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Limitations of Laboratory Pulsed Power Systems for Multi-Megagauss Field Generation

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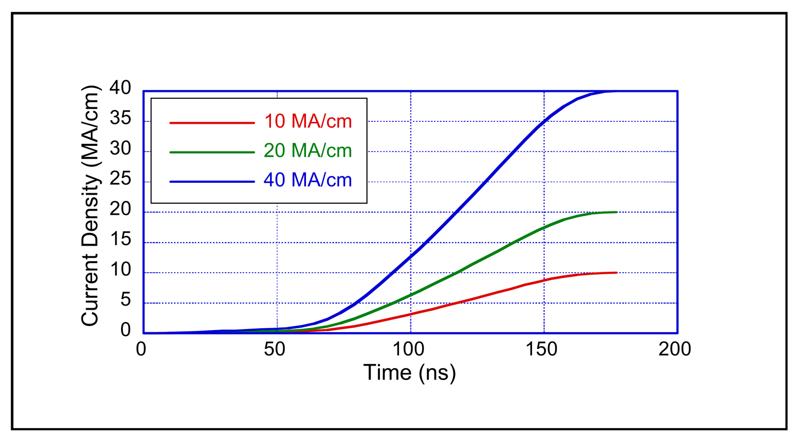
Outline

- Advances in pulsed power engineering have enabled new classes of pulsed power drivers such as ZR – capable of ~26 MA in 100 ns.
- Z-pinch and ICE designs will routinely reach linear current densities > 10 MA/cm.
- Losses in the "conductors" are now important. Ohmic losses, shock and pdV heating, and material motion will create unavoidable losses.
- We present calculations that suggest that the generation of magnetic fields > 3 kT, corresponding to current densities > 25 MA/cm, will be challenging.

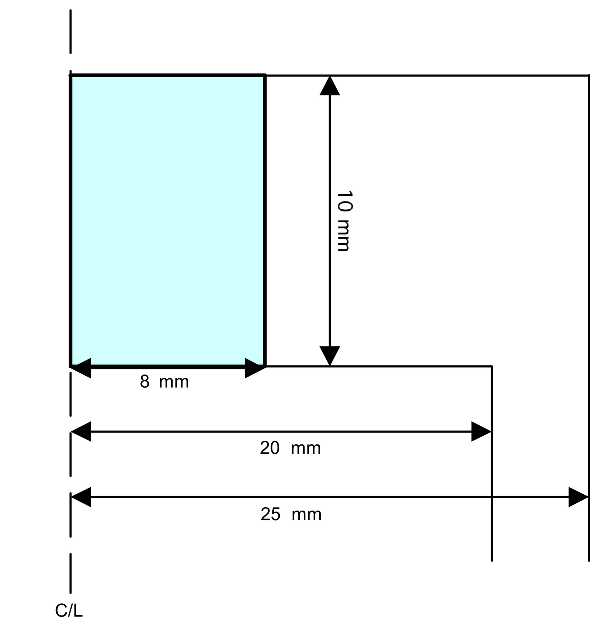
Baseline Current Waveform Used for Calculations



At High Current Densities Conductors Will Be Lossy

- Modern 2-D and 3-D RMHD codes (SNL's Alegra* code) coupled with high-power computing platforms allow us to model conductors under the influence of high current densities.
- We present 2-D RMHD calculations of simple co-axial conductors at current densities of 10 MA/cm, 20 MA/cm, and 40 MA/cm.
- We use LMD† resistivities and EOS (quantum molecular dynamics).

- The calculation only treats the inner conductor.
- The diameter of the inner conductor was chosen to minimize cylindrical convergence.
- Reflecting boundary conditions were used on the other conductors to reduce computing requirements.
- We modeled aluminum, stainless steel, and tungsten.

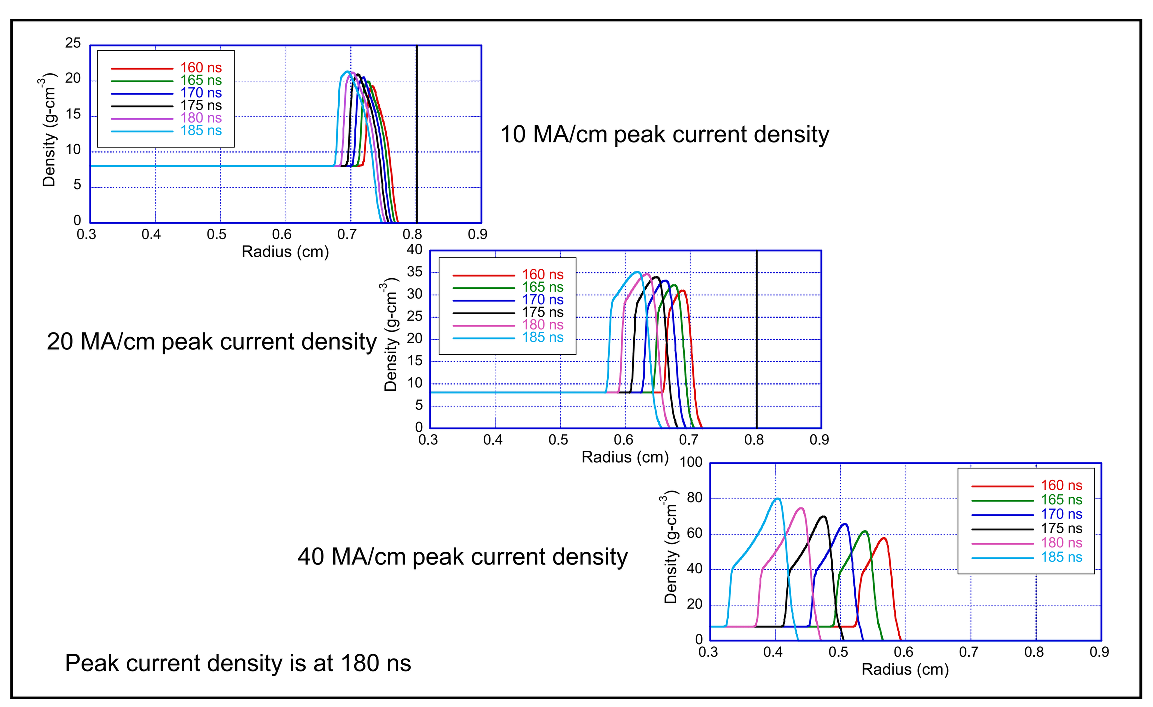


†M. P. Desjarlais, J. D. Kress, and L. A. Collins, Phys. Rev. E **66**, 025401(R) (2002)

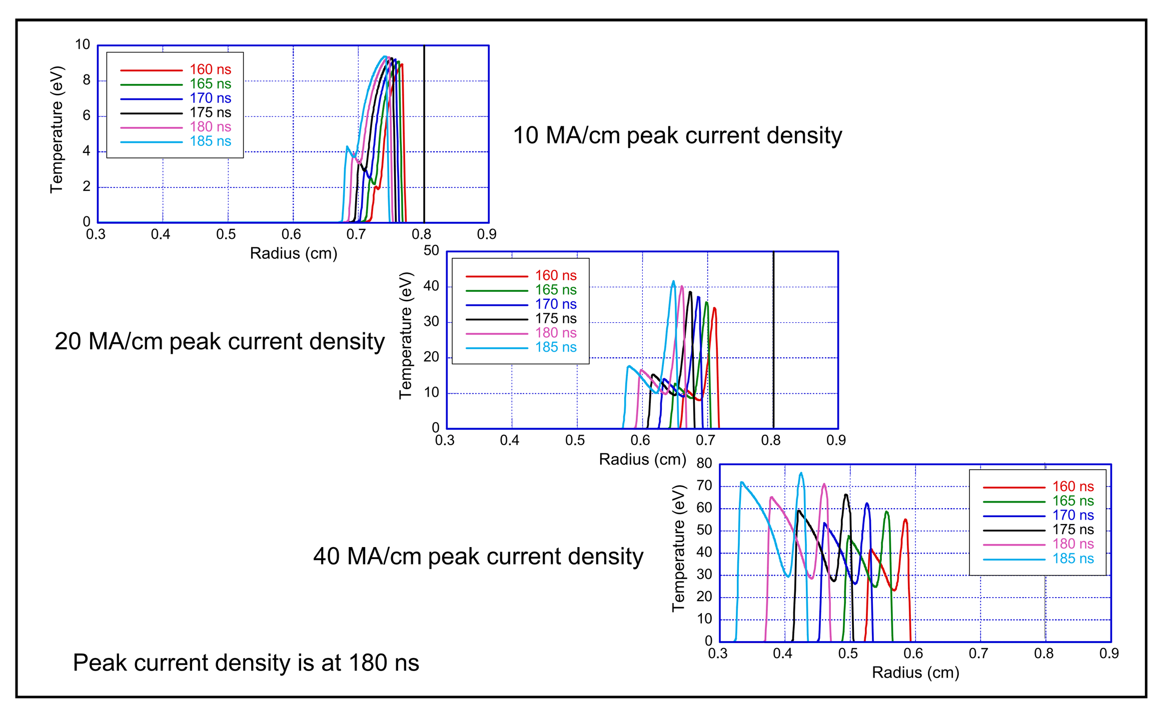
*J. S. Peery & D. E. Carroll, *Computer Methods in Applied Mechanics and Engineering* 187 (2000), p. 591.

Stainless Steel Conductors

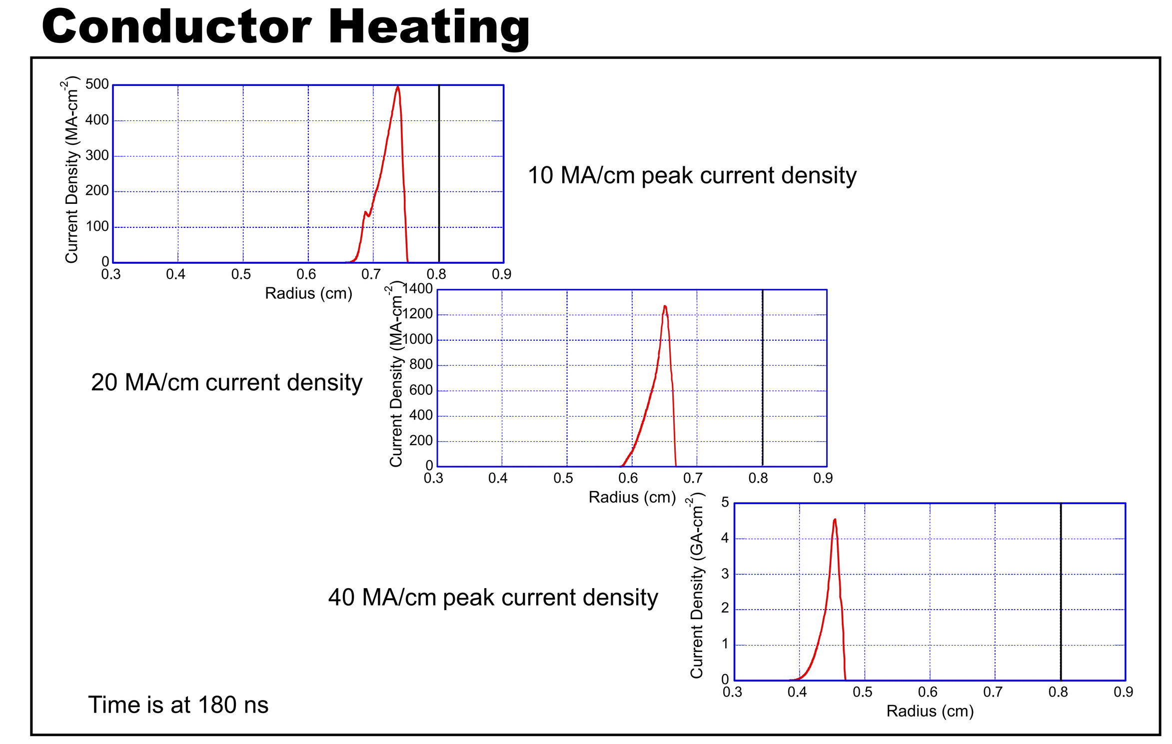
Calculations show Material Motion



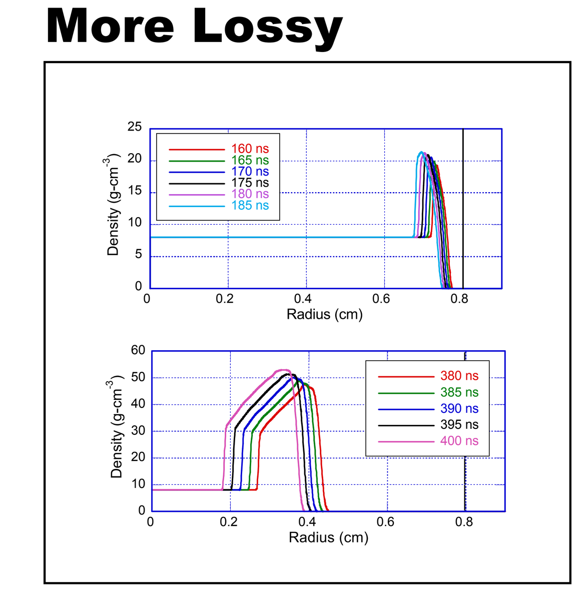
Ohmic & pdV Heating with Shock Transport of Energy into the Interior



Current Diffusion is Enhanced by Conductor Heating

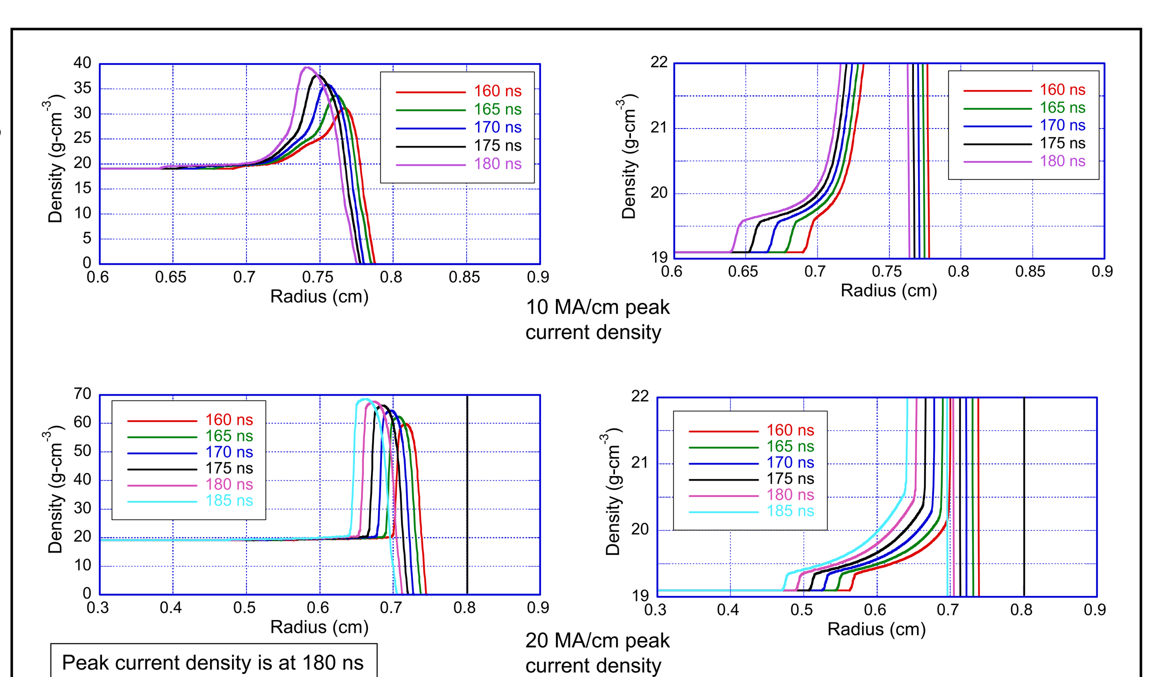


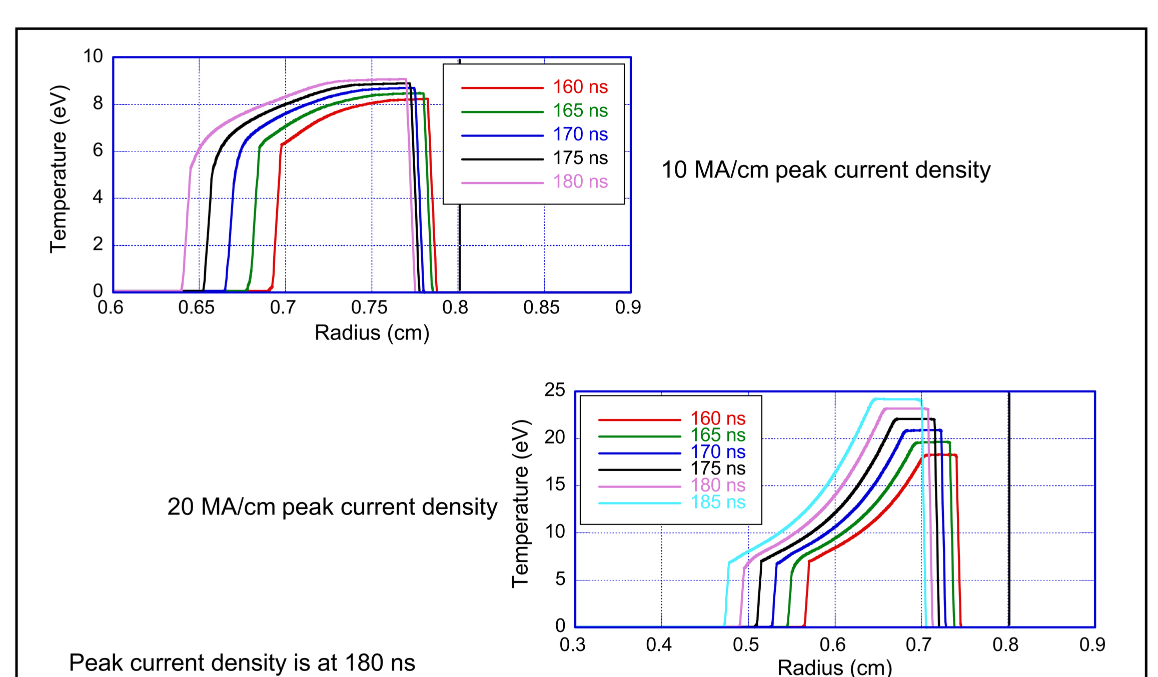
Long Pulses are Far More Lossy

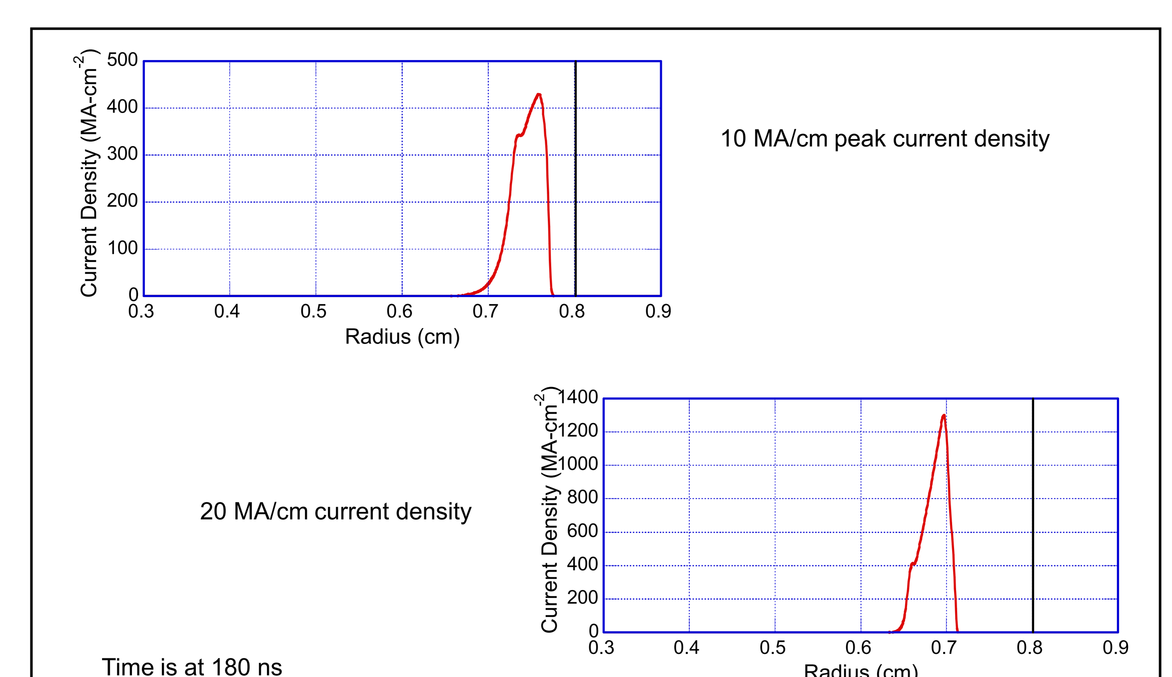


- Energy lost in stainless steel in 100 ns at 10 MA/cm
  - Internal: 4% (includes 2.75% joule heating)
  - Kinetic: 1.9%
- Energy lost in stainless steel in 300 ns at 10 MA/cm
  - Internal: 11.7% (includes 2% joule heating)
  - Kinetic: 15.6%

Tungsten Conductors







Reduced Compression and Interface Motion

- **Tungsten has less current diffusion and less density motion than stainless steel.**
- **Total energy dissipation in the conductors is 15% less with tungsten (23% less KE, 4% less internal energy) at 20 MA/cm.**

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