Magnetic & Pressure Measurements on the HyperV Plasma Gun

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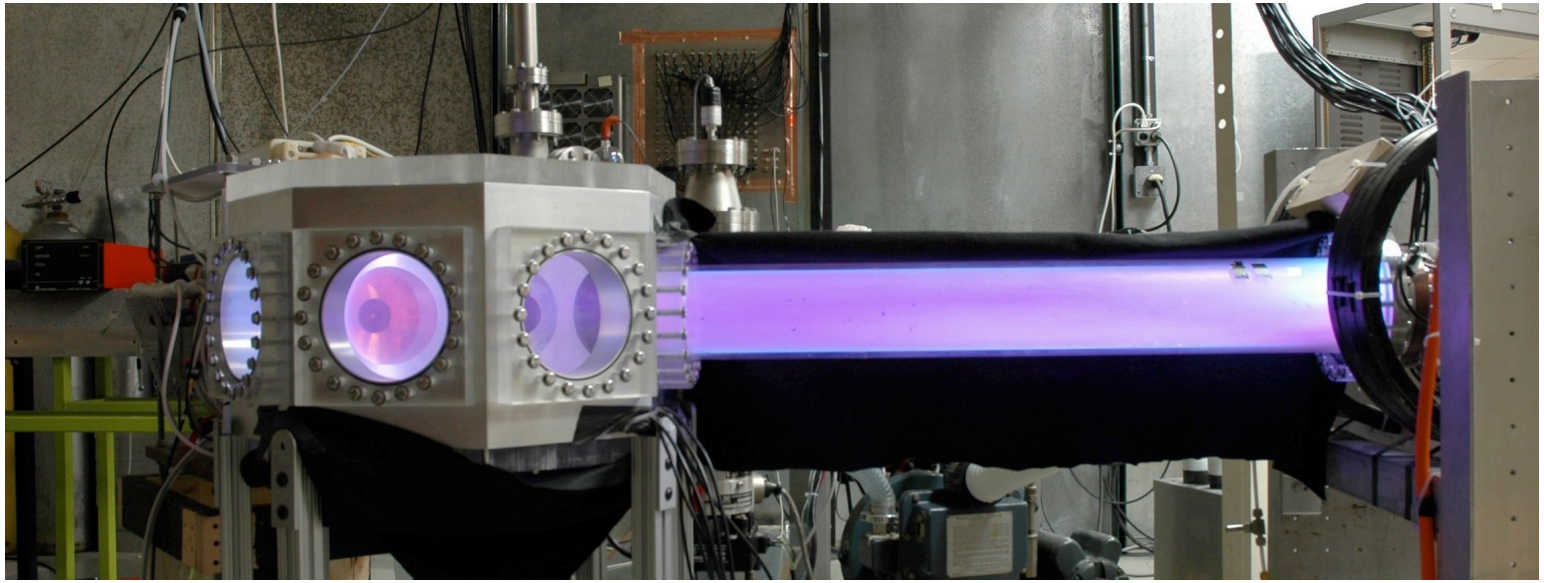
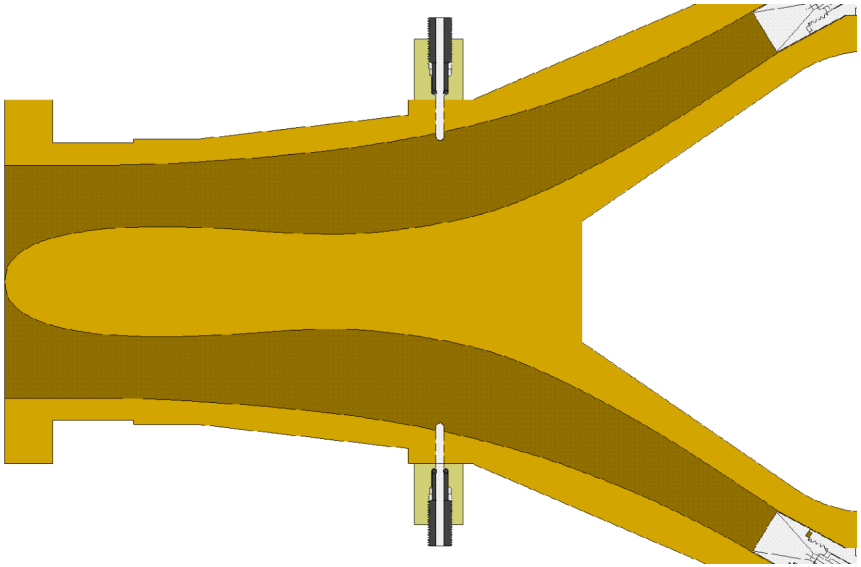


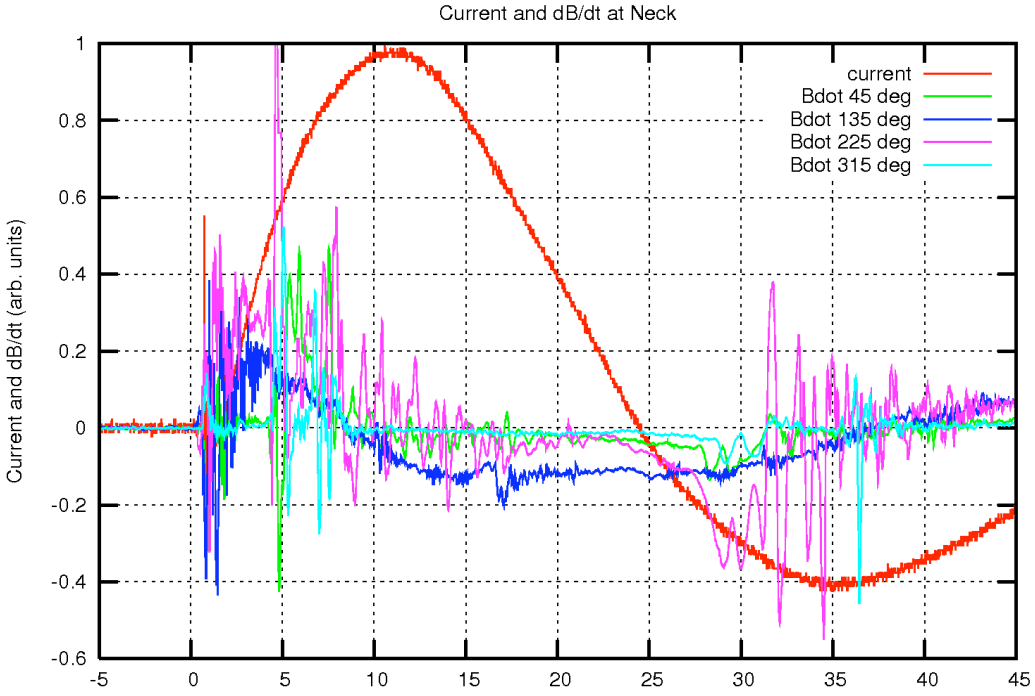
Magnetic Probes at Neck of Main Accelerator Section

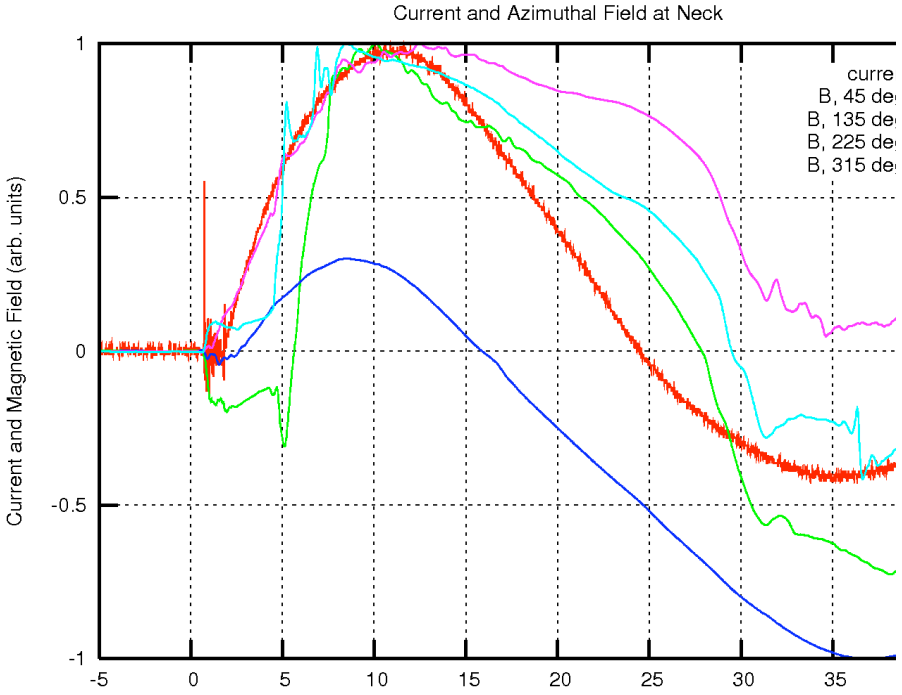


Probes measure azimuthal dB/dt.

Current sheet passes probes within 5 us after sw
fires.

After current sheet initially passes probes, magn
field is similar in shape to overall current.
suggests majority of current crosses from
electrode to outer electrode downstream
probes - i.e. any restrikes at the breech d
relatively small currents.

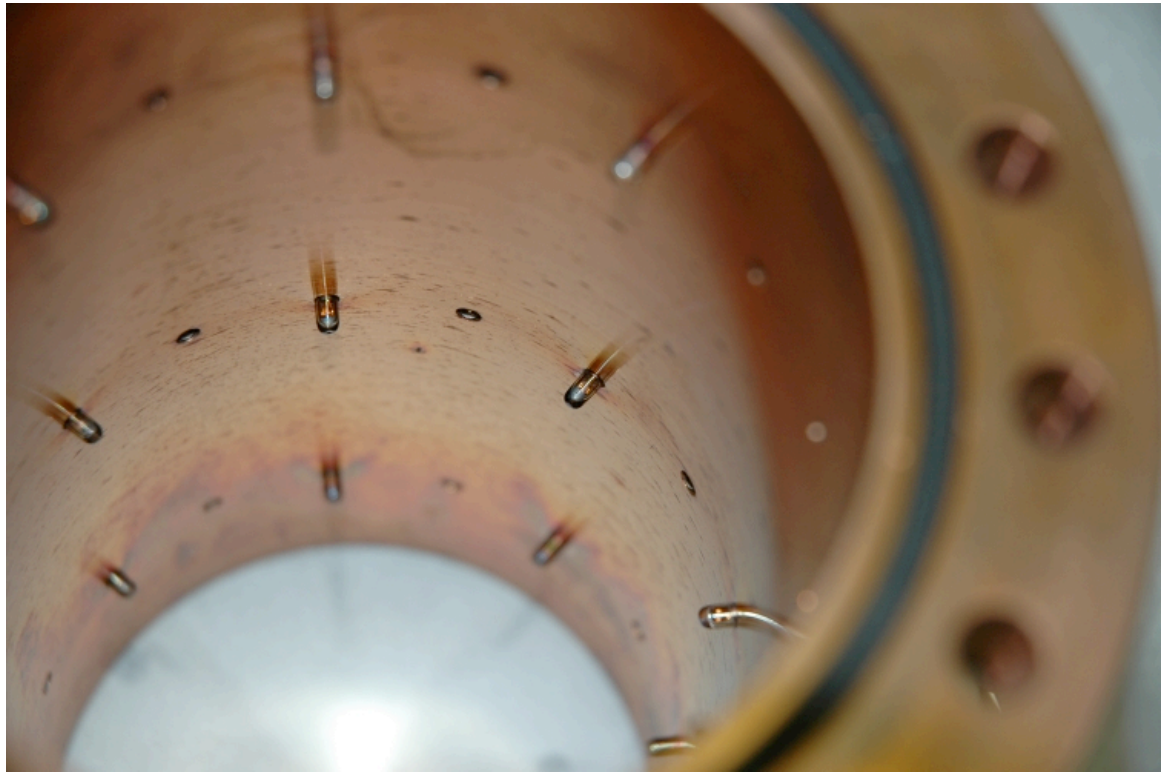


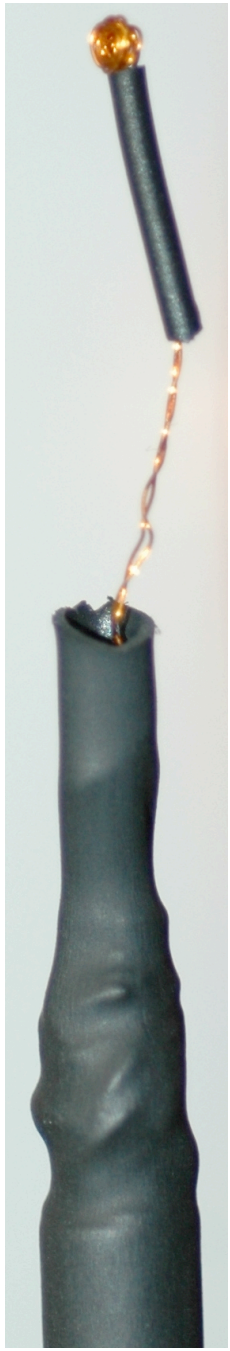


Pinch Section Magnetic Probe Array

Azimuthal B-dot probes have been installed in the pinch section:

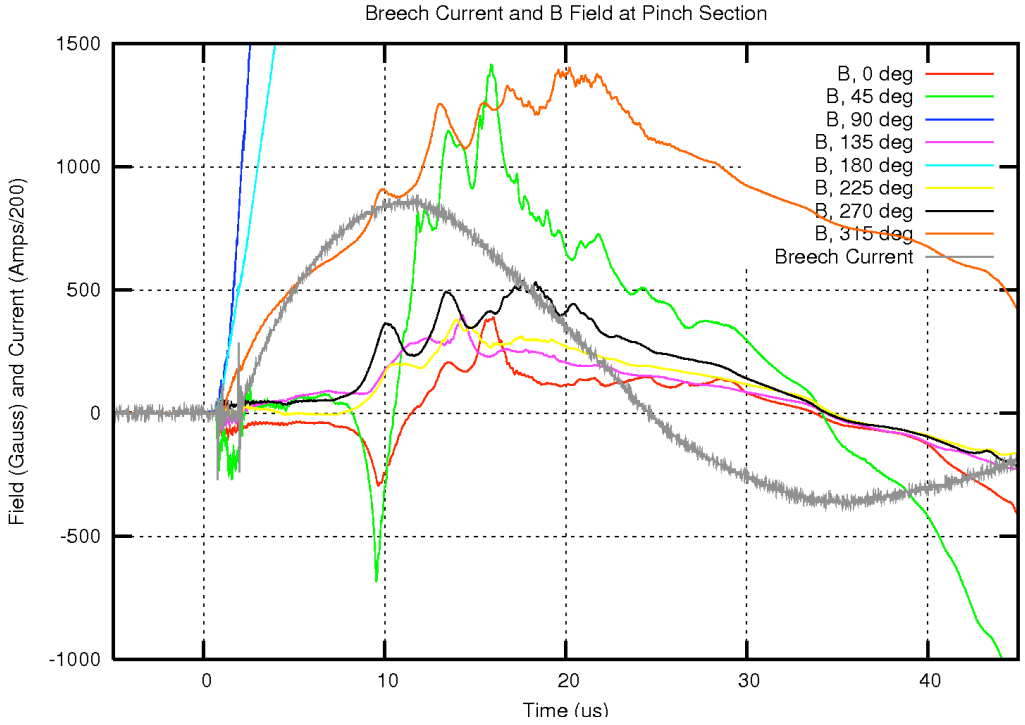
- 8 azimuthal positions (constant radius)
- 13 turns, 1 mm nominal probe diameter
- enclosed in a 3 mm OD quartz tube
- probe leads are twisted-pair to coaxial cable
- nominal sensitivity = 10^-9 Volt-sec/Gauss

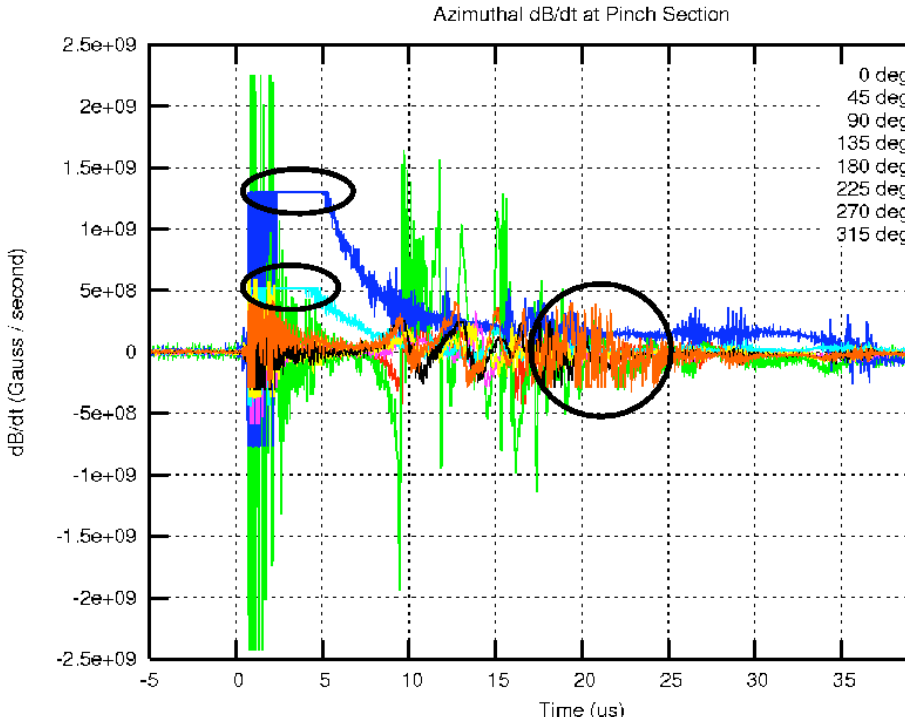




Magnetic Probes at Pinch Section (10 cm from gun tip)

Magnetic field at pinch section shows strong spatial and temporal structure.
Field at pinch section lags breech current by about 10 us.
Brief, strong bursts of noise may indicate arcs to magnetic probes.
When noise saturates the digitizer, the absolute value of the magnetic field is los

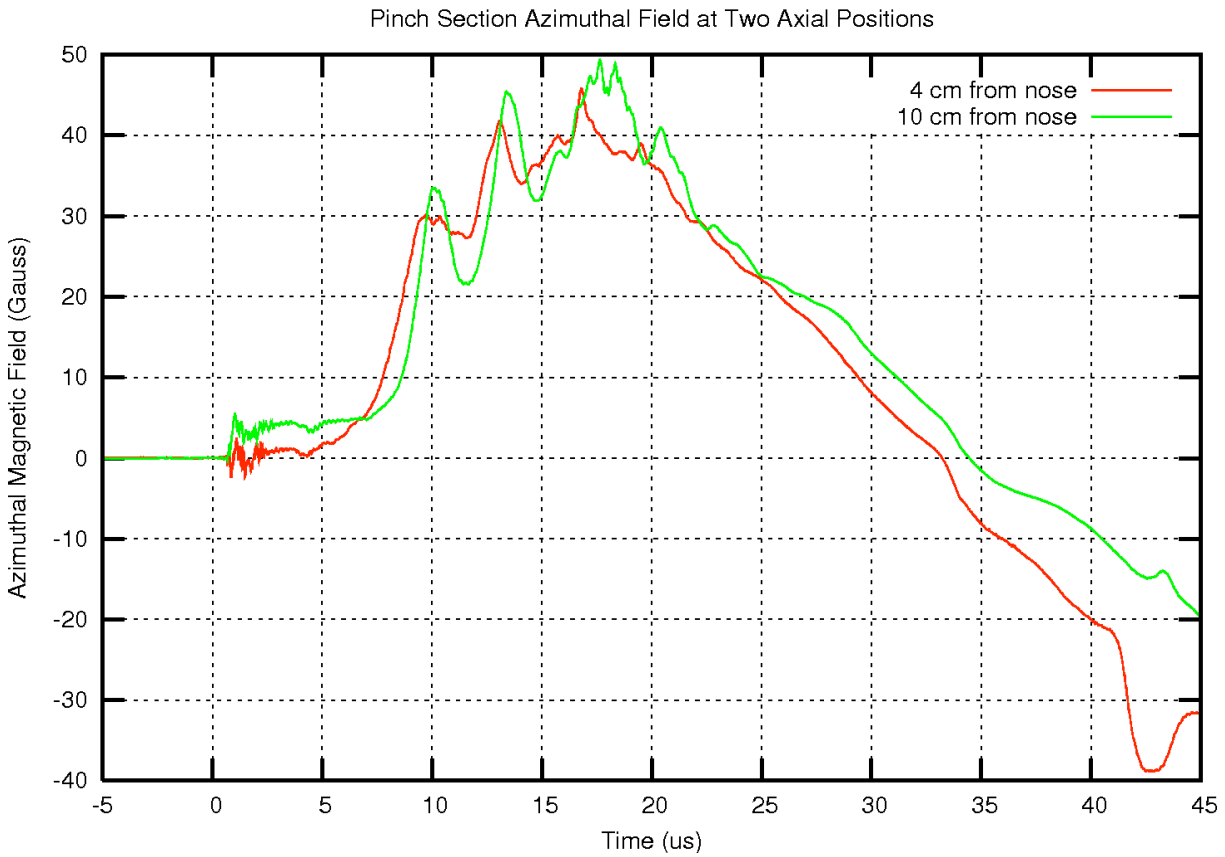




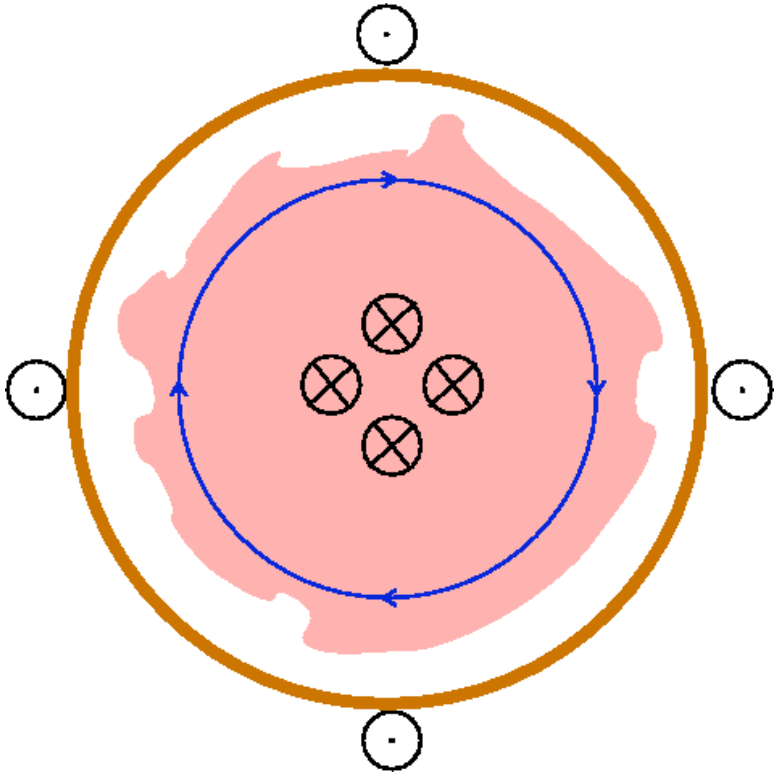
Time Delay Between Probes at Different Axial Positions

The plot below shows two B field measurements taken at same azimuth and separated by about 6 cm.

2 us delay between probe traces corresponds to a speed of 30 km/s - Wall magr field slows as pinch section stretches current sheet and compresses plas



Inductive Damping:
Magnetic Structure Extends Beyond Plasma

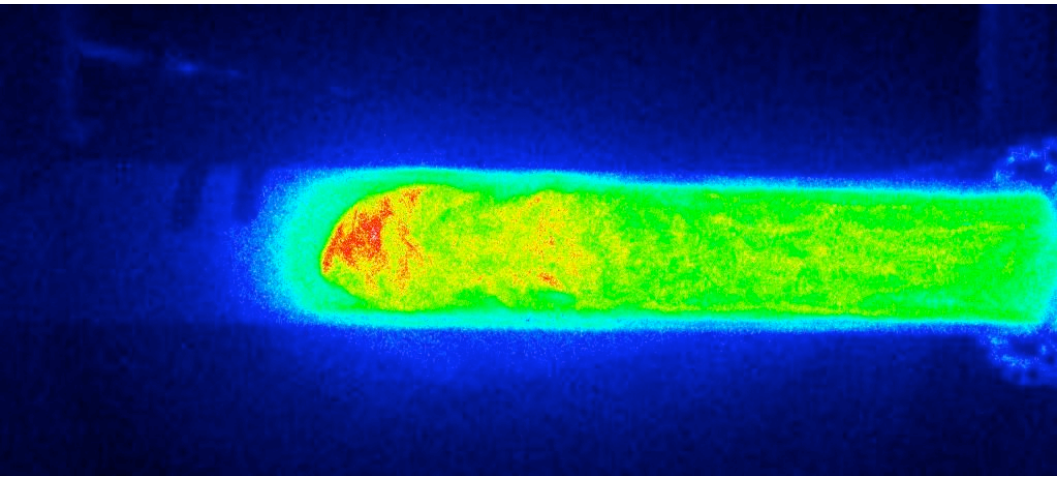


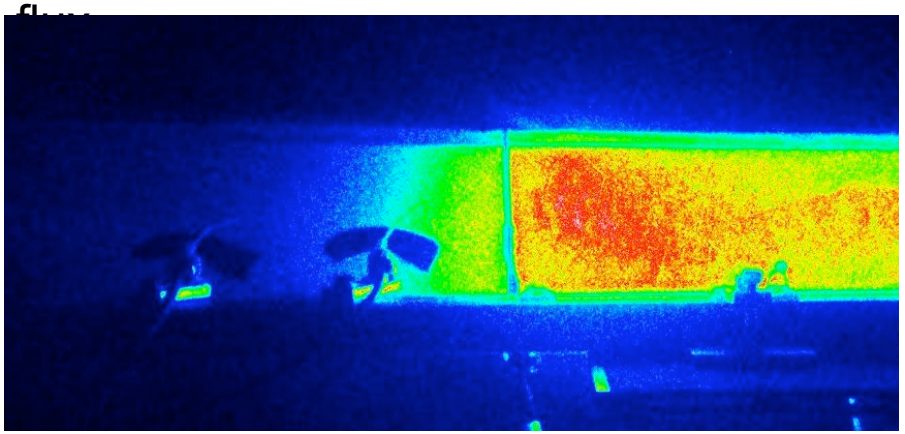
Current loops trapped in the plasma
generate magnetic fields which ma
extend well beyond the plasma.

If the plasma passes through a conductin
loop, changes in magnetic flux
generate
an electric field and current in the
loop.

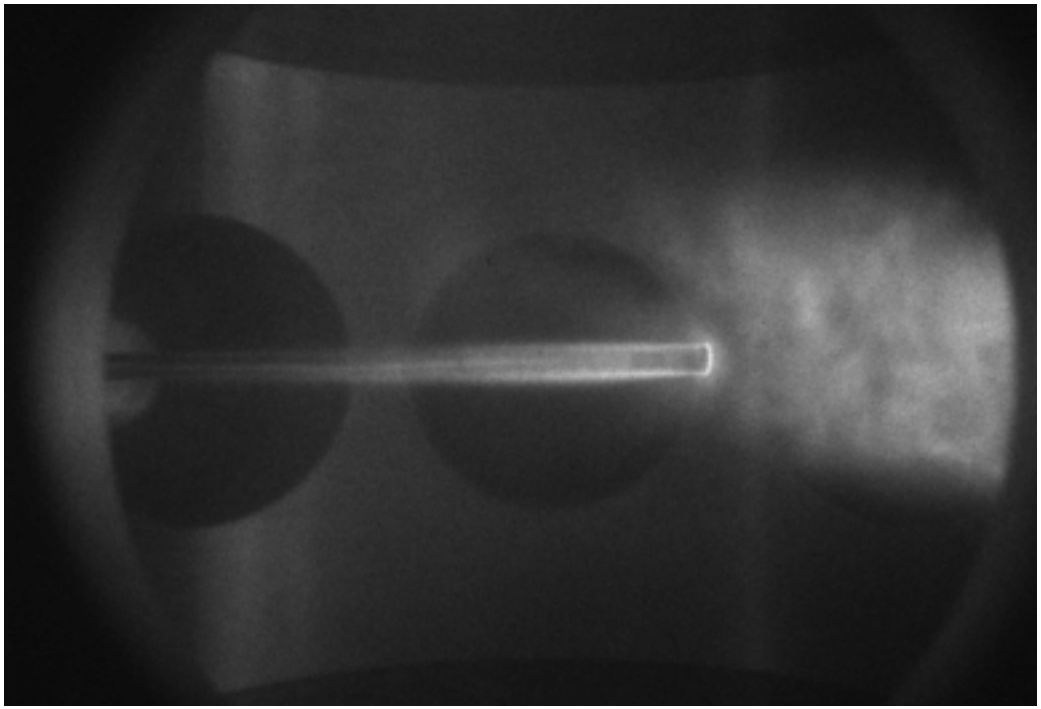
Resistive losses draw momentum and
magnetic energy from the plasma.

Note that azimuthal currents are necessa
generate these changes in magnet
flux.





Pressure Probe



Probe is a commercial piezoelectric ser
encased in a quartz tube.

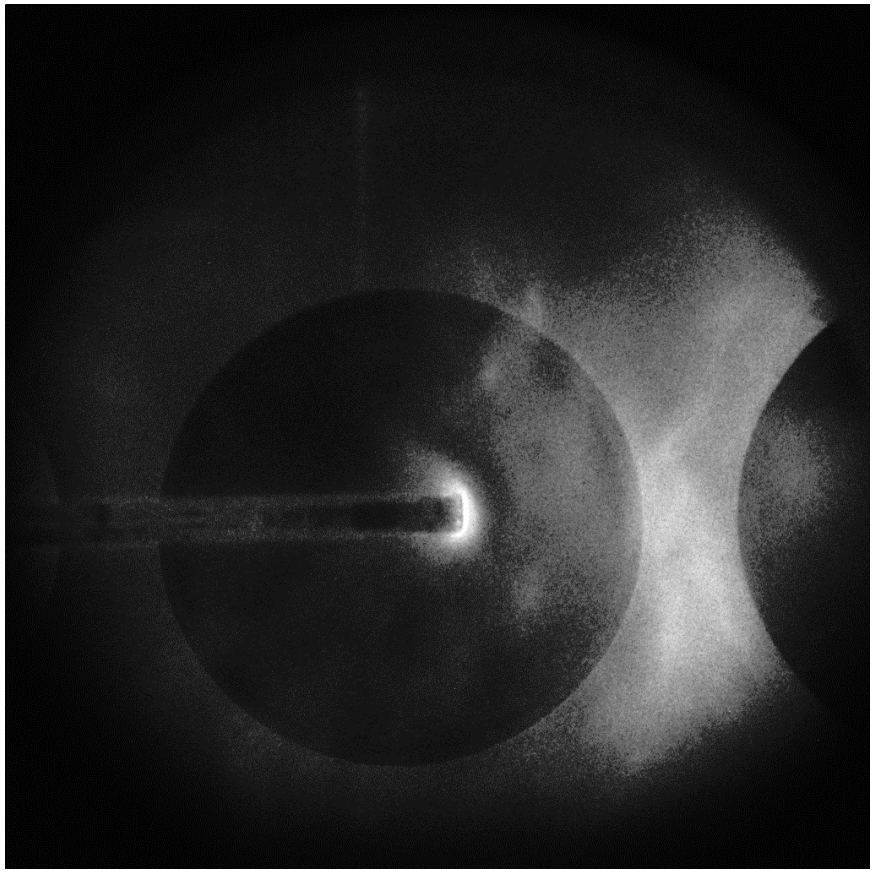
The pressure probe measures plasma
momentum flux along the probe'

It can sense:
time scales ≥ 1 us
pressure scales ≥ 4 kPa

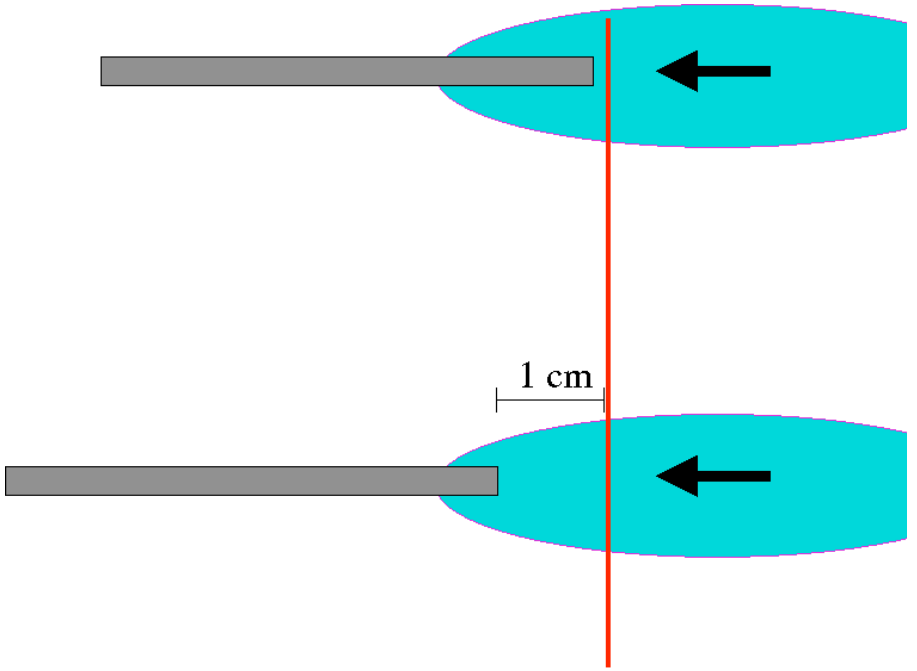
Interferometry implies electron density
increases by a factor of 2-6 acro
probe's bow shock.

Bow Shock on Pressure Probe Increases Electron Density

There is a visible shock front on the pressure probe.
The probe tip glows brightly.
Bright plasma is visible immediately upstream of the probe.
A reproducible dim arc is just upstream of this bright plasma.
We probed the bow shock by placing the interferometer beam just upstream of the probe



contrast enhanced photo

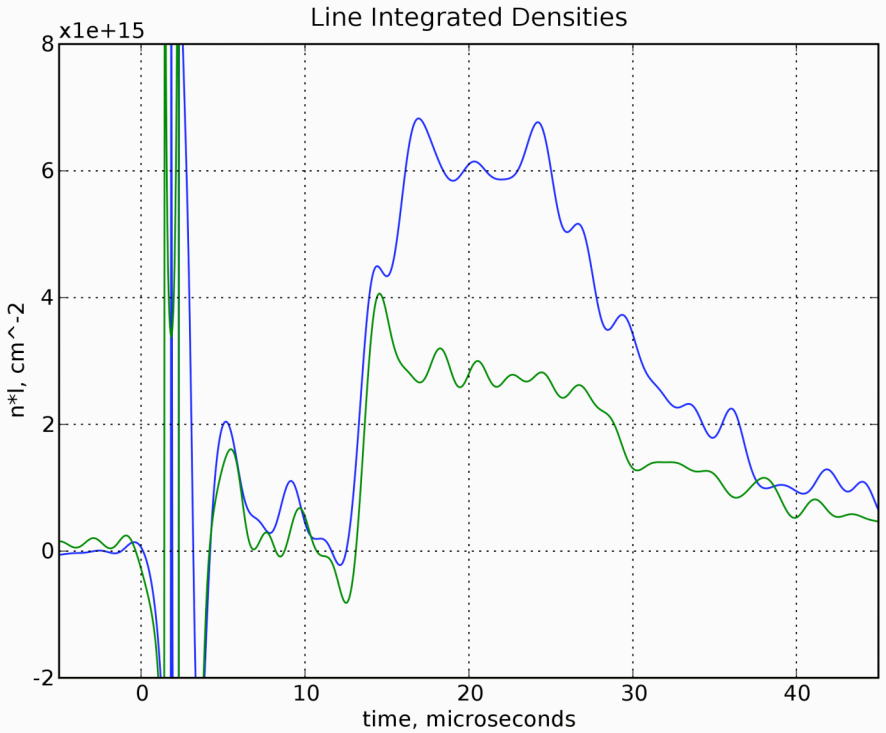


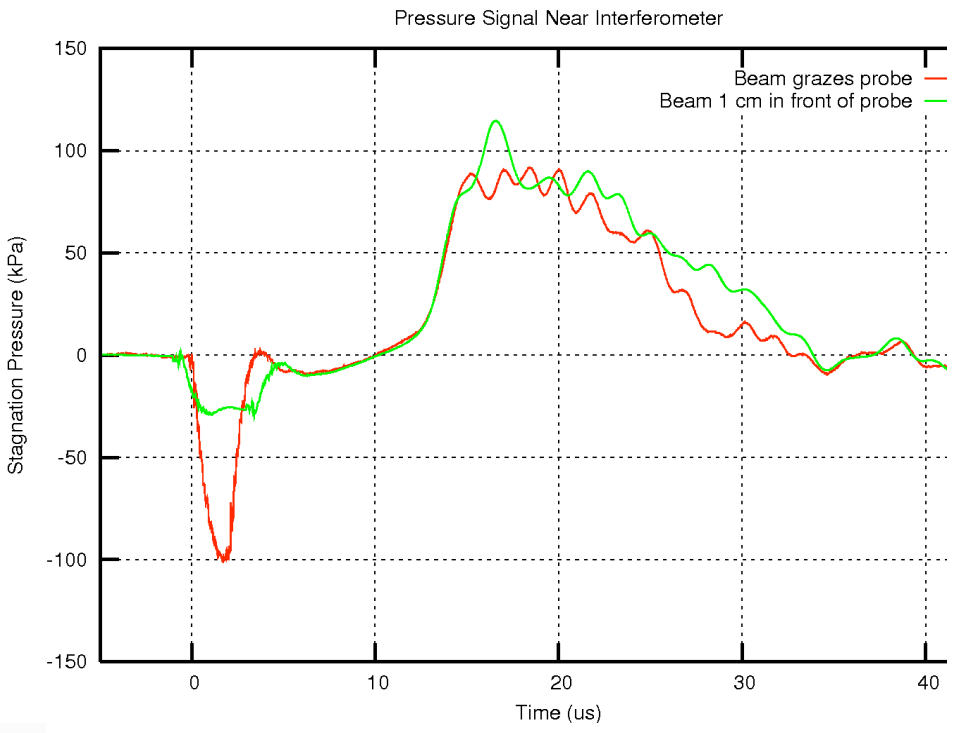
Bow Shock on Pressure Probe Increases Electron Density

When the interferometer's laser beam grazes the probe tip, it measures a stronger dens
wave than when the pressure probe is 1 cm downstream.
The increases in density and luminosity are in qualitative agreement with expectations
of a strong shock wave at the probe.

The sharp leading edge of the density and pressure waves are in qualitative agreement
expectations of a supersonic plume.

Tails of interferometry and pressure traces are consistent with adiabatic expansion



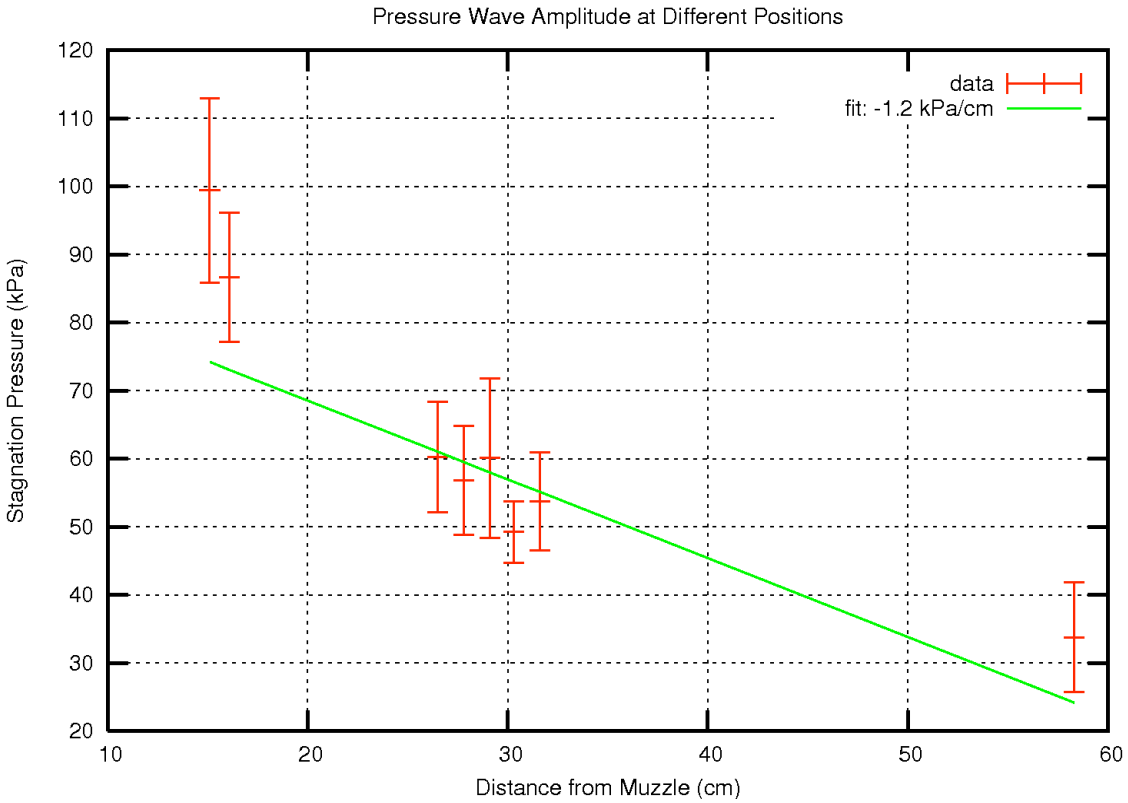


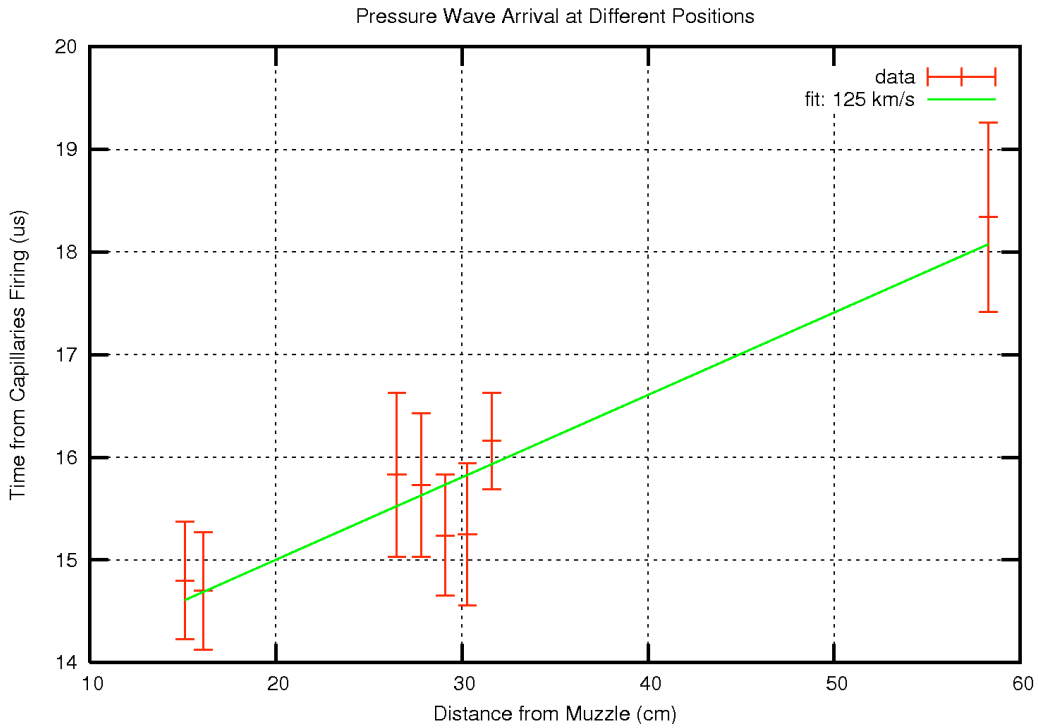
Both plots show smoothed data sets.

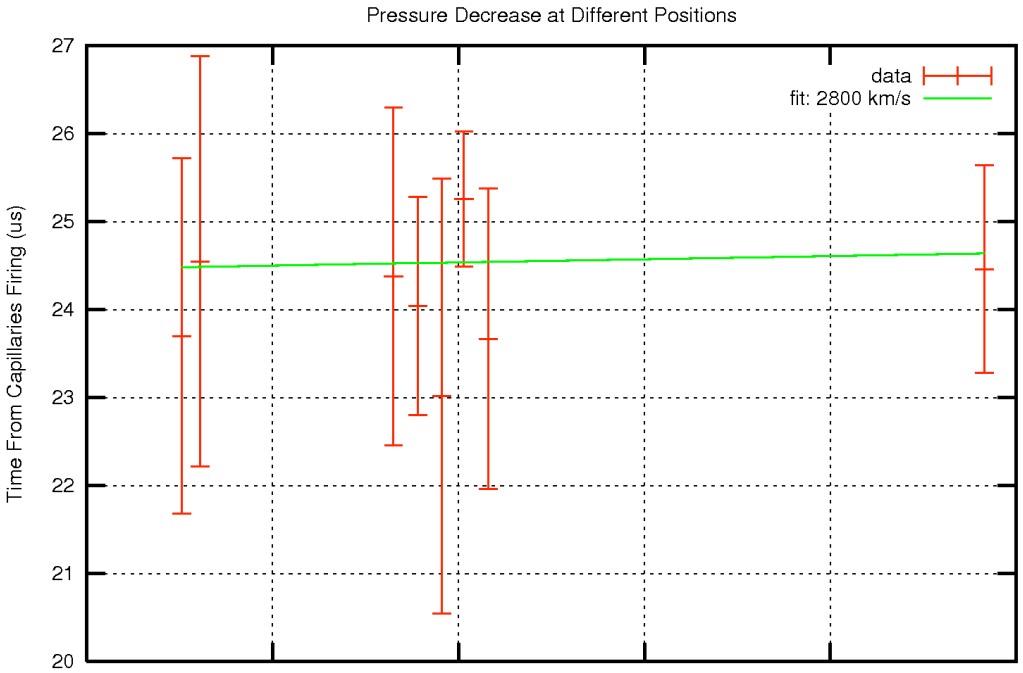
Amplitude of Pressure Wave Drops With Distance From Gun

Pressure drops quickly within first 30 cm from muzzle, then decreases more gradual
over the next 30 cm.
Momentum density of the pulse (the integral of pressure over time) shows a similar
pattern.

Red bars show mean of measurements with 1-standard-deviation error bars.
Green lines show result of linear least-squares fitting to the observed data and variar







Pressure front travels slightly faster than fluid velocity

Pressure front moves at 100-130 km/s, based on shot-to-shot comparisor

Spectroscopy shows bulk speed of 90 km with fastest components up to 14(

Pressure tail seems much faster. Pressu drop at all distances between 15 c 60 cm is near simultaneous within shot-to-shot variations. This spee high to be explained by ion-acous waves. Pressure and density cur are consistent with adiabatic expa

Summary

HyperV has built and tested a coaxial plasma gun for installation on the Maryland Centrifugal eXperiment (MCX).
Although initial momentum, mass, and velocity are high, the plasma expands and slows after leaving the gun, particularly in the presence of a strong magnetic field.
Although restrikes near the breech are minor, current waveforms near the muzzle section are more complex and likely involve pinching-off of current loops.
Probe measurements indicate a steep increase in plasma dynamic pressure followed by a gradual decrease consistent with adiabatic expansion.