required to reduce Nova data. First, the thickness of the hohlraum wall must be included when calculating the apparent size of the diagnostic hole. The 100-μm thickness results in a "tunnel effect" when calculating the open area, which decreases the apparent hole size faster than a simple cosine dependence. In addition, since the diagnostic hole was not monitored with a framing camera for these experiments, the effects of hole closure must be calculated. The diagnostic holes on these targets were not lined since the wall was already made of a low-*Z* material (epoxy). However, the low-energy channels may have been affected by blowoff from the walls of the hole. The results for radiation temperature, including the "tunnel effect" and effects of hole closure, are still lower than expected from Nova results and simple scalings. A number of other effects must be considered, and detailed analysis is in progress.

One of the advantages OMEGA has over Nova is the increased azimuthal symmetry due to the larger number of beams. By using beam cones 2 and 3 with the beams pointed to cross the hohlraum axis and form a single ring of beam spots, one obtains a nearly uniformly spaced set of 15 beam spots on each

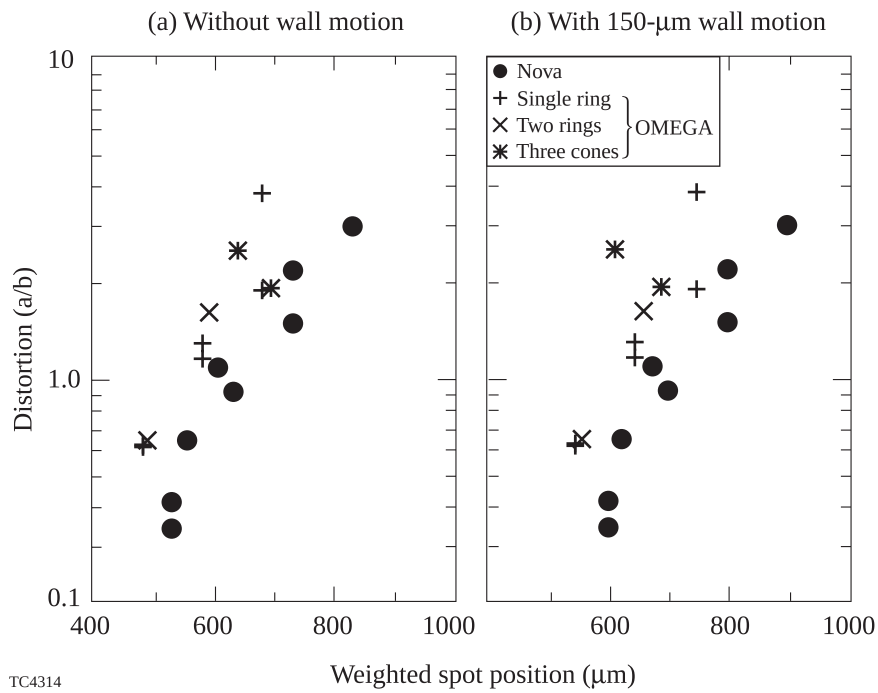

Figure 68.4
Distortion as a function of weighted spot position with and without a simple wall motion component included.

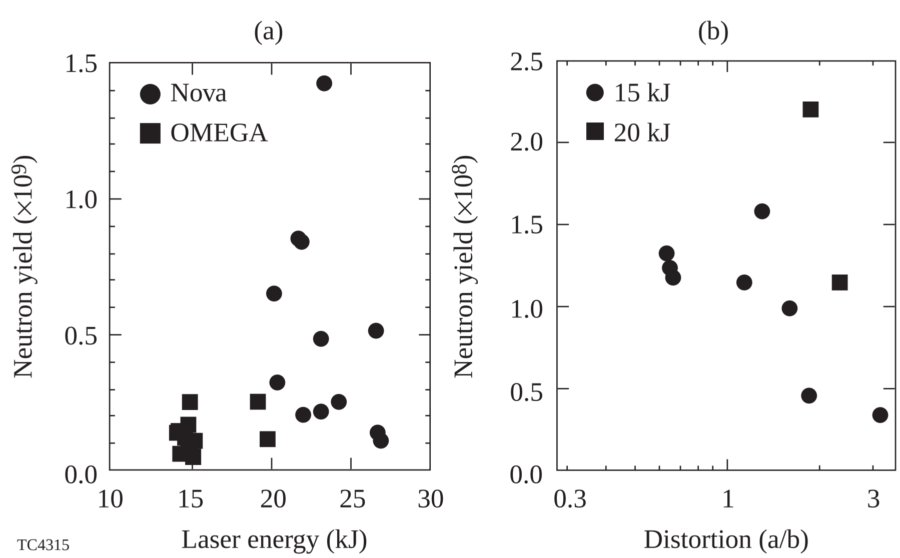

Figure 68.5
Yield as a function of (a) laser energy for OMEGA and Nova experiments, and (b) implosion distortion for OMEGA experiments. Neutron yields shown for the OMEGA experiments are approximate (±50%) and subject to change as a result of further calibration.

side of the hohlraum. Further, the rings on opposite sides are out of phase with each other so that a beam spot on one side of the hohlraum corresponds to a gap in the beams on the other.

A lack of comparable azimuthal symmetry on Nova, where there is a strong $m = 5$ beam pattern, may be responsible for some observed disagreements between Nova data and two-dimensional simulations. The $m = 15$ arrangement of the OMEGA beams offers the capability to test this hypothesis. Two sets of experiments were thus performed: one with the nominal $m = 15$ geometry, and the other with the beams moved to create an $m = 5$ geometry similar to that of Nova. A set of implosions were performed similar to the symmetry scans done previously. X-ray framing-camera imaging was, however, performed along the hohlraum axis. Preliminary inspection of the data shows that round implosion images were obtained in both cases. In the $m = 5$ case (Fig. 68.6) it is not possible to identify a clear $m = 5$ component in the radiation drive.

The $m = 5$ radiation pattern was also monitored with a reemission ball.[4] In these shots, a glass capsule coated with bismuth was substituted for the implosion capsule. As the bismuth heats up due to the impinging radiation from the hohlraum, it emits hard x rays in an amount dependent on its temperature. This method is particularly sensitive to early-time irradiation asymmetry. However, an image was obtained (Fig. 68.7) that again showed no clear $m = 5$ asymmetry.

An unanticipated feature of these experiments is the appearance of distinct stagnation features on the axis of the hohlraum. This stagnation is observable in the pinhole image in Fig. 68.3 but can be seen with greater clarity in the framing-camera images taken during the drive shots (Fig. 68.8). These are not usually seen on Nova and are attributed to the greater degree of symmetry available on OMEGA. Phenomena such as this will allow useful comparisons to be made with two-dimensional hohlraum simulations.

In summary, a wide range of indirect-drive experiments were successfully carried out on the OMEGA laser system. Results were generally consistent with the existing Nova database. Some of the experiments demonstrated unique features of the OMEGA system not available on Nova. Indirect-drive experiments will continue on an ongoing basis in collaboration with LLNL and LANL; those planned for the near future include beam phasing in cylindrical hohlraums and proof-of-principle experiments using tetrahedral hohlraums (see the following article).

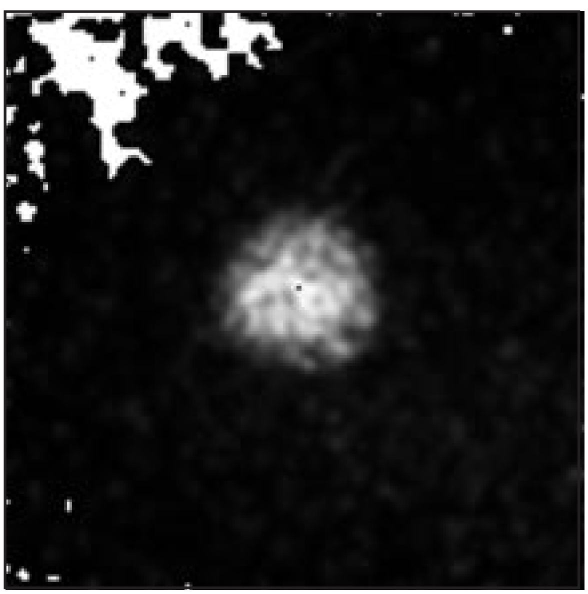

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Figure 68.6
Implosion image for an imposed $m = 5$ drive asymmetry, obtained from a framing camera viewing along the hohlraum axis.

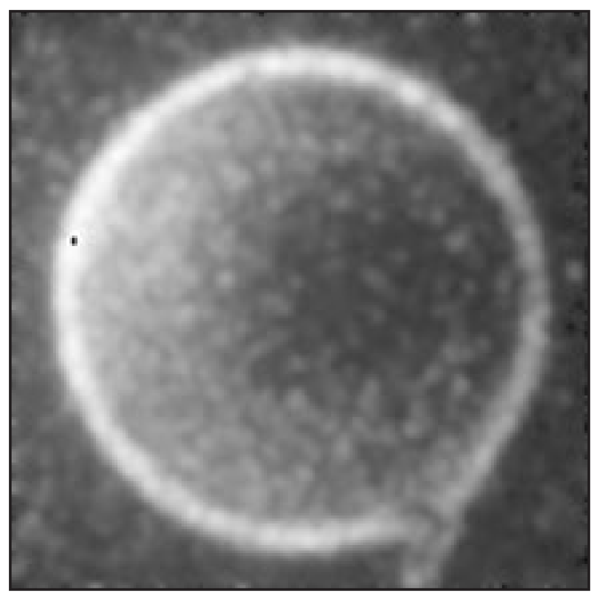

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Figure 68.7
Reemission image for an imposed $m = 5$ drive asymmetry, obtained from a framing camera viewing along the hohlraum axis.

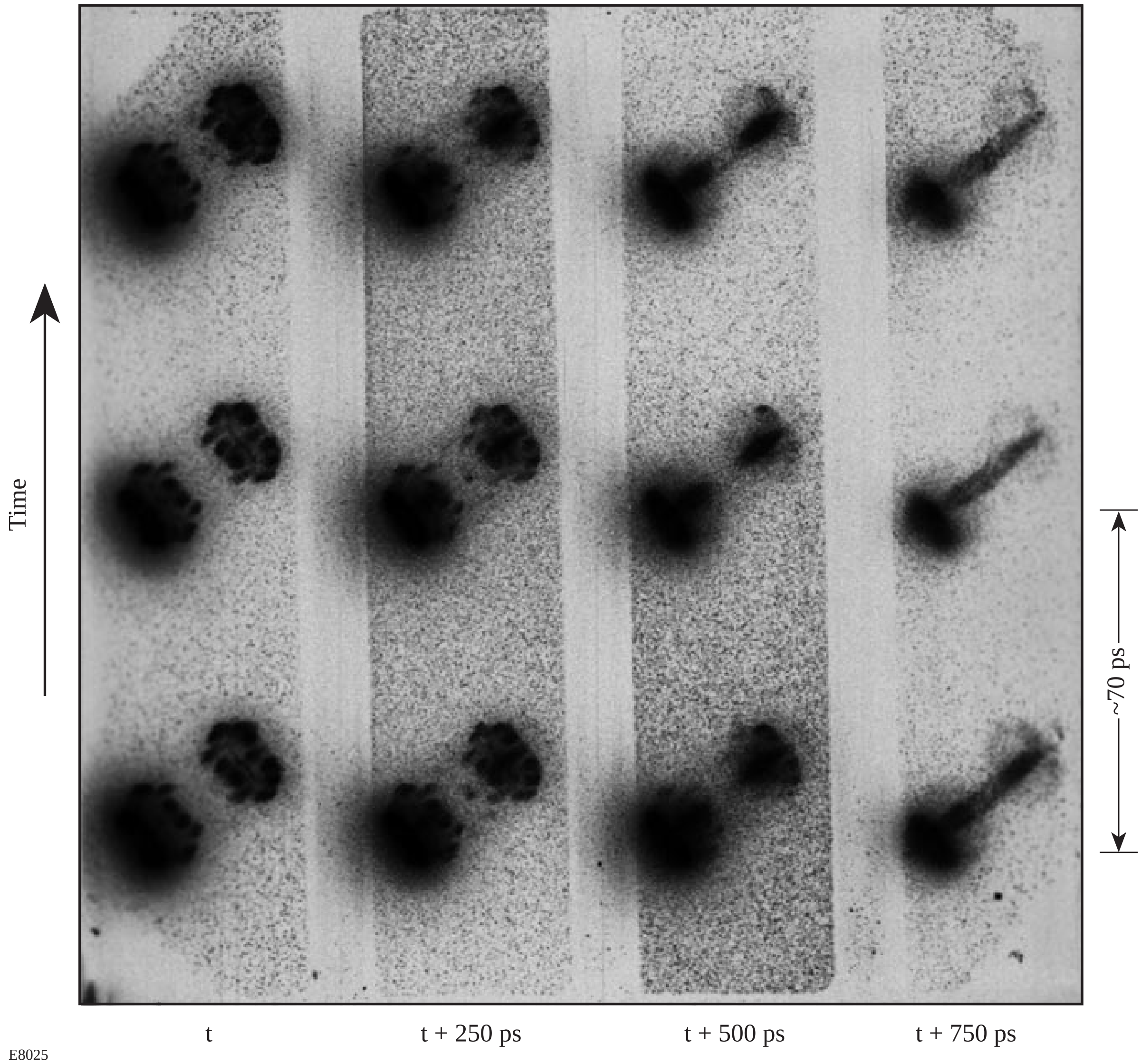

Figure 68.8
X-ray framing-camera images showing the formation of stagnation features on the axis of the hohlraum late in time.

ACKNOWLEDGMENT

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