SAND2003-1780P

ALEGRA-HEDP Three Dimensional Simulations of Low-wire Number Z-pinches

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Computational Physics R&D

Department 9231

Wire Array Workshop

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Discussion Outline

- ALEGRA-HEDP v1.0
- Electrify a wire and form a corona.
- Apply a perturbation to the core shape.
- 30-wire Z-drive Simulation.
- Analysis:
    - 2D vs 3D simulation mass ablation rate comparison.
    - Magnetic field topology.
    - Current density profile.
    - Current advected toward axis.

Observed Phenomenon

• Axially-varying streams of pre-cursor material from wires observed at early time.

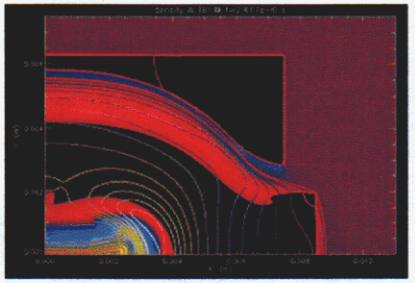
Image supplied by Sergey Lebedev, Imperial College

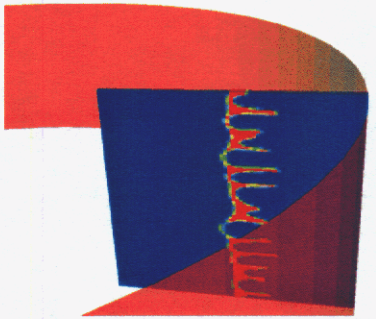
Details:

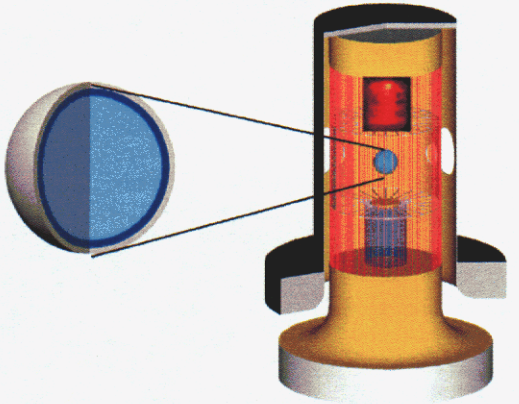
- Finite spacing between the streams of ablated mass.
- Flow is nearly orthogonal to wire.

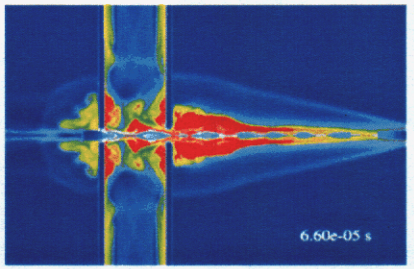
Redirected flow!

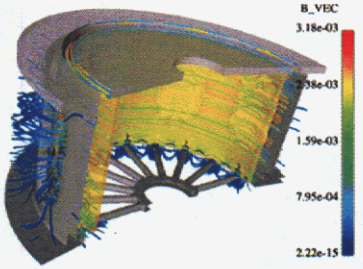
ALEGRA-HEDP v1.0

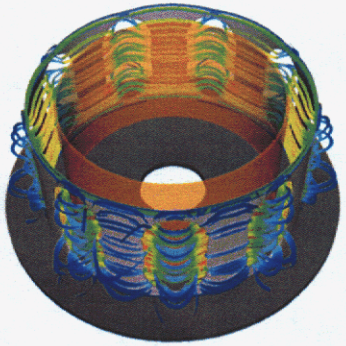


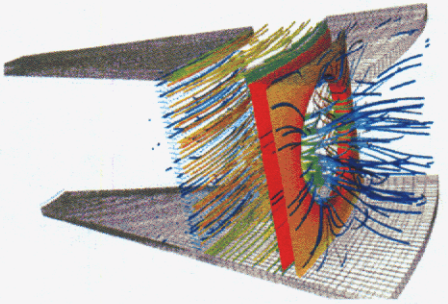










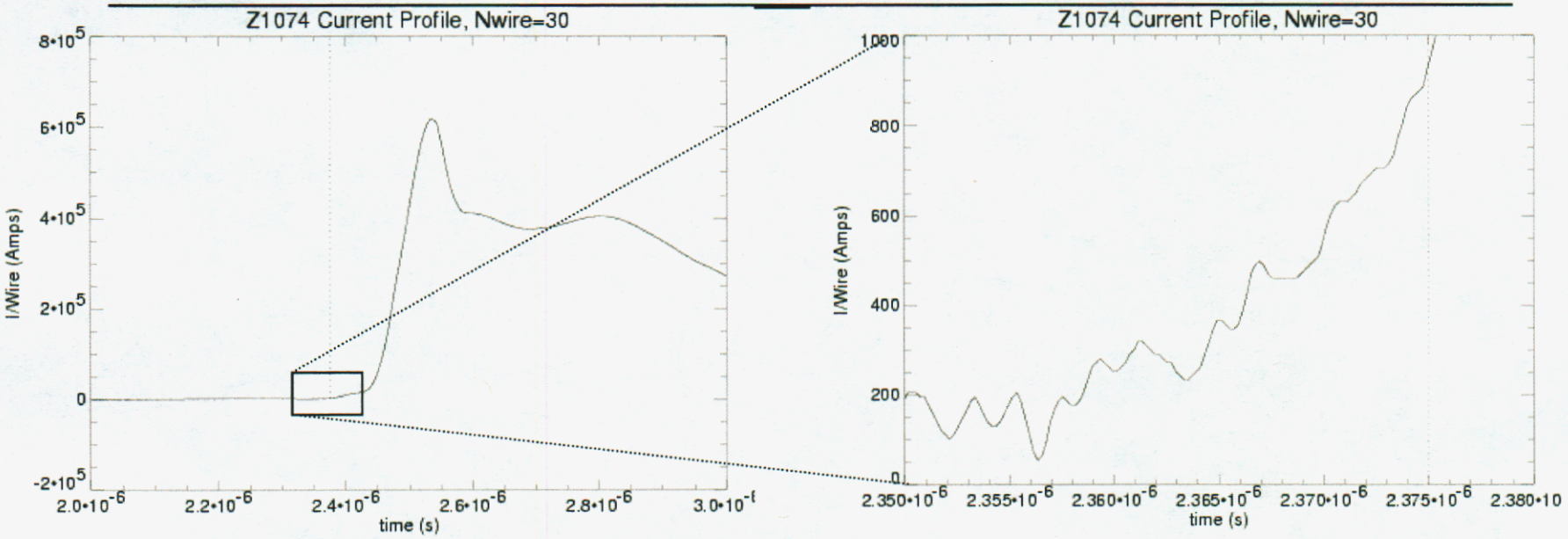


Features

2D (RZ & XY) & 3D (XYZ)
Unstructured Finite Element
Object Oriented
Parallelized (massively parallel)
Multi-material ALE
Coupled Physics
- hydrodynamics
- resistive MHD
- radiation transport
- thermal conduction

Recent 5x speedup in hardware/software for implicit magnetics solve

Electrify a Wire and Form a Corona



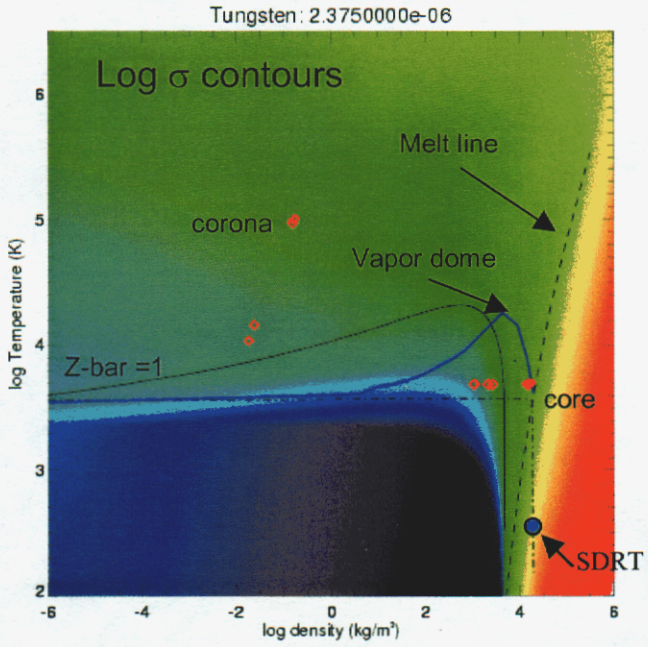
- Two-state Initial Condition:

Core:

- 19μm (I.C.); 17.925μm (cold)
- 0.43 eV

Corona:

- 28.5μm (I.C.)
- 10 eV
- 1.0e-5 ρ_o



Exploding wire studies indicate corona formation before entire wire is vaporized:

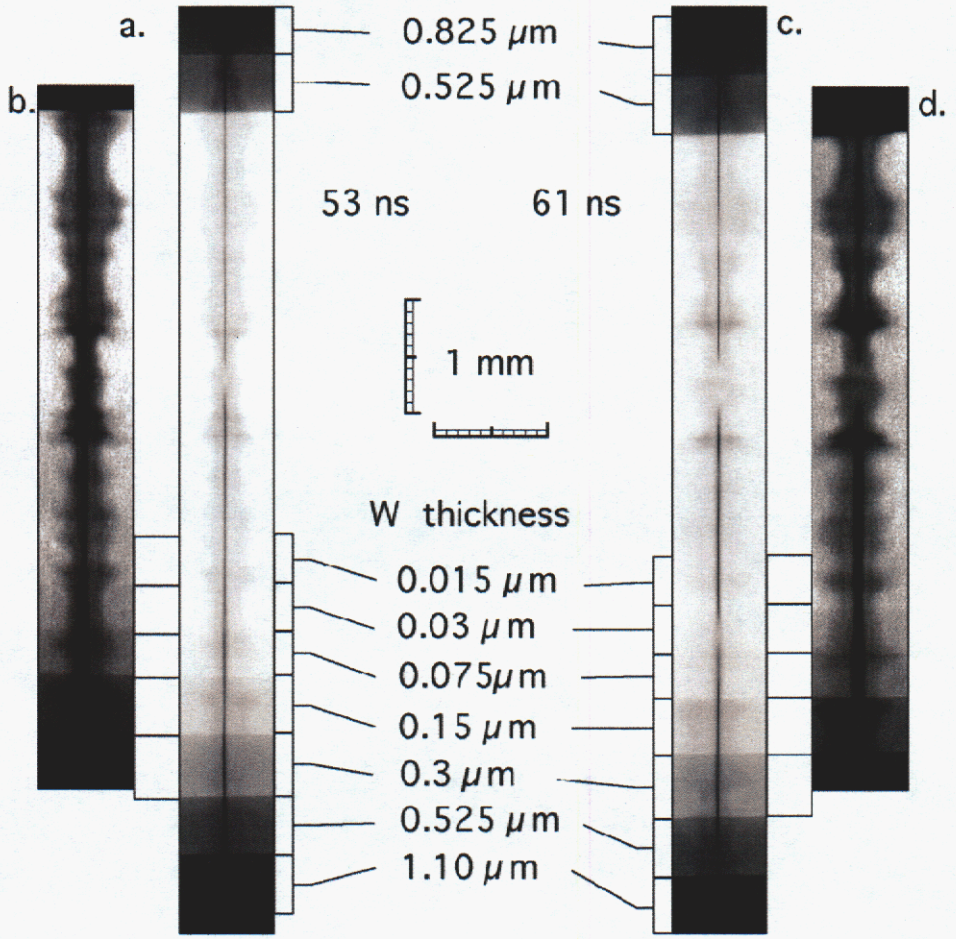
Sinars et al. 2000, Physics of Plasmas v7, #2, 429

Sinars et al. 2000, Physics of Plasmas v7, #5, 1555

Surface Structure

Pikuz et al. 1999

Phys. Plasmas, Vol. 6, No. 11, November 1999



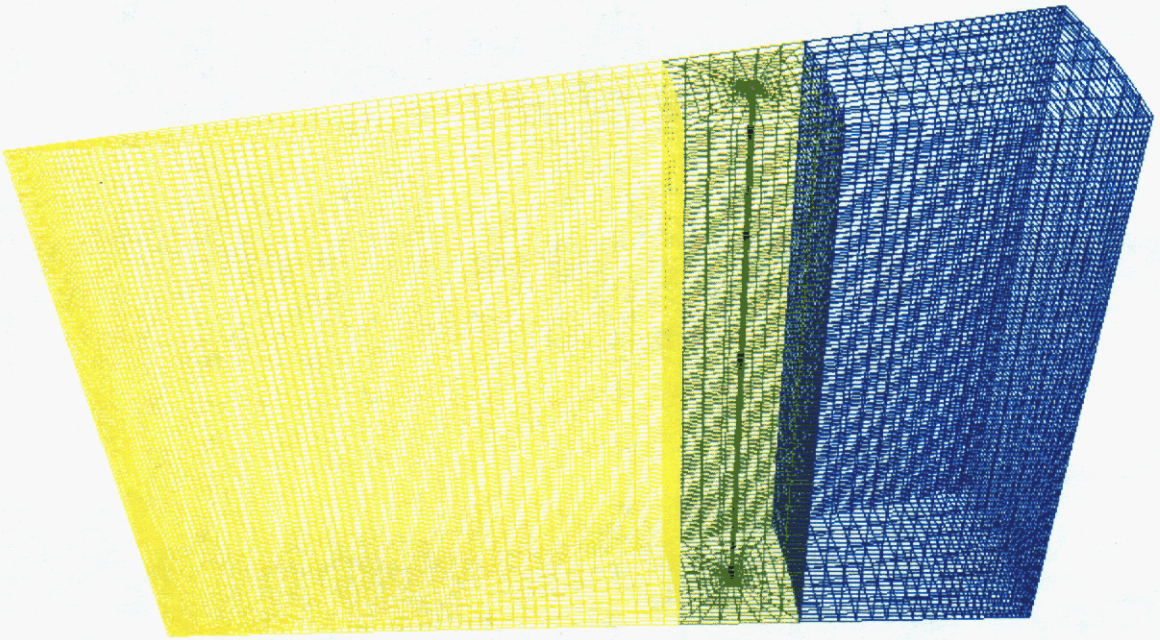
Initial Condition:

Core:

- 19μm (I.C.); 17.925μm (cold)
- 0.43 eV
- Rand(r_w, 1.5*r_w)
- Constant M/L

Mazarakis 30 wire Z-shot

Symmetry B.C Wedge (note the core resolution)



Initial Condition #2:

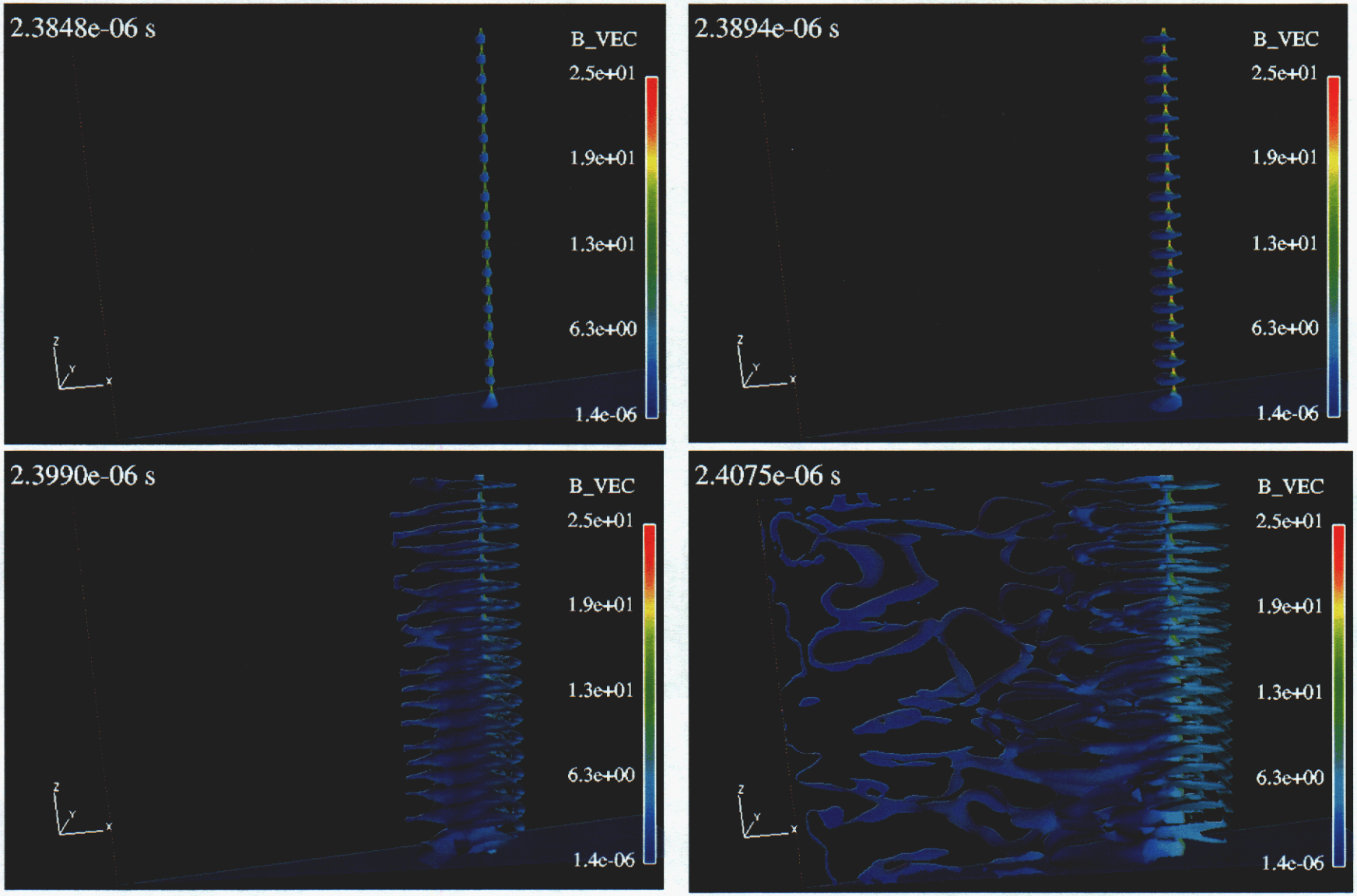
Core:

- 19μm (I.C.); 17.925μm (cold)
- 0.43 eV
- Rand(r_w, 1.5*r_w)
- Constant M/L

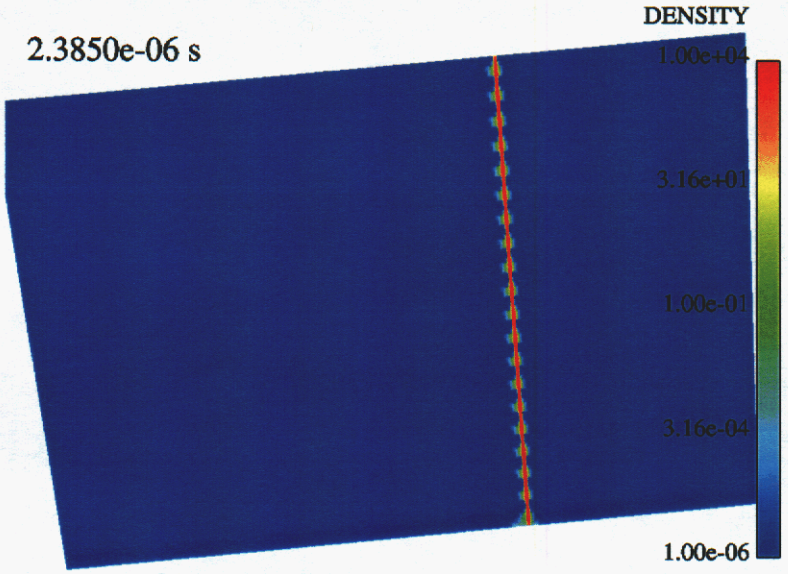
Corona:

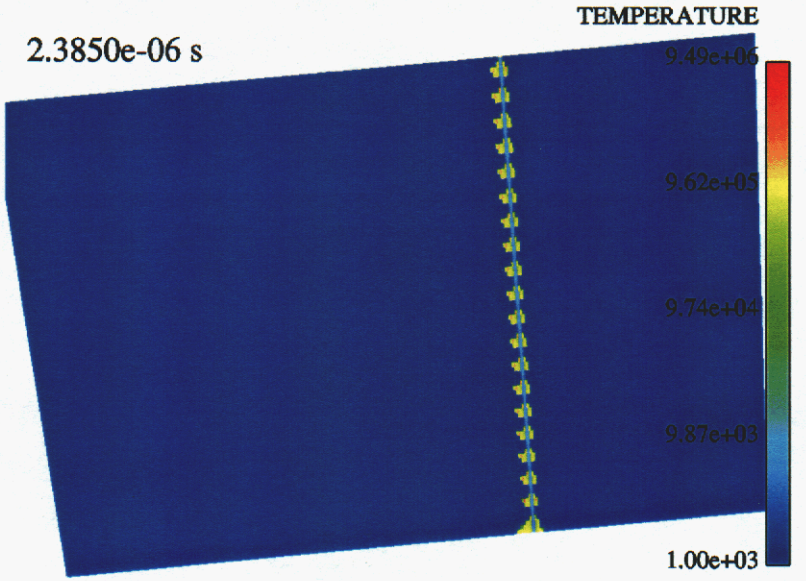
- 28.5μm (I.C.)
- 10 eV
- 1.0e-5 ρ_o
- Rand(r_c, 1.05*r_c)

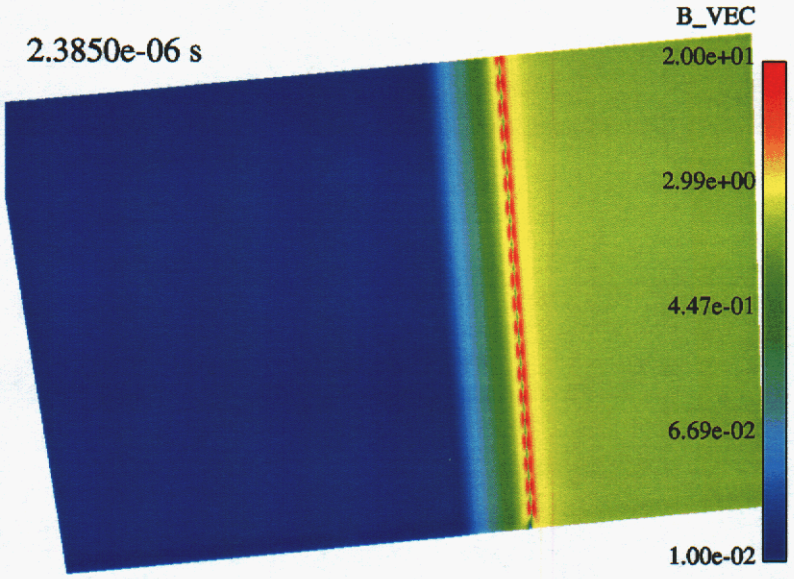
Sinusoidal Core Perturbation

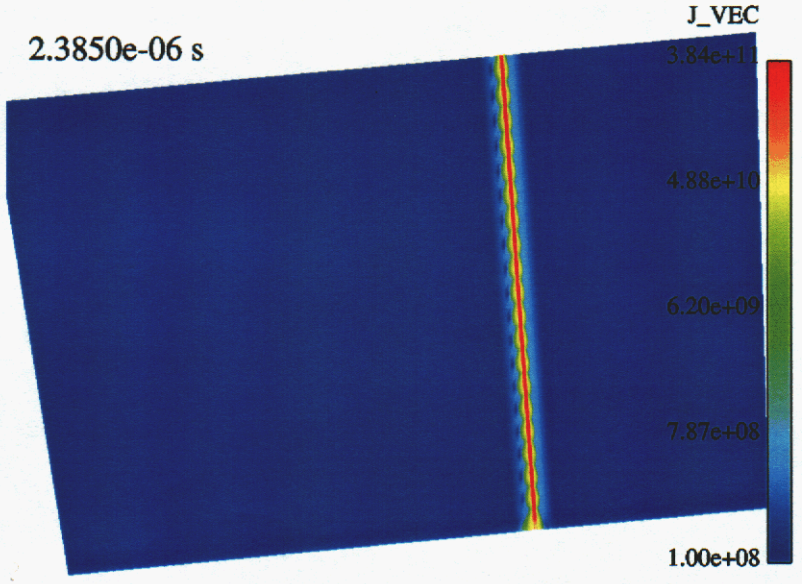


Sinusoidal Core Perturbation

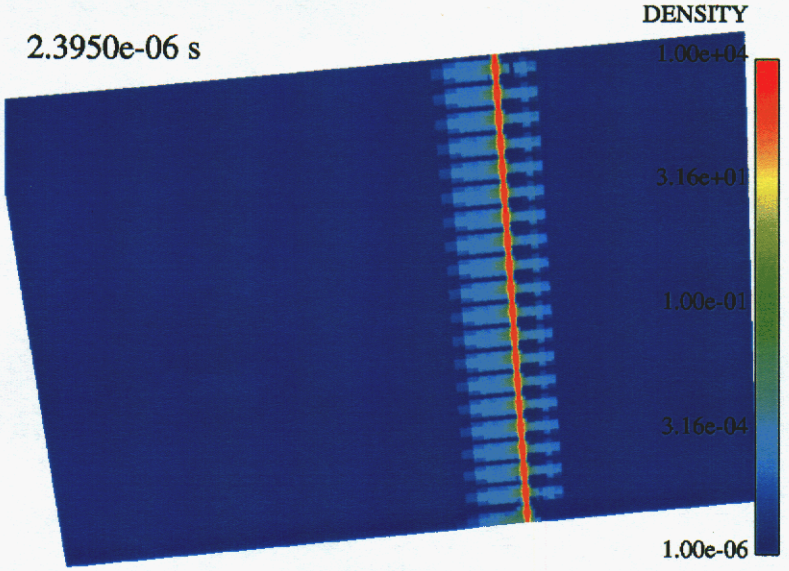


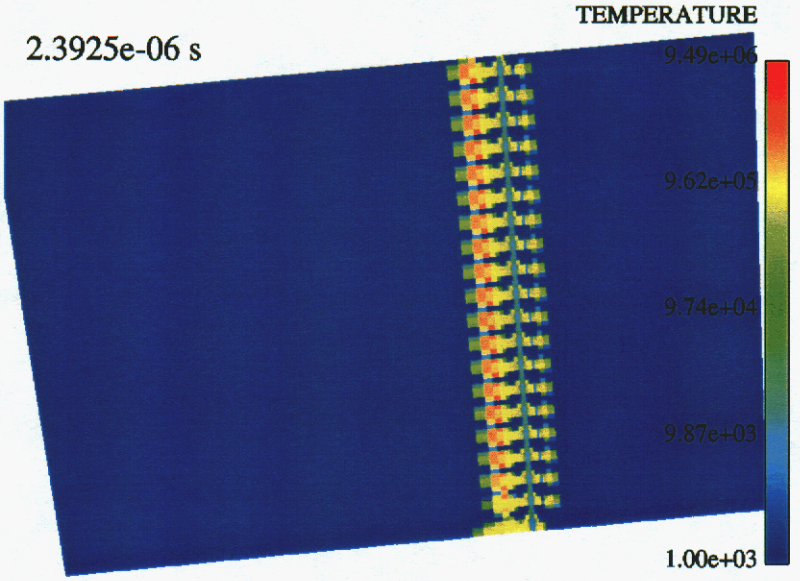


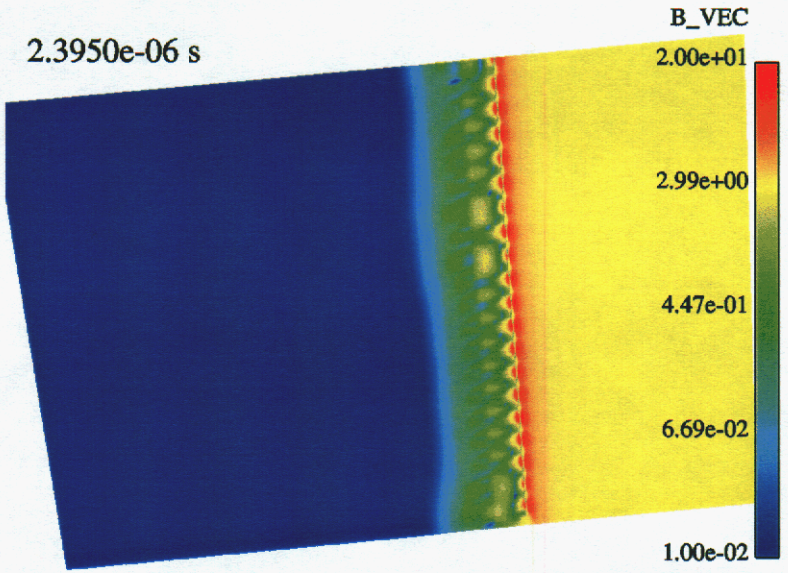


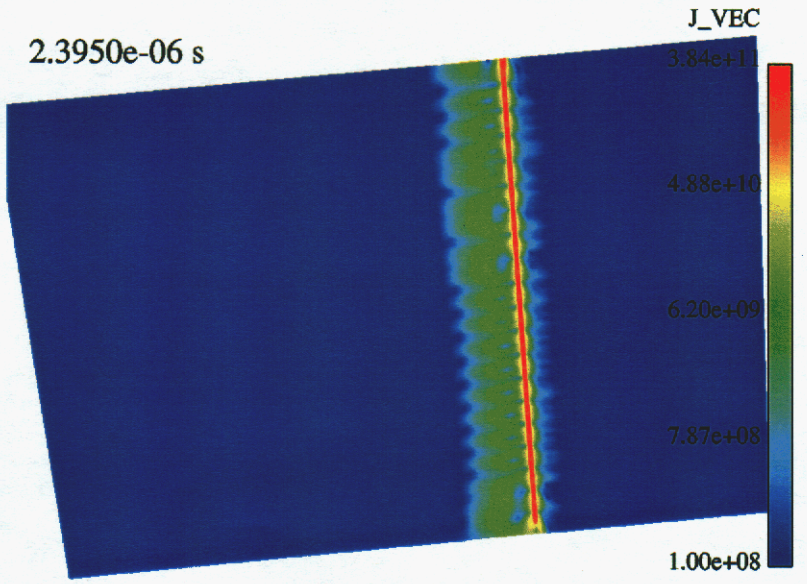


Sinusoidal Core Perturbation

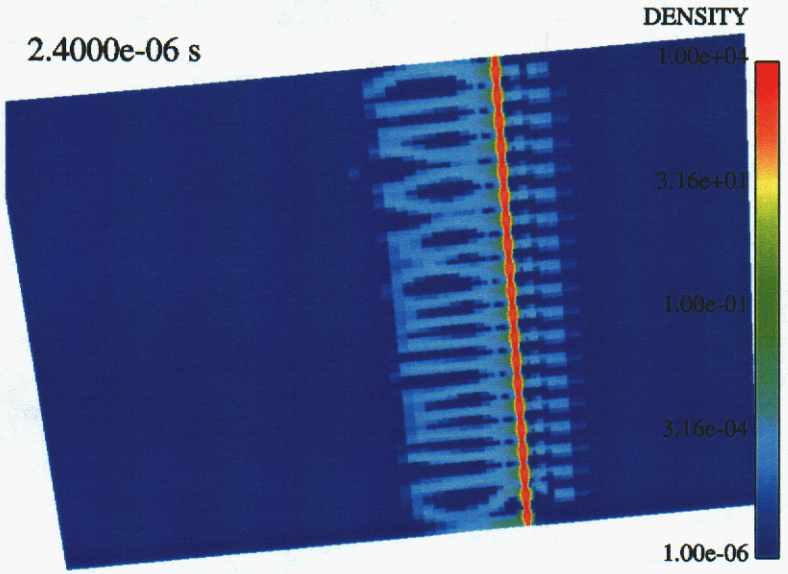


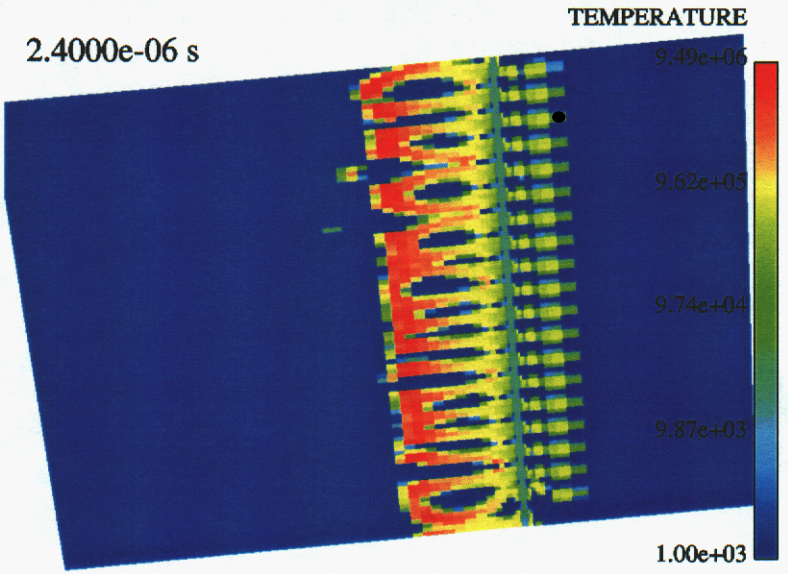


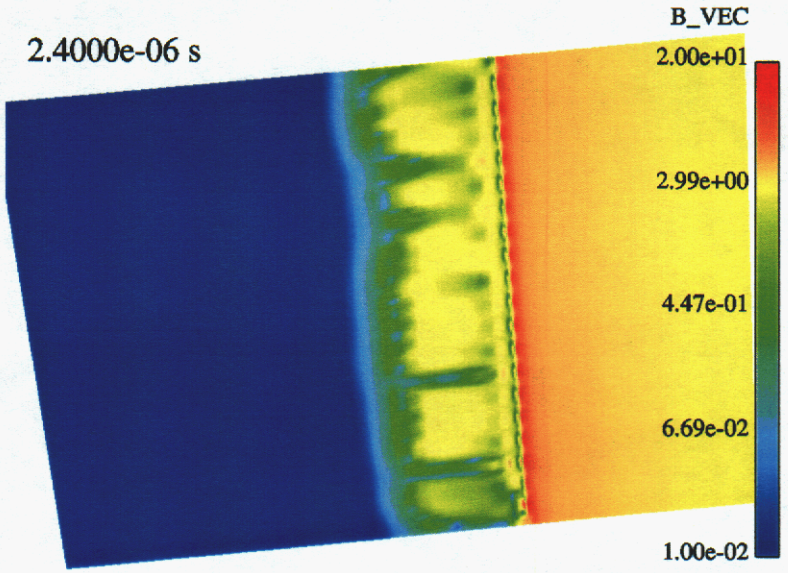


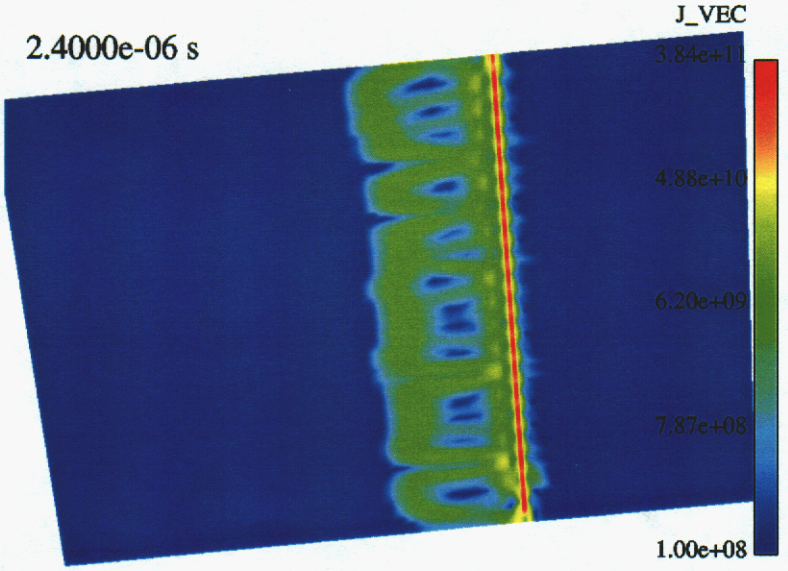


Sinusoidal Core Perturbation

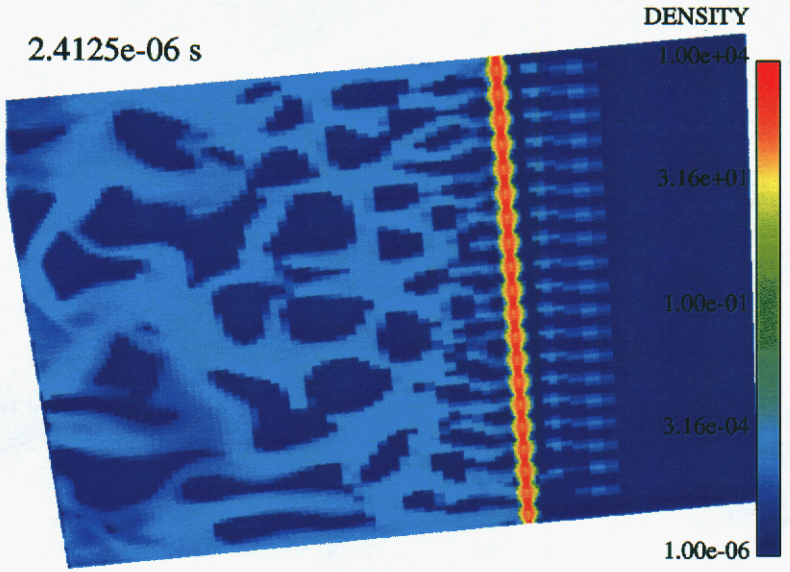


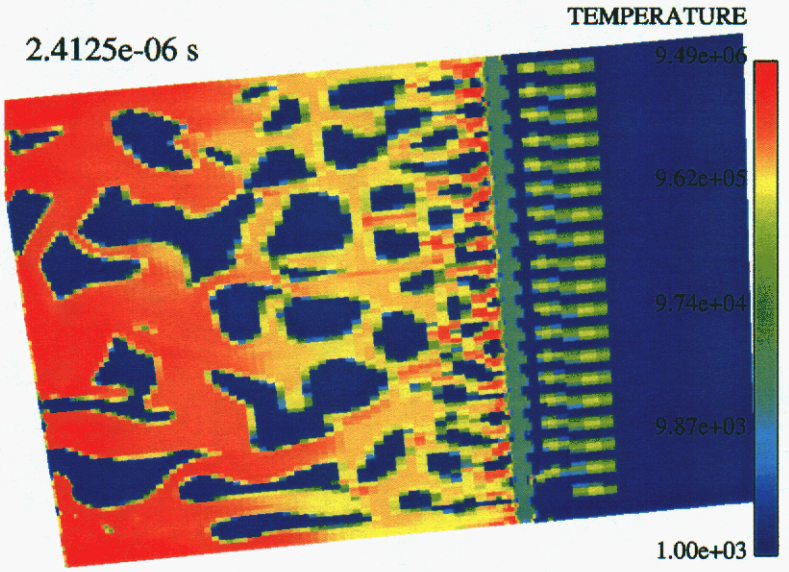


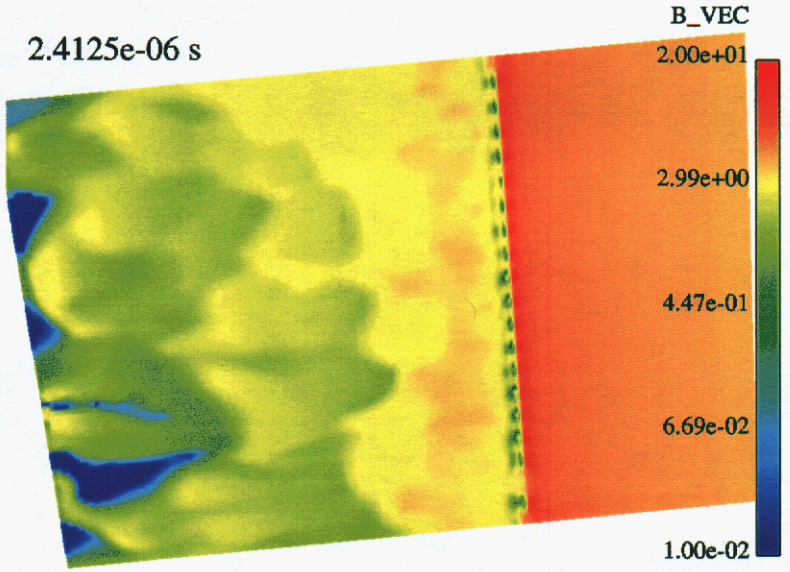


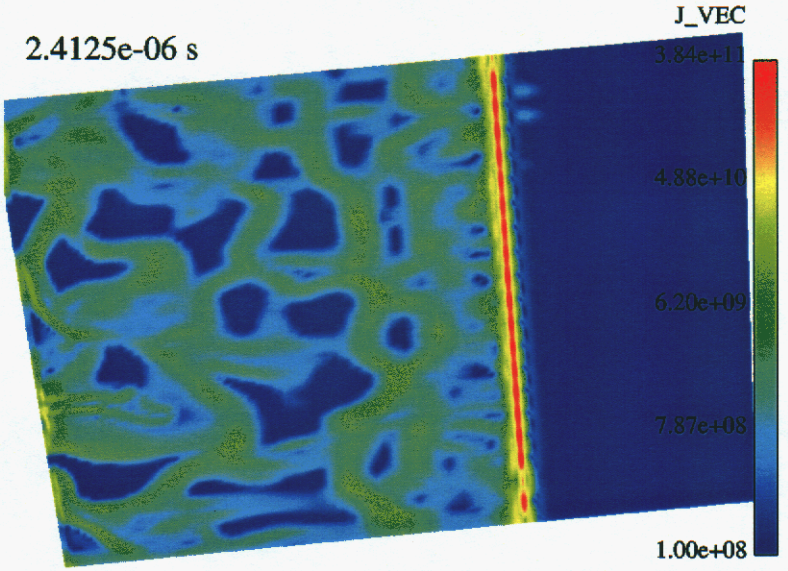


Sinusoidal Core Perturbation









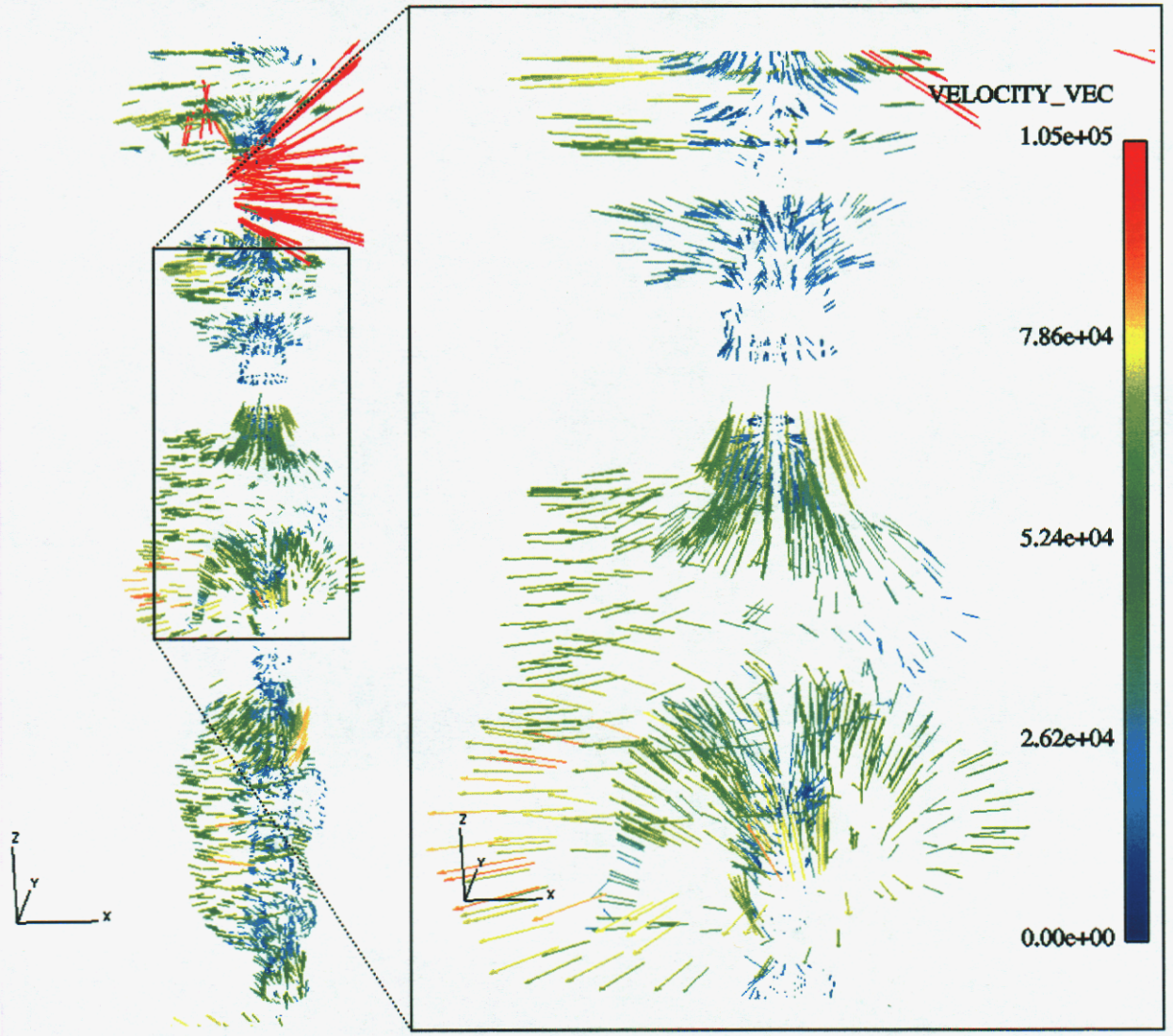
Unique Velocity Morphology

Symmetry B.C Wedge

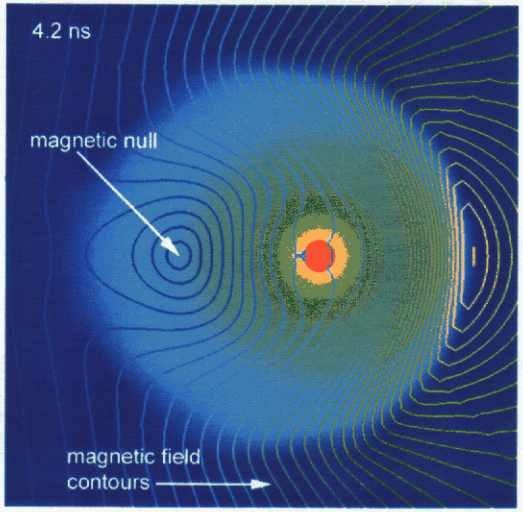
Interesting velocity field morphology:

-necked down regions have increased Lorentz forces

-axial outflow occurs at necks

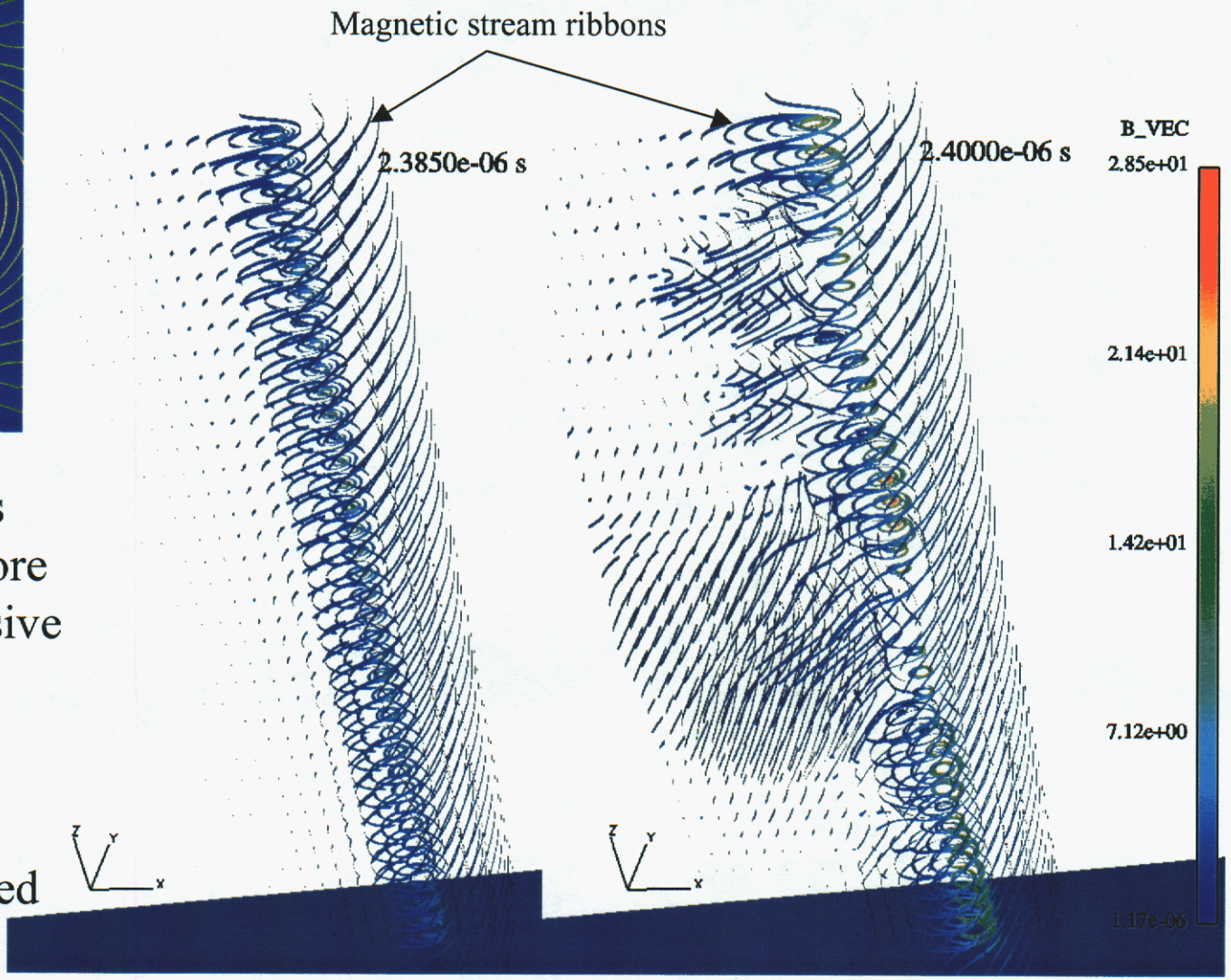


3D Magnetic Field Morphology



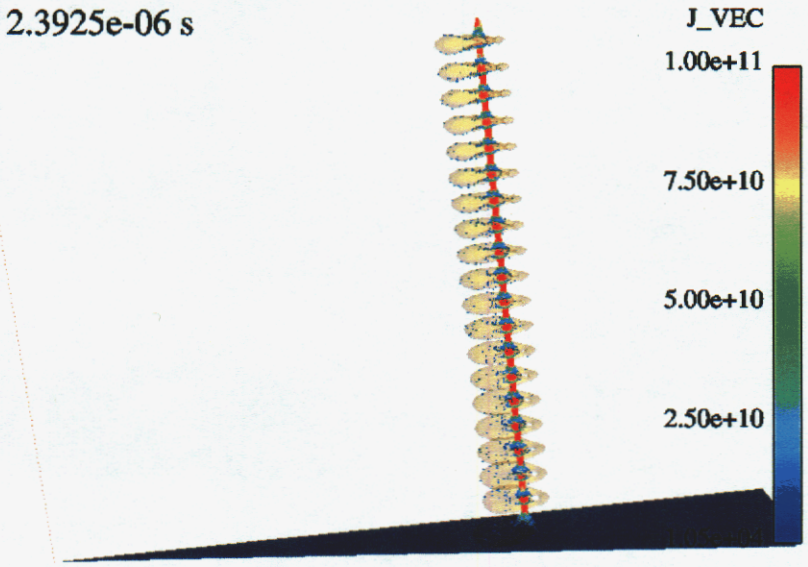
In 2D, magnetic null is translated from wire core due to advective/diffusive nature of flow.

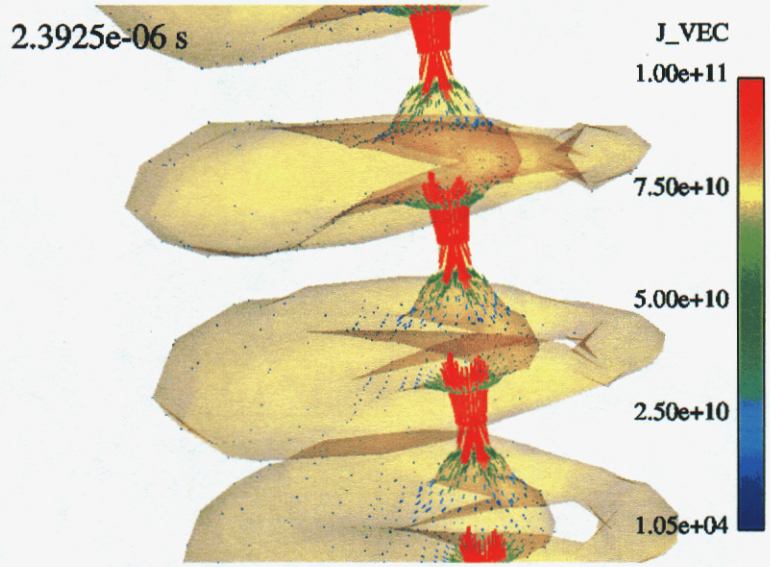
In the 3D nightmare, the null is also translated at various heights, but has additional constraints due to neighboring nulls.

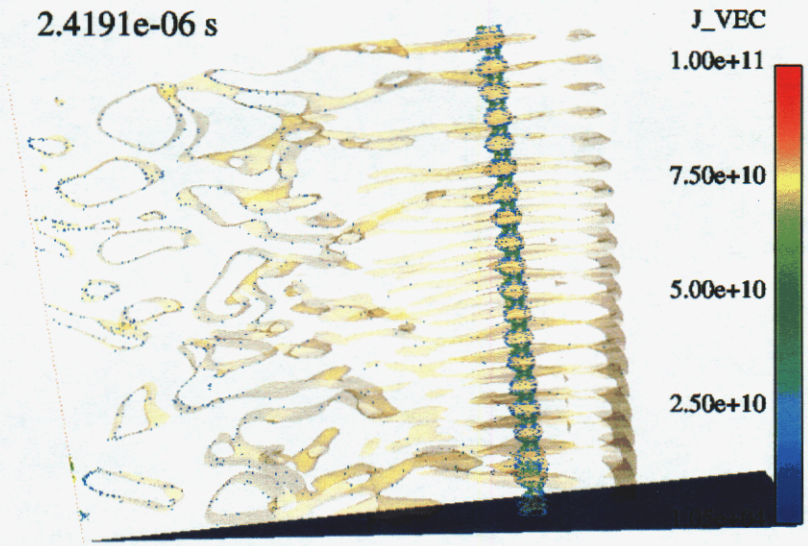


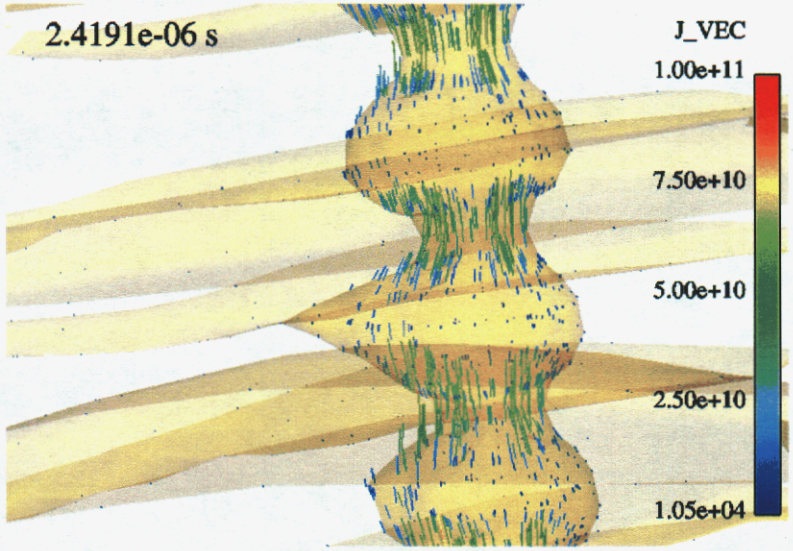
Coarse resolution makes this analysis difficult!

Current Density Distribution









2D versus 3D Wire Array Effects

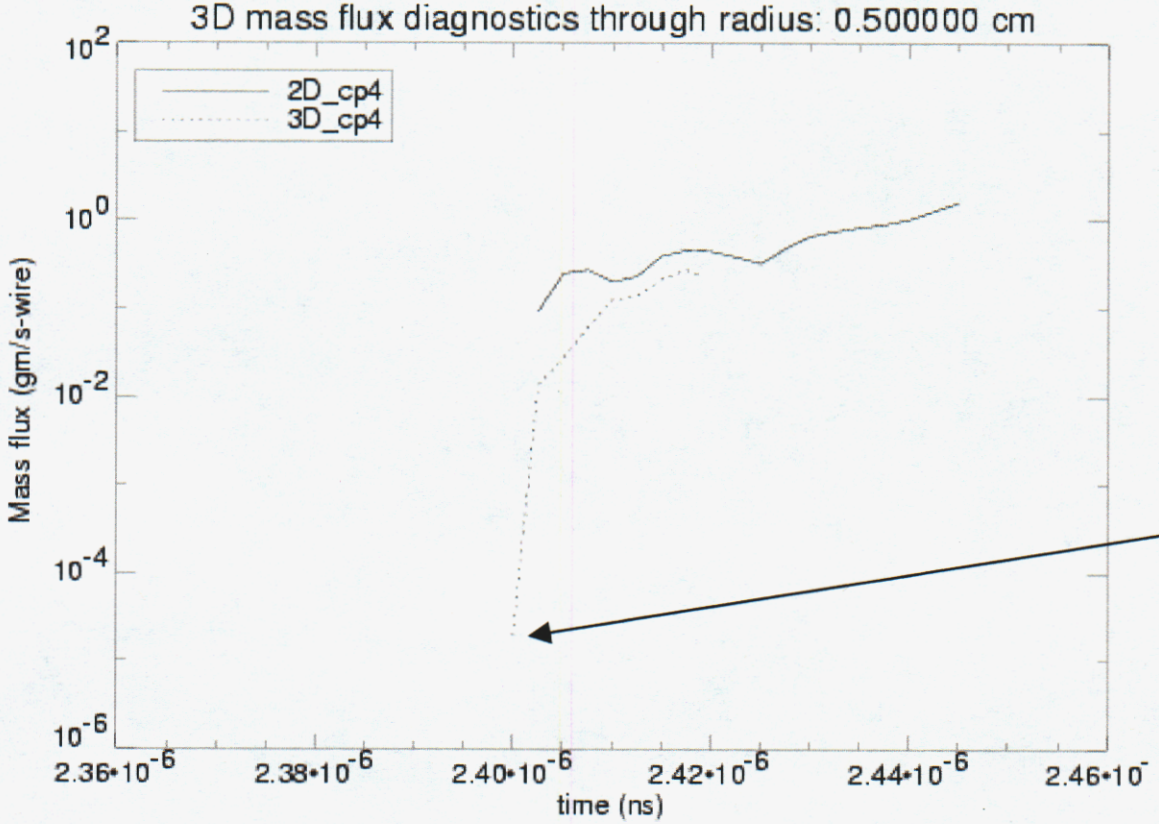
•Comparison of 2D Rθ simulation with experimental radial trajectory indicates that 2D array moves at an earlier time than experiment.

•Attempts to compensate by using different "measurements" of radius to do not account for mismatch between 2D simulation and experiment.

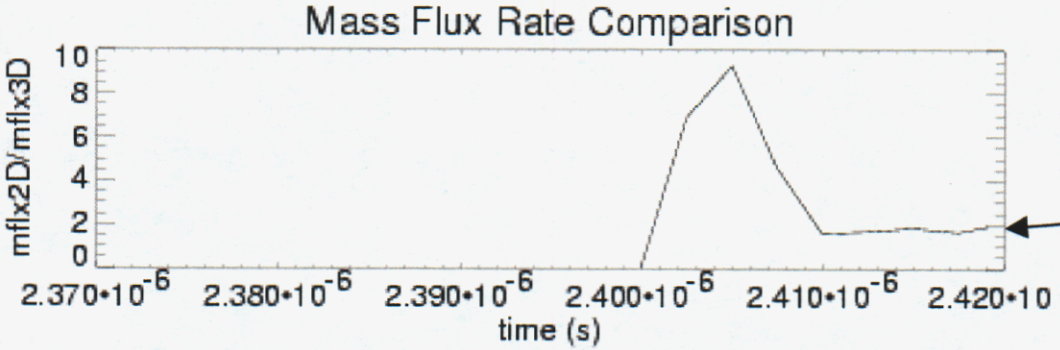
•Examination of wires during ablation indicate axial structure along the wire (all the way back to effectively t=0).

•In an averaged sense, this would imply that the ablation rate in 3D is less than the 2D approximation (no axial variation).

2D versus 3D Mass Ablation

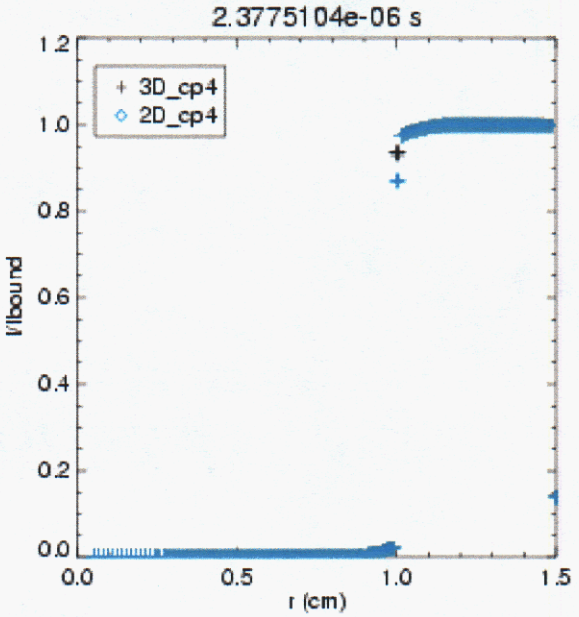


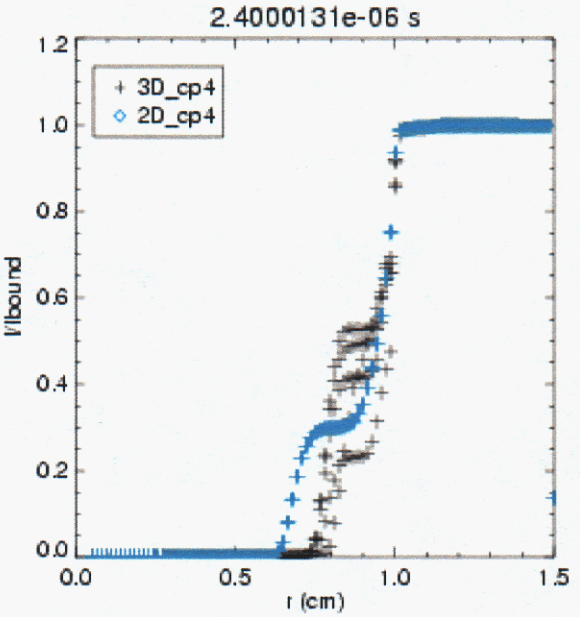
Perturbed 3D simulation reduced mass ablation rate, with material reaching axis faster than "2D" simulation.

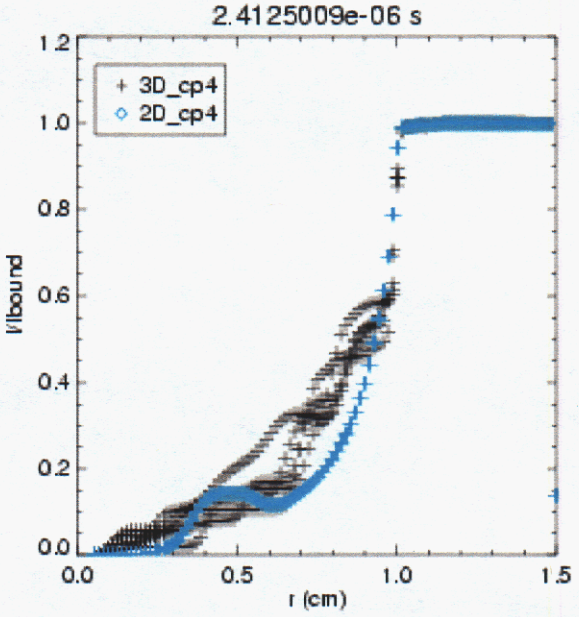


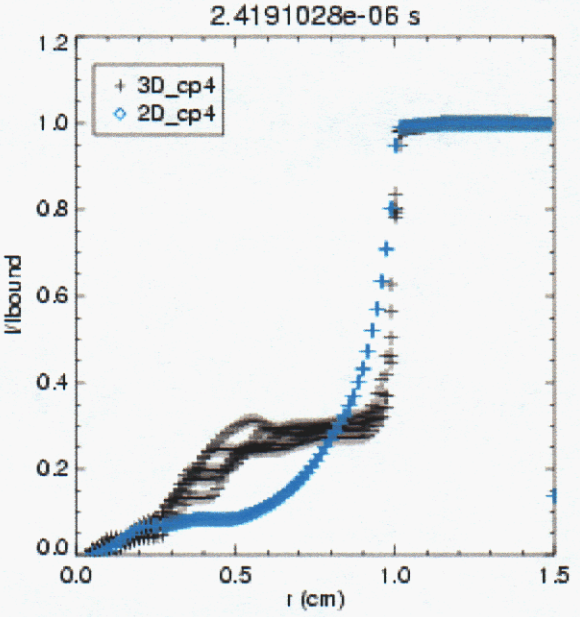
Comparison of "2D" simulation with perturbed 3D simulation indicates mass ablation rate is reduced by nearly x2.

Advected Current Density









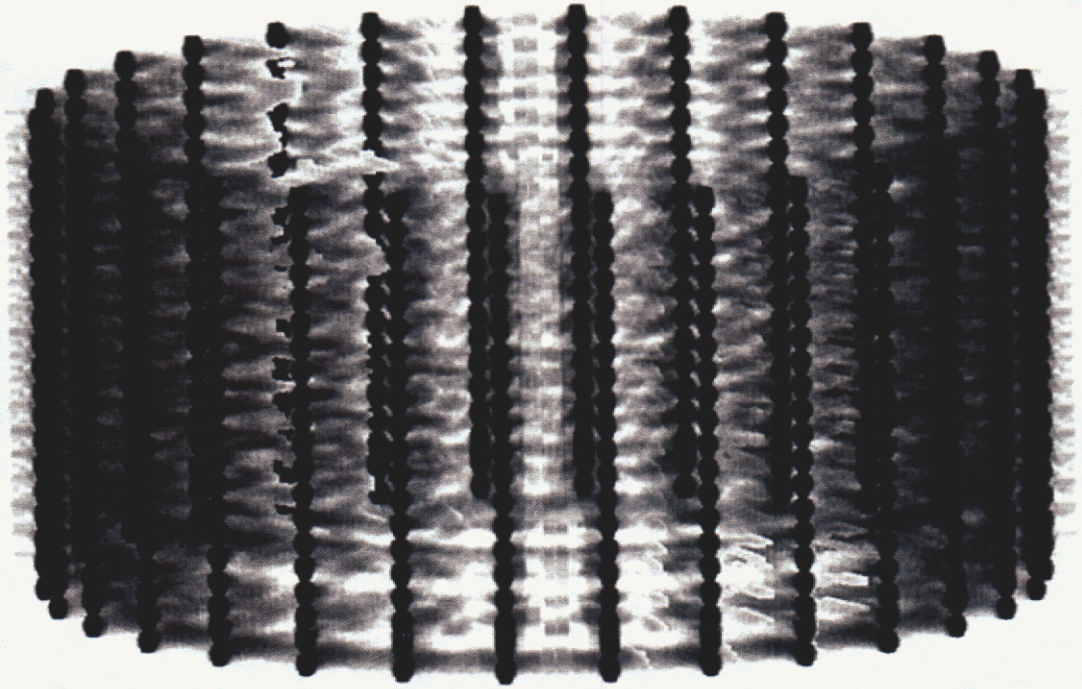
"3D" perturbed array advects more current toward axis.

Observed/Simulated Phenomenon

- Axially-varying streams of pre-cursor material from wires observed at early time.

Details:

- Finite spacing between the streams of ablated mass.
- Flow is orthogonal to wire.



Volume rendering of 30-wire sinusoidal perturbation simulation (density used as "opacity"); image generated using TNTvol

Image supplied by Sergey Lebedev, Imperial College