Sandia National Laboratories

Development of Hybrid Codes for Modeling Petawatt Laser Interactions with Dense Matter

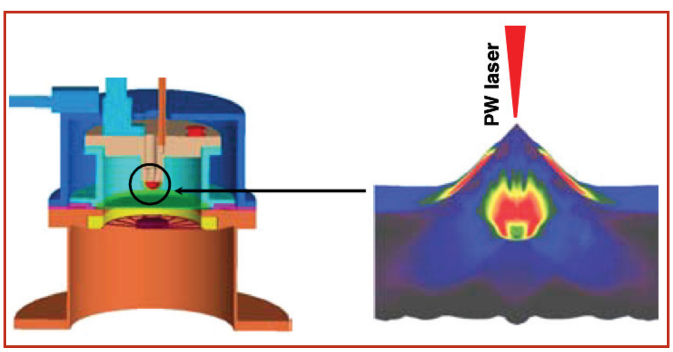
Principal Investigators: Heath Hanshaw (SNL) and G.V. Baydin (VNIITF)

Project Description

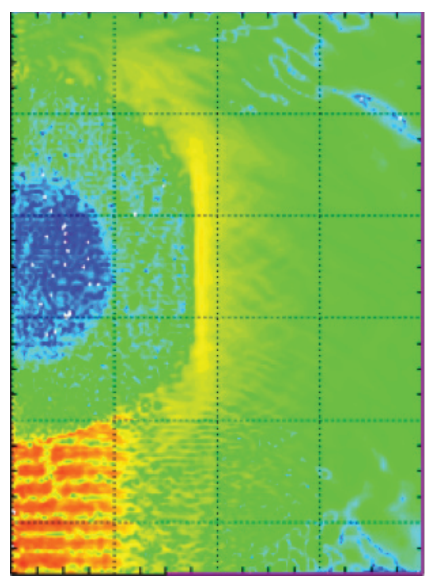
Accurate modeling of dense plasma physics is an extreme challenge, particularly in the case of short pulse petawatt (PW) lasers (like Z-PW at Sandia) used for creating pulsed electron, ion, or x-ray beams for inertial confinement fusion (ICF) experimental diagnostics or for fast ignition studies. Both Sandia and VNIITF have been pursuing state-of-the-art hybrid (Particle in Cell plus fluid) implicit code development projects.

Voss Scientific (formerly MRC), a Sandia contractor, has developed with Sandia the implicit hybrid code LSP, which can simulate most of the physics of PW-laser plasma interactions, a unique capability within the three U.S. defense laboratories. Sandia plans to bring LSP technology in-house, to integrate it with other Sandia code capabilities, to verify and validate the capability, and to use it to design experiments using Z-PW for ICF and other applications.

For this prospective code project to be successful, it is crucial to critically examine modeling approaches, from included physics to equations to numerical approaches. For example, simultaneous multiscale modeling of fine-scale spatial effects, like the Weibel instability, remains beyond LSP's capabilities (except when run as a standalone simulation whose results are modeled grossly as an anomalous resistivity in a large-scale simulation). Yet these small-scale physics can have drastic effects on beam evolution. Like Sandia, VNIITF is also combining several code capabilities into a hybrid implicit plasma code, and they also plan on using algorithms developed and previously published jointly by Voss and Sandia. One of the most interesting features of VNIITF's plan is to implement its hybrid implicit code in an adaptive mesh (AMR) setting, which could potentially aid modeling of this instability's effects (and those of other instabilities) on beam generation, allowing greatly improved experimental designs.



Fast ignition simulation.



Log of proton density accelerated from the rear side of a thin foil by electric fields generated by petawatt laser irradiation of the front surface.

Under this contract, VNIITF will complete development of a hybrid implicit code using adaptive mesh refinement and use that code to simulate the interaction of a short pulse PW laser with dense matter for cases of interest like fast ignition.

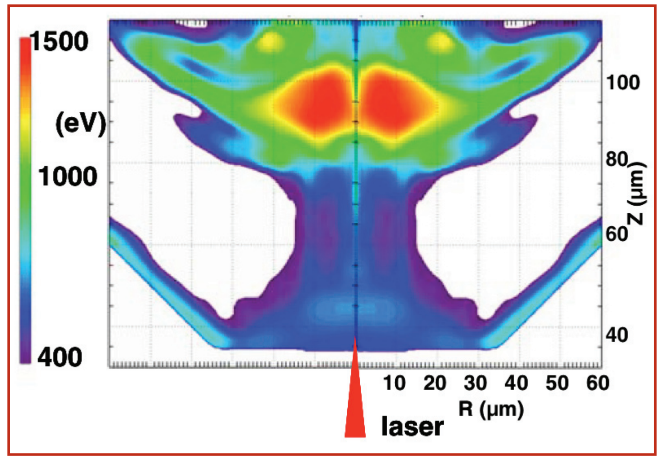
Five tasks will be performed at the discretion of the Sandia principal investigator:

- Develop models and test problems of different stages of laser plasma interaction;
- Simulate test problems and perform code comparisons with Sandia's;
- Develop initial 2-D AMR hybrid implicit code;
- Perform validation simulations of beam experiments and compare with Sandia's;
- Simulate the "fast-ignition" problem.

Technical Purpose and Benefits

A major inducement is utilizing the expertise resident at VNIITF in employing hybrid codes to model petawatt laser-plasma interactions for application at Sandia. Because this work represents cutting edge research, both institutions benefit, particularly in the area of comparing alternative modeling and techniques. The primary benefit lies in gaining validated modeling tools to effectively utilize Sandia's Z-beamlet-petawatt laser.

Technologist Benjamin Thurston examines the debris shield that protects the giant Z-Beamlet laser's final focusing lens from flying debris when the Z-accelerator fires.



Simulation of "fast-ignition."

Collaboration between Sandia National Laboratories (SNL), Albuquerque, NM, USA, and the Russian Federal Nuclear Center – All Russian Research Institute of Technical Physics (RFNC-VNIITF), Snezhinsk, Russia

Sandia National Laboratories

A Publication of the Office of Advanced Simulation & Computing, NNSA Defense Programs. SAND 2007-4400P
Issued by Sandia National Laboratories for NNSA's Office of Advanced Simulation & Computing, NA-114. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.