Wednesday, September 11, 2013

# OP.We_A1

## Developing an understanding of the evolution of low-mode density and shape asymmetries throughout the ignition drive

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In order to achieve ignition it is important to control the growth of low-mode asymmetries as the capsule is compressed. Developing an understanding of the evolution of variations in areal density and the final shape of the hot-spot and fuel is crucial to optimizing implosion performance. We have developed a design and experimental campaign to examine the sources of asymmetry and to measure the symmetry throughout the implosion using a wide range of experimental and diagnostic techniques.

The early-time symmetry of the radiation provides a drive during the first 2 ns that is measured along both the polar and equatorial directions using re-emission from a high-Z surrogate ball[1]. The sequence of shocks driven into the capsule throughout the first 3-4 rises in the drive pulse is measured using a VISAR propagating into a re-entrant cone[2]. The addition of extra mirrors inside the capsule allows simultaneous measurement of shock symmetry at up to 3 locations on a single shot, providing a measurement of asymmetries up to mode 4 in both the equatorial and azimuthal planes. In-flight x-ray radiography is used to capture images of the shell at radii between 300 and 100 μm, providing time-resolved information on low-mode shape and areal density variations. The shape of the hot-spot during final stagnation is measured using time-resolved imaging of the self-emission, and information on the shape of the fuel at stagnation can be obtained from Compton radiography using a wire-backlighter. Additional burn-weighted information on the shape of the hot-spot and surrounding shell can be obtained from a suite of nuclear diagnostics, including a neutron imager, and a series of neutron- (and proton-) time-of-flight and activation diagnostics.

The sensitivity of the in-flight and final implosion symmetry to imposed changes will be presented and compared to model predictions

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

OP.We_A2

# Hydrodynamic instabilities and hot spot mix in the ignition campaign on NIF: predictions, observations, and a path forward*

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An extensive campaign of inertial confinement fusion implosion experiments have been done on the National Ignition Facility (NIF). These implosions use hohlraums irradiated with shaped laser pulses to compress cryogenic DT fuel to high areal density on a low adiabat, $\alpha \sim 1.6$, at laser energies ranging from 1.3-1.9 MJ. [1] The peak power and duration at peak power were varied, as were the capsule ablator dopant concentrations and shell thicknesses. [2, 3] Hydrodynamic instabilities, such as the Rayleigh-Taylor (RT) instability, lead to mixing of ablator material into the hot spot, causing radiative loses, cooling the hot spot, and degrading performance. The amount of ablator mixed into the hot spot is inferred from the measured elevated x-ray emission from the hot spot. [4] Hot spot mix is also observed by preparing capsules with Ge and Cu spectroscopic tracer layers at specific locations in the ablator, and observing their emission and absorption signatures at peak compression. [5] We observe that DT neutron yield and ion temperature decrease abruptly as hot spot mix mass increases above a "mix cliff" at ~200 ng. Comparisons with radiation-hydrodynamics simulations indicate that low mode asymmetries and increased ablator surface perturbation growth may be partly responsible for the current performance levels. Several new experimental platforms and diagnostic techniques on NIF are under development to better quantify the mix levels and test leading hypotheses for the observed hot spot mix. Furthermore, a higher adiabat implosion platform predicted to be less RT unstable is under development. [6] Progress to date and plans going forward will be described.

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*Prepared by LLNL under Contract DE-AC52-07NA27344.

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OP.We_A3

# Overview of Direct-Drive–Implosion Physics: Results from OMEGA and the NIF

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Direct drive offers an alternative path toward ignition on facilities like the National Ignition Facility (NIF) and Laser Mégajoule (LMJ). Direct-drive–implosion physics will be discussed. Observations relating to implosion energetics, adiabat, and nonuniformity growth from several different platforms on OMEGA, including cryogenic deuterium–tritium layered implosions, are used to develop and validate models. These observations, comparisons with simulations, and their implication for ignition will be presented. When beams are arranged in cylindrical geometry, such as the NIF in its current x-ray-drive configuration, additional methods are employed in ignition designs to directly drive shells with sufficient velocity and with good symmetry, particularly near the target equator. “Polar-drive” (PD)–ignition simulations require repointing of beams toward the equator, higher energies for the beams closest to the equator, and custom beam profiles. OMEGA experiments in PD configuration and their relevance to ignition will be discussed. Limitations of these experiments can be addressed with NIF PD implosions. Results from initial NIF experiments will be presented and a path for validating ignition-relevant models on the NIF will be described.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-08NA28302, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

# PROGRESS IN SHOCK IGNITION AT THE LABORATORY FOR LASER ENERGETICS: EXPERIMENTS ON OMEGA AND TARGET DESIGNS FOR THE NATIONAL IGNITION FACILITY

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Recent experiments and target design work at the Laboratory for Laser Energetics (LLE), in collaboration with CELIA and CEA, have been carried out to validate the shock ignition (SI) concept and to develop a target design for ignition experiments on the National Ignition Facility. Among the most recent experiments, spherical targets have been used to demonstrate the generation of ultra-strong shocks with a driving pressure of hundreds of megabars. Since shock ignition relies on the generation of an ignitor shock at about 300Mbar pressure, the demonstration of such strong shocks is crucial to the validation of the SI concept. Another set of experiments was devoted to study the laser-plasma instabilities (LPI) at shock ignition relevant intensities of about 3-5×$10^{15}$ W/cm$^2$. Those LPI experiments are used to assess the level of reflectivity and hot electron generation. It is found that for SI-relevant intensities the hot electron temperature is relatively low ~50keV and the reflectivity below ~ 30%. These results indicate that hot electron preheat and laser energy coupling can be controlled within acceptable levels in an ignition target.

Within the constraints imposed by the hydrodynamics of strong shock generation and the laser plasma instabilities, target designs for SI experiments on NIF have been developed at LLE. Two-dimensional rad-hydro simulations of SI target designs for NIF predict ignition in the polar-drive beam configuration at sub-MJ laser energies. Design robustness to various 1-D effects and 2-D non-uniformities has been characterized. A target design has been developed that, according to 2D simulations, show ignition and gain (~30-50) at ~700kJ of laser energy in the polar drive NIF configuration including all the expected sources of nonuniformities.

# O.We_A5

## Status of Point Design for Cone-guided Fast Ignition

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We report on the status of a point design for cone-guided fast ignition developed using an integrated suite of codes that simulate fuel compression, ignitor pulse laser-plasma interaction, fast electron generation and transport, core heating, ignition, and burn. We use a re-entrant cone-in-shell target with an indirect-drive irradiation scheme compatible with the 1.8 MJ National Ignition Facility (NIF) at LLNL. 2-D integrated hohlraum and capsule simulations are performed with the radiation-hydrodynamics code, HYDRA, to optimize the peak density, areal density, and spatial uniformity of the compressed fuel around the cone tip, whilst maintaining its physical integrity [1]. 3-D particle-in-cell (PIC) simulations model the ignitor pulse laser-plasma interaction (LPI) at full spatial scale over picosecond time duration to compute an electron source distribution as a function of space, time, energy, and angle [2]. Transport of the full electron distribution to the compressed core is modeled with a hybrid-PIC code, ZUMA, coupled to the HYDRA code.

Initial PIC calculations predicted an energetic and divergent electron source that resulted in low energy coupling to the compressed core [3, 4]. Recent improvements have produced an electron distribution with a cooler spectrum and narrower divergence, resulting in a substantial 3-4x reduction in the required ignition energy. Additional improvements in the cone tip design that employ shaped self-generated magnetic fields at material interfaces to refocus fast electrons to the core enhance energy coupling and further reduce the ignition energy. Using these integrated calculations of the laser interaction, electron generation, core heating, and burn, we can determine the minimum energy requirements for fast ignition, and importantly, assess the effects of simulation uncertainties in the modeling of LPI and electron transport on the probability of ignition.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

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O.We_A6

# Areal density measurement of imploded cone-in-shell targets using monochromatic Cu K-alpha Radiography

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Understanding the formation of a laser-imploded dense core is critical for fast electron heating in the Fast Ignition (FI) [1, 2] Inertial Confinement Fusion (ICF). In cone-guided FI scheme, a spherical shell with a re-entrant cone is imploded with high-energy drive lasers and a high-energy, short-pulse ignition laser is injected into the cone to generate energetic electrons, locally heating the compressed core and initiating ignition. For efficient core heating, a high density core is required to be formed close to the cone tip without destroying the cone. The key parameters for the core formation are the core size, timing and value of peak areal density and the standoff distance between the core and the cone tip. We have conducted a joint OMEGA experiment to measure a temporal evolution of the areal density of an imploded cone-in-shell target using 8.05 keV monochromatic K-alpha radiography [3]. A 41 μm thick shell (15 μm CH outer/26 μm CD inner layer, 870 μm diameter capsule) with an re-entrant Au cone was imploded by 54 OMEGA beams with a low-adiabat, shaped drive pulse. A 1 mm$^2$ Cu foil positioned at 10 mm away from the target chamber center was irradiated with the 10 ps, 1.25 kJ OMEGA EP beam in a 200 μm spot size to produce uniform 8.05 keV Cu K-alpha x-ray emission in ~ 10 ps duration. The radiograph images were recorded using a spherical crystal imager with ~ 20 μm spatial resolution and 13.5 magnification [4]. The formation of the compressed core was clearly observed in the radiograph images taken at 3.68, 3.82, 4.02 and 4.22 ns. A preliminary comparison of the measurements and 2-D Radiation-hydrodynamic simulations using DRACO shows a good agreement in the timing of the peak compression at 4.0 ns. The detail of the analyses to infer areal density and comparisons to the simulations will be presented. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Security, LLC, Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and DE-FG02-05ER54834 (ACE)

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# O.We_A7

## The diagnostics of the energy coupling efficiency in the fast ignition integrated experiment

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Quantitative investigation of the energy coupling efficiency from the heating laser to the compressed fuel core in the fast ignition experiment has been made. In this study a wide variety of diagnostic methods providing neutron yield, neutron spectrum, electron temperature of the heated core, and density profile of the core were developed and applied for studying energy coupling efficiencies.

Deposit energy to the core plasma was estimated by the ion temperature measured with neutron TOF spectrum and the core density profiles obtained with the x-ray backlight image. The ion temperature was confirmed with neutron yield and core density, and with core electron temperature measured with x-ray spectrum. In this way important plasma parameters of the core are mutually confirmed.

A CD-shell attached with an Au cone was imploded by the Gekko and heated by LFEX at the maximum compression. The neutron yields were successfully measured by a newly developed liquid scintillator-based detector and a neutron collimator excluding neutrons originated via photonuclear reaction mainly occurring in the target chamber wall [1]. Core density ρ, and density-radius product ρR were measured by monochromatic x-ray backlighting. Ion temperatures estimated by using observed neutron yield, fuel density, and confinement time was $0.84 \pm 0.05$ keV for the shots with LFEX heating and $0.67 \pm 0.02$ keV for those without LFEX heating. This value was compared with the ion temperature measured via Doppler broadening in neutron spectrum provided by a multichannel single hit neutron detector “MANDALA”, showing good agreement. The electron temperature observed by streaked x-ray images with three different energy windows also confirmed these ion temperature.

In the presentation, details of these diagnostic instruments and methods will be discussed together with the key parameters of fast ignition plasma including the coupling efficiencies.

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# O.We_A8

## Transport of High Intensity Laser-driven Proton Beams in Solid-density, Isochorically Heated Matter

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We have studied transport of high intensity laser-driven protons beams in solid foils of either Mylar, Al, Cu, or Au. First we conducted an experiment using the TRIDENT laser (75 J, 0.6 ps) at Los Alamos National Laboratory in which protons driven by the short pulse interaction with a spherically curved foil [1,2] were focused to high intensity into a second flat foil of various material with a rear coating of Au. XUV emission from the proton-heated matter was found to be emitted from a tightly focused area. A clear dependence of the size of the emission region on transport foil material was observed and the variation in emission size was much larger than expected proton beam spread from Moliere scattering and cold Monte Carlo calculations. Further, the targets with a Au transport layer produced the tightest spot (40 $\mu$m) in spite of having the highest Z and areal density. By comparison, the Al transport layers resulted in large diffuse emission spots (as large as 180 $\mu$m) and diffuse filaments were observed in the CH cases. Particle-in-cell modeling using the LSP code [3], which required modification of the stopping power models to more accurately simulate proton stopping in warm, dense plasma will be discussed with regards to the dynamic ionization, stopping, and transport mechanisms relevant during the interaction of such a high intensity proton beam with solid material.

A follow-on scaled-up study is in preparation for further investigation using the kilojoule OMEGA EP lasers. Spherically curved CVD diamond targets will be irradiated by a 10-ps 1.25-kJ EP laser, generating a focusing proton beam to intensity >$10^{17}$ protons/cm$^3$. The proton beam will heat a Cu foil placed at the beam focus and proton-induced Kα emission profile will be imaged with a spherical crystal imager and the total Kα yield will be measured with a single photon counting camera. In addition, such an intense current proton beam propagating in vacuum will likely generate filamented self-fields [4] which will be temporally and spatially resolved using the proton radiography with a high energy proton beam created by a second high intensity EP pulse. We will present these experimental results complemented with the LSP simulations.

This work was supported by the U.S. Dept. of Energy under Contract DE-AC52-07NA27344 in collaboration with D.C. Gautier, J.C. Fernandez (LANL), and by the DOE/NNSA National Laser User Facility program, funding opportunity DE-FOA-0000681 in collaboration with S.N. Chen, J. Fuchs (LULI), and P.M. Nilson (LLE).

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O.We_B1

# Proton and ion acceleration by the $10^{21}$ $Wcm^{-2}$ intensity high contrast laser pulses interacting with the thin foil target

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Acceleration of ions to high kinetic energy in plasmas by the interaction between high-intensity laser pulses and thin-foil targets has been investigated for more than three decades [1], as demanded by many possible fields of applications, such as laser-driven ion beam radiotherapy, ion probing, proton imaging, proton induced fast ignition, isotope production, etc. However, there are many issues to be solved before the real application. For example, the most serious is the extension of the maximum energy of ions, if we consider the medical application. Achieving high quality energetic ion beams with accessible targets and relatively small laser pulse energy by using a compact laser system with a high repetition rate is the purpose of our investigation.

We recently demonstrated the 40 MeV proton acceleration from a micrometer thick metal foils irradiated by 7.5 J, 40 fs, 800 nm laser pulses with the temporal contrast of $10^{10}$ focused to the intensity of $1 \times 10^{21}$ W/cm$^2$ [2]. This is the highest proton energy obtained with the laser pulses having the energy of <10 J [1]. The conversion efficiency from laser to protons with the energies more than 15 MeV was achieved to be 0.1%. For investigating the background physics in order to optimize the ion acceleration as well as to find the scaling law, additional experimental campaign is now going. The dependency of the maximum proton/ion energies and the proton/ion footprints on the target material and thickness, a correlation with the electron temperature, reflectivity of the laser pulse, and the laser pre-pulse level will be discussed. Based on those, the future prospects will be discussed.

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O.We_B2

# GENERATION OF ELECTRON BEAM AND BETATRON X-RAY FROM LASER-DRIVEN ATOMIC CLUSTERS

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Hard x-ray emission from femtosecond laser produced plasmas has been studied in the past years [1]. Such hard x-ray sources have a number of interesting applications in the dynamic probing of matter and in medical/biological imaging. However, this source is always limited by its conversion efficiency, single-to-noise ratio and picosecond pulse duration. we present our recent progress in this field and introduce newly invented/optimized intense sources with ultrashort temporal duration.

At first, we show that the limitation on the hard x-ray emission enhancement can be overcome by using high contrast fs laser pulses on solid [2]. In this regime the “Vacuum Heating” is the main mechanism for the hot electron heating. It does not saturate and results in x-ray enhancement of ~ 4 $x10^{-4}$ in conversion efficiency. And then, in order to avoid the interacting column limitation on solid as well as to get higher single-to-noise ratio x-ray source, we present the result of x-ray spectroscopy from an Ar cluster target irradiated by laser pulse at $10^{17-18}$ W/cm$^2$ [3, 4]. The spectrum shows a high contrast characteristic K-shell emission, a compressed continuum and the elimination of the energetic x-ray tail. New electron heating mechanism is stimulated. Correlation between this intense K-shell emission with the laser channeling in the Ar gas is addressed. After optimization, this Ar K-shell x-ray possesses the measured flux of 2.5 x $10^{11}$ photons/J. The peak brightness is estimated to be ~1.2 x $10^{22}$ photons/s/mm$^2$/mrad$^2$, which is comparable to the third generation synchrotron radiation sources. For the first time, single-shot keV x-ray photon imaging is obtained which is suit for the ultrafast x-ray radiography [4]. This source is proved to be ultrashort with duration ~ 10fs.

In order to get the collimated photon beams, we performed electron acceleration experiment for stimulating betatron radiation [5]. Bright betatron x ray has been generated using an Ar clustering target irradiated with a 3 TW laser. The measured emission flux with photon energy > 2.4 keV reaches 2 x $10^8$ photons/shot. It is over ten-fold enhancement comparing to the emission flux produced by using the gas target. Simulations point to the existence of cluster in gas results in the increasing of electron injection and larger wiggling amplitude in wake-field, enriching the x-ray photons.

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# O.We_B3

## Recent Advances in Ultra-Low-Density Foams for Multi-KeV X-Ray Sources

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We report on recent experimental campaigns that have investigated and optimized x-ray yield from ultra-low-density ($\rho$ < 10 mg/cm$^3$) silica aerogel and metal-oxide foam targets. Recently, we have pursued a number of avenues of target development to increase the metallic-constituent concentration in our foam targets. We have worked with Ti (Z=22), V (Z=23), Cu (Z=29) and Zn (Z=30) in order to develop x-ray sources that emit K-shell radiation from 4.7 keV (Ti He$_\alpha$) to 9 keV (Zn He$_\alpha$). In the case of Ti and V, we have pursued two new technologies: one is to start with 1 mg/cm$^3$ $SiO_2$ aerogels and coat the high-Z element onto the silica substrate through Atomic Layer Deposition (ALD). We can achieve a final product with an aggregate density of ≈4 mg/cm$^3$ and ≥20 atom-percent Ti or V. Secondly, we have taken gold nanofibers and coated them with pure titania ($TiO_2$), then, through a chemical etch process, we have removed the gold and left a $TiO_2$ foam at densities that ranged from 5 to 18 mg/cm$^3$. We have investigated the x-ray output from these ALD and Au template targets through a series of experiments at the OMEGA laser at the University of Rochester Laboratory for Laser Energetics and at the GEKKO XII laser at the Osaka University Institute for Laser Engineering. We will report the laser-heating characteristics of the foams and the x-ray flux and fluence output by each target type. Good enhancement of x-ray yields is seen for these new targets.

Further, we have developed new Cu foam targets through two techniques. One technique is a four-step lithography process, in which we use an ion accelerator to put tracks in a 3-5-μm-thick polycarbonate substrate. We then etch out the intersecting damage tracks and electro-plate the Cu into the ≈10-nm-diameter holes left by the etch process. The final etched and plated substrates are assembled into the final target dimensions and the substrate is dissolved, leaving a pure Cu foam. The second approach uses mechanical trapping of Cu nanowires or nanoparticles in low-density pure carbon nanotube (CNT) foam. We succeeded in fabricating ~20 mg/cm$^3$ CNTs with Cu concentrations between ~5 and 15 atom-%. We have characterized the output of the Cu-loaded CNT foam targets, and some ALD-coated Zn targets on a $SiO_2$ template (4 mg/cm$^3$, 20 atom-% Zn) in a dedicated series of shots at the OMEGA laser. We will report the laser-heating characteristics of the foams and the x-ray flux and fluence output by each target type.

This work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52- 07NA27344 and was supported by the Defense Threat Reduction Agency under the IACRO 09-45501 and DTRA Basic Research Project #BRCALL08-Per3-C-2-0006.

O.We_B4

# Laser-driven Gamma-ray Source via Radiation Reaction Effect

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In the interactions of peta-watt class laser pulses and matters, a radiation reaction effect on an electron motion driven by the strong laser field plays an important role. The effect of radiation reaction is expected to lead to the generation of high flux of photons in the energy range of gamma-rays. In order to evaluate the detail of the gamma-ray characteristics and efficiency, we developed a Particle-in-Cell code incorporating the radiation reaction effect by using Landau-Lifshitz equation[1]. From the numerical analyses, it is found that the generated gamma-ray pulse has quite unique features such as high power, short duration, high directionality, and high conversion efficiency when choosing the optimum conditions[2]. Since the gamma-ray characteristics strongly depend on the laser and plasma parameters, it is important to clarify these dependences for generating a gamma-rays for application use and radiation protection as well. Figure 1 shows the gamma-ray power dependence on plasma scale length and laser power, indicating that there exist an optimum condition for effective gamma-ray generation. From further analyses, we showed how to control the photon number, photon energy, pulse duration and so on. These studies lead us to propose a new source of laser-driven gamma-rays via radiation reaction effect.

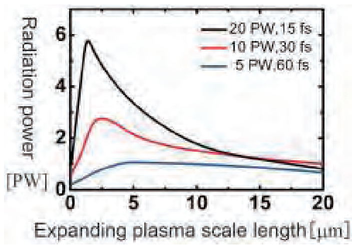


Fig. 1 Gamma-ray power dependence on laser and plasma parameters. Three lines correspond to different laser power with a fixed laser energy ($E_L$=300J). There exists an optimum scale length for the effective gamma-ray generation.

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O.We_C1

# UNDERSTANDING THE STAGNATION AND BURN OF HIGH CONVERGENCE IMPLOSIONS ON THE NIF

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Measuring the properties of the stagnated plasmas from high convergence implosions on the NIF is challenging because of both the small spatial and temporal scale-lengths and the spatial and temporal in-homogeneities, which are hard to avoid in high convergence implosions.

We have used time resolved x-ray emission and un-scattered neutron imaging to examine the implosion symmetry of the hot spot. X-ray continuum emission and x-ray line emission from tracer materials in the ablator measure mix but with limited resolution to date. Time resolved x-ray photoelectric absorption imaging measures the evolution of the shape of the cold compressed shell but is presently limited to just before the stagnation phase, although measurements are getting as close in as a few times the final radius. These measurement hint at a deviation from the idealized symmetric compressed ablator and fuel, surrounding and mixing into a smaller hot spot.

The comprehensive nuclear diagnostic suite on NIF measures the neutron emission spectrum as a function of direction by many techniques including radchem, and with limited temporal and spectral resolution the gamma emission. The isotropy in the ion "temperature" from the broadening of the primary neutrons is measured. A burn weighted averaged fluid velocity is seen from the energy shift of the primary neutron spectrum. The nuclear emissions from the hot spot are essentially a finite sized source for backlighting the surrounding cold material. At ~ 1 gm/cm$^2$ of compressed deuterium–tritium (DT), significant neutron scattering occurs modifying the escaping neutron spectrum. The isotropy of the down-scattered neutron spectrum is measured to sample the anisotropy of the compressed DT. Anisotropy in the un-scattered primary neutrons is measured with nineteen nuclear activation detectors. The low energy neutron spectrum is measured by radchem of the gold hohlraum. The time history of the neutron excited 4.4 MeV C gamma emission measures an areal density of un-ablated carbon from the plastic shell. The picture that is emerging is of a very in-homogenous compressed DT with indications of response to gross hydrodynamic features measured by the x-ray diagnostics.

*This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA277344.

# O.We_C2

## Results from neutron imaging of ICF experiments at NIF

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In 2011 a neutron imaging diagnostic was commissioned at the National Ignition Facility (NIF)[1]. This new system has been used to collect neutron images to measure the size and shape of the burning DT plasma and the surrounding fuel assembly. The imaging technique utilizes a pinhole neutron aperture, placed between the neutron source and a neutron detector. The detection system measures the two dimensional distribution of neutrons passing through the pinhole. This diagnostic has been designed to collect two images at two times. The long flight path for this diagnostic, 28 m, results in a chromatic separation of the neutrons, allowing the independently timed images to measure the source distribution for two neutron energies. Typically the first image measures the distribution of the 14 MeV neutrons and the second image of the 6-12 MeV neutrons. The combination of these two images has provided data on the size and shape of the burning plasma within the compressed capsule, as well as a measure of the quantity and spatial distribution of the cold fuel surrounding this core. Images have been collected for the majority of the experiments performed as part of the ignition campaign. Results from this data have been used to estimate a burn-averaged fuel assembly as well as providing performance metrics to gauge progress towards ignition. This data set and our interpretation will be presented.

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# O.We_C3

## Quantitative Kα line spectroscopy for energy transport in ultra-intense laser plasma interaction

Z. Zhang[1], H. Nishimura[1], T. Namimoto[1], S. Fujioka[1], Y. Arikawa[1], M. Nakai[1], H. Chen[2], J. Park[2], G. J. Williams[2], T. Ozaki[3], M. Koga[1], H. Shiraga[1], S. Kojima[1], H. Hosoda[1], N. Miyanaga[1], J. Kawanaka[1], Y. Nakata[1], T. Jitsuno[1] and H. Azechi[1]

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Kα emission, as a consequence of laser energy deposition and hot electron propagation, can provide abundant information about the laser plasma interaction. Quantitative Kα diagnostic is expected to be a potential way to quantify the laser energy transfer efficiency. In this way, a Laue spectrometer, composed of a cylindrically curved crystal and a detector, has been absolutely calibrated for high-energy x-ray from 17 to 77 keV. Either a visible CCD detector coupled with a CsI phosphor screen or an imaging plate can be chosen, depending on the signal intensities and exposure times. The absolute sensitivity of the spectrometer system was calibrated using pre-characterized laser-produced x-ray sources [1] and radioisotopes, for the detectors and crystal respectively. The integrated reflectivity for the crystal is in good agreement with predictions by an open code for x-ray diffraction.

The energy transfer efficiency from incident laser beams to hot electrons, as the energy transfer agency is derived as a consequence of this work. The absolute yield of Au and Ta Kα lines were measured in the fast ignition experimental campaign performed at ILE Osaka U.. By applying the electron energy distribution from ESM data and scaling laws, energy transfer efficiency of incident LFEX, a kJ-class PW laser, to hot electrons was derived, as shown in Fig. 1.

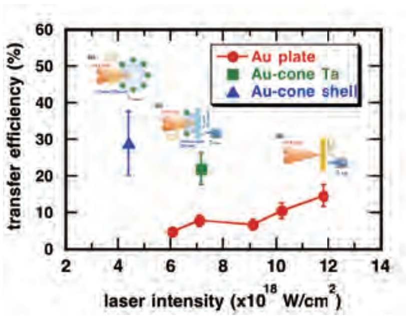


Figure 1: The transfer efficiency as a function of the laser intensity for three targets.

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# O.We_C4

## Radiographic measurements of areal density and areal density non-uniformities of ICF implosions

R Tommasini, O Landen, S Hatchett, J. R. Rygg, L Divol, O. S. Jones, M. A. Barrios, K. B. Fournier, R. Benedetti, T. Doeppner, D. C. Eder, J. E. Field, E. Dewald, S. M. Glenn, N. Izumi, S. F. Khan, T. Ma, J. L. Milovich, A MacKinnon, D. Kalantar, P DiNicola, P. Bell, G. W. Collins, R. P. J. Town, D. K. Bradley, J. Kilkenny, B. Macgowan, W. Hsing, J. Edwards, B. Van Wonterghem, J. Atherton, E.I. Moses

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Implosion efficiency depends on keeping the in-flight ablator and fuel as close as possible to spherical at all times. Asymmetries and areal density non-uniformities seeded by time-dependent drive variations and target imperfections grow in time due to instabilities. One way to diagnose them is imaging the self-emission from the implosion core. However this technique presents complications due to competition between emission gradients and reabsorption. Time resolved radiographic imaging, being insensitive to this effect, is therefore an important tool for diagnosing the ablator and the dense cold fuel surrounding the hot spot in inertial confinement fusion (ICF) implosions.

Experiments aimed at measuring areal density and areal density asymmetries of ICF implosions have been performed with different radiography techniques on the NIF. We will compare the results of hard-x-ray (~ 50-120 keV) point-projection radiography of the fuel in the Compton-scattering dominated regime1 and at peak compression, to those, sensitive to the ablator, at lower photon energies (~10keV) using pinhole imaging coupled to area backlighting and as close as 200ps to peak compression2. Recent developments in hard-x-ray radiography optimization, with emphasis on signal-to-background and signal-to-noise with gated detectors, by appropriate choice of filtering and backlighter configuration, will also be discussed.

*This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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