EUROnu and NF-IDS Target Meeting, CERN, 22-25 March 2008

Progress on Solid Target Studies

J. R. J. Bennett[1], G. Skoro[2], J. Back[3], S. Brooks[1], R. Brownsword[1], C. J. Densham[1], T. R. Davenne[1], R. Edgecock[1], S. Gray[1], P. Loveridge[1] and A. J. McFarland[1]

[1] *Rutherford Appleton Laboratory, Chilton, Didcot, Oxon. OX11 0QX, UK*
[2] *Department of Physics and Astronomy, University of Sheffield, Sheffield. S3 7RH, UK*
[3] *Department of Physics, University of Warwick, Coventry. CV4 7AL, UK*

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Outline

1. Reminder of the Solid Target Design and Studies.
2. Target lifetime.
3. Measuring thermal shock with the VISAR*.
4. Measuring thermal shock with a Vibrometer.

*Velocity Interferometer System for Any Reflector

Solid Target Studies

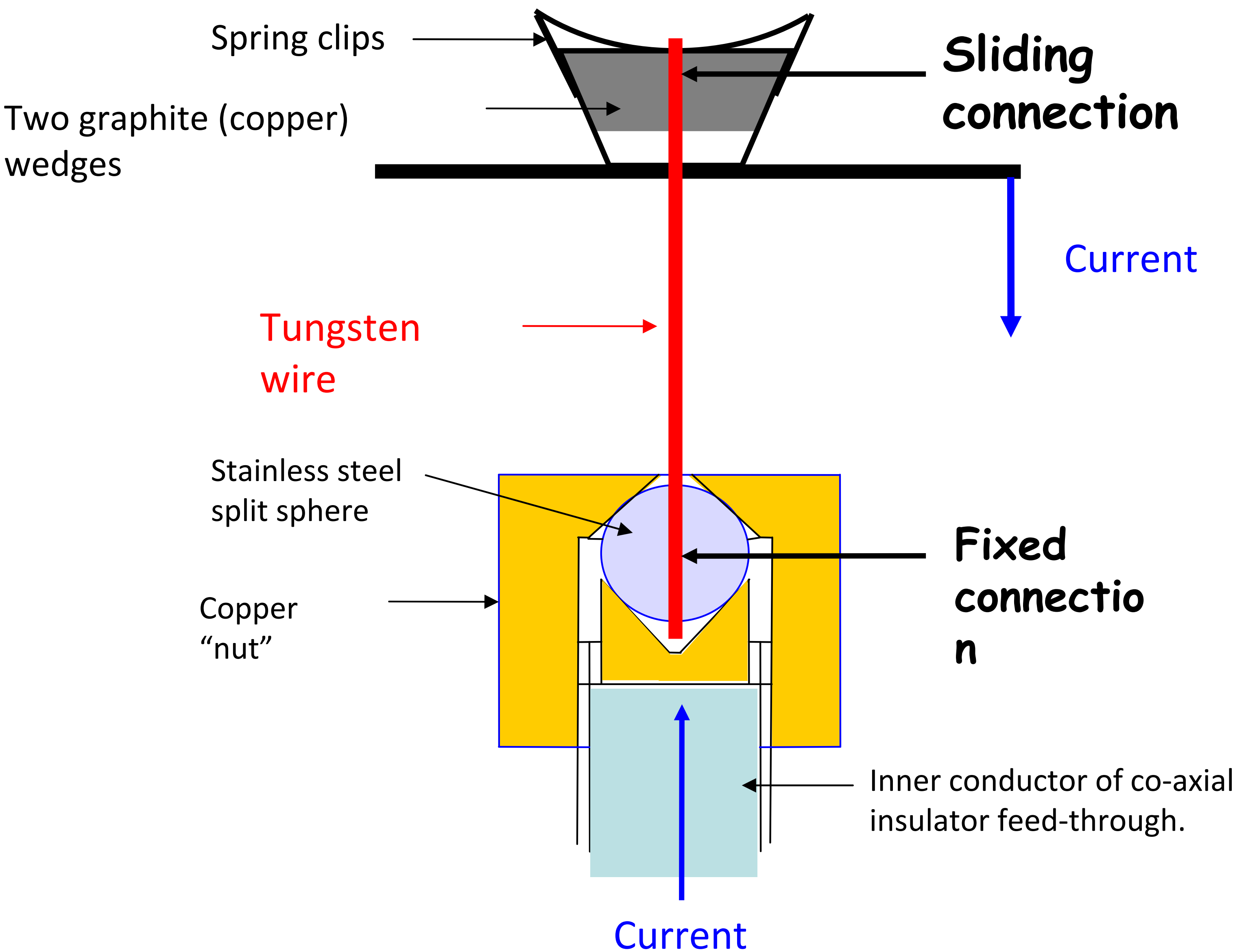
1. The original idea was to have a tantalum toroid rotate through the beam and threading the pion collection/focussing solenoid. The toroid operated at ~1600 K and radiated the heat to the surrounding water cooled walls.
2. The main problem was considered to be thermal shock generated by the ~2 ns long proton pulses (10 GeV, 50 Hz, 4 MW beam, dissipating ~700 kW in the target).

Thermal Shock Studies: Lifetime Test.

A high current pulse was passed through a 0.5 mm diameter tantalum wire, simulating the stress expected in a full size target. The number of pulses was counted before failure of the wire. Tantalum quickly proved to be too weak and was replaced by tungsten . Great care was needed to align the wire in the support structure to minimise the very large Lorenz magnetic forces. Most failures were probably due to this and to the wire sticking in the sliding free-end support /electrical connection.

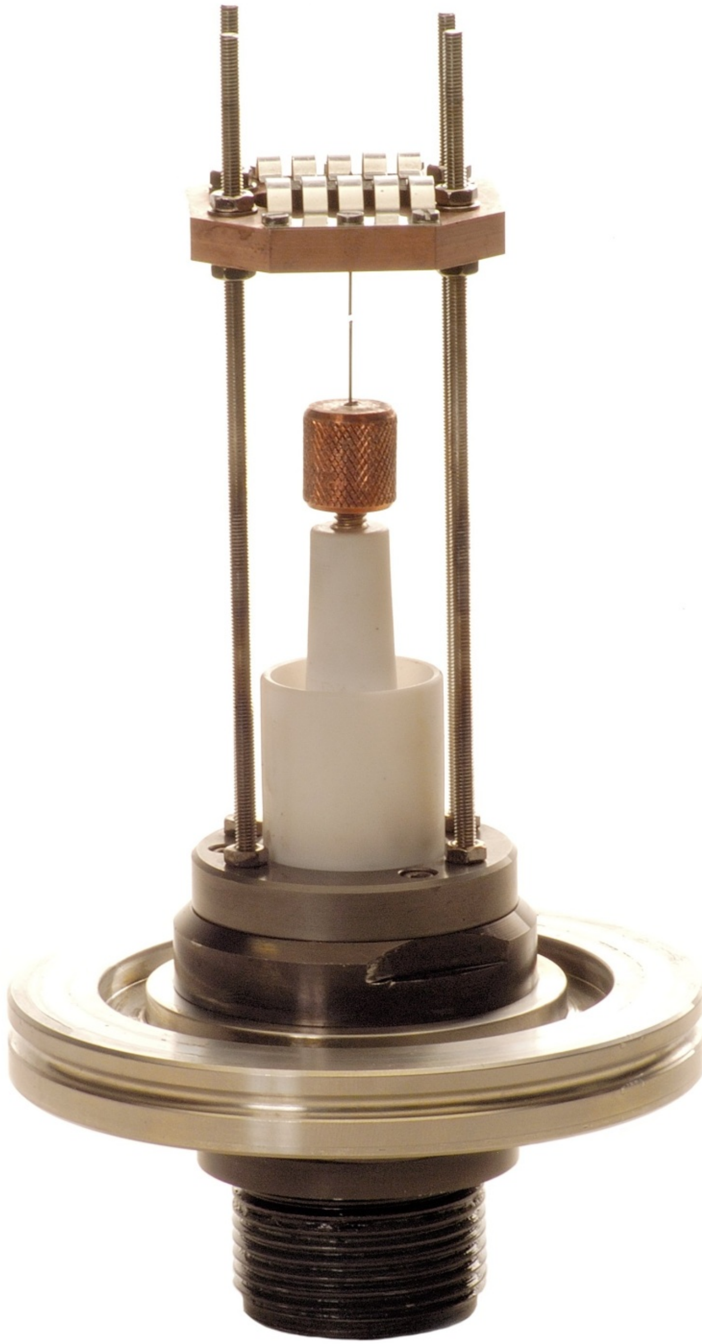
It soon became evident in the wire shock tests that thermal shock was not the problem. The wire was not failing from a single or a few shock pulses, but could survive tens of millions of pulses. The problem is not thermal shock but fatigue and creep. Fatigue and creep are not amenable to analysis. It is not possible to predict the number of cycles to failure with any accuracy.

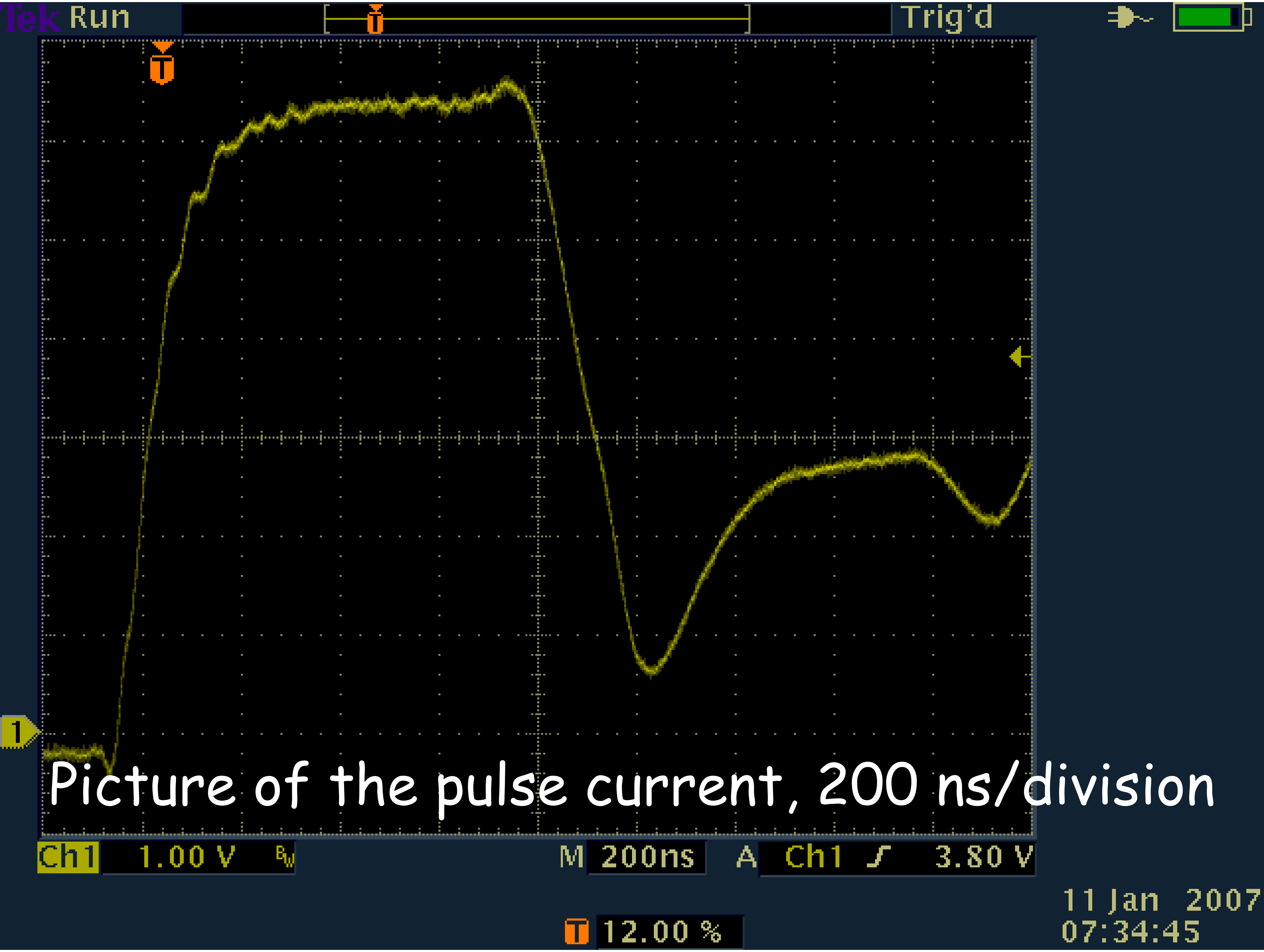
Vertical Section through the Wire Test Apparatus



W26

Tungsten Wire Assembly





Picture of the pulse current, 200 ns/division

We are proposing circulating a series of 200 - 500 tungsten bars through the beam at a rate of 50 bars per second to coincide with the beam pulses. This should give a lifetime of tens of years for each bar. The bars will be 1-2 cm in diameter and ~20 cm long.

Conclusions

I believe that the viability of solid tungsten targets at high-temperature for a long life (~10 years) has been demonstrated with respect to thermal shock and fatigue and will not suffer undue radiation damage.

Thermal Shock Studies

Measure Surface Motion and deduce the constitutive equations of state at high temperature under shock conditions.

Currently a **VISAR** is being used to measure the surface accelerations/velocities/displacements. We are measuring the longitudinal vibrations of the "free" end of the wire.

Results are very preliminary. The instability of the laser in the VISAR makes reproducible, accurate measurement difficult. Currently we are starting to using Fourier analysis to find the frequency spectrum. Young's modulus of elasticity is given by,

$$E \propto f^2$$

where f is the frequency of the longitudinal oscillation.

From this it should be possible to measure E as a function of stress and temperature and predict failure under shock

The University Of Sheffield.

VERY Preliminary Results

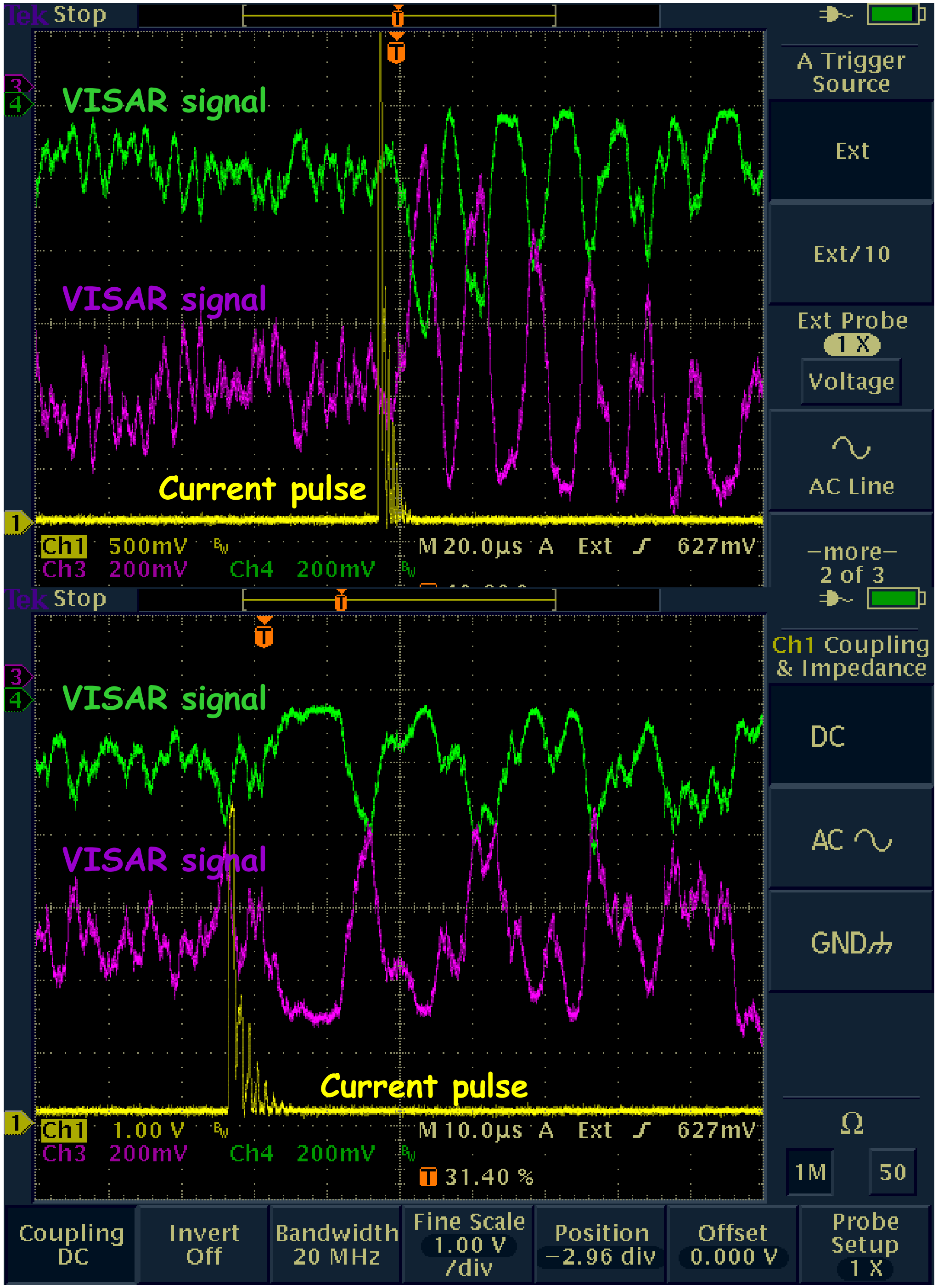
VISAR & FFT

Goran Skoro

25 February 2009

Goran Skoro
The University Of Sheffield

VISAR tests



VISAR tests have been performed with 0.3 mm diameter tungsten wire

Idea was to measure the VISAR signal and to extract the longitudinal oscillations of the pulsed wire

Two characteristic results (shots 3 and 5) shown on the left*

Yellow – Current pulse

Green, Purple – VISAR signal (2 channels)

VISAR signal obtained for the very first time – nice agreement with simulations results –

But, noise is an issue here!!!

Analysis shown on the following slides will try to address this problem

* Note the different time scale

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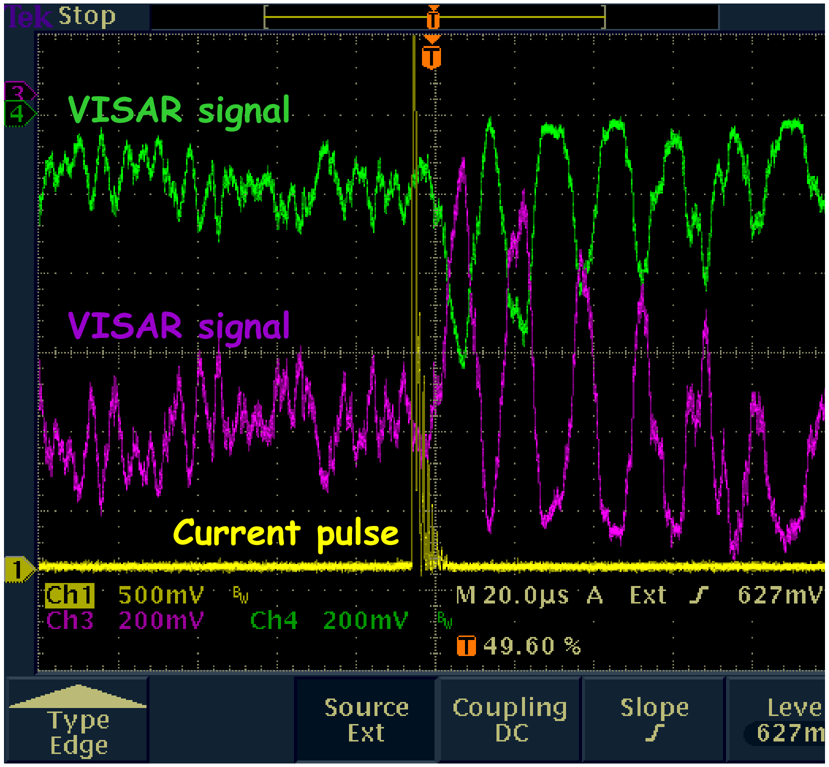
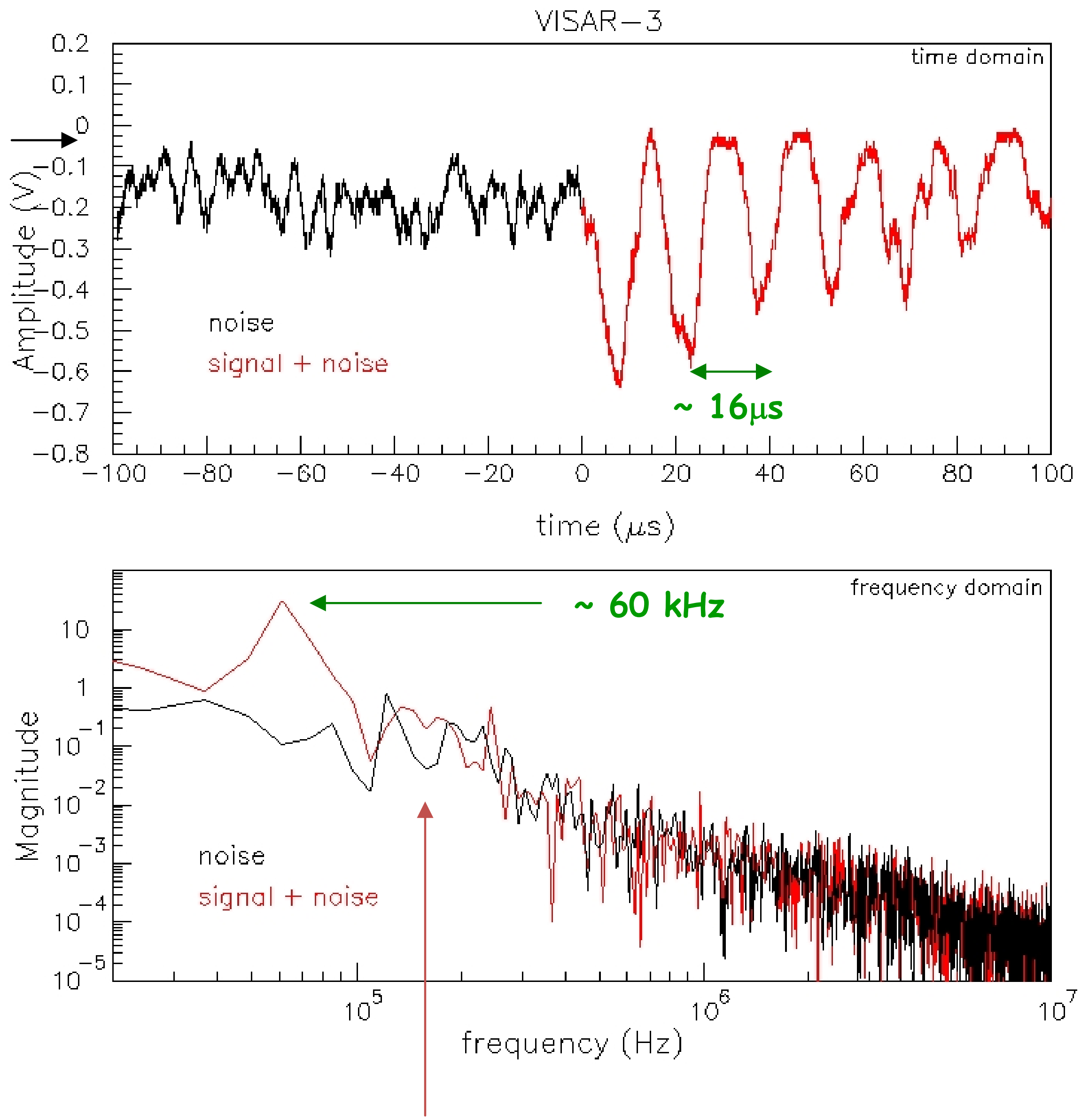
The University Of Sheffield.

Frequency analysis of the VISAR signal





FFT method (MATLAB) has been used
- from time to frequency domain -

Dominant signal frequency clearly seen in frequency spectrum (noise - negligible)

We need this region too in order to describe the wire motion properly (noise ~ signal)

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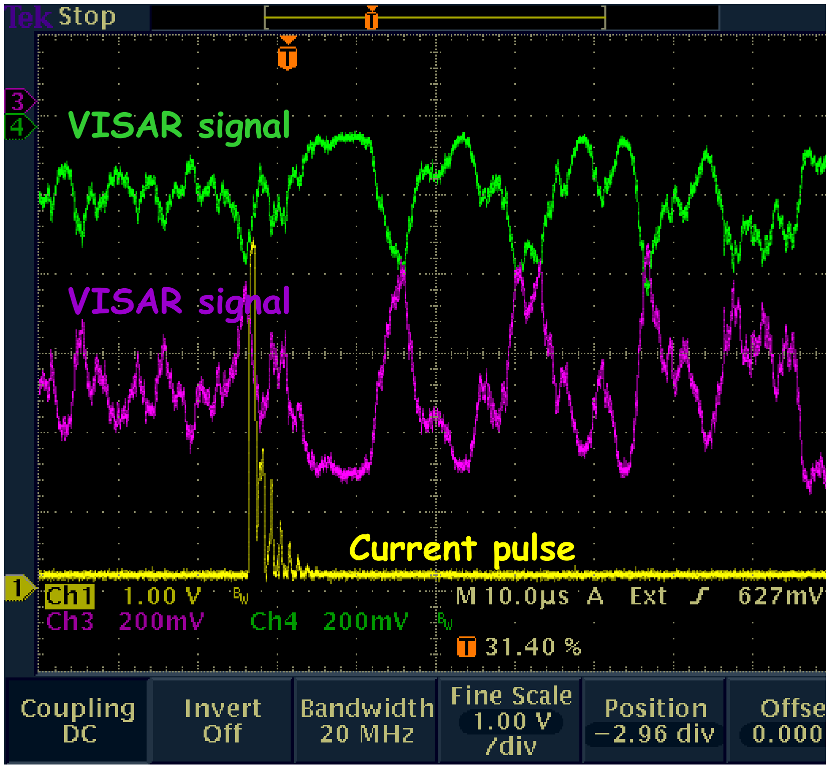
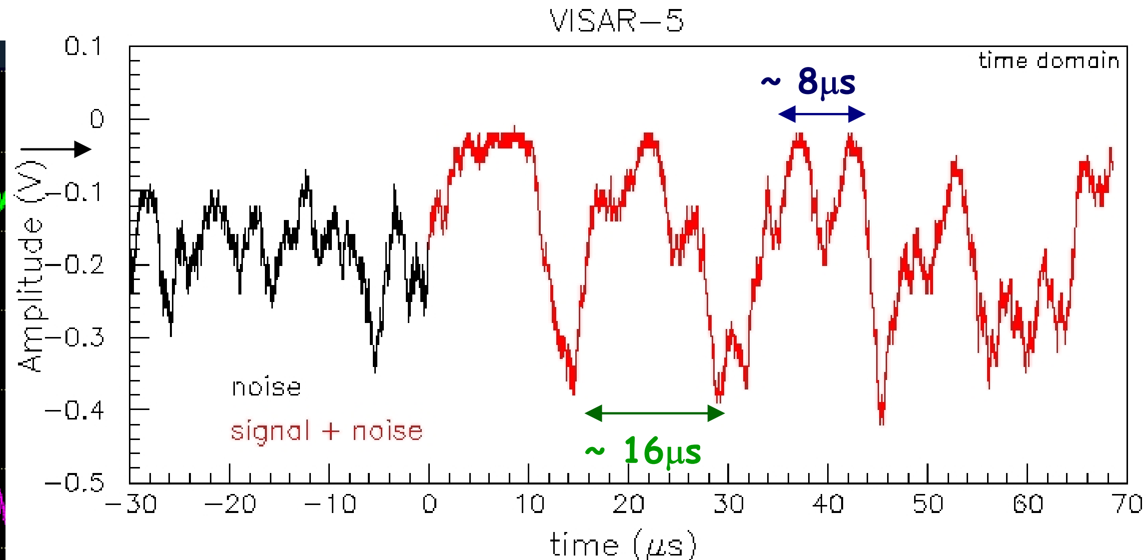
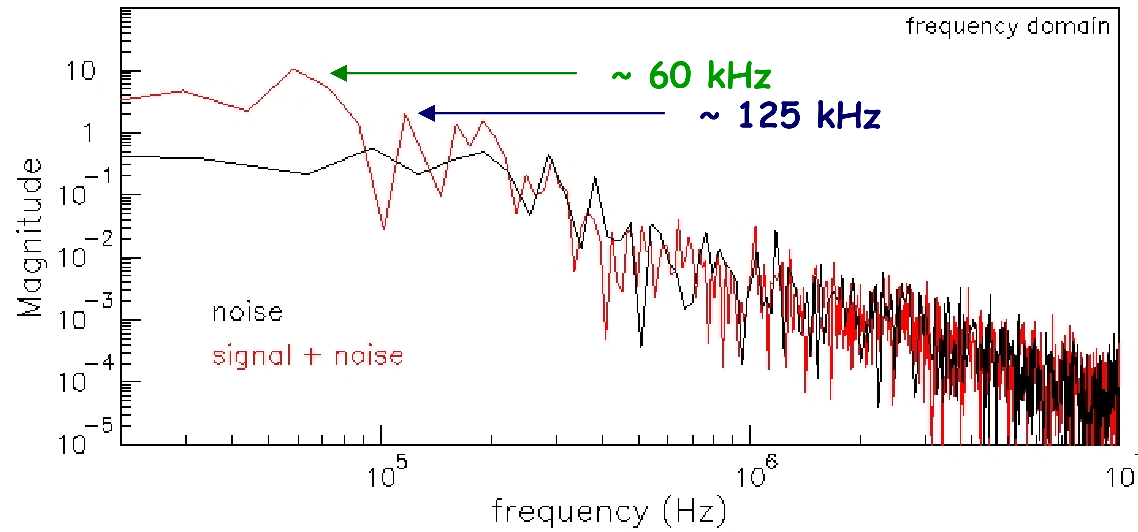
Frequency analysis of the VISAR signal







FFT method (MATLAB) has been used
– from time to frequency domain –

Dominant signal frequency (not so clearly) seen in frequency spectrum

Real effect (friction of wire's end) or noise?
Compare with previous plot – looks like a noise
(here: not enough data points for noise)

Really powerful method; we need more data from VISAR

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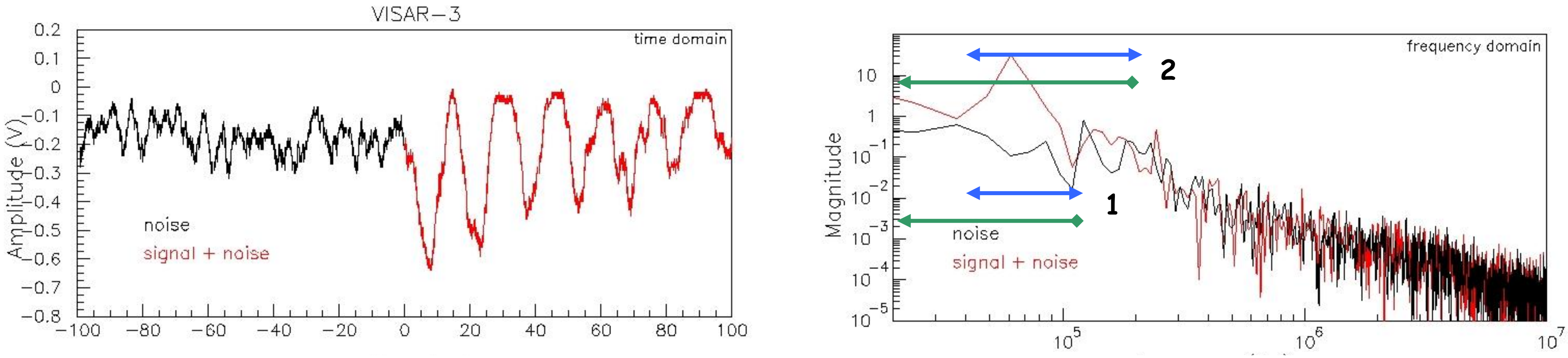
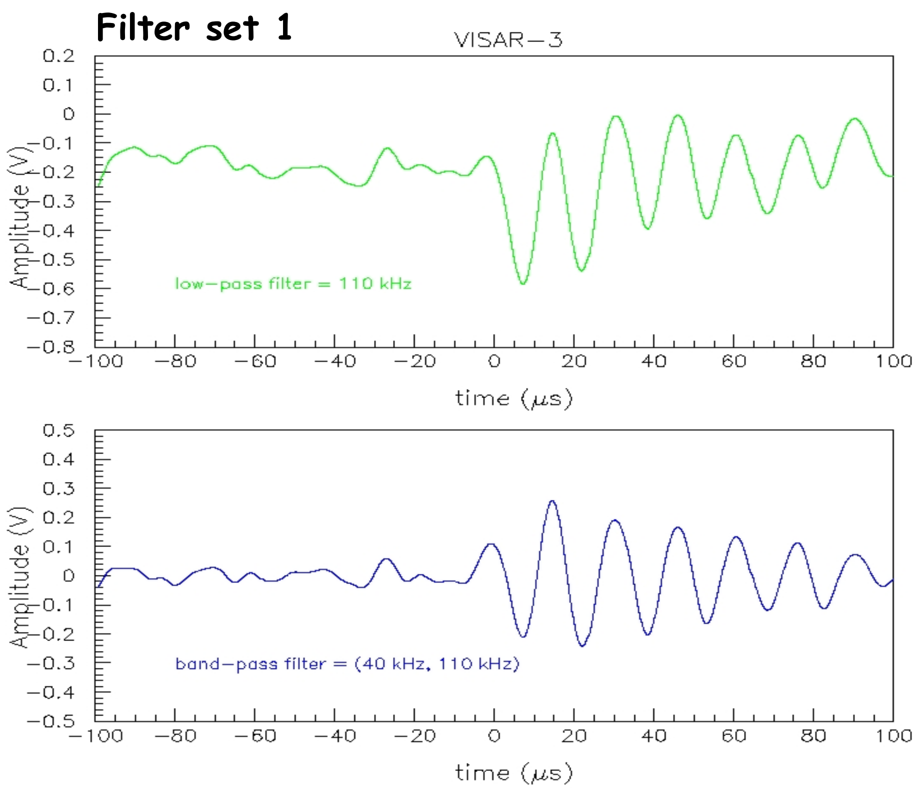
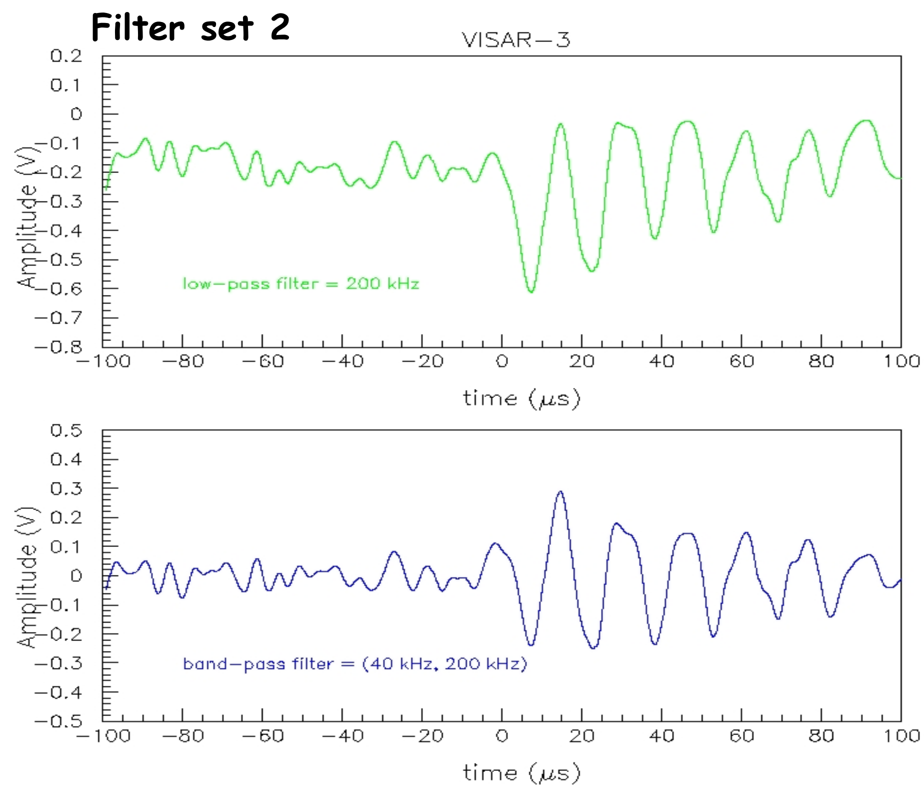
Frequency analysis of the VISAR signal - Filtering

A few examples how we can filter the data







Update I

17 March 2009

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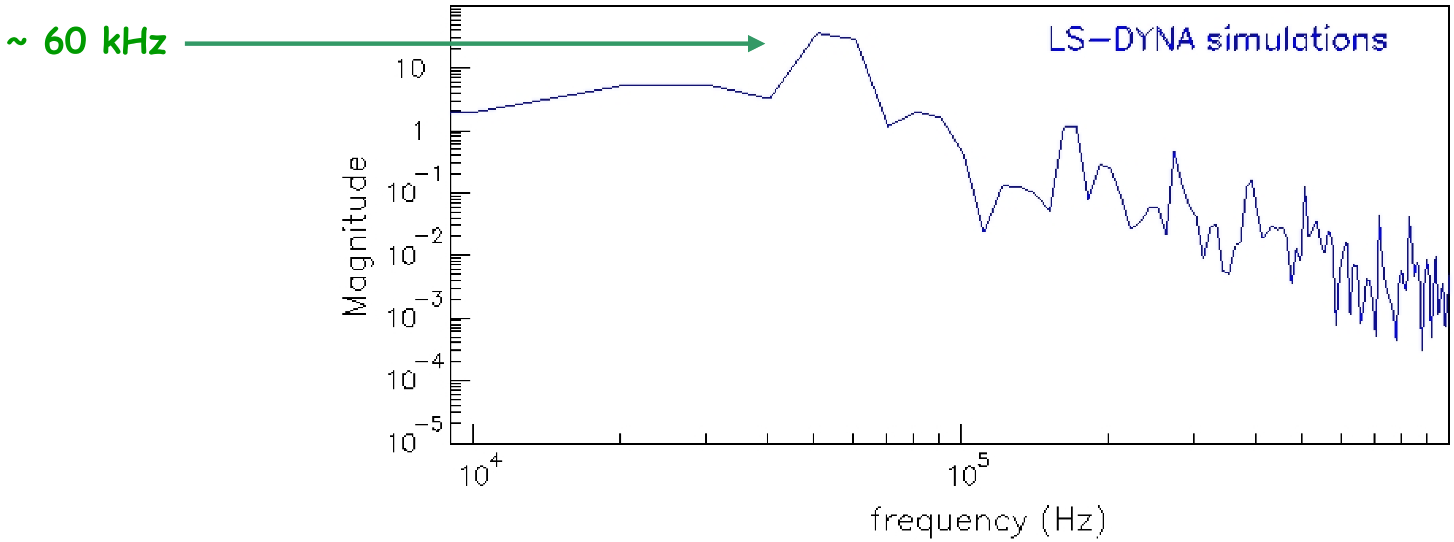
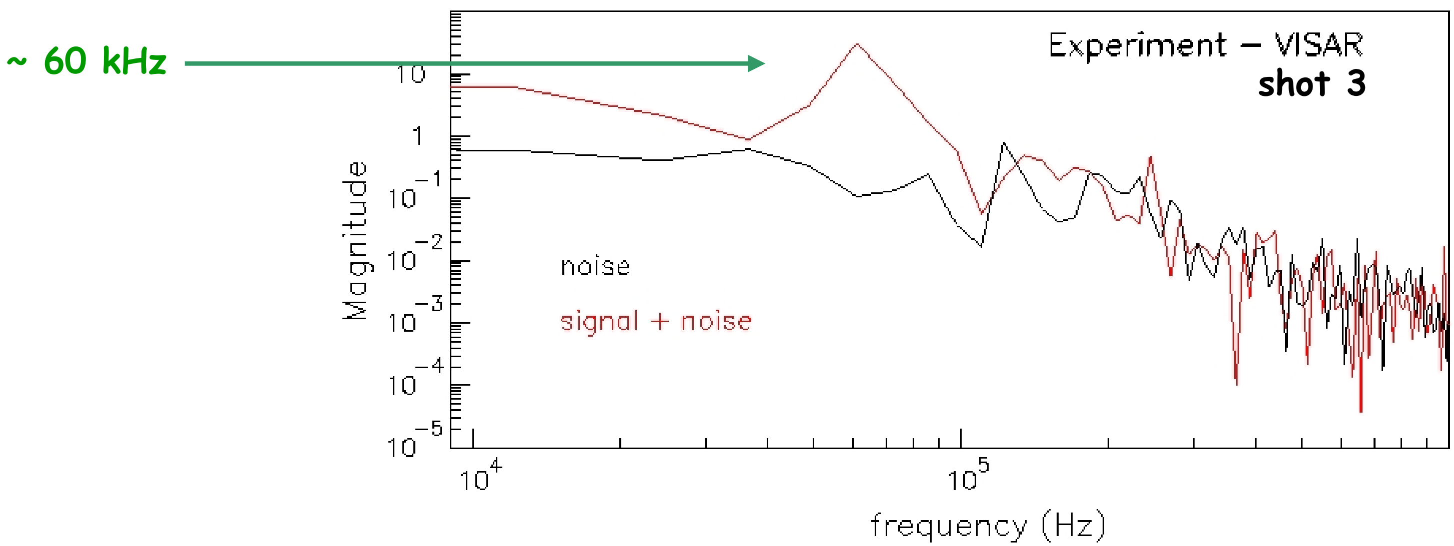
The University Of Sheffield.

Frequency analysis of the VISAR signal and LS-DYNA results





Dominant frequency that corresponds to longitudinal motion of the wire is clearly present in both frequency spectra

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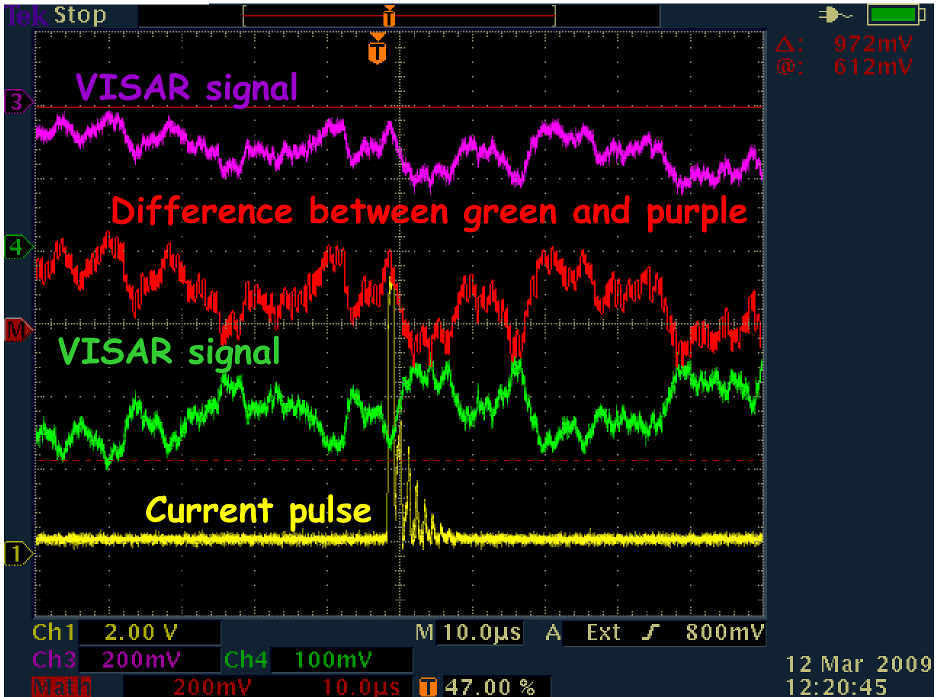
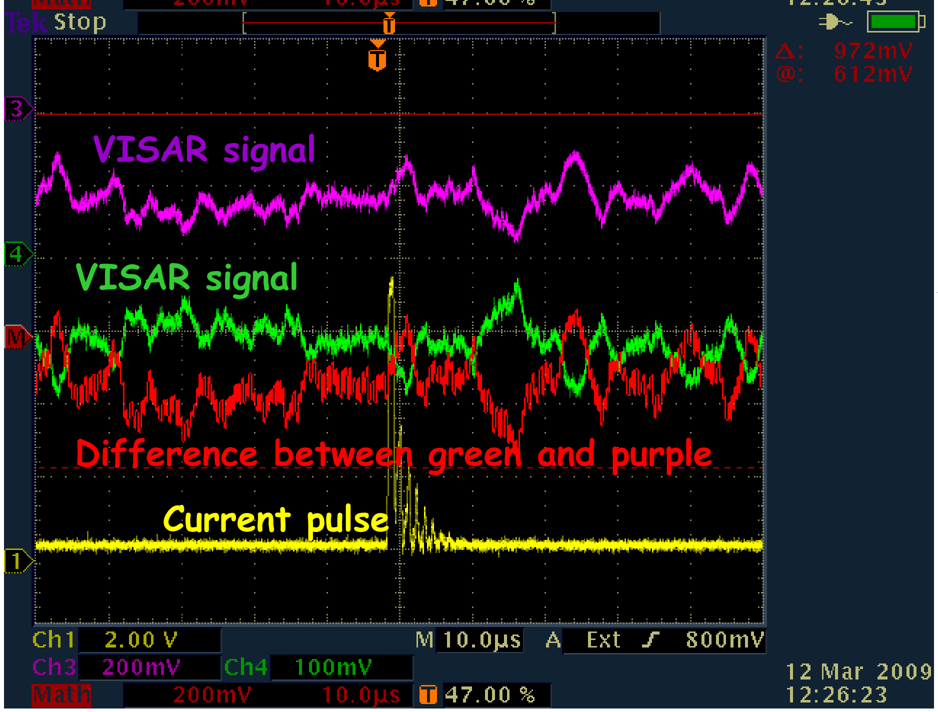
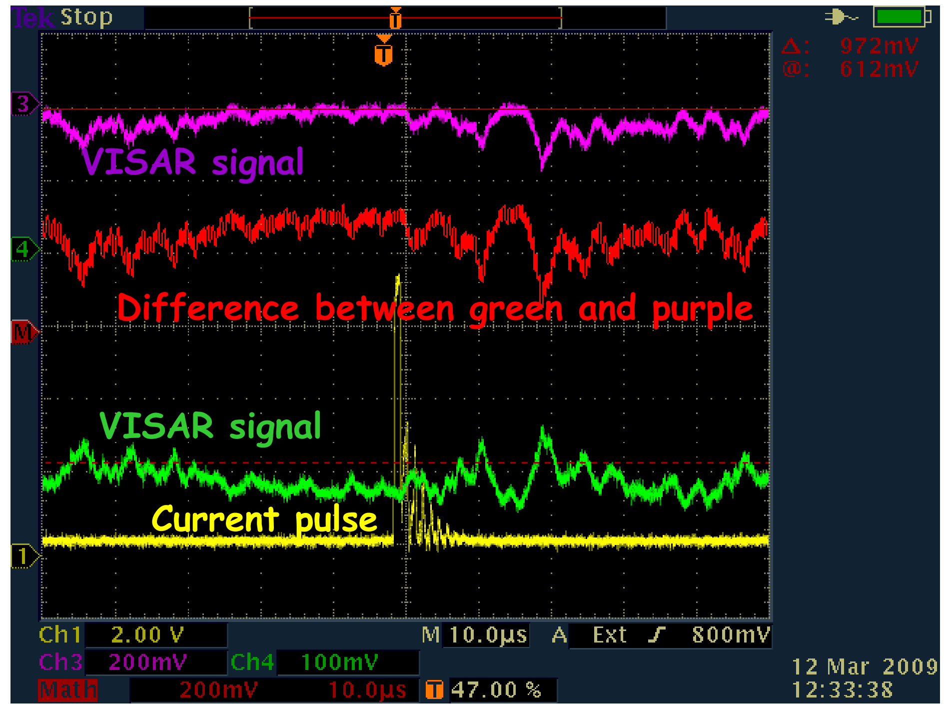
VISAR tests with a shorter wire (3 cm)

New tests have been performed with a shorter wire

A few characteristic results







First conclusion: no signal here!

But, interesting 'coincidence' in frequency spectrum…

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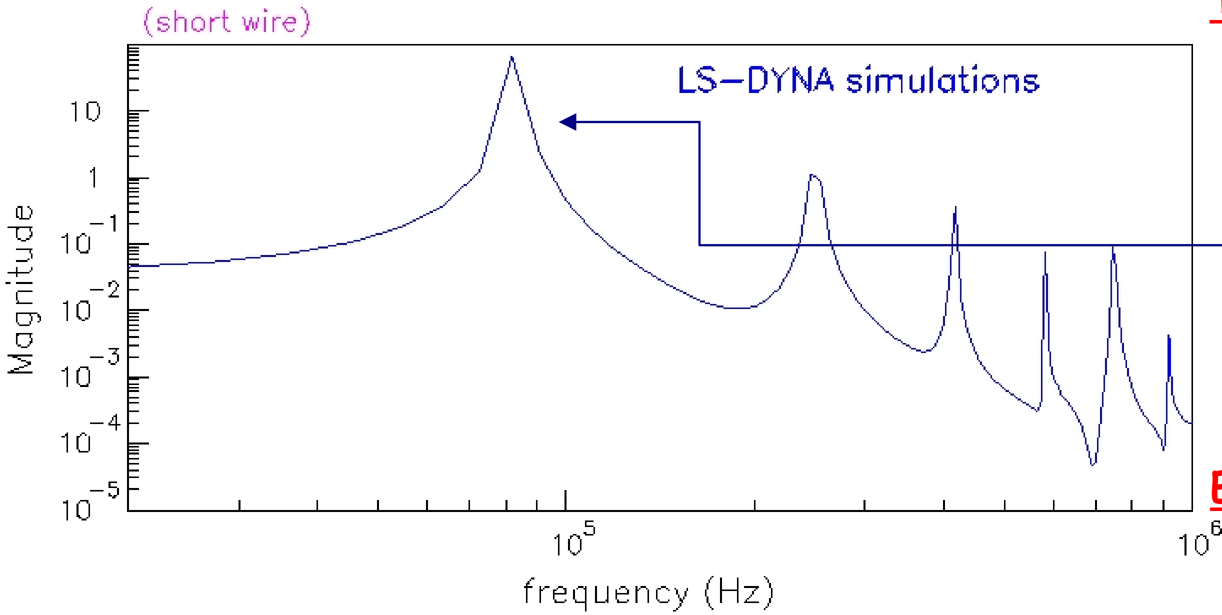
Frequency analysis of the VISAR signal

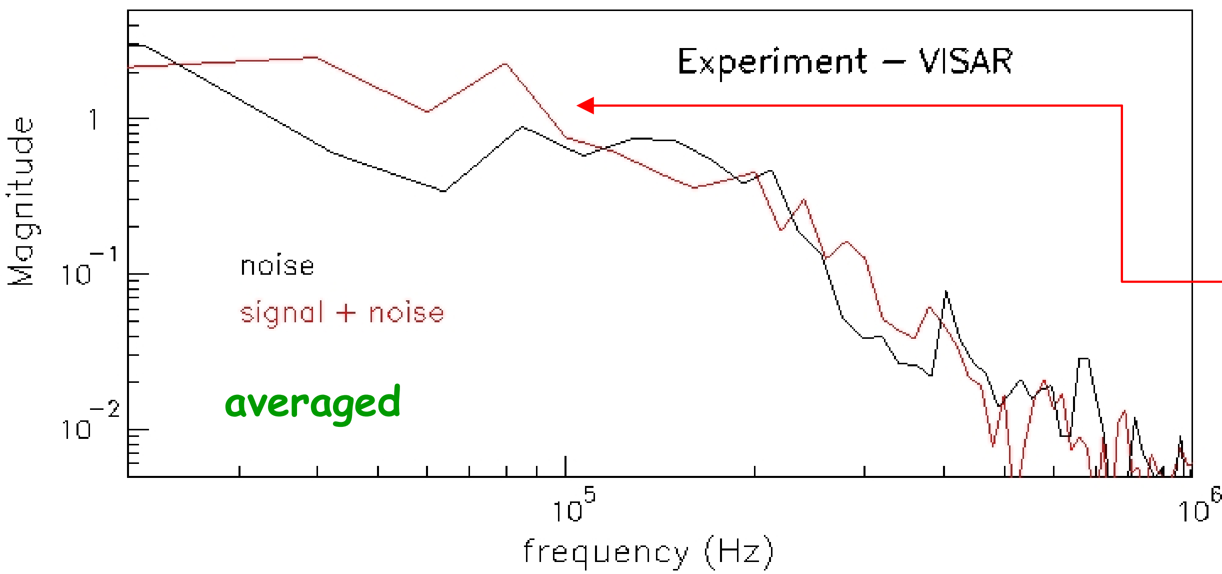
Tests with a shorter wire



We could expect to see this dominant frequency (~ 80 kHz)

Experiment

FFT analysis of each shot – no signal seen (expected, if we look at previous slide)



But, by averaging the frequency spectra, the 'structure' starting to appear exactly at the right position

Small statistics – so we can say it's a coincidence (but will be interesting to collect more data)

VIBROMETER

We have had a trial demonstration of a **Vibrometer** – a type of Michelson interferometer. This enables us to see the radial vibrations of the wire as well as the longitudinal under thermal shock.

Here is a very preliminary result.

Trial Run

Vibrometer & FFT

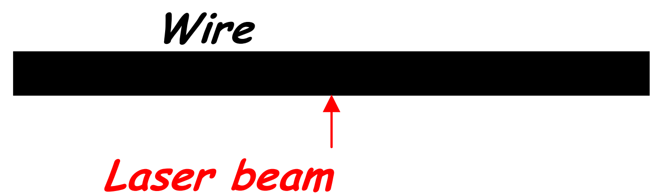
Goran Skoro

28 February 2009

Goran Skoro
The University Of Sheffield.

Vibrometer tests

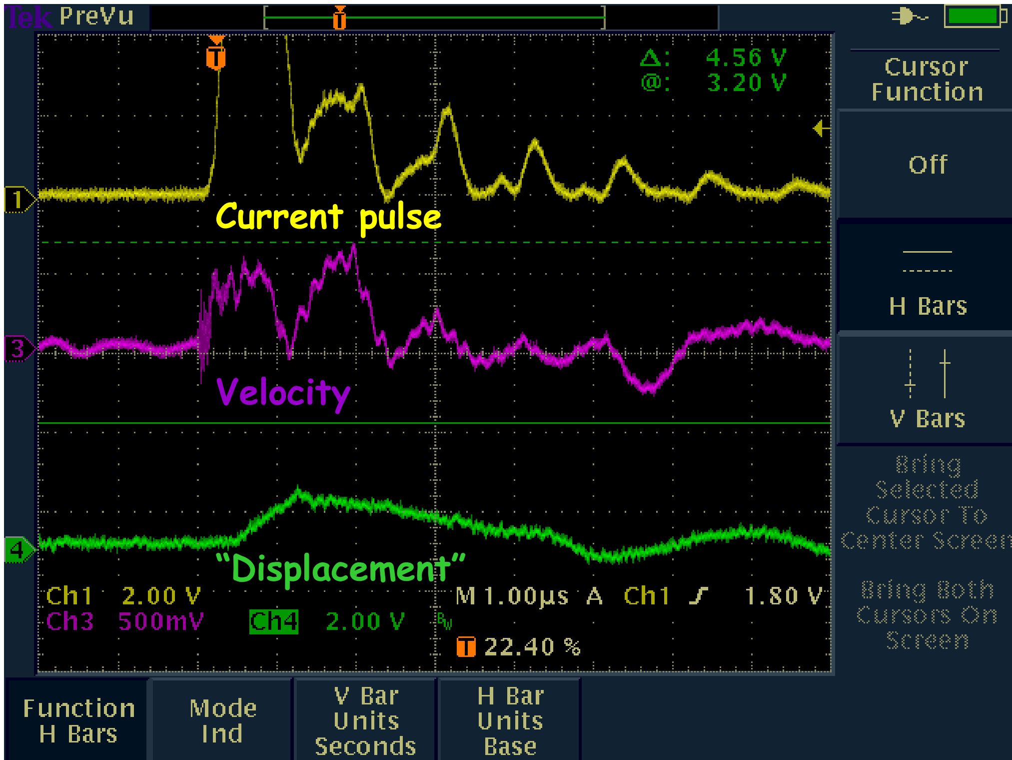
Laser Doppler Vibrometer tests have been performed with 0.5 mm diameter tungsten wire

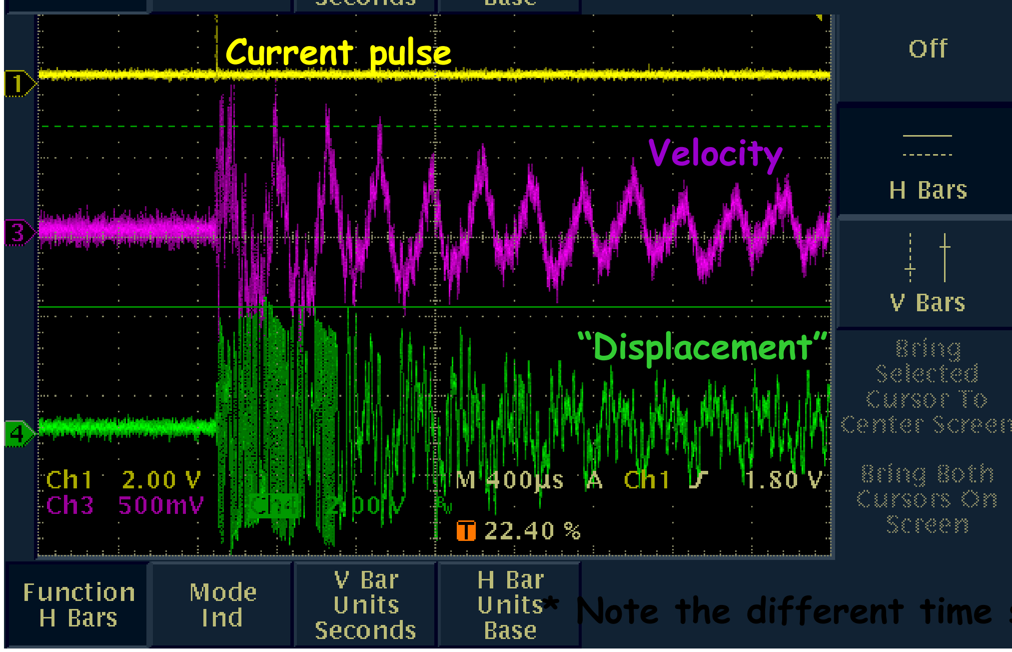


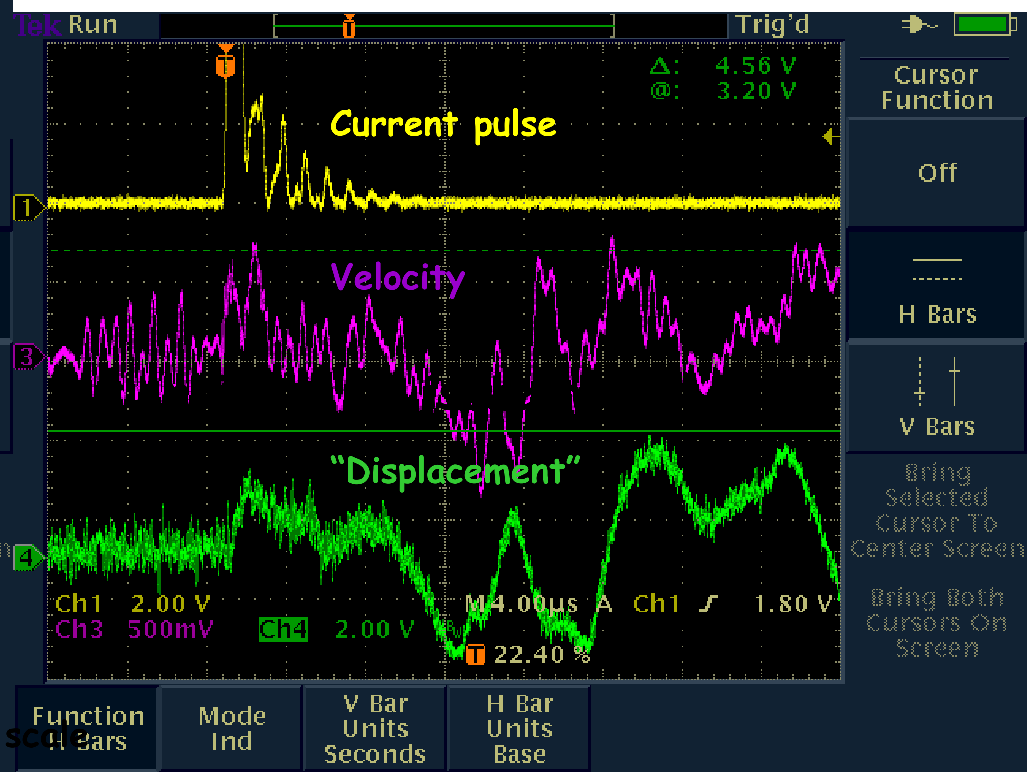
Only a few shots taken - shown on the left and below*

Yellow – Current pulse

Green, Purple – "Displacement", Velocity



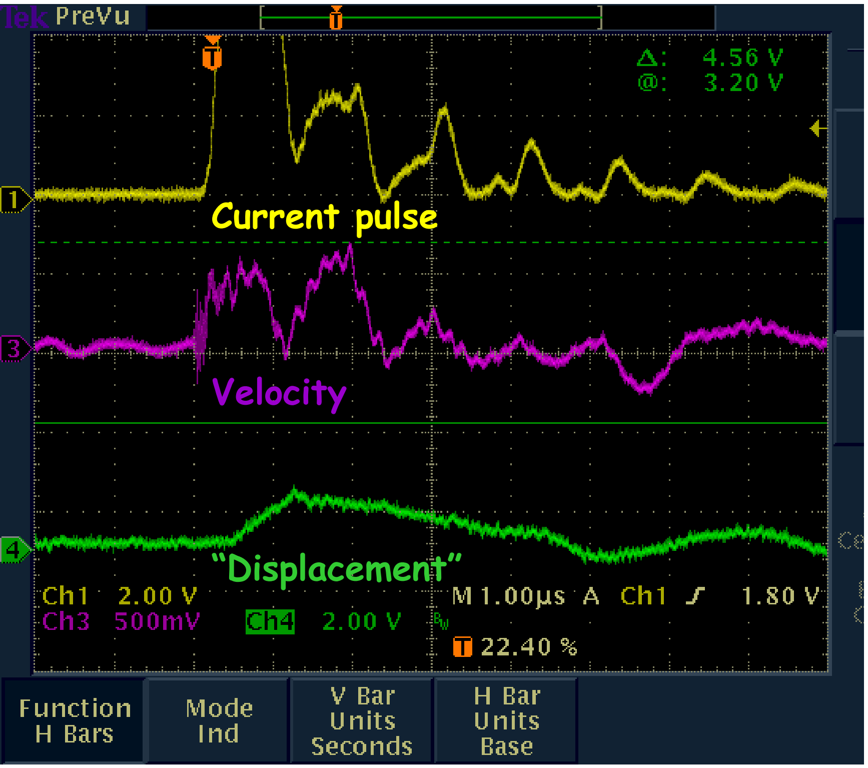


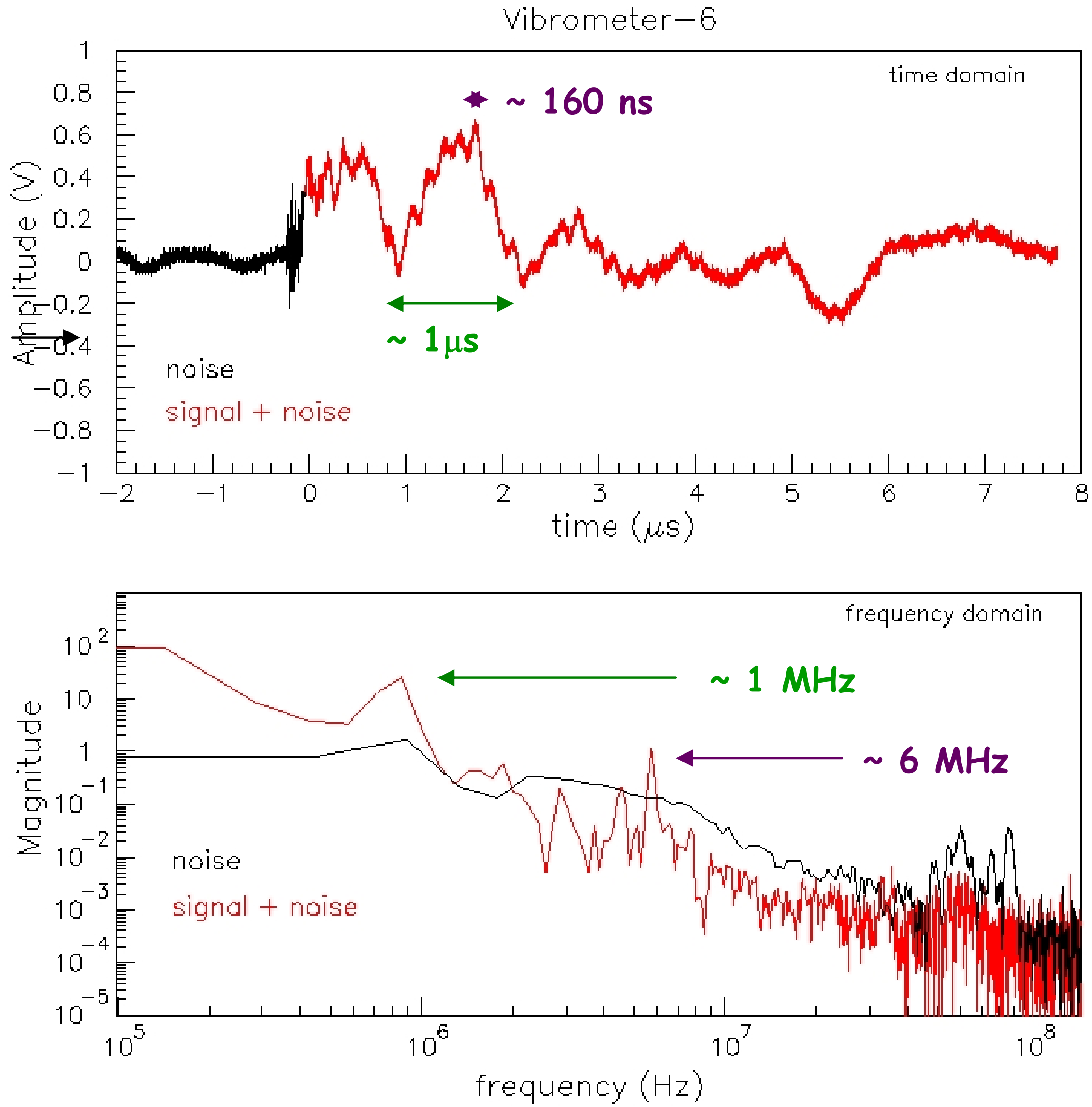


* Note the different time scale

Goran Skoro
The University Of Sheffield.

Frequency analysis of the Vibrometer signal





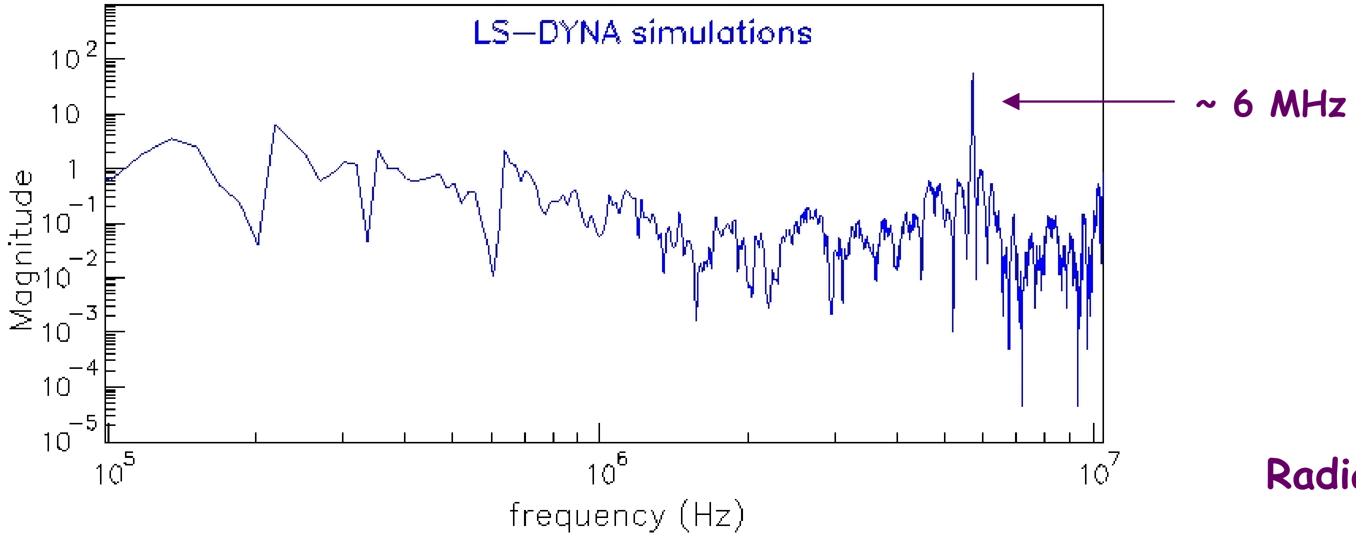
FFT method (MATLAB) has been used to analyse velocity signal
- here: **short** time scale -

We expect to see radial oscillations

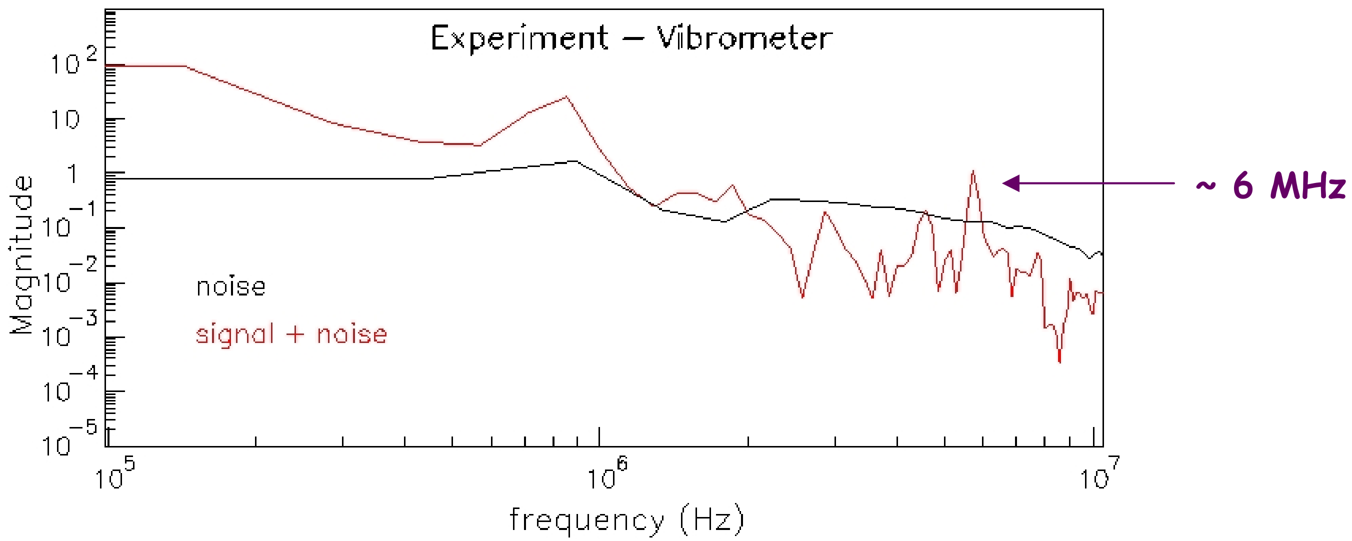
Current pulse (and reflections)

Radial oscillations of the wire

Frequency analysis of the Vibrometer signal and LS-DYNA results



Radial oscillations of the wire!!!



Better experimental data at medium time scale needed in order to compare longitudinal oscillations with corresponding calculations results (VISAR results, we have so far, are much better for this – see FFT & VISAR presentation for initial comparisons)

Conclusion

At long last I believe we are beginning to see our way to making an assessment of the strength of the tungsten under stress conditions at high temperatures.