Simultaneous Photonic Doppler Velocimetry and Dual-axis Framing Technique

Mike Bowden & Will Neal
AWE Plc

PDV Workshop, 2016

mike.bowden@awe.co.uk

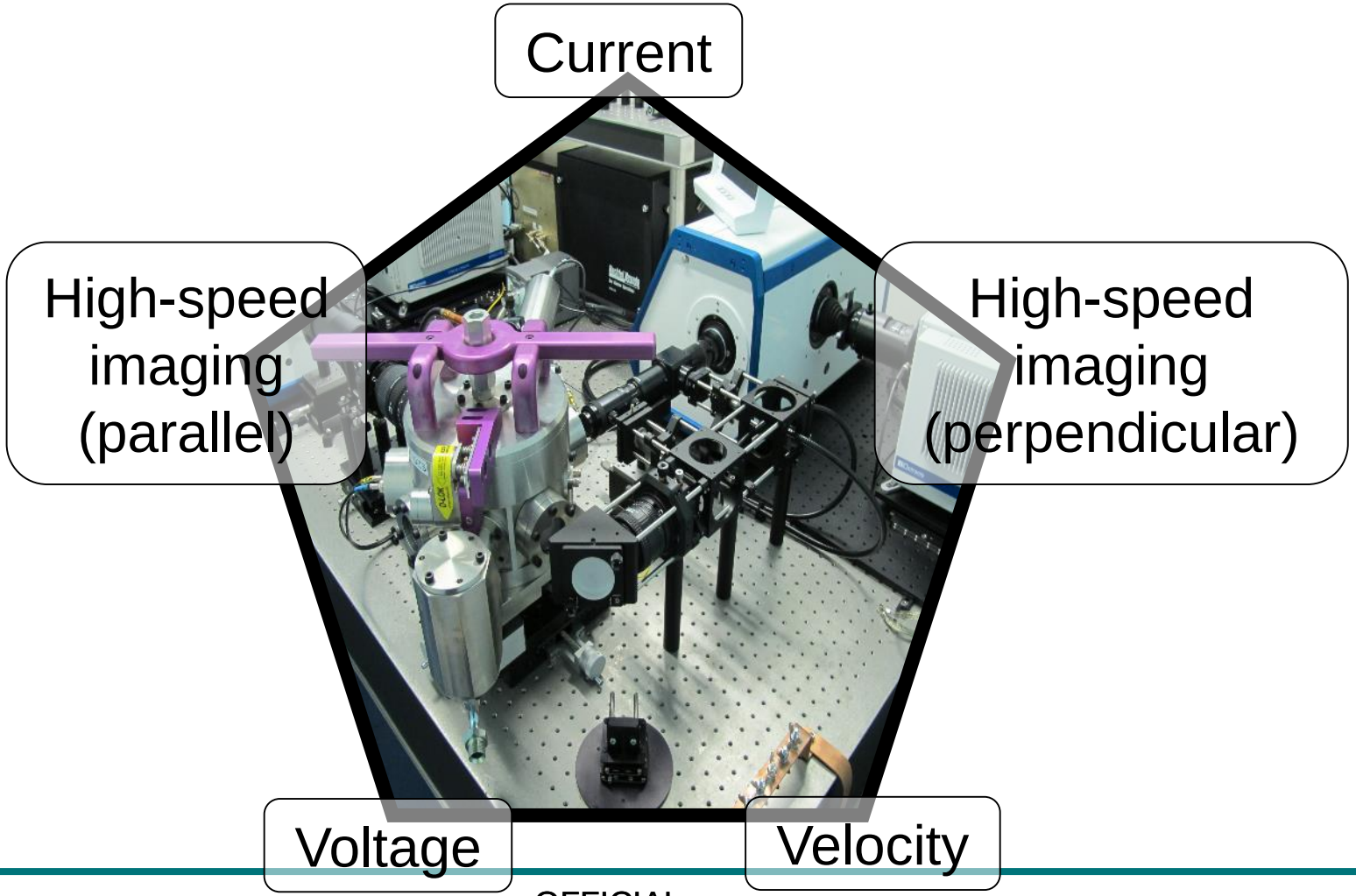
Introduction

- Experiments on detonator components have historically been routinely limited to three metrics: current, voltage, flyer velocity (the “trifecta”)
- This was consummate with the modelling capability available
- Recent advances in magentohydrodynamic modelling (ALEGRA, ALE-MHD) have driven an improvement in detonator experimental capability
- Current, voltage, flyer velocity and multi-axis high-speed imaging are now routine

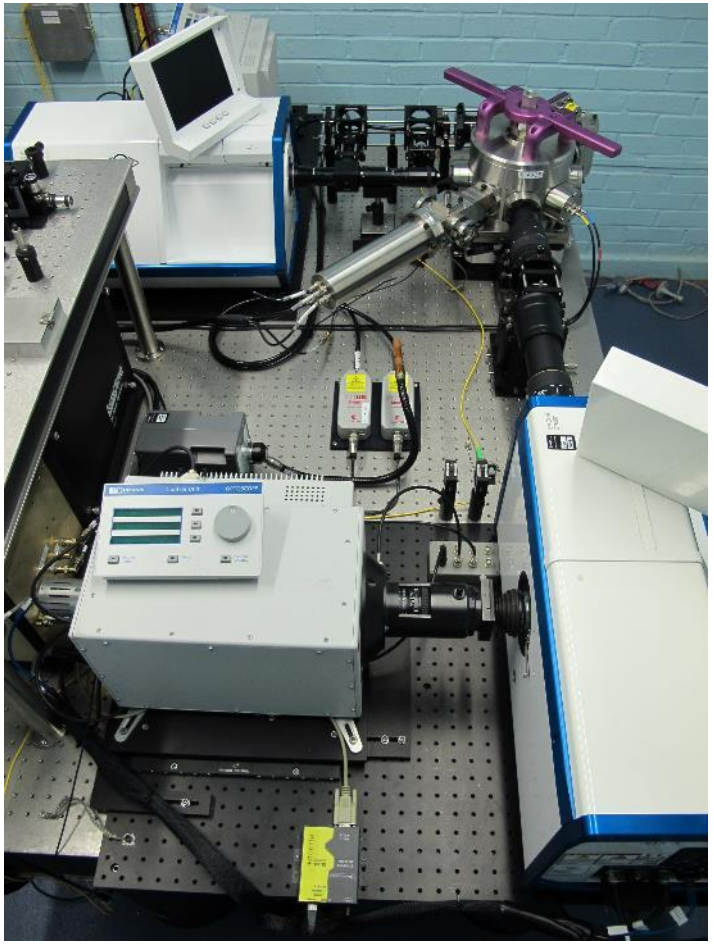
Improvements in experimental capability

- AWE has implemented a significant uplift in capability, realised in the Microdetonics Laboratory
- Designed for EFI & EBW detonators and components
- Multi-year effort by several staff members
- Highly-diagnosed experimental capability with current, voltage, velocity (PDV), dual axis streak and framing (the “pentafecta”)

The “Pentafecta” capability

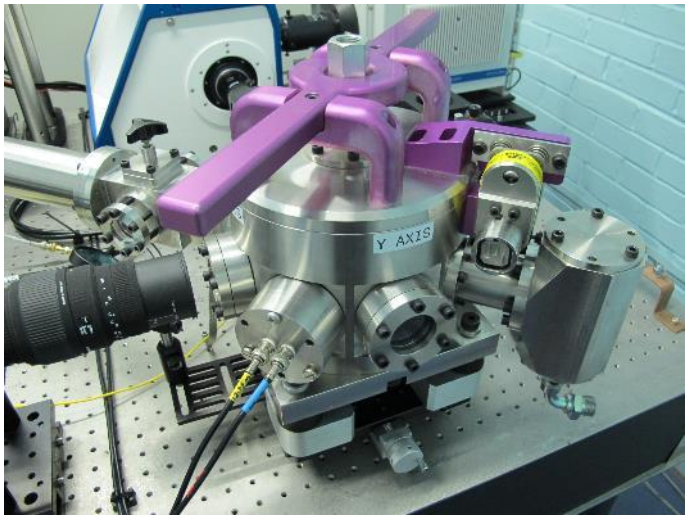


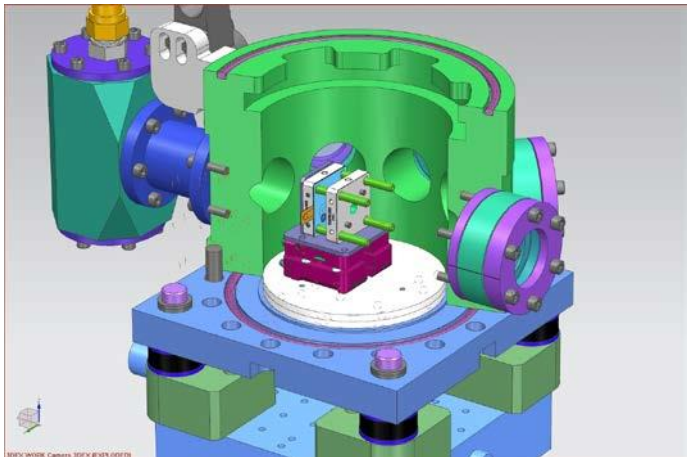
The Microdetonics Laboratory



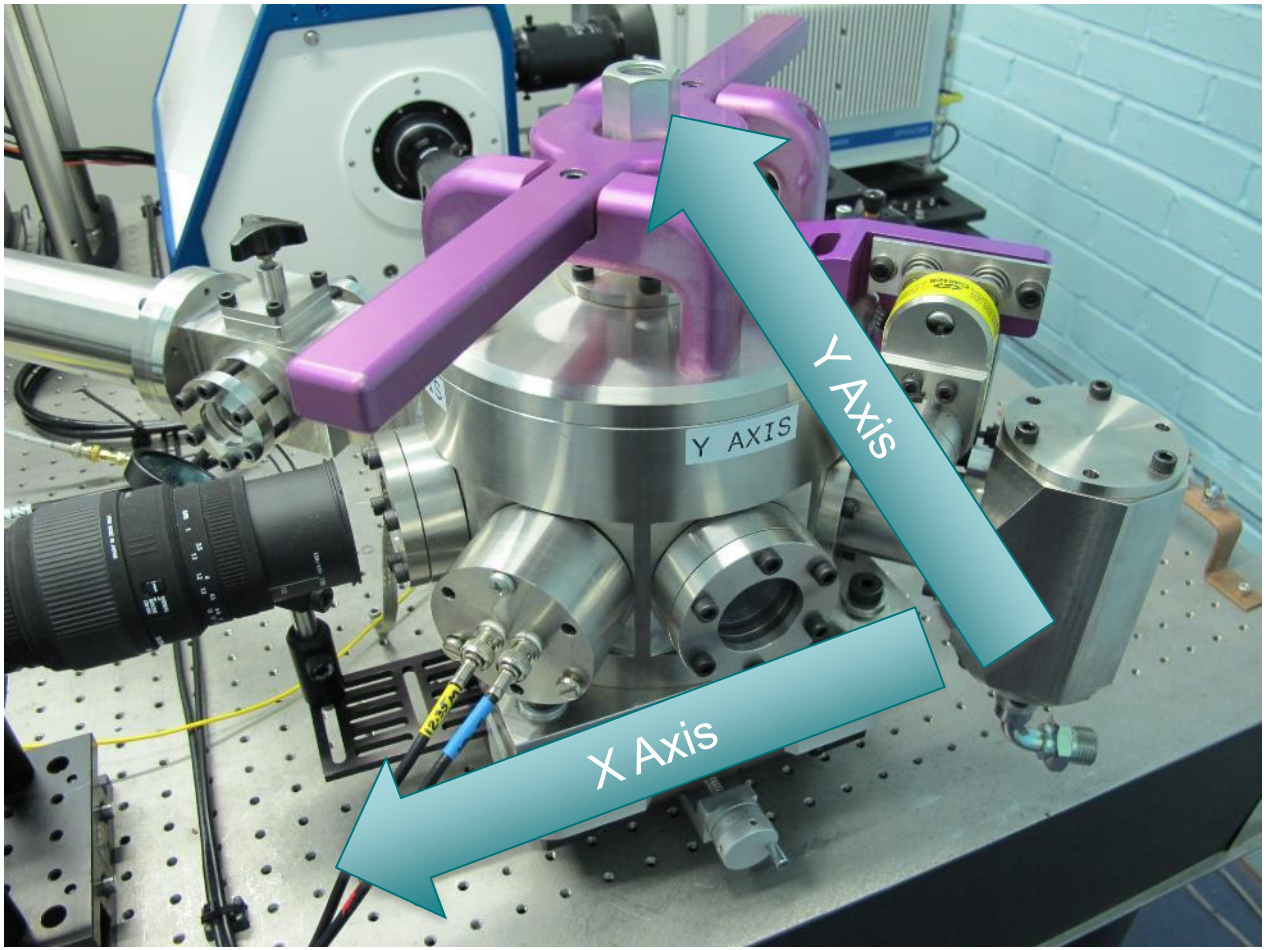
Firing enclosure

- 135 mm internal bore
- Bayonet closure
- Castell interlock
- X, Y alignment
- 8 ports (plus lid)
- Optical ports are 2x 12mm polycarbonate (angled to reduce reflections)
- Tested to 6.5 g TNT
- Rated to 1.2 g TNT



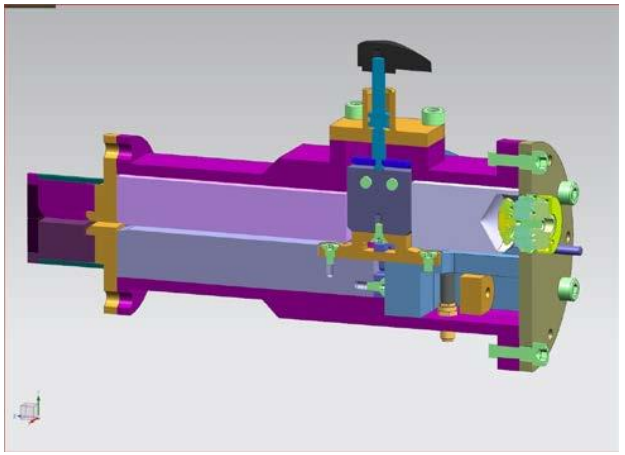


Firing enclosure



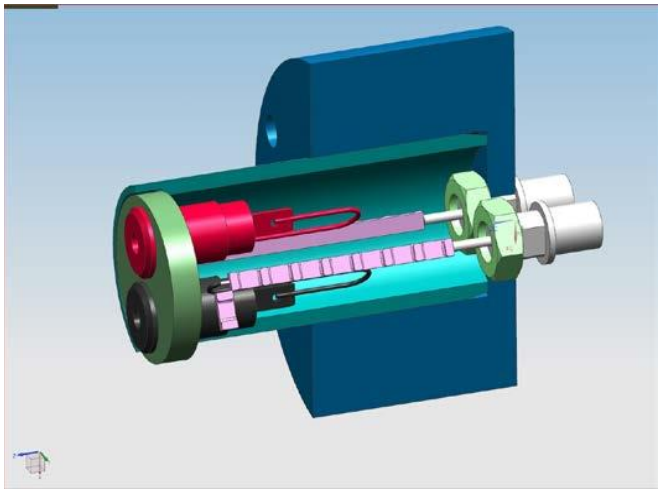
Firing unit & interface

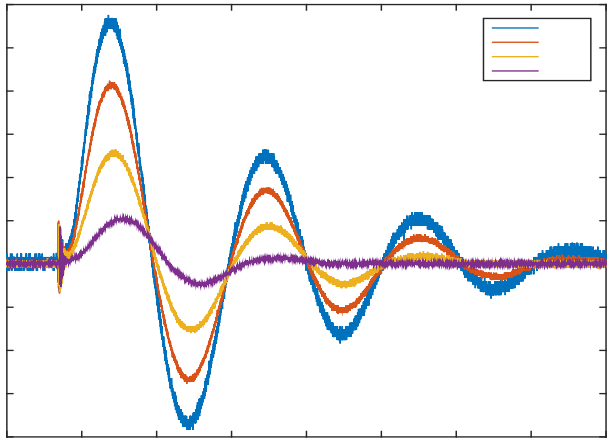
- **Capacitor discharge firing unit**
  - Designed by Pete Horn (AWE)
  - 50, 100, 165, 200, 350, 500, 830 nF
  - 20-4000 V
  - Thyristor switch >5000 shot switch life
- **Firing unit interface**
  - Prevent exposure to firing unit terminals
  - Seal enclosure against overpressure
- Teledyne Reynolds bullseye connector to interface box
- Copper C-clamp to join test cable
- Windows for inspection of joint



Current and voltage

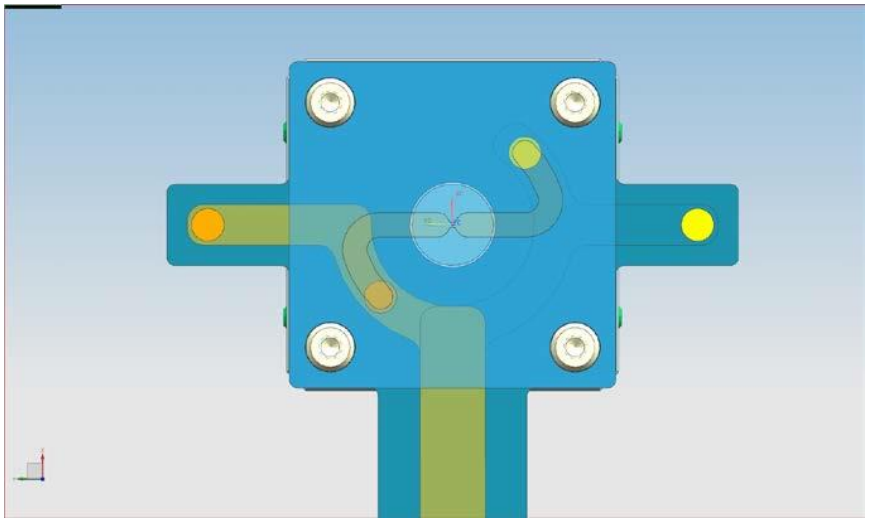
- Differential voltage probe directly across bridge
  - Recorded on two oscilloscope channels
  - Comparable response to Agilent and Barth HV probes
  - Estimated 1 GHz bandwidth
- Pearson 2879 current monitor (20 MHz bandwidth)





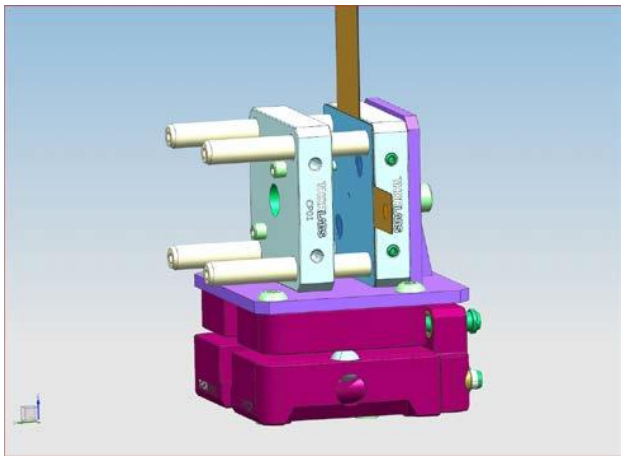
MISSEX EFI cable

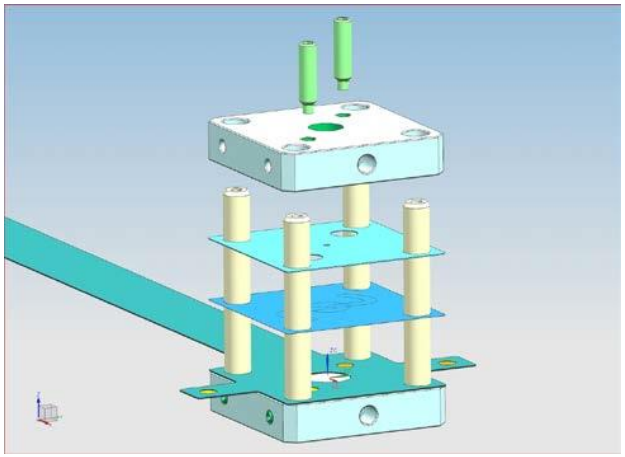
- Modular Instrumented Small Scale Explosive Experiment
- Low cost cable for flexible foil (and soon Chip) bridges
- Replaceable bridge
- Designed for dual-axis imaging and voltage measurement



Modular experimental fixture

- Modular design using Thorlabs 30 mm cage system
- Holds slapper cable, window, pellet, explosive flyer, etc
- 5 axis alignment
- Repeatable to 0.01 mm



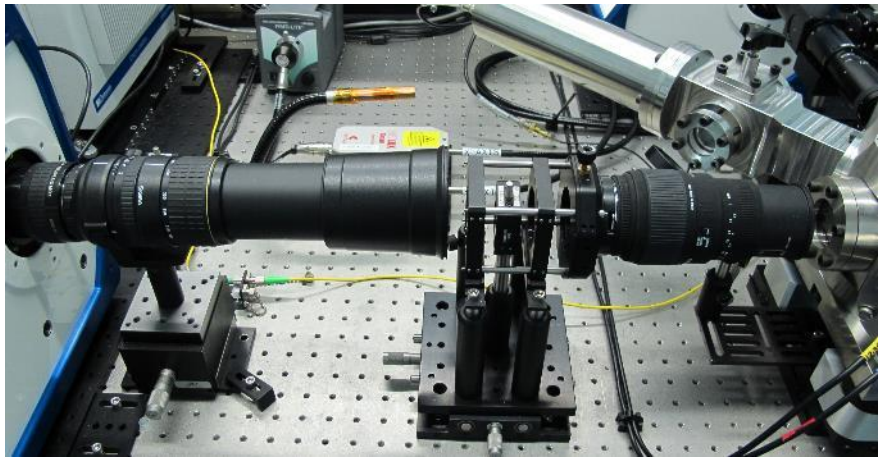


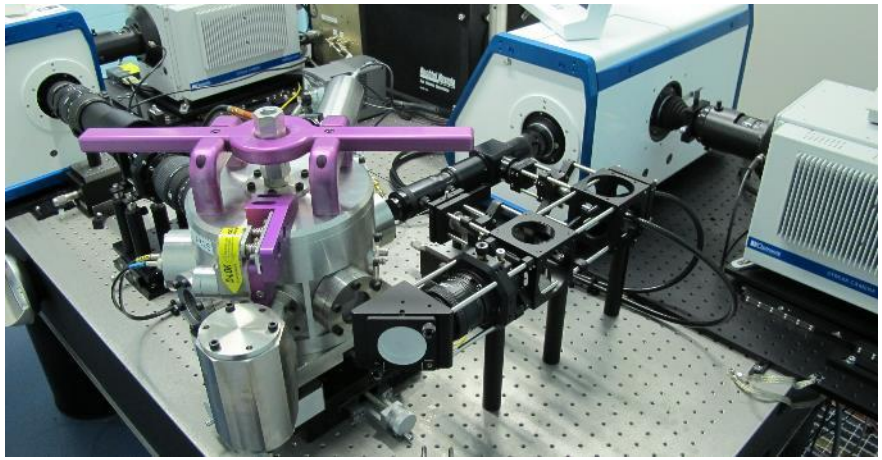
Laser illumination

- CAVILUX Smart spoiled-coherence diode lasers
- 400 W peak power, 10 µs pulse duration
- 640 nm wavelength
- One laser per axis
- Frontlighting (Y axis) and backlighting (X axis)

Imaging

- Specialised Imaging SIM 8 cameras
  - 8 frames, 5 ns exposures
  - Typical interframe time 25 ns to 100 ns
- Optronis streak cameras coupled to framing cameras

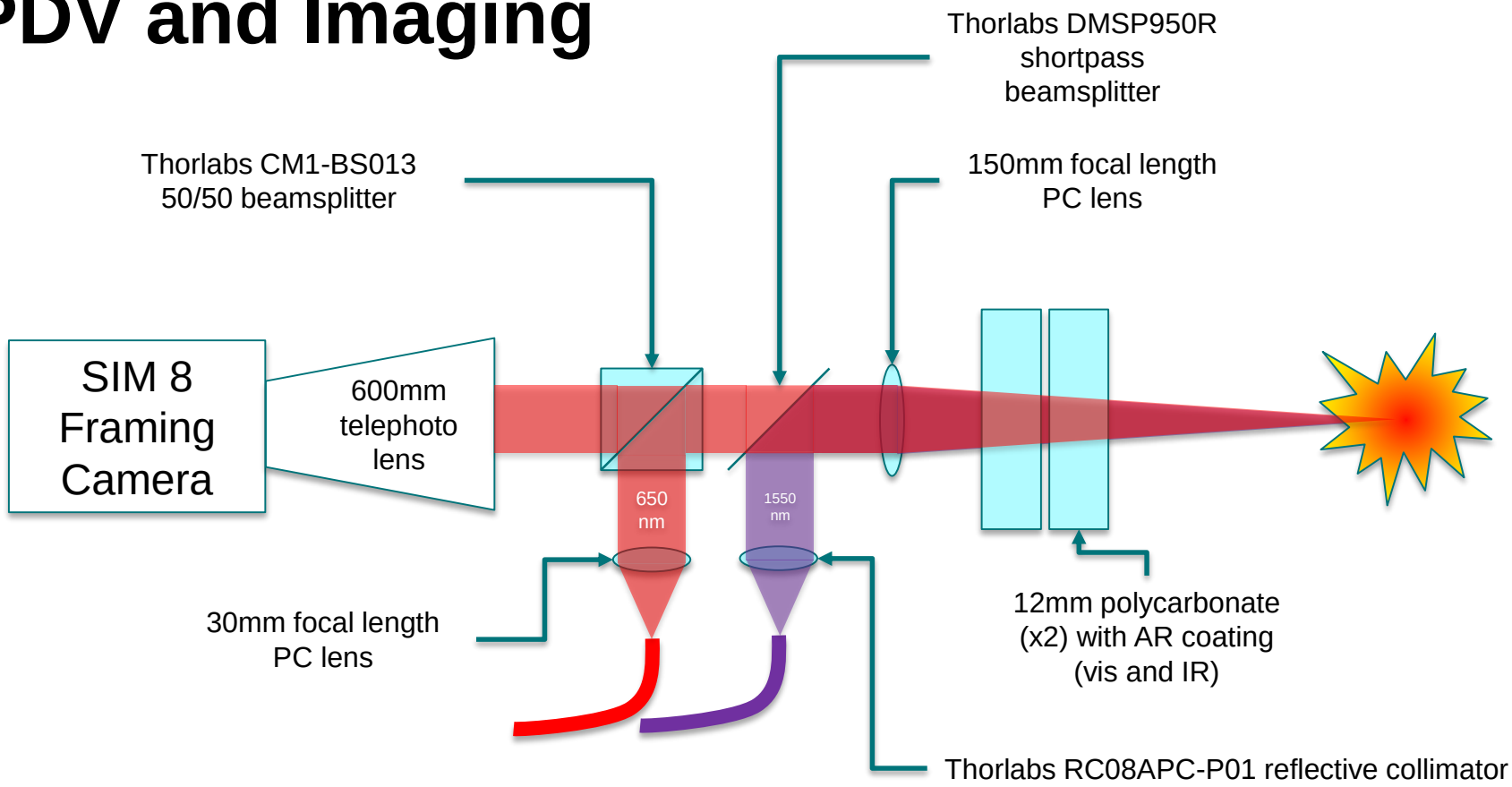




Imaging challenges

- Variable, high magnification (20x, 1 mm field of view) required
- Long working distance (175 mm)
- Limited space for lenses
- X axis – double SLR lenses
  - Primary lens – 175 mm focal length
  - Secondary lens – 1000 mm focal length

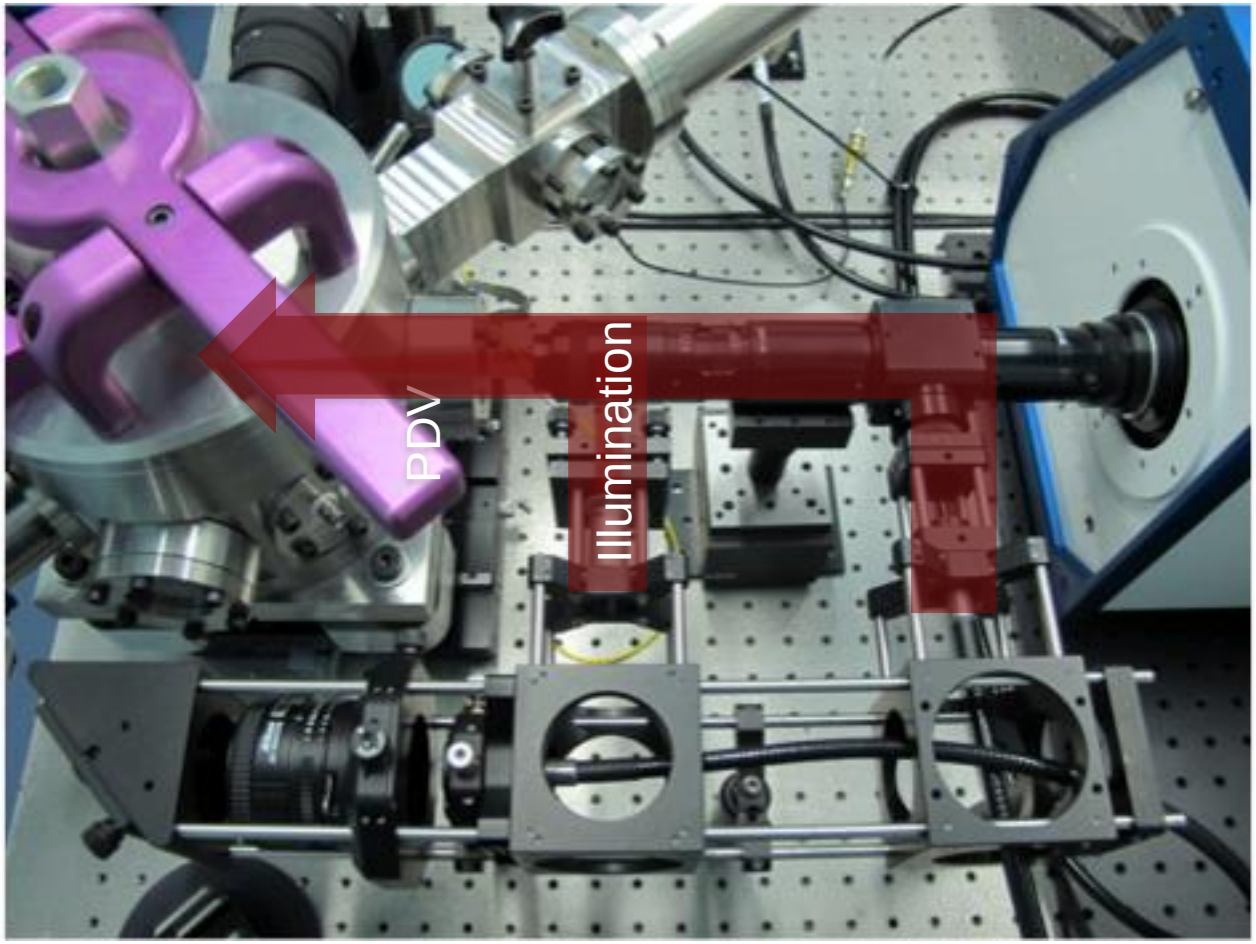
PDV and Imaging



PDV and Imaging

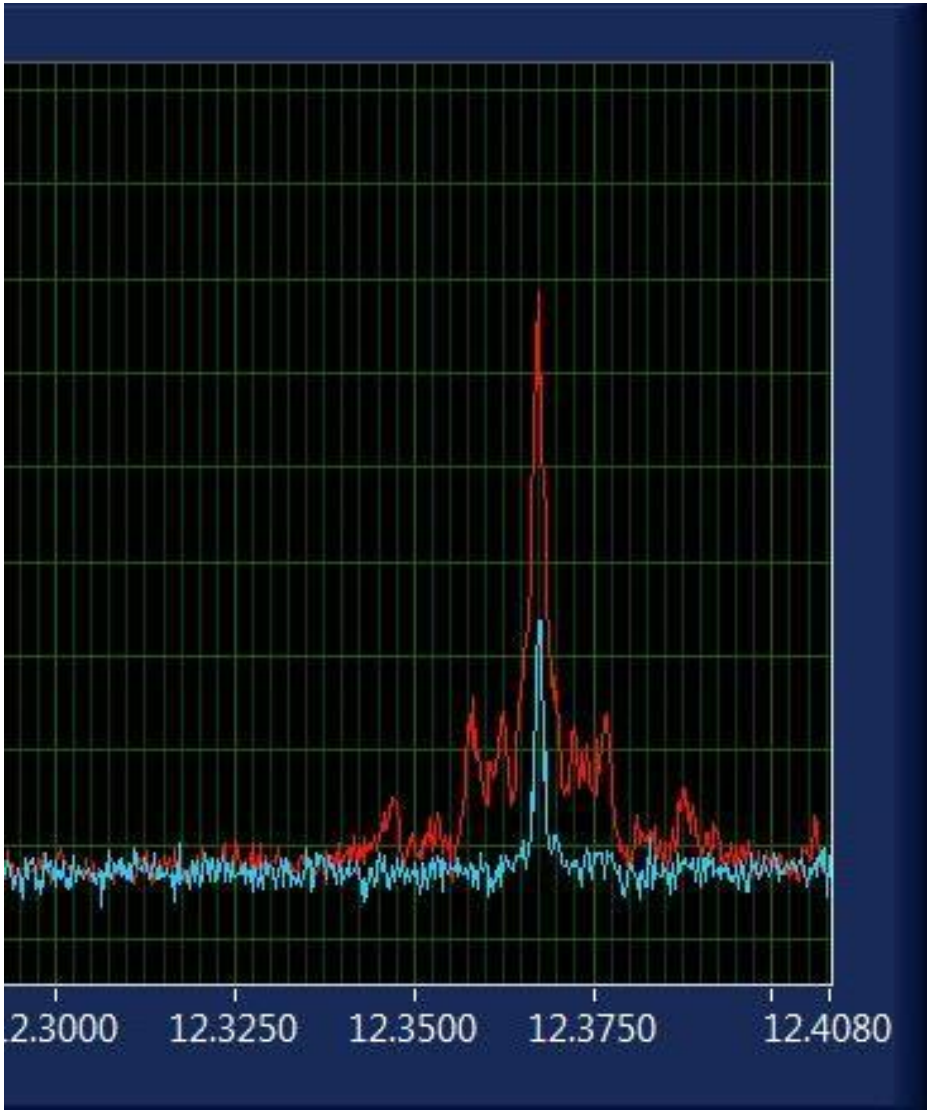
- 300mm telephoto lens with teleconverter (600mm) focussed at infinity hence collimated
- PDV and illumination folded into beam path
- 150mm focal length lens to focus onto target
- Magnification 600/150= 4x
- Very lossy – polycarbonate windows are absorbing
- NKT Photonics lasers with pulsed (100µs) EDFA (7 watts)
- Considering back-end EDFA also

PDV system



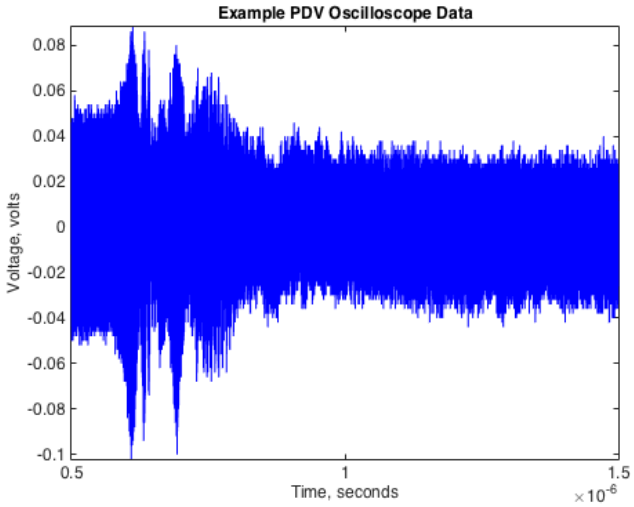
LUNA data

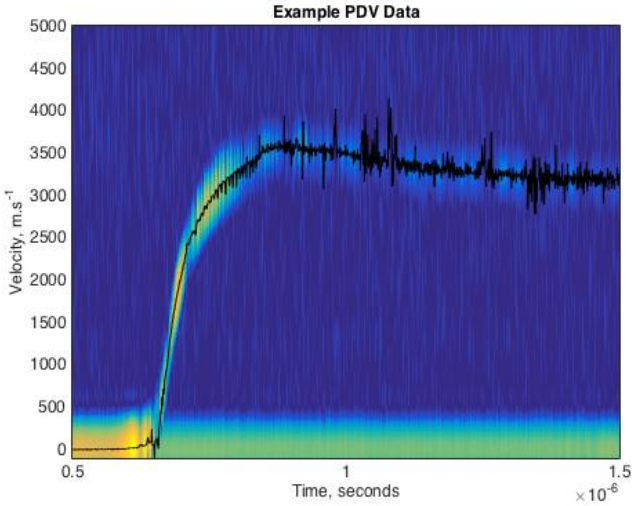
- LUNA OBR4600 optical backscatter reflectometer probes all optical interfaces, from circulator output to target
- Identifies spurious returns and losses
- Ensure PDV “sees” target



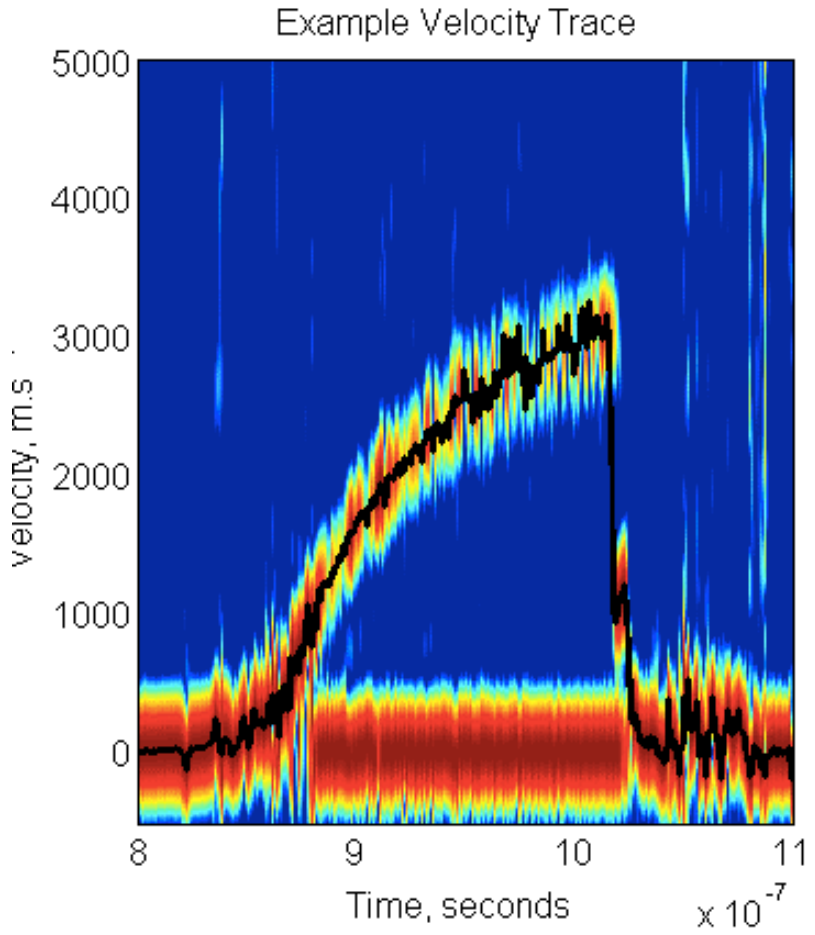
Example PDV data

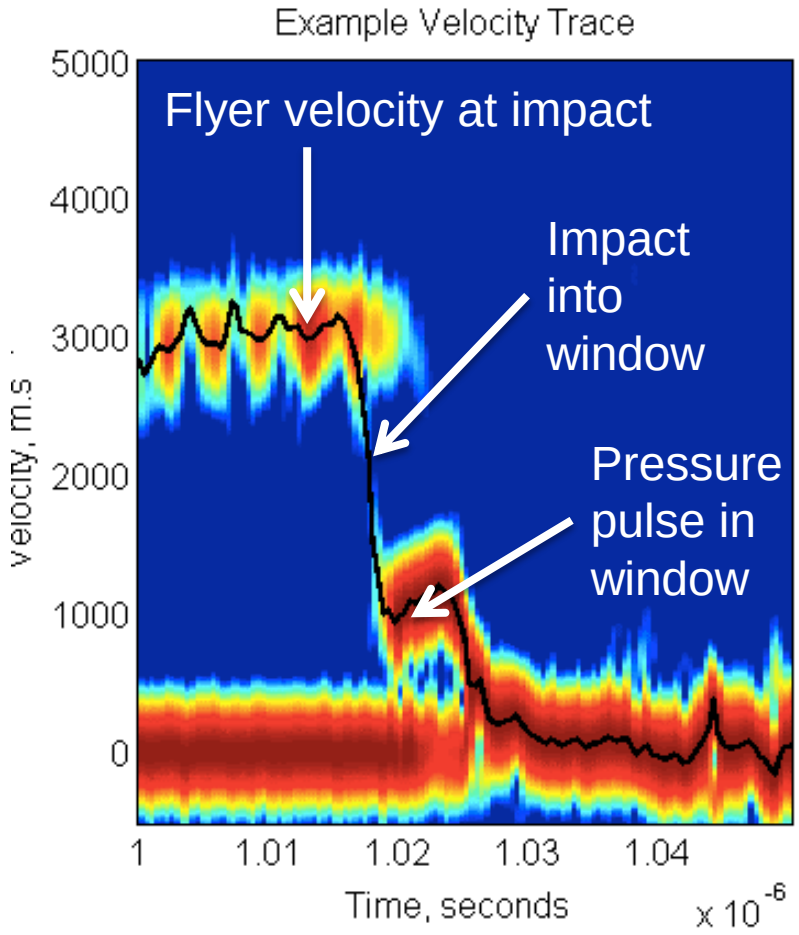
- Optical signal detected by Miteq 12 GHz receiver
- Electrical signal recorded by Tektronix DPO71604C 16 GHz oscilloscope at 100 $GS.s^{-1}$
- Can use two detectors to maximise contrast





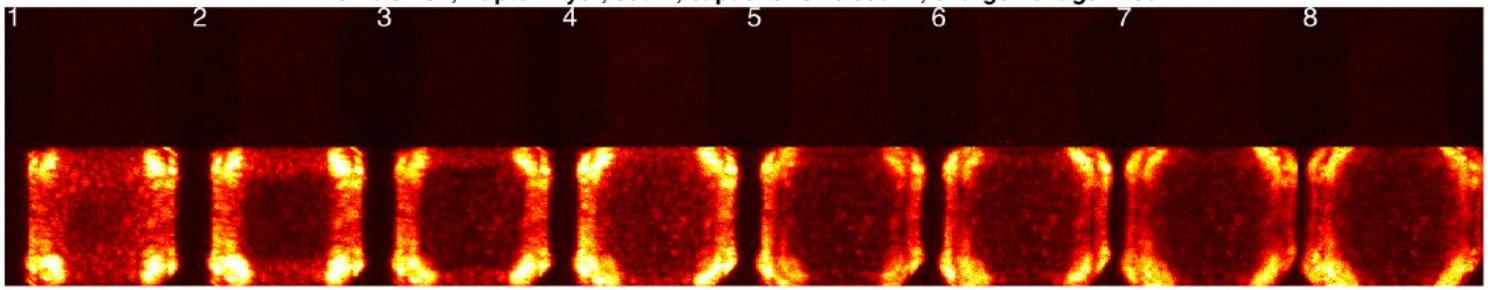
Flyer velocity history from PDV

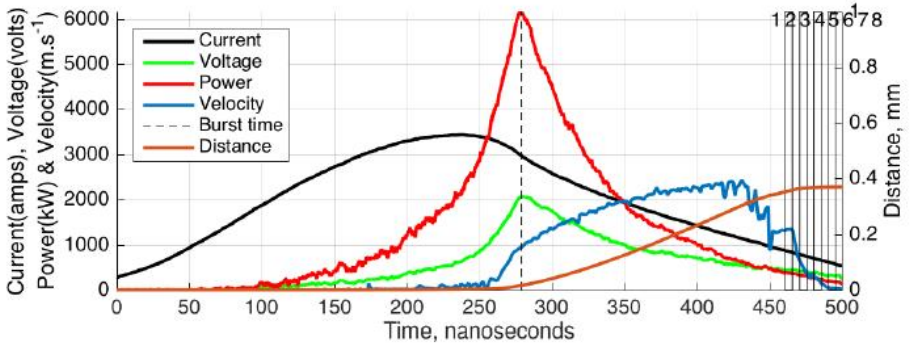


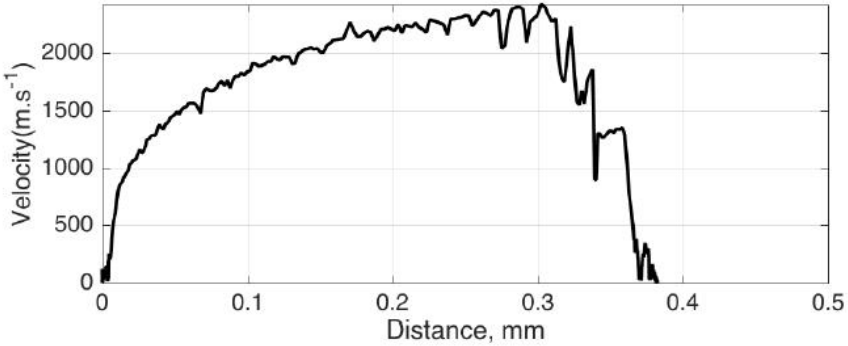


Example Data

Data acquired in the AWE Microdetonics Laboratory



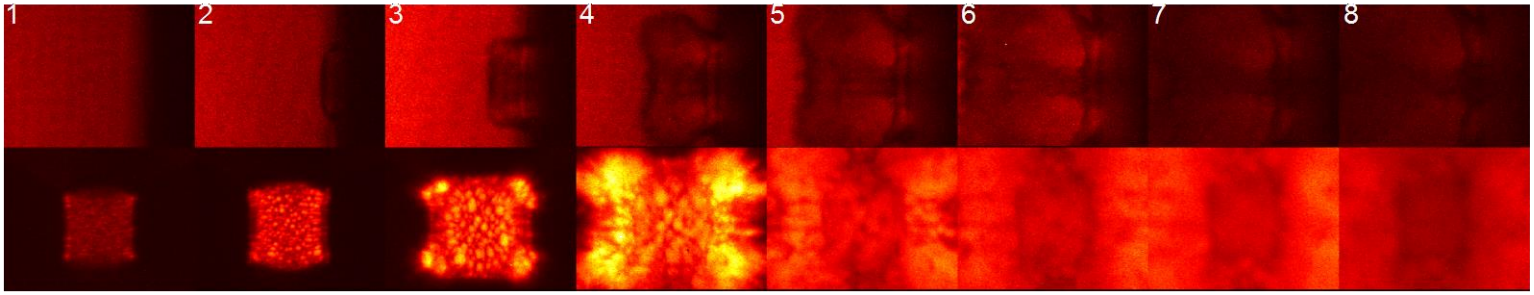


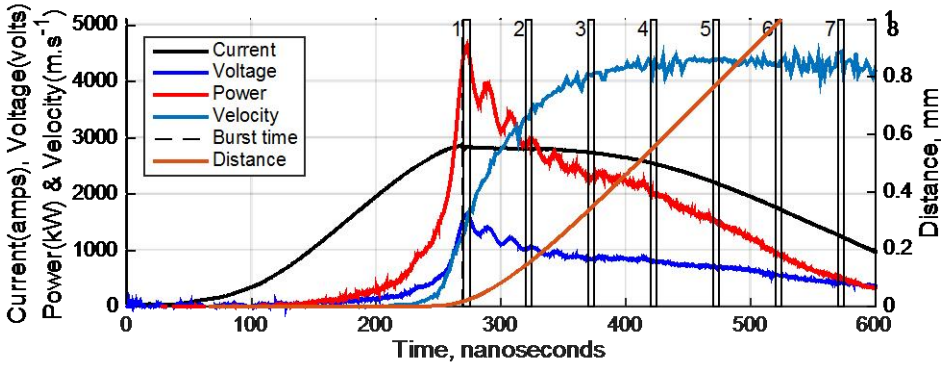


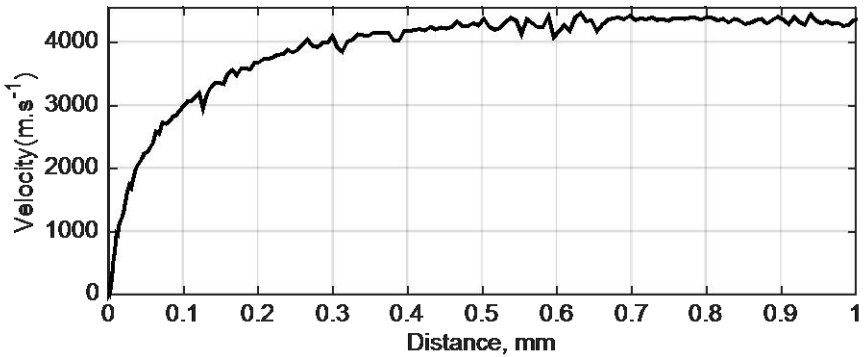
Example data

acquired in the AWE Microdetonics Laboratory

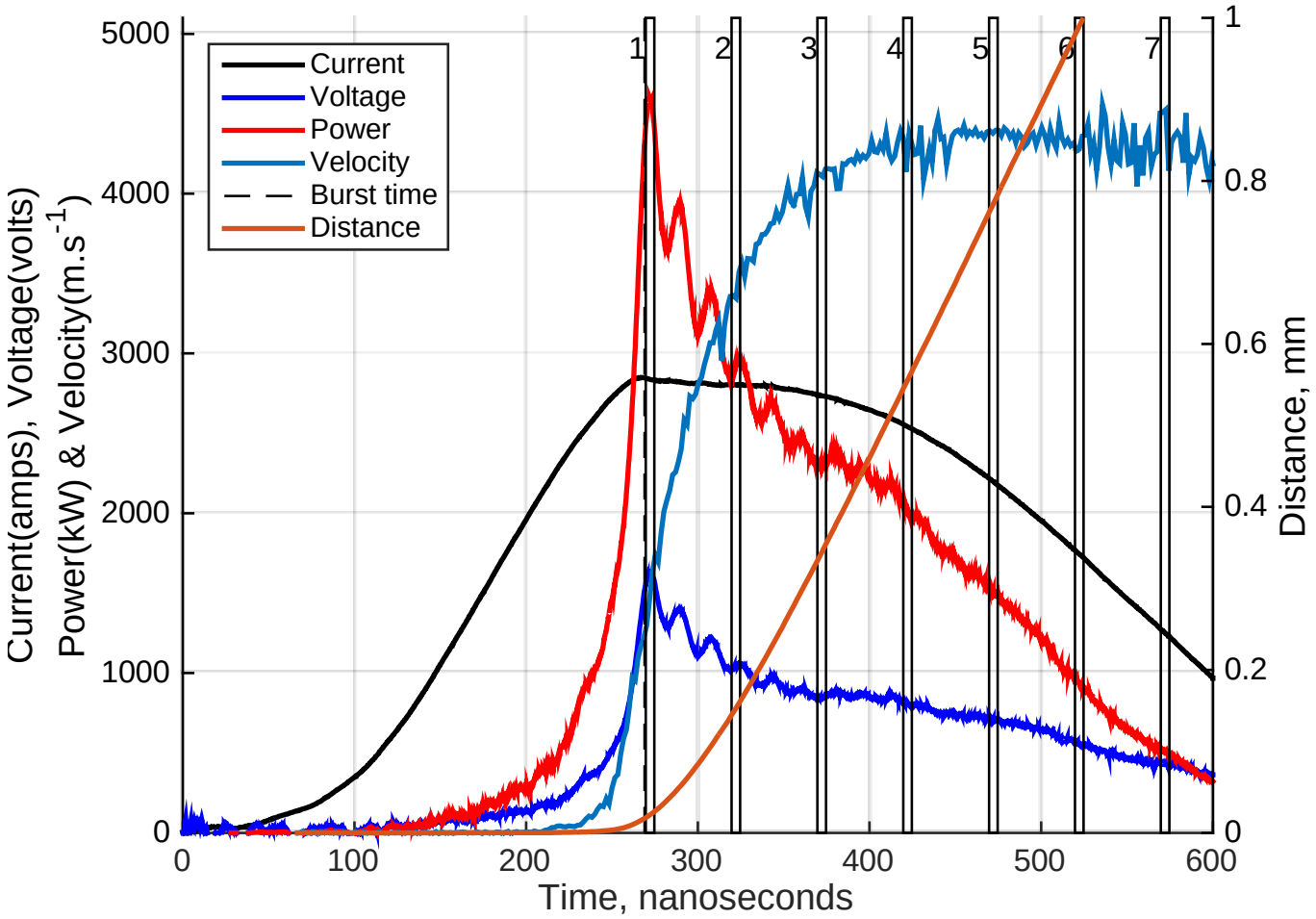
Shot SAND15, bridge size 380um, bridge thickness 5um copper
Flexible Foil, flyer 25um Kapton, capacitor size 350nF, charge voltage 3000V



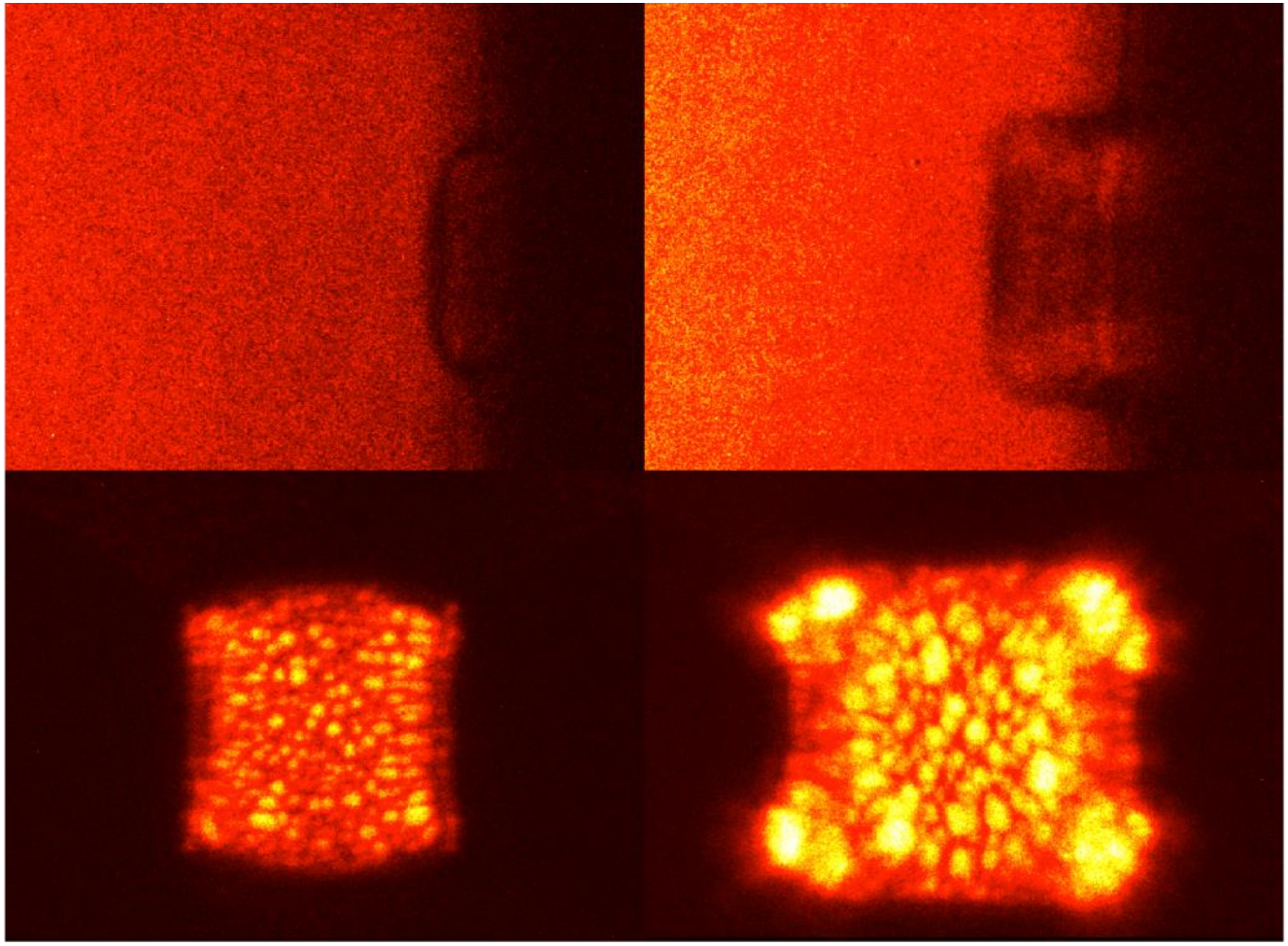




Example data



Example data



Conclusion

- AWE has significantly uplifted the capability for EFI and EBW experiments with the Microdetonics Laboratory
- Current, voltage, ***PDV and dual-axis imaging*** are standard
- Now able to investigate features such as bridge defects, flyer formation and break-up
- Aligns with high-fidelity magentohydrodynamic simulations

Acknowledgements

- Jon Botting – mechanical design
- Scott Aitken – experimental assistance
- Amy Mitchell – experimental assistance
- Dan Dolan (SNL) – SIRHEN PDV analysis software
- Chadd May (LLNL) – voltage probe design
- Cole Valancius (SNL) – technical discussions
- Chris Garasi (SNL) – technical discussions
- Dan Freyer (NSTec) – optical advice