first light

64th Annual Meeting APS, Division of Plasma Physics, Spokane, Washington October 17-21, 2022

First Light Fusion Facilities and Collaboration Efforts with Academia

Luis Sebastian Caballero Bendixsen on behalf of the First Light Fusion Team and Collaborators

lscb@firstlightfusion.com

First Light Fusion

- Privately funded fusion research company based in Oxfordshire, UK
- Spin out of Oxford University in 2011
- Currently we have an 80+ team, and growing (check our website)
- Research and development relevant to Inertial Confinement Fusion (ICF) using hypervelocity projectile-driven impact ICF
- Interested in High Energy Density Physics

In early 2022 we produced fusion in the lab in Oxford, demonstrating projectile fusion works – see www.firstlightfusion.com for media articles and our own whitepapers.

Projectile Fusion

a new method for inertial fusion

Two-Stage
Light Gas Gun

projectile
10 – 30 mm, e.g. Al
10 – 20 km/s
>100 GPa (1 Mbar) pressure on impact

fuel capsule
DT gas-filled
velocities 100+ km/s
stagnation pressures 10 – 100 TPa (0.1 – 1 Gbar)

Pulsed Power Driver
(Electromagnetic Launch)

amplifier
shock compression in time and space
~1 TPa amplified pressure (10 Mbar)
creates convergence
there is an efficiency

First Light Fusion Capabilities

Numerical Capabilities

- **High Performance Computing (HPC):**
  - New comprises of 174 Dell PowerEdge R6525 servers, using dual AMD EPYC 7402 processors 2.8-3.4 GHz; **8352 cores** each with 256 GB of RAM
    - Old: **2016 cores**, each with 256 GB of RAM
  - 1.8 PB of storage
- Numerical Physics: **inhouse** development of two simulation
  - **Hytrac** (**multi-material hydro code with front tracking and AMR**)
  - **B2** (**parallel multi-material resistive MHD**)
- In addition to the above we have simulation tools
  - COMSOL Multiphysics
  - A variety of circuit simulation tools including Xyce, Screamer

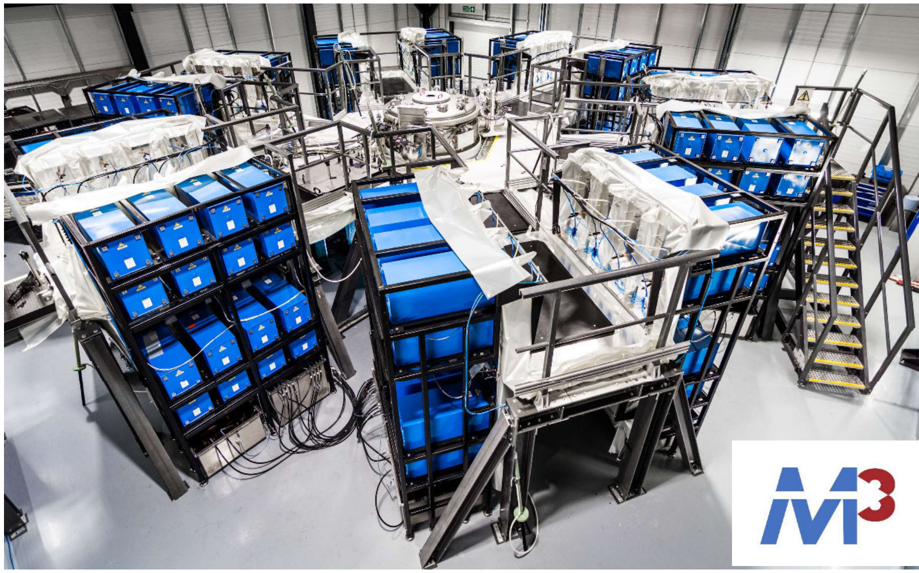
Experimental Capabilities: Gas Guns

- A pair of two-stage light gas gun
- Projectile velocities reaching up to 7 km/s

	Small Gun	Big Gun
Length [m]	7.5	20
Projectile Diameter [mm]	12.5	38
Projectile Weight [g]	1.5	100

Experimental Capabilities: Pulsed Power Drivers

- A pair of low inductance capacitor discharge pulsed power driver.
- **Used mainly for high velocity electromagnetic launch applications**
- **CEPAGE:** operates regularly at 80 kV, **3.5 MA peak current**, in **600ns**.
- **M3: Designed and built in-house** to 2.5MJ, +/-100kV, 14MA, 1.9us.
    - **Operates regularly at +/- 70kV, 8.2MA peak current in 1.9us.**
    - Launch Flyer Plate to measured velocities **in excess of 14 km/s.**
    - Shocks at impact on PMMA produced **pressures of more than 100 GPa**



Collaboration Programme at First Light Fusion

Students program at First Light

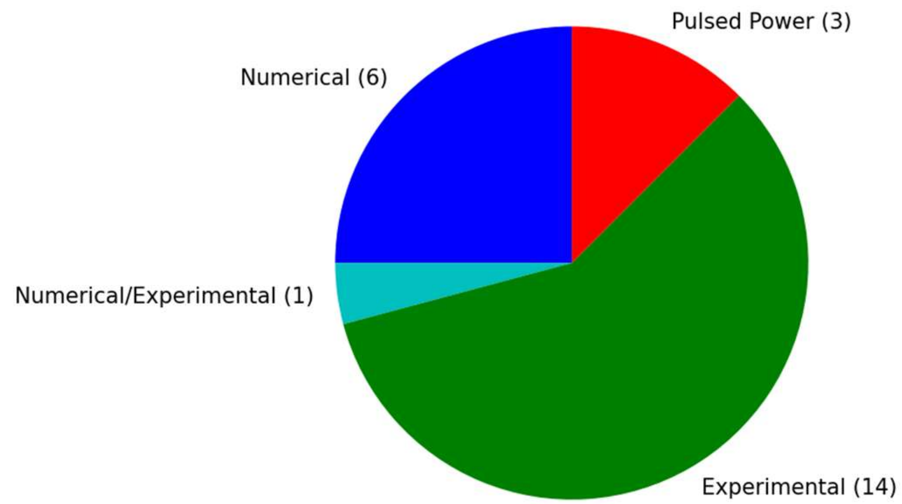
External Users at First Light

Student Program

- FLF has **invested** more than **1M£** in this programme.
- We have **hosted 24 students** over the years. They have work **mainly on their Master or Undergraduate projects**, in addition to work experience placements
- **25% of them have successfully applied for a permanent position at FLF**
- **5 of them have started a PhD program** at places including Oxford University, Imperial College London amongst others
- We have **sponsored 13 PhD students** (4 internal and 9 external) 38.5% have graduated to date.

Students Projects included:

- Development of an in chamber neutron detector for use on the BFG (Experimental)
- Design, implementation and characterization of an X-ray spectrometer on a DPF (Experimental)
- *Extending Hytrac's current method of manufactured solutions (MMS) code verification capabilities to curvilinear coordinate systems (Numerical)*
- Verification of radiation transport models (Numerical)
- High Voltage Surface breakdown studies (Pulsed Power)



Laboratory surrogates for studying supernova shock and supernova remnant interactions with dense interstellar clouds.

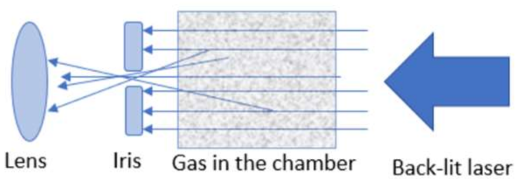
Student: Yuyao Wang, University of York

Supervised by: Nigel Woolsey (University of York), Tim Ringrose (FLF), Nathan Joiner (FLF)

UNIVERSITY of York

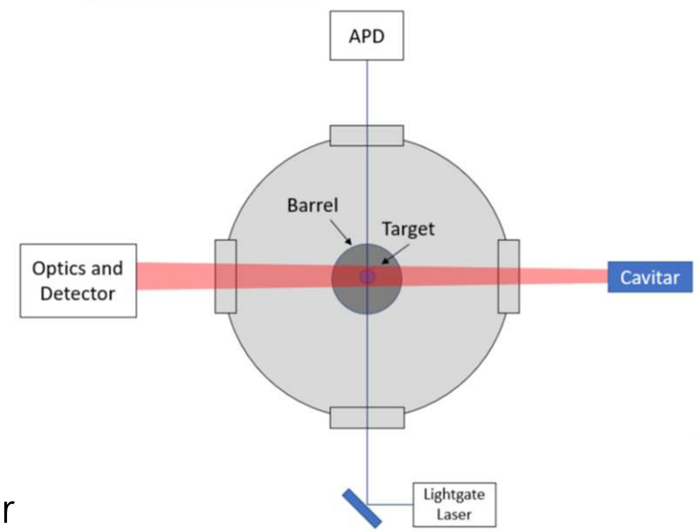
External User Project :

- In **astrophysics** turbulent mixing in supernova shock-cloud interactions plays important role in triggered star formation.
- In **ICF** material mixing between ablative layer and fuel prevents target ignition
- **Replicate supernova shock-cloud interactions on the laboratory scale** using FLF's 7.5m two-stage light gas gun to drive the shock to interact with a low-Z material target in plasmas.



Semi-Schlieren Imaging: Reduce collimated light through the chamber to observe gas structure clearer

- **Explore new conditions different from Laser experiments.**
- Develop advanced diagnostic technique.
- Benchmark Astro Code
- Characterise the shock driven by the gas gun
- Shock wave interactions with targets with different geometry (Block(test), Sphere, Hollowed Cylinder, wedge).
- Investigate the effect of Divergent nozzle



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Experimental results and future work

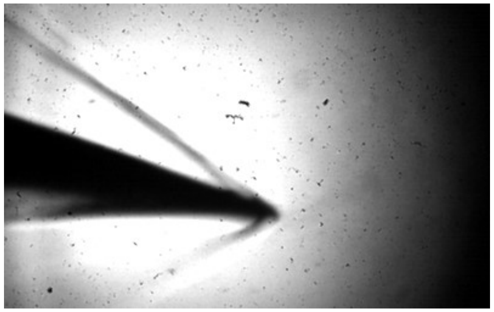
Next Experiment:

- Try boosting Shock speed by changing the gas gun configurations (~petal valve depth, propellant load etc.)
- Try improving the resolution of data.
- Explore other Nozzle designs
- Try X-pinch diagnostic

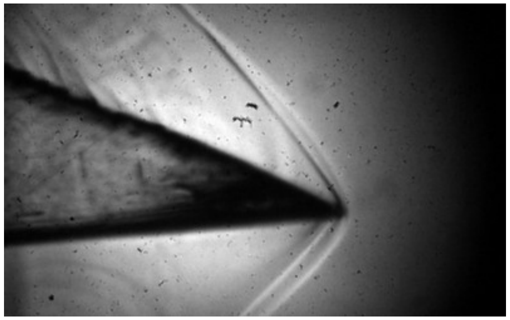
Future plan:

- Ionise the gas in the chamber/launch tube
- Introduce Magnetic field
- X-ray Phase contrast imaging/Coherence imaging

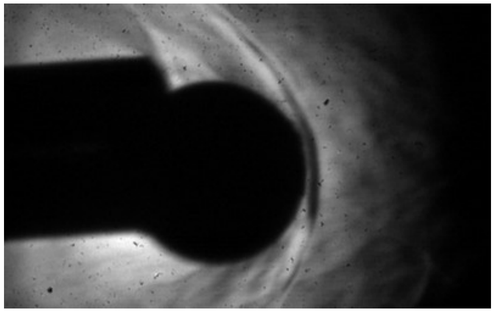
Attached oblique shock without(left) and with (Right) Nozzle



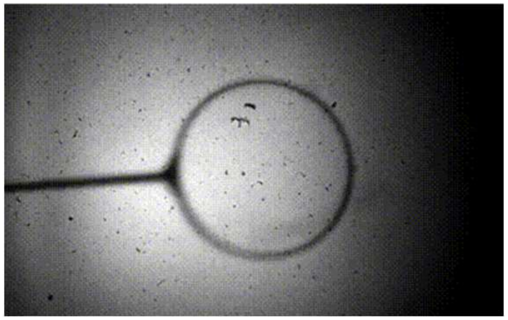
Normal Shock speed 7km/s
Wedge Angle = 25.7
Shock Angle = 47.2
M = 2.8
T1/T0 = 1.73
p1/p0 = 4.76



Normal Shock speed 6.2km/s
Wedge Angle = 30
Shock Angle = 58.4
M = 2.6
T1/T0 = 1.9
p1/p0 = 5.7



Bow shock in front of the spherical target



Collapse of Cylindrical target
Normal shock front 4.8±0.4 km/s
With Nozzle

Pulsed Power Driven Convergent Shock Waves

External Team: Simon Bland, Jergus Strucka, Savva P Theocharous, David Yanuka, Yifan Yao, Jeremy Chittenden

Details presented NP11:71 in a poster

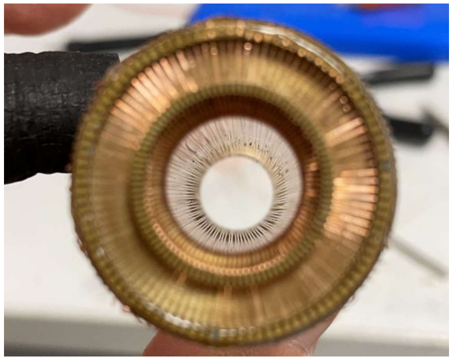
Imperial College London

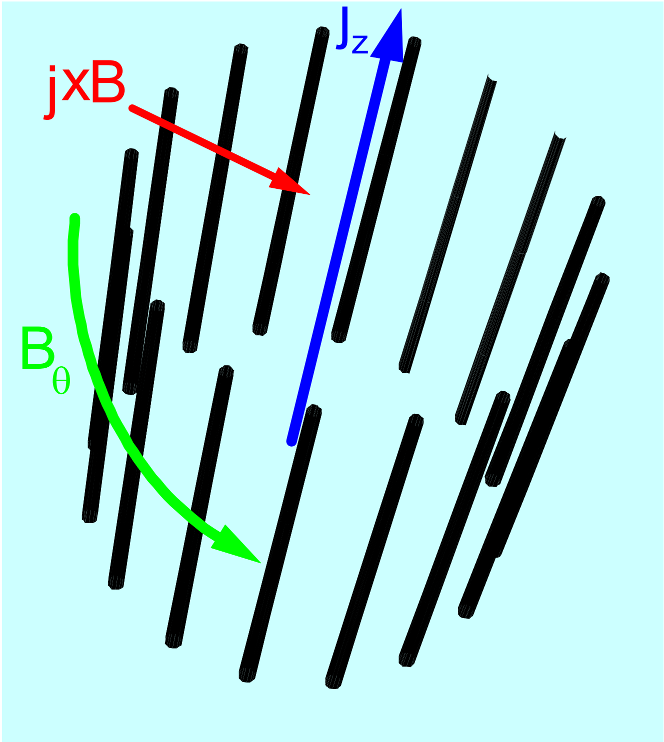
Pulsed Power Driven Convergent Shock Waves (1/2)

Imperial College London

- A **cylindrical array of wires in water**, mass matched to generator
- Each **wire will explode ohmically, creating cylindrical shockwave** – shockwaves then merge
- **Convergent shockwave heads towards axis**, any perturbations on shockwave rapidly smooth
- **Close to axis velocity should rapidly increase and very high pressures result**

Typically use laser probing along axis - but measurements of on axis conditions is difficult



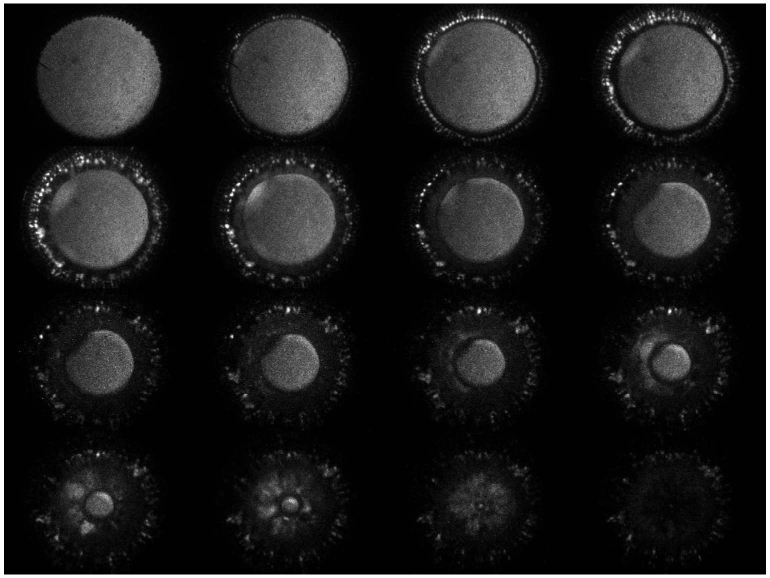


Wires too heavy to move via JXB but explode resistively

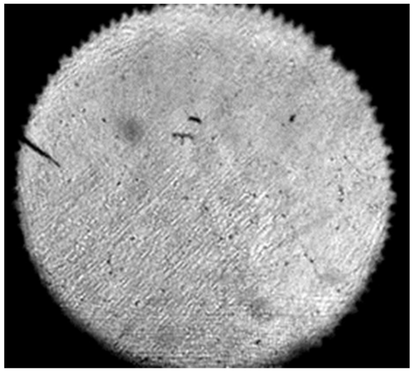
NOT A Z-PINCH

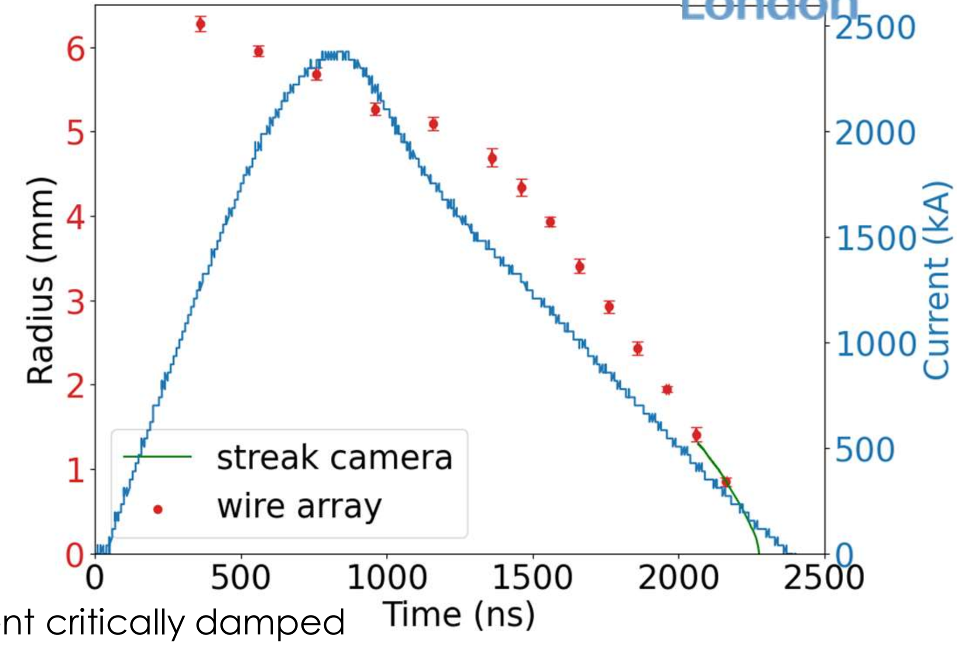
Pulsed Power Driven Convergent Shock Waves (2/2)

Imperial College London



16 frame image of 100 x 200µm copper wires on 13mm diameter 50mm long, 100ns interframe





- Current critically damped
- Deposited energy was 53kJ, 45kJ during explosion
- Highly uniform implosion, emission observed from behind shock
- Velocity of shock from exploded wires now ~5kms^{-1} prior to convergence (cf 3.5kms^{-1} at 600kA)
- In last mm, velocity measured by streak rapidly increases to 25kms^{-1} But is it real?
- Likely >3MBar on axis. Now looking to repeat shots with better diagnostics

At present we are extending our collaboration. If you are interested please contact us.

Main contacts:

Dr. Jonathan Skidmore (**jonathan.skidmore@firstlightfusion.com**)

Dr. Francisco Suzuki-Vidal (**Francisco.Suzuki-Vidal@firstlightfusion.com**)

first light – thank you for your attention

Other presentations from my FLF colleagues in the conference:

- Francisco Suzuki-Vidal: rotating plasmas on the OMEGA laser (TO05.00013)
- James Allison: A Bayesian approach to neutron spectra from projectile fusion (GO04:0010)
- Rosie Barker: Experimental measurement of planarity of a 1 TPa shock (TP11.00075)
- Emilio Escauriza: Ablation of a solid obstacle with a radiative shock driven by gas gun plate impact (TO05.00013)
- Zoran Pesic: Neutron emission from light-gas gun projectile driven targets (BP11.00132)
- Joshua Read: Pressure measurement of an amplified shock using VISAR (TP11.00076)

Please get in touch: **lscb@firstlightfusion.com**

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Thank you for your attention
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