first light

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Ablation of a solid obstacle with a radiative shock driven by gas gun plate impact

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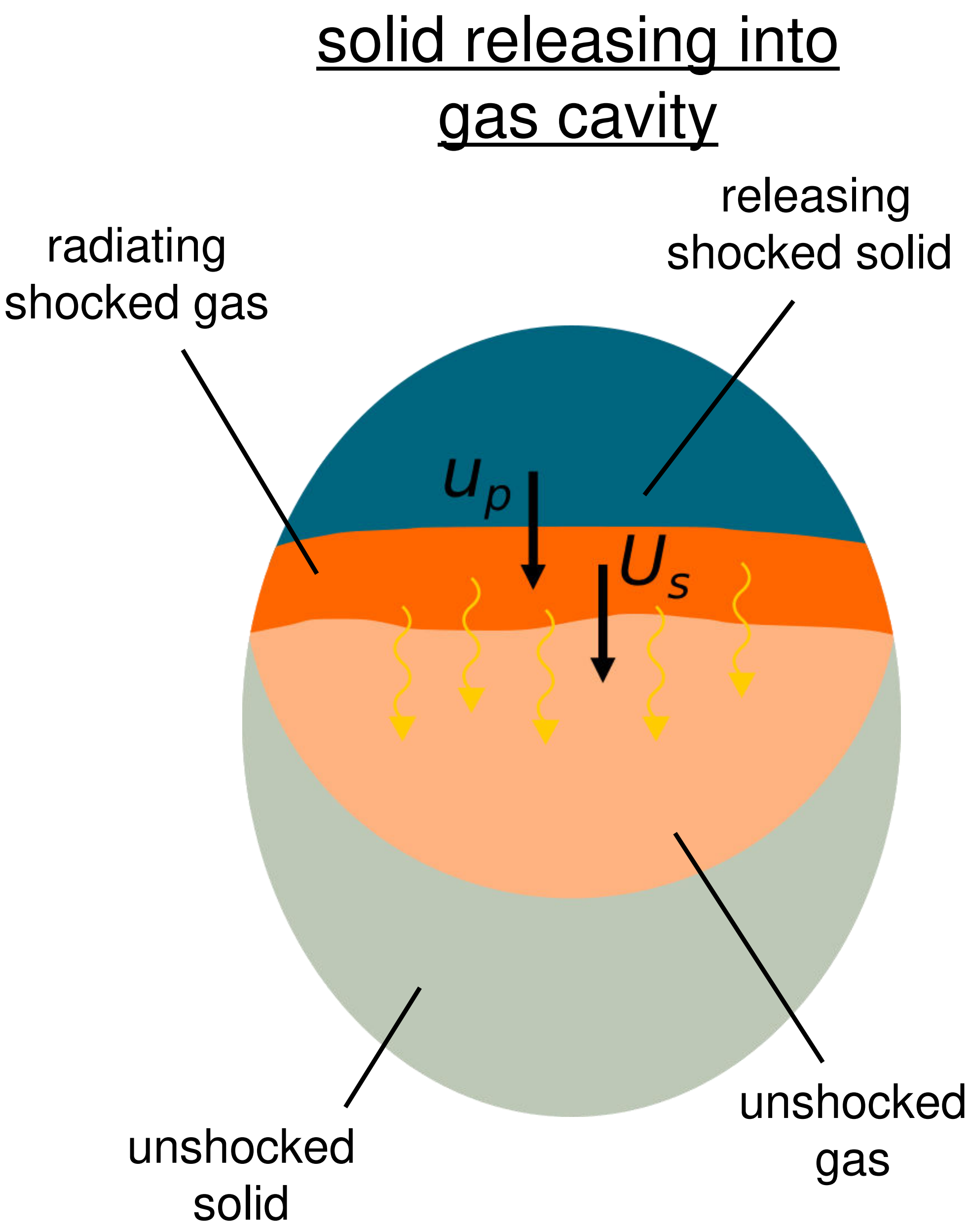
First Light Fusion

- I work as an experimental scientist at First Light Fusion
- Our founder and CEO Nicholas Hawker researched shock-driven cavity collapse for his PhD at Oxford
- He then founded the company based on the idea of ‘projectile fusion’
- In spring of this year we announced the fusion result (10 years in the making!)
- The goal now is to achieve gain
- To this end, lots of fundamental science research is being done at First Light Fusion

Experiment motivation

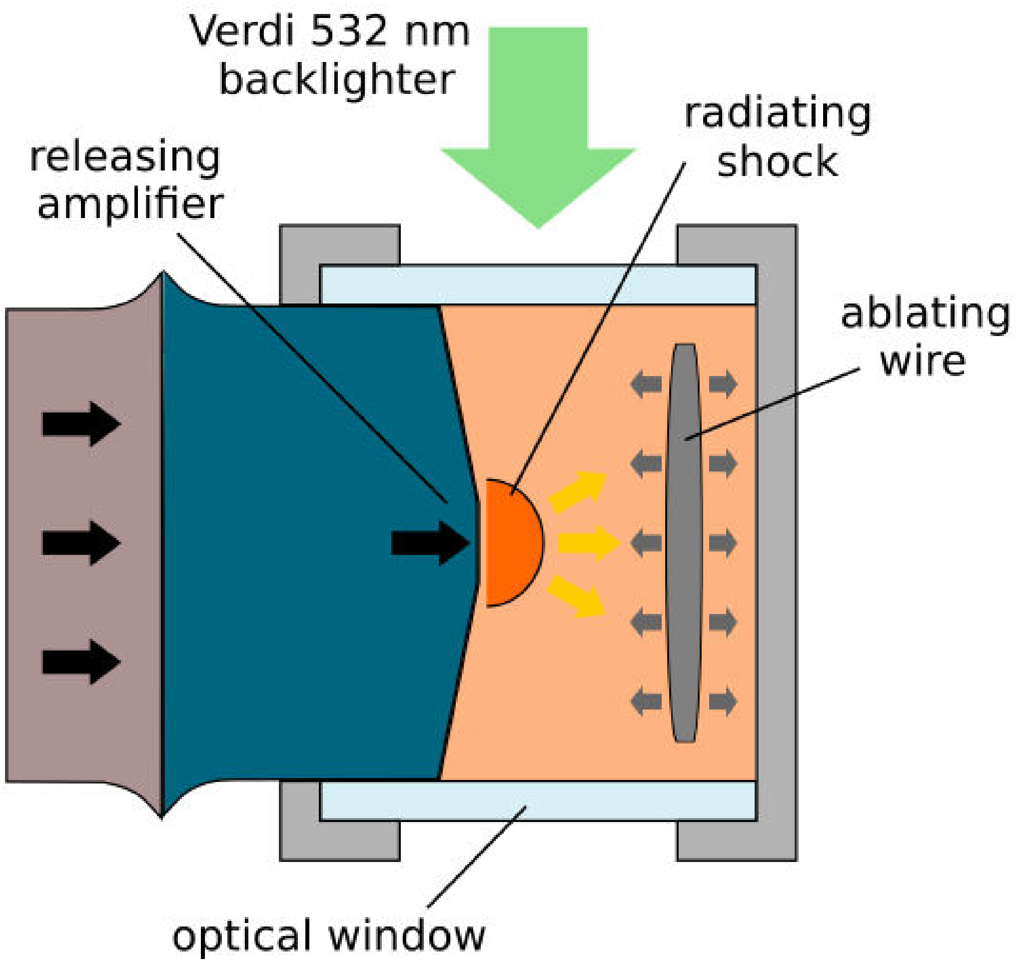
- By amplifying the intensity of a projectile impact, we generate a confined plasma
- A shock moves through the DD fuel inside a cavity
- The walls of this cavity are irradiated by the shock front
- We are thus motivated to understand two key aspects of target performance:

  1) Shock propagation in the fuel
  2) Effect of radiative expansion on the cell walls



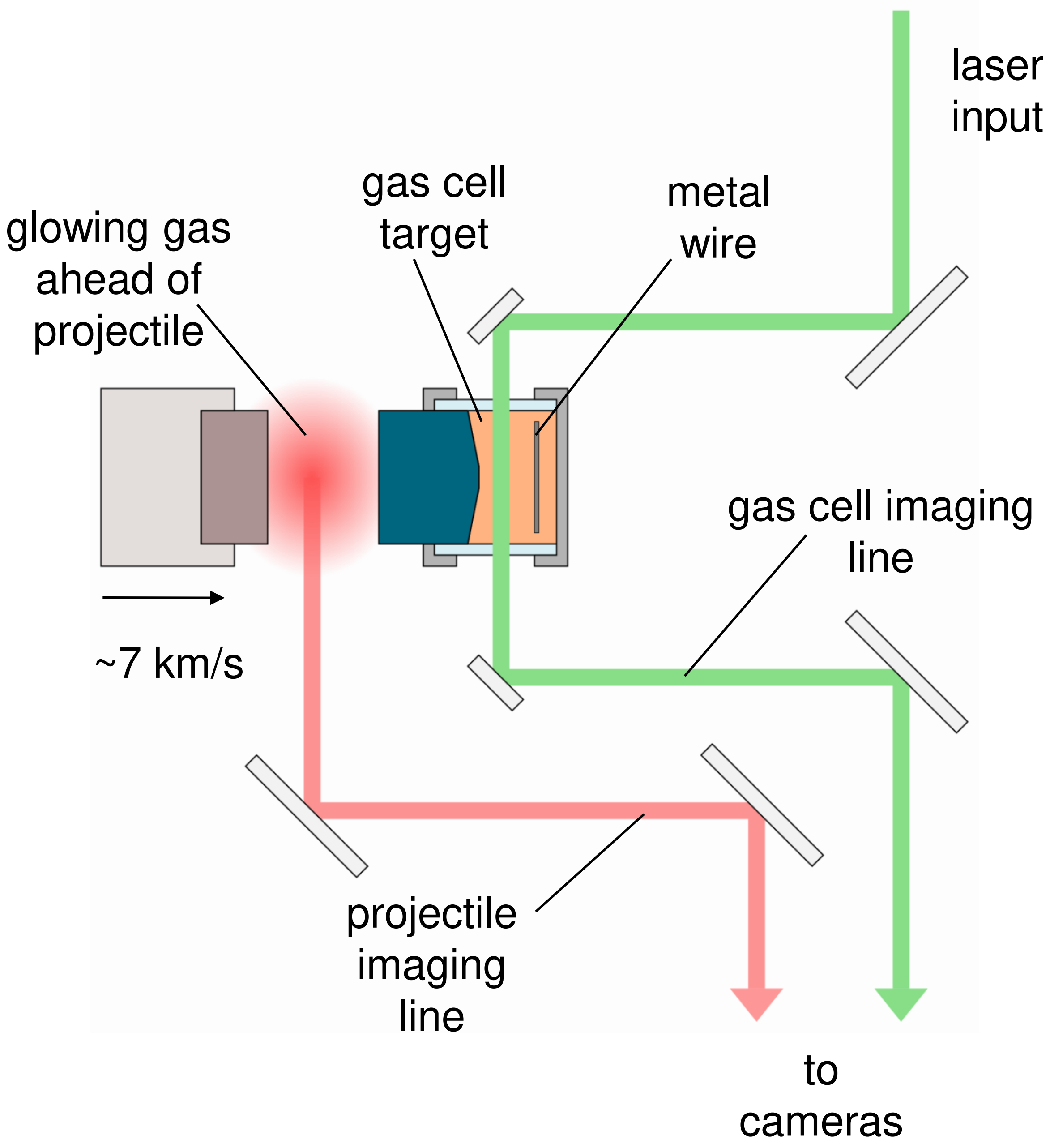
Experiment design

- Target designed to model the shock irradiating a solid obstacle
- Gas cell attached to the amplifier
- Wire placed ahead of amplifier exit to act as solid obstacle
- Green laser backlighter to capture:
  - Shock front
  - Wire expansion



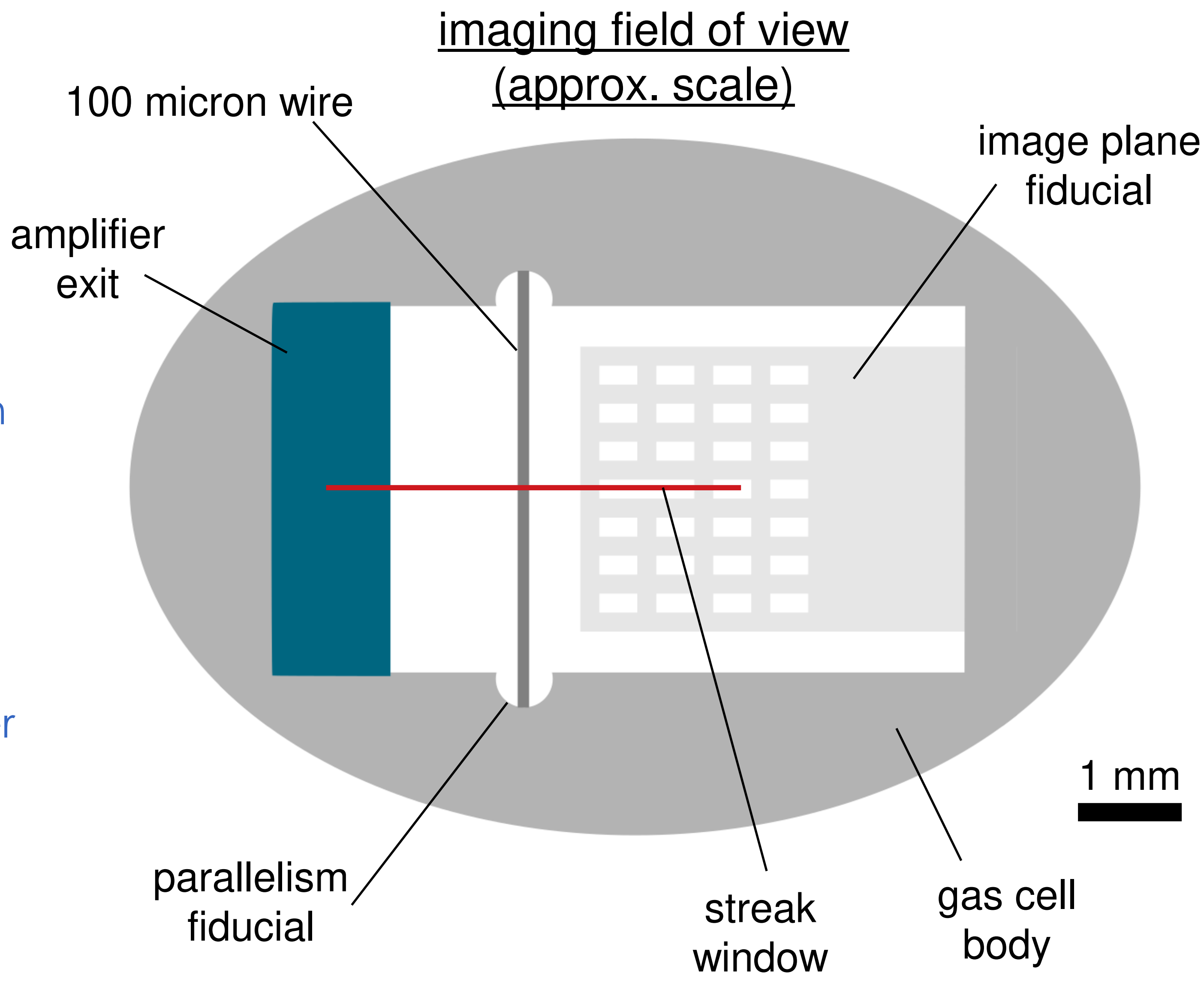
Experiment design

- Target impacted with our 38 mm projectile 2SLGG (the 'BFG')
- Sabot with tungsten flyer travels at approximately 7 km/s
- Diagnostics fielded:
  - 2x Shimadzu HPV-X2 cameras (100 ns inter-frame min.):
    - Projectile beamline
    - Gas cell beamline
  - 2x ROSS-2000 Sydor streak cameras (variable window) to capture gas cell beamline



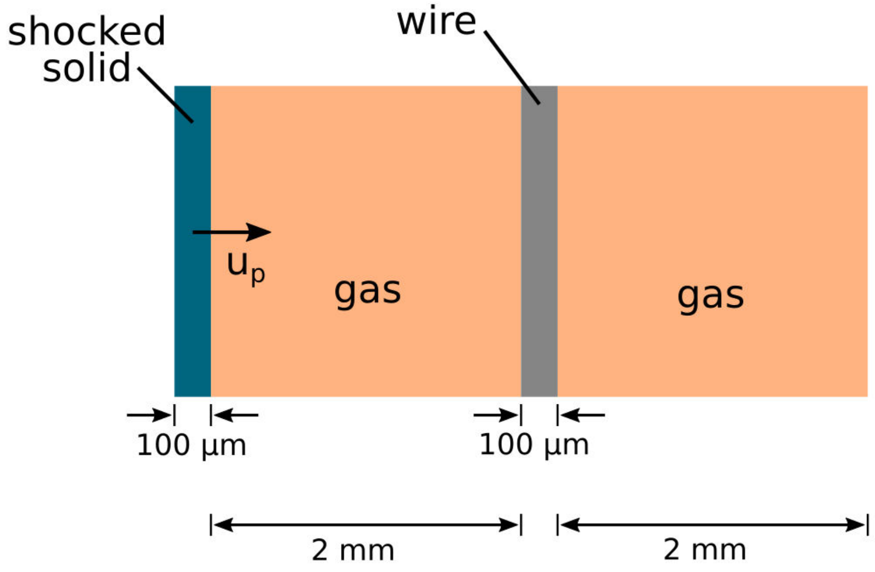
Imaging fiducials

- Two types of fiducials used for imaging
  - Image plane fiducial
    - Laser-cut grid from 100 micron aluminium foil
    - Middle grid double width to identify centre streak line
  - Parallelism fiducial
    - Two circular grooves cut either side of the gas cell windows
    - Lined up in the FOV to ensure line of sight is parallel

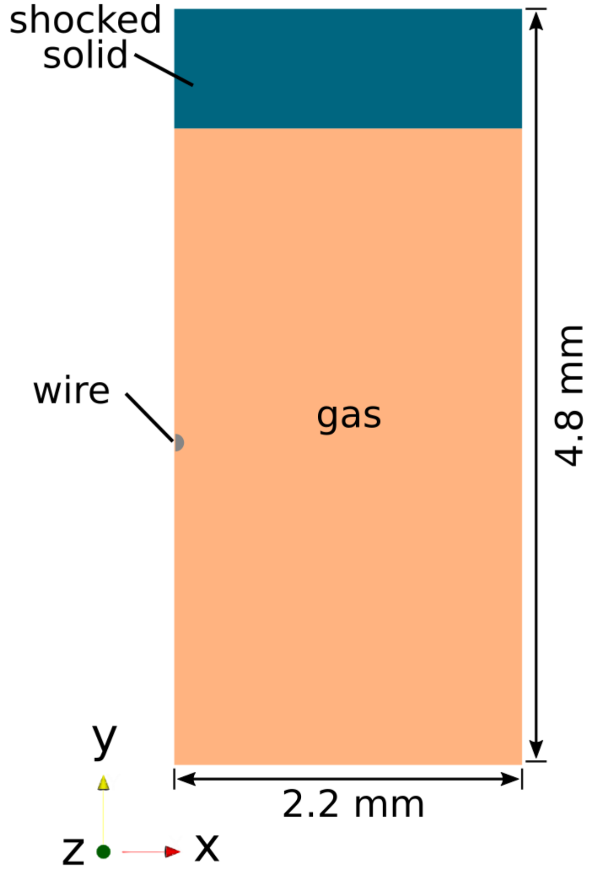


Simulations

- 1D in Helios (Prism Computational Sciences Inc.)

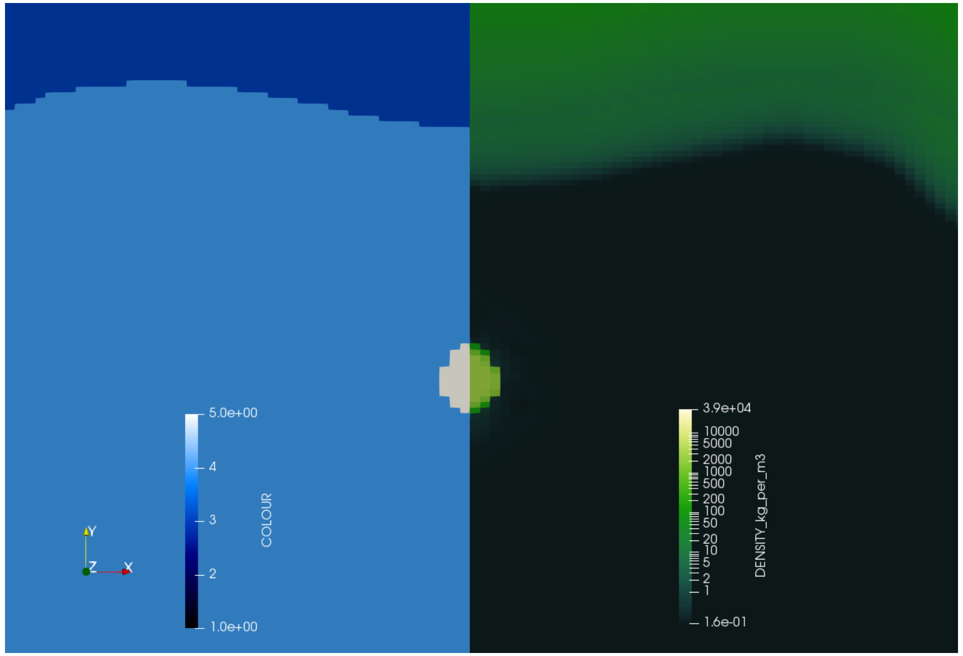


- 2D in Hytrac (in-house code)
  - Front tracking Euler-Lagrangian



Grid resolution effects in 2D

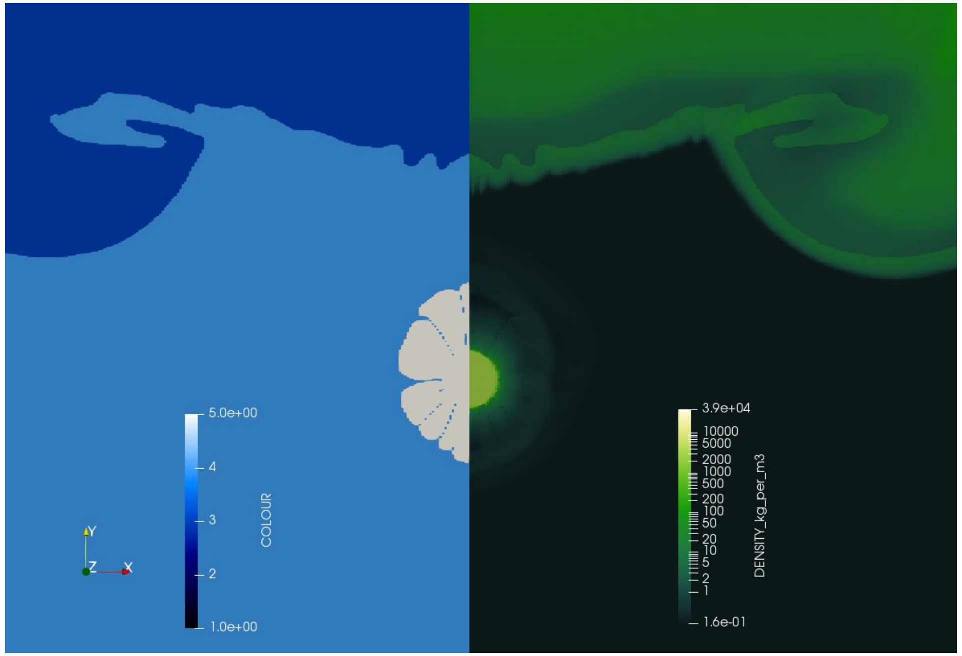
- 22.0 μm X 10.1 μm



material ID

density
[1e-1:3.9e4 kg/m^3]

- 5.5 μm X 2.7 μm (4x resolution)

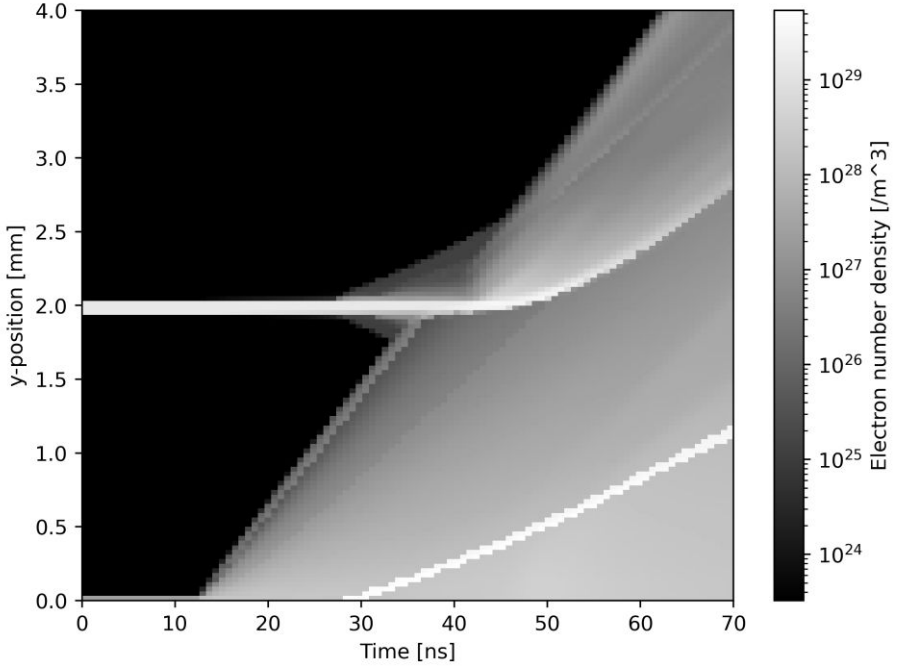


material ID

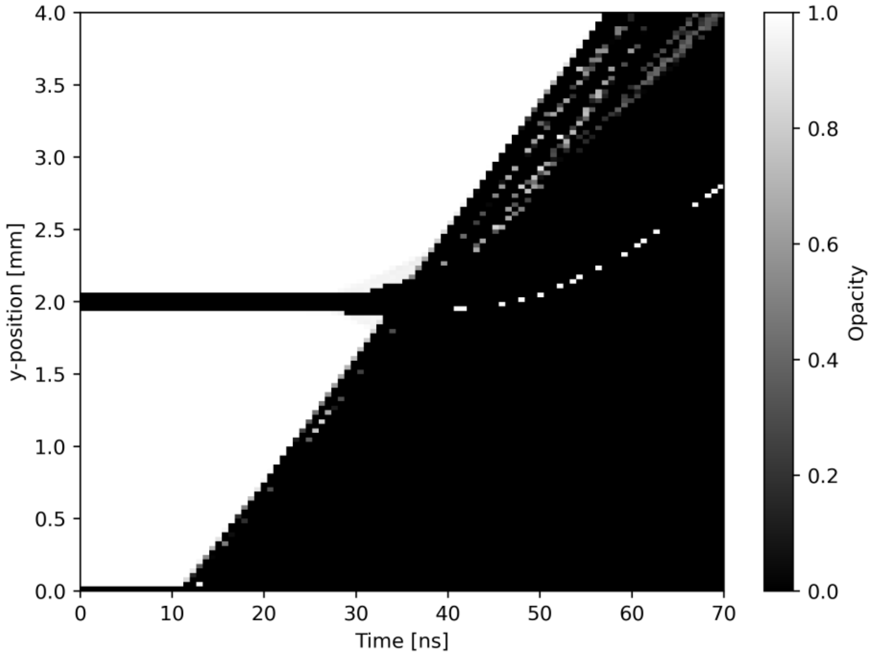
density
[1e-1:3.9e4 kg/m^3]

Synthetic streak images

- 2D Hytrac sims used to create imaged from lineout along central axis
- Electron number density calculated, from which an ‘opacity’ was defined (disregarding self-emission from the shock front)



- Electron number denisty



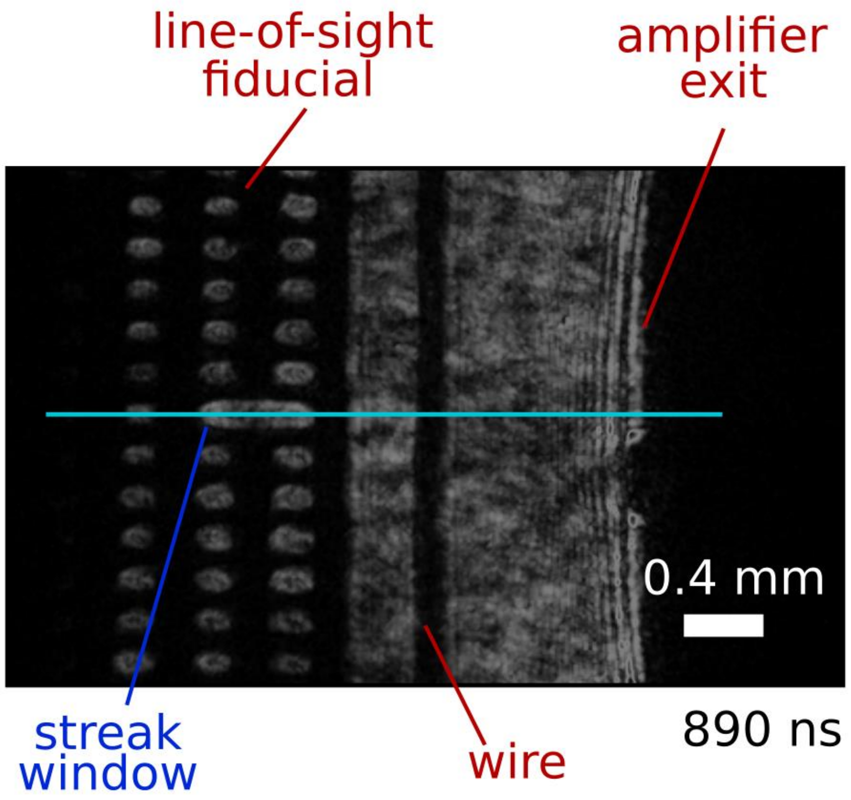
- ‘Opacity’

Experimental campaign summary

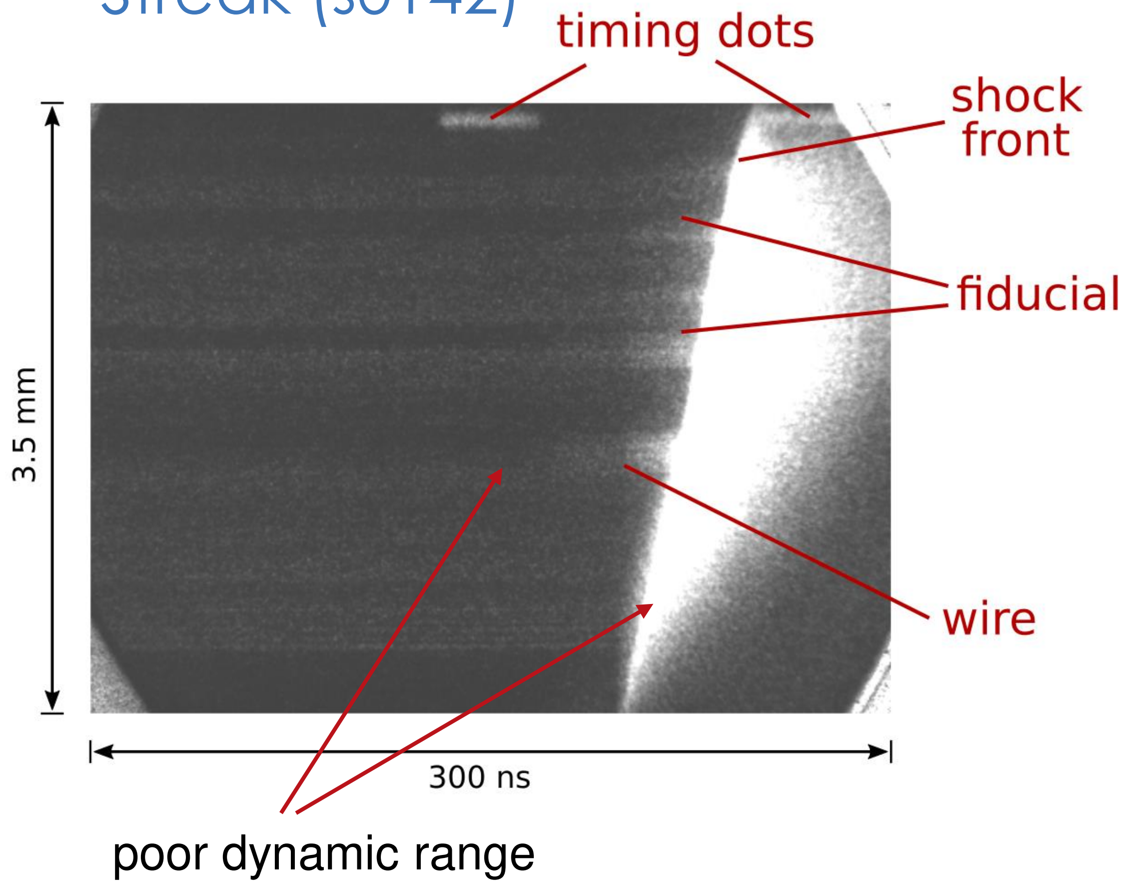
Shot number	Shot date	Wire material	Cell gas	Gas pressure [mbar]	V_i [km/s]
136	15/6/22	Al	Ar	235	N/A – early trig
137	16/6/22	Al	Ar	240	6.65
138	17/6/22	Al	Ar	100	6.57
140	8/7/22	Al	Ar	45	6.44
141	12/7/22	Al	Ar	55	N/A – broke up
142	13/7/22	Cu	D_2	1010	6.37
143	14/7/22	Al	D_2	500	6.68
144	15/7/22	Al	D_2:Ar(95:5)	1000	6.40

Results: backlighter images

- Shimadzu (s0137 only)

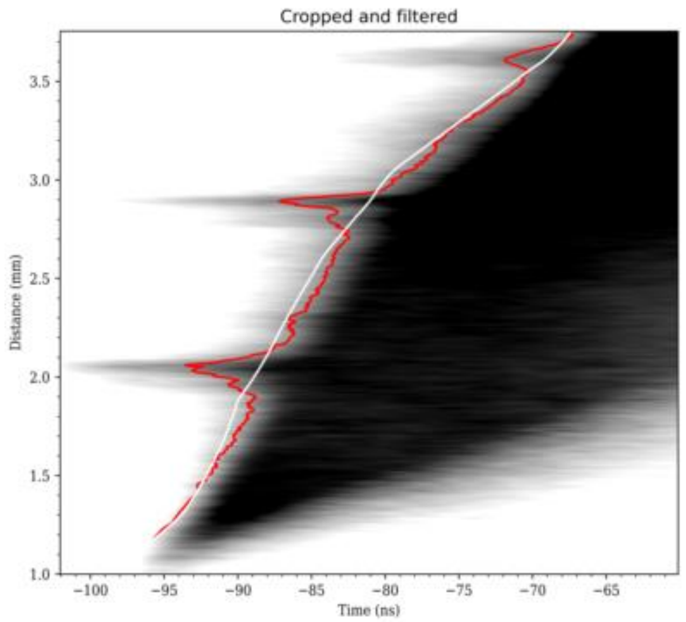


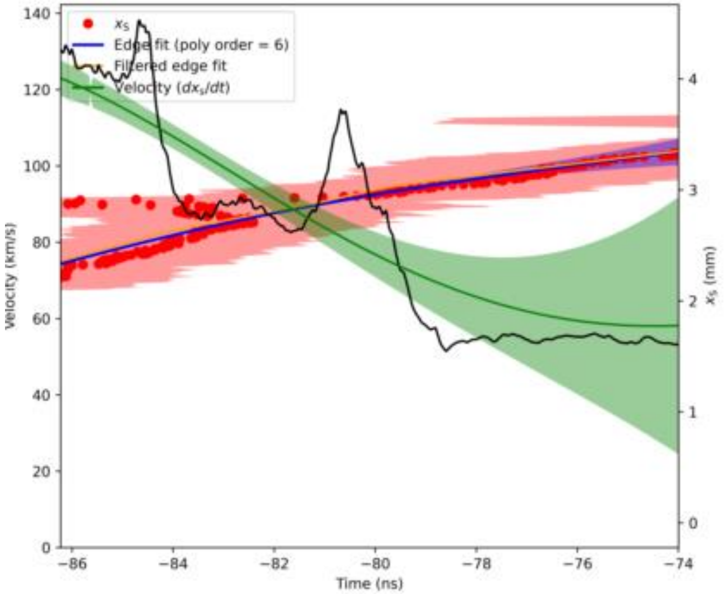
- Streak (s0142)



Shock front tracking analysis

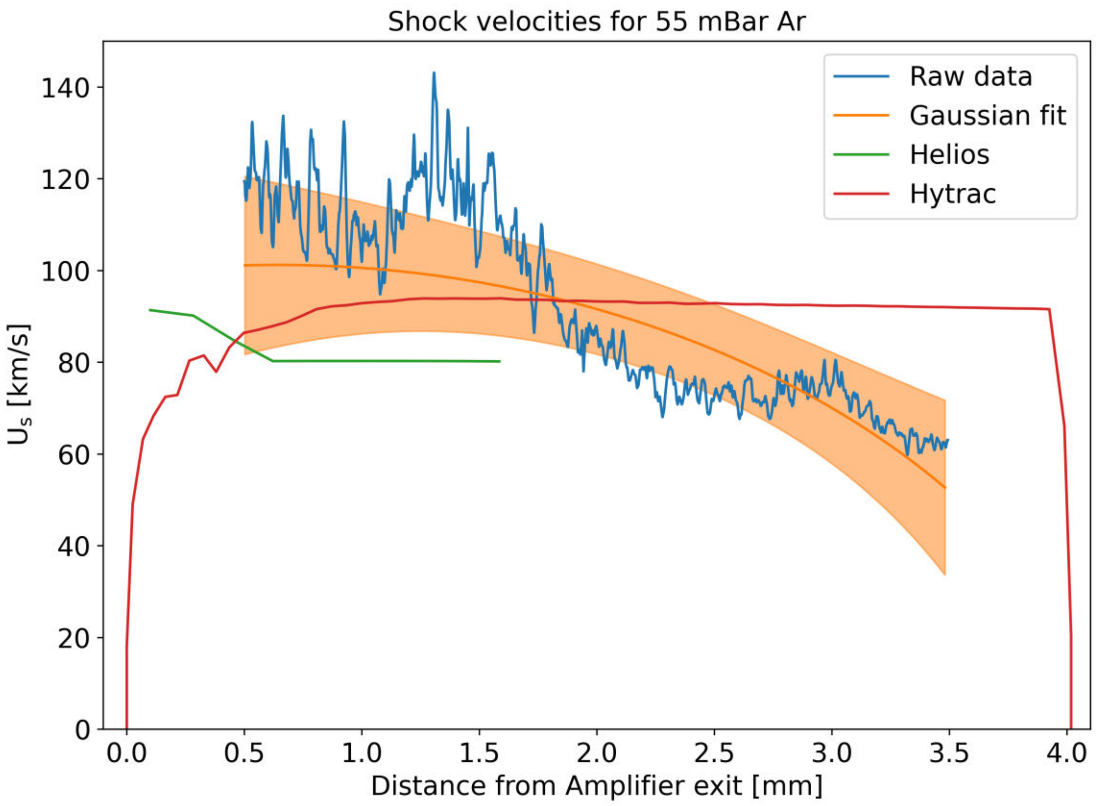
- Shock fronts tracked with horizontal lineoute and fitting of error function
- Raw position (red) and fitted position (white) extracted in top plot
- Respective velocities and errors calculated from raw and fitted data





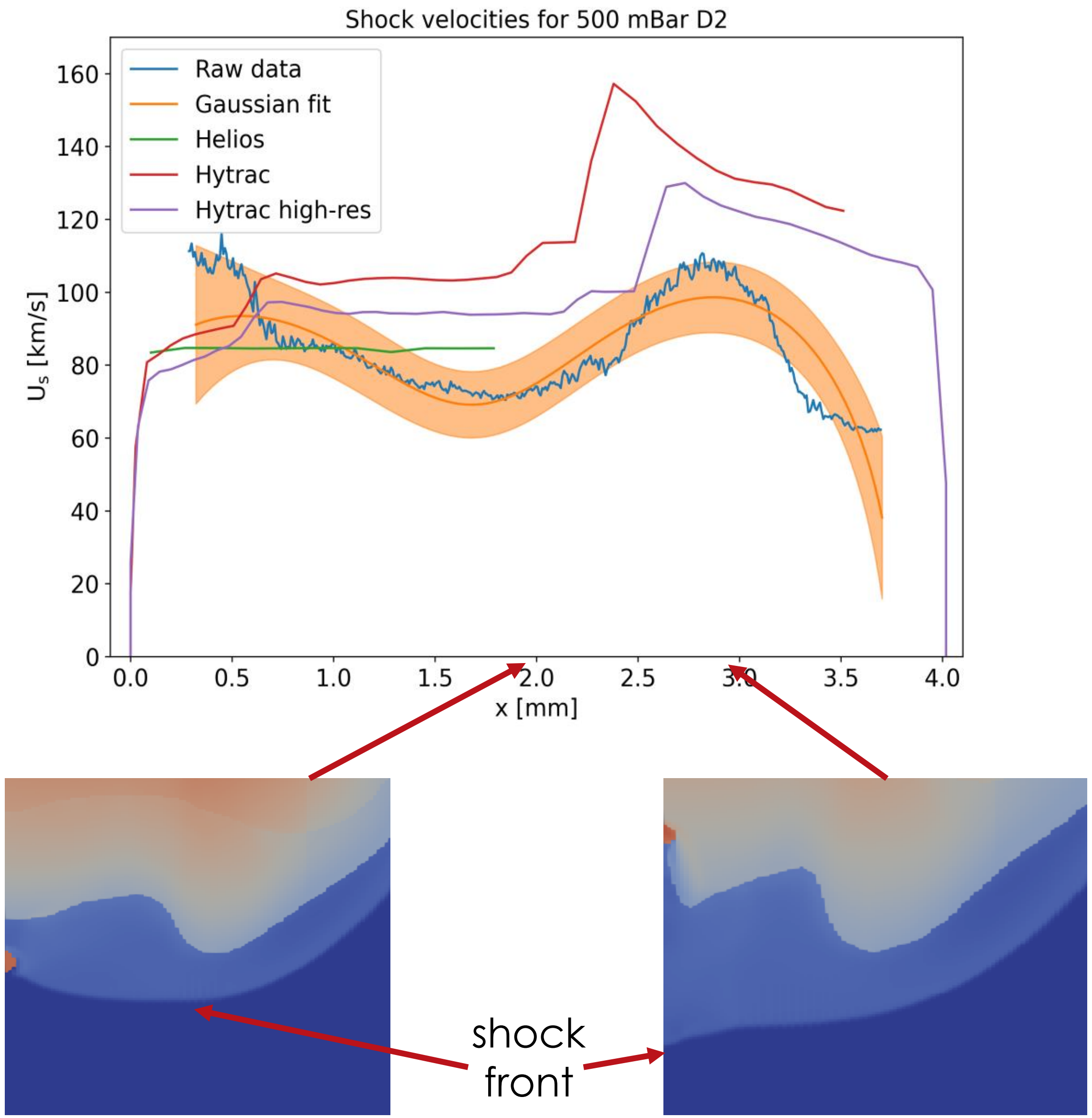
Comparison with 55 mbar argon

- No high resolution Hytrac simulation for this experiment
- Simulation speed lies within error of fitted curve
- There is an attenuation of shock speed in the experiment that isn't seen in the simulations
- Note the x-axis is distance from amplifier exit rather than time



Comparison with 500 mbar D_2

- Shock captured in experiment from 250 μm after amplifier exit
- Higher resolution Hytrac simulation agrees more with experiment
- Both experiment and simulations show an uptick in shock speed after wire position (2 mm from exit)



Conclusions

- Captured one of our amplifiers releasing directly into a gas
- Captured streak images of the glowing shock front for 6/8 shots
  - Three with Ar fill, two with D_2 and one with D_2:Ar mixture
- Simulation in Helios and Hytrac predict wire expansion up to 200 μm
  - However, laser power not enough to capture the wire in the experiments
- Shock front positions of simulations and experiment are comparable

Outlook and future work

- We have demonstrated a light gas gun platform capable of driving a highly radiative shock
  - Purely hydrodynamic (no laser pre-heating)
  - Over 150 ns of shock propagation time over 3 mm at speeds in excess of 100 km/s
- Improvements to the current experiment
  - More powerful laser will…
    - Improve S/N, allowing shock front and wire expansion to be diagnosed
    - Enable the use of interferometry (not attempted in this campaign)
  - Smaller streak windows and improved triggering to increase resolution of shock speed measurement

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Thank you for your attention
Please get in touch

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Upcoming talk from First Light Fusion:

- Francisco Suzuki-Vidal: rotating plasmas on the OMEGA laser (this session)

Presentations earlier in the conference:

- James Allison: A Bayesian approach to neutron spectra from projectile fusion (GO04:0010)
- Luis SC Bendixsen: FLF facilities and collaboration efforts with academia (PM09.00013)
- Zoran Pesic: Neutron emission from light-gas gun projectile driven targets (BP11.00132)
- Rosie Barker: Experimental measurement of planarity of a 1 TPa shock (TP11.00075
- Joshua Read: Pressure measurement of an amplified shock using VISAR (TP11.00076)

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