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Sandia National Laboratories

Numerical Magneto-Hydrodynamic Simulation of Z- and Z-θ Pinches at Pulsed Power Facilities at Sandia National Laboratories

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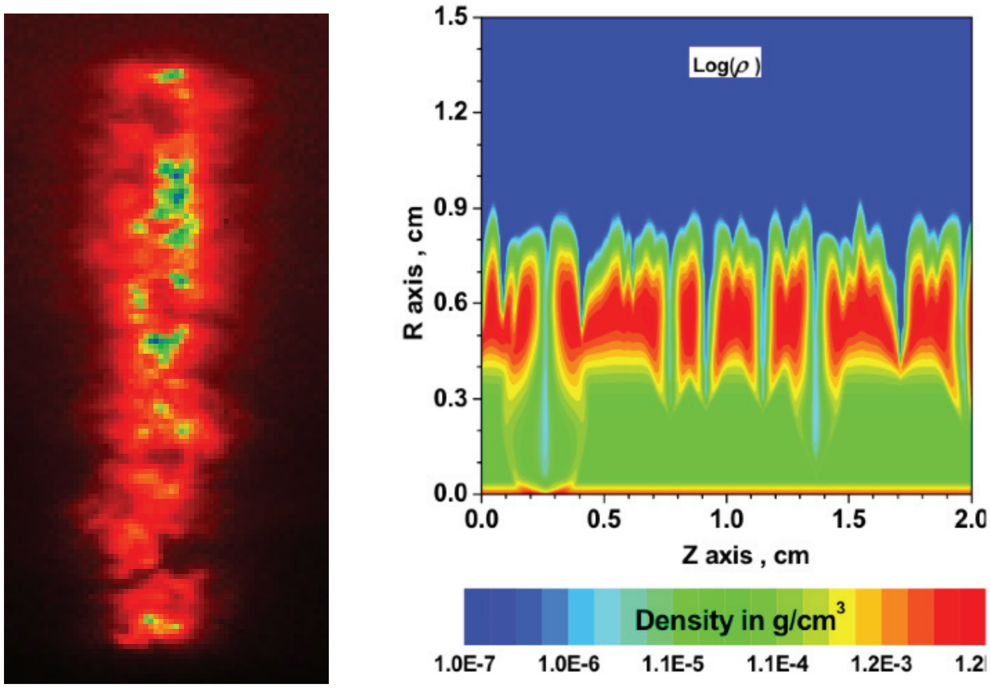
Project Description

Sandia has an ongoing effort to model and design Z-pinch radiation sources. Z-pinches achieve High Energy Density conditions, but low density kinetic effects and instabilities are important in their evolution. Though many elements of Z-pinch physics are not captured by fluid approximations, a fluid radiation magneto-hydrodynamic (RMHD) approach is the simplest and cheapest for design calculations. Approximate models are used in attempts to capture the missing physics. The Orlov group at VNIEEF is using a similar approach to model Z-pinches and explosively driven magnetic compression generators, but has made some different modeling choices, such as the choice of low density resistivity models, relativistic effects, and vacuum wave terms.

The goal of this effort is to validate numerical 2-D and 3-D RMHD models of Z-pinch experiments performed at Sandia. An existing VNIIEF 2-D code, FLUX-rz, will be used to axisymmetrically model Z-machine wire array shots, where the array is modeled as a liner including axial perturbations. Subsequently, more elaborate physics models including Hall effects will be performed in 2.5-D and 3-D simulations.

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

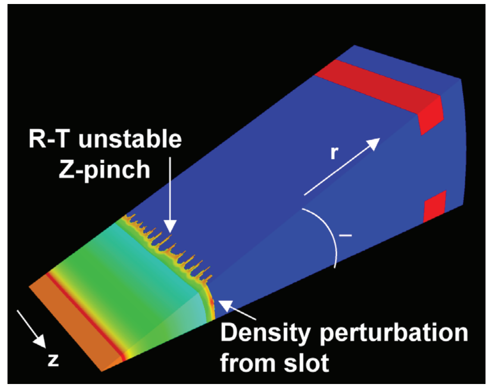
- Validate 2-D (*r-z*) numerical simulation of annular Z-pinches against Z-machine shots.
- Expand to 2.5-D (*r-z*) numerical simulations and evaluate Hall effects.
- Add radiation to FLUX-3-D code, and perform simulations to assess 3-D effects.



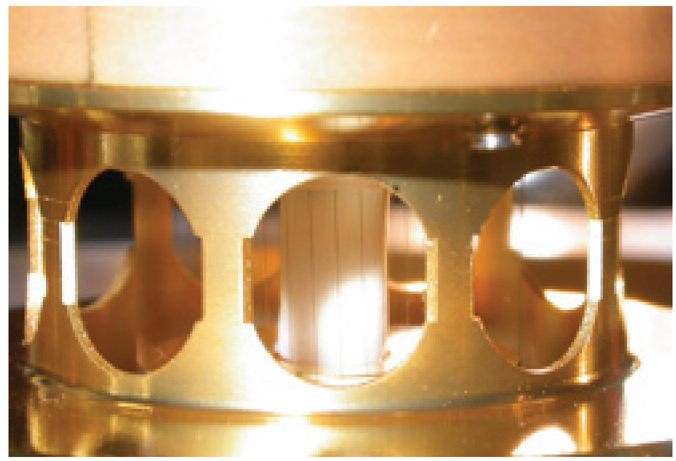
Measured time integrated thermal x-ray emission from a stagnating wire array on Z, showing the imprint of the Rayleigh Taylor instability. Right: Simulation of Z-shot 48 by Andrey Orlov of VNIIEF, showing how different Rayleigh Taylor bubbles stagnate at different times to produce axially varying x-ray radiation.

Technical Purpose and Benefits

Numerical 2-D and 3-D radiation magneto-hydrodynamic simulation is one of the tools to get a more detailed understanding of, and a quantitative description for, physical phenomena occurring in the imploding plasma loads. Using this numerical simulation of existing experimental results on pulse generation and magnetic field compression could lead to optimizing the Z- and Z-θ Pinches in future experiments. Prediction of liner loads using RMHD models is urgent because of the possible passage to longer Z-pinch implosion times at Sandia.



3D ALEGRA-HEDP simulation of a periodic cylindrical wedge of the slotted anode can wire array implosion, showing the imprint of the diagnostic slots on the implosion.



View of a cylindrical wire array and foam target through the oval diagnostic slots of the outer anode can.

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

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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.