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Analytical Analysis of the Ablation Phase of Low Wire Number Wire Arrays

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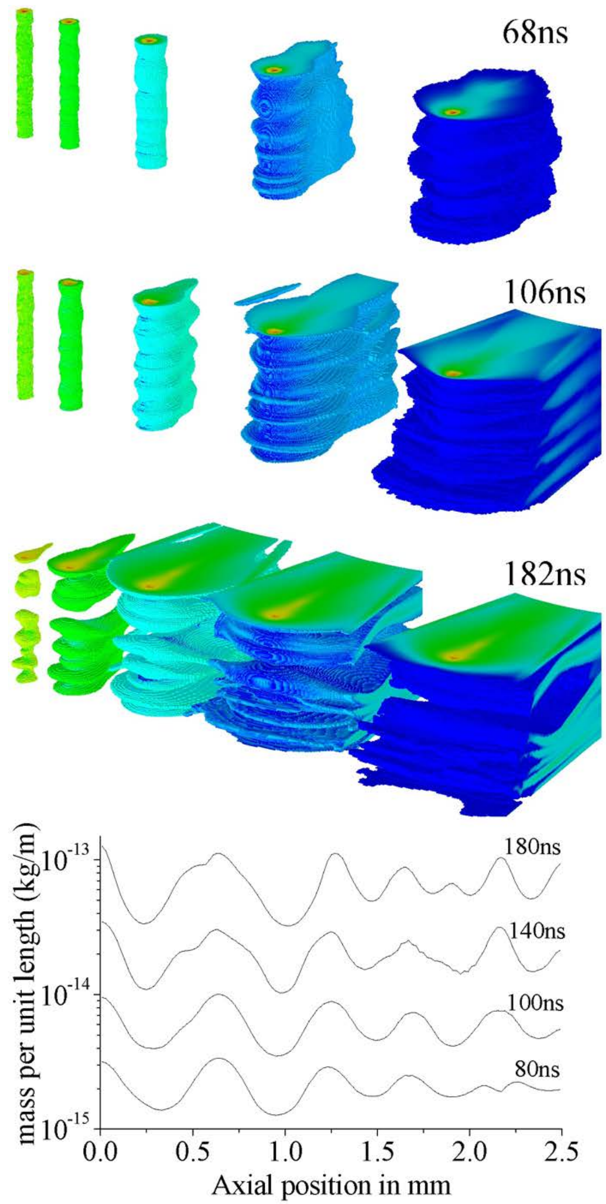
Simulation work is doing a good job

- Recent progress on flare initiation, spectroscopic output, simulated diagnostic views etc.
- Need more data from experiment
- A vital topic on which discussions are centered is the current convection and acceleration region in wire arrays

  i.e. where is the current?

- At UCSD several projects are looking at this issue:
  - o Proton probing of wire array
  - o Convective flows in planar arrays
  - o Analytical investigation of the acceleration region in cylindrical array



Chittenden & Jennings, *PRL* 2008

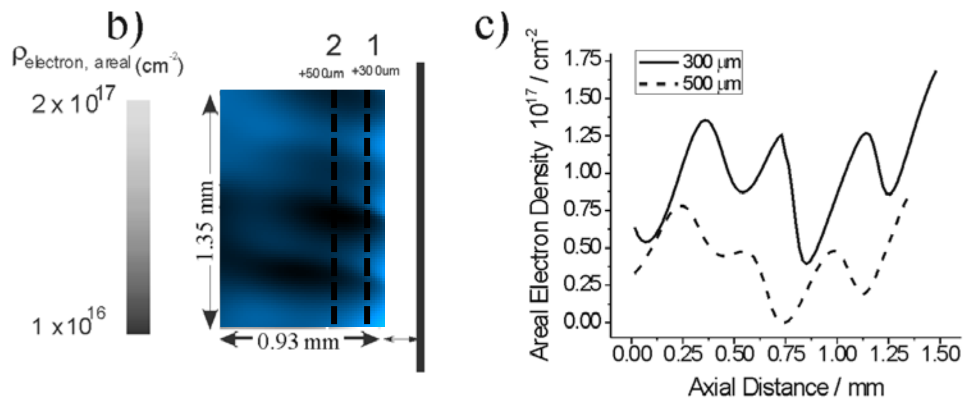
4-Wire Arrays on GenASIS

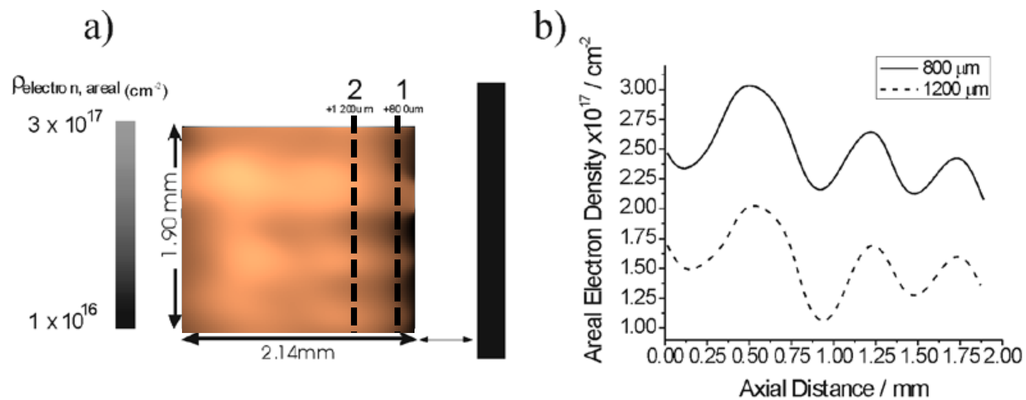
- Interferometer data taken on GenASIS (200 kA, 150ns)

- 2D areal electron density maps recovered

- The average density contrast, assuming fixed ionization for each case, is typically ~ 2 for W and ~1.3 for Al

- This is a maximum mass density contrast, since using a fixed ionization under-estimates density in cooler inter-flare regions





AXIAL DENSITY CONTRAST MEASUREMENTS

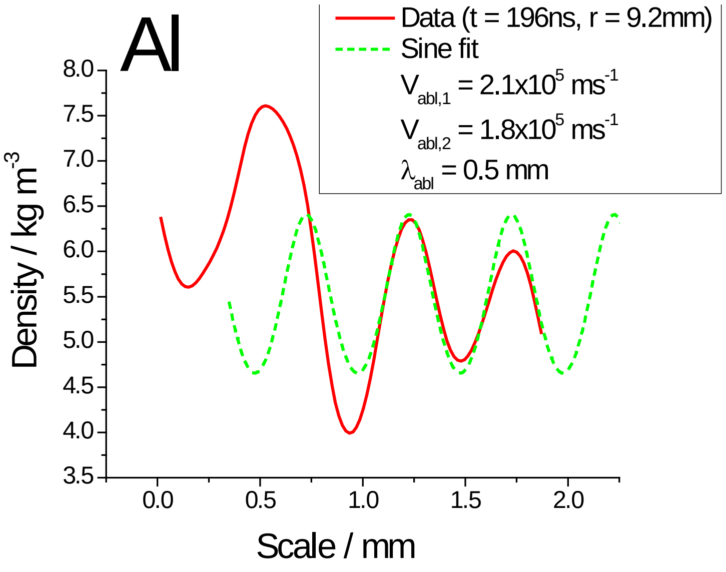
Material	Lineout position (radially inwards from wire)	Average Axial Density Contrast
W	0.3 mm	1.9 ± 0.4
W	0.5 mm	2.8 ± 1.1
Al	0.8 mm	1.2 ± 0.1
Al	1.2 mm	1.4 ± 0.2

Modified Rocket model of Ablation

$$V_{abl}(z) = \left[\left(\frac{V_{abl,1} - V_{abl,2}}{2}\right)\sin\left(\frac{2\pi z}{\lambda_{abl}}\right)\right] + \left(\frac{V_{abl,1} + V_{abl,2}}{2}\right)$$

$$\rho_{\mathrm{mod}}(r,z) = \left(\frac{\mu_0}{8\pi^2 R_0 r V_{abl}(z)}\right)\left[I\left(t - \left(\frac{R0 - r}{V_{abl}(z)}\right)\right)\right]^2$$

- Use of sinusoidal fit gives a reasonable representation of data
- Y-Offset is the typical rocket model using the average V_{abl}
- Frequency is the average flare wavelength
- Amplitude is the range of effective ablation velocities needed to describe the data
- Fit routine for V1, V2, λ_{abl} can be used for rapids analysis



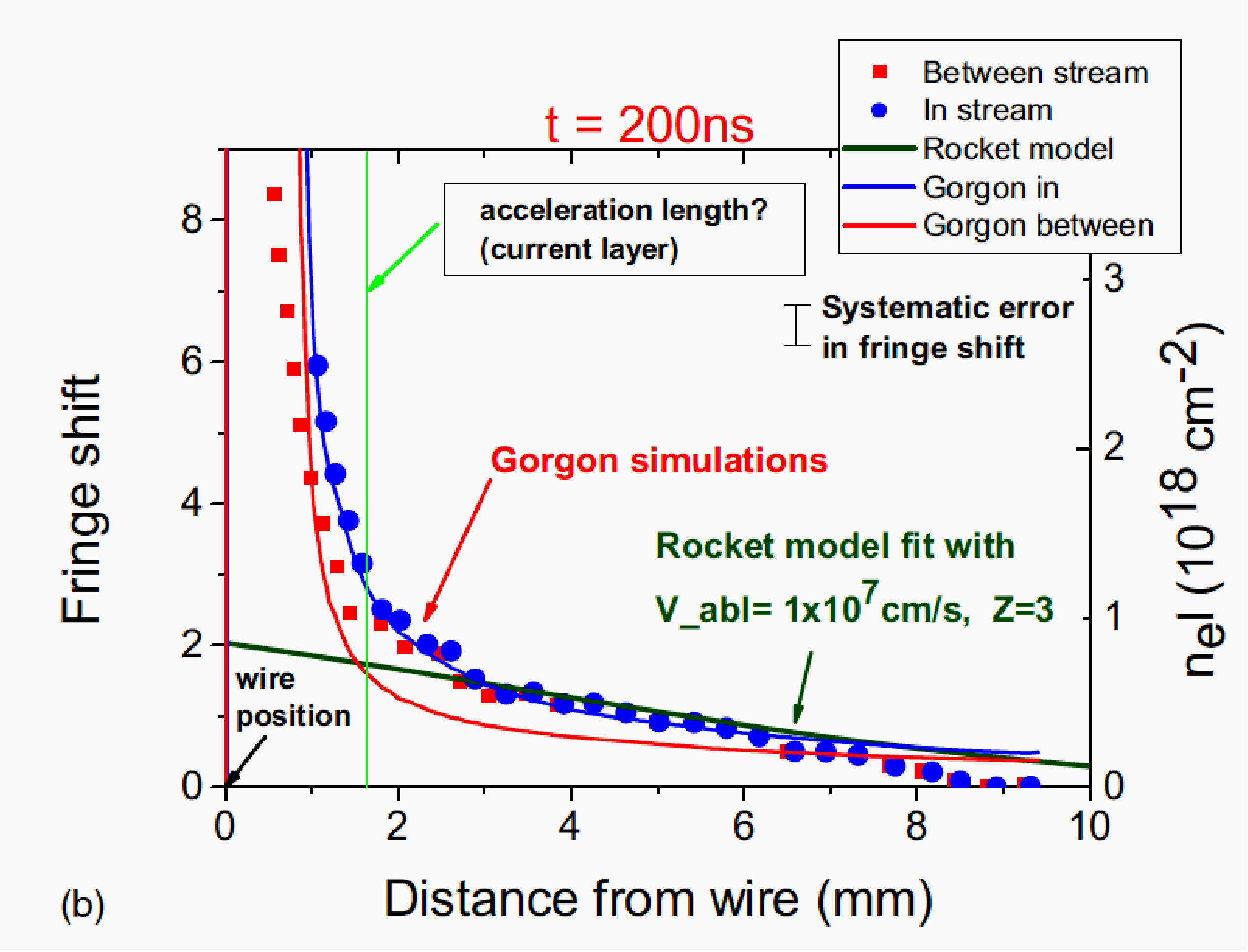
S.C.Bott *et al, IEEE TPS* 2010

Analysis of acceleration region in wire arrays

Inverse wire array configuration examined recently by Harvey-Thompson *et al* for Al, which suggested an acceleration region on ~1.8 mm radially outwards from wire

- Interferometry data compared to Gorgon MHD simulations to determine where these diverged

- Limited by the laser penetration of plasma close to the wire for W (i.e. $n_{e,corona} > n_{e,\ crit}$)

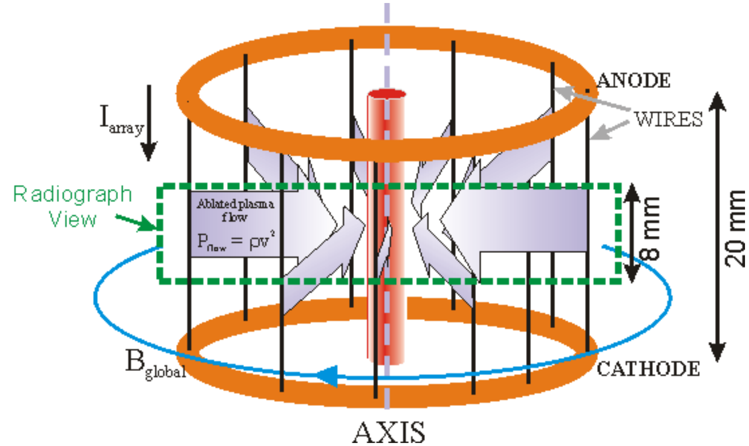


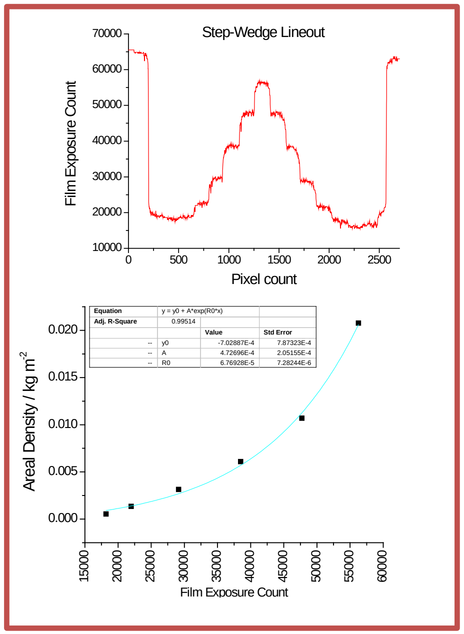
Harvey-Thompson *et al*, *Phys. Plasmas*, **16**, 022701 (2009)

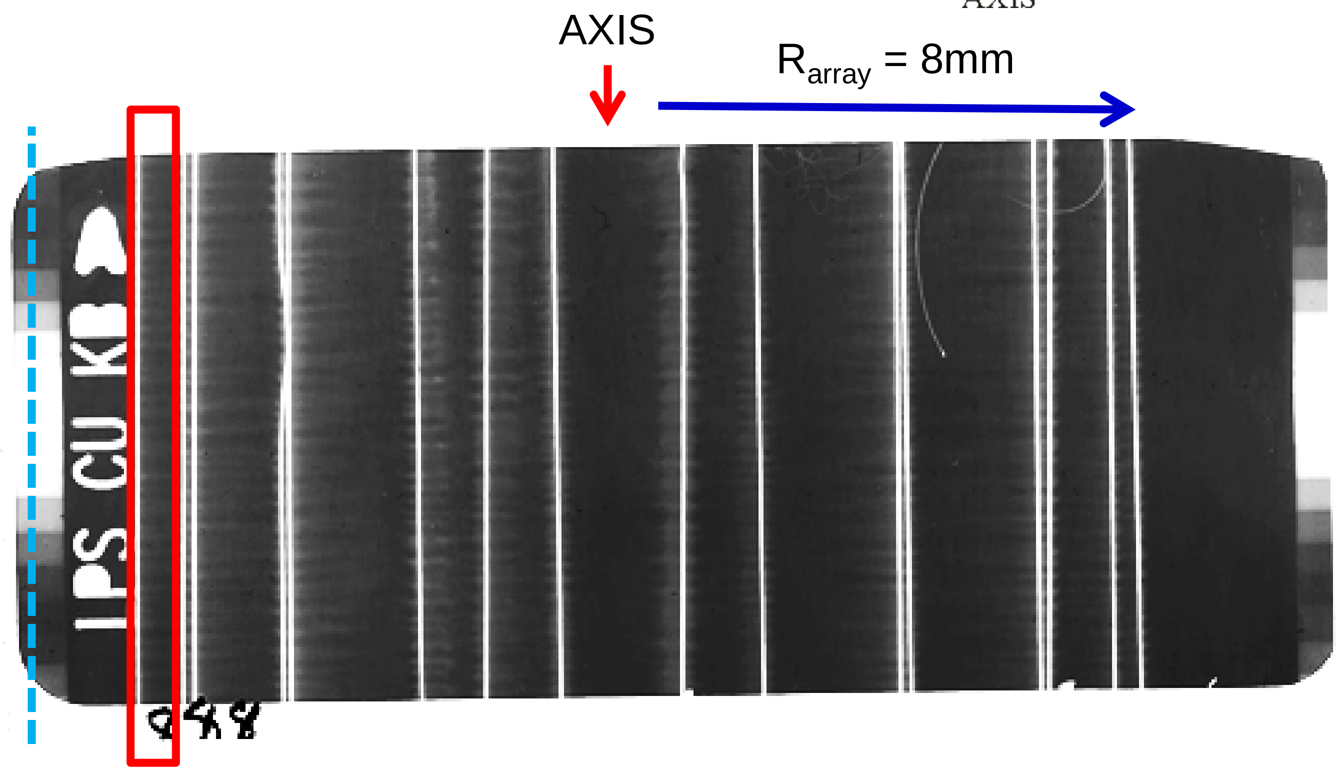
- Using radiography in non-imploding arrays we can examine regions very close to the wire

16 Wire tungsten Arrays on COBRA

- Radiography imaging of 16 wire W arrays on COBRA were taken as various times in the current rise, using the STAR system [Douglass, *Rev. Sci. Instrum.* 2008]

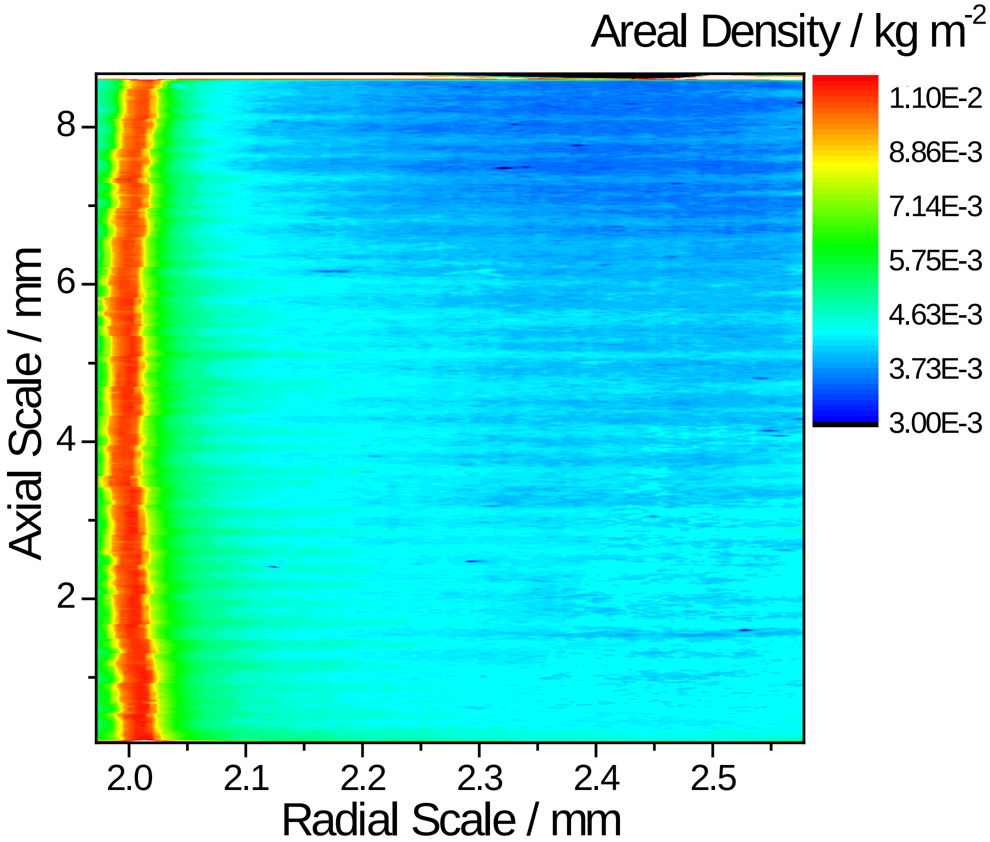


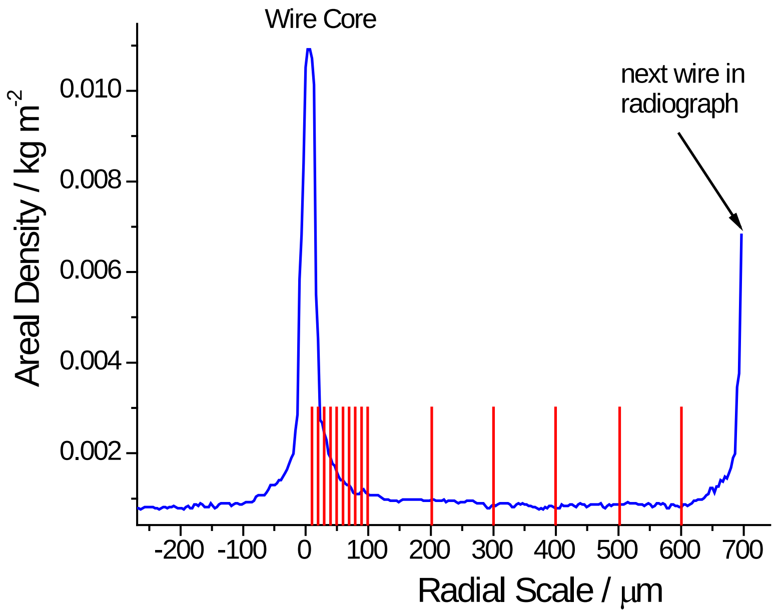




- Step-wedge imaged simultaneously, which allows for absolute calibration of areal mass density in image
- Spatial resolution < 5μm (pixel size = 3.3 μm)

Radiography Data from COBRA

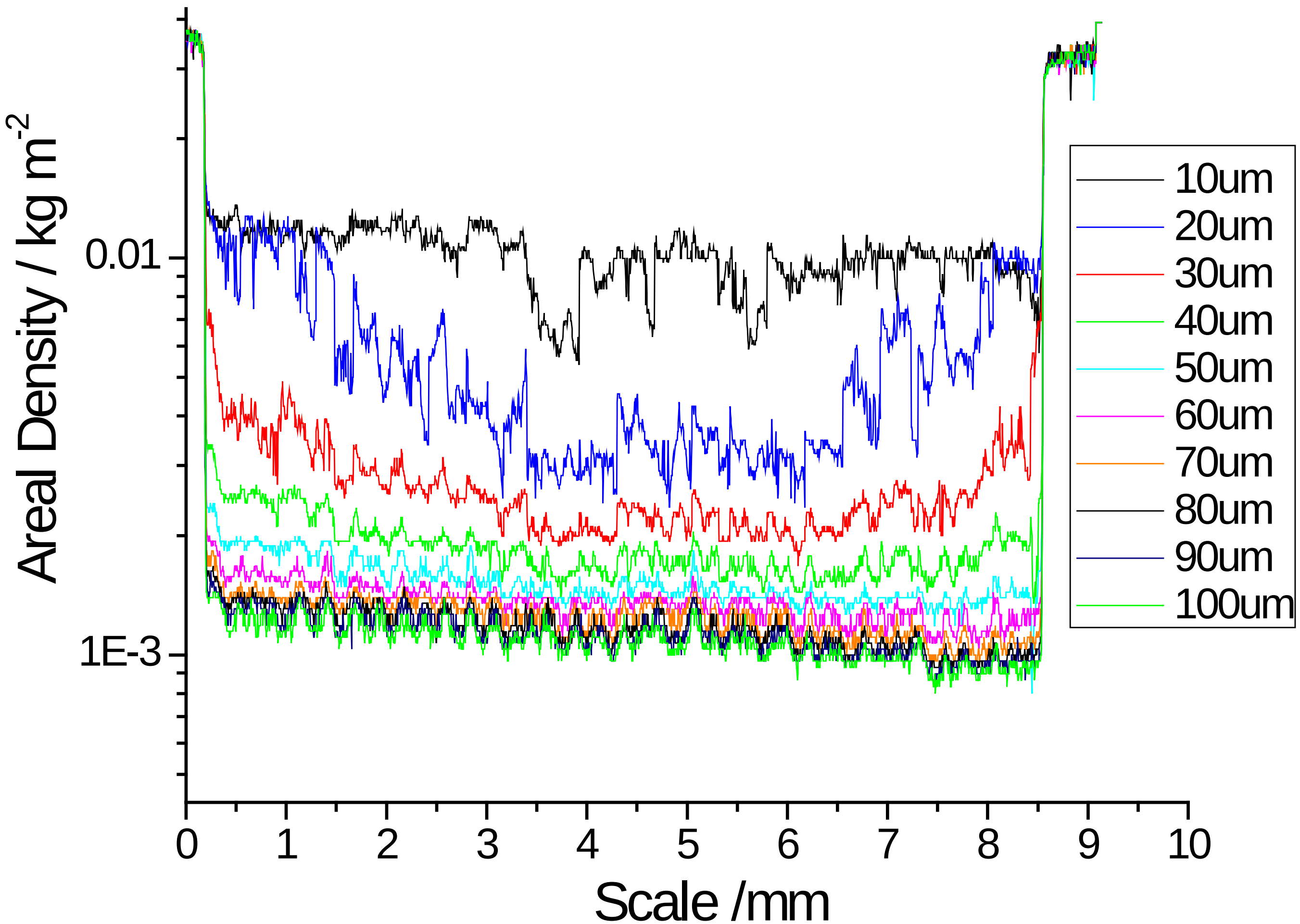




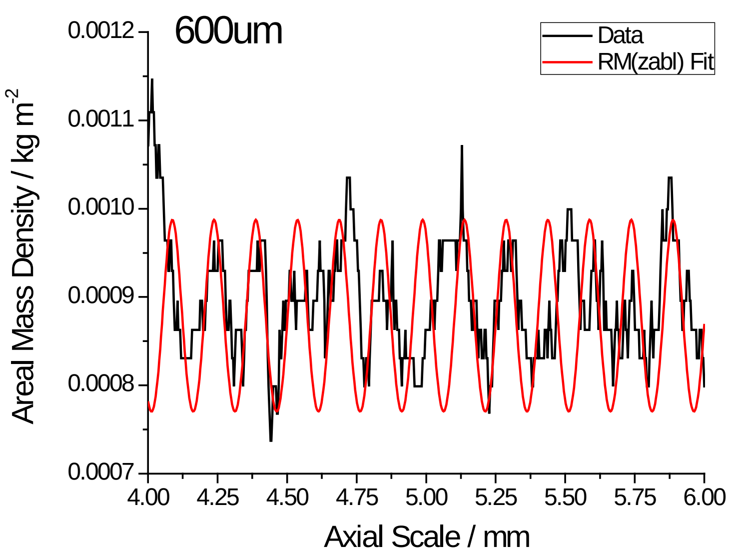
- High quality data from COBRA radiographs allow large areas to be examined
- Note details of wire which need correction in the analysis:
  - o Curvature – radial position needed for RM analysis
  - o Absolute separation of wires sets global field – wide radiograph view allow measurement of this for each position

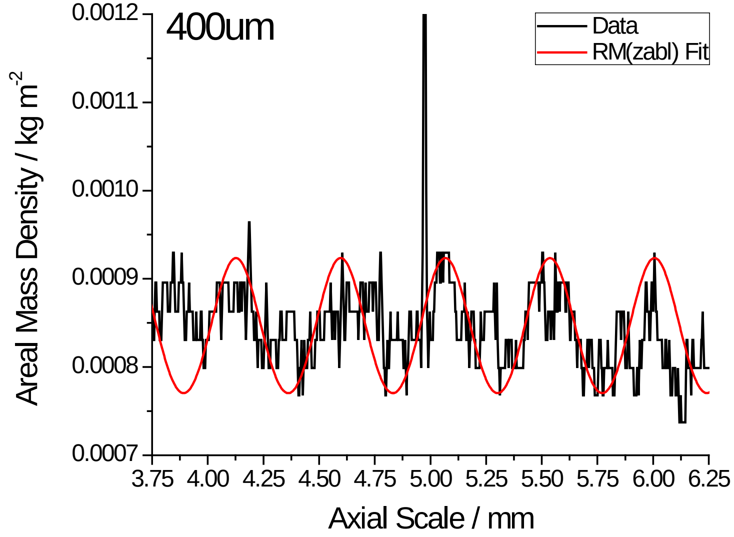
Radiography Analysis

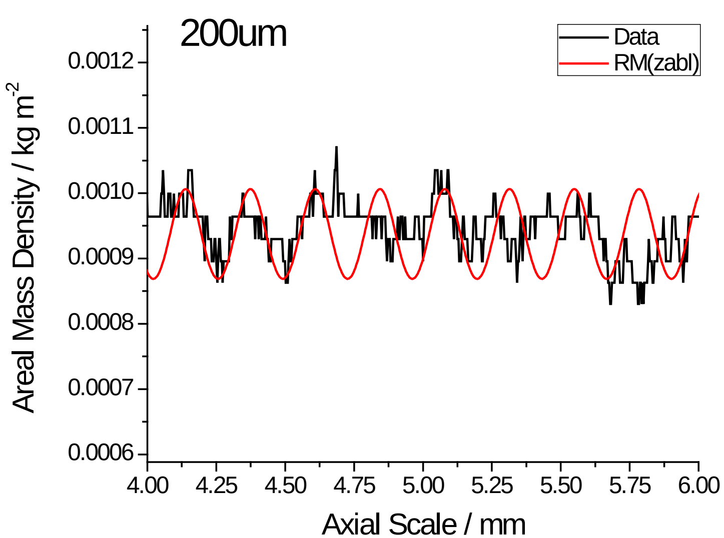
- Quantitative axial lineouts can be taken at different radial positions
- Allows assessment of both axial and radial density variation for a particular radiograph
- Region at z= 4-6mm selected for analysis due to curvature of wire

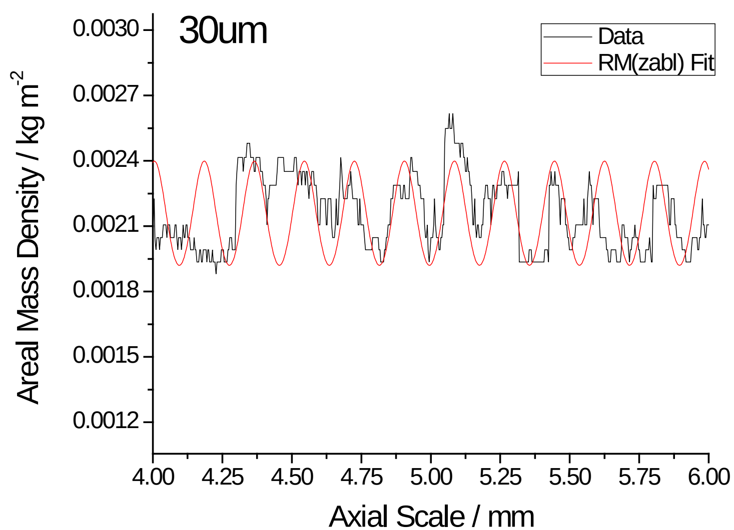


Modified Rocket model fits to lineouts









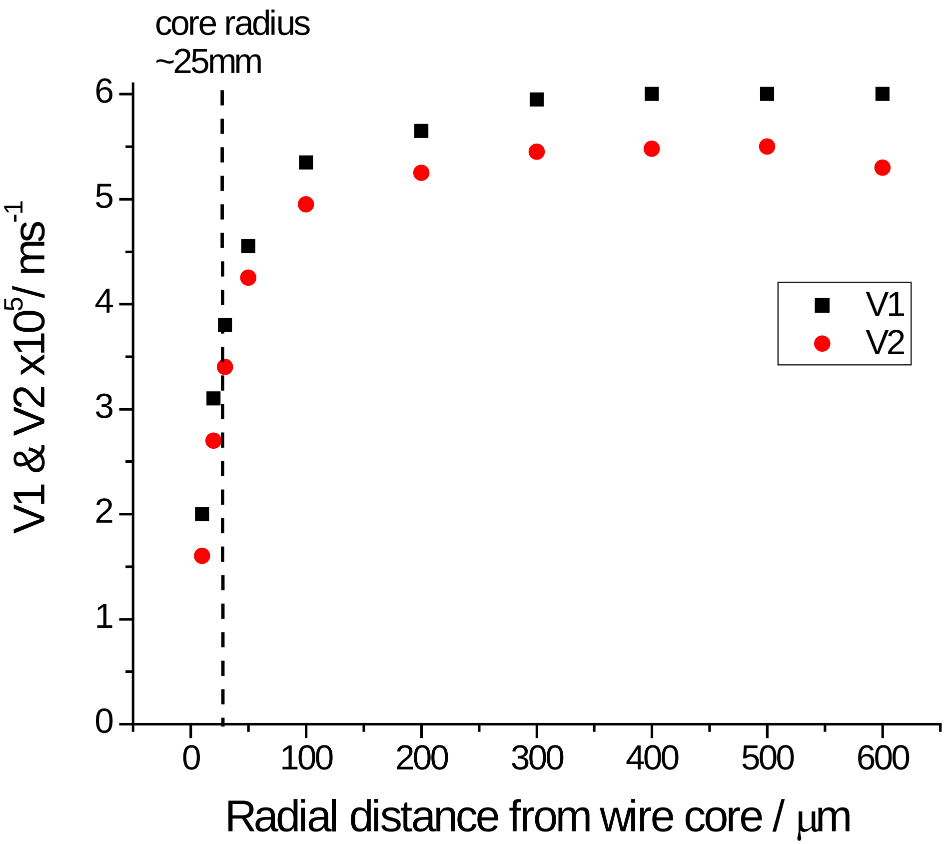
- Generally, fits are acceptable for most radial positions

Effective ablation Velocities as a function of radius

- At r > 300mm, fitted velocities close to constant but range needed seems to increase slowly

- Fitted velocities drops dramatically close to core position

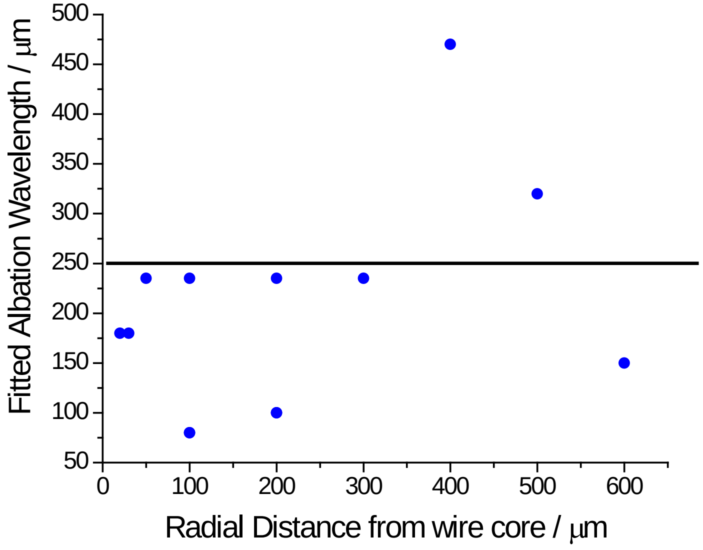
- Important to remember that this is a fitted parameter from a momentum balance model

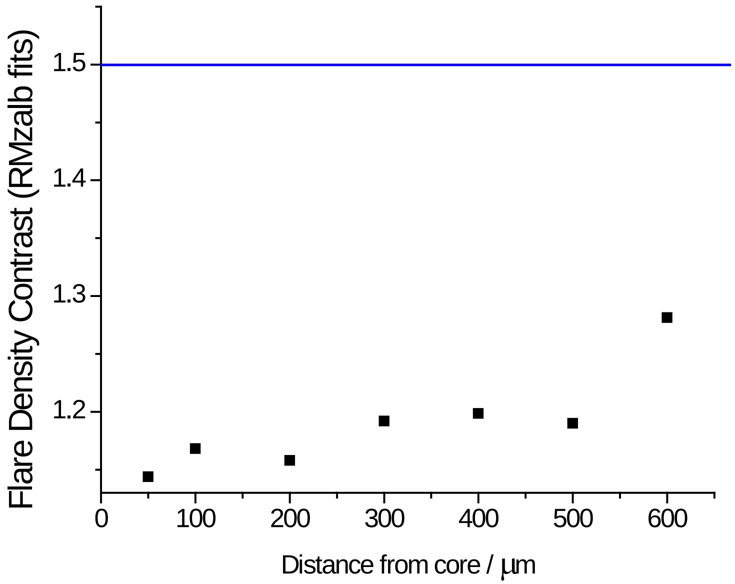


- However, the overall ablation rate for this experiment is described by the standard rocket model well (e.g. ablation rate from precursor column formation), so velocity is very high

Wavelength and density contrast as a function of radius

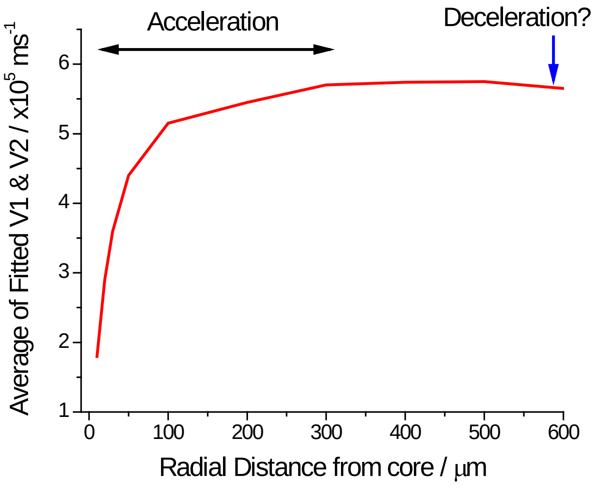
- Wavelength data rather scattered
- Very low density contrast close to wire, slowly increasing with radial distance





- Flare structure observed at smaller radius likely not fully established by 600 μm away from core

- Does this occur during a deceleration phase?



Conclusions

- ***Much more analysis needed:***
    - Acceleration region as a function of time
    - 8 wire arrays
    - Higher current (ZEBRA/MAGPIE)

- Results so far indicate a rapid increase in velocity 0-300μm from wire core
- High velocity after this may/may not fall to coincide with estimated global ablation rate from precursor formation experiments/analytics
- Detailed comparison to *existing* simulation work to come