Shocks in Magnetised Supersonic Plasma Flows

Imperial College London

Jacob Davies, Bartosz Krawczyk

Supervisors: Prof. Sergey Lebedev, Dr. Lee Suttle

Plasma Physics Research Group
MAGPIE facility

MAGPIE explained

General Operation of an Inverse Z-Pinch

- Capacitor banks discharge current to achieve a pulse of 1 MA in 500 ns
- Intense Ohmic heating combined with the Lorentz force results in a jet of magnetised supersonic plasma

Applications of Results

- Observations can be used to verify MHD simulations
- Scaling laws allow direct comparisons to astrophysical shocks and jets

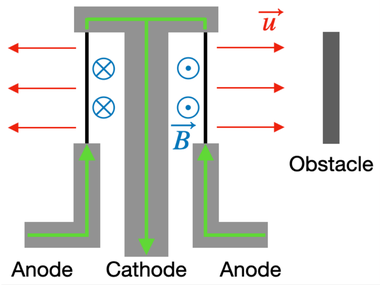


Fig. 1 *Cross-section of plasma generation set-up.*

Our Set-up

Soft Wire Obstacle

- Fine wire is suspended horizontally or vertically (Fig. 3)
- Current pulse expands the wire into a cool, dense plasma

Diagnostics

- Interferometry and Shadowgraphy images are taken
- Current is measured with Rogowski coils
- Self-emission inspected with an ultrahigh-speed camera

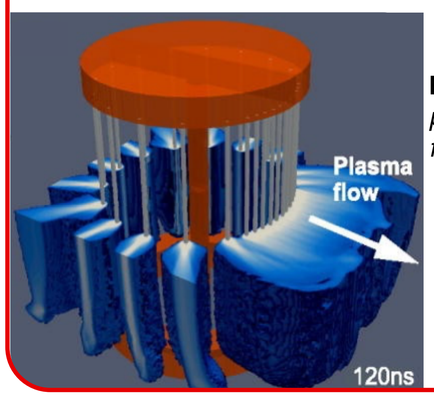


Fig. 2 *Simulation of plasma ablation from a wire array* [1].

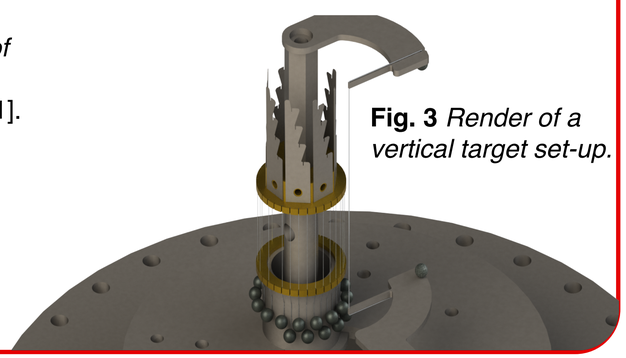


Fig. 3 *Render of a vertical target set-up.*

References

1. Burdiak, G.C., Lebedev, S.V., et al., 2017. The structure of bow shocks formed by the interaction of pulsed-power driven magnetised plasma flows with conducting obstacles. *Physics of Plasmas*, *24*(7), p.072713.
2. Swadling, G., Lebedev, S., et al., 2011, October. End-On Laser Interferometry of Wire Array Z-Pinch Implosions on the MAGPIE Generator. In *APS Division of Plasma Physics Meeting Abstracts* (Vol. 53, pp. GO6-008).

Results

Shock Structure

- Non-detached bow shocks are seen for both target orientations (Fig. 4)
- Ram pressure dominates over magnetic pressure

Instabilities of Target Wire

- ~ 2 mm structures were caused by cylindrical asymmetries of plasma flow
- ~ 0.5 mm structures are possibly Rayleigh-Taylor instabilities (Fig. 5)

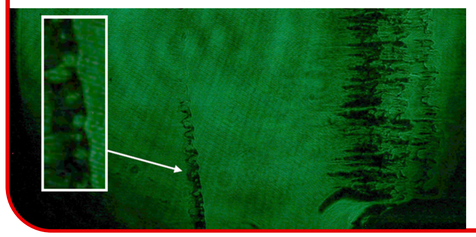
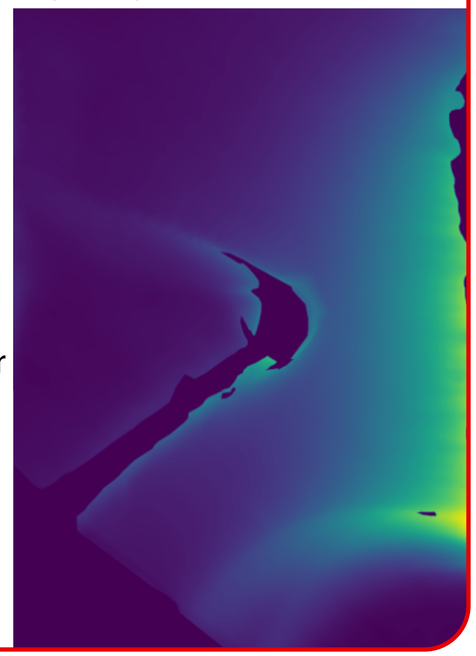


Fig. 5 *Shadowgraphy image of vertical wire in non-uniform flow.*

Fig. 4 *Plasma density for a horizontal target. Brighter means denser.*



Next steps

- Isolate Rayleigh-Taylor instabilities
- Analysing new diagnostics
  - Emission spectroscopy
  - Ultra-fast 12 frame camera
- Finish construction of new magnetic dipole obstacle (Fig. 6)

Fig. 5 *Render of a target coil.*

Conclusion

- New hardware was constructed for MAGPIE to position columns of dense plasma in this flow
  - Resultant shockwaves are visible in interferometry images
  - Thickness and orientation of wire has strong impact on collision geometry
- New data is being collected with better control of flow non-uniformity will allow investigation into Rayleigh-Taylor instabilities and shockwave parameters