SIMULATIONS EXAMINE PERFORMANCE OF PURE BORON, BORON CARBIDE, HIGH-DENSITY CARBON AND BORON NITRIDE ABLATORS—THE MATERIAL

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1-**The performance of pure boron, boron carbide, high-density carbon and boron nitride ablators—the material** that surrounds a fusion fuel and couples with the laser or hohlraum radiation in an experiment—in the polar direct drive exploding pusher (PDXP) platform. The platform uses the polar direct drive configuration to drive high ion temperatures in a room-temperature capsule and has potential applications for plasma physics studies and as a neutron source. Our simulations predict that the platform is not amenable to the electron-ion coupling measurements due to a lack of implosion symmetry, these alternate materials do enable better coupling between the lasers and capsule, we can test those predicted impacts on future neutron source experiments. Examining the improvement in coupling because it could help improve the yield of the polar direct drive neutron sources, and ultimately provide data on the validity of laser modeling for direct drive simulations. Inertial confinement fusion simulation code developers implement more advanced models for electron-ion coupling, and modeling the direct drive implosions have been closely coupled with that code development. One of the main goals has been to create ignition in deuterium-tritium plasma in the laboratory. The design of these experiments relies heavily on computer models that are based on an understanding and assumptions about the behavior of these hot plasmas. In these experiments, ions are heated more rapidly than the electrons via a very strong laser-generated shock. Intended to use time resolved spectroscopy, which is a measure of how much light is being emitted from the plasma at a specific frequency, in order to measure the temperatures of both the ions and the electrons as a function of time during the experiment. Electron-ion coupling is a parameter that describes how ions and electrons exchange energy in plasma. The PDXP platform was developed to study electron-ion equilibration but ended up being an ideal neutron source for several other campaigns. The great advantage of this platform is that it is simple —spherical shell filled with fuel—and allows multiple diagnostics from any ports to take data and produces high neutron yield. This research did a theoretical study of performance (neutron yield) versus composition of the shell materials and its thickness. Based on these models predicting a particularly useful improvement in performance, like higher yield, or the model predicting a large change in a measured quantity, like the trajectory of the imploding capsule or the temperature of the nuclear burn, we can execute to test if the calculation was indeed successful at predicting the change in performance.

2-Simulations examine performance of materials -

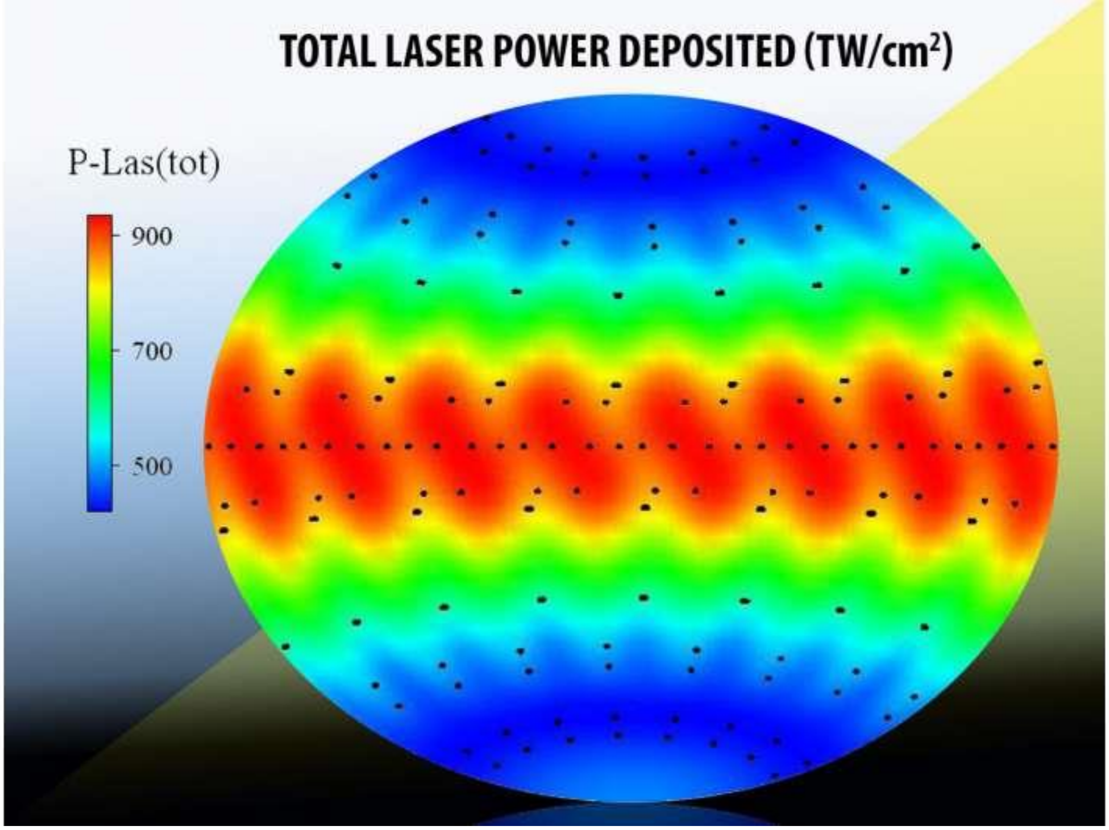
The performance of pure boron, boron carbide, high-density carbon and boron nitride ablators—the material that surrounds a fusion fuel and couples with the laser or hohlraum radiation in an experiment—in the polar direct drive exploding pusher (PDXP) platform. The platform uses the polar direct drive configuration to drive high ion temperatures in a room-temperature capsule and has potential applications for plasma physics studies and as a neutron source. The key findings of the work, featured in *High Energy Density Physics*, show that these alternate ablators do not improve the symmetry of the PDXP implosion. While our simulations predict that the platform is not amenable to the electron-ion coupling measurements due to a lack of implosion symmetry, the alternate materials do enable better coupling between the laser and capsule," "We plan to test those predicted impacts on future neutron source experiments."

Examining the improvement in coupling because it could help improve the yield of the polar direct drive neutron sources, and ultimately provide data on the validity of laser modeling for direct drive simulations. Inertial confinement fusion simulation code developers implement more advanced models for electron-ion coupling, and modeling the direct drive implosions have been closely coupled with that code development. One of the main goals has been to create ignition in a deuterium-tritium plasma in the laboratory. The design of these experiments relies heavily on computer models that are based on an understanding and assumptions about the behavior of these hot plasmas. Research and Development project was aimed at using high performance computing to study the physics of ignition plasmas. The goal was to develop new models that described heat and mass transport at a microscopic level in order help improve our modeling of ignition experiments.. Following the work on computer models, we wanted to test our new models with experimental data and developed the PDXP platform as a way of creating non-equilibrium plasma.

In these experiments, ions are heated more rapidly than the electrons via a very strong laser-generated shock. The team intended to use time resolved spectroscopy, which is a measure of how much light is being emitted from the plasma at a specific frequency, in order to measure the temperatures of both the ions and the electrons as a function of time during the experiment. The data would enable the team to make a direct comparison to the models the Cimarron Project had developed for something called "electron-ion coupling," which is a parameter that describes how ions and electrons exchange energy in plasma. The great advantage of this platform is that it is simple —spherical shell filled with fuel—and allows multiple diagnostics from any (and all) NIF ports to take data and produces high neutron yield.. This research did a theoretical study of performance (neutron yield) versus composition of the shell and its thickness. The work describes a particular way of moving through a very complicated physics calculation and then applies that methodology to predict how different capsule materials might perform when used in a NIF experiment. The work describes how data from the previous experiments on plastic capsules were used to understand why certain methods used were most effective at modeling the system and predicting the observations. The next step in the process was to make new predictions based on applying the methodology to different capsule materials.

New experiments based on these models mentioned hereafter predicting a particularly useful improvement in performance, like higher yield, or the model predicting a large change in a measured quantity, like the trajectory of the imploding capsule or the temperature of the nuclear burn. Then we execute the NIF experiments to test if the calculation was indeed successful at predicting the change in performance. The initial design from 2016 used a plastic shell—or ablator—that was filled with deuterium gas with a trace amount of argon dopant. The argon was used in the spectroscopic measurement, and the design ensured adequate temperature separation between the electrons and ions in order to make the measurements viable.

The images of the implosion from the 2016-2017 shots indicated that the plastic shell was very warped in the implosion. The laser beams that directly hit the capsule imprinted a very complicated structure on the imploding shell. Following these shots, team posited that switching to a different ablator material might enable a more symmetrical implosion, either by enabling increased deuterium pressure or by improving how the material interacts with the laser.



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1D model helps clarify implosion performance at NIF

In inertial confinement fusion (ICF) experiments at the National Ignition Facility (NIF), a spherical shell of deuterium-tritium fuel is imploded in an attempt to reach the conditions needed for fusion, self-heating and eventual ignition. Since theory and simulations indicate that ignition efficacy in one-dimension (1D) improves with increasing imploded fuel convergence ratio, it is useful to understand the sensitivity of the scale-invariant fuel convergence on all measurable or inferable 1D parameters. This is benchmarked to 1D implosion simulations spanning a variety of relevant implosion designs. This model is used to compare compressibility trends across all existing indirect-drive layered implosion data for three ablators. The best level of compression of the various designs of indirect-drive implosions at NIF that have used plastic polymer and beryllium shells follow the expectations of a simple physics model."This has allowed us to rule out certain previously hypothesized effects such as hot electron preheat. A major exception is the high-density carbon shells that have so far exhibited a remarkably constant lower level of compression, independent of the laser drive conditions.

Achieving ignition is fundamentally recognized as a trade-off between more energy coupled to the capsule requiring more efficient hohlraums or a larger laser, and improving the level of capsule compression. We varied laser and capsule parameters seemed important as a first step to motivating further research in improving compression without necessarily resorting to a higher laser energy demand. This trending work is part of improving understanding of and optimizing ICF implosion performance on the quest for robust ignition that also could be applied to the direct-drive ICF database. The work was conducted by first validating a simple analytic model for the level of capsule compression as a function of various laser and capsule parameters by comparing to 1D simulations. We compared the compression model scaling to all cryogenic implosions shot using optical X-ray and nuclear data. These also required developing approximate analytic models for relating the expected compressibility of the implosion to the X-ray driven pressure profile applied to it in the hohlraum as measured by the VISAR system. High-density carbon shells are currently giving the best neutron yields despite the reduced compression trends. Increased focus was on testing physics-based hypotheses such as hydrodynamic instabilities leading to mixing between the shell and DT, and as yet untested schemes for improving compression in high-density carbon shell implosions.

4-Study reveals cause of 3-D asymmetry in inertial confinement fusion implosions

Inertial confinement fusion (ICF) implosions require very high levels of symmetry in order to reach the high densities and temperatures required for fusion induced self-heating. Even percent-level deviations from perfect spherical symmetry can lead to significant distortions of the implosion and ultimately deg. Summarizes observations of areal-density asymmetries seeded by high-density carbon (HDC) capsule thickness asymmetries, helped to illuminate one of the principal causes of a significant degradation in ICF implosions. These asymmetries can decrease the energy available to heat the hotspot and reduce the confinement of that energy. It is like squeezing a balloon a little harder on one side than the other, at some point the balloon will attempt to vent out the weak spots.

Tiny imperfections in the capsule can grow into huge distortions of the implosion at peak compression. In fact, some recent experiments described in that sub-percent level non-uniformity (approximately 0.7 percent) in HDC capsule thickness can grow into approximately 25 percent variations in the fuel areal density and produce hotspot velocities on the order of 100 kilometers per second. This result is significant because if we know the causes for these asymmetries in ICF implosions, we are better able to predict them and understand their impact. Perhaps most important, if we know the causes we can work on fixing them. The work was conducted by radiographing the pre-shot capsules before the experiment to determine the level of non-uniformity. Then after the experiment is performed, the team looked for signs of asymmetry in the observed residual hotspot velocity and shell areal-density asymmetry. This work was enabled in part by advances in diagnosing implosion asymmetry through observations of the hotspot velocity using neutron spectrometry. along with advances in measuring shell non-uniformity through neutron activation anisotropies. It is like the analogy of the balloon that is being squeezed harder on one side, if we find the hotspot velocity is very high in some direction and aligned with significant non-uniformity of the shell, we know that some aspects of the implosion were not adequately symmetric looked at comparing the pre-shot radiographs of the capsule to the hotspot velocity. Found that capsule thickness variations deduced from the radiographs are often correlated in both direction and magnitude. This strongly suggests that the shell non-uniformities are at least one of the principal causes of asymmetry as diagnosed through the hotspot velocity. Understanding and improving the performance of ICF implosions is an important part. Found HDC shell non-uniformity to be an important degradation of implosion performance, we are working to increase the accuracy of our metrology of the shells and also to improve the manufacture of HDC to produce more uniform shells.

5-Fusion milestone reached as 'ignition' triggered in a LLNL-

The results from the experiment on 8 August 2021 indicate an energy output of over **one mega-joule,** which marks the threshold agreed for the onset of **'ignition'** and is **six times** the previous highest energy achieved. Fusion energy has very vast scope in future.