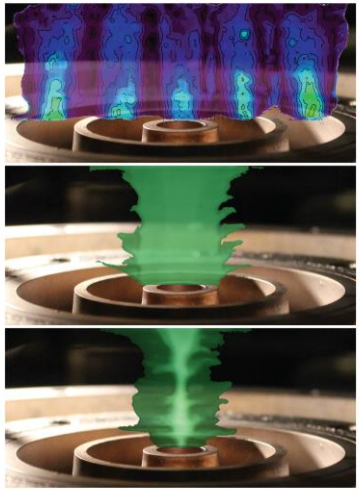
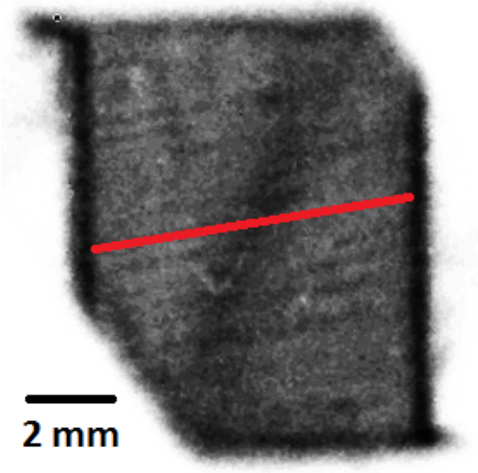
SSAP Symposium 2016

February 17-18

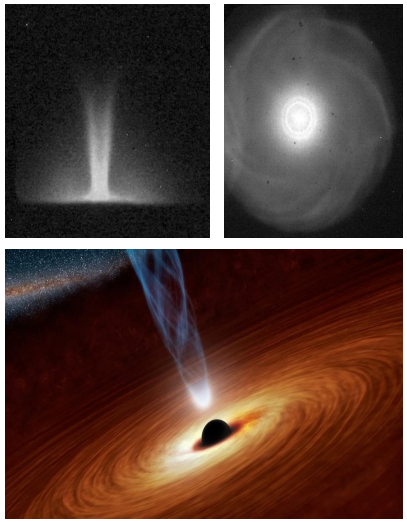
Cornell Center for Pulsed-Power-Driven High-Energy-Density Plasmas



Gas Puff Z-Pinch



Cylindrical Liner Z-Pinch Studies



Lab Plasma Jets

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National Nuclear Security Administration

Mission of the Cornell Center

- Advance the understanding of current-driven High Energy Density (HED) plasmas through experiments supported by computer simulations and theoretical modeling.

- Investigate the application of current driven HED plasmas to inertial fusion energy, intense radiation generation, laboratory plasma astrophysics, etc.

- Develop new HED diagnostics for HED research

- Train a new generation of HED research scientists

Home Team Faculty, Staff and Students at Cornell (2015-16)

Faculty: David Hammer (ECE), Bruce Kusse (AEP), Charles Seyler (ECE)

Senior Scientists: John Greenly; Steve Lantz

Visiting Senior Scientists: Sergei Pikuz, Tatiana Shelkovenko; Niansheng Qi

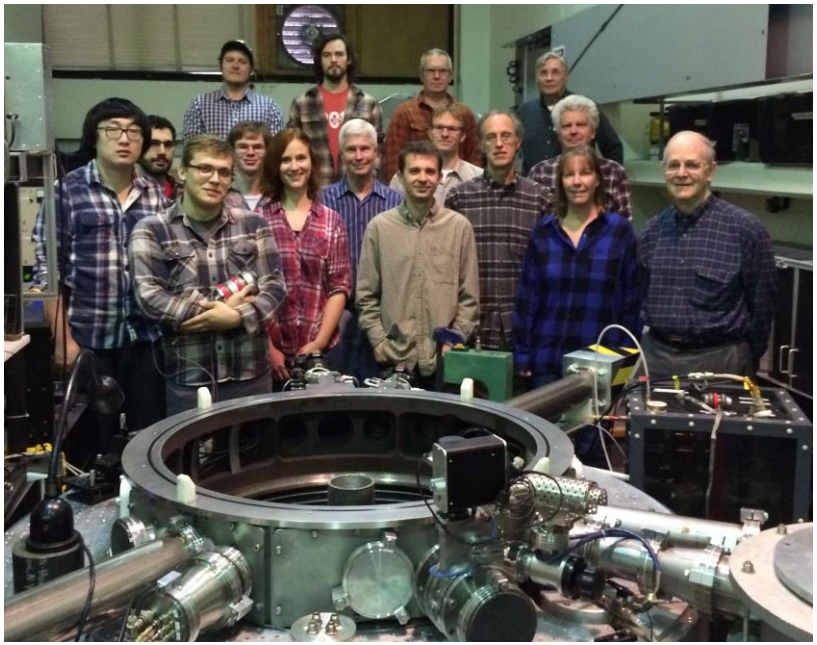
Postdoctoral Associates: Nathaniel Hamlin and Philip de Grouchy (now with I. C.)

Graduate students: Levon Atoyan, Jacob Banasek, Tom Byvank, Adam Cahill, Joseph Engelbrecht, Sophia Rocco, Shihao Tian

Technical Staff: Todd Blanchard, Dan Hawkes, Billy Potter, Harry Wilhelm

Undergraduates: Dillan Chang, Robert Duggan, Daniel Liang, Hannah Moore, Lauren Ransohoff

Administrative Staff: Cindy Vanostrand



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Subcontracted Collaborations

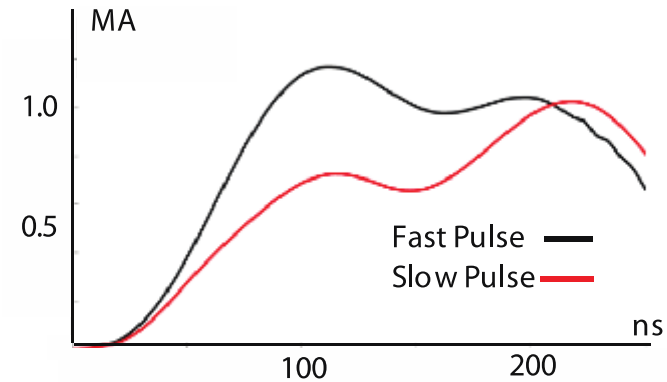
Simon Bland, Imperial College

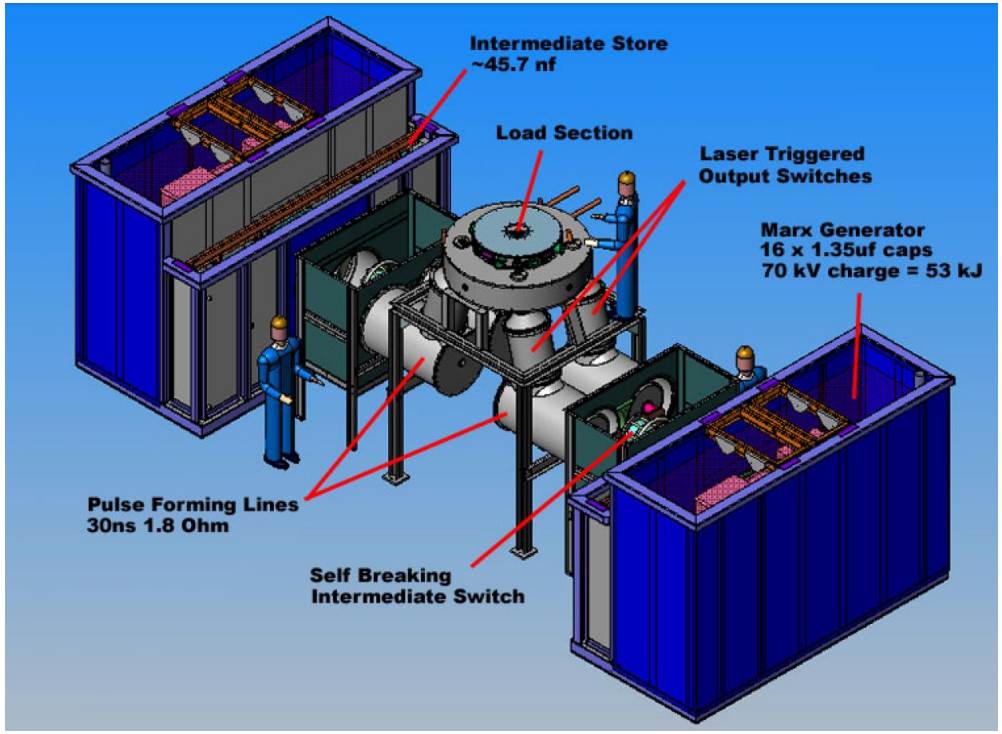
Simon Bott-Suzuki, University of California, San Diego

Nathaniel Fisch, Princeton University

Yitzhak Maron, Weizmann Institute of Science

Sergei Pikuz, P. N. Lebedev Institute





TOPICS

Gas Puff Experiments
Liner Experiments
Plasma Jet Experiments
Diagnostics
Simulations

COBRA: 0.9-1.2 MA, 95-250 ns,
negative pulse, reversible with a convolute
~ 100 kJ in the Two Marx Generators

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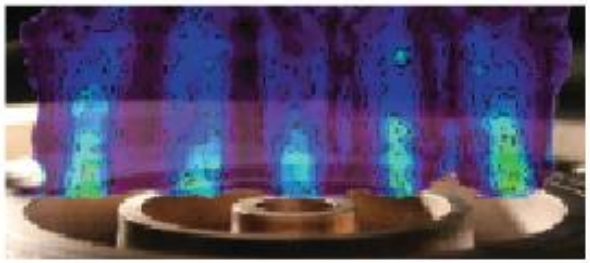
Gas Puff Z-Pinch Experiments

TriAxial Gas Puff Z-Pinch Experiment

Intense X-Ray Source

t < 0

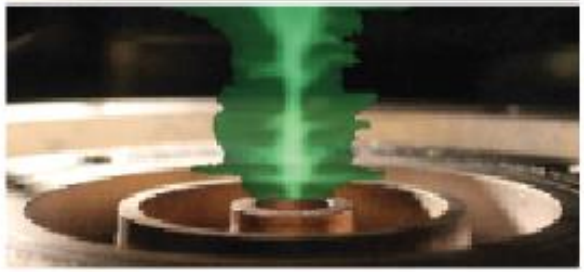


6 cm

Planar Laser Induced Fluorescence Measurement of Pre-Implosion Neutral Density

t=170ns

t=210ns



XUV Emission from an Imploding Gas Puff

Three Independent Plena for Different Pressures and Species

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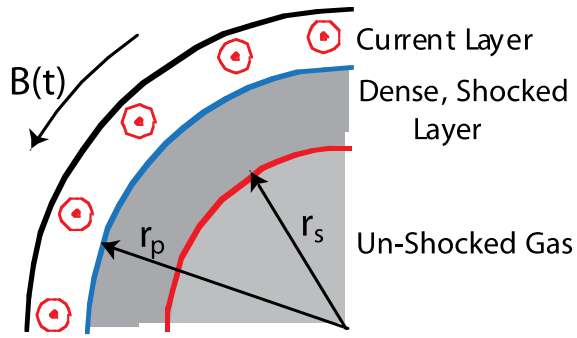
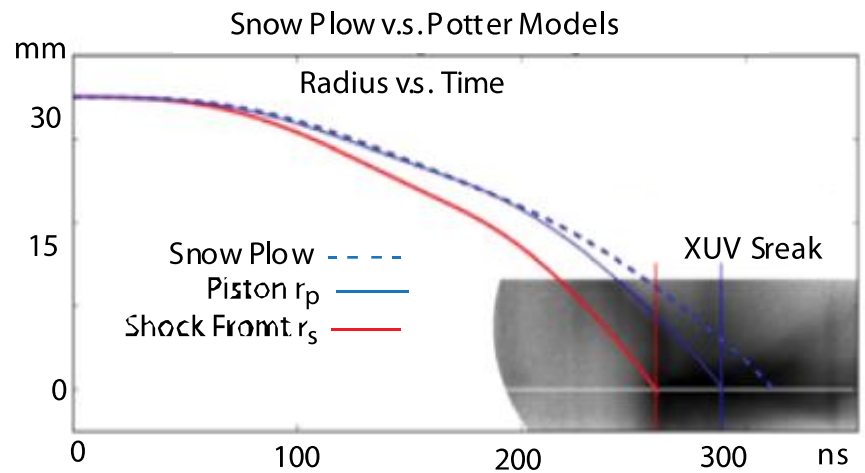
TriAxial Gas Puff Experiment

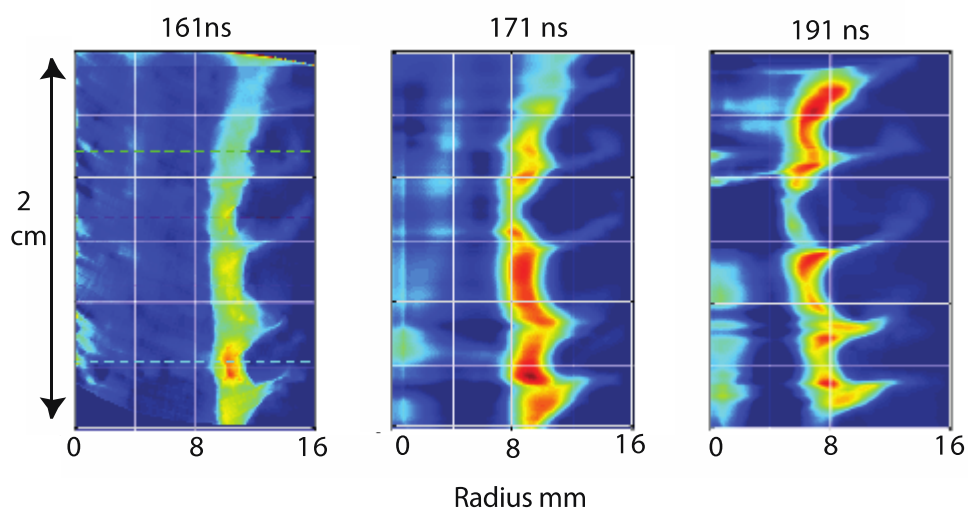
Potter Shock Model



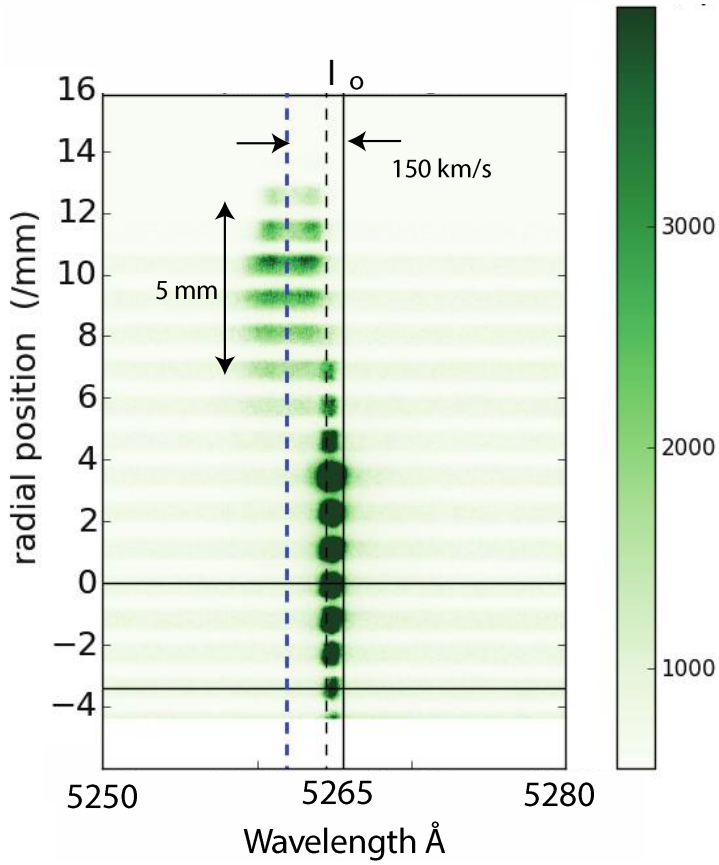
D.Potter, Nuclear Fusion,18 (1978)



z vs. r
Density Images of
the Implosion Showing
the Dense Shocked Layer



TriAxial Gas Puff Experiment



Thomson Scattering Picture of the Imploding Shell

- Shell thickness (FW) 5 mm
- Shell velocity 150 km/s
- Highly ionized center jet
- Ion acoustic peaks

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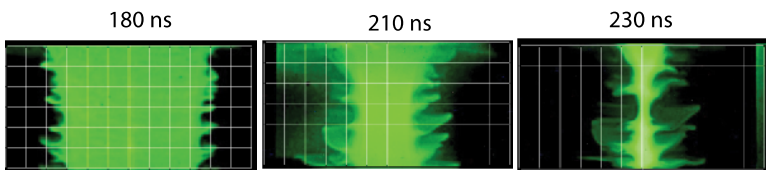
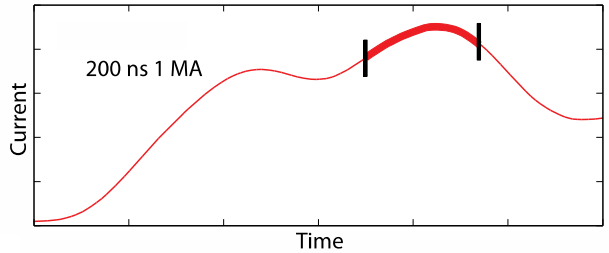
TriAxial Gas Puff Experiment

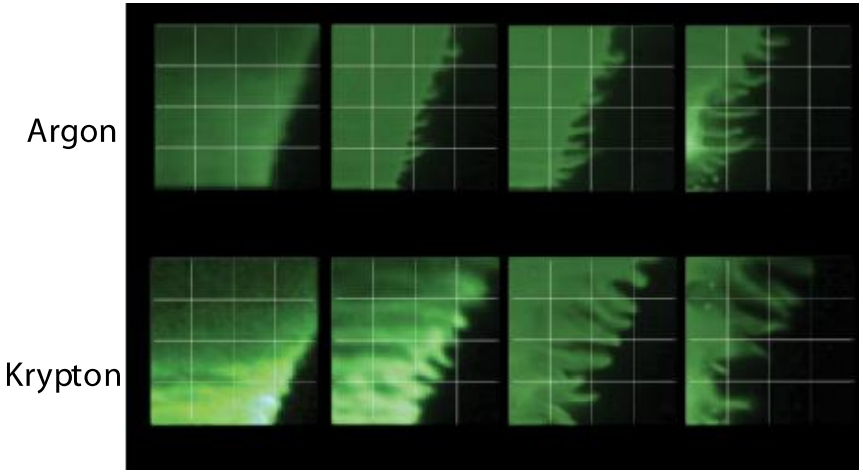
Magneto-Rayleigh Taylor Instabilities



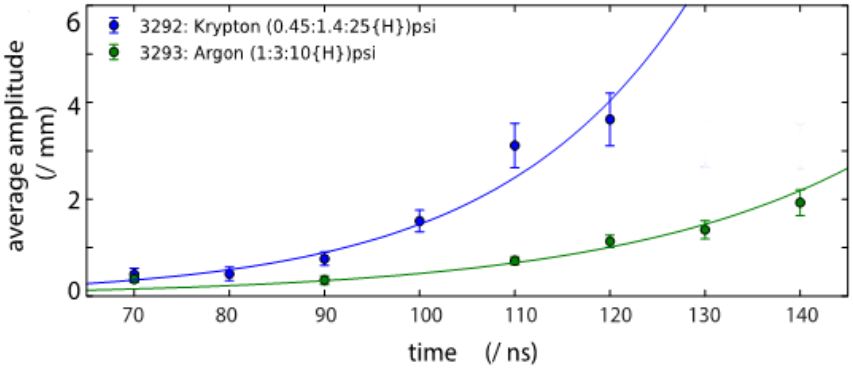
Argon Implosion



XUV Images



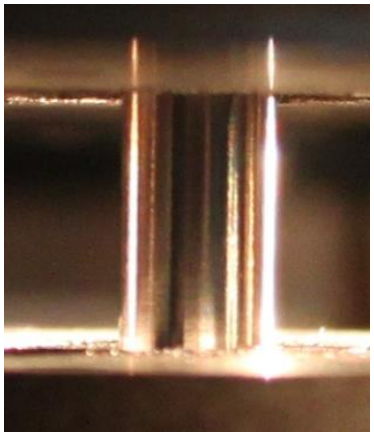
Growth rate studies show a dependence on radial density profile and species



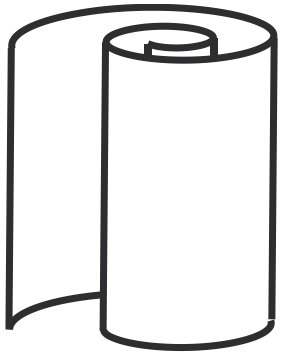
Cylindrical Liner Z-Pinch Initiation Experiments

Cylindrical Liner Experiments

- Supporting the SNL MAGLIF Fusion Concept
- COBRA can implode only very thin liners ~ a few microns
- Most of our recent liner work has looked at initiation, early time behavior of current flow and plasma formation



2-20 μ Cu



3 μ Al Foil

50-100 μ Al

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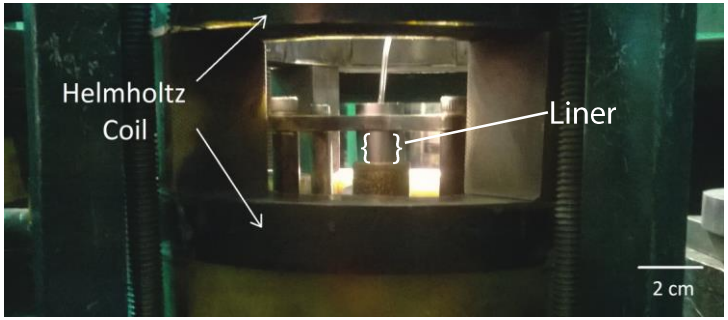
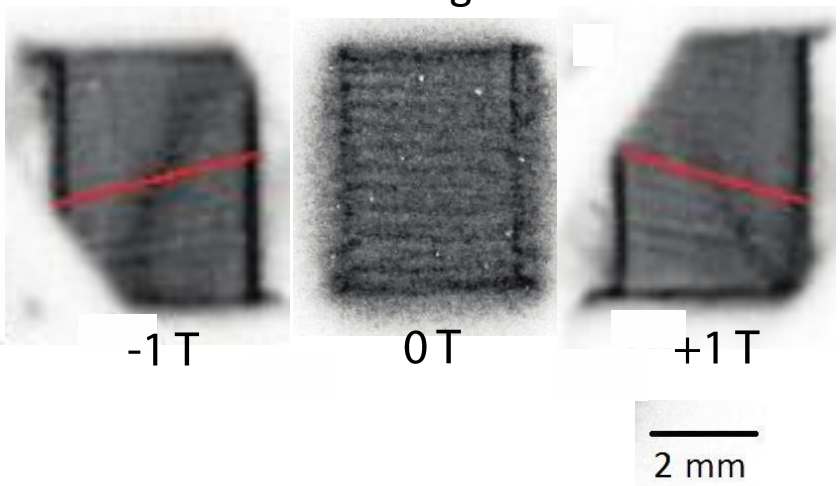
Cylindrical Liner Experiments

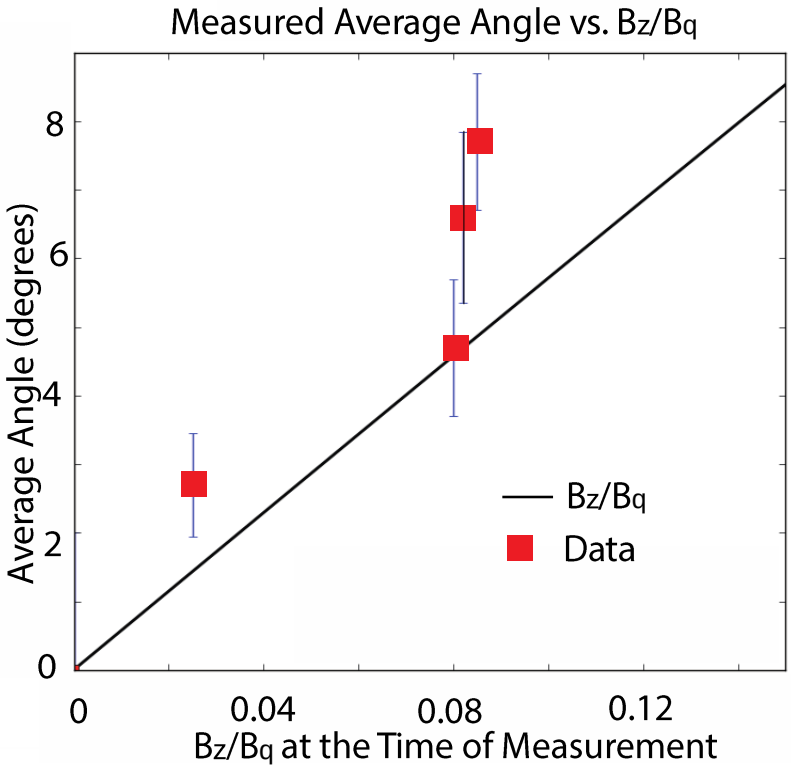
Helical Striations During Initiation may influence the implosion



1 MA, 100 ns current pulse
0-1.5 T Axial Magnetic Field

XUV Images





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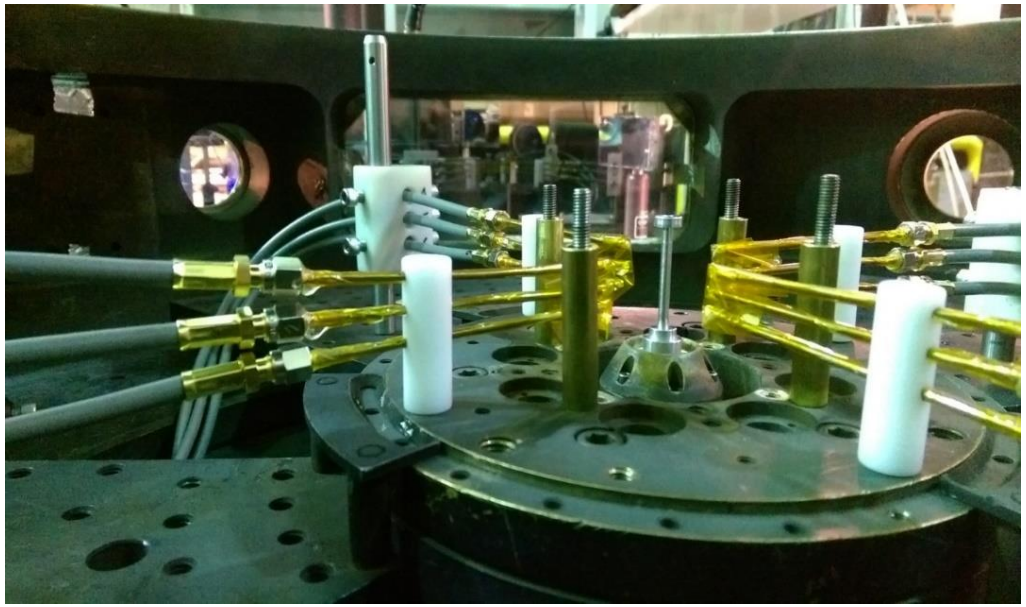
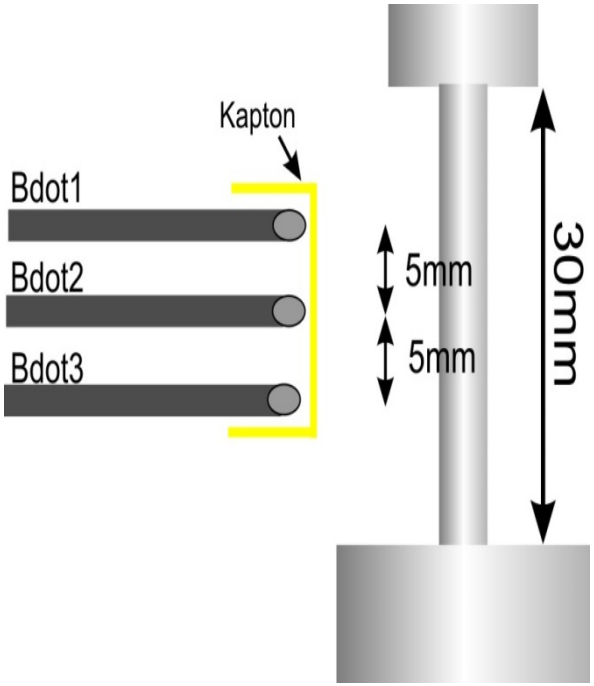
Cylindrical Liner Experiments

UCSD/CU Studies of Axial and Azimuthal Variations in Initial Current Generated by Azimuthally Localized Anode Contact





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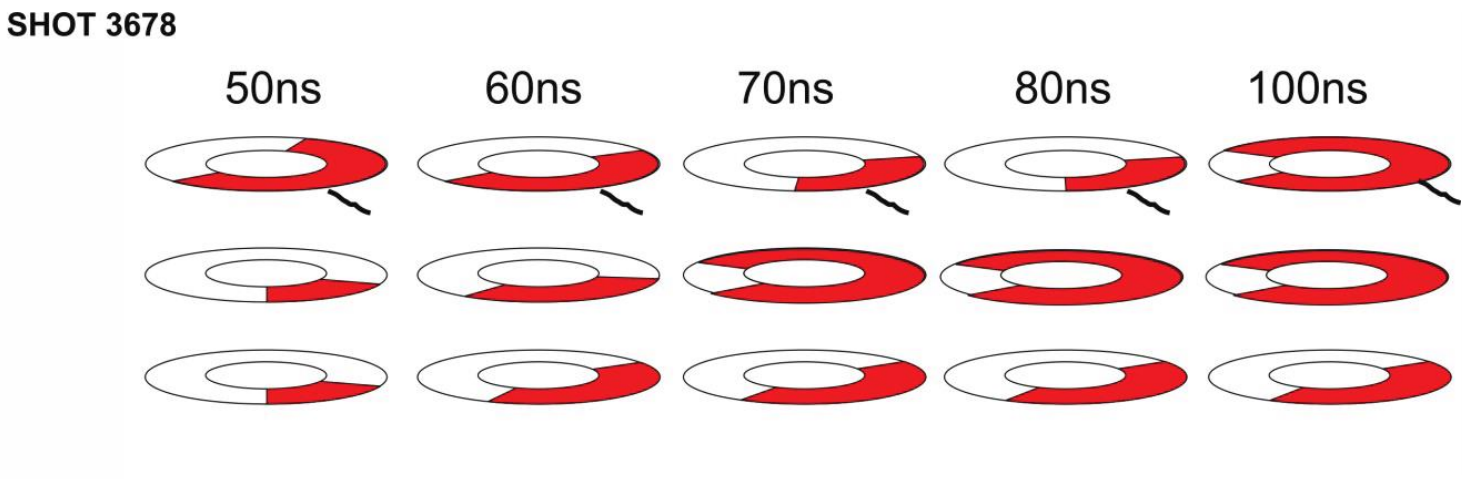
Cylindrical Liner Experiments

During current initiation, azimuthally induced anode contact asymmetry persists axially along the cylindrical liner.
These asymmetries can lead to an unstable implosion of the liner.



Laboratory Plasma Jets

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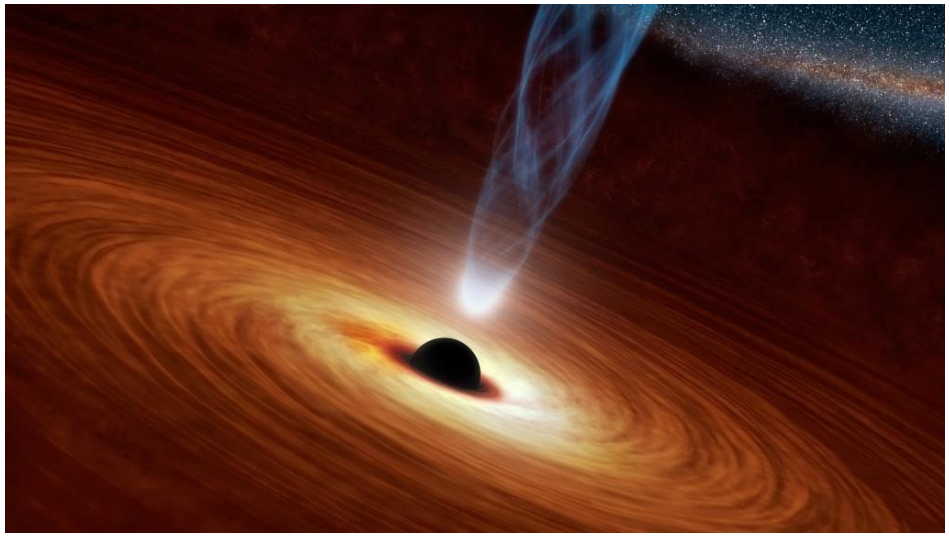
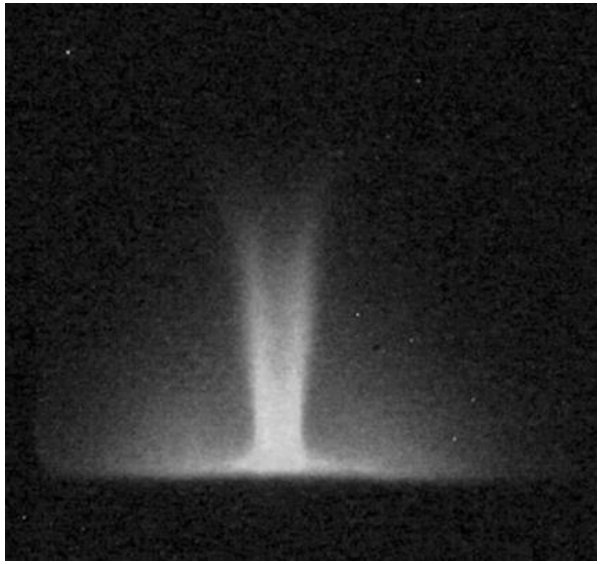
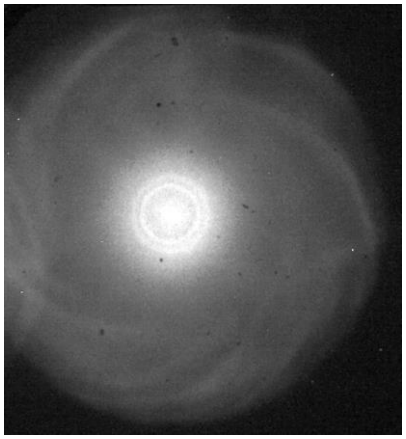
Laboratory Plasma Jets



http://apod.nasa.gov/apod/ap130312.html
R.V.E. Lovelace, *Dynamo model of double radio sources*, Nature, **267** (1976)

Rendering of a Magnetized Astrophysical Plasma Jet





Laboratory Plasma Jet

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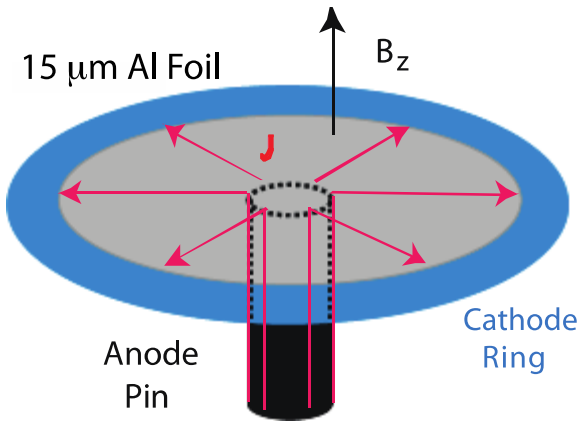
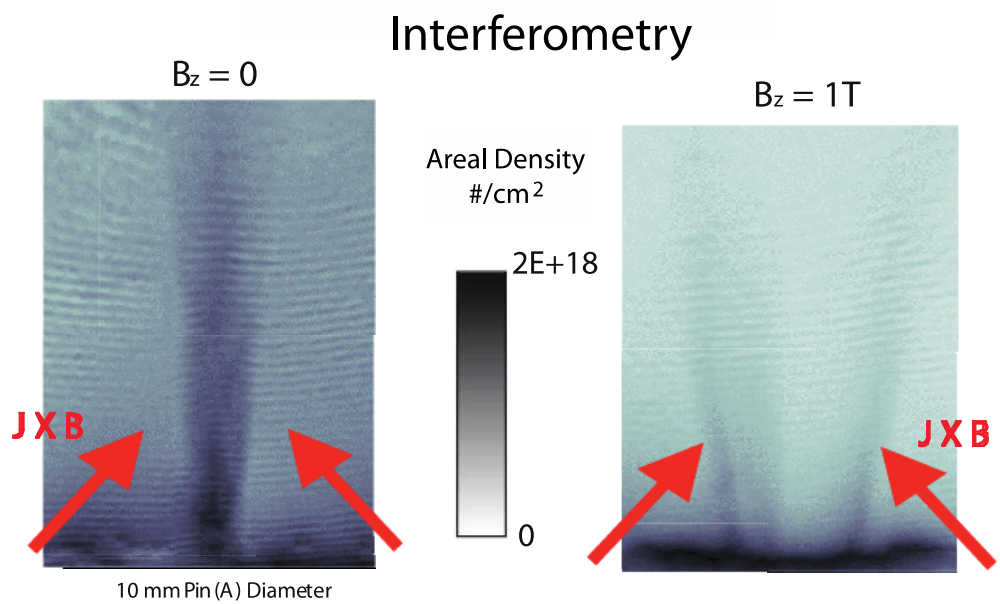
Laboratory Plasma Jets





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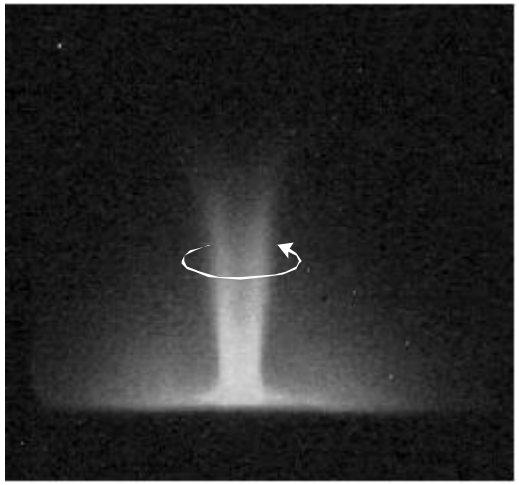
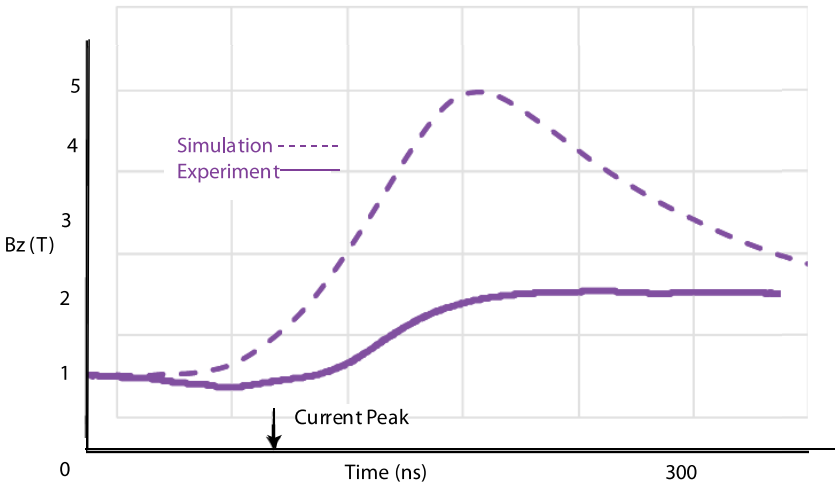
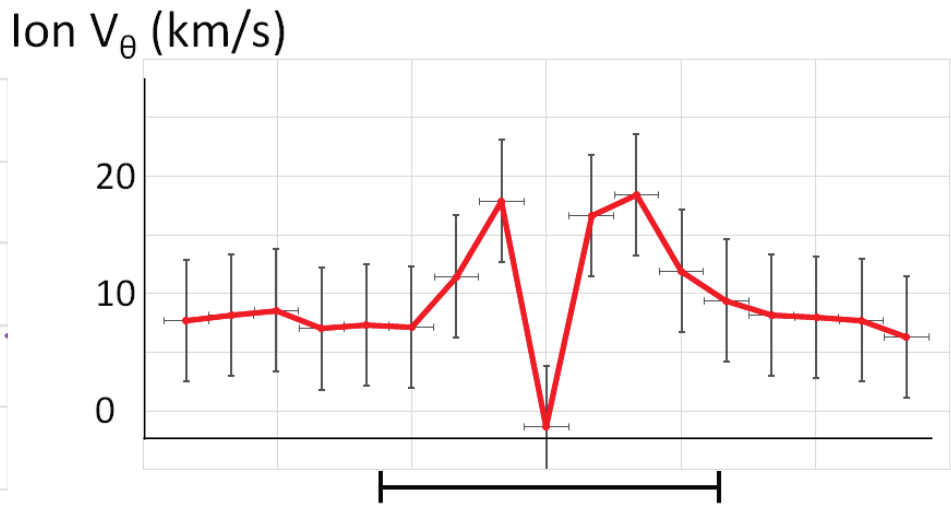
Laboratory Plasma Jets



Rotation of a Magnetized Plasma Jet
Consistent with Magnetic Field Compression



Experimental Ion Velocities from
Thomson Scattering



5 mm diameter pin

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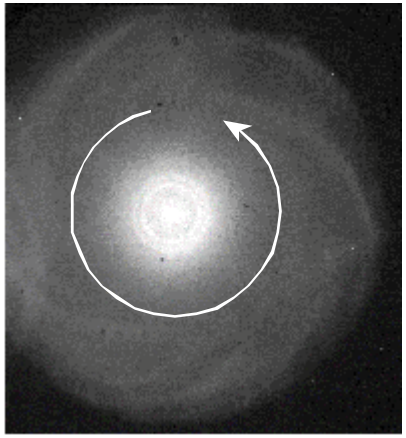
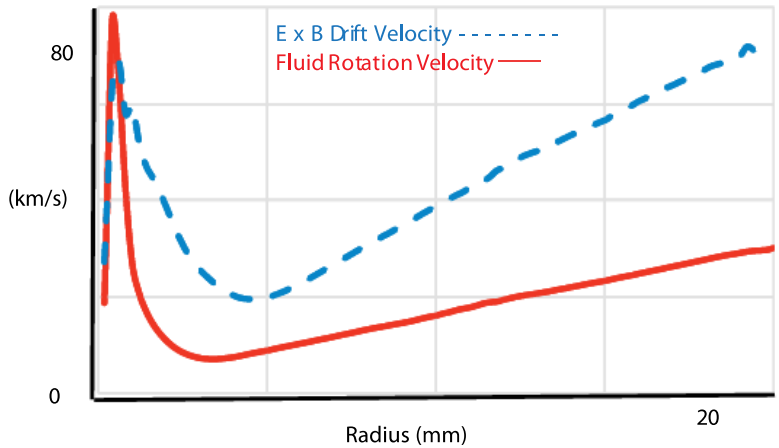
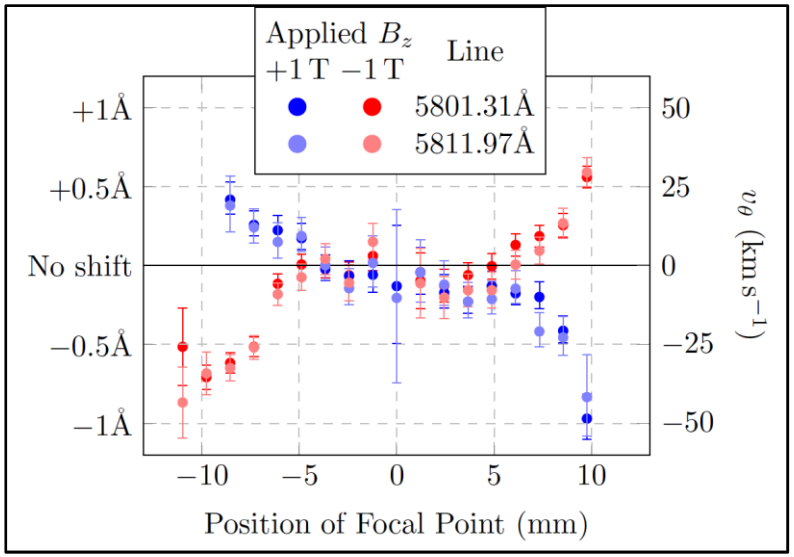
Laboratory Plasma Jets

E x B Rotation of the Ablated Surface Plasma Above the Radial Foil from Doppler Shift Spectroscopy







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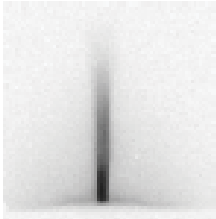
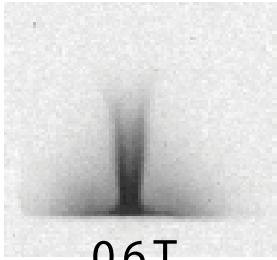
Laboratory Plasma Jets

Jet Disruption

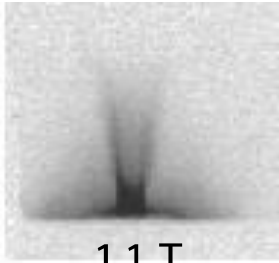
- With Al foils the plasma jets were observed to disrupt above a magnetic field threshold of approximately 1 Tesla.
- The magnetic field threshold value appears to dependent on the foil material. Preliminary experiments show a dependence on the electrical conductivity.
- The physics behind this disruption is currently being investigated.



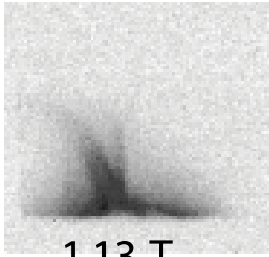
0 T



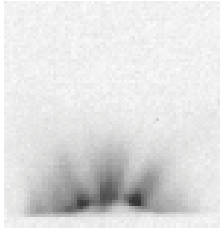
0.6 T



1.1 T



1.13 T

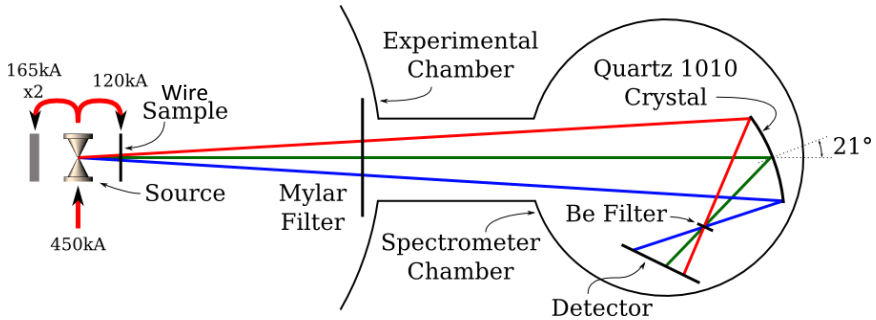


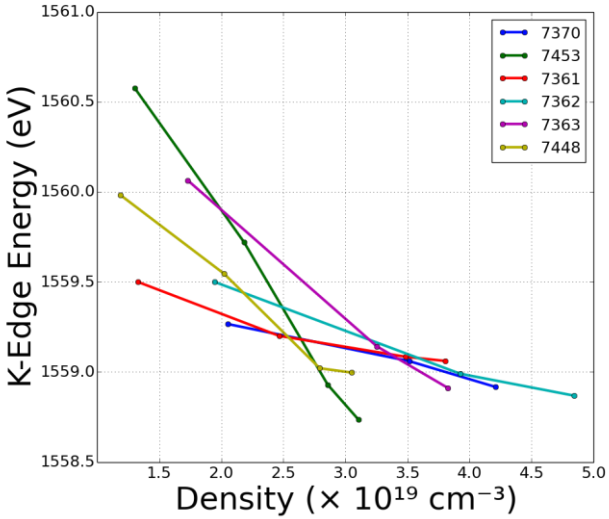
1.5 T

High Energy Density Diagnostics

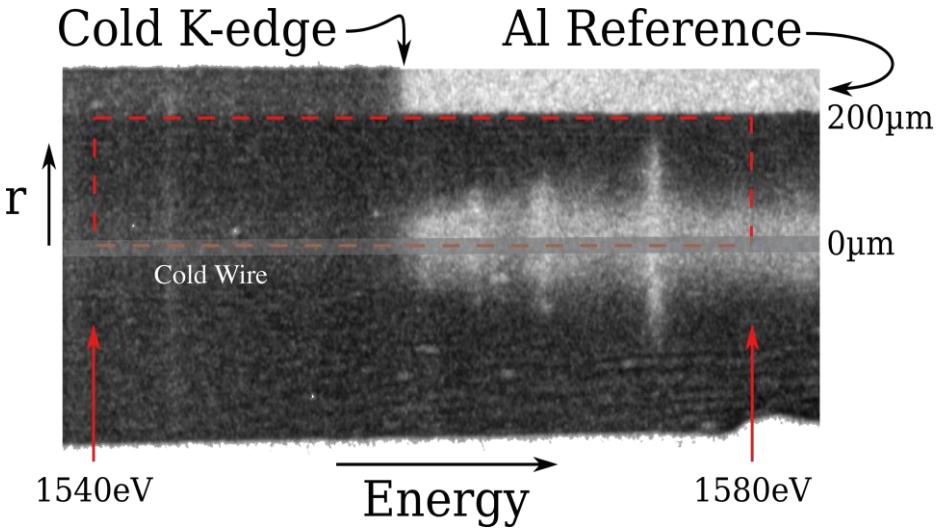
X-Ray Absorption Diagnostics

Physics of the K-Edge Energy Dependence on Density



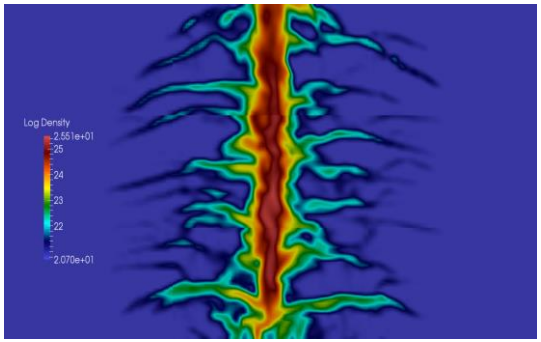


Absorption Spectrum

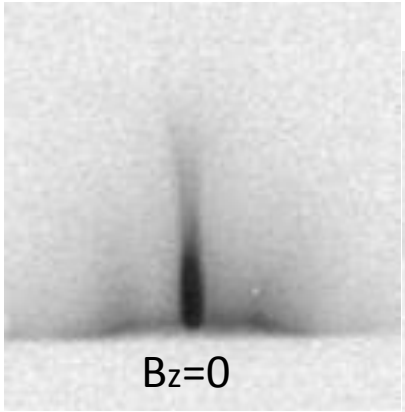


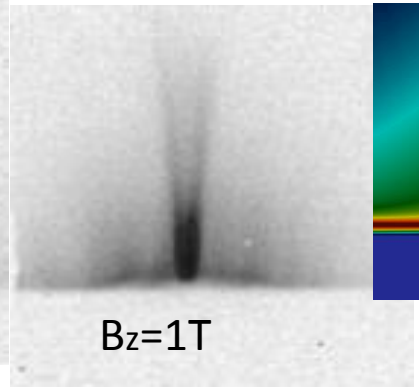
Computer Simulations

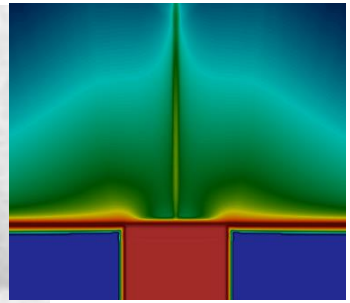
PERSEUS (Περσεύς) XMHD Simulations

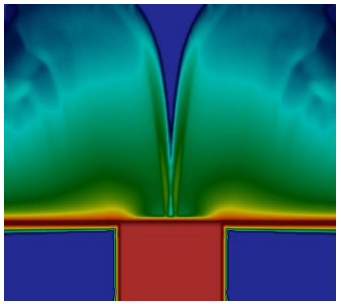


Gas Puff Implosions









Laboratory Plasma Jets

Simulation Work Is Not Just For Pretty Pictures

- **Gas puff simulations** have explained the ionization we have seen ahead of the shock and are investigating why Argon implosions are more stable than Krypton.
- **Liner simulations** have reproduced the striations and there is evidence that they may be explained by a Hall instability.
- **Plasma jet simulations** have helped to understand the rotation of the jet and the ablation plasma and the compression of the magnetic field and may be able to identify the physics of the jet disruption.

Summary

- Gas Puff Studies, Shocks, Stability & Implosions (HEDP-07)
- Cylindrical Liner Studies, Initiation Current & Striations (HEDP-09)
- Lab Plasma Jet Dynamics Studies (HEDP-14)
- HED Diagnostics, X-Ray Absorption (HEDP-08) & Zeeman Spectroscopy (HEDP-07)
- XMHD Computer Simulations (HEDP-32)

2015 Center Papers/Presentations

18 published in reviewed journals
4 Invited talks
Oral and Poster presentations at APS, ICOPS and DZP

Recent PhD Student Placement (2011-15)

7 at LLNL/SNL
4 Post Docs at IC/CU/MIT
4 at HED Companies; Raytheon/Ktech & Tri Alpha
2 at Tech Companies; Cylance, Inc. & Momentum Dynamics Inc.