Pulsed Power and Diagnostic capabilities for High Energy Density Physics Studies in the UC San Diego Pulsed Plasma Physics Group

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NNSA National Nuclear Security Administration

Sandia National Laboratories

LPS

Imperial College London

Fun projects on which we haven't made as much progress on as we'd like……

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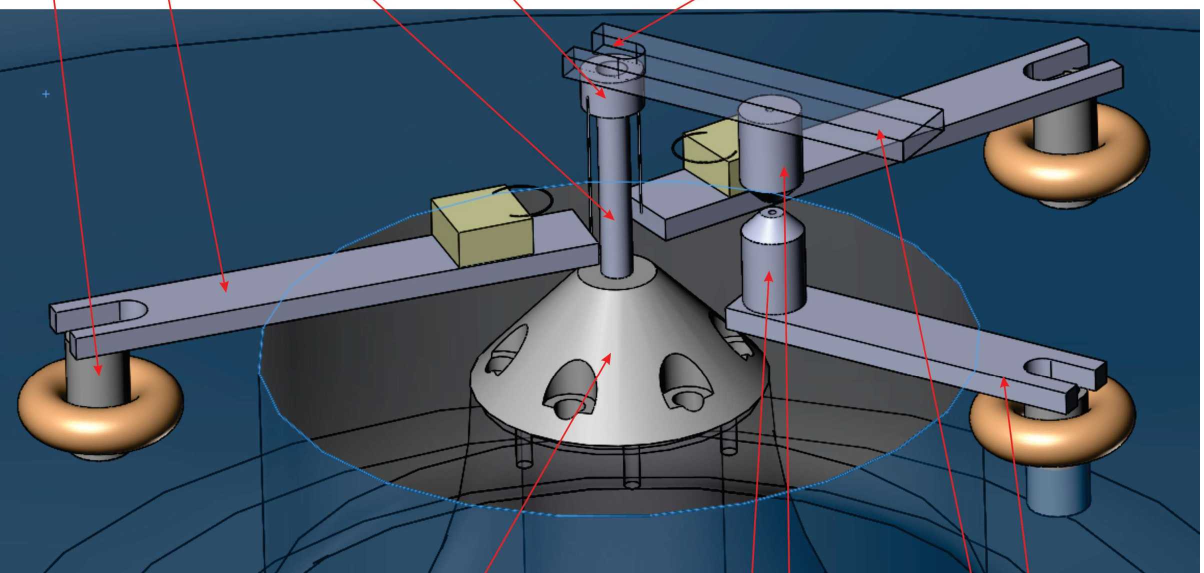
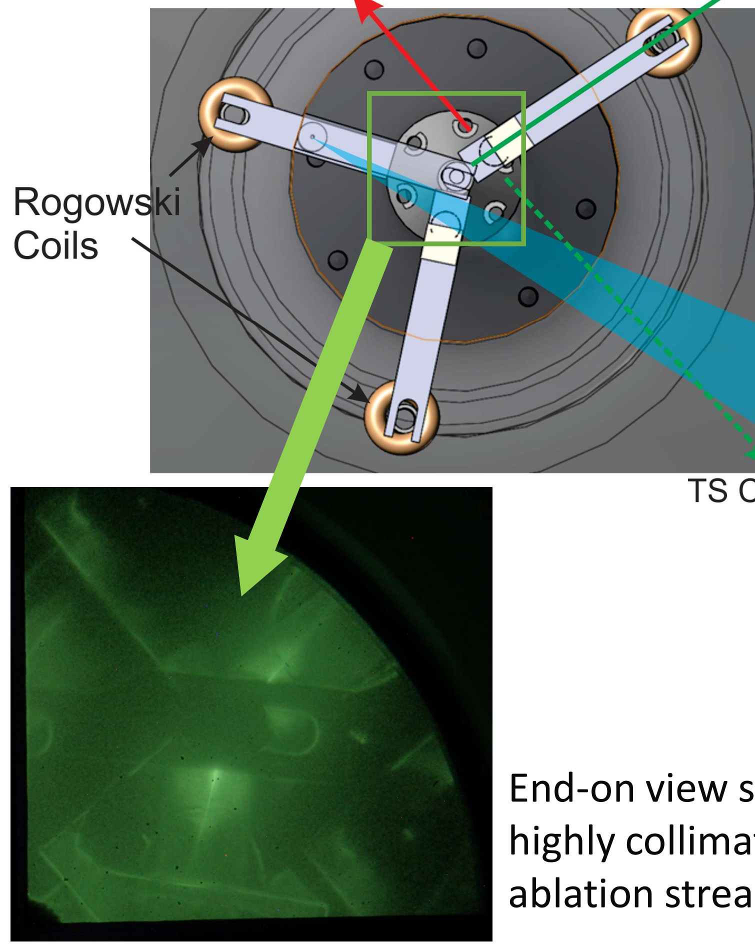
Bow-shock experiment to examine radiative effects on COBRA

- Bow-Shock Experiments on 1MA COBRA Generator

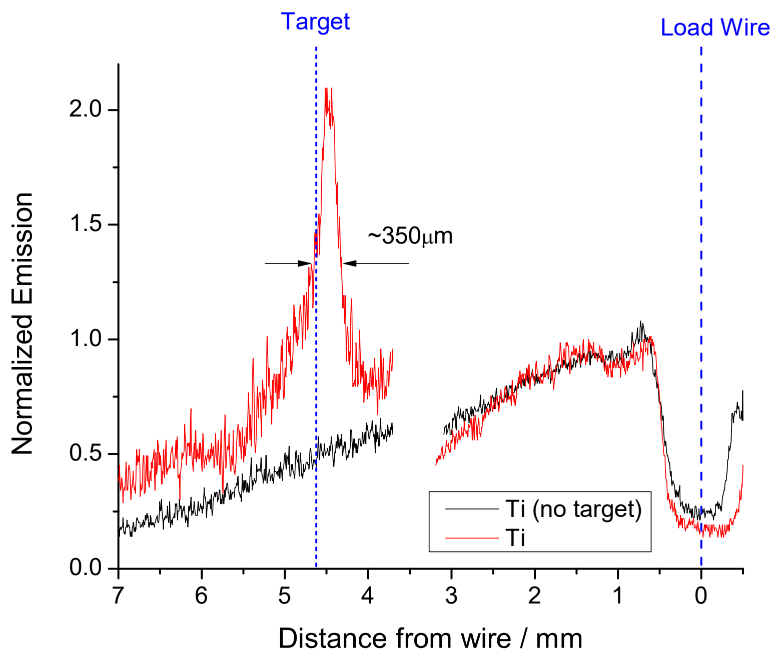


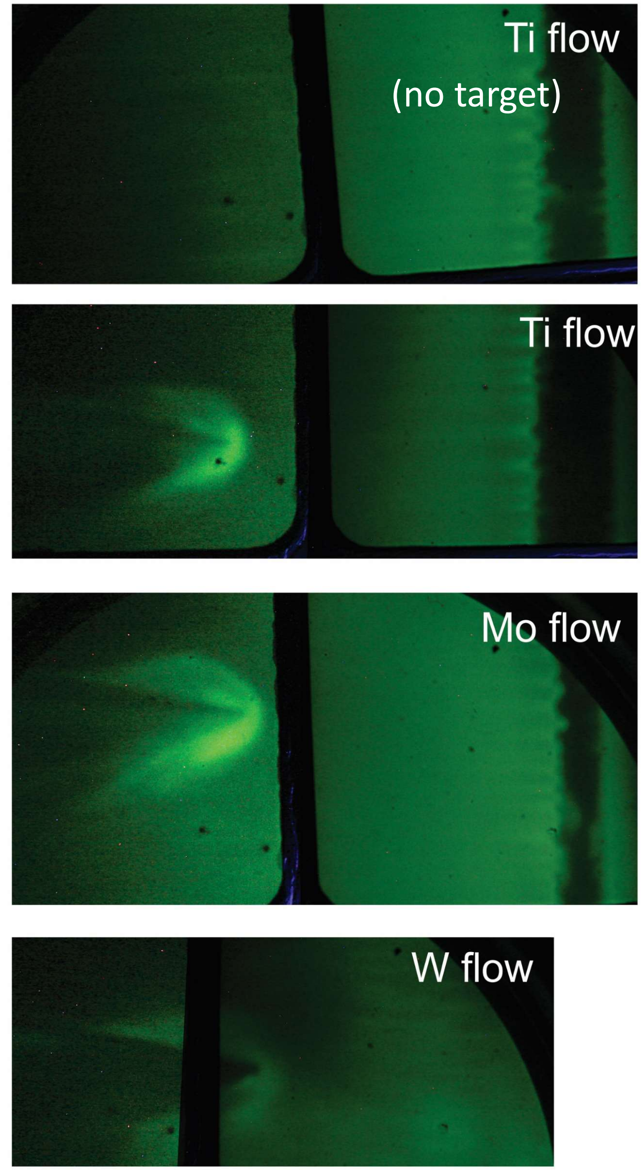


End-on view shows highly collimated ablation streams

Gated Self-emission XUV Imaging clearly demonstrates shock formation

- Spatial resolution ~ 60μm, frame exposure ~5ns and images radiation above 120 eV (T_e > 30eV)
- All wire materials show shock formation, and upstream emission region of several hundred microns.
- More readily observed than the XP experiments, likely due to the high density on COBRA (factor of ~6)





Thomson Scattering Set-up on COBRA measures T_e, V_{radial}

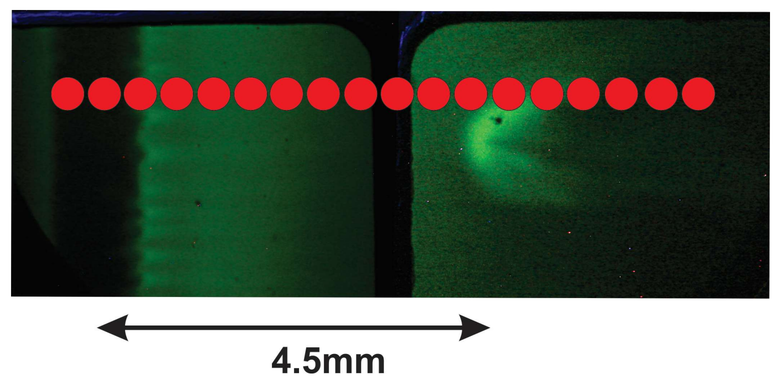
- COBRA laser has up to 10 J in a 526.5nm, 2.5ns pulse
- Scatter images onto a linear array of 18 fiber collection delivered to spectrometer (0.75m Andor, 2400l/mm)

T_e = 5-50 eV
n_e = 1×10^{17} to 1×10^{19} cm^{-3}

$$\alpha = \frac{1}{k\lambda_D} \approx \frac{\lambda_0}{4\pi\lambda_D \sin\left(\frac{\theta}{2}\right)}$$

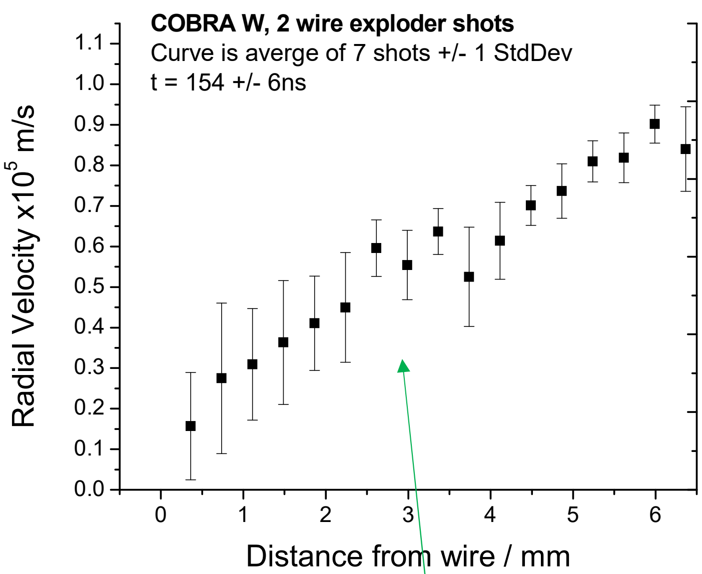
α parameter = 1-5 (collective regime)

- Fibers image a region ~250mm in diameter and cover a radial distance of ~7mm
- Observe only the Ion Acoustic features of the scattered spectrum, so can recover velocity and (sometimes) electron temperature

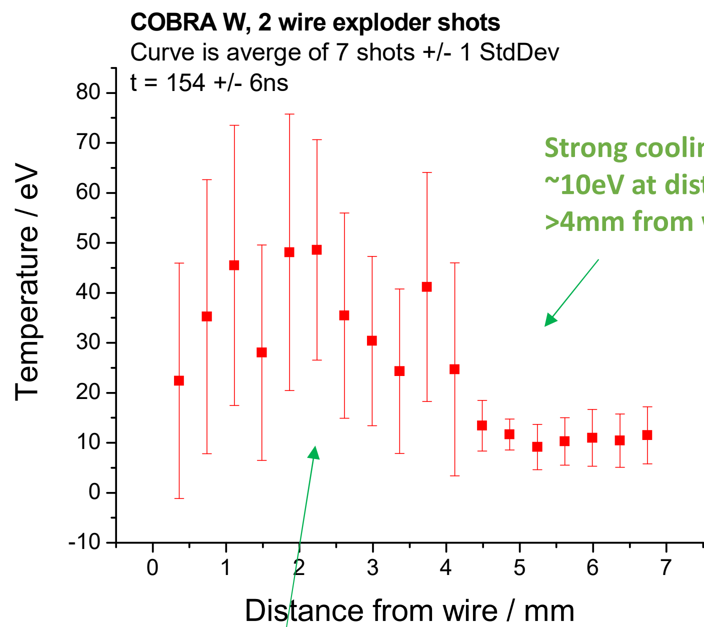


Thomson Scattering gives detailed measurements of local conditions in the flow

- Initial 'no target' shots allow determination of the average V_{radial} and T_e in flows



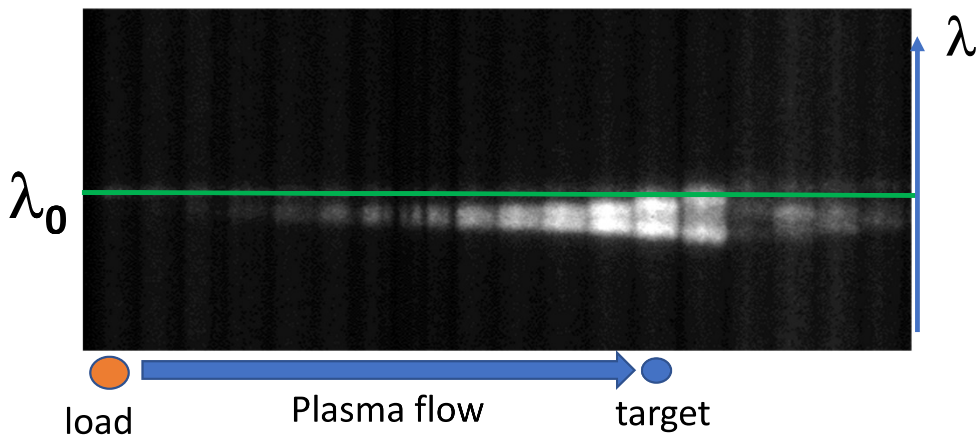
Continuous acceleration to ~90 km/s

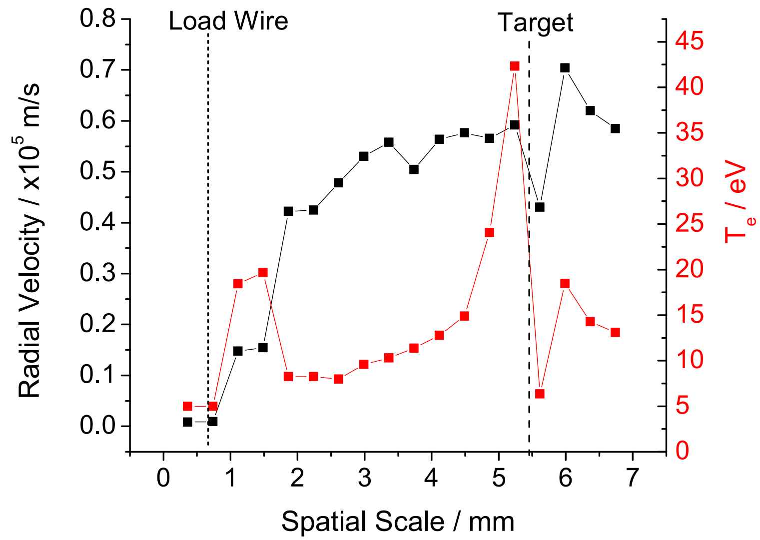


Strong cooling to ~10eV at distances >4mm from wire

Significant heating close to wire

Increase in T_e observed ahead of shock position



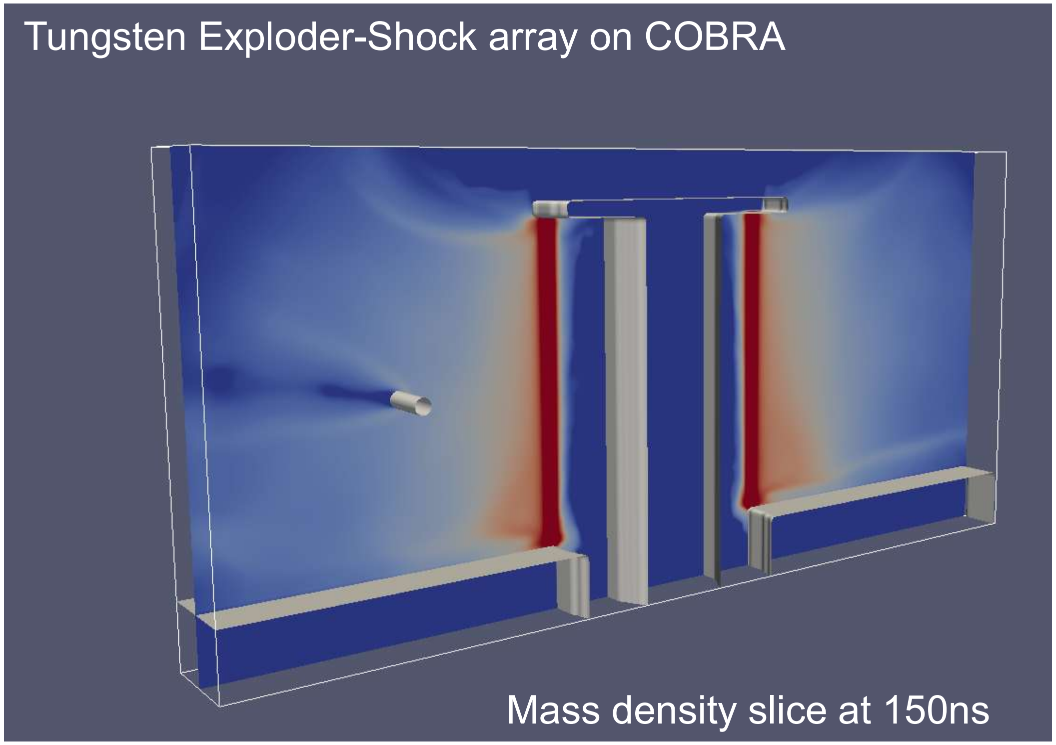


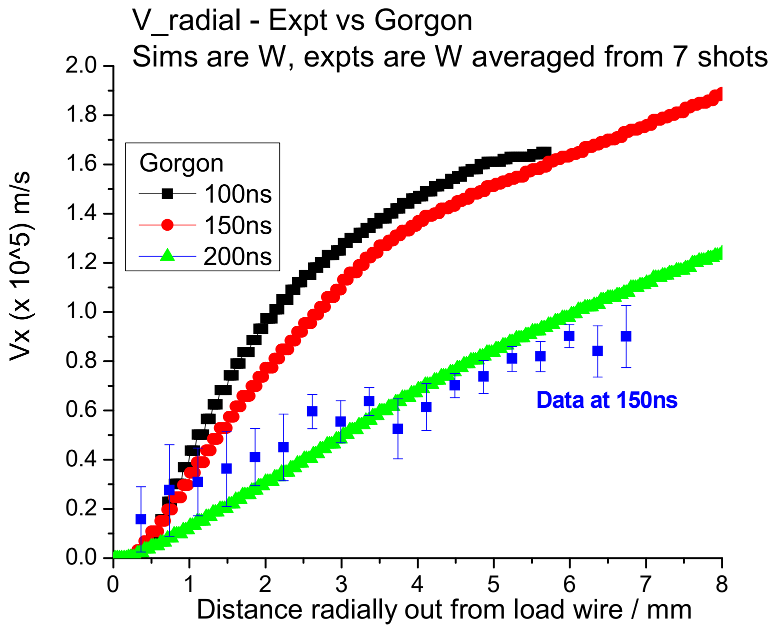
- Measured B-field in flow typically <10 T at target position, giving β > 100 (primarily hydro interaction)
- T_e increasing ahead of shock while velocity still increasing (i.e. not caused by flow stagnation)
- Emission ahead of the shock is not caused by electron heat transport, as the electron mean free path is << observed shock width

=> First convincing experimental evidence of a radiative precursor in the bow shocks on COBRA

3D Gorgon simulations of COBRA experiments show reasonable agreement with data

- Simulations run on 24-node machine at UC San Diego (3D, 100-200mm grid resolution)
- The comparison is still a work in progress, but initial plots are interesting

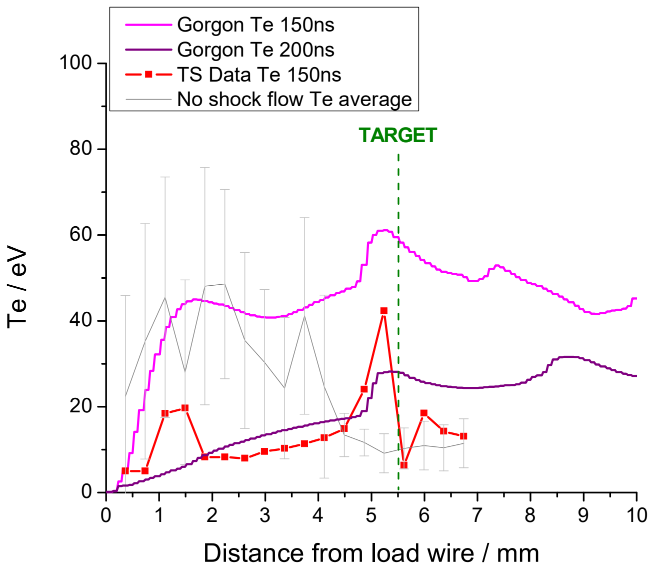


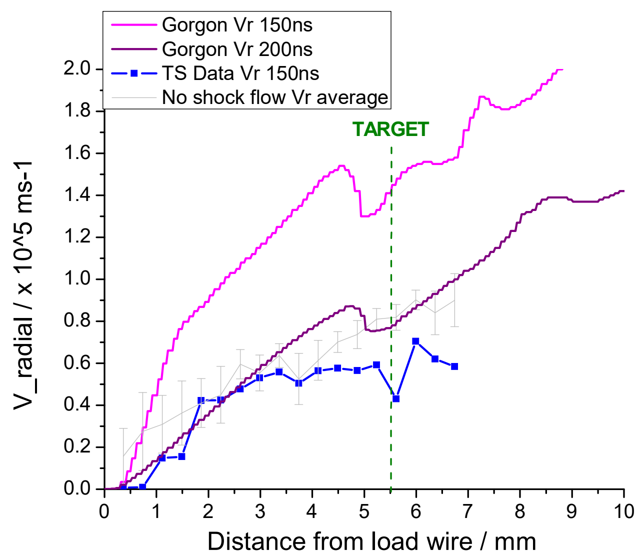


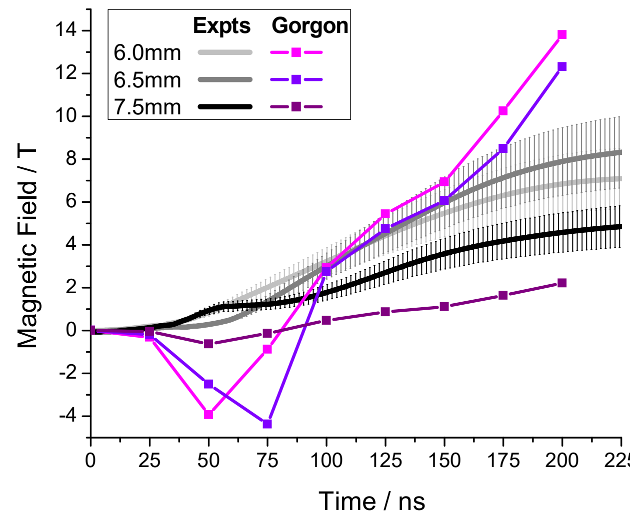
- Need more time evolution data from experiments

Comparisons to multiple parameters is on-going

- We are now getting a sufficient number of localized plasma measurements (T_e, V_{radial}, B) to strongly constrain codes.





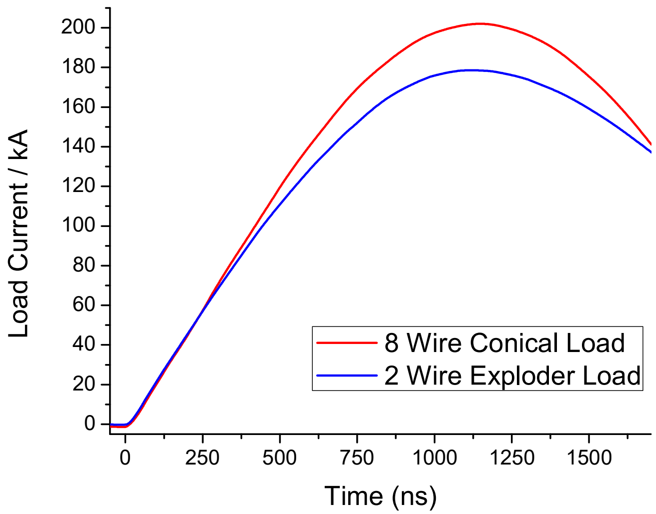


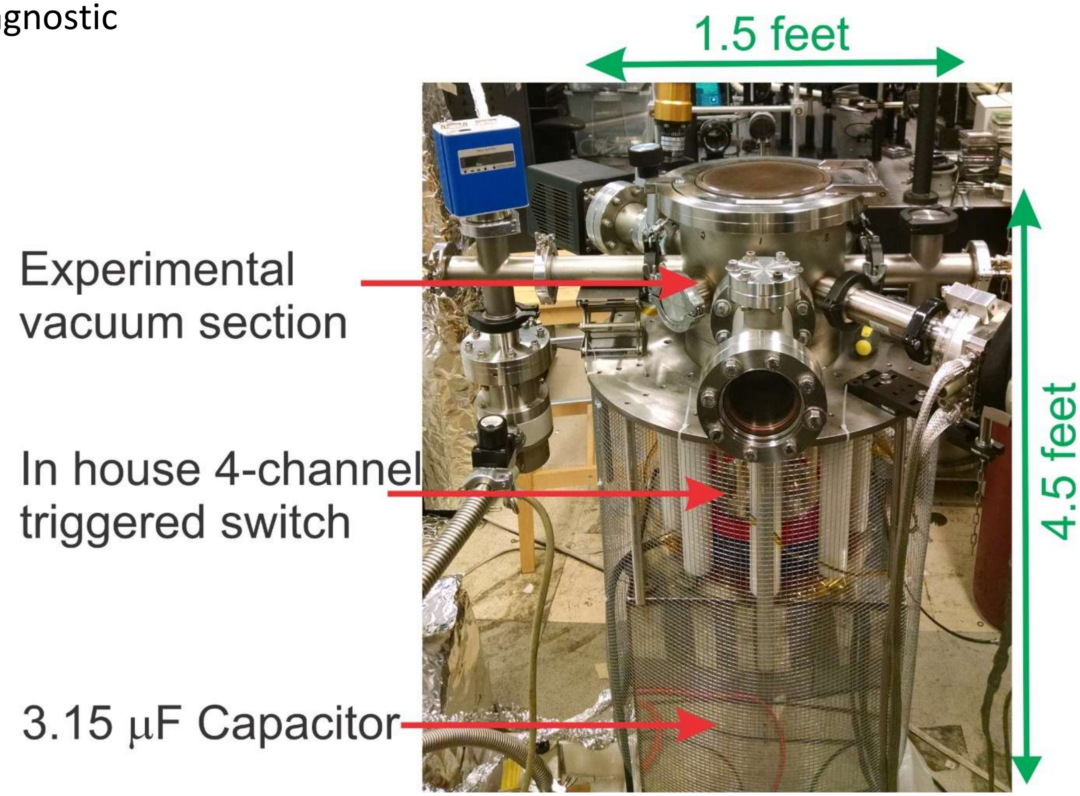
- Comparable trends, but significant difference in absolute values that required detailed refinement

UC San Diego bow- shock experiments

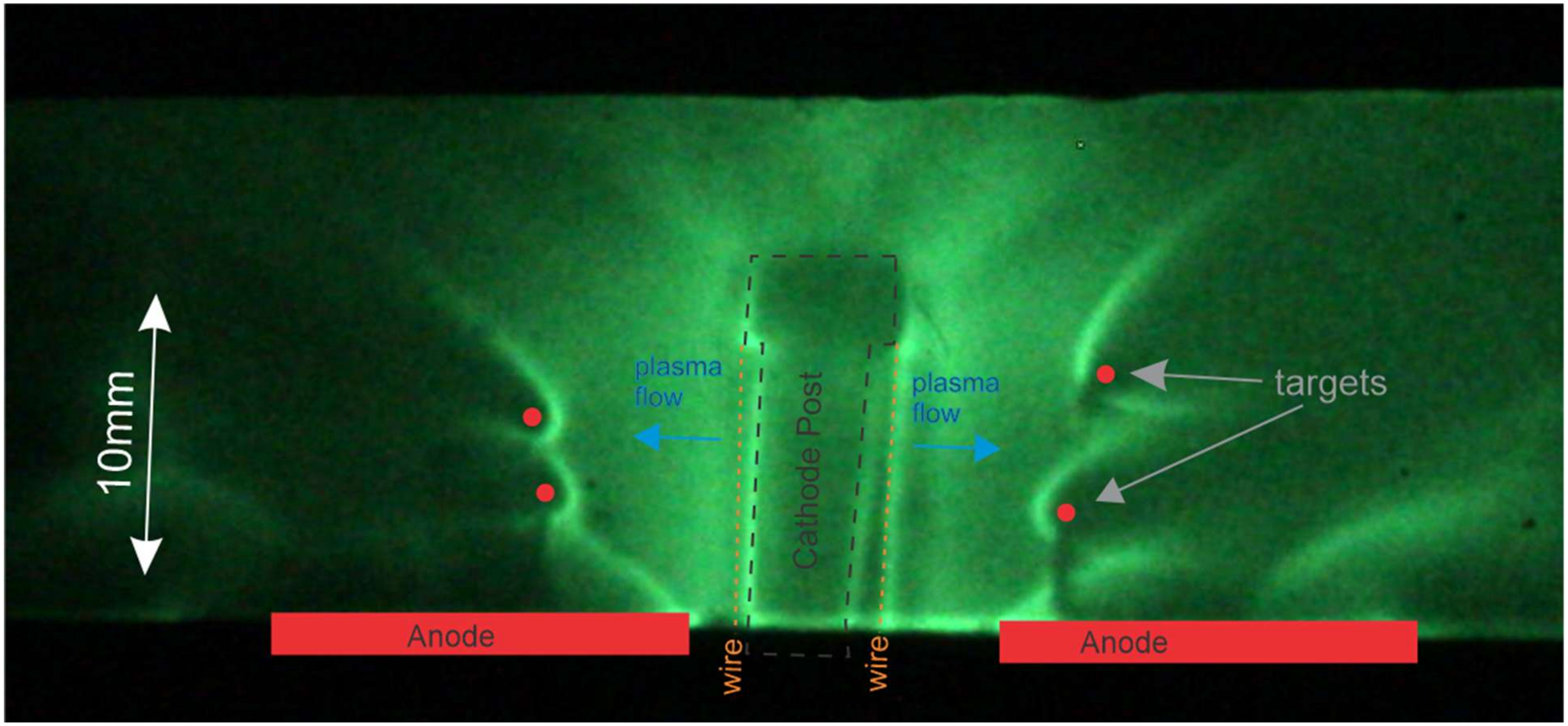
Bertha

- Bertha has served as a workhorse for load design and diagnostic development (180 kA, 1.1us)
- Single capacitor charged to 50kV, atmospheric air



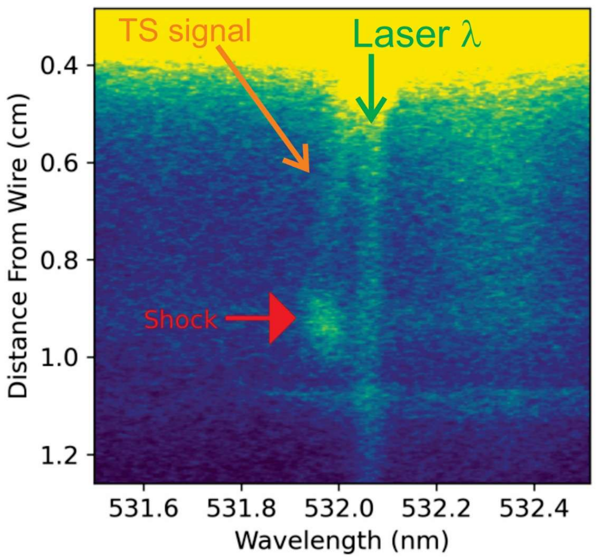


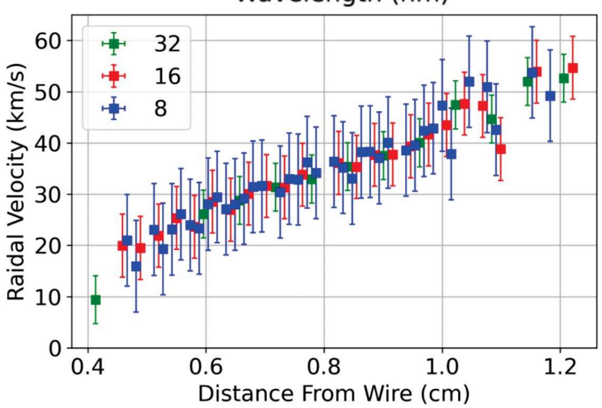
Free-space coupled Thomson scattering

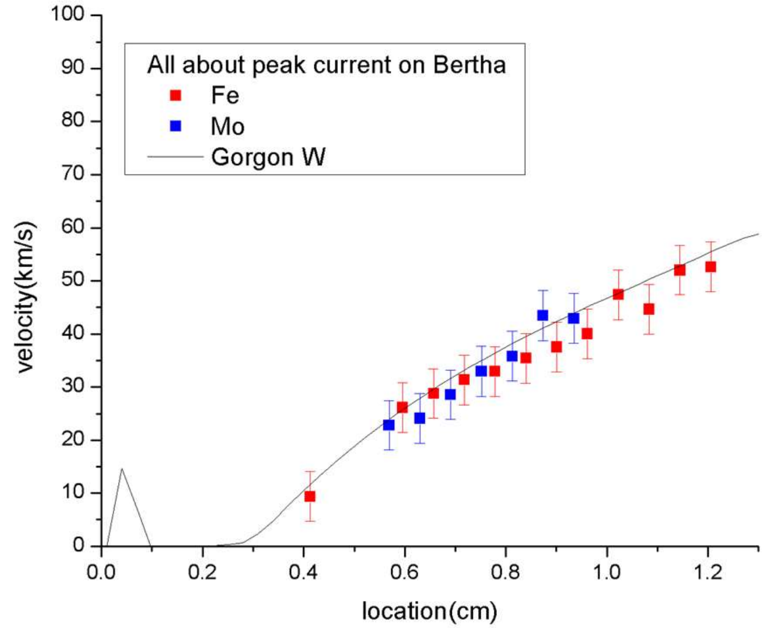


- Ion acoustic feature allows measurement of velocity (and nearly temperature)
- Signal transmission is by free space optics
- Analysis using the Banasek TS code

Initial Gorgon simulations are promising





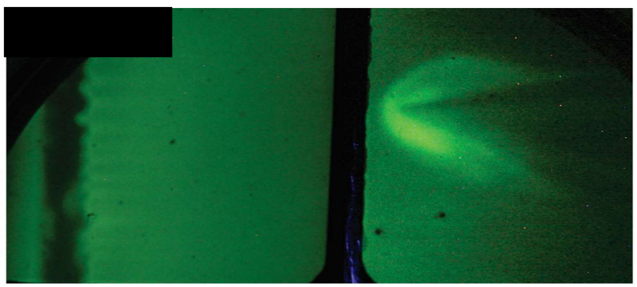


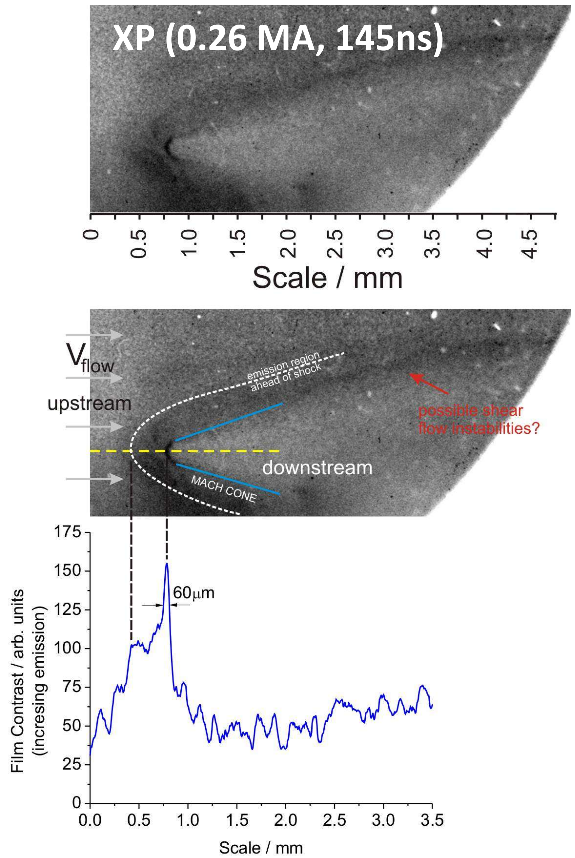
- Radiation transport likely to be less important for these experiments compared to COBRA experiments

J. T. Banasek *et al*, Review of Scientific Instruments 92, 093503 (2021)

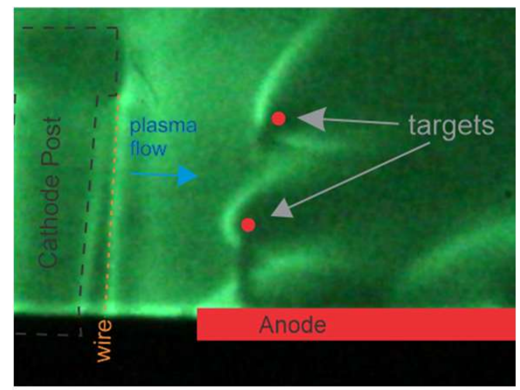
The Bow shock experiments are an excellent candidate for Radiation Transport routines

COBRA (1MA, 100ns)





Bertha (0.2 MA, 1100ns)

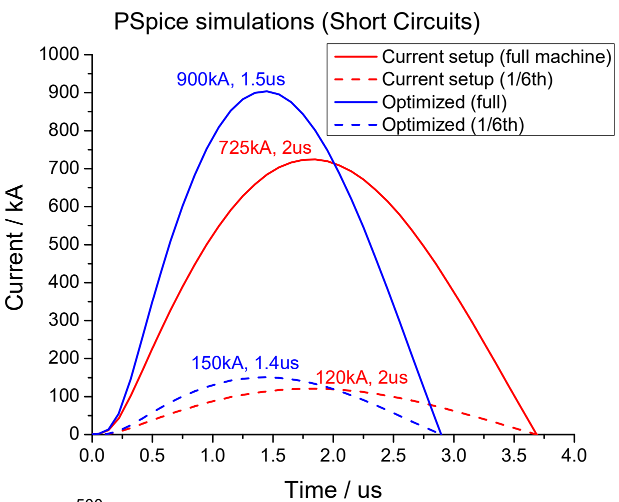


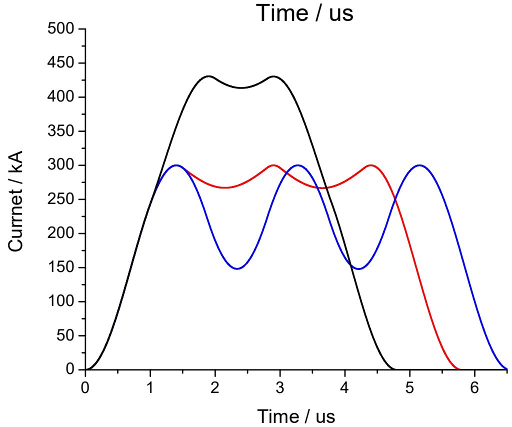
Increasing influence of radiation transport on dynamics

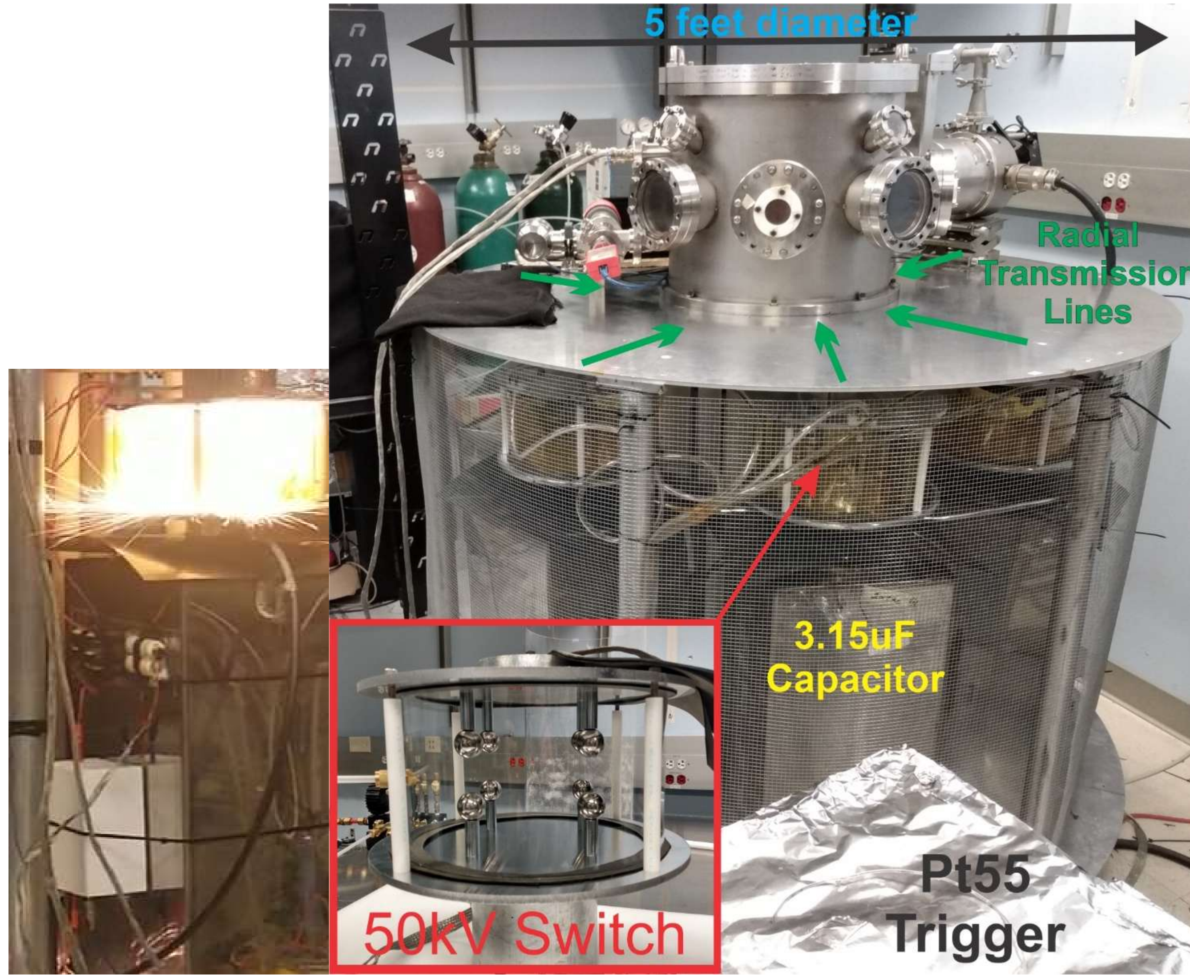
Bott-Suzuki *et al*, Physics of Plasmas 22, 052710 (2015)

A bigger hammer…….

Full driver capabilities depend on optimization of feed, but look very interesting





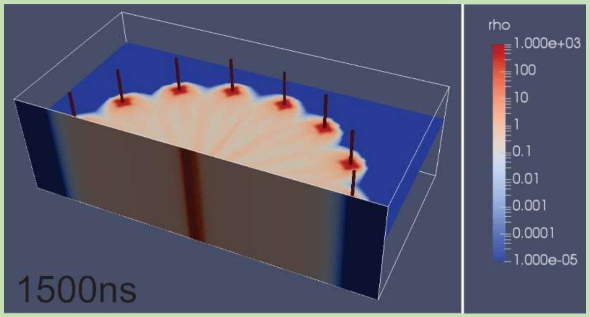


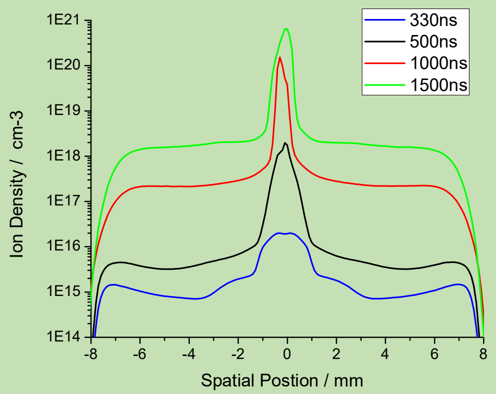
Triggering each of 6 switches allow pulse shaping

Rama

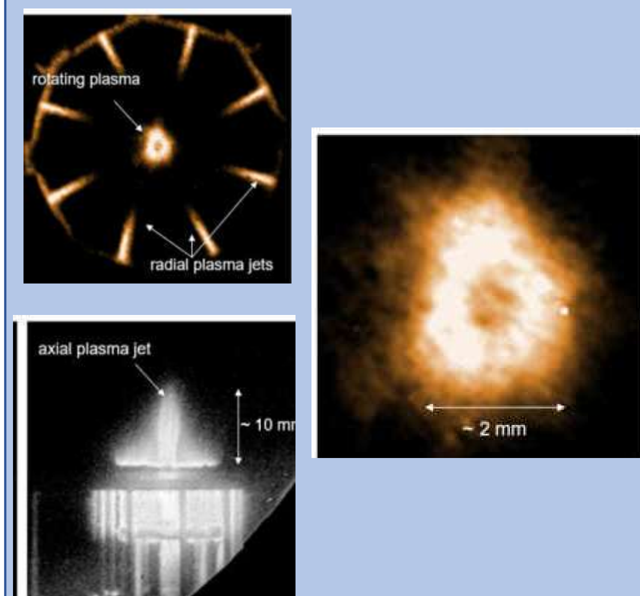
Quantitative measurement with errors are key

Slowly evolving high-density plasmas for basic parameter analysis



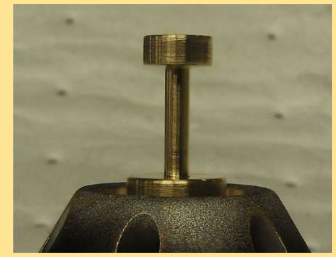


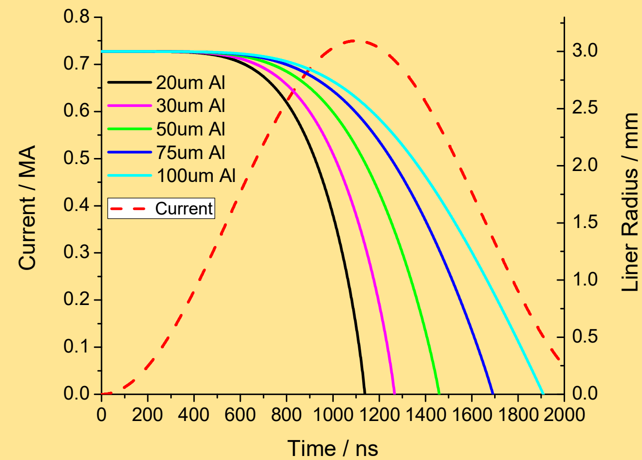
Plasma source for laboratory astrophysics with almost fixed in-flow conditions



Bennett *et al*, High Energy Density Physics 17 (2015) 63-67

Liner implosions with self-supported loads





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