SAND2002-3862P

Radiation Ablation gap closure calculations for Z and ZR

Eduardo Waisman,* R.A.Vesey, M.E. Cuneo, W.A. Stygar

K.R. Cochrane, T.A. Haill, T.A. Brunner

Sandia National Laboratories

Albuquerque, New Mexico 87185, USA

Presented to the 44th Annual Meeting of the Division of Plasma Physics

November 11-15, 2002

Orlando, Florida

Session KO2, (Z-Pinch)

* *Alameda Applied Sciences Corporation, San Leandro, CA94557, USA*

Sandia is a multiprogram laboratory operated by the Sandia Corporation, a Lockheed Martin company, for the United States Department of Energy under Contract No. DE-AC04-94AL85000.

Sandia National Laboratories

Outline

- Motivation for these RMHD 1D calculations
- Approach to studying radiation ablation driven gap closure
- Comparison with previous calculations and gap closure experimental data
- Scaling to ZR
- Conclusions

Motivation for 1D RMHD calculations

- **Investigate scaling of radiation ablation caused gap closure to ZR conditions (29 MA and 170 eV current and radiation temperature peaks, respectively)**

- **Investigate predictions of previous calculations [1], not including magnetic diffusion**

- **Validation of ALEGRA for this type of problem**

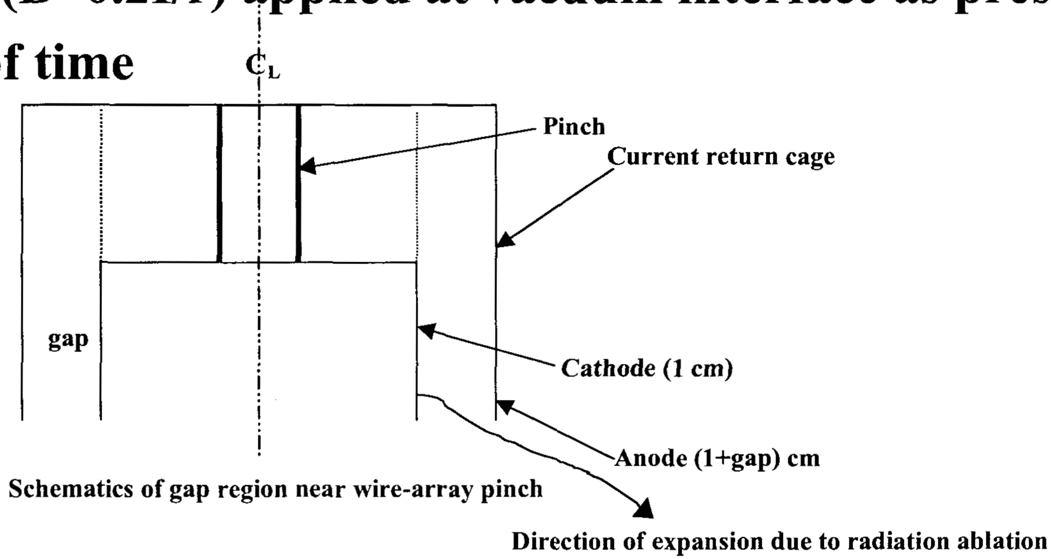
[1] M.E. Cuneo et al, Laser and Particle Beams (2001),19, 481-495

Sandia National Laboratories

1D RMHD Setup (1)

- 1D Lagrangian ALEGRA calculation for Au wall with the cathode surface expanding outward and the anode surface expanding inward

- Radiation Temperature (Plankian) and magnetic field boundary conditions (B=0.2I/r) applied at vacuum interface as prescribed functions of time



Schematics of gap region near wire-array pinch

1D RMHD Setup (2)

- ICF configuration: single array Tungsten wires 10 mm axial length and 20 mm initial diameter with current return cage at 12 mm diameter and AK gap 2 mm
- Power Flow experiments: current return cage at 14 mm, otherwise same configuration with major difference in being a more open geometry, having 9 diagnostic slots in return cage [2], resulting in lower radiation temperature than ICF shots
- Zero time defined by peak X-ray power. Implosion time approximately 102 ns
- Current as a function of time boundary condition from shot Z818 [2], I(t)

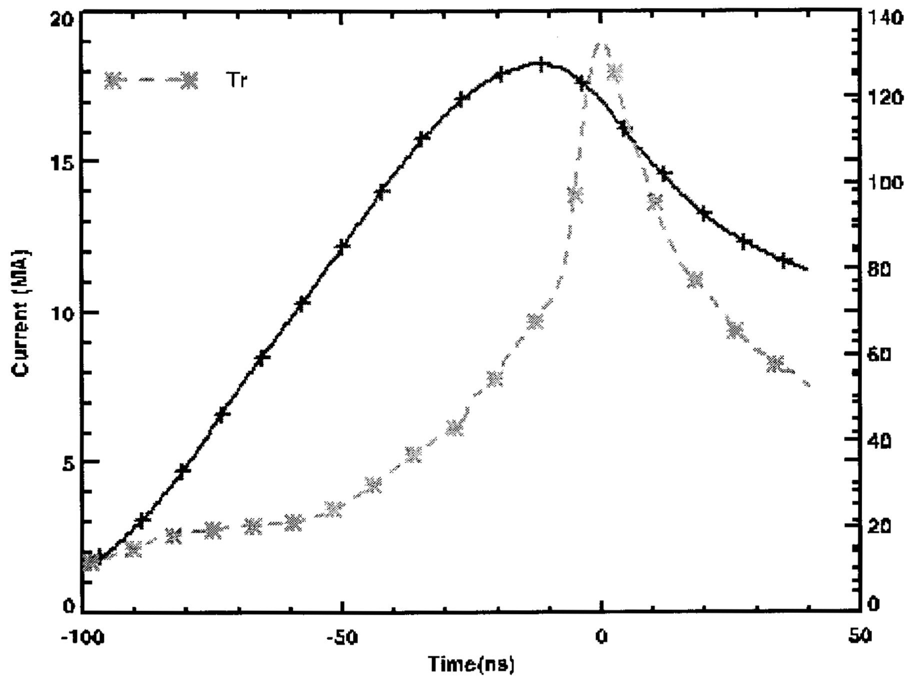
[2] W.A. Stygar et al, submitted for publication to Phys. Rev. Letters

1D RMHD Setup (3)

- Vacuum Radiation Temperature boundary Trad(t) reproduced from ICF Z shots # 358, 359 and 388, and scaled for ZR and Power Flow shots comparison
- Then:
  - Case 1: I(t) 0.8*Trad(t) power flow shots
  - Case 2: I(t) Trad(t) characteristic ICF Zshot
  - Case 3: $(1.25)^2$ *I(t) 1.25*Trad(t) ICF scaling to ZR assuming power goes like I^2
- In all three cases run 1 cm and (1+gap) cm expanding out/in vacuum interface
- Minimum cell size 0.07 microns at interface increasing geometrically, 100 cells for 1 mm of Au
- LMD electrical conductivity. 1group Rosseland mean opacity from XSN tables. Sesame EOS.

Sandia National Laboratories

1D RMHD Setup (4)



Load Current (MA) and Radiation Temperature (eV) Vs. time (ns) used for Case 2 ICF Zshot. Time = 0 ns corresponds to maximum X-ray power

Sandia National Laboratories

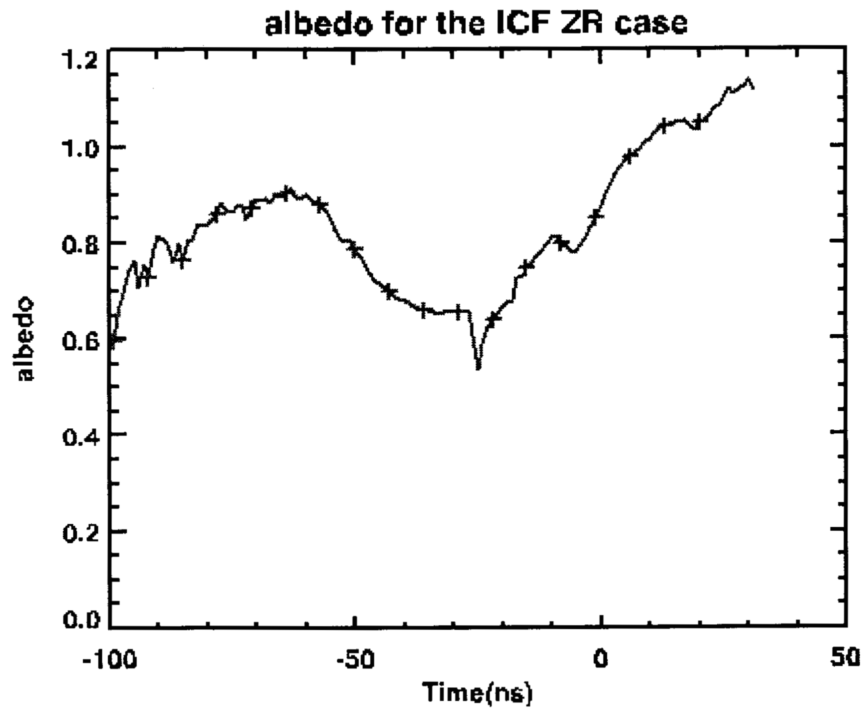
Results of Calculations (1)

Power Flow and ICF shot comparison and ZR scaling

t=0 refers to peak X-ray power and v to closure velocity (anode plus cathode)

	Power Flow Case 1	ICF Z shots Case 2	ZR ICF scaling Case 3
Closing time gap=1mm (ns)	-3.	-10.	-9.
Closing time gap=2mm (ns)	7.	1.	2.
Time (ns) when v=2cm/_s	-18.	-24.	-24.
v (cm/ _s) at t=0	10.	13.4	12.4
Pressure at t=0 (Mbar)	1.7	1.8	3.6
Max pressure (Mbar) 3ns	1.8	2.3	7.0

Results of Calculations (2)



Albedo Vs. Time for ICF ZR case with inward expansion starting at r=1.2 cm. Time=0 ns corresponds to maximum X-ray power

Sandia National Laboratories

Observations from calculations (1)

- **Although these calculations are not completely self-consistent the results are compatible with:**
  - **Observed closure of 1mm gap for Power Flow shots**
  - **Observations showing that 2 mm AK gaps stays "open" for Power Flow shots, insofar as in the calculations closure occurs 7 ns after peak X-ray power**
  - **Observation that 2mm AK gaps stays "open" for ICF Z shots, insofar as in the calculations closure occurs 1 ns after peak X-ray power, when most of the useful available energy has already been imparted to the pinch, which is consistent with experimental observations**

Sandia National Laboratories

Observations from calculations (2)

- **Other observations:**
  - Scaling to ZR as expected from previous calculations [1]: ZR slightly better than Z: later closure time and smaller closure velocity, even when scaling X-ray power as the square of the load current. A 2 mm gap setting should be adequate for radiation temperatures of about 170 eV and peak load currents of 28-30 MA
  - Energy for the ALEGRA code is conserved to within a few percent of the total energy in the material
  - The model used for opacities (XSN) is still insufficiently understood and validated

[1] M.E. Cuneo et al, Laser and Particle Beams (2001),19, 481-495

Observations from calculations (3)

- **Other observations:**
  - Observed sensitivity with respect to different parameter setting in XSN tables is of the order of a few ns for reported closure times. Reported trends with respect to ZR scaling and Power Flow shots Vs. ICF shots are not modified.
  - Most of the magnetic field pressure difference drops in the expanding plasma region, about 80% or higher after plasma starts significant motion.

Conclusions

- 1D RHMD calculations using ALEGRA in the one group radiation diffusion approximation are compatible with experimental observations in Z
- ZR slightly better than Z with respect to radiation ablation gap closure, even when scaling X-ray power as the square of the load current. A 2 mm gap setting should be adequate for radiation temperatures of about 170 eV and peak load currents of 28-30 MA
- Future work is required to improve the opacity data used by ALEGRA
- Once this improved opacity data is incorporated further calculations will be performed to provide a parametrization of the main physical quantities of interest in radiation ablation gap closure, such as ablation pressure, closure velocity, etc.