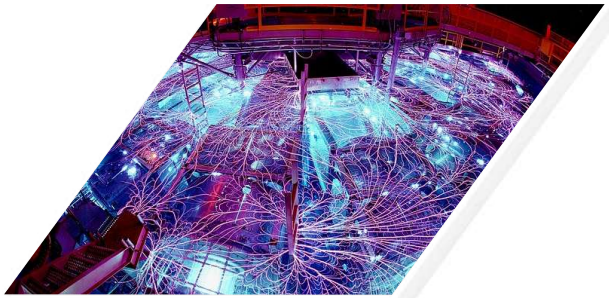
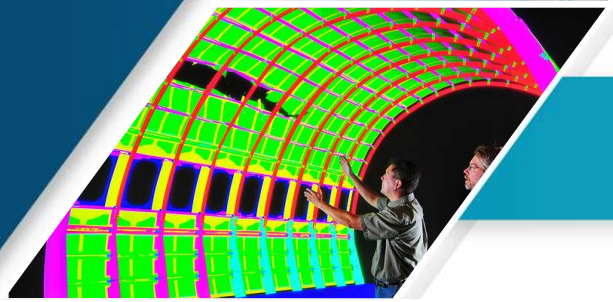
Sandia National Laboratories

Exceptional service in the national interest





Removal of Plasma Effects from PDV Surface Velocity Measurements

Nathan Brown,[1] Chris Jennings,[1]
Chris De La Cruz,[1] and Dan Dolan[1,2]

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2026 PDV Workshop

U.S. DEPARTMENT of ENERGY NNSA

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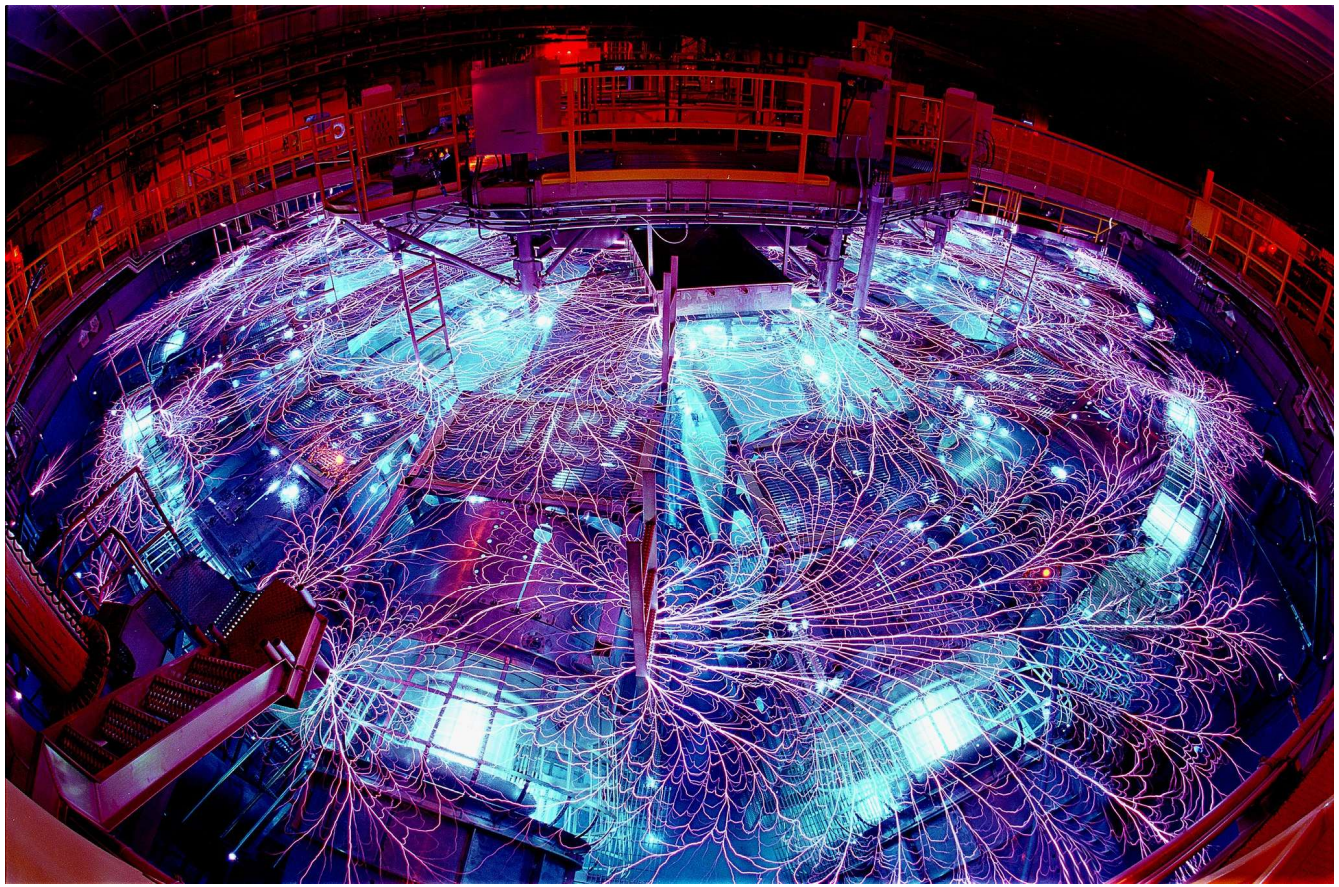
The Z Machine is the world's largest pulsed power device

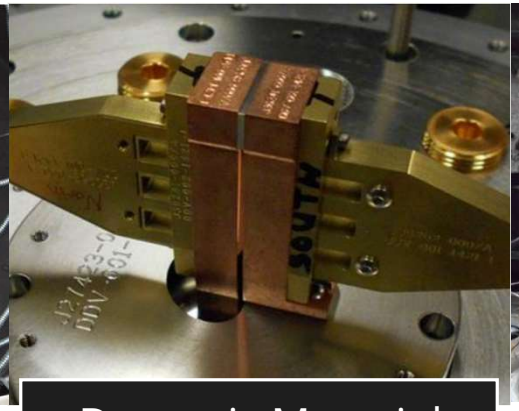


Facility Specs

- Size: **33 m** outer diameter
- Peak Power: **80 TW**
- Peak Current: **30 MA**
- Pulse Duration: **100 ns**

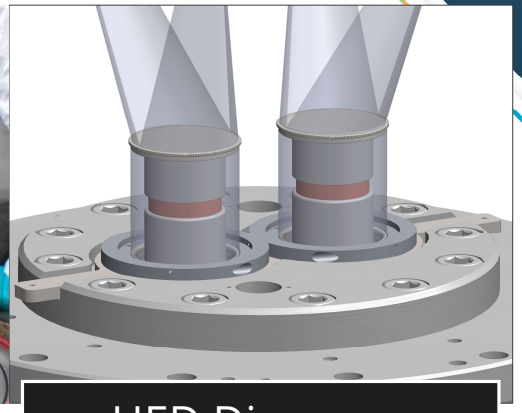
Z drives physics targets for fusion, radiation, and material studies

Radiation Science

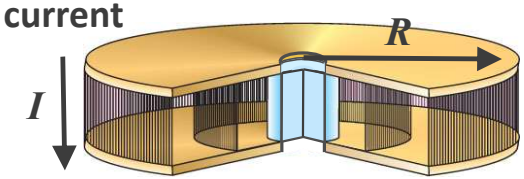


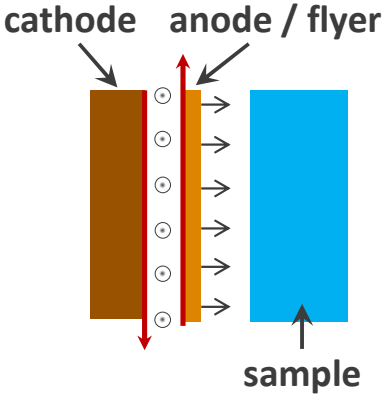
Dynamic Material Properties

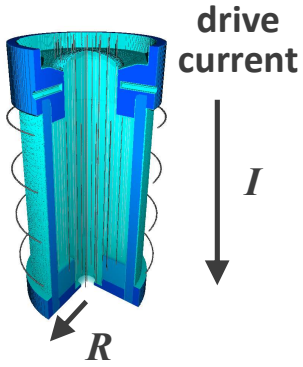
Inertial Confinement Fusion

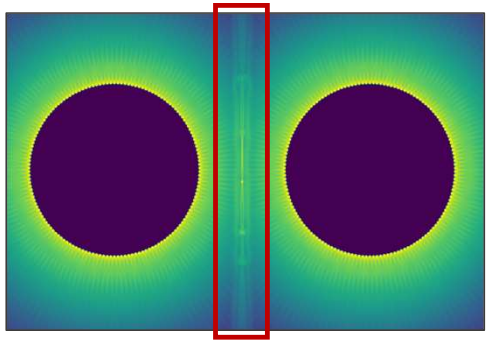


HED Discovery Science



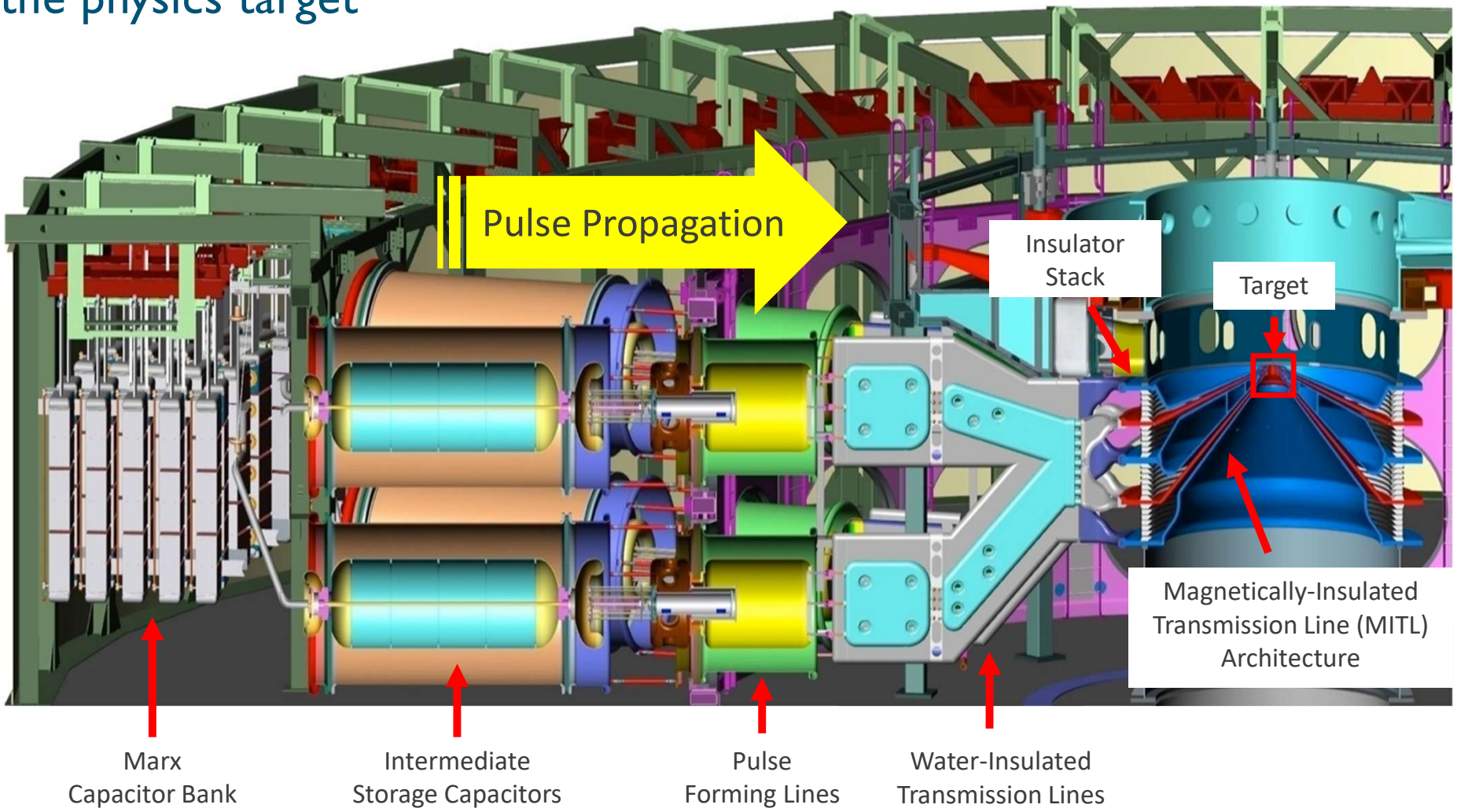




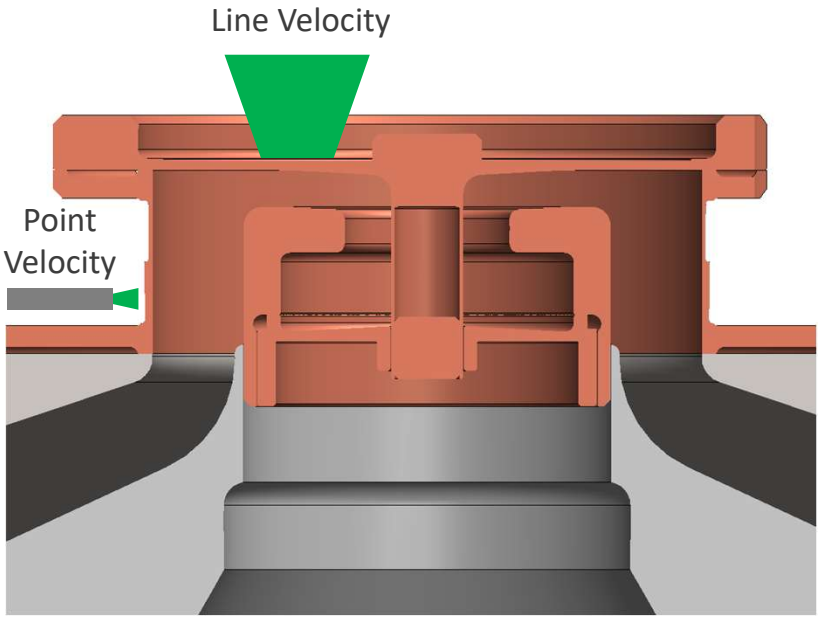


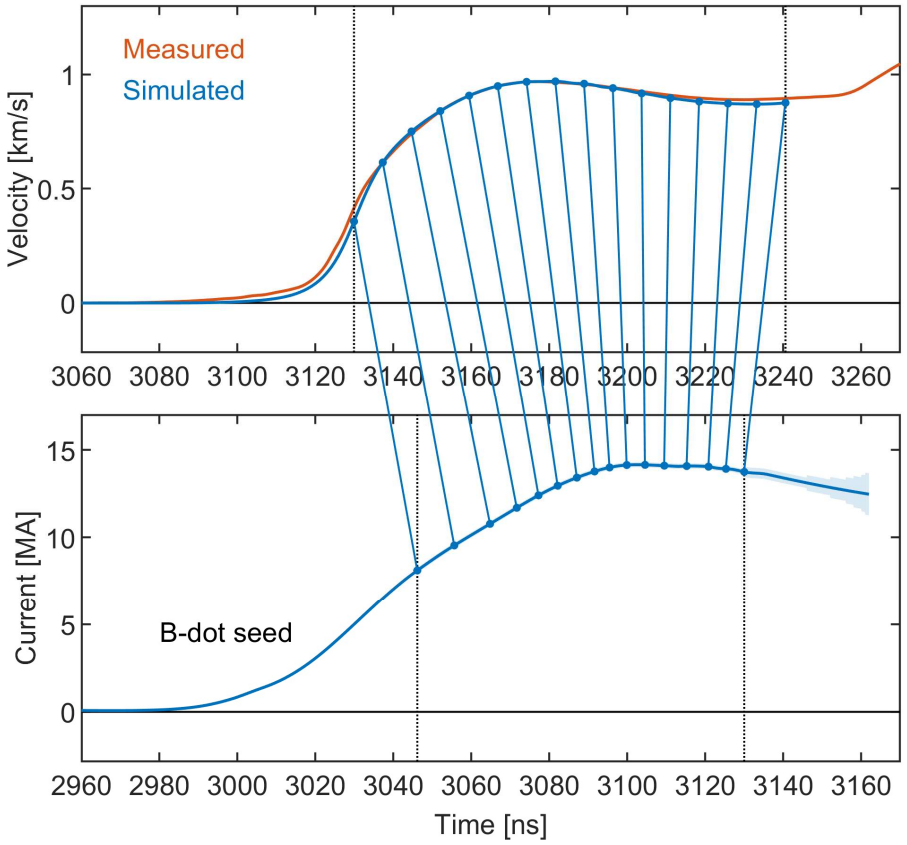
MARZ: Radiative reconnection

Z transmits energy from capacitors through pulse forming lines to the physics target



We measure current delivery via computational unfolds of measured velocities

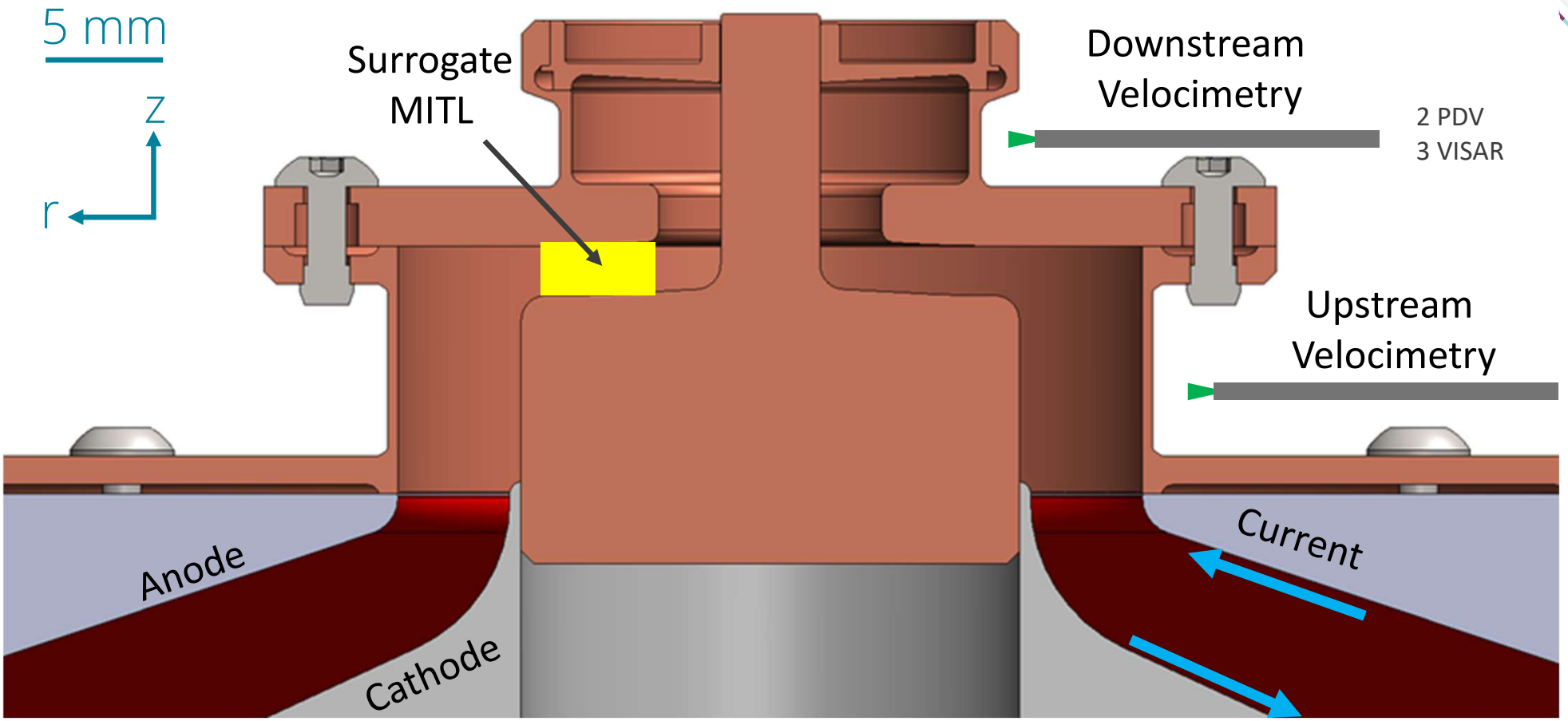




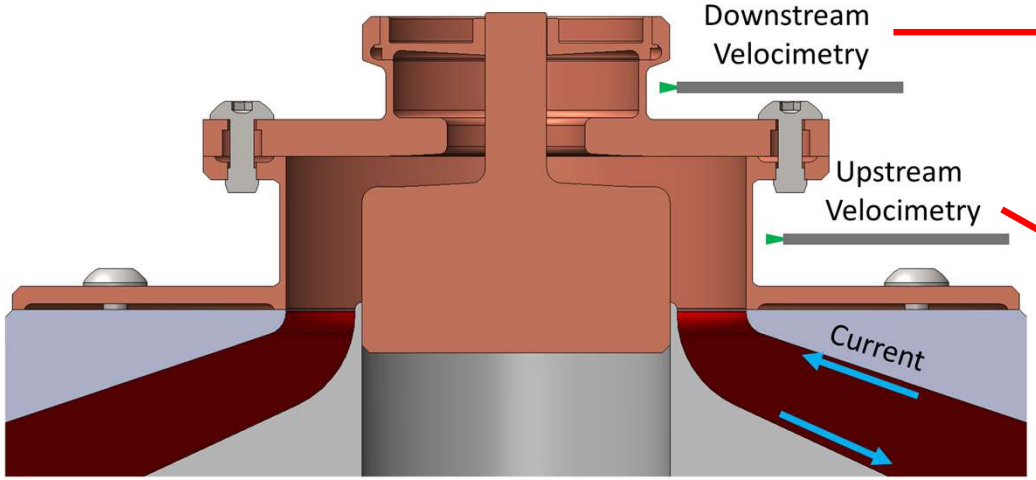
Velocity Probes

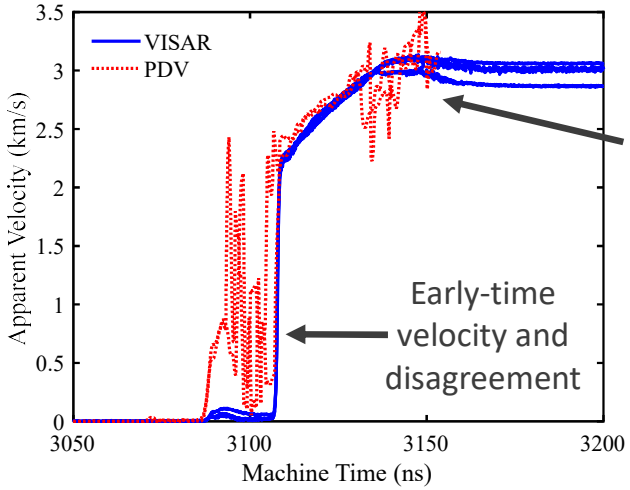
- PDV (Photonic Doppler Velocimetry)
- VISAR (Velocity Interferometer System for Any Reflector)
- Line VISAR

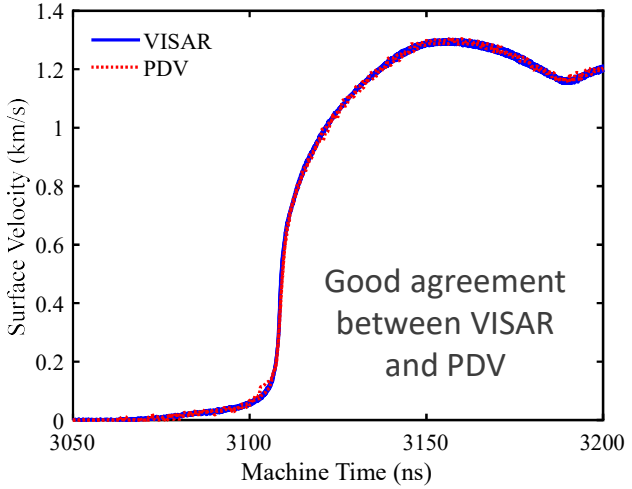
We measured the velocity upstream and downstream of a scaled MITL with PDV and VISAR



We collected high-quality upstream measurements and low-quality downstream measurements

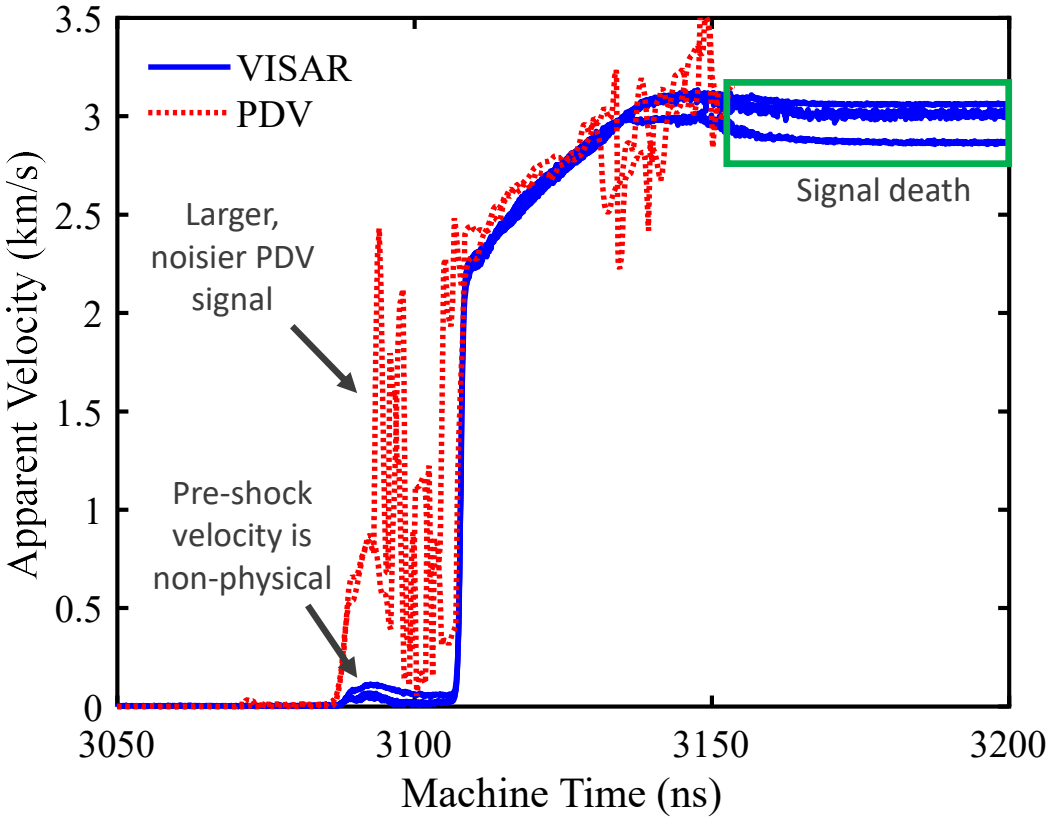




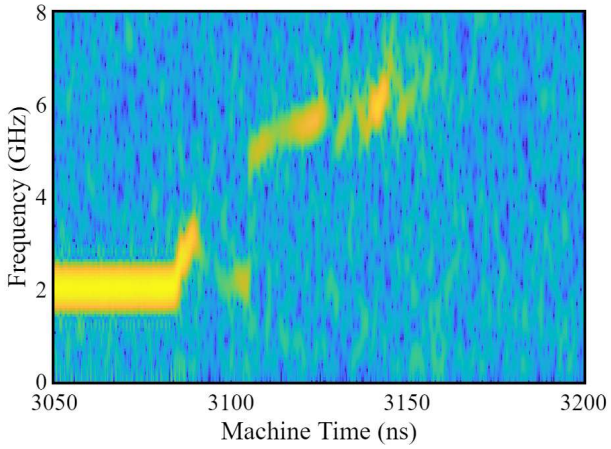


Plasma and radiation influenced the downstream velocity measurement

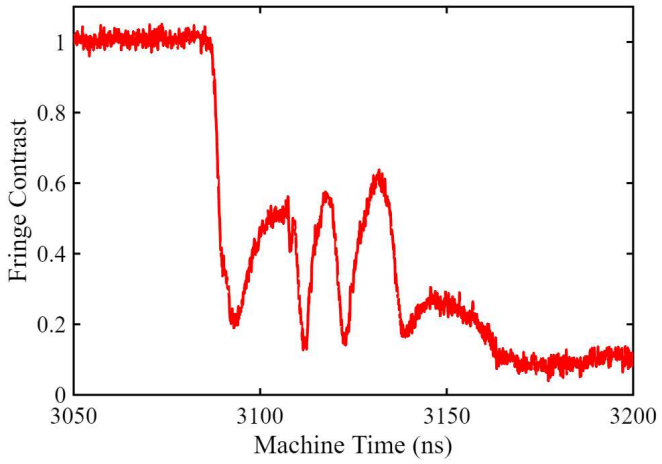
Downstream Apparent Velocities



PDV Spectrogram



VISAR Fringe Contrast



We leveraged the different wavelengths of PDV and VISAR to remove the influence of the plasma from the apparent velocity

Total apparent velocity is:

$$v^* = -\frac{d}{dt}\int n(x,t)dx = v(t)n_s(t) - \int \frac{\partial}{\partial t} n(x,t)dx$$

v^*: App Vel; $\frac{d}{dt}$: Ref. Index; $=$: Leibniz; $v(t)n_s(t)$: Ref. Index at surface; $\int \frac{\partial}{\partial t} n(x,t)dx$: v_p^*

Where:

$$n(x,t) = \sqrt{1 - \frac{N(x,t)}{N_c}}$$

$N(x,t)$: Plasma Density; N_c: Cutoff Density

And:

$$N_c = \frac{m_e \epsilon_0}{e^2}\left(\frac{2\pi c}{\lambda}\right)^2$$

λ: Wavelength

is a wavelength-dependent constant

Then:

$$\frac{\partial}{\partial t} n(x,t) = -\frac{1}{2N_c}\left(1 - \frac{N(x,t)}{N_c}\right)^{-\frac{1}{2}} \frac{\partial}{\partial t} N(x,t)$$

But if $N(x,t) \ll N_c$ everywhere:

$$\frac{\partial}{\partial t} n(x,t) \approx -\frac{1}{2N_c}\frac{\partial}{\partial t} N(x,t)$$

So:

$$v_p^* \approx \frac{1}{2N_c}\int \frac{\partial}{\partial t} N(x,t)dx$$

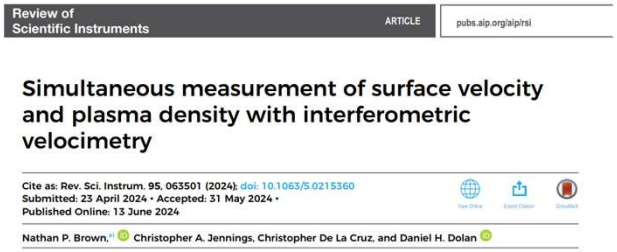
v_p^*: Plasma Comp; N_c: Cutoff density is now *outside* the integral

And then:

$$\frac{v_{p,PDV}^*}{v_{p,VISAR}^*} \approx \left(\frac{\lambda_{PDV}}{\lambda_{VISAR}}\right)^2 \approx 8.4887$$

Independent of plasma distribution!

$$v = v_{VISAR}^* - \frac{v_{PDV}^* - v_{VISAR}^*}{\left(\frac{\lambda_{PDV}}{\lambda_{VISAR}}\right)^2 - 1}$$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Simultaneous measurement of surface velocity and plasma density with interferometric velocimetry

Cite as: Rev. Sci. Instrum. 95, 063501 (2024); doi: 10.1063/5.0215360
Submitted: 23 April 2024 • Accepted: 31 May 2024 •
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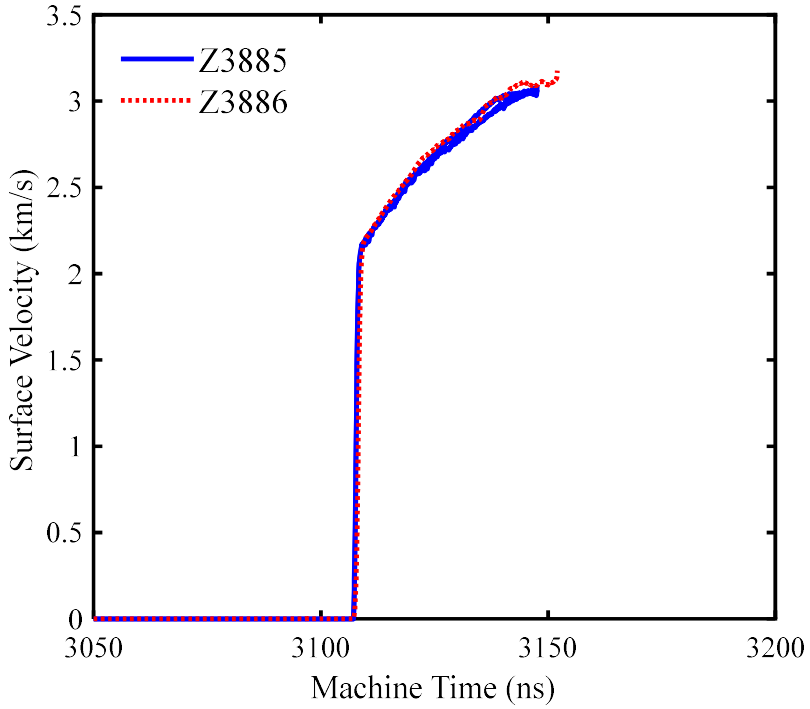
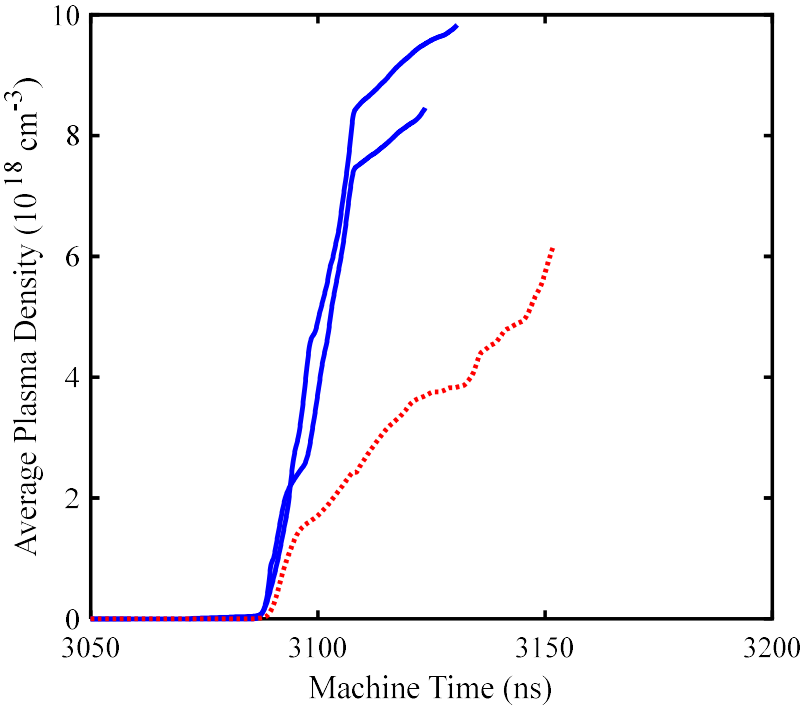
Nathan P. Brown, Christopher A. Jennings, Christopher De La Cruz, and Daniel H. Dolan

We leveraged the different wavelengths of PDV and VISAR to remove the influence of the plasma from the apparent velocity

Downstream Velocities

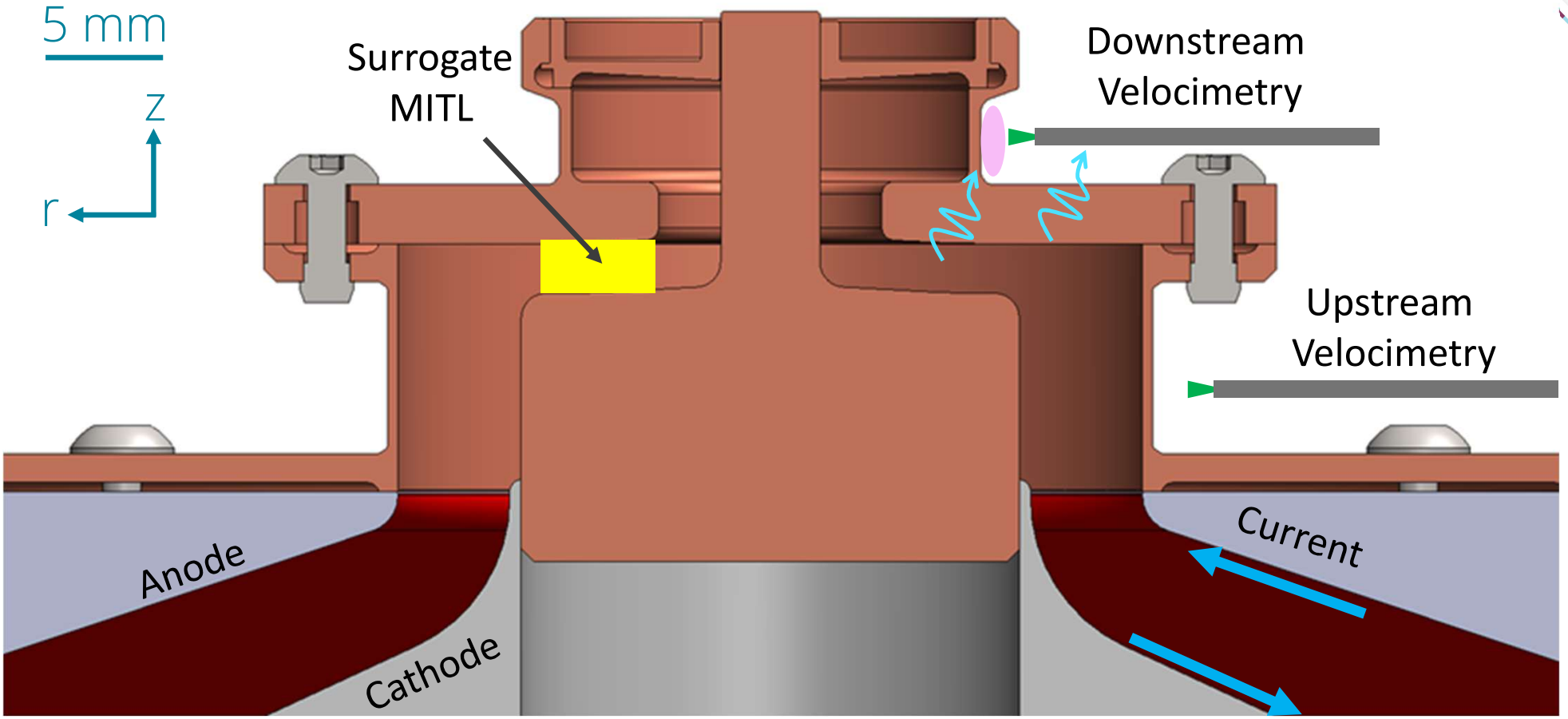


Plasma Densities

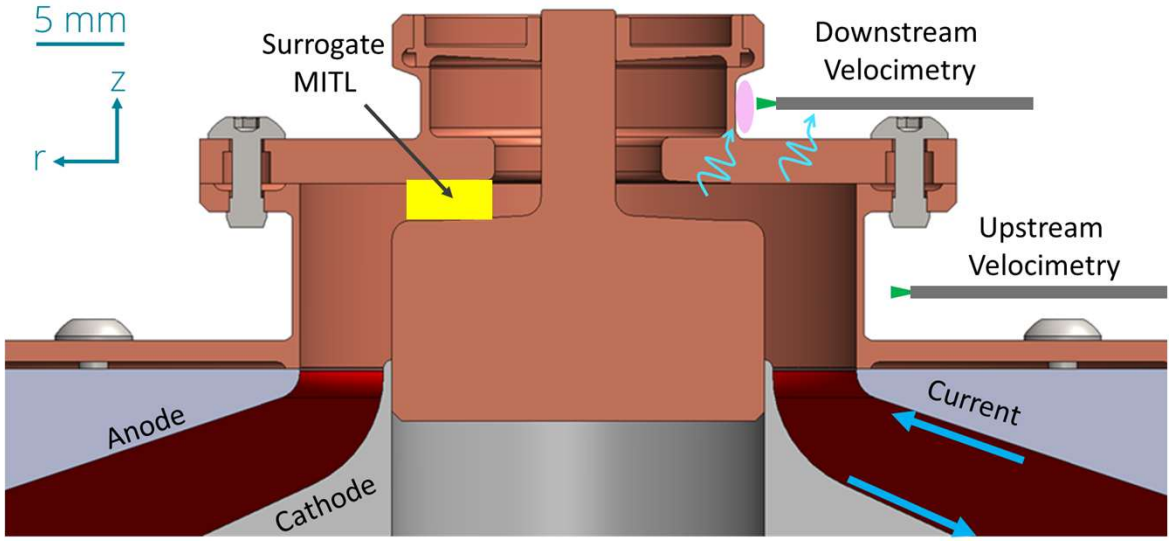


VISAR: $N/N_c < 0.003$
PDV: $N/N_c < 0.03$

We hypothesize that x-rays stemming from the surrogate MITL formed surface plasmas and blanked probes



Thank you for your time! Any questions?



$$\frac{v^*_{p,PDV}}{v^*_{p,VISAR}} \approx \left(\frac{\lambda_{PDV}}{\lambda_{VISAR}}\right)^2 \approx 8.4887$$

$$v = v^*_{VISAR} - \frac{v^*_{PDV} - v^*_{VISAR}}{\left(\frac{\lambda_{PDV}}{\lambda_{VISAR}}\right)^2 - 1}$$