Study of the collisional effects and increasing transverse magnetic field on the expansion of a laser produced plasma

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Introduction

- The study of laser produced plasmas is useful for understanding multiple phenomena such as energy conversion, confinement, and instabilities in transient plasmas.
- Previous work has investigated multiple plasmas using fields ranging from 0 to 1 T.
- Our goal is to show the results obtained from our experiments on the Magnetic Dusty Plasma Experiment (MDPX) superconducting magnet.
- We extended the ranges of previous studies into magnetic field strengths greater than 1 T and up to 3 T.

Objectives

- Our goal was to use gated imaging and optical emission spectroscopy to observe the plasma propagation across a strong uniform magnetic field.
- We wanted to observe the affect of the increased magnetic field on expansion dynamics, confinement, and instabilities observed in previous literature.

Materials and Methods

- Nd:YAG (532 nm) laser with a 10 ns pulse width and 275 mJ of energy was used to ablate a cylindrical carbon fiber target (1 mm diameter).
- The laser was focused to an ~ 1 mm spot size to increase our laser fluence to approximately 10 GW/cm2
- The magnetic field was created using the superconducting magnet located at Auburn University MDPX.
- The maximum attainable field is 4 T.
- A low-pressure environment was desired, so the target was placed in a 14 cm x 8 cm hexagonal vacuum chamber.
- Optical emission spectroscopy and gated imaging were used to diagnose the plasma expansion

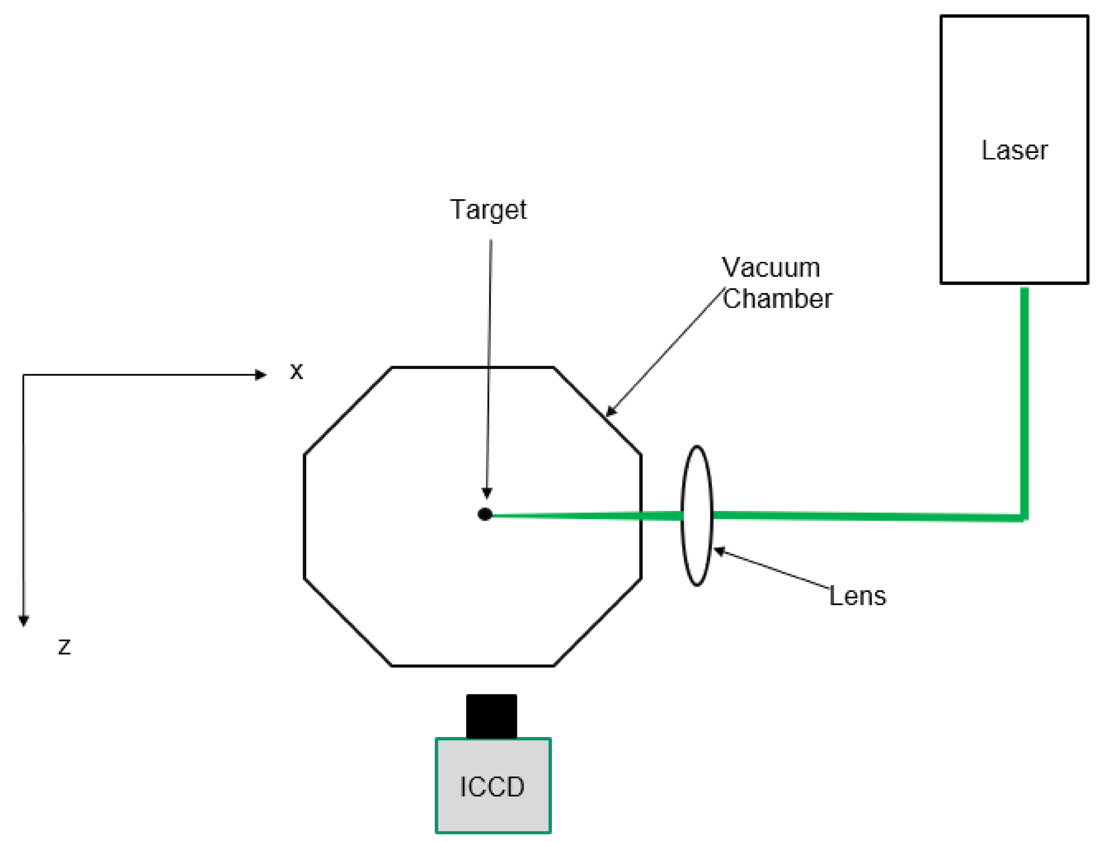

Figure 1: Experimental Setup

Results

- To fully investigate the effects of collisions and magnetic field on the plasma expansion, observations were made at a range of fields from 0 T to 3 T and pressures from 50 mTorr to 300 mTorr
- The camera delay was varied from 5 ns to 500 ns with 5 ns time steps. A broader range of 20 ns to 1000 using 20 ns steps was also used.

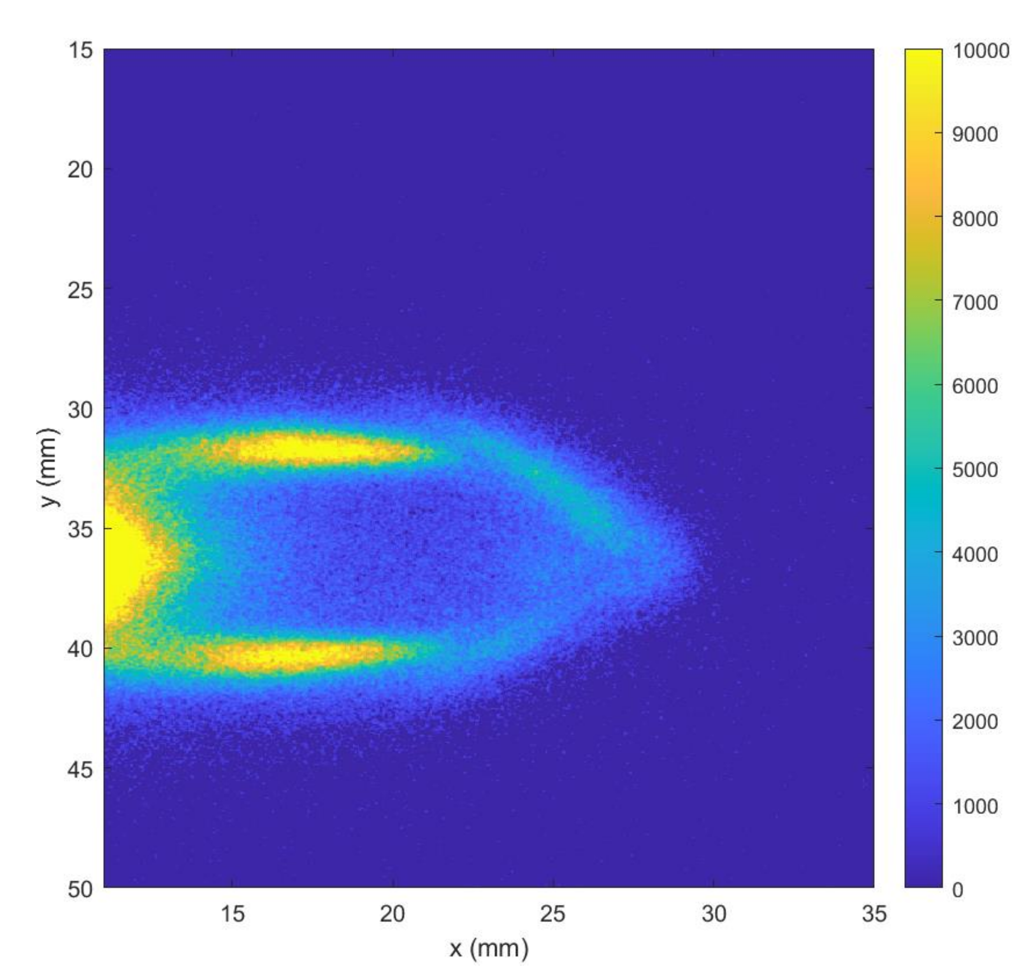

Figure 2: The expansion of the laser produced plasma across a uniform magnetic field strength of 0.25 T 700 ns after the laser pulse. In this high beta limit, the plasma propagates deeply into the external magnetic field.

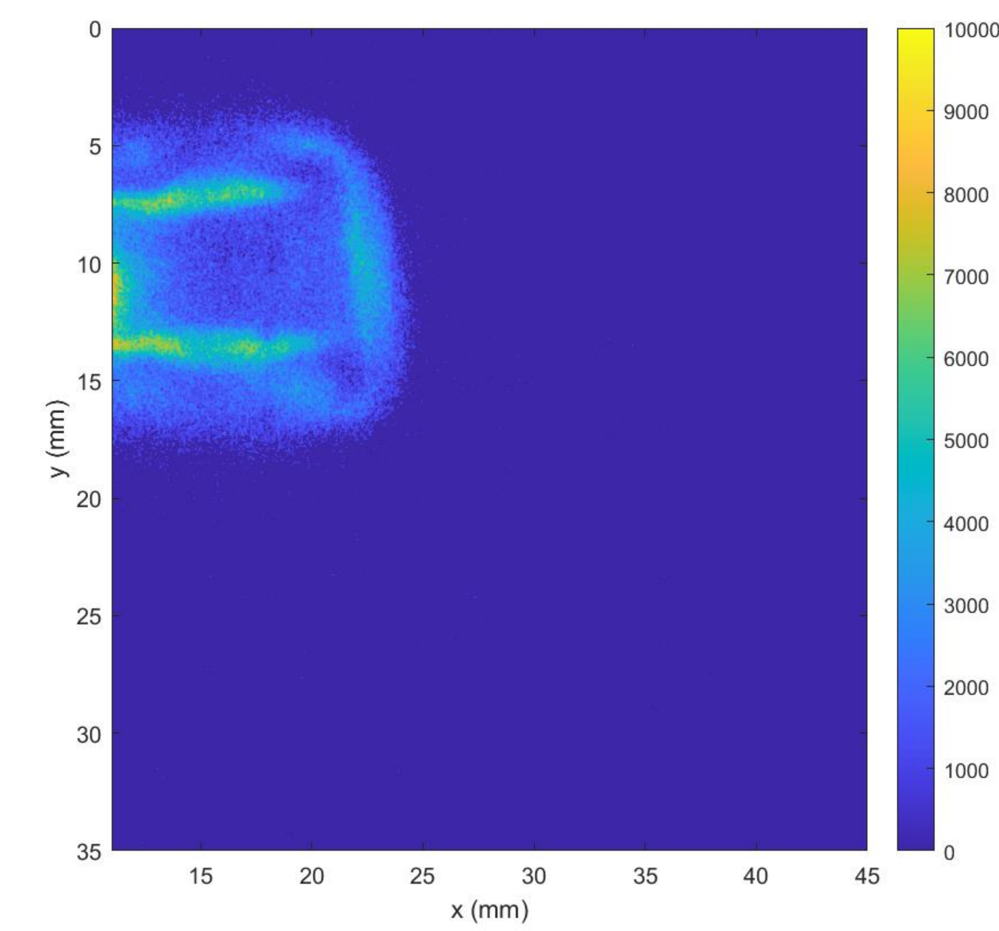

Figure 3: The expansion of the laser produced plasma across a uniform magnetic field strength of 1 T. Once again, the image is taken 700 ns after the laser pulse and at 200 mTorr

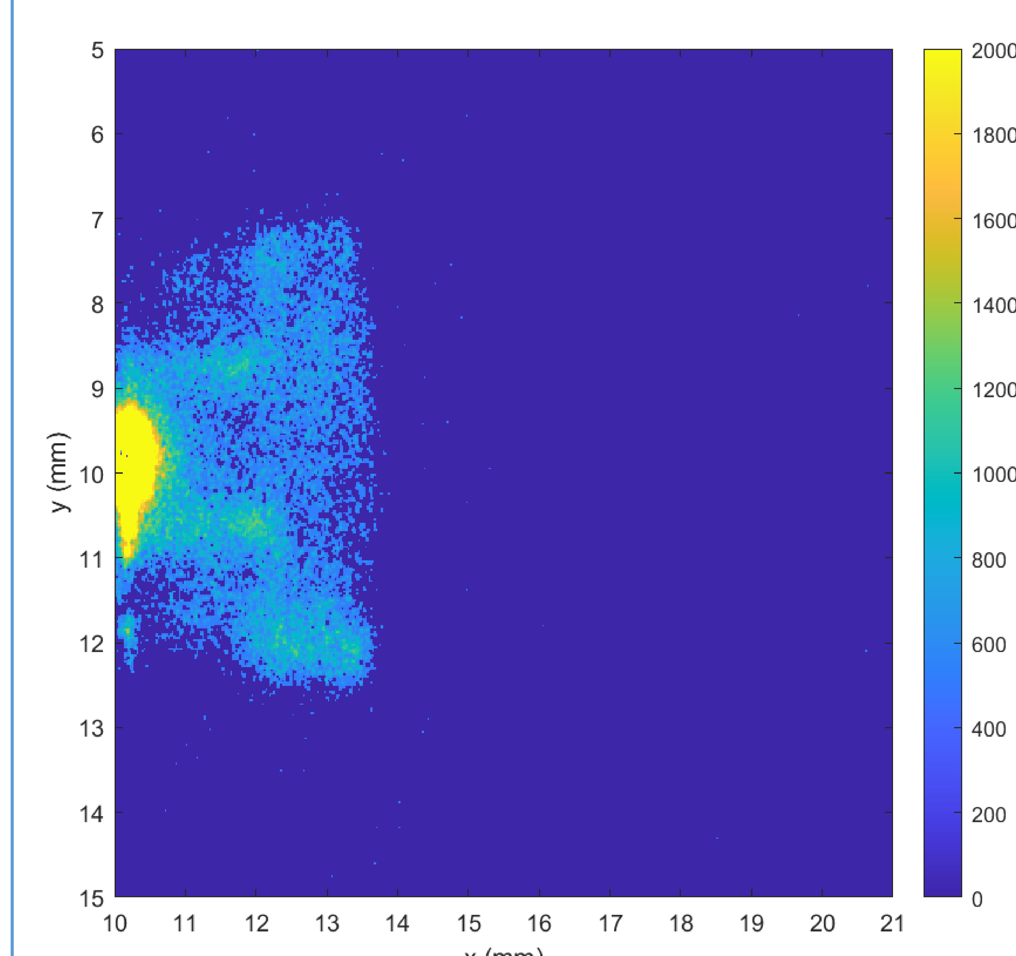

Figure 3: The expansion of the laser produced plasma across a uniform magnetic field strength of 3 T. Significant deceleration of the expansion is observed when the magnetic field is increased this high.

- In our study, β was taken to be the ratio between the ram pressure of the plasma and the magnetic pressure
- We were able to observe plasma expansion in both the diamagnetic and nondiamagnetic limits.
- Density was calculated using line integrated Stark broadening. Temperature was assumed to be 1 eV based on previous literature. Both were assumed to be uniform throughout the expansion.

Results

Table 1. Ion Larmor radius, critical expansion radius, velocity, and beta

B (T)	$r_{L\,(mm)}$	R_b (mm)	v (m/s)	β
0.25	28.3	10.8	28,300	1,045
1	1.0	7.38	8,200	1.65
3	0.5	3.7	10,300	0.35

Conclusions

- The shrinking of the critical radius perpendicular to the magnetic field because of an increase of the magnitude of the field was expected.
- For β greater than unity, the plasma effectively pushes the external magnetic field out of the volume that the expansion resides (diamagnetic limit)
- For β lower than unity, the magnetic field diffuses into the plasma relatively quickly (nondiamagnetic limit)
- Our results of β show that the plasma is in diamagnetic limit only for the magnetic fields approximately below 1 T.
- Further investigation into the diamagnetic nature of the cavity like structure is necessary.
- Striated structures are observed perpendicular and flutes are observed parallel to the magnetic field suggesting instability onset.

Acknowledgements

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