AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

May 6, 1994

SAND94-0993C

Conf-940552--5

RECEIVED
JUN 24 1994
OSTI

Lithium Ion Beam Driven Hohlraums for PBFA II[1]

Raymond J. Dukart

Sandia National Laboratories, Albuquerque, New Mexico 87185-1187

(Presented May 9, 1994)

[1] This work supported by the U.S. Department of Energy Contract No. DE-AC04-94-AL85000

In our light ion inertial confinement fusion (ICF) program, fusion capsules are driven with an intense x-ray radiation field produced when an intense beam of ions penetrates a radiation case and deposits energy in a foam x-ray conversion region. A first step in the program is to generate and measure these intense fields on the Particle Beam Fusion Accelerator II (PBFA II). Our goal is to generate a 100-eV radiation temperature in lithium ion beam driven hohlraums, the radiation environment which will provide the initial drive temperature for ion beam driven implosion systems designed to achieve high gain. In this paper, we describe the design of such hohlraum targets and their predicted performance on PBFA II as we provide increasing ion beam intensities.

I. INTRODUCTION

Current ICF target designs contain an implosion system filled with deuterium and tritium fuel which is driven indirectly by an intense radiation field. Energy is deposited inside a classical hohlraum which then radiates in the soft x-ray region driving the target to implosion by the pressure produced through ablation of its outer layers. Light ion beam drivers have the advantage of depositing energy volumetrically in the deposition region of a target, thus providing a very efficient method of coupling driver energy to the target.

On PBFA II, we are currently performing experiments designed to verify the efficient coupling of lithium-ion-beam energy to hohlraum targets, verify the scaling of radiation temperature in these targets as a function of ion beam intensity, and achieve a radiation temperature of 100 eV. In this paper we will describe how ion beam hohlraums work, establish radiation temperature scaling to 100 eV and above, and describe a near term ion beam hohlraum target and predict its performance relative to previous target experiments on PBFA II.

II. LIGHT ION BEAM HOHLRAUM TARGETS

A light ion beam hohlraum consists of a low-density-foam energy-deposition region surrounded by a thin hohlraum wall, a concept first developed at Sandia National Laboratories in 1980[1]. Ions, radially incident on this target, penetrate through the thin wall and deposit most of their energy in the foam. The foam region is heated and emits radiation characteristic of the foam material. This energy heats the hohlraum wall which then re-emits radiation with a near Plankian spectrum characteristic of the radiation temperature of the wall. For this to be true, the foam deposition region must be optically thin while the hohlraum wall must be optically thick. We have shown this to be the case both for proton-ion-beam driven targets[2] as well as recent lithium-ion-beam driven targets.

In a lithium-ion driven target series on PBFA II, we designed and fielded conical shaped targets which consisted of either a 0.5- or 1.0-μm gold wall, (4-mm diameter at the narrow end, 8-mm diameter at the wide end, 6-mm tall), filled with either 3- or 6-mg/cm^3 TPX foam[3]. The targets were suspended in a 1.0-μm thick polyethylene support structure.

When viewed from above (the large end of the cone), both the line of sight through the foam onto the gold wall and the line of sight through the foam only (out the bottom 4-mm aperture) could be seen. If the foam were optically thick the emission should be disk-like, that is, uniform across the surface of the foam. If it were optically thin, the emission will have a ring-like structure with the brightest emission coming from the line of sight viewing the gold wall through the foam. Emission from this target had the ring-like structure[3], which verified that the foam was optically thin. By measuring the diameter of the top and bottom apertures as a function of time, we were also able to show that the foam energy deposition region tamped the gold wall throughout the ion beam pulse. A brightness temperature measured during these experiments was 58 eV for a 2-TW/cm^2 lithium ion beam. These results were consistent with 2-D LASNEX[4] predictions of target performance in which 75% of the ion beam energy was deposited in the foam.

Having shown that the lithium-ion-beam targets behave as predicted, we now need to design and field targets which can achieve higher radiation temperatures.

III. AN OPTIMIZED HOHLRAUM FOR PBFA II

For the upcoming target experiments on PBFA II, we need to design hohlraum targets which can achieve higher radiation temperature for the same lithium ion beam power and scale to 100-eV radiation temperature and above as we increase the ion beam intensity. PBFA II supplies an axisymmetric ion beam with 2-D Gaussian spatial profile, 8-mm FWHM. The ion beam pulse width is typically 15-

to 17-ns long. For this ion beam profile, target configurations considered for the next target series included spherical hohlraums of 4- or 6-mm diameter and cylindrical hohlraums with 4- or 6-mm diameter and height. The latter targets preserve the optimum surface area to volume ratio of the spheres when their diameter and height are equal.

An analytic model was used in order to quickly evaluate the trade-offs for these targets, as well as predict performance losses with different size diagnostic apertures. In this simple analytic model, the ion beam intensity, I_A, required to achieve a given radiation temperature, T_r, is assumed to be the sum of three terms corresponding to the energy required to heat the foam, the radiation loss out the diagnostic aperture, and the radiation loss to the gold wall.

$$\eta_f \eta_x I_A = \frac{C_v \rho V T_r}{\Delta t \cdot A_b} + \frac{\sigma T_r^4 A_{ap}}{A_b} + \frac{\sigma T_r^4 (A - A_{ap})(1 - \alpha)}{A_b}$$

where η_f is the fraction of the beam which is incident on the foam deposition region, η_x the x-ray conversion efficiency, C_v the heat capacity of the foam, ρ the foam density, V the volume of the foam, T_r the radiation temperature of the foam, Δt the duration of the ion beam pulse, α the hohlraum wall albedo, A the total surface area of the wall, A_b the area of the target over which the ion beam is incident, and A_{ap} the area of the diagnostic aperture through which the radiation temperature will be observed. For these calculations we assume that $T_r = T_e$, $\eta_f \eta_x = 0.8$, and $\alpha = 0.8$. For a fixed gold wall thickness and target size, we use this model to calculate the optimum foam density based on the input beam and hohlraum target parameters. The ion-beam energy deposition was done assuming cold material stopping powers with a flat-top, 15-ns ion beam.

Spherical hohlraum targets are precluded for the near term target experiments because of the time required to develop target fabrication techniques for building a 1-3 µm gold shell, 4- or 6-mm in diameter, filled with 3-8 mg/cm^3 TPX foam. Targets with a 4-mm scale size were chosen since they will sample a higher specific intensity for an axisymmetric, 8-mm FWHM Gaussian beam. For the ion beam intensity between 2- and 8-TW/cm^2 on the target, the analytic model predicts a 10 to 14 eV decrease in performance from a spherical to cylindrical hohlraum, as shown in Figure 1. When diagnostic apertures of 1.5- or 3.0-mm diameter in a cylindrical hohlraum are included, the decrease in target performance is small for the 1.5-mm aperture but measurable in the case of the 3.0-mm aperture.

Based on this analytic optimization of the hohlraum targets, an initial target configuration was a 4-mm-diameter, 4-mm-high cylindrical hohlraum with 7.5 mg/cm^3 TPX foam energy deposition region with 1.5 µm gold wall. Two diagnostic apertures will be evaluated: 1.5- and 3.0-mm diameter. The former should show little degradation in performance from a target with no aperture, but will test the limits of the sensitivity and spatial resolution of the experimental diagnostics. The latter will allow better signal-to-noise and spatial sensitivity in the diagnostics with an acceptable loss in target performance.

IV. RADIATION/HYDRODYNAMIC CALCULATIONS FOR TARGET OPTIMIZATION

The target configuration was further optimized using the 1-D LASNEX radiation-hydrodynamics code. As input for the LASNEX simulations, we used an experimentally determined lithium-ion-beam time history, as shown in Figure 2, with an axisymmetric, 2-D Gaussian spatial profile with 8-mm FWHM. Radiation transport was performed via multigroup diffusion with relatively course photon binning over 0.1 to 5000 eV. An average atom approximation (XSN) was used to compute zone-by-zone electron densities, level populations, and multi-group opacities.

For these 1-D simulations, we assumed a spherical target geometry, since in 1-D for cylindrical geometry, the effect of radiation losses in the top and bottom walls of the cylinder is ignored. Also, the surface area to volume ratio for these targets is preserved in spherical geometry, since the cylindrical targets will have their height equal to their diameter. Thus, for the initial optimization of TPX foam density and gold hohlraum wall thickness, performing the calculations in spherical geometry is appropriate.

The LASNEX calculations showed that the target is relatively insensitive to changes in gold wall thickness and TPX foam density. Increasing the wall thickness from 1.0 to 2.0 μm only changed the radiation temperature by 2 eV. Increasing the foam density form 3 to 5 mg/cm^3 changed the radiation temperature by 3 eV. However, increasing the wall thickness to 3.0 μm or the foam density to 8 mg/cm^3 degraded the hohlraum radiation temperature by 5 eV. The optimum target for the near term experiments proved to be a hohlraum with 5-mg/cm^3 TPX foam and a 1.5 μm gold wall. In Figure 3, we show the predicted radiation temperature of the foam in an optimized target as a function of ion beam intensity as predicted with 1-D LASNEX overlaid on the analytic model scaling curves.

In Figure 4 we can compare the predictions for this new target design with those of the previous conical target. This figure shows that the 2-D LASNEX simulations agreed closely with the analytic model for the conic target. Therefore we believe the new cylindrical hohlraum target will achieve higher radiation temperatures than the conic target for the same ion beam intensities. This prediction will be further supported with 2-D LASNEX simulations and verified in the near term target experiments on PBFA II.

In the near term experiments, the lithium ion beam will be radially incident on the sides of the cylindrical hohlraum, as illustrated in Figure 5, depositing the majority of its energy in the TPX foam. We will characterize the spatial profile and intensity of the ion beam using ion-beam-induced inner-shell line radiation from titanium witness wires[5]. We will measure the hohlraum radiation temperature through either a 1.5- or 3.0-mm diameter diagnostic aperture on the top of the target. The two diagnostic aperture sizes will allow us to look for diagnostic hole closure, as well as measure the radiation temperature achieved in the experiments. We will also field a gold plated, aluminum step witness plate mounted on the bottom of the target. By reflecting a laser off the bottom of this witness plate, we will use changes in reflectivity of the step witness plate to determine the shock velocity in the plate and infer the radiation drive temperature in the hohlraum.

V. CONCLUSIONS

We have designed a hohlraum target for PBFA II which will achieve higher radiation temperatures than our previous conical targets (~70 eV for 2-3 TW/cm^2). The targets will be 4-mm scale size cylindrical hohlraums with diagnostic apertures on the top and an active shock breakout diagnostic on the bottom. We will be testing our standard diagnostic package on the top as well as the new shock breakout diagnostic on the bottom in preparation for experiments designed to achieve 100 eV hohlraum temperature as we achieve higher lithium ion beam intensities on PBFA II.

1. S. A. Slutz, private communication.

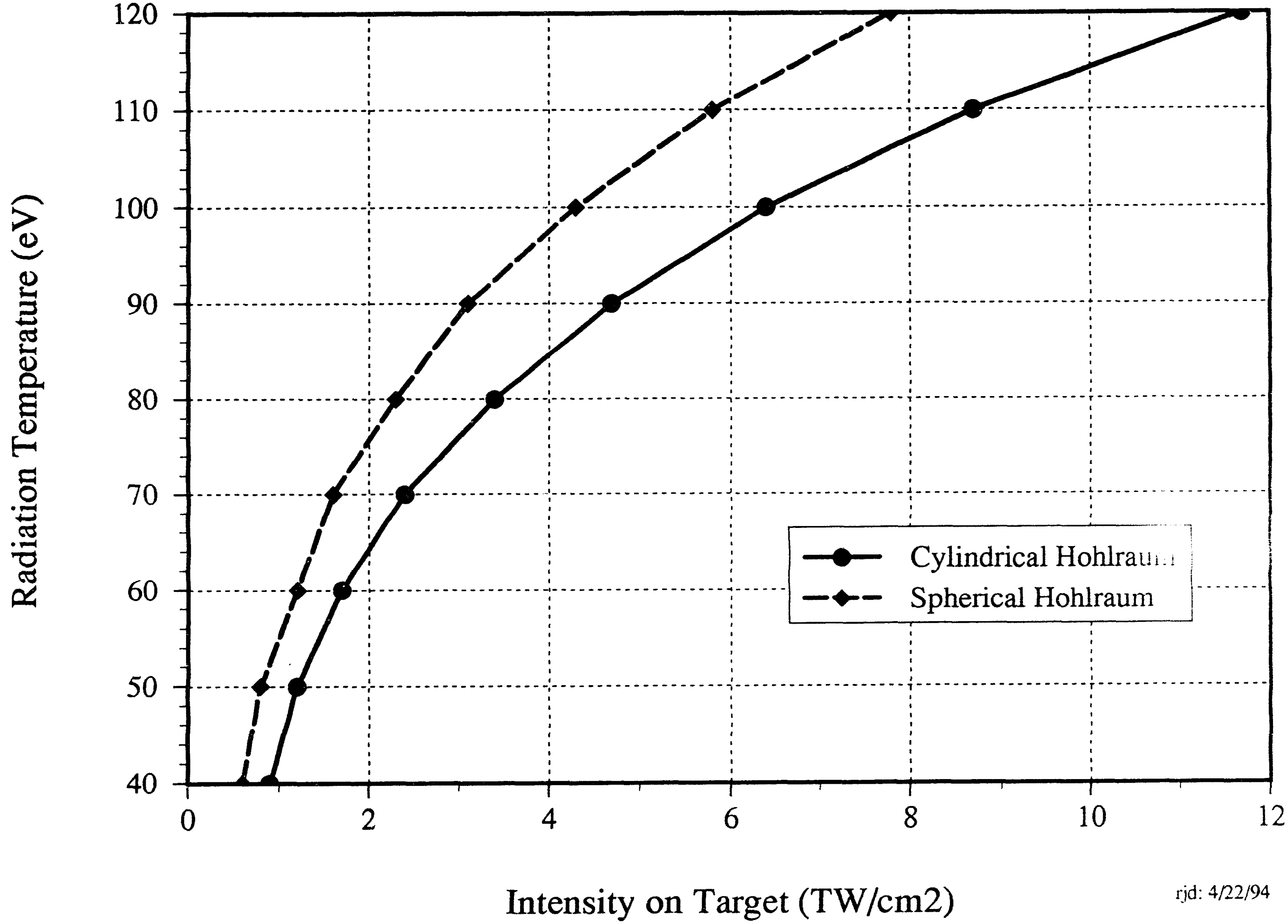
2. G. A. Chandler, et al., Rev. Sci. Instrum. 63, 4828 (1992)

3. G. A. Chandler, et al., this proceedings

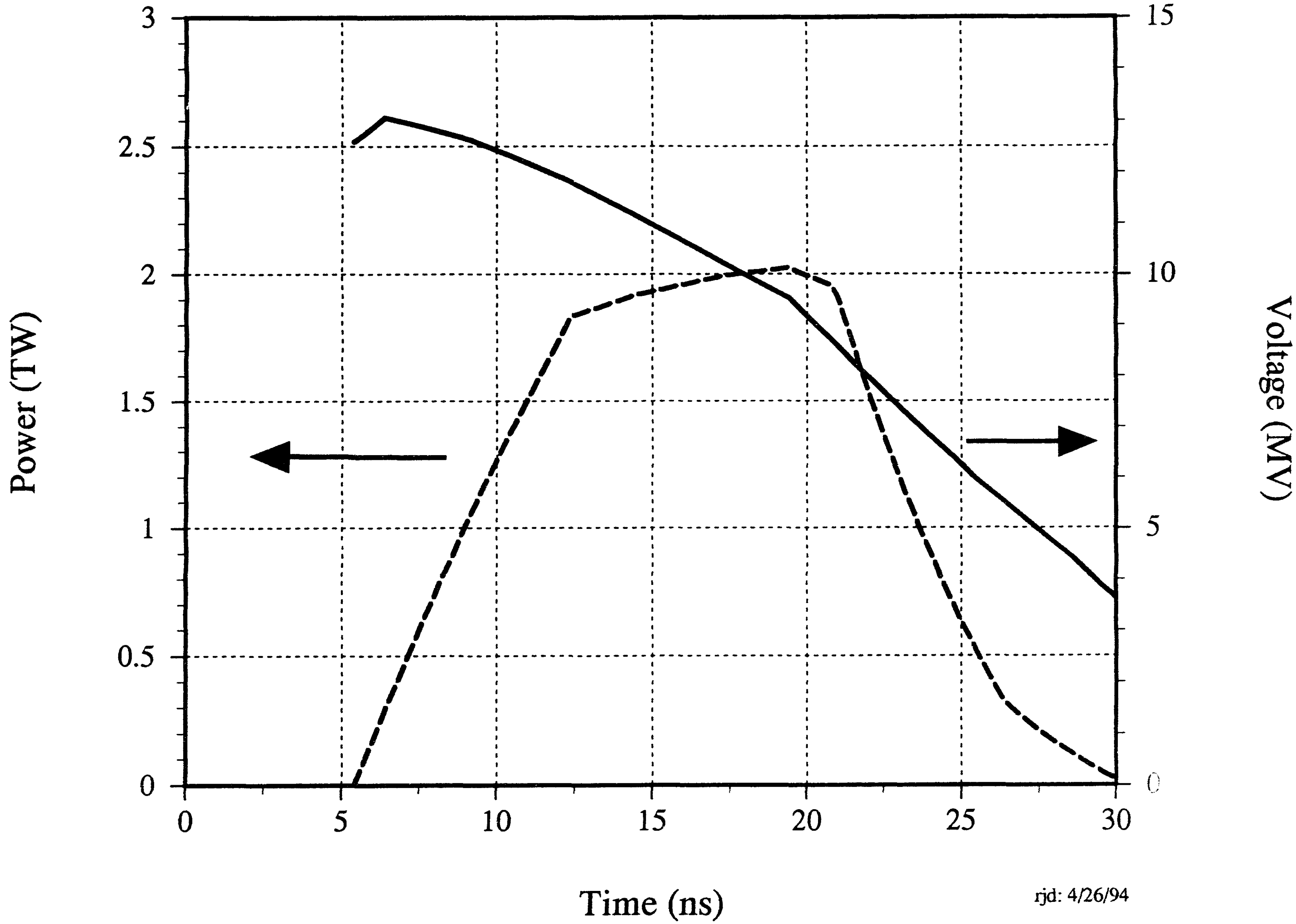
4. G. B. Zimmerman and W. L. Kryer, Comm. on Plasma Physics and Controlled Fusion, 2, 51 (1975)

5. A. R. Moats, et al., this proceedings

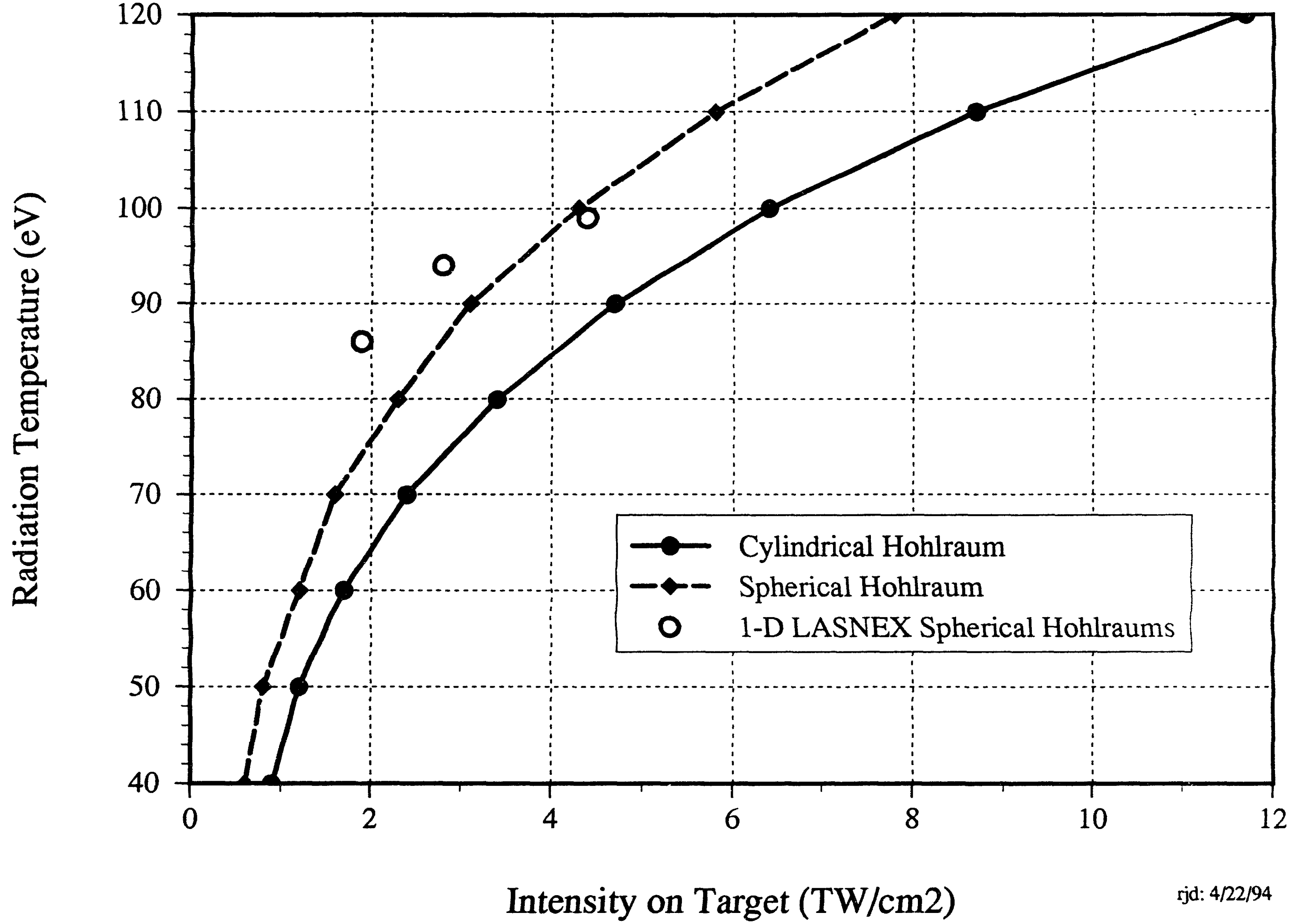
List of Figures



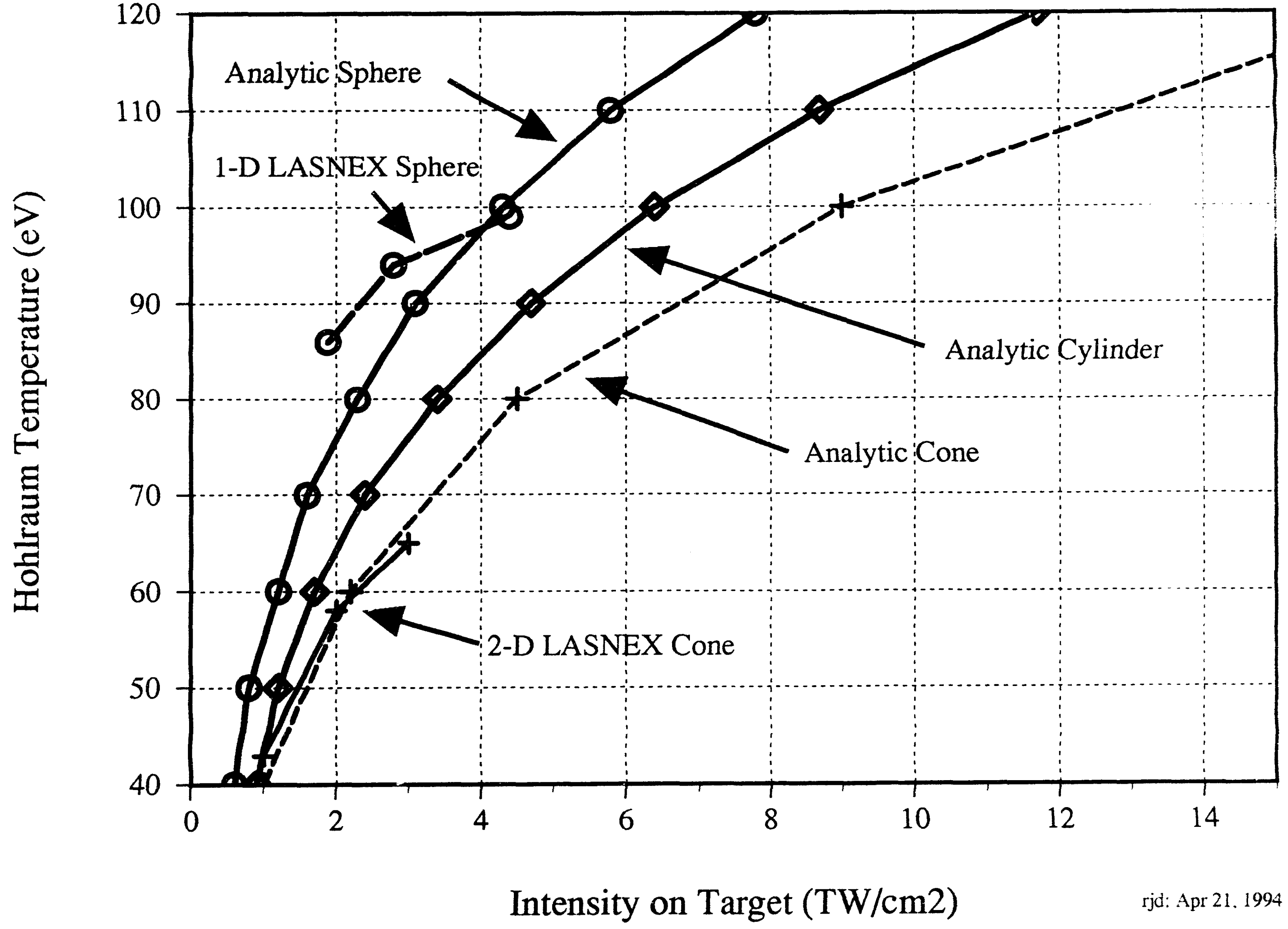
Radiation Temperature (eV)
120
110
100
90
80
70
60
50
40
0
2
4
6
8
10
12
Intensity on Target (TW/cm2)
Cylindrical Hohlraum
Spherical Hohlraum
rjd: 4/22/94

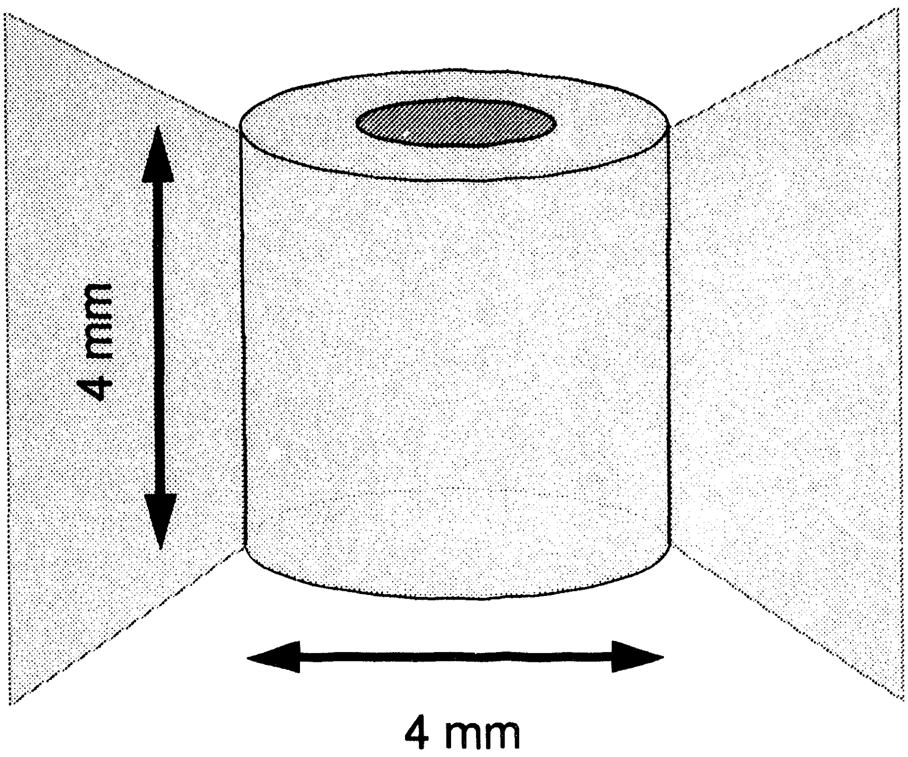


3
2.5
2
1.5
1
0.5
0
15
10
5
0
0
5
10
15
20
25
30
Power (TW)
Voltage (MV)
Time (ns)
rjd: 4/26/94



Radiation Temperature (eV)
120
110
100
90
80
70
60
50
40
0
2
4
6
8
10
12
Cylindrical Hohlraum
Spherical Hohlraum
1-D LASNEX Spherical Hohlraums
Intensity on Target (TW/cm2)
rjd: 4/22/94


Analytic Sphere
1-D LASNEX Sphere
Analytic Cylinder
Analytic Cone
2-D LASNEX Cone
Hohlraum Temperature (eV)
120
110
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
Intensity on Target (TW/cm2)
rjd: Apr 21, 1994


4 mm
4 mm

DATE
FILMED
6/29/94

END