VISAR pressure measurement of amplified shock delivered to an FLF fusion target

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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.

Fig. 1: Schematic of fusion method.

- A projectile driven by a large light gas gun impacts a shock amplifier at 6.5 km/s.
- The amplifier is designed to increase the velocity and pressure of the shock travelling through it.
- A 32 km/s, ~1 TPa, shock exits the amplifier and impacts the target where fusion conditions occur.
- The planarity and pressure of the shock exiting the amplifier is essential knowledge for:
  - validation of amplifier simulations
  - optimisation of fusion targets

Fig. 2: (Right) The large light gas gun facility at First Light Fusion Ltd.

Measuring Shock Pressure

- Shock pressure can be calculated from a measured shock velocity, temperature or density, given the EOS.
- To date, measurements of velocity and temperature have been attempted for this system, see **R. L. Barker's** poster [TP11.00076].
- Most successful method to date has been to measure velocity using backlit shadowgraphy.
- This method is easy to field but has drawbacks:
  - Non uniformities along line of sight are not captured.
  - Inherent noise in differentiating position–time data.
  - Difficult to measure close to amplifier exit due to self-aperturing.

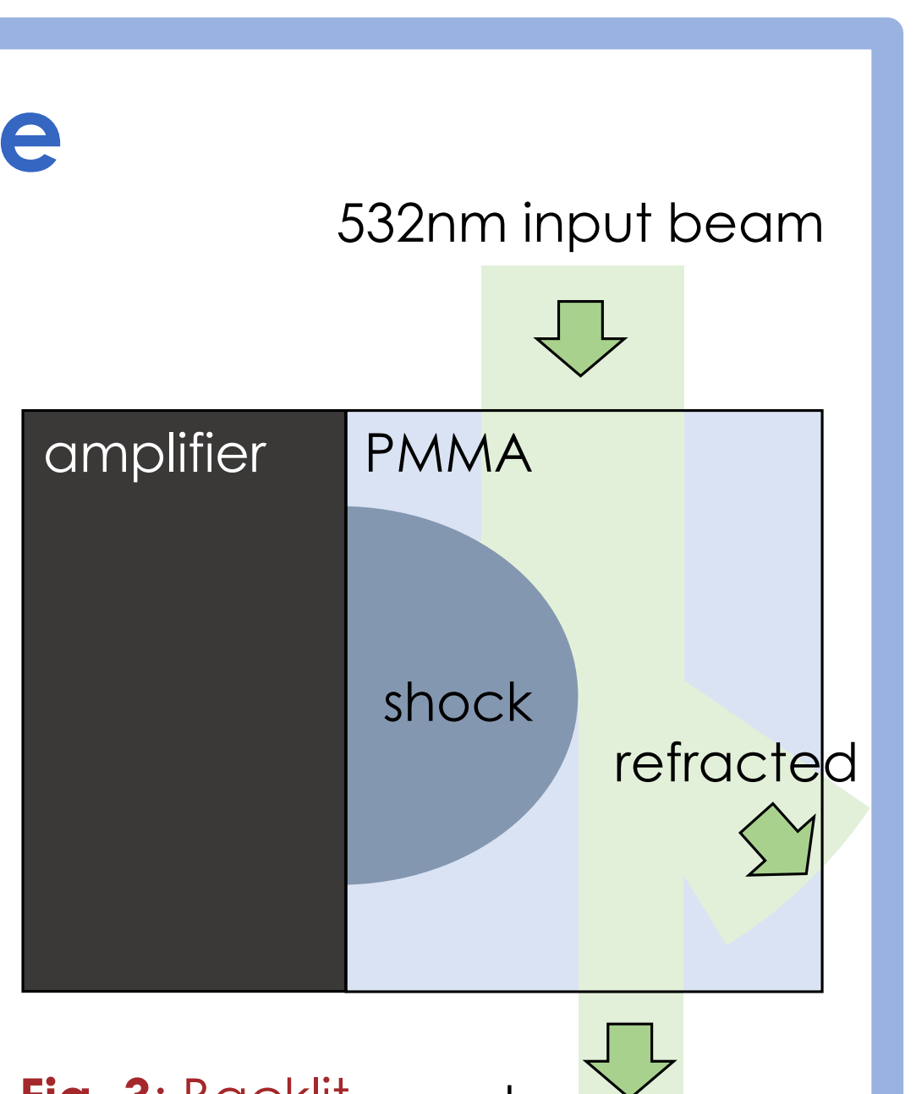

Fig. 3: Backlit shadowgraphy schematic. Probe beam is refracted by density gradient of shock.

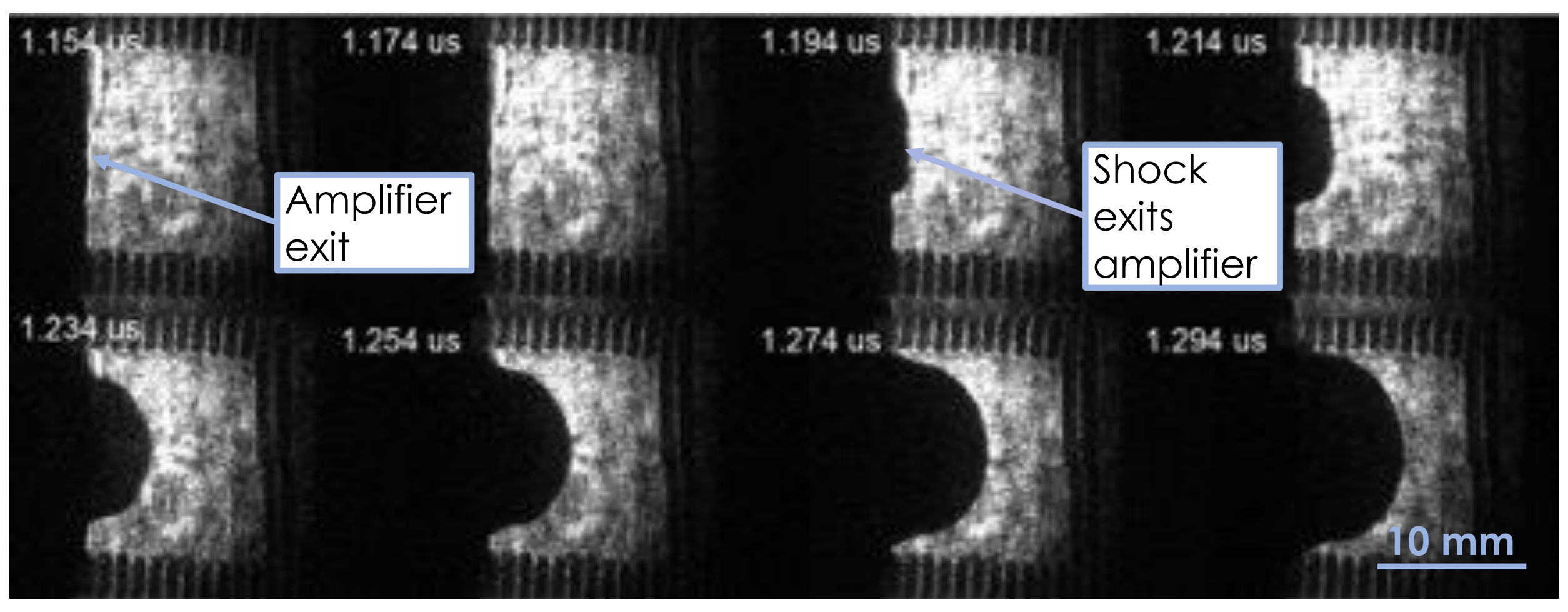

Fig. 4: (Right) Backlit shadowgraphy data captured using fast framing camera.

VISAR Theory

- Velocity Interferometry System (for) Any Reflector (VISAR) is a widely used technique in EOS experiments to measure shock velocity.
- A fast moving object imparts a doppler shift on a reflected probe beam. An interferometer is used to measure the rate of change in optical phase which can be used to calculate velocity.
- In a typical EOS experiment, a sample is backed by a well studied 'witness' material. When a shock passes from the sample into the witness material, it becomes reflective and the shock speed is measured. From this, the release state of the sample is inferred.

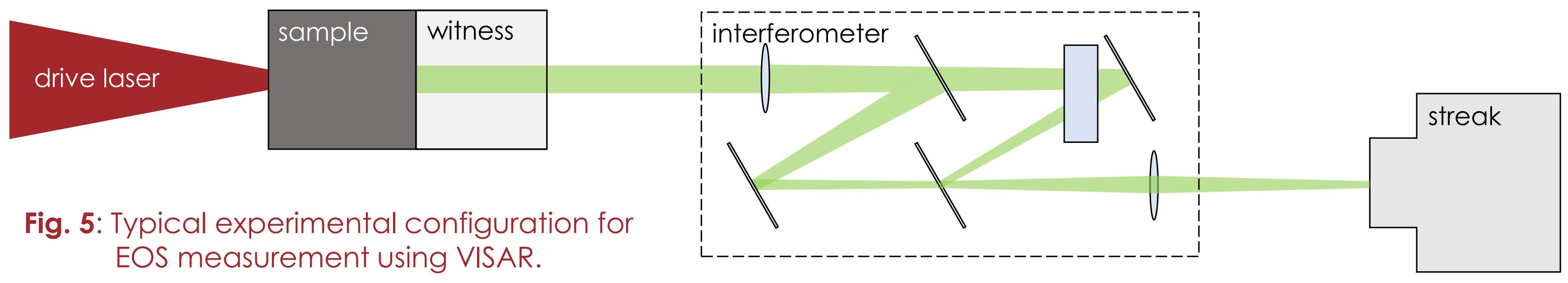

Fig. 5: Typical experimental configuration for EOS measurement using VISAR.

References

1. Celliers, P. M., et al. "Electronic conduction in shock-compressed water." Physics of Plasmas 11.8 (2004): L41-L44.

Target Configuration

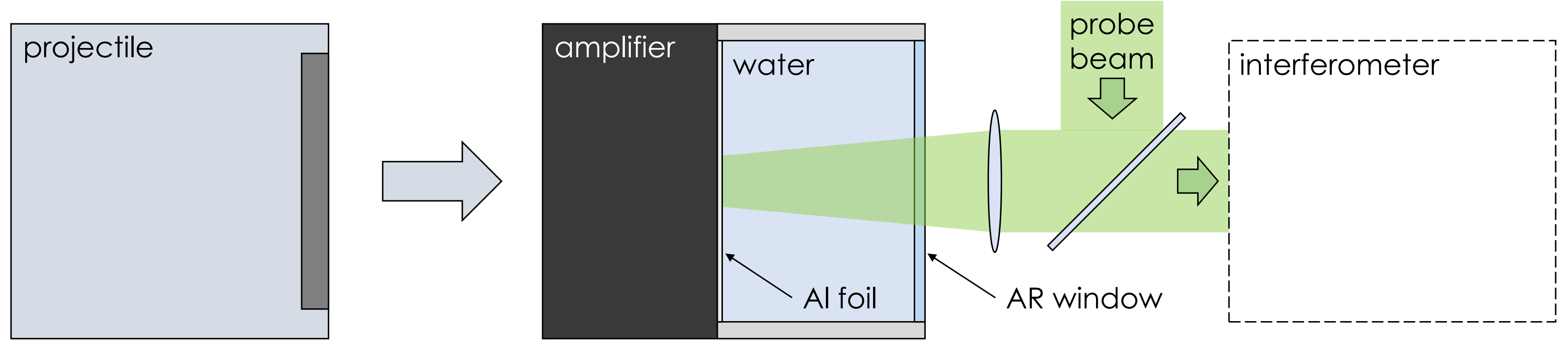

Fig. 6: Schematic of target configuration.

- The large light gas gun facility was used to impact a diagnostic development amplifier (simplified manufacture, 300-400 GPa planar shock output).
- The amplifier exit was covered by a 50 μm foil to provide a reflective surface to measure the t_0 fringe position.
- The rear of the amplifier was coupled to a cell filled with deionised water which has 40-50% reflectivity above 250 GPa [1].
- A 10 W, 532 nm, CW probe laser was focussed to produce a spot on the amplifier exit.
- This configuration has several advantages over backlit shadowgraphy:
  - End on measurement so non-uniformities in the velocity profile can be resolved.
  - Direct measurement of velocity so signal doesn't need to be differentiated.
  - Witness material is fluid which can couple directly to the amplifier output, so pressure can be measured closer to the amplifier exit.

Experimental Results

- The spot size on the amplifier exit had to be reduced down to just 1 mm in order to compete with self emission from the shocked water.
- The target configuration was simulated using our in house multi-material parallel resistive MHD code 'B2'.
- The measured velocity starts within error but then falls faster than predicted by simulation.
- There are several proposed causes for this disagreement:
  - 3D effects not captured in the axisymmetric simulation (seeded by non-planar impact with the projectile).
  - Unsimulated target features such as the glue layer between the amplifier and foil.
  - EOS uncertainty – the water EOS used in this simulation is known to disagree with data in literature (see future work).

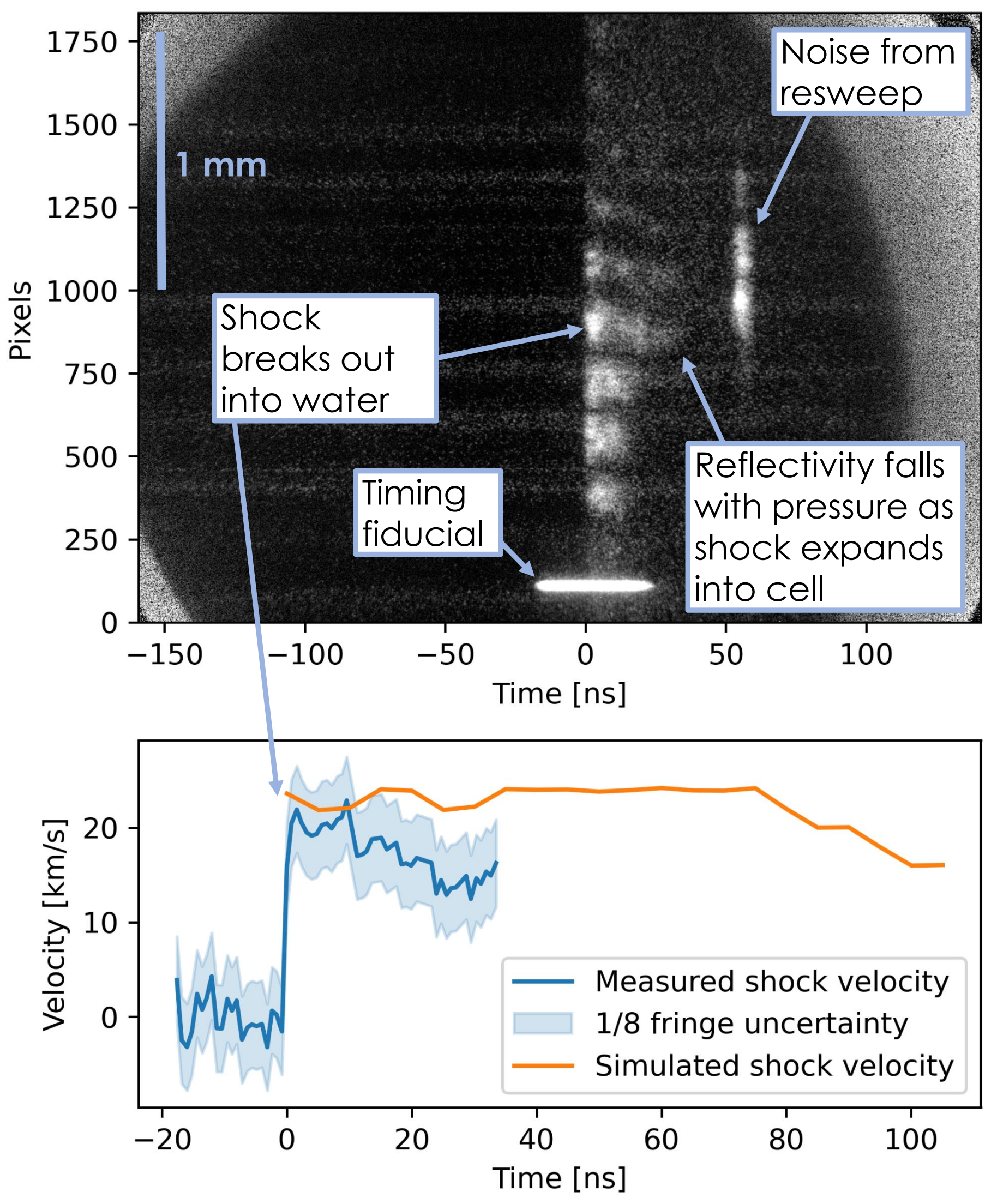

Fig. 7: Streak image of VISAR fringes (top) and plots of measured and simulated shock velocity (bottom).

Summary and Future Work

- Shock velocity from an FLF amplifier was measured using VISAR.
- Initial velocity matched within error but decayed more rapidly than predicted by simulation.
- Repeats planned with small tweaks to the target and optical design.
  - Ultra narrow band pass filter and cylindrical lens to increase the signal to noise ratio from self emission enabling a spatially resolved measurement across the whole amplifier exit.
  - Utilise physical vapour deposition process to flash the end of the amplifier, removing the unsimulated glue layer.
  - Improve the water EOS using experimental data from literature.
- Once a higher power laser has been procured and commissioned, repeat this experiment for our fusion amplifiers.

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