

# MHD Simulation of Laboratory-Based Expanding Magnetic Flux Tubes

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INSTITUTE FOR RESEARCH IN  
**ELECTRONICS**  
& **APPLIED PHYSICS**

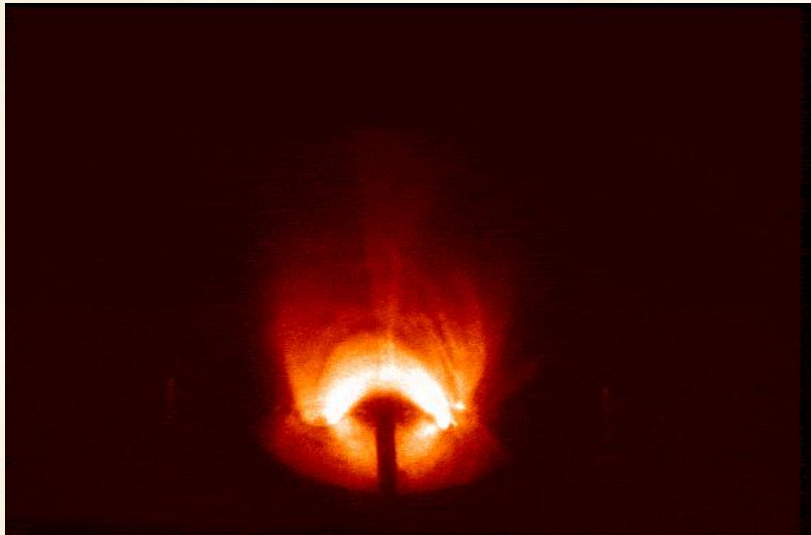
TREND Presentation -- August 6, 2010

# [ Project Outline ]

- Background & Motivation
- The MHD Model
- Experimental Setup
- Boundary & Initiation Conditions
- Some Plasma Physics
- Simulations
- Summary and Future Work

# Background and Motivation

- Existing solar flare experiments:
  - Caltech, Ruhr-Universität Bochum, MRX
- Reconnection and particle acceleration



Plasma gun at Caltech

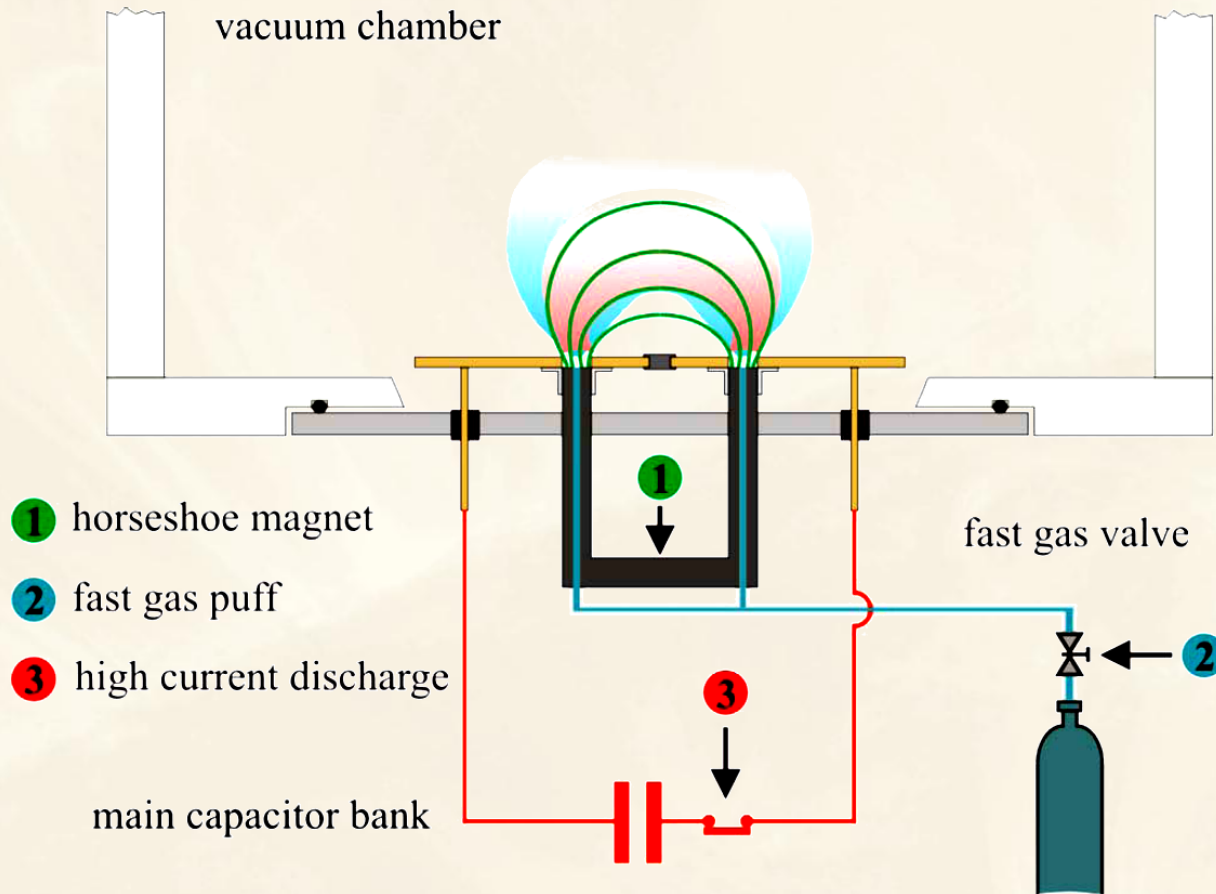


FlareLab in Bochum, Germany

# The MHD Model (Magnetohydrodynamics)

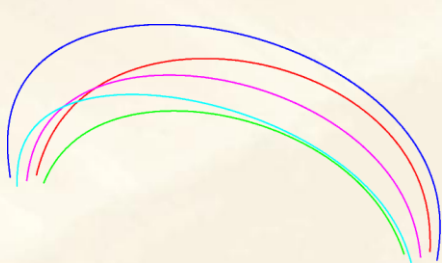
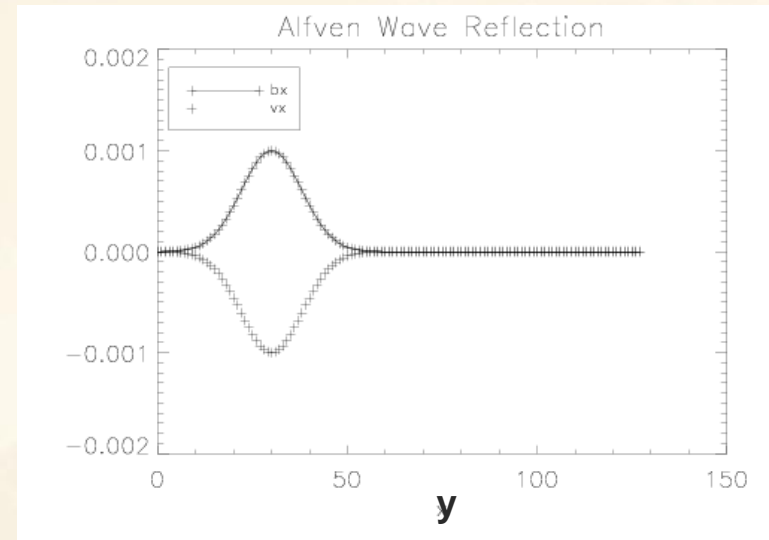
- $\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{v} = 0$  Continuity
- $\rho \left( \frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) = \frac{\mathbf{J} \times \mathbf{B}}{c} - \nabla p$  Momentum
- $\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\mathbf{v} \times \mathbf{B})$  Faraday's Law
- $\nabla \cdot \mathbf{B} = 0$  No monopoles
- $\mathbf{J} = \nabla \times \mathbf{B}$  Ampères Law
- $\mathbf{E} = -\frac{\mathbf{v} \times \mathbf{B}}{c} + \eta \mathbf{J} + \frac{\mathbf{J} \times \mathbf{B}}{nec}$  Ohm's Law

# Experimental Setup



# Boundary and Initial Conditions

- Conducting walls
  - Dirichlet BC's
  - Neumann BC's
  - Hall term
- Initial Magnetic Field



Electromagnet



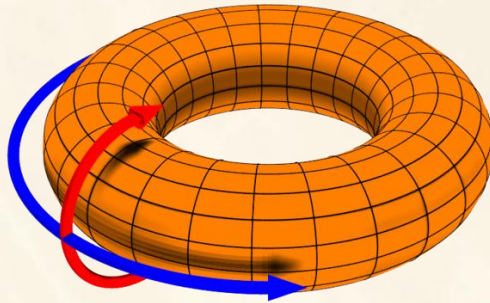
Current Discharge



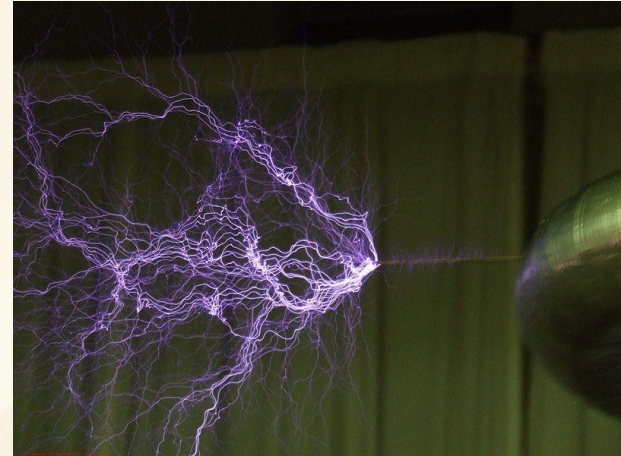
Superposition

# Some Plasma Physics

- Pinch effect

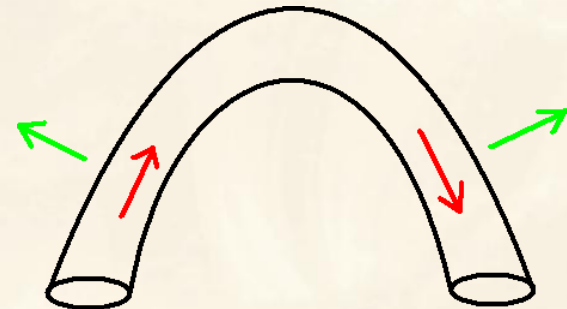
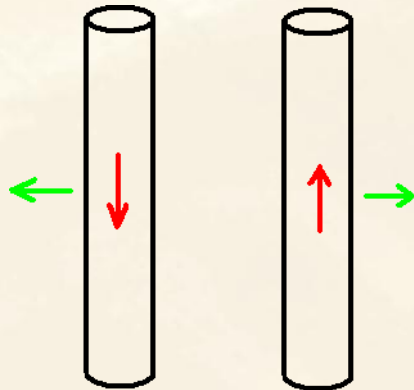


Source: Dave Burke, 2006 (Wikipedia)



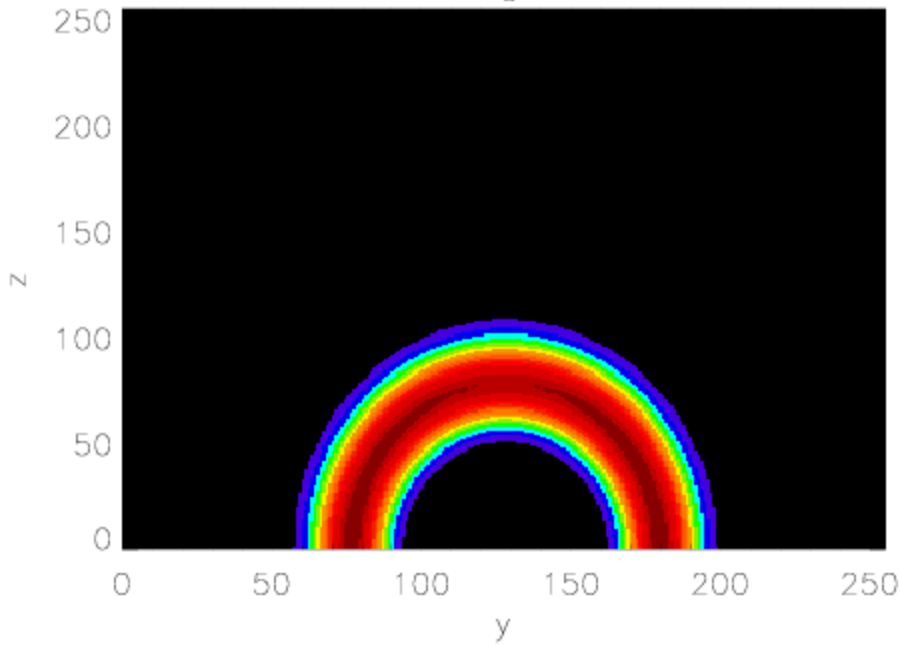
Source: Ian Tresman, 2005 (Wikipedia)

- Hoop force



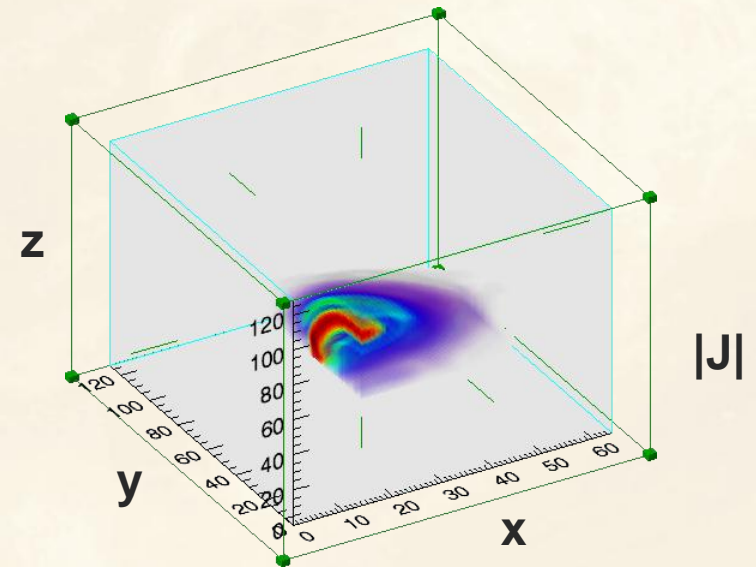
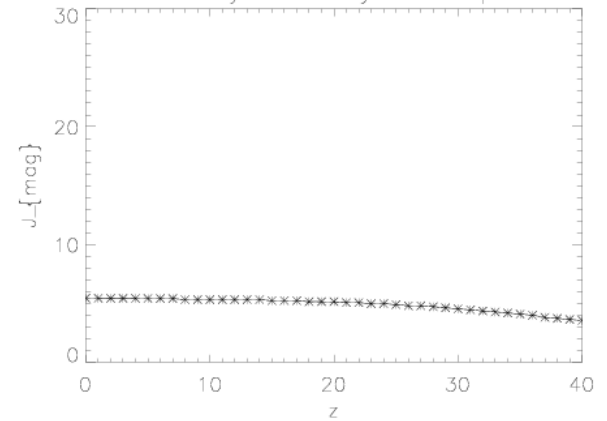
# Simulations

Z-Pinching Filament



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Boundary Instability at Footpoint



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# Summary and Future Work

- What was accomplished:
  - F3D code expanded to simulate flare experiments in a conducting cavity
- What remains to be done:
  - Incorporate Hall term
  - Explore other scenarios (e.g. more loops)
  - Build the experiment

## References

- [1] P.M. Bellan and J.F. Hansen, *Physics of Plasmas*, 5, 1991 (1998).
- [2] L. Arnold, J. Dreher, R. Grauer, H. Soltwisch and H. Stein, *Physics of Plasmas*, 15, 2008
- [3] N. Williams, E. Oz, M. Yamada, H. Ji, S. Dorfman, B. McGeehan, and J. Schroeder, <<http://meetings.aps.org/link/BAPS.2008.DPP.JP6.39>>
- [4] M. A. Shay, J.F. Drake, M. Swisdak and B.N. Rogers, *Physics of Plasmas*, 11, 2004