UCRL-JC-137622 Rev 1
PREPRINT

Status of our understanding and modeling of x-ray coupling efficiency in laser heated hohlraums

L. Suter, S. Glenzer, R. Turner, B. Lasinski, C. Decker, O Landen, B. MacGowan,
Lawrence Livermore National Laboratory

E. Dattolo, M–C Monteil, J–P Jadaud, N. Dague, D. Juraszek
Commissariat a l'Energie Atomique, Centre de Bruyeres-leChatel, Bruyeres-le-Chatel, France

This paper was prepared for submittal to
Physics of Plasmas

August, 2000

Lawrence Livermore National Laboratory

Status of our understanding and modeling of x-ray coupling efficiency in laser heated hohlraums

E. Dattolo[1], L. Suter[2], M-C Monteil[1], J-P Jadaud[1], N. Dague[1], S. Glenzer[2], R. Turner[2], D. Juraszek[1], B. Lasinski[2], C. Decker[2], O. Landen[2], B. MacGowan[2]

1- Commissariat a l'Energie Atomique, Centre de Bruyeres-le-Chatel, Bruyeres-le-Chatel, France

2- Lawrence Livermore National Laboratory, University of California, Livermore, California 94551

Recent changes in the manner of performing hohlraum drive experiments have significantly advanced the ability to diagnose, understand and control the x-radiation flux (or drive) inside a laser heated hohlraum. Comparison of modeling and data from a very broad range of hohlraum experiments indicates that radiation hydrodynamics simulation codes reproduce measurements of time dependent x-radiation flux to about ±10%. This, in turn, indicates that x-ray production and capsule coupling in ignition hohlraums will be very close to expectations. This paper discusses the changes to experimental procedures and the broad variety of measurements and tests leading to these findings. (PACS 52.58.Ns, 52.65.y, 52.70.La, 52.40.Nk)

I. Introduction

The Laser Megajoule (LMJ) [1] in France and the National Ignition Facility (NIF) [2] in the United States, the next generation of high-energy, high-power laser drivers, have the potential of achieving thermonuclear ignition and gain in the laboratory. One key element of achieving that goal is coupling a significant fraction of the lasers' energy to a fuel capsule. We can relate the quantity of x-rays absorbed by an indirect drive ignition capsule, E_{cap}, to the laser energy, E_L, via the expression

$$E_{cap} = \eta_{abs}\eta_{CE}\,\eta_{HR\text{-}cap}\,E_L \quad (1)$$

where η_{abs} is the fraction of incident laser energy absorbed by the hohlraum, η_{CE} is the conversion efficiency of laser light into x-rays and $\eta_{HR\text{-}cap}$ is the fraction of generated x-rays which are actually absorbed by the capsule. As indicated in Figure 1, η_{abs} is typically assumed to be

$$1-(f_{SBS}+f_{SRS})$$

where f_{SBS} is the fraction of incident laser light reflected or scattered out of the hohlraum by Stimulated Brillioun Scatter (SBS) and f_{SRS} is the fraction reflected by Stimulated Raman Scatter (SRS) [3]. Since E_L for both LMJ and NIF is nominally 1.8MJ, standard point design capsules [4,5] which absorb 150kJ of x-rays require $\eta_{abs}\eta_{CE}\,\eta_{HR\text{-}cap} = 0.083$. Additional constraints [4] are that the hohlraum be gas filled; the laser pulse shape be carefully tailored; and the peak radiation temperature (Tr) be 300eV.

Numerical simulations of the ignition hohlraum and capsule show a theoretical conversion efficiency of ~80% and a $\eta_{HR\text{-}cap}$ of ~14%, producing a theoretical $\eta_{CE}\ \eta_{HR\text{-}cap}$ of 0.11. Compared to the 0.083 required efficiency, this provides a 25% margin. This margin was intentionally incorporated into both French and US programs in the early 90's in order to compensate for uncertainties, allowing us to be off somewhat in our assumptions and still be able to achieve ignition. For example, if η_{abs}=1 and $\eta_{CE}\ \eta_{HR\text{-}cap}$ =0.11 then E_L =1.35MJ would successfully drive our ignition design. Or if stimulated backscattering losses proved to be as much as 25% but $\eta_{CE}\ \eta_{HR\text{-}cap}$ =0.11, then the expected 1.8MJ will successfully drive the ignition design. Similarly if η_{abs}>0.75 and E_L =1.8MJ, then values of $\eta_{CE}\ \eta_{HR\text{-}cap}$ <0.11 would also work.

Given this picture of capsule coupling efficiency, much of our ongoing experimental research on facilities such as Nova can be broken down into two tasks related to hohlraum energetics.

1- Make η_{abs} as close to 1 as possible in ignition hohlraums

2- Test if $\eta_{CE}\ \eta_{HR\text{-}cap}$ is as given by radiation-hydrodynamics simulations

Success in these two tasks will reduce the uncertainty associated with ignition and perhaps allow us to more profitably use the 25% margin built into the programs.

Recent Nova experiments and their related analysis indicate that NIF coupling efficiency will meet the requirements for ignition. Ongoing experiments studying stimulated Brillouin and Raman backscattering (also known as Laser Plasma Interactions or LPI) in ignition hohlraum "plasma emulators" imply that the total backscattered losses from these two processes should be <10%. These experiments are detailed elsewhere [6]. Here we discuss recent work examining the radiation environment of Nova hohlraums. This work indicates that x-ray production and capsule coupling, $\eta_{CE}\ \eta_{HR\text{-}cap}$, indeed is very close to our modeling.

We can test our ability to properly predict $\eta_{CE}\ \eta_{HR\text{-}cap}$ by testing our ability to model/predict the relationship between a hohlraum's drive (Tr(t)**4) and the incident laser power, P_L. To see this heuristically, rewrite Equation (1) as

$$\eta_{CE}\ \eta_{HR\text{-}cap}\ (\eta_{abs}P_L)=P_{cap}=(1-\alpha_{cap})A_{cap}\sigma Tr^{**}4 \qquad (2)$$

Where P_L is the laser power, P_{cap}=d E_{cap} /dt, A_{cap} is the area of the capsule, α_{cap} is the fraction of incident x-rays reemitted by the capsule (also known as its albedo), and σ is the Stephan-Boltzman constant. Thus, for a given capsule of known albedo and area, if we know η_{abs}, then a knowledge of the relationship between laser power, $\eta_{abs}P_L$, and Tr**4 gives us knowledge of $\eta_{CE}\eta_{HR\text{-}cap}$.

For a number of years experiments have been carried out on Nova [7,8] and on other facilities [9] to measure radiation flux, or drive, in laser heated hohlraums. The principal experimental technique was to measure absolute x-ray flux emerging from a diagnostic hole in the side of an empty hohlraum (which we call here "traditional dante") with approximately 2-D illumination as shown in Figure 1 (but without the capsule which would block the line of sight. Note that on Nova we approximated 2-D, axial symmetric illumination with five beams per side which filled about half the azimuth with equally spaced spots). The earliest experiments demonstrated the fundamental scaling of drive with laser energy, pulse duration and hohlraum dimensions. This work also demonstrated increasing hohlraum x-ray conversion efficiency with increased plasma filling; a consequence of the confined nature of the system [8]. Efforts were also made to use the traditional-dante data to test the ability of detailed numerical simulations to model the time dependent hohlraum drive. This work was done both by US researchers with the Lasnex computer code and by French scientists using the 2 dimensional Inertial Confinement Fusion (ICF) code, FCI-2. Unfortunately, comparisons with detailed modeling often suffered at later times [8] as shown in Figure 2. We long suspected that this disagreement was not due to fundamental errors in our two dimensional modeling but, rather, due to the three dimensional nature of our measurements. In particular, we suspected that a plume of cold plasma might be emerging from the hole at later times and scatter out of the diagnostic's line of sight some of the collimated x-ray flux emerging from the hole. For example, a cold plume of optical depth 0.2 could reduce the measured, collimated x-ray flux by 20%.

Since the publication of [7,8] we have redressed the issues related to detailed time dependent drive in the course of making a number of significant changes in the way in which we study hohlraum drive. These changes include adding Kinoform Phase Plates to Nova [10], thereby providing ten smoothed beams for experiments [11] and performing complementary indirect drive experiments on the University of Rochester's Omega laser [12]. However, the most important change may have been to explore and finally adopt a new diagnostic line of sight; one which measures absolute x-ray flux emerging from the laser entrance hole (LEH). See Figure 1 [13]. This was used first on Omega [13] and then on Nova [14]. We originally tried this on Omega because of our concerns, mentioned above, that the later time discrepancy between traditional dante and two dimensional modeling could be due to the three dimensional nature of the measurement. We reasoned that a 2D code which includes all the essential physics ought to be able to model an axi-symmetric line of sight, such as one through the LEH. Any plasma plume emerging from the LEH could, in principle, be modeled by a 2D code. Moreover, the plasma plume emerging from the LEH is typically heated to kilovolt temperatures by the entering laser and therefore is transparent to soft x-rays during the course of the laser pulse.

Given this background, the balance of the paper divides into two sections. In section II we quantitatively discuss how traditional dante measurements are consistently colder than modeling at late time when hohlraums fill with plasma. In particular, we discuss the set of experiments which conclusively demonstrated that the late time discrepancy between traditional dante and modeling becomes progressively worse with longer pulses. In contrast to this, are the measurements of drive made through the LEH which agrees reasonably well with simulation over all pulse length and hohlraum combinations investigated. These experiments led to a general acceptance of the LEH line of sight and a rejection of the traditional dante line of sight.

However, just because the LEH line of sight agrees with expectations doesn't mean it's right. In section IV we review work we have done to independently validate this line of sight with complementary measurements.

Note that in this paper measurements made along the traditional dante line of sight are plotted as radiation temperatures, in keeping with the long history of describing this measurement. However, measurements of radiation drive made through the laser entrance hole are plotted either as radiation flux or radiation flux/area, both proportional to Tr^4, reflecting a change we have recently made in the way we display and interpret drive data.

II. Nova drive measurements vs. modeling

The drive measurement of Figure 2 is a relatively extreme example of the late-pulse discrepancy that exists between traditional dante measurements and simulation. The hohlraum used in this experiment was a scale 0.75 Nova hohlraum (c.f. Figure 1 with diameter of 1200 microns, length of ~1800 microns and 800 micron diameter laser entrance holes). We irradiated this hohlraum with "ps22", an ~26kJ, 2.2ns, 3ω shaped pulse which has ~3:1 power ratio between the foot of the pulse and the peak [8]. All ten of Nova's beams were smoothed with Kinoform Phase Plates (KPP). The hohlraum was filled with 1 atm of propane gas in an attempt to mock-up a gas-filled ignition hohlraum. The incident laser power in our simulations was reduced by ~10% to correct for measured backscattered losses and KPP losses. Figure 2 shows that there is reasonably close agreement between simulation and experiment up until ~1.3ns. Beyond that time there is an ever increasing discrepancy which, taken at face value, suggests that modeling seriously overestimates the late-pulse drive. In contrast to that, however, is the measurement of drive, from the same hohlraum, made through the LEH line-of-sight indicated in Figure 1. This measurement, plotted in Figure 3 in units of radiation flux (proportional to Tr^4) is very close to the modeling throughout the entire pulse and even after the laser pulse ends at 2.2ns. This measurement indicates that we can very closely simulate drive in this scaled ignition hohlraum.

We have repeatedly seen, in a wide variety of hohlraums and with a wide variety of pulse shapes, this pattern of late-pulse disagreement through the traditional dante line-of-sight but excellent agreement with modeling through the LEH line of sight. We attribute it to problems with the traditional dante line of sight. In addition to hole closure, which has been repeatedly observed (and, indeed, researchers often try to quantify it with time resolved x-ray imaging) we also suspect there is an additional attenuation from expanding, cooling plasma emerging from the dante hole which can scatter the collimated radiation going towards the instrument. This becomes an effect on the measurement about the time, in our simulated hohlraums, at which wall blowoff stagnates on axis, thereby ending the hohlraum's free-expansion phase. Beyond this time simulations show a rapid increase in bulk plasma density and pressure throughout the hohlraum volume.

In order to better document the systematics, we performed an experimental scaling which demonstrated that in situations where there are increasingly gross disagreements between traditional dante and modeling, the LEH line of sight continues to indicate that the hohlraum is performing as expected. This "Build-a-pulse" (BAP) experimental series consisted of scale 1.0 vacuum hohlraums with 75% laser entrance holes (i.e. hohlraums of Figure 1 with 1600μm diameter, 2750μm length, 1200μm diameter laser entrance hole) irradiated with flattop laser pulses that varied from 0.6ns to 3ns. The dante holes themselves were the standard "Be-washer" type [7]. All these hohlraums were irradiated by flattop laser pulses. For example, Figure 4 plots the observed and simulated traditional dante flux vs. time for two hohlraums, one irradiated by a 600ps full-width-at-half-maximum (FWHM) pulse, the other by a 3ns FWHM pulse . With the 600ps pulse there is quite good agreement between traditional dante and the simulation throughout the pulse. It is only at late time, after the laser pulse is off, that a significant discrepancy appears, which we discuss below. For the 3ns flattop pulse a discrepancy between experiment and simulation sets in at approximately 1ns, consistent with the time at which the wall blow-off stagnates on axis and this hohlraum ends its free-expansion phase. If we consider the difference between simulated and measured drive in terms of flux, Tr^4, then the disagreement is particularly egregious; there is approximately a factor of three difference in integrated flux.

In contrast, the drive measurements made through the LEH on all these experiments agreed reasonably well with modeling. For example, Figure 5B plots the LEH drive, in units of GW/cm2/sr, from the 3ns experiment of Figure 4. In addition to plotting the LEH drive from this Build-a-pulse hohlraum, Figure 5 plots LEH drive from of the most extreme hohlraums we have shot and compares them with modeling by both FCI-2 and Lasnex. Figure 5 demonstrates detailed, quantitative understanding of drive which spans two orders of magnitude in radiation flux/cm2/sr. The upper curves show experiment and simulation for a scale 0.625 vacuum hohlraum irradiated by ps22. It achieved a peak Tr of ~283eV. The lower curves are the LEH drive from a scale 3.0 hohlraum irradiated by ~2TW for 13.5ns. (The rolling nature of the data in the lower temperature hohlraum is because Nova's beams were fired sequentially, in order to produce this long pulse shape, instead of simultaneously [15]. This rolling cannot be included in our axi-symmetric 2D modeling.)

III. Implications of agreement between LEH measurements and simulation

We have used Lasnex and FCI-2 to simulate, in detail, a wide variety of experiments. Examination of our entire collection of data leads us to estimate that our codes reproduce LEH measurements of time dependent $Tr(t)^4$ to

4%±7%. By this we mean that the experimental $Tr(t)^4$ measurement will be typically be contained within a band constructed by taking $1.04*T_{Simulated}(t)^4$±7%. However, the absolute calibration uncertainty of our principal x-ray flux diagnostic [16] is ±10%. Adding this in quadrature to the ±7% leads us to conclude that the true $Tr(t)^4$ will be 1.04±0.12 of simulated $Tr(t)^4$.

Given this, we conclude that for a capsule of given area and albedo, an ignition hohlraum's $\eta_{CE}\ \eta_{HR\text{-}cap}$ will be ~1.04±0.12 of coupling predicted by our simulations. Applying that to the NIF and LMJ point designs gives an estimated coupling of 0.115±0.012 .

Over the years various researchers have frequently speculated that hohlraums will begin to fail when they fill with plasma to ~10% critical density ($0.1n_C$). This has been based on the pessimistic assumption that laser plasma instabilities will necessarily wreak havoc with the intense laser beams at densities higher than this. However pulse shaped, reduced scale hohlraums, such as the 0.625 scale which provided the upper radiation flux plot of Figure 5, are part of a data base which belies this assumption. For example, we find the plasma density in the simulated 0.625 hohlraum is everywhere greater than $0.2n_C$ at the time of peak radiation drive. Indeed, most of the plasma volume traversed by the laser would appear to be $n_C/4$ or higher. In spite of this, the hohlraum radiation flux appears to be in very good agreement with expectations indicating that the hohlraum is working well. Moreover, the measured backscattering is relatively low; the time integrated sbs+srs being <10%.

In the case of the LEH line of sight, there is close agreement between simulated and experimental flux long after the peak of the laser pulse. This provides some validation of one important aspect of simulated hohlraum energetics; the way in which hohlraums manifest energy conservation at later times. In a long pulse hohlraum, considerable thermal energy can be stored in the hot corona blow-off that fills it. After the peak of the laser pulse this blow-off can cool, converting the released thermal energy to radiation. The later time release of stored plasma energy is a noticeable part of Nova scale energetics and an even more important part of larger scale ignition hohlraum energetics. Without it, significantly more late time laser power would be needed to maintain the desired radiation temperature. [8].

However, in the case of the traditional dante line of sight, the discrepancies between experiment and simulation, long after the pulse is off, may in part be an artifact of our fluid codes. Figure 6 plots thermal x-ray emission/cm^2, at 1.8ns, of each zone in an FCI-2 simulation of the scale 1.0 hohlraum irradiated by a 0.6ns square pulse (measured and simulated traditional-dante for this experiment is plotted in Figure 4). This figure underscores the potential pitfall of characterizing global Tr with a measurement which observes only a tiny fraction of the hohlraum area. The hydrodynamic flow in our simulated hohlraum leads to a build-up of hot, emitting plasma in the volume at the midplane at very late-times, even in the absence of a heating laser. In producing the synthetic dante temperature, our simulated dante line-of-sight passes right through this plasma. Most of the post-processed emission comes from this plasma. This leads to the very high temperature indicated by the star in Figure 4. In contrast, the LEH line of sight gets none of its signal from this midplane plasma, even if it were real.

Examination of the origin of photons in simulations shows that the LEH diagnostic sees a much bigger fraction of the hohlraum wall, one which is quite representative of what the capsule "sees" [13]. Analysis of our simulations repeatedly shows that for Omega, Nova, LMJ and NIF, measurements of drive through the LEH should yield a measured flux which is very close to the drive around a capsule in the center of these hohlraums [17].

Finally, we should bear in mind that the use of a 2-D code to model targets in a 3-D world is, at best, an approximation. For the experiments described here, where we tried to approximate 2-D illumination, we seem to have some success. However, care should be exercised in using 2-D codes for detailed modeling of more three-dimensional targets.

IV. Validating the LEH line of sight

Analysis of experiments such as the BAP scaling described above quickly led to the LEH line of sight becoming the preferred drive diagnostic for virtually all experiments. However, we remained concerned about the validity of this line of sight since results being consistently close to expectations does not necessarily guarantee that they are right. For example, one could construct a pathological situation which could make the LEH drive seem "right" yet still starve the center of the hohlraum of radiation. This scenario combines lower than expected radiation production with greater than predicted plasma evolution. This possibly could conspire to produce much more radiation close to the LEH than our simulations predict, where it would look bright but no longer effectively heat the center of the hohlraum (note that simulations of the hohlraums discussed in this paper indicate that only a small fraction of the total radiation produced comes from the plasma near the LEH).

In effort to validate the LEH line of sight we have made a several measurements on "half-hohlraums". The basic idea is to slice a hohlraum in half at the midplane, irradiate it through only one end and use the "LEH" drive diagnostic to measure the x-ray emission through the open, unirradiated end. If the open end of the hohlraum were, in fact, being starved of radiation at later times then it should be very evident in the "LEH" drive diagnostic. Figure 7 is a comparison of simulated and measured radiation flux vs. time from a scale 1.41 hohlraum irradiated by an 8ns long drooping pulse. In the simulated hohlraum there is a large amount of plasma evolution which progressively moves the laser deposition region closer to the LEH throughout the pulse. Nevertheless, the flux exiting the midplane of this half-hohlraum is quite close to what we expect, indicating that in this very long-pulse system the center of the hohlraum is not "starved" of radiation but is, in fact, receiving close to the expected amount.

Complementing the half-hohlraum measurements are experiments which measured the burn-through time of thin gold foils covering holes on wall during our second series of BAP experiments. Although not especially challenging tests of detailed drive, they can indicate which of two grossly different drive scenarios is more likely to be correct. These measurements indicate that the true flux in our long pulse hohlraums is consistent with our simulated flux (and, therefore, the flux measured by the LEH line of sight) and inconsistent with the much lower flux measurement made along the traditional dante line of sight.

Acknowledgements

We would like to thank the Nova and Omega staff for their support of experimental operations. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Figures

Figure 1- Our traditional technique for measuring hohlraum drive is to measure the absolute flux of x-rays emerging through a hole in the side of the hohlraum. More recently we have changed to measuring the absolute flux of x-rays emerging from the laser entrance hole (LEH) at an angle between 22 and 38 degrees.

Figure 2- "Traditional dante" measurements of time dependent hohlraum temperature (proportional to (absolute x-ray flux)$^{0.25}$) agrees with detailed simulations up to a certain point. Beyond that traditional dante is cooler than the modeling. This was a Nova scale 0.75 propane filled hohlraum irradiated by an ~26kJ, 2.2ns long shaped pulse (ps22 [8]).

Figure 3- LEH drive measurement and modeling from the propane filled Nova scale 0.75 hohlraum that produced the traditional dante drive plotted in Figure 2

Figure 4- Observed and simulated traditional dante Tr vs. time for a two scale 1.0 Nova hohlraums, one irradiated by a 600ps FWHM flattop pulse, the other by a 3ns FWHM flattop pulse.

Figure 5- LEH measurements (GW/cm^2/sr) and modeling from three very different types of experiments. A) is from a scale 0.625 hohlraum irradiated with ps22. B) is a scale 1.0 hohlraum irradiated with a 3ns flattop. C) is a scale

3.0 hohlraum irradiated with a 13.5ns pulse constructed by sequentially firing eight of Nova's ten beams. Measurements are the bold solid lines, FCI-2 results the dotted lines and LASNEX results the dashed lines.

Figure 6- Thermal x-ray emission/cm^2 from the zones of an FCI-2 simulations at 1.8ns of a scale 1.0 hohlraum that was irradiated by a 600ps square pulse. The hydrodynamic flow in the simulated hohlraum leads to a build-up of hot, emitting plasma on the midplane at very late-times, even in the absence of a heating laser. This leads to the very high "traditional" dante temperature indicated by the star in Figure 5.

Figure 7- Radiation flux emerging from the unirradiated, open end of a half-hohlraum heated by a very long laser pulse. This indicates that a real hohlraum mid-plane will not see a radiation flux that is significantly different than that expected from radiation hydrodynamic simulations.

References

1- M. Andre, "Laser Megajoule project status", p 32, Proceedings, 1st Conference on Inertial Fusion Sciences and Applications, Bordeaux, 1999, edited by C. Labaune et al. (ELSEVIER, Paris, 2000).

2- J. A. Paisner, E. M. Campbell and W. J. Hogan, Fusion Technology, **26**, 755 (1994).

3- See, for example, *The Physics of Laser Plasma Interactions*, by W. Kruer, Addison-Wesley Publishing Co., ISBN 0-201-15672-5 (1988).

4- S. W. Haan, S. M. Pollaine, J. D. Lindl, *et. al.*, Phys. Plasmas 2, 2480 (1995).

5- W. J. Krauser, N. M. Hoffman,. D. C. Wilson, *et. al.*, Phys Plasmas, 3, 2084 (1996).

6- S. H. Glenzer, L. J. Suter, R. L. Berger, K. G. Estabrook, et. al., Phys Plasmas, 7, 2585 (2000). See also, B. J. MacGowan, R. L. Berger, S. I. Glenzer, et. al., Laser Beam Smoothing and Backscatter Saturation Processes in Plasmas Relevant to National Ignition Facility Hohlraums, Proceedings of the 17th IAEA Fusion Energy Conference, Yokohama, Japan (October, 1998), International Atomic Energy Agency, Vienna.

7- R. L. Kauffman, L. J. Suter, C. B. Darrow, *et. al.*, Phys. Rev. Lett. 73, 2320 (1994).

8- L. J. Suter, R. L. Kauffman, C. B. Darrow, *et. al.*, Phys. Plasmas 3, 2057 (1996).

9- R. Siegel, R. Pakula, S. Sakabe and G. D. Tsakiris, *et. al.*, Phys. Rev. A 38, 5779 (1988).

10- See National Technical Information Service Document No. DE95011969 (S. N. Dixit, I. M. Thomas, M. R. Rushford, *et. al.*, "Kinoform Phase Plates for Tailoring Focal Plane Intensity Profile", ICF Quarterly UCRL-LR-105821-94-4 (1994).) Copies may be obtained from the National Technical Informatio Service, Springfield, VA 22161

11- S. H. Glenzer, L. J. Suter, R. E. Turner, *et. al.*, Phys. Rev. Lett., 80, 2845 (1998).

12- J. M. Soures. R. L. McCrory, C. P. Verdon, *et. al.*, Phys. Plasmas, 3, 2108 (1996).

13- C. Decker, R. E. Turner, O. L. Landen, *et. al.*, Phys. Rev. Lett., 79, 1491 (1997).

14- R. E. Turner and O. L. Landen, Rev. Sci. Inst., 70(1), 656 (1999).

15- O. L. Landen, Lawrence Livermore National Laboratory, Livermore, CA, private communication (1996).

16- H. N. Kornblum and R. L. Kauffman, Rev. Sci. Inst., 57, 2179 (1986).

17- E. Dattolo, *et. al.*, "Hohlraum x-ray drive control: an issue in the design of LMJ/NIF targets", p 158, Proceedings, 1st Conference on Inertial Fusion Sciences and Applications, Bordeaux, 1999, edited by C. Labaune et al. (ELSEVIER, Paris, 2000).

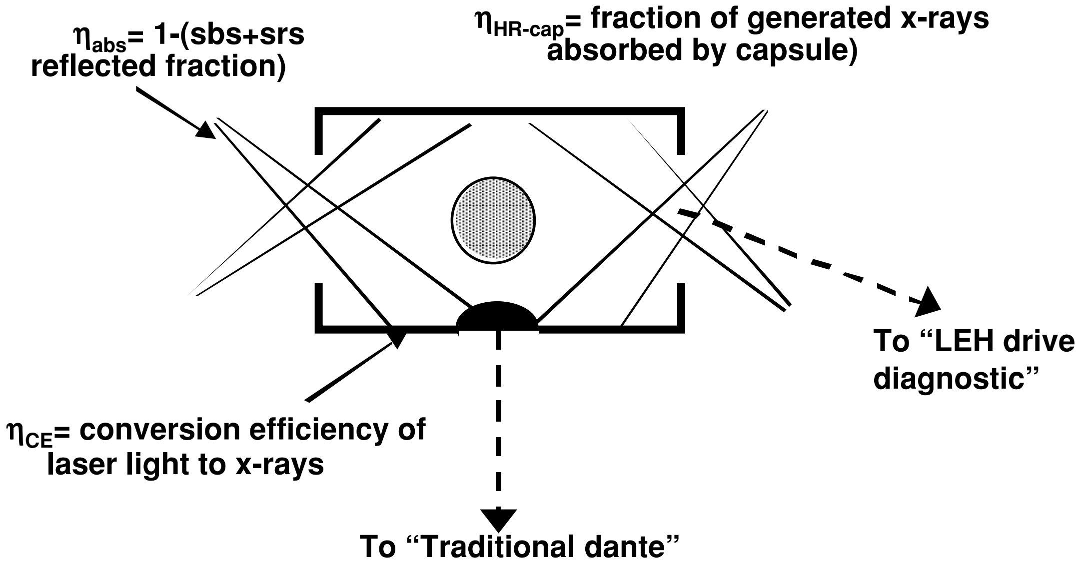
η_{abs}= 1-(sbs+srs reflected fraction)
η_{HR-cap}= fraction of generated x-rays absorbed by capsule)
To “LEH drive diagnostic”
η_{CE}= conversion efficiency of laser light to x-rays
To “Traditional dante”

Figure 1

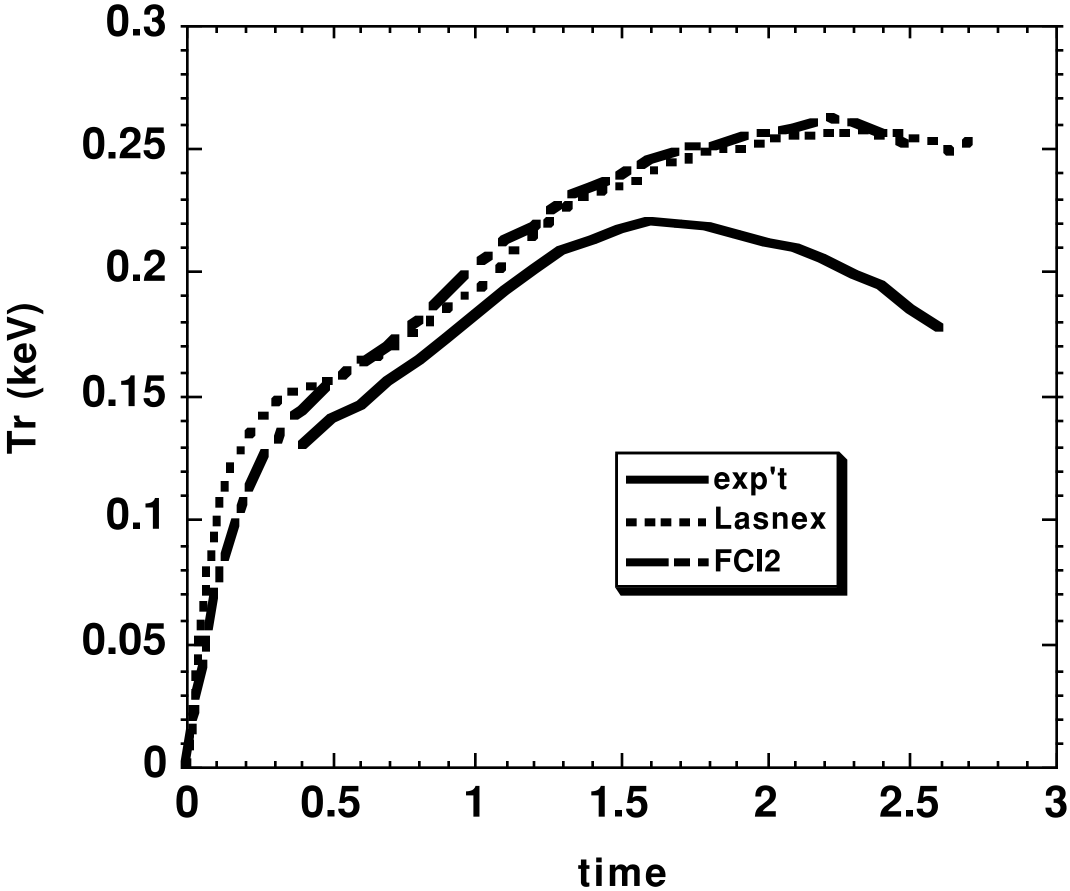

Figure 2

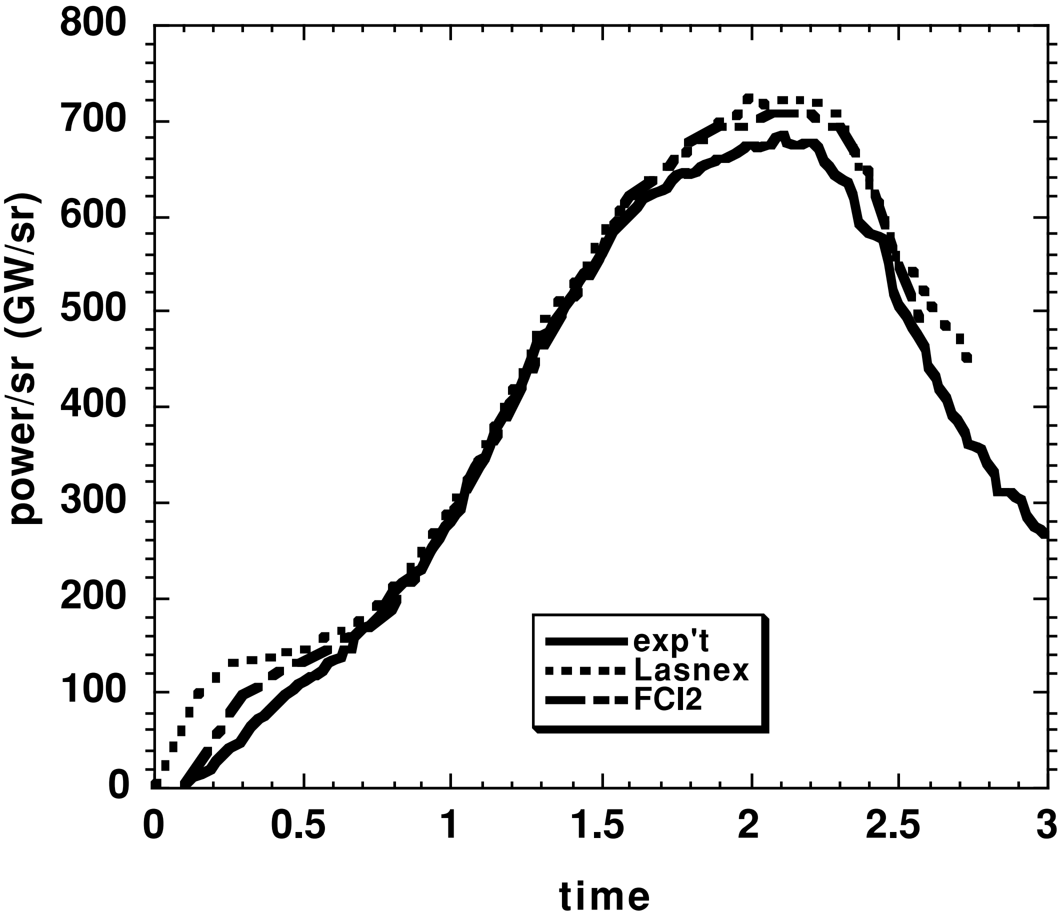
800
700
600
500
400
300
200
100
0
power/sr (GW/sr)
0
0.5
1
1.5
2
2.5
3
time
exp't
Lasnex
FCI2

Figure 3

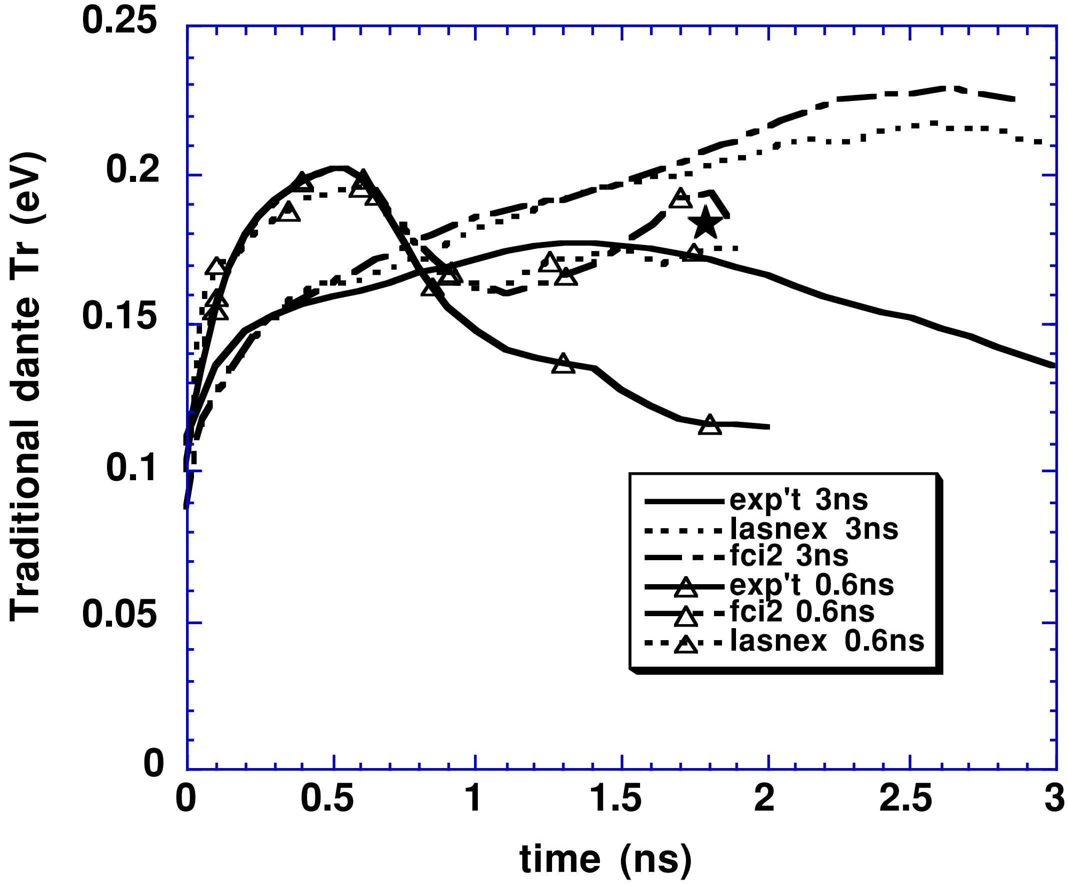
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
Traditional dante Tr (eV)
time (ns)
exp't 3ns
lasnex 3ns
fci2 3ns
exp't 0.6ns
fci2 0.6ns
lasnex 0.6ns

Figure 4

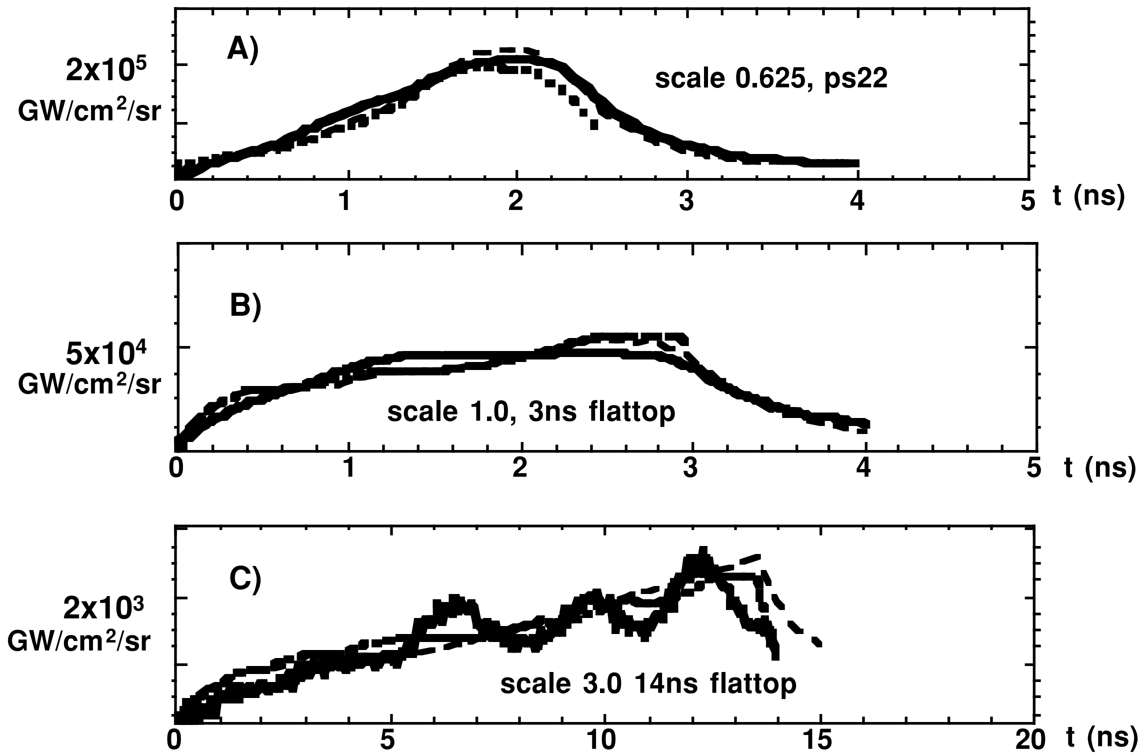
A)
2x10^5
GW/cm^2/sr
scale 0.625, ps22
0 1 2 3 4 5 t (ns)
B)
5x10^4
GW/cm^2/sr
scale 1.0, 3ns flattop
0 1 2 3 4 5 t (ns)
C)
2x10^3
GW/cm^2/sr
scale 3.0 14ns flattop
0 5 10 15 20 t (ns)

Figure 5

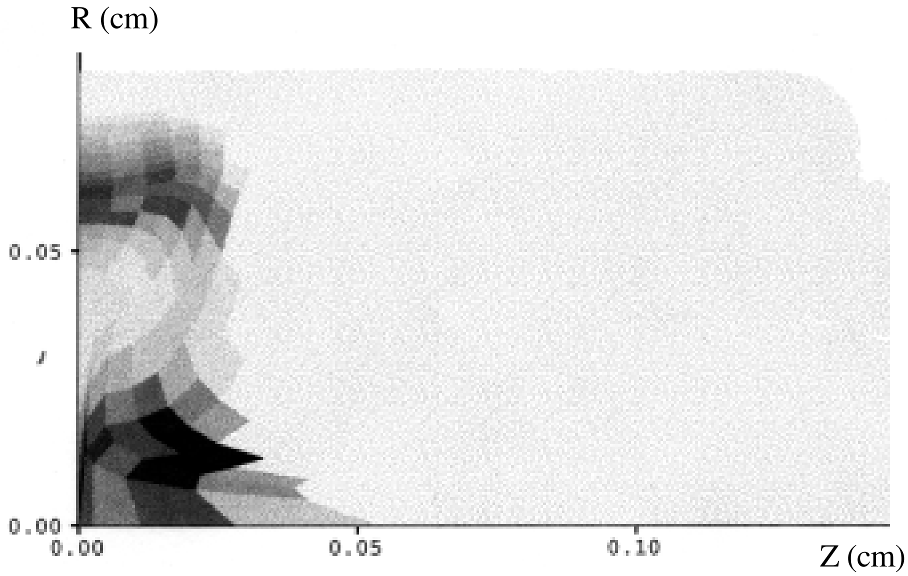

Figure 6

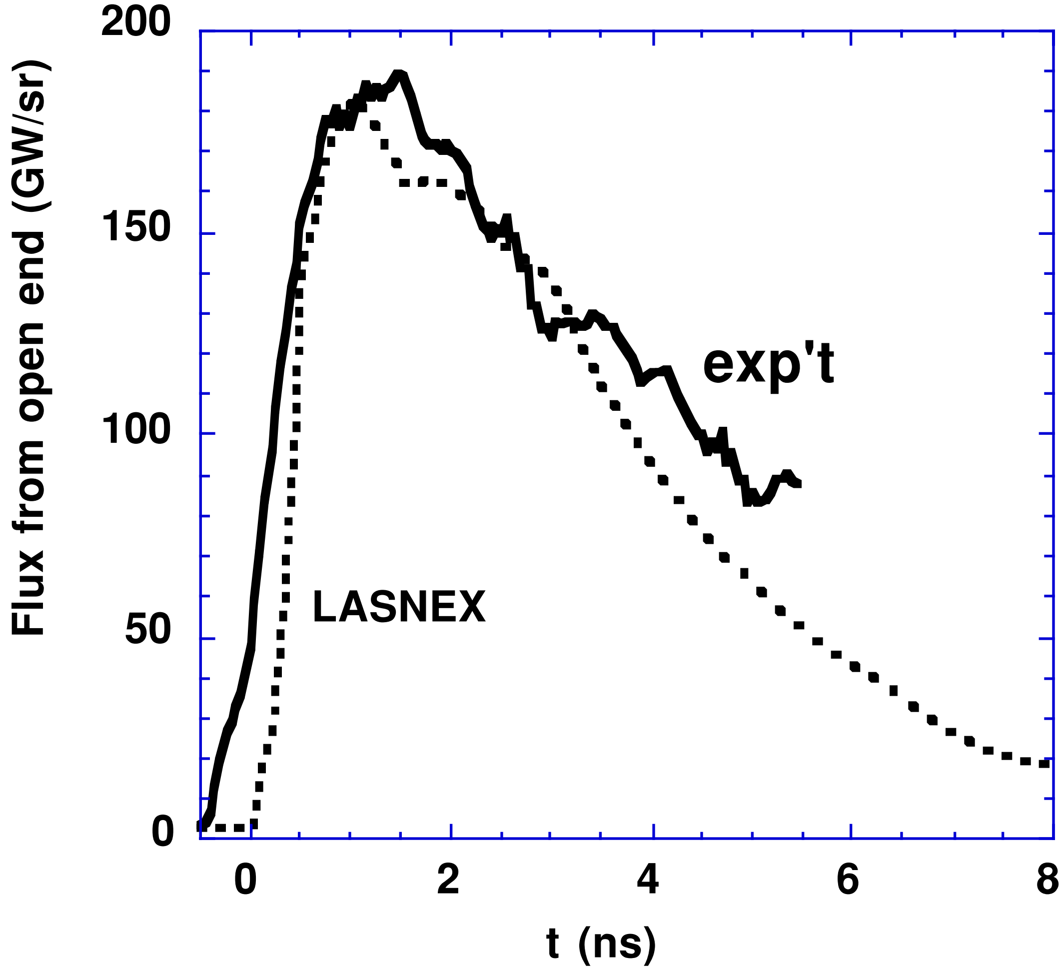

Figure 7