Pulsed-power Magnetized Shocks Under an External Magnetic Field

NUCLEAR ENGINEERING & RADIOLOGICAL SCIENCES
UNIVERSITY OF MICHIGAN

APPLIED PHYSICS

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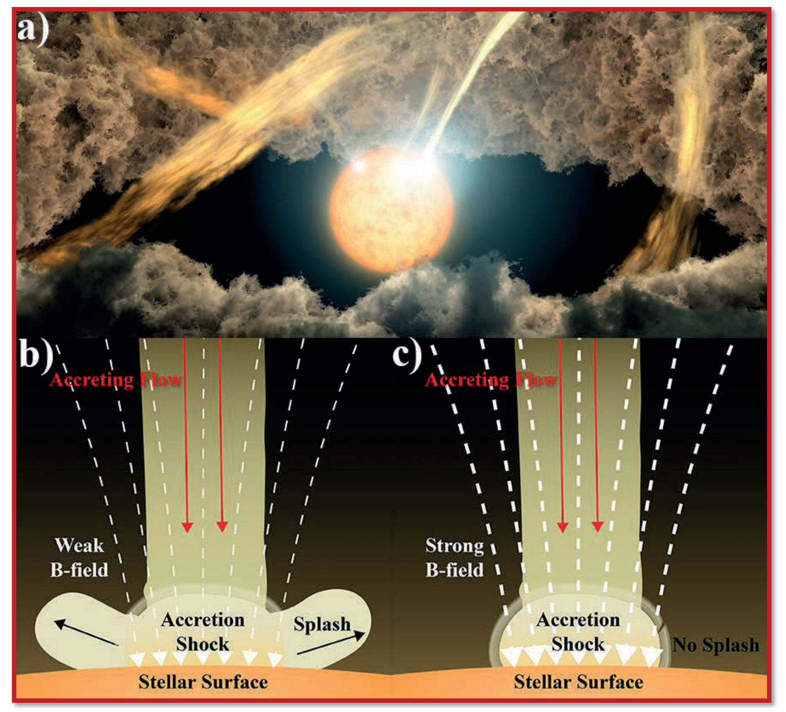
Introduction

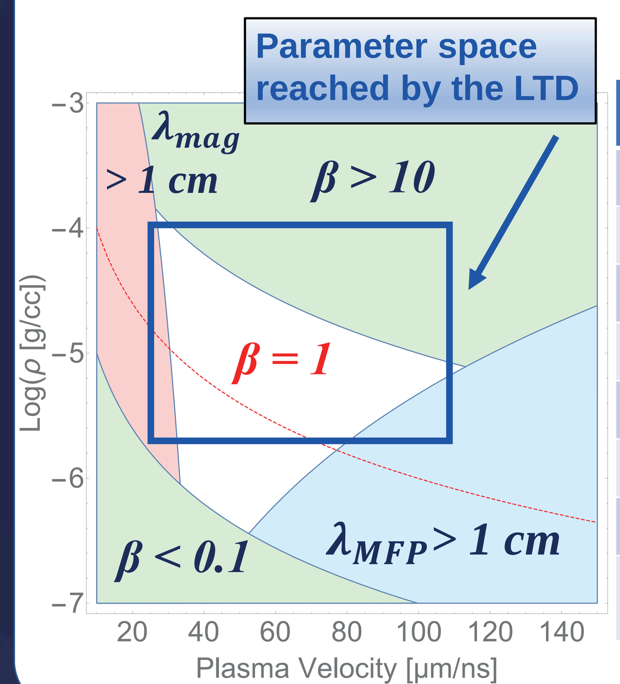
We aim to study the properties of accretion shocks generated by streaming material falling into growing stars that are characterized for having strong magnetic fields by scaling the behavior observed in astrophysical data with laboratory astrophysics experiments. In particular, we are interested in the effect of magnetic fields in shock expansion and its connection to the determination of mass accretion in the evolution of young stars. To accomplish this, we generate plasma jets via pulsed-power in the Michigan Accelerator for Inductive Z-Pinch Experiments (MAIZE) and subjecting the shock to a strong (5 T) magnetic field. Additionally, one of the primary goals for these experiment is to expand the laboratory astrophysics capabilities at the University of Michigan in order to build a framework for pulsed-power HEDP experiments.

Accretion Shocks

- Material is lifted out of the accretion disc and "funneled" along magnetic field lines
- The supersonic material impacts the star's surface creating a shock
- Increase in pressure and temperature (100 eV to 1 keV) emitting soft X-rays
- The magnetic field affects shock expansion, resulting in a difference in the "splash"

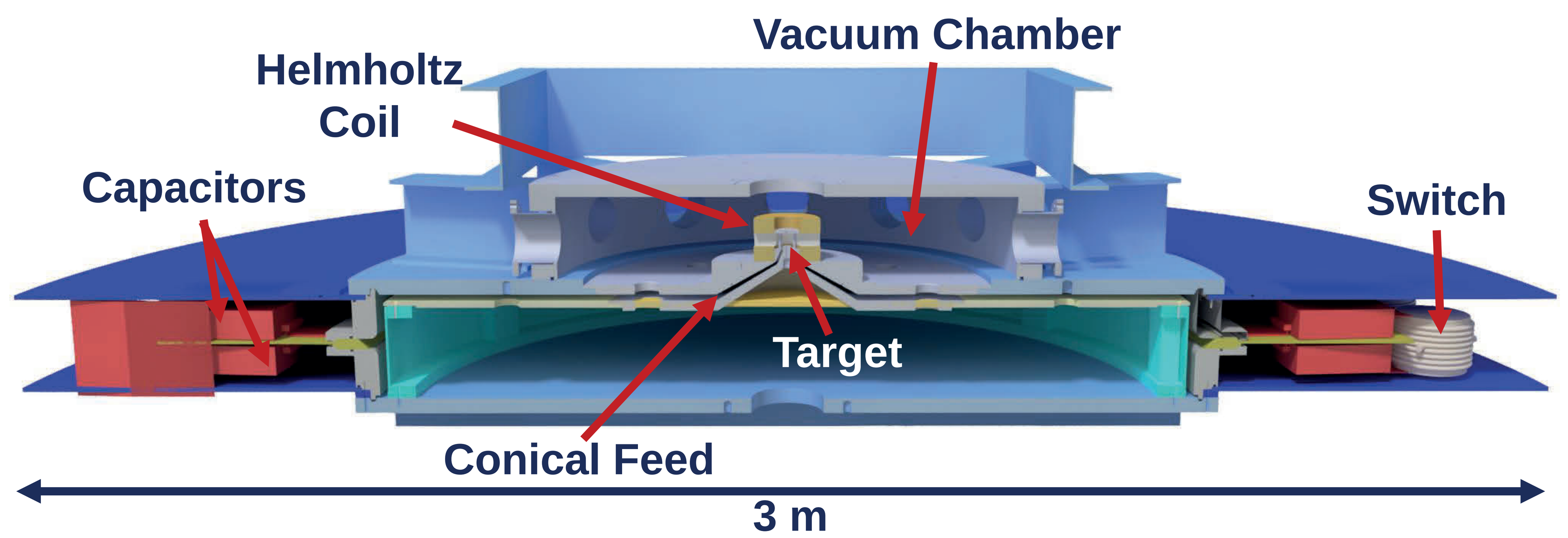


Scaling determines the plasma parameter goals

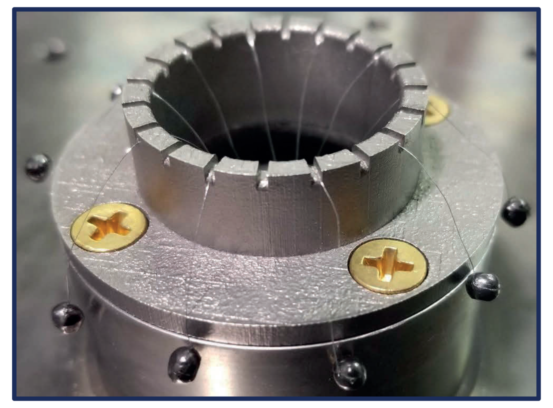


Accretion Shock Experiments on MAIZE		
Parameter	**Star [1]**	**Experiment [2]**
Length scale	10^9 cm	1 cm
Material	Hydrogen	Aluminum
Temperature	100 eV	10 eV
Imposed field	0.2 T	5 T
Velocity	400 km s^{-1}	30 - 150 km s^{-1}
Mass Density	10^{-11} g cm^{-3}	3.2×10^{-6} - 10^{-4} g cm^{-3}
Electron Density	10^{12} cm^{-3}	10^{17} - 10^{18} cm^{-3}

MAIZE Linear Transformer Driver



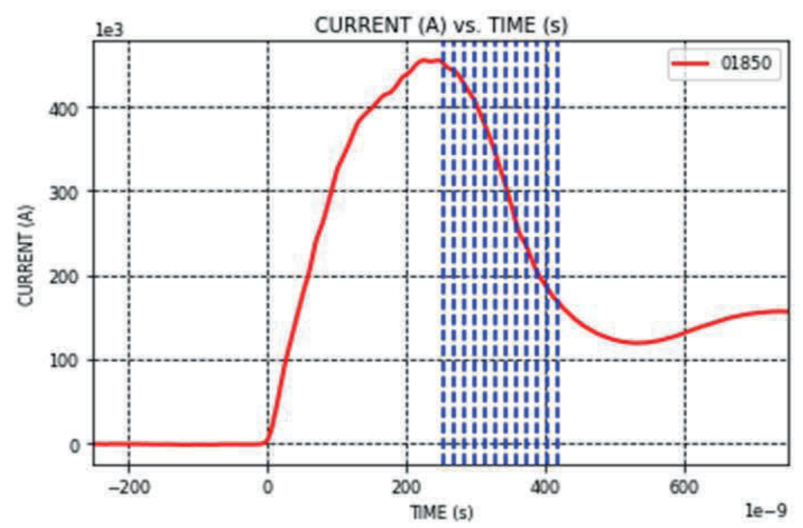
Magnetized plasma jets are created at the Michigan Accelerator for Inductive Z-Pinch Experiments (MAIZE) lab, using the Linear Transformer Driver (LTD). MAIZE can reach 1 Mega-Amp of current, with a 100 – 250 rise time.



Target

- 3D Printed
- Stainless steel
- Up to 20 wires
- 37° wire angle

LTD Current Profile at ±60 kV



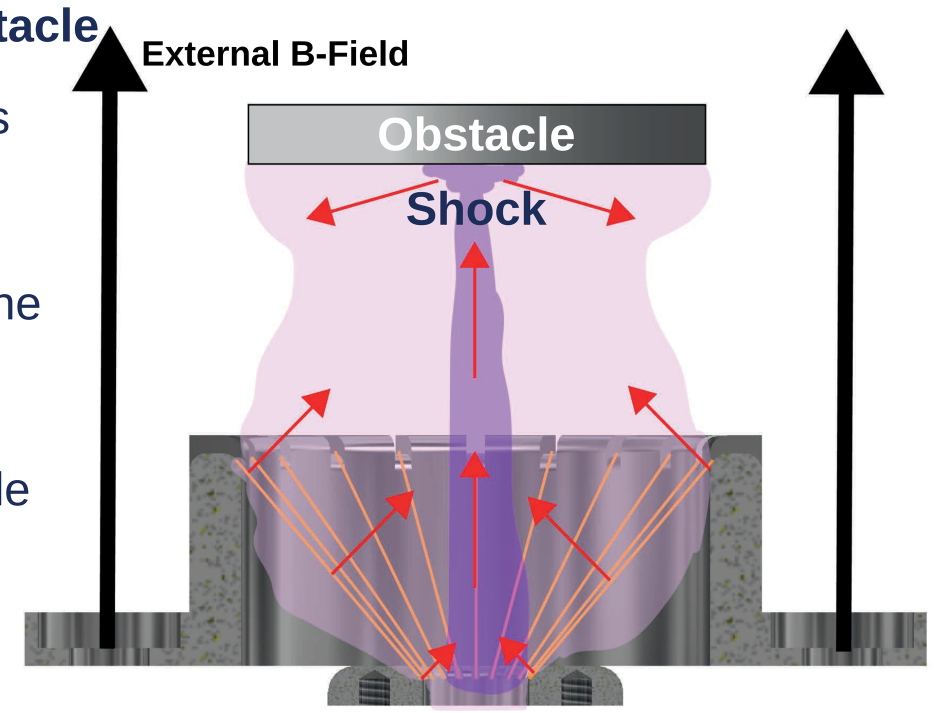
Calibrations and Diagnostics

- Self Emission: Fast Camera (up to 200,000 fps, 5 ns gate)
  - Speed of plasma flow
  - Structure of shock
- Rogowski coil and B-dots
  - Current
  - Magnetic Field

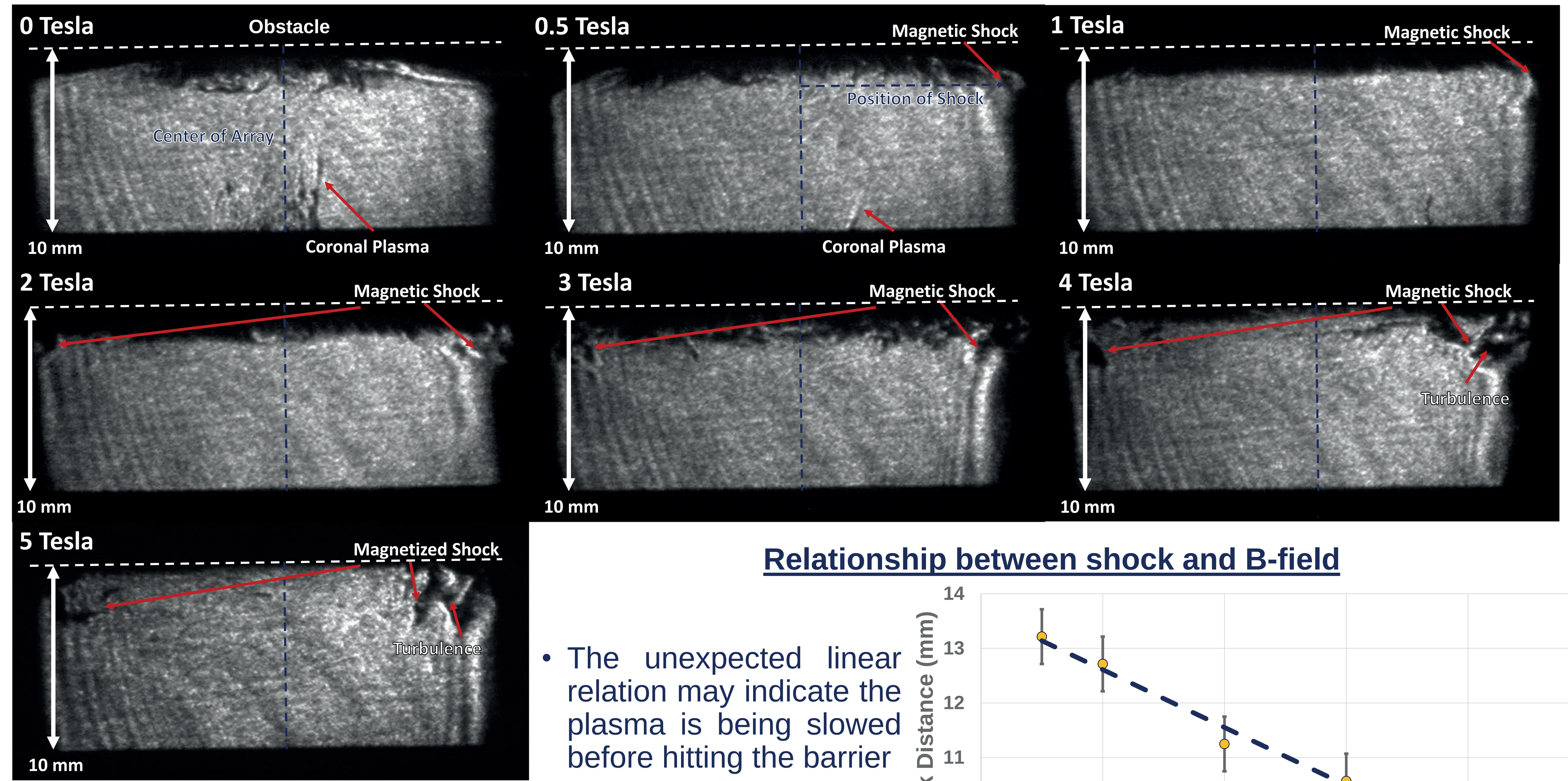
Experimental Set-Up

Conical wire array creates a plasma jet that is driven into the obstacle

- Current pulse ablates the wires
- Ablated plasma collides in the center, creating a narrow jet
- An external B-field parallel to the jet "funnels" the plasma
- A shock is generated as the plasma collides with the obstacle
- Strength of B-field should determine the spread of shock over the obstacle

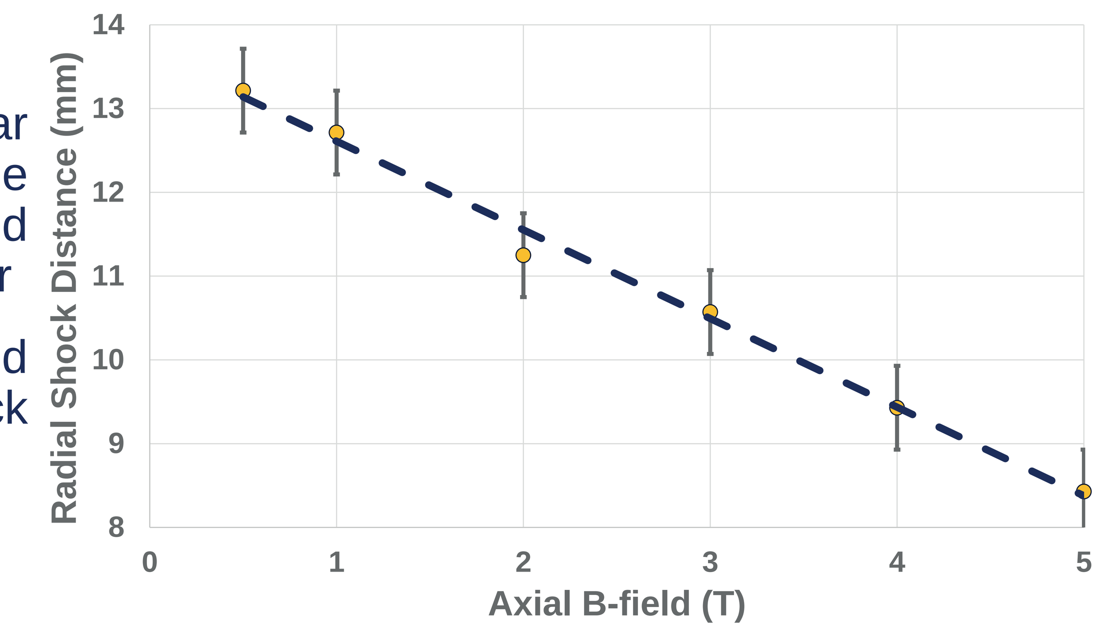


Comparison of the Plasma Shock Subjected to Different Magnetic Fields



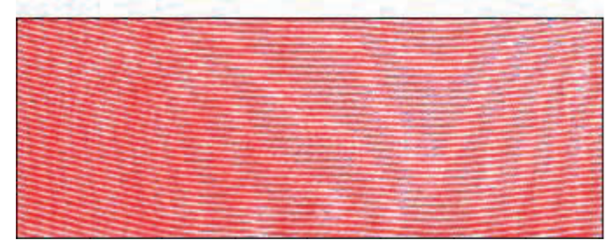
Relationship between shock and B-field

- The unexpected linear relation may indicate the plasma is being slowed before hitting the barrier
- A doubling of the B-field only shrinks the shock position by ~10%

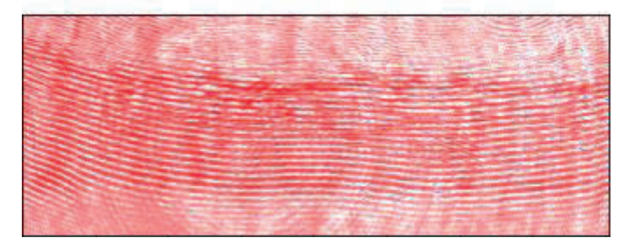


Preliminary Interferometry Analysis

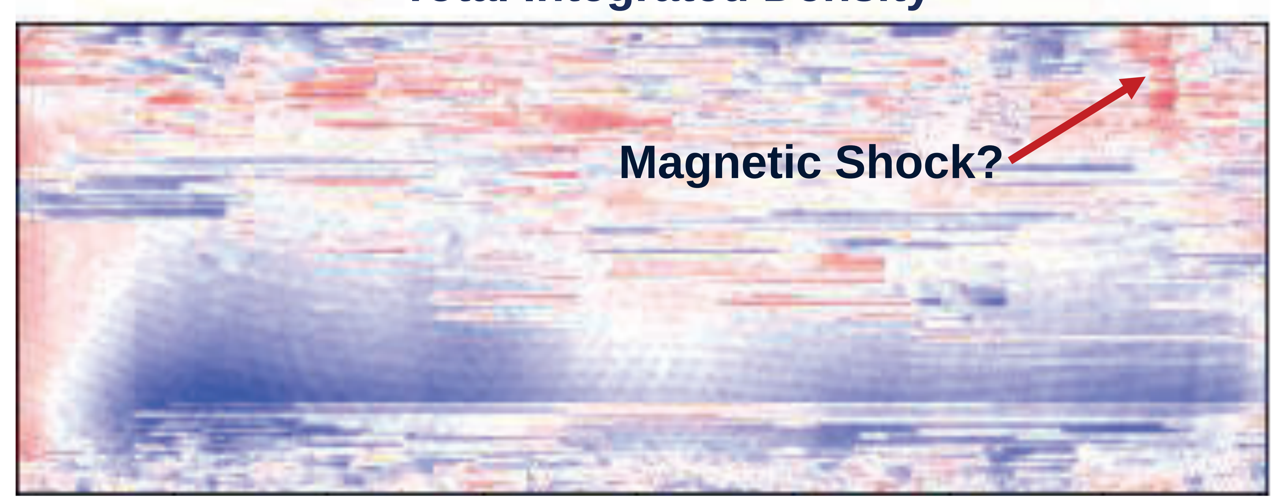
Reference Pattern



Pattern with Plasma



Total Integrated Density



Red: High Density Blue: Low Density

Summary and Conclusions

- We present the capabilities of MAIZE as a mega-amp, pulsed-power, university-scale facility for laboratory astrophysics research.
- Successful deployment of conical wire-arrays as a source of magnetized plasma flows.
- Successfully recorded interaction between the axial B-field and magnetized flow.
- The external magnetic field deflects the plasma shock proportionally to the strength of the field. But the linear relation presents an unexpected result that requires further analysis.
- Preliminary interferometry data seems to confirm the existence of a high-density shock perpendicular to the flow direction and parallel to the B-field.
- We will continue this analysis integrating both datasets and hope to find a better understanding of the behavior of magnetize shocks.

References

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Acknowledgments

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