Plasma Accelerator on the Swarthmore Spheromak Experiment

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Objective

The twisted Taylor state is the minimum energy state in MHD, and was observed in the SSX lab in 2013 (Gray, et al., PRL).

- Our main goal is to **accelerate** a Taylor state to higher velocity, then stagnate and to **compress** it to higher density. A Taylor state is an ideal MIF target (stability, aspect ratio, spring).
- We have been studying **magneto-thermodynamics** on these compressed Taylor states (manuscript submitted). Our focus now is on optimizing acceleration.
Adiabatic compression of a gas
Adiabatic compression of a gas

$P V^\gamma = \text{constant}$
Magnetized plasma production
Experimental Set-up schematic

Magnetized plasma gun

Copper sheet

40"

Stagnation Flux Conserver
Sequence of events

Magnetized plasma gun

Copper sheet

Stagnation Flux Conserver

40"
Sequence of events
Sequence of events

Magnetized plasma gun

Copper sheet

Glass tube

40"

Stagnation Flux Conserver

×4

×8

×4
Diagnostics of compressed plasma
Experimental set-up

- Expansion volume
- IDS Telescope
- Magnetized coaxial plasma gun
- HeNe Laser
- Interferometry port
- Glass extension Covered with Cu sheet
Measurement of magnetic field vectors

Time = 33.38 μs
Measurement of magnetic field vectors
Measurement of magnetic field vectors
Taylor state in stagnation flux conserver
Taylor state in stagnation flux conserver

Taylor state enters the stagnation flux conserver
Taylor state in stagnation flux conserver

Taylor state enters the stagnation flux conserver

Taylor state compression & heating
PV diagram helps in identifying Compressive heating events → Taylor state compression accompanied by ion heating.

Length reduces by 20%
Pressure increases by 80%
PV diagram

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Length reduces by 20%
Pressure increases by 80%
Compression conclusion

- Our results show compressive heating events.
- During compression events, the volume reduces by 10-30%.
- The events last for 1-4 μs.
- We are comparing various equations of state (see poster).
Present status

- Expansion volume
- IDS Telescope
- Pinch Coil
- HeNe Laser
- Interferometry port
- Glass extension Covered with Cu sheet
- Magnetized coaxial plasma gun
Accelerated Taylor state

(a) $n \left(10^{15} \text{cm}^{-3}\right)$

(b) $T_i \text{(eV)}$

(c) $|B| \text{(G)}$
Accelerated Taylor state
Ultimate goal

Four theta pinch coils will be triggered separately and sequentially to accelerate plasma to velocities over 200 km/s. Compression should increase density to over $10^{16}$ cm$^{-3}$ and ion temperature to over 100 eV.
Thank you
3D MHD simulation of coil compression

NIMROD with full 3D continuity equation, initial conditions for $v_{\perp z}$ and $n_{Te}$ as $f(z)$, and BC for $E_{\perp \varphi}$ for coil compression