Magnetically Driven Implosions in Dense Plasma Focus, Experiments and Simulation

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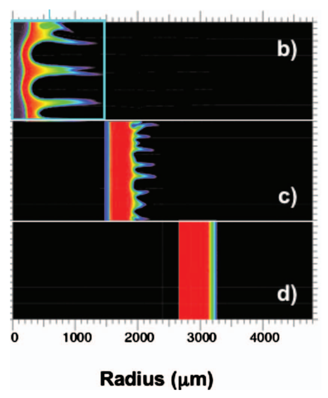
Introduction/Motivation

- Study fluid instabilities at the surface of Magnetically Driven Implosions (MDI) is key to understand the plasma-driver coupling improving its efficiency.
- Medium to small size drivers working at the appropriate plasma regime, can tackled fundamental questions in physical processes such as instability seeding, fuel compression, heat loss amongst others. All of them relevant to Inertial Confinement Fusion (ICF) and its efficiency.
- Working on experiments with excess of hundred of shots per day, allows an accurate statistical analysis, in great need to validate these fundamental physical phenomena where bigger experiment facilities lag on, mainly due to their shot limitation.
- Dense Plasma Focus offer a reliable, reproducible and in many cases high repetitively source of MDI with great assets which include hundred of shots per day and rapid variation of load characteristics (i.e. gas and pressure).
- The above gives the chance plan a comprehensive experimental campaign which will have a direct comparison between theory and contributing to understand these phenomena.
- Contribute with an accurate and a variety of measurable empirical parameters to have the first fully 3D simulation code of a Plasma Focus.
- Research on DPF has been concentrated in radiation and neutron yield mainly [1]
- Understand the instability growth along with the current diffusion losses, with and without the aid of external magnetic fields.

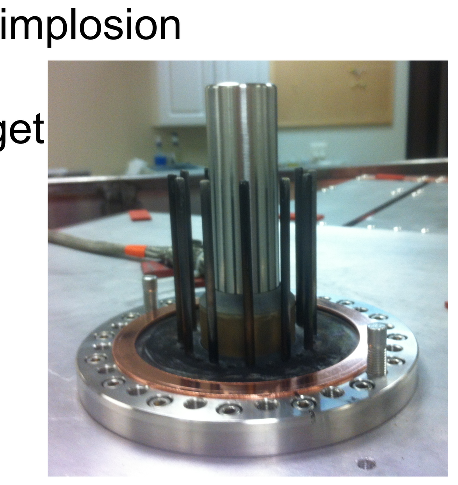
Magnetically Driven Implosions



2D Lasnex simulations of a beryllium liner at b) near c) midway and d) at the start of the current pulse [2].

- Lorentz force dominates the entire implosion
- Force accelerates the pusher.
- Pusher compresses fusion fuel target
  - Cylindrical plasmas
  - Liners

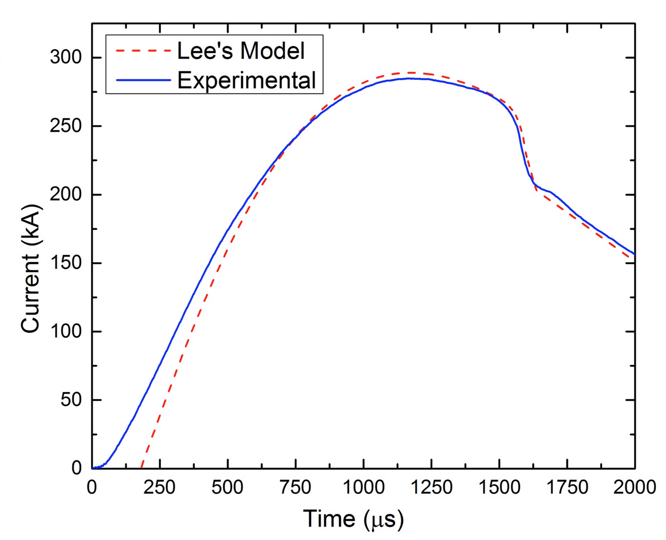
$$\vec{J} \times \vec{B}$$

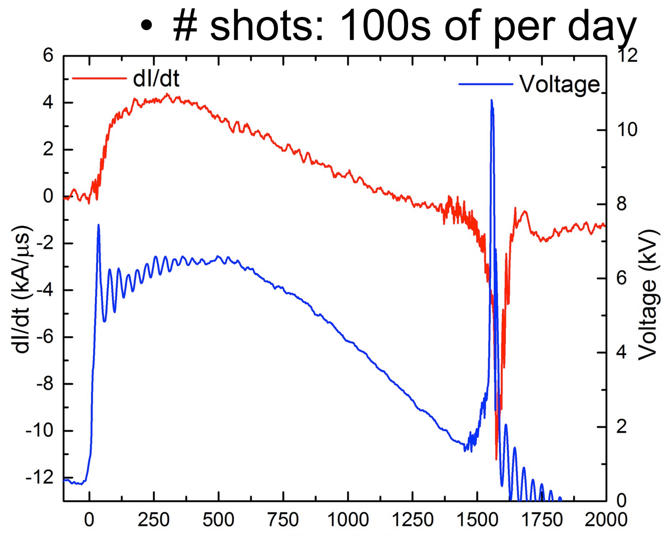


DPF3 anode and cathode rods

Dense Plasma Focus:

- The experiments are run at Alameda Applied Science Corporation (AASC) in their DPF3 Mather-type Dense Plasma Focus [3]
- Typical operational parameters are:
  - Ne and Ar gas loads at 1-20 Torr
  - Current: 300-600 kA
  - Charge Voltage: 10-20 kV
  - Stored Energy: few kJ
  - Rep. Rate: 0.1 – 10 Hz
  - # shots: 100s of per day





- Characteristic voltage and dI/dt waveform for a Ne load at 1.5 Torr at 11kV charged
- The ~10kV peak measured outside the vacuum chamber correspond to ~40kV at the pinch
- A good agreement between S. Lee model and experimental current is achieved

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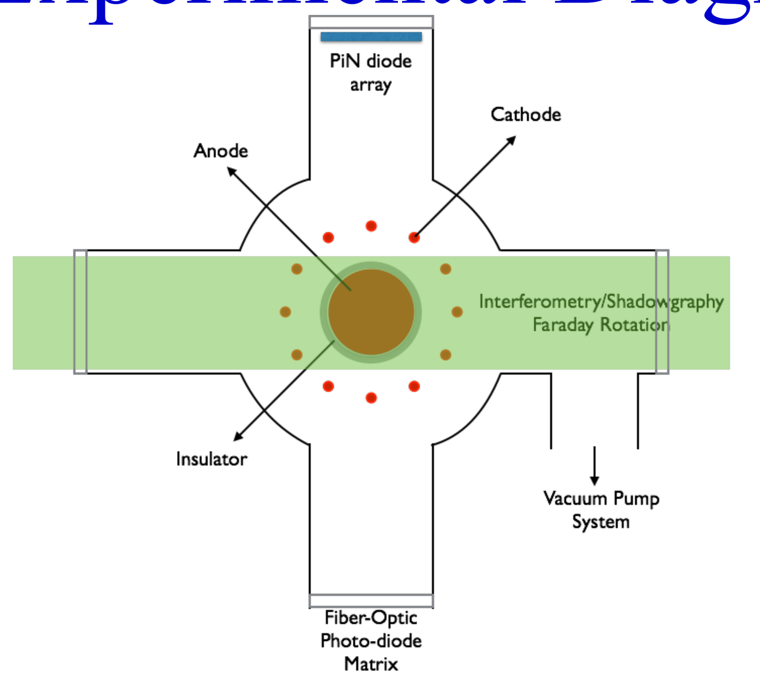
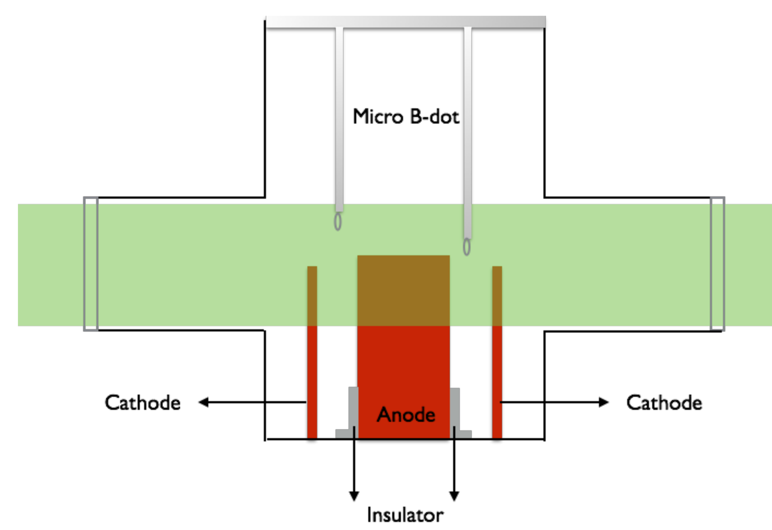
Experimental Diagnostics



End on diagram of diagnostic setup



Side on diagram of diagnostic setup

- A full set of diagnostics are under development in the DPF. Allow comprehensive and detailed map of several plasma parameters including
  - Plasma Sheath Axial Velocity and Acceleration
  - Plasma Sheath Sheath Shape
  - Radial Magnetic Field Mapping
  - Particle Density
  - Radiation Information
- Hundred shots diagnostic information
  - Rich statistical analysis
- Pin-diodes for a radiation comparison with previous experiments run at DPF3
  - Discard B-dots disturbance of the pinch

Axial Phase

- Linear optical fiber matrix array coupled to fast photodiodes diagnostic [4] will allow:
  - Sheath thickness and relative position at anode and cathode end
  - Axial (i.e. lift-off) plasma sheath tracking velocity and acceleration
- This diagnostic will constrain the initial conditions of our simulations
  - Plasma sheath dynamics priory to the radial and pinch phase
  - Feed simulation code experimental parameters to initiate the simulation

Radial Phase

B-dots assembly procedure at the DPF3

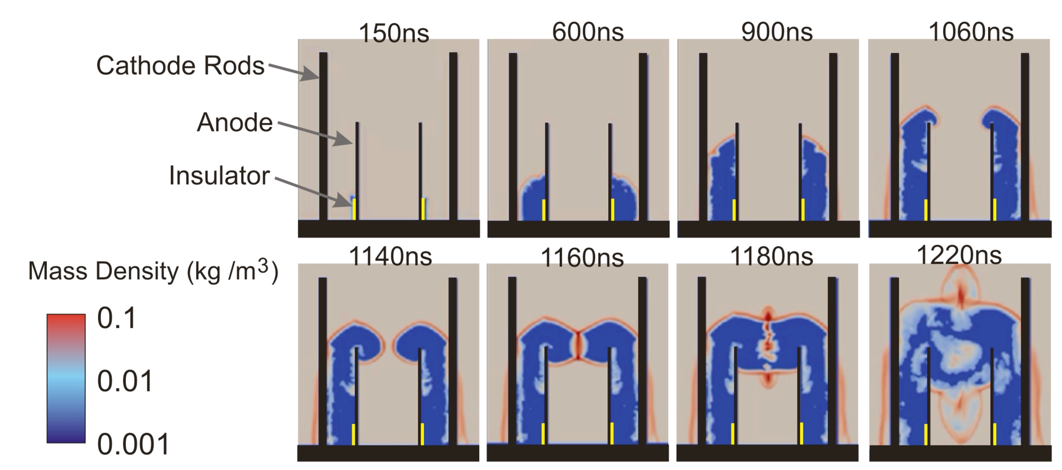
- Optical diagnostic including
  - Mach-Zender Interferometry and Shadowgraphy
    - Density profile and MDI dynamics
  - Laser Wave-front Analyzer Faraday Rotation system
    - Plasma Density
    - Current
- Home made B-dots probes
  - Magnetic field mapping during in the radial phase
    - Two different radii
    - Two different heights
- Typical calibration factor few 10^6 T/Vs

B-dots assembled at the DPF3

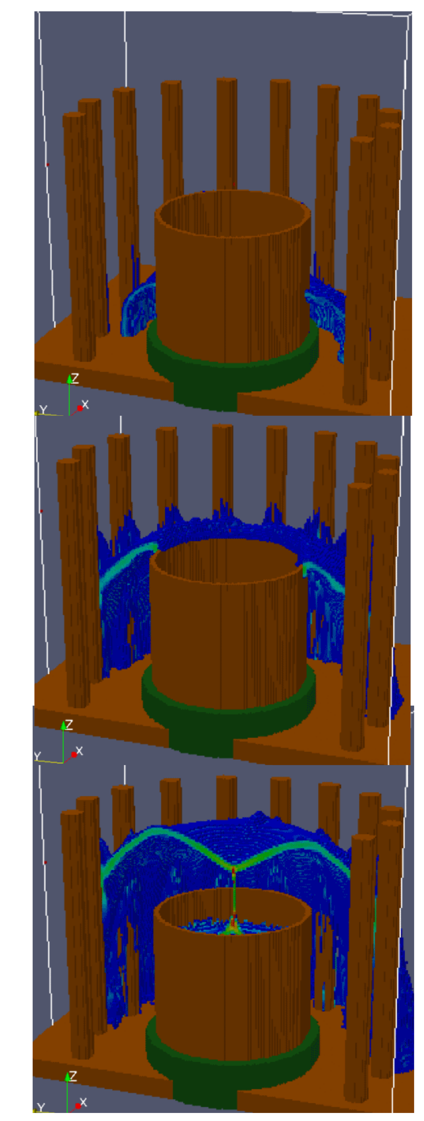
P³ Computational capabilities

- 92-core HP Blade cluster using 3Ghz processors with 4GB RAM per node
- GORGON simulations code is up and running in our laboratory

GORGON Simulations



Density time sequence from a 4.4 Torr Ne



3D density sequence

- Low resolution 2D simulations were performed to ensure that the broad dynamics of the discharge are well captured
- Computational grid: 210 x 240 cells (cell size of 400mm)
  - Domain of 8.4cm x 9.6cm
- Preliminary 3D simulations are now possible in our cluster

Final Remarks

- 92-core cluster is up and running at our laboratory
- 2D and 3D MHD simulation are possible using the GORON code at P³ group
- DPF3 at AASC is up and running healthy
- A reliable B-dot fabrication and calibration has been achieved
- Consistent, easy assemble and access to the B-dot at the DPF3 is ready
- Preliminary test showed a life spam of the B-dots is over 50 shots
- Preliminary test fiber-optic matrix array coupled to fast photodiodes showed easy alignment and access to the inter electrode volume
- Mach-Zender interferometer is under construction
- Faraday Rotation is aligned with preliminary tests under way
- A MatLab statistical analysis scrip is under development to coupe with the expected copious amount of data

References

[1] *M Krishnan, IEEE Transaction on Plasma Science Vol. 40, No. 12 December 2012*
[2] *S Slutz et al, Physics of Plasmas,* ***17****, 056303 (2010)*
[3] B Bures et al, *IEEE Transaction on Plasma Science Vol. 40, No. 4 April 2012*
[4] *F Veloso et al, Plasma Phys. Control. Fusion,* ***54****, 095007, (2012)*