Studying Shock Magnetohydrodynamics with Schlieren Systems

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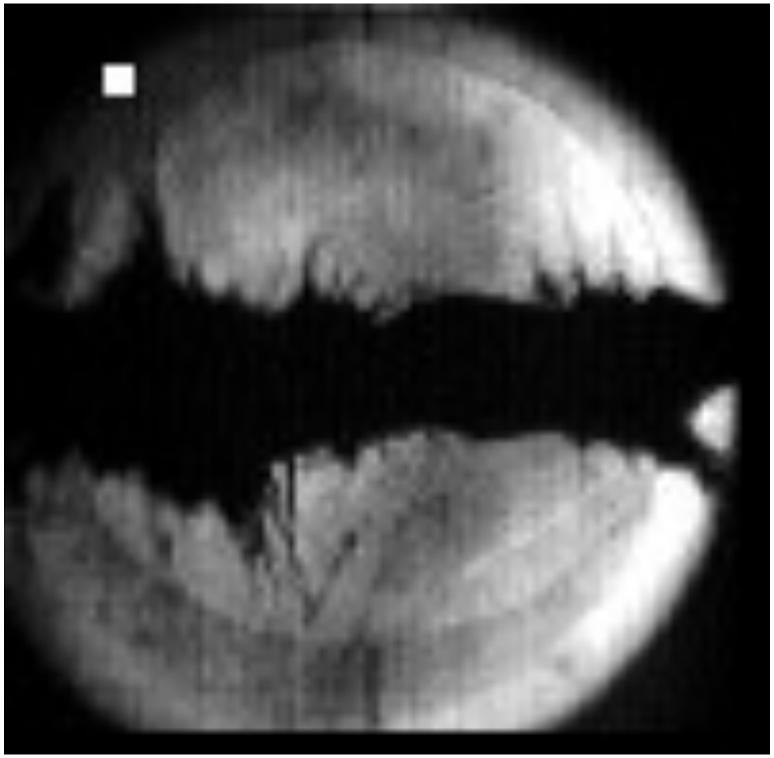
Muon Collaboration

The Problem

When multi-MW beams hit liquid targets they destroy them. The precise mechanism seems to be a Reyleigh-Taylor instability, where the hot inner liquid is forced to bore thru the cold outer layers in discrete places, causing jets of liquid.

In a magnetic field this instability would have more difficulty developing, since fast transverse motions are suppressed by eddy currents.



It may thus be desirable to look at how these jets develop in a magnetic field to understand the physics before instrumenting a full scale experiment with high density proton beams, liquid mercury and high field magnets.

Shocks in Electrolyte

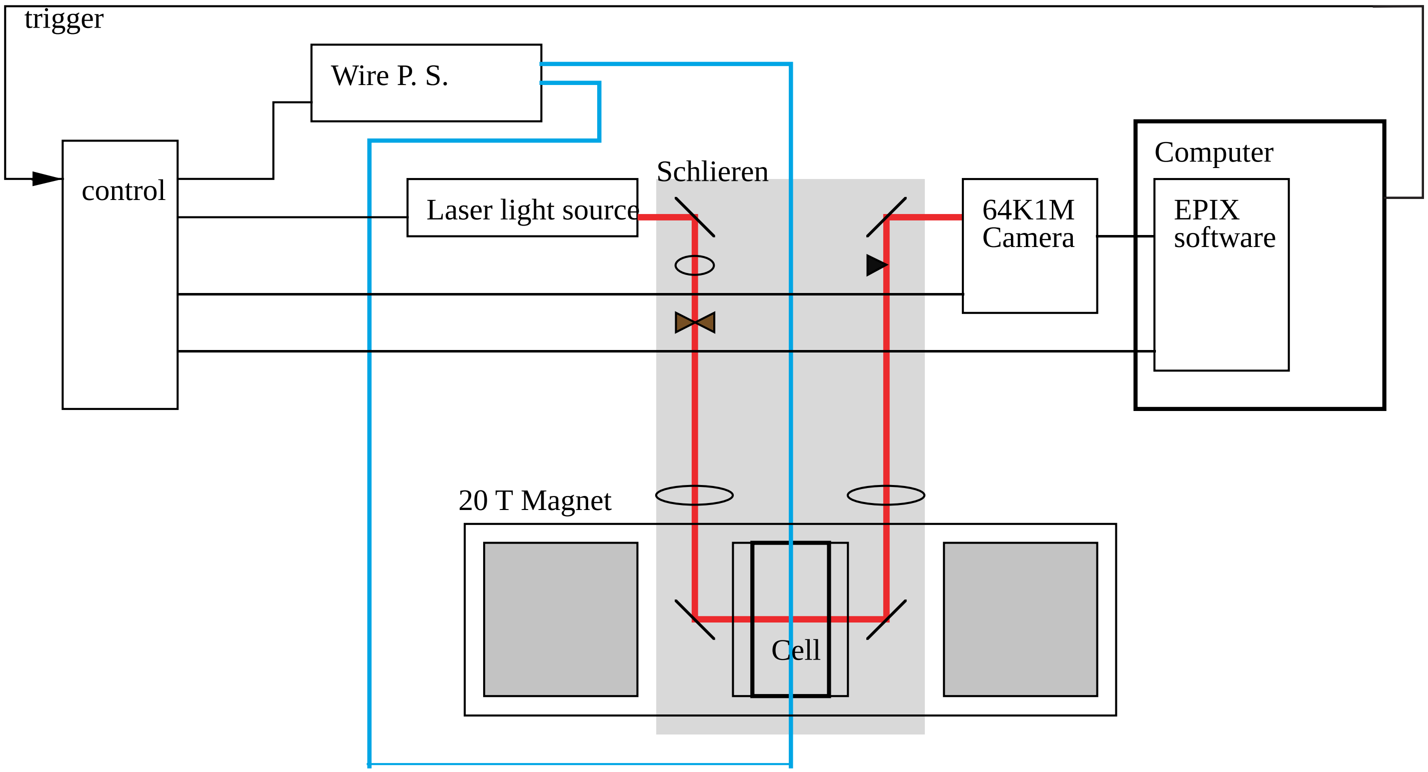
We can look at the development of cylindrically symmetric radial shocks in conducting liquids with a magnetic field by using:

Transparent electrolytes as the conducting fluid,

A 20 T, 20 cm bore magnet at the NHMFL to provide the field,

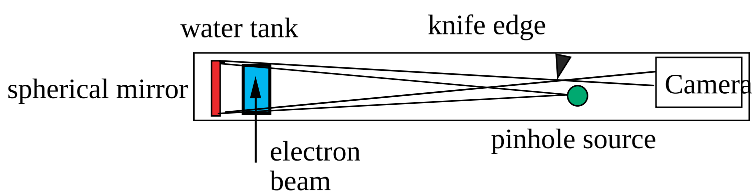
An exploding wire to provide the shocks,

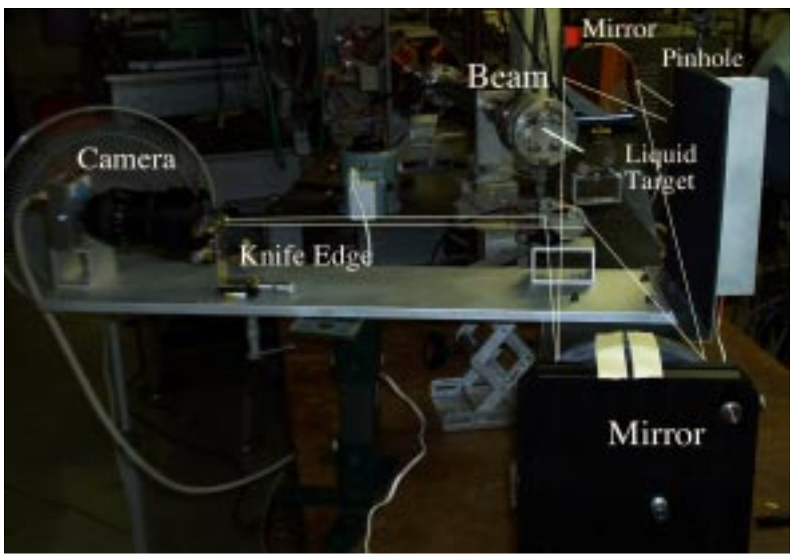
Schlieren instrumentation to describe what is happening.

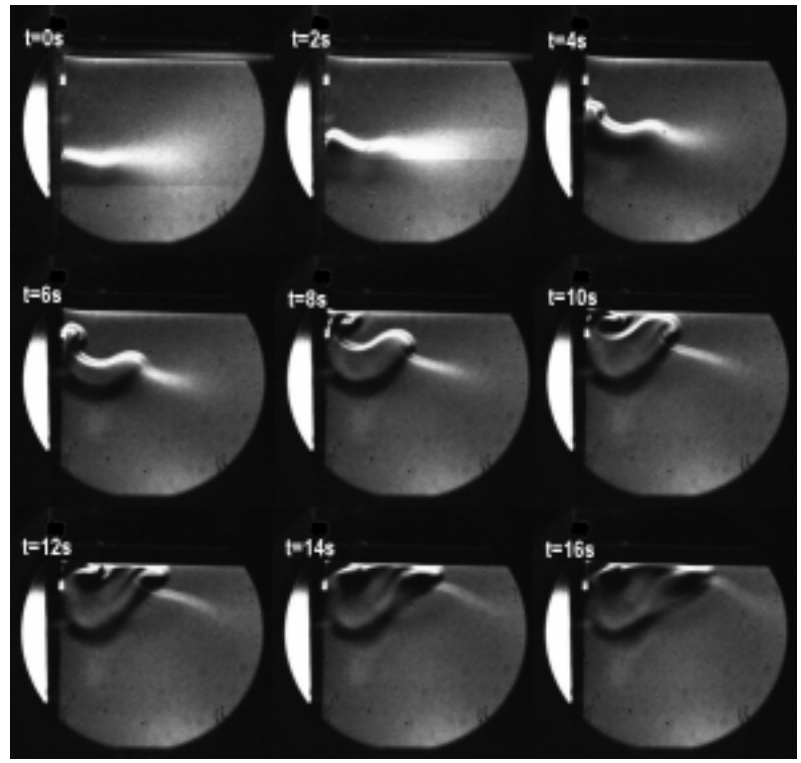


The Schlieren Method

We have been working with a system that looks at electron beam driven hydrodynamics in water. Deposited energies of 20 J give big signals, and the setup is sensitive to much smaller thermal inputs.





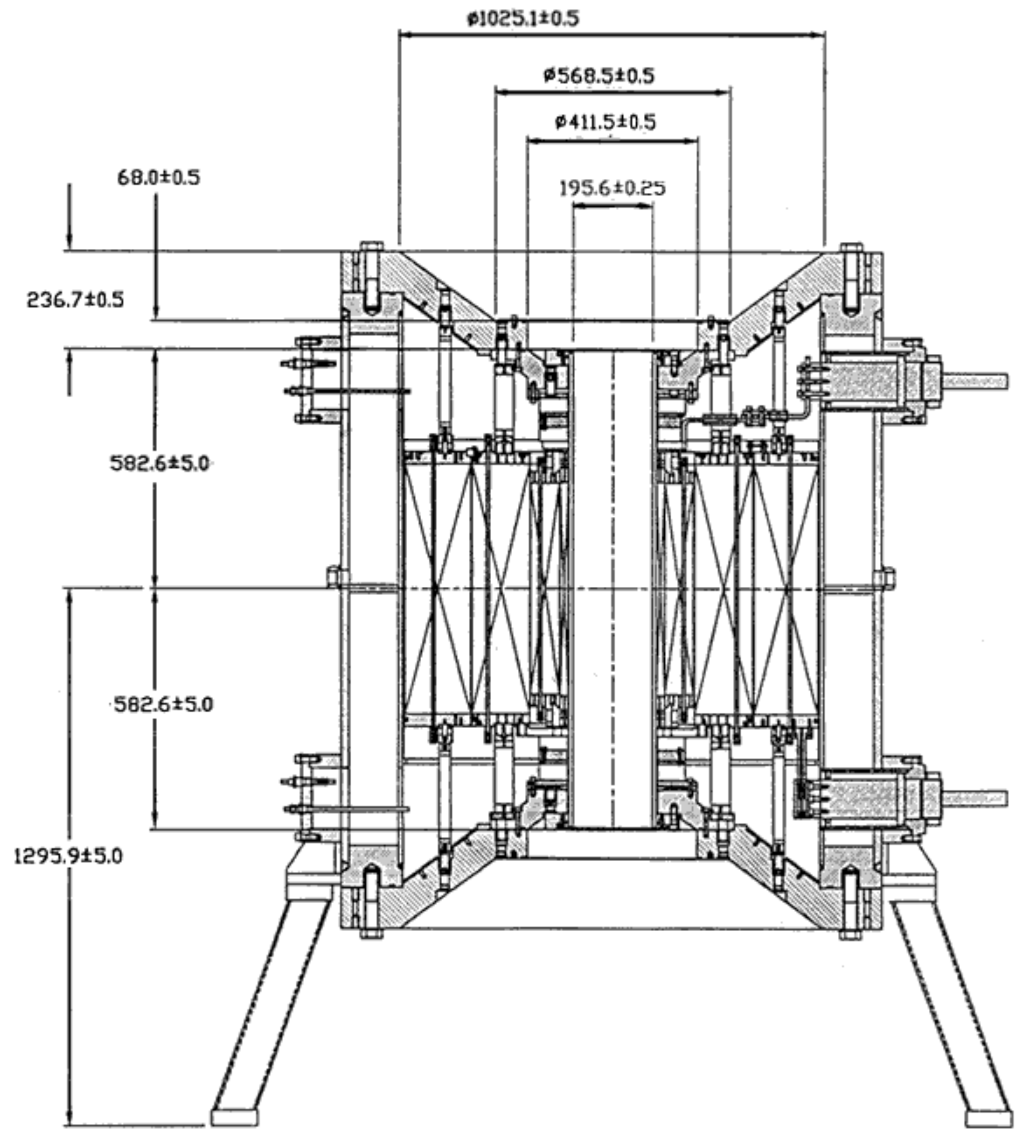


20 J of beam energy

The 20 T, 20 cm Magnet

The National High Magnetic Field Laboratory at FSU has a large normal conducting magnet that can be used in these tests.

This magnet has good access, it can be used on short notice and there are no charges to users.



The Exploding Wire System

Assume we need $I\,V\,\mathrm{d}t$ = 20 J.

We want to minimize the current, since $F = I \times B$, so we use high voltage.

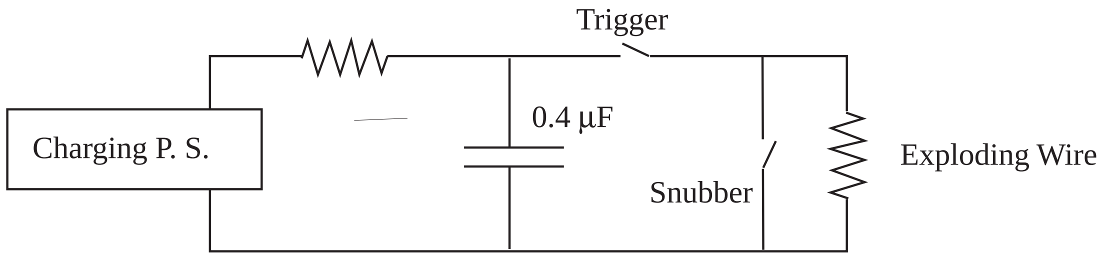
10 kV is a convenient voltage for capacitors.

Pulse length determined by (dx = 1 mm)/(v = 1500 m/s) = 0.7 μs.

Required current given by I = (20 J) / (10 kV * 0.7 sec) = 3.3 kA

Cable inductance will be low (2e-7 h/m).

The circuit might look like:



Real Explosives

We need experiments with a kick . .

Detonators give
- Radial and cylindrical shocks ?
- Reduced cost and complexity
- No Capacitor Wire P. S.
- No I x B torques
- Simpler physics.

Camera and Optics

We can use much of the E-951 optics. The AMD 64K1M seems to be more or less ideal for much of the data, since it can record frames at the rate of 1MHz. A similar laser could be used as a light source, however we would need to have the optical beam defined by a spatial filter used as a pinhole.

Area Scan Cameras

DALSA 64K1M

Our patented technology brings you frame rates up to 1 Million frames per second.

We've solved the problem of real-world interface to hyper-speed cameras.

The 64K1M digital camera opens new horizons in imaging, achieving speeds of one million frames per second—and in a small, affordable package.

The custom sensor's electronic shutter allows crisp, clear images without smearing, even at maximum frame rate. True 12-bit dynamic range preserves superior image quality, even in low light conditions.

The sensor's multiple parallel channels of image data are digitized, buffered, and output through four 12-bit wide ports at 10MHz each. Maximum readout is 15 bursts per second of 17 consecutive frames.

Sensitive to UV and near IR wavelengths, the camera offers asynchronous-mode frame capture, externally triggerable to within 250 nanoseconds.

Features

- Up to one million frames per second
- High quality images
- Flexible data readout
- Extended spectral response
- Programmable operation (via RS232)

Specifications

Resolution	240 x 240
Pixel Size	56µm x 56µm
Aperture	13.4mm x 13.4mm
Lens Mount	C-mount
Max. Line/Frame Rate	1Mfps (15 bursts/sec. of 17 frames)
Data Rate	4x10MHz
Data Format	4x12bit RS422 LVDS
Responsivity	not available at time of printing
Dynamic Range	3200:1
Nominal Gain Range	1 to 4x
Size	94x94x92mm
Mass	0.85kg
Operating Temp	10-45 C
Power Supply	+5V, -5V, +15V
Power Dissipation	30W
Regulatory Compliance	

Applications

- Ballistics
- Automotive crash testing
- Scientific research

Sensor

The 64K1M uses a custom ILT CCD. Contact SMD for more details.

Connectors

Control	SMA coax for sync
Data	2x MDR60
Power	DB15M
Other	RJ-11F for fiber link

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Summary

Ths schlieren method seems very useful at describing the hydrodynamics of liquids.

The physics of shock magnetohydrodynamics in targets seems to be complex, but may be experimentally accessible using inexpensive schlieren systems to study exploding wires in conducting electrolytes located in a magnetic field.

There are some loose ends:

- keeping the current out of the fluid with a cap power supply
- high currents in the magnet
- chemical explosives simplify the physics and may cost much less.
- what is the most conductive clear liquid?

On the other hand the experiment could help understand the phenomena involved, and improve the instrumentation required for further work.

An inexpensive experiment might produce timely, useful information for the development of high power liquid targets.