Application of Heterodyne Velocimetry to Hydrodynamics at AWE

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Diagnostic Development/Image Analysis

Hydrodynamics

AWE Aldermaston

PDV Conference ’08

Sandia National Laboratories

Main aims

- To provide simpler, cheaper (and better) velocimetry provision for hydro trials in the hydrodynamics firing area.
- To provide velocimetry capabilities beyond the range of existing techniques.

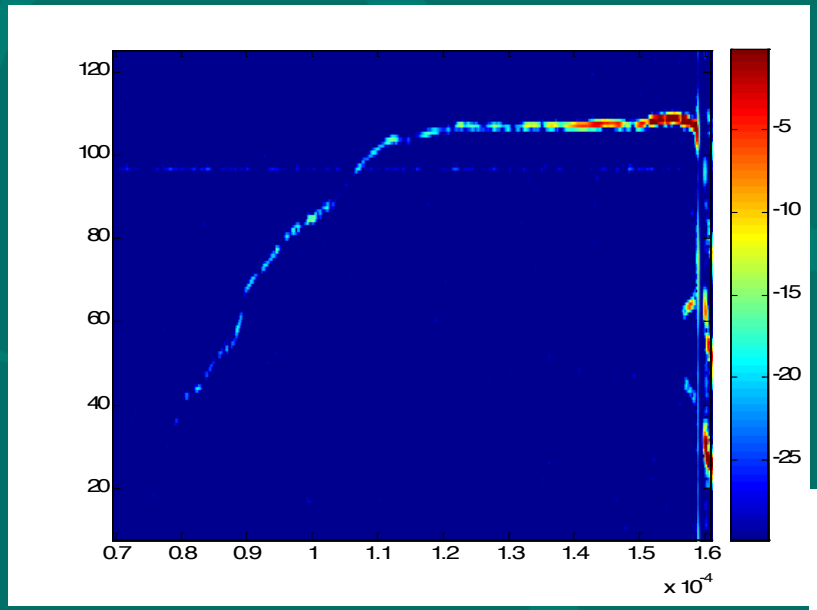
-More channels

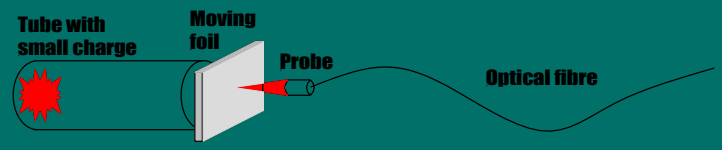
-New applications in Hydro Science

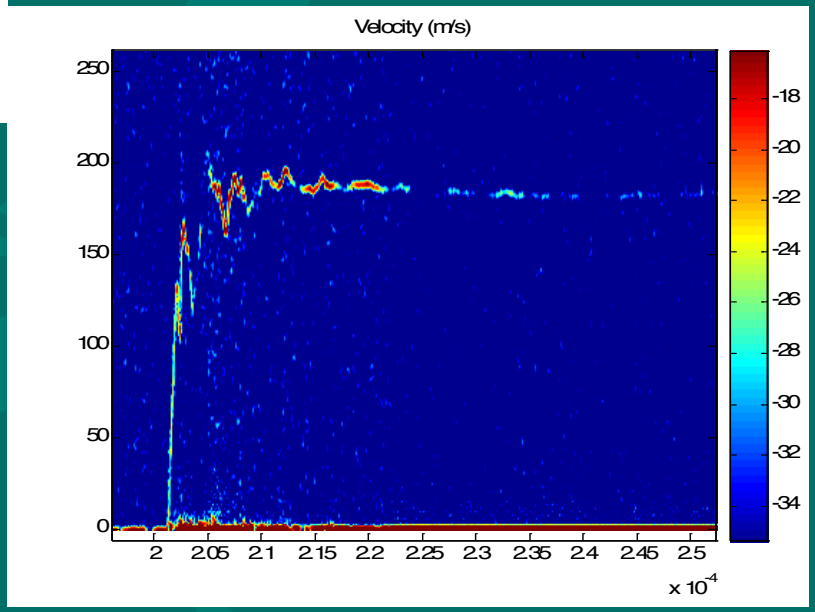
In reality

- General safety issues have stalled efforts to field the system on explosive trials. This has led to other applications being sought.
- The HetV system has now been used on a wide range of experiments from laser driven spall experiments to plasma driven flyers and gas guns.

Class 1 laboratory/gas gun experiments



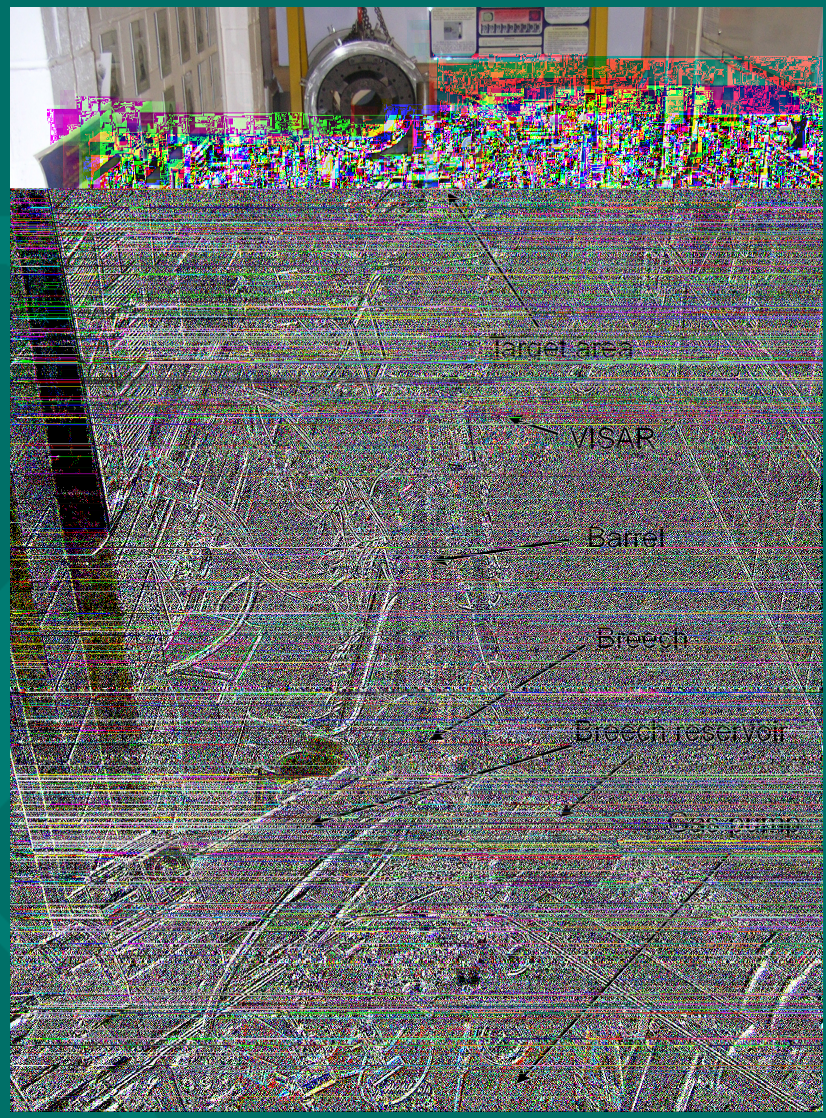


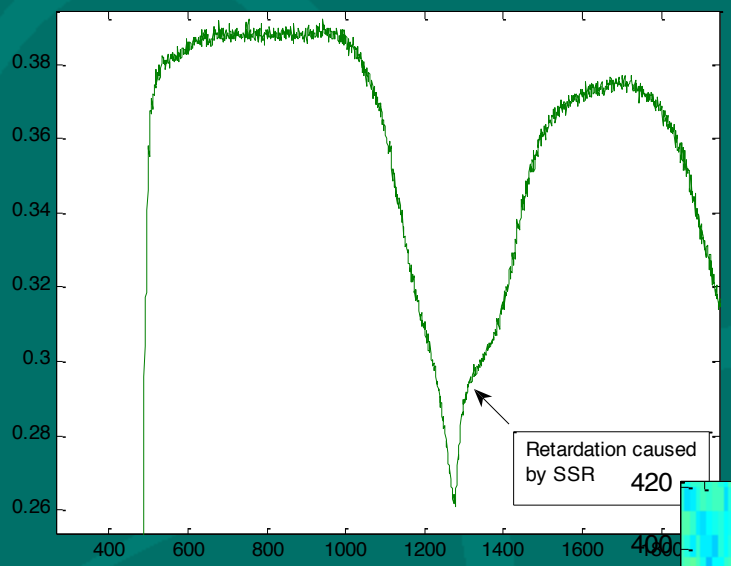


Allowed us to learn how the system operates and develop analysis routines

Experiments at “design power”

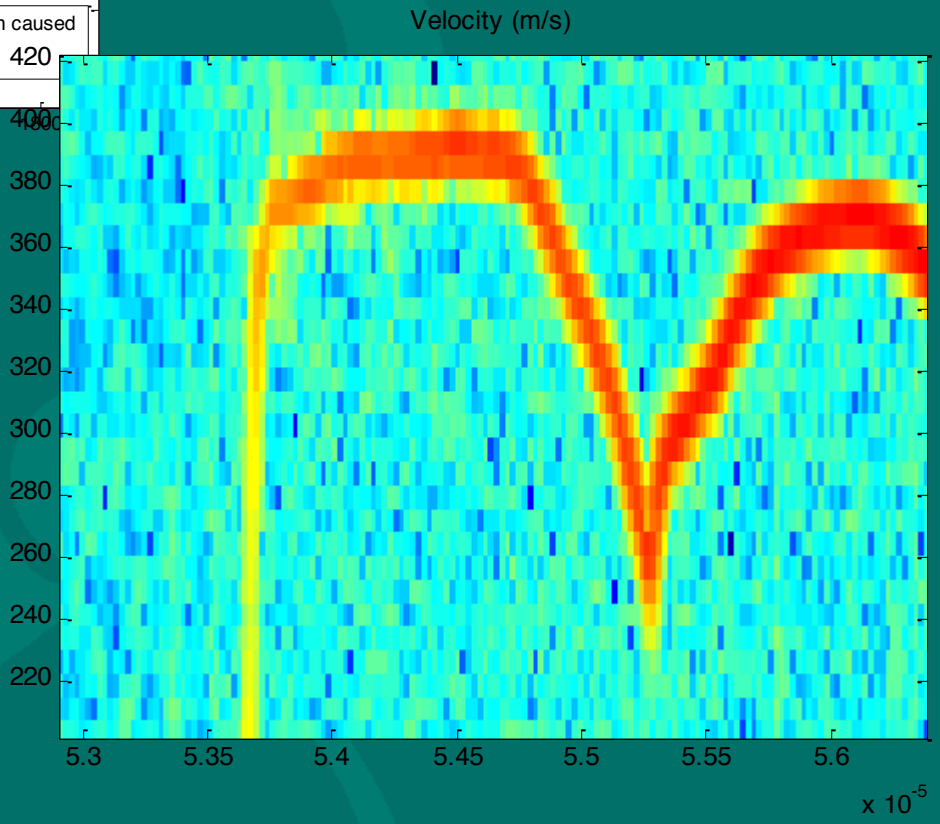
- Ta-Ta gun shots were performed on the large bore gun at the Cavendish Laboratory, University of Cambridge
- Excellent results were achieved and validated with VISAR and Fabry-Perot measurements



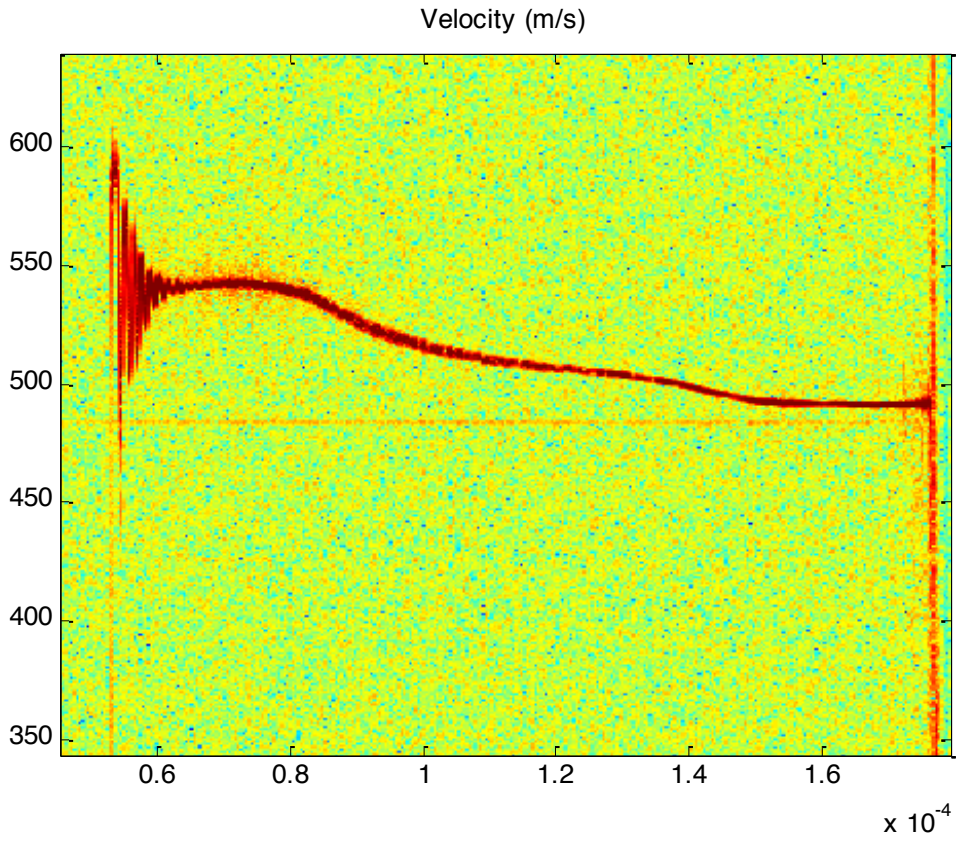

0.38
0.36
0.34
0.32
0.3
0.28
0.26
400
600
800
1000
1200
1400
1600
Retardation caused
by SSR

VISAR

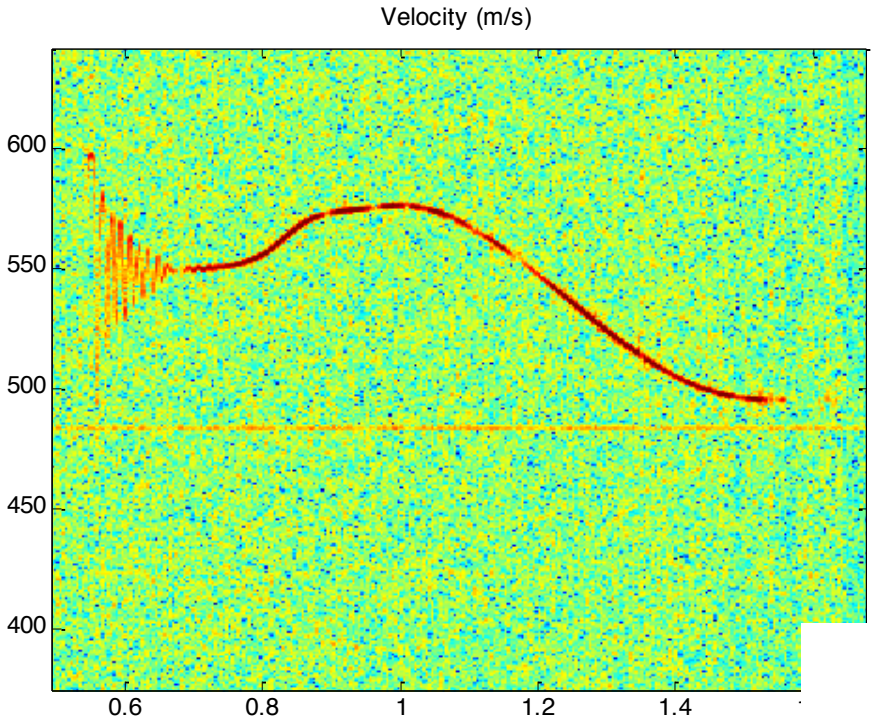
HetV


Velocity (m/s)
420
380
360
340
320
300
280
260
240
220
5.3
5.35
5.4
5.45
5.5
5.55
5.6
x 10-5

Interesting data at long standoff



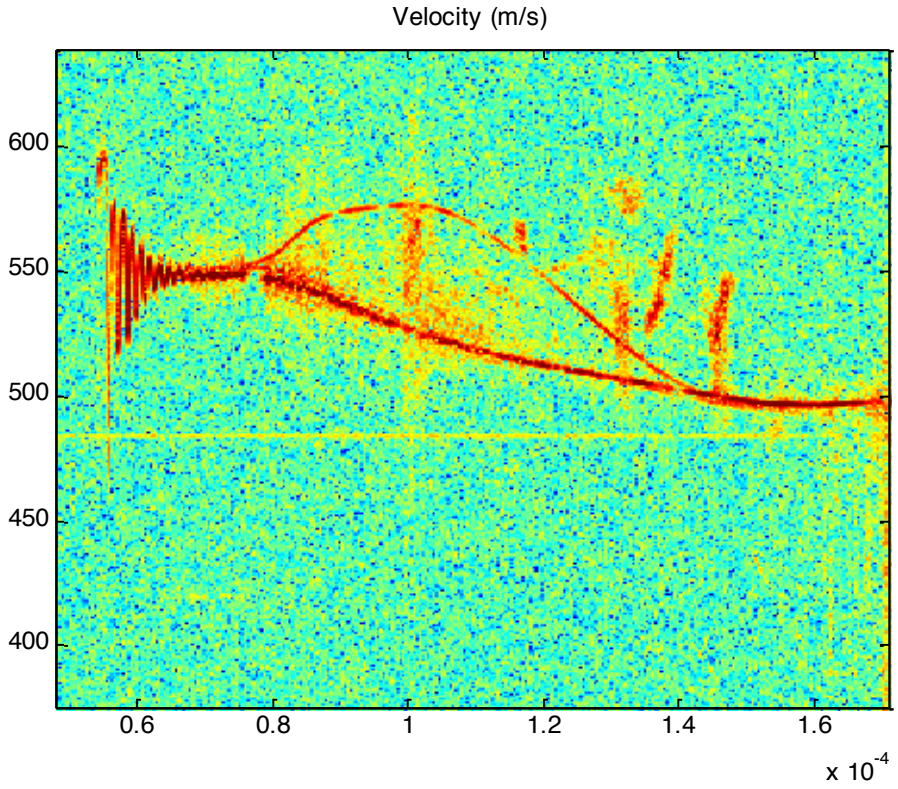
Ta spall shot 20GPa
60mm probe standoff
Probe positioned 10mm off centre of sample



Probe positioned to centre of spall layer

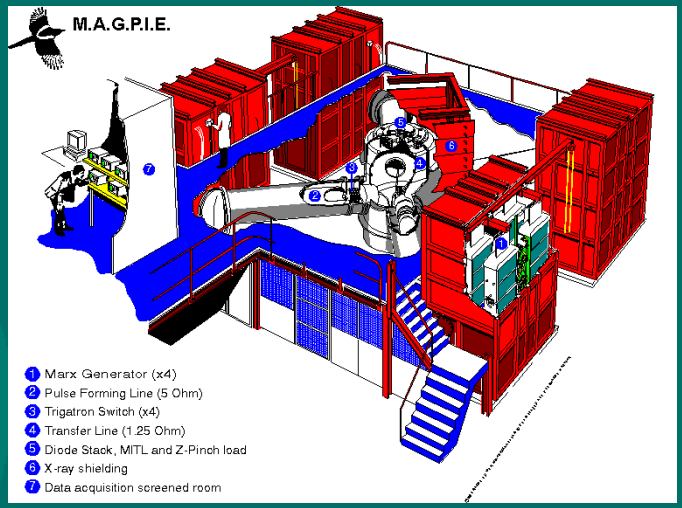
Overlaid channels, one in the centre of
the sample, another 10mm off centre

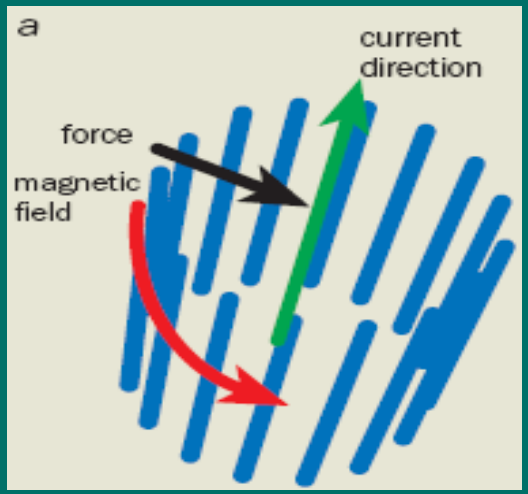
Any ideas most welcome!



Plasma driven flyers

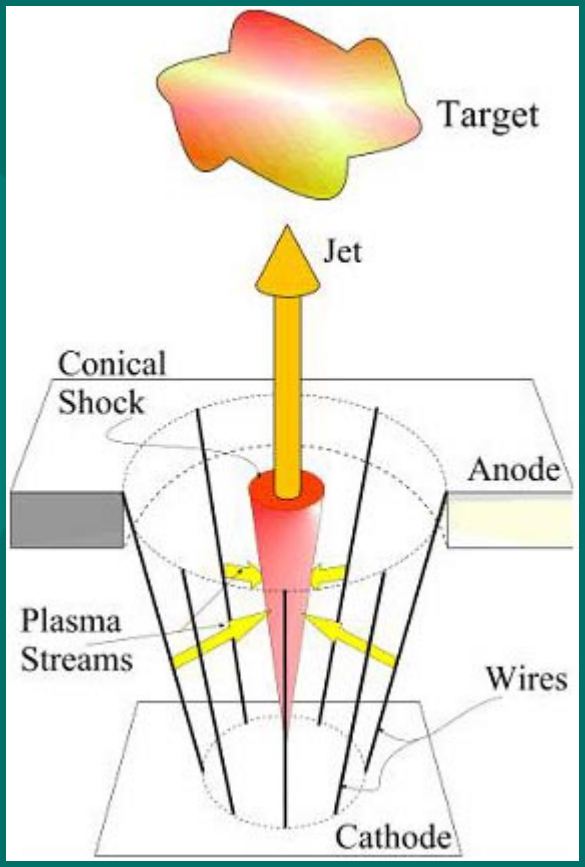
- The Magpie pulsed power machine at Imperial College London is used for the study of plasma interactions with applications in fusion, condensed matter physics and astrophysics.
- It is capable of providing >1MA over a period of ~300ns
- Workers in the Plasma Physics Group have been developing a Z-pinch radial wire array driven by Magpie to produce fast, dense plasma jets.



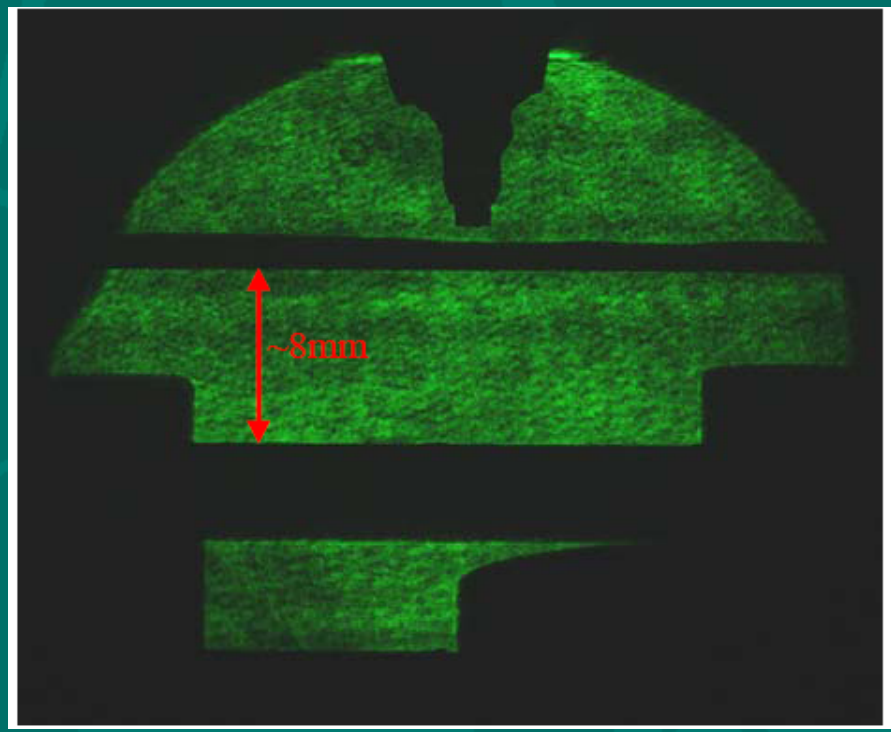


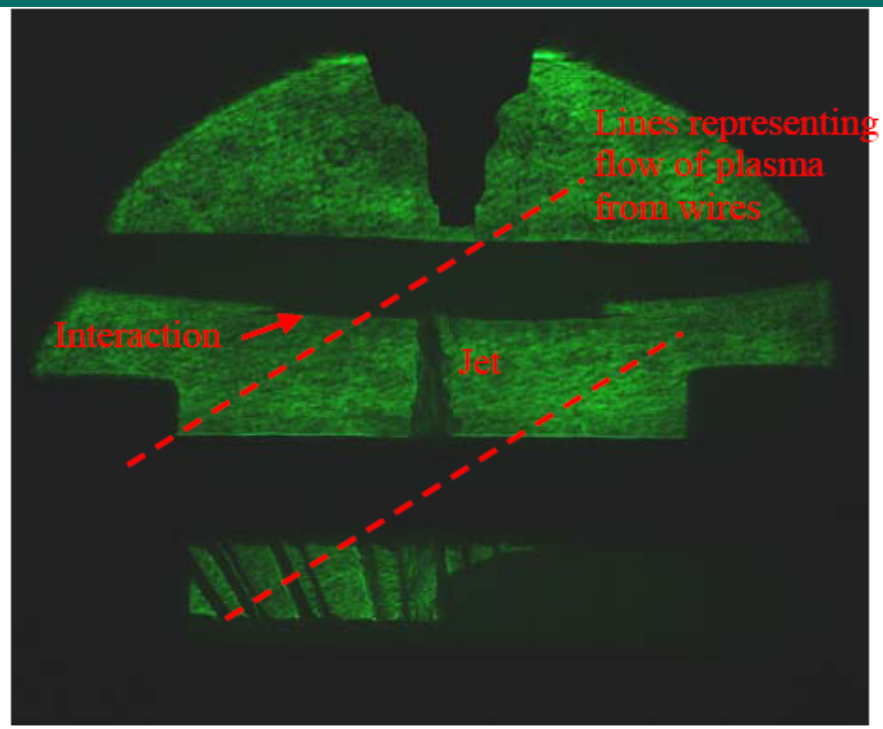
Experimental system

- Radial array Z-pinch creates a plasma jet along the Z-axis of the array
- This jet impinges on an Aluminium foil and HetV is employed to study the motion of the foil
- HetV should be able to measure velocities >5km/s although very rapid predicted accelerations mean the timescale is challenging

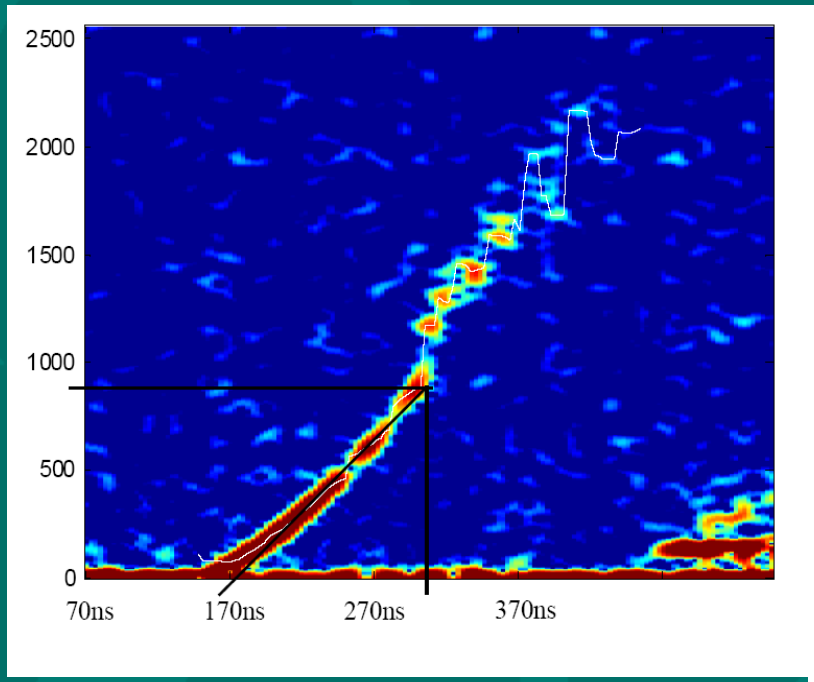


Laser imaging @ 332ns (shot s0821)





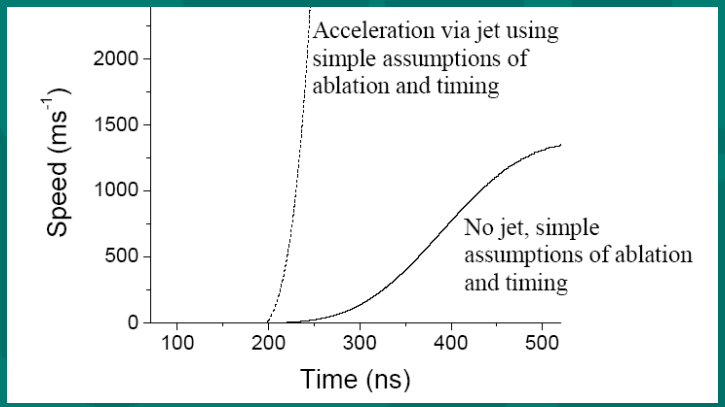
Analysed HetV data

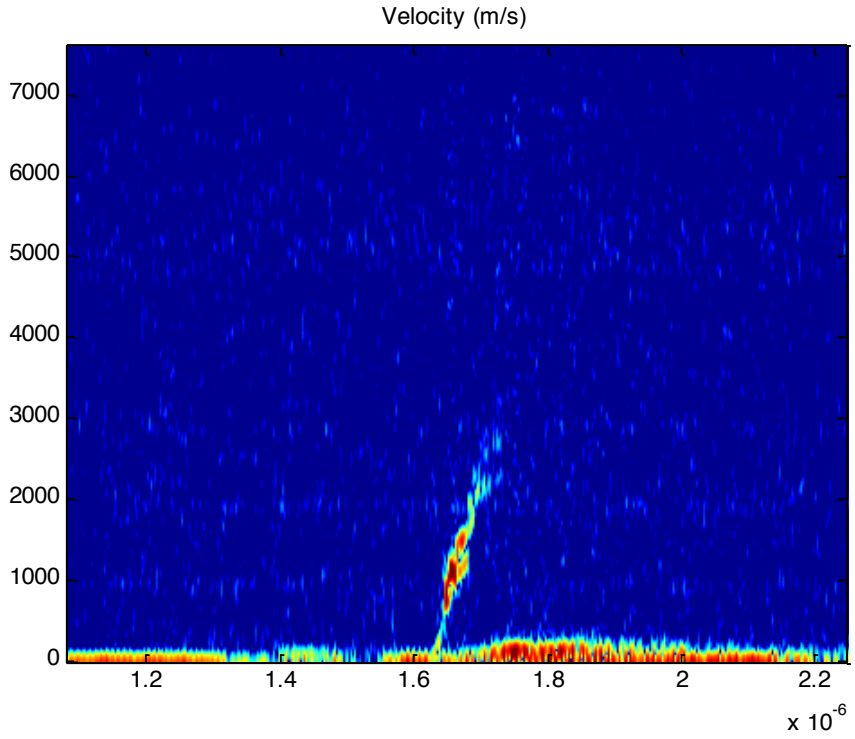


Accelerations to 2kms-1 over 100ns.

Very challenging timescale for STFT analysis of frequency data.

Good agreement with the basic models

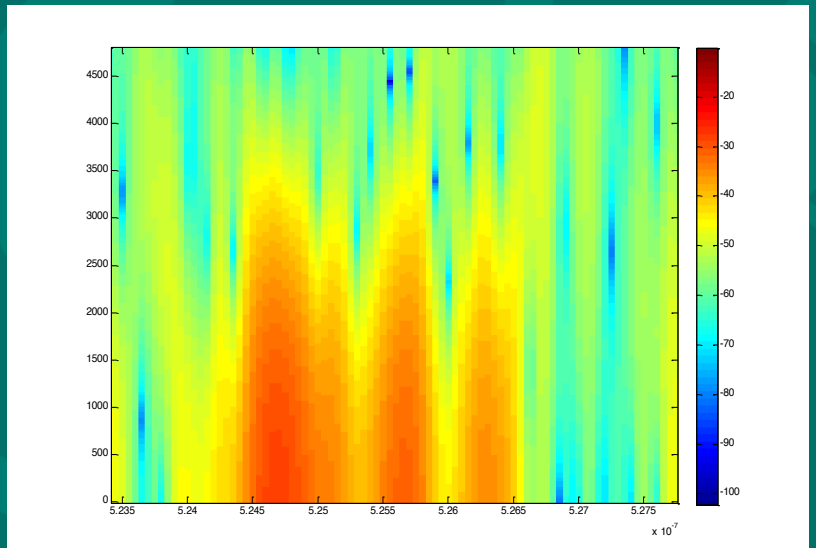




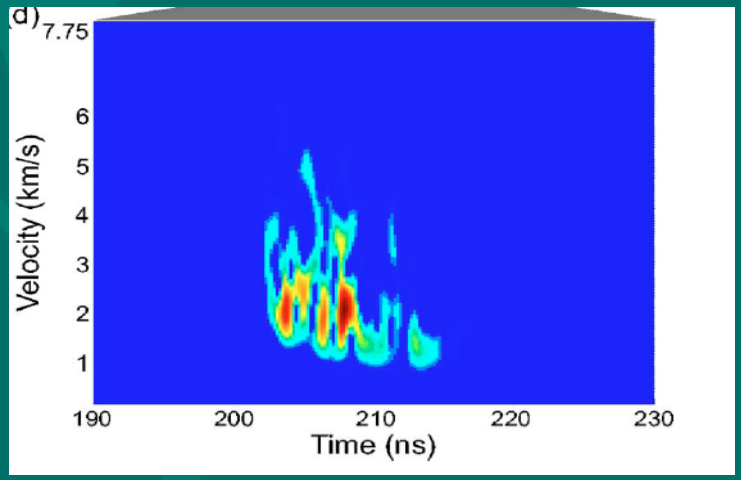
HELEN laser Al spall experiments

- HetV was employed on an experiment to study spall mechanisms. Line VISAR was the main diagnostic and this performed well although difficult to field
- Some “interesting” signals were seen on some shots but the cause of these has not been confirmed

AWE HetV data

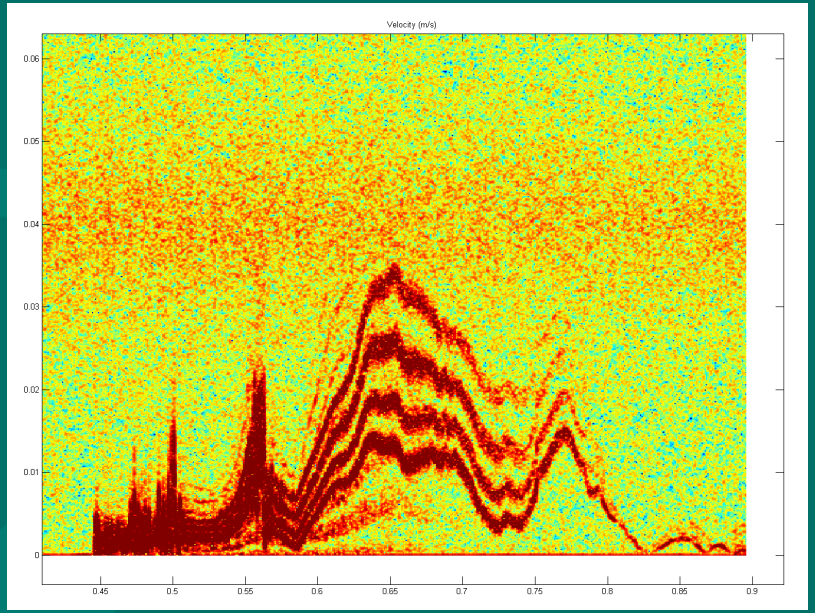


LANL data. “PDV of laser ablated ultra-thin metals”. Rev. Sci. Inst. 07 Valenzuela et. Al.

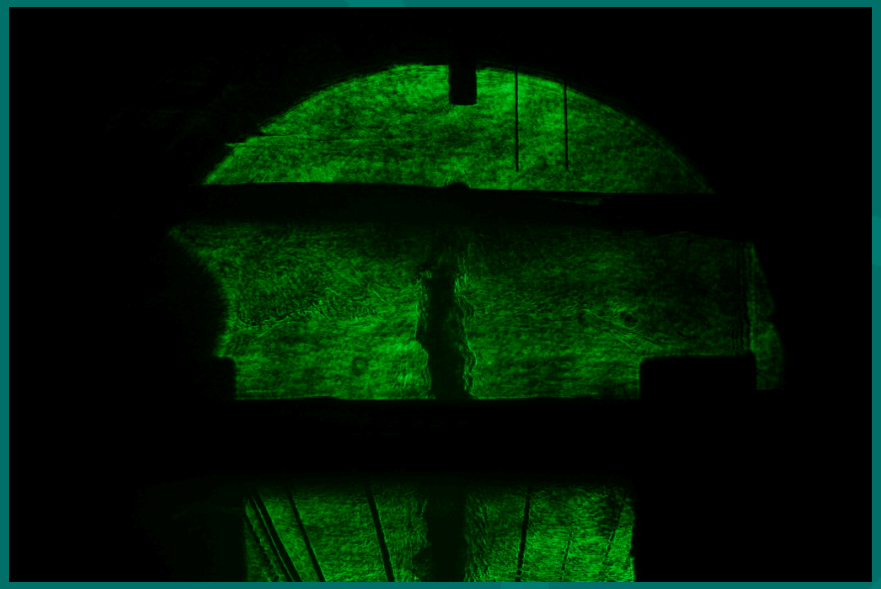


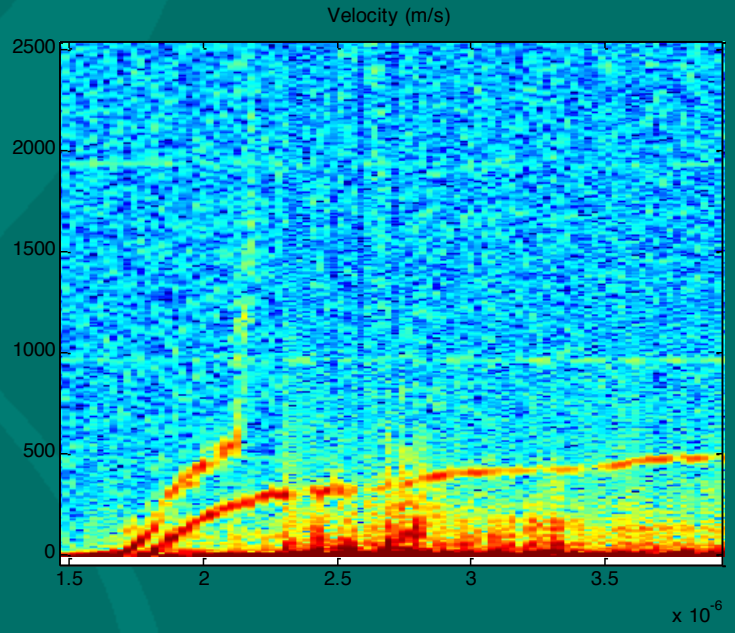
Diagnostics integration – Multipoint HetV

- Using a 1 to 4 splitter, a single HetV channel can be used with 4 different probes
- The signals are not unique and care must be taken in interpreting them
- Incorporating delay legs may improve the data in some circumstances



Multipoint applied to plasma driven flyer





Piezo integration (SPOT)

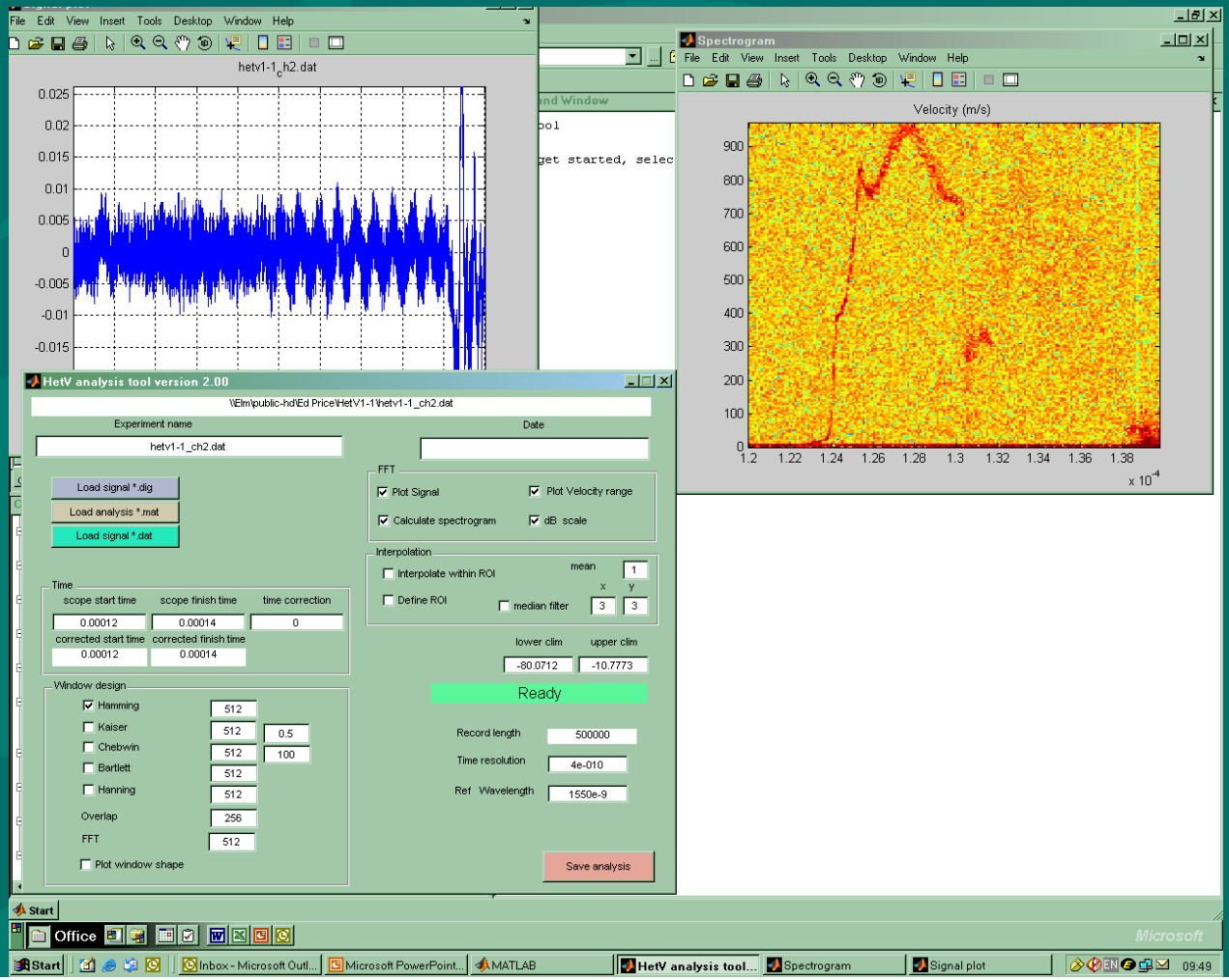
- Work is underway to produce an integrated piezo transducer/Hetv probe
- An integrated probe, (looking down the same axis), may produce better measurements where space is an issue or where engineering detail is present
- This is the Single-axis Piezo Optical Transducer (SPOT)

HetV/VISAR integration

- Plans are in place to upgrade an existing fibre VISAR system with the HetV laser and detectors
- Data from the two systems compliment each other
- Applications should include plasma flyer work at Imperial

Software development

- We’ve developed a Matlab based analysis package utilising the STFT technique.

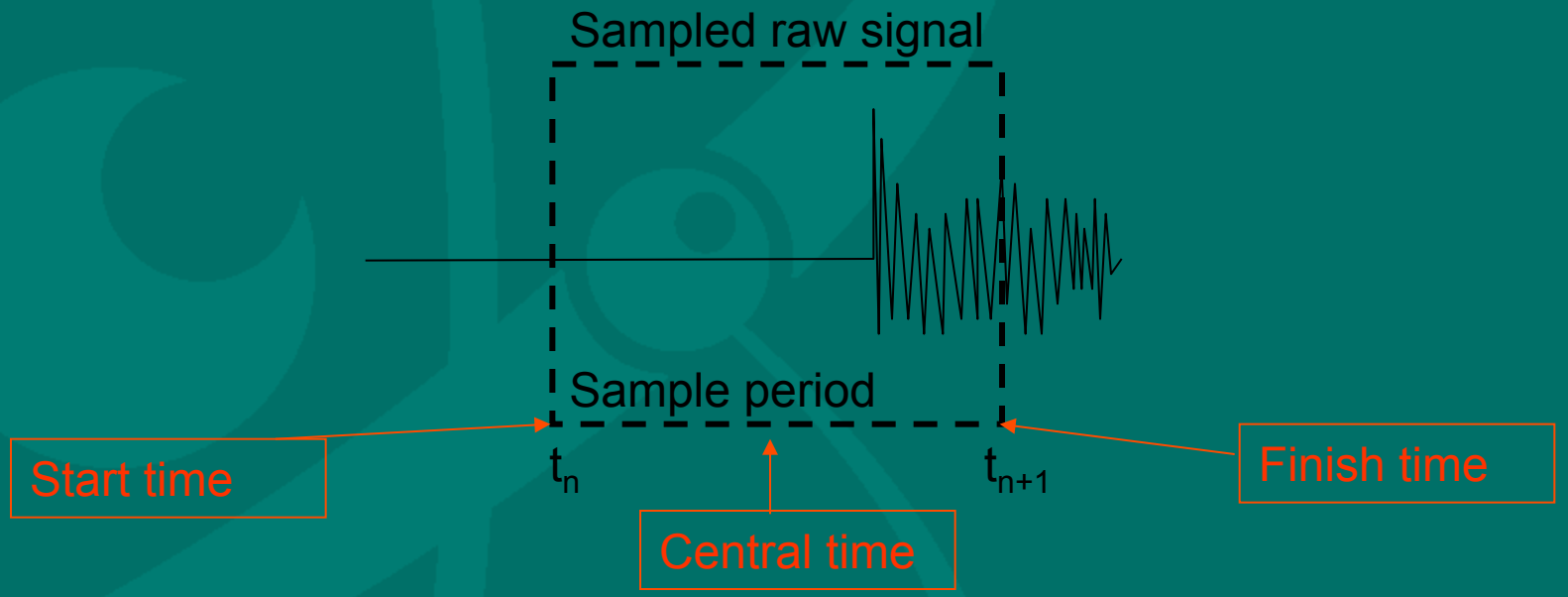


Inherent Matlab timing error

- The “specgram” function in Matlab has been found to introduce a timing error by assigning a time of the Fourier transform solution to the beginning of the transform window, not the middle
- Thus the data in the spectrogram leads the raw data by ½ the window size
- With data captured at 20GS/s and analysed with a 1024 point window this corresponds to a 25ns error

Correction required

- Add ½ a window size to the data in the spectrogram
- Alternativly employ a corrected version of the function called “spectgram”



Acknowledgements and H-area contacts

- D16 gas gun – Pete Keightley, Nathan Routley
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- R&D - Simon MacLeod, Andrew Critchley, David Bell
- Operations - Will Woolfenden, Jayesh Meghani, Mike Andrew
- External – Ted Strand (LLNL), David Holtkamp (LANL), Simon Bland (Imperial College), Sergei Lebedev (Imperial College), David Chapman (Cambridge University), Bill Proud (Cambridge University)

Thank you for your attention

Any Questions?