Mitigation of Electromagnetic Pulse Effects from Short-Pulse Lasers and Fusion Neutrons

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Electromagnetic pulse (EMP) is a known issue for LLNL short-pulse laser facilities such as Vulcan, Titan, and Omega EP; therefore, EMP will be an issue with NIF/Advanced Radiographic Capability (ARC). ARC uses up to four of NIF's 192 beams in a short picosecond pulse mode to provide short-pulse, high-energy, x-ray backlighting. The NIF program has a research effort to better understand short-pulse laser EMP issues using experiments in Titan. This effort seeks to improve the fundamental EMP theory and analysis.

During FY2008, this project focused on improving simulation capabilities of EM fields due to electrons from laser/target interactions; providing post-processing algorithms and software; and analyzing measurements from dedicated shots on Titan.

Project Goals

The overarching goal of this project is to simulate EMP in the Titan short-pulse laser due to electrons from laser/target interactions and to validate the simulation results with measurements. For simulations we use EMSolve, an LLNL EM solver. Unlike most available codes, EMSolve's architecture allows seamless integration of user-created sources and boundary conditions, and the developers have augmented EMSolve with electron beam sources. Validation of simulations is best accomplished by assisting the NIF team in the measurement process and by working with signal processing experts to calibrate and analyze the data.

Relevance to LLNL Mission

The National Ignition Campaign (NIC) will use NIF to demonstrate fusion in the laboratory. The ARC diagnostic is critical to the success of NIC and it is essential that the magnitude and the frequency dependence of EMP during ARC operation be understood so that appropriate mitigation techniques can be applied. An understanding of the EMP in Titan, through simulation and analysis in this project, can be extended to NIF and other short-pulse lasers around the world to better mitigate EMP effects.

FY2008 Accomplishments and Results

During FY2008, we assisted in dedicated shot measurements; continued

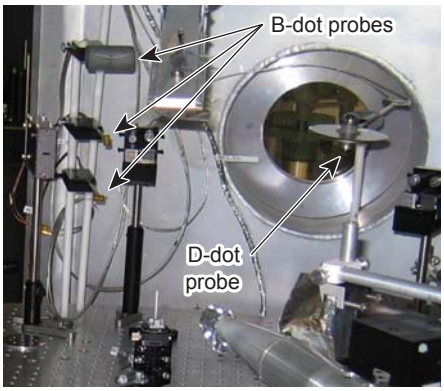

Figure 1. Interior of Titan showing some B- and D-dot probes for the 2008 dedicated shot series.

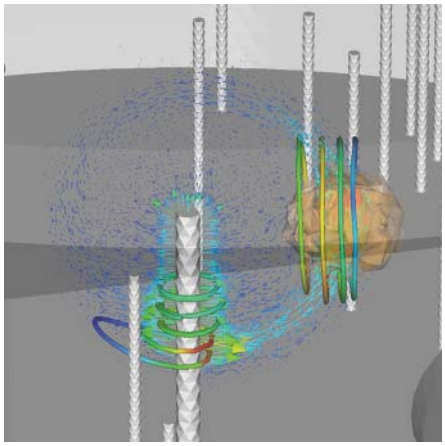

Figure 2. Zoomed view of EMSolve simulation of an electron beam pulse at 0.825 ns from leaving the target post. The pulse is Gaussian shaped with a 100-ps (full width at half maximum) duration and cosine-shaped transverse profile, with a 10° maximum axial angle from the direction of motion. The electron pulse is to the right of the target positioner, which is near the center of the image. The colored vectors represent the electric field, and the streamline tubes depict the magnetic field.

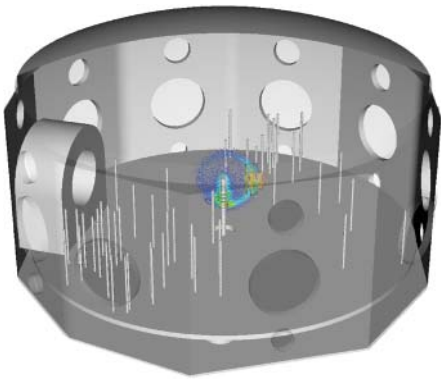

Figure 3. Figure 2 in context of a full view of the Titan laser chamber.

work in post-processing algorithms and software; began ongoing analyses of the dedicated shot measurements; further augmented EMSolve; and performed additional EMSolve simulations.

In particular:

1. We assisted the NIF team in documenting the 2007 dedicated shot series and aided in planning, execution, and documentation of the EM measurement portion of the 2008 dedicated shot series (Fig. 1) and helped analyze the resulting data.
2. We developed and implemented an adaptive filtering technique to reduce noise in measurements due to direct interaction of electrons and gamma rays with the probes, and also implemented automated processing to determine trends in the measurements.
3. We provided guidance in measurement planning and signal processing.
4. Our continued efforts to further augment EMSolve have resulted in development of a method for simulating late-time EM fields in lossy cavities using an eigenmode expansion. We have also implemented a particle-in-cell method for more faithfully simulating stiff electron beams (the electron motion is predetermined and not affected by the EM fields) in EMSolve (Figs. 2 through 5).

Earlier EMSolve simulations of Titan using a previous, less accurate method of simulating stiff electron beams and post-processed using VisIt, an LLNL code for visualizing simulation data, have received much attention.

Related References

1. Mead, M. J., *et al.*, "Electromagnetic Pulse Generation within a Petawatt Laser Target Chamber," *Rev. Sci. Instr.*, **75**, pp. 4225–4227, 2004.
2. Brown, Jr., C. G., *et al.*, "Electromagnetic Pulses at Short-Pulse Laser Facilities," *Journal of Physics: Conference Series*, **112**, 032025.

FY2009 Proposed Work

Our analysis, application to Titan and NIF, and the publication of our results will continue in FY2009.

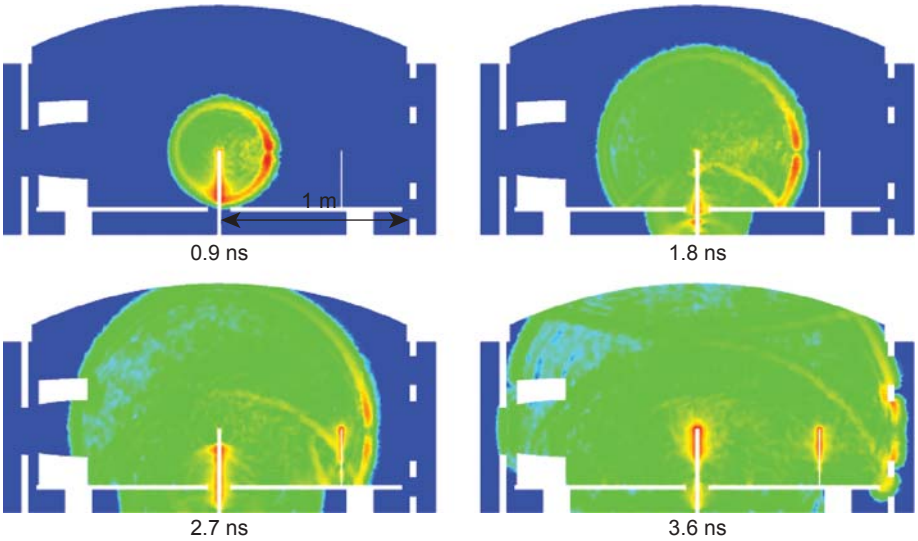

Figure 4. Vertical cross section through simulation in Figs. 2 and 3 for different time steps.

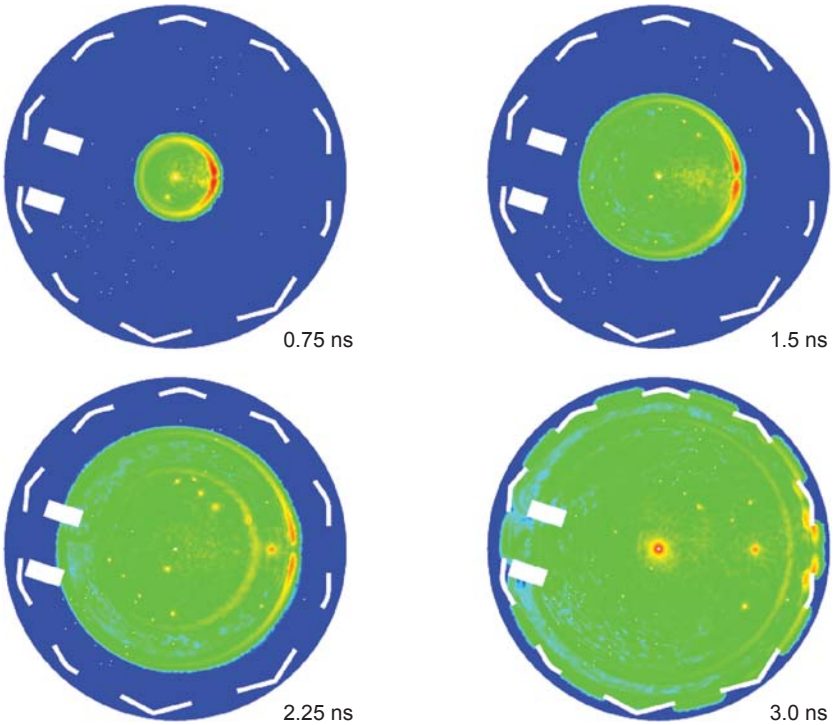

Figure 5. Horizontal cross section through simulation in Figs. 2 and 3 for different time steps.