The M3 pulsed-power facility and EM launch experiments

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First Light Fusion

First Light Fusion Ltd. is a privately funded company researching ICF target designs that are driven by strong shocks from high velocity projectile impacts.

A new pulsed-power generator called M3 has been commissioned. The large current pulse from the generator is used to launch flyer plates for impact into targets.

Experiments are performed to study launch mechanisms and benchmark our hydrodynamics and MHD codes, which we use for designing fusion targets.

Electromagnetic launch at FLF

The magnetic pressure in a strip-line electrode geometry is used to launch flyer plates to high velocity. The flyer drives a shock into a target upon impact.

To achieve projectile velocities >10 km/s, FLF has developed electromagnetic launch capabilities over the last 3 years on smaller low inductance machines:

M1: Mega-Amp
- Test bed for switches, diagnostics and EM launch.
- 28 kJ stored at 60 kV.
- 1 MA in ~1 μs rise time.

M2: CEPAGE
- Leased from ITHPP in January 2017.
- 110 kJ at 80 kV.
- 3.5 MA peak current in ~500ns rise time.

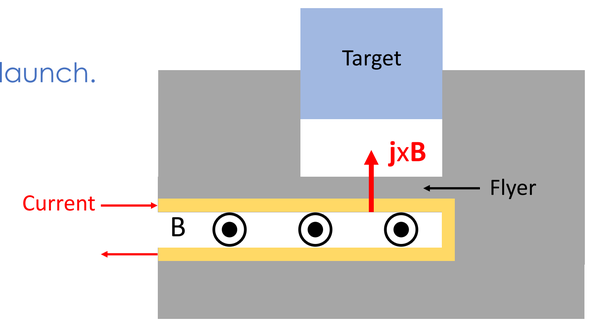


Fig. 1: Schematic of a flyer plate experiment.

M3: a low inductance pulsed power driver

New machine built to demonstrate fusion at FLF.

125 μF bipolar capacitor discharge. +/- 100 kV.

92 multi-channel ball gap switches.

Low inductance parallel plate transmission lines with multilayer Mylar insulation.

2.5 MJ of stored energy at full charge.

8 MA in 1.5 μs through a flyer plate load.

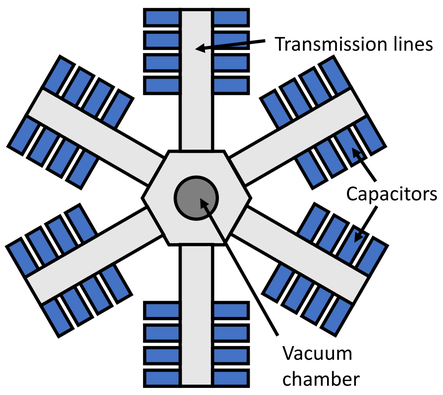


Fig. 2: Top-down schematic of M3.

Fig. 3: Photograph of completed M3.

Machine and target diagnostics on M3

Machine
- 1550 nm fibre-based Faraday rotation to measure the current
- 96 B-dot probes monitoring each switch
- 120 V-dot probes monitoring the switches and transmission lines

Load / target
- VISAR – 1D streaked and 2D imaging for measuring flyer velocity and planarity
- Optical backlighting and self-emission imaging
- PMT-coupled plastic scintillators to detect neutrons

Flyer plate experiments

The first flyer plate experiments have been performed on M3. A typical experimental setup is shown in Figure 4.

The velocity profile of the flyer plate is measured with 1D streaked VISAR. Example data from an Al flyer experiment are shown in Figures 5 and 6.

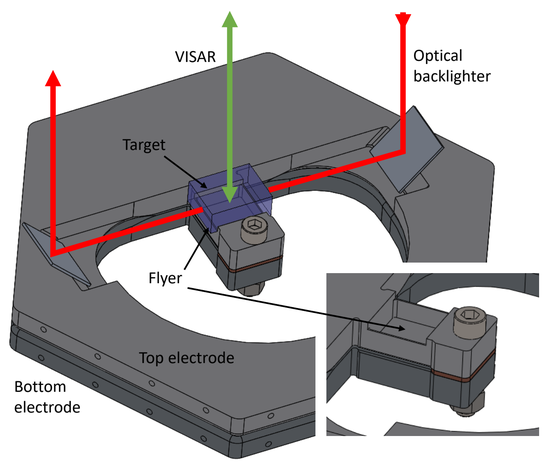


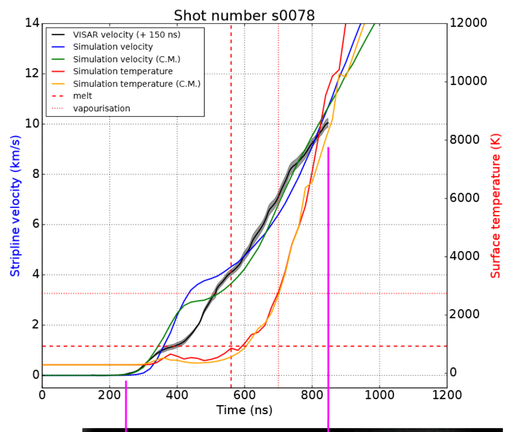
Fig. 4: Flyer plate experimental setup.

The experimental data are compared to simulations from our 3D resistive MHD code 'B'. See Figure 5.

The simulations can be driven by a circuit model, or by a measured current profile. This allows us to assess any current losses in the load region. Agreement between experiment and simulation is very good up to the point where we lose VISAR reflectivity.

The simulations inform us about the density and temperature of the flyer, which are challenging to measure directly.

Fig. 5: Comparison of experimental and simulated flyer velocity profiles



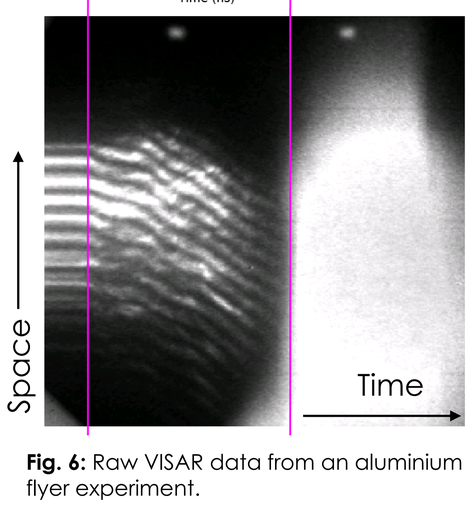


Fig. 6: Raw VISAR data from an aluminium flyer experiment.

The flyer impacts a clear plastic target (as shown in Figure 1 and 4) and drives a shock through it. By optically backlighting from the side, we can measure the shock velocity and infer the shock pressure. This provides us with an additional experimental measure of the integrated flyer performance, and a further data point for comparison to simulations. Data from an impact experiment are shown in Figure 7.

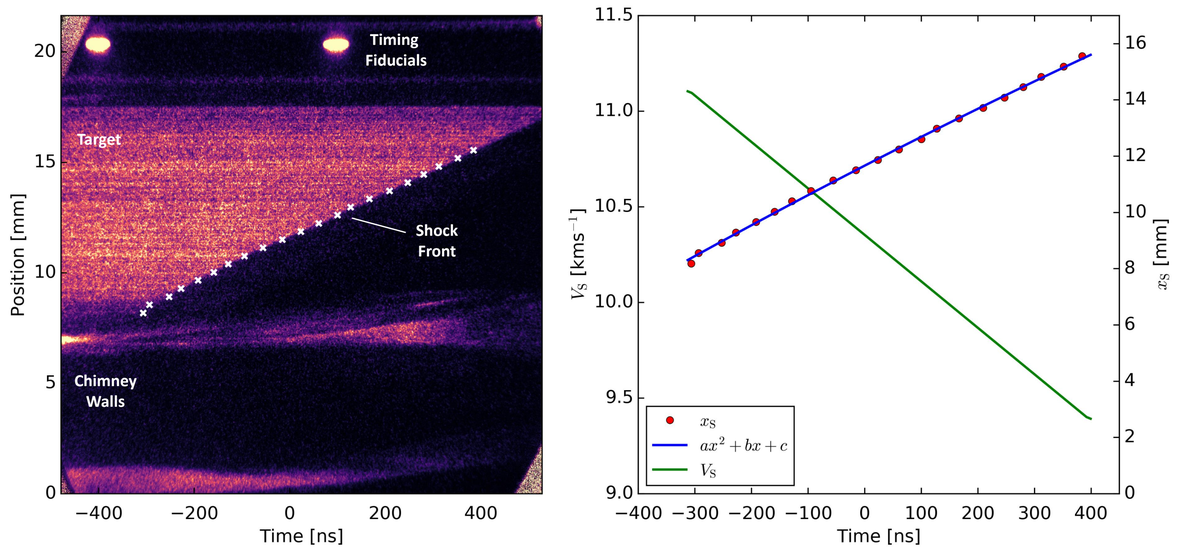


Fig. 7: Streaked optical radiography data of a flyer drive shock in a PMMA target (left). The shock front position is tracked (white crosses) as it traverses up through the target. A fit to the time-position data (right plot) allows the shock velocity to be inferred (green trace). We observe a peak shock velocity of around 11 km/s decaying to 9.5 km/s.

Summary and future work

- We have designed, built and commissioned a 2.5 MJ pulsed power facility for performing EM launch and target fusion experiments
- The facility is equipped with a range of machine and experimental diagnostics
- Initial experiments have demonstrated flyer plate velocities of up to 10 km/s

- Future work:
  - Further load design studies
  - EM launch flyer optimisation
  - Fusion target shots

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