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The interaction of dense colliding plasmas with a background Magnetoplasma.

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Summary: Basic laboratory Experiments on the collision of dense plasma fireballs in a magnetized background plasma.

There are many instances of collisions of ionized material in nature ranging from flares on the sun, and astrophysical jets to man made events such as above atmospheric nuclear detonations. Astrophysical processes such as supernovae explosions and pulsar wind outflows are often associated with regions of colliding plasmas. Although we cannot create these extreme conditions in a laboratory experiment, a detailed study of interpenetrating dense plasmas can shed light on some of the processes involved. These include magnetic turbulence and the generation of intense localized magnetic fields, electron beams and ion jets, three-dimensional current systems and magnetic field line reconnection. In an ongoing basic plasma study performed in the LArge Plasma Device (LAPD) the collisions and their aftermath can be studied in great detail. Two Carbon targets immersed in a 18 m long, 60 cm diameter, magnetized Helium plasma, were simultaneously struck by lasers with intensity of approximately 1011 Watts/cm2. The plasma and the laser pulses are highly reproducible, and the experiment is repeated at 1 Hertz. Fully three dimensional data is acquired for up to a million experimental shots.

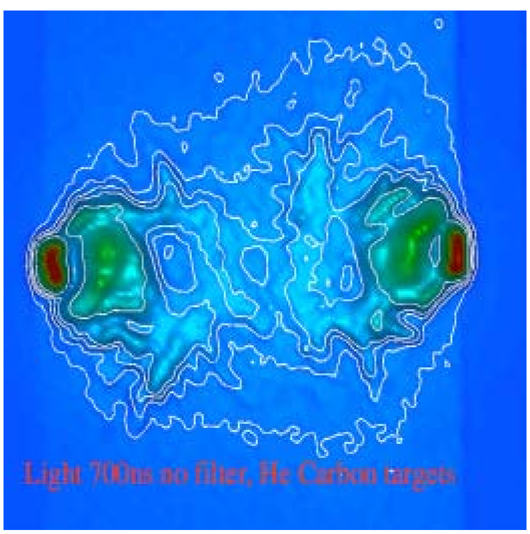

Figure 1 on the left was taken with a CCD camera and 3 nanosecond exposure 700 ns after the targets are struck. The targets are 11 cm apart (visible as two vertical dark blue bars). The background plasma is Helium and the radius of gyration of these ions in the background magnetic field (which points into the page and is 600 Gauss) is 3 mm. Two rapidly expanding plasma bubbles, in which the background magnetic field is expelled, are observed to collide. The collision generates highly structured plasmas and internal currents accompanied by turbulent localized magnetic fields. Fast electrons jet out of the plane of the photograph and radiate a variety of intense waves. The measured magnetic field lines of one of these waves, an Alfvén wave, is shown in the figure below taken 5.25 microseconds after the collision and 1 meter downstream from the collision site. Large currents flow through the center of the magnetic tornados and the “X” shaped region above the center is a magnetic reconnection site. (At a magnetic reconnection site magnetic energy is transformed into kinetic energy, flows, and heat in the background plasma.) The measured magnetic fields are fully three-dimensional. Current channels associated with the magnetic field merge and twist about each other throughout the plasma volume. In addition to Alfvén waves, lower hybrid, whistler and ion acoustic waves are observed, all on different timescales and spatial scales.

Basic plasma experiments such as this permit highly detailed space-time exploration of phenomena that are related to astrophysical situations. Dimensionless parameters such the magnetic Reynolds number, normalized expansion speed etc., can be used to scale these. (Often these numbers are estimated in astrophysics and cannot be measured). The scaling is never exact but a great deal can be learned in the laboratory, and this can serve as a guide to astronomers and plasma astrophysicists.

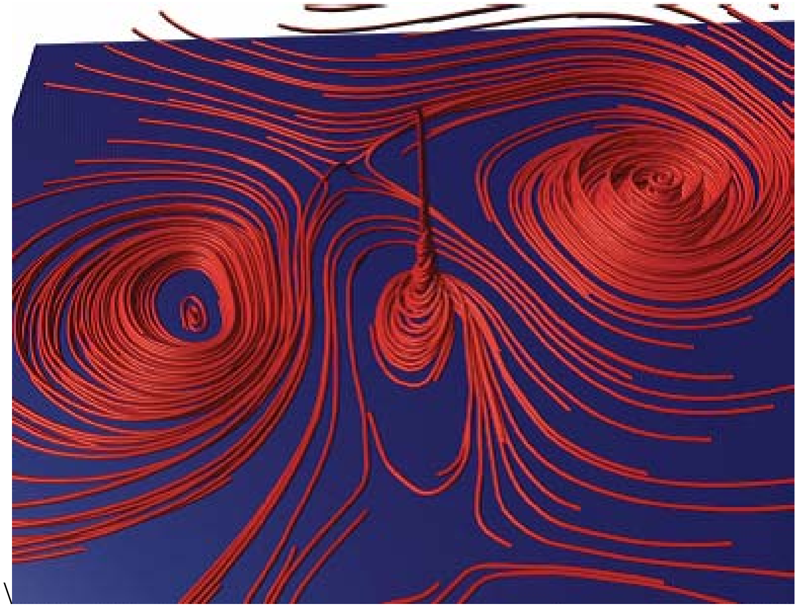

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Figure 2. Magnetic Field lines generated from the three dimensional data

Abstract: GP1.00046 Magnetic Turbulence in colliding laser produced plasmas