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ILLUMINATION OF 3 AND 4 HOLE SPHERICAL LASER DRIVEN HOHLRAUMS

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Illumination of 3 and 4 Hole Spherical Laser Driven Hohlraums*

D.C.WILSON, C.A.WINGATE, J.MCLEOD, and W.C.MEAD, *Los Alamos National Laboratory* – We have considered what laser beam orientations entering static spherical hohlraums through three or four holes are needed to uniformly distribute the incident laser energy on the hohlraum wall. Each incident beam is characterized by its angle of incidence, i , with respect to the normal to the laser entrance hole. In the the set of beams needed to cover the hohlraum interior, let i_{min} be the minimum angle of incidence of beams in this set, i.e. the beam which most closely approaches the center. Let i_{max} be the beam which passes most obliquely through the entrance hole. To leave the maximum unexposed central volume we desire the largest i_{min} . To minimize the entrance hole diameter i_{max} should be minimized. For a hohlraum with three holes located 120° apart in a plane through the hohlraum center, the wall can be covered uniformly by a set of beams with $i_{min} = 30°$ and $i_{max} = 60°$. For a hohlraum with four holes located at the corners of a tetrahedron there exist two sets, one with $i_{min} = 27.3°$ and $i_{max} = 54.6°$, and another with $i_{min} = 35.4°$ and $i_{max} = 62.6°$.
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I. INTRODUCTION

Achieving excellent drive symmetry is one of the most important hohlraum physics issues. Almost all previous laser hohlraum theory has been devoted to hohlraums with one or two entrance holes. If these hohlraums contain a capsule and have reasonably small laser entrance holes, it is impossible to uniformly illuminate the walls. We have considered static spherical hohlraums with three or four laser entrance holes in an effort to uniformly distribute the incident laser energy on the hohlraum wall. In a static hohlraum without holes, a uniform wall irradiation will provide uniform capsule irradiation. We will not discuss compensation for the laser entrance holes.

II. ILLUMINATION GEOMETRIES

Uniform wall illumination is possible with either three or four entrance holes. Using a computer program we calculate the angular origins required of laser beams entering the hohlraum, passing through an entrance port and uniformly illuminating the interior of a spherical hohlraum. We used several assumptions and constraints to derive different illumination geometries.

We assumed that a large number of beams were available so that we need only place the center of the beams uniformly on the hohlraum interior surface. This should be a very good assumption. For example the Los Alamos AURORA KrF laser has 96 beams and LMF facilities may have as many as 1000 or more individual beams or beamlets. For any finite number of beams the intensity distribution on the hohlraum wall must be nonuniform. Beam spots will necessarily overlap on the hohlraum wall, but when averaged over several beam diameters, the distribution will be approximately uniform.

We sought collections of beams which covered the hohlraum wall and also satisfied two constraints. First they should minimize the angle of incidence (w.r.t. normal to the entrance port) made by the laser beams. Second they should pass as far from the hohlraum center as possible.

The first viewgraph shows the beam geometry. Each incident beam is characterized by its angle of incidence, i . with respect to the normal to its entrance port. Consider the set of all beams needed to uniformly irradiate the hohlraum interior. Let i_{min} be the minimum angle of incidence of beams in this set, i.e. the beam which most closely approaches the hohlraum center. Let i_{max} be the incident angle of the beam which passes most obliquely through the entrance port. To leave the largest central volume free from laser light we desire the largest i_{min} . To minimize the footprint on the entrance hole i_{max} should be as small as possible since the beam spot projection on the entrance port increases with i.

The second viewgraph summarizes three illumination geometries.

For a hohlraum with three holes located 120° apart in a plane through the hohlraum center, the hohlraum wall can be covered uniformly by a set of beams with $i_{min} = 30^\circ$ and $i_{max} = 60^\circ$. The angular origins for these beams are shown in Figures 2A and 2B. For these and the following figures 1000 beams were placed approximately uniformly on the interior of a spherical hohlraum. They were then projected back through the entrance holes to find their incoming angular direction. We neglected the very small correction due to the beams being pointed at an entrance port and not the hohlraum center. The angular locations of these beams are shown in Figures 3A and 3B as plotted on the surface of a unit radius sphere. In Figure 3A we view the unit sphere from along the direction of the beam port. To simply the plot we show only the locations of beams which pass through this port. Notice how no beams are located within a cone half angle of 30° about the entrance port direction. There are three such sets of beams on the full unit sphere, one for each port and rotated 120°. Figure 3B shows the unit sphere beam directions as seen from above the plane of the entrance ports. Only the beams on the upper hemisphere are shown.

For a hohlraum with four holes located at the corners of a tetrahedron there exist two illumination geometries, one with i_{min} = 27.3° and i_{max} = 54.6°, and another with i_{min} = 35.4° and i_{max} = 62.6°. Figures 4A and 5A show the angular positions on a unit sphere of beams which pass through one entrance port, as viewed along the direction into that entrance port. Figures 4Band 5B show the unit sphere as seen from above a plane splitting the tetrahedron (entrance ports are at plus and minus 30°). Only beams from the upper hemisphere are plotted. Figures 4C and 5C view beam locations from below. Only beams from the lower hemisphere are plotted.

III.COMBINING DIRECT AND INDIRECT ILLUMINATION GEOMETRIES

One of the original purposes of this study was to learn what commonality could be found between direct and indirect illumination geometries. For a concrete example we assumed the laser contained 162 beams, (a possible configuration for the proposed 100 kJ KrF system) which could be directed toward the target from any of the 482 directions which uniformly tesselate the surface of a sphere. Unfortunately only about 39 % of 4π steradians are used by the three or either of the four hole illumination geometries. This means that at least 61% of the beams will have to be redirected to achieve a uniform illumination for direct drive.

IV. SUMMARY

We have shown that static spherical laser driven hohlraums with either three or four laser entrance ports may be uniformly illuminated on their interior. This should cause better capsule irradiation symmetry and produce the lowest average laser flux on the wall. With three entrance ports the laser entrance holes lie in a plane through the hohlraum center. Laser beams enter the ports with incident angles between 30 and 60 degrees. With four entrance port the holes lie at corners of a tetrahedron. There are two geometries that allow uniform illumination. One has beams with incident angles between 27.3 and 54.6 degrees; the other between 35.4 and 62.6 degrees. Because radiation losses are less with three holes than four (if the holes are the same diameter) the three hole geometry may be preferred.

ORIENTATION OF LASER BEAMS

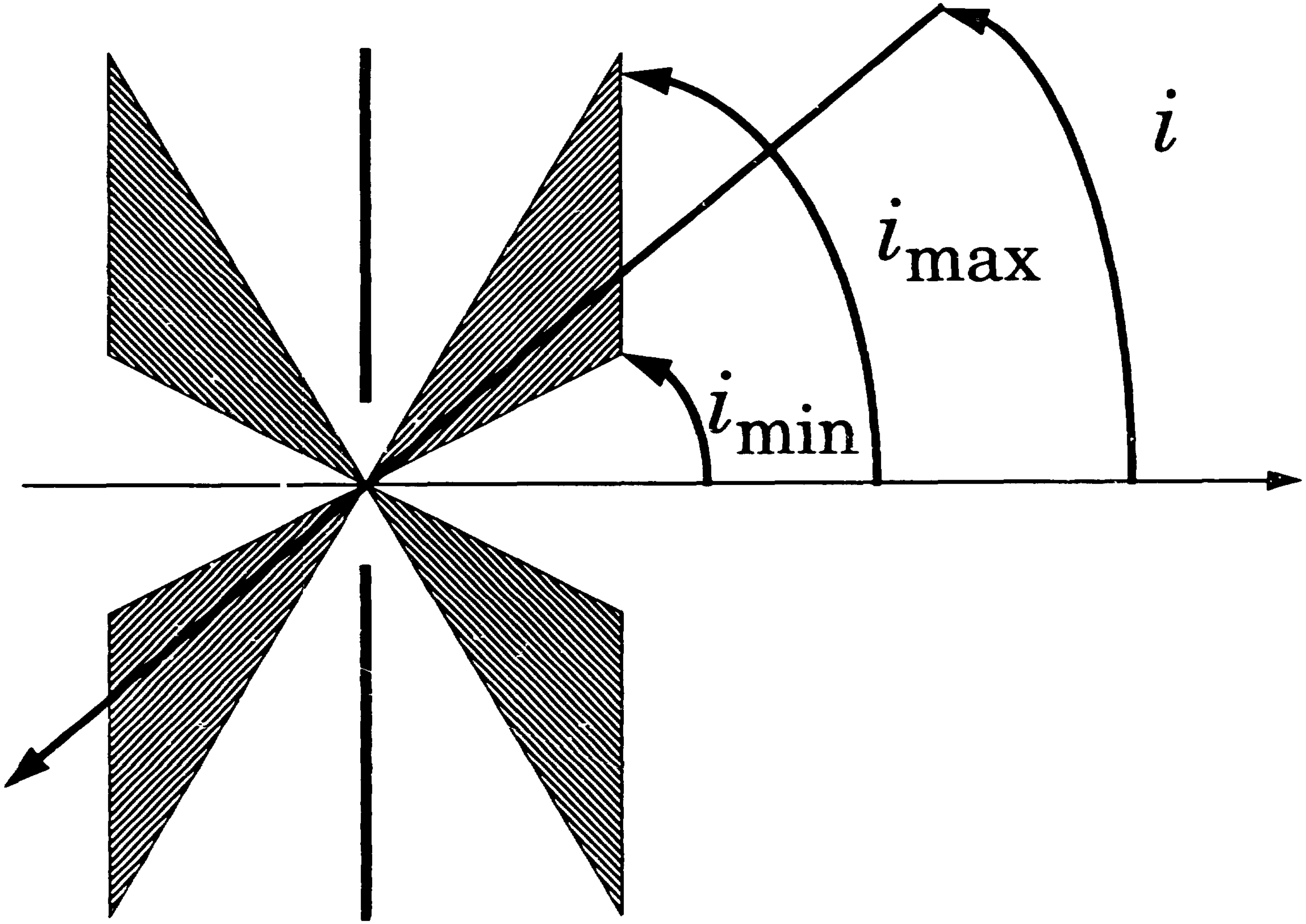


Figure 2

THREE ATTRACTIVE ILLUMINATIONS EXIST

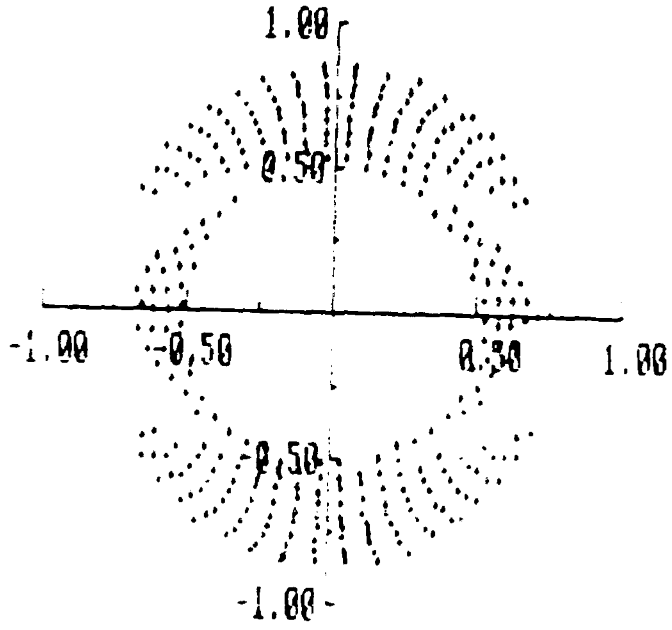
GEOMETRY	Imin (degrees)	Imax (degrees)
3 CO-PLANAR ENTRANCE PORTS AT VERTICES OF AN EQUILATERAL TRIANGLE	30	60
4 ENTRANCE PORTS AT CORNERS OF A TETRAHEDRON	27.3	54.6
4 ENTRANCE PORTS AT CORNERS OF A TETRAHEDRON	35.4	62.6

Figure 3

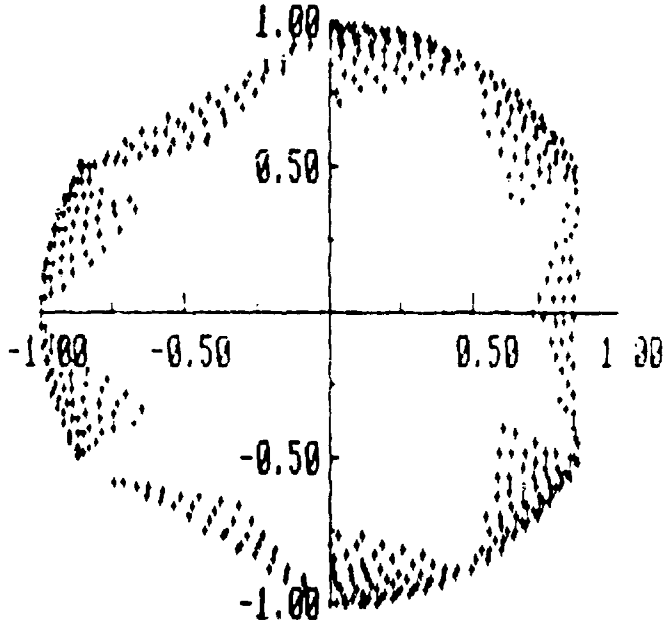
MIRROR LOCATIONS ON A SPHERICAL TARGET CHAMBER VIEWED FROM OUTSIDE

3 TRIANGULAR PORTS Imin = 30 deg Imax = 60 deg

Along Port Axis
(this Port's beams only)



From Above the Port Plane
(upper hemisphere beams only)



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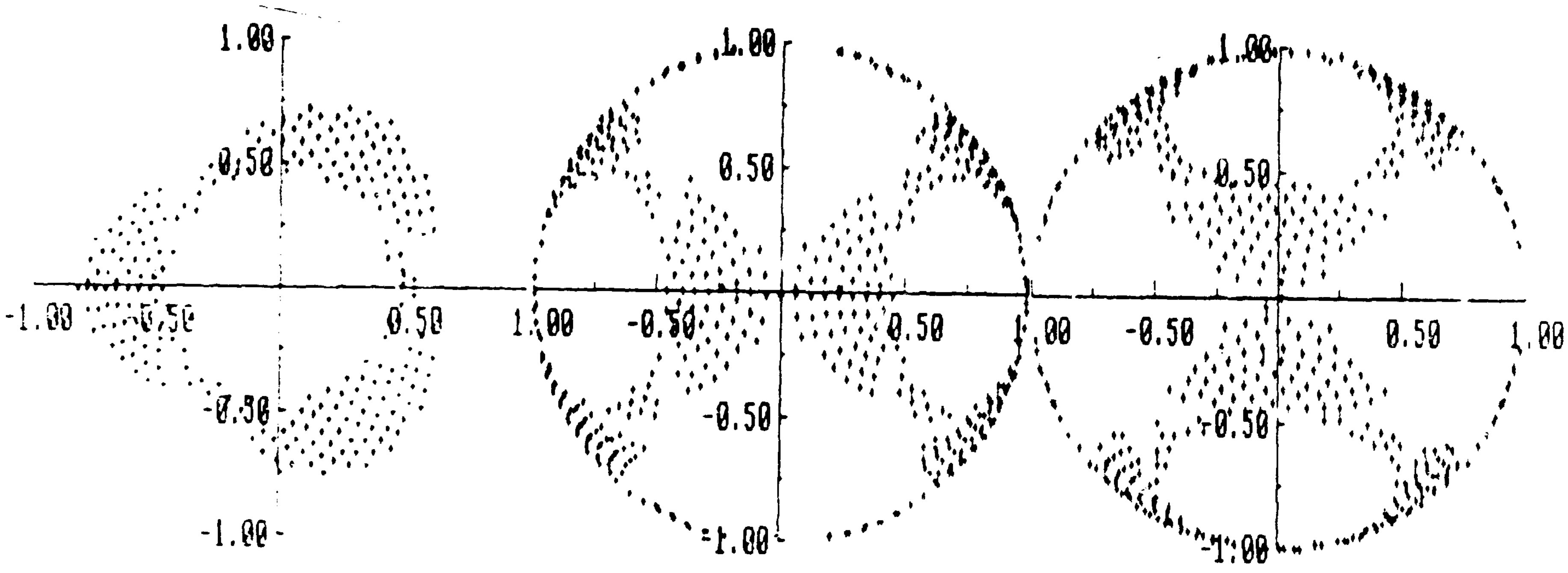
MIRROR LOCATIONS ON A SPHERICAL TARGET CHAMBER VIEWED FROM OUTSIDE

4 TETRAHEDRAL PORTS Imin = 27.3 deg Imax = 54.6 deg

Along Port Axis
(this Port's beams only)

From Above Port Plane
(upper beams only)

From Below Port Plane
(lower beams only)



MIRROR LOCATIONS ON A SPHERICAL TARGET CHAMBER VIEWED FROM OUTSIDE

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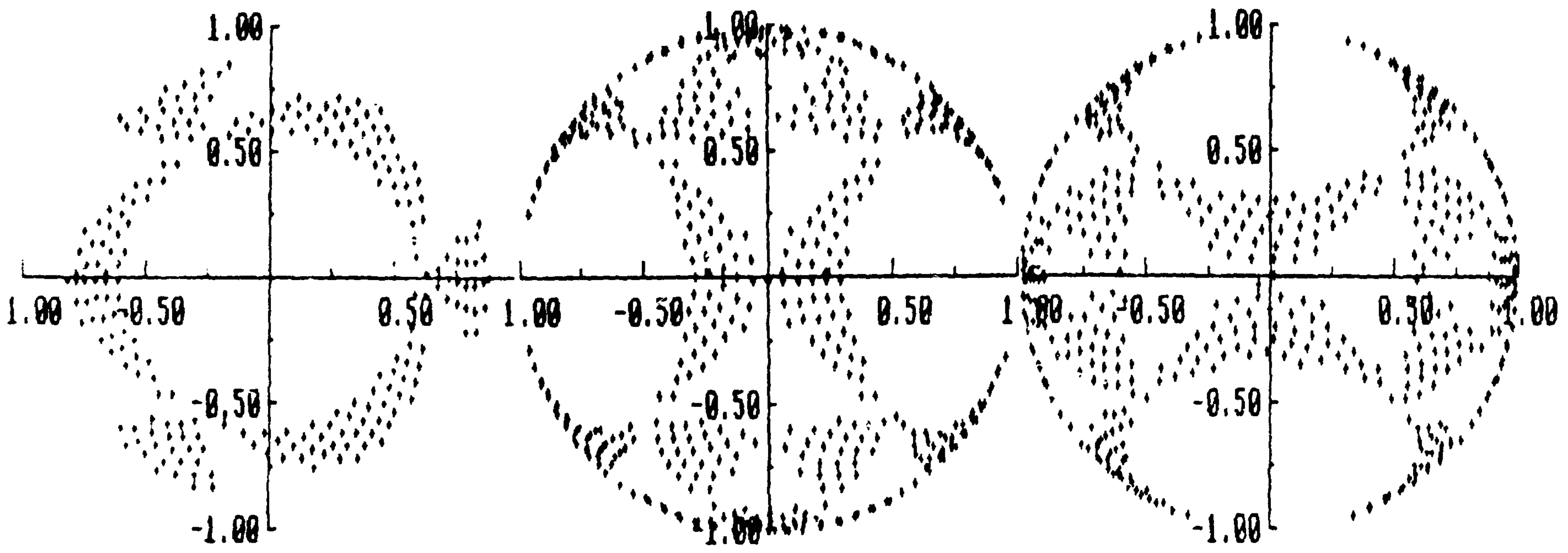
4 TETRAHEDRAL PORTS Imin = 35.4 deg Imax = 62.6 deg



Along Port Axis (this Port's beams only)

From Above Port Plane (upper beams only)

From Below Port Plane (lower beams only)

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