

Target Formation and Integrated Experiments for Plasma-Jet Driven Magneto-Inertial Fusion



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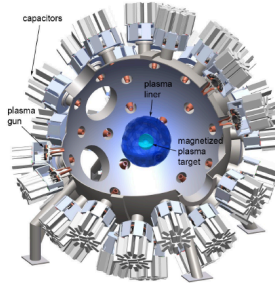


PJMIF AND THE PLASMA LINER EXPERIMENT (PLX) AT LANL

Plasma Jet-Driven Magneto-Inertial Fusion (PJMIF):

"Reactor-friendly" alternative approach to fusion energy

- Magneto-inertial fusion (MIF) or magnetized target fusion (MTF) – blend of magnetic and inertial confinement concepts. Heat conduction + alpha stopping from magnetic field, heating and compression from inertial implosion.
- A magnetized plasma target is injected into the target chamber, and then compressed and heated by a heavy high-velocity plasma liner, assembled from discrete jets



PJMIF Advantages:

- Spherical compression + MIF
- All-gas / all-plasma architecture – no repetitive hardware destruction
- Physical "standoff" distance from burn location

The Plasma Liner Experiment (PLX) at LANL is an experiment to study the physics and feasibility of plasma liner formation.

- Quasi-spherical array of supersonic ($V \sim 50$ km/s, $M \gg 1$) medium-density ($\sim 10^{16}$ cm⁻³) plasma jets
- Resolution of liner formation, jet merging, convergence, and stagnation – **no target plasma yet**

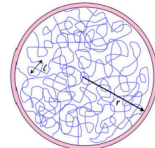
PLX experimental scale:

- 9 ft diameter spherical chamber
- Total stored energy ~ 0.25 MJ
- Plasma densities 10^{14} cm⁻³ – 10^{17} cm⁻³
- Capacitor-driven j x B coaxial plasma guns
- 36 independent plasma guns (HyperJet HJ-1)
- Pulsed operation, ~ 10 μ s shots

TARGET PLASMA DEVELOPMENT

Desirable Characteristics of a PJMIF Target:

- Plasma Beta and Hall parameter $\gg 1$, sidestep MHD instabilities while retaining thermal insulation
- Compatibility with spherical geometry, just-in-time formation and/or magnetization
- Line-replaceable (no repetitive hardware destruction)

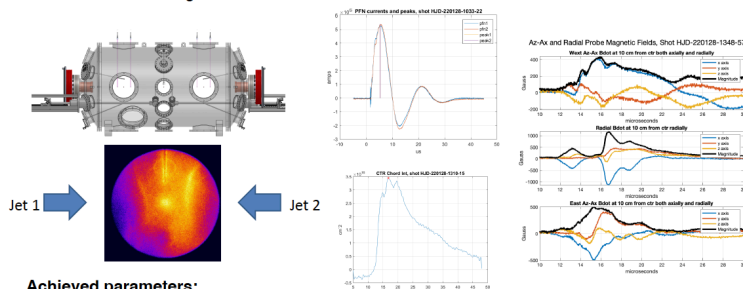


Magnetic Field Configuration:

- For spherical compression, need to insulate heat flux in three dimensions
- Highly "tangled" magnetic fields may do this
- Configuration may be formed by confluence of high-speed magnetized jets

Magnetized Jet Development:

- Adding solenoidal bias field to coaxial guns, embed helicity -- Spheromak gun configuration
- HyperJet has developed a magnetized version of their plasma gun and are studying two-jet collisions relevant to target formation:



Achieved parameters:

n (cm ⁻³)	5.0×10^{14}	β	1.9E+00
T_e (eV)	4	X_e	9.4E-01
T_i (eV)	12	X_i	1.6E-01
B (G)	500		

Future goals:

- Decrease insulator impurities
- Increase stagnation temperature

FIRST RESULTS OF SPHERICAL LINER EXPERIMENTS AT PLX

Spherical liner campaigns are being performed at PLX using:

- 36 argon plasma jets, $V \sim 55$ km/s, $n_{jet} \sim 10^{16}$ cm⁻³, $T_{jet} \sim 1.5$ eV, avg. merging half angle $\sim 20^\circ$

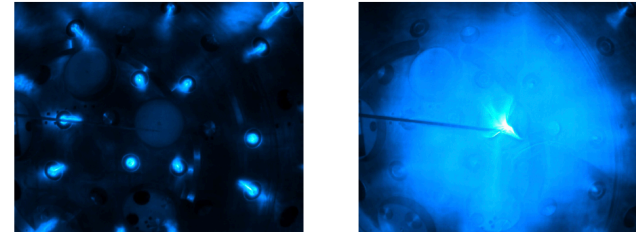


Figure 1. Visible light emission recorded on fast framing cameras. First results of spherical liner experiments were obtained in early 2021, resolving liner formation, convergence, stagnation and rebound.

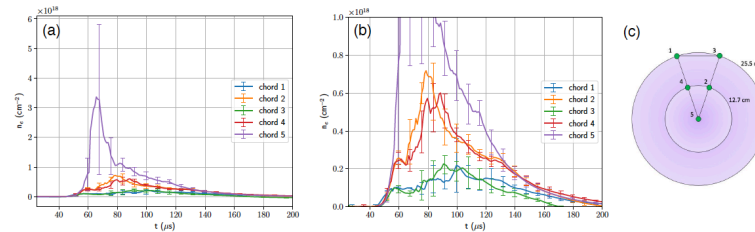
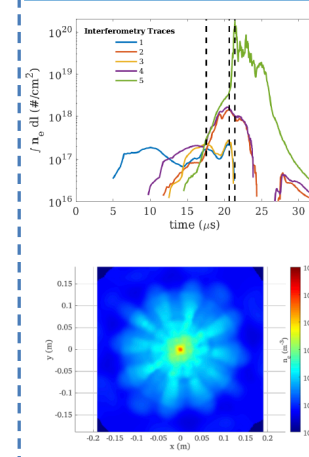


Figure 2. (a)–(b) Interferometry: time-dependent plasma density profiles. (c) Interferometry chord locations.

Comparisons with hydrodynamic simulations indicate that mitigation of velocity imbalances between jets can significantly improve liner density and ram pressure.

Simulation: Jets perfectly balanced



Sim Jets imbalanced ($\pm 5\%$ velocity)

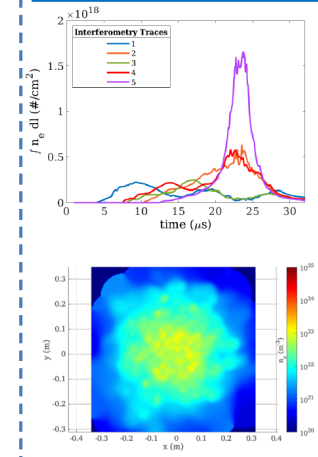


Figure 4. Smoothed-particle hydrodynamics (SPH) simulation performed by Jason Cassibry and Aalap Vyas, University of Alabama in Huntsville.

Control and diagnostic upgrades are in progress at PLX to decrease velocity imbalance and maximize the liner performance, to support upcoming integrated campaigns.